STUDIES ON THE LIFE HISTORY OF SOME CARIDEANS OF THE SOUTHWEST COAST OF INDIA

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MAY 1991

DEDICATED
TO MY
BELOVED FATHER
Shri . K. P.NARAYANA PILLAI.

DECLARATION

I hereby declare that this thesis entitled **"STUDIES ON THE LIFE HISTORY OF SOME CARIDEANS OF THE SOUTHWEST COAST OF INDIA"** has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON THE LIFE HISTORY OF SOME CARIDEANS OF THE SOUTHWEST COAST OF INDIA"** is the bonafied record of the work carried out by Mr. N. NEELAKANTA PILLAI under my guidance and supervision and that no part thereof has been presented for the award of any other Degree.

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CONTENTS

PREFACE

The penaeid and caridean prawns are the most sought after decapod crustaceans all over the world. This is because of their importance as an esteemed food of gourmet and economic significance. There is an ever increasing demand for prawn products in the international and national markets. At the same time it is realised that enhancing of their production from the coastal waters from where they are largely exploited at present may not be possible due to the limited availability of stocks, heavy fishing pressure and increasing environmental hazards. This has led to frantic search for additional resources or methods of augmenting the production either through culture in suitable systems or exploitation of the resources in the under exploited and/or new grounds. Towards this direction, considerable R&D efforts are now being made by several nations of the world including India.

The prawn fishery of the world during 1988 with an annual production of 2.2 million tonnes (Pekham, 1990) - ocean caught and farm raised - is by and large supported by the species belonging to Penaeidae, Palaemonidae, Pandalidae and Crangonidae. Among these, Penaeid prawns rank foremost in production both in capture as well as culture fisheries and in trade. Due to this, a wealth of information on the biology, fisheries, resource characteristics of the economically important species and in the technology of their culture is now available. Relative to the penaeid prawn fishery, the carideans contribute to only a fraction of the world prawn production, although some of them constitute fishery of considerable regional importance at several places. Besides, in terms of numerical species abundance, wide geographical distribution and diversified habitat occupied, they surpass the penaeids. Further, the carideans including the small and the large species, play a significant role as food species, forage species, baits and by-products. Exhibiting remarkable adaptation to different environmental conditions and co-existing with other organisms, they play an important role in the ecological niches. Despite these, the group has received relatively little attention in the research front, except a few species belonging to Palaemonidae, Pandalidae and Crangonidae.

The faunal investigations carried out on the prawns of India since the turn of this century have shown the richness and the varieties available in the country. Of these, about 56 species are either commercially exploited at present or have great commercial potentialities. These belong to the families Penaeidae, Sergestidae, Palaemonidae, Oplophoridae, Hippolytidae, Pandalidae and Atyidae. While about 71.58% of the marine prawn production of the country estimated at an average of 1,42,115 tonnes per annum is contributed by penaeid prawns, the carideans such as Hippolysmata (Exhippolysmata) ensirostris, Palaemon (Expalaemon) styliferus and P. (Nematopalaemon) tenuipes are also significantly exploited from the marine region, and Macrobrachium rosenbergii and M. malcolmsonii from the freshwater systems. As observed elsewhere, in India too, the information on the prawns of the country and their biology and fishery, is mostly related to penaeids rather than the caridean prawns. Most of the information available at present on the caridean prawns pertains mainly to their taxonomy and geographical distribution. The information on biological aspects such as reproduction, age and growth, recruitment, and of population characteristics of the important species available in our country is generally inadequate. However, since such information is basic to ensure rational exploitation of the species as well as to develop viable technologies of propagation, the present investigation on the life history of certain caridean prawns of southwest coast of India is taken up. As there appears to be greater opportunity to develop culture fisheries rather than their capture, and since the ontogenetic studies could afford insight into the taxonomic status of the species, emphasis has been laid in the present study on larval development and related aspects.

The thesis is presented in two parts. The first part contains five sections. The larval history studies made by the candidate on eleven carideans belonging to four families namely, Atyidae, Palaemonidae, Hippolytidae, and Alpheidae are presented in the first four sections. The species dealt with are Caridina longirostris H. Milne Edwards, 1837 and C. pseudogracilirostris Thomas, 1973 (Atyidae) in the first section; Macrobrachium equidens (Dana, 1852), M. striatus Pillai, 1990, M. idella (Hilgendorf, 1898), Palaemon (Palaemon) concinnus Dana, 1852, Leptocarpus potamiscus (Kemp, 1917), Leandrites celebensis (De Man, 1881), (Palaemonidae) in the second section; Hippolysmata (Exhippolysmata) ensirostris Kemp, 1914, (Hippolytidae) in the third section, and Alpheus rapacida De Man, 1908, Alpheus euphrosyne De Man, 1898, (Alpheidae) in the fourth section. Besides the larval descriptions, the observations made on the breeding behaviour, incubation of eggs in the berry and on the salinity tolerance of adult and larvae of some of the species are also presented and discussed. The fifth section of the first part is devoted for a comparative account on the morphology of larvae, and the development pattern in the different species and families on the basis of the observations made by the candidate and by earlier workers.

The second part of the thesis deals with the preliminary experiments conducted and the results obtained on the salinity requirements of different larval and postlarval stages of M. idella. The suitable salinity range for the optimum development, growth and survival of different larval stages is discussed.

Original contributions in the thesis include complete life history studies of Caridina longirostris, C. pseudogracilirostris, Macrobrachium equidens, M. striatus and M. idella; complete larval history of Leptocarpus potamiscus, Leandrites celebensis and Hippolysmata (Exhippolysmata) ensirostris and early larval history of Alpheus rapacida, A. euphrosyne and Palaemon (Palaemon) concinnus. The information gathered on the larval development of the species has enabled to provide greater insight into the taxonomical status of M. striatus and M. equidens which are now considered as two distinct species. Among the species studied, at present H. ensirostris contributes to fairly a good fishery on the northwest coast of the country and in the Godavari Estuary. The larval description of the species provided at present would further add to our understanding of the larval characteristic and biology of the species. M. equidens, M. striatus and M. idella grow to a medium size of 75 to

85 mm in total length and contribute to a subsistence fishery. They are also considered as potential species for culture in the freshwaters. The description of larvae, the rearing techniques adopted and the results obtained on the salinity requirements are relevant for the development of a viable culture technology for these species. It is hoped that the candidate's work presented in the thesis would thus, add considerably to our existing knowledge on the biology of the carideans of the southwest coast of India and encourage further studies on this fascinating and complex group comprising of several economically important species.

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INTRODUCTION

The caridean prawns included under 11 superfamilies and 22 families (Bowman and Abele, 1982), constitute one of the largest and most diverse groups of decapod Crustacea. Being well represented in different tropic and temperate geographical areas, the members of the group have successfully occupied the varied aquatic ecosystems ranging from deep sea, sub-littoral, littoral, estuaries, brackishwaters to freshwaters. The carideans are important faunistically due to the diversity of their forms which makes the group complex. Economically, the group contains species which support fisheries of considerable regional importance, and are used for human food and as livestock feed. Biologically, several of the species which besides constituting as food of larger animals, play a significant role in the dynamics of the ecosystem. The technological advances made since 1962, when the artificial propagation of the palaemonid prawn Macrobrachium rosenbergii was achieved, have led to world wide interest in the culture of this species as well as a dozen related species which have shown marked farming potentials. Similarly, the appreciable progress made on the controlled reproduction and rearing of larvae, have greatly helped to unravel the taxonomic confusion of the species complex and their phylogenetic relationships. The group thus, in recent years, is not only increasingly attracting the attention of research workers, but also assuming greater importance in the national fisheries development programmes leading to increased Governmental assistance, enhanced investments and support services.

A general survey of the literature on caridean prawns reveals that most of the works pertain to their taxonomy and distribution. Among the several works on this aspect from different regions, the most important ones include Bouvier (1905), De Man (1904, 1905, 1911, 1920), Borradaile (1907), Calman (1910, 1913, 1926, 1927, 1939), Kubo (1936, 1938, 1940, 1942, 1955), Barnard (1947, 1950, 1955), Holthuis (1949, 1950, 1951, 1952a, 1952b, 1956, 1965, 1966a, 1966b, 1973), Yaldwyn (1954, 1957, 1960, 1971), Johnson (1963, 1966, 1973), Williams (1965), Bruce (1965, 1968, 1969, 1970, 1971), Thompson (1966), Kensley (1968, 1977, 1981), Hayashi and Miyake (1969), Chace (1972, 1975, 1983, 1984, 1985, 1986), Chace and Manning (1972), Crosnier and Forest (1973) and Kensley et al. (1982). Holthuis (1980) has given an annotated catalogue on species of carideans of fisheries interest in different regions of the world.

The caridean prawns contribute to significant fisheries in the temperate, subtropical and tropical waters. It is estimated that about 15 to 16% of the total world prawn catch is formed of carideans. Several workers have discussed the fisheries and biological aspects of the constituting species. Wickins (1976) gave a detailed review on the biology and culture of penaeid and caridean prawns, while Gulland (1971) in his excellent paper, gave a comprehensive account of the existing fisheries along with the biological information of the important species and estimated the potentials of certain fisheries. Recently Neal and Maris (1985) discussed the major caridean fisheries, selected species contributing to the regional fisheries, population characteristics and management aspects. Lloyd and Yonge (1947), Forster (1951, 1959) and Allen (1959, 1960, 1963) have given extensive reviews on the biology of certain caridean prawns. Similarly the metabolism, physiology and biochemistry of some of the caridean species have been reviewed by Ceccaldi (1982), Mantel (1983) and Vernberg and Vernberg (1983).

Investigations on crustacean larvae including carideans date back to early nineteenth century. Initially most of the studies were devoted to descriptions of larval stages of various species essentially aimed at understanding the early life history and the systematic relationships. Subsequently these studies were expanded and directed to obtaining information on the biology of the larvae and on their rearing in large scale leading to the development of culture technology. Among the early works, the monumental works of Gurney (1939, 1942) are very important. Since then, a large number of publications dealing with the larval development of carideans belonging to different groups, reared from egg to postlarval stages and often through the entire life cycle, is available. Synthesising these informations, reviews on aspects such as larval morphology, larval diversity, identification and larval development pattern have been provided by Dobkin (1969), Williamson (1969, 1972, 1982) and Felder et al. (1985). The progress made in the commercial culture of carideans has been reviewed from time to time by Bardach et al. (1972), Goodwin et al. (1977), Ling (1977), New (1982), Provenzano (1985) and Wickins (1982).

The history of our knowledge of caridean prawns of the Indian waters is not a long one. The early works of Bate (1888), Wood-Mason and Alcock

(1891, 1894), Alcock and Anderson (1894), Anderson (1896), Alcock and McArdle (1901), MacGilchrist (1905), Lloyd (1907) and Kemp and Sewell (1912) described the caridean prawns of deep water collected largely by R.I.M.S.S. 'Investigator'. In 1910, Henderson and Matthai presented the taxonomic notes and figures of 9 species of Palaemon (= Macrobrachium) collected from different areas of South India. This was followed by a series of studies of Kemp (1913-1925) on different groups of Caridea in the collections of the Indian Museum and those collected from other areas, which considerably enriched our knowledge on the caridean fauna of India. Among the significant taxonomic studies carried out after Kemp, mention may be made of the works of Chopra and Tiwari (1947), Tiwari (1947a, 1947b, 1952, 1955a, 1955b, 1958, 1961, 1964) and Tiwari and Pillai (1968, 1971, 1973). Faunal discussions with taxonomic notes were presented by Jagadisha (1978) for Karwar; Natarajan (1942), Kurian (1949, 1952, 1954), Pillai (1955), John (1958), Jayachandran and Joseph (1989, 1990) for Kerala; Gravely (1927), Panikkar and Aiyar (1937) and Chacko et al. (1953) for Tamilnadu; Dutt and Ravindran (1974) for Andhra Coast and Shukla et al. (1981) for Gorakhpur region. Suseelan (1974) presented a comprehensive account on the taxonomy, distribution, biology and fisheries of the deep sea carideans along the southwest coast of India. Recently, studying the endophragmal skeleton of Macrobrachium javanicum and M. idae, Reddy et al. (1985) pointed out the utility of these structures as taxonomic tool. Jayachandran and Joseph (1985, 1986) described two species of Macrobrachium from the southwest coast of India.

According to Mohamed and Rao (1971) 25 species of carideans that are either exploited at present or have great commercial potentialities, occur in the Indian waters. These belong to the families Palaemonidae, Hippolytidae, Pandalidae and Oplophoridae. The most important species contributing to the fisheries are Palaemon (Nematopalaemon) tenuipes, P. (Exopalaemon) styliferus and Hippolysmata (Exhippolysmata) ensirostris in the inshore waters and Macrobrachium rosenbergii, M. malcolmsonii and M. idae in the freshwaters. Good concentrations of Plesionika spinipes, P. martia, P. ensis, Heterocarpus woodmasonii and H. gibbosus have also been observed in the commercial exploratory catches from the deeper water of 200-300 m along the west and southwest coasts, particularly off Kerala Coast (Silas, 1969; Suseelan et al., 1990). The general aspects of the littoral commercial caridean prawns and their fisheries were discussed by Chopra (1939, 1943), Bhimachar (1962, 1965), Jones (1969), George (1969b), Gopalakrishnan (1973), Kurian and Sebastian (1982), Ravindranath (1982), Prakash and Agarwal (1985) and Rao (1985). Studies on the biological and fishery characteristics of particular species and their fisheries were presented by Rajyalakshmi (1966), Subramanyam (1966) and Kunju (1969) for P. (N). tenuipes; Kunju (1955, 1969) and Rajyalakshmi (1966) for P. (E) styliferus; Kunju (1969) for H. ensirostris; John (1947, 1957), Rajyalakshmi (1964), Raman (1964, 1967), Mallikarjuna Rao (1965, 1967) for M. rosenbergii; Ibrahim (1962b), Rajyalakshmi and Ranadhir (1969), Rajyalakshmi (1980) for M. malcolmsonii; Prakash and Agarwal (1985, 1986) for M. birmanicum Choprai. Besides, a selection of studies on the structure and function of gastric mill of 18 species of Caridea (Patwardhan, 1935), spermatogenesis of Palaemon lamarrei (= M. lamarrei) (Nath, 1937), oogenisis (Nath and Bhatia, 1930), morphology and anatomy of Palaemon (Patwardhan, 1937), reproductive system of Palaemon idae (= M. idella) (Aiyer, 1953), embryology and anatomy of Caridina laevis (Nair, 1949; Pillai, 1960), moulting and reproduction of M. idella (Joseph and Jayachandran, 1986; Shyama, 1987), sexual dimorphism of M. lamarrei and M. dayanum (Koshy, 1969, 1971), growth pattern in M. scabriculum and M. idella (Jayachandran and Joseph, 1985b, 1987, 1988), bopyrid parasites of Carideans (Chopra, 1923) and parasites and diseases of M. equidens (Natarajan et al., 1982), on the endocrine control of reproduction (Patil et al., 1987) and effect of unilateral eyestalk ablation on moulting, growth and reproduction of M. malcolmsonii (Murugadass et al., 1988) are available. Recently successful cross breeding between the freshwater prawns M. rosenbergii and M. malcolmsonii has been reported by Sankolli et al. (1982). A few works have dealt with the effect of industrial effluent on Macrobrachium sp. (Verma and Mathur, 1974).

Historically, information on the caridean eggs and larvae from India dates back to 1910 when Henderson and Matthai observed the hatching of eggs of P. lamarrei (= M. lamarrei) and subsequent development of larvae. Later Kemp (1916) gave an account of the late larval and postlarval stages of H. ensirostris collected from the Orissa Coast. Das (1935) described the developmental stages of M. lamarrei within the egg and the first free larval stage reared in the laboratory. This was followed by a series of works by Menon (1938, 1940, 1949) on certain larval stages of M. rosenbergii, M. rudis, Hippolysmata sp., Lysmata sp., Alpheus sp., and Periclimenes (Periclimenes) indicus. Aiyer (1949) gave a comprehensive account on the embryology of Palaemon idae (= M. idella) from four celled stage to the newly hatched larvae. The larvae of other species dealt with during the period were Periclimenes (Ancylocaris) brevicarpalis (Nayar, 1947), Palaemon idae (= M.idella) (Nataraj, 1947), P. (Ancylocaris) grandis (Pillai, 1950), H. vittata (Kuriyan, 1951).

The significant studies produced in the sixties were by Rajyalakshmi (1960, 1961) on the embryonic development, hatching and description of the early larvae of M. malcolmsonii, M. rudis, M. scabriculum, M. lamarrei, M. mirabile and Leptocarpus fluminicola; Ibrahim (1962a) on a comparison of early development of M. malcolmsonii and M. scabriculum; Pillai (1966a, 1966b) H. vittata and P. tenuipes and Bensam and Kartha (1967) on the eggs and early larval stages of H. ensirostris. Most of these works in general, were based on the material collected from nature and raising a few subsequent stages in the laboratory or from the egg. Due to inadequate knowledge on the techniques of larval rearing and facilities available, none of these works gave full account of the larval history of these species except that of Babu (1963) who traced the complete series of developmental stages of Caridina propinqua collected from the river Mahanadi at Cuttack.

With the advancement of larval rearing techniques and increasing interest on the culture of prawns, the research endeavours since nineteen sixties were mainly directed to study the complete larval history of the species with emphasis on rearing techniques providing suitable feed and rearing environment. Thus in 1971, Kewalramani et al., described the complete larval history of

M. malcolmsonii passing through 16 stages; Pillai and Mohamed (1973) presented the larval development of M. idella; Jalihal and Sankolli (1975) dealt with the abbreviated metamorphosis of M. hendersodayanum and Jalihal et al. (1978) on M. tiwari. In the thesis submitted by Jagadisha (1977) the life history of 13 species of carideans, 6 belonging to Palaemoninae, 3 to Pontoninae 2 to Hippolytidae and one each to the family Processidae and Crangonidae were presented and described. Similarly Jalihal in the following year (1978) dealt with the complete larval development of 10 species (4 belonging to Caridina and 6 to Macrobrachium) collected mainly from the freshwater bodies of Dharwar District of Karnataka State. The distribution of decapod larvae including the caridean larvae in the Arabian Sea and those collected during the International Indian Ocean Expedition were discussed by Menon et al. (1969), Menon and Williamson (1971), Menon and Paulinose (1973), Vijayalakshmi and Paulinose (1980) and Paulinose et al. (1987). Rao and Suseelan (1967) described the egg and prezoea of the deep sea pandalid H. woodmasoni and later Menon (1972), the various larval stages of this species.

Although a traditional practice of culture of prawns and fin fishes in the low lying fields adjoining the estuaries and backwaters is prevalent in India since long time, the prawn production from this system has been principally constituted by penaeid prawns. Similarly, though successful rearing from egg through entire life cycle has been reported for some caridean species (as discussed above) and considerable efforts are being made in the country to develop and expand prawn culture to augment the prawn production, the endeavour by and large, have been directed to the culture of penaeid prawns.

Serious mass culture efforts of caridean species are restricted to a single species, namely M. rosenbergii (Meeran and Sebastian, 1976; Subramanyam, 1984a ;Alikunhi et al. 1980. Despite the wide distribution of this species in the several river systems of the country and its commercial importance, information on its culture in the grow out ponds is meagre. However, the recent experimental pond culture studies have indicated a production rate of 578 kg/ha/3 months with supplementary feeding and the feasibility of its farming along with surface and columnar feeding fishes such as Catla, Rohu Silver carp (Subramanyam, 1984b). Thus, the caridean prawn culture in the country is in an infant stage, although rapidly growing.

In India, as elsewhere, the most important species of carideans from the point of view of capture and culture fisheries belong to the genus Macrobrachium. Besides this, the group contains economically potential pandalids in the deep sea, hippolytids that change sex with age (Kagwade, 1981) and several interesting, multicoloured smaller varieties that could serve as ornamental species. Despite these, the group has not attracted much attention on the research front. However, in recent years the significance of the group is increasingly realised and emphasis is being given on wider propagation of the economically important species both for human consumption and as livestock feed. It is in this context, the present study on the life history of the certain caridean prawns of the southwest coast of India is taken up. The present work is presented in the following order:

PART ONE

Larval characters, growth and reproductive biology

SECTION ONE : Family Atyidae De Haan, 1849

Genus *Caridina* H. Milne Edwards, 1837

1. *Caridina longirostris* H. Milne Edwards, 1837
2. *Caridina pseudogracilirostris* Thomas, 1973

SECTION TWO : Family Palaemonidae Rafinesque, 1815

Genus *Macrobrachium* Bate, 1868

1. *Macrobrachium equidens* (Dana, 1852)
2. *Macrobrachium striatus* Pillai, 1990
3. *Macrobrachium idella* (Hilgendorf, 1898)

Genus *Palaemon* Fabricius, 1798

1. *Palaemon (Palaemon) concinnus* Dana, 1852

Genus *Leptocarpus* Holthuis, 1950

1. *Leptocarpus potamiscus* (Kemp, 1917)

Genus *Leandrites* Holthuis 1950

1. *Leandrites celebensis* (De Man, 1881)

SECTION THREE : Family Hippolytidae, Dana, 1852

Genus *Hippolysmata* Stimpson, 1860

1. *Hippolysmata (Exhippolysmata) ensirostris* Kemp, 1914.

SECTION FOUR : Family Alpheidae Rafinesque, 1815

Genus *Alpheus* Fabricius, 1798

1. Alpheus rapacida De Man, 1908
2. Alpheus euphrosyne De Man, 1897

SECTION FIVE : Comparative account of the larval stages of different species.

PART TWO

Some observations on the salinity requirements of the zoeal and postlarval stages of Macrobrachium idella

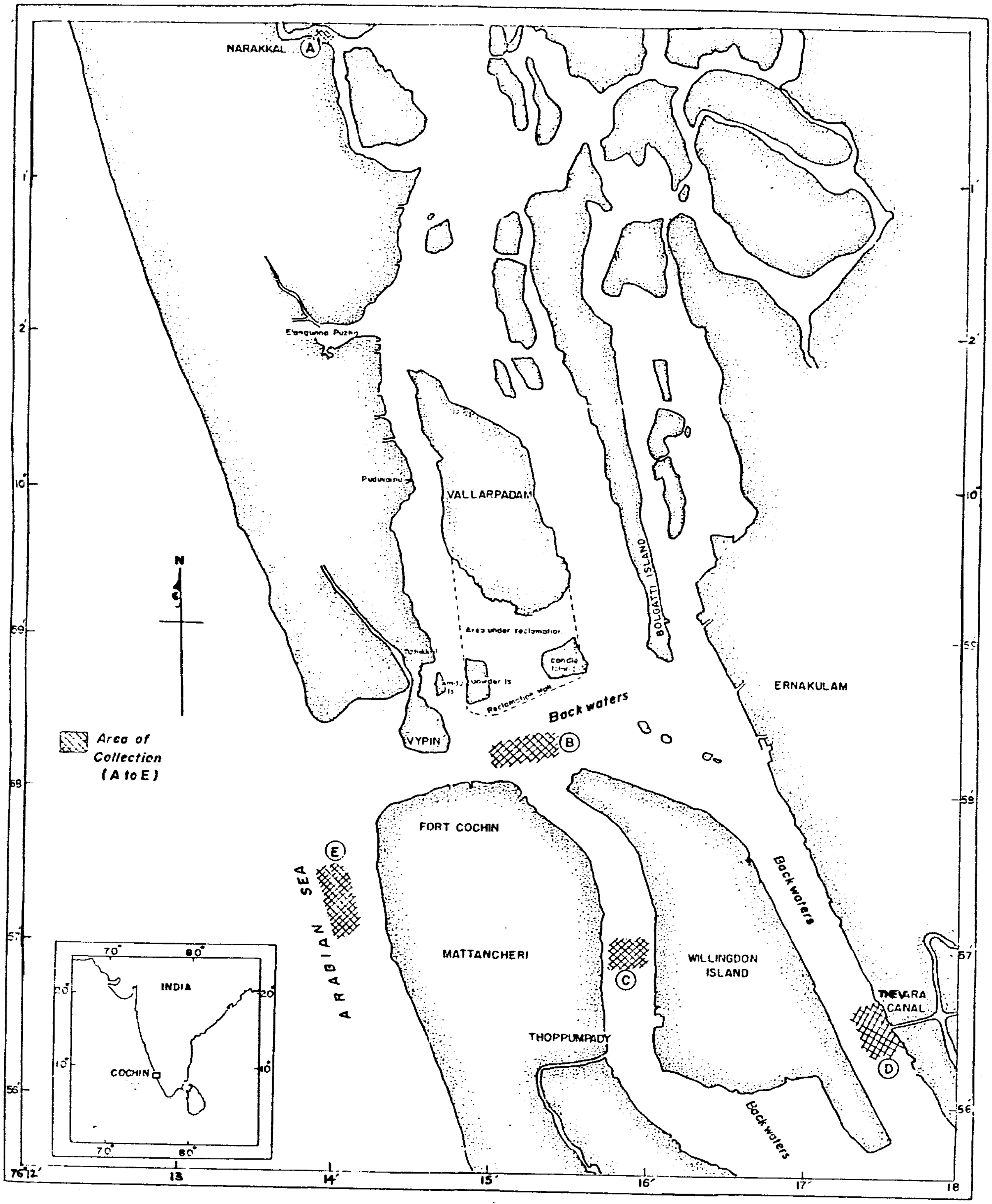
MATERIAL AND METHODS

The work was carried out by the candidate at the Central Marine Fisheries Research Institute, Cochin from 1978 to 1988. Adult males and berried females of Macrobrachium equidens, M. striatus, M. idella, Palaemon (Palaemon) concinnus, Leandrites celebensis, Leptocarpus potamiscus, Caridina longirostris, C. pseudogracilirostris, Alpheus rapacida and A. euphrosyne were collected from Cochin Backwater during July - December, and Hippolysmata (Exhippolysmata) ensirostris from the inshore waters adjoining the Cochin Barmouth (Fig.1). The method of collection, transportation, maintenance of adults in the laboratory and rearing of the larvae were as follows:

Macrobrachium spp.

Different species of Macrobrachium were collected by operating cast net (1.5 cm mesh size) during low tide from the canals of Thevara region of Cochin Backwater (Fig.1 D). Live and healthy specimens of M. equidens, M. striatus and M. idella measuring 50 to 85 mm in total length were picked out from the catch and immediately transferred to 50 l capacity plastic bins with wide mouth containing about 45 l of the water collected from the same locality from where the adults were fished. They were transported to the laboratory in bins (each 50 l bins with 12 to 15 specimens) within 45 minutes. In the laboratory the animals were retained for 12 hours in the same medium to obviate the transportation stress and then carefully transferred to glass aquarium tanks of 60 l capacity containing water of 10 to 12‰ salinity. The water in the container was continuously aerated. In each tank, 3 females and 2 males of size ranging from 70 to 85 mm in total length were placed.

Fig. 1 Cochin Backwater and coastal area of the Arabian Sea where materials for the present study, were collected.



NARAKKAL
A
Elangunna Puzha
Puduvaipu
VALLARPADAM
BOLGATTI ISLAND
N
Area under reclamation
Reclamation wall
VYPIN
Back waters
B
ERNAKULAM
Area of Collection (A to E)
FORT COCHIN
E
ARABIAN SEA
MATTANCHERI
C
WILLINGDON ISLAND
Backwaters
THEVARA CANAL
D
THOPPUMPADY
Backwaters
INDIA
COCHIN
76°12′
13
14′
15′
16′
17′
18

Fig.1

The experimental animals in each of the tanks were fed *ad libitum* with fresh meat of *Metapenaeus dobsoni* and bits of cooked tapioca, once in a day at 1800 hrs. On the following day the left over food and the sediments were removed and 50% of the water was exchanged with freshly filtered water of the same salinity. All the tanks were covered with mosquito net cloth to prevent the animals from jumping out.

Healthy berried females with advanced stage of eggs (recognised by the dull white colour of the egg mass with clearly visible eye spots of the developing embryos) were selected from the stock and individually kept in 60 l containers for hatching of eggs. Aeration was given continuously and the salinity of the medium was maintained between 10 to 15‰. Hatching of eggs took place during night. On the following morning, the zoea I larvae were collected using a glass beaker after stopping the aeration and attracting them towards a source of light provided at a corner outside the tank. These larvae were used for further rearing.

Soon after the complete release of the larvae from the berry, the females were removed to 60 l aquarium tanks. In each tank one female and 2 adult males were kept for observing further maturation of the gonad and the breeding behaviour.

Rearing of larvae

Rearing of the zoeae of *Macrobrachium* spp. were carried out in one litre glass jars as well as in 6 litre glass troughs containing 800 and 5000 ml water respectively. *M. idella* zoeae were reared in 12 to 18‰ salinity and that of *M. equidens* and *M. striatus* in 20 to 25‰. The zoeae I larvae collected from the breeding tanks were counted and transferred to the larval rearing containers using fillers, generally, at the rate of 50 to 80 zoeae/litre. From second day onwards, zoeae were fed ad libitum with freshly hatched Artemia nauplii. From the larval rearing containers, bottom sediments along with exuviae were removed daily. Half of the water from the larval rearing containers were removed and replaced with freshly filtered water of the same salinity. Zoeae were also reared individually in 250 ml beakers to study moulting periodicity. Larvae were daily examined individually to find out whether moulting had taken place. The postlarvae I, as soon as they had metamorphosed from the last zoeal stage, were counted and removed to other containers for further rearing.

Caridina spp.

Berried female specimens of C. longirostris and C. pseudogracilirostris were collected from the canals and ponds around Narakkal (Fig.1 A) area using either tow nets made of organdy cloth (36 strands/cms) or half metre rectangular scoop net of 30 x 20 cms made of mosquito netting. Active and healthy berried females were transported to the laboratory in 5 l plastic containers, in water collected from the same area from where the adults were obtained. The salinity of the surface water at the collection site varied from 6.8 to 18‰. Females with advanced stage berry were sorted out from the collections and maintained individually in one litre or 5 l glass containers. Release of zoeae took place invariably during the early morning hours. After the completion of the hatching process, the mother was removed from the spawning container to another container. It was observed that the mother prawn moulted invariably within 24 hours after releasing the berry. Freshly hatched zoeae were either retained in the same container or removed to another container and stocked at the rate of 130 larvae per container of 5 l capacity having 4 l of brackishwater medium.

In the initial rearing experiments, it was seen that the larvae reared in the medium containing moderate amount of phytoplankton, copepodites and detritus thrived well, while those reared in filtered water devoid of phytoplankton and zooplankton mix and detritus and fed with freshly hatched Artemia nauplii did not survive or develop satisfactorly to the next stage. Therefore throughout the rearing experiments thereafter, care was taken to retain adequate copepodite population in the rearing medium and the detritus at the bottom of the container. Daily one third water from the container was siphoned out using a filter to prevent the escape of copepodites and larvae and replaced with water having the same salinity. Reared thus, the larvae were found to be active and mortality was negligible. Salinity of the rearing medium varied from 6.8 to 10.2‰ in the case of C. longirostris and 15 to 16‰ in the case of C. pseudogracilirostris. Postlarvae were further reared until they metamorphosed to adult stage.

Alpheus spp.

Berried females of A. rapacida and A. euphrosyne in healthy conditions were collected from the stake nets operated at Thoppumpadi region of Cochin Backwater (Fig.1 C) and transported to the laboratory in 5 l plastic containers.

Selected berried specimens were maintained individually in 5 l glass containers, containing 4 l of water. The adults and the larvae were reared in a salinity range of 20 to 25‰. Feeding of adults and larvae and the water management were same as in the case of Macrobrachium spp.

Palaemonid and Hippolytid prawns

Palaemon (Palaemon) concinnus and Leptocarpus potamiscus were collected from the Thevara region (Fig.1 D); Leandrites celebensis from the backwater near the barmouth (Fig.1 B) and Hippolysmata (Exhippolysmata) ensirostris from the inshore waters of the Arabian Sea near Cochin Barmouth (Fig.1 E). The method of collection of all these species, along with their transportation, water management, feeding, rearing of larvae and adult and description of larval stages were given in detail in the published papers by the candidate enclosed in the relevant chapters in this thesis.

Medium: The rearing medium of required salinity for rearing of adults and larvae, were prepared by diluting, sediment free inshore seawater of salinity 30 to 34‰, with chlorine free tap water. After diluting, the medium was well aerated and filtered through 50 micron bolting cloth before using for rearing purpose. However, for rearing caridina larvae the medium was not filtered and was used as such.

Artemia nauplii as food: For obtaining newly hatched Artemia nauplii, 5 to 6 grams of dry cyst of Artemia was kept in one litre beaker containing 45 to 50‰ salinity water. The required quantity of raw common salt was mixed with seawater of 32 to 34‰ salinity to prepare this medium. The water was continuously aerated. Within 48 hours, 80 to 90% of the cyst hatched out into nauplii. Aeration was stopped and the nauplii were attracted to one side of the container using powerful external light. The active nauplii were siphoned out to a small scoop net of 50 micron mesh, thoroughly washed with clear filtered seawater and used for feeding the larvae.

Temperature: No effort was made to control the temperature of the rearing medium. The temperature of the medium varied between 23.0°C to 29.0°C. Daily variations of temperature was within a range of $\pm$ 2.0°C.

The larval history of different species described in the thesis, is based on the complete tracing of the development from hatching out of zoea from the egg of an individual specimen to postlarva/juvenile stage in the laboratory under controlled condition. To confirm the observations made, the rearing experiments were repeated to a minimum of three times and the larval stages were compared. Wherever possible, the larvae were reared upto juveniles and in certain cases upto the adult stage when the prawn attained maturity under captivity.

Preservation, measurement and drawing: For detailed morphological studies the undamaged larvae and postlarvae at different stages were carefully preserved in 5% formaldehyde so that no body structures were lost. The measurements of eggs and larvae were made from preserved materials, using micrometer. The appendages were dissected out immersingin 5% formaldehyde using entomological needles. Drawings were made using camera lucida mounted on a monocular compound microscope. The total length of the zoeae was taken from the tip of rostrum to the tip of telson excluding the terminal spines. The carapace length was measured from the tip of the rostrum to the mid dorsal point of the posterior margin of the carapace.

Terminology: The Indo-Pacific Fisheries Council held at Tokyo in 1955, had suggested that the world 'prawn' could be applied to the penaeids, pandalids and palaemonids and 'shrimps' to the smaller species belonging to the other families. In the present work, the smaller groups belonging to Aytids and Alpheids are also dealt along with palaemonids. Hence, to avoid confusion while using both terminologies 'shrimps' and 'prawns', the term 'prawn' is used instead. This procedure has also been adopted by Kurian and Sebastian (1982).

For the present work all the caridean larval stages were named as zoea I, zoea II, etc. When the pleopods became functional and the larva moved about at the bottom acquiring the shape of an adult prawn it was called postlarva. The term 'intermediate' had been used to designate the stage after last zoea which possessed a combination of zoeal and postlarva I characters.

Zoeal stages were distinguished only when some major changes (such as development of spines as well as the sequence of development of pereiopods or pleopods) were brought about by a moult.

PART ONE

Larval characters, growth and reproductive biology

SECTION ONE

Family Atyidae De Haan, 1849

Genus Caridina H. Milne Edwards 1837

INTRODUCTION

Atyid prawns belonging to the genus Caridina H. Milne Edwards, 1837, are distributed widely in tropical and sub-tropical estuaries, mangrove swamps, freshwater lakes and high land streams. They form an important faunal component of these ecosystems. The larval descriptions of several species of caridina, either by rearing of various stages in the laboratory under controlled conditions or by describing the stages collected from the wild, are now available from different authors. Daday (1907) studied for the first time the larval stages of C. wyckii (Hicks), collected from the lake Victoria and Nyansa. In 1927 Gurney described three larval and two postlarval stages of C. nilotica var. typica Bouvier. This was followed by Shen's (1939) description of five larval stages of C. denticulata de Haan and after a decade by Nair's (1949) excellent work on C. laevis Heller. The period between fifties and sixties did not produce any noteworthy works except that of Babu (1963) on C. propinqua De Man. However, increased interest coinciding with the general trend of enhanced studies on the larvae of commercially important crustaceans and their culture was evident in this group also since 1970, as revealed from the several works published since then. The most important of them are on C. brevirostris Stimpson (Shokita, 1973), C. weberi de Man (Chinnayya, 1974), C. pseudogracilirostris (Pillai, 1975), Caridina sp. (Lakshmi, 1975), C. nilotica aruensis Roux (Glaister, 1976), C. denticulata ishigakiensis Fujino (Shokita, 1976), C. williamsoni, C. kempi, C. shenoyi and C. gurneyi (Jalihal, 1978), C. mccullochi Roux (Benzie, 1982), C. singhalensis Ortmann (Benzie and de Silva, 1983), C. babaulti basrensis Al-Adhub and Hamzah

(Salmen, 1987) and on C. gracilipes and C. prox Shenoy (Kadrekar and Sankolli, 1987). In the present investigation complete larval development of two species of Caridina namely, C. longirostris and C. pseudogracilirostris, inhabiting the Cochin Backwater are presented.

1. Caridina longirostris H. Milne Edwards, 1837

In July 1980, large number of Caridina sp. were found among the submerged grass growing on the bund of a brackishwater pond belonging to the Central Marine Fisheries Research Institute at Narakkal. These prawns were collected by scoop net made of mosquito netting. The collection was composed of a single species which agreed in certain characters with C. nilotica and in certain other characters to C. longirostris. Hence in view of some of the differences noticed, the berried specimen which provided the larvae for the present study and 4 specimens obtained by rearing the eggs through different larval stages to the adult stage were studied to elucidate and compare the taxonomic characters. The specimens were identified as C. longirostris. A brief description of the material is given below.

Caridina longirostris H. Milne Edwards (Fig.2)

Caridina longirostris H. Milne Edwards, 1837 p. 363

Caridina wyckii gracilipes Coutiere, 1900, p. 1267

Caridina nilotica brachydactyla Lenz, 1910 p. 568. Bouvier, 1925, p. 155

Caridina nilotica gracilipes Bouvier, 1925, p. 152

Caridina nilotica brevidactyla J. Roux, 1926, p. 204. 1929, p. 303

Caridina longirostris Holthuis, 1965, p. 20

Caridina longirostris Holthuis, 1969, p. 94

Fig. 2 Caridina longirostris: Adult a. anterior region of carapace showing rostrum, b. pereiopod I, c. pereiopod II, d. pereiopod III, e. pereiopod V, f. egg, g. diaeresis, h. tip of telson.

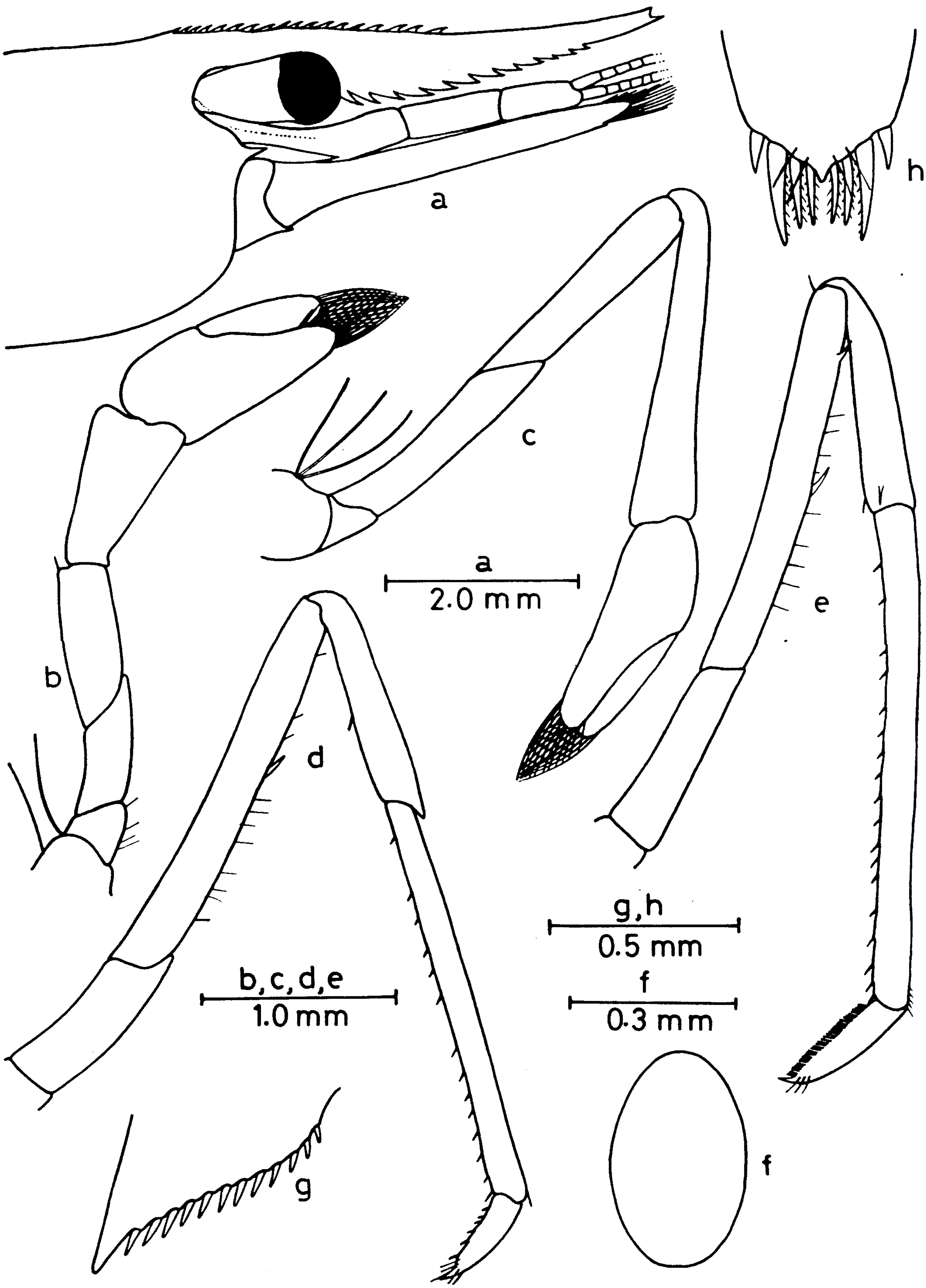


Fig. 2

Rostrum long, extending beyond scaphocerite or reaching atleast as far as scaphocerite, curved upwards distally, bifid at the tip and bears 16-25 teeth on the dorsal side and 11-15 teeth on the ventral side. Lower orbital angle of the carapace very distinct and rounded, antennal spine strong and sharply pointed, pterygostomial angle rounded (Fig.2a).

The ratio between the length and breadth of carpus and chela and between the length of finger and palm of first and second pereiopods are given in Table I. The table also contains the ratio between the length and breadth of propodus and dactylus as well as the ratio between the length of propodus and that of dactylus of pereiopod III and V.

Carpus of first pereiopod (Fig.2b) longer than merus and 1.7 to 1.8 times as long as wide. The ratio between the length of propodus and dactylus is 1.2 to 1.5. Carpus of the second pereiopod (Fig.2c) 3.8 to 5.0 times as long as wide, the ratio of propodus and dactylus 1.3 to 1.9, propodus of third pereiopod (Fig.2d) 4.3 to 5.3 times as long as dactylus (Table 1).

Endopod of first pleopod of male with a well developed appendix interna. Endopod of uropod bears 8 to 15 spinules (Fig.2g) on the diaeresis.

Posterior margin of telson narrow and ends in a median point (Fig.2h). It bears 4 to 5 pairs of spines distally and the outer spine is less than 1/3rd of the length of lateral. Dorsal surface of telson usually with 4 to 5 spines on either side of the mid dorsal line, but in some specimens six spines are also observed.

TABLE - 1

Caridina longirostris : Comparison of measurements of appendages of typical form of *Caridina nilotica* (Roux) from Cairo, Egypt, its varieties and the present material.

	Present material: Berried female used for experiment	Present material: Adult Specimens reared in the laboratory (1)	(2)	(3)	(4)	Range of Measurements of present material	*Caridina nilotica*	*Caridina nilotica* (Roux) var. *Natalensis* nov.	*paucipara* max Weber	*longirostris* H.M.Edwards	*brachydactyla* nov.	*bengalensis* nov.	*gracilipes* de Man	*menahassa* de Man
Total length (mm)*	29.0	17.25	23.3	24.3	23.6	17.25-29.0	17.5-29.0	34.0-39.0	29.0-34.0	14.0-19.0	29.0-33.0	10.0-28.0	27.0-28.5	...
Rostral formula	26+1 / 15	19+1 / 12	18+1 / 9	19+2 / 15	18+1 / 12	18-26+1-2 / 9-15	18-23+1-2 / 11-20	17-20+1 / 14-18	13-19+1 / 12-20	15-21+1 / 12-17	19-26+1-2 / 13-16	17-27+1-3 / 11-17	13-20+1 / 11-17	...
First Pereiopod: Carpus Length / Breadth	1.85	1.73	1.73	1.88	1.74	1.73-1.88	1.80-2.50	2.0-2.2	1.8-2.3	1.50-1.90	2.1-2.5	1.6-2.4	2.0-2.37	1.25-1.71
First Pereiopod: Length of finger / Length of palm	1.21	1.24	1.54	1.5	1.43	1.21-1.54	1.39-1.84	1.31-1.60	1.11-1.65	1.16-2.10	2.0-2.5	1.2-1.75	1.34-1.74	1.2-1.7
First Pereiopod: Length of Chela / Breadth of Chela	2.05	1.69	2.10	1.92	2.04	1.69-2.10	1.90-2.30	2.10-2.20	1.83-2.10	1.80-2.04	2.2-2.56	1.9-2.5	2.0-2.3	1.8-2.0
Second Pereiopod: Carpus Length / Breadth	4.78	5.0	3.80	4.68	4.56	3.80-5.00	4.10-5.00	4.6-5.0	4.63-5.10	3.40-4.70	4.5-6.0	4.2-6.0	5.4-5.5	3.5-4.5
Second Pereiopod: Length of finger / Length of palm	1.68	1.52	1.32	1.48	1.90	1.32-1.90	1.40-2.00	1.6-1.75	1.50-2.10	1.15-2.60	2.2-2.55	1.65-2.1	1.8-2.0	1.4-2.0
Second Pereiopod: Length of Chela / Breadth of Chela	2.45	2.33	2.09	2.6	2.76	2.09-2.76	2.35-2.70	2.5-2.6	2.40-2.66	1.90-2.60	2.5-2.9	2.3-3.1	2.54-2.7	2.0-2.32
Third Pereiopod: Propodus Length / Breadth	13.93	8.92	10.7	9.68	10.7	8.92-13.93	11.0-13.8	13.7-15.0	10.5-14.0	12.0-14.7	13.8-18.2	12.0-15.00	13.8-16.0	13.0-16.0
Third Pereiopod: Length of Propodus / Length of dactylus	5.18	4.29	4.86	5.25	5.2	4.29-5.25	3.3-4.2	4.4-4.6	3.9-4.5	3.40-3.7	5.8-6.2	3.33-4.1	3.84-4.4	3.6-4.20
Third Pereiopod: Dactylus Length / Breadth	3.30	2.57	2.31	2.5	2.69	2.31-3.30	3.5-3.93	3.5-3.7	3.3-3.8	4.0-4.8	2.7-3.5	3.8-4.7	4.2-4.8	4.1-4.9
Third Pereiopod: No.of spines on dactylus inclul-ing terminal	7	7	7	7	8	7-8	7-12	7-9	8-9	7-10	6-7	6-10	9-10	---
Fifth Pereiopod: Propodus Length / Breadth	16.9	13.66	11.25	15.8	14.06	11.25-16.9	12.72-15.0	16.42-18.0	15.0-18.0	14.7-17.1	17.1-20.0	14.0-19.0	17.0-19.0	17.0-19.0
Fifth Pereiopod: Length of Propodus / Length of dactylus	4.35	4.31	4.65	5.04	4.55	4.31-5.04	3.1-3.44	4.1-4.5	3.12-3.5	3.20-3.54	5.4-6.0	2.87-3.35	3.7-3.8	3.3-3.50
Fifth Pereiopod: Dactylus Length / Breadth	5.0	4.2	3.22	4.27	3.64	3.22-5.0	4.0-4.6	4.1-4.4	4.6-6.2	4.6-5.0	3.4-3.8	5.0-5.7	5.0-6.0	5.0-5.50
Fifth Pereiopod: No. of spines of dactylus includ-ing terminal	43	49	44	44	48	39-48	35-46	46-50	62-72	30-39	34-50	40-54	46-57	....

* Tip of rostrum to tip of telson

The size of the adult specimens collected from the wild ranged from 24.5 to 31.3 mm in total length and 8.4 to 12.0 mm carapace length. The four specimens reared from egg to adult ranged from 17.2 to 24.3 mm in total length. The number of eggs in the berry varied from 435 to 1325 and are relatively small and oval (Fig.2 f) measuring 0.35 to 0.45 in greatest length and 0.21 to 0.25 mm in greatest width (Table 2).

REMARKS

A perusal of the literature on the taxonomy of this complex group reveals that the identification of the various species of the genus Caridina is rendered difficult due to the wide variation and inconsistency observed in the rostral formula, relative length and breadth of the different segments of the pereiopods, nature of telson and size of eggs in the berry. In the characters relating to the ratio between length and breadth of carpus of first pereiopod as well as that of propodus of the fifth pereiopod, the present species resembles C. nilotica and its varieties C. nilotica var. pausipara, C. nilotica var. longirostris and C. nilotica var. bengalensis described by de Man (1908). However, in the ratio between length of propodus/length of dactylus as well as length/breadth of dactylus of third pereiopod, the present specimens showed variations when compared with those of C. nilotica, C. nilotica var. paucipara, C. nilotica var. longirostris and C. nilotica var. bengalensis. Again differences in the ratio between length/breadth of dactylus of fifth pereiopod were also noticed when the present specimen was compared with the above ones. Another important character employed by de Man (1908) to distinguish the different varieties of C. nilotica was the size of eggs in

Table 2. Caridina longirostris: Details of measurements of berried females.

Carapace length (mm)		Total length with rostrum (mm)	Rostral formula	Number of eggs on the pleopods	Egg measurements			
Without rostrum	With rostrum				Longest (mm)	Mean (mm)	Shortest (mm)	Mean (mm)
4.5	9.5	26.2	$\frac{19+2}{14}$	435	0.38 0.42	0.39	0.21 0.25	0.24
4.8	9.6	27.7	$\frac{20+1}{13}$	927	0.34 0.45	0.41	0.21 0.24	0.22
4.7	9.7	27.2	$\frac{19+1}{15}$	670	0.35 0.42	0.39	0.22 0.25	0.24
6.0	12.0	31.3	$\frac{25+2}{15}$	1325	0.35 0.39	0.38	0.21 0.24	0.22
4.2	8.4	24.5	$\frac{20+2}{14}$	510	0.35 0.41	0.39	0.21 0.24	0.22
			(Range)					
4.2 6.0	8.4 12.0	24.5 31.3	$\frac{19-25+1-2}{13-15}$	435 1325	0.35 0.45	0.38 0.41	0.21 0.25	0.22 0.24

the berry. The smaller egg size of the present species (0.35 - 0.45 x 0.21 - 0.25 mm) as compared to that of the C. nilotica (Roux) (0.70 - 0.86 mm) and C. nilotica var. paucipara (0.96 - 1.06 mm) clearly distinguishes it from these varieties. The egg measurements of C. nilotica var. longirostris were 0.33 - 0.39 x 0.21 - 0.26 mm and that of C. nilotica var. bengalensis 0.42 - 0.49 x 0.28 - 0.30 mm. In this respect, particularly in the breadth of the egg, the material at hand resembles C. nilotica var. longirostris. Thus it is seen that among the different varieties of C. nilotica the present specimen comes closer to C. nilotica var. longirostris, but differs from it in the ratio between length of propodus and length of dactylus of third and fifth pereiopods and length and breadth of dactylus of third pereiopod.

Holthuis (1965) described C. longirostris as a distinct species based on the material from Madagascar. In the characters such as size, rostral shape and spination, presence of well developed appendix interna on the endopod of first pereiopod of males, number of spines on the diaeresis, egg measurements, presence of pre-anal carina and the presence of a median point at the posterior margin of the telson, the present material agrees closely with C. longirostris. The point of difference from this species relates mainly to the ratio between propodus and dactylus of third and fifth pereiopod. Holthuis (1969) comparing and discussing the Caridina species from New Calidonia, noted similar differences in the measurements of walking legs, but finally assigned the Calidonian material to C. longirostris with some reservation stating that the Calidonian material agreed in most of the characters with those of Madagascar described earlier (Holthuis, 1965).

Comparing C. longirostris from Madagascar and New Calidonia he noted the range of ratio of measurements of walking leg of the latter was wider. Thus the carpus of first pereiopod was 1.7 to 3.0 times as long as wide and that of second pereiopod 4.3 to 6.0 times. Propodus of third leg 4.5 to 5.5 times as long as dactylus and that of the fifth leg 3.7 to 5.0 times. These measurements on pereiopods agree well with the present material. Holthuis (1969) had also compared C. longirostris from Calidonia with the descriptions given by J. Roux (1926) on three varieties of C. nilotica viz., C. nilotica gracilipes, C. nilotica brevidactyla and C. nilotica meridionalis from Calidonia. While discussing he stated that the "characters show so much variation and the differences between the varieties are of such a minor nature and overlap so considerably, that I do not think the separation of these varieties justified". He further stated that the characters based on the relative size of various segments of the legs are not as valuable as Bouvier and J. Roux seemed to think. The same argument holds good in the case of the varieties of C. nilotica described by de Man (1908) as the characters overlap and the wide variation make it difficult to separate them to distinct species. As the present material confirms with the descriptions of C. longirostris provided by Holthuis (1965, 1969) they are assigned to this species and its larval development studied and presented below. Although the distribution of C. longirostris is rather wide in the Indo-West Pacific (Madagascar and New Caledonia, Holthuis, 1969), it has not so far been recorded from India.

REARING OF LARVAE

Methods of larval rearing, water management, feeding of larvae and so on are given in the chapter dealing with Material and Methods. In the development of larvae, distinct morphological changes at each moult were noticed which were hence considered as a stage. Thus eight distinct zoeal stages and one intermediate stage were recognised during the development of first zoeae to first postlarvae. The salient features of each of these stages are given in Table 3. The ambient temperature of the water during the experiment varied from 23 to 28°C.

The postlarvae were further reared to a period of 173 days. By this time they had metamorphosed to the adult stage. The postlarvae /juveniles were examined every day to understand the major developmental changes. They were found to feed on detritus mainly from the bottom.

DESCRIPTION OF LARVAL STAGES

Zoea I (Fig. 3)

Number of larvae examined : 10

Total length : 1.23 to 1.36 mm. Carapace length : 0.38 to 0.42 mm.

A typical first stage caridean larva with large sessile eyes. Rostrum slender, unarmed, reaching upto the tip of antennular peduncle. Carapace smooth and its anterolateral angle produced to form a small pterygostomial spine (Fig. 3 a). Abdomen 6 segmented, sixth segment joins the broadly triangular telson without an intervening articulation.

Fig. 3 Caridina longirostris: Zoea I a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. first maxilliped, h. second maxilliped, i. third maxilliped, j. telson.

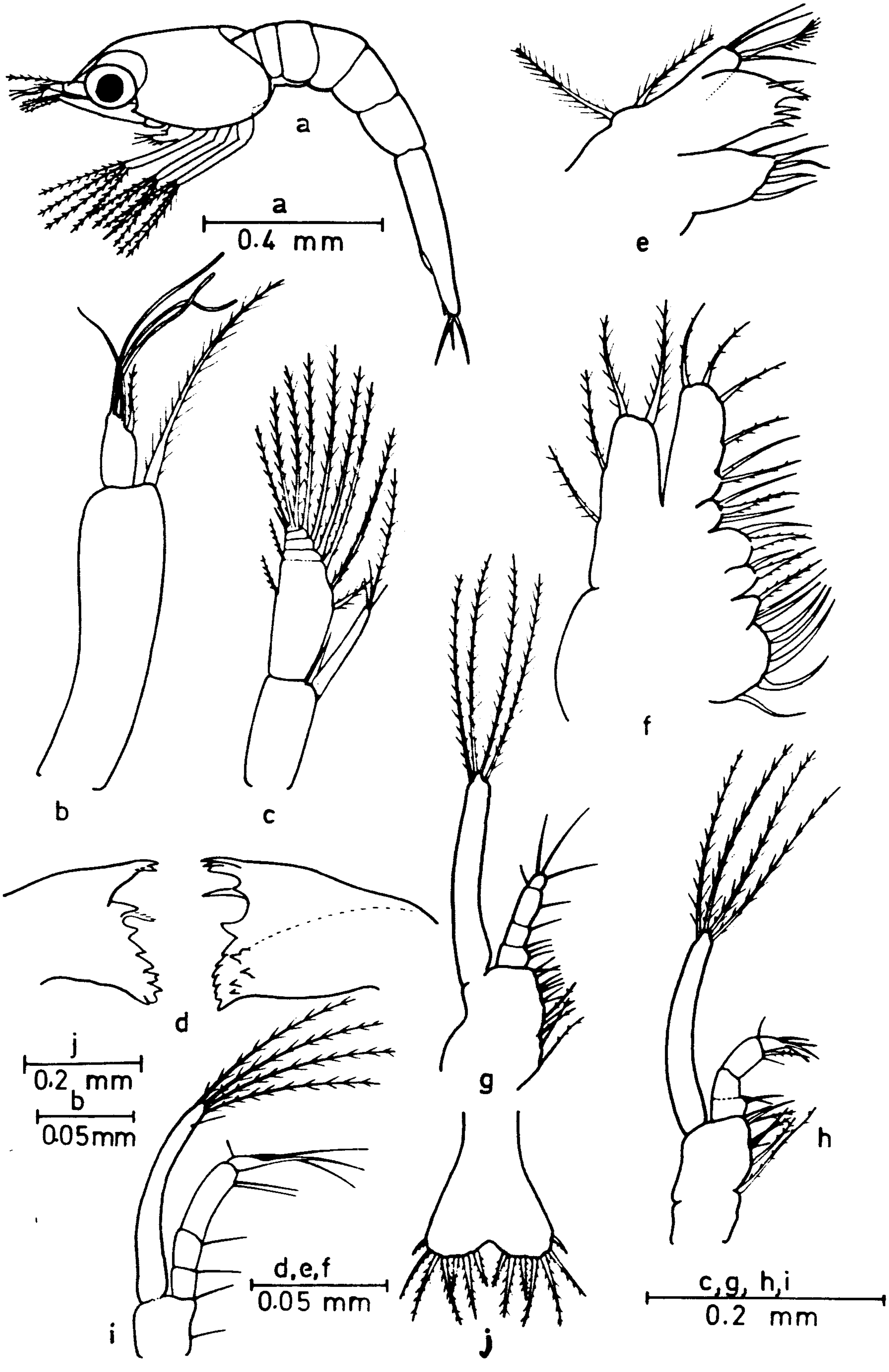


Fig. 3

Table 3. Caridina longirostris: Salient features of the different larval stages reared in the laboratory.

Larval stage	Carapace length (mm) Range (Mean)	Total length (mm) Range (Mean)	Salient feature
Zoea I	0.30-0.42 (0.398)	1.23-1.36 (1.273)	Eyes sessile. Pterygostomial spine present. Antennular peduncle unsegmented. Antennule, antenna, mandible, maxillule, maxilla and all maxilipeds developed. Telson with 7+7 spines and not demarcated from the last abdominal segment.
Zoea II	0.44-0.49 (0.458)	1.48-1.54 (1.505)	Eyes stalked. Rostrum smooth. Antennular peduncle 2-segmented. Biramous bud of first and second pereiopods developed. Telson with 8+8 spines.
Zoea III	0.52-0.56 (0.545)	1.65-1.85 (1.736)	Antennular peduncle 3-segmented; first periopod developed. Biramous bud of second pereiopod present. Telson clearly demarcated from the last abdominal segment. Uropod developed. Endopod without setae.
Zoea IV	0.56-0.59 (0.574)	1.88-2.02 (1.963)	Second pereiopod developed. Biramous bud of third and fourth pereiopods developed. Endopod of uropod with setae.
Zoea V	0.63-0.70 (0.659)	2.09-2.34 (2.237)	A small antennal spine developed. Third periopod developed. Fifth pereiopod developed only as a bud. Uniramous buds of pleopods developed.
Zoea VI	0.62-0.67 (0.638)	2.30-2.44 (2.354)	Rostrum smooth, but a small knob-like papilla developed at its base. Pterygostomial and antennal spines well developed. Fourth pereiopod developed. Fifth pereiopod present as a biramous bud. Pleopod buds biramous.
Zoea VII	0.77-0.87 (0.825)	2.72-3.04 (2.916)	Rostrum with one to two dorsal teeth. Fifth pereiopod well developed. Pleopods biramous bearing short non-plumose setae and non-functional. Telson narrower toward the distal end and convex posteriorly.

Table 3. (Contd...)

Larval stage	Carapace length (mm) Range (Mean)	Total length (mm) Range (Mean)	Salient feature
Zoea VIII	0.81-0.99 (0.889)	2.91-3.30 (3.093)	Rostrum with two to three dorsal spines. Pleopods with plumose setae. 2nd to 5th endopod of pleopods bearing appendix interna.
Intermediate	0.91-1.01 (0.956)	2.67-3.25 (3.037)	Rostrum with 4 to 5 dorsal teeth. Antennal flagellum longer than scale. Pleopods functional.
Postlarva I	1.72-1.75 (1.740)	4.72-4.91 (4.835)	Rostrum with 6 to 8 dorsal and 2-4 ventral teeth. Exopod of pereiopods absent or rudimentary and non-functional.

Antennule (Fig. 3 b): Uniramous. Peduncle long, unsegmented, carrying 2 flagella distally. Inner flagellum is in the form of a long plumose seta. Outer flagellum bears 3 aesthetes and 2 setae distally; of the 2 setae, one is slender ,long, non-plumose and the other stout and plumose.

Antenna (Fig. 3 c): Biramous. Peduncle short, unsegmented bearing a scale (exopod) and a flagellum (endopod) and has a long spine at its base. Flagellum unsegmented, reaching more than half the length of the scale and carries distally one long plumose seta and 3 short non-plumose setae. Scale with 4 distal segments and bears 10 setae along its inner and distal margin and 2 short plumose setae at its outer margin.

Mandible (Fig. 3 d): Asymmetrical, without palps. Incisor and molar processes differentiated. Incisor process carries 2-3 teeth and molar process of both sides with a number of short stout teeth and with rough cutting edges. The 2 processes are separated by a shallow depression which bears 2 teeth of which one is slender and serrated.

Maxillule (Fig. 3 e): Biramous. Protopod unsegmented with 2 endites. Distal endite (basal) with 5 short stout teeth of which one is serrated. Proximal endite (coxal) with 5 long setae. Palp (endopod) unsegmented bearing 4 apical setae of which 3 are long and slender, one stout with bristle-like setae distally and shows a characteristic tilt at its distal end. Exopod is small carrying 2 long plumose setae.

Maxilla (Fig. 3 f): Biramous. Protopod unsegmented with 4 endites, 2 basal and 2 coxal. Proximal coxal endite with 6 setae while others with

2 setae each. Some of the setae are plumose. Endopod unsegmented and reaches a little beyond the exopod. It has 2 lobes on the inner side, each with 3 and 2 setae respectively. Distally it bears 3 apical and one sub-apical setae. Exopod broad, flat (scaphognathite) with 4 long plumose setae along its margin.

First maxilliped (Fig. 3 g): Biramous. Coxa with 2-3 long plumose setae. Basis broad ,bearing 9-10 setae. Exopod longer than endopod carrying distally 4 long plumose setae. Endopod 4-segmented, distal segment with 4 setae, proximal with 3 and other segments each with one seta respectively.

Second maxilliped (Fig. 3 h): Biramous. Coxa with one plumose seta and basis with 7-8 setae. Exopod longer than endopod bearing distally 4 long plumose setae. Endopod 4-segmented. Distal segment with 4 setae along the apical and sub-apical region, one small seta present at the outer proximal margin. Third segment carried 2 long setae of which one is plumose along the inner proximal margin. First segment bearing 2 setae on the inner distal margin.

Third maxilliped (Fig. 3 i): Biramous. Protopod with 2 slender setae on the inner side. Exopod bearing 4 long plumose setae distally and one short seta sub-apically. Endopod 4-segmented, distal segment bearing 4 setae, of which one is very short; first, second and third segments with 1, 1 and 2 setae respectively along the inner margin.

Telson (Fig. 3 j): Broadly triangular with a median notch on the posterior margin dividing telson into two symmetrical lobes. Each lobe carries 7 plumose setae of which the first two setae plumose only on the inner side.

Zoea II (Fig. 4)

Number of larvae examined: 10

Total length: 1.48 - 1.54 mm. Carapace length: 0.44 - 0.49 mm.

Eyes stalked. Rostrum smooth and extends beyond the second segment of the antennular peduncle (Fig. 4 a). Pterygostomial spine present. Biramous buds of first and second pereiopods developed.

Antennule (Fig. 4 b): Peduncle 2-segmented. Anterodorsal surface of the distal segment with a small prominence (antennular lobe) carrying 2 short plumose setae. Inner flagellum seen as a small lobe with a long plumose seta. Outer flagellum bears 4 long aesthetes and one short slender seta.

Antenna (Fig.4 c): Flagellum only half the length of scale carrying one long plumose seta and another short seta at its distal end. Scale and protopod same as in the previous stage.

Mandible (Fig. 4 d): Incisor with 3-4 teeth. In between incisor and molar processes, 2-3 serrated teeth present.

Maxillule (Fig. 4 e): Distal endite of protopod with 6-7 teeth.

Maxilla (Fig. 4 f): Coxal endite with 7+3 setae and basal endite with 3-5 setae. Exopod has 5 long plumose setae.

First maxilliped (Fig. 4 g): Few setae along the inner margin of protopod longer.

Second maxilliped (Fig. 4 h): Endopod has become 5-segmented.

Third maxilliped (Fig. 4 i): Protopod with 3 long slender setae along the inner margin. Endopod 5-segmented.

Pereiopods (Fig. 4 j): First and second pereiopods developed as biramous buds, of which the second is smaller.

Telson (Fig. 4 k): Each lobe of the telson with 8 setae. Outermost seta plumose on the inner side only. Other setae plumose on both the sides. Developing uropod can be seen clearly demarcated in the telson of advanced zoea II.

Zoea III (Fig. 5)

Number of larvae examined : 10

Total length : 1.65 - 1.85 mm. Carapace length : 0.52 - 0.56 mm.

Rostrum smooth and carapace same as in the previous stage (Fig. 5 a). Antennular peduncle 3-segmented. First pereiopod developed. Biramous buds of second pereiopod further developed. Telson separated from the sixth abdominal segment by an articulating joint and uropod developed.

Antennule (Fig. 5 b): Peduncle 3-segmented. Basal segment broad proximally indicating the region of developing stylocerite. Second and third segments almost similar in size and second segment with 2 plumose setae, of which the inner one longer. Third segment carries distally 2 small plumose setae on the dorsal and 2 long plumose setae on the ventral side. The falgella are well developed. Outer flagellum with one long aesthetes and one slender seta and inner flagellum with one long seta.

Fig. 5 Caridina longirostris: Zoea III a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. first maxilliped, h. second maxilliped, i. third maxilliped, j. first pereiopod, k. telson and uropod.

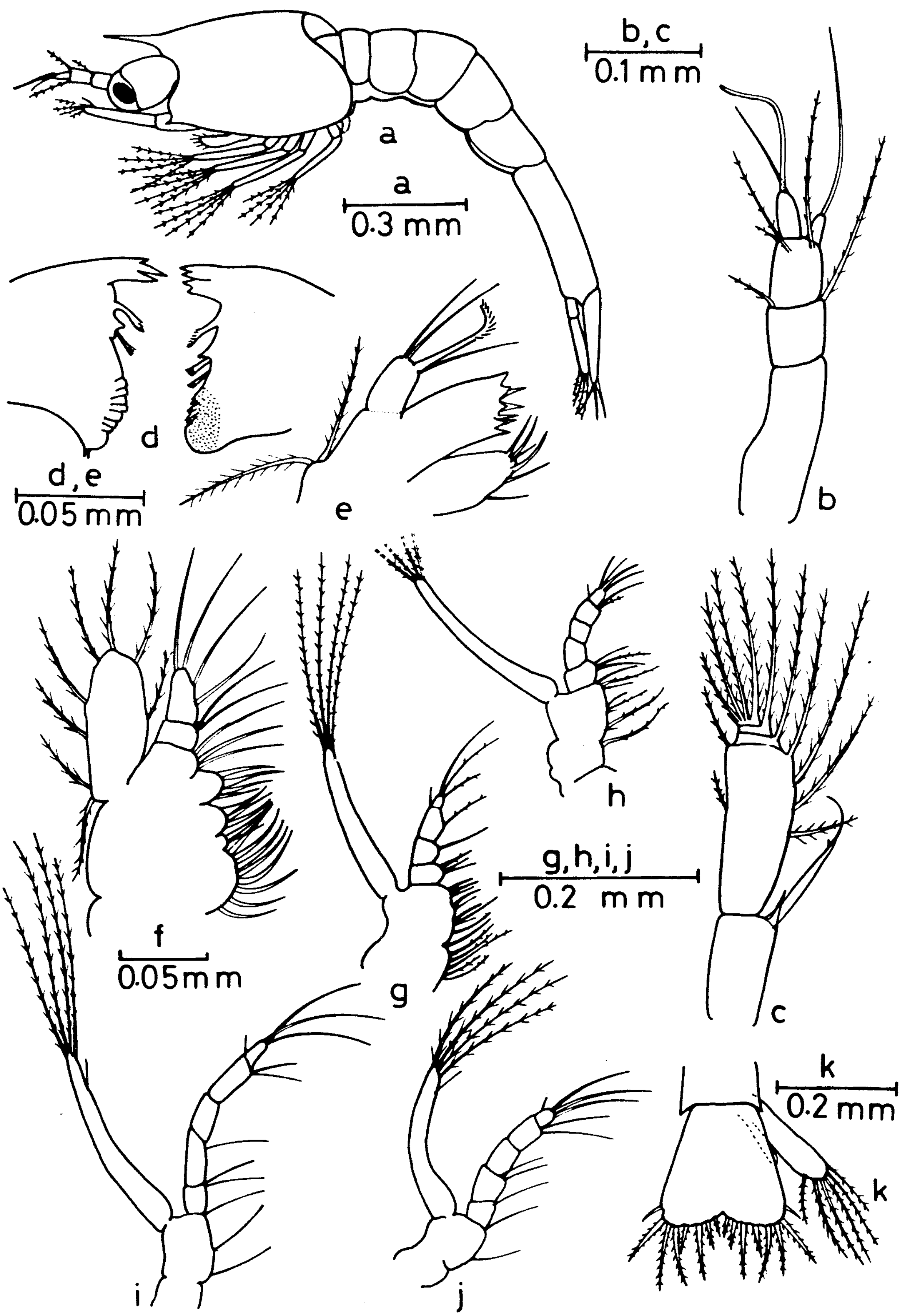


Fig. 5

Antenna (Fig. 5 c): Scale distally segmented and carried 11 setae along its inner and distal margin, of which the distolateral seta on the outer margin small and spine like.

Mandibles: Same as in the previous stage in most of the characters (Fig. 5 d).

Maxillule (Fig. 5 e): Distal endite with 8-9 stout teeth. Exopod with 2 plumose setae.

Maxilla (Fig. 5 f): Exopod bearing 8 long plumose setae along its margin.

First maxilliped (Fig. 5 g) and second maxilliped (Fig. 5 h): Same as in the previous stage in most of the characters.

Third maxilliped (Fig. 5 i): Protopod bearing 3 long slender setae on the inner side. First segment of endopod with 2 long slender setae at the distal inner margin.

First pereiopod (Fig. 5 j): Biramous. Protopod with 2 setae at the inner margin. Exopod as long as endopod bearing distally 4 long plumose setae and one sub-apical seta. Endopod 5-segmented, distal segment with 3 long setae and one short seta. Second and fourth segments carry 2 long setae at the distal inner margin. First segment bearing one seta on the distal margin.

Uropod (Fig. 5 k): Biramous. Endopod bare and exopod with 6 plumose setae.

Telson (Fig. 5 k): Each of the lobe with 7 setae and one distolateral spine. Setae are plumose. The median notch has become shallow.

Zoea IV (Fig. 6)

Number of larvae examined : 10

Total length: 1.88 - 2.02 mm. Carapace length : 0.56 - 0.59 mm.

Rostrum smooth (Fig. 6 a). Second pereiopod fully developed. Biramous buds of third and fourth pereiopods developed. Telson longer and narrower than that of the previous stage. Endopod of uropod with setae (Fig. 6 h).

Antennule (Fig. 6 b): Stylocerite not developed although the proximal segment of the peduncle slightly bulged bearing a short plumose seta. A stout spine present on the ventral side of this segment. Distal region of the first and second segments with 2 setae each. Inner flagellum same as in the previous stage and outer flagellum with 2 aesthetes and one long slender non-plumose seta.

Antenna (Fig. 6 c): Segmented nature of the scale observed in the previous stages is lost and it carries 13 plumose setae and one distolateral spine at the outer margin. Endopod about 2/3rd of exopod bearing apically one sigmoid non-plumose seta.

Mandible: Incisor of the right mandible with 4 stout teeth and 2 serrated long teeth. Molar process with a series of rough cutting edges. In between the 2 processes, are present 1-2 stout and 2-4 slender teeth of which some are serrated.

Fig. 6 *Caridina longirostris*: Zoea IV a. lateral view, b. antennule, c. antenna, d. maxilla, e. first maxilliped, f. first pereiopod, g. second pereiopod, h. uropod, i. telson

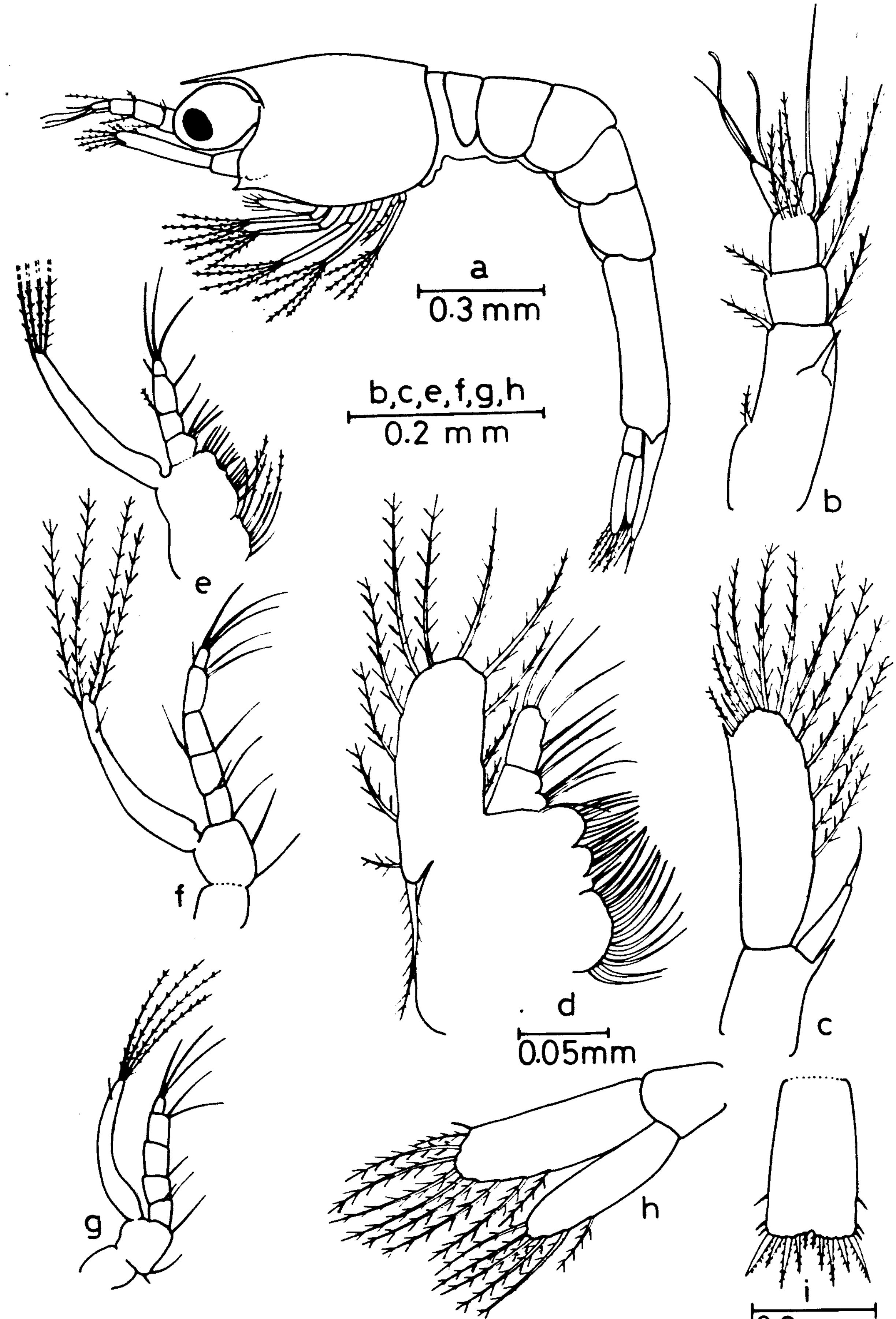


Fig. 6

Maxillule: Exopod present on the previous three stages is absent. Endopod same as in the previous stage except that one of the slender seta plumose distally. Distal endite with 7-9 stout teeth and proximal endite with 6-7 long setae.

Maxilla (Fig. 6 d): Number of setae on the endite of protopod increased. Exopod with 12 long plumose setae. A short proximal projection bearing one plumose seta developed at the proximal outer part of the scaphognathite.

First maxilliped (Fig. 6 e): Proximal segment of protopod with 7-8 long setae of which some are plumose. Basis with 14 setae. Endopod 4-segmented, second segment bearing one plumose seta at the distal outer margin. Distal segment with 3 long setae and one small sub-apical seta.

Second pereiopod (Fig. 6 g): Basis of protopod with 2-3 setae. Endopod 5-segmented with 3 long setae apically. First and fourth segments bear 2 setae at the distal inner margin, while the second segment has one seta on the inner distal margin. Exopod as long as the endopod bearing 4 long plumose setae apically and one short seta subapically.

Uropod (Fig. 6 h): Exopod with 9-10 plumose setae and one short spine. Endopod with 6 plumose setae.

Telson (Fig. 6 i): Longer and narrower, and the median notch shallower than in the previous stage; each lobe with 5 setae of which the outer most one plumose only on the inner side. 3 short spines on either side of the telson at the distolateral margin present. Thus each lobe has 5 setae and 3 spines.

<u>Zoea V</u> (Fig. 7)

Number of larvae examined: 10

Total length: 2.09 - 2.34 mm. Carapace length: 0.63 - 0.70 mm.

Rostrum smooth, carapace with a pterygostomial and small antennal spine (Fig. 7 a). Third pereiopod developed. Fourth pereiopod is developed in some and in others fourth and fifth remain as biramous buds. Uniramous buds of pleopods developed. Telson triangular.

Antennule (Fig. 7 b): Peduncle 3-segmented, proximal segment has a broad stylocerite with 2 short plumose setae. Antennular lobe of third segment with short plumose setae and the same segment on the ventral side carries 4 long plumose setae. Inner flagellum as long as the outer, carrying a long slender seta; outer flagellum with 2 aesthetes and 2 long slender setae.

Antenna (Fig. 7 c): Scale with 15 plumose setae and one spine. Flagellum unsegmented less than half the length of scale bearing a short sickle shaped seta at its apex.

Mandible (Fig. 7 d): Incisor with 4 teeth and molar with a number of short teeth and rough cutting edges. In between the two processes 2-4 serrated teeth present.

Maxillule (Fig. 7 e): Basal endite of protopod with 9 teeth and coxa with 7-8 setae. Endopod same as in the previous stage.

Fig. 7 Caridina longirostris: Zoea V a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. first pereiopod, h. second pereiopod, i. third pereiopod, j. biramous buds of fourth and fifth pereiopods, k. uropod, l. telson

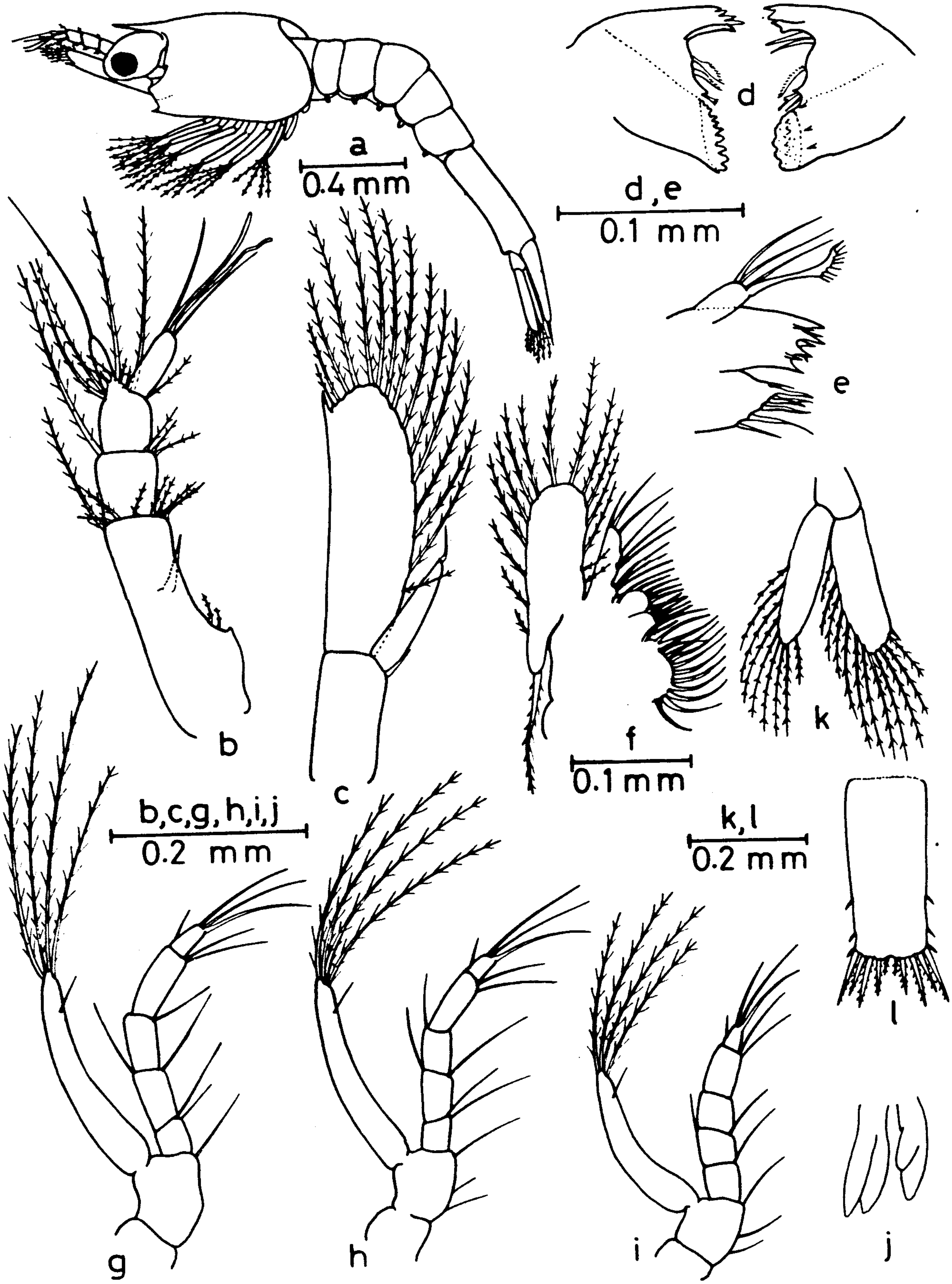


Fig.7

Maxilla (Fig. 7 f): Distal 2 endites of protopod bearing 5-7 setae. Third endite carries 2-3 setae and proximal endite with 10-13 plumose setae. Some of the setae have a segmented appearance. Exopod with 16-17 plumose setae.

First maxilliped: Proximal endite of protopod with 5-6 long setae of which a few are plumose. Distal endite with 14-15 setae. Endopod 4-segmented; first and fourth segments bearing 3 setae each and the other 2 with one seta on the inner side. In addition second and fourth segments also carry one seta at its outer margin. Exopod with 4 long plumose setae apically.

Second maxilliped: Coxa and basis with 2 and 8-10 setae on the inner margin. Endopod 5-segmented. Exopod longer than endopod, bearing distally 4 long plumose setae and one short sub-apical seta.

Third maxilliped: Protopod with 3 long slender setae at its inner margin. Endopod 5-segmented, distal segment with 3 long setae, first, second and fourth segments carrying 2, 1 and 2 setae respectively on the inner side; in addition second segment has a long seta on the outer margin also. Exopod long, bearing 4 long setae one short sub-apical seta distally.

First and second pereiopod (Fig. 7 g, h): Almost identical. Protopod with 1-3 setae on the inner margin. Endopod 5-segmented; first and fourth segments bearing 2 long slender setae on the distal inner margin while second segment bearing one seta on the distal inner margin. In addition, second segment bears a long slender seta on the distal outer margin. Exopod shorter than endopod and with 4 long plumose setae apically and a short seta sub-apically.

Third pereiopod (Fig. 7 i): Protopod with 3 slender setae along the inner margin. Endopod 5-segmented, first, second and fourth segments carrying 1, 2 and 2 setae respectively. Distal segment with 3 setae at its apex and a short seta sub-apically. Exopod shorter than endopod bearing distally 4 long plumose setae.

Fourth pereiopod (Fig. 7 j): Usually not fully developed and seen only as a biramous bud.

Fifth pereiopod (Fig. 7 j): Developed only as a small biramous bud of which one ramus is much shorter than the other.

Uropod (Fig. 7 k): Exopod with 12 plumose setae and one non-plumose seta. Endopod with 9 plumose setae.

Telson (Fig. 7 l): Almost rectangular, the median depression at the posterior boarder much reduced and each lobe carries 5 plumose setae of which the outer one being plumose only on the inner side. In addition disto-lateral margin of the telson bears on each side 3 spines also.

Zoea VI (Fig. 8)

Number of larvae examined : 10

Total length: 2.30 to 2.44 mm. Carapace length: 0.62 to 0.67 mm.

Rostrum smooth and slender and a small dorsal tubercle developed on the carapace at the base of rostrum (Fig. 8 a). Pterygostomial and antennal spines well developed. Fourth pereiopod well developed. Pleopod buds biramous.

Fig. 8 *Caridina longirostris:* Zoea VI a. lateral view, b. antennule, c. antenna, d. maxillule, e. maxilla, f. first maxilliped, g. second maxilliped, h. third maxilliped, i. first pereiopod, j. third pereiopod, k. fourth pereiopod, l. uropod, m. telson

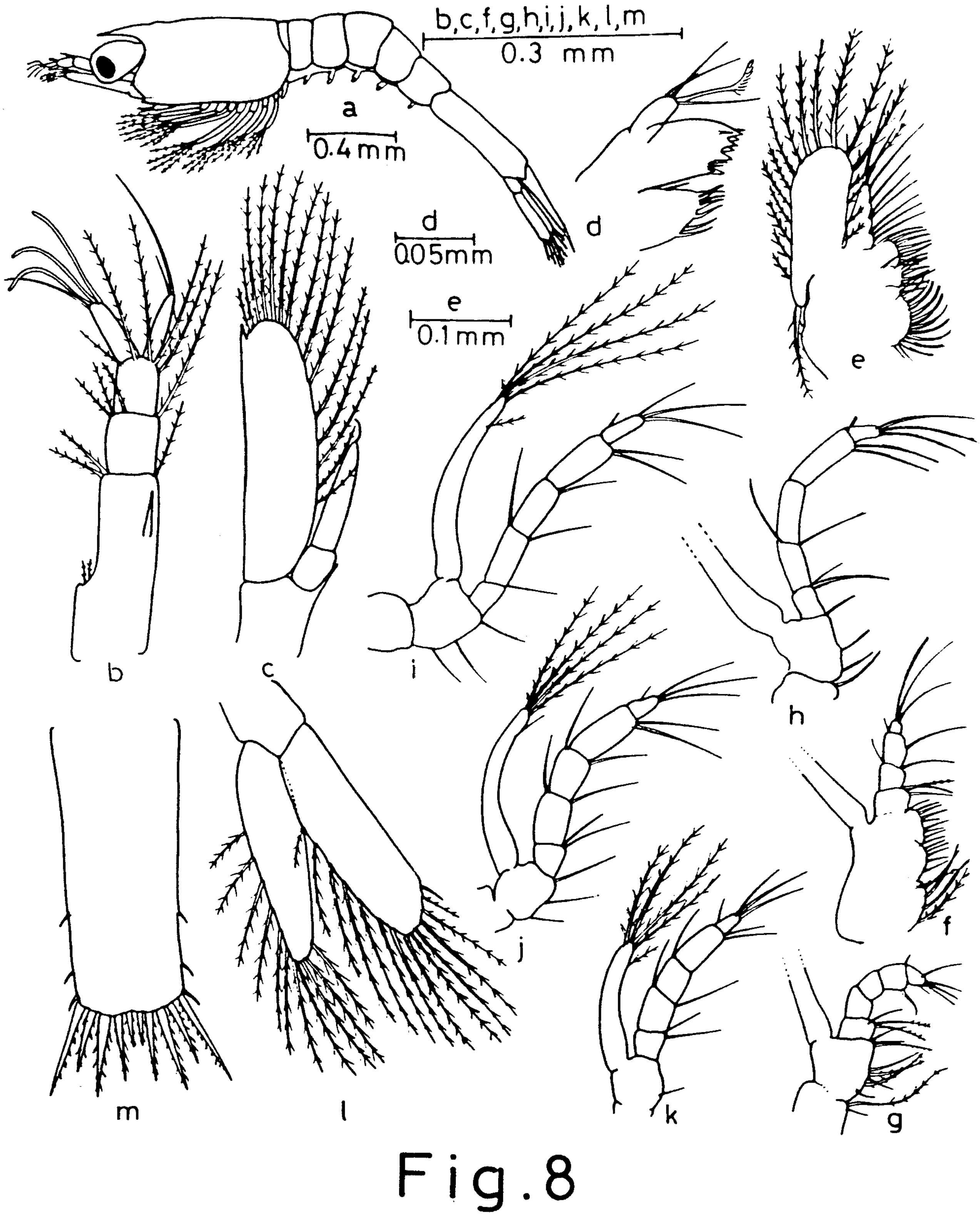


Fig.8

Antennule (Fig. 8 b): Distal segment bears 5 long plumose setae along the ventral side anteriorly. Inner flagellum with 2 setae of which one is long and slender. Outer flagellum carries 3 aesthetes and one long slender seta.

Antenna (Fig. 8 c): Exopod narrower than that of the previous stage and endopod segmented.

Mandible: No major changes from those of previous stage.

Maxillule (Fig. 8 d): Basal endite with 10 - 11 teeth and coxa with 8 - 9 setae.

Maxilla (Fig. 8 e): Exopod carries 18 setae.

Maxillipeds (Fig. 8 f, g, h), first and second pereiopods (Fig. 8 i): No major changes from those of the previous stage.

Third (Fig. 8 j) and fourth pereiopod (Fig. 8 k): Almost identical. Endopod 5 segmented. Distal segment with 3 long setae. First and fourth segments carry 2 slender long setae along the distal inner margin and second segment carries 2 setae at its distal margin. Exopod shorter than the endopod bearing 4 long plumose apical setae and one short subapical seta.

Fifth pereiopod: Not fully developed and remains as a biramous bud.

Pleopods (Fig. 8 a): Developed as biramous buds which are non-plumose.

Uropod (Fig. 8 l): Exopod with 13 plumose setae and one non-plumose seta. Endopod with 10-11 plumose setae.

Fig. 9 *Caridina longirostris*: Zoea VII a. lateral view, b. antennule, c. antenna, d. maxillule, e. maxilla, f. first maxilliped, g. second maxilliped, h. first pereiopod, i. third pereiopod, j. fifth pereiopod, k. first pleopod, l. second pleopod, m. uropod, n. telson.

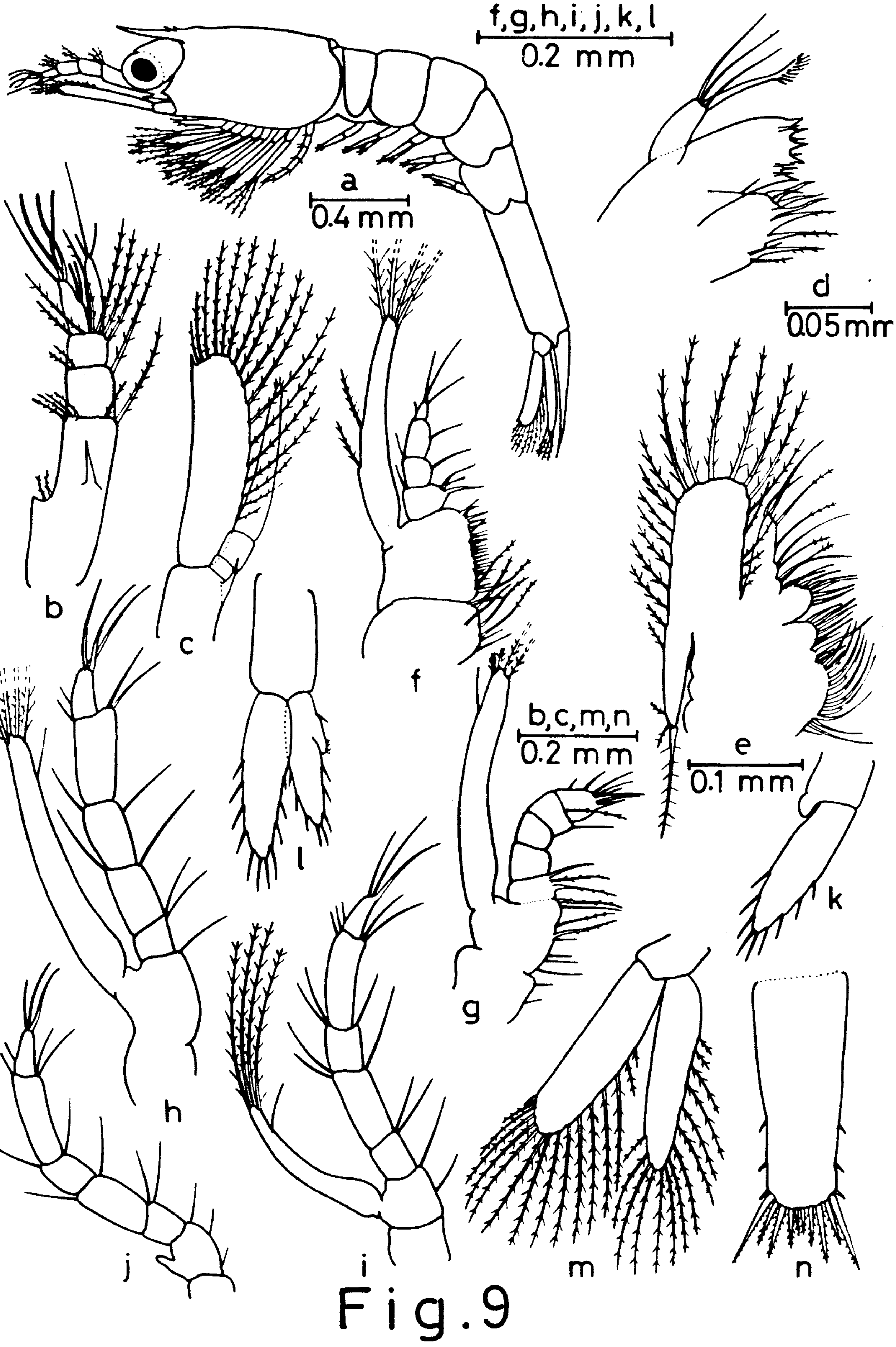


Fig. 9

Telson (Fig. 8 m): No major changes when compared with the same of the previous stage.

Zoea VII (Fig. 9)

Number of larvae examined : 10

Total length: 2.72 to 3.04 mm. Carapace length: 0.77 to 0.87 mm.

Rostrum with 1 - 2 dorsal teeth (Fig. 9 a). Fifth pereiopod well developed. Pleopods biramous, but non-functional, bearing short non-plumose setae. Telson narrower towards the distal end and convex posteriorly.

Antennule (Fig. 9 b): Number of short plumose setae along the anterior margin of first and second segments increased. Distal segment carries ventrally 6 long plumose setae. Inner flagellum longer than outer, indistinctly segmented carrying one long and 2 short slender setae distally and outer flagellum with one long seta and 5 aesthetes in 2 rows of 3 and 2.

Antenna (Fig. 9 c): Scale with 16 - 17 long plumose setae and one spine. Flagellum 3 - 4 segmented bearing at its apex 3-4 short setae.

Maxillule (Fig. 9 d): Coxal endite has become more broader bearing 10 - 11 setae of which some are plumose.

Maxilla (Fig. 9 e): Number of setae on the endite increased. Exopod with 23 - 24 plumose setae and its posterior lobe elongated.

First maxilliped (Fig. 9 f): Coxa and basis more flattened and the number of setae on the inner margin of basis increased. Coxa bears 7 - 8 setae and basis 22 - 24 setae . Exopod with 4 long plumose setae at the distal end and 2 short plumose setae at the outer middle region.

Second maxilliped (Fig. 9 g): Endopod has become slightly expanded and the number of setae at the distal segment increased.

Third maxilliped: Coxa and basis with 2 - 3 slender long setae on the inner side. Fourth segment of endopod bearing 2 short bristle-like setae on the outer distal margin and 2 long setae at the inner distal margin.

First and second pereiopod (Fig. 9 h): Almost identical. Propodus of endopod slightly stouter and developing chela seen as a projection bearing 2 long setae at its apex.

Third and fourth pereiopods (Fig. 9 i): Almost identical. Second and third segments of endopod bearing 1 - 2 setae on the distal outer margin.

Fifth pereiopod (Fig. 9 j): Uniramous. Basis with 3 setae at the inner margin. Exopod seen only as a very small papilla. Endopod 5 segmented. First, second and third segments bearing 2 setae each and fourth segment bears 3 setae. Distal segment carrying 3 setae distally of which one is stout.

First pleopod (Fig. 9 k): Biramous. Exopod with 9 short non plumose setae and endopod small and bare.

Second to fifth pleopods (Fig. 9 l): Biramous. Exopod with 10 - 11 non-plumose short setae along its margin. Appendix interna developed which bore at its distal inner side 3 - 4 small curved hooks.

Uropod (Fig. 9 m): Exopod with 15 - 16 plumose setae and one spine. Endopod with 14 - 15 plumose setae along its margin.

Telson (Fig. 9 n): Slightly tapering towards the posterior end which is convex and bears 10 setae. In addition 3 short spines are also present on either side of the telson.

Zoea VIII (Fig. 10)

Number of larvae examined : 5

Total length : 2.91 to 3.30 mm. Carapace length: 0.81 to 0.99 mm.

Rostrum with 2 - 3 dorsal spines (Fig. 10 a). Antennal flagellum just as long as or slightly longer than the scale. Pereiopods (1 to 4) with functional exopods. Chela of first two pereiopods further developed. Pleopods with plumose setae. Appendix interna fully developed on second to fifth pleopods.

Antennule (Fig. 10 b): Peduncle with a well developed stylocerite with 3 short plumose setae on inner margin and 4 long slender bristle-like setae on the outer margin. 7 long plumose setae present at the anterior ventral side of the third segment. Inner flagellum segmented. Outer flagellum with 6 aesthetes in 2 rows of 3 each.

Antenna (Fig. 10 c): Scale bearing 20 long plumose setae and one spine. Flagellum longer than scale and 5 - 7 segmented.

Mandibles (Fig. 10 d): 3 - 6 teeth present in between incisor and molar processes.

Maxillule (Fig. 10 e): More flattened than in the previous stage and coxopodite with 10 - 11 setae which are serrated.

Maxilla (Fig. 10 f): Exopod with 28 - 30 plumose setae and its posterior lobe elongated.

First maxilliped (Fig. 10 g): Segmentation between third and fourth segment indistinct.

Fig. 10 *Caridina longirostris*: Zoea VIII a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. first maxilliped, h. second maxilliped, i. first pereiopod, j. second pereiopod, k. third pereiopod, l. fifth pereiopod, m. uropod, n. telson.

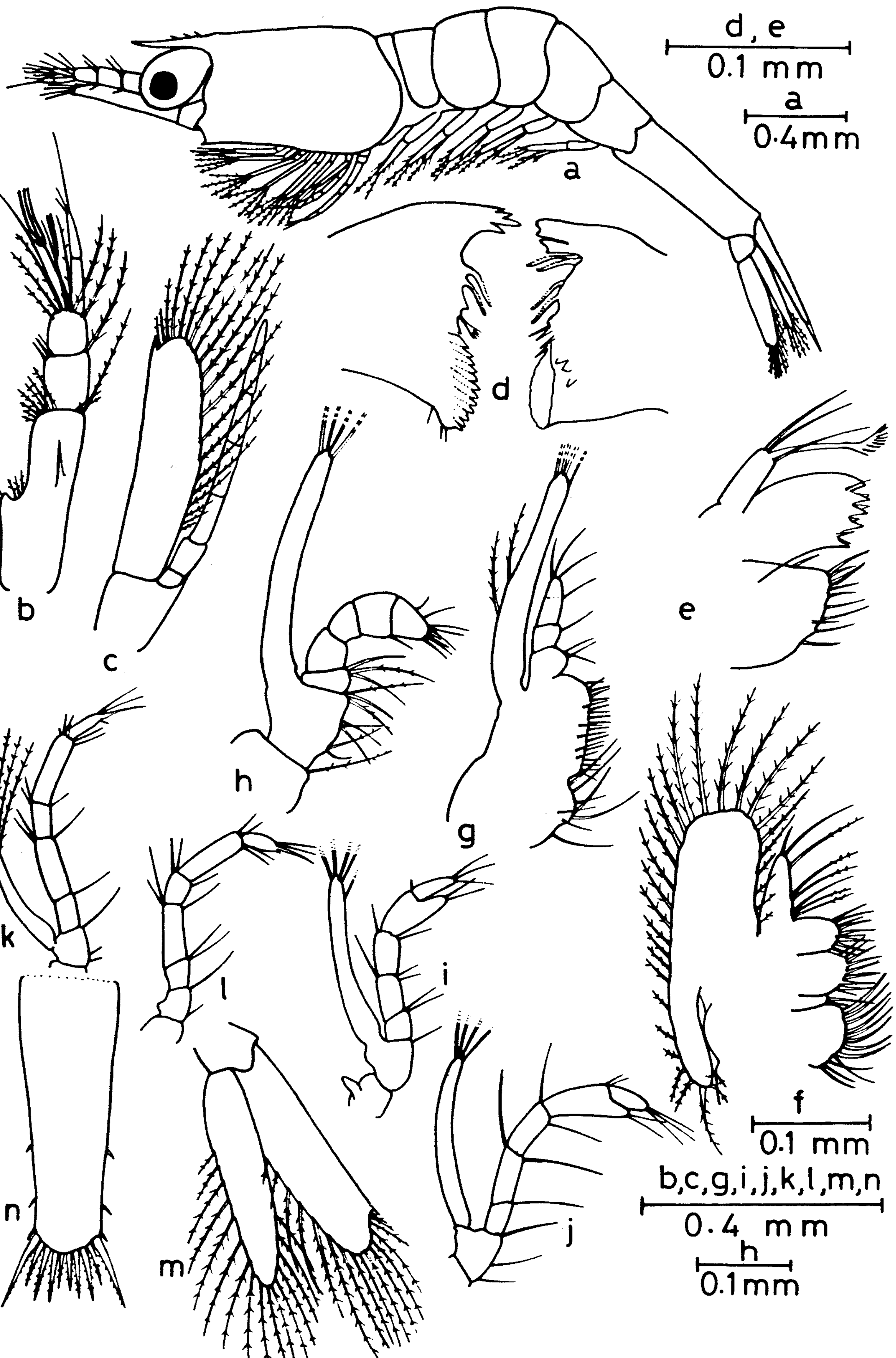


Fig.10

Second maxilliped (Fig. 10 h): Distal 2 segments of endopod expanded. The distal segment carries 9 short setae at its distal and outer regions.

Third maxilliped: Endopod slightly bent towards the inner side. Fourth segment bearing 2 short bristle-like setae at the middle region. Exopod shorter than endopod.

First and second pereiopods (Fig. 10 i, j): They are almost identical. Developing chela of propodus more pronounced. Propodus of second pereiopod slightly longer than that of first.

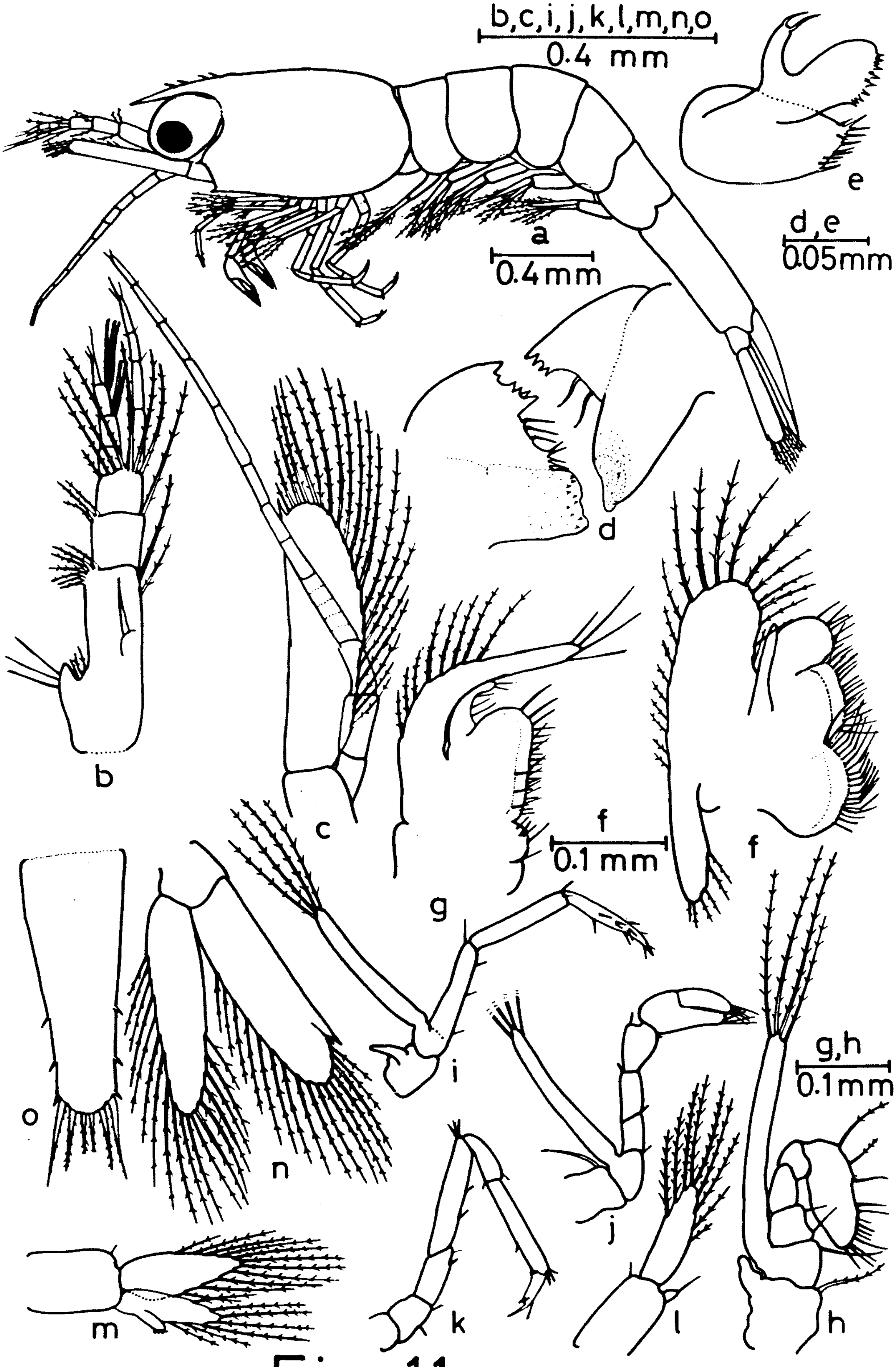
Third pereiopod (Fig. 10 k) and fourth pereiopods: Almost identical. Protopod with 2 short setae. Dactylus of endopod bearing one stout spine at its apex. It also carries 2 setae and a short spine. Fourth segment carries distolaterally 4 - 6 setae. Second and third segment carry 3 setae. Exopod as long as the first 2 segments of endopod, bearing 4 plumose setae at its distal end.

Fifth pereiopod (Fig. 10 l): Uniramous. Dactylus with a stout spine distally. It also bears one short spine and 2 setae. First, second, third and fourth segments carry distolaterally 2, 3, 3 and 4 setae respectively.

Pleopods: Bear plumose setae and are functional. Exopod with 10 - 11 setae and endopod of second to fifth pleopods with 6 setae. Appendix interna bears 4 - 6 hooks.

Uropod (Fig. 10 m): Exopod with 16 - 17 plumose setae and 1 - 2 spines. Endopod with 16 plumose setae.

Fig. 11 Caridina longirostris: Intermediate stage a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. first maxilliped, h. second maxilliped, i. third maxilliped, j. first pereiopod, k. fifth pereiopod, l. first pleopod, m. second pleopod, n. uropod, o. telson.


b,c,i,j,k,l,m,n,o
0.4 mm
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0.4mm
d,e
0.05mm
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0.1mm
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c
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Fig.11

Telson (Fig. 10 n): Distal part is highly convex bearing 10 stout setae. Laterally it bears 3 spines on either side.

Intermediate stage (Fig. 11)

Number of larvae examined : 5

Total length : 2.67 to 3.25 mm. Carapace length : 0.91 to 1.01 mm.

Rostrum with 4 - 5 dorsal teeth (Fig. 11 a). Antennal flagellum twice as long as scale. Pleopods as well as exopods of pereiopods bearing plumose setae and functional. Compared to the previous stage, major changes are noticed in the maxillule, maxillipeds and telson.

Antennule (Fig. 11 b): Inner flagellum 4 segmented, longer than outer flagellum. Outer flagellum 4 segmented bearing 5 aesthetes in two groups of 3 and 2 each.

Antenna (Fig. 11 c): Scale bearing 20 plumose setae and one spine. Flagellum two times longer than scale bearing 12 - 13 segments.

Mandibles (Fig. 11 d): Asymmetrical. Incisor process bearing 4 - 6 teeth. Molar partially demarcated, in between the 2 processes 2 - 7 teeth are present.

Maxillule (Fig. 11 e): Coxa more flattened with 11 setae and basipod with 12 - 13 short teeth. Endopod short, unsegmented bearing 2 short setae at its distal end.

Maxilla (Fig. 11 f): Endopod unsegmented without setae. Endites of basipod and coxopod have become more flattened. Proximal lobe of exopod more pronounced bearing 6 short plumose setae and devoid of the single long plumose seta which was present till the last zoeal stage. Distal part of exopod carrying 19 - 20 plumose setae.

First maxilliped (Fig. 11 g): Basis and coxa expanded and beset with 25 - 27 and 5 - 7 setae respectively. Endopod without segmentation, small and bearing 5 short non-plumose setae. Exopod slightly expanded at the basal region, bears 8 plumose setae along its outer margin and shows the characteristic bent, right angles to the basipod and terminally bears 4 short non-plumose setae.

Second maxilliped (Fig. 11 h): Segmentation between the dactylus and propodus lost and together they form a flattened segment bearing 13 - 15 short setae of which some are plumose. This segment is as long as the first three segments of endopod and forms an 'U' shape and acquire the appearance of the adult appendage.

Third maxilliped (Fig. 11 i): Ischium and merus as well as propodus and dactylus of the endopod coalesed to form 3- segmented structure and acquires the appearance of the adult appendage. Poximal segment bears 2 - 3 short setae.

First and second pereiopod (Fig. 11 j): Carpus of the first pereiopod becomes shorter and broader. Chela bears a tuft of setae distally. Exopod with 4 long apical plumose setae. A long mastigobranch present at the coxopod.

Third and fourth pereiopods: Almost identical. Both retain the functional exopods. Ischium and merus each bears a single spine on the inner side. Dactylus ends in a strong spine. It also carries 2 short spines terminally.

Fifth pereiopod (Fig. 11 k): Uniramous; ischium and merus with one and 2 short spines respectively on the inner side. Dactylus bears 3 spines distally of which one is stout and long.

First pleopod (Fig. 11 l): Endopod small, knob-like, bearing a short non-plumose seta distally. Exopod with 9 long plumose setae.

Second to fifth pleopod (Fig. 11 m): Almost identical. Exopod and endopod carries 11 and 7 - 9 plumose setae respectively. Appendix interna bears 3 - 5 hooks on the distal region.

Uropod (Fig. 11 n): Exopod with 16 - 18 plumose setae and a spine. Development of diaeresis observed for the first time at this stage and it bears a spine. Endopod with 18 plumose setae.

Telson (Fig. 11 o): Tapers posteriorly. Distal margin convex bearing 4 pairs of spines of which the lateral ones are the shortest. Distal half of the telson bearing laterally 2 spines on either side.

Post larva I (Fig. 12)

Number of larvae examined : 5

Total length : 4.72 to 4.91 mm. Carapace length : 1.72 to 1.75 mm.

Rostrum with 6 - 8 dorsal and 2 - 4 ventral teeth. More space, between the distal and penultimate dorsal tooth observed. Rostrum not exceeding

Fig. 12 *Caridina longirostris*: Postlarva I a. lateral view, b. antennular flagellum, c. antenna, d. mandible, e. maxillule, f. maxilla g. first maxilliped, h. second maxilliped, i. second pleopod, j. uropod, k. diaeresis, l. telson.

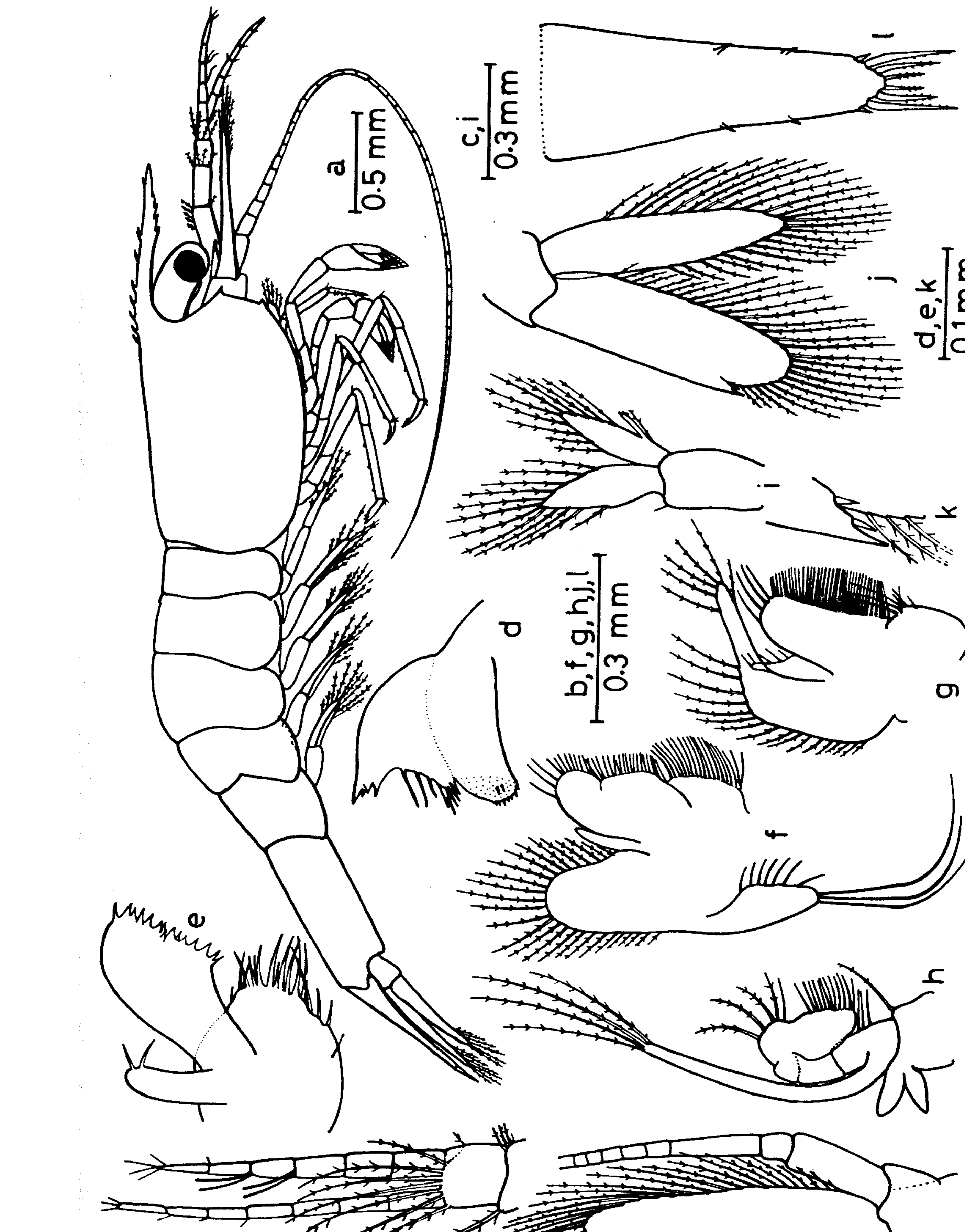


Fig.12

scaphocerite (Fig. 12 a). Antennal flagellum 4 - 5.5 times longer than the scale. Exopod usually absent from pereiopods and if present remains as rudimentary and non-functional.

Antennule: 3 segmented peduncle. Stylocerite well developed. Distal segment carrying 7 long plumose setae on the ventral side, distally and 5 short plumose setae on a prominence on the dorsal side. Flagellae are 6 - 7 segmented. Outer flagellum carried 4 aesthetes in two groups of 2+2 (Fig. 12 b).

Antenna (Fig. 12 c): Scale with 26 - 28 plumose setae. Flagellum segmented 4.0 to 5.5 times longer than scale.

Mandibles (Fig. 12 d): Molar process of mandible further demarcated.

Maxillule (Fig. 12 e): Proximal masticatory process flattened, becomes more or less semicircular in shape with 15 - 18 setae along its inner margin. Basipod becomes broader distally bearing 15 - 16 short teeth. Endopod short possessing 2 distal setae.

Maxilla (Fig. 12 f): Number of setae on the protopodal endites increased. Proximal part of the exopod produced, more flattened and bears 9 - 10 setae, of which the distal 3 are longer. Distal part of the exopod with 26 - 27 plumose setae.

First maxilliped (Fig. 12 g): Protopod further flattened. Basal portion of exopod too flattened possessing 17 plumose setae along its outer margin. Distally, exopod carries 6 - 7 plumose setae.

Second maxilliped (Fig. 12 h): Number of setae on the distal endopodal segment increased.

Third maxilliped: Almost same as that of the previous stage.

First pereiopod (Fig. 13 a): Exopod palp-like, much reduced and bears 4 non-plumose short setae. Chela well developed. The ratio between the length/breadth of chela is 1.7 and that of length/breadth of carpus 1.35.

Second pereiopod (Fig. 13 b): Exopod reduced and non functional as in the first pereiopod. The ratio between length/breadth of carpus and chela is 2.86 and 1.92 respectively. A mastigobranch present on the exopod.

Third pereiopod (Fig. 13 c) and fourth pereiopod: Almost identical. Uniramous. In addition to the terminal spine dactylus carries 2 short teeth.

Fifth pereiopod (Fig. 13 d): Uniramous. Dactylus bearing 5+1 spines.

First pleopod (Fig. 13 e): Exopod with 11 - 12 plumose setae. Endopod short, knob-like and bears 3 plumose setae.

Second to fifth pleopods (Fig. 12 i): Exopod and endopod each with 10 - 15 plumose setae. Appendix interna possesses 4 - 5 hooks.

Uropod (Fig. 12 j): Exopod with 27 - 28 plumose setae and one spine. Endopod with 24 - 26 plumose setae. Diaeresis with 2 spines (Fig. 12 k).

Telson (Fig. 12 l): With 2 pairs of short lateral spines and 4 pairs of spines at the distal end. The posterior region further tapers, but without a median spine.

Fig. 13 *Caridina longirostris* Postlarva I : a. first pereiopod, b. second pereiopod, c. third pereiopod, d. fifth pereiopod, e. first pleopod, Specimen of TL 5.45 to 6.17 mm, f. carapace, g. antennule, h. mandible, i. maxilla, j. third maxilliped, k. fifth pereiopod, l. diaeresis, m. telson.

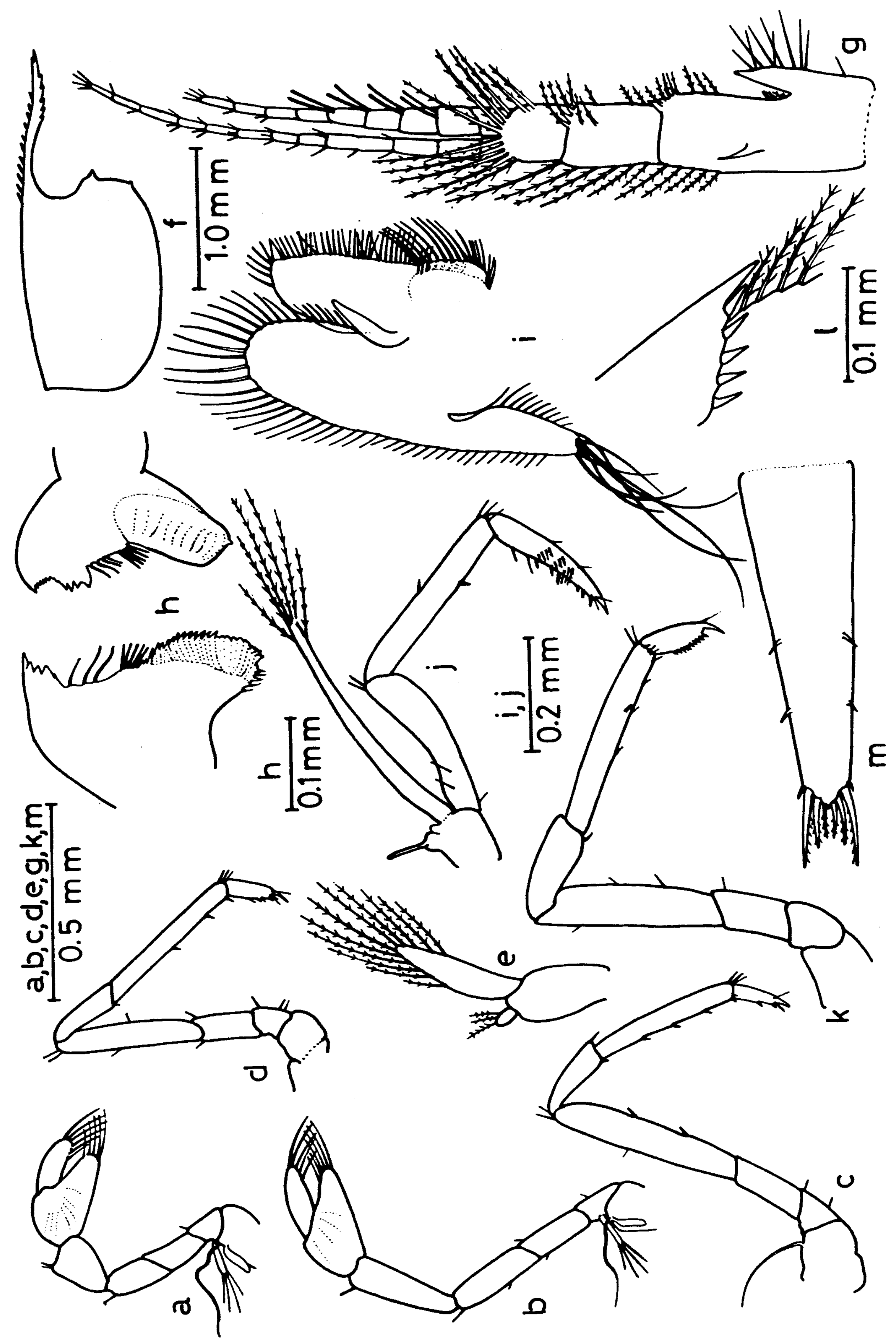


Fig.13

DEVELOPMENT OF POSTLARVAE

First zoea took a minimum period of 15 days to metamorphose to postlarva I. The postlarvae I were further reared in the same container for 173 days when majority of them reached the adult size. The major changes observed during the course of development of postlarva I to the adult stage are as follows:

a) Postlarva of 6.17 mm total length:

Carapace length: 2.25 mm. Rostral formula was 11+1/5. Pterygostomial spines reduced in size (Fig. 13 f). Telson tapering posteriorly and ends in a median spine. At the distal margin, it carried 8 spines. Dorsolaterally 2 pairs of spines were observed (Fig. 13 m). Inner antennular flagellum 11 - 14 segmented. Outer flagellum smaller, 9 - 10 segmented carrying 8 aesthetes in 2+2+2+2 groups (Fig. 13 g).

Mandible asymmetrical, incisor with 5 - 12 teeth and molar with a number of prominent ridges (Fig. 13 h). Between the 2 processes a number of slender teeth in 2 groups were present. Near the incisor 3 - 5 slender teeth and below it 5 - 8 teeth were discernible.

Distal lobe of exopod of second maxilla bearing 7 - 8 long setae (Fig. 13 i). Number of serrated teeth on the distal endopodal segment of third maxilliped (Fig. 13 j) increased.

Fifth pereiopod uniramous (Fig. 13 k). Dactylus with 11 spines. The ratio between length/breadth of propodus was 7.54 and that of propodus/dactylus 3.46.

b) Postlarva of 7.61 mm in total length:

Carapace length 2.82 mm. Rostrum with 15+1 dorsal and 8 ventral teeth. Distinct unarmed portion in the distal part of the upper margin of rostrum behind the sub-apical tooth present (Fig. 14 a). Rostrum reaches the antennular peduncle. Lower orbital angle well developed and distinctly separated from the strong antennal spine. Pterygostomial spine absent and the angle rounded.

Distal lobe of exopod of maxilla expanded tapering distally, bearing 10 long setae (Fig. 14 b). Endopod very small, devoid of setae. Endites of protopod and exopod are expanded bearing a number of setae.

Basis of first maxilliped slightly concave with a number of setae. Exopod broader proximally, carrying 26 plumose setae (Fig. 14 c), distally it bears 8 plumose setae.

Propodus of the endopod of second maxilliped (Fig. 14 d) carries 8 setae, of which 3 are longer and plumose. Dactylus flattened with 22 - 25 long bristle-like setae along its topographically inner margin. Exopod bears plumose setae at its distal end.

Carpus of first pereiopod (Fig. 14 e) shorter than chela and 1.3 times as long as broad, with a shallow excavation anteriorly. Chela 2.0 times as long as broad.

Carpus of second pereiopod (Fig. 14 f) 3.1 times as long as broad and chela 2.24 times as long as broad.

Dactylus of fourth pereiopod (Fig. 14 h) bears 4 spines and propodus 4.2 times longer than dactylus (Fig. 14 g).

Dactylus of fifth pereiopod bearing 19 spines (Fig. 14 j). Propodus 4.6 times as long as dactylus (Fig. 14 i).

Endopod of first pleopod (Fig. 14 k) knob-like carrying 4 plumose setae.

Diaeresis of exopod has 8 spines (Fig. 14 m).

Telson tapering to a distal median spine, on either side of which 4 pairs of spines present. Besides on the dorsal side of the telson 3 pairs of short spines are located (Fig. 14 l).

c) Postlarva of 14.15 mm total length:

Carapace length 4.93 mm. Rostrum bears 24 dorsal and 9 ventral teeth and exceeds scaphocerite and antennular peduncle (Fig. 15 a).

Dactylus of third pereiopod with 6 spines. Propodus 9 times as long as broad and 3.43 times as long as dactylus (Fig. 15 c).

Propodus of fifth pereiopod 13.3 times as long as broad (Fig. 15 d) and dactylus bearing 33 spines (Fig. 15 e).

Endopod of first pleopod without appendix interna (Fig. 15 f) and that of second pleopod with an appendix interna and an appendix masculina (Fig. 15 g).

Diaeresis of uropod bears 10 spines (Fig. 15 h).

Telson with 4 pairs of spines distally and 4 pairs of short spines on the dorsal side of distolateral margin (Fig. 15 i).

Fig. 15 Caridina longirostris: Specimen of TL 14.15 mm a. rostrum and anterior part of carapace, b. second pereiopod, c. third pereiopod, d. fifth pereiopod, e. dactylus of fifth pereiopod, f. endopod of first pleopod, g. endopod of second pleopod, h. diaeresis, i. telson.

Specimen of TL 23.3 mm j. anterior part of carapace, k. first pereiopod, l. dactylus of third pereiopod, m. diaeresis n. telson.

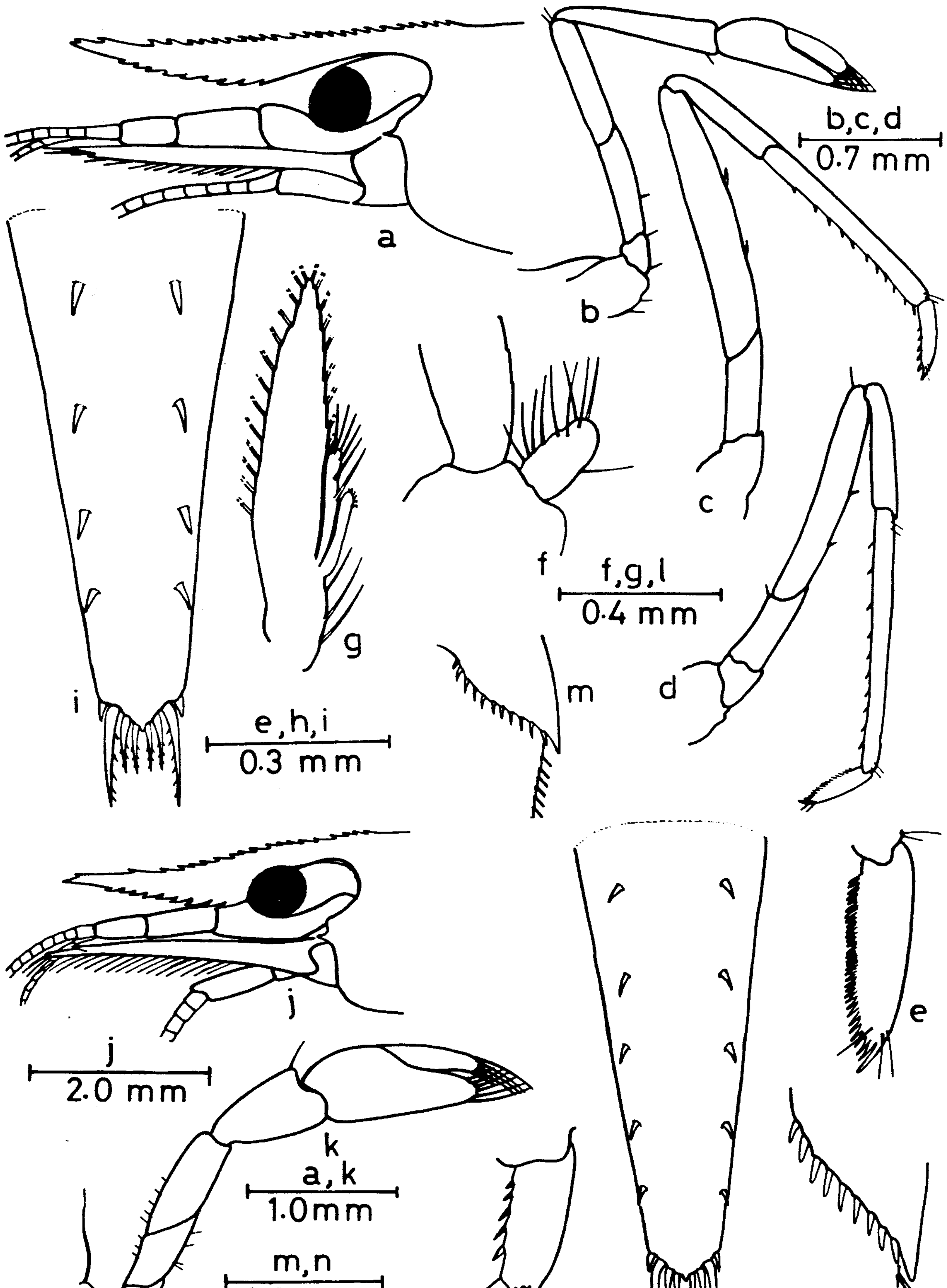

a
b
c
d
b,c,d
0.7 mm
f
g
i
f,g,l
0.4 mm
m
e,h,i
0.3 mm
j
e
j
2.0 mm
k
a,k
1.0mm
m,n
0.6 mm
l
n
h

Fig.15

d) Postlarva of 17.25 mm total length:

Carapace length 6.16 mm. Rostral formula 16+1/11 (Fig. 16 a).

Incisor of mandible with 5 - 9 teeth (Fig. 17 f). In between incisor and molar bristle-like teeth present in 2 groups. One group of 4 - 10 numbers near the incisor process and another group of 10 - 14 near molar process.

Proximal process of maxillule (Fig. 16 b) flattened and in the form of a semicircle and bears 30 - 32 slender setae. Distal process with 17 - 20 teeth along the inner margin and 17 - 20 setae along the outer margin.

Margin of coxopod of maxilla almost like a semicircle with a number of arched long setae. Basipod also with a number of short setae along its inner margin. Endopod unsegmented and small. Distal part of exopod bearing 49 setae, proximal part expanded with 27-28 setae along its inner margin and 12 long setae terminally (Fig. 16 c).

Coxopod of first maxilliped with 6 setae. Basipod further expanded and slightly concave on the inner margin. Proximal portion of exopod expanded and the distal margin bears 14 setae (Fig. 16 d).

Exopod of second maxilliped has 5 setae at its proximal outer region and 11 setae at its distal outer margin (Fig. 16 e).

Carpus of first pereiopod 1.73 times as long as broad. Chela 1.69 times as long as broad (Fig. 16 f).

Carpus of second pereiopod (Fig. 16 g) 5 times as long as broad and longer than chela. Chela 2.3 times as long as broad.

Fig. 16 Caridina longirostris: Specimen of TL 17.2 mm a. rostrum, b. maxillule, c. maxilla, d. first maxilliped, e. second maxilliped, f. first pereiopod, g. second pereiopod, h. third pereiopod, i. dactylus of third pereiopod, j. fifth pereiopod, k. dactylus of fifth pereiopod.

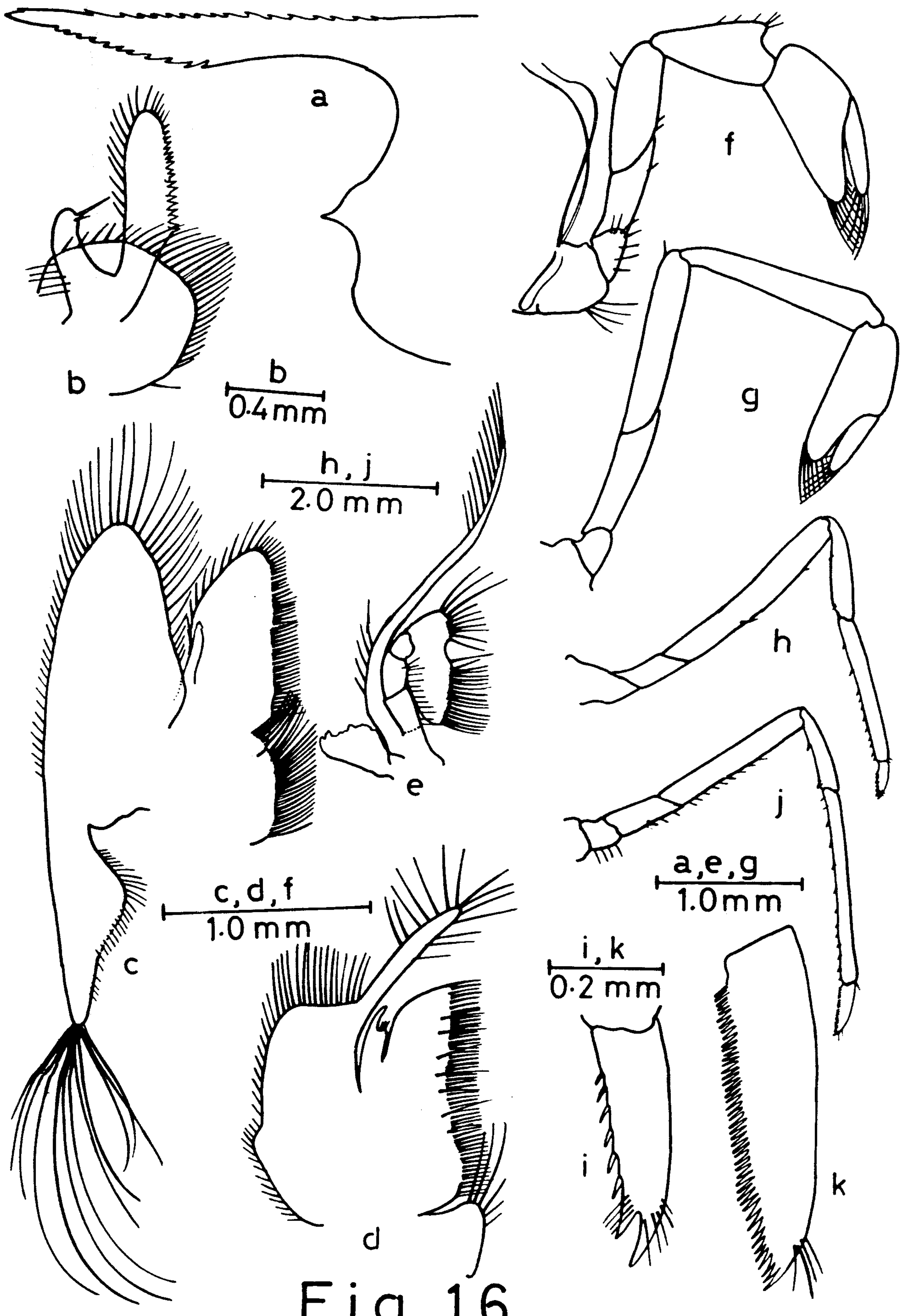


Fig.16

Dactylus of third pereiopod bears 8 spines (Fig. 16 i). Propodus 4.3 times as long as dactylus and 8.9 times as long as broad (Fig. 16 h).

Dactylus of fifth pereiopod bears 47 spines (Fig. 16 k). Propodus 13.6 times as long as broad and 4.3 times as long as dactylus (Fig. 16 j).

An appendix interna developed now on the endopod of first pleopod (Fig. 17 g) while that of second pleopod carries 7 - 8 hooks distolaterally and appendix masculina with 10 - 12 bristle-like setae (Fig. 17 h).

Preanal carina bears a spine (Fig. 17 i).

Diaeresis bears 11 spines (Fig. 17 j).

Telson tapers to a well developed median spine (Fig. 17 l). It bears 4 pairs of distal and 4 pairs of distolateral spines placed dorsally (Fig. 17 k).

e) Postlarva of 23.3 mm total length:

Carapace length 8.4 mm. Rostrum bearing 18 + 1 dorsal and 9 ventral teeth (Fig. 15 j).

Carpus of first pereiopod 1.73 times as long as broad and shorter than chela (Fig. 15 k). Chela 2.09 times as long as broad.

Carpus of second pereiopod 3.8 times as long as broad and longer than that of chela (1.13 times). Chela 2.09 times as long as broad (Fig. 17 a).

Propodus of third pereiopod (Fig. 17 b) 10.7 times as long as broad and 4.8 times as long as dactylus. Dactylus bears 7 spines (Fig. 15 l).

Fig. 17 Caridina longirostris: Specimen of TL 14.15 mm a. second pereiopod, b. third pereiopod, c. fifth pereiopod, d. first pleopod, e. second pleopod.

Specimen of TL 17.2 mm f. mandible, g. endopod of first pleopod, h. appendix interna and appendix masculina, i. preanal carina with spine, j. diaresis, k. telson, l. telson tip.

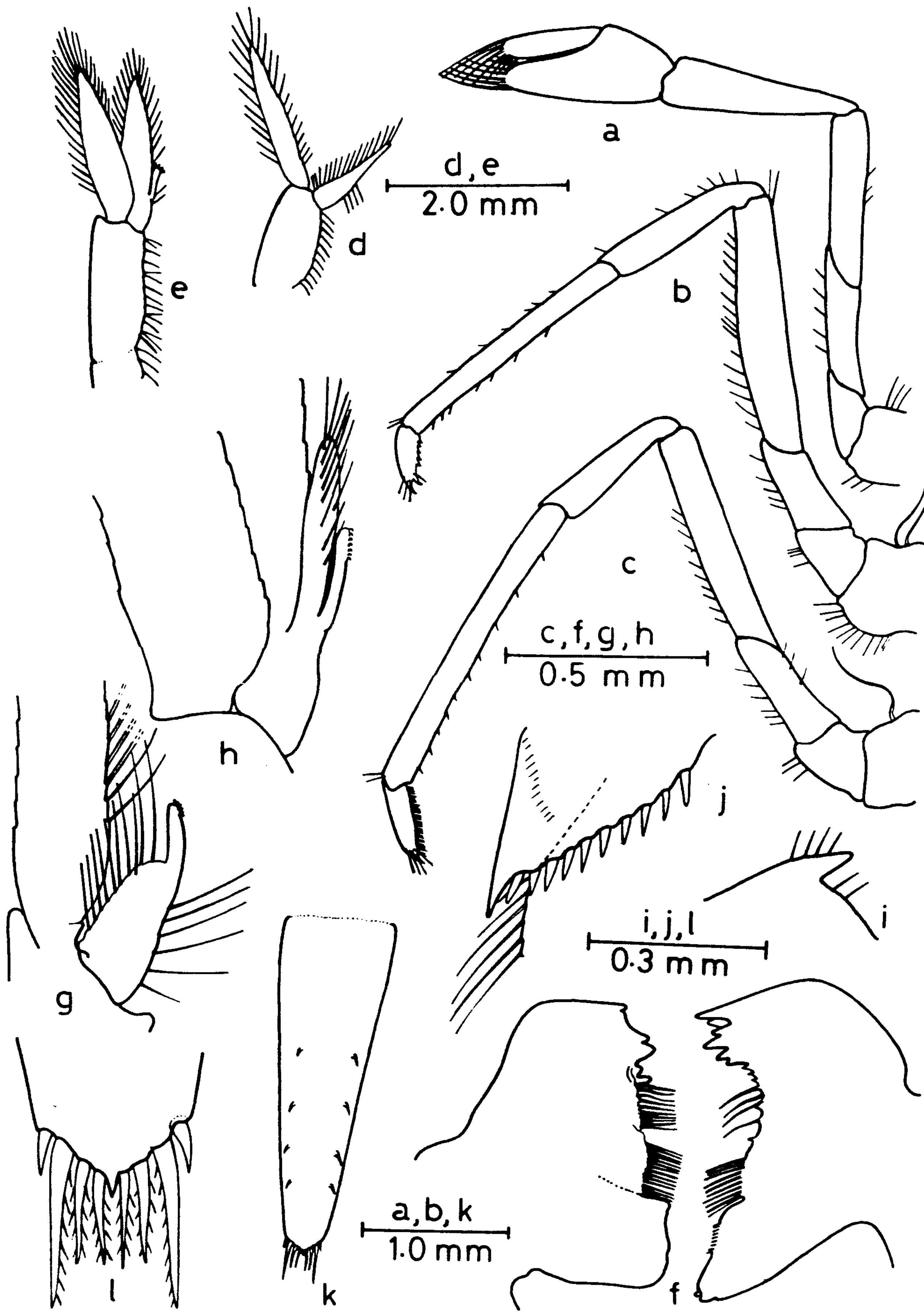


Fig. 17

Propodus of fifth pereiopod 11.25 times as long as broad and 4.65 times as long as dactylus (Table 3). Dactylus bears 44 spines (Fig. 17 c).

The setose endopod of first pleopod becomes smaller and tapers distally, thus attaining the typical shape of the adult female (Fig. 17 d).

Endopod of second pleopod of female bears an appendix interna. Protopod with ovigerous setae (Fig. 17 e).

Telson distally tapering to end in a spine and carries 8 spines. In some specimens 5 pairs of dorsal spines were encountered (Fig. 15 n).

The salient features of development of postlarvae during a period of 173 days in the laboratory are shown in Table 4. The pattern of growth of the postlarvae during this period is depicted in Fig. 18. A gradual increase in the size of postlarvae was obtained during a period of 140 days. However, the growth rate during this period was seen varying from 0.117 mm in the first 72 days, decreasing to 0.06 mm in the next 15 days, again increasing to 0.169 mm in the following 23 days and finally decreasing to 0.08 mm in the next 27 days. After 140 days, the growth rate was reduced appreciably. As the postlarva reaches an average size of 20 mm, it attains all the adult characters including the secondary sexual characters such as the ovigerous setae in the pleopods of females and appendix interna and appendix masculina in the second pleopod of males.

The development of spines on the dorsal and ventral aspect of the rostrum during the course of development of postlarva to adult was observed

Table 4. *Caridina longirostris*: Important changes occurring during the development of first postlarva to adult

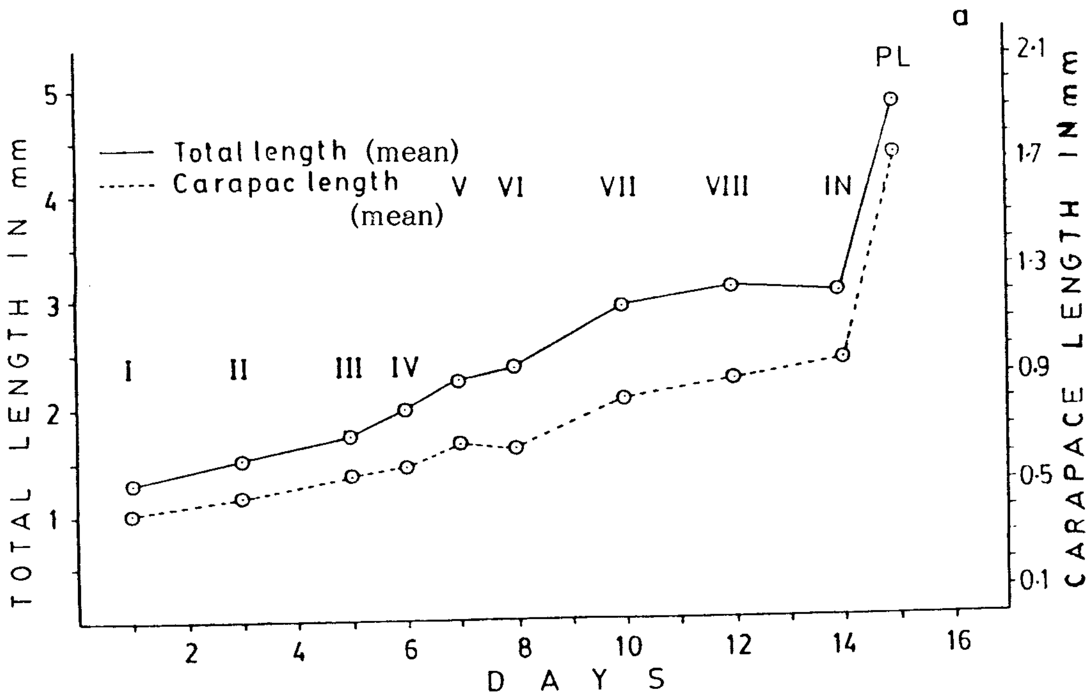
No. of days after becoming postlarva first	Carapace length (mm) Range (Mean)	Total length (mm) Range (Mean)	Salient feature
First post-larva	1.72-1.75 (1.740)	4.72-4.91 (4.835)	Rostrum with 6-8 dorsal and 2-4 ventral teeth. Exopods of pereiopods absent or rudimentary and non-functional.
3	2.06-2.41 (2.178)	5.45-6.17 (5.825)	Rostrum with 11 dorsal and 5 ventral teeth. Pterygostomial spine not, as well developed as antennal, distal median spine of telson developed. Telson with 4 pairs of distal and 2 pairs of distolateral spines.
7	2.06-2.87 (2.31)	4.56-7.83 (6.17)	Rostrum with 15-16+1 dorsal and 7-8 ventral teeth. There is a distinct unarmed portion behind the sub-apical tooth. Pterygostomial spine absent. Lower orbital angle well developed bearing a strong antennal spine. Telson with 4 pairs of distal and 3 pairs of distolateral spines.
41	2.91-4.23 (3.45)	7.71-10.34 (9.11)	
75	4.11-5.47 (4.69)	12.03-15.19 (13.64)	
81	4.09-5.59 (4.85)	12.31-15.26 (13.96)	

Table 4. (Contd...)

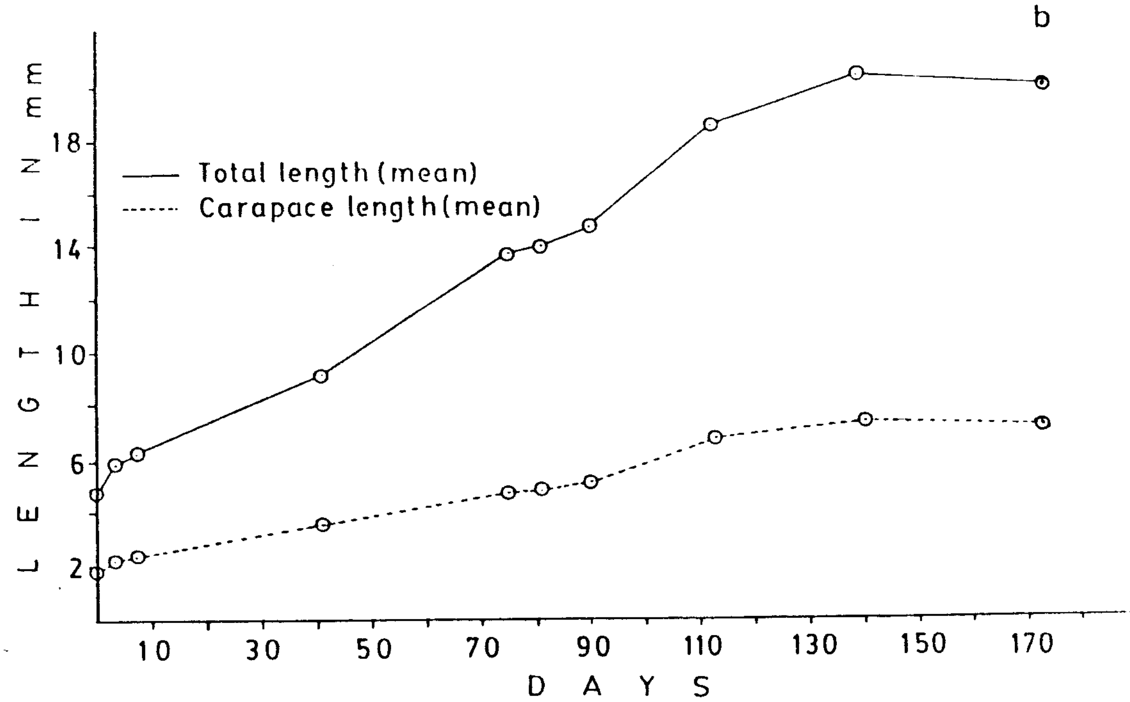
No. of days after becoming postlarva first	Carapace length (mm) Range (Mean)	Total length (mm) Range (Mean)	Salient feature
90	4.70-5.69 (5.11)	13.35-15.89 (14.57)	Telson with 4 pairs of spines distally and 4 pairs of short spines on the dorsal side towards lateral margin. Appendix masculina developed on the second pleopod. But correspondingly appendix interna on 1st pleopod was not developed.
113	5.40-7.99 (6.69)	15.13-21.81 (18.47)	
140	5.83-8.46 (7.31)	17.53-24.44 (20.73)	Exopod of first pleopod of male with appendix interna. Appendix masculina present on the 2nd pleopod.
173	5.69-8.6 (7.16)	17.11-23.26 (19.95)	Secondary sexual characters are well developed. Females with ovigerous setae on the inner side of protopod of pleopods. Males with a well developed appendix interna on the first pleopod and appendix masculina on second pleopods. In females the endopod of the first pleopod tapers distally, bearing setae.

Fig. 18 *Caridina longirostris*: a. growth pattern from zoea I to postlarva I, I to VII. Zoea I to zoea VII, IN. Intermediate stage, PL. Postlarva I.

b. growth pattern from postlarva I to adult.



a
TOTAL LENGTH IN mm
CARAPACE LENGTH IN mm
Total length (mean)
Carapac length (mean)
I
II
III
IV
V
VI
VII
VIII
IN
PL
DAYS



b
LENGTH IN mm
Total length (mean)
Carapace length (mean)
DAYS

Fig.18

to vary from specimen to specimen even among those belonging to the same brood. The rostral formula of animals of 23.6 and 24.4 mm total length was 18+1/12 and 19+1-2/15-16 respectively. But in some specimens having a total length of 14.15 and 15.13 mm, the rostral formula was 23+2/9 and 22+2/13 respectively. Again animals having an almost same total length of 17.11 and 17.25 mm showed the rostal formula as 22+2/10 and 18+1/12 respectively. All these clearly indicate that there is no clear relationship between the total length of the animal and the rostal formula.

The important changes observed in the carapace during the development of the postlarva relate to the pterygostomial spine and the lower orbital region. The pterygostomial spine which was present in the first zoea was retained, though reduced in size until the postlarva attained 6.7 mm and disappeared as the animal grew to 7.6 mm. Similarly the lower orbital angle bearing a strong antennal spine was found to develop only when postlarva grew to a length of 7.6 mm. By the time the antennal spine also attained the adult character and the pterygostomial angle became rounded without spine.

In the adult of C. longirostris the ratios between the length and breadth of carpus of the first pereiopod is 1.7 to 3.0 and of second pereiopod 4.3 to 6.0, the ratio between the propodus and dactylus is given as 4.5 to 5.5 for third pereiopod and 3.7 to 5.0 for fifth pereiopod (Holthuis, 1969). These relationships, except in the case of third pereiopod, was obtained in the laboratory reared animals, as they grew to a size of 14.5 to 17.25 mm in total length. For third pereiopod, this ratio was obtained only when the animal reached a size of 23.3 mm.

The presence of appendix interna on the endopod of first pleopod and appendix masculina on the second pleopod are external characters of distinction of male specimens. In the laboratory reared C. longirostris the appendix masculina was seen to develop on the endopod of second pleopod as it measured a size of 14.5 mm. But at this stage appendix interna did not develop on the first pleopods. It started appearing only when the animal grew to a total length of 17.2 mm.

The telson of the adult C. longirostris tapers to end in a median spine and it carried posteriorly 4+4 spines and dorsally 4+4 spinules. In the laboratory reared animals, the median spine was absent in the first postlarva although the telson carried 4+4 spines distally and 2+2 spinules on the dorsal aspect. The median distal spine appeared for the first time when the animal grew to a size of 5.4 to 6.2 mm. At this stage the dorsal spinules of the telson was 3+3. The number increased to 4+4 only when the animal attained 14.15 mm size. Holthuis (1969) observed that this species generally carried 3 to 4 pairs of dorsal spines on the telson. But in some of the laboratory reared animals 5+5 or 5+6 and sometimes even 6+6 dorsal spines were also observed.

To sum up, the larval development of C. longirostris passes through 8 zoeal stages, one intermediate stage and one postlarval stage. The post-larvae grew gradually upto 140 days and thereafter the growth rate reduced considerably. As the larvae attained 17 to 20 mm size, the adult characters, including the development of secondary sexual characters are seen and enter into reproductive phase of life cycle.

DISCUSSION

Complete or partial larval descriptions of several species of Caridina such as Caridina wyckii (Daday, 1907); C. nilotica (Gurney, 1927); C. denticulata (Shen, 1939); C. laevis (Nair, 1949); C. propinqua (Babu, 1963); C. brevirostris (Shokita, 1973); C. weberi (Chinnaya, 1974); Caridina sp. (Lakshmi, 1975); C. pseudogracilirostris (Pillai, 1975); C. nilotica (Glaister, 1976); C. denticulata (Shokita, 1976); C. mccullochi (Benzie, 1982); C. singhalensis (Benzie and de Silva, 1983); C. babaulti (Salman, 1987) and C. gracilipes and C. prox (Kadrekar and Sankolli, 1987) are available. Besides, Jalihal (1978) described four new species namely C. williamsoni, C. kempi, C. gurneyi and C. shenoyi from Dharwar area and studied their larval histories in detail.

C. singhalensis (Benzie and de Silva, 1983), C. brevirostris (Shokita, 1973) and C. denticulata (Shokita, 1976) exhibit a highly abbreviated larval development. In these species well developed pereiopods and functional, setose pleopods were observed even from the first stage. However, in species such as C. wyckii (Daday, 1907) C. weberi (Chinnaya, 1974), C. williamsoni (Jalihal, 1978) a prolonged larval development having 9 to 10 larval stages was noticed. In the case of C. weberi (Chinnaya, 1974) 26 days were taken to complete the larval development; in this as well as in C. wyckii pereiopods and setose pleopods were seen only in the seventh or eighth larval stages. In between these two patterns of development several species of this genus showed intermediate mode of development with varying duration and sequence of development of thoracic and abdominal appendages. Thus the newly hatched out zoea of C. mcculochi (Benzie, 1982) metamorphosed to postzoea within

18 to 24 hours. The average duration taken to complete the larval development of C. gurneyi (Jalihal, 1978) was 3 to 4 days, C. propinqua (Babu, 1963) 4 days, C. pseudogracilirostris (Pillai, 1975) 9 days, C. kempi (Jalihal, 1978) 10 days and C. nilotica (Glaister, 1976) 12 days. With a duration of 15 days to complete the larval development and in the sequence of appearance of various appendages the larval development of C. longirostris compare with those of C. williamsoni (Jalihal, 1978) and C. shenoyi (Jalihal, 1978). All these indicate that considerable variations exist in the larval development of different species of caridina.

As in the case of other crustaceans the major changes noticed during the course of development of carideans relate to the mouth parts, pereiopods, pleopods, uropod and telson. When the larval development is abbreviated and consequently the number of stages are reduced, these characters are accomodated in the fewer number of stages. However, the stage at which most of the structures make their first appearance vary from species to species. Details of the development pattern of some of the species are given in Table 5. In this connection Benzie's (1982) observation is worth mentioning. Although variations do exist in the pattern of development of various appendages in different species of Caridina, the groups of appendages related more broadly in function tend to show major changes at the same time. For example he opined that "maxillae and maxillipeds both involved in feeding achieve their adult forms in the same or neighbouring moults even in the longest larval developments. Similarly pereiopods and pleopods both involved in locomotion also attain their full development at the same or neighbouring moults".

Table 5. *Caridina longirostris*: Characteristics of given stages and the stages at which major morphological changes occur for *Caridina* spp. for which adequate description are available

	Caridina longirostris	*Caridina singhalensis*	*Caridina mccullochi*	*Caridina williamsoni*	*Caridina kempi*	*Caridina shenoyi*	*Caridina gurney*	*Caridina denticulata*	*Caridina nilotica*	*Caridina pseudo-gracilirostris*	*Caridina weberi*	*Caridina brevirostris*	*Caridina propingua*	*Caridina laevis*	*Caridina wyckii*
	Present work	Benzie and Desilva(1983)	Benzie (1982)	Jalithal (1978)	Jalihal (1978)	Jalihal (1978)	Jalihal (1978)	Shokita (1976)	Glaister (1976)	Pillai (1975)	Chinnayya (1974)	Shokita (1973)	Babu (1963)	Nair (1949)	Daday (1907)
Egg size (mm)	0.38-0.41 X 0.22-0.24	1.81 X 1.24	0.98 X 0.61	0.30-0.50 X 0.50-0.67	0.58-0.65 X 0.33-0.40	0.57-0.68 X 0.33-0.44	0.75-0.90 X 0.50-0.65	1.07 X 0.67	0.64 X 0.40	0.42-0.48 X 0.25-0.28	0.51 X 0.32	1.24 X 0.79	0.50 X 0.40	0.95 X 0.56	..
Number of days taken for the development of functional pleopods	15	..	..	15	10	15	4	..	12	9	26	..	4	3 - 4	..
Number of setae on telson at Zoea I	7 + 7	10 + 10	7(8)+7(8)	7 + 7	7 + 7	7 + 7	7 + 7	8 + 8	7 + 7	7 + 7	7 + 7	8 + 8	7 + 7	8 + 8	7 + 7
Development of uropod	Z III	Z II	Z III	Z III	Z III	Z III	Z III	Z II	Z III	Z III	Z III	Z II	Z III	Z III	Z III
First antenna flagellate	Z VIII	Z I	Z II	Z V	Z V	Z IV	Z II	Z I	Z IV	Z V	Z IX	Z I	Z III	Z III	Z VI
Second antenna flagellate	Z VI	Z I	Z II	Z VI	Z VI	Z IV	Z II	Z I	Z III	Z V	Z VIII	Z I	Z III	Z III	Z VII
Maxillipeds in adult form	intermediate stage	Z I	Z II	Z IX	Z VIII	Z VI	Z IV	Z I	Z V	PLI	Z X	Z I			Z IX
Pereiopods biramous (P-pereiopod)	ZII(P1,P2) ZIV(P3,P4) ZV (P5)	..	Z I	ZII (P1,P2) ZIII(P2,P3) ZIV(P4,P5)	Z I(P1,P2, P3) ZII(P4,P5)	ZII(P1,P2,P3,P4) ZIII (P5)	ZI(P1,P2,P3 P4 & P5)	..	Z I	Z II(P1) ZIII(P2,P3)	ZII (P1,P2) ZVI(P3,P4)		Z I	Z I	Z III(P1) Z IV(P2) Z V (P3) Z VI(P4)
All pereiopods well developed at	Z VII	Z I	Z II	Z VI	Z VI	Z V	Z II	Z I	Z III	Z V	Z VIII	Z I	Z II	Z II	Z VII
Pereiopods 1st and 2nd chelate at	Z VIII	Z I	Z II	Z IX	Z VII	Z VI	Z III	Z I	Z IV	Z PLI	Z IX	Z I	Z III	..	Z VII
Pleopod buds	Z V	..	..	Z VI	Z IV	..	Z I	..	Z II	Z IV	Z VII	..	Z II	Z I	Z VI
Pleopod biramous	Z VI	..	Z I	Z VII	Z V	Z IV	Z II	..	Z III	Z V	Z VIII	..	Z III	Z II	Z VII
Pleopod setose	Z VIII	Z I	Z II	Z VIII	Z VII	Z VI	Z III	Z I	Z IV	Z PLI	Z IX	Z I	Z IV	..	Z VII

Presence of rudimentary exopod of maxillule bearing plumose setae are noticed in the first two zoeal stages of C. pseudogracilirostris (Pillai, 1975), C. longirostris (present work), C. babaulti (Salman, 1987), C. nilotica (Gurney, 1927), and C. williamsoni, C. kempi and C. shenoyi (Jalihal, 1978). Except in the case of C. williamsoni (Jalihal, 1978) where exopod bears 3 setae, in all other cases only 2 setae are noticed. In C. pseudogracilirostris (Pillai, 1975) and C. longirostris these setae are retained in the first 3 stages where as in other species it is retained only for the first 2 stages. But larvae belonging to C. weberi (Chinnaya, 1974), Caridina sp. (Lakshmi, 1975), C. nilotica aurensis (Glaister, 1976), and C. gurney (Jalihal, 1978) lack these plumose setae and exopod. But exopod bearing setae are noticed in the larval stages of Atya lanipes (Hunte, 1975), Micratya poeyi (Hunte, 1979a) and Atya innocous (Hunte, 1979 b). The presence of exopod bearing setae on the maxillule of first few larval stages of Caridina species with prolonged larval development may represent some affinity to other genera such as Atya and Micratya.

2. Caridina pseudogracilirostris Thomas et al. 1973

C. pseudogracilirostris is a common caridean prawn occuring in the upper and lower reaches of Cochin Backwater (Fig. 1 A). Berried specimens of this species migrate to the lower reaches of Cochin Backwater from the adjoining rivers for spawning during July to November when the salinity of the backwater decreases to less than 15‰ due to influx of rain water. Total length of berried females varied from 28.3 to 30.5 mm. The number of eggs in the berry were found to fluctuate from 363 to 848. The details of size, number of eggs in the berry and measurements of eggs of five berried specimens are given in Table 6.

The scientific paper dealing the complete larval development of C. pseudogracilirostris Thomas et al. studied by the author by rearing the eggs through various larval stages up to the juvenile stage and published earlier is given in the following pages.

Table 6. Caridina pseudogracilirostris: Details regarding total length, carapace length, number of eggs and egg measurements of berried females.

Total length excluding rostrum (mm)	Carapace length excluding rostrum (mm)	Number of eggs in the berry	Egg measurements			
			Longest (mm)	Longest (mean) (mm)	Shortest (mm)	Shortest (mean) (mm)
21.5	5.0	520	0.394 to 0.478	0.436	0.239 to 0.267	0.253
23.4	5.0	370	0.436 to 0.506	0.478	0.267 to 0.281	0.281
23.8	5.4	848	0.408 to 0.464	0.422	0.267 to 0.295	0.281
20.7	4.4	363	0.394 to 0.478	0.450	0.239 to 0.281	0.253
21.4	4.7	463	0.408 to 0.492	0.450	0.267 to 0.309	0.281

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LARVAL DEVELOPMENT OF *CARIDINA PSEUDOGRACILIROSTRIS* REARED IN THE LABORATORY

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ABSTRACT

Complete larval development of *Caridina pseudogracilirostris* Thomas *et al.* was studied by rearing in the laboratory. Six zoeal stages were recognised in the larval development of this species. These stages are completed within nine days from hatching, after which the zoea transforms into first postlarva Detailed descriptions of !zoea, postlarva and juvenile are given.

INTRODUCTION

SPECIES belonging to the genus *Caridina* H. Milne Edwards are distributed widely and are common in the fresh and brackish waters. Daday (1907) studied for the first time, the larval stages of *Caridina wyckii* (Hicks), collected from the Lake Victoria and Nyansa. This was followed by Gurney's work (1927) on the three larval and two postlarval stages of *Caridina nilotica* var. *typica* Bouvier and Shen's (1939) description of the five larval stages of *Caridina denticulata* de Haan. Glaister (1976) described four zoeal and one postzoeal stages of *Caridina nilotica aruensis* Roux by rearing them in the laboratory. From Indian waters, Nair (1949) described the first zoea of *Caridina leavis* Heller, while Babu (1963) studied the complete larval history of *Caridina propinqua* de Man by rearing experiments. Recently Lakshmi (1975) gave description of the early larval stages of *Caridina* sp. collected from the inshore waters of Cochin. The present work deals with the complete larval history of *Caridina pseudogracilirostris* Thomas *et al.*, a common shrimp found in the fresh and brackish water areas of Cochin.

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MATERIAL AND METHODS

A live berried specimen, measuring 29.0 mm in total length from tip of rostrum to the tip of telson was caught by the plankton net operated in the Cochin Backwater at a station north of Cherai on 16th September 1972. The 'berry' was found to be in an advanced stage of development. The specimen was carefully brought to the laboratory and kept in a 1000 ml capacity glass container having brackish water of 15–16‰ salinity. On the following morning (17-9-72) all the eggs in the berry were hatched and the first zoeae were seen actively moving about in the medium. About 500 zoeae were obtained from the hatching of eggs. They were further reared in brackish water medium having a salinity range from 15 to 16‰. Half of the medium along with the bottom sediment, was siphoned out from the container, twice in a week, and the original water level was maintained by adding fresh brackish water of the same salinity. No special food was given to the larvae, however they were found to feed actively on the algal layer formed on the sides of the container and the copepodites developed in the culture medium. During the experiments the water temperature in the container ranged between 23.0 to 28.0° C. Larvae were sturdy and active and the mortality was found to be negligible. In the development of larva from zoea I to postlarva I, distinct morphological changes occured at each moult, which is hence, considered as a stage. Zoea I moulted six times to become postlarva I. The entire experiment was done for a period of 92 days from the time of hatching of eggs. By this time the larvae reached the juvenile stage. Time taken for metamorphosis from zoea I to postlarva I as well as the total duration of each stage is given in Table 1.

Every day five larve were preserved in 5% formalin for detailed morphological studies. Total length was measured from the tip of rostrum to the tip of telson, excluding spines, and the carapace length from the tip of rostrum to the mid-posterior border of the carapace. Illustrations of the appendages were made with the aid of monocular microscope and camera lucida.

DESCRIPTION OF LARVAL STAGES

Zoea I (Fig. 1 a to i; 2 a): Total length (Tl) 1.40 to 1.54 mm; Carapace length (Cl) 0.49 to 0.52 mm.

A typical first stage caridean larva with large sessile eyes fused with carapace; rostrum small, unarmed, slightly decurved at tip; anterolateral angle of carapace slightly produced; abdomen six segmented, last segment joining the broadly triangular telson without an intervening articulation; three pairs of maxillipeds present.

Antennule (A 1) (Fig.1 b): peduncle long, unsegmented, carrying 2 flagella distally; outer with 3 aesthetes and 2 setae, inner seta long and plumose and reaches tip of aesthetes. Antenna (A 2) (Fig. 1 c): peduncle unsegmented, carrying a scale and flagellum, a long spine present at the base of flagellum; flagellum unsegmented, half the length of scale,carrying distally one long plumose and 3 short nonplumose setae; scale indistinctly 3-segmented distally, carrying 2 outer, 10 inner and apical setae, the outer apical seta being short, spine like and non-plumose. All other setae plumose. Mandible (Md) (Fig. 1 d): asymmetrical; incisor process with 2 to 4 stout teeth; molar process with rough cutting edge and 1 or 2 teeth; in between the processes 2 to 5 short stout teeth present. Maxillule (Mx 1) (Fig.1e): bilobed: proximal masticatory process with 5 to 6 spines and a small seta on inner anterior side: distal process with 6 short stout teeth; palp (endopod) unsegmented, carrying 4 apical setae of which 2 are slender; vestigial exopod present as a small lobe carrying 2 long plumose setae. Maxilla (Mx 2) (Fig. 1 f): bilobed; protopod with 4 lobes, proximal lobe broad, bearing 9 bristle-like arched setae, other 3 lobes each with 2 stout setae; endopod without any distinct segment, but bears 2 inner lobes, proximal and distal

TABLE 1. *Larval development and moulting periodicity of* Caridina pseudogracilirostris

Date	Stage	Intermoult period in days	Number of days after hatching	Salient feature of the stage
17– 9–'72	Zoea I	..	..	Sessile eyes; A–1, A–2, Md–1, Mx-1, Mx-2, Mxp–1, Mxp–2 and Mxp–3 developed; telson not distinct from the last abdominal segment and with 7 pairs of spines.
18– 9–'72	Zoea II	1	1	Eyes stalked; A–1 peduncle 2–segmented; biramous bud of P–1 developed; telson with 8 pairs of spines.
20– 9–'72	Zoea III	2	3	A–1 peduncle 3–segmented; P–1 developed; biramous buds of P–2, P–3 and uniramous buds of P–4 and P–5 developed; telson distinct from the last abdominal segment; uropod developed.
22– 9–'72	Zoea IV	2	5	Base of rostrum with a small knob-like papilla; P–2 and P–3 developed; uniramous bud of pleopods developed.
23– 9–'72 24– 9–'72	Zoea V	1 to 2	6 to 7	P–4 and P–5 developed; pleopod buds biramous.
24– 9–'72 25– 9–'79	Zoea VI	1 to 2	7 to 8	Rostrum with a single dorsal tooth.
25– 9–'72 26– 9–'72	Postlarva I	1 to 2	8 to 9	Rostrum with 3 dorsal teeth; pleopods with setae, and the endopods of 2nd and 5th with appendix interna.
4–10–'72	Eight days old postlarva	8 to 9	17	Tl 3.09 to 3.68 mm; Cl 1.02 to 1.24 mm; rostrum with 4 to 5 dorsal and a single ventral teeth.
13–10–'72	Seventeen days old postlarva	9	26	Tl 7.1 to 7.8 mm; Cl 2.8 to 3.1 mm; rostrum with 8 dorsal and 11 ventral teeth; pereiopods without exopods; telson with 3 pairs of lateral and 4 pairs of terminal spines.
27–10–'72	Thirtyone days old postlarva	14	40	Tl 11.5 to 12.3 mm; Cl 4.69 to 5.01 mm; rostrum with 19 ventral teeth; carapace with only antennal spine.
18–12–'72	Juvenile	52	92	Rostrum with 9 to 10 dorsal and 24 to 27 ventral teeth; adult males with appendix masculina.

lobes with 3 and 2 setae respectively; inner distal margin of the endopod with 4 long setae; exopod broad without proximal extension and bears 5 long plumose setae along its margin. First maxilliped (Mxp 1) (Fig. 1 g): biramous; protopod with 12 to 13 long setae; endopod 4-segmented, distal segment with 3 long setae at its apex, 1st, 2nd and 3rd segments carry on its inner side 3, 1 and 1 setae respectively, a single seta present on the outer distolateral margin of 3rd segment; exopod longer than endopod, bearing 4 long apical and 2 sub-apical plumose setae. Second maxilliped (Mxp 2) (Fig. 1 h): biramous; protopod with 5 to 7 long plumose setae; endopod 4-

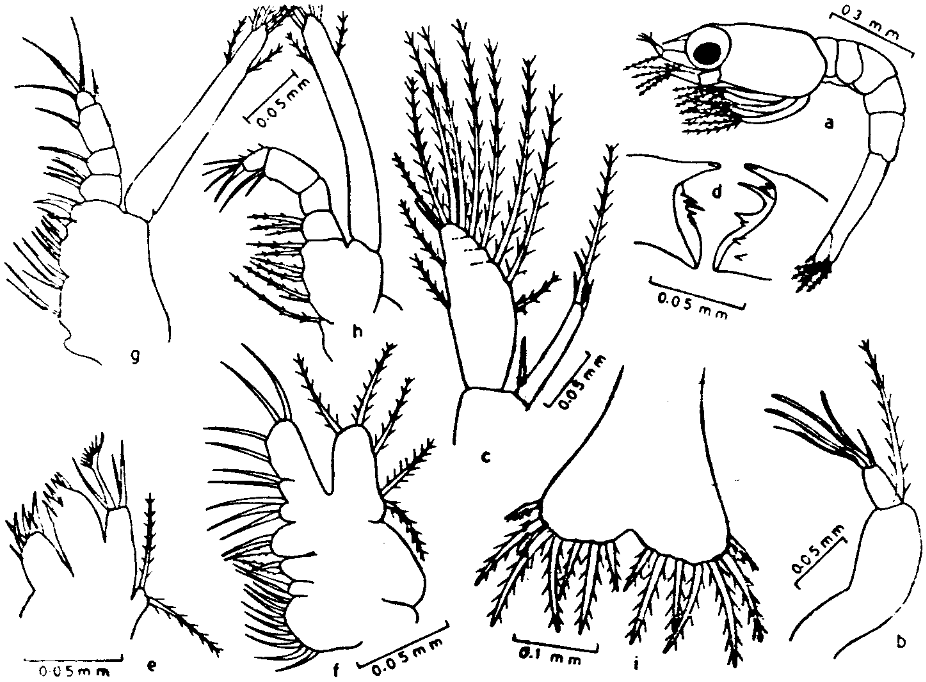

Fig. 1. *Caridina pseudogracilirostris.* Zoea I: a. lateral view; b. A–1; c. A–2; d. Md; e. Mx–1; f. Mx–2; g. Mxp–1; h. Mxp–2; i. T.

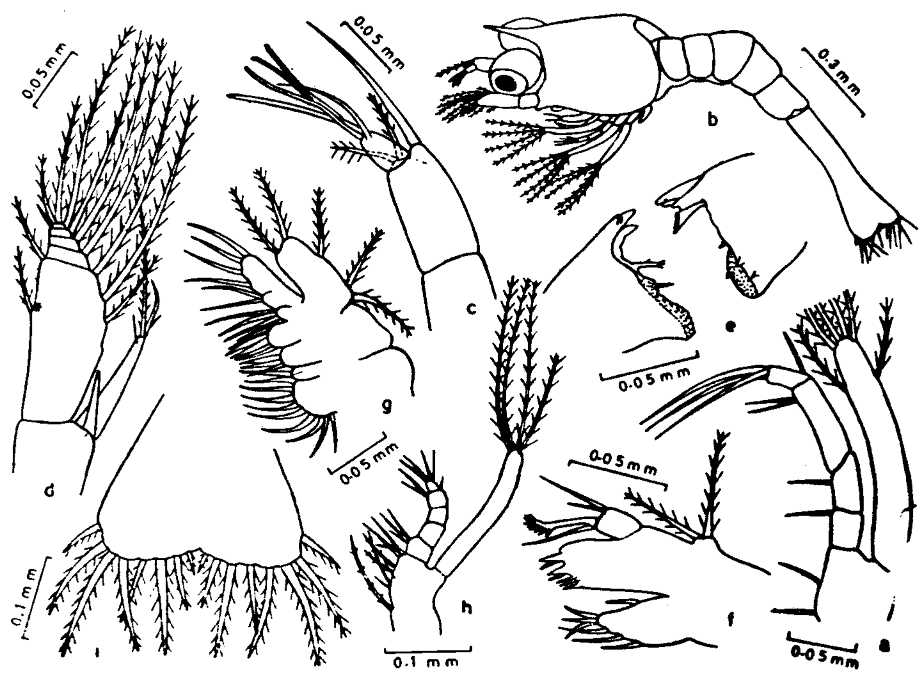

Fig. 2. *Caridina pseudogracilirostris.* Zoea I: a. Mxp–3. Zoea II: b. lateral view; c. A–1; d. A–2; e. Md; f. Mx–1; g. Mx–2: h. Mxp–2; i. T.

segmented, first segment with 3 and third segment with 2 setae on the inner side, distal segment with 4 setae, 2 of which are stout and spine-like; exopod longer than endopod carrying 4 long apical and 2 short sub-apical plumose setae. Third maxilliped (Mxp 3) (Fig.2 a):biramous; protopod with 2 setae on the inner side; endopod 4-segmented, first two segments, each carrying one slender seta on the inner side, third segment with 2 setae, distal segment with 3 long stout claw-like setae; exopod as long as endopod with 4 long apical and 2 stout sub-apical plumose setae. Telson (T) (Fig. 1i): broadly triangular with a median notch on the posterior margin, carrying 7 pairs of plumose setae, of which, the outer most one shortest and plumose on the inner side.

Zoea II (Fig. 2 b to i): Tl - 1.48 to 1.58 mm; Cl - 0.49 to 0.52 mm.

Eyes stalked (Fig. 2 b); carapace with a well defined pterygostomial spine; peduncle of antennule 2-segmented; biramous bud of first pereiopod (P 1) developed; telson with 8 pairs of spines.

A 1 (Fig. 2 c): peduncle 2-segmented, distal segment carries two plumose setae on its apical dorsal region; outer flagellum with 4 aesthetes and one long spine-like seta. A 2 (Fig. 2 d): distal part of scale 4-segmented; flagellum only half the length of scale carrying at its apex one long plumose seta and one short spine-like stumpy seta, in some cases 2 very small setae also seen. Md (Fig. 2 e): asymmetrical; incisor with 4 to 5 stout teeth on one side; below the incisor teeth, one movable tooth serrated on one side present. Mx 1 (Fig. 2 f): proximal masticatory process with 7 long setae and the distal with 7 teeth. Mx 2 (Fig. 2 g): distal lobe of protopod with 5 stout setae. Mxp 2 (Fig. 2 h): 3rd segment of endopod shows a faint division in the middle. Mxp 3: basis with 3 setae; endopod 5-segmented. T (Fig. 2 i): posterior margin with 8 pairs of plumose setae, outermost seta plumose only on the inner side, innermost pair of setae shortest.

Zoea III (Fig. 3 a to e): Tl–1.84 to 2.07 mm; Cl–0.51 to 0.58 mm.

Antennular peduncle 3-segmented; first pereiopod developed; biramous buds of 2nd and 3rd and uniramous buds of 4th and 5th pereiopods developed; telson separated from 6th abdominal segment by an articulating joint; uropod developed.

A 1 (Fig. 3 a): peduncle 3-segmented, proximal part of 1st segment swollen and carries a short seta, one plumose seta present on inner distal region; 2nd segment carries distally 2 plumose setae of which the inner one longer, and reaches almost to the tip of aesthetes, third segment with 2 long plumose setae; outer flagellum with one aesthetes and a seta; inner flagellum in the form of a papilla and carries a long seta. A 2 (Fig. 3 b): scale without distal segmentation, carrying one outer, 11 inner and apical setae, distolateral seta small, spine-like and non-plumose; flagellum short not reaching half the length of scale, carrying distally one short stout and 2 small slender setae. Md (Fig. 3 c): incisor with 4 to 6 stout teeth; cutting edge of molar further developed; in between incisor and molar processes 2 to 3 slender teeth present, of which one movable and serrated on one side. Mx 2: Exopod with 8 plumose setae around its outer and inner margin, its outer proximal region slightly extended. Mxp 1: number of setae on the inner side of protopod increased. Mxp 2: protopod with 9 setae, of which the proximal one long and plumose; endopod 5-segmented, distal segment with 4 setae of which one stout and claw-like. P 1 (Fig. 3 d): biramous; not fully developed; endopod 5-segmented; protopod and first 2 segments of endopod each

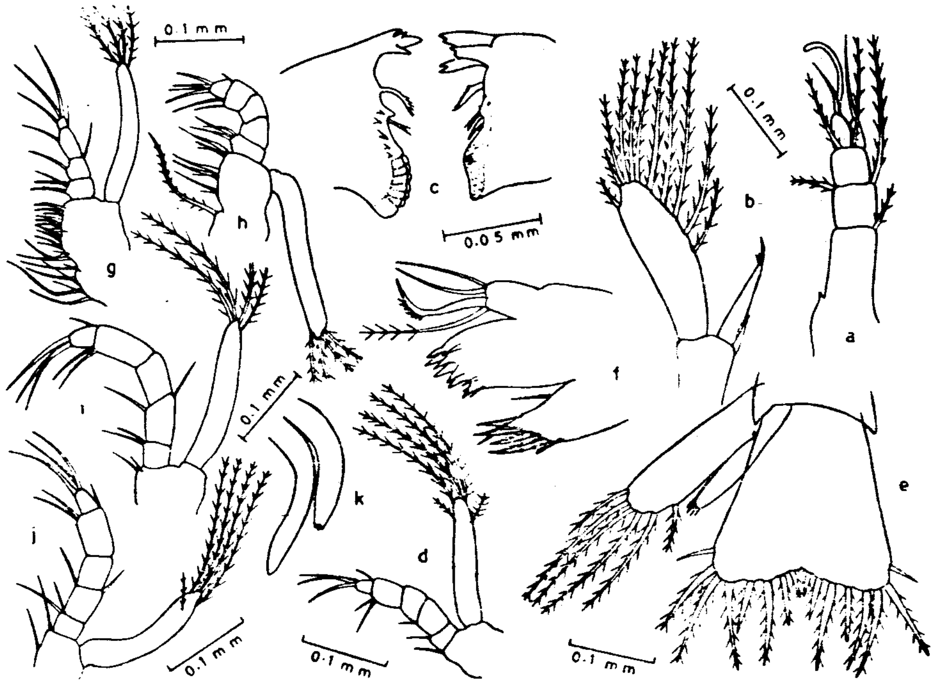

Fig. 3. *Caridina pseudogracilirostris*. Zoea III: a. A–1; b. A–2; c. Md; d. P–1; e. uropod and T. Zoea IV: f. Mx–1; g. Mxp–1; h. Mxp–2; i. Mxp–3; j. P–1; k. uniramous bud of P–4 and P.–5.

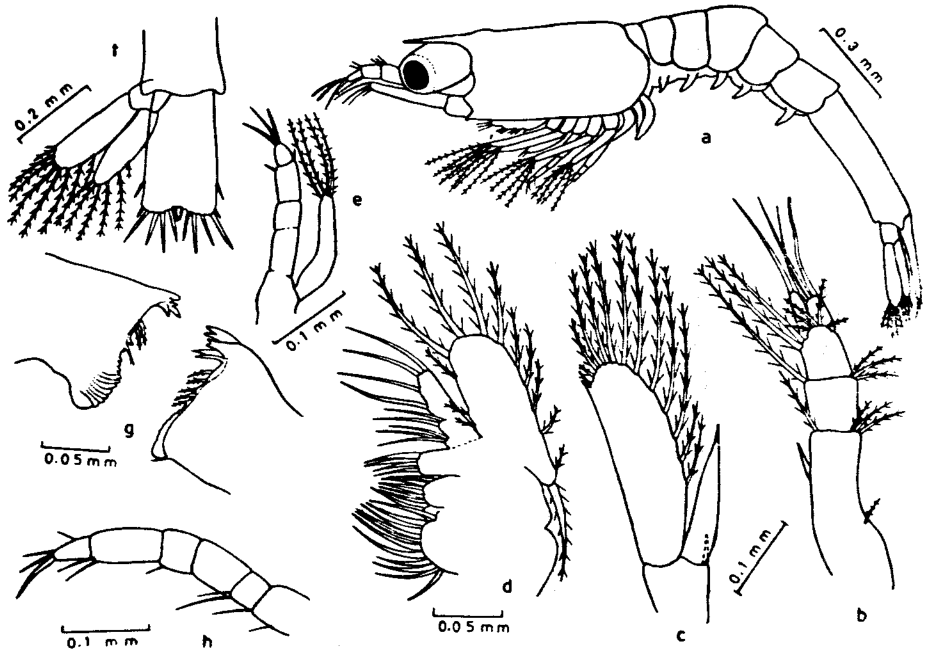

Fig. 4. *Caridina pseudogracilirostris*. Zoea IV: a. lateral view; b. A–1; c. A–2; d. Mx–2; e. P–3; f. uropod and T. Zoea V: g. Md; and h. P–5.

with one seta on the inner side, 4th segment with 2 setae on the inner side and one on the outer distolateral margin, distal segment with 3 long setae at its distal end, of which one is claw-like; exopod slightly longer than endopod with 4 long apical and 2 short sub-apical plumose setae. Exopod of uropod (Fig. 3 e) with 6 long plumose setae; endopod with 4 short setae at its apex. T: broader posteriorly, with 8 pairs of setae, outermost seta on either side non-plumose.

Zoea IV (Fig. 3 f to k; 4 a to f): Tl-2.05 to 2.22 mm; Cl-0.57 to 0.65 mm.)

Rostrum long and slender, at its base a small knob like papilla developed (Fig. 4 a); 2nd and 3rd pereiopods developed, uniramous buds of 4th and 5th pereiopods further enlarged, developing setae are indicated as small knob-like projections at the apex of the bud (Fig. 3 k); uniramous buds of pleopods appeared (Fig. 4 a).

A 1 (Fig. 4 b): proximal segment of peduncle slightly bulged outwards carrying a short plumose seta, a stout spine also present on ventral side of the segment. Distal region of the first and second segments beset with 4 plumose setae, 5 plumose setae present on the distal dorsal aspect of the 3rd segment, ventrally the same segment carries 4 long plumose setae; inner flagellum longer than the outer and carries a long seta apically; outer flagellum stumpy with one seta and 2 aesthetes. A 2 (Fig. 4 c): scale with 13 plumose setae at its inner and apical margin and one short spine at the outer distal margin; flagellum stumpy, with a short seta at its apex; the spine on protopod becomes smaller. Mx 1 (Fig. 3 f): proximal masticatory process with 7 setae and distal with 10 teeth; palp with 4 apical setae; exopod completely disappears. Mx 2 (Fig. 4 d): exopod with 13 plumose setae. Mxp 1 (Fig. 3 g): number of setae on protopod increases, some of proximal setae long and plumose, a single additional seta develops on the outer side of 2nd segment. Mxp 2 (Fig. 3 h): Segments of endopod more flattened. P 1 and P 2 (Fig. 3 j): almost identical; protopod with 2 to 3 setae, on inner side; endopod 5-segmented, 1st and 2nd segments each with 2 setae, 3rd segment with 2 to 3 setae, terminal segment with 3 long claw like setae. P 3 (Fig. 4 e): not fully developed; endopod 4-segmented; segmentation on 1st segment faint, terminal segment with 3 setae; exopod shorter than endopod with 4 long apical plumose setae. Exopod and endopod of uropod with 8 and 6 plumose setae respecively; exopod with a small spine at the distolateral edge (Fig. 4 f). T: almost rectangular in shape, with a pair of lateral spines and 6 pairs of distal setae.

Zoea V (Fig. 4 g, h; 5 a to k): Tl-2.50 to 2.64 mm; Cl-0.71 to 0.74 mm. 4th and 5th pereiopods uniramous and fully developed; all pleopod buds biramous but bare (Fig. 5 h to j).

A 1 (Fig. 5 a): 3rd segment of penduncle with 5 long plumose setae on the distal ventral side; inner flagellum nearly twice the length of outer and with a faint segmentation in the middle and carries 3 setae terminally, one of which twice the length of others; outer flagellum with 2 setae and 3 aesthetes. A 2 (Fig. 5 b): scale with 15 plumose setae and one spine; flagellum as long as scale, 2-segmented, the distal segment shows 2 faint notches indicating segmentation and bears an apical seta; the spine on the distal aspect of protopod 2/3rd the length of first segment of flagellum. Md (Fig. 4 g): incisor with 5 to 6 stout teeth; in between incisor and molar process, 3 to 5 serrated stout teeth present. Mx 1 (Fig. 5 c): proximal process with 8 long setae and distal with 11 teeth. Mx 2: exopod with 15 plumose setae on the broader and one plumose seta on narrower part. Mxp 2 (Fig. 5 d): endopod more flattened, terminal segment with 5 setae. Mxp 3 (Fig. 5 e): protopod with 4 long setae; exopod

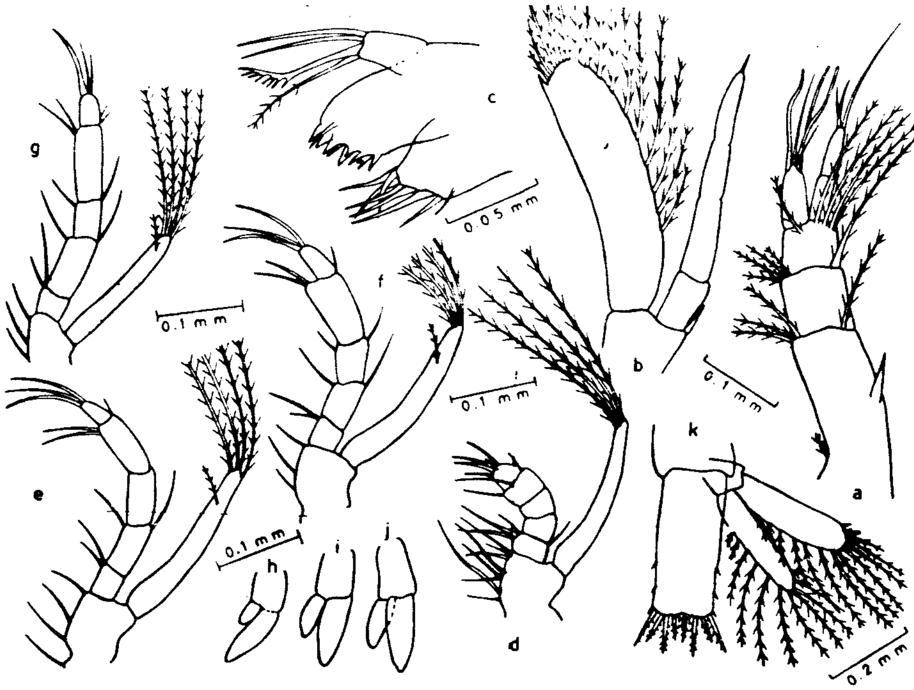

Fig. 5. *Caridina pseudogracilirostris*. Zoea V: a. A–1: b. A–2; c. Mx–1; d. Mxp–2; e. Mxp–3; f. P–1; g. P–3; h. pleopod I; i. pleopod II; j. pleopod III; k. uropod and T.

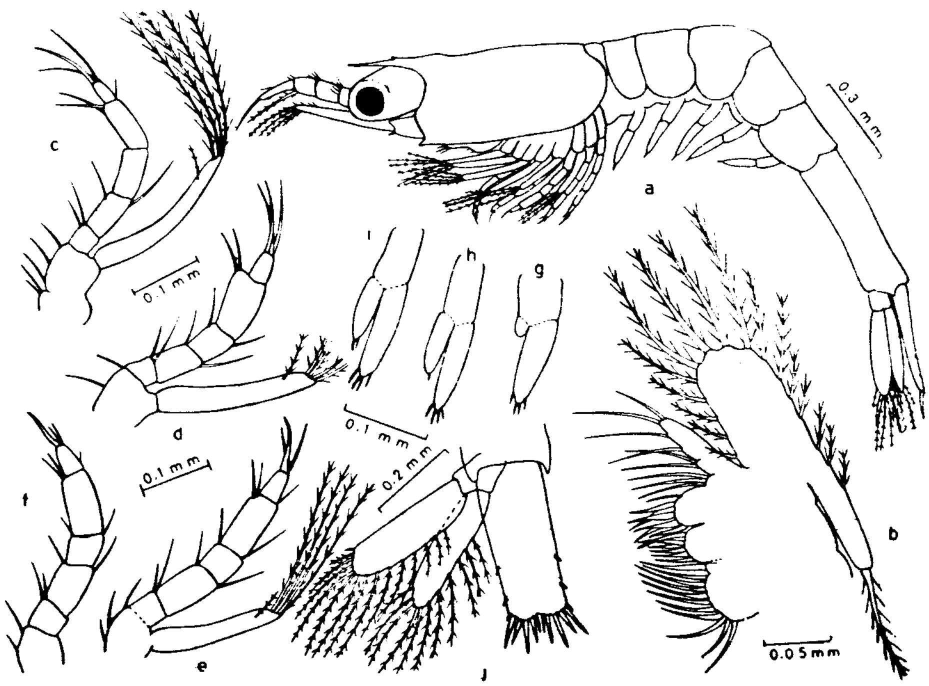

Fig. 6. *Caridina pseudogracilirostris*. Zoea VI: a. lateral view; b. Mx–2; c. Mxp–3; d. P–1; e. P–3; f. P–5; g. pleopod I; h. pleopod II; i. pleopod III; j. uropod and T.

shorter than endopod. P1 and P 2 (Fig. 5f): almost identical, propodus stouter, developing chela seen as a projection with 2 long setae at its apex: exopod shorter than endopod. P 3 (Fig. 5 g): protopod with 3 setae; endopod 5 segmented, 1st four segments carry 2 setae each, distal segment carries 3 setae at its apex, of which one curved and claw-like; exopod as long as the first 3 segments of endopod bearing 4 long apical and 2 short sub-apical plumose setae. P 4 and P 5 (Fig. 4 h): both uniramous and almost identical in structure; protopod with 2 setae on its inner side; endopod 5 segmented; 1st and 4th segments each with 2 and 3rd segment with a single seta respectively, terminal segment carries 3 setae, of which one long and sickle-shaped. Endopod of 1st pleopod (Fig. 5 h) smaller as compared to that of 2nd and 5th pleopods. Exopod of uropod (Fig. 5 k) with 13 plumose setae and one spine; endopod with 11 plumose setae. T: rectangular with 3 pairs of short spines laterally and 5 pairs of setae distally.

Zoea VI (Fig. 6 a to j): Tl-2.47 to 2.68 mm; Cl-0.67 to 0.75 mm.

Rostrum with a single dorsal tooth (Fig. 6 a); exopod of all pleopods tipped with 4 short non-plumose setae, endopod of 2nd to 5th pleopods with 1 to 2 short non-plumose setae (Fig 6 g to i).

A 1: proximal segment with a bulge at the basal outer region which carries 3 short plumose setae; outer flagellum with one seta and 3 aesthetes. A 2: scale with 16 plumose setae and one spine. Mx2 (Fig. 6 b): exopod with 17 plumose setae, narrower region produced further. Mxp 3 (Fig. 6 c): basis with 4 to 5 setae; exopod as long as the first three segments of endopod. P 1 and P 2 (Fig. 6 d): both appendages almost identical in shape; protopod with 2 to 3 long setae; propodus thicker and the developing chela seen as a projection carrying at its apex 2 slender setae. Exopod of uropod (Fig. 6 j) with 14 plumose setae and one spine and endopod with 11 plumose setae.

Postlarva I (Fig. 7 a to j; 8 a to g): Tl-2.54 to 2.96 mm; Cl-0.70 to 0.86 mm.

Rostrum with 3 dorsal teeth (Fig. 8 a); carapace with pterygostomial and antennal spines; appendix interna developed on the endopod of 2nd to 5th pleopods.

A 1: peduncle 3-segmented, protuberance at proximal outer region of basal segment with 4 short setae; number of plumose setae at 1st and 2nd joints increase; outer flagellum 2 to 3-segmented, the distal segment with 3 terminal short setae (Fig. 7 a), 5 aesthetes in 2 groups of 3 and 2 present; inner flagellum 4-segmented with 4 short setae terminally. A 2 (Fig. 7 b): scale with 17 to 18 plumose setae and one spine; flagellum nearly 2 times the length of scale with 11 to 13 segments, basal 2 segments stouter. Md (Fig. 7 c): asymmeterical; incisor with 6 to 8 stout teeth; numerous grooves and transverse ridges present on the molar in addition to a few slender teeth; in between the 2 processes 4 to 5 slender teeth present. Mx 1 (Fig. 7 d): proximal masticatory process becomes more flattened bearing 9 to 10 long setae; the cutting edge of the distal masticatory process with 12 short teeth; palp with 2 distal setae. Mx 2 (Fig. 7 e): proximal masticatory process with 14 long arched setae; distal process with numerous bristle-like setae; endopod small and unsegmented; the flattened exopod with 19 plumose setae along its margin, of which 3 placed on the proximal extension of exopod. Mxp 1 (Fig. 7 f): exhibits great change; basis and coxa expanded and beset with setae; those on coxa being longer; endopod triangular, its inner basal region with 2 short setae; exopod slightly broader at proximal region bearing 7 to 8 plumose setae at outer and terminal

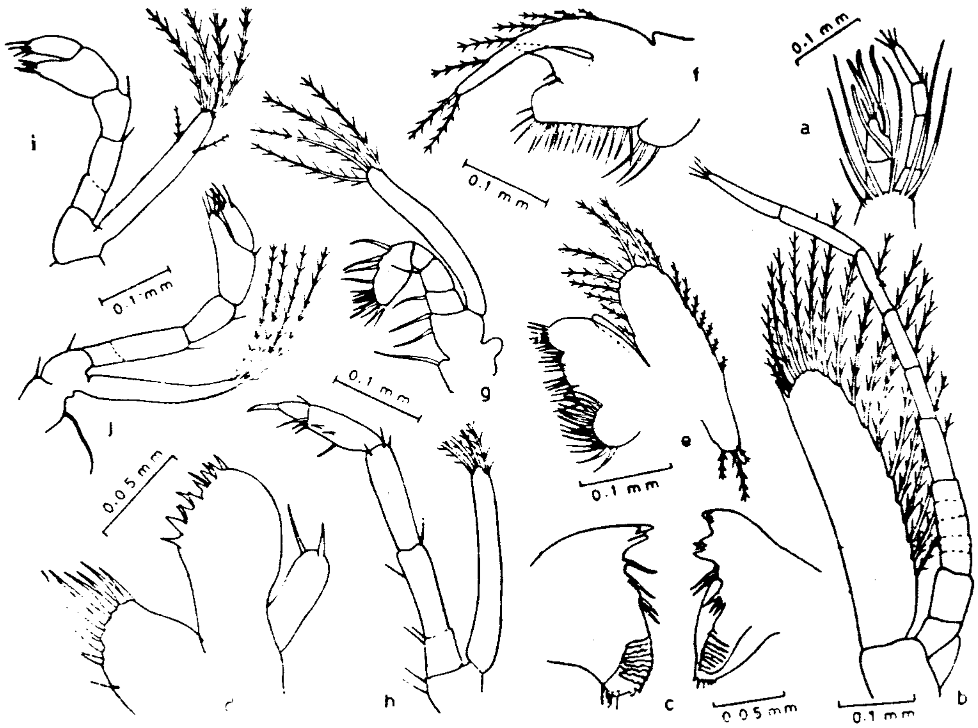

Fig. 7. *Caridina pseudogracilirostris*. Post larva I: a. antennular flagellum; b. A–2; c. Md; d. Mx–1; e. Mx–2; f. Mxp–1; g. Mxp–2; h. Mxp–3; i. P–1 and j. P–2.

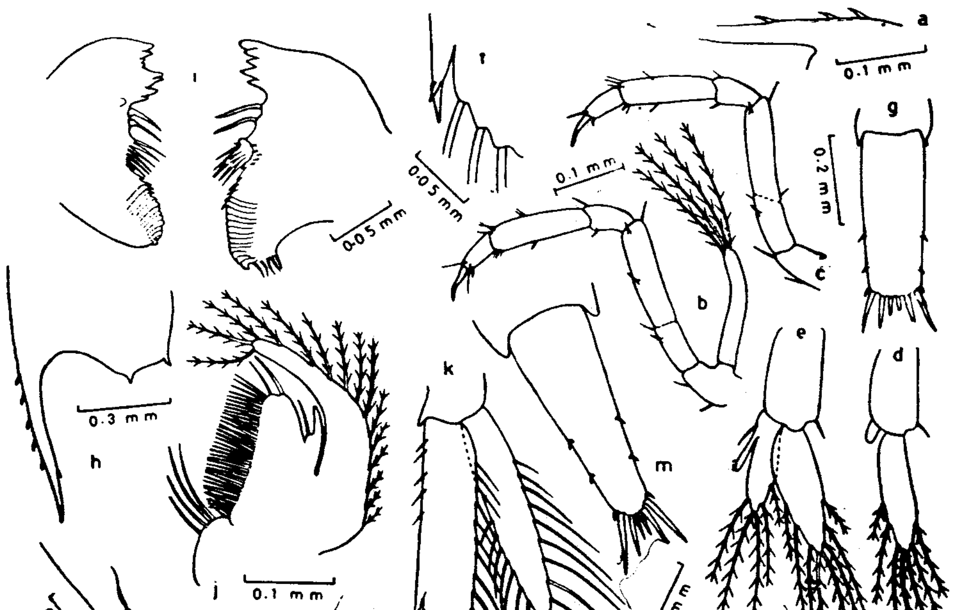

Fig. 8. *Caridina pseudogracilirostris*. Post larva I: a. rostral tip; b. P–3; c. P–4; d. pleopod I; e. pleopod II; f. diaeresis of uropodal exopod; g. T. Eight days old postlarva: h. rostrum; i. Md; j. Mxp–1 k. uropod; l. diaeresis of uropodal exopod and m. T.

regions. Mxp 2 (Fig. 7 g): dactylus and propodus not separate and together forms a flattened segment bearing a number of setae; bud of podobranch developed; exopod longer than endopod bearing 4 long apical plumose setae. Mxp 3 (Fig. 7 h): protopod with 2 setae on inner side; endopod 5-segmented, ischium, merus and carpus with 2 setae each, propodus slightly expanded bearing a number of bristle-like setae, dactylus ends in a claw-like seta; exopod shorter than endopod carrying 4 long plumose apical setae. P 1 (Fig. 7 i): chela fully developed, with a few terminal tuft of setae; exopod with 4 apical and 2 sub-apical plumose setae. P 2 (Fig. 7 j): longer than P1; chela fully developed with terminal tuft of setae; exopod shorter than endopod. P 3 (Fig. 8 b): dactylus of endopod ends in a claw-like spine and 2 small setae; 1st five segments carry 1, 2, 1, 2 and 1 spines respectively; exopod very small reaching middle of 2nd segment of endopod. P 4 and P 5 (Fig. 8 c): almost similar and uniramous; the division between ischium and merus indistinct, terminal segment ends in claw-like spine, first 4 segments carry one spine each. First pleopod (Fig. 8 d): exopod with 7 long plumose setae: endopod small and bare. 2nd to 5th pleopods almost identical in structure (Fig. 8 e): exopod with 8 to 9 and endopod with 4 to 6 plumose setae: appendix interna developed. Exopod of uropod with 15 to 16 and endopod with 14 to 15 plumose setae. Development of diaeresis started and it carries 2 spines (Fig. 8 f). T: with 2 pairs of short spines on the lateral margin (Fig. 8 g) and 4 pairs of spines distally, lateral spines placed at distal half of the telson.

Although rearing experiments of postlarva I were continued for 83 days, when it attained almost all the adult characters, only four samples were preserved for detailed studies (Table 1). Major changes occurred in the process of development during this period are given below.

Eight days old postlarva is characterised by having a rostrum with 4 to 5 dorsal and one ventral teeth (Fig. 8 h); carapace with pterygostomial and antennal spines; exopod present on first three pereiopods; telson with 2 pairs of lateral and 4 pairs of terminal spines. A 1: a circlet of plumose setae seen on the distal aspect of 1st segment; number of setae on 2nd and 3rd segments also increased; outer flagellum 3-segmented, carrying 5 aesthetes in 2 groups of 3 and 2, terminal segment with 2 short setae; inner flagellum 6-segmented longer than outer flagellum. Md (Fig. 8 i): 8 to 9 long and slender teeth present in between the incisor and molar processes. Mx 1 (Fig. 9 b): proximal masticatory process more flattened and carrying 13 long setae along its inner margin; distal process with 14 teeth. Mx 2 (Fig. 9 c): number of setae on the 3 masticatory processes increased; proximal part of the exopod produced further and slightly flattened distally carrying 5 setae, of which 2 long. Mxp 1 (Fig. 8 j): endopod unsegmented, slightly expanded at the proximal end bearing a plumose seta; exopod broader at the proximal region, carrying 15 plumose setae, distal ones longer. Mxp 2: basis and ischium, and propodus and dactylus coalesced: propodus bearing 4 long setae and the flattened dactylus bearing numerous long setae; podobranch further developed. Mxp 3 (Fig. 9 d): as ischium and merus, and propodus and dactylus are coalesced, endopod is only 3-segmented; distal segment broad with a row of closely set brush-like setae; exopod as long as the first segment of endopod with 4 long plumose terminal setae. P 1 (Fig. 9 e): chela becomes thicker; exopod present. P 2 (Fig. 9 f): exopod becomes smaller and only as long as the first segment of endopod. P 3 (Fig. 9 g): exopod represented only as a small bud-like projection; dactylus carries 2 more spines in addition to the terminal one. P 4 and P 5 (Fig. 9 h): both appendages almost same in structure; ischium with 1 and merus with 2 spines respectively; in addition to the terminal spine the dactylus carries 1 to 2 spines. Exopod and endopod of uropod (Fig. 8 k) with 21 plumose

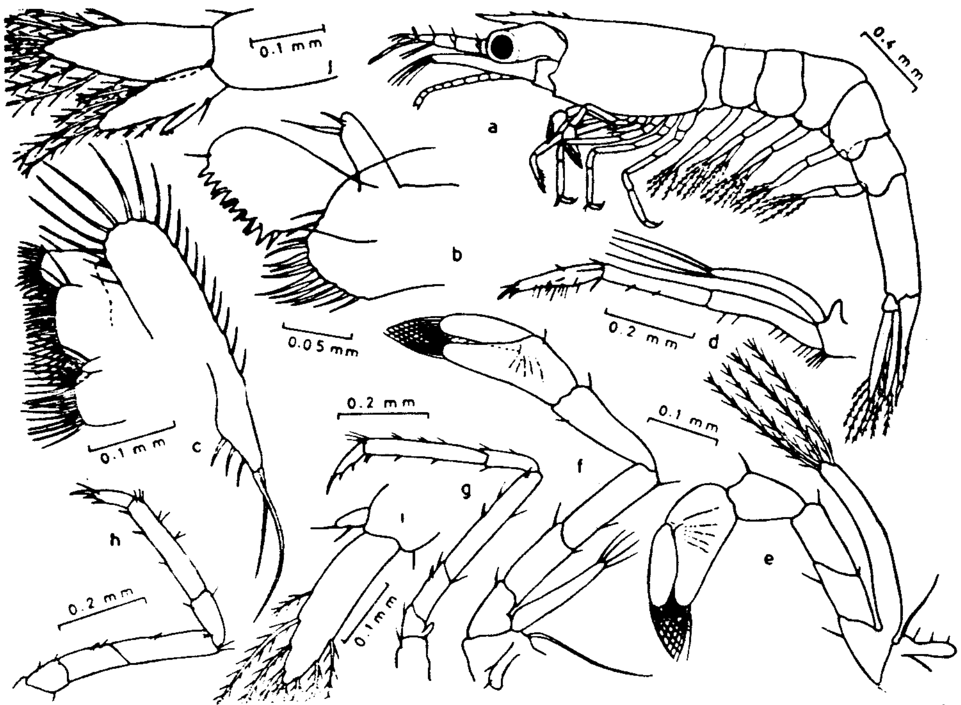

Fig. 9. *Caridina pseudogracilirostris*. Eight days old postlarva: a. lateral view; b. Mx-1; c. Mx-2; d. Mxp-3; e. P-1; f. P-2; g. P-3; h. P-5; i. pleopod I; j. pleopod II.

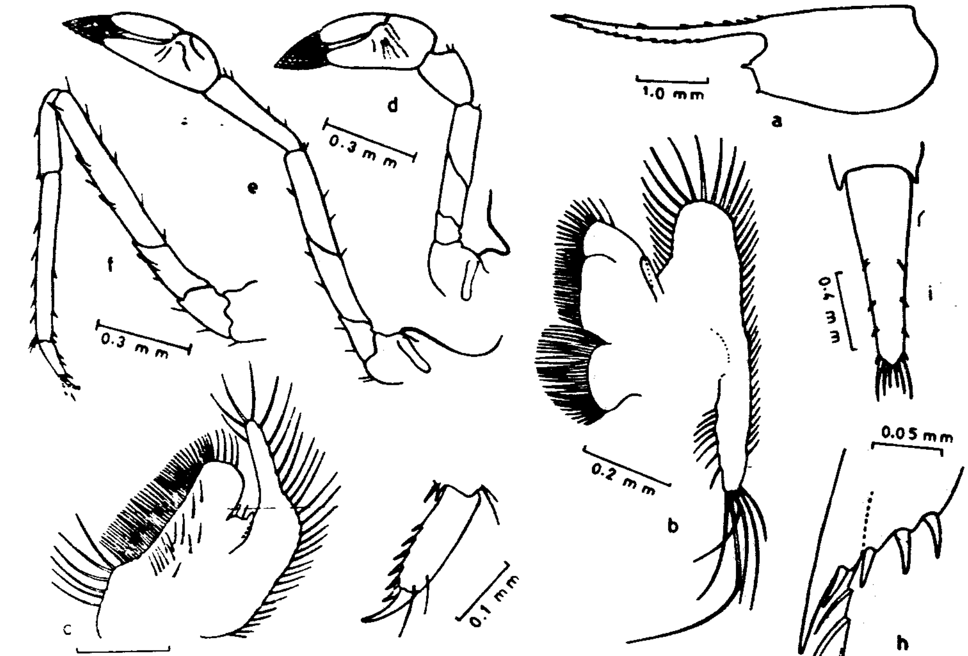

Fig. 10. *Caridina pseudogracilirostris*. Seventeen days old post-larva: a. Carapace; b. Mx-2; c. Mxp-1; d. P-1; e. P-2 f. P-4; g. dactylus of P-5; h. diaeresis of uropodal exopod; i. T.

setae, diaeresis with 3 spines. T (Fig. 8 m): tappering towards posteriorly bearing 4 pairs of spines.

Seventeen days old postlarva is characterised by rostrum with 8 dorsal and 11 ventral teeth; carapace with pterygostomial and antennal spines (Fig. 10 a); pereiopods without exopods; telson with 3 pairs of lateral and 4 pairs of terminal spines. A 1: apical spine of basal segment developed; outer flagellum 9-segmented, proximal segments broader bearing aesthetes; inner segment with 14 segments longer than outer. Mx 2 (Fig. 10 b): number of setae on masticatory processes and exopod increased, proximal extension of exopod bearing 6 long setae. Mxp 1 (Fig . 10 c): inner margin of the broad basis slightly concave; exopod broader proximally, distally it tappers and bears plumose setae along its margin. P 1 (Fig. 10 d): carpus shorter than chela, 1.5 to 1.7 times as long as broad with a small excavation anteriorly; fingers longer than palm, chela 1.9 to 2.0 times as long as broad; exopod absent. P 2 (Fig. 10 e): carpus shorter than chela, 3.4 to 3.6 times as long as broad; chela 2.2 times as long as broad. P 3: propodus 3.8 times as long as dactylus, dactylus with 4 spines of which the distal one more prominent. P 4 (Fig. 10 f): dactylus with 4 spines, terminal one being longer and stouter, propodus 4 times as long as dactylus. P 5: dactylus with 7 spines (Fig. 10 g.); and propodus 3.5 times as long as dactylus. Diaeresis with 5 spines (Fig. 10 h). T: with 3 pairs of lateral and 4 pairs of terminal spines (Fig. 10 i); the proximal 2 pairs of spines have shifted towards the dorsal surface of telson.

Thirty-one days old postlarva is characterised by rostrum longer than carapace with 8 dorsal and 19 ventral teeth (Fig. 11 a): carapace with antennal spines only; telson with 3 pairs of lateral and 4 pairs of terminal spines. Mx 2 (Fig. 11 b): the proximal extension of exopod further developed, carrying distally more than 10 long setae, the number of setae on exopod and protopod increased. Mxp 2 (Fig. 11 c): propodus carries 7 long setae; dactylus flattened and slightly concave on its topographically inner margin and bears a number of long setae; podobranch fully developed; exopod with a number of plumose setae distally. Mxp 3: number of closely set brush-like setae on the distal segment increased. P 3 and P 4: dactylus with 5 spines, terminal one being the longest (Fig. 11 d); P 5: dactylus with 14 spines (Fig. 11 e); diaeresis with 6 spines (Fig. 11 f). T: with 3 pairs of lateral and 4 pairs of terminal spines; the lateral spines shifted towards the dorsal surface of telson (Fig. 11 g).

Juvenile (Fig. 11 h to j; 12 a to g; 13 a to j): Tl-14.0 to 14.39 mm; Cl-5.88 to 6.21 mm.

Rostrum has attained the adult shape. Appendix masculina is fully developed on the 2nd pleopod of males. Rostrum is longer than carapace with 9 to 10 dorsal and 24 to 27 ventral teeth, reaches distinctly beyond the scaphocerite; tip of the rostrum is slightly curved upwards, considerable portion of the dorsal margin behind the sub-apical teeth being entire. Orbital angle is distinct and rounded. Antennal spine is present and the antero-lateral angle of the carapace is rounded. In one specimen, pterygostomial spine was present (Fig. 11 h).

A 1 (Fig. 12 a): stylocerite slender and pointed, reaching beyond the middle of basal segment; anterolateral tooth well developed. Md (Fig. 12 b): asymmetrical; incisor with 7 to 10 stout teeth; molar with a number of prominent ridges; in between the processes a number of slender teeth in 2 groups present, near the incisor 5 to 6 slender teeth and below it 11 to 13 bristle-like teeth present, the lower ones of these

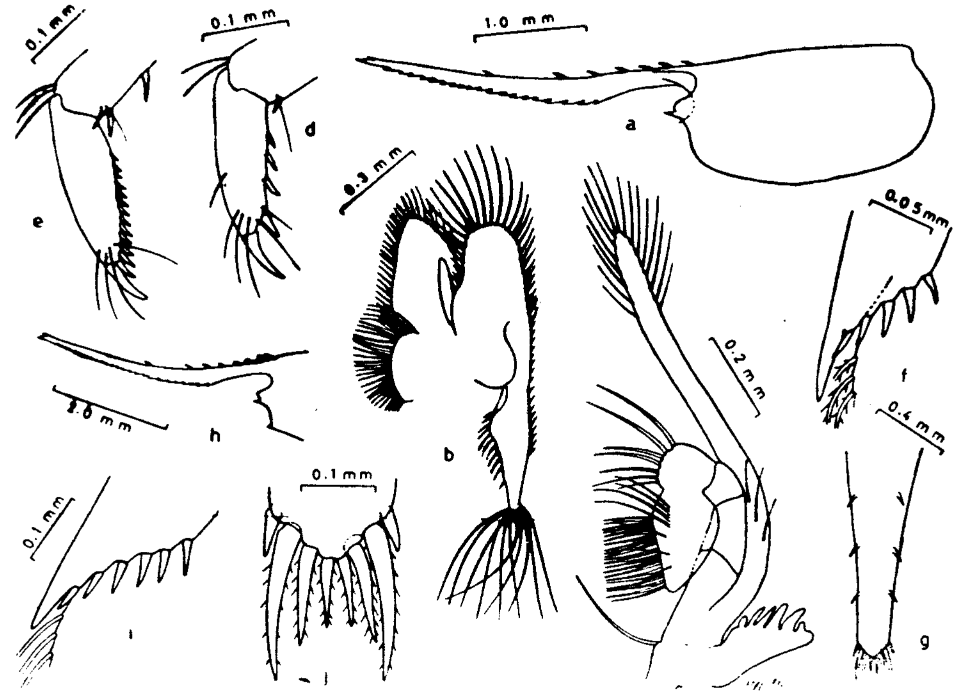

Fig. 11. *Caridina pseudogracilirostris*. Thirtyone days old post-larva: a. carapace; b. Mx-2; c. Mxp-2; d. dactylus of P-4; e. dactylus of P-5; f. diaeresis of uropodal exopod; g. Tuenile; h. rostrum; i. diaeresis of uropodal exopod; j. tip of T.

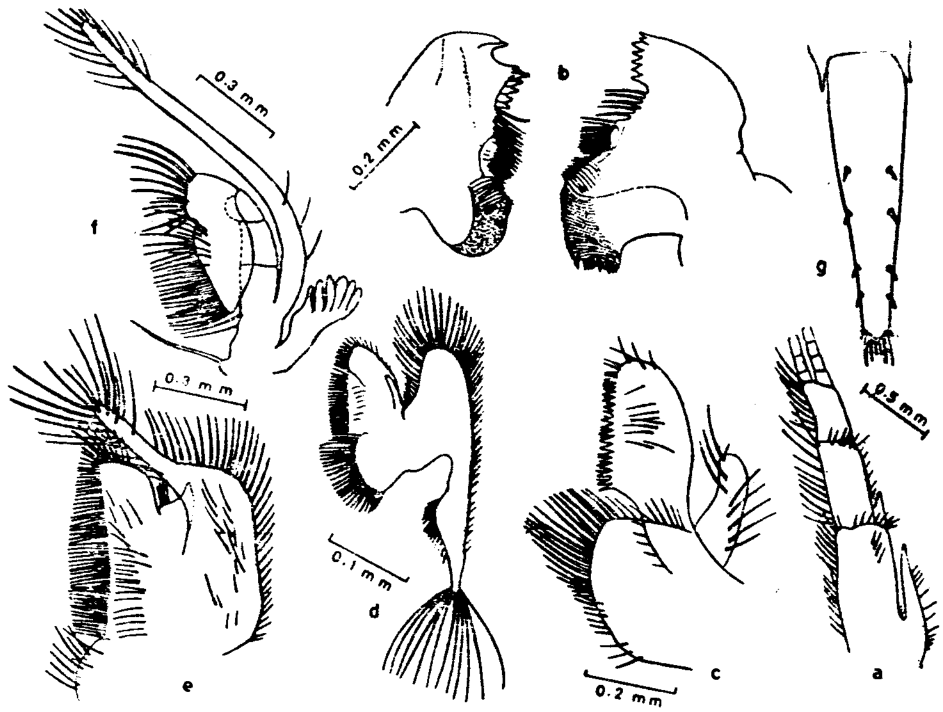

Fig. 12. *Caridina pseudogracilirostris*. Juvenile: a. A-1; b. Md; c. Mx-1; d. Mx-2; e. Mxp-1; f. Mxp-2; g. T.

teeth being smaller. Mx 1 (Fig. 12 c): having typical adult shape; proximal masticatory process flattened and the cutting edge in the form of a semicircle, bearing 35 to 40 slender setae along its margin; distal process with 30 to 35 teeth and a number of slender bristle-like setae; endopod with 8 to 10 slender setae. Mx 2 (Fig. 12 d): outer margin of coxopod almost like a semicircle bearing a number of long arched setae along its margin; basipod with a number of short bristle-like setae along its outer and distolateral margin; endopod small and unsegmented; distal process of the exopod bearing terminally 12 to 15 long setae, its proximal part expanded on the inner side bearing 15 short setae. Mxp 1 (Fig. 12 e): basipod elongated and inner margin slightly concave bearing rows of setae; exopod proximally expanded bearing a number of setae (about 34) along its outer margin: anterior part narrower bearing a number of long setae around its distal part: endopod small, triangular bearing 4 short setae on the proximal inner part. Mxp 3 (Fig. 13 a): endopod 3-segmented, distal segment with a row of short bristle-like setae;exopod with 9 pairs of plumose setae distally. P 1 (Fig. 13b): carpus shorter than chela, 1.8 to 2.0 times as long as broad with a shallow excavation anteriorly; chela 2.2 times as long as broad and fingers longer than palm. P 2 (Fig. 13 c): longer than P 1; carpus slightly longer than chela, 4.3 to 4.8 times as long as broad: chela 2.6 times as long as broad. P 3 (Fig. 13 d): ischium with 1 and merus with 3 spines; propodus 3.4 times as long as dactylus; dactylus with 8 spines of which the distal one being longer and stouter. P 4 (Fig. 13 e): almost same as P 3: propodus more than 4 times as long as dactylus; dactylus carries 7 spines. P 5 (Fig. 13 f): dactylus with 23 spines (Fig. 13 g), the spines branched (Fig. 13 h); propodus more than 4 times as long as dactylus. Endopod of first pleopod of male ovate, without appendix interna (Fig. 13 i). Appendix masculina developed on the endopod of 2nd pleopod of male (Fig. 13 j), longer and broader than appendix interna and bears terminally a tuft of bristles; apical hook-like bristles present on appendix interna. Diaeresis with 7 spines (Fig.11 i). T (Fig. 12 g): bears 4 pairs of dorsal spines, distal margin narrow and convex carrying 4 pairs of spines, the outermost spine on either side short and non-plumose, other 3 pairs of spines plumose (Fig. 11 j).

DISCUSSION

Six well defined zoeal stages are distinguished in the larval development of *Caridina pseudogracilirostris*. Six stages have also been reported in the larval history of *C. wyckii* (Hicks) by Daday (1907). However, the corresponding larval stages of these two species show marked differences, particularly in the pattern of development of pereiopods. In *C. wyckii* the bud like rudiments of pereiopods make their first appearance in the zoea I itself and in the subsequent stages a progressive development is observed. In the present species, the pereiopod buds develop for the first time in the zoea II stage only. First and second pereiopods are fully developed in the third stage (metazoea) of *C. wyckii*, whereas second pereiopod is only in the form of bud in the same stage of the present species. Fourth pereiopod which is fully developed in *C. wyckii* at the fourth stage (protomysis) is not developed to the same extent in the corresponding stage of *C. pseudogracilirostris*.

In *C. denticulata* (Shen, 1939), *C. nilotica* (Gurney, 1927), *C. propinqua* (Babu, 1963), and a *Caridina* sp. (Lakshmi, 1975) the larval development is abbreviated and their first zoea shows advanced development. Except in the case of *C. propinqua* even pleopod buds are developed in the first zoea of all the above mentioned species. In *C. pseudogracilirostris* pleopod buds make their appearance only on the fourth zoeal stage.

The various morphological features of first zoea of *Caridina nilotica aruensis* (Glaister, 1976) are almost comparable with that of the present species. But the first zoea of the present species can easily be distinguished from the other by the presence of exopod with 2 setae on maxillule. The 2nd, 3rd and 4th zoeal stages of *C. nilotica aruensis* however differ from the same stages of the present species particularly in the pattern of development of pereiopods. In *C. pseudogracilirostris*, only first pereiopod bud is developed in zoea II, whereas in the comparable stage of *C. nilotica aruensis* both first and second pereiopods are developed. In fourth zoea of the present species second and third pereiopods are developed, while all the pereiopods are developed in the same stage of *C. nilotica aruensis*. Further fourth pereiopod is biramous in the zoeal stage of *C. nilotica aruensis* while it is uniramous in the present species.

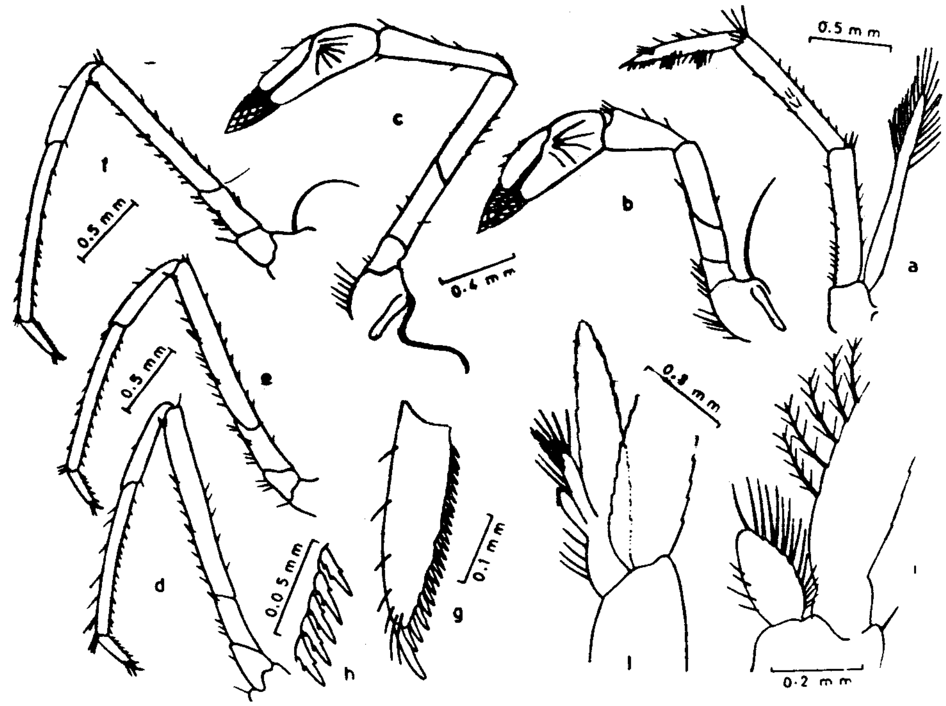

Fig. 13. *Caridina pseudogracilirostris*. Juvenile: a. Mxp–3; b. P–1; c. P–2; d. P–3; e. P–4; f. P–5; g. dactylus of P–5; h. spines on the dactylus of P–5; i. endopod of pleopod I of male; j. endopod of pleopod II of male.

One of the noteworthy characters observed in the development of *C. pseudogracilirostris* is the presence of a small vestigial exopod with 2 long plumose setae in the first maxilla of the first zoea. As in *Atyaephyra desmaresti* (Millet) (Gauthier, 1924), this vestigial exopod is retained in the first three zoeal stages.

Carapace of the first postlarva of *C. pseudogracilirostris* possesses an antennal spine and a small tooth at the anterolateral angles, while in advanced postlarval stages this tooth disappears completely. However in one of the laboratory reared juveniles this tooth is retained as a small pterygostomial spine. In *C. weberi* var.

sumatrensis de Man, Kemp (1918) observed such variations and opined that such variations cannot be regarded as having specific value in *C. weberi* group. In the light of this, the present observation on isolated instances of retention of a small pterygostomial spine in one of the specimens may be treated only as an aberration.

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SECTION TWO

Family Palaemonidae Rafinesque, 1815

Genus *Macrobrachium* Bate, 1868

INTRODUCTION

Ling and Merican in 1961 successfully reared all the larval stages of Macrobrachium rosenbergii in the laboratory and paved way for the commercial culture of this species and that of several other freshwater and brackish-water Macrobrachium sp. in confined waters. Since then, a number of workers have studied various aspects of rearing of different species of Macrobrachium from various parts of the world (Ling, 1962, 1964, 1969; Lewis and Ward, 1965; Uno and Kwon, 1969; Kwon and Uno, 1969; Fielder, 1970; Shokita, 1970; Choudhury, 1970, 1971a; Kewalramani et al. 1971; Williamson, 1972; Pillai and Mohamed, 1973; Dugger and Dobkin, 1975; Monaco, 1975; Greenwood, 1976; Ngoc-Ho, 1976; Atkinson, 1977; Guest, 1979). Commercial culture of M. rosenbergii is now being practised in countries such as Malaysia, Thailand, Taiwan, Mexico, Brazil and U.S.A. (Hawaii) and attempts are being made to popularise the culture of this species in other parts of Asia including India. In addition to M. rosenbergii there are several species of the same genus in India, which are suitable for culture. The life history of two of such species, namely M. malcolmsonii (Kewalramani, 1971) and M. idella (Pillai and Mohamed, 1973) have been worked out by rearing them in the laboratory. The data gathered on the rearing, larval biology and behaviour both of M. equidens and M. striatus in the present study have shown that these two species are also suitable for culture in the freshwater ecosystem available in the country. The information presented on the larval rearing would greatly help in developing suitable technology for the seed production and further propagation.

Our knowledge of the taxonomy and distribution of the species of Macrobrachium in South India is limited to a few works. Henderson and Matthai (1910) dealt with 9 species namely Palaemon carcinus (= M. rosenbergii) P. malcolmsonii (= M. malcolmsonii), P. idae (= M. idella), P. sulcatus (= M. equidens), P. rudis (= M. rude), P. nobili (= M. aemulum), P. scabriculum (= M. scabriculum), P. dubius (= M. scabriculum). Later Nataraj (1942) and Kurian (1954) recorded M. rosenbergii, M. idella, M. scabriculum, M. equidens and M. dayanum from the erstwhile Travancore. During the survey of the Kayankulam Lake, John (1958) listed two species namely M. idella and M. equidens. George (1969a) had given a key for the identification of the ten common species of Indian namely M. rosenbergii, M. idae, M. villosimanus, M. lamarrei, M. malcolmsonii, M. rude, M. equidens, M. mirabile, M. javanicum and M. scabriculum. Recently Jayachandran and Joseph (1985, 1986) described two new species namely M. veliense and M. indicum.

M. equidens is one of the common palaemonid prawns found in the backwaters of Kerala. The species was originally described by Dana (1852). Subsequently Cowles (1914), Kemp (1918) and Holthuis (1950) gave further taxonomic information on the species. Although a fairly good description of the species is now available, certain morphological variations and difference in the colour pattern of this species complex have been noted. Thus one group of specimens had a number of greenish/greyish spots all along the body and the other group had greenish/greyish longitudinal crenulated stripes along the entire length of the body. However, in the absence of more conclusive evidence to recognise these specimens as two distinct species, these variations and differences have been considered to be within the morphological diversity and the species has been hither to considered as monospecific. While trying to establish the identify of M. equidens collected from the Cochin Backwater for the present study, the author experienced the same difficulties as encountered by the earlier workers to interpret the variations and differences found among the specimens. However, the detailed studies made on the morphological characters, larval characters and on breeding of the two forms have provided adequate evidence to consider them as separate species, one as M. equidens and the other a new species M. striatus (Pillai, 1990). A detailed description of the adults as well as larvae of both the species are given below.

1. Macrobrachium equidens, Dana, 1852

Palaemon equidens Dana, 1852, Proc. Acad. Nat. Sci. Phila., 6:26

A complete synonymy is given by Holthuis (1950).

Description: The body is compressed and robust. Details regarding the total length, carapace length, rostral formula, relative length of segments of second pereiopod of adult males, number of eggs in the berry and their size are given in Tables 7 & 8. The rostrum is long and slender, reaching almost upto the distal margin of antennal scale and bear 11-14 dorsal and 4-7 ventral teeth. Distal end of the rostrum is slightly upturned (Fig. 19). Three dorsal teeth are placed behind the orbit. Hepatic and antennal spines are well developed and lie in one line. Antennal spine has a strong carina which almost reaches the hepatic spine. Pleura of the fifth abdominal segment ending in a rather acute apex directed backwards and that of sixth ends

Table 7. Macrobrachium equidens: Total length, Carapace length, rostral formula and length of segments of second pereiopod of adult male.

Total length (mm)	Carapace length (mm)	Rostral formula	Length of segments of second pereiopod (right side) (mm)				
			Ischium	Merus	Carpus	Propodus + dactylus	Dactylus
73.0	32.5	14/5	12.0	13.0	21.0	24.0	10.0
85.0	37.5	11/4	10.0	13.0	19.0	24.0	10.0
77.0	36.0	11/6	13.0	21.0	40.0	43.0	17.0
73.0	32.0	12/5	10.0	12.5	18.0	21.0	8.0
71.0	30.0	11/6	10.0	11.0	17.5	21.0	8.0
72.5	31.0	11/6	10.0	14.0	25.0	26.0	10.5
70.5	30.0	11/6	10.0	11.5	17.0	22.0	9.0
83.5	36.5	16/7	12.0	17.0	29.5	33.0	13.0
78.0	35.0	11/5	14.0	20.0	35.0	41.0	16.0
72.0	32.5	13/6	10.5	16.0	28.5	30.3	12.5

Table 8. *Macrobrachium equidens*: Total length, carapace length, number of eggs in the berry and measurement of eggs of adult females.

Total length (mm)	Carapace length (mm)	No. of eggs in the berry	Egg measurements in (mm)			
			Longest		Shortest	
			Range	Average	Range	Average
53.0	23.0	2278	0.57-0.70	0.68	0.47-0.57	0.54
51.0	21.0	1958	0.66-0.74	0.71	0.56-0.64	0.61
55.0	22.0	1709	0.66-0.83	0.77	0.57-0.67	0.63
68.0	29.0	5834	0.61-0.71	0.68	0.53-0.64	0.60
86.5	33.0	7395	0.58-0.73	0.68	0.51-0.73	0.60
77.5	33.5	4288	0.54-0.73	0.71	0.56-0.61	0.59
67.5	28.0	2727	0.66-0.76	0.71	0.54-0.64	0.58
68.5	28.5	3348	0.68-0.78	0.74	0.54-0.63	0.59
54.0	21.0	756	0.68-0.77	0.76	0.54-0.61	0.57

Fig. 19 *Macrobrachium equidens*: Adult male

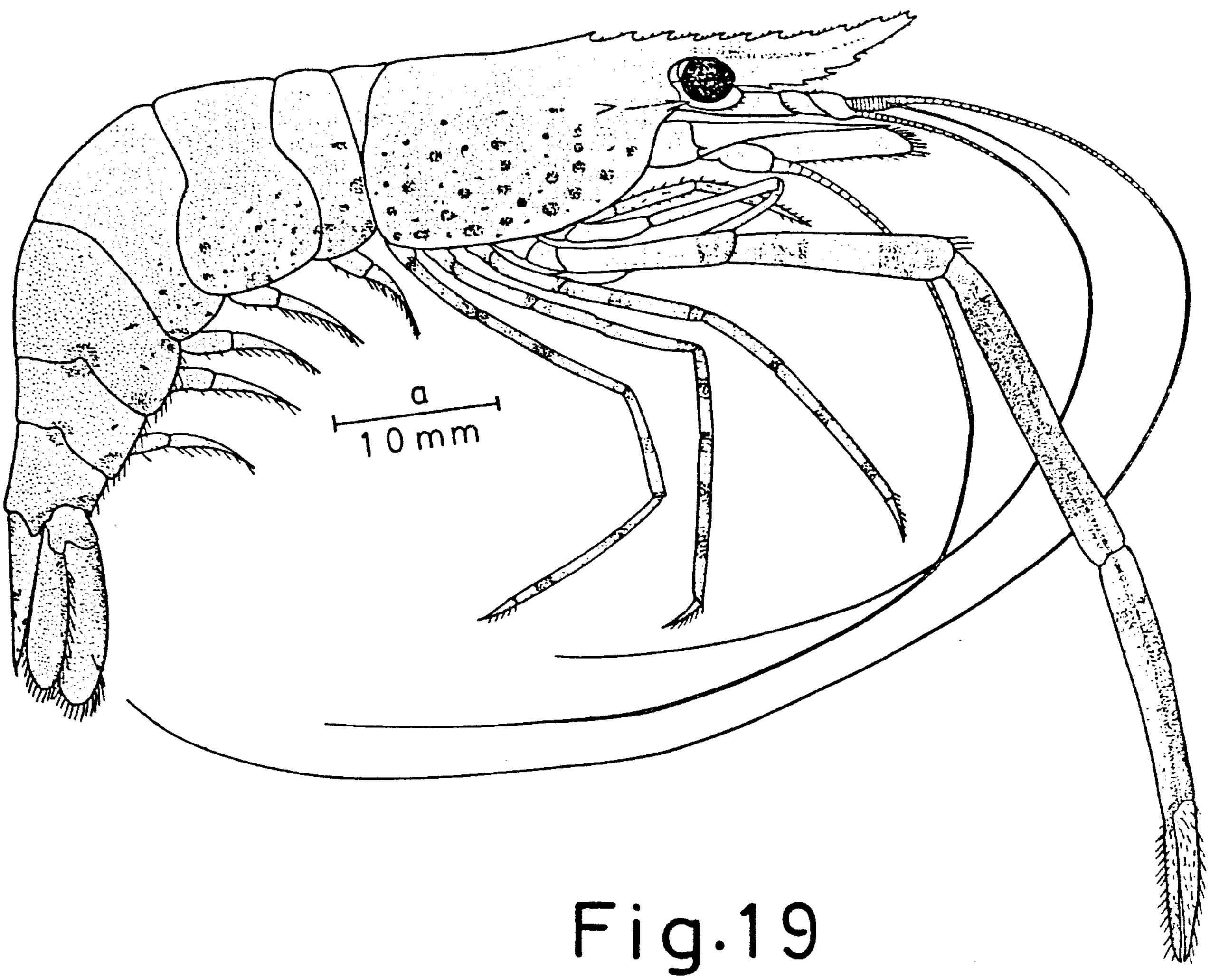

Fig.19

in a spine. In adult males the distal end of merus of second pereiopod reaches upto the tip of rostrum. Antennular peduncle with 3 segments of which the basal segment broadest and 2nd and 3rd shorter (Fig. 20 a). The upper antennular flagellum with 2 rami which are fused in the basal part. Antenna 2.7 to 3.0 times as long as broad with outer margin ending in a strong terminal teeth (Fig. 20 b). Mandible with 3 jointed palp. Incisor with 3 blunt teeth and molar with a number of ridges and blunt knobs (Fig. 20 c). Maxillule (Fig. 20 d) with well developed palp which is bilobbed and the distal lobe bearing 9 - 12 setae and proximal with 2 short ones. Maxilla has the endite deeply cleft and the scaphognathite large (Fig. 21 c). The caridean lobe of first maxilliped (Fig. 20 e) broad bearing a number of setae distally. Exopod of second maxilliped (Fig. 20 f) longer than endopod and distally carries a number of setae. Exopod of third maxilliped as long as the first segment of endopod and carries distally a number of setae (Fig. 21 c). Carpus of first pereiopod of adult male 2.2 - 2.3 times as long as chela and 1.2 - 1.3 times as long as merus. The palm of second pereiopod 1.2 - 1.6 times that of fingers. Both fingers are velvety (Fig. 19). Carpus 1.2 - 1.3 times that of chela and 1.2 - 1.8 times that of merus. Last 3 pereiopods are almost identical (Fig. 21 e, f, g). Telson slender, long ponted at the distal end which bear 2 pairs of spines. Outer spine small and the inner one 3 times longer than that of the outer. A number of plumose setae present in between the spines (Fig. 20 h). Dorsally the telson bears two pairs of spines of which the proximal pair located about half way along the telson.

Fig. 20 *Macrobrachium equidens*: a. antennule, b. antenna, c. mandible, d. maxillule, e. first maxilliped, f. second maxilliped, g. distolateral outside margin of exopod of uropod, h. telson.

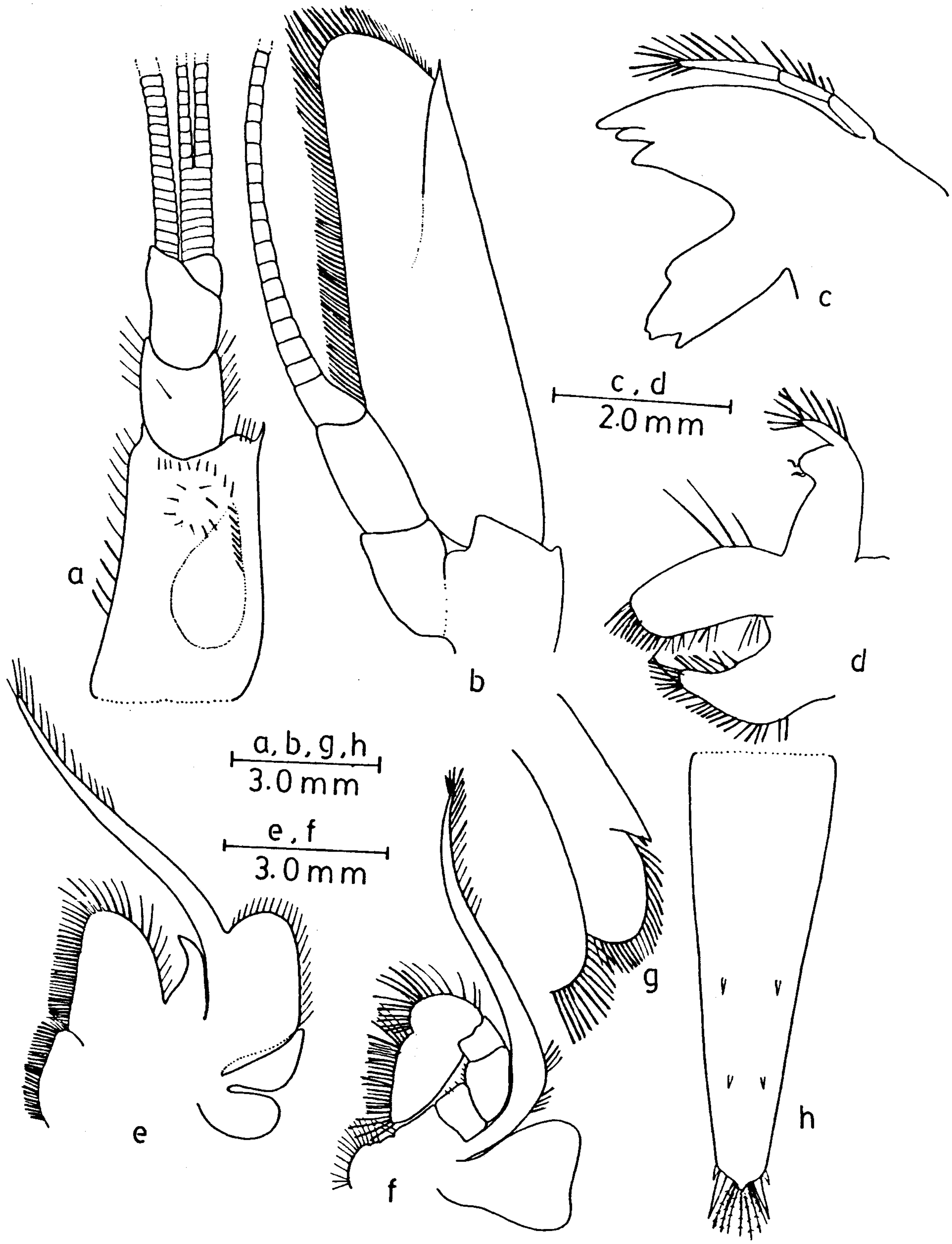

Fig. 20

Fig. 21 Macrobrachium equidens: b. maxilla, c. third maxilliped, d. first pereiopod, e. third pereiopod, f. fourth pereiopod, g. fifth pereiopod.

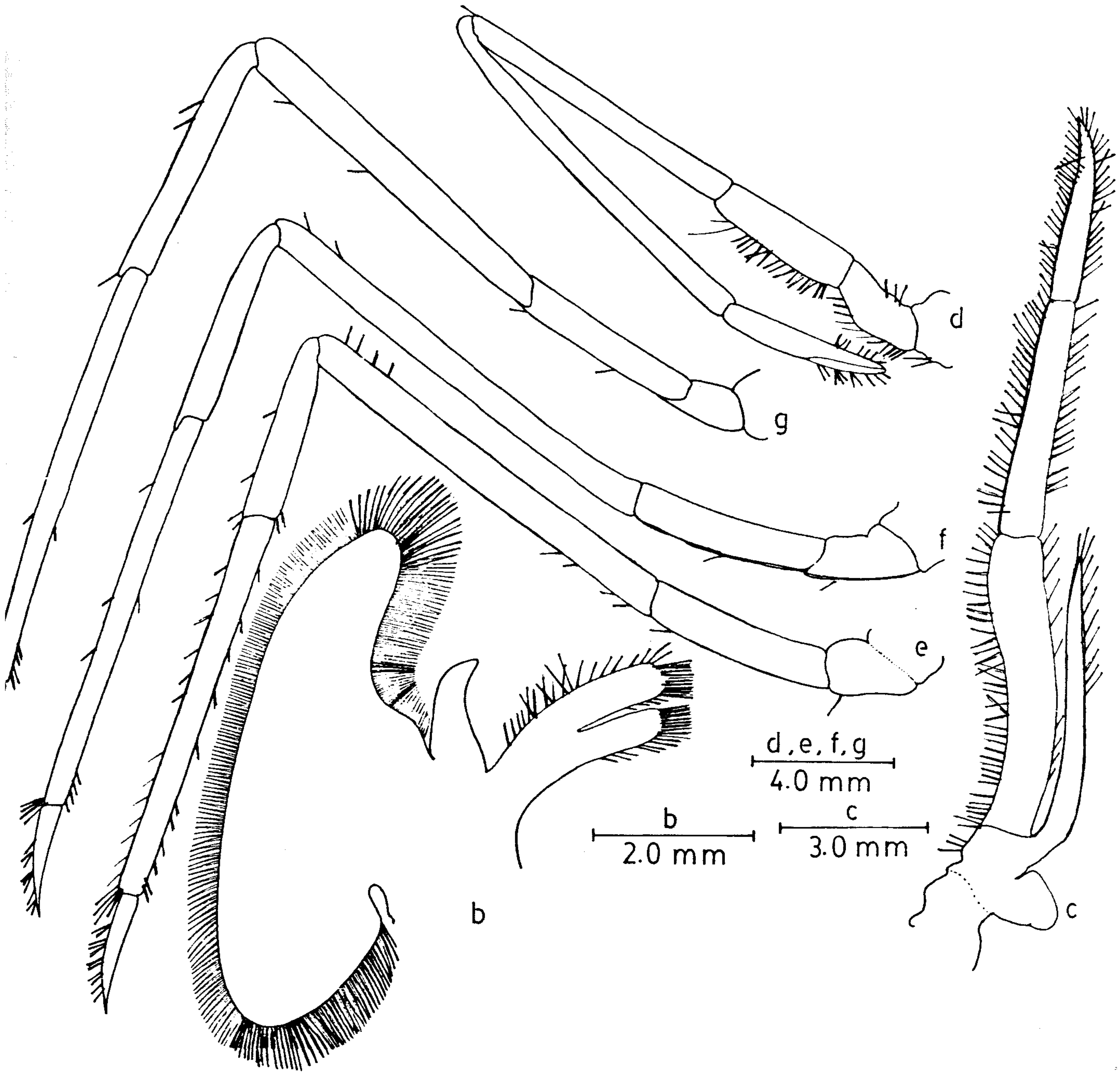

Fig. 21

Colour: The specimens have translucent body bearing a number of greenish or greyish spots all along the body. The spots on the carapace are relatively larger than those of abdomen (Fig. 19; 22 a). Along the abdominal sides, the spots on the pleura are relatively larger and conspicuous than those of the upper region. Small variations are some times noticed on the number of spots and their distributional disposition along the sides of carapace and abdomen, from individual to individual. All the pereiopods bear a number of transverse stripes of yellowish orange alternating with greenish or greyish bands in juvenile forms. In addition to these bands, the inner side of the second pereiopod of adult male shows a characteristic dark brown or greyish and yellow mottling. The mottling is very prominent on the fingers. This colour pattern is retained even after the preservation of the specimens for 35 days in formaldehyde (Fig. 22 b).

Distribution: This species is widely distributed in the Indo-West Pacific from South and East Africa through the coast of India, Andaman-Nicobar Islands, to South China, Riu Kiv Islands and Malay Archipelago (Holthuis, 1950). Although it does not contribute to a noteworthy fishery anywhere in India, it commonly occurs in most of the major river systems, backwaters and estuaries. In the latter region it is mainly encountered during the rainy season when the salinity of estuarine waters declines due to the influence of freshwater influx.

Remarks: Holthuis (1950) and Henderson and Matthai (1910) have pointed out the following characters as diagnostic to this species: i) hepatic and antennal spine lie in one line; ii) both fingers of second periopod of adult male velvety; iii) characteristic mottling on the second pereiopod; iv) rostrum slightly upturned distally. The above mentioned diagnostic characters fully tally with the characters of the present materials collected from Cochin Backwater and hence there is no doubt about the identity of the species being Macrobrachium equidens.

Reproductive biology: Macrobrachium equidens is a medium sized prawn growing to a maximum of 100 mm in total length (George, 1969a). M. equidens collected from Cochin Backwater is mainly a freshwater species which is never found in Cochin Backwater during October to May/June period when the salinity of this area increases. During July to September months when the salinity of the backwater is reduced due to rainwater to about 10-15‰ they migrate to this area for breeding. The zoeal stages of this species also showed wide range of salinity tolerance. Ngoc-Ho (1976) has collected the ovigerous females of M. equidens from offshore water of Phuket and studied the larval development of this species by rearing them in 32.8‰ salinity. Some variations were observed when the zoeal stages of the present species were compared with the corresponding stages described by Ngoc-Ho (1976). Therefore a detailed study of all the larval stages of M. equidens was carried out by rearing the larvae in the laboratory. The details are given below.

Methods adopted for the collection of adults, their transportation and maintenance in the laboratory, the rearing of larvae and feeding the adults and larvae are given in the chapter Material and methods.

Spawning season: With the onset of monsoon, when the salinity of the backwater declines to about 10 to 15‰, matured females and males start appearing in the Cochin Backwater. As appreciable number of females in the sample are with berry, M. equidens as in the case of other species of Macrobrachium from the area obviously migrates to the lower reaches of backwater/estuaries during August-November for breeding.

Courtship and mating: To study the courting and mating behaviour, glass aquarium tanks of 60 l capacity containing 50 l of brackishwater of 10 to 15‰ salinity were set up. In each of the tanks two adult males and one female possessing mature head roe, but without 'berry' were introduced. Three sets of experiments were thus carried out to observe their courtship and mating behaviour.

Soon after the introduction of prawns in the tank, the female occupied a corner of the tank. The males, however, were observed to initiate a fight using their well developed second pereiopod to establish territory and supremacy. The fight continued and lasted for about 20 to 25 minutes or until the weaker male was chased away or cornered. During fighting, the appendages were seen damaged or broken. The successful male finally keep the female in front of it between the extended second pereiopod.

Generally, prespawning moulting of the female took place during the night. After moulting, mating was observed between the soft female and the hard male. The establishment of territory by the male, mating behaviour and spermatophore transfer to the ventral surface of the female in between the fourth and fifth pereiopods, in M. equidens were found to be similar to those described by Rao (1965) for M. rosenbergii and Ching and Velez (1985) for M. heterochirus.

Spawning, incubation of eggs and rematuration of ovary: After 3 to 12 hours of mating the female prawn enters into the spawning phase. The mature ova from the ovary are extruded through the gonopore on the base of the third pereiopod. As the ova pass through the sternal plate of fourth and fifth pereiopods, they get fertilised and transferred to the ovigerous setae in the pleopods. Initially, the egg mass attached to the pleopod is green in colour. As the eggs develop further the colouration of the egg mass changes to yellow and subsequently to dull white, when the embryo inside develops eye spot. At this stage, the eggs in the berry generally hatch out releasing zoea larvae.

The incubation period of eggs in the pleopods is found to be 16 to 17 days at temperature ranging from 27 to 29°C. During the incubation period the egg mass is well aerated by the frequent fanning movements of the pleopods. Using the first pereiopods they continuously clean the body, remove foreign particles from the eggs, as well as the damaged eggs from the berry.

Simultaneous with the development of eggs in the pleopods, the ovary inside the body also develops and attains mature condition within 16 days. Thus by the time the eggs on the pleopods are released, the ovary inside develops fully and the female becomes ready to mate and release the eggs.

Repeating the process, an individual female is observed to spawn, become berried and mature again, as many as 5 to 7 times in an year if the requirements such as food, mature males, protection from diseases and predators are ensured. One female measuring 62 mm in total length, maintained in the laboratory under controlled conditions, moulted, spawned and acquired berry giving viable eggs six times over a period of 123 days.

Occassionally it was also observed that the adult female with fully mature ovary, after the prespawning moulting, transferred the ovarian eggs to the pleopods without mating. But the unfertilized eggs were invariably discarded within 3 to 4 days. Ching and Velez (1985) have also reported similar behaviour in M. heterochirus.

Development and hatching of eggs: Berried females were maintained generally in brackishwater medium of 10 to 15‰ salinity. Eggs develop and hatch out at this salinity range. Berried specimens of M. equidens were also maintained separately in different aquarium tanks containing water of 5‰ and 30‰ salinity. At 5‰ salinity berried females never showed any unrest and behaved normally. Whereas at 30‰ salinity the berried females showed unrest by moving backwards with quick jerking movements and tried to jump out of the tank. However, within 20-25 minutes they were seen adjusted to the medium and settled to the bottom of the tank exhibiting the normal behaviour of frequently moving the pleopods carrying eggs forward and backward and also cleaning the eggs with first pereiopod. It was observed that the berried females survived in both 5‰ and 30‰ salinity medium and the eggs in the berry developed normally and healthy zoeae were released.

DESCRIPTION OF LARVAL STAGES

Zoea I (Fig. 23 a-k)

Number of larvae examined : 10

Total length: 2.18 to 2.46 mm (2.34 mm).* Carapace length: 0.65 to 0.70 mm (0.68 mm).*

Rostrum pointed, slender, directed slightly downwards and reaches more than half the length of antennular peduncle (Fig. 23 a). Carapace smooth and the anterolateral angle with a small pterygostomial spine. Eyes sessile and large. Antennule, antenna, mouth parts and biramous buds of first and second pereiopods developed (Fig. 23 j). Abdomen six segmented. Telson with 7+7 setae and not demarcated from the sixth abdominal segment.

Antennule (Fig. 23 b): Uniramous, long and unsegmented bearing distally 2 flagellae. Inner flagellum is in the form of a long plumose seta. Outer flagellum unsegmented bearing 3 aesthetes and 2 setae, of which one plumose.

Antenna (Fig. 23 c): Biramous. Exopod with 5 segments distally and bears 9 plumose setae and one short non-plumose seta along its inner margin. Outer margin bearing 2 short setae. Endopod shorter than exopod, unsegmented having a long plumose seta and a short spine distally.

Mandible (Fig. 23 d): Almost asymmetrical. Incisor with one tooth. Molar rounded with or without a small tooth. One tooth present in between incisor and molar processes.

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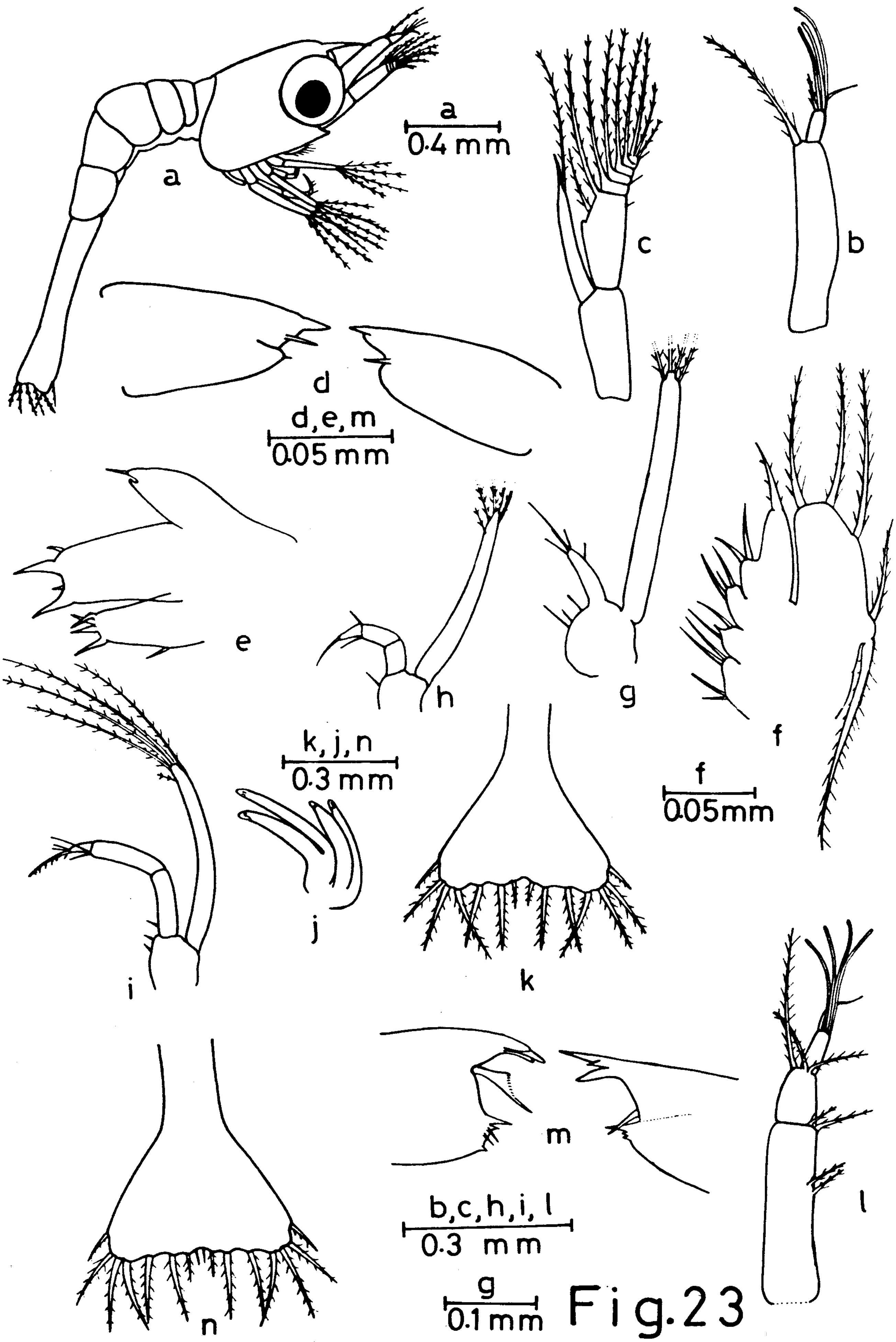
* Mean in parenthesis

Fig. 23 Macrobrachium equidens; Zoea I a. laterval view, b. antennule c. antenna, d. mandible, e. maxillule, f. maxilla, g. first maxilliped, h. second maxilliped, i. third maxilliped, j. biramous buds of first and second pereiopods, k. telson. Zoea II l. antennule, m. mandible, n. telson.


a
a
0.4 mm
c
b
d
d, e, m
0.05 mm
e
h
g
f
k, j, n
0.3 mm
f
0.05mm
j
i
k
m
l
b, c, h, i, l
0.3 mm
g
0.1 mm
n
Fig.23

Maxillule (Fig. 23 e): Uniramous. Endopod with 2 small distal processes. Distal endite with 2 stout and 2 small teeth, proximal endite with one marginal and 4 long terminal setae.

Maxilla (Fig. 23 f): Biramous. Protopod with 3 endites. Proximal with 4 setae and distal two endites each with 2-3 setae. Exopod broad bearing 5 long plumose setae along its outer margin. Endopod bilobed; distal lobe with one stout seta and proximal with 2 distal setae.

First maxilliped (Fig. 23 g): Biramous. Basipod protuberant with 3 setae on its margin. Endopod unsegmented bearing one lateral and 3 terminal setae. Exopod more than 3 times longer than endopod and has 4 plumose setae distally.

Second maxilliped (Fig. 23 h): Biramous. Basipod has one seta on its inner margin. Endopod 3-segmented. The distal segment with a claw like spine. The penultimate segment bears one seta each on its inner and outer distal margins. Exopod longer than endopod with 4 long plumose setae and one sub-apical seta.

Third maxilliped (Fig. 23 i): Biramous. Basipod has 2 setae. Endopod 3-segmented; distal segment bearing one serrated claw and 2 setae apically; second segment at the distal margin possesses 2 setae and first segment has a small seta.

Telson (Fig. 23 k): Broader distally bearing 7+7 setae. All setae are plumose, but the outer one on either side plumose only on inner side.

Fig. 24 Macrobrachium equidens: Zoea II a. lateral view, b. antenna, c. maxillule, d. maxilla, e. first maxilliped, f. second maxilliped, g. third maxilliped, h. first pereiopod, i. second pereiopod.

Zoea III j. antenna, k. telson and uropod.

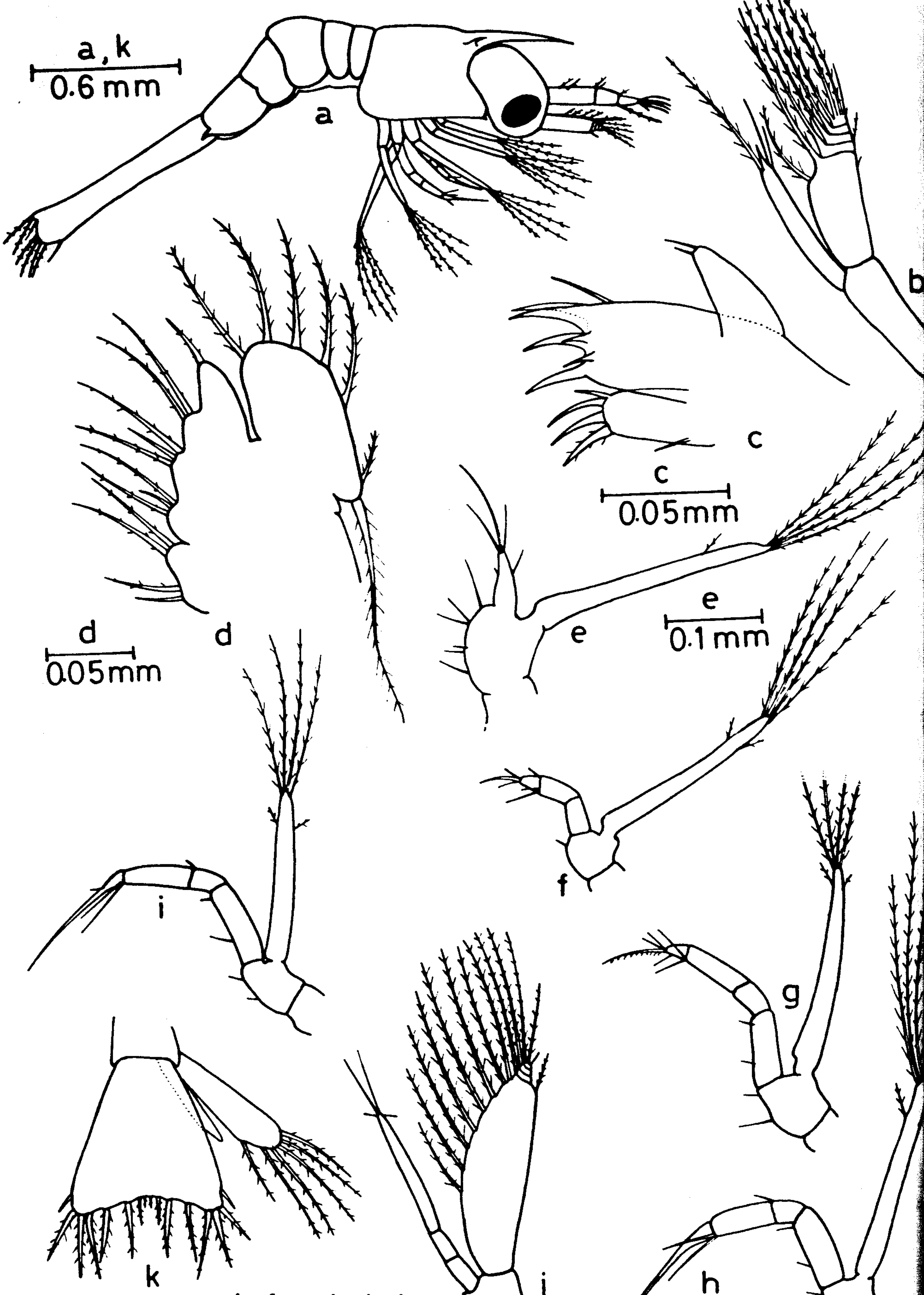


Fig.24

Zoea II (Fig. 23 l-n; 24 a-i)

Number of larvae examined : 10

Total length: 2.39 to 2.56 mm (2.45 mm). Carapace length: 0.70 to 0.81 mm (0.74 mm).

Rostrum slender and pointed. Carapace with supraorbital and pterygostomial spines (Fig. 24 a). Eyes stalked. Fifth abdominal segment with a pair of prominent lateral spines. First and second pereiopods fully developed.

Antennule (Fig. 23 l): Peduncle 2-segmented. Distal segment bears 2 short plumose setae at the base of outer flagellum. Outer flagellum with 4 aesthetes and one short non-plumose seta.

Antenna (Fig. 24 b): Exopod 4 segmented distally. It bears 8 plumose setae and 2 non plumose setae along its inner margin. Endopod shorter than exopod with one spine and 3 setae distally.

Mandible (Fig. 23 m): Asymmetrical. Incisor with 3 teeth. Molar with 3-5 teeth. One tooth present in between the incisor and molar processes.

Maxillule (Fig. 24 c): Endopod with 2 short setae at its apex. Distal lacinia with 7 teeth of which 4 are stout, 2 short and one slender.

Maxilla (Fig. 24 d): Exopod bears 7 plumose setae. Other characters same as in the previous stage.

First maxilliped (Fig. 24 e): Basipod with 6 setae along its margin. Endopod has 3 terminal and 2 lateral setae. Exopod bearing 4 apical and 1-2 sub-apical plumose setae.

Second maxilliped (Fig. 24 f): Second segment of endopod carries 3 setae. The distal segment bears a claw like seta at its apex along with 2 bristle like setae.

Third maxilliped (Fig. 24 g): Endopod 4-segmented. Distal segment has a claw like seta which is serrated at its inner side. First segment with 2 small setae on the inner side.

First and second periopods (Fig. 24 h, i): Almost identical in structure and biramous. Endopod 4-segmented. Distal segment carries a long claw apically and 2 setae at its distal inner margin. Second segment with a seta at its distal outer margin. First segment with 2 setae on its inner margin. Exopod carries 4 apical and 2 sub-apical plumose setae. Basipod bearing 2 setae at its inner margin.

Telson (Fig. 23 n): Telson with 8+8 setae. Outer seta plumose on its inner margin only and inner seta non-plumose.

Zoea III (Fig. 24 j-k; 25 a-i)

Number of larvae examined : 10

Total length: 2.59 to 2.83 mm (2.73). Carapace length: 0.70 to 0.76 mm (0.73 mm).

Rostrum with an epigastric tooth and a small hump behind it. Carapace with supraorbital, pterygostomial and branchiostegal spines (Fig. 25 a). Biramous bud of third and uniramous bud of fifth pereiopod developed (Fig. 25 i). Telson and uropod separated from the sixth abdominal segment with an articulating joint.

Fig. 25 Macrobrachium equidens: Zoea III a. lateral view, b. antennule c. mandible, d. maxillule, e. first maxilliped, f. second maxilliped, g. first pereiopod, h. second pereiopod, i. biramous bud of third pereiopod and uniramous bud of fifth pereiopod. Zoea IV j. mandible, k. third pereiopod, l. fifth pereiopod, m. uropod, n. telson.

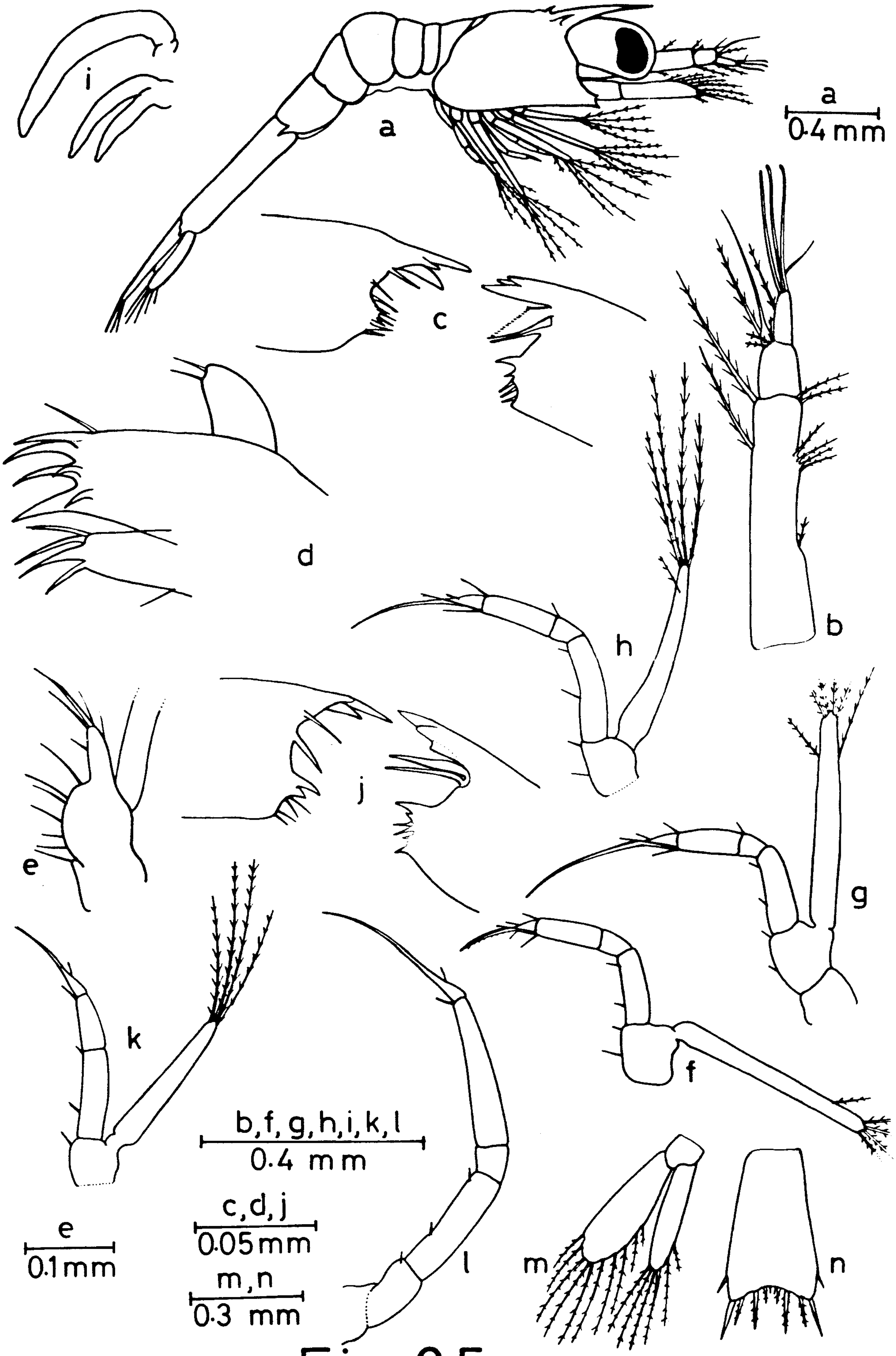


Fig. 25

Antennule (Fig. 25 b): Outer flagellum with 3 aesthetes and one non-plumose seta. Inner flagellum knob like shorter than outer bearing one non-plumose seta apically. Distal segment with 2 long plumose setae. The antennular lobe bears 3 short plumose setae. Proximal segment with 2 short and one long setae distally. In addition it also carries 5 short plumose setae on the outer side and one long plumose seta on the inner side.

Antenna (Fig. 24 j): Exopod 3-segmented distally and bears one non-plumose and 12 plumose setae along the margin. It carries at its distal outer margin one plumose seta. Endopod 3-segmented bearing at its apex 4 short non-plumose setae.

Mandible (Fig. 25 c): Insicor with 3 stout teeth and molar with 5-6 short teeth. 2 teeth are present in between the two processes.

Maxillule (Fig. 25 d): Endopod with 2 terminal setae which are of equal length. No change in the distal and proximal lacinia when compared with those of the previous stage.

Maxilla without any major changes from that of the previous stage.

First maxilliped (Fig. 25 e): Coxopod and basipod bearing one and 6 setae respectively.

Second maxilliped showed no variation from those of the previous stage.

Third maxilliped (Fig. 25 f): Third segment of endopod with 3 setae and in other characters it agreed with those of the previous stage.

First and second pereiopods (Fig. 25 h): Almost identical in structure. Third segment of endopod bear 3 setae. Terminal segment has a long claw and a short seta. Claw of the first pereiopod is longer than that of the second pereiopod. One seta on the inner margin of first segment is longer in second pereiopod when compared with those of the first pereiopod.

Uropod (Fig. 24 k). Biramous. Exopod with 6 setae along its distal margin and endopod bare.

Telson (Fig. 24 k): With 8+8 setae of which the outer most alone is non-plumose.

Zoea IV (Fig. 25 j-n; 26 a-e)

Number of larvae examined : 10

Total length: 2.69 to 3.04 mm (2.86 mm). Carapace length: 0.74 to 0.77 mm (0.76 mm).

Rostrum with 2 dorsal rostral teeth (Fig. 26 a). Third and fifth pereiopods well developed. Endopod of uropod bearing setae.

Antennule (Fig. 26 b): Outer flagellum bearing 3 aesthetes and 2 short non-plumose setae. Inner flagellum below half the length of the outer and carries one long non-plumose seta at its apex. Proximal segment has 6 plumose setae at its inner margin.

Antenna (Fig. 26 c): Exopod unsegmented carrying one spine and 16 setae along its inner and distal margins. Endopod 3-segmented, shorter than exopod bearing distally 5 short bristle-like setae.

Mandible (Fig. 25 j): Incisor with 3 short teeth and molar with 6 short teeth. In between the 2 processes are present 2 teeth.

Maxillule: Proximal lacinia with one marginal and 5 distal setae. Endopod and distal lacinia same as in the previous stage.

Maxilla (Fig. 26 d): Exopod with 7 setae. Proximal endite of protopod bearing 5 setae.

First maxilliped (Fig. 26 e): Coxopod with 2 and basipod with 6 setae. Exopod and endopod same as in the previous stage.

Second maxilliped, third maxilliped and first and second pereiopods. No major changes observed in these appendages when compared with those of the previous stage.

Third pereiopod (Fig. 25 k): Biramous. Basipod has one seta. Exopod as long as endopod bearing 4 long plumose setae. Endopod 3-segmented. Distal segment carries one long claw and a small seta. First and second segments bearing 2 and one seta respectively.

Fifth pereiopod (Fig. 25 l): Uniramous. Exopod 5-segmented. Dactylus bears a long 'sigma' shaped spine and a small seta. Fourth segment carries a seta at the distal inner margin. First and second segments with one and 2 setae respectively.

Uropod (Fig. 25 m): Exopod and endopod bearing 10 and 6 plumose setae respectively.

Telson (Fig. 25 n): Distal margin with 5+5 setae and lateral margin with 1+1 spines.

Fig. 26 Macrobrachium equidens: Zoea IV a. lateral view, b. antennule

c. antenna, d. maxilla, e. first maxilliped.

Zoea V f. mandible, g. maxilla, h. uropod, i. telson

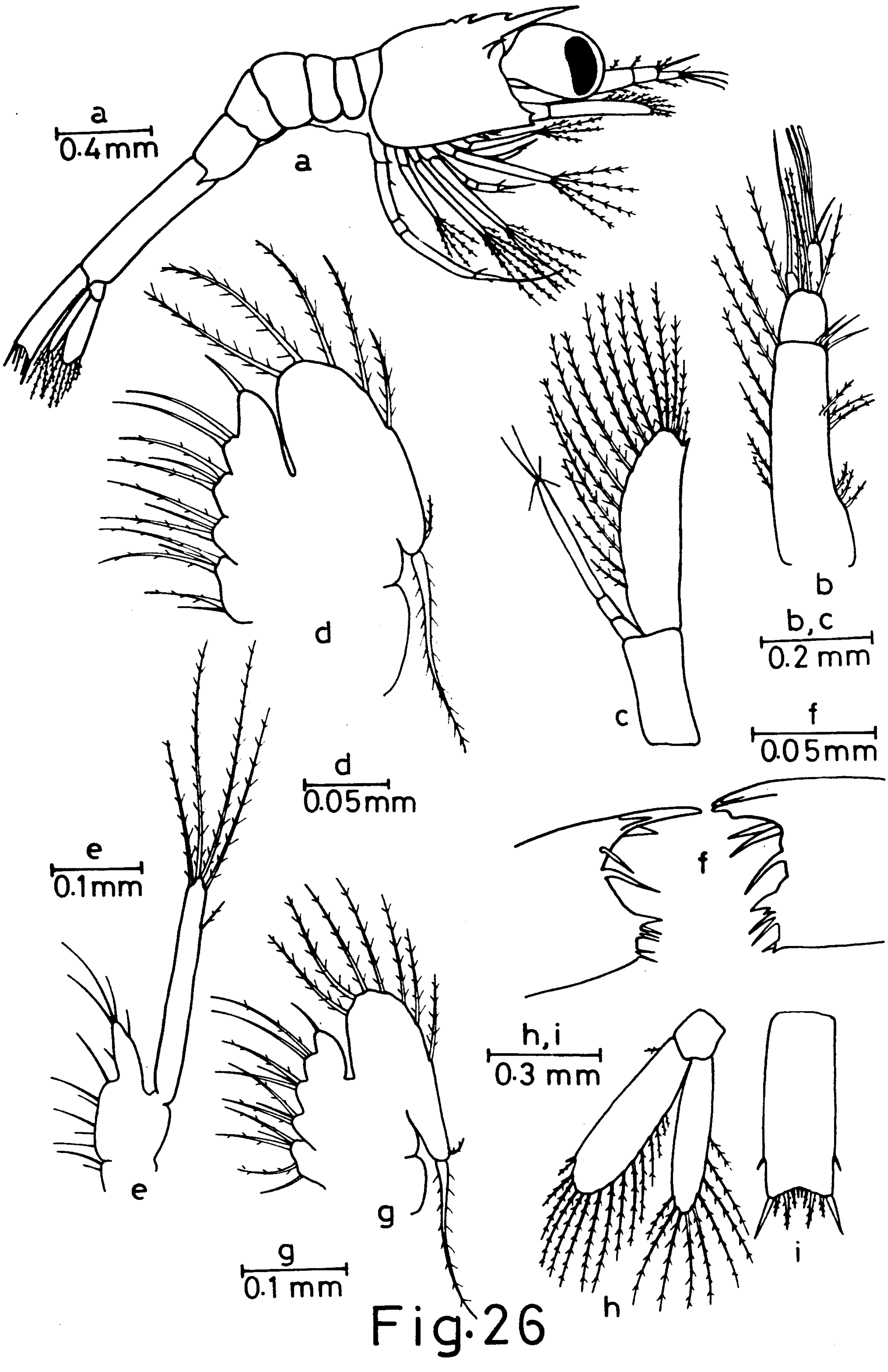


Fig. 26

<u>Zoea V</u> (Fig. 26 f-i; 27 a-k)

Number of larvae examined : 10

Total length: 3.21 to 3.35 mm (3.28 mm). Carapace length: 0.85 to 0.87 mm (0.86 mm).

Dorsal rostral tooth serrated on the inner side (Fig. 27 b). Biramous bud of fourth pereiopod developed (Fig. 27 a). Telson rectangular in shape.

Antennule (Fig. 27 c): Outer flagellum bearing 3 aesthetes and 2 short non-plumose setae. Inner flagellum more than half the length of outer bearing at its apex a long non-plumose seta. Number of setae on the distal segment increased. Protuberance of stylocerite developed, bearing 3 short plumose and 3 long non-plumose setae. A short stout spine also developed on the proximal segment.

Antenna (Fig. 27 d): Exopod with one spine and 18 plumose setae. Endopod 3-segmented, as long as exopod bearing 5 short bristle like setae apically.

Mandible (Fig. 26 f): 3 slender teeth present in between the molar and incisor processes of the left mandible.

Maxillule almost same as that of the previous stage.

Maxilla (Fig. 26 g): Exopod with 9 plumose setae. Endites of protopod with 3+3+5 setae.

First maxilliped without any major changes from those of the previous stage.

Fig. 27 Macrobrachium equidens: Zoea V a. lateral view, b. dorsal rostral tooth, c. antennule, d. antenna, e. second maxilliped, f. third maxilliped, g. first pereiopod, h. second pereiopod, i. third pereiopod, k. fifth pereiopod.

Zoea VI l. mandible, m. first maxilliped.

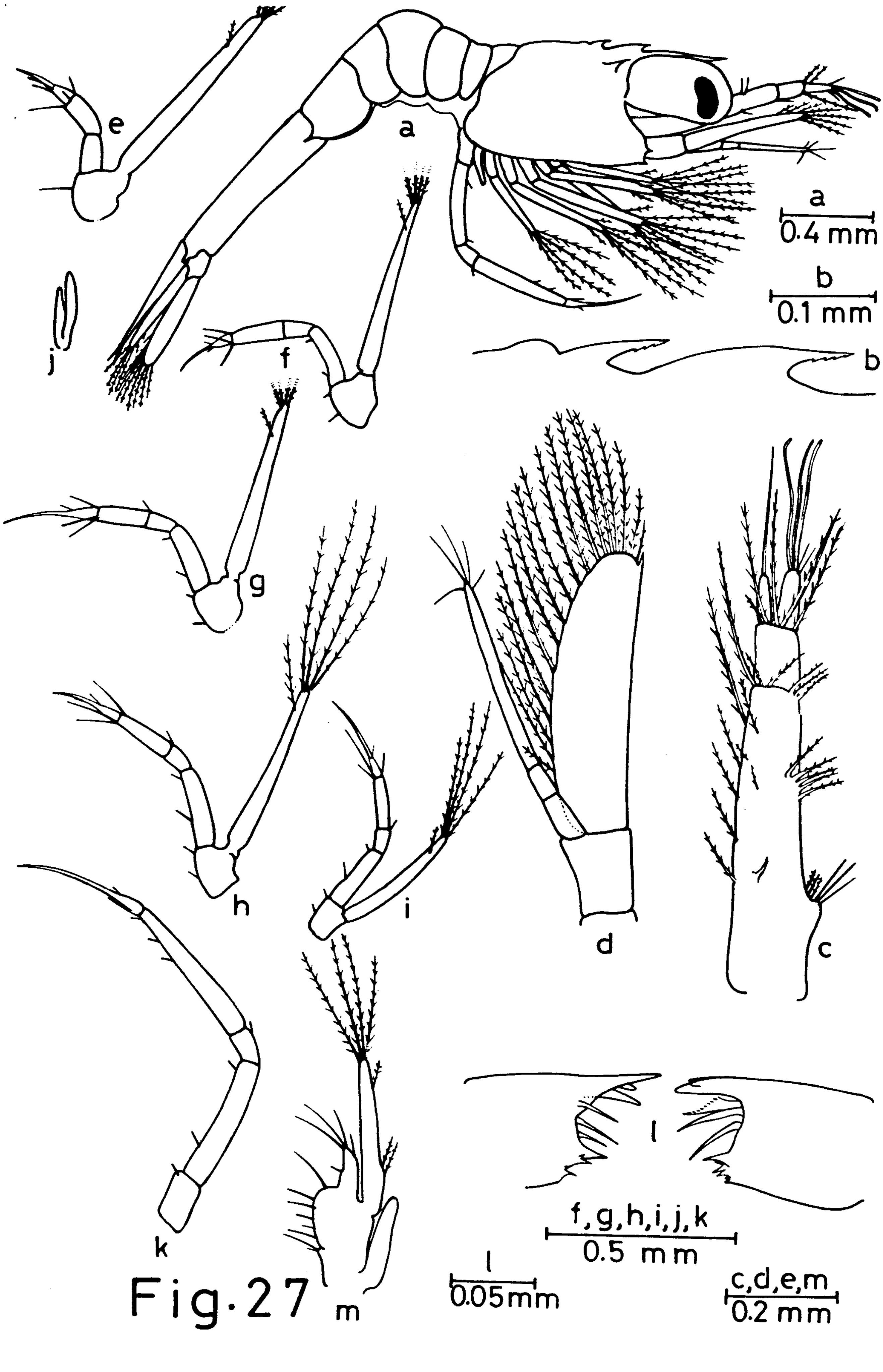


Fig. 27

Second maxilliped (Fig. 27 e): Segments of the endopod have become more flattened.

Third maxilliped almost same as that of the previous stage.

First and second pereiopod (Fig. 27 g, h): Both are identical in shape except that the claw of the first pereiopod is longer than that of the second pereiopod. Further the 2 setae on the inner margin of first segment of first pereiopod is of the same size where as in second pereiopod they are of different lengths.

Third pereiopod (Fig. 27 i): Basipod with 2 setae. First segment of endopod bears 2 setae on its inner margin. Second segment carries one seta at its distal outer margin. Third segment has 3 setae at its distal end. Exopod as long as the first 2 segments of endopod bearing 4 apical and one sub-apical plumose setae.

Fifth pereiopod (Fig. 27 k): Dactylus with a strong spine on the proximal inner margin in addition to one long claw and a small seta at its distal end. Propodus has 3 setae on the inner margin.

Uropod (Fig. 26 h): Exopod with 14-15 plumose setae and one spine. Endopod with 9 plumose setae.

Telson (Fig. 26 i): Rectangular with distal margin bearing 5+5 setae. Laterally it bears one spine on each side.

Zoea VI (Fig. 27 l-m; 28 a-j)

Number of larvae examined : 10

Total length: 3.65 to 4.20 mm (3.87 mm). Carapace length: 0.98 to 1.12 mm (1.04 mm).

Fourth pereiopod fully developed. Abdomen without any pleopod bud (Fig. 28 a). Telson tapers towards the posterior side.

Antennule (Fig. 28 b): Inner flagellum slightly shorter than outer, bearing apically 2 long non-plumose setae. Outer flagellum with 4 aesthetes and one short non-plumose seta. Protuberance of stylocerite has 3 short plumose and 4 long slender non-plumose setae.

Antenna (Fig. 28 c): Exopod bearing one spine and 19-20 plumose setae.

Mandible (Fig. 27 l): In between the incisor and molar processes are present 3 teeth of which one is serrated and movable on the left mandible.

Maxillule without any major changes when compared with those of the previous stage.

Maxilla (Fig. 28 d): Exopod with 12 plumose setae.

First maxilliped (Fig. 27 m): Coxopod with 2 and basipod with 6 setae respectively. Endopod bearing 3 terminal and 2 lateral setae. Exopod has 4 apical and one sub-apical plumose setae. Base of exopod possesses 2 plumose setae at its outer side. Epipod developed.

Second and third maxillipeds (Fig. 28 e): Characters are almost same as that of the previous stage.

First pereiopod (Fig. 28 f): Terminal segment of endopod with 2 setae of which one is claw-like. Second and third segment distally carry one and 3 setae respectively. Exopod bearing 4 apical and 2 sub-apical plumose setae.

Fig. 28 Macrobrachium equidens: Zoea VI a. lateral view, b. antennule c. antenna, d. maxilla, e. third maxilla, f. first pereiopod, g. third pereiopod, h. fourth pereiopod, i. uropod, j. telson.

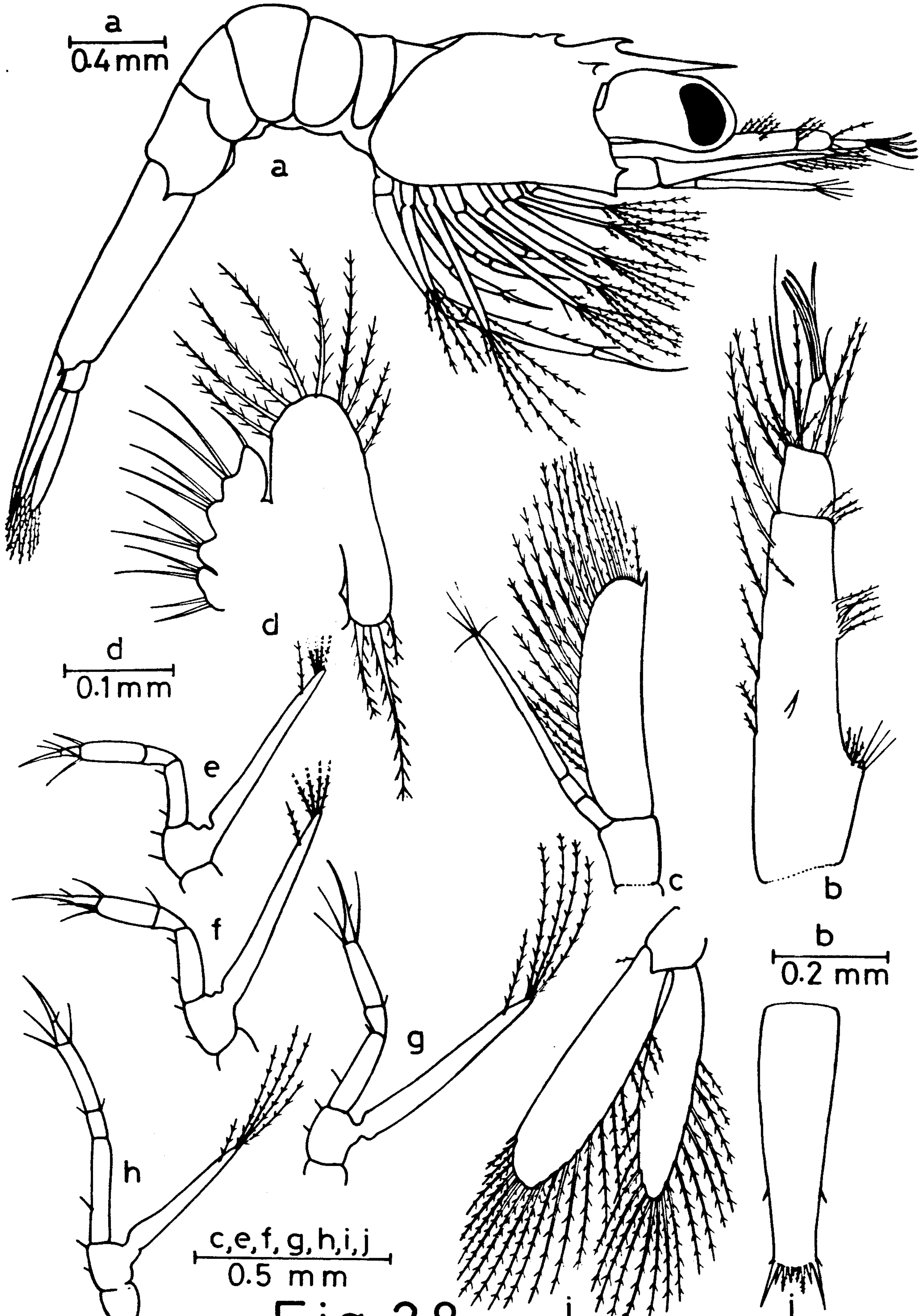


Fig. 28

Second pereiopod: Same as that of first, except that second and third segments are broader in first pereiopod compared with those of the second pereiopod.

Third pereiopod (Fig. 28 g): Third segment of endopod bearing 3 long setae at its distal margin. Exopod as long as endopod carrying 4 apical and 2 sub-apical plumose setae.

Fourth pereiopod (Fig. 28 h): Biramous. Endopod 4-segmented. Dactylus with a strong spine and a small seta at its apex. Third segment has 3 long setae at its distal margin. Second segment carries 2 and first segment one seta respectively. Exopod as long as the first two segments of endopod bearing 4 apical and one or two long sub-apical plumose setae. Basipod with 2 setae.

Fifth pereiopod: Fourth segment of the endopod bearing 4-5 setae at its inner margin (Fig. 28 a).

Uropod (Fig. 28 i): Exopod with 19-20 plumose setae and one spine. Endopod carries 16-18 plumose setae.

Telson (Fig. 28 j): Tapers towards the distal end. Distally it bears 6+6 setae of which the outer ones are very small and non-setose. Laterally it carries one spine each on either side.

Zoea VII (Fig. 29 a-l)

Number of larvae examined : 10

Total length: 4.23 to 4.90 mm (4.56 mm). Carapace length: 1.15 to 1.37 mm (1.24 mm).

Uniramous buds of pleopods developed (Fig. 29 a).

Antennule (Fig. 29 b): Outer flagellum at its inner side carries 6 aesthetes in 2 groups of 4+2. Apically it has 2 short non-plumose setae. Inner flagellum shorter than outer bearing apically 3 non-plumose setae. Distal segment carries 5 long plumose setae on one side and 5 short plumose setae on the other side. Proximal segment with 9 setae at its inner margin. The protuberance of stylocerite possesses 4 short plumose and 5 long non-plumose setae.

Antenna (Fig. 29 c): Exopod carrying one spine and 23-24 plumose setae.

Mandible: Same as that of the previous stage except that in some specimens 4 teeth are present in between the incisor and molar processes.

Maxillule: Endopod with 2 setae distally. Distal lacinia with 8 teeth and proximal lacinia with 5 distal and one marginal setae.

Maxilla (Fig. 29 d): Exopod carries 19-20 plumose setae.

First maxilliped (Fig. 29 e): Base of exopod slightly expanded bearing 3 plumose setae at its proximal outer margin.

Second maxilliped: Compared with the same appendage of the previous stage no major changes have been noticed.

Third maxilliped (Fig. 29 f): Second segment of endopod bearing a seta on its distal outer margin. Exopod with 4 apical and 2 sub-apical plumose setae.

Fig. 29 Macrobrachium equidens: Zoea VII a. abdomen and telson, b. antennule, c. antenna, d. maxilla, e. first maxilliped, f. third maxilliped, g. first pereiopod, h. third pereiopod, i. fourth pereiopod, j. uropod, k. telson, l. telson tip.

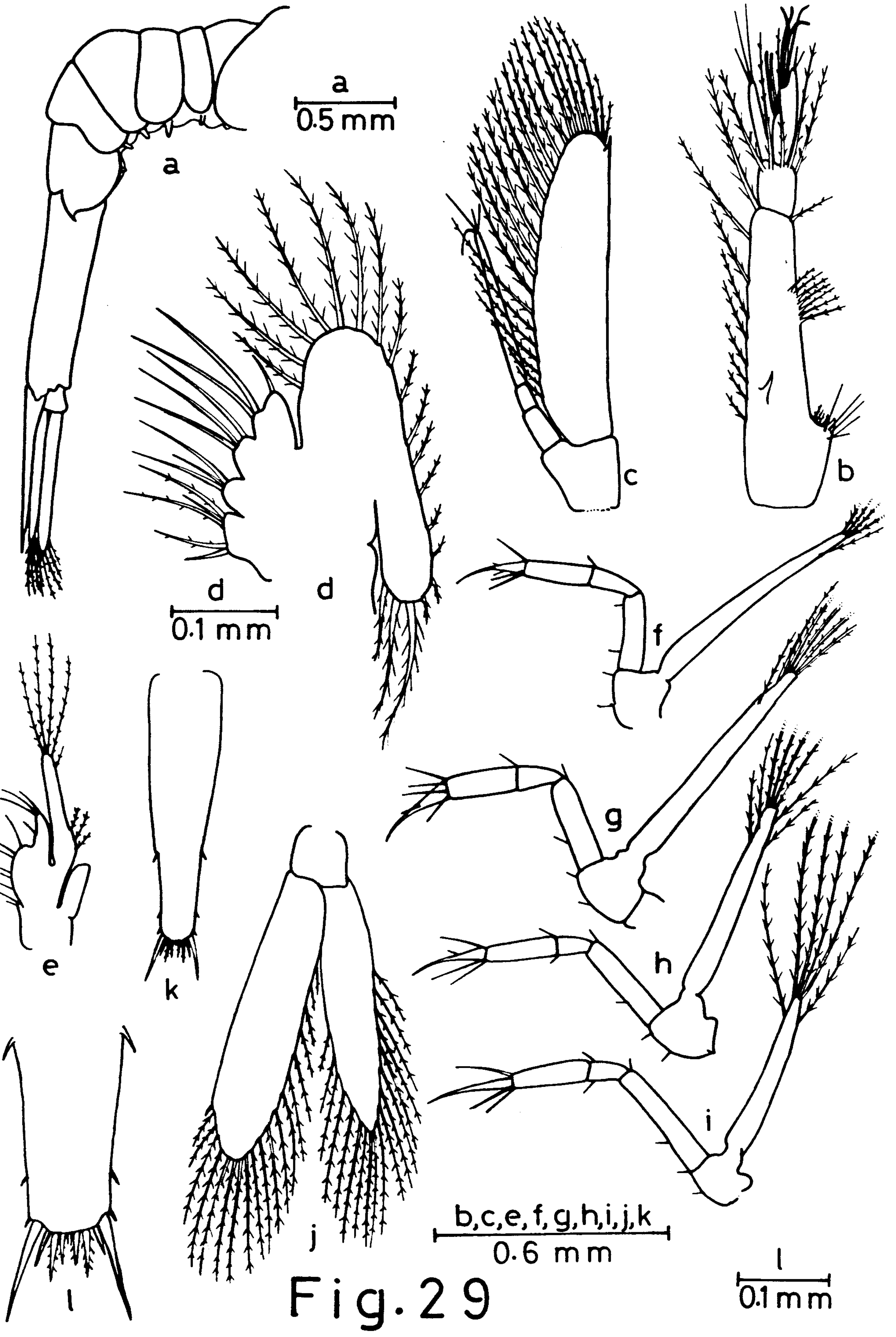


Fig. 29

First pereiopod (Fig. 29 g): Distal margin of third segment of endopod with 4 setae. Exopod bearing 4 apical and 3-4 sub-apical plumose setae.

Second pereiopod: Same as that of the previous stage.

Third pereiopod (Fig. 29 h): Second segment of endopod with 2 setae at its distal margin. Exopod bearing 4 apical and 3-4 sub-apical plumose setae.

Fourth pereiopod (Fig. 29 i): First segment of endopod with one seta at its distal outer margin in addition to one seta on the inner side. Exopod bearing 4 apical and 2 sub-apical plumose setae.

Fifth pereiopod: First and second segments of endopod with one and 3 setae respectively. Third and fourth segments carry 2 and 5 setae respectively.

Pleopod: 5 uniramous pleopod buds are developed. They are small and knob like, first and fifth being the smallest (Fig. 29 a).

Uropod (Fig. 29 j): Exopod carrying 19-20 plumose setae and one spine. Endopod with 17-18 plumose setae.

Telson (Fig. 29 k): Distally it is convex bearing 5+5 setae and laterally 3+3 spines (Fig. 29 l).

Zoea VIII (Fig. 30 a-p)

Number of larvae examined : 10

Total length: 5.01 to 5.82 mm (5.41 mm). Carapace length: 1.40 to 1.57 mm (1.48 mm).

Propodus of first and second pereiopods showing the developing chela as a protuberance on their distal outer margin. Pleopod buds have become biramous but bare (Fig. 30 a).

Antennule (Fig. 30 b): Outer flagellum bearing 6-9 aesthetes arranged in 2-3 groups of 4+2 or 4+3+2 respectively. Stylocerite with 7-8 long non-plumose and 4 short plumose setae.

Antenna (Fig. 30 c): Exopod with 26-29, plumose setae and one spine. Endopod longer than exopod, 5-7 segmented, bearing at its apex 5-6 short non-plumose setae.

Mandible: 4 to 5 teeth are present in between the incisor and molar processes.

Maxillule (Fig. 31 d): Endopod with 2 distal setae of which one is much longer than the other. Distal lacinia with 8 teeth. Proximal lacinia with 6-7 distal and one marginal setae.

Maxilla (Fig. 30 e): Exopod bearing 28-31 plumose setae.

First maxilliped (Fig. 30 f): Coxopod and basipod with 2 and 9 setae respectively. Basal expanded portion of exopod bearing 5 plumose setae.

Second maxilliped: Same as in the previous stage except that the distal segment of endopod bears at its apex one claw and 3 setae.

Third maxilliped (Fig. 30 g): Endopod 4-segmented. Distal segment carries a claw and 2 short setae, and second and third segments carrying respectively 3 setae each at its distal margin. First segment with 2 setae on the inner and one seta on the outer distal margin.

Fig. 30 Macrobrachium equidens: Zoea VIII a. lateral view, b. antennule c. antenna, d. maxillule, e. maxilla, f. first maxilliped, g. third maxilliped, h. first pereiopod, i. second pereiopod, j. third pereiopod, k. fourth pereiopod, l. second pleopod, m. fourth pleopod, n. fifth pleopod.
O. telson, p. tip of telson

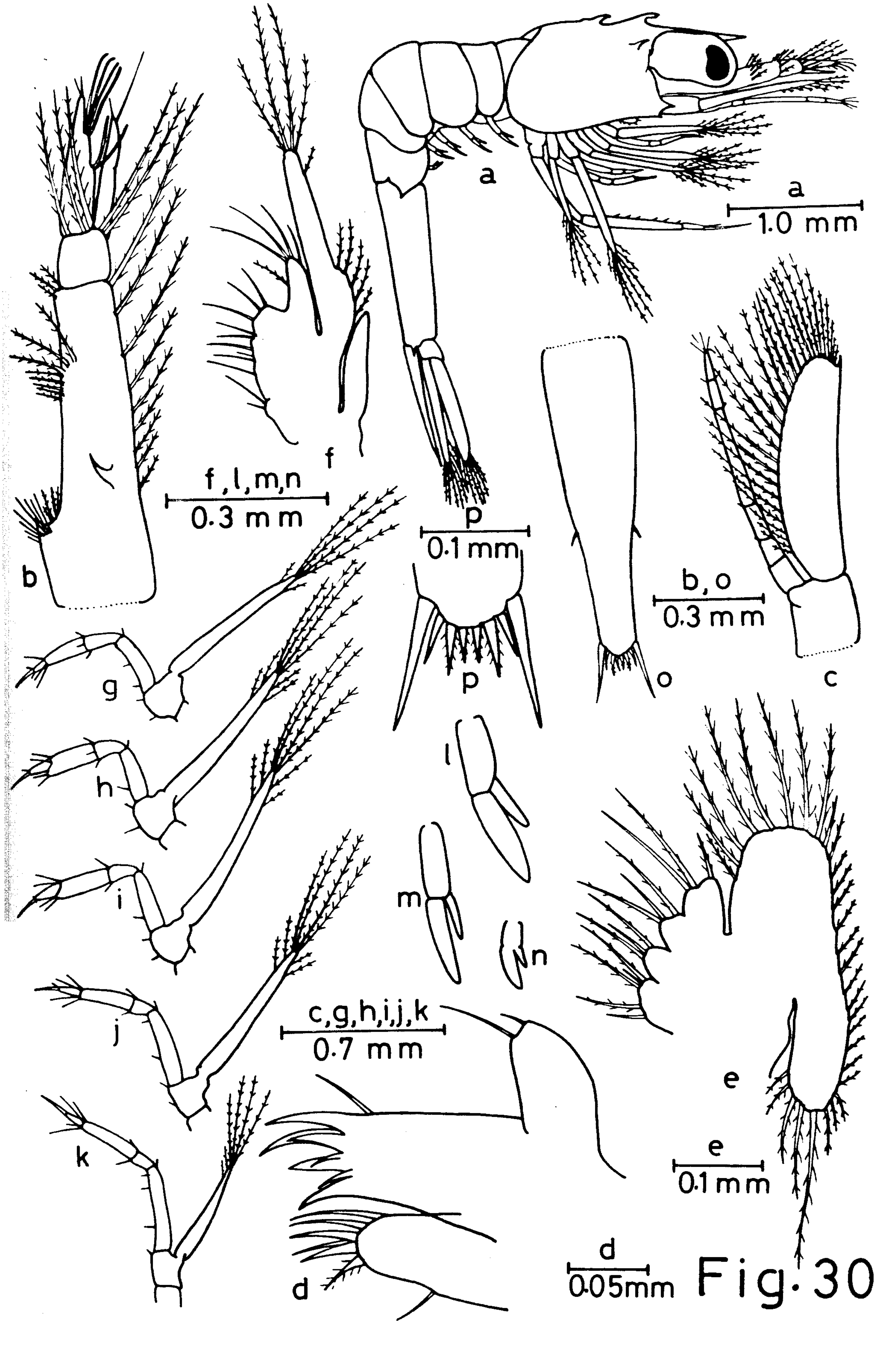

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Fig. 30

First pereiopod (Fig. 30 h): First segment of endopod with one seta each at its inner and outer margins. Second segment bearing 3 setae at its distal margin. Third segment carries 4 setae. The developing chela is seen as a protuberance on the inner distal margin, which bears 2 short setae distally. Distal segment has a stout spine and a short seta at its apex.

Second pereiopod (Fig. 30 i): Developing chela seen as a protuberance at the distal lower margin of third segment and it bears 2 setae at its apex. Third segment at its distal outer margin bear 2 setae. Exopod with 4 apical and 4 sub-apical plumose setae.

Third pereiopod (Fig. 30 j): Third segment of endopod bearing 4 setae at its distal margin. First segment with 2 inner and one outer distolateral setae. Exopod with 4 apical and 4 sub-apical plumose setae.

Fourth periopod (Fig. 30 k): Third segment of endopod bearing 4 setae at its distal margin. First segment with 3 setae at its inner margin and one on its distolateral outer margin. Exopod as long as the first segment of endopod carrying 4 apical and 3-4 sub-apical plumose setae.

Fifth pereiopod: Propodus has 6 setae at its inner margin (Fig. 30 a).

Pleopods: One to fifth pleopods in the form of biramous buds (Fig. 30 a). These buds are non-setose (Fig. l-m). Fifth pleopod bud is the smallest (Fig. n).

Uropod: Exopod with 24-25 plumose setae and one spine. Endopod bearing 23 plumose setae.

Telson (Fig. 30 o): Telson is convex distally bearing 4+4 setae of which the inner 2 pairs are setose (Fig. 30 p). Laterally it bears 1+1 spines.

Zoea IX (Fig. 31 a-o)

Number of larvae examined : 10

Total length: 5.73 to 5.8 mm (5.75 mm). Carapace length: 1.51 to 1.65 mm (1.62 mm).

Exopod of second to fourth pleopods with 2-3 setae.

Antennule (Fig. 31 a): Proximal segment bearing a circlet of short plumose setae towards 2/3rd distance from the proximal end. Protuberance of stylocerite with 4 plumose and 8 non-plumose setae. Outer flagellum with 2+3+4 aesthetes on the inner side and distally it carries 4-5 short setae.

Antenna (Fig. 31 b): Exopod with 26-30 plumose setae and one spine. Endopod 7-9 segmented.

Mandible (Fig. 31 c): Incisor with 3 and molar with 6 teeth. In between the two processes it bears 4-5 teeth of which 1-2 are serrated and movable in the left mandible.

Maxillule: No major changes have been noticed when compared with those of the previous stage.

Maxilla (Fig. 31 d): Exopod has become more flattened bearing 32-33 plumose setae.

First maxilliped (Fig. 31 e): Basipod with 10 setae. Basal portion of exopod further expanded bearing 6 plumose setae.

Fig. 31 *Macrobrachium equidens*: Zoea IX a. antennule, b. antenna, c. mandible, d. maxilla, e. first maxilliped, f. third maxilliped, g. first pereiopod, h. second pereiopod, i. third pereiopod, j. fourth pereiopod, k. fifth pereiopod, l. third pleopod, m. fifth pleopod, n. uropod, o. telson.

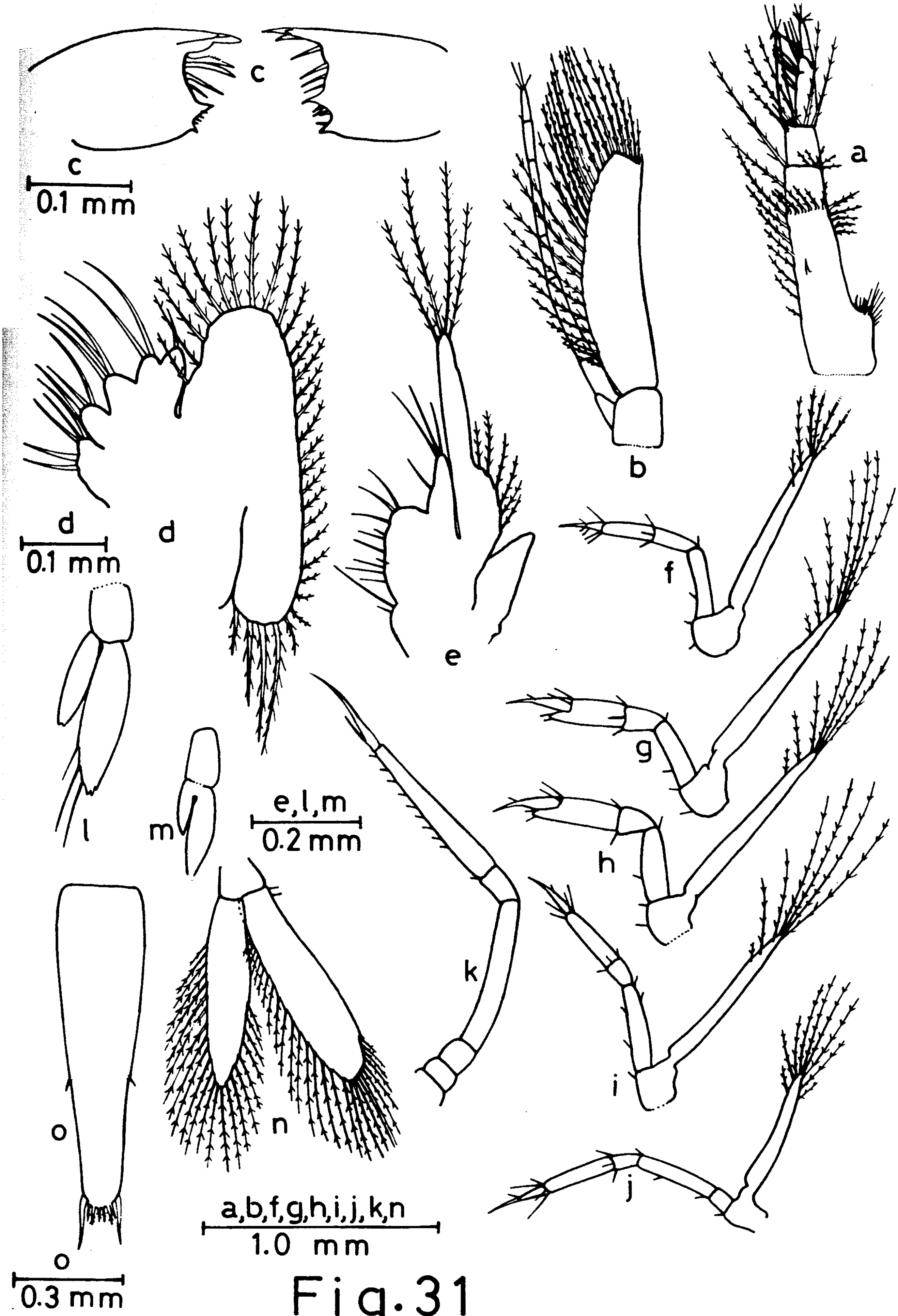
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Fig. 31

Second maxilliped: Distal segment of endopod bearing 4 small setae and a claw apically.

Third maxilliped (Fig. 31 f): Distal segment of endopod bearing terminal claw and 3 setae. Exopod with 4 long apical and 4 short sub-apical plumose setae.

First pereiopod (Fig. 31 g): Fingers of chela further developed. The third segment of endopod has become more thick. Exopod with 4 apical and 5 sub-apical plumose setae.

Second pereiopod (Fig. 31 h): Fingers of chela further developed. Exopod bearing 4 apical and 5-6 sub-apical plumose setae.

Third pereiopod (Fig. 31 i): First segment of endopod with 2 setae each on the inner and outer margin. Second segment bearing 3 setae at its distal margin. Exopod has 4 apical and 5-6 sub-apical plumose setae.

Fourth pereiopod (Fig. 31 j): Second segment of endopod bearing 3 setae at its distal margin. Exopod with 4 apical and 4 sub-apical plumose setae.

Fifth pereiopod (Fig. 31 k): Propodus bearing 8-9 setae along its inner margin.

Pleopods: Exopods of first to fourth pleopods with 5-6 ridges at its distal margin and it bears 2-3 non-plumose setae at its inner margin on the ridges (Fig. 31 l). Endopod of second to fourth pleopods with 2 small ridges at its apex. None of the endopods are with setae.

Uropod (Fig. 31 m): Exopod with 26-29 plumose setae and one spine. Endopod carries 24-25 plumose setae.

Telson (Fig. 31 o): Tapers distally bearing 4+4 setae. Laterally it bears one spine on either side.

Zoea X (Fig. 32 a-n)

Number of larvae examined : 10

Total length: 6.22 to 7.35 mm (6.93 mm). Carapace length: 1.75 to 2.04 mm (1.92 mm).

Chelae of first and second pereiopods well developed. Exopod and endopod of second pleopod to fifth pleopod with setae and bear appendix interna (Fig. 32 l, m, n).

Antennule (Fig. 32 b): Outer flagellum has 10 aesthetes and at its outer side it bears a 3-segmented flagellum. Inner flagellum 2-segmented shorter than outer bearing apically 4-5 short setae. Protuberance of stylocerite carries 4 plumose and 11 non-plumose setae.

Antenna (Fig. 32 c): Exopod with 28-30 plumose setae and one spine. Endopod nearly 1½ times longer than exopod bearing 8-9 segments.

Mandible: Same as in the previous stage except that in between the two processes 5 teeth were present.

Maxillule (Fig. 32 d): Endopod with 2 distal setae of which one is more than 2 time the length of the other. Distal lacinia with 9 teeth. Proximal lacinia more flattened and bearing 7-8 distal and one marginal setae.

Fig. 32 *Macrobrachium equidens*: Zoea X a. lateral view, b. antennule, c. antenna, d. maxillule, e. first maxilliped, f. second maxilliped, g. third maxilliped, h. first pereiopod, i. second pereiopod, j. third pereiopod, k. fourth pereiopod, l. first pleopod, m. third pleopod, n. second pleopod, o. telson.

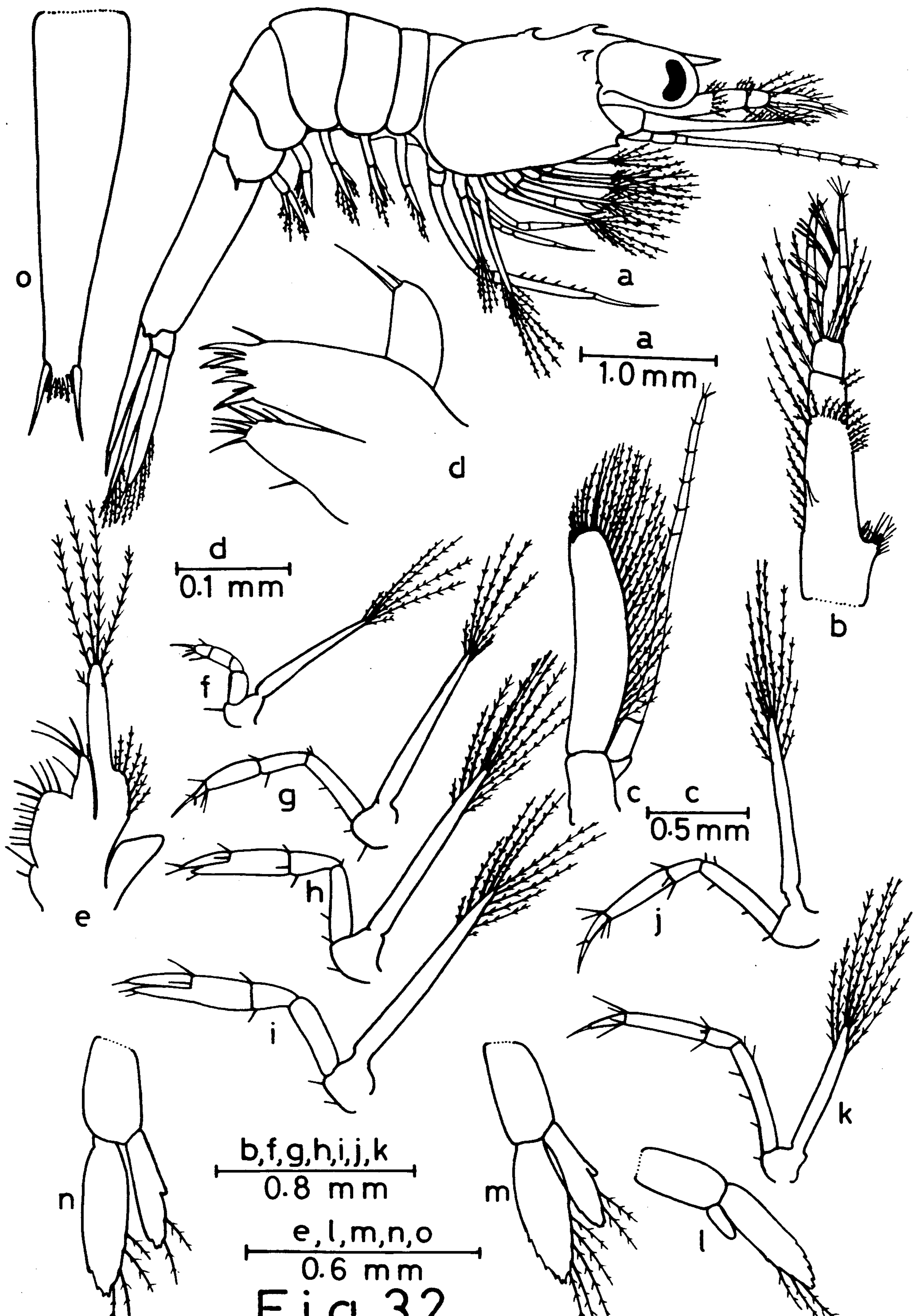

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Fig. 32

Maxilla: Exopod bearing 33-36 plumose setae. Endites of protopod with 4+4+5 setae.

First maxilliped (Fig. 32 e): Basipod with 12 setae. Basal expanded portion of expod with 7 setae.

Second maxilliped (Fig. 32 f): Endopod 4 segmented and slightly curved towards inside.

Third maxilliped (Fig. 32 g): First segment of endopod with 2 setae at its outer margin. Inner margin carries 2 setae.

First pereiopod (Fig. 32 h): Fingers are almost fully developed. Exopod bearing 4 apical and 6-8 sub-apical plumose setae.

Second pereiopod (Fig. 32 i): Fingers are almost fully developed. Chela longer than that of first pereiopod. The distal spine of the last segment short. Exopod bearing 4 apical and 6-8 sub-apical plumose setae.

Third pereiopod (Fig. 32 j): Same as that of the previous stage.

Fourth pereiopod (Fig. 32 k): First segment of endopod bearing 3 inner and 2 outer setae. Exopod as long as the first segment of endopod bearing 4 apical and 4 sub-apical plumose setae.

Fifth pereiopod: No major development when compared with that of the previous stage.

Pleopods: Endopod of first pleopod small with out setae. Exopod with 10 ridges along its distal margin and bearing 3 plumose setae (Fig. 32 l).

Endopod of second to fifth pleopod with 5 to 7 ridges and each bearing 2 plumose setae. Appendix interna developed in all the second to fifth pleopods (Fig. 32 m, n).

Uropod: Exopod and endopod bearing 29-30 plumose setae.

Telson (Fig. 32 o): Distally it bears 4+4 setae. Lateral margin in some cases without spines and rearly it bears one spine each on either side.

Postlarva I (Fig. 33 a-m; 34 a-k)

Number of larvae examined : 5

Total length: 5.98 to 6.79 mm (6.35 mm). Carapace length: 2.17 to 2.32 mm (2.24 mm).

Rostrum with one to two ventral teeth (Fig. 33 b). Exopods of pereiopods rudimentary and non-functional. Pleopods bearing plumose setae and are functional (Fig. 34 f, g, h). Appendix interna bears hooks.

Antennule (Fig. 33 c): Outer and inner flagellae segmented and almost of the same length. Outer flagellum carries 2+2+3+3-4 aesthetes. Peduncle 3-segmented. Stylocerite well developed.

Antenna (Fig. 33 d): Exopod (Scale) with 32-35 plumose setae and one spine. Endopod more than 5 times as long as exopod.

Mandible (Fig. 33 e): Incisor and molar processes are distinctly separated from one another. Incisor process ends in 3 stout teeth. Molar process of the right side with 5-6 blunt teeth. Left molar with irregular ridges and bearing few slender teeth.

Fig. 33 Macrobrachium equidens: Postlarva I a. lateral view, b. rostrum c. antennule, d. antenna, e. mandible, f. maxillule, g. maxilla, h. first maxilliped, i. second maxilliped, j. third maxilliped, k. uropod, l. exopodal spine of uropod, m. telson.

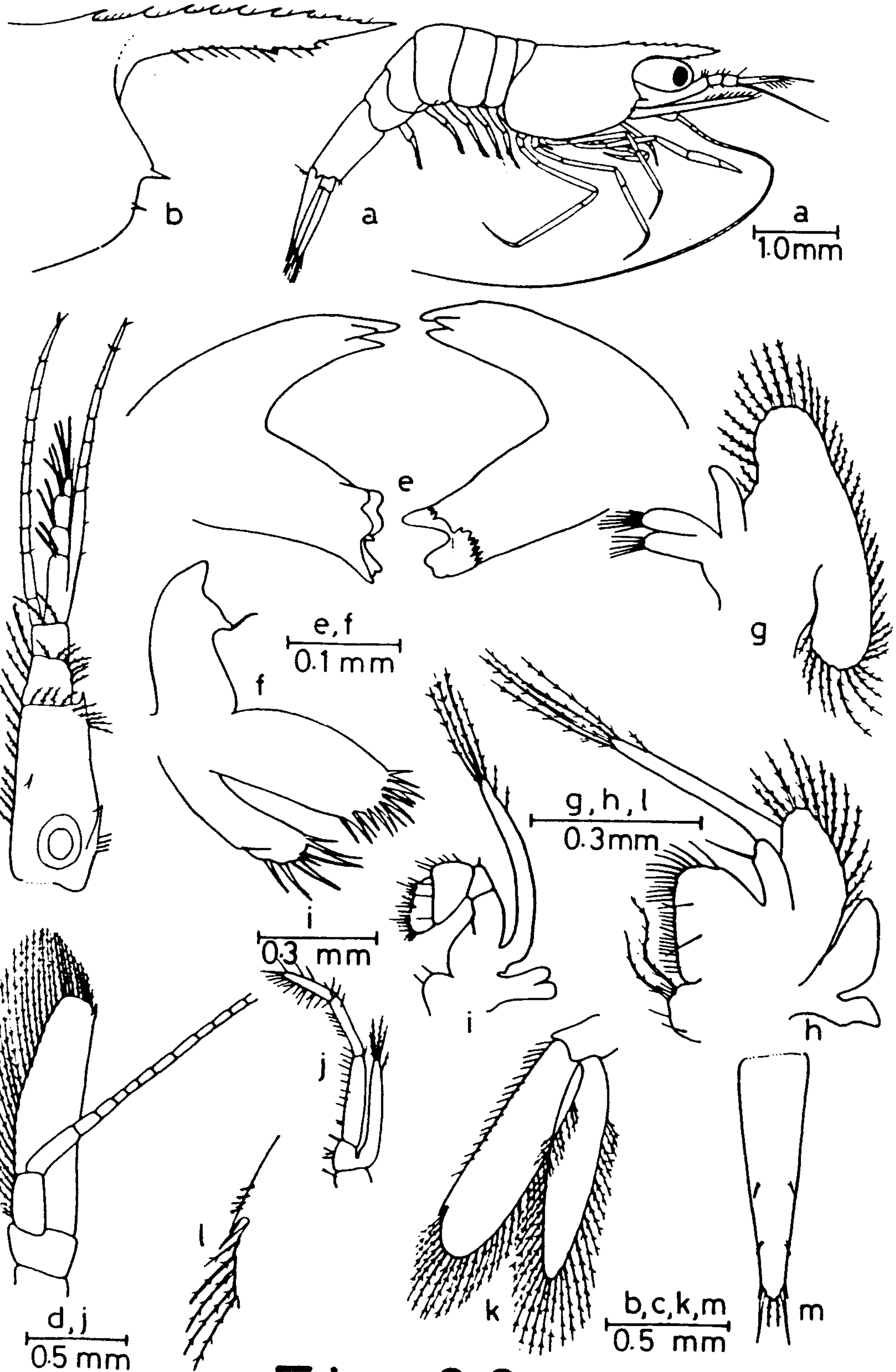
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Fig. 33

Maxillule (Fig. 33 f): Shape of endopod has changed. Distally it has two small projections of which one carries a slender seta. Distal lacinia with 13 teeth. Shape of proximal lacinia much changed bearing distally 7-8 teeth and marginally one tooth.

Maxilla (Fig. 33 g): A number of changes have noticed in the shape. Exopod becomes more flattened bearing 40-45 plumose setae. Endopod simple and bare and basis with 2 endites carrying 7+5 bristle like setae distally.

First maxilliped (Fig. 33 h): Basipod and coxopod expanded bearing a number of setae along its margin. 2 setae on the coxopod long and plumose. Endopod with one sub-apical seta. The distal portion of the exopod bent over the endopod and bears 4 apical and one sub-apical plumose setae.

Second maxilliped (Fig. 33 l): Endopod is bent towards the inner side and assumed the characteristic shape of the adult appendage. Dactylus and propodus flattened and bearing a number of setae. Exopod with 4 apical and 1-2 sub-apical setae. Bud of podobranch developed.

Third maxilliped (Fig. 33 j): Exopod shorter than the endopod, only as long as the first segment of endopod, and bears apically 4 short and one sub-apical plumose setae. Endopod 3 segmented. Third segment with a terminal spine and profusely setose all round. First and second segments bear a number of setae along its inner margin.

First pereiopod (Fig. 34 a): Shorter than second pereiopod. Exopod vestigial and only as long as the first segment of endopod and non-functional. Endopod 5-segmented bearing a number of setae distally.

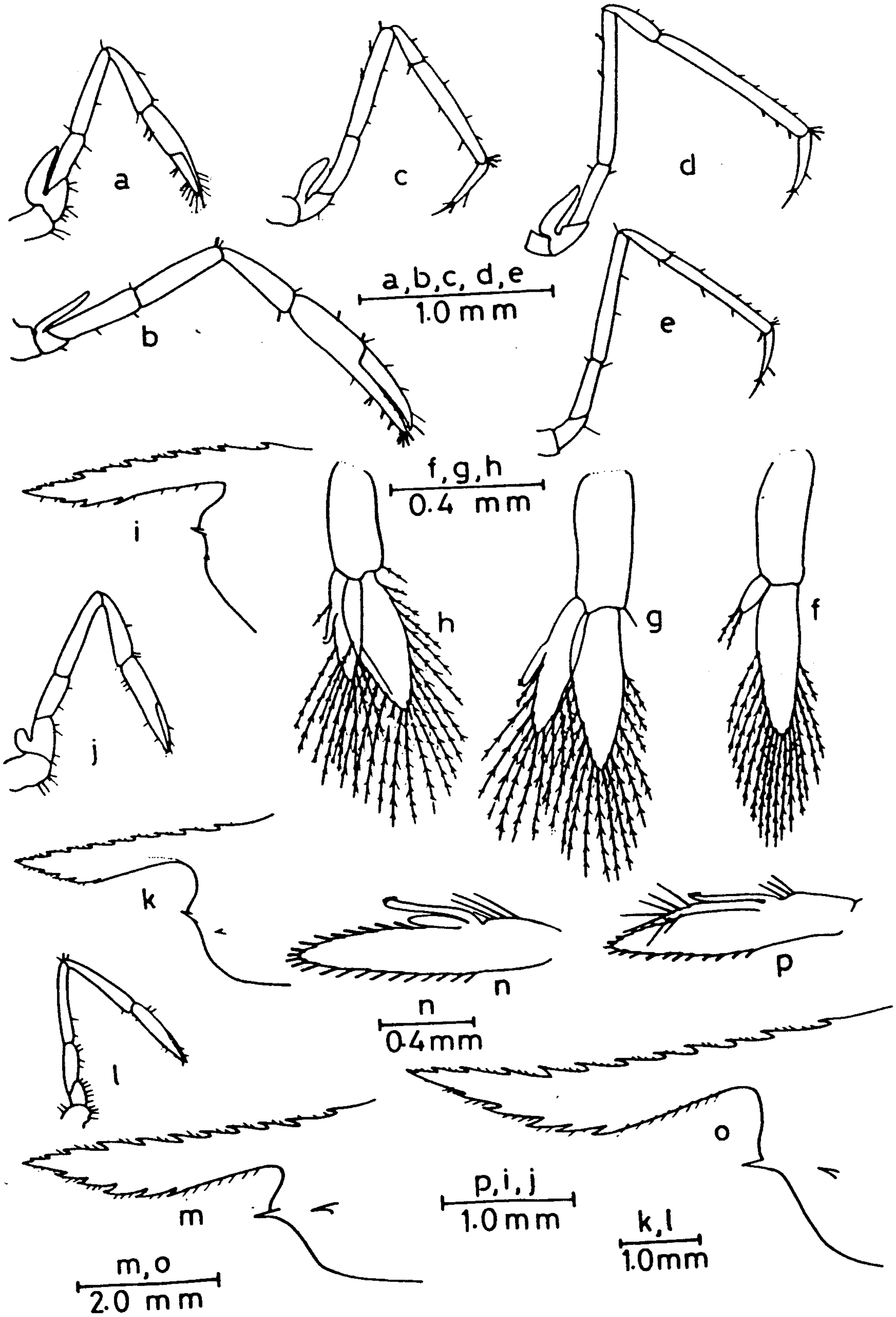
Fig. 34 . Macrobrachium equidens: Postlarva I a. first pereiopod, b. second pereiopod, c. third pereiopod, d. fourth pereiopod, e. fifth pereiopod, f. first pleopod, g. second pleopod, h. fourth pleopod,

Postlarva II i. rostrum, j. second pereiopod

Postlarva of TL 10.32 mm k. rostrum, l. first pereiopod

Postlarva of TL 18.76 mm m. rostrum, n. endopod of second pleopod.

Postlarva of 20.0 mm TL o. rostrum, p. endopod of second pleopod.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i
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g
f
j
k
n
p
n
0.4mm
l
o
m
p,i,j
1.0 mm
k,l
1.0mm
m,o
2.0 mm

Fig. 34

Second pereiopod (Fig. 34 b): Endopod 5-segmented and chela fully developed and bear setae at its distal margin. Exopod small and non-functional.

Third pereiopod (Fig. 34 c): Exopod reduced to a small palp without setae and non-functional. Endopod 5-segmented, dactylus bearing an apical spine.

Fourth pereiopod (Fig. 34 d): Exopods are reduced to a small palp and non-functional. Endopod 5-segmented.

Fifth pereiopods (Fig. 34 e): Endopod 5-segmented. Dactylus bearing a small spine at its apex.

Pleopods (Fig. 34 f): Endopod of first pleopod small with 2 plumose setae distally. Exopod with 14-16 plumose setae. Endopod of pleopods second to fifth bearing appendix interna, which bear 3-4 hooks at its distal margin. Endopod with 10-11 and exopod with 16-18 plumose setae (Fig. 34 g, h).

Uropods (Fig. 33 k): Exopod and endopod with 30-34 plumose setae. Exopod bearing 2 spines of which one is movable (Fig. 33 l).

Telson (Fig. 33 m): Telson with sharply pointed tip bearing 4 spines and 2 setae. 2 pairs of lateral spines present, which have shifted towards the dorsal aspect of the telson.

Postlarval development: The first postlarvae were further reared in the laboratory until they developed secondary sexual characters. The major changes that occurred in the rostrum, carapace, pereiopods and pleopods are recorded below:

First postlarva moulted within 2-3 days. Second postlarva had a total length of 7.03 mm and carapace length of 2.41 mm. Rostral formula was 10/3 (Fig. 34 i). The pterygostomial spine had shifted from the margin further upwards. Non-functional exopod of pereiopods still remained as a palp (Fig. 34 j).

Postlarva at 10.32 mm total length registered a carapace length of 4.11 mm with rostral formula of 10/4 (Fig. 34 k). The pterygostomial angle became rounded and devoid of any spine. The hepatic spine was well developed. Pereiopods were uniramous with the absence of exopods (Fig. 34 l).

As the animal grew to a total length of 18.76 mm, its carapace measured 6.85 mm. Rostral formula increased to 11/5 (Fig. 34 m). Appendix masculina developed at the endopod of second pleopod (Fig. 34 n). But it was bare without any seta.

At a total length of 20.0 mm and carapace length of 7.66 mm the rostral formula was same as that of the previous stage (Fig. 35 o). The appendix masculina in males was seen well developed, bearing 7-9 bristle-like setae (Fig. 34 p). In the laboratory reared postlarvae the secondary sexual characters were fully developed when the animal grew to a total length of 20.0 mm.

Some observations on the larval biology

i) Food and feeding behaviour: The residual yolk present in the first zoea was found to be sufficient for their survival after hatching to about 4 to 5 days. It was also observed that within 48 hours, the first zoea moulted to the next stage even without feeding. Though the freshly hatched zoea can survive 4 to 5 days without taking food from outside, they became weak and heavy mortality was observed later if the larvae were not fed within 48 hours of their hatching. Therefore the larvae were fed from the second day onwards regularly with the freshly hatched Artemia nauplii.

The feeding behaviour of the larvae is interesting to observe. Whenever larva comes in contact with the Artemia nauplii, it suddently moves backwards a little and then with a darting forward motion captures the food by the terminal long setae of the endopod of the maxilliped and the first two pereiopods and hold the prey close to the mouth. From zoea IV onwards, the comparatively long and well developed fifth pereiopod with its terminal 'sigma' shaped seta was mainly used to capture the prey. If the moults and dead larvae are present in the container, the larvae are seen clinging to them. Advanced stages of larva (zoea VII to X) are often seen attacking the newly moulted larvae if food is not readily available. Mortality due to cannibalism was found to be high among the advanced stage larvae. It was frequently observed that younger stage larvae (zoea III to VI) attack and kill the newly moulted advanced stage larvae. Further it was also noticed that the larvae generally preferred relatively large size particles (about 1/3rd the size of the larvae) which they can hold by their appendages and feed as they move about in the medium.

ii) Moulting and growth: The observations made in the moulting and growth of the larvae during the rearing experiments have revealed that in normal healthy conditions the zoea larva generally moults once in every

2 to 4 days. Moulting invariably takes place during the later half of the night. The first zoea moults within 48 hours. However, the second zoea onwards no uniformity in moulting frequency is observed, even among the larvae from the same brood, as they moult at different times taking a minimum period of 2 to 4 days for each moult. Thus after about 10 to 12 days after hatching the larval population in the rearing container may be represented by different stages although they would have come from the same brood. Such differential growth was observed in most of the rearing experiments carried out during the study.

Upto zoea VI, each moult results in the transformation of the next stage with definite morphological changes. But from zoea VI onwards, some of the larvae moulted two times before developing to zoea VII. As zoea III and VI took maximum time to develop to the next stage, these stages may be considered as critical stages in the development of this species. The duration taken by zoea I to develop to postlarva I, larval measurements and the salient features of the larvae are presented in Table 9.

Although the minimum duration taken for the metamorphosis of zoea I to postlarva I was 25 to 30 days for this species, some variations were also noticed in some of the experiments. As mentioned earlier, from zoea VI onwards each moult need not necessarily bring about corresponding changes which characterise the next stages. In a couple of experiments it was also observed that a few zoea VI moulted regularly every 3 to 4 days without developing to the next stage for 25 days. In another experiment it was noticed

Table 9. Macrobrachium equidens: Inter-moult duration, measurements and salient features of the different larval stages.

Stage	Inter moult period in days	Total length		Carapace length		Salient feature of the stage
		Range (mm)	Mean (mm)	Range (mm)	Mean (mm)	
Zoea I	2	2.18-2.46	2.34	0.65-0.70	0.68	Sessile eyes; mouth parts developed; pereiopods I & II developed only as buds. Telson not demarcated from last abdominal segment.
II	2-4	2.39-2.56	2.45	0.70-0.81	0.74	Stalked eyes; pereiopods I & II fully developed.
III	3-8	2.59-2.83	2.73	0.70-0.76	0.73	Rostrum with epigestric tooth, telson demarcated from last segment, uropod developed; endopod without setae. Buds of III and V pereiopods developed.
IV	2-4	2.69-3.04	2.86	0.74-0.77	0.76	Rostrum with 2 dorsal teeth pereiopods III & V developed.
V	2-4	3.21-3.35	3.28	0.85-0.87	0.86	Buds of pereiopod IV developed.
VI	3-8	3.65-4.20	3.87	0.98-1.12	1.04	All pereiopods developed; no pleopod buds developed.
VII	2-4	4.23-4.90	4.56	1.15-1.37	1.24	Pleopod buds uniramous.
VIII	2-4	5.01-5.82	5.41	1.40-1.57	1.48	Pleopod buds biramous but bare.

Table 9. (Contd...)

Stage	Inter moult period in days	Total length		Carapace length		Salient feature of the stage
		Range (mm)	Mean (mm)	Range (mm)	Mean (mm)	
IX	2-4	5.74-5.80	5.75	1.51-1.65	1.62	Exopod of pleopod setose endopod bare.
X	3-6	6.22-7.35	6.93	1.75-2.04	1.92	Exopod and endopod of pleopod with setae. Appendix interna developed.
First post-larva	3	5.98-6.79	6.35	2.17-2.32	2.24	Exopod of pereiopods non-functional. Pleopods functional. Rostrum with ventral tooth not planktonic like zoeal stages.

that zoea VI after moulting 3 times developed to an intermediate stage possessing characters both of zoea VI and VII. In different experiments, intermediate stages were also observed after zoea VII, VIII, IX and X. These intermediate stages generally form only a negligible percentage of the total larvae. The fact that majority of the larvae skip these intermediate stages totally and complete the metamorphosis and develop to healthy postlarva I, clearly indicate that these intermediate stages are not necessary for the normal development, of the larvae and hence need not be considered as a separate stage.

As mentioned earlier, the intermediate stages generally form only a small percentage of the total larvae. Out of the various experiments carried out during the present study, only in two experiments intermediate stages were found in good numbers. In both the experiments, upto zoea VI development was normal. After 21 days 20 larvae from each experimental containers were examined and the results are given in Table 10. In the first experiment 50% and in the second experiment 30% were in zoea VI and VIII stages. The remaining larvae showed combined characters of zoea VI and VII as well as VII and VIII. Neverthless, these intermediate stage larvae were found to be as active as the normal larvae, feeding and moulting at regular intervals of 3 to 4 days. The occurence of these stages among zoeae of same brood and reared in identical conditions may probably be due to factors which are genetic rather than environmental.

Postlarva I is colourless and the typical colour pattern characteristic of this species, appears when they reach about 33 mm in total length (Fig. 35).

Table 10. Macrobrachium equidens: Details of larval stages after 21 days of hatching.

Larval stage	Macrobrachium equidens		
	Number of Larvae		Salient features of the stage
	Experiment 1	Experiment 2	
Zoea VI	7	3	All pereiopods fully developed; no pleopod buds developed.
VI/VII	5	7	1 to 4th pleopods developed as uniramous bud. 5th not developed.
VII/VIII	2	4	1-4th pleopods partially biramous 5th uniramous.
VII/VIII	3	3	1-4th pleopods fully biramous 5th uniramous.
VIII	3	3	All buds of pleopods (1-5) biramous and bare.
Total Number of larvae examined	20	20	

Postlarva of 7.14 mm in total length grew to 35 mm within a period of 50 days registering 0.557 mm in growth per day. Ovary started developing when the prawn reached a size of 44 mm in total length. Thus in captivity M. equidens became mature at 44 mm in total length.

iii) Observation on the salinity tolerance of larvae: To find out the most suitable range of salinity for the larval rearing four preliminary experiments were carried out using zoea I. Rearing of zoea I was carried out in 6 l glass troughs containing 5 l of rearing medium. 400 zoea I were released to each of the troughs. From second day onwards larvae were fed with freshly hatched Artemia nauplii in sufficient numbers. Daily in the morning, half of the water from the troughs was removed along with the bottom sediments, moults and dead larvae. The water level was made up with freshly prepared water of the same salinity. Daily all the larvae were counted and 10 larvae were examined to determine the stage of development of larvae. Postlarva I, as soon as it was metamorphosed from the last zoea, was counted and removed from the troughs. Experiments were continued until all the larvae were dead or developed to postlarva I. The results of the experiments are given below:

a) When zoea I were reared in 15 to 20‰ salinity, 86% of the larvae survived for the first 9 days and developed to zoea III, IV and V. Mortality started from 10th day onwards and only 8% survived and developed to zoeae VII and VIII on 21st day. First postlarva started appearing on 38th day. By 42 days, 4% of the zoea I developed to postlarva I.

b) In the 20 to 25‰ salinity range, 25% of the larvae survived and developed to postlarva I within a period of 30 days. Mortality was observed when the larvae were in advanced stage of zoea IX and X.

c) When the zoeae were reared in 30 to 35‰ salinity medium, 50% mortality was observed between 14th and 26th days, by which time larvae developed to zoea V to X stages. 10% of the larvae metamorphosed to postlarva I within 24 to 51 days.

d) The above experiment revealed that better survival and development of larvae occur only when they were reared in 20‰ salinity and above. As faster larval development was observed initially in 30‰ salinity and above another experiment was set up to study the survival when the larvae were initially reared in 30‰ to 35‰ salinity and later in the medium with 20‰ to 25‰ salinity. Thus zoeae I were reared in 34.9‰ salinity for 14 days. It was observed that upto zoea III there was no mortality. Afterwards a gradual reduction in the number was noticed and on 9th day 62.5% survived and developed to zoea IV and V. On 14th day 52.5% survived and reached zoea V to VIII stages. The salinity of the medium was gradually reduced from 34.9‰ to 22.1‰ between 14th and 26th days. Afterwards the salinity was maintained between 22.0 to 22.5‰. Postlarva I started appearing from 25th day. 25% of the zoeae survived and metamorphosed to postlarva I within 25 to 58 days. However, maximum number metamorphosed to postlarva I between 35th and 38th day in 22.8‰ salinity, an observation which could be a pointer towards further studies for hatchery purpose. Details are given in Table 11.

Results of these experiments revealed that 20 to 25‰ salinity range was ideal for the larval development of M. equidens. Further it was also found that almost the same result could be obtained by rearing the larvae

Table 11. Macrobrachium equidens: Experiment on the rearing of larvae at 22-34.9‰ salinity.

No. of days	No. of larvae	Zoeal stage	Postlarva I obtained	Salinity of the rearing medium ‰
0	400	I	-	34.9
4	400	III	-	34.9
5	360	III	-	34.9
7	320	III & IV	-	34.9
9	250	IV & V	-	34.9
10	230	IV, V	-	34.9
11	220	IV, V, VI	-	34.9
14	210	V, VI, VII	-	34.9
15	205	VI, VII, VIII	-	27.6
21	205	VI, VII, VIII, IX	-	23.1
23	205	VI, VII, VIII, IX, X	-	23.1
25	204	VII, VIII, IX, X	1	23.1
26	202	VII, VIII, IX, X	2	22.1
28	199	VIII, IX, X	3	22.1
29	196	VIII, IX, X	2	22.1
30	193	VIII, IX, X	3	22.1
31	189	VIII, IX, X	-	22.1
32	184	IX, X	5	22.8
33	181	IX, X	3	22.8
34	175	IX, X	6	22.8
35	165	IX, X	10	22.8

Table 11. (Contd...)

No. of days	No. of larvae	Zoeal stage	Postlarva I obtained	Salinity of the rearing medium ‰
36	145	IX, X	20	22.8
37	135	X	10	22.8
38	123	X	12	22.8
39	118	X	-	22.8
40	113	X	5	22.0
41	108	X	5	22.0
42	104	X	4	22.0
44	99	X	3	22.0
45	98	X	-	22.0
46	88	X	-	22.0
47-58	-	-	8	22.0

initially for 14 to 15 days in 30 to 35‰ salinity and later reducing the salinity gradually to 20 to 25‰.

In all the experiments, although postlarva I started appearing within 24 to 30 days, to complete the metamorphosis of all the larvae, of the same brood, it took 50 to 58 days.

Postlarvae I of M. equidens were individually reared for 20 days in 10, 15, 20 and 30‰ (Table 12). In 10 to 30‰ salinity, 6 days were taken by postlarva I to develop to postlarva III. Postlarva III took 7 days to develop to postlarva IV in 10‰ salinity. Whereas within 3 days it developed to post-larva IV in 15-30‰ salinity. Only in 30‰ postlarva I developed to postlarva VII in 19 days. These results have shown that postlarva I is euryhaline and can survive and develop in salinity ranging from 10 to 30‰.

2. Macrobrachium striatus Pillai, 1990

The specimens belonging to this species were collected from the Cochin Backwater during August-November, along with M. idella and M. equidens by operating cast nets. It closely resembles M. equidens. However, in live condition the specimens of M. equidens and M. striatus could be easily distinguished by their distinct colour pattern. Jagadisha (1977) while studying the caridean prawns of Karwar area had also reported the occurrence of the striped and non-striped forms of M. equidens. Besides the differences in the colour pattern, he had also observed certain morphological differences such as rostral type, number and position of dorsal and ventral teeth, relative

Table 12. Macrobrachium equidens: Rearing of postlarva I in different salinity ranges

Number of days	SALINITY							
	10 ‰		15 ‰		20 ‰		30 ‰	
	Stage	Inter moult period	Stage	Inter moult period	Stage	Inter moult period	Stage	Inter moult period
0	PL I	3	PL I	3	PL I	3	PL I	3
3	PL II	3	PL II	3	PL II	3	PL II	3
6	PL III	7	PL III	3	PL III	3	PL III	3
9	-	-	PL IV	3	PL IV	3	PL IV	4
12	-	-	PL V	4	PL V	4	-	-
13	PL IV	3	-	-	-	-	PL V	3
16	PL V	3	PL VI	-	PL VI	-	PL VI	3
19	PL VI	-	PL VI	-	PL VI	-	PL VII	-

length of carpus and chela and velvety nature of finger of second pereiopod in the adult males between the two forms. But he has not observed any difference in the characters of first three zoea larvae of the two forms and hence did not recognise them as two distinct species or sub-species and concluded as monotypic. However, the evidences collected during the present study with differences in the larval characters, failure to interbreed them in addition to the differences observed in the morphological characters of the adults, compelled the author to consider these forms as two distinct species. Accordingly the type exhibiting greenish/greyish brown longitudinal stripes along the entire length of the body (Fig. 36 a, b), with the second pereiopod of the adult male showing stripes (Fig. 36 c) and not exhibiting the mottled appearance on the carpus and palm (a character very distinct in M. equidens), was considered as a new species and published by the candidate just before the submission of this thesis to have the priority. The published paper giving the full details of the adult male is presented in the following pages (106 to 111).

SECTION TWO

Family Palaemonidae Rafinesque, 1815

Genus *Palaemon* Fabricius, 1798

1. Palaemon (Palaemon) concinnus Dana, 1852

The scientific paper dealing with the first seven zoeal stages of this species reared in the laboratory and published earlier by the author is placed below (Pages 160-166).

Contributions to Marine Sciences Dedicated to Dr. C. V. Kurian, 1979: 243–255

EARLY LARVAL STAGES OF *PALAEMON* (*PALAEMON*) *CONCINNUS* DANA (DECAPODA, PALAEMONIDAE)

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ABSTRACT

First seven zoeal stages of *Palaemon (Palaemon) concinnus* Dana were reared in the laboratory and the developments studied. Rearing was carried out in the medium having a salinity range of 10-12‰ and by feeding with freshly hatched *Artemia* nauplii. In the larval development each of the successive moult leads to the following stage upto zoea VI and thereafter moults 2-3 times before developing into zoea VII. Relatively high mortality was observed in zoea III and zoea VI stages.

INTRODUCTION

Palaemon (Palaemon) concinnus Dana, a widely distributed shrimp in the Indo-Pacific region, was recorded for the first time from Indian waters from the irrigation canals of river Krishna opening into the Bay of Bengal (Dutt and Ravindranath, 1974). A single berried specimen collected from Cochin backwaters was reared in the laboratory. When the eggs hatched out the larvae were reared up to zoea VII and the following description deals with the first seven zoeal stages of the species.

MATERIAL AND METHODS

During an experimental cast net operation to collect caridean prawns for biological studies, one berried female of *Palaemon (Palaemon) concinnus* was caught on 22.9.1973 from the Thevara canal near Cochin. Total length (from tip of rostrum to tip of the telson excluding terminal spines) and carapace length (from tip of rostrum to the mid dorsal posterior margin of carapace) of this species were 54 and 24 mm respectively. The specimen was brought to the laboratory alive and kept in a 5-litre glass trough containing 4 liters of filtered water having a salinity of 10‰. Continuous aeration was provided. The trough was covered with organdy cloth to prevent the shrimp from jumping out of water. Eggs started hatching out during the early morning hours on 23.9.1973. The female was removed from the trough immediately after completion of hatching of all the eggs. The sides of the trough was covered by black cloth to ensure uniform distribution of larvae. In order to clean the trough the larvae were attracted to one side by a light from a table lamp after stopping the aeration and the bottom sediments carefully siphoned out. Then half of the water was changed daily with water having a salinity range of 10–12‰ which was prepared by diluting the seawater with chlorine free tap water. Temperature of the medium varied between 25°C to 28°C during the period of experiments. From the third day onwards larvae were fed with freshly hatched out, *Artemia* nauplii. While the individual larvae by each moult metamorphosed to the next stage, 1st and 2nd zoea took 3 days, zoea III took 2 days, zoea IV and V from 5 to 7 days to develop to the next stage. Zoea VI moulted 2 to 3 times before developing to the next stage, taking 7 to 13 days in the process. There was no significant mortality in the first 2 stages but from stage III onwards mortality was considerable and it occurred during the time of moulting to the next stage. Maximum mortality was observed in zoea VI. None of the larvae survived beyond zoea VII.

Larvae in all stages were preserved in 5% formaldehyde for detailed morphological studies. 5 specimens were examined in each stage for detailed study.

The following abbreviations are used in describing various larval stages:-

Tl—Total length; Cl—Carapace length; A1—Antennule; A2—Antenna; Md—Mandible; Mx1—Maxillule; Mx2—Maxilla; Mxp1—Maxilliped I; Mxp2—Maxilliped II; Mxp3—Maxilliped III; P1—Pereopod I; P2—Pereopod II; P3—Pereopod III; P4—Pereopod IV; P5—Pereopod V; Ur—Uropod; T—Telson.

DESCRIPTION OF LARVAL STAGES

Zoea I (Fig. 1 a to k); Tl 2.37—2.62 mm (2.45 mm*); Cl 0.70—0.74 mm (0.73 mm*).

Rostrum slender and pointed without any tooth; carapace smooth, antero-lateral angle produced to form pterygostomial spine (Fig. 1a); eyes large and sessile; A1, A2, mouth parts and biramous buds of P1 (Fig. 1j) and P2 developed; abdomen 6 segmented; T not demarkated from the last abdominal segment.

A1 (Fig. 1b): uniramous; long, slender and unsegmented, more than 4 times the length of outer flagellum; carrying distally 2 flagella; outer flagellum carries at its apex 3 aesthetes and 2 setae, of which inner seta plumose; inner flagellum long and plumose. A2 (Fig. 1c): biramous; endopod as long as the proximal segment of exopod, bearing at its apex a short spine and one long plumose seta; exopod 5 segmented, proximal segment longest, 9 long plumose setae present along the inner and distal margin of exopod, a short non plumose seta present at the distal outer aspect, 2 short plumose setae present at the lateral outer aspect; peduncle unsegmented. Md (Fig. 1d): almost symmetrical; incisor with 1–2 stout teeth; molar with one small tooth on one side; in between the 2 processes 2 slender teeth present. Mx1 (Fig. 1e): not fully developed; uniramous; endopod with 2 short setae at its distal end; distal and proximal lacinia each with 4 short stout teeth apically. Mx2 (Fig. 1f): exopod with 5 long plumose setae along its margin, of which the outer proximal one being the longest and directed backwards; endopod bearing 2 setae, one apical and another at the basal projection on inner side; protopod with 3 masticatory processes, 2 distal processes each with 3 setae and proximal process with 6 setae. Mxp1 (Fig. 1g): biramous; basipod protuberant, bearing 3 to 5 setae; endopod unsegmented, with 3 apical and 2 lateral setae; exopod more

*Figure in bracket pertains of the mean length.

than twice the length of endopod bearing apically 4 long plumose setae. Mxp2 (Fig. 1h): biramous; basis with a short seta on the inner side; endopod 3 segmented, distal segment with a claw-like seta and 3 short setae, middle segment distally with 2 setae; exopod twice as long as endopod bearing 4 long plumose setae apically. Mxp3 (Fig. 1i): biramous; basipod with one long slender seta on the inner margin, endopod 3 segmented, proximal segment bearing 2 short setae on the inner side,

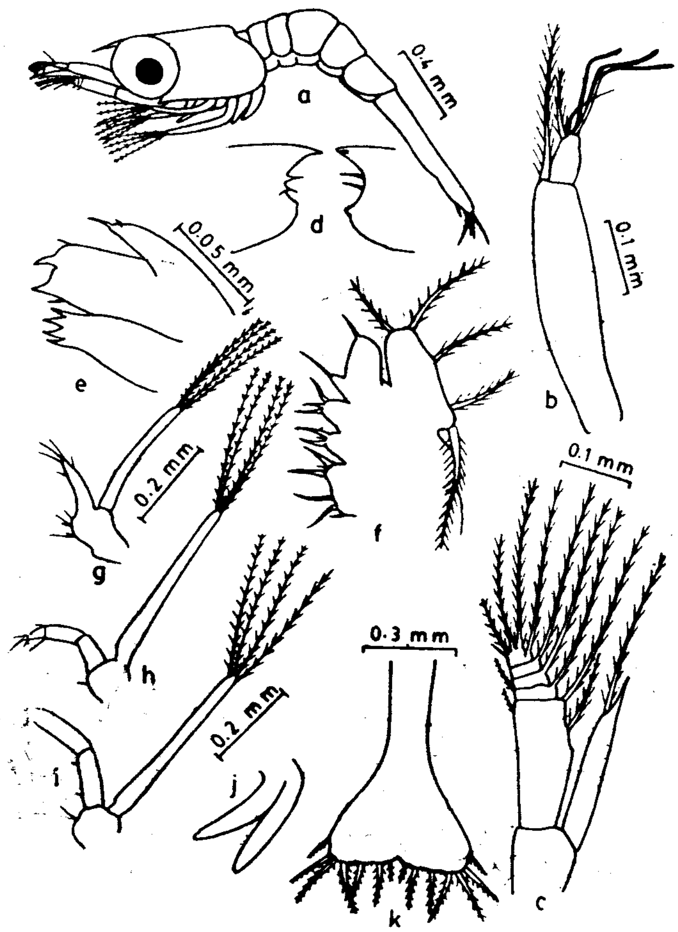

Figure 1. *Palaemon (Palaemon) concinnus. Zoea* 1.
a—lateral view; b—A1; c—A2; d—Md; e—Mx1; f—Mx2; g—Mxp1; h—Mxp2; i—Mxp3; j—bud of P1; k—T.

middle segment with 2 slender setae at the distal inner margin, apical segment ends in a claw like seta and a short hair-like seta; exopod longer than endopod bearing 4 long plumose setae at its apex. T (Fig. 1k): broad, concave posteriorly bearing 7 spines on each side, outer 2 distal spine on either side plumose only on the inner side.

Zoea II (Fig. 2a to j; 3 a, b); Tl 2.36—2.46 mm (2.45 mm); Cl 0.71—0.75 mm (0.72 mm)

No appreciable change in Tl; eyes stalked; supraorbital and pterygostomial spines present; P1 and P2 developed (Fig. 2a); T with 8+8 spines (Fig. 2j).

A1 (Fig. 2b): peduncle faintly segmented; 3 short plumose setae seen at the outer aspect of the peduncle at the place of segmentation; distally the peduncle carries 2 flagella and 2 short plumose setae; outer flagellum with 3 aesthetes and one non plumose seta; inner flagella long and plumose. A2 (Fig. 2c): endopod bearing one spine and 3 setae distally of which one seta long and plumose. Md

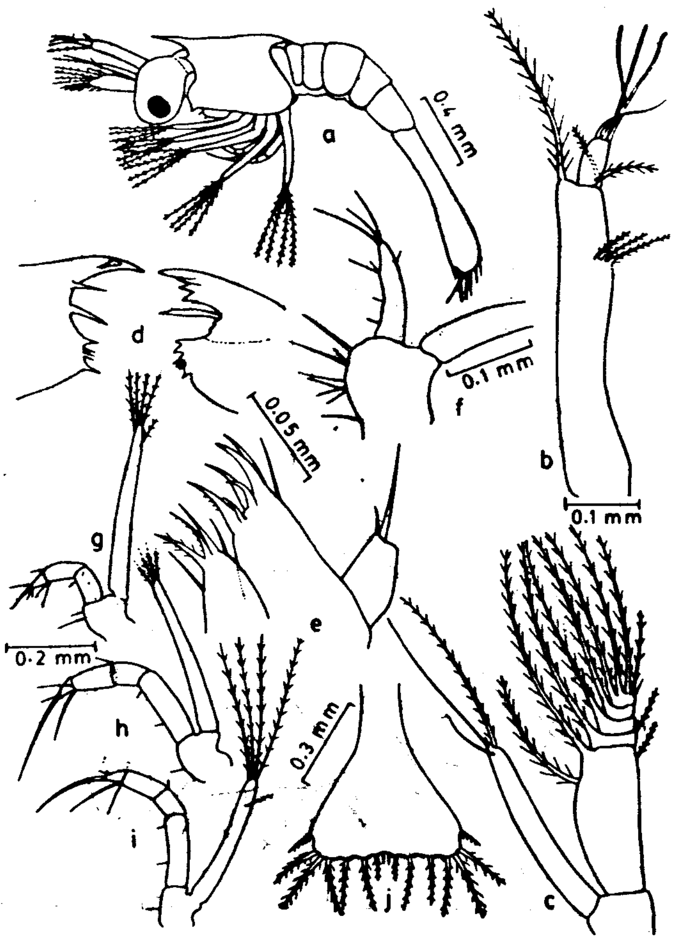

Figure 2. *Palaemon (Palaemon) concinnus. Zoea II*
a—lateral view; b—A1; c—A2; d—Md; e—Mx1; f—Mxp1; g—Mxp2; h—P1; i—P2; J—T.

(Fig. 2d): asymmetrical; incisor on one side with 4 and the other side with 3 stout teeth; molar with a number of short teeth; in between the 2 processes 1 to 2 slender teeth present. Mx1 (Fig. 2e): fully developed; endopod with 2 distal setae of which one is long; distal lacinia with 4 long and stout and 2 short and stout and one slender teeth; proximal lacinia with 5 long teeth of which some are plumose. Mx2 (Fig. 3a):

exopod with 7 plumose seate; basal seta of endopod becomes longer; distal masticatory process of protopod with 3 long and 1 short seta, middle with 2 long setae and proximal process with 4 long and one short setae. Mxp1: basipod with 8 setae along the inner side; endopod unsegmented with 3 apical and 3 to 4 inner lateral and one outer lateral small seate (Fig. 2f). Mxp2 (Fig. 2g): basis with 2 seate on the inner side; proximal segment of endopod with one short inner seta, middle segment distally carries 3 setae; exopod with 4 long apical and 1 short sub apical plumose seta. Mxp3 (Fig. 3b): endopod 4 segmented, distal segment bears

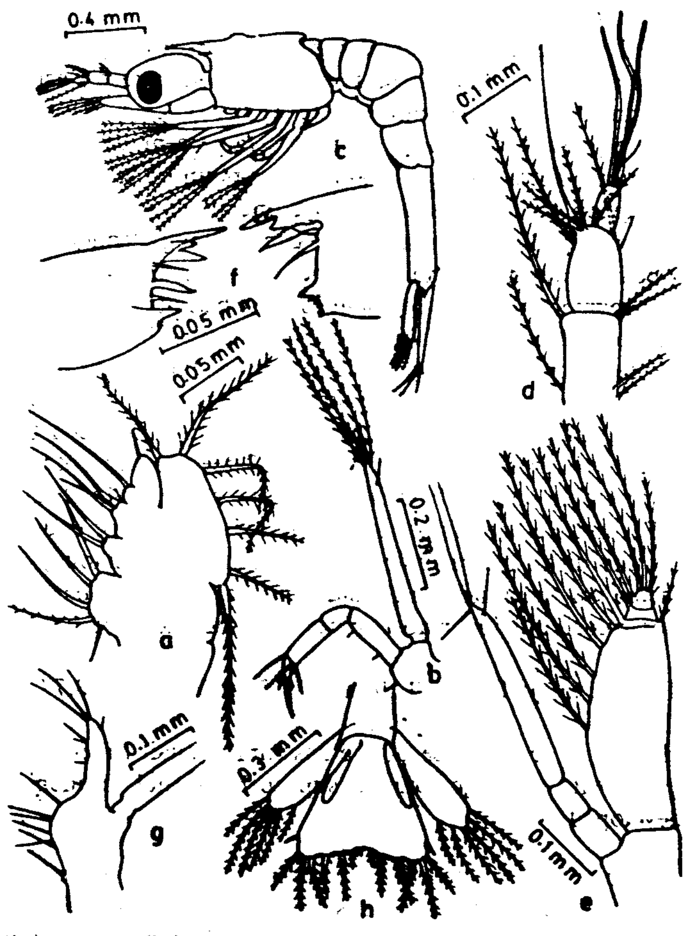

Figure 3. *Palaemon (Palaemon) concinnus. Zoea II.* a—Mx2; b—Mxp3. *Zoea III.* c—Lateral view; d—anterior part of A1; e—A2; f—Md; g—basipod and endopod of Mxp1; h—Ur and T.

2 short setae and one claw like seta which is serrated, 3rd segment distally carries 3 serrated setae; exopod with 4 long pumose apical and one short sub apical seta. P1 and P2 (Fig. 2 h, i): identical; basipod with one seta at the inner side; endopod 4 segmented 1st segment with 2 setae on the inner side, 2nd with one seta on the outer distal margin, 3rd carries 2 long setae at the inner distal margin; terminal segment

with 1-2 short setae and one long seta which is more than half the length of the endopod; exopod as long as endopod bearing 4 long plumose setae apically and one short sub apical seta. T (Fig. 2 j): 8 spines on each side, innermost spine on both sides non plumose, outer most spine on either side plumose only on the inner side.

Zoea III (Fig. 3 c to h); TI 2.65-2.95 mm (2.82 mm); CI 0.73-0.78 mm (0.76 mm).

Biramous buds of P3 developed; T demarkated from last abdominal segment by an articulating joint; Ur developed (Fig. 3 c,h).

A1: peduncle 2 segmented; proximal segment bears a long plumose seta at the distal inner aspect and 2 short plumose setae at the outer distal aspect, above the middle of this segment 2 short plumose setae at the outer and one long plumose seta at its inner side present, one short plumose seta present on a prominence at the proximal outer region; distal segment bears 2 long plumose setae on one side and 4 short plumose setae on the other side distally, one small seta present at the distal outer margin; inner flagellum papilla like bearing a long slender seta at its apex; outer flagellum bears 3 aesthetes and one seta (Fig. 3d). A2 (Fig. 3e): endopod as long as exopod, 3 segmented, distal segment longest bearing 4 slender setae apically, segmentation of exopod becomes faint, proximal segment has become flat and leaf like, 11 plumose setae present along the inner and distal margin of exopod, a very small non plumose seta present at the distal outer margin, a short plumose seta present at the outer margin of exopod. Md (Fig. 3 f): in between the incisor and molar processes 2 teeth present on one side and 3 teeth on the other side. Mxp1 (Fig. 3g): no appreciable change from the previous stage. Mxp2 and Mxp3 same as in zoea II. P1 and P2 are almost identical, 3rd segment of endopod bearing 3 serrated setae at the distal lateral margin. Ur (Fig. 3h): biramous; exopod with 6 long plumose setae on the inner and distal margin; endopod bare. T (Fig. 3h): 8 + 8 spine, outermost and innermost spines on either side non plumose.

Zoea IV (Fig. 4 a to g); TI 3.06-3.19 mm (3.15 mm); CI 0.74-0.77 mm (0.75 mm).

Rostrum devoid of tooth, base of the rostrum a small tubercle like projection present; carapace with pterygostomial, supraorbital and branchiostegal spines (Fig. 4a); P3 developed.

A1 (Fig. 4b): number of setae at the proximal segment of peduncle increased, basal prominence with 2 short plumose setae, distal segment with 3 short and 4 long plumose setae at the distal aspect; outer flagellum with 3 aesthetes and one seta. A2 (Fig. 4 c): exopod unsegmented, bearing 14 plumose setae along its inner and distal margin, distally the outer margin of exopod is produced to form a spine, in some specimens a non plumose short seta is observed in between the last and penultimate setae at the distal margin. Md: in between the incisor and molar processes 3 teeth are present. Mx1 no appreciable change from the previous stage. Mx2: no appreciable change from the previous stage except the setae on the middle and proximal masticatory processes become plumose; terminal short seta of endopod has also become plumose. Mxp1: exopod with 4 plumose apical and one short subapical seta. Mxp2 (Fig. 4d): basis with 3 setae on the inner side of which middle one long and slender. Mxp3: basipod with 2 setae on the inner side, distal segment of endopod carrying 3 short setae and a serrated claw like seta distally. P1 and P2 same as in the previous stage. P3 (Fig. 4e): biramous; basipod with 1 short seta on the inner margin; endopod 4 segmented, 1st segment with 1 seta on the inner margin, 2nd segment with one seta on the outer distolateral margin, 3rd segment with 2 long setae at the distolateral margin on the inner side, terminal segment with 2 short seta and one long claw like seta; exopod shorter than endopod

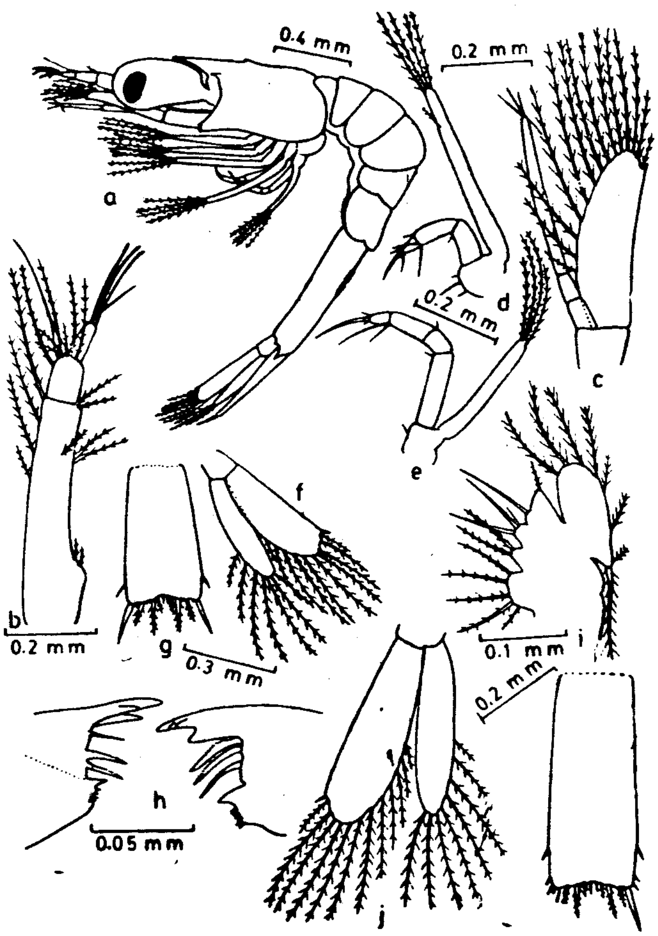

Figure 4. *Palaemon (Palaemon) concinnus. Zoea IV.*
a—lateral view; b—A1; c—A2; d—Mxp2; e—p3; f—Ur; g—T. *Zoea V.* h—Md; i—Mx2; j—Ur; k—T.

bearing 4 long plumose setae apically. Ur (Fig. 4f): exopod with 10 long plumose setae along its inner and distal margin and one distolateral spine on the outer margin, endopod with 7 long plumose setae; T (Fig. 4g) narrower than in the previous stage, carrying one lateral and 5 terminal spines on either side, inner and 2 outer spines on both sides non plumose.

Zoea V (Fig. 4 h to k; 5 a to d); TI 2.88-3.21 mm (3.05 mm); CI 0.74-0.78 mm (0.75 mm).

P5 developed; bud of P4 developed (Fig. 5 a); T almost rectangular (Fig. 4 k).

A1 (Fig. 5 b): 3 short setae present on the distal prominence of the proximal segment of peduncle, a circlet of short plumose setae developed at about 2/3rd distal distance from the bottom of this segment; distal segment bears 5 long plumose setae on one side and 4 short plumose setae on a prominence on the other side at

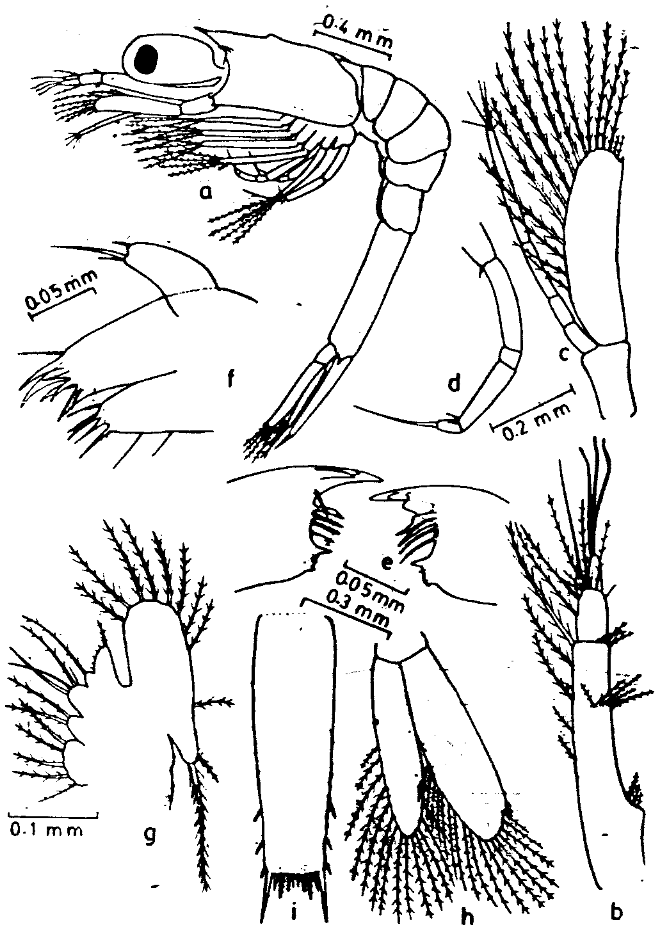

Figure 5. *Palaemon (Palaemon) concinnus*. *Zoea V*.
a—lateral view; b—A1; c—A2; d—P5. *Zoea VI*. e—Md; f—Mx1; g—Mx2; h—Ur; i—T.

the proximal region; inner flagellum reaching ½ the length of outer, and bear a long slender seta at its apex; outer flagellum bearing 3 aesthetes at its apex. A2 (Fig. 5c): endopod 4 segmented, of which the distal one is the longest bearing 6 slender non plumose setae at its apex; exopod with 16 plumose setae and 1 spine.

Md (Fig. 4 h): and Mx1 without much change from the previous stage. Mx2 (Fig. 4 i): exopod with 8 plumose setae. No change in Mxp1, Mxp2, Mxp3, P1 and P2. P3: basipod with 2 short setae; 1st segment of endopod with 2 short setae on the inner side; exopod with 4 long plumose apical and 1 short sub apical seta. P5 (Fig. 5 d): uniramous; basipod with 1 short seta on the inner side; endopod 4 segmented, 3rd segment with 2 short setae distolaterally, distal segment ends in a long claw like seta. Ur (Fig. 4 j): exopod with 11 to 12 long plumose setae and 1 spine and endopod with 8 long plumose setae. T (Fig. 4 k): almost rectangular, 3 lateral and 5 terminal spines on either side, of the 5 terminal spines the inner and outer are non plumose.

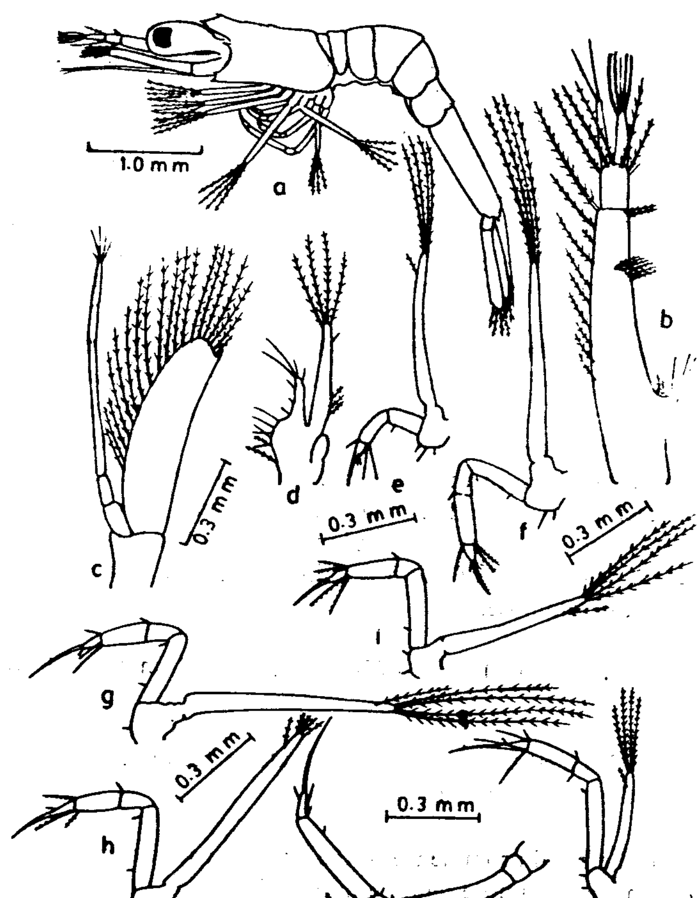

Figure 6. *Palaemon (Palaemon) concinnus. Zoea VI.*
a—lateral view; b—A1; c—A2; d—Mxp1; e—Mxp2; f—Mxp3; g—P1; h—P2; i—P3; j—P4; k—P5.

Zoea VI (Fig. 5 e to i; 6 a to k); TI 3.62-3.83 mm (3.73 mm); CI 0.82-0.92 mm (0.88 mm).

Rostrum with a dorsal tooth; P4 developed; (Fig. 6a).

AI (Fig. 6b): the prominence at the outer distal aspect of distal segment of peduncle bears 4 short plumose setae and 3 to 5 long slender non plumose setae, inner side bears 6 to 10 plumose setae and the number of setae forming a circlet in the distal segment increased; inner and outer flagellum are of equal size; outer flagellum bears 3 to 4 aesthetes and 1 seta and inner flagellum with 2 non plumose setae. A2 (Fig. 6c): endopod 5 segmented apically bearing 5 to 6 short slender non plumose setae; exopod leaf like bearing 19 to 24 plumose setae and one spine. Md (Fig. 5e): in between the incisor and molar processes 4 teeth are present on one side and 4 to 5 on the other side. Mx1 (Fig. 5f): endopod with 3 setae apically of which one is long; distal lacinia with 8 teeth and proximal lacinia with 7 teeth. Mx2 (Fig. 5g): exopod with 11 to 14 plumose setae. Mxp1 (Fig. 6d): base of exopod slightly expanded carrying 3 plumose setae, in advanced stages rudiments of gill developed. Mxp2 (Fig. 6e): no appreciable change noticed. Mxp3 (Fig. 6f): 2nd segment of endopod bearing on the outer distal margin a short seta. PI (Fig. 6g); and P2 (Fig. 6h): are almost identical; 2nd segment of the endopod of advanced zoea VI with 2 setae at its distal margin; exopod longer than endopod bearing 4 long apical plumose setae and 1 to 3 subapical plumose setae. P3 (Fig. 6 i): 3rd segment with 4 serrated setae at the distolateral margin; exopod with 4 long apical and 1 to 2 short subapical setae. P4 (Fig. 6 j): biramous; basipod with 1-2 short setae; endopod 4 segmented, 1st segment with 1 to 2 setae on the inner side, 2nd segment with 2 distolateral setae, 3rd segment with 3 to 4 setae at the distolateral margin, distal segment with 1 short seta and a long claw like seta; exopod shorter than endopod bearing apically 4 long plumose setae and in advanced stage larvae one short subapical seta present. P5 (Fig. 6k): 1st segment of endopod with 1 to 2 short setae on the inner side; 2nd segment with 1 to 2 short setae at the distolateral margin; 3rd segment carries on the inner margin 2 to 4 short setae, distal segment carries on the inner proximal end a long claw like seta. Ur (Fig.5h): exopod with 17 to 21 plumose setae and one spine; endopod with 14 to 21 long plumose setae. T (Fig. 5 i): tapers posteriorly, of the 5 terminal spines on either side, inner and 2 outer spines are non plumose.

Zoea VII (Fig. 7 a to k); TI 4.75-5.26 mm (5.01 mm); CI 1.18-1.31 mm (1.23 mm).

Rostrum with 2 dorsal teeth; uniramous buds of pleopods developed (Fig. 7a); T tapers towards the posterior end (Fig. 7k).

AI (Fig. 7b): the basal prominence of the proximal segment with 3 to 4 plumose setae and 5 to 6 long non plumose setae; number of setae on the segments of peduncle increased; outer flagellum bearing 7 aesthetes in 2 groups of 3 and 4, distally this flagellum bears 2 to 3 long slender setae; inner flagellum as long as outer, bearing at its apex 3 slender non plumose setae. A2 (Fig. 7c): endopod longer than exopod, 5 to 8 segmented, apical segment bearing 5 short non plumose slender setae; exopod bearing 28 to 29 plumose setae and 1 spine. Md (Fig. 7 d): 5 to 7 teeth on one side and 5 to 6 teeth on the other side in between incisor and molar processes. No change in Mx1. Mx2 (Fig. 7e): exopod with 18 to 21 plumose setae. Mxp1 (Fig. 7 f): base of exopod slightly expanded bearing 3 to 4 plumose setae on the outer margin. Mxp3 (Fig. 7g): 2nd segment of endopod with 2 setae distally and

3rd segment with 4 setae. Pl (Fig. 7h): 3rd segment of endopod with 4 setae along its distal lateral margin. P3: 2nd segment of endopod sometimes with 3 distolateral setae; exopod with 4 long plumose setae apically and 2 to 3 subapical setae. P4 (Fig. 7i): and P5 (Fig. 7 j): without much appreciable change from the previous stage. Ur: exopod with 26 to 28 plumose setae and one spine; endopod with 26 to 27 long plumose setae. T (Fig. 7 k): tapers posteriorly, convex at the distal region bearing 3 pairs of lateral and 5 pairs of teιminal setae.

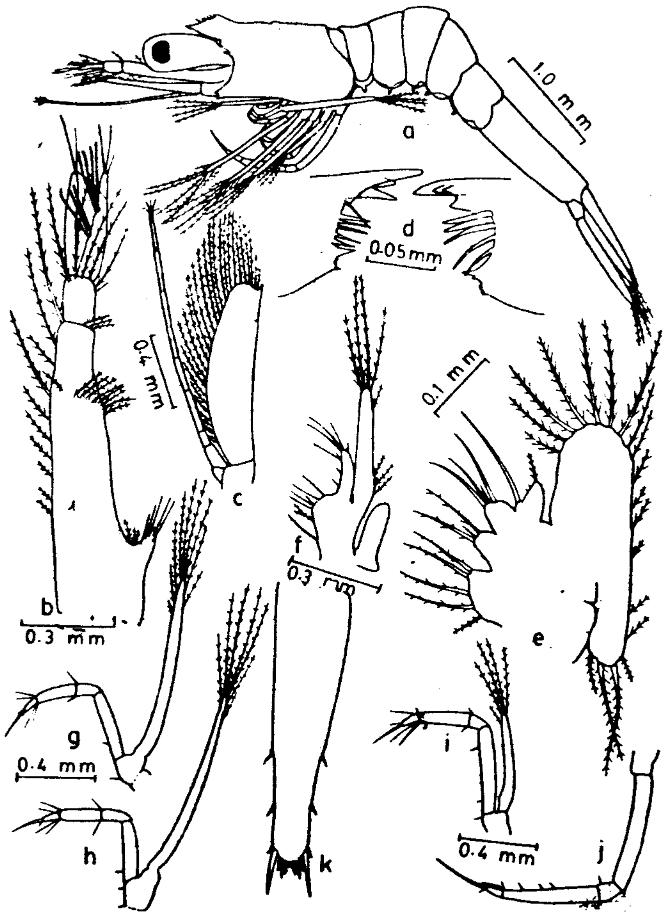

Figure 7. *Palaemon (Palaemon) concinnus. Zoea VII.*
a—lateral view; b—A1; c—A2; d—Md; e—Mx2; f—Mxp1; g—Mxp3; h—P1; i—P4; j—P5; k—T.

DISCUSSION

The sequence of development of pereopods in *Palaemon (Palaemon) concinnus* closely resembles that of *Macrobrachium rosenbergii* (Ling, 1969; Uno and Kwon, 1969): *M. nipponense* (Kwon and Uno, 1969); *M. idella* (Pillai and Mohamed, 1973): *Palaemon macrodactylus* (Georgiandra Little, 1969); *Leptocarpus potamiscus* (Pillai, 1973); *Leandrites celebensis* (Pillai, 1973). In all these species P1 and P2 develop in zoea II and P3 and P5 in the subsequent stage, P4 being the last one to develop among the pereopods. But in *Palaemon elegans* (Tsurnamal, 1963) first four pereopods develop in zoea II and P5 is developed later. In all these species a minimum of three stages were observed between the stages after the development of the uniramous bud of pleopods and postlarva I. In the present species uniramous buds of pleopods are developed in zoea VII, and as such a minimum of three more zoeal stages could be expected before the larvae develop to postlarva I.

A reduction in length of rostrum was observed from zoea IV onwards and in zoea VII it reaches only to ½ the length of eye. This indicates that the short nature of rostrum becomes apparent in zoeal stages and continues in the young specimens which according to Holthuis (1950) differ from the older by having shorter rostrum. Such a reduction in length of rostrum is not seen in *Palaemon (Palaender) semmelinkii* (Jagadisha and Sankolli, 1977).

The basal lobe of endopod of Mx2 in *Macrobrachium* sp. (Ling, 1969; Kwon and Uno, 1969: Uno and Kwon 1969; Pillai and Mohamed, 1973); *Leander* sp. (Gurney, 1942); *Leptocarpus* sp. (Pillai, 1973); *Palaemon* sp. (Tsurnamal, 1963; Pillai, 1966; Georgiandra Little, 1969); *Palaemonetes* sp. (Hubschman and Broad, 1974) ; *Palaemon (Palaender) semmelinkii* (Jagadisha and Sankolli, 1977) carry 2 setae. But in all the zoeal stages of the present species there is only a single seta, in which character it agrees with the zoea of *Periclimenes* sp. (Gurney, 1942; Pillai, 1950; Pillai, 1955).

From the second zoea onwards in all the zoeal stages of *Macrobrachium* sp. (Ling, 1969; Kwon and Uno, 1969; Uno and Kwon, 1969; Pillai and Mohamed, 1973); *Leptocarpus* sp. (Pillai, 1973); *Leandrites* sp. (Pillai, 1974); *Leander* sp. (Gurney, 1942); *Periclimenes* sp. (Gurney, 1942; Pillai, 1955); *Palaemon* sp. (Tsurnamal, 1963; Georgiandra Little, 1969); *Palaemon (Palaender) semmelinkii* (Jagadisha and Sankolli, 1977) a prominent lateral spine was observed on the 5th abdominal segment. This spine is absent in all zoeal stages of the present species. In *Palaemon tenuipes* (Pillai, 1966) also this spine is absent. This feature does not seem to be a diagnostic character of the larvae of species of *Palaemon* since some species possess this spine (Tsurnamal, 1963; Georgiandra Little, 1969) while others including the present species do not have the spine (Pillai, 1966).

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SECTION TWO

Family Palaemonidae Rafinesque, 1815

Genus *Leptocarpus* Holthuis, 1950

1. Leptocarpus potamiscus (Kemp, 1917)

The complete larval history of L. potamiscus studied by the author by rearing them in the laboratory and published earlier is presented in the following pages 168-175.

J. mar. biol. Ass. India, 1973, **15** (2) : 669–684

LARVAL DEVELOPMENT AND REARING OF THE BRACKISH WATER SHRIMP *LEPTOCARPUS POTAMISCUS* (KEMP, 1917) (DECAPODA, PALAEMONIDAE)

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ABSTRACT

Complete larval development of the brackish water shrimp, *Leptocarpus potamiscus* has been studied by rearing the larvae hatched out under laboratory conditions. The larvae undergo 16 or 17 moults during a period of 86 to 96 days and pass through 6 zoeal and 9 post-larval stages before metamorphosing into juveniles. The zoeal and post-larval stages are described in detail and illustrated. The early larval stages of *L. potamiscus* and *L. fluminicola* are compared and the salient features of the development of *L. potamiscus* are discussed. Observations made on the moulting periodicity, feeding habits and rearing of the larvae are also included in the paper.

INTRODUCTION

THE genus *Leptocarpus* created by Holthuis (1950), included two known species namely *Leptocarpus potamiscus* (Kemp) and *L. fluminicola* (Kemp). *L. potamiscus* (as *Leander potamiscus*) was first described by Kemp (1917) from Goa and it was subsequently reported from Bombay (Rai, 1933), Andaman Archipelago, Malayasia (Kemp, 1917, 1918a), Siam (Suvatti, 1937), Sumatra (Gordon, 1935 a) and from Java (Holthuis, 1950). The species thus appears to be widely distributed in the Indo-Pacific region and is known to occur in the marine and freshwater environment of the coastal areas. Rai (1933) reported that this species occurs in large numbers in the Bombay region, and that it grows to a size of 51 mm. Rajyalakshmi (1961) described the first three zoeal stages of *L. fluminicola* (as *Leander fluminicola*) obtained by rearing the larvae in the laboratory, and added further, a description of the fifth larval stage of the species collected by tow nets from Hooghly estuary. The present paper deals with the detailed description of the larval and post-larval stages of *L. potamiscus*, its moulting behaviour, feeding habits and salinity tolerance during rearing experiments.

The author is greatly indebted to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute for his keen interest in this work and the encouragements and to Shri K. H. Mohamed and Dr. P. Vedavyasa Rao for going through the manuscript and giving helpful suggestions through out the period of work. He is grateful to Shri M. Aravindakshan for providing *Artemia* eggs for rearing experiments.

MATERIAL AND METHODS

An ovigerous *L. potamiscus* measuring 48 mm in total length and 21 mm in carapace length was caught in a cast net while carrying out experimental fishing at the Thevara Canal connected with the Cochin Backwater on 14th August 1973. The shrimp was brought to the laboratory in live condition and was kept in a glass trough (7 litre capacity) containing 6 litres of brackish water, the salinity of which was 17.2‰. To prevent the shrimp from jumping out of water, the mouth of the trough was kept covered with an organdy cloth. Finely minced and washed prawn meat was offered as food once a day, generally in the morning and the excess food was removed after an hour. When the eggs were hatched out completely, the mother was removed from the container. Fixed number of active and healthy larvae were transferred to one litre glass beakers containing prepared water of various salinity ranges. The medium of required salinity was prepared by diluting the sea water with fresh tap water devoid of Chlorine. Half of the water of the container along with bottom sediments and moults was siphoned out from the container once a day and an equal quantity of freshly prepared water of the same salinity was added.

The temperature of the medium varied between 24.5°C and 28.0°C and no effort was made to control it. Daily variations of temperature was within a range of ± 2°C. Zoeal stages were fed with freshly hatched *Artemia* nauplii abundantly, while the post-larval stages were offered minced prawn meat and fresh crab eggs.

For detailed morphological studies, the larvae and post-larvae at different stages were preserved in 5% formaldehyde. The appendages were carefully dissected out and drawings were made using camera lucida mounted on a monocular compound microscope. The distribution of chromatophores was observed from live larvae.

The total length of the larva was taken from the tip of the rostrum to the tip of the telson excluding the terminal spines. The carapace length was measured from the tip of the rostrum to the middorsal point on the posterior margin of the carapace.

The following abbreviations are used in the description of different larval stages:

Tl-Total length; Cl-Carapace length; A1-Antennule; A2-Antenna; Md-Mandible; Mx1-maxillule; Mx2-Maxilla; Mxp1-Maxilliped I; Mxp2-Maxilliped II; Mxp3-Maxilliped III; P1-Pereiopod I; P2-Pereiopod II; P3-Pereiopod III; P4-Pereiopod IV; P5-Pereiopod V; Ur-Uropod; T-Telson.

Spawning: The shrimp was transferred to the trough at about 10 A. M. on 14th August 1973 and it soon got acclimatised to the new surroundings. It appeared to be sensitive and tried to jump out of the container when disturbed. It exhibited characteristic movements of the pleopods for the purpose of aerating the developing eggs. The shrimp did not take food on 15th August 1973. Spawning took place in the early morning hours of 16th August 1973, and the process continued for about 4 hours. The zoea I were seen actively swimming about in the relatively more lighted area of the trough.

DESCRIPTION OF LARVAL STAGES

Zoea I (Fig. 1 a to l); Tl 2.2-2.4 mm (2.3 mm*); Cl 0.6-0.7 mm (0.6 mm*).

* Figure given in the bracket pertains to the mean length

Diagnostic characters: Rostrum slender, pointed and slightly decurved at tip; carapace smooth, anterolateral angles drawn out into small pterygostomial spines; eyes large, sessile; antennule, antenna, mouth parts, and biramous buds of 1st and 2nd pereiopods (Fig. 1k) developed; abdomen 6-segmented; telson not separated from 6th segment.

*A*1-uniramous, long, slender and unsegmented, carrying 2 flagella at apex; inner one long and plumose; outer unsegmented with 3 aesthetes and 2 short setae, one of which being plumose (Fig. 1 b). *A*2-biramous, exopod 5-segmented distally, bearing 9 plumose and one non-plumose setae along its terminal and inner margins; endopod unsegmented with a long plumose seta and a short spine at tip (Fig. 1c). *Md*-of both sides almost identical, incisor with one stout prominent tooth, in some specimens an additional small tooth discernible; molar with one small tooth; a stout tooth in between incisor and molar processes (Fig. 1 d , e). *Mx*1- uniramous, endopod with 2 small distal processes; distal lacinia with 2 stout spines and a small seta; proximal lacinia with 4 small teeth and a marginal seta (Fig. 1 f) *Mx*2-biramous, exopod with 5 long plumose setae along outer margin, hindermost being longest and directed backwards; endopod bilobed, distal lobe with one and proximal lobe with 2 non-plumose setae at tip; protopod with 3 masticatory processes, proximal process with 4 and both the distal processes with 3 non-plumose setae (Fig.1g). *Mxp* 1-biramous, basis protuberant with 2 setae on its margin; endopod unsegmented with 5 setae, of which 3 are terminal; exopod longer than endopod and tipped with 4 long plumose setae (Fig. 1 h). *Mxp*2-biramous, basis with a long and slender seta at inner margin; endopod 3-segmented, with 2 setae at distal region, 3rd segment ending in a claw and 2 small setae; exopod long and with 4 apical and 2 subapical plumose setae (Fig. 1 i). *Mxp*3-biramous, basis with a short seta on inner margin; endopod 3-segmented, 2nd segment with 2 setae anteriorly, 3rd segment ending in a claw and 2 slender setae; exopod same as in *Mxp*2-(Fig. 1 j). *T*-broad and posterior margin concave, and bears 7 spines on each side, inner margin of the outer most two spines setose (Fig. 1 l). *P*1 and *P*2-present in the form of biramous buds.

Zoea I moulted to the next stage after 24 hours from the time of hatching.

Zoea II (Fig. 1 m-r; 2 a-h); Tl 2.3 –2.4 mm (2.4 mm); Cl 0.6-0.7 mm (0.6 mm).

Diagnostic characters: Carapace with supra-orbital and pterygostomial spines (Fig. 1 m); eyes stalked; 5th abdominal segment with a pair of prominent lateral spines (Fig. 1 r). *Colouration*: Larvae as a whole appear light yellowish, peduncle of *A* 1 with light bluish and yellowish chromatophores, ventral side of eye stalk with yellowish branching chromatophores, the branches extending towards the sides also; junction of eye stalk with carapace deep bluish; orange branching chromatophores present at basis of *Mxp*2 and *Mxp*3, on the dorsal aspect of the 3rd abdominal segment as well as on plura of 2nd and 3rd abdominal segments and at base of telson; 2 branching blue chromatophores also present on dorsal surface of 3rd abdominal segment.

*A*1-peduncle 2-segmented; proximal segment with 4 plumose setae near the joint and 2 on inner side; distal segment carries 2 flagella; inner flagellum long and plumose; outer flagellum with 4 aesthetes and one slender seta; antennular lobe at base of outer flagellum with 2 plumose setae (Fig. 2 a). *A*2-endopod unsegmented, carrying one short spine and 3 setae at apex, one of which is long and plumose (Fig. 2 b). *Md*-incisor process with 3 stout teeth and molar with 4to7 short teeth; between the two processes of right *Md* (Fig. 1 n) 2 slender teeth present while the

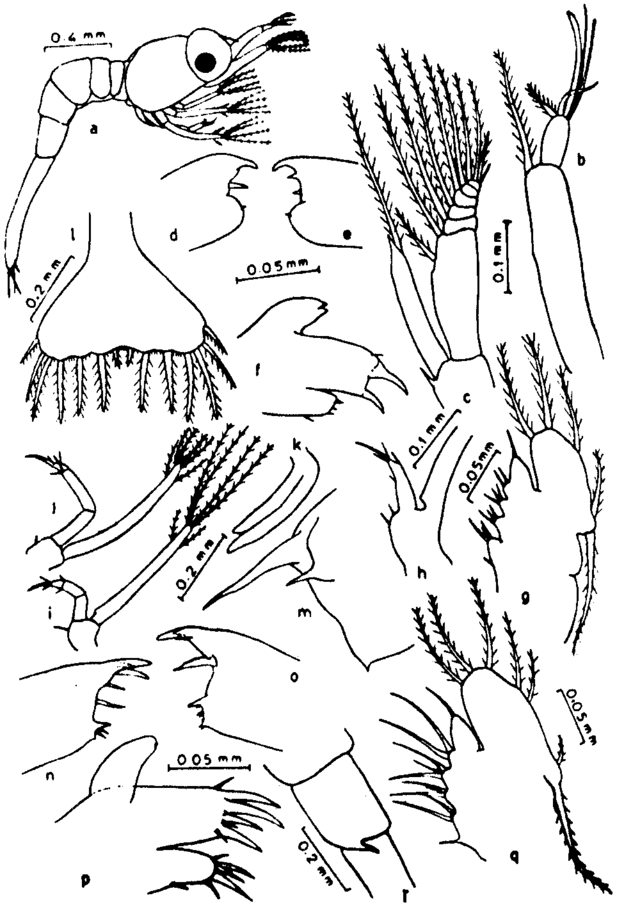

Fig. 1. *L. potamiscus*. Zoea I: a. lateral view; b. A-1; c. A-2; d. right Md; e. left Md; f. Mx-1; g. Mx-2; h. Mxp-1; i. Mxp-2; j. Mxp-3; k. bud of P-1; l. T. Zoea II: m. rostrum; n. right Md; o. left Md; p. Mx-1; q. Mx-2; and r. lateral view of 5th abdominal segment.

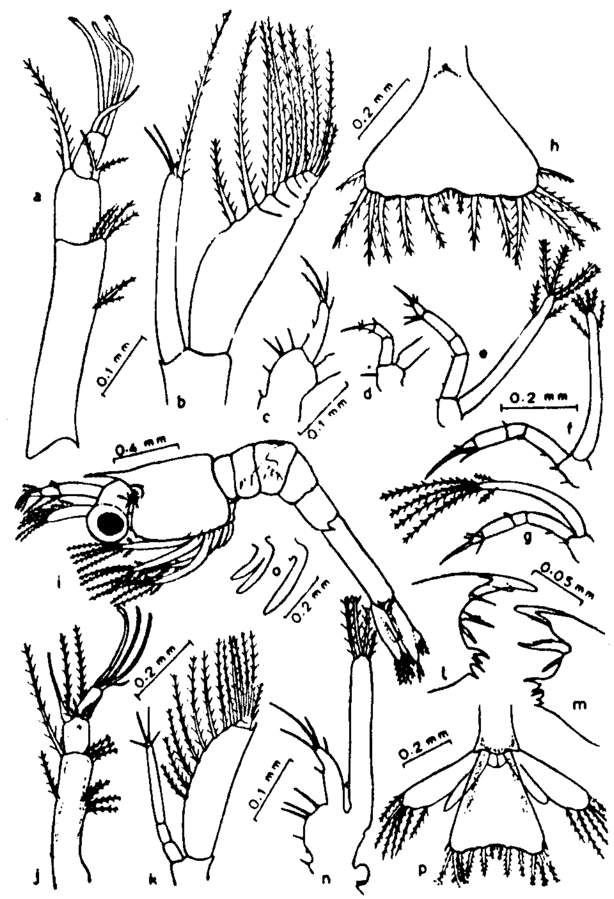

Fig. 2. *L. potamiscus*. Zoea II: a. A-1; b. A-2; c. Mxp-1; d. Mxp-2; e. Mxp-3; f. P-1; g. P-2; h. T. Zoea III: i. lateral view; j. A-1; k. A-2; l. right Md; m. left Md; n. Mxp-1; o. bud of 3rd and 5th P; and p. T.

left *Md* (Fig. 1 o) only one serrated movable tooth present between the processes. *Mx* 1-endopod with a distal projection; proximal lacinia with 5 teeth on posterior and a slender tooth on lateral margins; distal lacinia with 4 stout and 3 slender teeth (Fig. 1 p). *Mx2*-margin of exopod with 7 long plumose setae (Fig. 1 q). *Mxp*1-coxa with a single seta; protuberance of basis with 4 stout setae (Fig. 2 c) *Mxp*2- distal segment of endopod ending in a claw and 3 setae (Fig. 2 d). *Mxp*3-biramous basis with one seta on inner margin; endopod 4-segmented, 1st segment with 2 setae, 3rd segment with 2 long setae on inner side, 4th segment with a claw and 3 setae (Fig. 2 e). *P*1-basipod with 2 small setae; endopod 4-segmented 1st and 2nd segments with 2 and one setae respectively, 3rd with 2 long setae, 4th with a claw and one seta terminally; exopod long, with 4 apical and 2 sub-apical plumose setae (Fig. 2 f). *P*2-basipod and 1st segment of endopod with a single seta on inner margin, other characters similar to *P*1 (Fig. 2 g). *T* broad, not separated from 6th abdominal segment, posterior margin concave and bears 8 spines on either side, inner margin of outermost spines setose, the innermost spine non-setose, and all the rest setose on both sides (Fig. 2 h).

Two days after the first moulting, Zoea II moulted to the next stage.

Zoea III (Fig. 2 i-p; 3 a-f); Tl 2.7-3.2 mm (3.0 mm); Cl 0.7-0.8 mm (0.7 mm).

Diagnostic characters: Biramous bud of 3rd pereiopod and uniramous bud of 5th pereiopod developed (Fig. 2 0); telson and uropods were separated from 6th abdominal segment by an articulating joint.

Colouration: Basis of *Mxp* 2, *Mxp* 3, *P* 1, *P* 2, lateral and dorsal aspects of 3rd abdominal segment, sides of 2nd abdominal segment, proximal dorso-lateral region of telson with orange branching chromatophores. Junction between eye stalk and carapace, mid-dorsal side of 3rd abdominal segment and junction between telson and 6th abdominal segment with blue chromatophores. Peduncle of *A* 1 with orange and blue chromatophores.

*A*1-base of inner flagellum swollen; outer flagellum with 3 aesthetes and one seta; antennular lobe with 5 plumose setae; distal side of peduncle with 2 long plumose setae ventrally; proximal segment with 2, 4 and 3 plumose setae on inner and outer margins and near the articulation of joint respectively (Fig. 2 j). *A*2-scale with 14 setae along margin, the outermost seta being slender, small and non-plumose, disto-lateral tip spine-like; flagellum 3-segmented carrying 4 slender terminal setae (Fig. 2 k). *Md* 3- stout teeth on incisor process and 4 to 5 short teeth on molar; between these processes 3 slender teeth, the middle one of which is long on right *Md* (Fig. 2 l); while in the left *Md* only 2 teeth one of which movable and serrated, present in between the incisor and molar processes (Fig. 2 m). *Mx* 1-distal process of endopod disappears (Fig. 3 a). *Mx* 2- exopod with 9 marginal plumose setae (Fig. 3 b). *Mxp*1-bud like rudiments of epipod develop (Fig. 2 n). *Mxp*3-basipod with 2 small setae on inner side and 3 setae, near the articulation of segments 3 and 4 (Fig. 3 d). *P*1-provided with 3 setae near the articular joint of segments 3 and 4 (Fig. 3 e). *P*2-basipod with 2 short setae on inner side; endopod 4-segmented, 1st with 2 setae on inner side, 2nd with a single seta on outer side, 3rd with 3 setae, and 4th ending in a claw and a small seta (Fig. 3 f). *T*-separated from last abdominal segment by an articulating joint, broad, posterior margin less concave bears 8 spines on either side, outer-most and inner-most spines being non-setose (Fig. 2 p). *Ur*-biramous, exopod with 6 long plumose setae; endopod bare.

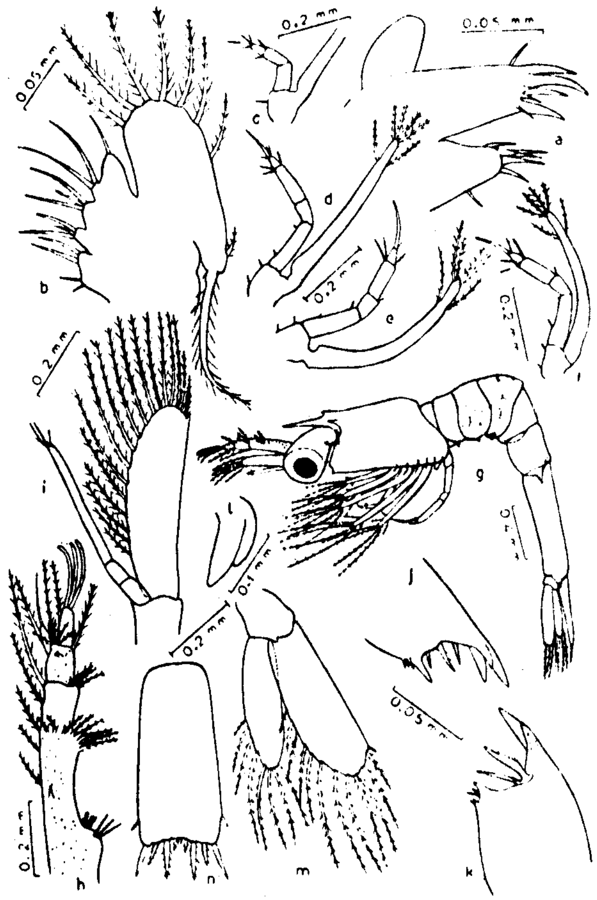

Fig. 3. *L. potamiscus*. Zoea III: a. Mx-1; b. Mx-2; c. Mxp-2; d. Mxp-3; e. P-1; f. P-2. Zoea IV: g. lateral view; h. A-1; i. A-2; j. right Md; k. left Md; l. bud of P-4; m. Ur; and n. T.

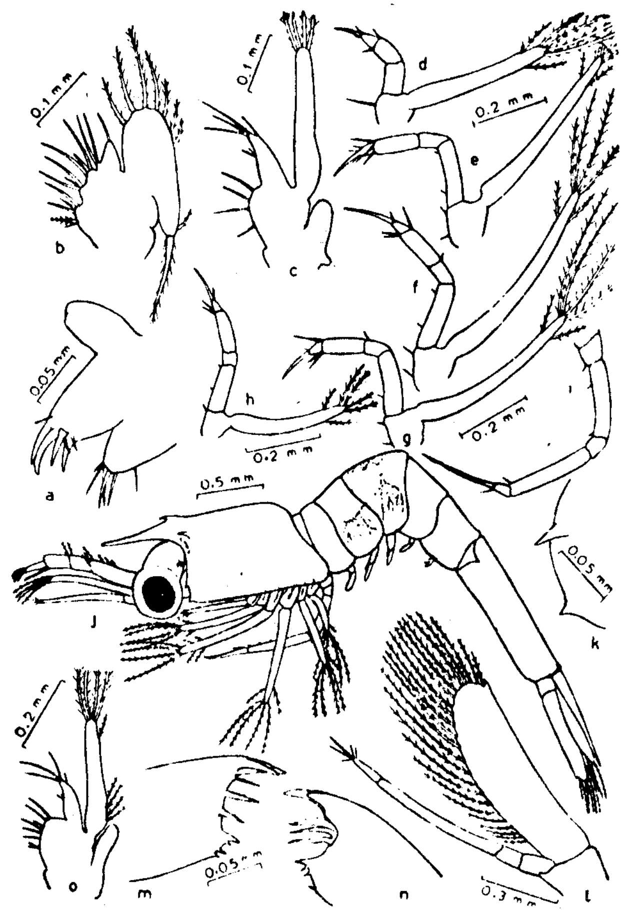

Fig. 4. *L. potamiscus*. Zoea IV: a. Mx-1; b. Mx-2; c. Mxp-1; d. Mxp-2; e. Mxp-3; f. P-1; g. P-2; h. P-3; i. P-5. Zoea V: j. lateral view; k. anterolateral side of carapace; l. A-2; m. right Md; n. left Md; and o. Mxp-1.

Zoea III moulted to zoea IV after 2 days from the second moulting.

Zoea IV (Fig. 3 g-n; 4 a-i); Tl 3.3-3.6 mm (3.5 mm); Cl 0.9 mm.

Diagnostic characters: Rostrum with an epigastric tooth; 3rd and 5th pereiopod and biramous buds of 4th pereiopod developed; rudimentary pleopod buds on 1st to 5th abdominal segments and endopod of uropod setose (Fig. 3 m).

Colouration: Orange chromatophores on ventral side of eye stalk, basis of *Mxp* 2, *Mxp* 3, *P* 1, *P* 2, dorsal and lateral aspect of 3rd abdominal segment, sides of 2nd abdominal segment and at the junction between 6th abdominal segment and telson. Orange and blue chromatophores present on the peduncle of *A* 1. Orbital margin of carapace with deep blue chromatophores.

*A*1-proximal segment with 5 plumose setae on inner side, and a spine and circlet of plumose setae near the middle of the segment; stylocerite bears 6 setae 3 of which plumose; inner flagellum shorter than outer and with a non-plumose seta at apex; outer flagellum with 3 aesthetes; antennular lobe with 5 plumose setae; distal segment with 4 long plumose ventral setae situated below the flagellum (Fig. 3 h). *A2*-distal part of scale unsegmented, 18 plumose setae and a spine; flagellum 3-segmented, with 4 slender terminal setae (Fig. 3 i). *Md*-same as in the previous stage, molar with 4 to 5 small teeth (Fig. 3 j, k). *Mx* 2-proximal masticatory process of protopod with 5 setae, one of which plumose (Fig. 4 b). *Mxp*1 - endopod with 6 setae, 3 of which terminal and long; epipod further developed and biramous (Fig. 4 c). *Mxp* 2, *Mxp* 3, *P* 1, and *P*2-same as in the previous stage. *P* 3-biramous, basipod with a single seta on inner side, endopod 4-segmented, 1st segment with 2 small setae on inner side; at the 3rd joint 2 long setae present; last segment terminates in a claw and one slender seta; exopod with 4 apical and 2 sub-apical plumose setae (Fig. 4 h) *P*5-uniramous; 5-segmented, 1st, 2nd and 4th segments with one, 2 and one seta on inner side, 5th segment with a long terminal claw and one small seta (Fig. 4 i). *T*-almost rectangular, with 5 posterior spines on each side, innermost and outermost being non-plumose; a small spine on lateral margin on either side (Fig. 3 n).

Zoea IV moulted to Zoea V after 2 to 4 days from the 3rd moulting.

Zoea V (Fig. 4 j-o, 5 a-o); Tl 4.4-4.9 mm (4.7 mm); Cl 1.2-1.4 mm (1.3 mm).

Diagnostic characters: 4th pereiopod well developed; pleopod buds on abdominal segments 1 to 5 biramous (Fig. 5 k - m).

Colouration: more conspicuous than in the previous stage.

*A*1- proximal segment with 8 plumose setae and a spine on inner margin; stylocerite with 7 setae, of which 3 are short and plumose; inner flagellum as long as outer and with 4 apical non-plumose setae; outer flagellum with a terminal finger-like projection bearing 2 setae and 4 aesthetes on inner side; antennular lobe with 5 plumose setae; distal segment with 5 plumose setae on ventral aspect below the flagellum (Fig. 5 a). *A2*-scale with 24 plumose setae and a spine; flagellum 4-segmented and with 5 setae at tip (Fig. 4 l). *Md*-incisor with 3 stout teeth and molar with 4 to 6 short teeth; in between the two processes 3 long teeth present (Fig. 4 m, n). *Mx*1-distal lacinia with 4 stout and long, 3 stumpy and one long

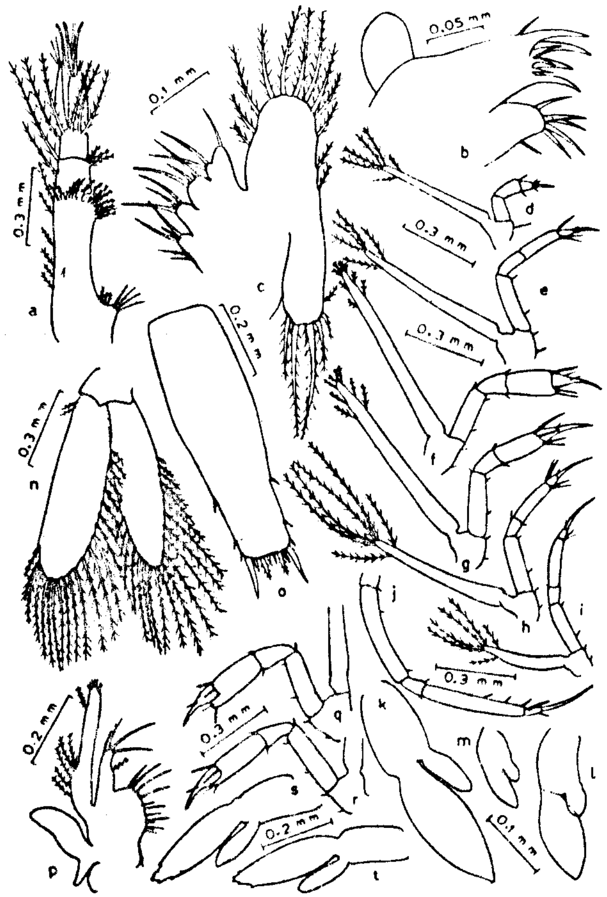

Fig. 5. *L. potamiscus*. Zoea V: a. A-1; b. Mx-1; c. Mx-2; d. Mxp-2; e. Mxp-3; f. P-1; g. P-2; h. P-3; i. P-4; j. P-5, k. pleopod III; l. pleopod IV; m. pleopod V; n. Ur; o. T. Zoea V A: p. Mxp-1; q. P-1; r. P-2; s. pleopod II; and t. pleopod III.

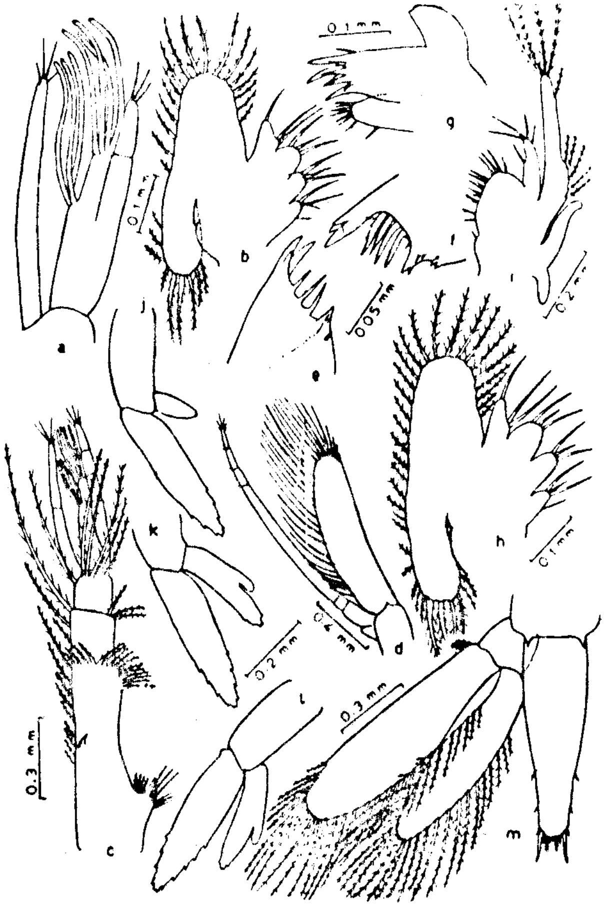

Fig. 6. *L. potamiscus*. Zoea V A: a. A-1 flagella, b. Mx-2. Zoea VI: c. A-1; d. A-2; e. right Md; f. left Md; g. Mx-1; h. Mx-2; i. Mxp-1; j. pleopod I; k. pleopod II; l. pleopod III; and m. Ur and T.

and slender teeth (Fig. 5 b). *Mx*-2 margin of exopod with 18 to 20 plumose setae (Fig. 5 c). *Mxp*-1 protuberance of basis with 8 slender and long setae along inner margin; exopod with 4 proximal, 4 apical and one sub-apical plumose setae (Fig.4 o). *Mxp* 2 and *Mxp*3 - same as in the previous stage. *P*1- (Fig. 5 f) and *P* 2 (Fig. 5g)- basis with 2 short setae on inner side; endopod 4 segmented, distal segment ending in a claw and small seta, 3rd segment develops as inner lateral projection indicating developing chela, 3rd joint carries 4 setae, 1st and 2nd segments carry 3 and 2 setae respectively; exopod long and with 4 apical and 4 sub-apical plumose setae. *P*3- basis with 2 setae on inner side; endopod 4–segmented, 1st and 2nd segments with 2 setae each, 3rd joint with 4 long setae, 4th segment ending in a distinct claw and a seta (Fig. 5 h). *P*4- biramous, shortest, basis with 2 setae on inner side; endopod 4-segmented, 1st and 2nd with 2 and one setae respectively, 3rd with 2 setae on inner anterior margin, 4th terminates in a claw and a seta; exopod as long as the proximal 2 segments of endopod and bears 4 apical and 2 sub-apical plumose setae (Fig. 5 i). *P*5-further developed, 2nd segment with 2 setae, 4th with 3 setae in inner side, 5th with a stout spine on inner margin (Fig. 5 j). Pleopods on 1st to 5th abdominal segments, biramous, first 3 similar in size, 5th shortest; margin of exopods and endopods of all pleopod buds naked; *T*-lateral margin tapering posteriorly, 3 lateral and 4 posterior spines on each side, the outermost being stout and long; 3rd spine on each side at the posterior border plumose (Fig. 5 o). *Ur*-exopod with 22 plumose setae along anterior and inner margins and with a spine at the postero-lateral margin; outer margin of exopod with 2 plumose setae; endopod with 20 plumose setae (Fig.5 n).

Zoea V moulted to Zoea VA 2 to 4 days after the 4th moulting.

Zoea VA (Fig. 5 p–t; 6 a , b): Tl 5.1-5.6 mm (5.3 mm); Cl 1.4–1.6 mm (1.5 mm).

Since the larva shows no significant morphological changes from the previous stage, but undergoes ecdysis, this zoeal stage is considered as a sub-stage of zoea V and designated as zoea VA.

*A*1-outer flagellum branched, outer branch 2–segmented and with 3 apical setae, inner branch with 7 aesthetes in 2 groups of 4 and 3 (Fig. 6 a). *A*2–scale with 27 plumose setae and an anterolateral spine; flagellum 5–segmented. *Md*- between the incisor and molar processes 4 long teeth present one of which serrated and movable; *Mx*1–endopod with a small inner distal projection; proximal lacinia with 6 teeth on distal and one tooth on lateral margin. *Mx*2-exopod with 26 plumose setae (Fig. 6 b) *Mxp*1-protuberance of basis with 11 setae; endopod with 5 setae, 3 of which long and terminal; base of exopod with 5 plumose setae; epipod bilobed (Fig. 5 p). *P*4–3rd joint encircled with 3 long setae, 2 of which placed on inner side. Exopod of pleopod 1 to 3 with a few small rudimentary projection representing the developing setae of later stage (Fig. 5 s . t). *Ur*-exopod with 27 plumose setae and a postero-lateral spine, endopod with 23 plumose setae.

Zoea VA moulted to the next stage after 2 to 4 days of 5th moulting.

Zoea VI (Fig. 6 c–m; 7 a– g); Tl 5.6 – 6.2 mm (5.9 mm); Cl 1.6– 1.7 mm (1.7 mm).

Diagnostic characters: 5 to 6 small plumose setae in front of epigastric tooth developed. 1st and 2nd pereiopod chelate. Endopods of pleopods 2 to 5 with appendix interna.

Colouration: Orange red chromatophores present on eye stalk, lateral aspect of 1st, 2nd and 3rd abdominal segments, basis of *Mxp* 1, *Mxp* 2, *P* 1, *P* 2, and at the junction between last abdominal segment and telson. Dorsal side of 3rd abdominal segment provided with branched orange and blue chromatophores.

*A*1-inner side of proximal segment with 10 to 12 setae; a shallow depression to accommodate eye developed on dorsal surface of the proximal segment; inner flagellum 2 to 3 segmented and with 5 slender setae at apex; outer branch of outer flagellum 3 or 4 segmented and with 5 terminal setae, inner branch with 7 aesthetes in 2 groups of 4 and 3; distal segment bears 6 long plumose setae ventrally below the flagellum (Fig. 6 c). *A*2–scale with 29 plumose setae and one spine, flagellum 6 segmented and longer than scale (Fig. 6 d). *Md*–molar with 6 to 7 teeth; the region between incisor and molar process of right *Md* (Fig. 6 e) bears 4 teeth and that of left *Md* (Fig. 6 f) 3 teeth. *Mx*1–distal lacinia with 9 teeth, of which 4 stout and long, 4 stumpy and one slender; proximal lacinia with 6 to 7 teeth and one seta (Fig. 6 g). *Mx*2–exopod with 32 to 35 plumose setae (Fig. 6 h). *Mxp*1-coxa with one seta; protuberance of basis with 12 to 14 setae; basal region of exopod with 5 to 7 plumose setae (Fig. 6 i). *Mxp*2-terminal segment of endopod bears a claw and 4 to 5 setae; exopod with 4 apical and 4 sub-apical plumose setae (Fig. 7 b). *Mxp*3 – exopod with 4 apical and 6 sub-apical plumose setae (Fig. 7 c). *P*1–(Fig. 7 d) and P 2 (Fig. 7 e)–chela further developed. *P*3–exopod with 4 apical and 6 sub-apical plumose setae. *P*4-junction of 3rd and 4th segment of endopod beset with 4 long setae; exopod with 4 apical and 6 sub-apical plumose setae (Fig. 7f). *P*5-4th segment with 4 to 5 setae on inner side (Fig. 7 g). Appendix interna present on endopod of pleopods 2 to 5; exopod of pleopods 1 to 5 (Fig. 6 j-1) with 9, 9 to 10, 10 to 11, 9, and 6 to 9 incipient setae respectively; endopod of 2 to 5 pleopods with 4, 4 to 5, 2 to 3 and 2 incipient setae. *Ur*–exopod with 29 to 30 plumose setae and one spine; endopod with 26 to 28 plumose setae (Fig. 6 m).

After moulting into zoea VI, it took 2 to 4 days for moulting to the next stage.

Zoea VIA (Fig. 7 h–p); Tl 6.2–6.7 mm (6.4 mm); Cl 1.7–1.9 mm (1.8 mm).

*A*1-proximal segment with 13 plumose setae and one spine on inner side; stylocerite with 12 setae, 4 of which are plumose; inner flagellum 3-segmented, outer branch of outer flagellum 4–segmented, inner branch with 9 aesthetes in 3 groups of 4, 3 and 2 (Fig. 7 h). *A*2-scale with 34 plumose setae and one spine; flagellum 7–segmented. *Mx*2–exopod with 43 plumose setae; 3 masticatory processes with 4, 4 and 3 to 4 setae respectively (Fig. 7 i). *Mxp*1– proximal region of exopod with 7 plumose seta (Fig. 7 j). Exopod of endopod of 1st to 5th pleopods (Fig. 7 1-o) with 11/0, 12/8, 11/6, 13/7 and 9/4 incipient setae respectively. *Ur*-exopod with 33 plumose setae and one spine and endopod with 31 plumose setae.

Zoea VI A moulted to post-larva I after 2 to 4 days of 7th moulting.

Post-larva I (Fig. 8 a– m; 9 a– f); Tl 5.8 – 6.3 mm (6.0 mm); Cl 1.8-2.0 mm (1.9 mm).

Diagnostic characters: Larvae leave the planktonic life and settle to the bottom life. Rostrum well developed with 7 to 8 dorsal teeth, and carapace with pterygo-stomial and antennal spines. Antennular peduncle 3–segmented. Pereiopod with degenerated exopods.

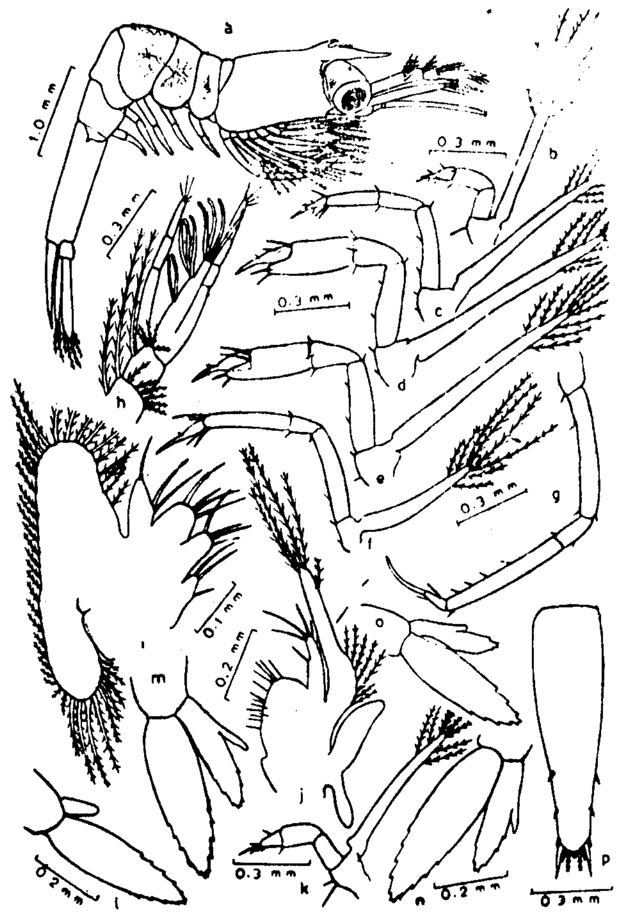

Fig. 7. *L. potamiscus.* Zoea VI: a. lateral view; b. Mxp-2; c. Mxp-3; d. P-1; e. P-2; f. P-4; g. P-5. Zoea VI A: h. A-1 tip; i. Mx-2; j. Mxp-1; k. Mxp-2; l. pleopod I; m. pleopod II, n. pleopod IV; o. pleopod V; and p. T.

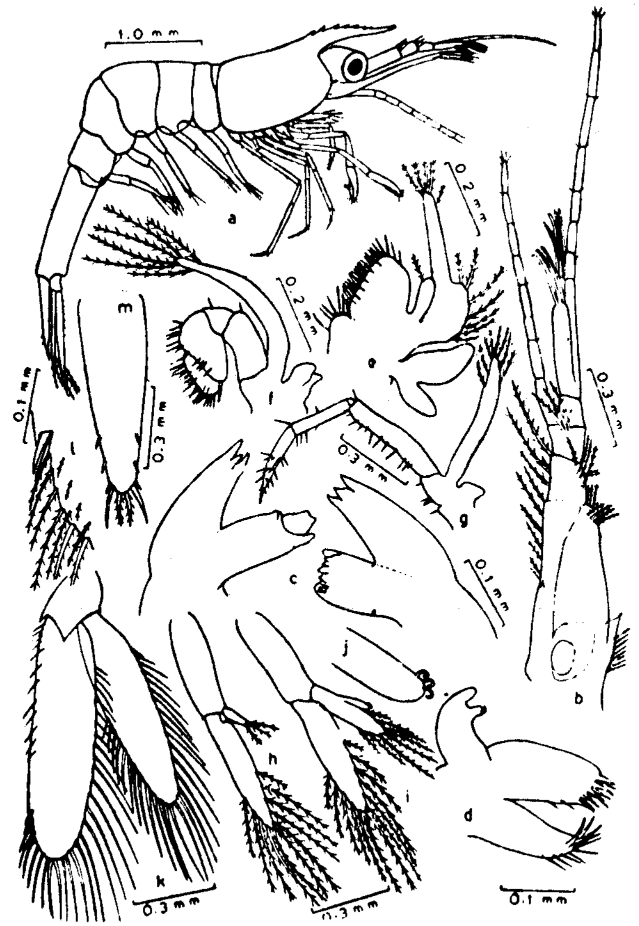

Fig. 8. *L. Potamiscus.* Post-larva I: a. lateral view; b. A-1; c. Md; d. Mx-1; e. Mxp-1; f. Mxp-2; g. Mxp-3; h. pleopod I; i. pleopod III; j. tip of appendix interna of pleopod III; k. Ur; l. disto-lateral margin of exopod of uropod; and m. T.

Colouration: Orange chromatophores present on eye stalk, lateral aspect of carapace and at junction of telson with 6th abdominal segment; bases of 1 to 5 pleopods with conspicuous orange red chromatophores.

*A*1-peduncle 3-segmented; inner and outer flagellum each 8-segmented, inner branch of outer flagellum with 7 aesthetes in 2 groups of 4 and 3; proximal segment longest with stylocerite and a well developed antero-lateral spine; depression to

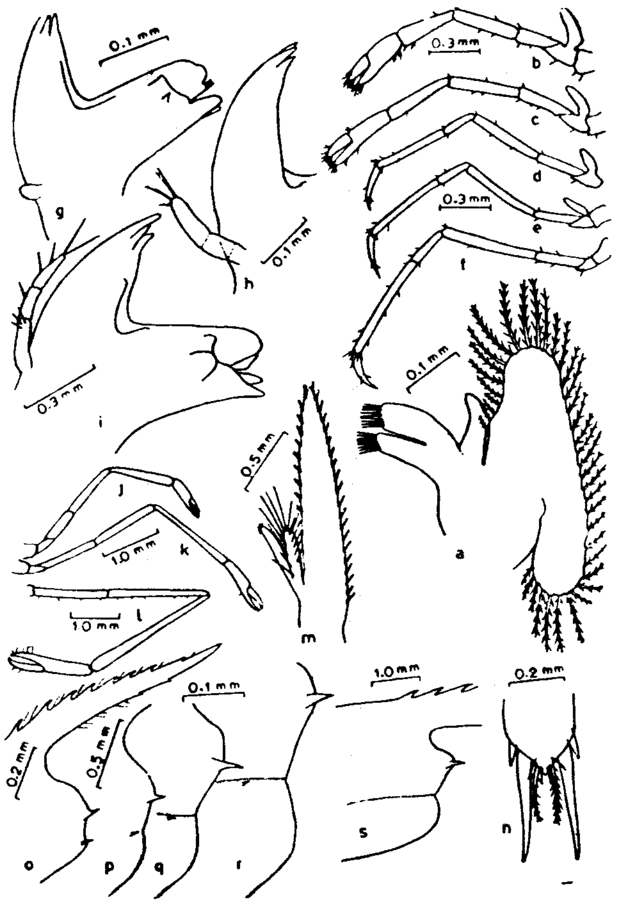

Fig. 9. *L. potamiscus*. Post-larva I: a. Mx-2; b. P-1; c. P-2; d. P-3; e. P-4; f. P-5. Advanced post-larva: g. Md of post-larva III; h. Md of post-larva IV; i. Md of post-larva IX; j. P-1 of post-larva V; k. P-2 of post-larva V; l. P-2 of post-larva IX; m. endopod of pleopod II of post-larva of Tl-25 mm; n. T tip of post-larva of Tl 24 mm; o. antero-lateral aspect of carapace of post-larva II, p. carapace of post-larva IV; q. carapace of post-larva VI; r. carapace of post-larva and IX; s. carapace of juvenile of Tl 30 mm.

accommodate eye well defined (Fig. 8 b). *A*2-scale with 32 plumose setae and one spine; flagellum long, slightly more than 4 times the length of scale. *Md*-incisor process with 3 stout teeth and molar process with 5 to 7 blunt teeth at the distal end (Fig. 8 c). *Mx*1-endopod with 2 distal projections, proximal projection with a small seta; distal lacinia with 2 lateral and 11 apical teeth; proximal lacinia with 10 apically arranged teeth (Fig. 8 d). *Mx* 2–exopod with 39 plumose setae along the entire margin; endopod simple and bare, basis with 2 endites each with 9 to 10 bristle-like setae (Fig. 9 a). *Mxp*1-basal portion bilobed, outer margin with numerous setae; endopod with a single plumose seta; exopod with 4 apical and one sub-apical plumose setae; epipod bi-lobed (Fig. 8 e). *Mxp*2–endopod 4–segmented, distal two segments with several short setae; exopod with 4 apical and 2 sub-apical plumose setae; bilobed epipod present (Fig. 8 f). *Mxp* 3-endopod 3–segmented, profusely setose; exopod as long as 1st segment of endopod, and bears 4 apical and 4 sub-apical plumose setae (Fig. 8 g). *P* 1 (Fig. 9 b) and P 2 (Fig. 9 c)-chelate; P1 stoutest and P5 longest (Fig. 9 f); endopod of pleopods 2nd to 5th with appendix interna, which possess 3 hooks on inner margin of the distal end (Fig. 8 j). *T*-bearing posteriorly 4 spines and 2 plumose setae; 2 lateral spines on either side shifted to dorsal aspect (Fig. 8 m). Distolateral margin of exopod of uropod with 2 spines, one of which is movable (Fig. 8 k, l).

After 2 days of moulting into post-larva I, it moulted to post-larva II.

Advanced post-larvae (Fig. 9 g – s).

Unlike the zoeal stages that essentially swim about at the surface and sub-surface waters in the container, post-larva I settles down to the bottom and begins to live a bottom life. The post-larva undergoes 8 to 9 moults within a period of 67 to 75 days and becomes juvenile at a total length of 28 to 30 mm. In the course of development 9 post-larval stages may be recognised. During the course of this development and growth, the various appendages gradually attain the adult form. As the post-larva I transforms to post-larva II, the rostrum acquires ventral teeth. exopods of pereiopod 1 to 4 disappear, endopod of 3rd maxilliped becomes 5 segmented. As the development proceeds, mandibular palp makes its appearance in post-larva III (Fig. 9 g) and it increases in size to become 3-segmented in post-larva IV (Fig. 9 h). The characteristic branchiostegal groove of the adult appears for the first time in post-larva VI (Fig. 9 q). The pterygostomial spine, situated in the lateral angle of the carapace in post-larva I gradually shifts upwards towards the branchiostegal groove and gets reduced in size (Fig. 9 o - s). The spine finally disappears when the post-larva transforms into juvenile after a period of about 90 to 96 days of larval and post-larval development.

MOULTING BEHAVIOUR

The larval development of *Leptocarpus potamiscus* passes through 8 moults and the post-larval development through 8 or 9 moults. Upto zoea V, each moult results in a distinct stage, but zoea V and VI stages undergo ecdysis twice before passing to the next stage. Such variations in the number of moults between 2 successive stages have been recorded in the larval development of several palaemonid prawns such as *Macrobrachium acanthurus* (Choudhury, 1970), *M. carcinus* (Choudhury, 1971) and *M. idella* (Pillai and Mohamed, 1973). Newly hatched zoea takes 24 hours to moult to zoea II. The interval between the second and third zoeal stages is found to be 48 hours. From the 4th zoeal stage onwards the duration between each moult varies between 2 to 4 days. Post-larva I takes 48 hours for the 1st moult. The intervening period between the two ecdysis gradually increases to 5 or 6 days in post-larva II and III, and 8 to 11 days from post-larva IV to juvenile (Table 1).

TABLE 1. *Moulting periodicity and development of post-larvae of* L. potamiscus

Post-larva	Duration of the Stage in days	Days after hatching	Tl (mm)	Cl (mm)	Rostral formula	Salient features
I	2	23	6.0	1.9	7–8/0	Carapace with antennal and pterygostomial spines. Branchiostegal groove absent. Mandible without palp. Endopod of *Mxp* 2 4-segmented. Rudimentary exopods present on *P* 1 to *P* 4
II	5	25	7.3	2.5	8/2	No exopod on *P* 1 to *P* 4; endopod of *Mxp* 2 5-segmented
III	6	30	8.2	2.9	9/2	Buds of *Md* palp present.
IV	8	36	10.3	4.3	7–8+2/4	*Md* palp 3-segmented.
V	8	44	13.8	5.0	7–8+2/5	
VI	11	52	18.0	7.5	7–8+2/5	Branchiostegal groove developed.
VII	11	63	20.5	9.5	7–8+2/5–6	
VIII	10	74	24.0	9.0	7–8+2/5–6	Pterygostomial spine which is shifted towards the branchiostegal groove is 1/5th of antennal spine.
IX	10	84	25.0	10.0	7–8+2/6	Pterygostomial spine 1/6th of antennal spine.
Juvenile	...	94	30.0	12.0	7–8+2/6	No pterygostomial spine.

REARING

Zoeae were reared in two types of media where salinity was ranging between 13–15‰ and 30–35‰. The post-larval stages were reared in three salinity media namely, 4 to 6‰, 13–15‰ and 30–35‰. The results obtained showed that higher mortality rate occurred when larvae were reared in salinity ranges below 15‰. Higher salinity ranges were found to be suitable for the culture of this species upto the juvenile stage. Further rearing of the species in the laboratory was rendered difficult due to excessive mortality and cannibalistic tendencies.

DISCUSSION

Early larval development of *L. potamiscus* closely resembles that of *L. fluminicola* described by Rajyalakshmi (1961). The general larval morphology of the first 3 zoeal stages of the two species is similar in all respects except for the size of the larvae and the segmentation of the endopod of the 2nd and 3rd maxillipeds. The larvae of *L. potamiscus* are relatively smaller than that of *L. fluminicola.* The larvae collected from Hooghly estuary and described as possibly of zoea V of *L. fluminicola* by Rajyalakshmi (1961) show significant differences from the corresponding zoeal stages of *L. potamiscus.* Zoea V of *L. fluminicola* is characterised by the presence of two dorsal teeth on rostrum, 3-segmented antennular peduncle, chelate first and second pereiopods, relatively broader nature of posterior margin of telson and by the non-setose endopod of uropods. But the earlier zoeal stages as well as zoea V of *L. potamiscus* has only one dorsal tooth on the rostrum and the antennular peduncle is composed of two segments. The first and second pereiopods become chelate only in zoea VI. The posterior margin of the telson which is broader upto zoea III becomes rectangular in zoea IV and from zoea V onwards it gradually gets narrower and attains the adult shape in post-larva I. The endopod of the uropod acquires setae in zoea IV. In view of the very close similarity of development upto zoea III in both the species, the differences noticed in the larva collected from Hooghly estuary from the corresponding stage larvae of *L. potamiscus* reared in the laboratory makes it difficult to reconcile that they belong to any of these species.

One of the interesting features observed in the development of *L. potamiscus* is the gradual shifting of the pterygostomial spine which makes its first appearance in post-larva I, at its normal position on the antero-lateral margin of the carapace. As the development of post-larva proceeds, the position of this spine shifts and with every ecdysis it moves towards the branchiostegal spine in post-larva VI. In further development, the size of the spine is gradually reduced and it ultimately disappears completely when the post-larva develops into the juvenile (Fig. 9 o-s). Such shifting of position of spine was also observed by Gurney and Lebour (1941), in the development of the larvae of Palaemonidae. These authors opined that it would seem most probable that the 'pterygostomial' is not a spine in the usual sense, but rather a notch in the margin without homology to spine. They also suggested that in the larvae of the Palaemoninae the carapace may at first have an anterior point which has been called the pterygostomial spine. Later, this point becomes a well-defined spine and moves upwards, while a second spine appears either below it (*Leander*) or behind it (*Brachycarpus*). Although the pterygostomial spine is present in some of the larval stages of *L. potamiscus,* it is completely absent in the juveniles and adults. As absence of this spine is the most important generic character of the adults, the late disappearance of the spine is of special significance in the context of identity of the post-larvae belonging to the sub-family Palaemoninae.

The larvae of *L. potamiscus* are voracious feeders and they continuously feed when provided with sufficient food. These larvae generally prefer large sized food particles, even as big as the size of the larva itself. The larva carry the food particles by their pereiopods and feed on them while swimming about. When large size food is offered, the larvae cling on to the food and feed on them. Cannibalism is also observed among these larvae and it has been observed that this habit increases gradually as the development of the larvae advances. This habit of the larva is one of the main reasons for the mortality encountered during the rearing experiments of larvae.

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SECTION TWO

Family Palaemonidae Rafinesque, 1815

Genus *Leandrites* Holthuis, 1950

1. Leandrites celebensis (De Man, 1881)

The scientific paper dealing with the complete larval history of this species studied by rearing the eggs through various stages to postlarva by the author and published earlier is presented in the following pages 176-182.

LARVAL DEVELOPMENT OF *LEANDRITES CELEBENSIS* (DE MAN) (DECAPODA : PALAEMONIDAE), REARED IN THE LABORATORY

J. mar. biol. Ass. India, 1974, **16** (3) : 708-720

LARVAL DEVELOPMENT OF *LEANDRITES CELEBENSIS* (DE MAN) (DECAPODA : PALAEMONIDAE), REARED IN THE LABORATORY

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ABSTRACT

Early larval history of *Leandrites celebensis* (de Man), is described as a result of rearing the larvae obtained by laboratory spawning of berried females collected from tow-net operations. Zoea I, passed through 7 to 8 moults, to become post-larva I, within a period of 13-21 days. 7 well defined zoeal stages were described. Larvae were reared in a salinity range of 20 to 25‰. They were fed by freshly hatched *Artemia* nauplii.

INTRODUCTION

LEANDRITES CELEBENSIS (DE MAN), is a small brackish water shrimp growing up to 30 mm, in size, occurring in large numbers in Cochin backwaters during the period July to December. It was first described as *Leander celebensis* by de Man (1881) but Holthuis (1950) accommodated it under his new genus *Leandrites* and described it as *Leandrites celebensis*. Kemp (1925) recorded this species from Indian waters (Cochin and Tuticorin) and Nataraj (1942) has reported it from Vembanad Lake near Cochin as *Palaemonetes hornelli*. Pillai (1955) described an advanced post-larval stage of this shrimp from the plankton collections of Travancore Coast. A detailed study of the larval development of this species was undertaken by the present author and the results are presented here.

The author is grateful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute and late Dr. K. V. Sekharan for encouragements. Author is indebted to Shri K. H. Mohamed and Dr. P. V. Rao for going through the manuscript and giving helpful suggestions throughout the period of work. The author is also grateful to Shri M. Aravindakshan for getting a constant supply of *Artemia* eggs for rearing experiments.

MATERIAL AND METHODS

Ovigerous females of *Leandrites celebensis* were collected from Cochin Backwaters during July-December 1972 using experimental tow-nets. Females (TL-24-27 mm ; number of fertilized eggs on pleopods 426-596 ; size of eggs 0.45-0.66 mm along the long axis) with advanced stage of berry were sorted out and kept in six-litre glass troughs containing brackish water having a salinity range 20-25‰. Adults were fed on finely chopped and washed prawn meat once a day and excess food materials were removed after two hours.

The larvae were reared in the same salinity range in one litre beakers, each of which carried about 75 larvae. At a time five sets of rearing experiments were conducted. Larvae were fed by freshly hatched *Artemia* nauplii from zoea I onwards.

Larvae in each stage were preserved in 5% formalin. Measurements and camera lucida drawings were made from preserved larvae. Total length of the larvae was measured from the tip of the rostrum to the tip of the telson (excluding terminal spine). Carapace length includes rostrum also and was taken from the tip of the rostrum to the posterior margin of the mid dorsal region of the carapace.

Following abbreviations are used for describing the larvae: A_1—antennule; A_2—antenna; Md—mandible; Mx_1—maxillule; Mx_2—maxilla; Mxp_1—maxilliped I; Mxp_2—maxilliped II; Mxp_3—maxilliped III; P_1—pereiopod I; P_2—pereiopod II; P_3—pereiopod III; P_4—pereiopod IV; P_5—pereiopod V; T—telson; TL—total length; CL—carapace length.

Results

Hatching took place during the early morning hours. Zoea I moulted to the next stage, 24 hours after hatching. From zoea II onwards its larvae took 2 to 3 days for every moult. Zoea I moulted 7 to 8 times before metamorphosing into post-larva I within a period of 13 to 21 days. As the survival rate was 1 to 2%, from zoea III onwards, a number of rearing experiments were conducted separately to collect all the zoeal stages.

Description of larval Stages

Zoea I (Fig. 1 a-k): TL—1.7-1.8 mm (1.8 mm)*; CL—0.5-0.6 mm (0.5 mm)*. Number of larvae examined: 8.

Rostrum slender, pointed, reaching 2/3 length of antennular peduncle; carapace smooth, antero-lateral edge slightly produced; eyes large and sessile; antennule, antenna and mouth parts developed; biramous buds of first two pereiopods developed; telson not separated from 6th abdominal segment.

A_1 (Fig. 1 b): uniramous; peduncle unsegmented, more than four times the length of outer flagellum, carrying distally 2 flagella; outer flagellum rectangular carrying one aesthetes, 3 long slender setae, and one short plumose seta, inner flagellum long and plumose. A_2 (Fig. 1 c): scale 4-segmented distally, bearing 9 plumose and 2 non-plumose setae at its distal and lateral margins: flagellum long, shorter than scale, carrying at its apex one short spine and one long plumose seta. Md (Fig. 1 d): slightly asymmetrical; incisor process with 3 stout teeth; molar with 3-4 bristle-like teeth; one serrated movable tooth and a slender one in between the two processes. Mx_1 (Fig. 1 e): uniramous; palp with 2 long setae at its apex; distal lacinia with 5 teeth, 2 of which are stout and setose; proximal lacinia with 4 terminal teeth and one lateral seta. Mx_2 (Fig. 1 f): biramous; protopod with 3 masticatory processes, distal process with 4 and proximal 2 processes with 2 setae

* Average size is given in brackets.

respectively ; endopod terminates in a seta ; exopod with 5 plumose setae along its margin, hindermost being longest. Mxp_1 (Fig. 1 g): biramous ; basipod with 8-9 setae on the inner margin ; endopod unsegmented, reaching 2/3rd length of exopod, bearing 3 long apical and 3 short lateral setae ; exopod with 4 long plumose setae terminally. Mxp_2 (Fig. 1 h) : biramous ; basis with 2 small setae and a stout spine ; endopod 3-segmented, disto-lateral aspect of 2nd segment with one seta and 2 spines, terminal segment with a claw and 3 short setae; exopod long with 4 long apical and 2 short sub-apical plumose setae. Mxp_3 (Fig. 1 i) : biramous ; basis with one spine and 2 short setae ; endopod 3-segmented, one small seta and a spine on the inner side of 1st segment, 2 long movable spines present on the inner disto-lateral aspect of 2nd segment, terminal segment with 2 spines ; exopod long with 4 long plumose apical and 2 short plumose sub-apical setae. T (Fig. 1 j) : broad, concave posteriorly carrying 7 spines on either side, outermost 2 spines on each side setose only on the inner side.

Zoea II (Fig. 2 a-m) : TL—1.8-2.0 mm (1.9 mm) ; CL—0.5-0.6 mm (0.6 mm). Number of larvae examined : 8.

The characteristic features of the larvae are the stalked eye, anterolateral angle of the carapace produced to form a pterygostomial spine which is slightly pointed downwards (Fig. 2 b), development of first two pereiopods, uniramous bud of 5th pereiopod and a pair of prominant lateral spines on 5th abdominal segment.

A_1 (Fig. 2 c) : peduncle 2-segmented, proximal segment with 3 plumose setae on outer distal aspect, a rounded prominence bearing 2 short plumose setae on dorsal side on distal segment, behind outer flagellum ; outer flagellum with 2 aesthetes and 2 long slender setae. Md (Fig. 2 e) : incisor process with 3-4 stout teeth ; molar with 5 stout bristle-like teeth ; one movable and serrated tooth and two long slender ones in between the two processes. Mx_1 (Fig. 2 f) : distal lacinia with 7 teeth. Mx_2 (Fig. 2 g) : exopod with 7 plumose setae along its margin ; 2 setae on proximal masticatory process setose. Mxp_2 (Fig. 2 i) : basis with 2 spines and 2 small setae. Mxp_3 (Fig. 2 j) : endopod 4-segmented, 3rd segment with one long spine and 2 setae, terminal segment with 2 spines and 2 setae. P_1 (Fig. 2 k) : biramous ; basis with a short seta ; endopod 4-segmented, 1st segment with a stout seta on the inner side, 2nd segment with a short seta on outer side, 3rd segment carrying 2 long movable spines on inner disto-lateral aspect of segment, one of which serrated, terminal segment ends in a claw ; exopod as long as 1st segment of endopod with 4 long apical and 2 short sub-apical plumose setae. P_2 (Fig. 2 1) : same as P_1 but seta on inner side of 1st segment of endopod comparatively small in P_2. T (Fig. 2 m) : 8 spines on either side of broad concave posterior margin, outermost spine on either side setose only on one side, innermost spine is smallest.

Zoea III (Fig. 3 a-m) : Tl—2.1-2.2 mm (2.2 mm) ; CL—0.6 mm. Number of larvae examined : 5.

Rostrum with an epigastric tooth ; telson distinctly separated from last abdominal segment by an articulating joint ; uropods developed with bare endopods.

A_1 (Fig. 3 b) : peduncle 2-segmented ; proximal segment with a long plumose seta on inner distal region and 2 short plumose setae on outer distal region, outer margin with 4 short plumose setae 2 of which are in middle, distal segment with 2 long plumose setae on ventral side and 4 short plumose setae on a prominence on

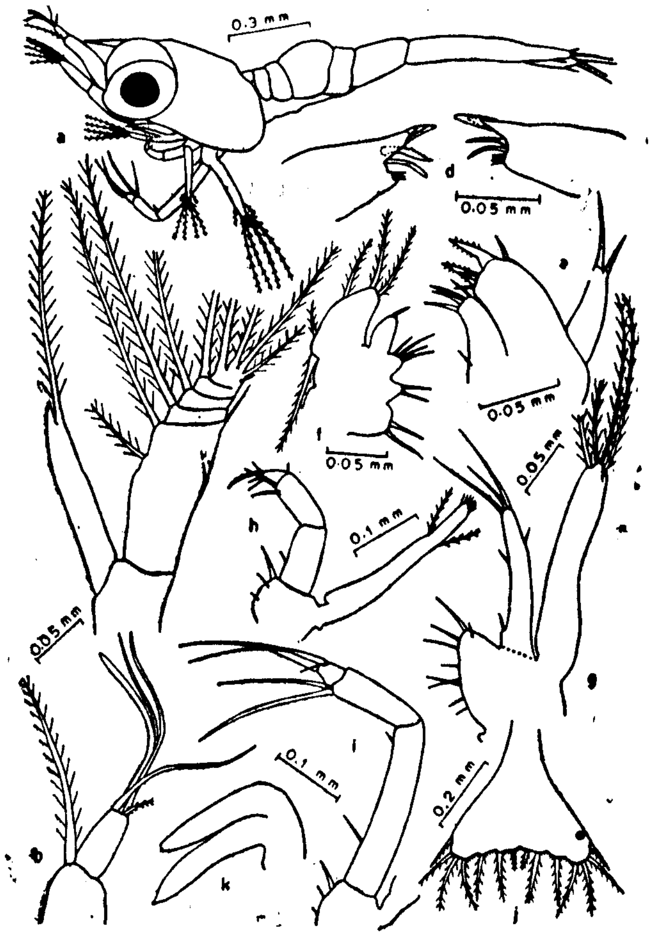

Fig. 1. *L. celebensis*-Zoea I : a. lateral view, b. tip of antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. telson and k. bud of pereiopod I.

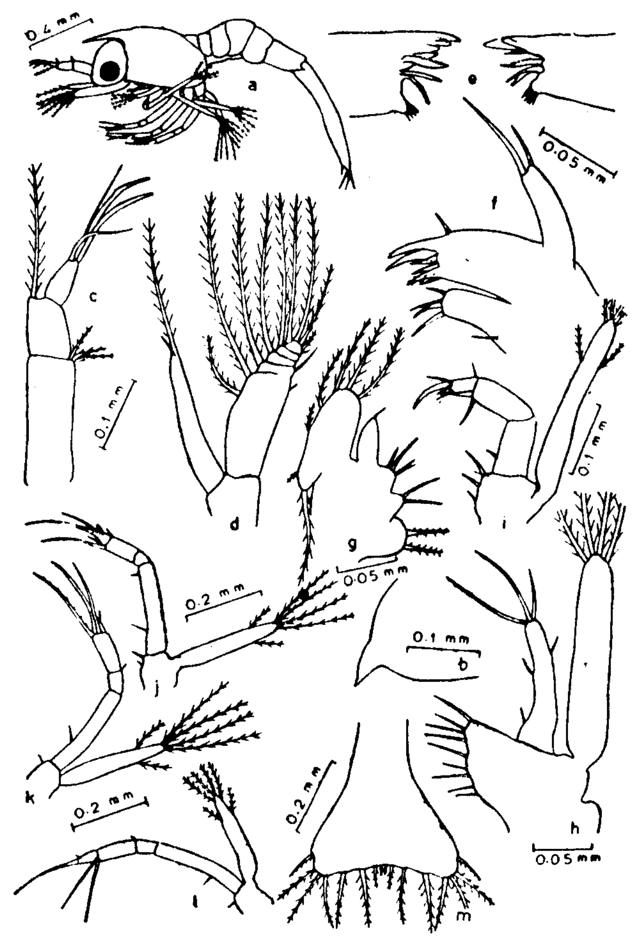

Fig. 2. *L. celebensis*-Zoea II : a. lateral view, b. anterolateral part of carapace, c. antennule (ventral view), d. antenna, e. mandible, f. maxillule, g. maxilla, h. maxilliped I, i. maxilliped II, j. maxilliped III, k. pereiopod I, l. pereiopod II and m. telson.

Fig. 3. *L. celebensis*-Zoea III : a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. pereiopod I, k. pereiopod II, l. bud of pereiopod V and m. uropod and telson.

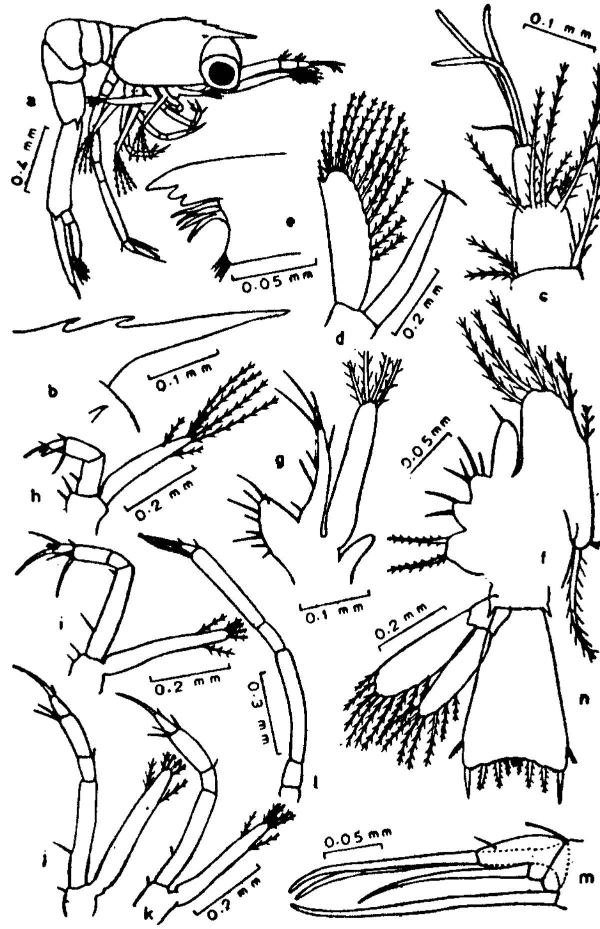

Fig. 4. *L. celebensis*-Zoea IV : a. lateral view, b. rostrum, c. tip of antennule, d. antenna, e. mandible, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. pereiopod I, k. pereiopod II, l. pereiopod V, m. dactylus of pereiopod V, n. uropod and telson.

dorsal side ; outer flagellum with 3 aesthetes and one short seta ; inner flagellum is like a small papilla. A_2 (Fig. 3 c) : scale partially segmented distally with 10 long plumose and 2 short non-plumose setae along distal and lateral margins ; flagellum shorter than scale carrying 2 slender setae terminally. P_2 (Fig. 3 k) : same as in previous stage except for presence of 3 long spines on 3rd joint of endopod. Uniramous bud of P_5 (Fig. 3 1) developed. T (Fig. 3 m) : separated from last abdominal segment by an articulating joint, carrying 8 spines on each side of concave posterior margin, outermost and innermost spines non-setose ; uropod biramous ; exopod with 6 long plumose setae ; endopod bare.

Zoea IV (Fig. 4 a-n) : TL—2.5-2.7 mm (2.6 mm) ; CL—0.7 mm. Number of larvae examined : 2.

Rostrum with 2 dorsal teeth, tip of rostrum as well as inner side of rostral teeth serrated (Fig. 4 b) ; carapace with supra-orbital and pterygostomial spines ; 5th pereiopod developed and is the longest appendage of the larvae ; biramous bud of 3rd pereiopod and uniramous bud of 4th pereiopod developed ; endopod of uropod with plumose setae.

A_1 (Fig. 4 c) : proximal segment of peduncle with 4 plumose setae at outer middle region and 2 short plumose and 2 long slender setae at outer basal prominence, inner side of proximal segment with 3 long plumose setae ; distal segment with 4 long plumose setae on one side and 4 short plumose setae on a prominence on outer side ; outer flagellum with 3 aesthetes and one seta ; inner flagellum small and short. A_2 (Fig. 4 d) : scale not segmented distally, with a spine and 14 long plumose setae, one short non-plumose seta ; flagellum as long as the scale with 3 setae terminally one of which is very small. Md (Fig. 4 e) : incisor with 3-4 stout teeth ; molar with 5-7 slender teeth ; 3-4 long teeth in between two processes, of which one is serrated. Mx_2 (Fig. 4 f) : proximal masticatory process with 2 long plumose setae, exopod with 8 plumose setae along margin. Mxp_1 (Fig. 4 g) : endopod with 3 long terminal setae, laterally 4 setae present of which middle one on inner side longest ; epipod buds developed. P_1 (Fig. 4 j) : endopod 4-segmented, 1st segment with a stout seta on inner side, 2nd segment with a small seta on outer side, 3rd segment with 2 setae on inner distal region and terminal segment ends in a claw and a short seta. P_2 (Fig. 4 k) : same as P_1 except for presence of 3 setae on 3rd segment of endopod, seta on inner side of 1st segment just half size of seta on P_1, P_5 (Fig. 4 1) : uniramous ; long and reaching beyond eye ; endopod 5-segmented, distal part of propodus with 2 long spines and a short seta ; in addition to terminal long spine, dactylus carries one short seta on outer side and one long spine on inner side (Fig. 4 m). T : narrower than in previous stage, carrying one lateral and 5 terminal spines on either side, outermost spines longest on both sides and non-setose. Exopod and endopod of uropod (Fig. 4 n) with 9 and 7 plumose setae respectively.

Zoea V (Fig. 5 a-j) : TL—2.8-3.0 mm (2.9 mm) ; CL—0.8 mm. Number of larvae examined : 2.

Rudimentary chela seen in 1st and 2nd pereiopods ; biramous bud of 3rd pereiopod and uniramous bud of 4th pereiopod (Fig. 5 g) developed ; uniramous buds of pleopods on all abdominal segments (Fig. 5 a) ; telson rectangular.

A_1 (Fig. 5 b) : proximal segment of peduncle on outer side with 3 short plumose setae anteriorly, 4 near middle and 3 short plumose and 3 long slender setae on stylocerite, distal segment with 5 long plumose setae on ventral side ; inner flagellum finger-shaped, almost half length of outer flagellum, which carries 3 aesthetes and one seta. A_2 (Fig. 5 c) : scale with 17 plumose setae and one spine ; flagellum longer than scale and 4-segmented with 2 small terminal setae 3rd segment longest. Md : same as in previous stage except for presence, of 4-5 long teeth in between incisor and molar processes, of which two are serrated. Mx_2 : exopod with 10 plumose setae along margin. Mxp_1 : epipod bilobed. Mxp_3 (Fig. 5 d) : basis with 2-3 setae, 1st segment of endopod with a spine and seta on inner side, 3rd segment with 3 setae, 2 of which are at inner disto-lateral region. P_1 (Fig. 5 e) and P_2 (Fig. 5 f) : are almost identical but P_1 can easily be distinguished by longer seta on inner side of 1st segment of endopod, disto-lateral part of 3rd segment slightly protruded indicating developing fingers of chela, this protuberance carries 2 slender setae at its distal end, terminal segment ends in a claw and a small seta ; exopod of uropod (Fig. 5 i) with 12 plumose setae and a spine, endopod with 10 plumose setae.

Zoea VI (Fig. 5 k-n ; 6 a-l) : TL—3.4-3.7 mm (3.6 mm) ; CL—1.0 mm. Number of larvae examined : 4.

Chela of 1st and 2nd pereiopods further developed ; 3rd and 4th pereiopods developed ; telson narrower posteriorly.

A_1 (Fig. 6 a) : a circlet of plumose setae developed towards middle of proximal segment of peduncle, stylocerite with 3 short plumose and 5 long slender, non-plumose setae, distal segment carries 5 short plumose setae on a prominence on dorsal side, and 5 long plumose setae on ventral side, outer flagellum carries a small seta on finger-shaped prominence, towards inner side of outer flagellum 3 aesthetes present, inner flagellum finger-shaped and smaller than the outer. A_2 (Fig. 6 b) : scale with 18 plumose setae and a spine. Mx_1 (Fig. 5 m): distal lacinia with 8 teeth of which 3 are stout and setose. Mx_2 (Fig. 6 c) : exopod with 12 plumose setae along its margin, 3 of which are in hinder most region. Mxp_1 (Fig. 6 d): endopod with 3 long terminal setae, of 3 long setae on inner side, middle one is longest ; bi-lobed epipod developed. Mxp_3 (Fig. 6 f) : same as in the previous stage except for presence of a short seta on outer side of 2nd segment of endopod. P_1 (Fig. 6 g), P_2 (Fig. 6 h) : chela further developed, fingers of chela almost of same size. P_3 (Fig. 6 i) : biramous ; endopod 4-segmented, 2nd and 3rd segments with one and 3 small setae respectively, terminal segment with a spine and a small seta ; exopod carrying 4 long apical and 2 short sub-apical plumose setae and as long as first segment of endopod. P_4 (Fig. 6 j) : uniramous ; endopod 4-segmented, 1st segment with a small seta on outer margin, terminal segment with a spine and small seta. Pleopod buds biramous but bare. T : longer than uropod, narrower posteriorly, with one lateral and 5 terminal spines on either side, outermost and innermost terminal spines on either side non-setose (Fig. 6 l). Exopod of uropod with one spine and 16 plumose setae and endopod with 13 plumose setae.

In the course of the experiments, a single zoea, showing some intermediate characters of 5th and 6th zoeal stages was found after the fifth moult. TL and CL oft this zoea were 2.99 and 0.88 mm respectively. Antenna, mouth parts, 1st, 2nd and 5th pereiopods resembled those of zoea VI. As in zoea V, uniramous buds of pleopods were present on abdominal segments. 3rd pereiopod was well developed and uniramous bud of 4th pereiopod present. Telson carried 2 small lateral and 5 terminal spines on either side, in contrast to the single lateral and 5 terminal spines of zoea V and VI.

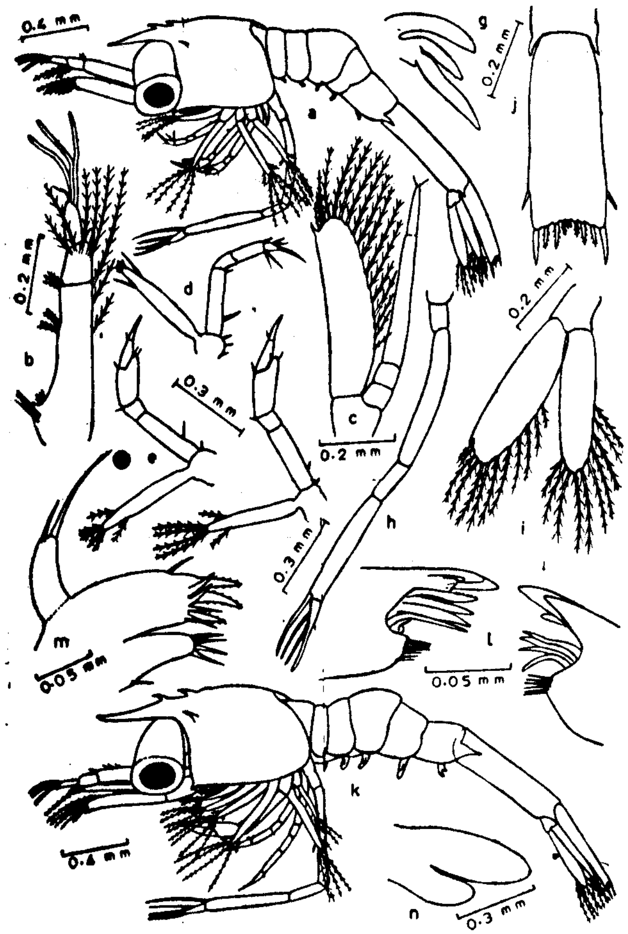

Fig. 5. *L. celebensis*-Zoea V : a. lateral view, b. antennule, c. antenna, d. maxilliped III, e. pereiopod I, f. pereiopod II, g. bud of pereiopod III and IV, h. pereiopod V, i. uropod, j. telson. Zoea VI : k. lateral view, l. mandible, m. maxillule and n. pleopod IV.

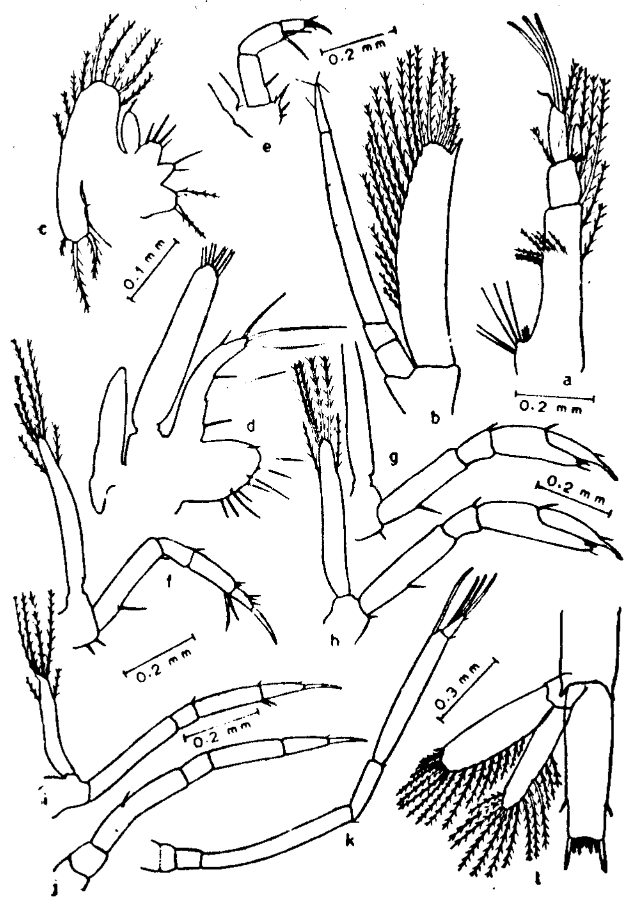

Fig. 6. *L. celebensis*-Zoea VI : a. antennule, b. antenna, c. maxilla, d. maxilliped I, e. maxilliped II, f. maxilliped III, g. pereiopod I, h. pereiopod II, i. pereiopod III, j. pereiopod IV, k. pereiopod V and l. uropod and telson.

Zoea VII (Fig. 7 a-k) : TL—4.2 mm ; CL—1.2 mm. Number of larvae examined : 1.

2nd pereiopod stouter and longer than the 1st. Pleopods non-setose but well developed, appendix interna present on the endopod of 2nd to 4th pleopods.

A_1 (Fig. 7 a) : number of plumose setae on proximal segment increased, stylocerite with 3 short plumose and 7 long slender non-plumose setae, depression to hold eye well developed. A_2 (Fig. 7 b) : scale with 21 plumose setae and one spine, flagellum 6-segmented distal segment with 3 setae. Md (Fig. 7 c) : 4-5 teeth present in between incisor and molar processes, of which 3-4 are serrated. Mx_2 (Fig. 7 d) : protopod with 3 masticatory processes, distal process with 3 and proximal 2 processes with 2 setae each, setae on proximal process long and plumose, exopod with 14 plumose setae of which 4 are at hinder most region. P_1 (Fig. 7 e), P_2 (Fig. 7 f) : chela well developed, P_2 longer and stouter than P_1 ; P_3 : endopod 4-segmented, 1st and 2nd segments with one seta on outer side, 3rd segment with 3 setae at distal end, last segment ends in a spine, exopod smaller than 1st segment of endopod bearing 4 apical and 2 sub-apical plumose setae ; pleopods are bare but well developed, endopod of 2nd to 4th pleopods with appendix interna (Fig. 7 g, h, i). T : narrower posteriorly with 4 spines on either side, outermost spine longest and non-setose, one spine each on lateral side of telson. Exopod of uropod with one spine and 18 plumose setae, endopod with 16 plumose setae (Fig. 7 j).

Post-larva I (Fig. 7 l-o ; 8 a-j ; 9 a-c) : TL—4.2 mm ; CL—1.4 mm. Number of larvae examined : 1.

Larvae acquire a bottom-living habit and freely move about the bottom of the container using walking legs ; rostrum with 9 dorsal teeth and a single ventral tooth, carapace with pterygostomial and branchiostegal spines ; exopods on 1st to 3rd pereiopods have become rudimentary ; exopod and endopod of pleopods setose and endopod of pleopod 2 to 5 with appendix interna.

A_1 (Fig. 8 b) : peduncle 3-segmented, proximal segment longest, with a spine at outer antero-lateral aspect, statocyst developed ; outer flagellum with 2 branches, outer branch 2-segmented, inner branch with 4 aesthetes in 2 groups of 3 and, inner flagellum 3-segmented. A_2 : scale with 26 plumose setae and one spine ; flagellum segmented and 7 times the length of scale, basal segment of flagellum with a circlet of setae. Md (Fig. 8 c) : acquire shape of Md of adult ; incisor and molar processes are distinctly separated ; incisor ending in 3 stout teeth, molar with 5 stout short teeth. Mx_1 (Fig. 8 d) : palp without setae ; distal lacinia with 9 teeth ; 9-12 slender teeth present all round distal part of proximal lacinia. Mx_2 (Fig. 8 e) : considerable change is noticed from previous stage ; basis with 2 endites, proximal and distal endites with 3 and 4 bristle like setae ; endopod bare ; 28 plumose setae around margin of exopod. Mxp_1 : number of setae on inner side of basis increased ; endopod with a single plumose seta on inner side ; base of exopod slightly expanded bearing 3 long plumose setae at outer margin, terminally exopod has 4 long plumose setae, outer most setae on either side smaller than inner ; bilobed epipod present. Mxp_2 (Fig. 8 f) : basipod with a seta on inner side ; endopod 4-segmented, 1st segment shows an indistinct segmentation in middle, last two segments with several setae ; exopod with 4 long apical and 2 short sub-apical plumose setae ; bilobed epipod present. Mxp_3 (Fig. 8 g) : endopod 3-segmented, profusely setose on inner side ; exopod as long as 1st segment of endopod with 4 apical and 2 sub-apical plumose setae. P_1 (Fig. 8 h) :

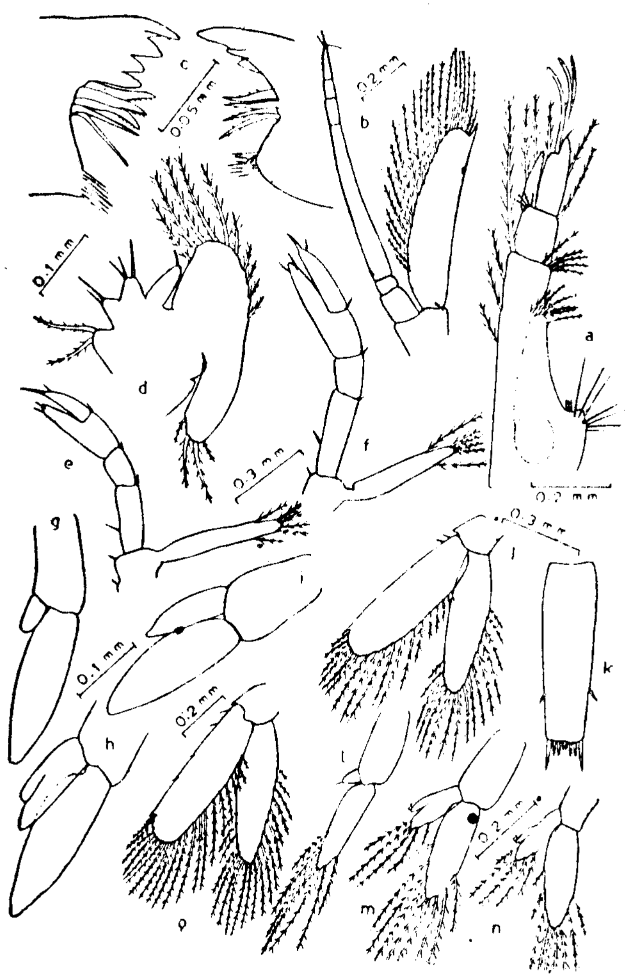

Fig. 7. *L. celebensis*-Zoea VII : a. antennule, b. antenna, c. mandible, d. maxilla, e. pereiopod I, f. pereiopod II, g. pleopod I, h. pleopod II, i. pleopod V, j. uropod, k. telson ; Post larva I: l. pleopod I, m. pleopod III, n. pleopod V and o. uropod.

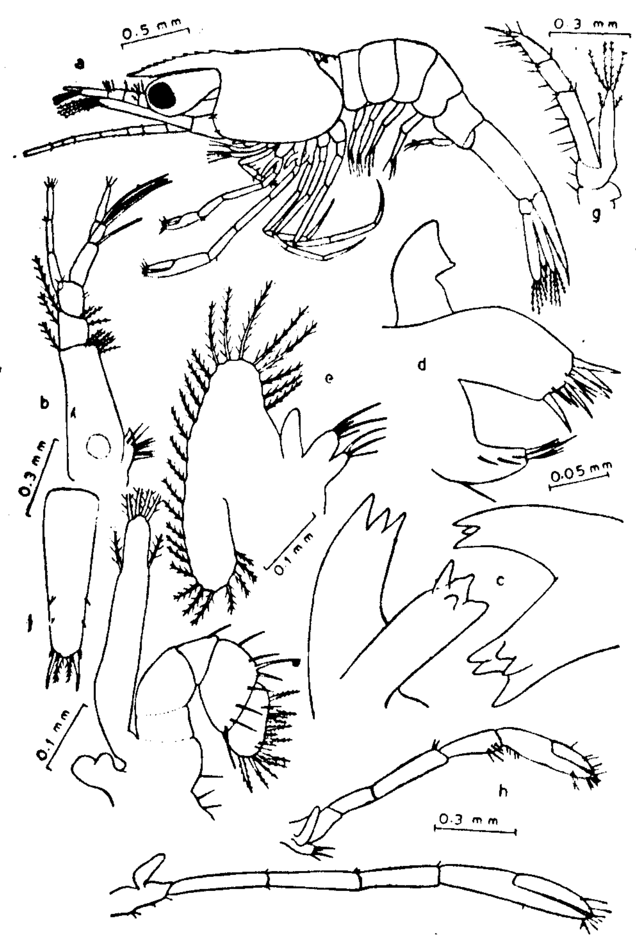

Fig. 8. *L. celebensis* Post-larva I : a. lateral view, b. antennule, c. mandible, d. maxillule e. maxilla, f. maxilliped II, g. maxilliped III, h. pereiopod I, i. pereiopod II and j. telson.

endopod 5-segmented, fingers of chela terminate a small claw surrounded by bristle-like setae, disto-lateral aspect of 3rd segment and inner lateral aspect of 4th segment with several small stout setae; rudimentary exopod present. P_2 (Fig. 8 i): longer and stouter than P_1; endopod 5-segmented, fingers of chela terminate in a small claw surrounded by bristle-like setae; rudimentary exopod present. P_3 (Fig. 9 a): endopod 5-segmented, dactylus terminates in a long spine; rudimentary exopod present. P_4 and P_5 (Fig. 9 b, c): almost identical with 5-segmented endopod, distal segment ending in a long spine; exopod and endopod of pleopods with plumose setae; endopod of pleopod 1 (Fig. 7 1) small with a single seta; endopod of pleopods 2nd to 5th (Fig. 7 m, n) with appendix interna, which has got 2 curved small hooks on subapical region. T (Fig. 8 j): posterior margin convex with a single stout plumose seta and 2 spines on either side, outermost spine is smaller, 2 lateral spines on either side slightly shifted towards dorsal aspect of telson. Exopod of uropod with 22 plumose setae and 2 spines of which one is movable; endopod with 19 plumose setae (Fig. 7 o).

Post-larva II (Fig. 9 d-1): TL—4.6 mm; CL—1.6 mm. Number of larvae examined: 1.

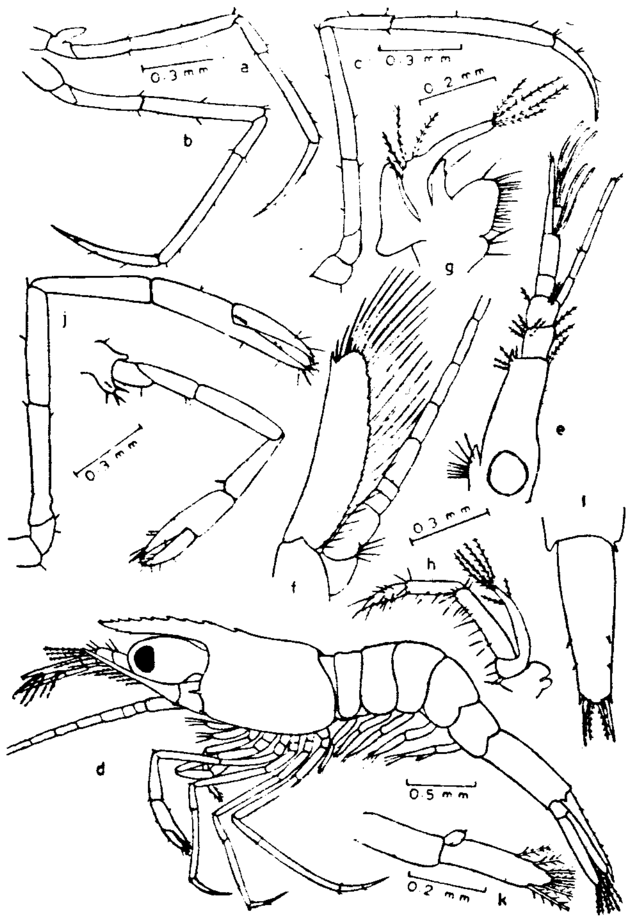

Fig. 9. *L. celebensis*-Post-larva I: a. pereiopod III, b. pereiopod IV, c. pereiopod V. Post-larva II: d. lateral view, e. antennule, f. antenna, g. maxilliped I, h. maxilliped III, i. pereiopod I, j. pereiopod II, k. pleopod I and l. telson.

Rostrum with 9 dorsal and 2 ventral teeth; no exopods on pereiopods.

A_1 (Fig. 9 e): inner branch of outer flagellum with 5 aesthetes in two groups of 3 and 2; inner flagellum 4-segmented. A_2 (Fig 9 f): scale with 26 plumose setae and one spine. Mx_1: palp terminates in 2 small protuberances one of which with a small seta, number of teeth on lacinia increased. Mxp_1 (Fig. 9 g): same as in previous stage except for presence of 4 plumose setae at base of exopod. Number of setae on exopod and endopod of pleopods increased (Fig. 9 k). Exopod of uropod with 24 plumose setae and 2 spines of which one is movable; endopod with 21 plumose setae.

DISCUSSION

The first three zoeal stages of *Leandrites celebensis* closely resemble the equivalent stages of other palaemonid shrimps having protracted life history. First zoea in all these forms are characterised by the sessile eyes, fully developed maxillipeds with functional exopods and with 7 spines on either side of the broad concave posterior margin of the telson which is not separated from the 6th abdominal segment as also noticed by Menon (1940). But the first zoea of *L. celebensis* can easily be distinguished by the conspicuous endopod of 3rd maxilliped in which the movable spines on the penultimate segment function like a prehensible organ. The development of supra-orbital spine, stalked eye, first and second pereiopods, lateral spine on the 5th abdominal segment and an extra spine on either side of telson are the chief characteristics of the zoea II of all these forms. The absence of supra-orbital spines in *L. celebensis* is perhaps a specific character which is not shared with other species of the group. The epigastric tooth and the uropod appear in the 3rd stage when telson gets separated from the last abdominal segment with an articulating joint. In zoea III of *Macrobrachium* spp. (Uno and Kwon, 1969; Pillai and Mohamed, 1973) and *Leptocarpus potamiscus* (Pillai, 1973) the biramous buds of third pereiopod and uniramous buds of fifth pereiopods are developd whereas in *L. celebensis* only the latter has developed in the 3rd stage. From zoea IV onwards there is only very little similarity between the corresponding zoeal stages of these species. With the development of fifth pereiopod in zoea IV, the prehensile function which was hitherto carried out by other limbs is completely taken over by this appendage. Consequently the spines on the terminal segments of other limbs show reduction in size and mobility. Till the zoea metamorphoses into the post-larva I, this prehensile function of fifth pereiopod continues.

In the course of the experiments, a zoea obtained after the fifth moult showed certain intermediate characters of 5th and 6th stages. Although the characters of this zoea showed certain deviation, it cannot be considered as a separate stage as some of its characters are not in the usual pattern of development. The presence of 2 lateral spines on either side of telson of this zoea is only an abnormal condition as only one spine is observed in all stages of normal development of this species. Such deviations and abnormal characters in larval development stages are observed by Provenzano and Dobkin (1962) in *Tozeuma carolinensis* and Pillai and Mohamed (1971) in *Macrobrachium idella*. Again, different developmental rates among decapod larvae, which may be caused by external as well as internal factors have been noticed by earlier workers (Broad, 1957; Fraser, 1936; Heegaard, 1953).

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SECTION THREE

Family Hippolytidae Dana, 1852

Genus *Hippolysmata* Stimpson, 1860

1. _Hippolysmata_ _(Exhippolysmata)_ _ensirostris_ Kemp, 1914

The scientific paper dealing with the complete larval history of this species studied by rearing the eggs through various stages to postlarva by the author and published earlier is presented in the following pages 184-191.

LABORATORY REARED LARVAL FORMS OF *HIPPOLYSMATA* (*EXHIPPOLYSMATA*) *ENSIROSTRIS* KEMP (DECAPODA : HIPPOLYTIDAE)

J. mar. biol. Ass. India, 1974, **16** (2): 594-608

LABORATORY REARED LARVAL FORMS OF *HIPPOLYSMATA* (*EXHIPPOLYSMATA*) *ENSIROSTRIS* KEMP (DECAPODA: HIPPOLYTIDAE)

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ABSTRACT

Complete larval history of the marine caridean, *Hippolysmata* (*Exhippolysmata*) *ensirostris*, has been studied by rearing in the laboratory. Nine well defined zoeal stages are observed during development and first zoea took 43 days to become post-larva. Detailed description of nine zoeal stages and post-larva are given. Larvae have been reared in a salinity range of 34.5 to 35.0°/ₒₒ, and fed on freshly hatched *Artemia* nauplii.

INTRODUCTION

HIPPOLYSMATA (EXHIPPOLYSMATA) ENSIROSTRIS Kemp is a marine caridean prawn attaining a size of 80 mm (George, 1969) in total length and is distributed in the waters around India, Ceylon, Burma and Sumatra (Holthuis, 1947). The fishery importance of the species in Indian waters has been pointed out by Shaikhmahmud and Tembe (1960) and Kunju (1969). Though there is no account of the biology of the species, information is available on the post-larval stages (Kemp, 1916; Gurney, 1936) and the eggs and very early larvae (Bensam and Kartha, 1967). The present communication embodies the description of the complete larval stages of *H. ensirostris* reared in the laboratory.

MATERIAL AND METHODS

One berried specimen of *H. ensirostris* (measuring 73 mm in total length) was obtained at a depth of 20 m off Cochin along with some penaeid prawns and fishes on 8-4-1975 during one of the fishing trips of the research vessel 'Cadalmin I' and was brought alive to the laboratory. The animal was kept in a glass trough containing sea water collected from the area of fishing with a salinity of 35.14°/ₒₒ. Hatching of larvae started at 0700 hrs on the morning of the next day (9-4-1975) and initially 25 zoeae were released up to 1130 hrs. After an interval of 8½hrs, 108 zoeae hatched out (at 2000 hrs) on the same day, thus making a total of 133 larvae. Though 80% of the eggs were still attached to the pleopods of the mother, the animal moulted on 11-4-1975 and all the remaining eggs were discarded along with the exuvia. Within a few hours after moulting the female again acquired berry. As the berry was not fertilized the eggs did not develop.

Larvae were reared in batches of 50 numbers in 1000 ml beakers. Every day 75% of the water was siphoned out along with the excreta and exuvia at the bottom and water level was made up by adding fresh sea water of salinity range 34.5 to 35.0°/ₒₒ. Larvae were fed with freshly hatched nauplii of brine shrimp (*Artemia*). No mortality was observed during the first two stages. But there was heavy mortality at the third zoeal stage. To prevent the breaking of the extremely long 5th pereiopods from stage IV onwards, extreme care was taken during the change of water. Water was poured into the beaker slowly along the inner side of the stem of an inverted glass funnel.

The following abbreviations are used for describing the larvae : Tl : total length ; Cl : carapace length ; A-1 : antennule ; A-2 : antenna; Md : mandible ; Mx-1 maxillule ; Mx-2 : maxilla ; Mxp-1 : maxilliped I ; Mxp-2 : maxilliped II ; Mxp-3 : maxilliped III ; P-1 : pereiopod I ; P-2 : pereiopod II ; P-3 : pereiopod III ; P-4 : pereiopod IV ; P-5 : pereiopod V; and T : telson.

The author wishes to express his gratitude to Dr. E. G. Silas, Director, C.M.F.R. Institute, for kindly providing the berried specimen and suggesting this problem and to Dr. K. V. Sekharan for the encouragements. He is thankful to Mr. K. H. Mohamed for giving helpful suggestions. He is grateful to Dr. M. J. George, National Institute of Oceanography, for going through the manuscript and offering valuable comments for the improvements.

Description of Larval Stages

In the case of the first 2 zoeal stages, the differences noticed from the description of the corresponding stages given by Bensam and Kartha (1967) are figured (Fig. 1 a-j) and tabulated below in Table 1.

Table 1. *The salient differences of the first two larval stages of* H. ensirostris.

Characters (1)	Bensam and Kartha (1967) (2)	Present work (3)
First Stage		
Tl	2.15 mm	1.89 to 2.23 mm
Md	Asymmetry not mentioned.	Asymmetrical (Fig. 1, a).
Mx-1		
proximal endite :	with 4 setae.	with 7 setae (Fig. 1, b)
distal endite :	with 3 spines.	with 4 setae.
endopod :	with 4 setae.	with 5 setae.
Mxp-2		
distal part of exopod	not segmented.	clearly segmented (Fig. 1, c).
Posterior margin of 5th abdominal segment	without spine.	with spine.
Time taken for moulting to next stage	3 days.	2 days.
Second Stage		
Tl	no increase in length.	length increased 2.49 to 2.75 mm
Cl	Not given	0.70 to 0.77 mm
Supra-orbital spine :	absent	present (Fig. 1, e).
Antennular peduncle :	feebly segmented.	Unsegmented (Fig. 1, f).
Antennal scale :	distally without segmentation.	distally with 3 segments (Fig. 1, g).
Antennal flagellum :	stumpy without apical seta.	with a long plumose seta (Fig. 1, g).
Md :	no change from previous stage.	left incisor with 5 teeth of which one movable, right incisor with 4 teeth (Fig. 1, h).
P-1 :	absent	biramous bud present.

According to Bensam and Kartha (1967) the larvae were devoid of pigmentation, whereas the present larvae in all stages are beautifully pigmented. Orange red chromatophores are distributed dorsally in between the eyes in the first stage, and on the dorsal side of the eye in the second stage. In both stages the following pigmentation pattern is also seen: orange red chromatophores on either side of the distal aspect of carapace ; second abdominal segment ; tip of antennular peduncle ; last 3 segments of the endopod of Mxp-3 and the base of telson.

The description of the 3rd stage given by Bensam and Kartha (1967) does not seem to be complete.

Zoea III (Fig. 1, k to l ; 2, a to b) ; Tl 2.69 to 2.82 mm ; Cl 0.84 to 0.91 mm.

After 24 hours zoea II moults to the next stage.

Eye stalk has become long (Fig. 1, k) ; rostrum reaches beyond half the length of the first antennal segment ; antennal spine developed ; P-1 developed ; biramous bud of P-2 and uniramous bud of P-5 developed ; T demarcated from last abdominal segment by an articulating joint ; uropod distinct ; pigmentation same as in the previous stages.

A-1 (Fig. 1, l) : peduncle 2-segmented, proximal and distal segments carrying 5 and 4 plumose setae respectively ; outer flagellum with 2 aesthetes and one long plumose seta ; inner stumpy carrying single long plumose seta. A-2 (Fig. 2, a) : with short flagellum carrying apically a spine-like seta ; scale with 2 distal segmentations and 13 setae, of which the outermost alone non-plumose and spine like, one plumose seta present on the distal outer margin. Md : in between the incisor and molar processes 1 to 2 short slender teeth present. Mx-1 : distal and proximal endites with 7 short and 6 long setae of which some are serrated. Mx-2 : proximal

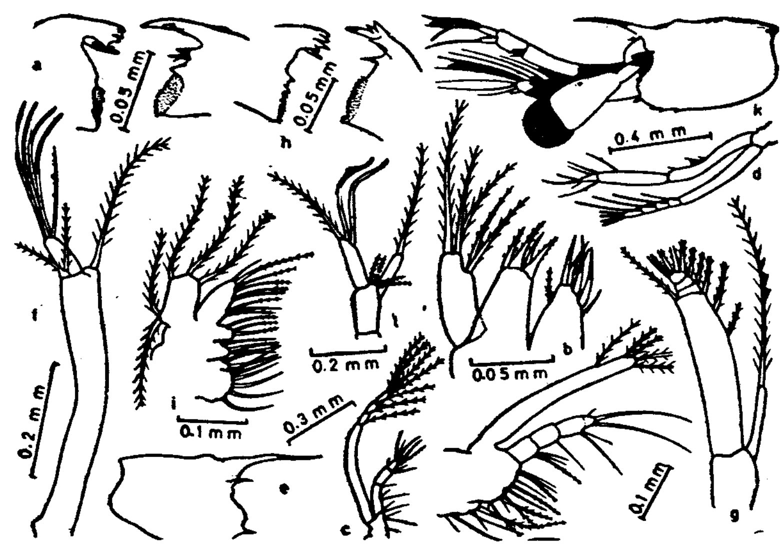

Fig. 1. *Hippolysmata* (*Exhippolysmata*) *ensirostris* : *Zoea I* : a- Md, b- Mx-1 ; c- Mxp-2, d- Mxp-3. *Zoea II* : e-carapace, f- A-1, g- A-2, h- Md, i- Mx-2, j- Mxp-1. *Zoea III* : k-anterior part of the body, l-flagellum of A-1.

endites roughly semicircular with 9 to 10 arched setae, 2nd endites is separated from the proximal one only by a small arch and bears 3 setae, distal endites with 3 to 4 long setae ; endopod unsegmented carrying 3 terminal and 6 inner setae ; exopod with 7 plumose setae. Mxp-1 : coxopod with 4 to 5 and basipod with 10 to 11 plumose setae ; endopod 4-segmented, distal segmentation faint, 1st, 2nd, 3rd and 4th segments with 3, 2, 2 and 3 setae respectively ; exopod longer than endopod with 4 apical and 1 sub-apical plumose setae ; Mxp-2 : exopod twice the length of endopod carrying 4 apical and 6 sub-apical plumose setae. P-1 (Fig. 2, b) : endopod 4-segmented, distal segment with 3 setae of which one is stout and serrated, penultimate and 1st segments with 4 and 3 setae respectively ; exopod as long as endopod with 4 apical and 6 sub-apical plumose setae ; T : triangular, broader posteriorly, carrying 7 pairs of spines, innermost spine being non-plumose and short. Uropod : biramous ; exopod with 9 plumose setae and endopod with 2 short apical non-plumose setae ;

Zoea III moults to the next stage after 48 hours.

Zoea IV (Fig. 2, c to j) ; Tl 3. 53 mm ; Cl 1.01 mm.

Dorsal surface of the carapace with prominent grooves, a tubercle with a spine present at the base of the rostrum. Supra-orbital, antennal and pterygostomial spines present ; behind the pterygostomial spine are seen 2 lateral spines. Eyes large, borne on elongated peduncle, a projection is developed on the distal part of the peduncle (Fig. 2, c) ; P-2 and P-5 developed, and behind P-2 is seen the biramous bud of P-3 ; the propodus of P-5 much flattened and brightly coloured due to the presence of orange red chromatophores.

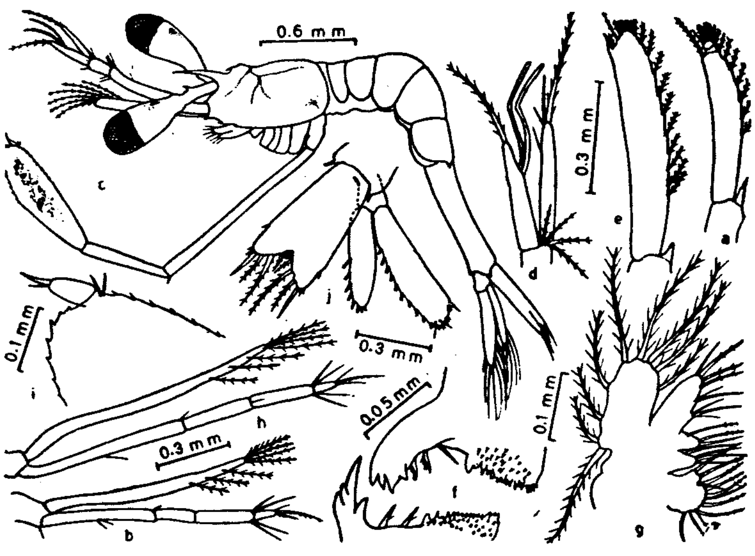

Fig. 2. *Hippolysmata* (*Exhippolysmata*) *ensirostris* : *Zoea III* : a- A-2, b- P-1. *Zoea IV* : c-lateral view (P-5 only shown), d- flagellum of A-1, e- A-2, f- Md, g- Mx-2, h- P-2, i- dactylus of P-5, j- uropod and telson.

A-1 : peduncle 2-segmented, 1st segment with 6 setae at the proximal outer region ; inner flagellum longer than the outer carrying a long plumose seta and 2 short non-plumose setae terminally (Fig. 2, d). A-2 (Fig. 2, e) : flagellum short devoid of apical seta ; scale with 17 setae and a spine, and without distal segmentation. Md (Fig. 2, f) : incisor produced carrying 4 to 5 teeth ; molar with rows of short stout teeth ; 2 to 3 slender teeth present in between the 2 processes. Mx-1 : proximal and distal endites with 7 to 8 and 6 to 7 setae, of which some are serrated distally. Mx-2 (Fig. 2, g) : exopod bears 9 plumose setae. Mxp-2 : protopod with 5 to 6 setae ; endopod 3-segmented, terminal segment with 5 setae of which 3 are stout, claw-like and serrated on the inner side ; exopod 3 times the length of endopod carrying 10 plumose setae distally. Mxp-3 : protopod with 2 setae ; endopod 4-segmented, distal segment bearing 3 setae of which 2 are pectinate, 3rd segment bears 6 setae of which 4 are pectinate ; P-1 : setae on the 2nd and 3rd endopod segments increased. P-2 (Fig. 2, h) : endopod 4-segmented, distal segment with 3 setae, 1st and 2nd joints carry one seta each ; exopod shorter than endopod with 4 apical and 3 pairs of sub-apical setae. P-5 (Fig. 2, c) : uniramous, more than 1.2 times the total length of the animal, 1st segment longest with a spine on the distal outer side, propodus highly flattened with serrated border carrying few spines ; dactylus small flat and with 2 small distal setae (Fig. 2, i). T : with a pair of lateral spines, distally it carries 7 pairs of spines, outermost 2 pairs are short, inner 4 pairs of spines plumose (Fig. 2, j). Exopod of uropod with one spine and 15 plumose setae ; endopod with 8 plumose setae.

This zoea moults to the next stage within 3 to 4 days.

Zoea V (Fig. 3, a to f) ; Tl 3.68 mm ; Cl 0.96 to 1.01 mm.

The presence of spine on the eye stalk, absence of lateral spines behind pterygostomial spines, presence of fully developed P-3, development of biramous buds of P-4 and the rectangular shape of the telson are the characteristic features of this zoeal stage.

A-1 : longer than carapace ; proximal segment of peduncle with 8 plumose setae on the inner side ; outer side distally carries 4 plumose setae and proximally carries 9 setae ; flagellae as long as the proximal segment of peduncle and show indistinct segmentation ; outer flagellum towards the middle carries 3 aesthetes ; both flagellae apically carry 3 setae of which one is long and plumose. A-2 : flagellum short and stumpy ; scale long and 7 times as long as wide and bears 21 plumose setae along its inner and distal margin and one spine at the outer distal margin. Md : incisor with 3 to 5 stout teeth ; teeth on the molar process show a serrated appearance. Mx-2 : exopod bears 14 plumose setae, distally it is produced and bears a long plumose seta at its apex. Mxp-3 : propodus of endopod with 9 to 10 pectinate setae ; exopod with 4 apical and 5 pairs of sub-apical long plumose setae. P-1 (Fig. 3, b) : basipod with one short spine-like seta on inner side ; endopod 4-segmented, carpus and propodus are almost of the same length, 1st segment with 3 short setae, 1st and 2nd joints with 1 and 3 setae respectively, propodus with 4 setae on the sides and 4 pectinate setae distally, dactylus with one stout claw-like seta and 2 slender setae of which one is pectinate ; exopod longer than endopod with 4 terminal and 7 pairs of lateral long plumose setae. P-2 (Fig. 3, c) : longer than P-1 and can be distinguished easily by the long carpus which is 1½ times the length of propodus, dactylus same as that of P-1 (Fig. 3, d). P-3 (Fig. 3, e) : biramous ; basipod with one seta ; endopod 4-segmented, distal aspect of propodus with 4 pectinate setae ; dactylus same as in P-1 and P-2 ; exopod shorter than endopod, bearing 6 pairs of setae. P-5 elongated ; carpus with 4 short setae and one spine. T : rectangular in shape with 2 pairs of lateral and 6 pairs of terminal spines of which the 2nd and 4th pairs being the longest (Fig. 3, f). Exopod of uropod with 20 plumose setae and one spine and endopod with 16 plumose setae.

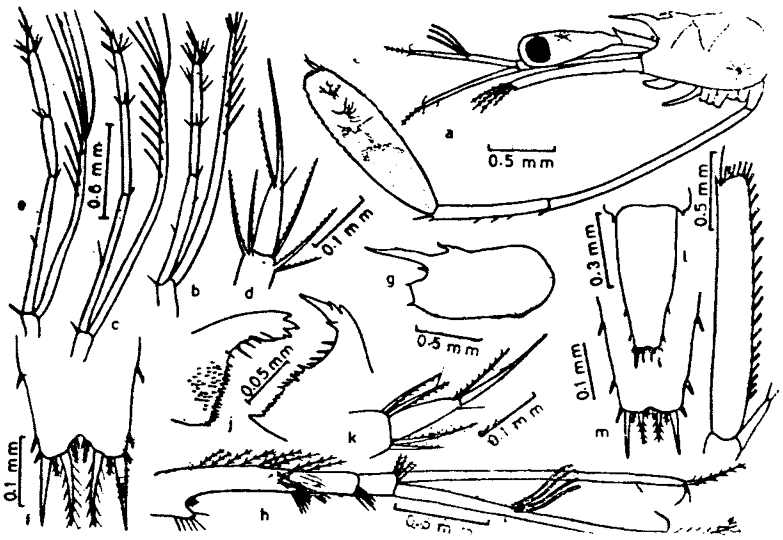

Fig. 3. *Hippolysmata* (*Exhippolysmata*) *ensirostris* : *Zoea V* : a- lateral view of cephalothorax (only P-5 shown), b- P-1, c- P-2, d- dactylus of P-2, e- P-3, f- tip of telson. *Zoea VI* : g- carapace, h- A-1, i- A-2, j- Md, k- dactylus of P-4, l- telson, m- tip of telson.

This zoea moults to the next stage after 2 to 3 days.

Zoea VI (Fig. 3, g to m ; 4, a) ; Tl 4.0 mm ; Cl 1.17 mm.

This stage is characterised by the presence of one dorsal rostral tooth (Fig. 3, g) and the development of P-4.

A-1 (Fig. 3, h) : proximal segment of the peduncle bearing 8 plumose setae on the inner side, a circlet of plumose setae developed towards the anterior part of the peduncle ; flagellae longer than the peduncle and show indistinct segmentation ; outer flagellum carries 4 aesthetes towards its middle. A-2 (Fig. 3, i) : flagellum short, 1/5 the length of scale, bearing 2 short setae at its apex ; scale with 25 plumose setae and one spine ; Md (Fig. 3, j) : number of teeth in between the processes increased. Mxp-3 : endopod 4-segmented, at the distal margin of the propodus 4 long pectinate setae present, in addition to these 5 pectinate setae also present in the distal half of the segment. P-2 : first segment of endopod bears 2 setae towards the middle on the lateral aspect, a spine present on the outer distolateral aspect, distal margin of the propodus with 5 pectinate setae ; exopod as long as endopod with 4 apical and 8 pairs of sub-apical plumose setae. P-3 : 1st segment of endopod twice the length of 2nd carrying 2 setae at its middle region, outer distal end bearing a strong spine, propodus slightly swollen carrying a number of setae along its surface and distally bearing 4 long pectinate setae ; exopod as long as the first two segments of endopod bearing 10 pairs of setae. P-4 (Fig. 4, a) : almost resembles P-3 ; propodus of endopod bearing distally 4 pectinate setae, dactylus with 3 apical setae of which one is pectinate and another stout and claw-like (Fig. 3, k) ; exopod as long as the 1st segment of endopod bearing 5 pairs of plumose setae. P-5 : 1st segment of endopod twice the length of 2nd, carrying one long seta in middle, one stout spine present on the distolateral margin of this segment, 2nd segment carries 4 spines of which the distolateral one on the outer side is long and stout. T : tapering towards the posterior end (Fig. 3, l) bearing 2 pairs of lateral and 6 pairs of terminal spines, the innermost 2 pairs of spines being the smallest (Fig. 3, m).

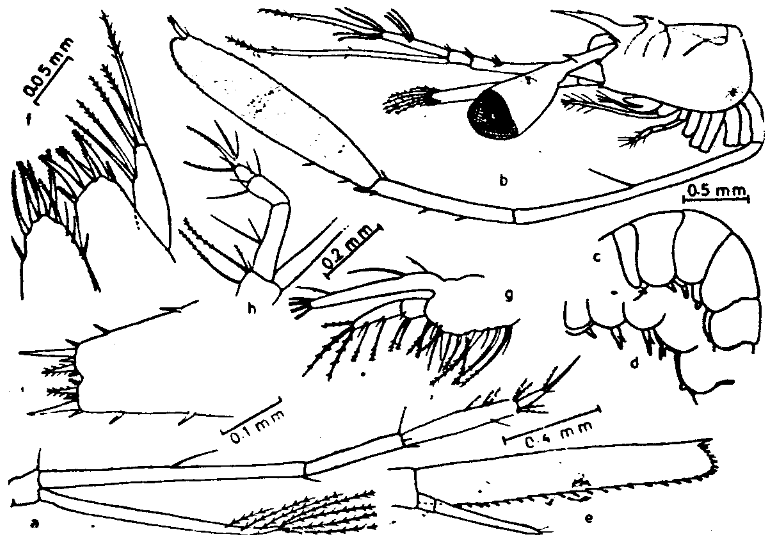

Fig. 4. *Hippolysmata (Exhippolysmata) ensirostris : Zoea VI :* a- P-4, *Zoea VII :* b- lateral view of cephalothorax, c- abdomen with uniramous pleopod buds, d- abdomen with some biramous pleopod buds, e- A-2, f- Mx-1, g- Mxp-1, h- Mxp-2, i-telson tip.

2 to 3 days are taken by zoea VI to moult to the next stage.

Zoea VII (Fig. 4, b to i) ; Tl 4.88 to 5.00 mm ; Cl 1.40 to 1.41 mm.

This stage is characterised by the development of uniramous pleopod buds which are bare (Fig. 4, c). In advanced larvae of this stage 2nd to 4th pleopod buds become biramous (Fig. 4, d).

A-1 : number of setae on the proximal segment increased ; flagellum longer than peduncle, carrying at their apex 3 setae of which one is long and plumose ; flagellae show indistinct segmentation ; outer flagellum bears 5 to 7 aesthetes in 2 groups of 1 to 3 and 4. A-2 (Fig. 4, e) : flagellum 2-segmented, ½ the length of scale, distal segment longest bearing 3 small setae at its apex ; scale with 29 plumose setae and one spine. Md : incisor process with 4 to 5 stout teeth on the right Md ; molar process bears a large number of small teeth, which have an irregular granulated appearance. Mx-1 (Fig. 4, f) : proximal endite with 10 to 12 and distal endite with 7 setae, majority of the setae are pectinate distally. Mx-2 : exopod with 25 to 26 plumose setae. Mxp-1 (Fig. 4, g) : coxopod with 4 to 5 setae of which one is stout and long ; basipod with 10 to 13 setae, many of them are plumose and endopod carries apically 2 long plumose and 2 small birstle-like setae ; on the inner side 7 setae in 3 groups of 2, 2, and 3 present ; exopod slightly expanded in the proximal region bearing 2 plumose setae, distally it bears 4 apical and one sub-apical plumose setae. Mxp-2 (Fig. 4, h) : protopod with 4 setae of which 2 are long and distally plumose ; endopod 3-segmented distal segment ends in a stout claw-like spine and around this 4 to 5 setae present. Mxp-3 : propodus on the distal half bears 11 pectinate setae. P-3 : propodus bears 12 setae. T : tapering posteriorly bearing 2 pairs of lateral and 5 pairs of distal spines (Fig. 4, i).

Zoea remains in this stage for 5 to 8 days. It moults twice before passing on to the next stage.

Zoea VIII (Fig. 5, a to j ; 6, a) ; Tl 6.11 to 9.11 mm ; Cl 1.8 to 2.7 mm.

Presence of 3 to 4 dorsal rostral teeth (Fig. 5, a) and the biramous pleopods with short setae on the exopods (Fig. 5, g to h) are the important characters of this stage. Eyes are prominent, as long as the peduncle of A-1 (Fig. 5, a).

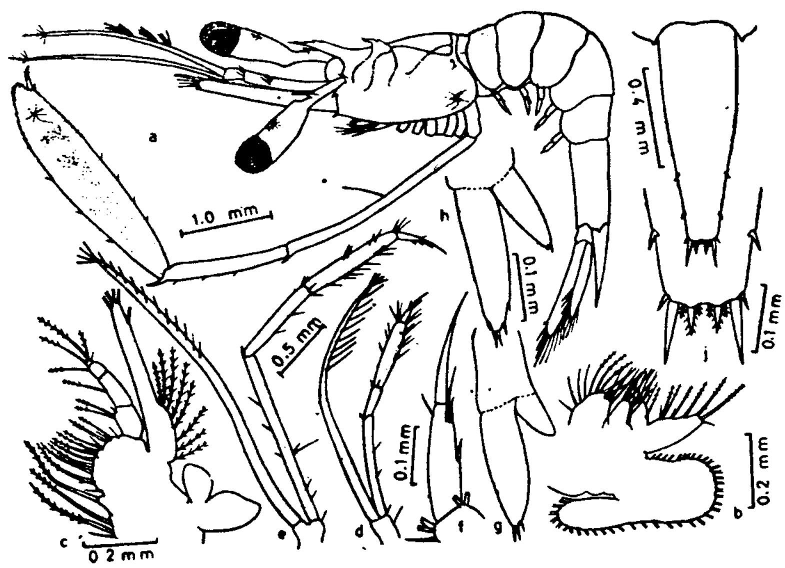

Fig. 5. *Hippolysmata* (*Exhippolysmata*) *ensirostris* : *Zoea VIII* : a- lateral view (P-1 to P-4, not shown), b- Mx-2, c- Mxp-1, d- Mxp-3, e- P-3, f- dactylus of P-4, g- pleopod I, h- pleopod II- i-telson, j- tip of telson.

A-1 : number of setae on the proximal segment increased, flagellum nearly twice the length of peduncle carrying apically 4 to 5 setae of which one is stout, longer than the rest and plumose ; outer flagellum with 10 aesthetes in 3 groups of 3, 3 and

4. A-2 : flagellum 2-segmented and longer than the scale. Mx-2 (Fig. 5, b): exopod with 40 to 45 plumose setae. Mxp-1 (Fig. 5, c) : base of exopod flattened bearing 8 plumose setae along the margin : bilobed epipodite present. Mxp-3 (Fig. 5, d) : setae on the propodus increased. P-3 (Fig. 5, e) : number of setae on the propodus increased and dactylus with 2 additional spines on the inner margin. P-4 : same as in the previous stage except for the presence of 2 additional spines on the inner side of dactylus (Fig. 5, f). P-5 : longer than the total length of the body (Fig. 5, a) ; propodus longer than the carapace, highly flattened, bearing marginal spines and setae and brightly coloured. P-5 : on one side, which was totally broken in the previous stage has been seen regenerated in one zoea of this stage. Though it is smaller than that of the P-5 on the other side, the general appearance is the same and the last segment is broader and longer (Fig, 6, a). T : narrower posteriorly (Fig. 5, i) bearing 2 pairs of lateral and 5 pairs of terminal spines, of which the inner 3 pairs of spines plumose (Fig. 5, j).

This zoea takes 6 to 12 days to moult to the next stage.

Except for the presence of lateral spines on the telson, this zoea closely resembles the *Eretmocaris* species A.I described by Gurney (1936).

Zoea IX (Fig. 6, b to k ; 7, a to g) ; Tl 11.39 mm ; Cl 3.5 mm.

Rostrum with 9 dorsal teeth (Fig. 7, a). Supra-orbital spine has become small. 1st and 2nd pereiopods chelate, and exopod and endopod of pleopods with marginal setae (Fig, 6, j). 2nd to 5th pleopods (Fig. 6, j) with appendix interna.

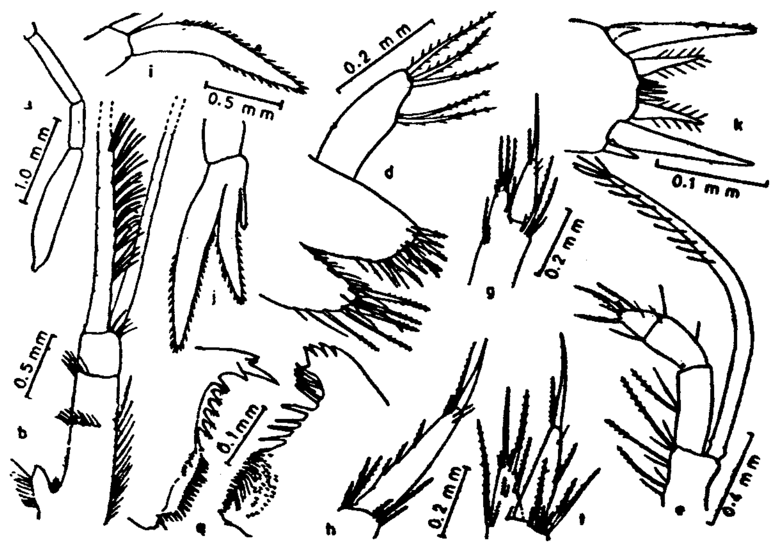

Fig. 6. *Hippolysmata (Exhippolysmata) ensirostris : Zoea VIII* : a- regenerated P-5. *Zoea IX* : b- A-1, c- Md, d- Mx-1, e- Mxp-2, f- chela of P-1, g- chela of P-2, h- dactylus of P-4, i- pleopod I, j-pleopod II, k- tip of telson.

A-1 (Fig. 6, b) : stylocerite prominent ; flagella 4 times the length of peduncle ; proximal part of the outer flagellum with a number of indistinct segments. Md (Fig. 6, c) : incisor process with 4 to 5 stout teeth ; molar process with numerous rows of short teeth which are serrated ; in between the processes 7 to 11 slender teeth present of which some are serrated. Mx-1 (Fig. 6,d) : proximal endite terminally bears 4 to 5 slender spine-like setae which are pectinate distally, in addition to these a number of slender bristle-like setae present all along the distal aspect of this endite ; distal endite with 7 stout serrated setae and a number of bristle-like slender setae. Mx-2 (Fig. 7, b) : setae on the exopod increased, distal lobe has become more

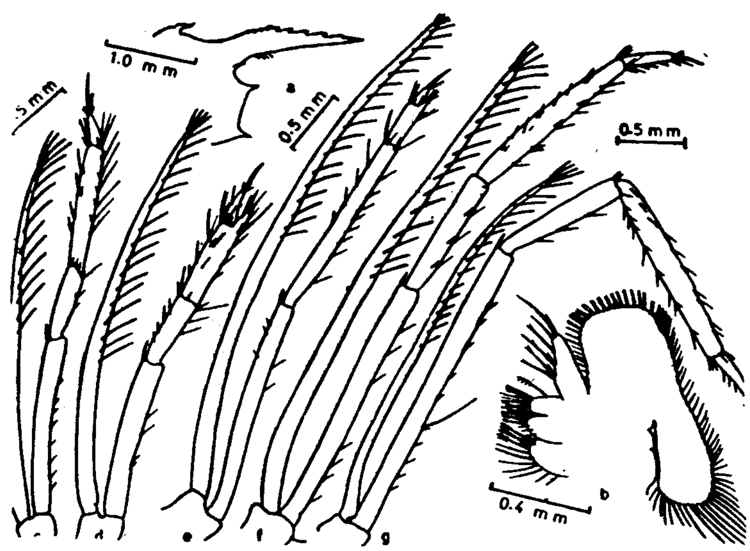

Fig. 7. *Hippolysmata (Exhippolysmata) ensirostris : Zoea IX :* a- rostrum, b- Mx-2, c- Mxp-3 d- P-1, e- P-2, f- P-3, g- P-4.

flattened. Mxp-1 : basal portion of the exopod flattened bearing 22 to 23 plumose setae along its broader, distally it carries 4 apical and 6 pairs of sub-apical plumose setae. Mxp-2 (Fig. 6, e) : endopod slightly expanded, dactylus has terminal claw-like pectinate setae, in addition to this 2 large pectinate and 4 bristle-like setae also present ; some of the setae on the basipod and 1st segment of endopod long and plumose distally. Mxp-3 (Fig. 7, c) : propodus with numerous setae and spines, inner margin of the 1st segment with 8 setae, one spine also present at the outer distal part. P-1 (Fig. 7, d) : distal part of the propodus elongated forming chela with dactylus ; fingers of the chela with a number of bristle-like pectinate setae (Fig. 6, f) ; bristle-like setae and spines are present on the carpus and propodus ; carpus shorter than propodus. P-2 (Fig. 7, e) : longer than P-1 : carpus four times the length of propodus ; fingers of the chela with a number of pectinate setae (Fig. 6, g). P-3 (Fig. 7, f) : endopod longer than exopod ; dactylus with 4 spines on the inner side ; bristle-like setae present on all the segments, and their number is more in propodus.

P-4 (Fig. 7, g) : longer than P-3, dactylus with 4 serrated spines on the inner side (Fig. 6, h), propodus with a number of bristle-like setae, 1st segment with numerous setae on the inner side of which one is very long. T : tapering posteriorly and carries 3 pairs of spines and 2 pairs of bristle-like setae, inner pair of spines plumose, outermost spine very short (Fig. 6, k).

The zoea takes 6 to 8 days to metamorphose into the post-larva I.

Post-larva I (Fig. 8, a to h ; 9, a to h ; 10, a to b) : Tl 11.14 mm ; Cl 3.55mm.

Body moderately stout ; rostrum with 12 dorsal and 6 ventral teeth, the dorsal tooth on the carapace is separated by a wide space from the 1st rostral tooth ; carapace with pterygostomial and antennal spines ; eyes large but not exceeding rostral tip, peduncle short and devoid of any spine (Fig. 10, a). At this stage larva leaves the planktonic life, pleopods become functional and are used for swimming.

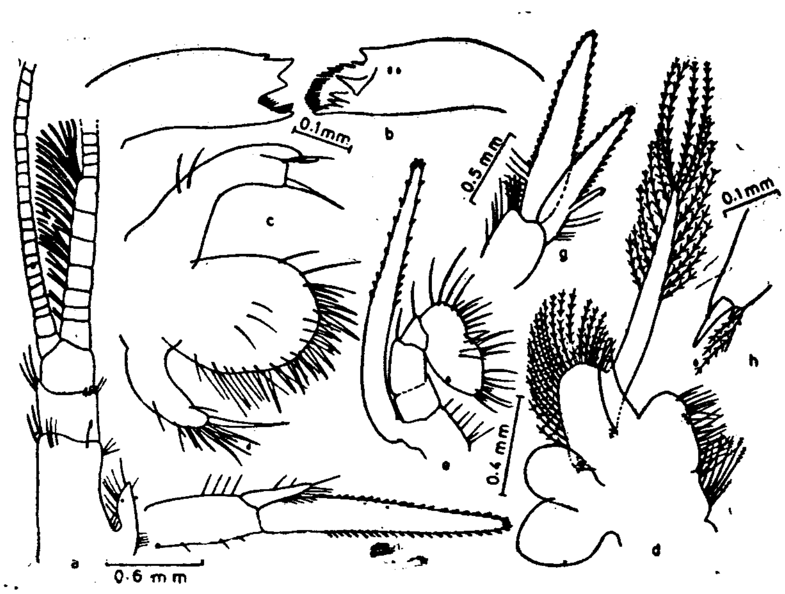

Fig. 8. *Hippolysmata (Exhippolysmata) ensirostris : Post-larva I :* a- A-1, b- Md, c- Mx-1, d- Mxp-1, e- Mxp-2, f- pleopod I, g- pleopod V, h-lateral spine on exopod of uropod.

A-1 (Fig. 8, a) : peduncle 3-segmented, proximal segment longer than the outer 2 combined ; stylocerite reaches beyond the middle of the proximal segment ; middle segment carries 3 small spines on the distal outer margin ; outer flagellum uniramous, basally stout bearing a number of aesthetes ; both the flagellum segmented ; A-2 : scale 4 times as long as broad ; basal 2 segments of flagellum stouter. Md (Fig. 8, b) : only molar process present, it bears 5 to 7 stout ridges and a number of bristle-like teeth. Mx-1 (Fig. 8, c) : proximal endite bears 5 to 7 stout spines and a number of bristle-like setae, this endite is arranged horizontally to the distal endite ; distal endite is circular in shape bearing a number of stout teeth and bristle-like long setae along its outer margin ; endopod terminally bilobed, distal lobe with a short seta apically, proximal lobe with 2 setae, about the middle 2 slender setae are also present. Mx-2 (Fig. 9, a) : 3 endites are seen ; proximal endite is smallest bearing a number of bristle-like setae along its inner margin ; endopod unsegmented bearing 2 apical and 2 lateral setae ; exopod expanded distally bearing a number of plumose setae along its margin. Mxp-1 (Fig. 8, d) : basipod broad with numerous bristle-like setae ; endopod unsegmented ; base of the exopod expanded bearing a number of plumose setae on the margin, distally it carries 4 long apical and 7 pairs of sub-apical plumose setae ; epipod bilobed and large. Mxp-2 (Fig. 8, e) : basipod with 7 slender setae : endopod 4-segmented, 1st segmentation very faint, propodus and dactylus coalesced and flattened bearing numerous setae ; exopod long with 4 apical

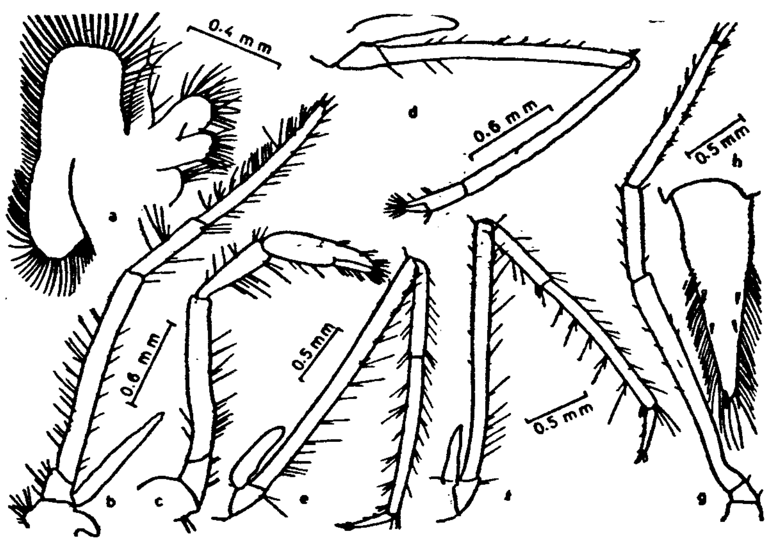

Fig. 9. *Hippolysmata* (*Exhippolysmata*) *ensirostris* : *Post-larva I* : a- Mx-2, b- Mxp-3, c- P-1, d- P-2, e- P-3, f- P-4, g- P-5, h- telson.

and 10 pairs of sub-apical plumose setae. Mxp-3 (Fig. 9, b) : endopod 3-segmented carrying a number of pectinate setae ; terminal segment carries stout spines ; exopod has become rudimentary ; epipod small. P-1 (Fig. 9, c) : merus twice the length of carpus; all segments carry bristle-like setae; exopod completely absent. P-2 (Fig. 9, d): longer than P-1 ; endopod 5-segmented ; merus and carpus almost of the same length, carpus shows indistinct segmentation ; exopod rudimentary without setae. P-3 and P-4 (Fig. 9, e and f) : almost identical in shape ; exopod rudimentary and bud-like without setae ; endopod 5-segmented, merus with 2 to 5 spines on the distal inner margin, propodus with spines and bristle-like setae, dactylus bearing 3 lateral and 1 distal spine. P-5 (Fig. 9, g) : endopod 5-segmented propodus with 13 spines and a number of setae, dactylus with 3 inner and 1 distal spine. Pleopod I (Fig. 8, f) : exopod 4 times the length of endopod carrying a number of plumose setae along its margin. Pleopod II (Fig. 8, g) : to pleopod V : almost identical in shape ; endopod smaller than exopod and carries appendix interna. T (Fig. 9,h) : shorter than uropod, carrying 2 pairs of dorso-lateral spines in the posterior half. T : tapers posteriorly and ends in a median point, on either side of which 2 spines are present

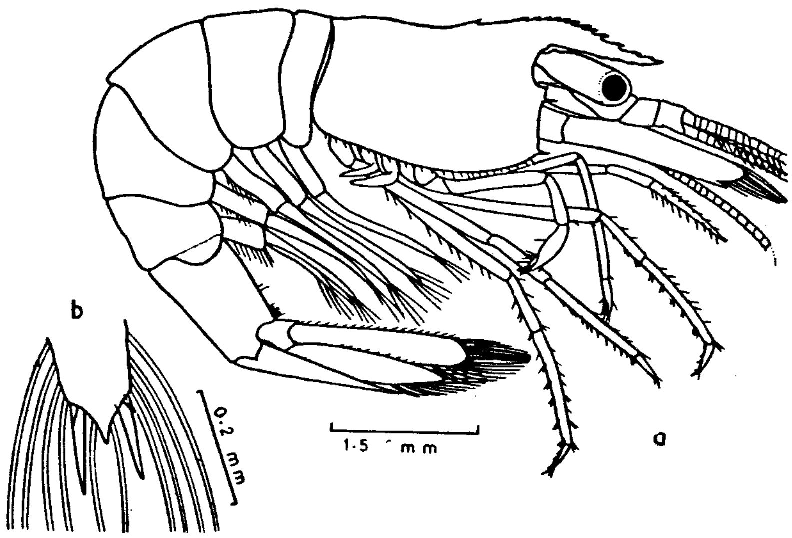

Fig. 10. *Hippolysmata (Exhippolysmata) ensirostris : Post-larva I* a- lateral view, b-tip of telson.

(Fig. 10, b) the outermost being small and placed slightly above the inner spine. All along the margin, telson carries a number of long plumose setae. Exopod of uropod has 2 spines placed inner to the outer distal angle, of which the longer and stouter one is movable (Fig. 8, h).

Discussion

One of the striking features in the larval development of this species is the possession of a highly elongated fifth pereiopod with an expanded oar-shaped propodus in the 4th zoea. This character is retained in the succeeding zoeal stages till the last moult into post-larva. Even when it is broken it is regenerated in the same form within two moults. Another important character noticed in the advanced larval stages of this species is the presence of a spine on the elongated eye stalk. The development of spine is indicated as a small tubercle on the eye stalk of 4th zoea. This becomes a conspicuous spine in the next stage and is retained until the zoea metamorphoses to post-larva. The presence of this spine in all the advanced stages clearly distinguishes these larvae from those described as *Eretmocaris* by Gurney (1936) (except *Eretmocaris* species A.I) ; by Dakin and Colefax (1940) and by Pillai (1955) as well as stage VI and VIII of *Lysmata* sp. by Menon (1940). *Eretmocaris* species A.I (Gurney, 1936) closely resembles the zoea VIII of the present species especially in the presence of spine on the eye stalk, but differs from it in the absence of lateral spines on the telson.

As mentioned earlier heavy mortality was noticed during the 3rd zoeal stage. This may be due to the fact that yolk granules present in the first 2 larval stages are completely absorbed in this stage and the larvae depend solely on external food from zoea III onwards. Further, owing to the development of long 5th pereiopods which is one of the important changes when the zoea passes on to the fourth stage, there may be greater physiological strain during moulting of 3rd zoea to 4th. The failure of rearing larvae of *H. vittata* by Pillai (1966) and *H. ensirostris* by Bensam and Kartha (1967) beyond the 3rd stage and the heavy mortality observed in this stage during the present observation clearly show that the 3rd moult is the critical one in the larval development of these shrimps.

Several differences are noticed in the early larvae of *H. ensirostris* described by Bensam and Kartha (1967) and the early larvae in the present series. Both being reared from known parents in the laboratory it is highly intriguing that such differences occur in the same species. The first 3 stages of *H. vittata* described by Pillai (1966) closely resemble the corresponding stages of *H. ensirostris*. The 1st zoea described by him is however longer than that of *H. ensirostris*. But the 1st zoea of *H. vittata* described by Kuriyan (1951) more or less agrees in length with the same stage of the present species. The distal expansion of one of the aesthetes on the outer antennular flagellum of the 1st stage of *Hippolysmata* sp. described by Menon (1940), is not present in the 1st stage of this species. The absence of this is also observed by Pillai (1966) in the description of 1st stage of *H. vittata*.

The description and figure of the late larvae of *H. ensirostris* given by Kemp (1916) closely resembles that of the 9th zoea of the present work. His post-larval description probably refers to the 2nd or 3rd post-larval stage. The presence of ventral rostral teeth, complete absence of mandibular incisor process and the telson ending in a sharp point carrying a pair of spines on either side clearly distinguish the post-larva I of the present species from *H. vittata* described by Pillai (1955).

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SECTION FOUR

Family Alpheidae Rafinesque, 1815

Genus Alpheus Fabricius, 1798

Genus _Alpheus_, Fabricius, 1798

INTRODUCTION

Alpheid prawns, belonging to the genus, _Alpheus_, Fabricius, are one of the most common caridean groups, distributed widely in the tropical marine and estuarine regions. Although a significant portion of the inshore meroplankton is formed of alpheid larvae, studies on the larval history, particularly on the basis of rearing them in the laboratory, are scanty. From India, Menon (1940) described the larvae of two species of _Alpheus_ collected from the plankton from the inshore waters of Madras. Later, Pillai (1955) dealt with an advanced postlarva of _A. pacificus_ and one postlarva of _Alpheus_ sp., both collected from the plankton of Travancore coast. Prasad and Tampi (1957) subsequently described one zoeal stage of _A. rapacida_ by rearing them in the laboratory. Bhuti _et al._ (1977) stating that very little information on laboratory reared alpheid larvae was available took up studies on the larvae of 4 genera viz; _Automate_, _Athanas_, _Synalpheus_ and _Alpheus_. But in the published paper (1977) he excluded the larvae of _Alpheus_, perhaps to be published at a later date. Knowlton (1973) successfully maintained _A. heterochaelis_ in the laboratory and studied the complete zoeal stages by rearing them under controlled conditions.

For the present study, two species of _Alpheus_, namely _A. euphrosyne_ and _A. rapacida_ were collected from the catches of the stake nets operated at Cochin backwaters near Thoppumpadi area (Fig. 1 C). Of these, the latter species was represented in small numbers. They were used locally as duck feed. Both these species are recorded from the southwest coast of India for the first time.

The methods of collection of adults, transportation, maintenance of adult and larvae and water management during the rearing experiments were similar to those presented in the chapter dealing with the 'Material and Methods'. Berried specimens with advance stage of berry were selected and individually maintained in 5 l glass troughs containing 4 l of water having a salinity range of 20-25‰. Hatching invariably occurred during the early morning hours. After all the eggs have been hatched and zoea released the mother alpheid was removed from the trough. The larvae from each brood were maintained separately in troughs and reared. First moult was observed within 3 hours. Second moult took place within 24-36 hours. From zoea I onwards the larvae were provided ad libitum food of freshly hatched Artemia nauplii. As they did not accept this food, attempts were made to rear the larvae with rotifers, chopped and graded polychete worm, Moina sp. and copepod spp. In a few experiments, live zooplankton collected from inshore areas and egg custard were also tried. However, there was no sign of the larvae accepting any of these food items. The larvae survived upto zoea III stage utilizing the reserve yolk. At zoea III stage, they thrived for 48 to 60 hours and died subsequently without moulting. The morphological characteristics of the first three zoeal stages of A. euphrosyne and A. rapacida are studied and presented here.

Alpheus euphrosyne De Man, 1897 (Fig. 59)

Alpheus euphrosyne De Man, 1897, p. 745., 1898, p. 317; Banner and Banner, 1966, p. 130-133; Thomas, 1976, 667-668.

Crangon euphrosyne Suvatti, 1937, p. 48.

The specimens at hand agree well with the descriptions given by Banner and Banner (1966) and Thomas (1976). Cornea of the eyes entirely covered by orbital hoods (Fig. 59 a). Rostrum short reaching the middle of first antennular segment. Rostral carina developed and orbitorostral grooves shallow. Pterygostomial margin rounded. Stylocerite broad, leaf-like, extending to the end of the antennular article. Distolateral spine of scaphocerite reaches to the end of the antennular peduncle. Large chela very massive in comparison with carpus and merus, 2.5 times as long as wide and with saddle-shaped depression (Fig. 59 c). Merus 2 times as long as wide. The small chela (Fig. 59 d) bearing balaeniceps dactylus, 4 times as long as broad, fingers shorter than palm, lateral margin of the dactylus with setae, tips of fingers crossing when closed; merus 2.6 times as long as wide. Dactylus of the third leg flattened (Fig. 59 f); ischium with a small spine (Fig. 59 e); merus 5.4 times as long as broad, carpus 0.5 as long as merus and propodus 0.7 as long as merus bearing 3 spines.

Distribution: Japan, Phillippines, Thailand, Indonesia, Australia, West Indies, Southwest coast of India. This species has been recorded for the first time from the Southeast coast of India.

Fig. 59 Alpheus euphrosyne: Adult male 43 mm in total length
a. anterior region, dorsal part, b. pereiopod II, c. large cheliped
d. small cheliped, e. pereiopod III, f. dactylus of pereiopod III.

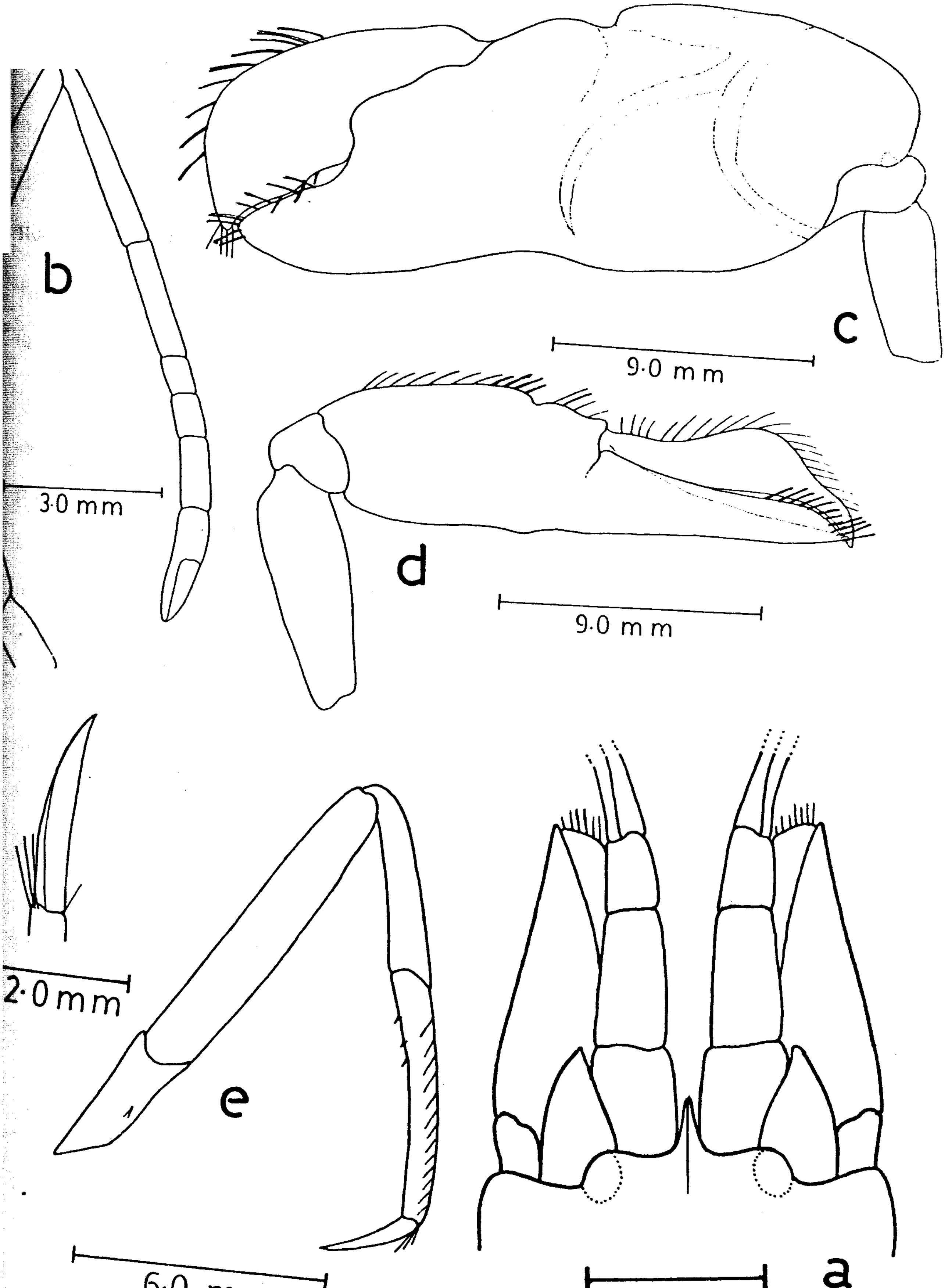


Fig. 59

DESCRIPTION OF THE LARVAL STAGES

Zoea I (Fig. 60 a-j)

Number of larvae examined : 10

Total length: 2.12 to 2.32 mm (2.25 mm). Carapace length: 0.59 to 0.67 mm (0.65 mm).

A typical first stage caridean larva with large sessile eyes. Rostrum slender, short, not reaching beyond eye (Fig. 60 a). Carapace smooth and its anterolateral edge produced into a small pterygostomial spine. Antennule, antenna and mouth parts developed. Buds of first and fifth pereiopods developed (Fig. 60 j). Abdomen 6-segmented; triangular telson joining with the sixth abdominal segment without an intervening articulation.

Antennule (Fig. 60 b): Uniramous. Peduncle long, unsegmented bearing 2 flagella distally, inner one in the form of a slender plumose seta. Outer flagellum stumpy and carries 3 aesthetes and 2 setae at its apex, of which one is plumose.

Antenna (Fig. 60 c): Biramous. Peduncle unsegmented, long and has one spine at its distal margin. It bears a scale (exopod) and a flagellum (endopod). Scale 4-segmented and bears 2 short plumose setae at its outer margin and ten setae along the inner and distal margin, of which the outer one is short and non-plumose while the rest are plumose. Endopod shorter than exopod, undivided and carries terminally one short non-plumose and another plumose seta.

Fig. 60 Alpheus euphrosyne: Zoea I a. dorsal view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. biramous bud of pereiopod I and uniramous bud of pereiopod V.

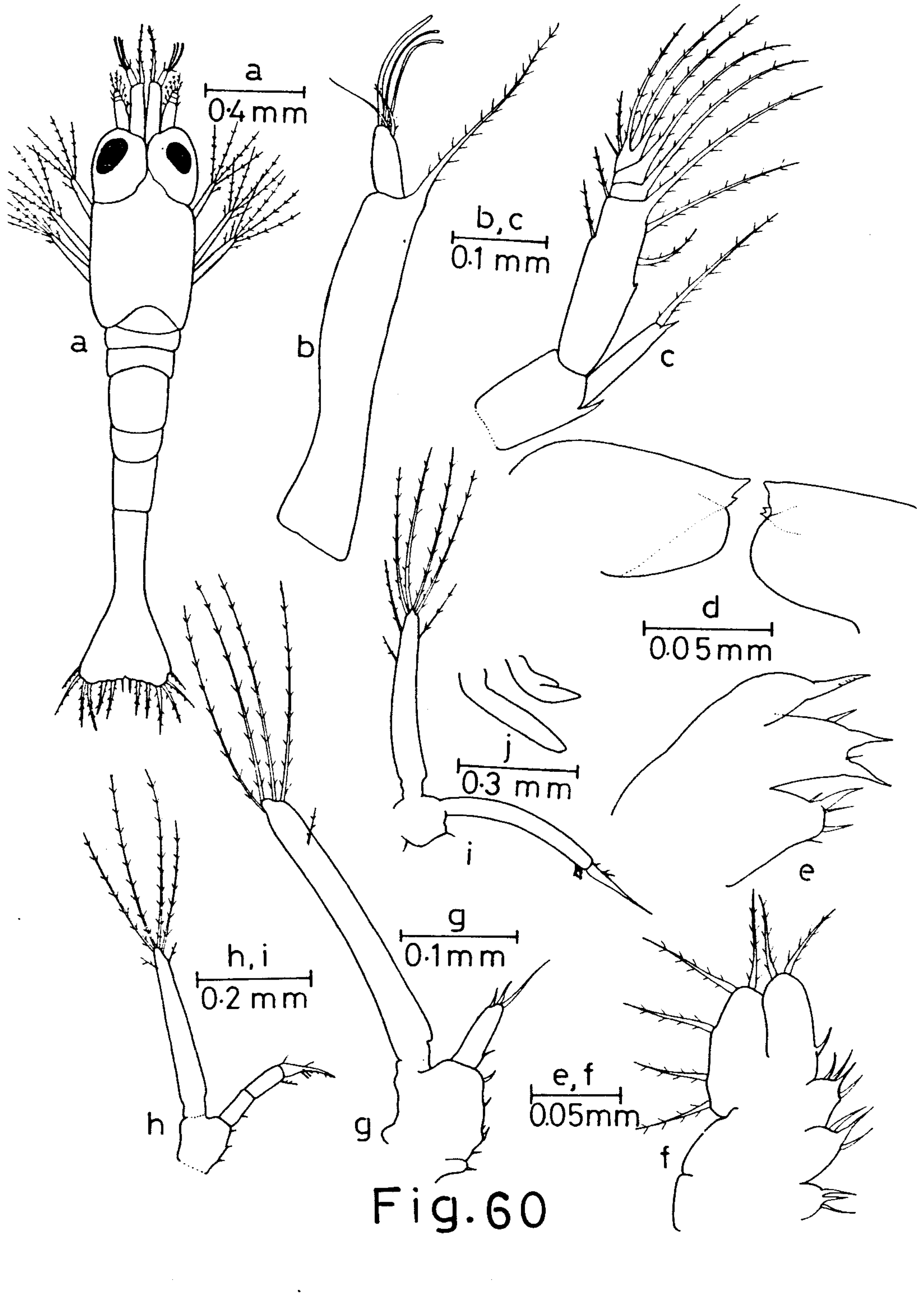


Fig. 60

Mandible (Fig. 60 d): Not fully developed, almost symmetrial and bears no palp. Incisor process bearing 2-3 short teeth, while molar smooth.

Maxillule (Fig. 60 e): Uniramous; Protopod unsegmented, with 2 endites. Basal endite with 5 setae of which 3 are slender. Distal endite carrying 2 short, slender and 2 stout spines. Endopod unsegmented bearing a stout seta at its apex.

Maxilla (Fig. 60 f): Biramous. Protopod with 3 endites, each of which carrying 3-4 short setae. Endopod unsegmented bearing 3 setae. Majority of the setae are non-plumose. Exopod bears 5 plumose setae.

First maxilliped (Fig. 63 g): Biramous. Basipod protuberant possessing 5-6 short setae. Endopod unsegmented carrying one seta on the lateral and 3 setae on the distal region. Exopod long and carries 5 plumose setae distally.

Second maxilliped (Fig. 60 h): Biramous. Basipod bears 3 short setae. Endopod 3-segmented; distal segment carries one serrated spine and 4 slender setae; first segment bears one spine and middle segment bears one short seta. Exopod longer than endopod and has 4 long and 2 short plumose seta.

Third maxilliped (Fig. 60 i): Biramous. Basipod has a short seta. Endopod 2-segmented and as long as exopod; distal segment carried one long and 3 short setae; first segment has 2 short setae. Exopod carries 2+4+1 plumose setae distally.

Biramous buds of pereiopods I and uniramous buds of pereiopod V developed (Fig. 60 j).

Telson (Fig. 60 a): Broad and posterior margin concave bearing 7+7 setae. Setae on the outer distal margin, plumose on the inner side only.

<u>Zoea II</u> (Fig. 61 a-j)

Number of larvae examined : 10

Total length: 2.31 to 2.55 mm (2.41 mm). Carapace length: 0.64 to 0.72 mm (0.69 mm).

Rostrum short but fully developed, eyes stalked (Fig. 61 a).

Antennule (Fig. 61 b): Peduncle 2-segmented. Inner flagellum short, bulbous bearing a long plumose seta at its apex. Distal segment carries 4 short plumose setae on one side. Proximal segment with one plumose seta at its distal margin.

Antenna (Fig. 61 c): No major changes when compared with the same of the previous stage.

Mandible (Fig. 61 d): Incisor with 3 and molar with 5-6 short teeth. 1-2 slender teeth present in between the two processes.

Maxillule (Fig. 61 e): Proximal endite carries 5-6 short setae. Endopod bears a long plumose seta at its apex.

Maxilla (Fig. 61 f): Further developed and setae on the endite plumose.

First maxilliped (Fig. 61 g): Basipod has 6-7 short setae.

Second maxilliped (Fig. 61 h): Basipod with 4 short setae. Endopod 4-segmented.

Fig. 61 <u>Alpheus</u> <u>euphrosyne</u>: Zoea II a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. biramous bud of pereiopod I and uniramous bud of pereiopod V, k. telson.

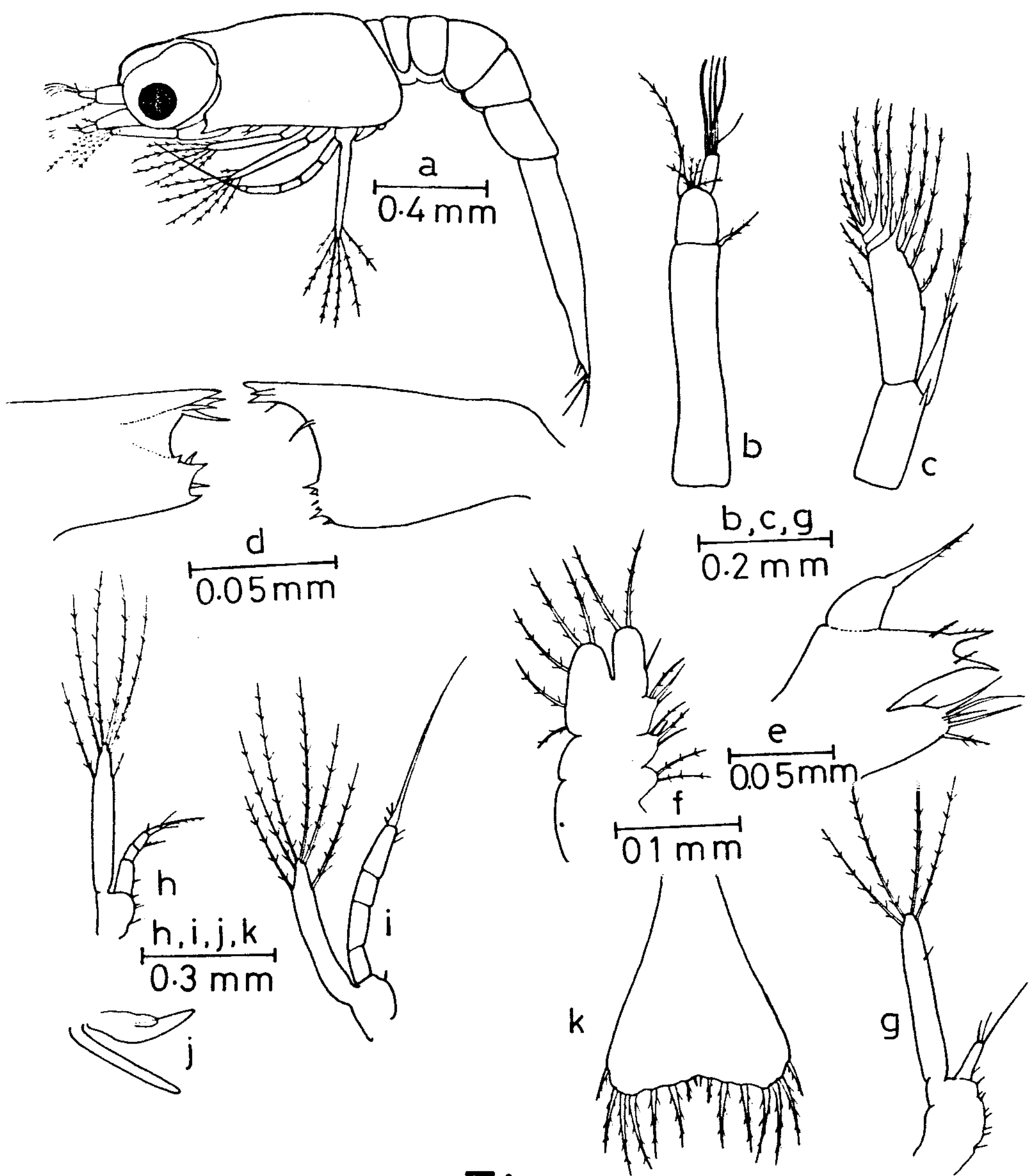


Fig. 61

Third maxilliped (Fig. 61 i): Endopod 4-segmented. Distal segment ends in a long seta which is as long as the endopod.

Biramous buds of pereiopod I and uniramous buds of pereiopod V further developed (Fig. 61 j).

Telson (Fig. 61 k): With 8+8 setae. Outer distal seta on either side plumose on the inner side. Innermost pair of seta short and non-plumose.

Zoea III (Fig. 62 a-m)

Number of larvae examined : 10

Total length: 2.10 to 2.46 mm (2.25 mm). Carapace length: 0.64 to 0.68 mm (0.66 mm).

Pereiopod I and pereiopod V developed (Fig. 62 a). Telson separated from the last abdominal segment by an articulating joint and uropods developed.

Antennule (Fig. 62 b): Inner flagellum half the length of the outer, bearing a long seta at its apex. Outer flagellum carries one slender seta and 2 aesthetes. Distal basal segment has 4 short setae on one side and 2 long plumose setae on the other.

Antenna (Fig. 62 c): Exopod with 11 setae along its inner and distal margins and one seta at the outer distal margin. Endopod shorter than exopod bearing 2 non-plumose setae distally.

Maxillule (Fig. 62 e), and mandible (Fig. 62 d): almost same as that of the previous stage.

Fig. 62 Alpheus euphrosyne: Zoea III a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. pereiopod I, k. biramous buds of pereiopods, l. pereiopod V, m. uropod and telson.

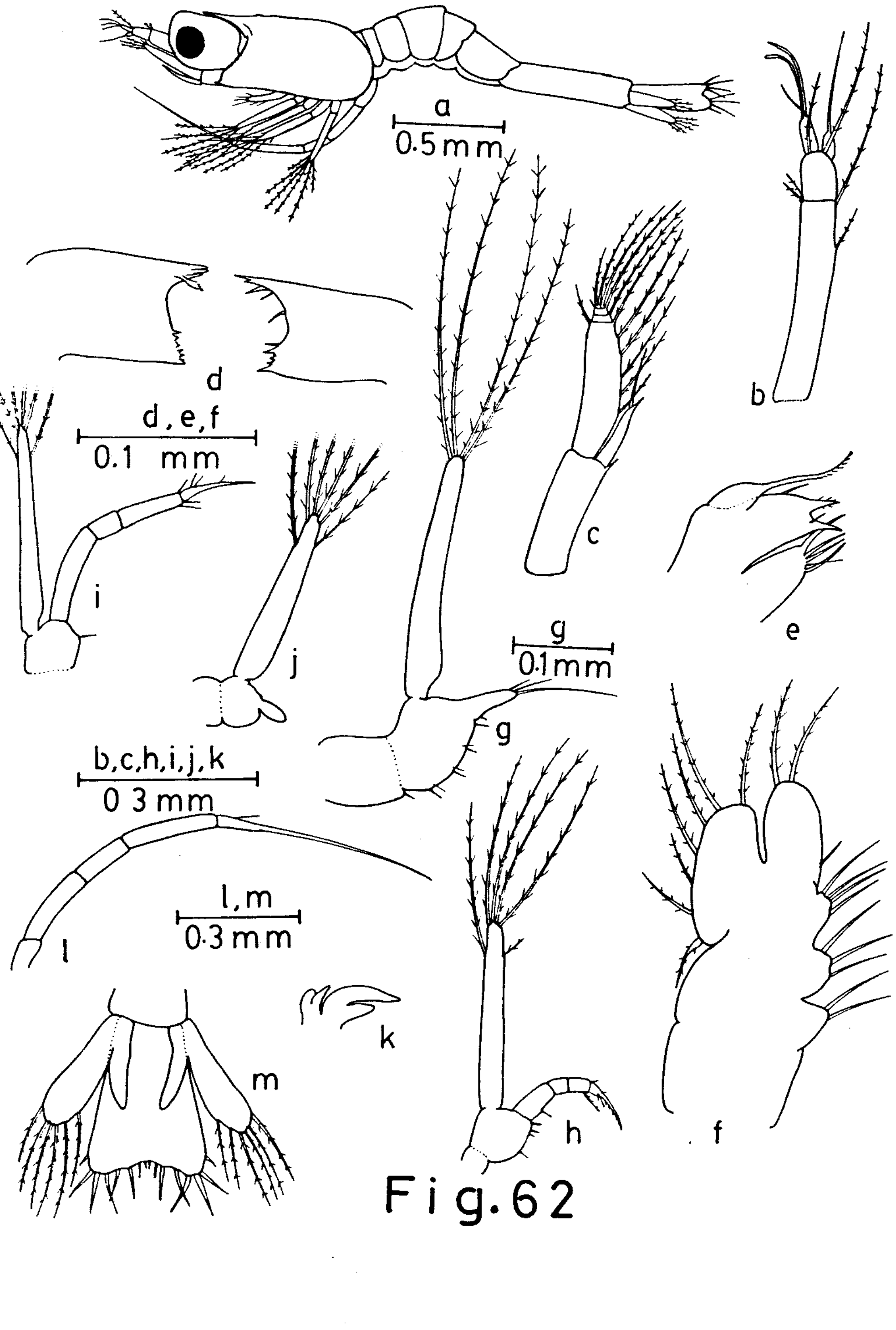


Fig. 62

Maxilla (Fig. 62 f): Exopod carries 7 plumose setae along its margin. Setae on the endites become slender and long.

First and second maxilliped (Fig. 62 g, h): No major changes observed when compared with those of the previous stage.

Third maxilliped (Fig. 62 i): The terminal seta on the distal endopodal segment shorter as compared to that of the previous stage. In addition, it bears 3 small setae. Third segment carrying 2 stout setae at its distolateral margin.

First pereiopod (Fig. 62 j): Biramous. Endopod small and palp-like. Exopod long bearing 1+4+1 plumose setae distally.

Fifth pereiopod (Fig. 62 l): Uniramous. Endopod 4-segmented. Distal segment ends in a long seta which is as long as the endopod.

Two biramous buds have developed behind pereiopod I (Fig. 62 k).

Telson and uropod (Fig. 62 m): Telson triangular and broad posteriorly bearing 8+8 setae. Innermost and outermost setae short and non-setose. Uropod biramous. Endopod bare. Exopod bearing 6 plumose setae distally.

2. Alpheus rapacida De Man, 1908

Alpheus rapacida De Man, 1908, p. 105, 1911, p. 394.

Banner and Banner, 1966, p. 118.

The characters of this specimen agree well with the descriptions given by Banner and Banner (1966). The diagnostic features are: Rostrum short and triangular. Rostrum and stylocerite reach almost to end of first antennular

Fig. 63 Alpheus rapacida: Adult female of 68 mm in total length a. anterior region, dorsal part, b. large cheliped, c. small cheliped, d. dactylus of pereiopod III, e. pereiopod III.

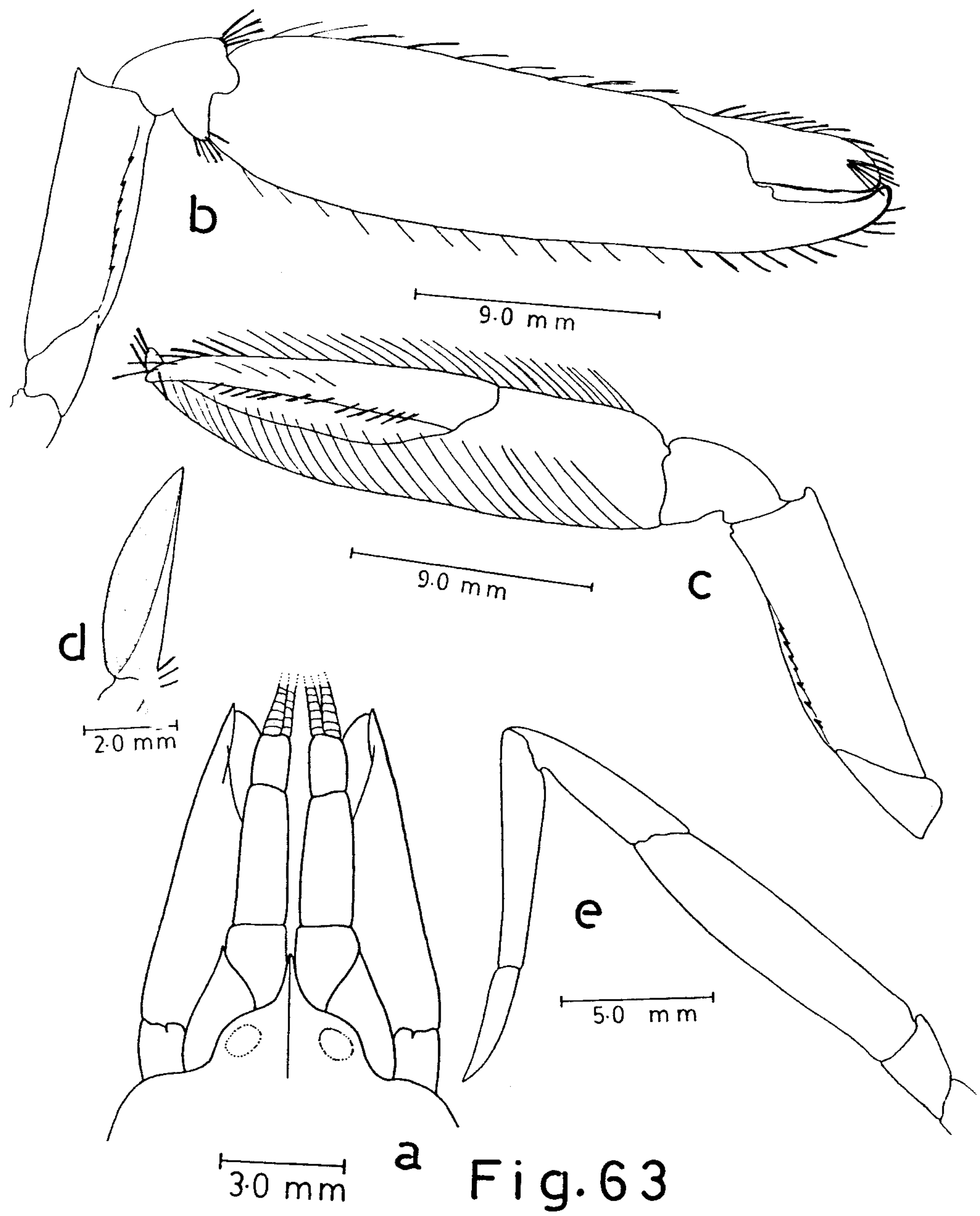


Fig. 63

article (Fig. 63 a). No orbital tooth and orbital hood inflated. Frontal margin between orbital hoods and base of rostrum concave. Carapace without mid-dorsal tooth. Scaphocerite with outer margin straight and distolateral spine reaching to end of antennal peduncle. Basicerite with a short acute lateral spine.

Large chela highly compressed, with smooth surface, without any sculpturing but both margins carrying setae. Chela 3.9 times as long as broad. Merus slender, 3 times as long as broad, internal margin bearing 7 spines. Small chela compressed, 4.2 times as long as broad (Fig. 63 c); finger 1.5 times as long as palm and merus 3.3 times as long as broad; ischium of third leg 0.2 times as long as broad; merus 4.6 times as long as wide; carpus and propodus 0.49 and 0.67 times as long as merus respectively. Dactylus 0.38 as long as merus (Fig. 63 e).

Distribution: Japan, Phillippines, Thailand, Indonesia, Australia and southwest coast of India.

DESCRIPTION OF THE LARVAL STAGES

Zoea I (Fig. 64 a-k)

Number of larvae examined : 10

Total length: 1.83 to 1.99 mm (1.93 mm). Carapace length: 0.47 to 0.52 mm (0.50 mm).

Body elongated. Eyes sessile. Rostrum very small and carapace with a pterygostomial spine (Fig. 64 a). Antennule, antenna and mouth parts developed. Buds of pereiopod I and V developed (Fig. 64 j). Telson not demarcated from the last abdominal segment.

Antennule (Fig. 64 b): Uniramous. Peduncle unsegmented, long bearing distally two flagella. Inner flagellum represented as a long plumose seta. Outer flagellum unsegmented bearing distally 3 aesthetes and 2 setae of which one seta is plumose.

Antenna (Fig. 64 c): Biramous. Basal segment has a small spine. Exopod 3-segmented distally bearing 10 setae along the inner and distal margin, of which the outermost one short and non-plumose. In addition, outer margin bears 2 plumose setae. Endopod unsegmented, less than half the length of exopod and terminally bearing one short and another long plumose setae.

Mandible (Fig. 64 d): Almost symmetrical and rudimentary. Incisor with 1-3 very small teeth while molar is smooth.

Maxillule (Fig. 64 e): Uniramous. Basal segment unsegmented, bears 2 endites, of which the distal one carries one slender and 2 stout teeth while the proximal one with 4 slender setae. Endopod unsegmented bearing one stout and non-plumose seta.

Maxilla (Fig. 64 f): Biramous. Basipod with 3 endites, each bearing 2 to 4 setae which are not fully developed. Endopod unsegmented and carries 3 setae. Exopod leaf-like, with 5 setae along its outer margin.

First maxilliped (Fig. 64 g): Biramous. Basipod with 5 small setae. Endopod small, unsegmented, bearing 3 setae distally of which one is very small. Exopod long bearing distally 4 long plumose setae.

Fig. 64 Alpheus rapacida: Zoea I a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. biramous bud of pereiopod I and uniramous bud of pereiopod V, k. telson.

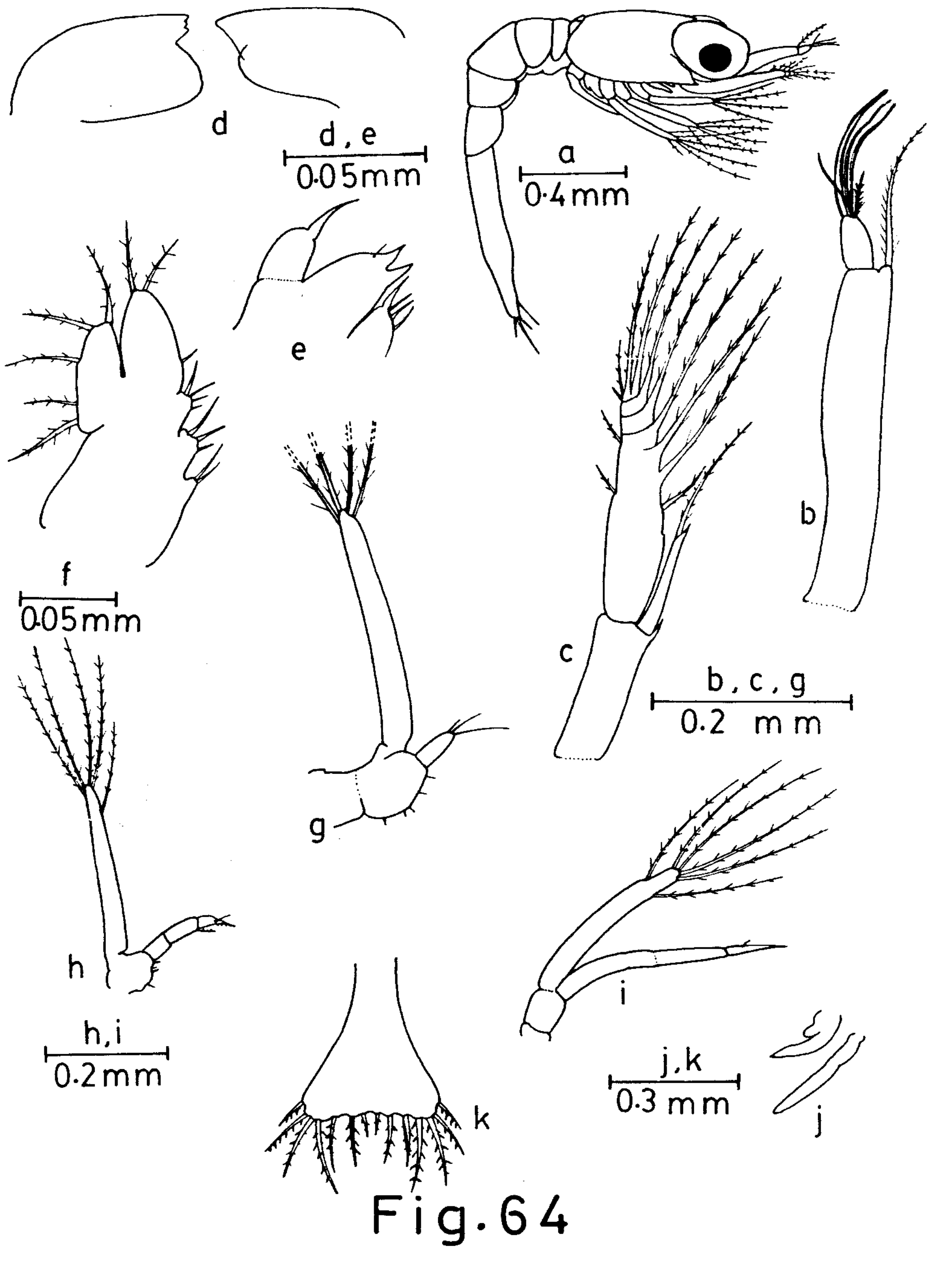


Fig. 64

Second maxilliped (Fig. 64 h): Biramous. Basipod with 4 short setae. Endopod 3-segmented. Distal segment with one serrated spine and slender seta. Middle segment distally carries one serrated spine. Exopod longer than endopod bearing distally 4 apical and one sub-apical plumose setae.

Biramous bud of pereiopod I and uniramous bud of pereiopod V developed (Fig. 64 j).

Telson (Fig. 64 k): Broadly triangular with concave posterior margin bearing 7+7 plumose setae of which the outer seta on both sides plumose only on the inner margin.

Zoea II (Fig. 65 a-i)

Number of specimens examined : 10

Total length: 1.88 to 2.09 mm (1.99 mm). Carapace length: 0.49 to 0.51 mm (0.50 mm).

Rostrum short and eyes stalked (Fig. 65 a).

Antennule (Fig. 65 b): Peduncle 2-segmented. Distal and proximal segments with 2 and 3 short plumose setae respectively. Outer flagellum carrying 4 aesthetes and 2 setae.

Antenna (Fig. 65 c): No major changes when compared with those of the previous stage.

Mandible (Fig. 65 d): Asymmetrical. Incisor with 3 and molar with 4-5 teeth. In between the two processes 1-2 slender teeth present.

Fig. 65 <u>Alpheus</u> <u>rapacida</u>: Zoea II a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III.

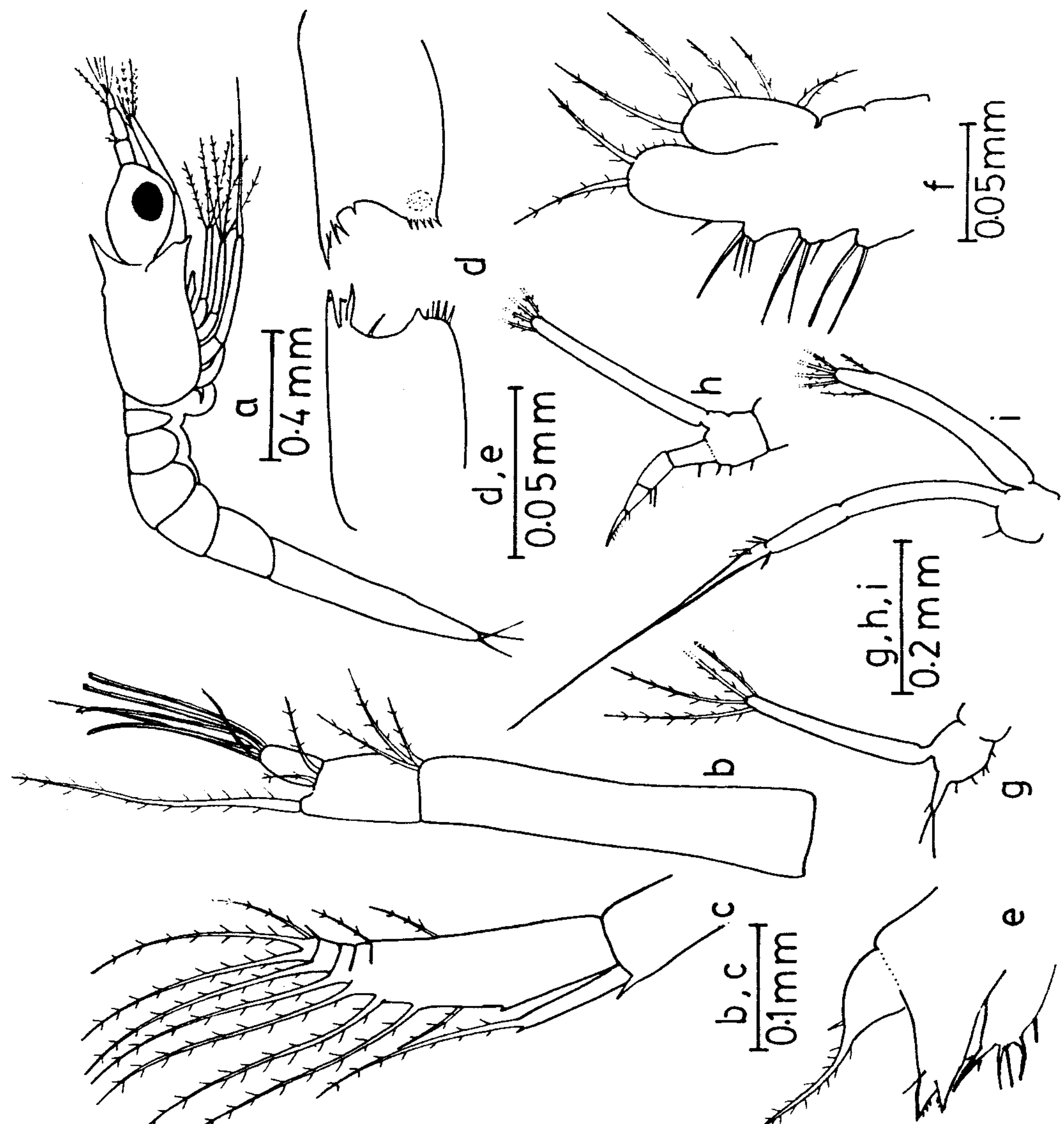


Fig.65

Maxillule (Fig. 65 e): Endopod with one stout long plumose seta along with a short slender non-plumose one. Proximal endite of basipod with 5 setae.

Maxilla (Fig. 65 f): Some of the setae on the basal endites became long and slender. Setae on the endopod and exopod plumose.

First maxilliped (Fig. 65 g) and maxilliped II (Fig. 65 h): Without any major changes as compared with those of the previous stage.

Third maxilliped (Fig. 65 i): Terminal seta on the endopod as long as that segment. 2 slender small setae are also present on distal segment in addition to terminal long one. Exopod with 4 apical and 2 sub-apical plumose setae.

Buds of first and last pereiopods further developed. Telson with 8+8 setae.

Zoea III (Fig. 66 a-l)

Number of larvae examined : 10

Total length: 1.88 to 1.99 mm (1.93 mm). Carapace length: 0.48 to 0.53 mm (0.50 mm).

Uropod developed and telson demarcated from the last abdominal segment by an articulating joint (Fig. 66 a, l).

Antennule (Fig. 66 b): Peduncle 3-segmented. First segment with one and second with 3-4 plumose setae. Distal segment carries 4 short plumose setae on one side and 2 long plumose setae on the other side. Inner flagellum short and bulbous bearing apically one long plumose seta. Outer flagellum more than 2 times longer than inner one, bearing one seta and 2 aesthetes.

Antenna (Fig. 66 c): Exopod bearing 11 plumose setae along its inner and distal margin and another plumose seta along the outer margin. Endopod less than half the length of exopod, unsegmented without any setae.

Mandible (Fig. 66 d): Without any further development than that of the previous stage.

Maxillule (Fig. 66 e): Proximal endite of basipod with 6 slender setae.

Maxilla (Fig. 66 f): Without any major changes when compared with those of the previous stage.

First maxilliped (Fig. 66 g): Basipod with 6 short setae.

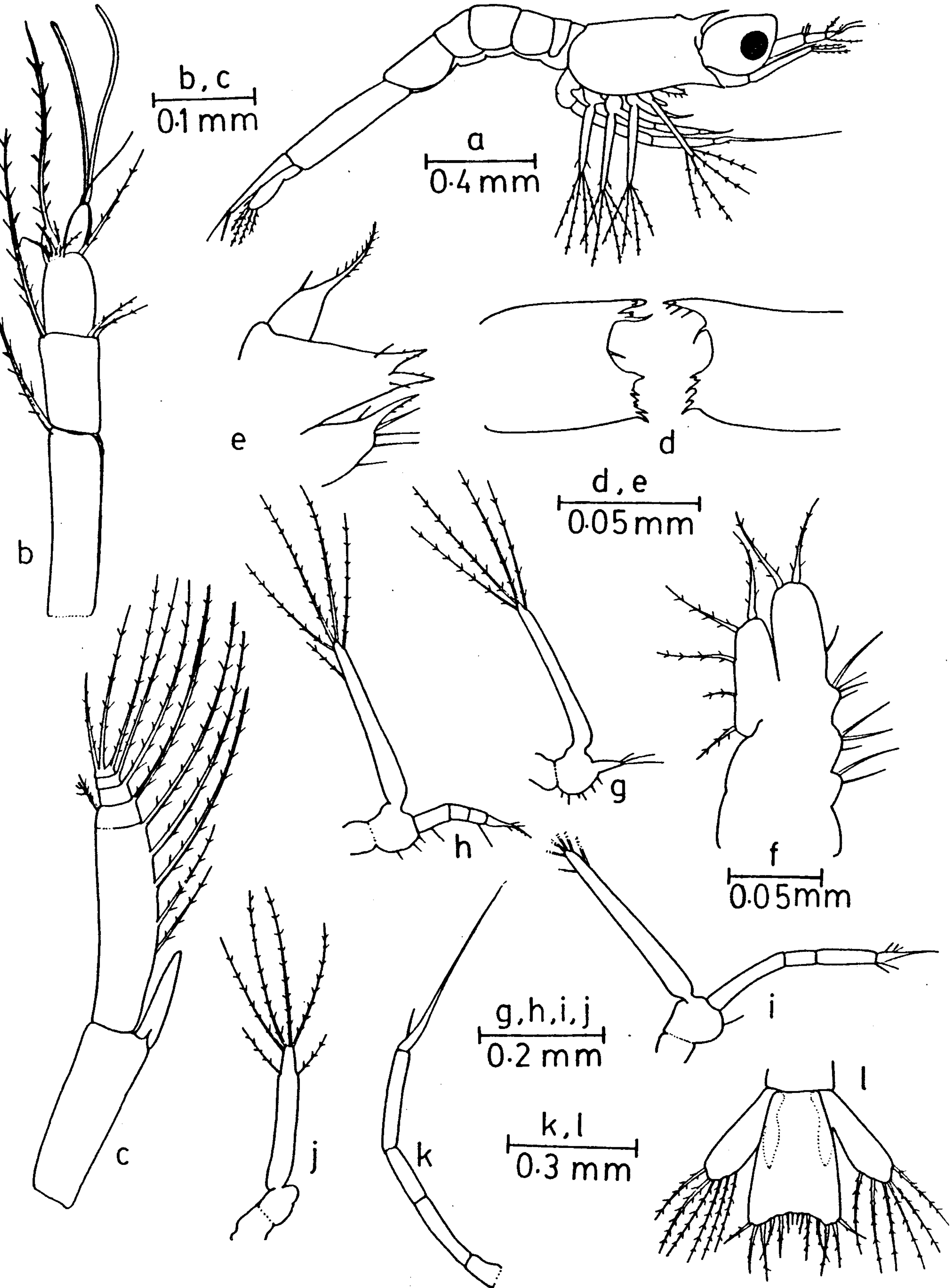
Second maxilliped (Fig. 66 h): Basipod with 3 setae. Endopod 4-segmented, distal segment with 3 slender and one stout setae, first and third segments carrying one seta on the inner side respectively.

Third maxilliped (Fig. 66 i): Segmentation on the endopod clear and the distal segment with 3 short and one stout setae.

First pereiopod (Fig. 66 j): Biramous. Endopod very small, palp-like and not developed. Exopod long bearing distally 4 apical and 2 sub-apical plumose setae.

Fifth pereiopod (Fig. 66 k): Uniramous. Endopod 5-segmented bearing distally a long slender seta which is as long as the endopod.

Fig. 66 Alpheus rapacida: Zoea III a. lateral view, b. antennule, c. antenna, d. mandible, e. maxillule, f. maxilla, g. maxilliped I, h. maxilliped II, i. maxilliped III, j. pereiopod I, k. pereiopod V, l. uropod and telson.



b, c
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h
i
j
k
l

Fig. 66

Uropod and telson (Fig. 66 l): Uropod biramous. Endopod bare and exopod with 6 plumose setae. Telson triangular, concave posteriorly bearing 7+7 setae. Generally this will be 8+8 and in this particular case the reduction in the number of seta cannot be explained properly without conducting further rearing experiments.

DISCUSSION

A comparison of the various morphological characters of the first three zoeal stages of A. euphrosyne and A. rapacida showed no major differences in the larval characters. However, it is noteworthy that the zoeae of A. rapacida were relatively smaller in size as compared to that of the corresponding stages of A. euphrosyne. Similarly, zoea III of both the species is found to be smaller as compared to zoea II of the same species. Nevertheless, these smaller differences noticed in the size of the zoeae of these two species cannot be considered as significant until all the zoeal stages are reared in captivity and compared. The endopod of maxillule of A. euphrosyne possesses a single seta in all the three zoeal stages. In A. rapacida along with this stout seta another smaller seta is also observed. But this small seta is absent in the descriptions given for the zoea II of the same species described by Prasad and Tampi (1957). However, until all the zoeal stages are studied, this character cannot be used as a distinguishing one between the two species.

The zoea of A. rapacida described by Prasad and Tampi (1957) appeared to belong to zoea II stage, as eyes are stalked, the telson has 8+8 setae and the uropod is not developed. The basipod of maxilla carries two endites and the exopod has 4 setae in the larvae described by Prasad and Tampi (1957). Further they have shown that the endopod of maxilliped II as unsegmented. In the corresponding stage of the present work, the basipod of maxilla had 3 endites, the exopod had 5 setae and the endopod of maxilliped II was 3-segmented.

Williamson (1967, 1970) while observing the decapod larvae collected from plankton from the Mediterranean coast of Israel and east coast of Sinai Peninsula, sorted the various zoeal stages of Alpheus under different groups. Majority of the larvae were found to be in the advance stage of development showing pleopod buds, in some of the larvae the pleopod buds were even biramous. As in the early zoeal stages of the present two species, all the zoeae of Alpheus described by Williamson (1967, 1970) had a well developed pterygostomial spine, and lacked the lateral spine on the fifth abdominal segment. Supraorbital spine was found to be absent in the zoeal stages of the both the species dealt with at present. The same was noticed by Williamson (1967, 1970) in the early larval stages of Alpheus spp. collected from plankton. However, he has observed a well developed supraorbital spine in the advanced zoeal stages of Alpheus spp. collected from the plankton. It is probable that the supraorbital spine develops only in the advance stage zoeal stages of species of Alpheus. The zoeal stages of A. heterochaelis described by Knowlton (1973) exhibited 'abbreviated mode of development'. Within 3 moults the freshly hatched zoea of this species developed to postlarva I. Further, biramous buds were observed to develop even in zoea II. As the larvae of the 2 species presented here have a prolonged larval development, they were not comparable with the larvae of A. heterochaelis having an abbreviated larval development.

SECTION FIVE

Comparative account of the larval stages of different species

SECTION FIVE

Comparative account of the larval stages of different species

COMPARATIVE ACCOUNT OF THE LARVAL STAGES OF DIFFERENT SPECIES

The caridean prawns, as mentioned earlier, are widely distributed in different ecosystems ranging from sea, estuaries, mangrove swamps to feshwater lakes and streams. On the basis of their natural habitat and distribution, they can broadly be classified into four groups, namely, 1. purely marine forms, 2. marine forms entering into estuaries/brackishwaters, 3. freshwater forms entering into estuaries/brackishwaters, and 4. purely freshwater forms. Among the caridean prawns studied at present, none is represented in the first category which generally includes the species living in the deeper marine regions. The littoral form, Hippolysmata (Exhippolysmata) ensirostris, which enters the estuaries in the early stages, belongs to the second group. All the other species fall under the third group. Here again, depending on the capacity of their tolerance to varying levels of salinity, they may further be categorised into two groups. The first group comprising of species whose adults essentially inhabit low salinity brackishwater and do not penetrate very deep into freshwaters. The second group comprises animals which spend their adult phase in freshwater (Macrobrachium sp.). However both the groups require brackishwater environment for breeding and larval development.

A general appraisal of the life histories of the caridean prawns which utilise the estuaries/brackishwaters, brings out several similarities in their life processes. These are particularly pronounced in their reproductive strategy and larval development. Several investigators (Sollaud, 1923; Knowlton, 1973;

Magalhaes and Walker, 1988) working on this aspect have observed three basic types. In the first type are included those species which produce relatively large number of small eggs and show prolonged larval development with several free swimming zoeal stages. The intermediate type is characterised by a fewer number of eggs and relative to their fecundity, a sequence of progressively abbreviated larval development. The third type includes the species which generally live in freshwaters and produce only a few large eggs and exhibit almost a direct larval development, where the newly hatched larva exhibit most of the postlarval characters. Considering this classification, all the species studied at present belong to the first type showing an extended larval development pattern with 6 to 10 well developed zoeal stages.

Although some of the species of Macrobrachium (M. dayanum and M. choprai) are known to complete their life cycle in the freshwater, most of the species move out into estuaries/brackishwaters for purpose of breeding. After spawning, the adults as well as the juveniles return to their natural habitat which is freshwater. That certain amount of saline environment is essential for the larval development and survival for the species of Macrobrachium studied at present is evident from the results of the experiments carried out on the salinity requirements of larvae vide. supra. The experiments revealed that although the eggs could develop and hatch out into zoea larvae in freshwater, the zoeae fail to develop further. Again, it has been observed that the berried females, the early zoeae (zoea I to zoea III) as well as the advanced zoeae (zoea VIII to zoea X) and postlarva I could tolerate wide salinity variations from 5 to 30‰. This ability of the breeders and larval stages to withstand wide fluctuations in salinity is obviously an adaptation for their survival in the estuary where they are exposed to great changes in salinity. Discussing the distribution of Indo-Burmese freshwater prawns, Tiwari (1955 b) suggested that the genus Palaemon originated rather late in the geological history, probably in littoral areas, and began migrating to freshwater. Some of the species which had migrated to freshwater early, got themselves completely established in the inland system, whereas, others which started invading freshwater recently had not yet completed the process. This is substantiated by the migration of certain species to brackishwater for breeding and ability of the larvae to tolerate higher salinities. The present observations on the breeding behaviour and larval history of M. equidens, M. striatus and M. idella also confirm to this pattern and indicate the absolute requirement of certain amount of saline conditions for the development and survival of the larvae and their adaptation to withstand varying salinity regimes. Further it is also observed that maximum survival and development of zoea I to postlarva I are recorded when they are reared in the salinity range of 15-20‰ in the case of M. idella and 20-25‰ in respect of M. equidens and M. striatus. These observations lend support to the inference of Tiwari (1955 b) that these species are still in the process of evolving into freshwater forms.

Although these prawns in nature breed essentially in the estuaries during July to September, when the salinity of the estuarine waters lowers due to the influx of rain water and land drainage, in the laboratory, when they were kept at 10-15‰ salinity and provided with appropriate food and suitable males the breeding process continued upto March - April. Thus it is observed that the incubation period of eggs in the berry of M. equidens, M. striatus and M. idella is 16 to 17 days at temperature 27 to 29°C. At a total length of 42 to 44 mm laboratory reared females of M. equidens and M. idella attained maturity. Further, females of M. equidens and M. striatus maintained in the laboratory were found to moult, spawn and acquire berry and give viable eggs 5 to 7 times over a period of 123 to 126 days.

One of the important morphological characters which has attracted considerable differences of opinion and discussion among the workers is the spines in the carapace, its pattern of development and terminology. Gurney and Lebour (1941) have suggested that "in the larvae of palaemoninae the carapace may at first have an anterior point which has been called as pterygostomial spine". Later this point becomes a spine and moves upwards and another spine develops below or behind it. The first spine eventually becomes antennal spine and the second, branchiostegal or hepatic spine. In Mesocaris there is a pterygostomial spine and at the same time another spine also presents above it which could be antennal. The former, therefore is considered as a homologue of branchiostegal - hepatic, but not the antennal spine. In view of these seeming inconsistencies in the development of spine, they have concluded that it is difficult to adopt a consistent nomenclature for the spines of the larvae and these may be referred by names which indicate their position at the moment rather than the names which describe their homology or final position. Further Gurney (1942) stated that "antennal, branchiostegal and hepatic spines would seem to belong properly to the post larval phase and their homologies are not clear". But during the present investigations the author was privileged to observe the development of pterygostomial and branchiostegal spines from the first zoea through all the subsequent stages upto the adult phase. In this connection it is worth mentioning that there are again variations in the terminology used by different scientists to describe these spines in the zoeae. Choudhury (1970, 1971), Kewalramani (1971), Williamson (1972), Greenwood (1976), Atkinson (1977) consider the two spines at the anteroventral margin of carapace as pterygostomial (bifurcated). Where as Pillai and Mohamed (1973) and Dugger (1975) consider the anteroventral spine developed in the zoea I and zoea II stages as pterygostomial and the next one to develop above it as branchiostegal. Jalihal (1978) while describing the abbreviated larval history of M. tiwarii and M. kistnensis described the anteroventral spine as pterygostomial while the second spine developed later in zoea III as antennal, which is retained as the antennal spine of the adult. For the present discussion the terminology used by Pillai and Mohamed (1973) and Dugger (1975) is followed and thus the anteroventral spines on the carapace of zoeal larvae are named as pterygostomial and branchiostegal respectively.

Zoea I of all the Macrobrachium species dealt with in this work carried a pterygostomial spine at the anteroventral margin of the carapace (Fig. 67 a). A branchiostegal spine just above this developed in zoea III (Fig. 69 a). These two spines were retained as such in all the subsequent zoeal stages (Fig. 67 b; 69 b) until they metamorphosed to postlarva I (Fig. 69 c). It was observed

Fig. 67 Carapace and abdomen of caridean larvae: *Macrobrachium equidens*: a. zoea II, b. zoea IV.

Caridina longirostris: c. zoea II, d. zoea IV.

Palaemon (Palaemon) concinnus e. zoea II, f. zoea IV.

Leptocarpus potamsicus g. zoea IV.

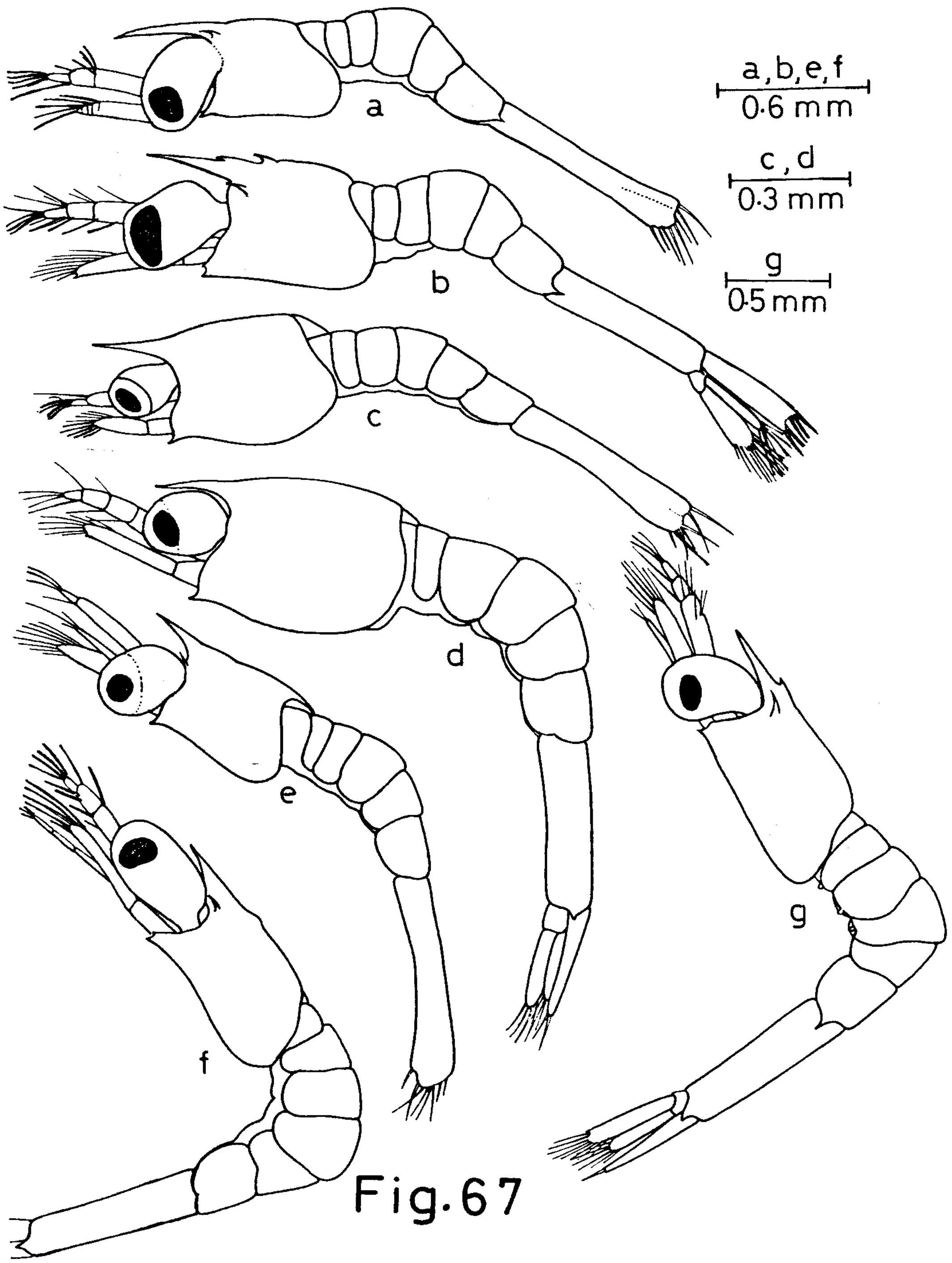


Fig. 67

that from postlarva I onwards, the pterygostomial spine gradually moved towards the hepatic region, each time the larva moulted (Fig. 69 d, e). Thus after a series of moults, this spine became fully developed and occupied the hepatic region as hepatic spine (Fig. 69 f). Likewise the branchiostegal spine had shifted and developed to the antennal spine of the adult (Fig. 69 f). Thus the hepatic spine and the antennal spine of the adult were developed from the pterygostomial and branchiostegal spines of the zoea larvae.

In the case of Leandrites celebensis the adult specimens are characterised by the presence of a well developed antennal and branchiostegal spines. The zoea larvae had a pterygostomial spine from the second stage which was retained up to the last zoea stage (Fig. 68 a, b; 69 k). Branchiostegal spine was absent in the zoeal stages (Fig. 68 a, b). When the last zoea metamorphosed to postlarva I, the pterygostomial spine although of the same size as that of the previous stage gets shifted away from the pterygostomial position, towards the branchiostegal position (Fig. 69 l). In the postlarva II the pterygostomial spine further moved towards the branchiostegal position and the antennal spine appeared in the postlarva I was observed to be fully developed (Fig. 69 m). Thus it could be stated that pterygostomial spine in the zoea of Leandrites celebensis moved to branchiostegal position and became the branchiostegal spine when the zoea metamorphosed to postlarva and the antennal spine developed for the first time at the postlarva I was retained as such during further development.

The presence of a well developed antennal spine and branchiostegal groove are the characteristic features of the adult specimens of Leptocarpus

Fig. 68 Carapace and abdomen of caridean larvae: Leandrites celebensis a. zoea II, b. zoea IV.

Hippolysmata (Exhippolysmata) ensirostris c. carapace of zoea II, d. eye, carapace, abdomen and pereiopod V of zoea IV, e. eye and carapace of zoea V.

Alpheus rapacida: f. zoea II, g. zoea III.

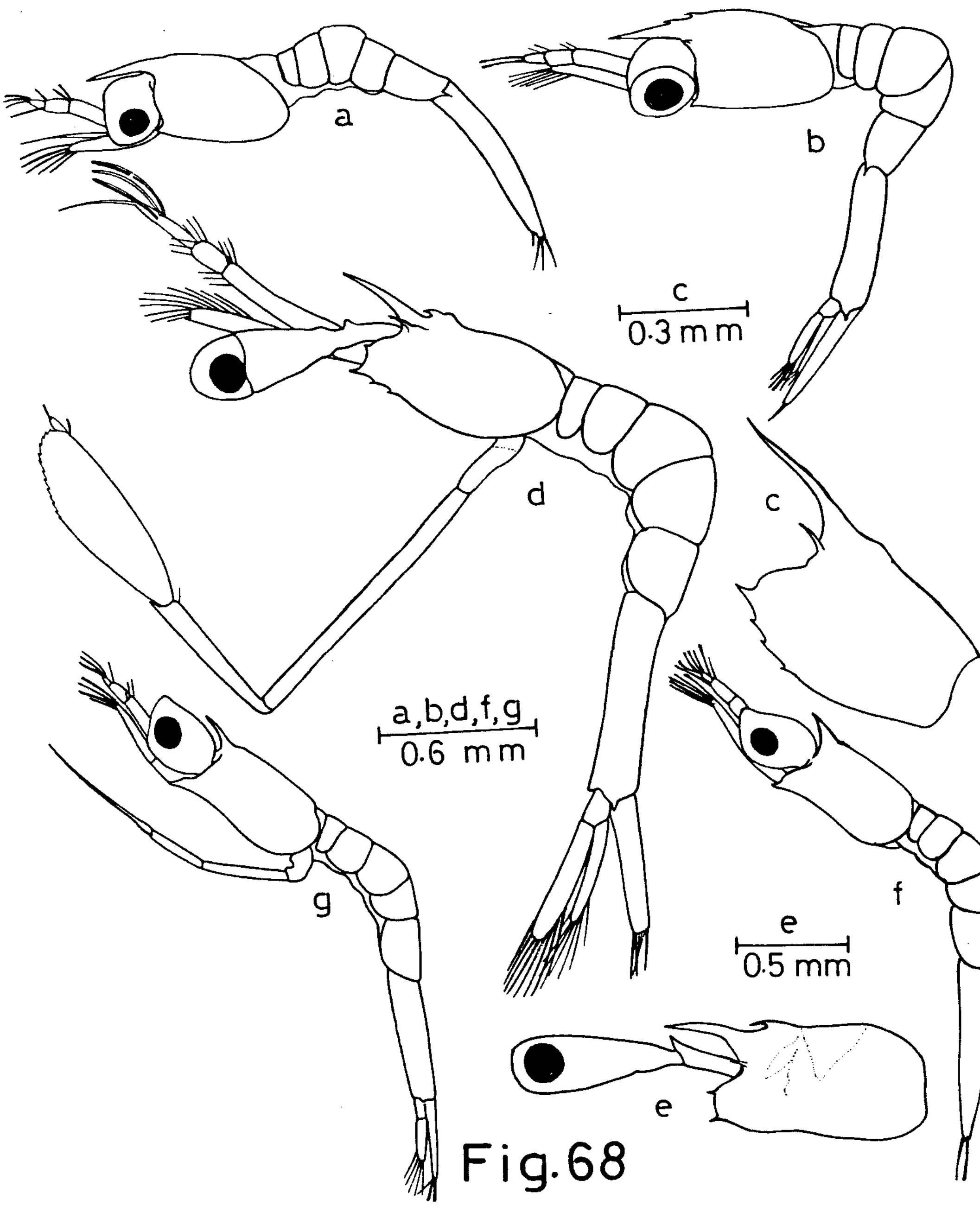


Fig. 68

potamiscus. Zoea I of the species carried a small pterygostomial spine which was retained upto the last zoeal stage (Fig. 67 g; 69 n). Branchiostegal spine which developed at zoea III persisted upto the last zoeal stage. When the last zoea metamorphosed to postlarva I both these spines were also retained (Fig. 69 o). From postlarva II onwards a gradual shifting of the pterygostomial spine towards hepatic region was observed during the successive moults (Fig. 69 p, q), similar to that observed during the development of Macrobrachium sp. As the adult is without any hepatic spine, along with the progressive shifting of this spine, the size became smaller and smaller and the spine completely disappeared when the postlarva reached a size of 30 mm in total length (Fig. 69 r). Thus the tendency of the pterygostomial to develop in to hepatic was clearly indicated. The branchiostegal spine was observed to shift upwards and occupy the antennal position and became the antennal spine of the adult (Fig. 69 r). Thus it was clear that the branchiostegal spine of the zoea larva became the antennal spine of the adult.

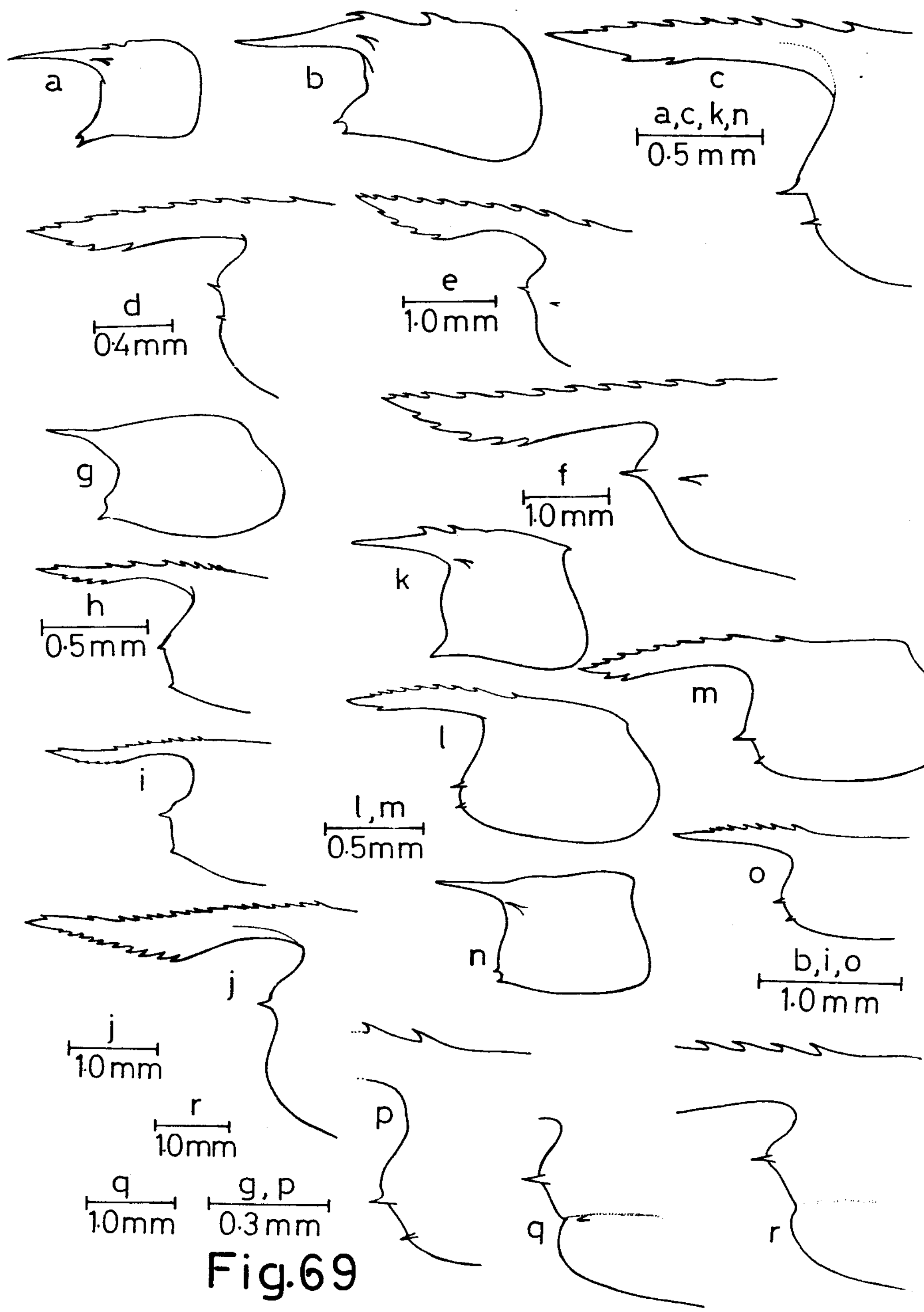
The zoea I of both the Caridina species included in this thesis had a small pterygostomial spine which became prominent in zoea II (Fig. 67 c). This spine was retained in all zoeal stages and even in postlarva I (Fig. 67 d; 69 g). Branchiostegal spine was completely absent in the zoeal stages. A fully developed antennal spine made its appearance for the first time in postlarva I. The pterygostomial spine of postlarva I became progressively smaller as the development advanced and completely disappeared when they became juveniles (Fig. 69 h, i, j). As in the case of Leptocarpus potamiscus there

Fig. 69 Carapace of the caridean larvae: Macrobrachium equidens: a. zoea III, b. zoea X, c. postlarva I of TL 6.2 mm, d. postlarva of TL 7.03 mm, e. postlarva of TL 11.17mm,f. postlarva of 18.7 mm.

Caridina longirostris: g. zoea III, h. postlarva II, i. postlarva III, j. adult of TL 23.3 mm.

Leandrites celebensis: k. zoea V, l. postlarva I, m. postlarva II.

Leptocarpus potamiscus: n. zoea III, o. postlarva I, p. postlarva of 7.3 mm, q. larva of TL 24.0 mm, r. larva of TL 30.0 mm.



a
b
c
a,c,k,n
0·5 mm
d
0·4mm
e
1·0mm
g
f
1·0mm
h
0·5mm
k
m
i
l
l,m
0·5mm
o
n
b,i,o
1·0mm
j
j
1·0mm
r
1·0mm
p
q
1·0mm
g,p
0·3mm
q
r

Fig.69

was no shifting of pterygostomial spine. Thus it is obvious that the pterygostomial spine has not shifted to become the antennal spine. All the above mentioned observations clearly indicate that the pterygostomial spine of zoeae becomes either the hepatic spine or the branchiostegal spine of the adult, but never the antennal spine. Similarly the branchiostegal spine becomes the antennal spine of the adult and not the hepatic spine. Almost a similar observation was made by Williamson (1972) when he dealt with the larvae of M. intermidium and M. niloticum. Jalihal (1978) while working on the abbreviated life history of 4 species of Macrobrachium also found that the pterygostomial spine of the zoea shifted and occupied the hepatic position in the postlarva during development.

All the previous workers, including the present, have observed that in zoea I and II pterygostomial spine developed at the anteroventral angle of the carapace. The second spine (branchiostegal) developed a little above the first spine. Only in the case of M intermedium (Williamson, 1972) the second spine was observed to develop below the first one.

The first zoea of all these species exhibited the characteristic feature of a typical palaemonid zoea having extended larval history. Antennule, antenna and mouthparts are well developed. Eyes are sessile and the telson is provided with 7+7 setae. In all these species the uropod developed in zoea III and became functional in zoea IV. None of the larvae showed any sign of development of pleopods during the first three zoeal stages. A comparative study of the zoeae of all the eleven species studied (Table 16)

Table 16. Sequence of development of different appandages during the larval development of 11 species of *Carideans*.

	Macro-brachium equidens	*Macro-brachium striatus*	*Macro-brachium idella*	*Caridina longi-rostris*	*Caridina pseudo-gracilin-nostris*	*Hippolysmata (Exhippolys-mata) ensirostris*	*Leandrites celebensis*	*Lepto-carpus potami-scus*	*Palaemon-(Palaemon) concinnus*	*Alpheus euphro-syne*	*Alpheus rapacida*
Zoeal Stages	10	10	10	8	6	9	7	6	..	..	..
Minimum time to develop into postlarva I	25	25	39	15	8	43	13	15	..	..	..
Antennule,antenna and mouth parts developed	Z I	Z I	Z I	Z I	Z I	Z I	Z I	Z I	Z I	Z I	Z I
Development of bud:											
Pereiopod I	Z I	Z I	Z I	Z II	Z II	Z II	Z I	Z I	Z I	Z I	Z I
Pereiopod II	Z I	Z I	Z I	Z II	Z III	Z III	Z I	Z I	Z I	..	..
Pereiopod III	Z III	Z III	Z III	Z IV	Z III	Z IV	Z IV	Z III	Z III	..	..
Pereiopod IV	Z V	Z V	Z V	Z IV	Z III	Z V	Z IV	Z IV	Z V	..	..
Pereiopod V	Z III	Z III	Z III	Z V	Z III	Z III	Z II	Z III	Z IV	Z I	Z I
Development of:											
Pereiopod I	Z II	Z II	Z II	Z III	Z III	Z III	Z II	Z II	Z II	Z III	Z III
Pereiopod II	Z II	Z II	Z II	Z IV	Z IV	Z IV	Z II	Z II	Z II	..	..
Pereiopod III	Z IV	Z IV	Z IV	Z V	Z IV	Z V	Z VI	Z IV	Z IV	..	..
Pereiopod IV	Z VI	Z VI	Z VI	Z VI	Z V	Z VI	Z VI	Z V	Z VI	..	..
Pereiopod V	Z IV	Z IV	Z IV	Z VII	Z V	Z IV	Z IV	Z IV	Z V	Z III	Z III
Nature of pereiopod IV	Biramous	Biramous	Biramous	Biramous	Uniramous	Biramous	Uniramous	Biramous	Biramous	..	..
Nature of pereiopod V	Uniramous	Uniramous	Uniramous	Uniramous	Uniramous	Uniramous	Uniramous	Uniramous	Uniramous	..	
Development of Pleopod:											
Uniramous bud	Z VII	Z VII	Z VII	Z V	Z IV	Z VII	Z V	Z IV	Z VII	..	..
Biramous bud	Z VIII	Z VIII	Z VIII	Z VI	Z V	Z VIII	Z VI	Z V	..	..	..
Exopod alone setose	Z IX	Z IX	Z IX	Z VII	Z VI	Z VIII	..	..	..	..	..
Endopod & Exopod of setose	Z X	Z X	Z X	Z VIII	PL I	Z IX	Z PLI	..	..	..	..
Telson setae:											
7+7	ZI,ZVI	ZI ZIX	ZI ZIX	ZI	ZI	ZI,ZVII ZIII,ZVIII	ZI	ZI ZVI	ZI	ZI	ZI
8+8	ZII,ZIII ZVII	ZII ZIII	ZII,ZV ZIII,ZVI ZVII	ZII,ZV ZIII,ZVI ZIV,ZVII	ZII,ZV ZIII,ZVI ZIV	ZII,ZVI ZIV,ZV	ZII ZIII	ZII ZIII	ZII,ZV,ZVII ZIII,ZVI	ZII ZIII	ZIII ZII
6+6	ZIV ZV	ZIV,ZVII ZV,ZVIII ZVI,ZX	..IV	..	..	..	ZIV ZV,ZVI	ZIV	ZIV	..	..
5+5	ZVIII ZIX	..	..	,,	..	ZIX	ZVII	..	..	..	..
4+4	ZX	..	..	..	..	..	..	..	..	..	..
Development of:											
Uropod	Z III	Z III	Z III	Z III	Z III	Z III	Z III	Z III	Z III	Z III	ZIII
Functional uropod	ZIV	ZIV	ZIV	ZIV	ZIV	ZIV	ZIV	ZIV	ZIV	..	..
Development of spines:											
Pterygostomial	Z I	Z I	Z I	Z I	Z II	Z I	Z II	Z I	Z I	Z I	Z I
Branchiostegal	Z III	Z III	Z III		..	..	..	Z IV	Z IV	..	..
Supraorbital	Z II	Z II	Z II	..	..	Z II	Z IV	Z II	Z II	..	..
Epigastric	Z III	Z III	Z III	..	Z VI	Z IV	Z III	Z IV	Z VI	..	..
Lateral spine on 5th abdominal segment	Z II	Z II	Z II	..	..	Z IV	Z II	Z II	..	..	..

showed a general uniformity in the pattern of development and sequence of appearance of appendages until they become zoea IV. Variations in the development pattern of appendages, particularly pleopods are noticed after zoea IV, when in between two successive stages they moult 2 or 3 times without undergoing much changes. In the case of *Macrobrachium* spp. included in this thesis some intermediate stages are observed between zoea VI and VIII and zoea X and postlarva I. Although these intermediate stages are skipped over and not always found to be necessary for the normal development of larvae, their presence in some experiments, atleast in fairly good numbers make it difficult to ignore them entirely. Williamson (1982) has stated that increased number of zoeal stages however should not be regarded as abnormal and probably occured in nature. He has further pointed out that in some caridean prawns which are confined to shallow waters" there is a long series of larval stages and fully developed zoeae seem able to delay metamorphosis for a considerable number of moults if they have not reached coastal region". While Williamson's contention might indeed be probable, the occurrence of intermediate stages along with the individuals which have skipped these stages and have straight away developed to the next stage during the development of *M. equidens* and *M. idella* in zoea arising from the same brood and existing in the same medium in the present experiment indicate the possibility of other factors also.

The sequence of development of appendages such as antennule, antenna and mouth parts, is almost similar in all the zoeal stages of different species studied at present. Generally the development of pereiopods precedes that of pleopods. They sometimes develop simultaneously or at varying intervals. When such a condition occurs, it is generally associated with the reduction in the number of zoeal stages in the larval development. In the zoeae of Caridina pseudogracilirostris as well as Leptocarpus potamiscus pleopods started developing along with pereiopods. Uniramous buds of pleopods appear at zoea IV although pereiopod IV is not developed at this stage. This overlapping has reduced the number of zoeal stages to 6 in these species. In this connection, the observation made by Benzie (1982) that "synchrony of development is consistantly achieved in functionally related groups of appendages" is worth mentioning. The groups of appendages related more broadly in function tend to show major changes at the same moult. Thus maxillae and maxillipeds both involved in feeding develop in the same or neighbouring moults even in the longest larval development. Similarly pereiopods and pleopods both involved in locomotion attain full development in the same or neighbouring moults.

In the case of carideans in general, comparison of the different larval stages belonging to different genera and quite often, of the different species of the same genus, is made difficult due to: i) insignificant or unrecognisable morphological differences between the corresponding stages of zoea of different species; ii) varying number of zoeal stages during metamorphosis from species to species, thereby making the comparison of corresponding stages difficult; iii) differences observed in the rate of development of zoeae even among the same brood and iv) wide variations in the zoeal stages brought out by the varying degree of abbreviated development occurring in the species of the same genus.

On the basis of the detailed comparisons of the morphological characters of the zoeae of the different species attempted at present, and of the important works carried out by the earlier workers on the species of the same genera (Caridina: Jalihal, 1978; Macrobrachium: Uno and Kwon, 1969; Kwon and Uno, 1969; Choudhury, 1970, 1971; Kewalramani et al. 1971; Williamson, 1972; Dugger and Dobkin, 1975; Ngoc-Ho, 1976; Greenwood, 1976; Palaemon: Tsurnamal, 1963; Jagadisha, 1977; Leandrites: Pillai, 1975; Leptocarpus: Rajyalakshmi, 1961; Pillai, 1973; Alpheus: Williamson, 1970; Hippolysmata: Jagadisha, 1977), it may be concluded that the caridean larvae possessing well developed antennule, antenna, mouth parts, sessile eyes and telson with 7+7 spines in zoea I; uropod developed in zoea III, becoming functional in zoea IV and not showing any sign of development of pleopod buds up to zoea III stage may be considered as belonging to the groups of caridean prawns exhibiting extended larval development. Further, despite the close similarities in the general pattern of larval development and larval morphology, the characters such as the setal counts of various appendages, position and development of spines in the carapace in the different zoeal stages and a combination of differences seen in other appendages were found useful in differentiating the larvae at generic level. Restricting the comparisons to only the genera studied at present, and the species showing extended type of larval history, the diagnostic features of the zoeae of these genera have been identified and the observations are summarised below:

Genus Caridina

All the zoeal stages with pterygostomial spine (Fig. 67 c, d) branchiostegal spine present except in C. longirostris and C. pseudogracilirostris;

Fig. 70 Maxillule of caridean larvae: Macrobrachium equidens: a. zoea I

b. zoea IV.

Caridina longirostris: c. zoea I, d. zoea IV.

Palaemon (Palaemon) concinnus: e. zoea I, f. zoea IV.

Leptocarpus potamiscus: g. zoea I, h. zoea IV.

Leandrites celebensis: i. zoea I, j. zoea IV.

Hippolysmata (Exhippolysmata) ensirostris: k. zoea I.

Alpheus rapacida: l. zoea I, m. zoea III.

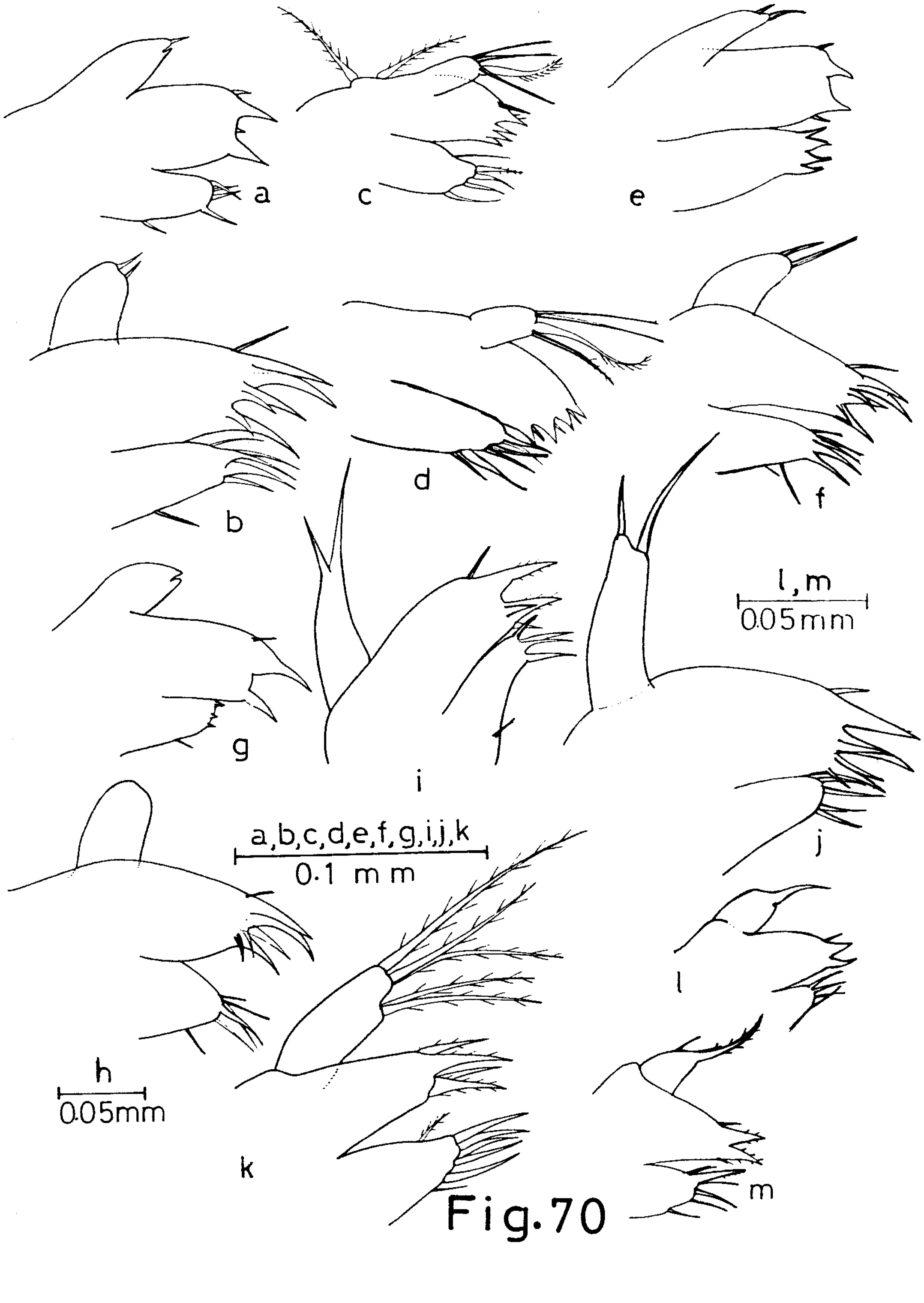


Fig. 70

supraorbital spine and the lateral spine on the fifth abdominal segment in zoea II are absent (Fig. 67 c, d); rostral spines absent in the early zoeal stages; molar process of mandible with a series of ridges from zoea III and this number progressively increasing as the larval development advances (Fig. 71 i); exopod of maxillule bearing 2-3 plumose setae upto zoea II/III (Fig. 70 c); endopod carrying 3 to 4 setae distally, of which one is stout, slightly curved distally and bear short setae (Fig. 70 c, d), this stout seta is characteristic of the genus; the four lobes of protopod of maxilla broader (Fig. 71 b) as compared to that of Macrobrachium (Fig. 71 a) and Palaemon (Fig. 71 c) and bear a number of setae; endopod of maxilliped I, 4-segmented, longer than basipod, bears 3-4 distal setae (Fig. 72 b); endopod of maxilliped III segmented and the distal segment carries 3 long setae of equal length (Fig. 72 i); endopod of pereiopod I & V with 3 setae of equal length at the distal margin of distal segment (Fig. 73 b, i).

Genus Macrobrachium

Pterygostomial spine develops in zoea I, supraorbital in zoea II and branchiostegal in zoea III and IV and retained thereafter (Fig. 67 a, b; 69 a, b); lateral spine on fifth abdominal segment present from zoea II; maxillule without exopod (Fig. 70 a, b), endopod unsegmented with 2 setae at its distal margin; endopod of maxilliped I unsegmented (Fig. 72 a), shorter or as short as

Fig. 71 Maxilla of caridean larvae: Macrobrachium equidens: a. zoea II.

Caridina longirostris: b. zoea II.

Palaemon (Palaemon) concinnus: c. zoea II.

Leptocarpus potamiscus: d. zoea II.

Leandrites celebensis: e. zoea II.

Hippolysmata (Exhippolysmata) ensirostris: f. zoea II.

Alpheus rapacida: g. zoea II.

Mandible of caridean larvae: Macrobrachium equidens: h. zoea VI.

Caridina longirostris: i. zoea VI.

Hippolysmata (Exhippolysmata) ensirostris: j. zoea IV.

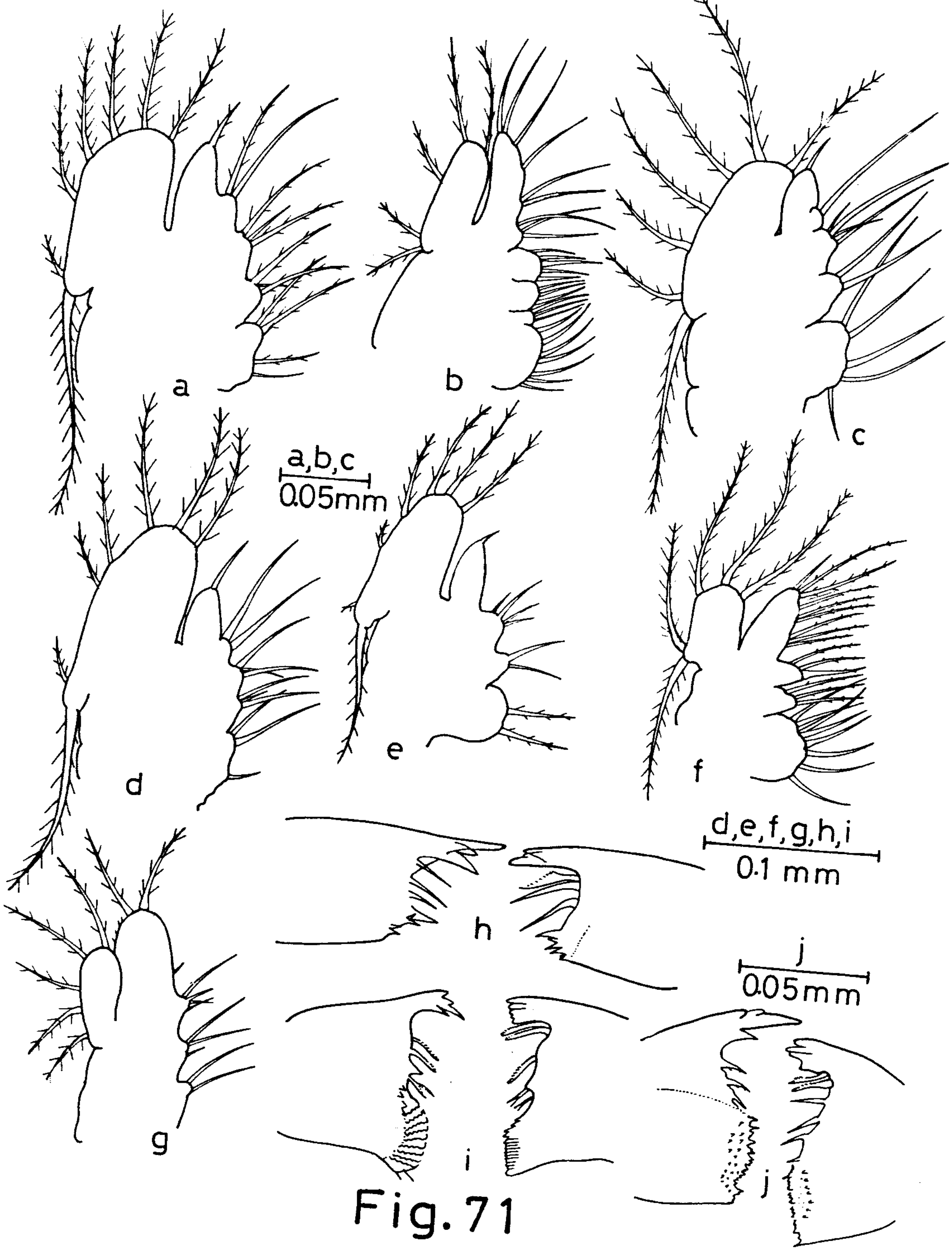


Fig. 71

the basipod and carries 3 apical setae; the endopod of pereiopod I of zoea II terminate in a long seta (Fig. 73 a); pereiopod V develops in zoea IV (Fig. 73 h) and apically bear a long seta.

Genus Palaemon

Rostrum well developed in zoea I to III (Fig. 67 e), progressively reducing in length from zoea IV in some species; branchiostegal spine and lateral spine on fifth abdominal segment generally not present (Fig. 67 e, f); endopod of maxillule (Fig. 70 f) with a long seta in advanced zoeae which is as long as endopod; endopod of maxilliped I (Fig. 72 c) longer than basipod and bears more than 3 setae.

Genus Leandrites

Branchiostegal spine absent, lateral spine of fifth abdominal segment develops in zoea II and is retained thereafter (Fig. 68 a, b); endopod of maxillule with 2 terminal setae, the inner one as long as endopod and the other, half the length of the inner seta (Fig. 70 i, j); basipod of maxilliped I (Fig. 72 e) prominent and protruded and is characteristic to this genus. It bears 8 to 10 setae, endopod unsegmented, longer than basipod, reaching 2/3 of endopod and bearing 6 or more setae; dactylus of maxilliped III (Fig. 72 k) of zoea I carries 2 long and one to two short setae, propodus on its distal margin with 2 long setae, all these setae forming an effective clasping organ to hold prey; pereiopod I (Fig. 73 e)

Fig. 72 Maxilliped I of caridean larvae: Macrobrachium equidens: a. zoea II.

Caridina longirostris: b. zoea II.

Palaemon (Palaemon) concinnus: c. zoea II.

Leptocarpus potamiscus: d. zoea II.

Leandrites celebensis: e. zoea II.

Hippolysmata (Exhippolysmata) ensirostris: f. zoea II.

Alpheus rapacida: g. zoea II.

Maxilliped III of caridean larvae: Macrobrachium equidens: h. zoea II.

Caridina longirostris: i. zoea II.

Palaemon (Palaemon) concinnus: j. zoea I.

Leandrites celebensis: k. zoea II.

Leptocarpus potamiscus: l. zoea II.

Hippolysmata (Exhippolysmata) ensirostris: m. zoea II.

Alpheus rapacida: n. zoea II.

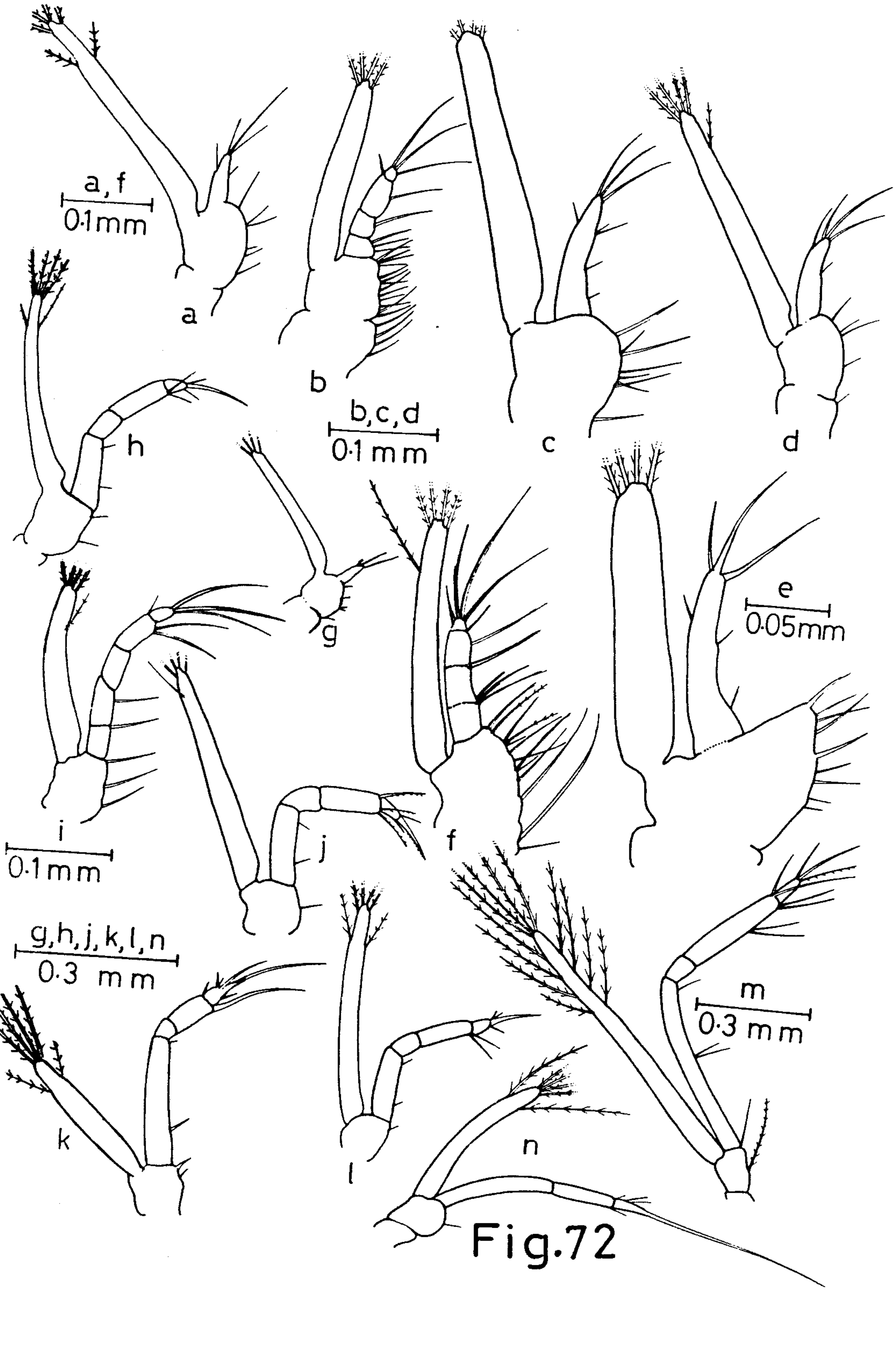

a, f
0·1mm
a
b
b, c, d
0·1 mm
c
d
h
g
e
0·05mm
i
0·1mm
j
f
g, h, j, k, l, n
0·3 mm
m
0·3 mm
k
l
n

Fig.72

Fig. 73 Pereiopod I of caridean larvae: Macrobrachium equidens: a. zoea II. Caridina longirostris: b. zoea III. Palaemon (Palaemon) concinnus: c. zoea III. Leptocarpus potamiscus: d. zoea III. Leandrites celebensis: e. zoea II. Hippolysmata (Exhippolysmata) ensirostris: f. zoea III.
Alpheus rapacida: g. zoea III.
Pereiopod V of caridean larvae: Macrobrachium equidens: h. zoea V. Caridina longirostris: i. zoea VII. Palaemon (Palaemon) concinnus: j. zoea VI. Leptocarpus potamiscus: k. zoea V. Leandrites celebensis: l. zoea V. Hippolysmata (Exhippolysmata) ensirostris: m. zoea V.
Alpheus rapacida: n. zoea III.

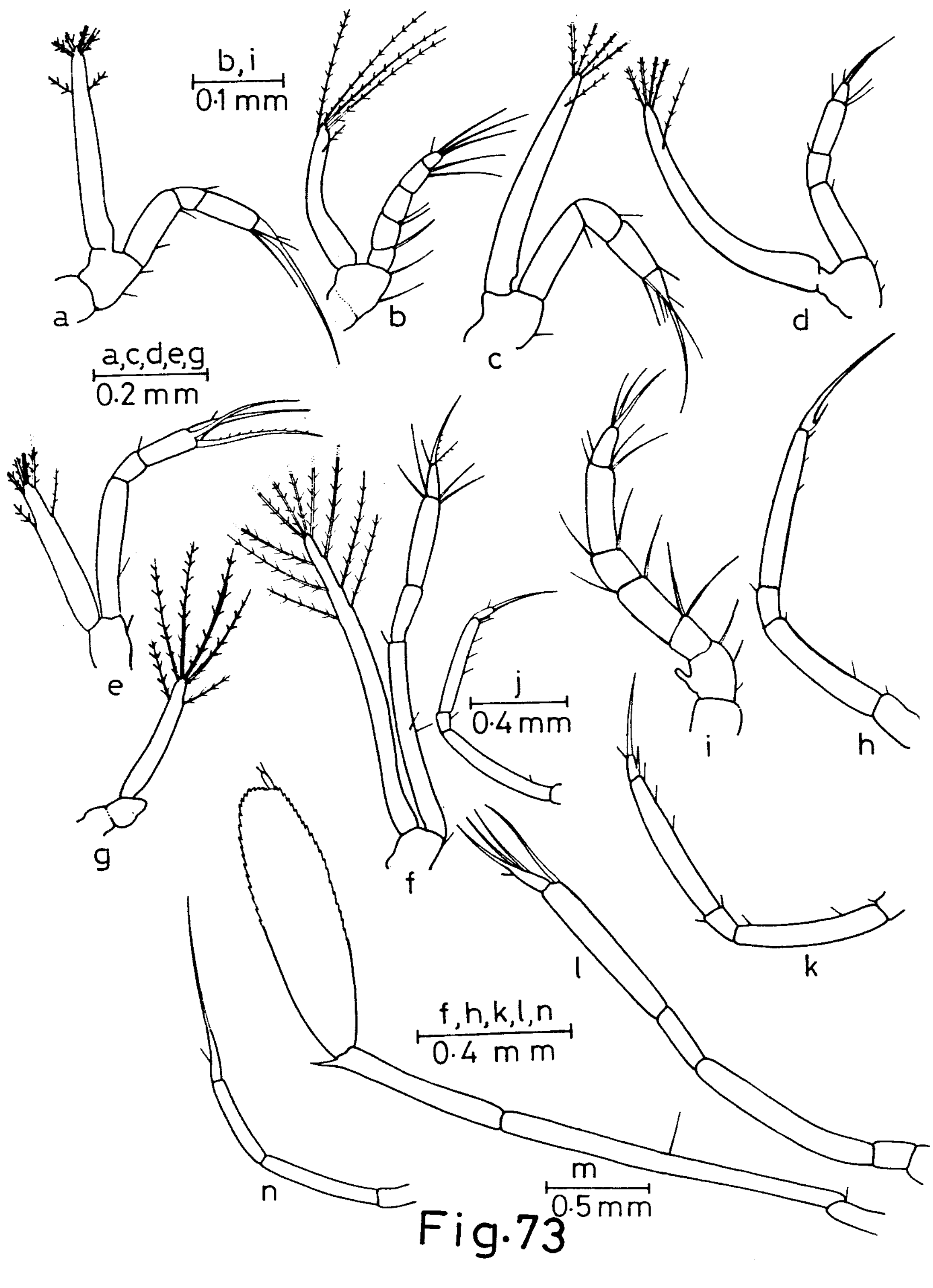


Fig. 73

develops in zoea II and pereiopod V (Fig. 73 l) in zoea IV; both the appendages bearing long setae at the distal margin of propodus and dactylus which could be used as clasping organ.

Genus Leptocarpus

Epigastric tooth developed in zoea IV (Fig. 67 g) and is retained thereafter; endopod of maxillule without setae (Fig. 70 g, h); endopod of maxilliped I (Fig. 72 d) unsegmented, not longer than basipod and bears a minimum of 5 setae from zoea II onwards, except in L. fluminicola where it is slightly longer.

Genus Alpheus

Zoeae generally slender as compared to those of other genera; rostrum short, reaching upto the middle of eye stalk (Fig. 68 f, g); pterygostomial spine present; supraorbital spine absent in the early zoeal stages but develop in the advanced stages; lateral spine on the fifth abdominal segment absent; endopod of maxillule distally bearing a stout seta which is as long as or longer than endopod (Fig. 70 l, m); endopod of maxilla (Fig. 71 g) broader with 2 setae, basipod with 3 endites, characteristic to the genus; endopod of maxilliped III (Fig. 72 n) distally bears a long seta; endopod of pereiopod I in zoea III (Fig. 73 g) very small, palp-like, without setae and segmentation.

Genus Hippolysmata

Eye stalks very long and prominent from zoea III (Fig. 68 d); carapace with supraorbital, antennal and pterygostomial spines from zoea II onwards (Fig. 68 c), on the carapace a tubercle with spine present from zoea III/IV; antennule long and flagellum longer than peduncle from zoea V onwards; endopod of maxillule (Fig. 70 k) bears 5 plumose setae at its distal and inner margin; endopod of maxilliped I (Fig. 72 f) longer than basipod and 4-segmented bearing a number of setae; pereiopod V develops in zoea III/IV (Fig. 68 d; 73 m) and is relatively long, propodus much flattened and brightly coloured; pereiopod I to IV are long when developed and their endopods bear a number of plumose setae distally.

In the background of the life history studies presented at present and the information gathered on the larval rearing of these species, it is worthwhile to consider their potentials for culturing them in enclosed waters. As mentioned earlier, the three species of Macrobrachium studied at present, grow to a medium size of 75-85 mm. The larval development of M. equidens and M. striatus takes place within 25 days and that of M. idella a slightly longer duration of 39 days. It has been shown that the adults and brood stock of these species can easily be maintained in the laboratory and can be bred as and when required under laboratory condition. The larvae are hardy and amenable to mass culture providing appropriate feed and environmental conditions with not much problem. These characteristics together with the evolution of a natural life cycle which is adopted to freshwater ecosystems in the pre-adult and adult stages and to estuarine life in the larval and early juvenile stages make it possible to cultivate these species in enclosed fields. In view of the latter facts of their life, these species are also found to be ideally suitable for cultivation along with paddy both in the freshwater and brackishwater areas as available in different states such as West Bengal, Karnataka, Kerala and Goa, and thus brightening the prospects of increasing the prawn production of the country and the economics of the farmers.

PART TWO

Some observations on the salinity requirements of the zoeal and postlarval stages of *Macrobrachium idella*.

INTRODUCTION

Some of the caridean prawns living in freshwater are known to utilise the estuarine/brackishwater ecosystems for breeding and subsequent development of the larvae. Its migration to brackishwater for spawning and the returning of juveniles upstream to freshwater has been described by Visco (1920), Nataraj (1947), Panikkar (1968) and George (1969b). Similarly, the littoral forms enter the estuaries in the early life stages and spend a part of their life in this ecosystems. This interesting feature of their life has attracted several investigations to elucidate the different aspects of their bioecology and physiology. These studies have also helped to obtain data on their growth and survival at different environmental regimes, and in turn, to develop suitable technologies of their culture, under controlled conditions.

Of the various environmental parameters investigated, the salinity requirements of the larvae, its tolerance and related aspects form a widely studied subject matter. Thus, Panikkar (1939, 1940, 1941 and 1968), Parry (1954, 1957), Dobkin and Manning (1964), Potts and Parry (1964), Parry and Potts (1965) and Spaagaren (1972) studied the salinity tolerance and osmoregulation of the palaemonid prawns of the genera Palaemon and Palaemonetes, and Denne (1968), Sandifer et al. (1975), Guest and Durocher (1979) and Lee and Fielder (1981) of the genus Macrobrachium.

In nature, several species of Macrobrachium that inhabit primarily the freshwater regimes, move to brackishwaters where salinity fluctuates from 6‰ to 17.5‰, for breeding and larval development. The adults after breeding and the juveniles after completing the larval and postlarval phases of development return to freshwater regions. For rearing of larvae of these species under controlled conditions, the requirement of certain amount of salinity for the development, survival and growth is now well known. However, this requirement is found to vary from species of species, being 15-20‰ and 16‰ for M. acanthurus (Choudhury, 1970; Dugan et al., 1975); 14‰ to 17.5‰ for M. carcinus (Choudhury, 1971 a); 1 to 15‰ for M. amazonicum (Moreira et al., 1986); 0 to 15‰ for M. australiense (Lee and Fielder, 1981); 20 to 30‰ for the early larval stages and 15 to 20‰ for the later stages of M. americanum (Holtschmit and Pfeiler, 1984). Denne (1968) studying the osmotic and ionic regulation of the freshwater species, M. australiense, has shown that the prawn regulates hyperozmotically at all salinities from freshwater to about 25‰.

Discussing the estuarine phase in the life history of prawns of the west coast of India, Mohamed and Rao (1971) reported that the commercial palaemonid prawns of the country too spend a part of the life cycle in brackish water environment. However, their dependance on this ecosystem varies from species to species. Among the species of Macrobrachium, according to these authors, M. rosenbergii, M. idae and M. rude use the estuaries to a greater extent than M. lamarrei, M. malcolmsonii, M. mirabile, M. equidens and M. villosimanus. M. scabriculam and M. dayanum are found to be essentially the denizens of freshwater. The salinity requirement for breeding and larval development of some of the species studied is found to be 12-18‰ for M. rosenbergii (Subrahmanyam, 1986), 15‰ for M. rosenbergii (Nair et al., 1977), and 14.2 to 14.8‰ for M. malcolmsonii (Rao, 1986). For the early larvae of M. idae the optimum salinity range for the development was recorded between 5 to 20‰ salinity (Subramanian, et al., 1980). Kewalramani (1973), studying the salinity requirement of larvae of M. malcolmsonii, has shown that a gradual rise of salinity from 2 to 22‰ is found necessary for the development of zoea I to advance stages.

M. idella supports a small fishery along the south western region of India and along the east coast (Kurian and Sebastian, 1982). It contributes to a subsistence fishery in the Cochin Backwater and connected canal systems during June/July-November. As the spawning season, which is found to be from September to November, approaches, the females migrate to the lower reaches of the estuary in July - August. The adults after spawning, and the larvae on completion of development, start migrating towards freshwater regions by January-February. The species is not generally encountered in the brackishwaters of this region during March-May, when relatively higher saline conditions prevail. The early larval history of the species was studied by Pillai and Mohamed (1973). As in the case of other Macrobrachium species studied, a salinity of 12-18‰ is found necessary for the larvae to undergo development through the various stages. Except for this general observation on the salinity requirement of the species no detailed study is available. M. idella is considered a potential species for commercial culture, the present study on the hatching of eggs and on the development, growth and survival of larvae and postlarvae in different salinity regimes has been carried out and the results are presented.

EXPERIMENTS CONDUCTED AND RESULTS

The following experiments were carried out to study the effect of different salinities on the hatching of eggs and on the growth and survival of larvae of M. idella. The procedure followed with respect of the preparation of the medium, its renewal, feeding of adult and larvae are similar to those described for the rearing of larvae as presented in Material and methods.

Experiment I

This experiment was carried out to study the effect of different salinities on berried females with eggs in the advanced stages of development (dull white eggs having clearly visible eye spots of the developing embryo). The experiment was conducted in 60 l capacity containers each having 50 l of test medium of salinities 0, 10, 20 and 30‰. Two specimens of berried females stocked initially in 10 to 15‰ salinity were transferred to each of the containers and its mouth was covered with nylon screen to prevent the animals from jumping out. The experiment was continued for six days. Details regarding the total length, carapace length, number of eggs and their measurements, of ten specimens are given in Table 17. The data on hatching performance in different media were recorded.

Results

When berried females maintained in 10 to 15‰ salinity, were transferred directly to different salinity ranges, they showed unrest initially and tried to jump out of the container frequently. However, within 30 to 45

Table 17. *Macrobrachium idella*: The total length, carapace length, number of eggs in the berry and their measurements.

Serial No.	Total length (mm)	Carapace length (mm)	Weight (gms)	Weight of berry (gms)	Number of eggs in the berry	Egg measurements	
						Range (mm)	Mean(mm)
1	73	17	5.0	0.7	9,450	0.50-0.59	0.56
2	76	17	4.9	0.66	9,762	0.49-0.57	0.55
3	75	17	4.5	0.48	6,221	0.42-0.52	0.49
4	66	16	3.6	-	4,355	0.55-0.67	0.64
5	71	17	4.2	0.43	7,800	0.45-0.55	0.49
6	71	16	4.2	0.41	8,003	0.43-0.52	0.49
7	69	14	3.9	0.45	6,309	0.57-0.67	0.62
8	69	14	3.7	0.31	5,292	0.43-0.52	0.49
9	65	14	3.5	-	4,996	0.50-0.56	0.53
10	66	15	3.3	0.36	5,457	0.55-0.59	0.56

minutes, the prawns were found to have got adjusted to the different test media, and there after showed normal behaviour by occupying a corner of the container and moving their pleopods providing aeration to the berry. During the experimental period majority of these prawns with advanced stage of berry showed reluctance to accept the food offered to them. Hatching periodicity of eggs in the berry, with reference to different media are presented in Table 18.

On the third day of starting of the experiment, one female reared in 10‰ salinity, released the zoea larvae. Release of zoea was observed in the fourth day by the prawns reared in freshwater; on the fifth day in 30‰ and on the sixth day in 20‰. Cent percent hatching was observed in all the cases and the zoea I released in different media were active and normal, without showing any difference in the various morphological characters. Thus the experiments indicate that the berried females of M. idella with advanced stage of berry could develop and hatch in freshwater and in salinity ranges upto 30‰.

Experiment II

This experiment was conducted to study the survival and growth of freshly hatched zoea I larvae in salinities of 0, 5, 10, 15, 20, 25, 30 and 35‰. Zoea I larvae for this experiment were obtained from the berried females maintained in 60 l aquarium tanks at a salinity range of 10-15‰. The different zoeal stages of M. idella were distinguished on the basis of characters provided by Pillai and Mohamed (1973). Eight one litre glass beakers

Table 18. Observations on the hatching of eggs of *Macrobrachium idella* at different salinity ranges.

Experimental Salinity	Size & weight of berried specimens used in the experiment		Hatchery performance of eggs at different period of observations (hrs)					
	Total length (mm)	Weight (gms)	24	48	72	96	120	140
0‰	73	5.0	NH	NH	NH	H	-	-
	76	4.9	NH	NH	NH	H	-	-
10‰	66	3.6	NH	NH	H	-	-	-
	71	4.2	NH	NH	NH	NH	H	
20‰	69	3.7	NH	NH	NH	NH	NH	H
	65	3.5	NH	NH	NH	NH	H	-
30‰	65	3.0	NH	NH	NH	NH	H	-
	73	4.0	NH	NH	NH	NH	H	-

were set up and each filled with 800 ml of water having salinities mentioned above. To avoid the stress of sudden release of larvae to lower and higher test salinities of below 20‰ and above 25‰, the zoea I larvae hatched out at 10-15‰ salinity were first acclimatised to 15‰ and 30‰. One set of larvae acclimatised for 6 hrs to 15‰ were released to each of the beakers containing test medium of 5, 10, 15 and 20‰. Another set of larvae acclimatised for 6 hrs to 30‰ were released to each of the beakers containing test medium of 25, 30 and 35‰. 50 numbers each of active healthy larvae were introduced into the different beakers. Daily, they were examined individually to study their development and the dead ones when found were removed after making necessary entries. The experiment was continued until the larvae metamorphosed to postlarva I or till their death before becoming first postlarvae.

Results

The survival and development of the larvae at different salinities are given in Table 19 and depicted in Fig. 74 to 79. Zoea I introduced into freshwater did not survive for more than four days. They never moulted during this period (Fig. 74). At 5‰ salinity zoea I survived for 18 days during which period they metamorphosed to zoea V stage with 6% survival rate (Fig. 74). However, beyond this stage, they did not develop and all succumbed. Development of zoea I to postlarva I was observed in the salinities 10-25‰ with the highest percentage survival of 22% in 15‰, followed by 6% at 25‰, 4% at 20‰ and 2% at 10‰ (Fig. 75, 76, 77, 78). In the higher salinity values of 30‰ and 35‰, zoea I survived for 40 days and 22 days respectively without becoming postlarva (Fig. 79). Apart from the freshwater, the survival of

Fig. 74. Survival and development of zoea I larva of Macrobra idella in 0‰ and 5‰ salinity media.

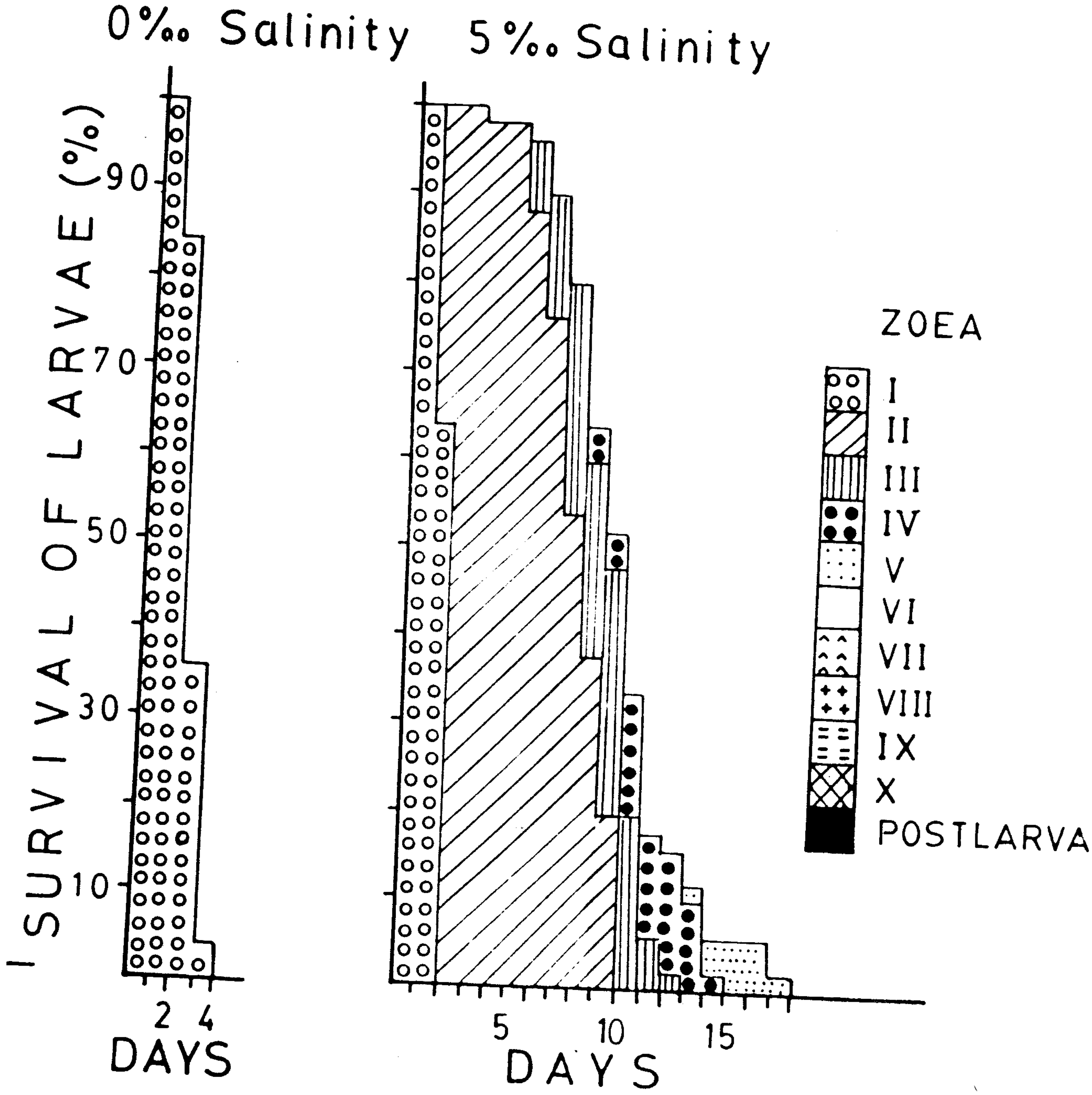

0‰ Salinity
5‰ Salinity
SURVIVAL OF LARVAE (%)
90
70
50
30
10
2
4
DAYS
5
10
15
DAYS
ZOEA
I
II
III
IV
V
VI
VII
VIII
IX
X
POSTLARVA

Fig. 74

Fig. 75. Survival and development of zoea I larva of Macrobrachium idella in 10‰ salinity medium.

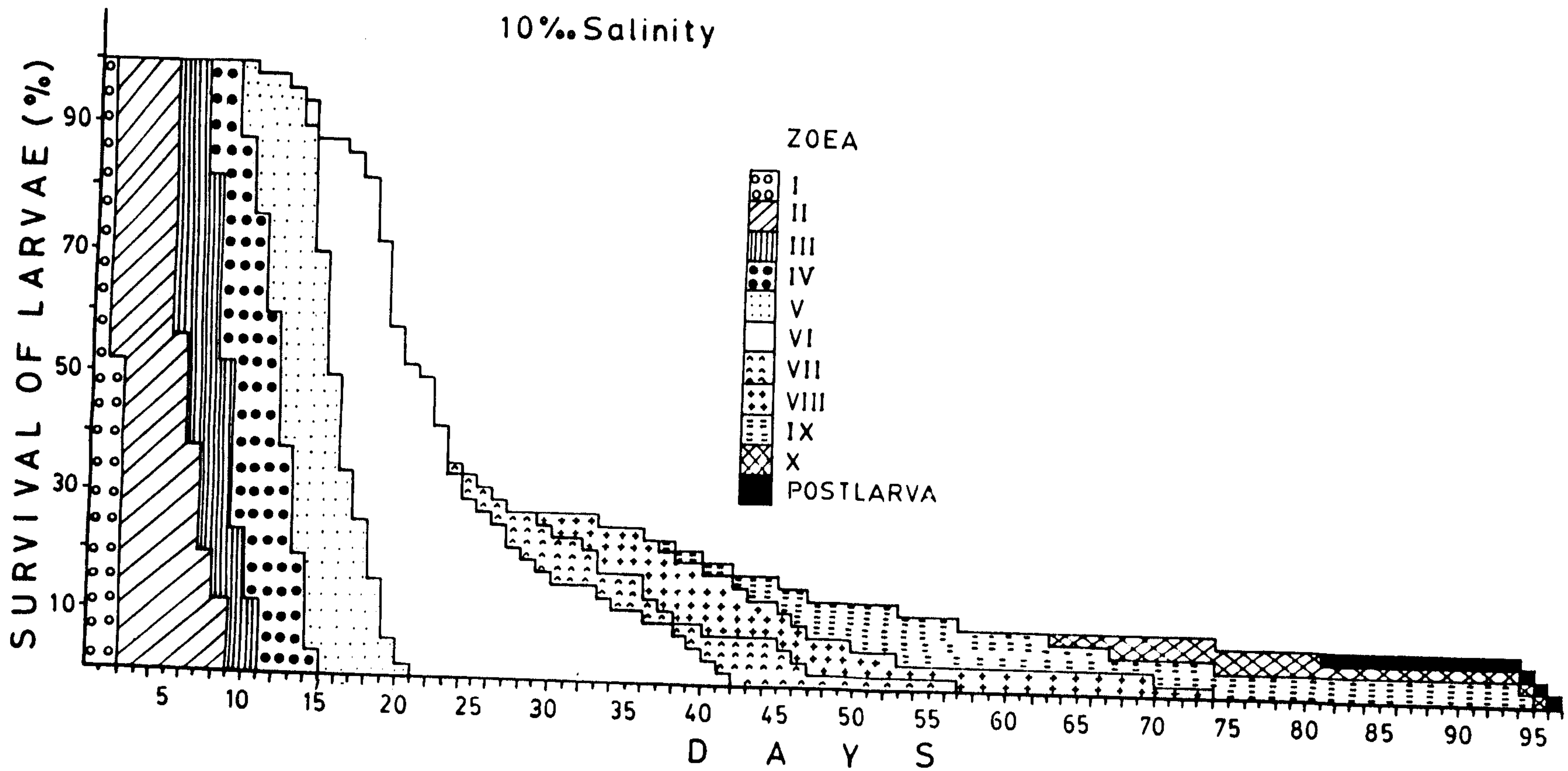

10‰ Salinity
SURVIVAL OF LARVAE (%)
10
30
50
70
90
ZOEA
I
II
III
IV
V
VI
VII
VIII
IX
X
POSTLARVA
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
D A Y S

Fig.75

Fig. 76. Survival and development of zoea I larva of Macrobrachium idella in 15‰ salinity medium.

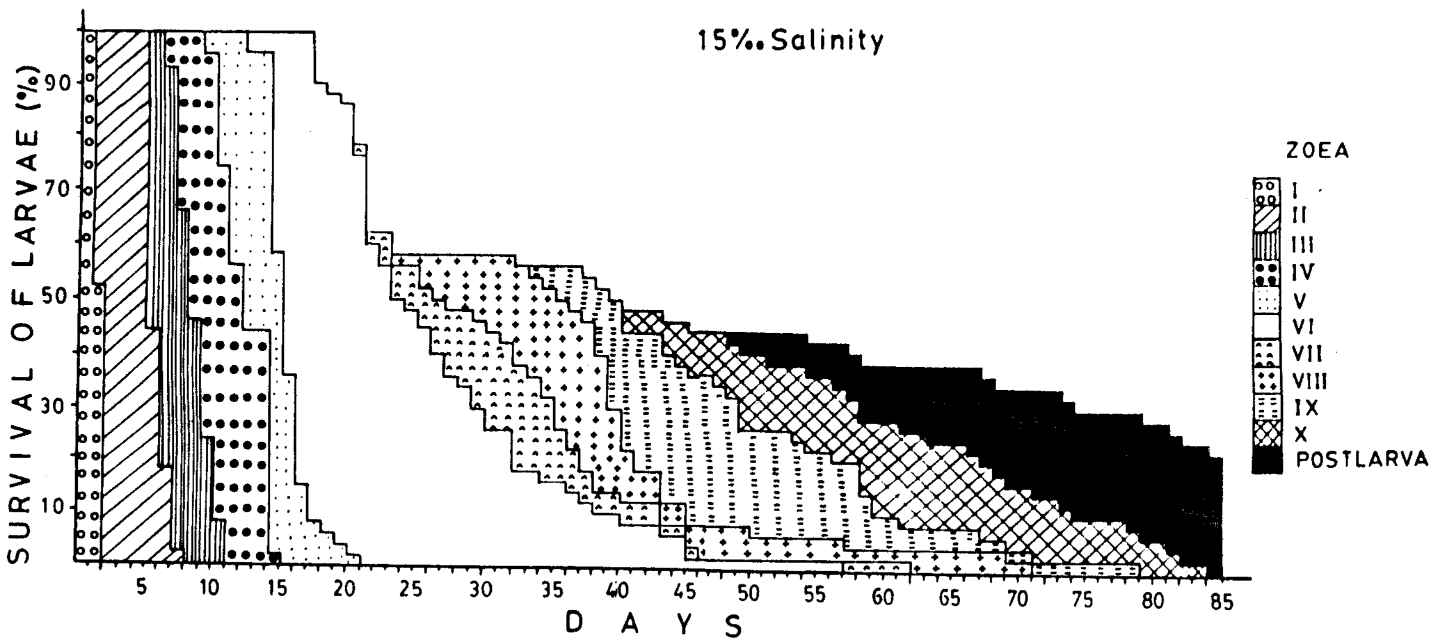
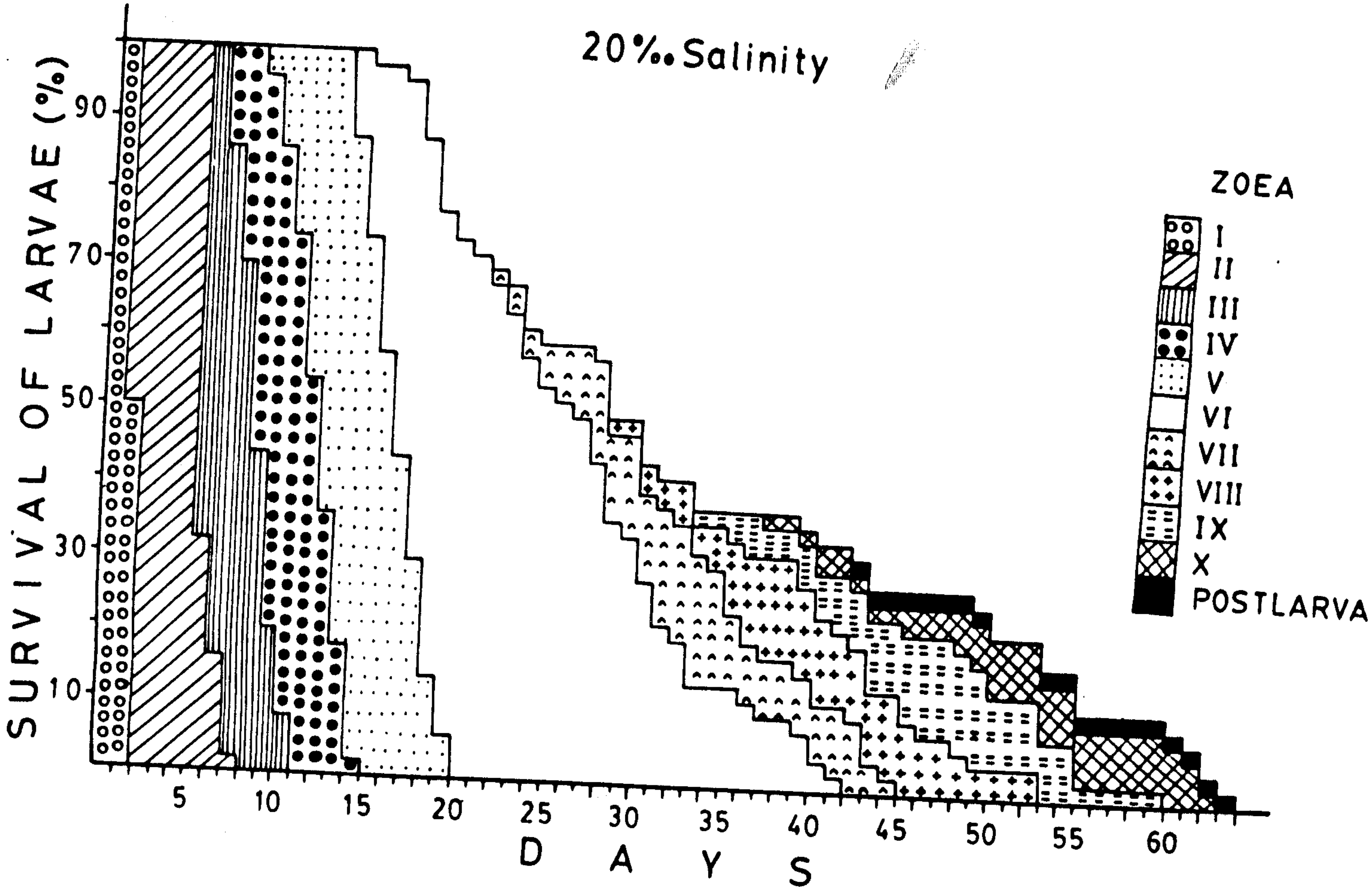

15‰ Salinity
SURVIVAL OF LARVAE (%)
90
70
50
30
10
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
D A Y S
ZOEA
I
II
III
IV
V
VI
VII
VIII
IX
X
POSTLARVA

Fig. 76

Fig. 77. Survival and development of zoea I larva of Macrobrachium idella in 20‰ salinity medium.



20‰ Salinity
SURVIVAL OF LARVAE (%)
90
70
50
30
10
5
10
15
20
25
30
35
40
45
50
55
60
D A Y S
ZOEA
I
II
III
IV
V
VI
VII
VIII
IX
X
POSTLARVA

Fig.77

Fig. 78. Survival and development of zoea I larva of Macrobrachium idella in 25‰ salinity medium.

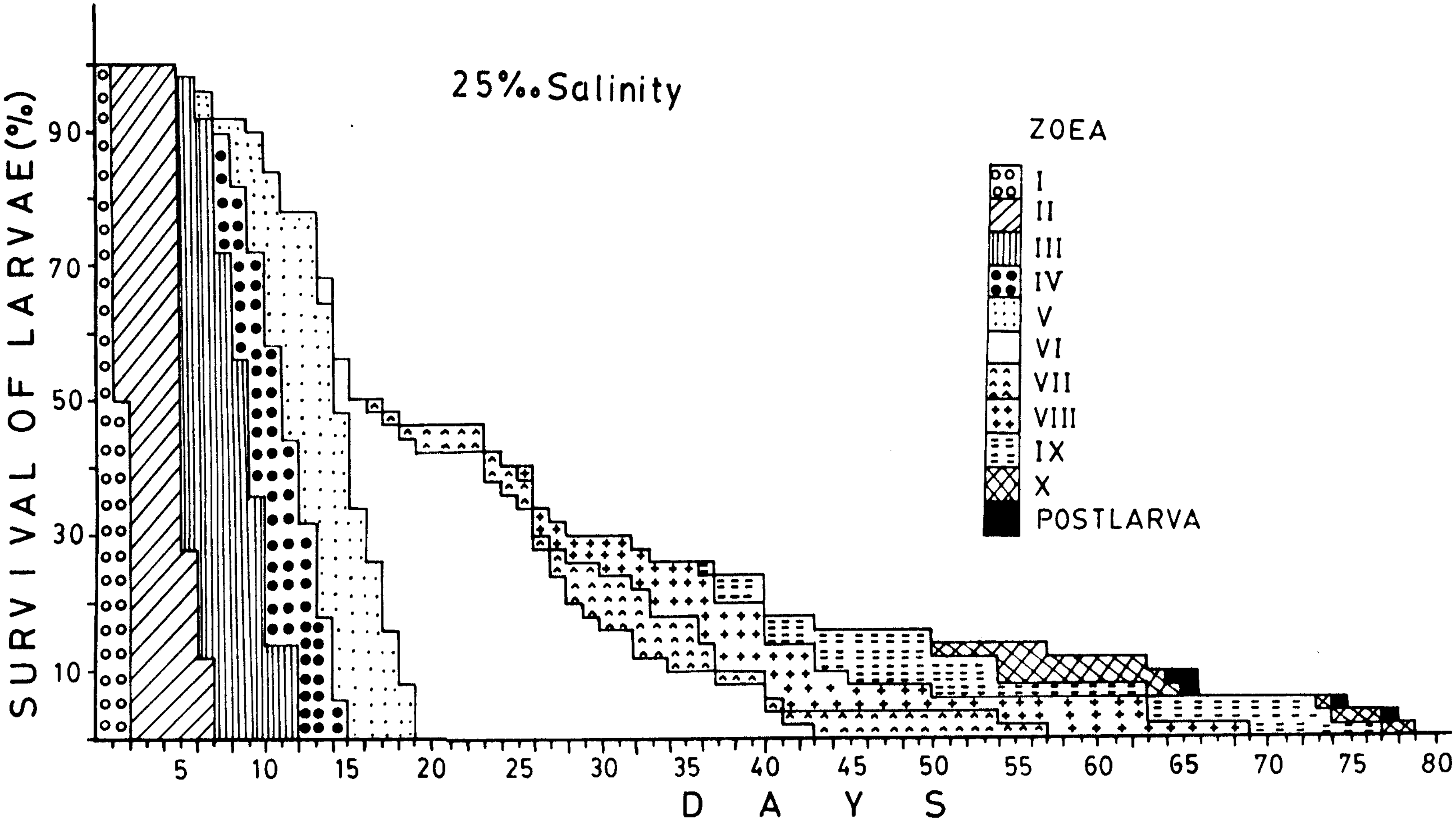

25‰ Salinity
SURVIVAL OF LARVAE (%)
90
70
50
30
10
ZOEA
I
II
III
IV
V
VI
VII
VIII
IX
X
POSTLARVA
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
D A Y S

Fig.78

Fig. 79. Survival and development of zoea I larva of *Macrobrachium idella* in 30‰ and 35‰ salinity media.

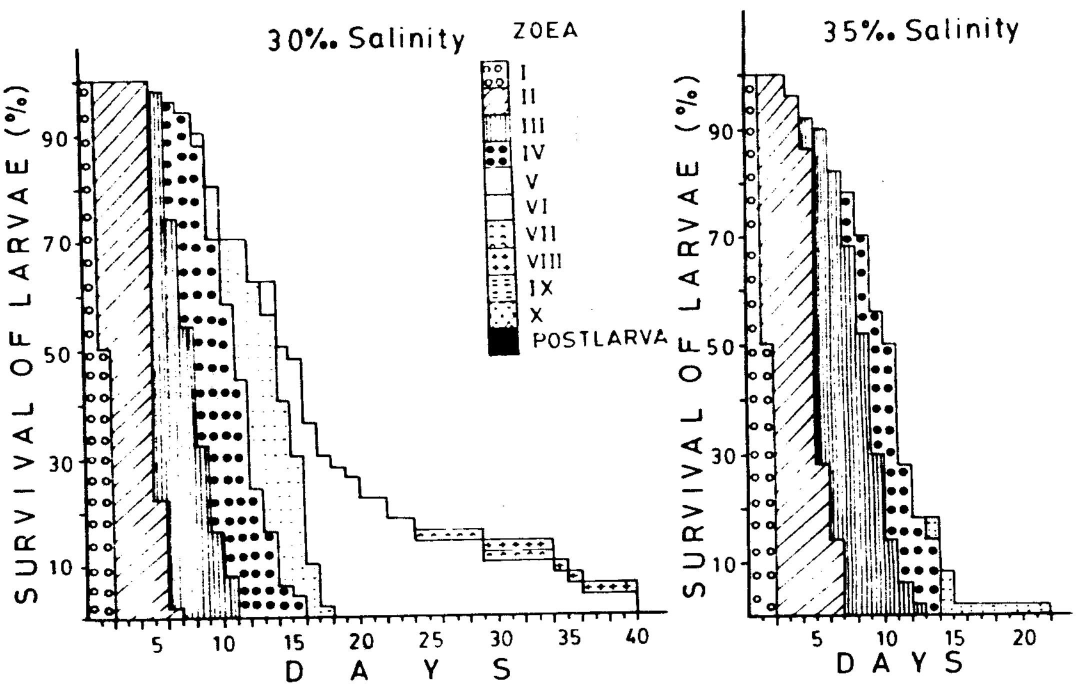

30‰ Salinity
ZOEA
I
II
III
IV
V
VI
VII
VIII
IX
X
POSTLARVA
SURVIVAL OF LARVAE (%)
10
30
50
70
90
5
10
15
20
25
30
35
40
D A Y S
35‰ Salinity
SURVIVAL OF LARVAE (%)
10
30
50
70
90
5
10
15
20
D A Y S

Fig.79

zoea I was least in the lowest (5‰) and highest (35‰) salinities. Hundred percent survival was observed in zoea II in 5-35‰, zoea III in 10-20‰, in zoea IV in 15 and 20‰ and zoea V in 15‰ (Table 19). Next highest percentage of survival was observed in the case of zoea V in salinities 10‰ and 20‰.

The minimum time taken by the zoea I to metamorphose to the different stages - zoea II to postlarva I - in different salinities is given in Table 29. The minimum time taken by zoea I to metamorphose to zoea II was one day in all salinities except 0‰; to zoea II, 5 days in salinity 5 to 30‰ and 4 days in 35‰. From zoea IV onwards, the influence of salinity on the larval development and growth becomes apparent. In 15 to 30‰ zoea IV first appeared on the 6th day, whereas at 10 and 35‰ it took 7 days and in 5‰, 8 days. A minimum of 13 days was taken to reach zoea V in 5 and 35‰, while 7 to 9 days were required to reach this stage in the salinities 10-30‰. Similarly zoea VI took 12 to 13 days in 10-30‰ salinities to moult to the next stage. Thereafter the minimum duration spent by each of the stages at different salinities was found varying.

The fastest overall development of zoea I to postlarva I was seen in 20‰ wherein the larvae took a minimum of 42 days to complete the development. In 15‰, the minimum duration taken for larval development was 48 days (Fig. 76) and it was 64 days in 25‰. In 10‰ the larvae took as many as 81 days to reach the postlarva I stage (Fig. 75).

Experiment III

Separate experiments on similar design as described above were also conducted, on each of the developmental stages from zoea I to zoea X, in

Table 19 : Survival and larval development of zoea I of *Macrobrachium idella* in different salinity media

Salinity °/oo	Zoea I No.	Zoea I Duration (days)	Zoea II Duration (days)	Zoea II Survival Zoea I-II No. (%)	Zoea III Duration (days)	Zoea III Survival Zoea I-III No. (%)	Zoea IV Duration (days)	Zoea IV Survival Zoea I-IV No. (%)	Zoea V Duration (days)	Zoea V Survival Zoea I-V No. (%)	Zoea VI Duration (days)	Zoea VI Survival Zoea I-VI No. (%)	Zoea VII Duration (days)	Zoea VII Survival Zoea I-VII No. (%)	Zoea VIII Duration (days)	Zoea VIII Survival Zoea I-VIII No. (%)	Zoea IX Duration (days)	Zoea IX Survival Zoea I-IX No. (%)	Zoea X Duration (days)	Zoea X Survival Zoea I-X No. (%)	Post larva I Survival Zoea I-PL No. (%)
0 °/oo	50	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5 °/oo	50	1-2	4-9	50 (100)	3-8	17 (34)	5-7	7 (14)	5	3 (6)	...	...	...	...	...	...	...	...	...	...	...
10 °/oo	50	1-2	4-8	50 (100)	2-6	50 (100)	2-8	49 (98)	4-12	44 (88)	10-29	28 (56)	6-34	9 (18)	8-45	6 (12)	26-58	4 (8)	18-33	2 (4)	1 (2)
15 °/oo	50	1-2	4-7	50 (100)	1-6	50 (100)	3-9	50 (100)	3-12	50 (100)	8-45	43 (86)	3-42	21 (42)	10-48	21 (42)	7-46	19 (38)	8-44	16 (32)	11 (22)
20 °/oo	50	1-2	4-7	50 (100)	1-6	50 (100)	2-9	50 (100)	5-12	49 (98)	8-29	36 (72)	7-24	16 (32)	5-25	14 (28)	4-27	11 (22)	5-26	10 (20)	2 (4)
25 °/oo	50	1-2	4-6	50 (100)	1-7	46 (92)	1-9	39 (78)	6-12	25 (50)	3-30	23 (46)	9-41	8 (16)	11-44	7 (14)	14-41	5 (10)	14-15	4 (8)	3 (6)
30 °/oo	50	1-2	4-6	50 (100)	1-6	47 (94)	2-10	35 (70)	5-10	22 (44)	11-27	14 (28)	5-10	2 (4)	11	1 (2)	...	...	...	...	...
35 °/oo	50	1-2	3-6	50 (100)	3-9	39 (78)	6-8	18 (36)	9	2 (4)	...	...	...	...	...	...	...	...	...	...	...

the different salinities to evaluate the optimum salinity requirement for the normal development of each stage.

Results

The effect of different salinities on the survival and growth of each of the larval stages (zoea I to zoea X) is given in Table 20 to 28. Zoea I larvae reared in salinities 15-25‰ became postlarva I with highest percentage of survival of 28% in 15‰, 4% in 20‰ and 16% in 25‰ salinities. Similar to the results of experiment II, zoea I survived in the freshwater only for four days and in the next higher salinity of 5‰ up to zoea V. In the higher salinity of 30‰ the larvae survived a minimum of 40 days to become zoea VIII and in 35‰ most of them succumbed as they reached the zoea V (Table 20).

The zoea II to X survived only for a few hours (2-6 hrs) in freshwater (Table 21 to 28). At 5‰, zoea II thrived for a minimum of 12 days and developed up to zoea V (Table 21). Zoea III-V developed only to the next one stage (Table 22, 23, 24). However, in the salinities 15-35‰ zoea II and IV metamorphosed upto zoea VI with varying percentage of survival (Table 21, 23) but did not develop to become postlarva I. Zoea VI survived only for 9 days in 5‰ salinity. Between 10 and 35‰ salinities this larval stage developed upto zoea X. The highest survival rate was registered in 15‰ salinity (Table 25). Zoea VII reached postlarval stage in 10 and 15‰ salinity (Table 26). In the lowest salinity of 5‰ the larvae survived upto 7 days without moulting. In the highest salinity of 35‰ the larvae survived 16 days but did not moult. In contrast, zoea VIII-X developed equally well in the salinities between ten to twentyfive parts per thousand and reached the postlarval stage (Table 27,28). Thus each of the stages when

Table 20 : Survival and larval development of zoea I of *Macrobrachium idella* in different salinity media

Salinity ‰	Zoea I No.	Zoea I Duration (days)	Zoea II Duration (days)	Zoea II Survival Zoea I-II No. (%)	Zoea III Duration (days)	Zoea III Survival Zoea I-III No. (%)	Zoea IV Duration (days)	Zoea IV Survival Zoea I-IV No. (%)	Zoea V Duration (days)	Zoea V Survival Zoea I-V No. (%)	Zoea VI Duration (days)	Zoea VI Survival Zoea I-VI No. (%)	Zoea VII Duration (days)	Zoea VII Survival Zoea I-VII No. (%)	Zoea VIII Duration (days)	Zoea VIII Survival Zoea I-VIII No. (%)	Zoea IX Duration (days)	Zoea IX Survival Zoea I-IX No. (%)	Zoea X Duration (days)	Zoea X Survival Zoea I-X No. (%)	Post larva I Survival Zoea I-PL No. (%)
0 ‰	50	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5 ‰	50	1-2	3-8	50 (100)	3-8	24 (48)	5-7	14 (24)	4	6 (12)	...	...	...	...	...	...	...	...	...	...	...
10 ‰	50	1-2	3-7	50 (100)	2-6	50 (100)	2-7	50 (100)	4-10	48 (96)	10-19	36 (72)	6-34	16 (32)	8-45	12 (24)	27-52	8 (16)	16	4 (8)	...
15 ‰	50	1-2	3-6	50 (100)	1-6	50 (100)	2-9	50 (100)	6-10	50 (100)	7-27	48 (96)	3-26	36 (72)	10-32	34 (68)	7-33	32 (64)	8-39	20 (40)	14 (28)
20 ‰	50	1-2	3-6	50 (100)	1-6	50 (100)	2-8	50 (100)	6-12	50 (100)	8-29	40 (80)	7-24	30 (60)	6-26	28 (56)	4-28	22 (44)	5-26	10 (20)	2 (4)
25 ‰	50	1-2	3-5	50 (100)	1-6	46 (92)	1-8	46 (92)	6-12	44 (88)	3-43	42 (84)	9-35	22 (44)	11-43	20 (40)	14.40	10 (20)	14-18	10 (20)	8 (16)
30 ‰	50	1-2	3-5	50 (100)	1-5	48 (96)	2-8	42 (84)	5-10	38 (76)	12-28	26 (52)	13	20 (40)	3	20 (40)	...	...	...	...	...
35 ‰	50	1-2	3-5	50 (100)	2-8	42 (84)	6-8	24 (48)	10	4 (8)	...	...	...	...	...	...	...	...	...	...	...

Table 21. Survival and larval development of zoea II of Macrobrachium idella in different salinity media

Salinity ‰	Zoea II		Zoea III		Zoea IV		Zoea V		Zoea VI	
	No.	Duration (days)	Duration (days)	Survival Zoea II-III No. (%)	Duration (days)	Survival Zoea II-IV No. (%)	Duration (days)	Survival Zoea II-V No. (%)	Duration (days)	Survival Zoea II-VI No. (%)
0‰	50	2-6	-	-	-	-	-	-	-	-
5‰	50	5-10	3-10	10 (20)	2-8	6 (12)	2	2 (4)	-	-
10‰	50	3-9	4-7	12 (24)	3-9	8 (16)	9	4 (8)	-	-
15‰	50	3-9	3-6	14 (28)	1-5	10 (20)	5-11	5 (10)	7	3 (6)
20‰	50	3-8	2-8	20 (40)	2-10	16 (32)	3-10	9 (18)	8	6 (12)
25‰	50	3-6	2-8	25 (50)	3-7	20 (40)	3-9	19 (38)	8	10 (20)
30‰	50	3-6	2-5	23 (46)	3-7	20 (40)	5-9	10 (20)	6	5 (10)
35‰	50	3-5	2-5	30 (60)	2-6	27 (54)	2-11	21 (42)	9	12 (24)

Table 22. Survival and larval development of zoea III of *Macrobrachium idella* in different salinity media

Salinity ‰	Zoea III		Zoea IV		Zoea V		Zoea VI	
	No.	Duration (days)	Duration (days)	Survival Zoea III-IV No. (%)	Duration (days)	Survival Zoea III-V No. (%)	Duration (days)	Survival Zoea III-VI No. (%)
0‰	50	2-4*	-	-	-	-	-	-
5‰	50	4-6	5	3 (6)	-	-	-	-
10‰	50	2-6	3-5	15 (30)	6-8	10 (20)	2	3 (6)
15‰	50	3-5	3-4	30 (60)	7	5 (10)	-	-
20‰	50	3-7	4-5	15 (30)	1	3 (6)	-	-
25‰	50	3-7	3-4	15 (30)	7	13 (26)	2	3 (6)
30‰	50	2-4	2-5	20 (40)	7-10	10 (20)	4	8 (16)
35‰	50	3-8	3-6	18 (36)	6	8 (16)	-	-

* hours

Table 23. Survival and larval development of zoea IV of <u>Macrobrachium idella</u> in different salinity media.

Salinity ‰	Zoea IV		Zoea V		Zoea VI	
	No.	Duration (days)	Duration (days)	Survival Zoea IV-V No. (%)	Duration (days)	Survival Zoea IV- VI No. (%)
0 ‰	50	2-3*	-	-	-	-
5 ‰	50	3-8	7	5 (10)	-	-
10 %	50	1-5	5-8	23 (46)	3	5 (10)
15 ‰	50	1-6	5-11	18 (36)	7	5 (10)
20 ‰	50	1-6	5-13	23 (46)	11	8 (16)
25 ‰	50	1-6	7-10	25 (50)	6	5 (10)
30 ‰	50	1-5	7	18 (36)	4	3 (6)
35 ‰	50	1-4	4-10	28 (56)	9	10 (20)

* hours

Table 24. Survival and larval development of zoea V of *Macrobrachium idella* in different salinity media.

Salinity ‰	Zoea V		Zoea VI		Zoea VII	
	No.	Duration (days)	Duration (days)	Survival Zoea V-VI No. (%)	Duration (days)	Survival Zoea V-VII No. (%)
0‰	50	2-3*	-	-	-	-
5‰	50	1-3	3	3 (6)	-	-
10‰	50	1-6	19	28 (56)	1	5 (10)
15‰	50	1-8	20	23 (46)	1	3 (6)
20‰	50	1-8	20	23 (46)	1	3 (6)
25‰	50	1-7	8-15	25 (50)	8	5 (10)
30‰	50	1-6	10-15	10 (20)	5	5 (10)
35‰	50	1-8	16	18 (36)	-	-

*hours

Table 25. Survival and larval development of zoea VI of Macrobrachium idella in different salinity media.

Salinity ‰	Zoea VI		Zoea VII		Zoea VIII		Zoea IX		Zoea X	
	No.	Duration (days)	Duration (days)	Survival Zoea VI-VII No. (%)	Duration (days)	Survival Zoea VI-VIII No. (%)	Duration (days)	Survival Zoea VI-IX No. (%)	Duration (days)	Survival Zoea VI-X No. (%)
0‰	50	2-4*	-	-	-	-	-	-	-	-
5‰	50	9	-	-	-	-	-	-	-	-
10‰	50	10-21	3-25	35 (70)	6-28	23 (46)	20-22	15 (30)	4	5 (10)
15‰	50	6-33	4-28	30 (60)	2-26	28 (56)	7-27	20 (40)	20	10 (20)
20‰	50	5-29	3-18	25 (50)	5-21	18 (36)	5-17	13 (26)	12	8 (16)
25‰	50	7-20	4-16	20 (40)	7-16	18 (36)	5-11	8 (16)	6	3 (6)
30‰	50	9-26	3-12	13 (26)	3-15	10 (20)	3-12	8 (16)	10	5 (10)
35‰	50	6-25	6-9	18 (36)	3-18	18 (36)	4-17	10 (20)	12	3 (6)

*hours

Table 26. Survival and larval development of zoea VII of Macrobrachium idella in different salinity media

Salinity ‰	Zoea VII		Zoea VIII		Zoea IX		Zoea X		Postlarva I
	No.	Duration (days)	Duration (days)	Survival zoea VII-VIII No. (%)	Duration (days)	Survival zoea VII-IX No. (%)	Duration (days)	Survival zoea VII-X No. (%)	Survival zoea VII-PL No. (%)
0‰	50	2-3*	-	-	-	-	-	-	-
5‰	50	7	-	-	-	-	-	-	-
10‰	50	14-27	15-17	20 (40)	5	5 (10)	6	5 (10)	5 (10)
15‰	50	15-23	11-24	30 (60)	17	10 (20)	6	5 (10)	5 (10)
20‰	50	2-17	16-17	20 (40)	14	5 (10)	-	-	-
25‰	50	7-19	20-13	25 (50)	7	5 (10)	-	-	-
30‰	50	10-26	19-25	30 (60)	9-10	15 (30)	8	10 (20)	-
35‰	50	16	-	-	-	-	-	-	-

*hours

Table 27. Survival and larval development of zoea VIII of *Macrobrachium idella* in different salinity media

Salinity ‰	Zoea VIII		Zoea IX		Zoea X		Postlarva I
	No.	Duration (days)	Duration (days)	Survival Zoea VIII-IX No. (%)	Duration (days)	Survival Zoea VIII-IX No. (%)	Survival Zoea VIII - PL No. (%)
0‰	50	2-3*	-	-	-	-	-
5‰	50	6-12	13	15 (30)	-	-	-
10‰	50	5-11	9-18	25 (50)	12	10 (20)	5 (10)
15‰	50	5-18	13-22	20 (40)	13	5 (10)	5 (10)
20‰	50	2-15	31	20 (40)	5	5 (10)	5 (10)
25‰	50	2-22	7-25	30 (60)	20-21	10 (20)	5 (10)
30‰	50	6-16	10-24	40 (80)	16	10 (20)	5 (10)
35‰	50	2-23	17-29	35 (70)	15	10 (20)	-

* hours

Table 28. Survival and larval development of zoea IX and zoea X of Macrobrachium idella in different salinity media.

Salinity ‰	Zoea IX No.	Zoea IX Duration (days)	Zoea X Duration (days)	Postlarva I Survival Zoea IX-X No. (%)	Postlarva I Survival Zoea IX-PL No. (%)
0‰	50	2-4*	-	-	-
5‰	50	2-6	8	5 (10)	-
10‰	50	5-21	28-38	10 (20)	10 (20)
15‰	50	2-21	3-29	25 (50)	10 (20)
20‰	50	2-30	4-25	25 (50)	10 (20)
25‰	50	2-33	12-29	15 (30)	5 (10)
30‰	50	5-29	11	15 (30)	-
35‰	50	21	-	-	-

Salinity ‰	Zoea X No.	Zoea X Duration (days)	Postlarva I Survival Zoea X-PL No. (%)
0‰	50	2-4*	-
5‰	50	3-20	5 (10)
10‰	50	8-28	15 (30)
15‰	50	2-20	20 (40)
20‰	50	8-29	15 (30)
25‰	50	18-40	15 (30)
30‰	50	23-30	5 (10)
35‰	50	41	-

* hours

Table 29. Minimum duration (days) taken by the zoea I of *Macrobrachium idella* to develop to different larval stages and postlarva I in different salinity media.

Salinity ‰	Zoea									Postlarva I
	II	III	IV	V	VI	VII	VIII	IX	X	
5‰	1	5	8	13	-	-	-	-	-	-
10‰	1	5	7	9	13	23	29	37	63	81
15‰	1	5	6	9	12	20	23	33	40	48
20‰	1	5	6	8	13	21	28	33	37	42
25‰	1	5	6	7	13	16	25	36	50	64
30‰	1	5	6	8	13	24	29	-	-	-
35‰	1	4	7	13	-	-	-	-	-	-

separately introduced to the different salinities, indicated that while zoea I larvae survived and developed to reach the postlarval stage in salinity 10-25%, zoea II-V failed to reach the postlarval stage in any of the salinities, perhaps due to their poor adaptability compared to zoea I when initially introduced to these salinities. However, from zoea VIII onwards the larvae were capable of adapting to change in salinities and developed to postlarva I.

Experiments IV

The aim of this experiment, was to observe the effect of different salinities on the growth and survival of postlarva I. Postlarva I reared in 10 to 15% salinity were individually kept in 500 ml beakers containing fresh-water and salinities of 1, 2, 3, 4, 5, 10, 15, 20, 25, 30 and 35‰.

Results

The postlarva I reared in all the salinities survived for five days without mortality except those in 1‰ which survived only for 3 days. Within 48 hours, the postlarva reared in 5, 10 and 15‰ moulted. This experiment thus indicated that the postlarva I could withstand a wide range of salinity from 2 to 35‰.

DISCUSSION

The successful rearing of the larvae and adults of Macrobrachium rosenbergii by Ling and Merican (1961) and Ling (1962) generated world wide interest on the culture of prawns of this genus. Though considerable information is now available on the larval development and technology of culture of important commercial species of Macrobrachium detailed studies on the effects of environmental factors on the breeding, development of larvae and on their growth and survival are limited. As indicated earlier, among the different environmental factors, salinity is known to exert profound influence on hatching success of eggs in the berry and the subsequent development of larvae and postlarvae. The observations on the optimum salinity requirements for these functions are found to be inconsistent not only in different species, but also in the same species at different regions. The results of the present experiments on the hatching of eggs of M. idella have shown that females with advanced stage of berry could survive in freshwater and in the salinities from 5‰ to 30‰ and give rise to healthy larvae. Thus, M. idella though considered to be essentially a freshwater species becomes euryhaline during its breeding phase.

Kinne (1906) distinguished three phases of acclimation starting from i) a phase of immediate shock reaction within seconds with substantial increase or decrease in metabolic activity; ii) a stabilizer, commencing minutes, hours or days after change and gradually approaching a steady level and iii) the new steady state commencing after hours, days or weeks which hallmarks the completion of adjustments. M. idella appears to belong to the second category of animals in this adaptation to changes in the environment.

The experiments showed that in the freshwater, the freshly released zoea larvae survived without mortality for 24 hours. Further after 24 hours, mortality started and zoea I never developed to the next stage in freshwater. Thus the experiments indicated that the zoea I would have to move away from freshwater region within 24 hours to an environment with a salinity at least around 5‰ to avoid mortality, which explains migration of berried females of M. idella towards estuaries or backwaters during the breeding season. George (1969 b)and Ling (1969 b) opined that although the hatching of eggs of M. rosenbergii could take place in both fresh and brackish water, it is necessary that the larvae reach the estuaries within 4-5 days for their further development. Similarly, Choudhury (1971 a) observed that eventhough the adults of M. carcinus could live and breed in the freshwater, the larval develop ent would take place only in the brackish water and the first zoea could survive more than 5-6 days in the freshwater.

The first zoea of M. idella, although could not develop to the next stage in freshwater, is found to be capable of tolerating wide ranges of salinity from 5 to 35‰. The time taken for the zoea I to moult to zoea II in different salinities is also found to be uniform (1 to 2 days) with cent per cent survival (Tables 19 and 20). This natural adaptation to a wide salinity range is very important for the survival of zoea as their immediate habitat is the estuary in nature, which is subjected to fluctuating salinities in the environment with the possibility of their being drifted to inshore area of sea or to less saline areas of backwaters. However, as zoea I develops to zoea III, a narrowing down of their tolerance range is observed (Table 19 and 20). The percentage of survival in third, fourth and fifth zoea has been relatively less in 5‰ and 35‰. On the other hand, zoea VIII to postlarva I were able to survive in 5‰ and developed to the next stage. Thus a wider range of tolerance (5‰ to 30‰) in salinity was observed as the larvae developed to higher stage of zoea X and postlarvae. Relatively higher percentage of survival was registered between 15‰ and 25‰. The higher percentage of survival was observed in 15‰ salinity.

Emphasising the role of salinity on the survival and growth of larval stages of species of Macrobrachium under controlled conditions, most of the earlier workers (Ling, 1969 b; Fujimura, 1966; Wickins, 1972; Pillai and Mohamed, 1973; Kewalramani, 1973; Dugan *et al.*, 1975; Goswami *et al.*, 1977) employed the salinity range of 12 to 18‰ for rearing the larval stages. Wickins (1972) found that 26‰ salinity was more suitable for rearing the earlier larval stages of *M. rosenbergii.* However, Lee and Fielder (1981) found that salinity ranges 0 to 15‰ did not markedly affect the survival of larvae of *M australiense*. Moreira *et al.* (1986) reported that the laboratory rearing of *M. amazonicum* could be rapid and highly successful at the temperature of 28°C and salinities between 12 and 18‰.

That the salinity range between 15‰ and 25‰ is optimal among the salinity range tested at present for the larval rearing of *M. idella* is evident from the data on the overall development and growth of the larvae reared in the different salinity media. Besides recording highest percentage of survival, the minimum duration taken for the development of zoea I through different larval stages to postlarva was 48 days in 15‰ and 42 days in 20‰ (Table 29). In the low salinity value (10‰) it was 81 days while in 25‰ the larval development from zoea I to postlarva I took 64 days. Thus the combined data on survival and growth of larvae at different salinities indicate that the most suitable salinity range for the larval development of *M. idella* is 15 to 20‰.

From the results of the experiments conducted it may be concluded that:

1. The eggs in the advanced stage of M. idella would develop and hatch out releasing healthy zoea I in the freshwater as well as in any salinity range up to 35‰.

2. None of the larval stages from zoea I to postlarva I moults and grows in freshwater.

3. Zoea I to III and VIII to X and postlarva I would tolerate wide salinity ranging from 5 to 30‰. However, a narrowing down of the tolerance range of larva is observed as they develop to zoea III stage. Within this range, relatively better survival rate and development are found in the salinity between 15 and 25‰.

4. The optimal salinity for greater survival and rapid development of the larvae of M. idella is 15-20‰.

S U M M A R Y

SUMMARY

1. The larval history of eleven caridean prawns namely, Caridina longirostris, C. pseudogracilirostris, Macrobrachium equidens, M. striatus, M. idella, Palaemon (Palaemon) concinnus, Leptocarpus potamiscus, Leandrites celebensis, Hippolysmata (Exhippolysmata) ensirostris, Alpheus euphrosyne, and A. rapacida dealt with in this thesis, were studied by rearing them in the laboratory. Adult specimens for this study were collected from the southwest coast of India. The results of the experiments conducted on the salinity requirements of larvae and adults of Macrobrachium idella are also presented and discussed.

2. Live berried females and mature adult males of the eleven species collected from nature were maintained in the laboratory under controlled conditions. The zoea larvae hatched out from such known parentage were further reared in the laboratory providing suitable feed and environment upto postlarval/juvenile stage, and in certain cases, extended till they attained maturity and spawned in the laboratory.

3. The larval rearing techniques followed for the different species are presented and discussed. The spawning behaviour, under different conditions of environment, hatching of eggs and larval behaviour were observed and the pattern discussed. The thesis embodies detailed studies on the morphological characters of different stages of larvae and postlarvae of different species based on the materials reared in the laboratory. The diagnostic

characters of the larvae are compared with those of the closely related species to understand their relationship and to delineate the distinguishing features. The larval growth and moulting pattern were also studied.

4. Caridina longirostris has been recorded for the first time from India and its larval development studied by rearing them in the laboratory. 8 well defined zoeal stages, one intermediate stage and one postlarval stage were observed during its larval development. Larvae were reared in 6.8 to 10.2‰ salinity range. Adult characters were fully developed as the larvae attained 17 to 20 mm in total length.

5. The zoea I of Caridina pseudogracilirostris passed through 6 zoeal stages before metamorphosing to postlarva I within a period of 9 days. Larvae were reared in a salinity range of 15 to 16‰. Postlarva I took 84 days to develop to juvenile stage.

6. The striped and non-striped forms included in the hitherto Macrobrachium equidens species complex were studied in detail. On the basis of the external morphological characters of the adult males of these two forms, the distinct colour pattern of the juveniles and adults, incompatibility of interbreeding and certain differences in the larval characters, the taxonomic status of the two forms are discussed pointing to their separate species identities. The striped form, on the basis of the studies was elevated to the species status and described as a new species designating as Macrobrachium striatus.

7. Adults of Macrobrachium equidens and M. striatus when kept separately were found to breed readily in captivity. The incubation period

of eggs in the berry for both the species were observed to be 16 to 17 days.

8. Experiments to interbreed M. equidens and M. striatus did not meet with success.

9. M. equidens and M. striatus had ten well defined zoeal stages before they developed to postlarva I. The postlarva I of both the species is transparent and devoid of deep pigmentation. But when they attain a total length of 27 to 30 mm the characteristic colour pattern of these species were clearly developed. No mixing of colour patterns of intermediate stages were observed when the larvae of both the species were reared in the laboratory.

10. Major differences between the zoeae of M. equidens and M. striatus were noticed in total length, setation of telson and in the endopod of maxillule.

11. One female specimen of M. equidens measuring 62 mm in total length, maintained in the laboratory under controlled conditions, moulted, spawned and acquired berry giving viable eggs 6 times over a period of 123 days.

12. Zoea I of M. idella passed through 10 well defined zoeal stages before metamorphosing to postlarva I, within a period of 39 days.

13. First 7 zoeal stages of Palaemon (Palaemon) concinnus were reared in the laboratory and their development studied. Larvae were reared at a salinity range of 10 to 12‰.

14. During the larval development of Leptocarpus potamiscus the zoea I underwent 16 to 17 moults during a period of 86 to 96 days and passed through 6 zoeal and 9 postlarval stages before metamorphosing into the juvenile. Larvae were reared in 17.2‰ salinity medium.

15. Seven well defined zoeal stages were observed in the larval development of Leandrites celebensis. Zoea I passed through 7 to 8 moults within a period of 13 to 21 days.

16. Larvae of Hippolysmata (Exhippolysmata) ensirostris were studied by rearing them in the laboratory at a salinity range of 34.5 to 35.0‰. 9 well defined zoeal stages were observed and zoea I took 43 days to develop to postlarva I.

17. First three zoeal stages of Alpheus euphrosyne and A. rapacida were studied by rearing them in the laboratory.

18. All the zoeal stages of the 11 species mentioned above were described in detail and their larval rearing techniques discussed.

19. Investigations on the larval history of M. equidens, M. striatus, and M. idella revealed the absolute dependance of their zoeae on salinity in the range 5-35‰ for development. Maximum survival of zoea I to postlarva I was observed when the larvae reared in brackish water medium having salinity 20-25‰ in the case of M. equidens and M. striatus and 15-20‰ in the case of M. idella.

20. Observations were made on the development of pterygostomial and branchiostegal spines and their further transformation in the postlarval, juvenile and adult phases. The studies revealed that the pterygostomial spine of zoeae either developed into hepatic or antennal spine of the adult and branchiostegal spines of zoeae developed into antennal spine of adult.

21. The sequence of development of various appendages during the larval development was discussed. Even though all the species belonged to the "extended larval development" category, the number of zoeae varied from 6 in Leptocarpus potamiscus to 10 in Macrobrachium spp. This was mainly brought about by the overlapping in the developmental sequence of pereiopods and pleopods.

22. Attempts were made to compare the zoeae of different genera included in this thesis. Based on the characters mainly of the rostrum, spines on the carapace and 5th abdominal segment, maxillule, maxilla, maxilliped I and III and pereiopods I and V, certain distinguishing features which could be used to sort out the zoeae of these genera were identified and are discussed in detail.

23. Preliminary observations made on the salinity tolerance of adults and larvae of M. idella revealed the following facts;

i) The eggs in the advanced stage of this species would develop and hatch out releasing healthy zoea I in the freshwater as well as in a salinity range of 5 to 35‰.

ii) None of the larval stages from zoea I to postlarva I could moult or grow in freshwater.

iii) Zoea I to III and VIII to postlarva I could tolerate wide salinity ranges from 5 to 30‰. However, a narrowing down of the tolerance range of larvae was noticed as they develop to zoea IV. Better survival rate was observed when larvae were reared in a salinity of 15 to 25‰.

iv) The optimal salinity for greater survival and rapid development of the larvae was noticed at 15-20‰.

24. In the light of the observations made on the rearing of the larvae and postlarvae of these species and on the general life history, attention is drawn to their potential for aquaculture in the freshwater and brackish-waters.

LIST OF PUBLICATIONS OF THE CANDIDATE

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