FURTHER OBSERVATIONS ON ZOOPLANKTON OF THE POTENGI ESTUARY (NATAL, RIO GRANDE DO NORTE, BRAZIL) WITH SPECIAL REFERENCE TO THE LARVAE OF BRACHYURA (CRUSTACEA, DECAPODA)

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ABSTRACT. The present paper deals with data on zooplankton collected from the estuary of Potengi, Natal, Rio Grande do Norte, Brazil covering a period of one year from October 1992 to October 1993. Three fixed stations within the estuary located at varying distances from the mouth of the river were sampled. Sampling was done monthly when the tide was lowest. Analysis of the samples has shown clear pattern of seasonal variations in abundance of the dominant zooplankton components which are composed of Copepoda, Appendicularia, larvae of Brachyura, larvae of Cirripedia and Chaetognatha. A detailed study of the larvae of Brachyura was also attempted which showed that seven species can be identified in the samples, of which those of *Aratus pisonii* (H. Milne Edwards) and *Cardisoma guanhumi* Latreille have already been described. Other five species are designated here numerically and description of various stages present in the samples are given.
KEY WORDS. Brachyura, seasonal abundance, taxonomy, larvae, estuary, Brazil

Zooplankton of estuaries has received much attention in recent decades offering not only basic information on the productivity of an estuary but also evidences of environmental modifications due to natural as well as human interferences. Most of the estuaries along Brazilian coastal areas have been studied with varying degree of emphasis (TUNDISI 1970; PARANAGUÁ *et al.* 1979; MONTÚ 1980).

The estuary of Rio Potengi, Natal, Rio Grande do Norte, Brazil was subjected to various investigations (SANTOS 1977; ESNAL *et al.* 1985; SANKARANKUTTY *et al.* 1985; SANKARANKUTTY & MEDEIROS 1985; NAIR & SANKARANKUTTY 1988; SANKARANKUTTY 1991; SANKARANKUTTY *et al.* **in press**). The present study was undertaken as a follow-up of the investigations initiated in 1980 and has sampled three fixed stations located at varying distances from the mouth

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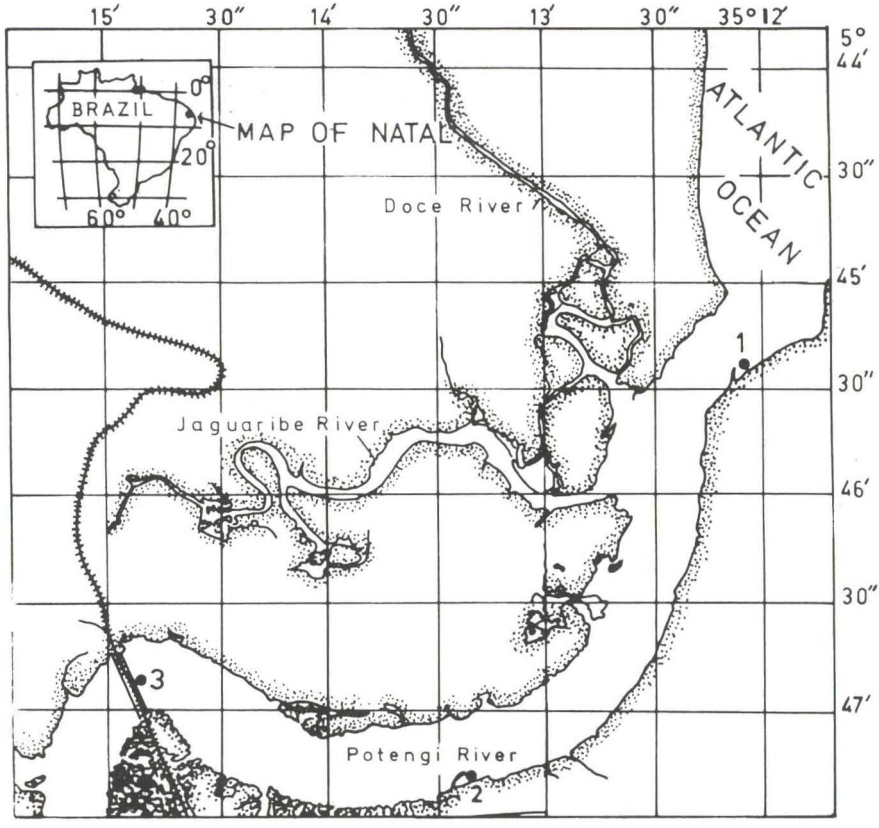

Fig. 1. Map of the estuary of Potengi, Natal showing the location of the stations sampled.

of the river and consequently representing different hydrological conditions. Past studies (*loc. cit.*) have shown that larvae of Brachyura are important components in the zooplankton samples collected from the estuary.

Among the species of Brachyura known to inhabit the estuary, *Callinectes danae* Smith, *Aratus pisonii* (H. Milne Edwards), *Ucides cordatus* (Linnaeus) and *Cardisona guanhumi* Latreille are being exploited on a subsistence level by the local fishrmen (SANKARANKUTTY *et al.* 1991). Though larvae of Brachyura are abundant in the samples throughout the year, their identify is difficult to determine due to the lack of our knowledge on the larvae except on those of *A. pisonii* (WARMER 1968) and *C. guanhumi* (COSTLOW & BOOKHOUT 1959). During the present study, larvae of these species were encountered in large numbers in addition to those of five other species.

The present study gives the description of the common but undescribed larvae of Brachyura as well as seasonal abundance of some of the common larvae. Since larvae of *A. pisonii* is the dominant component, detailed analysis of the data relating to their distribution and abundance is also given.

Unidentified larvae are designated by numbers and their identify will be determined by obtaining larvae of common estuarine species of crabs to be collected from the locality and reared in the laboratory.

MATERIAL AND METHODS

Three fixed stations were chosen for sampling (Fig. 1). At Station 1, located close to the mouth of the river, a floating platform of Yacht Club was used for sampling. A pier of the Naval Base and the bridge at Igapo represented Stations 2 and 3 respectively for sampling purposes. The data presented here covered an year of sampling from October 1992 to October 1993 at monthly interval and the sampling was done between 08:00 and 10:00 hours when the tide was the lowest. Vertical hauls sampled same water column at each station (5.0m, 4.5m and 4.0m at stations 1, 2 and 3 respectively).

Since salinity is the most important environmental factor in an estuary, it was recorded with the help of a refractometer. Surface temperature was also measured at each station.

The samples of zooplankton were collected with a zooplankton net of 48cm mouth diamenter and mesh size of 125 micron. At each sampling five samples were obtained at each station. Laboratory analysis of the zooplankton involved identification and counting of major components. Larvae of Brachyura were separated and futher analysis of this group was done at the Department of Fisheries and Marine Biology of the University of Bergen, Norway. Average value from the five samples was used to calculate the number of organisms per cubic metre of water filtered.

The larvae described here were separated from the rest of the components and studied in detail. Among the larvae in the samples, those of *Aratus pisonii* and *Cardisoma guanhumi* were identified with the help of available literature. Data on *A. pisonii* were analysed in detail as these larvae were the dominant component with all four zoeal stages seen in the samples. Seasonal abundance of two other species, besides *C. guanhumi*, are also given here.

For taxonomic purposes, larvae of undescribed species were studied in detail. Preserved larvae were tranferred to lactic acid and stained with lignin pink. Dissection of individual larva was done in polyvinyl lactophenol. Needles for dissection were specially prepared from tungsten wire employing electrolysis method given by HUYS & BOXSHALL (1991). All the drawings were made with a camera lucida. A maximum of five larvae for each species were studied to confirm the morphological features. Measurements of individual larva was done with the help of an ocular micrometer of a stereo microscope which was calibrated with a slide micrometer.

RESULTS

The results obtained are presented in two sections. First section deals with the distribution and seasonal fluctuation in the abundance of zooplankton in general

as well as those of the common zoea larvae of Brachyura and second section gives description of some common larvae of Brachyura.

The observed values of temperature and salinity are given in table I. As can be seen from the table, annual fluctuation of temperature was between 28°C and 31°C and there is practically no diference in the value from one station to another. Salinity, on the other hand, has oscillated very significantly showing a range of fluctuation of about 16p.p.m. with the minimum value observed in October at all stations.

Table I. Values of physico-chemical parameters observed in the estuary of Rio Pontegi, Natal, during the period October 1992 to October 1993.

Stations	Parameters	Months											
		Oct.	Nov.	Dec.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
1	Temperature (°C)	28.0	28.0	28.0	29.0	29.0	30.0	29.0	28.0	28.0	28.5	28.0	28.0
	Salinity (‰)	23.8	39.0	38.0	36.0	38.0	34.0	29.0	35.0	33.0	35.0	37.0	35.0
2	Temperature (°C)	28.0	28.0	29.0	29.0	30.0	31.0	30.0	29.0	29.0	27.5	28.0	27.0
	Salinity (‰)	23.7	39.0	38.0	36.5	38.0	36.0	33.0	35.0	33.0	33.0	36.0	35.0
3	Temperature (°C)	28.0	28.5	29.0	29.5	30.0	31.0	30.5	29.0	29.0	28.5	28.0	27.0
	Salinity (‰)	23.8	39.0	38.0	36.5	38.0	37.0	35.0	37.0	34.0	33.0	35.0	35.0

Distribution and seasonal fluctuation of zooplankton and Zoea of Brachyura

An analysis of zooplankton (Fig. 2) showed pronounced annual fluctuation with peaks between December and March and the largest concentration of zooplankton was observed in February at Station 2 (37,527/m^3). It was also seen that Station 2 invariably had the largest concentration of zooplankton. Zooplankton population was low at all stations during the period between July and October.

Copepoda which is the dominant component in the samples (Fig. 2) presents identical pattern of annual fluctuation.

Appendiculllaria (Fig. 3) is another important component collected throughout the year. A pronunced annual fluctuation is also evident with the peak observed between December and March. The largest peak occurred at Station 1 in March (401/m^3). Low concentration of appendicularians was seen at Station 3 throughout the year. From September to November they were present in low concentration.

Larvae of Brachyura (Fig. 3) were present throughout the year and two distinct peaks of annual fluctuation are evident, between November and March and another between May and August. Their number is reduced during October and November and again between March and April. Larger concentration of zoeae ocorred at Station 2, except during the period between August and October when

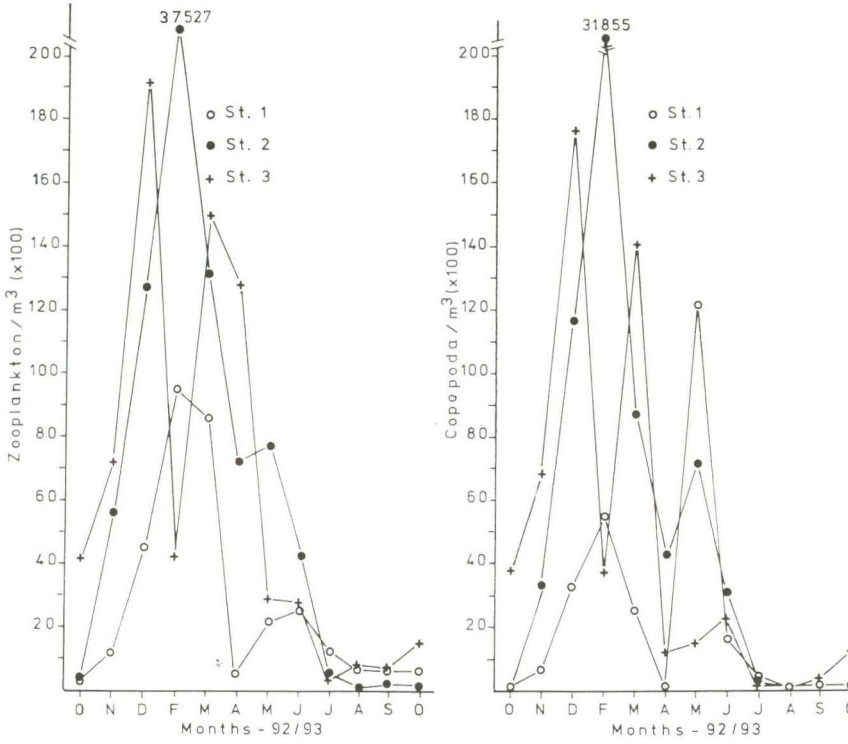

Fig. 2. Seasonal fluctuation of zooplankton and Copepoda during the period October 92 to October 93 at the three stations sampled.

they were collected in larger numbers at Station 3, while Station 1 had fewer larvae compared to other stations during most of the months.

Nauplii of Cirripedia (Fig. 4) is another conspicous component in the samples. They were present in larger numbers during the period between February and July with the exception of a drop in their number in April. Their presence at Station 3 is markedly reduced throughout the year compared to Stations 1 and 2. They were most abundant at Station 1 all through the year except for the months of March and June when Station 2 had more of them.

Chaetognatha (Fig. 4) represent another important group in the samples. They were collected in larger number at all stations during the period November to March. Lowest concentration of Chaetognatha was observed during the period between July and October. An exceptional peak of 1,078/m^3 was recorded at Station 3 in December. Disregarding this peak, Station 2 had invariably larger number of Chaetognatha.

Tables II, III and IV gives the annual fluctuation of minor zooplankton components at the three stations within the estuary.

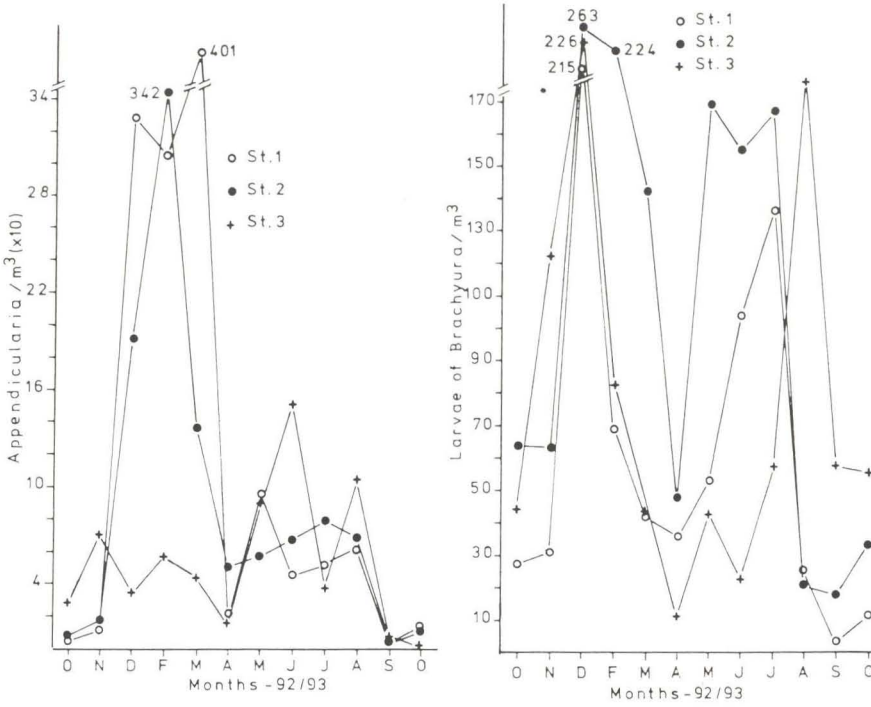

Fig. 3. Seasonal fluctuation of Appendicularia and larvae of Brachyura during the period October 92 to October 93 at the three stations sampled.

Table II. Frequency of occurence of minor zooplankton components (in m^3 of water filtered) collected at Station 1 during the period October 1992 to October 1993.

Components	Oct.	Nov.	Dec.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Medusae	-	-	-	9	10	7	-	-	2	4	3	3
Ctenophora	-	-	-	-	4	20	-	-	-	-	-	-
Larvae of Polychaeta	1	1	1	-	370	588	-	36	1	23	7	62
Larvae of Gastropoda	-	-	-	-	35	5	-	7	3	-	-	5
Larvae of Bivalvia	-	-	-	-	4	-	-	-	2	-	-	4
Ostracoda	-	-	-	-	-	1	-	-	-	-	-	-
Isopoda	3	9	9	-	-	-	-	-	-	-	-	-
Amphipoda	68	2	2	-	5	1	10	1	1	75	36	5
Lucifer	-	-	-	5	4	-	-	-	-	-	-	-
Larvae of Decapoda	5	21	21	19	54	4	3	-	2	3	2	-
Megalopae of Brachyura	-	-	-	2	3	-	-	1	1	-	-	-
Larvae of Ascidia	13	13	13	-	5	-	-	-	3	26	6	11
Fish eggs	-	-	-	-	7	4	-	4	-	1	3	2
Fish larvae	1	3	3	3	10	3	1	2	1	3	3	1

The larvae of *Aratus pisonii* were collected throughout the year (Fig. 5) with two peaks, the first observed during the period between November and

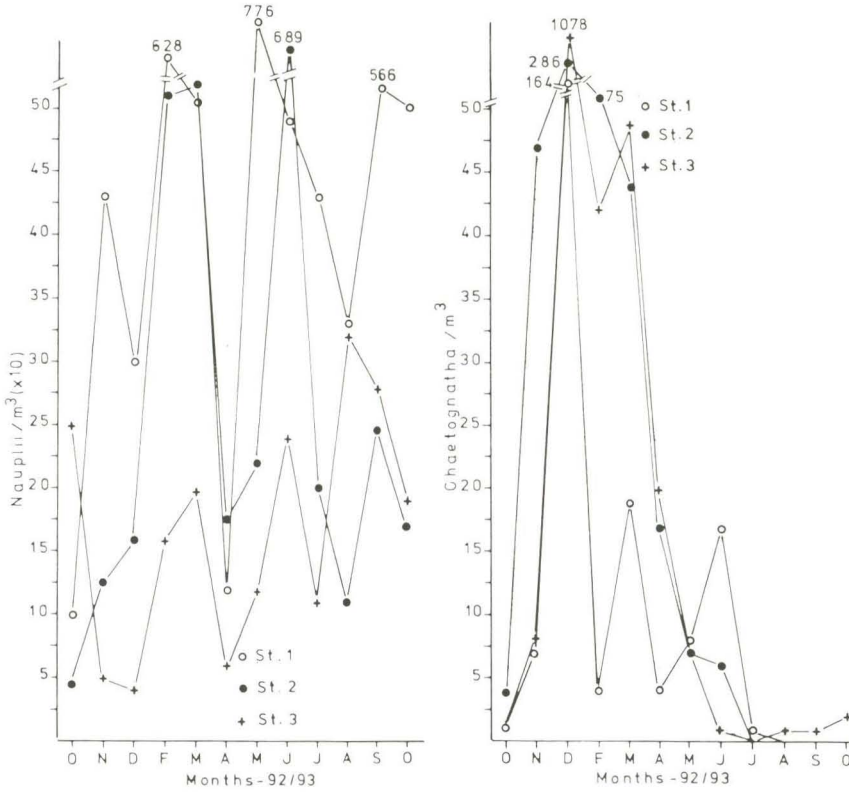

Fig. 4. Seasonal fluctuation of nauplia larvae of Cirripedia and Chaetognatha during the period October 92 to October 93 at the three stations sampled.

February and a subsequent smaller peak in July. Among the three stations sampled, the larvae of *A. pisonii* were more numerous at Station 2. They were fewer at Station 1 all through the year except on a few occasions.

Figure 5 represents the seasonal abundance of the four zoeal stages of *A. pisonii* observed at three stations. Stage I larvae always represented the dominant stage in the samples with two clear peaks, the first and most dominant in December ant the second in July. The subsequent stages are less numerous but present a relatively small peak in February.

The percentage contribution of zoeae of *A. pisonii* in comparison with the zoeae of the rest of Brachyura at the three stations are given in figure 6. As can be seen from these figures, they contributed significantly to the zoeal component of zooplankton. At Station 1 where they were least abundant, they represented between 30% and 70%. At Station 2 they constituted between 45% and 95% of the total zoeal component whereas at Station 3 they contribute between 30% and 96%. Among the larvae identified, those of *Cardisoma guanhumi* (Fig. 7) are the second most common component. They were present in the samples all through

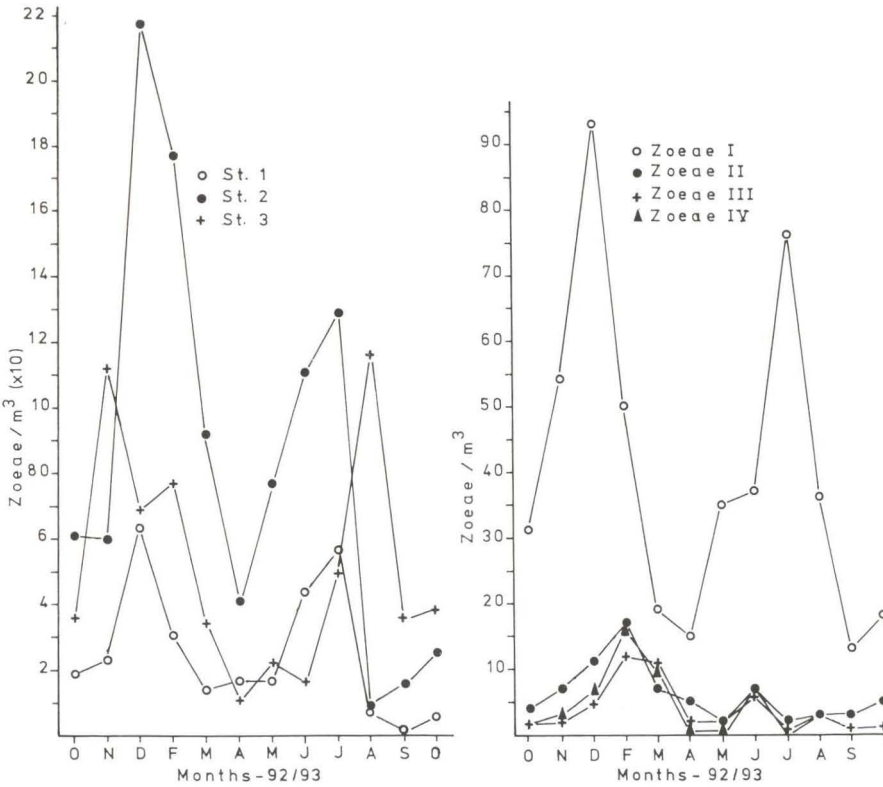

Fig. 5. Seasonal fluctuation of zoea larvae of *Aratus pisonii* during the period October 9 to October 93 at the three stations and seasonal fluctuation of the four zoeal stages.

Table III. Frequency of occurence of minor zooplankton components (in m^3 of wate filtered) collected at Station 2 during the period October 1992 to October 1993.

Components	Oct.	Nov.	Dec.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Medusae	-	-	4	192	53	31	10	2	-	-	3	1
Ctenophora	-	-	-	-	23	5	-	-	-	-	-	-
Larvae of Polychaeta	2	4	9	281	2189	2180	31	11	1	5	3	5
Larvae of Gastropoda	-	18	49	148	180	17	41	-	-	-	7	2
Larvae of Bivalvia	-	-	9	9	10	5	21	-	-	-	-	-
Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	-	1	18	-	-	5	5	5	-	-	-	1
Amphipoda	7	3	4	1	10	-	-	4	2	-	1	2
Lucifer	-	-	-	-	7	-	-	-	-	-	-	-
Larvae of Decapoda	12	3	11	283	184	27	7	6	1	-	1	1
Megalopae of Brachyura	-	-	-	10	2	-	1	1	-	-	-	-
Larvae of Ascidia	4	-	39	18	13	12	12	13	-	1	6	12
Fish eggs	-	-	-	11	12	5	-	-	-	-	2	4
Fish larvae	2	-	-	-	-	-	-	-	-	4	1	1

the year with three distinct peaks, the largest observed in July and two smaller peaks of same dimension in December and May. During the period from February to April and again from August to October, few of these larvae were taken in the samples.

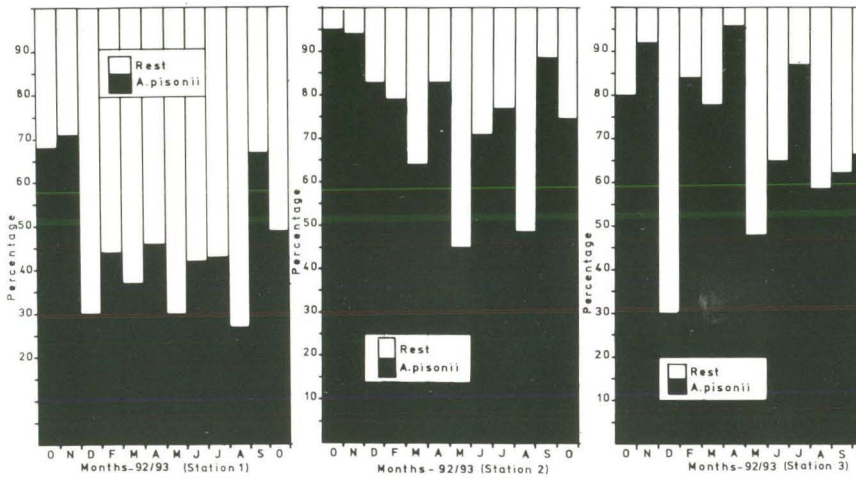

Fig. 6. Percentage participation of the larvae of *Aratus pisonii* and the rest of zoea of Brachyura at the three stations during the period October 92 to October 93.

Table IV. Frequency of occurence of minor zooplankton components (in m^3 of water filtered) collected at Station 3 during the period October 1992 to October 1993.

Components	Oct.	Nov.	Dec.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Medusae	-	-	-	36	35	5	3	-	1	4	3	3
Ctenophora	-	-	-	19	25	-	-	-	-	-	-	-
Larvae of Polychaeta	4	9	12	2176	4238	145	11	56	15	23	7	62
Larvae of Gastropoda	-	5	-	533	490	43	-	74	-	-	-	5
Larvae of Bivalvia	-	28	-	-	21	8	-	15	-	-	-	4
Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	3	2	-	5	-	-	-	5	-	-	-	-
Amphipoda	3	3	8	-	5	3	3	4	2	75	36	5
Lucifer	-	-	-	8	5	-	-	5	-	-	-	-
Larvae of Decapoda	3	3	10	117	186	10	5	26	4	3	2	-
Megalopae of Brachyura	-	-	4	3	1	-	-	5	-	-	-	1
Larvae of Ascidia	4	4	-	24	14	3	12	18	8	26	6	11
Fish eggs	-	-	-	5	7	-	-	5	-	1	3	2
Fish larvae	2	3	3	5	11	8	3	5	1	3	3	1

Two other larvae which are abundant enough in the samples to study their seasonal fluctuation are Zoea 002 and Zoea 003 (Fig. 7). Of these, larvae of Zoea 002 were present all through the year and did not present any clear pattern of seasonal abundance except for the peak observed in May. On the other hand, the

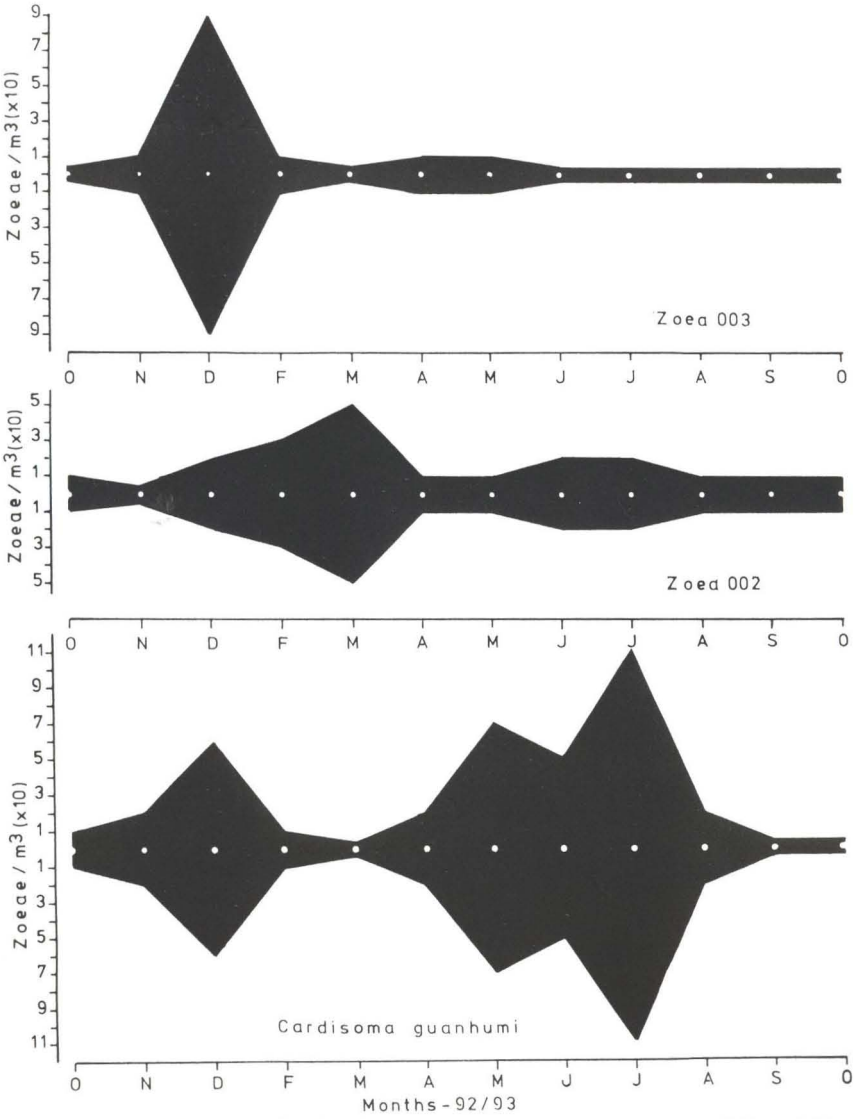

Fig. 7. Seasonal fluctuation in abundance of zoeae of *Cardisoma guanhumi*, Zoea 002 and Zoea 003.

larvae of Zoea 003 showed a very distinct peak of abundance in December; during the rest of the year number of these larvae was very much reduced.

Remarks. A similar study was carried out within the estuary during the period 1979-1980 (SANKARANKUTTY *et al.* in press) when only one station (Station 1) was sampled. A comparison of the data obtained now with those of the previous study shows some clear changes in seasonal fluctuations in the abundance of zooplankton. The period of peak of zooplankton abundance in the past was in

August and subsequently in November whereas during the present study this was the period of low zooplankton productivity. As can be seen from the present investigation, the period between November and April can be considered the peak period of zooplankton production within the estuary. The divergence between the two observations mentioned above obviously demonstrates the need for long term study to establish the pattern of zooplankton production and to accompany any environmental changes taking place within the ecosystem.

TAXONOMY

An estuary subjected to fluctuations in salinity enforces limitations on the diversity of fauna which can survive in such environment. This was clearly reflected in the present study when relatively few species of larvae were observed in the samples. It was possible to distinguish seven types of larvae of which the larvae of *Aratus pisonii* and *Cardisoma guanhumi* have already been described previously. Five other types of larvae which could not be identified with certainly are described here and designated by numbers. A thorough survey of the estuary will be done to obtain all the species of Brachyura which inhabit the estuary and attempts will be made to obtain their larvae in the laboratory which can then establish the identity of the larvae described here.

ZOEA 001

(Fig. 8)

This larva was found throughout the year but only the first stage of zoeae was present in the samples.

Diagnosis. Carapace rather rounded and has all the spines (Fig. 8A, B), dorsal, rostral and lateral; rostral spine is slightly larger and stouter than dorsal spine, lateral spine is smallest with ventrally directed tip. Abdomen (Fig. 8J) is composed of five segments and a telson; second segment has a carina across the segment closer to the posterior margin which ends laterally in a spiny projection; lateral border of third segment bulging; fifth segment is laterally expanded and projects distally as a lobe; telson is broader in the middle and narrows slightly towards the base of the fork; distal end of telson has a median triangular lobe as well as three pairs of setae.

Measurements (in mm). Carapace length 0.40; length of dorsal spine 0.12; length of rostral spine 0.16; length of lateral spine 0.10; length of telson 0.20.

Antennule (Fig. 8C) is short and stumpy, much larger than antenna and carries one spines and two short aesthetases.

Antenna (Fig. 8D) is very minute, consisting of a simple spinous process.

Maxillule (Fig. 8E) has a two-segmented endopodite which carries at its distal end four setae; basal endite has four stout setae and coxal endite three setae.

Scaphognathite of maxila (Fig. 8F) has four plumose setae on the lateral border while at the posterior end a long plumose process is situated. Basal endite and coxal endite carry six setae each; former bilobed while latter not clearly bilobed.

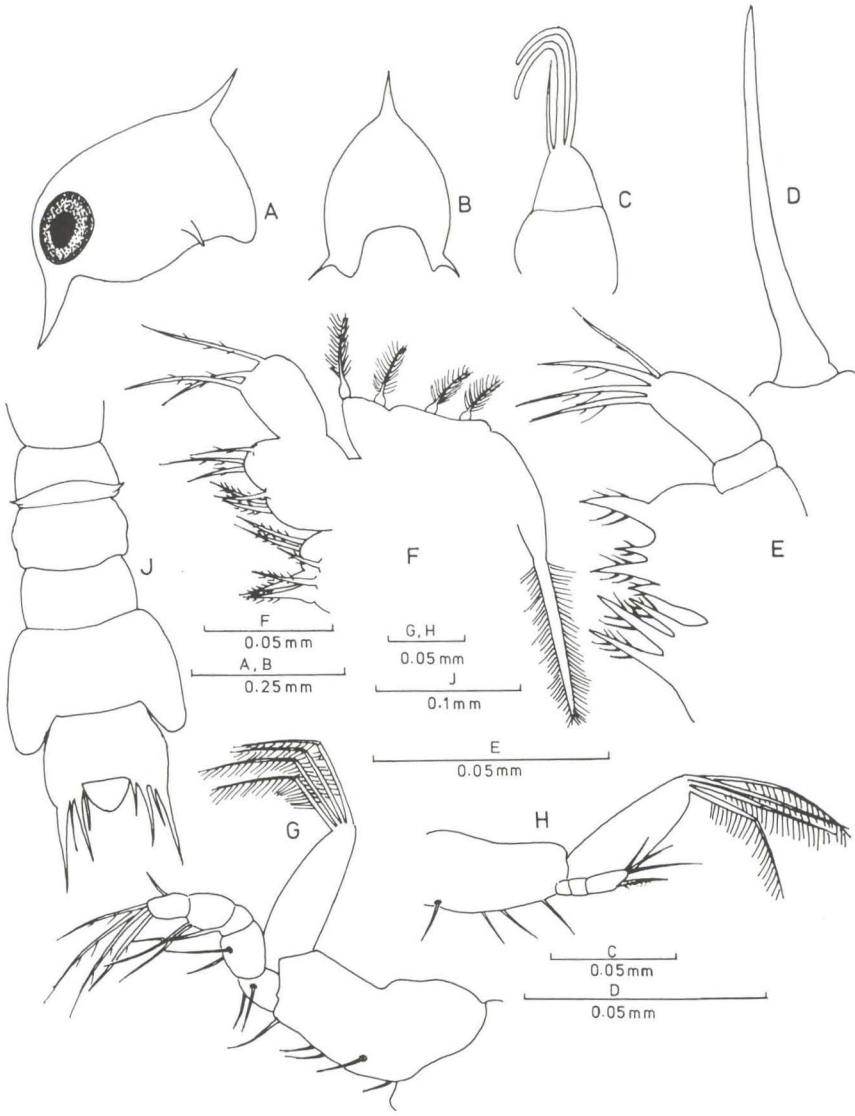

Fig. 8. Zoea 001, Stage I larva. (A,B) Carapace, lateral and posterior views; (C) antennule; (D) antenna; (E) maxillule; (F) maxilla; (G) maxilliped I; (H) maxilliped II; (J) abdomen.

Basipodite of maxilliped I (Fig. 8G) has five setae; five-segmented endopodite has 2, 2, 1, 2 and 5 setae from first to fifth segment, second segment longest and third shortest; exopodite with four plumose swimming setae at distal end.

Basipodite of maxilliped II (Fig. 8H) has two to four setae; 3-segmented endopodite with four setae at the distal end of last segment; one of them stouter and serrate; exopodite carries four plumose swimming setae.

Remarks. The larva described above has some striking features such as the flattened abdomen with lateral expansion of the fifth segment and the presence of a triangular lobe in the middle of the distal end of telson. The presence of the median lobe on the telson is a characteristic feature of some of the species of *Pinnotheres* (LEBOUR 1928; SANDOZ & HOPKINS 1947; NOBLE 1974; RICE 1975; PREGENZER 1979) and also that of *Ostracotheres tridacnae* Ruppell (GOHAR & AL-KHOLY 1957). Reduced antenna is another characteristic feature of the larvae of the species of *Pinnotheres* as well as those of *Ebalia* and *Elamena* (NOBLE 1974). However the expanded fifth segment is a distinct feature of the larvae described here.

Table V. Zoea 002, comparison of morphological features of four zoeal stages.

Features	Stage I	Stage II	Stage III	Stage IV
Length carapace (mm)	0.50	0.50	0.70	0.70
Rostral spine	0.74	0.96	1.54	1.74
Dorsal spine	0.72	0.82	1.16	1.30
Antennal spine	0.64	0.94	1.50	1.72
Telson	0.36	0.46	0.68	0.92
Antennule	1 spinule and 2 aesthetacs	As in Stage I	As in Stage I	2 spinules and 3 aesthetacs
Antenna	Simple, long and slightly spiny	As in Stage I, but unarmed	Presence of exopod	As in Stage III
MAXILLULE				
Endopodite	1^{st} segment with 1 and 2^{nd} with 5 setae	As in Stage I	2^{nd} segment with 6 setae	Same as in Stage III
Basal endite	4 setae	7 setae	8 setae	10 setae
Coxal endite	4 setae	5 setae	7 setae	7 setae
MAXILLA				
Scaphognathite	4 plumose setae	9 plumose setae	18 plumose setae	25 plumose setae
Endopodite	3 + 5 setae	As in Stage I	As in Stage I	As in Stage I
Basal endite	9 setae	10 setae	10 setae	12 setae
Coxal endite	5 setae	8 setae	6 setae	7 setae
MAXILLIPED I				
Protopodite	8 setae	10 setae	11 setae	10 setae
Endopodite	Setation from 1^{st}-5^{th} segment 2, 2, 1, 2, 4	Setation same as in Stage I	Setation from 1^{st}-5^{th} segment 2, 2, 1, 2, 6	Setation as in Stage III
Exopodite	4 plumose setae	6 plumose setae	As Stage II	9 plumose setae
MAXILLIPED II				
Protopodite	4 setae	4 setae	3 setae	3 setae
Endopodite	Setation from 1^{st}-3^{rd} segment 1, 1, 5	Setation as in Stage I	Setation as in Stage I	Setation as in Stage I
Exopodite	4 plumose setae	6 plumose setae	7 plumose setae	9 plumose setae
Maxilliped III	Absent	Absent	Small bilobed bud	As in Stage III
Pereiopods I-V	Absent	Absent	Represented as buds	As in Stage III
Abdomen	5 segments + telson	As in Stage I	6 segments + telson	As in Stage III
Pleopods	Absent	Absent	Bilobed bud	Larger than in Stage III

ZOEA 002

(Figs 9-12)

These larvae were common in the samples and during the period of sampling four zoeal stages were collected and identified.

Stage I Zoea (Fig. 9)

Diagnosis. Carapace (Fig. 9) has very long and thin rostral spine and antenna, rostral spine distinctly longer than dorsal spine which is also long and thin; lateral spine is very reduced and slightly up-turned towards the tip. Eyes are sessile at this stage. Abdomen (Fig. 9H) consists of five segments and telson, second segment has a pair of anterolaterally directed lobes located nearer anterior border, third segment has a pair of much smaller projection also placed closer to the anterior border; telson deeply forked, long and is almost three-fourth total length of five segments, distal end of telson has normal three pairs of setae as well as a small seta on the dorsal surface just beyond the outermost seta of the distal border.

Antennule (Fig. 9B) is almost oval in shape and elongated and with a spinule and two asthetases.

Antenna (Fig. 9C) is extremly long and only very slightly shorter than long rostral spine, it is in the form of a long process which has a few spicules near the distal end.

Maxillule (Fig. 9D) has a two-jointed endopodite which is provided with five long setae at the distal end as well as another seta on the basal segment; basal and coxal endites have four setae each.

Scaphognathite of maxilla (Fig. 9E) carries four plumose setae on its outer border; endopodite is bilobed and has three and five setae on proximal and distal lobes respectively; basal endite is bilobed and armed with nine setae and coxal endite has five setae.

Protopodite of maxilliped I (Fig. 9F) is provided with eight setae and five-segmented endopodite has setae distributed as follows from first to fifth segment: 2, 2, 1, 2 and 4; exopodite carries four swimming setae at the tip.

Protopodite of maxilliped II (Fig. 9G) carries four setae; endopodite has a seta each on first and second and five setae on distal segment; exopodite has four swimming setae.

Remarks. Since the larvae described here are extremly common and four different developmental stages were obtained, it is quite likely that we can expect a sizable population of the species within the estuary. Only an intensive survey of the estuary and larviculture of the common species of the estuary can help in determining the identity of the larvae.

Zoea 003 (Fig. 13)

This larva was also collected all through the year as mentioned before but all the larvae in the samples belonged to Stage I.

Dignosis. Carapace (Fig. 13A) has all three spines, dorsal, lateral and

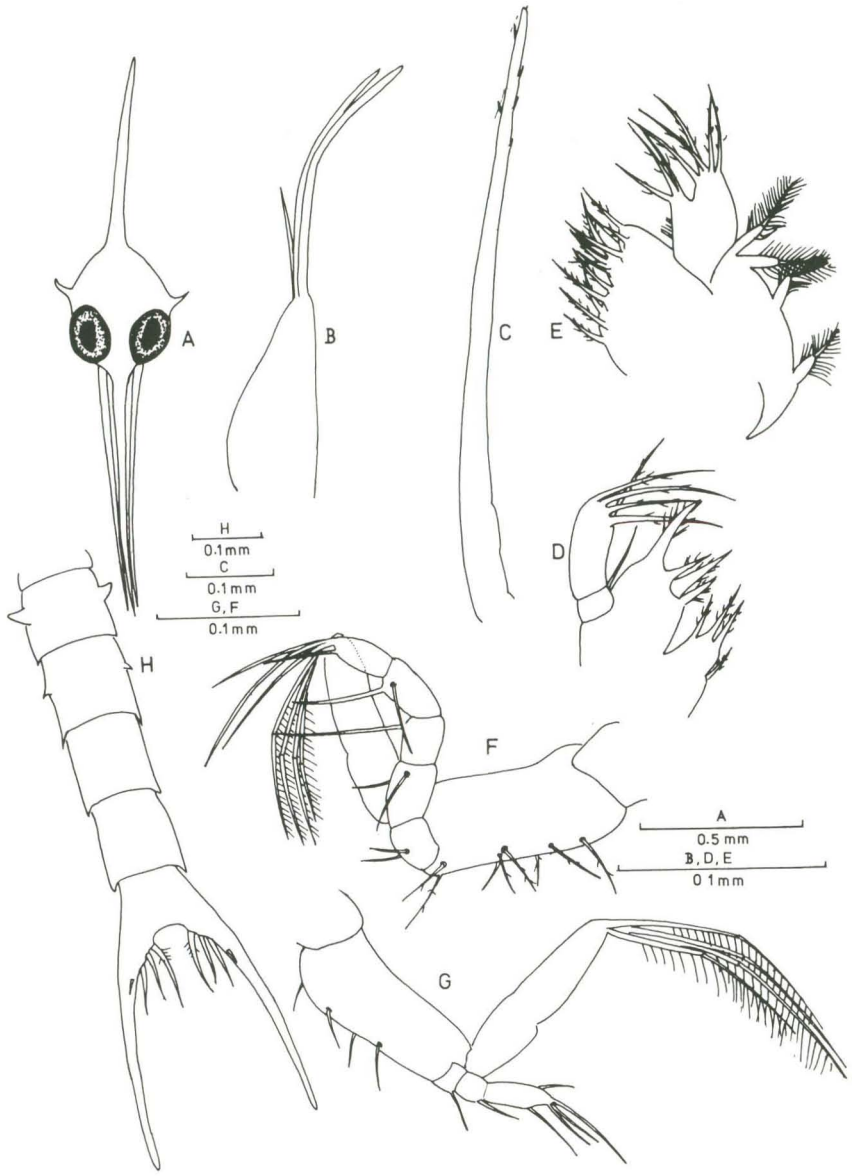

Fig. 9. Zoea 002, Stage I larva. (A) Carapace, viewed from front; (B) antennule; (C) antenna; (D) maxillule; (E) maxilla; (F) maxilliped I; (G) maxilliped II; (H) abdomen.

rostral; dorsal spine largest and curved posteriorly, lateral spine shortest. Eyes are sessile at this stage. Abdomen (Fig. 13D) consists of five segments and telson; second segment has an anteriorly curved lobe placed in the middle of the segment; the lobe on third segment smaller and pointing postero-laterally and located closer to anterior border of segment; postero-lateral corner of third to fifth segments end

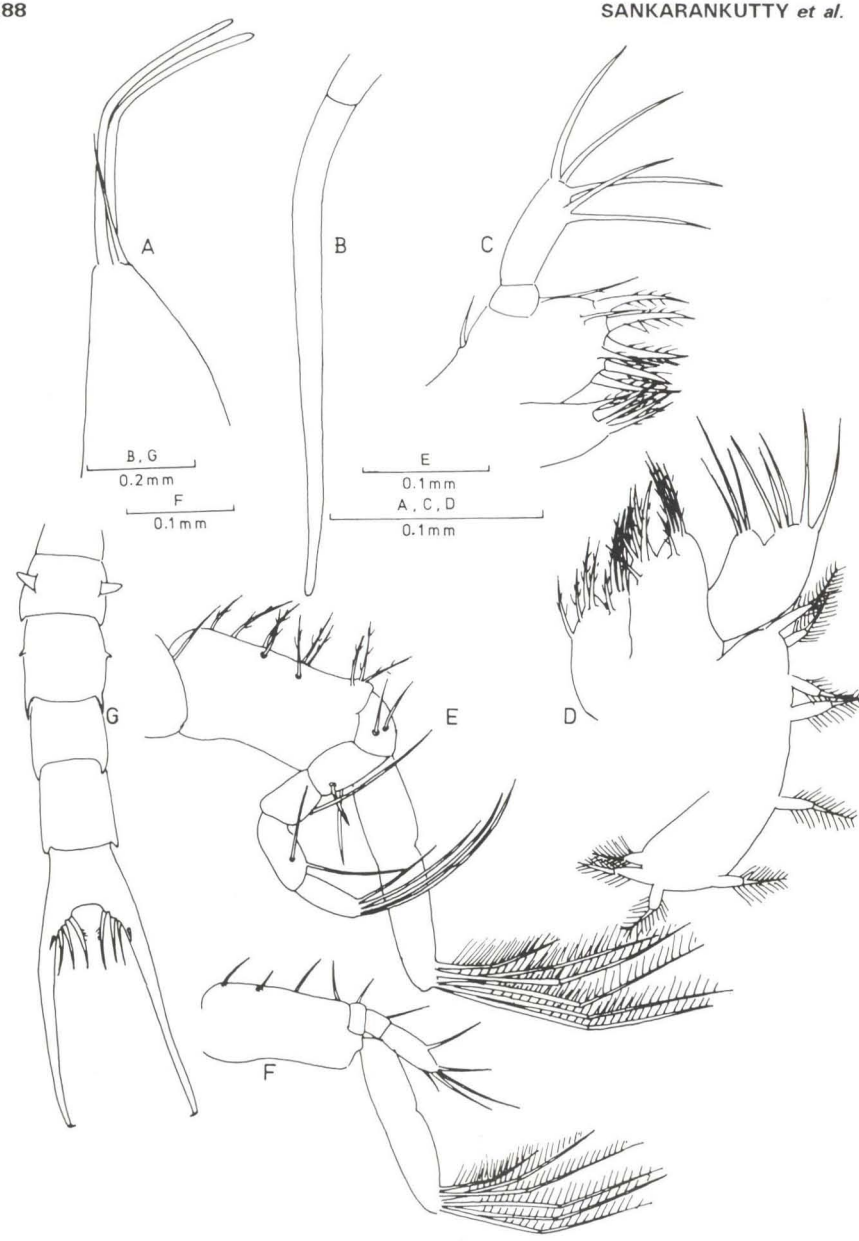

Fig. 10. Zoea 002, Stage II larva. (A) Antennule; (B) antenna; (C) maxillule; (D) maxilla; (E) maxilliped I; (F) maxilliped II; (G) abdomen.

in spiny projections; telson is forked and has the normal complement of three pairs of setae within the fork; telson has a large spine on the lateral border placed closer to the proximal end of telson than to tip of fork, a much smaller spine is also found on the dorsal surface of fork.

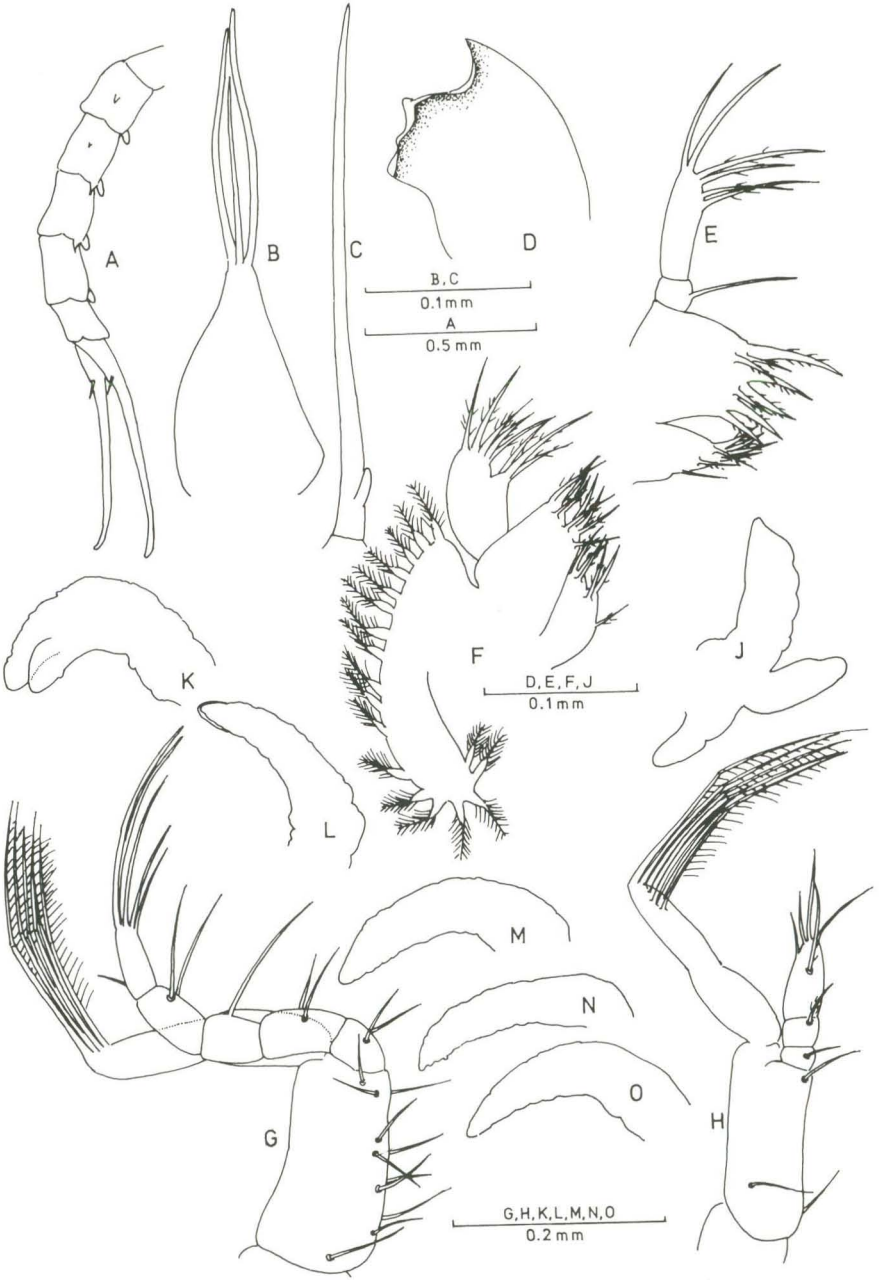

Fig. 11. Zoea 002, Stage III larva. (A) Abdomen; (B) antennule; (C) antenna; (D) mandible; (E) maxillule; (F) maxilla; (G) maxilliped I; (H) maxilliped II; (J) maxilliped III; (K) pereiopod I; (L) pereiopod II; (M) pereiopod III; (N) pereiopod IV; (O) pereiopod V.

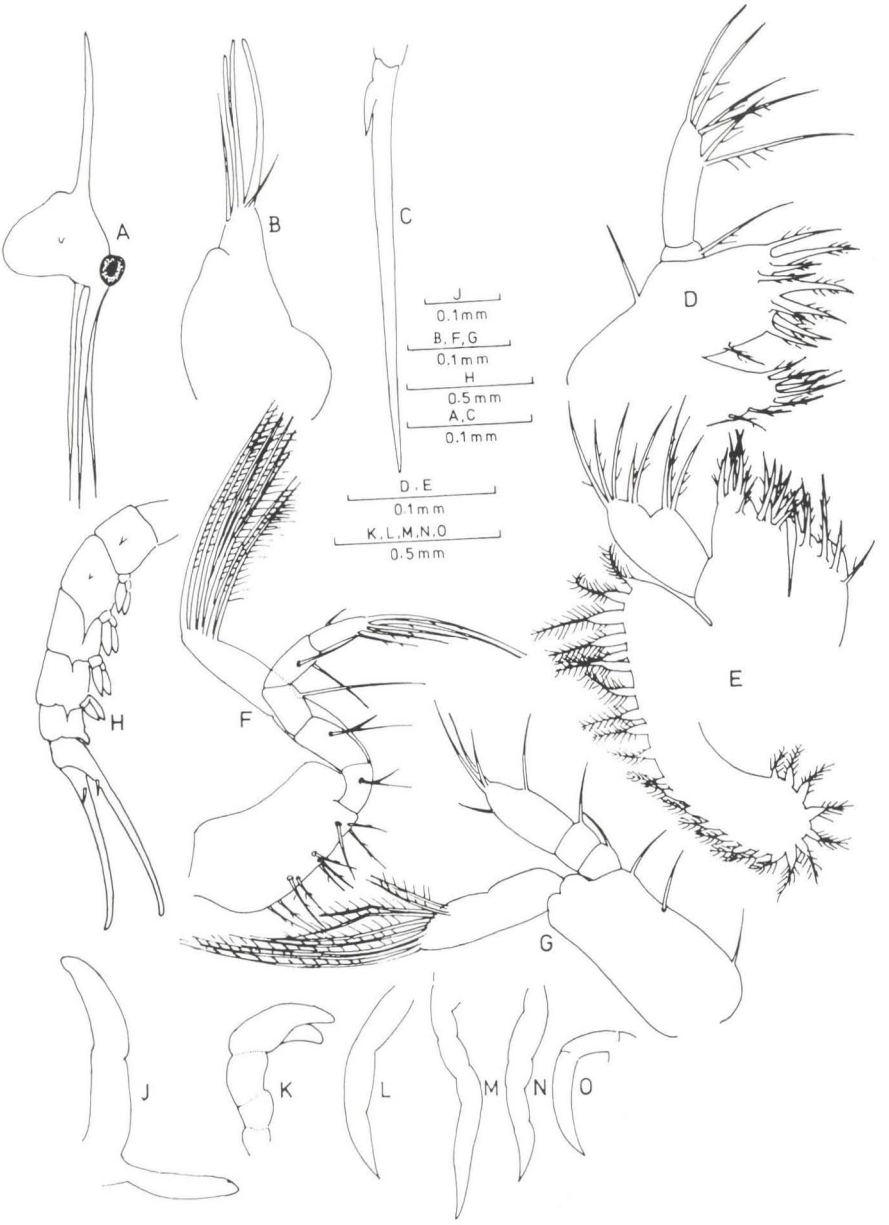

Fig. 12. Zoea 002, Stage IV larva. (A) Carapace, lateral view; (B) antennule; (C) antenna; (D) maxillule; (E) maxilla; (F) maxilliped I; (G) maxilliped II; (H) abdomen; (J) maxilliped III; (K) pereiopod I; (L) pereiopod II; (M) pereiopod III; (N) pereiopod IV; (O) pereiopod V.

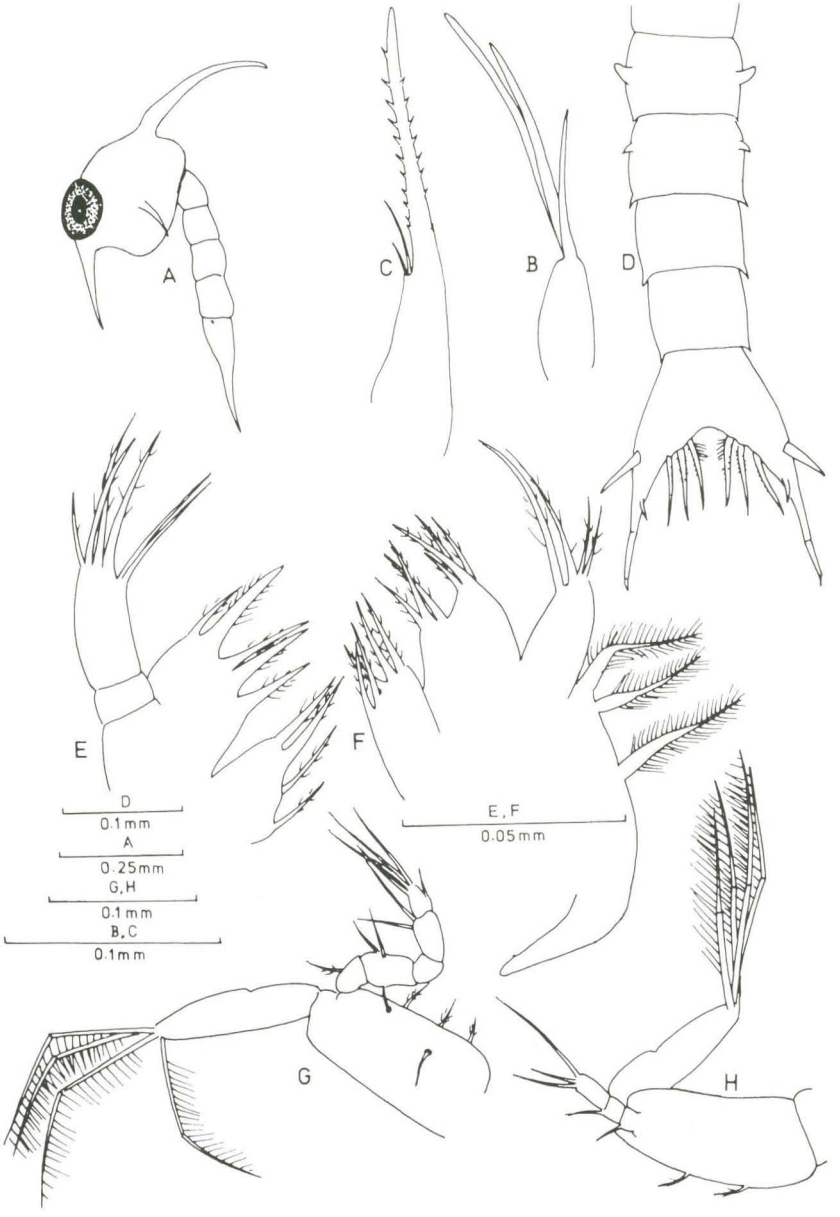

Fig. 13. Zoea 003, Stage I larva. (A) Carapace, lateral view; (B) antennule; (C) antenna; (D) abdomen; (E) maxillule; (F) maxilla; (G) maxilliped I; (H) maxilliped II.

Measurements (in mm). Carapace length 0.24; length of dorsal spine 0.32; length of rostral spine 0.18; length of lateral spine 0.12; length of telson 0.26.

Antennule (Fig. 13B) is almost oval in shape and has a spinule and two aesthetascs of unequal size.

Antenna (Fig. 13C) is represented by a long spiny process and two small setae of enequal size located closer to the base of protopodite.

Maxillule (Fig. 13E) has two segmented endopodite which carries six setae on the distal segment. Basal and coxal endites have five and four setae respectively.

Scaphognathite of maxilla (Fig. 13F) is armed with three plumose setae which are placed nearer the anterior end, endopodite ends in four setae - two larger and two smaller; basal and coxal endites have seven and five setae respectively.

Protopodite of maxilliped I (Fig. 13G) has a total of five setae; setation on five-segmented endopodite is: 1, 2, 0, 2 and 5 from first to fifth segment; second and fourth segment are subequal in length so are first and thrid segments; four swimming setae are present on exopodite.

Protopodite of maxilliped II (Fig. 13H) has two setae; three-segmented endopodite has 1, 1 and 3 setae from first to third segment respectively; exopodite has four swimming setae.

Remarks. The larvae described here has, with minor variation, remarkable resemblence to the larvae of *Callinectes sapidus* (COSTLOW & BOOKHOUT 1959). Since *C. danae* is very abundant in the estuary, it is probable that this larvae may belong to that species. However, only laboratory culture of the larvae from ovigerous female can confirm this presumption.

ZOEA 005

(Figs 14-16)

The samples studied contained three zoeal stages of this larva which are described below.

Stage I Zoea (Fig. 14)

Diagnosis. Carapace (Fig. 14A, B) is provided with dorsal, rostral and lateral spines, rostral spine largest and slightly curved to the tip, lateral spine almost as long as dorsal spine, eyes are sessile at this stage. Abdomen (Fig. 14J) consists of five segments and a telson; is curved and pressed close to the body; second segment has a curved carina which ends on either side in a spiny projection close to the posterior border; a pair of spicules can be found on segments two to five situated closer to posterior border; fifth segmented expanded laterally and ends in a truncated lobe at the posterior end; telson is forked, wider in the middle and narrows distally, distal end carries three pairs of setae.

Antennule (Fig. 14C) is bi-segmented and oblong in shape narrowing to the distal end and carries a spine and one aesthetasc.

Antenna (Fig. 14D) is very much reduced and is in the form of a long spiny process which has two rows of spicules.

Two-segmented endopodite of maxillule (Fig 14E) has only four setae at the distal end of last segment; basal endite has a total of five setae in two groups; coxal endite carries four setae.

Scaphognathite of maxilla (Fig. 14F) is provided with four plumose setae on its lateral border and elongated posterior end also end in a plumose process;

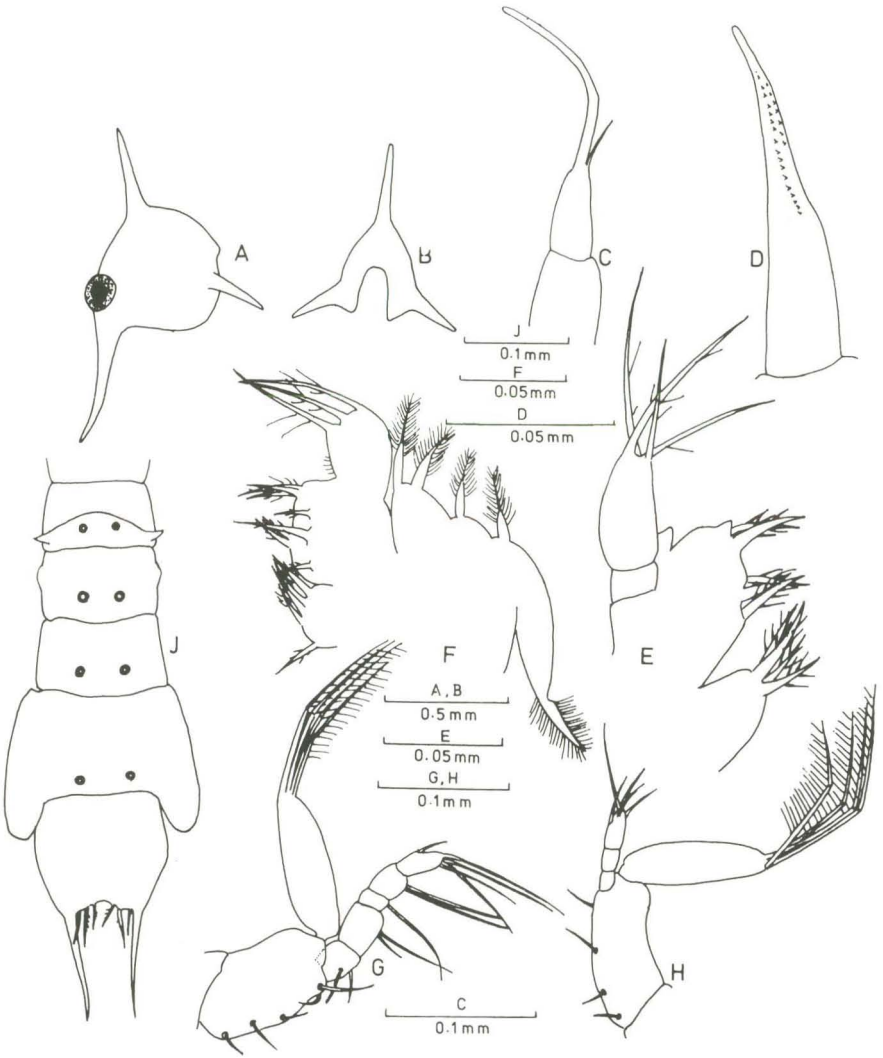

Fig. 14. Zoea 005, Stage I larva. (A,B) Carapace, lateral and posterior view; (C) antennule; (D) antenna; (E) maxillule; (F) maxilla; (G) maxilliped I; (H) maxilliped II; (J) abdomen.

endopodite has three long setae; basal and coxal endites have eight and five setae respectively.

Basipodite of maxilliped I (Fig. 14G) carries five setae, setation on the five segments of endopodite is: 2, 2, 1 and 5; swimming setae on expodite are four in number.

Basipodite of maxilliped II (Fig. 14H) has three to four setae; three-segmented endopodite terminates in five setae; exopodite is provided with four swimming setae.

Table VI. Zoea 005, comparison of morphological features of four zoeal stages.

Features	Stage I	Stage II	Stage III
Length carapace (mm)	0.40	0.56	0.80
Rostral spine	0.30	0.58	1.64
Dorsal spine	0.22	0.44	1.58
Lateral spine	0.22	0.40	1.58
Telson	0.18	0.22	0.34
Antennule	1 spinule and 1 aesthetacs	1 spinule and 2 aesthetacs	As in Stage II
Antenna	Spiny process minutely armed	Spine process unarmed but with a small seta	Spiny process with an enlarged base
MAXILLULE			
Endopodite	2nd segment with 4 setae	As in Stage I	As in Stage I
Basal endite	4 setae	6 setae	9 setae
Coxal endite	4 setae	4 setae	4 setae
MAXILLA			
Scaphognathite	4 + 1 plumose setae	5 + 3 plumose setae	7 + 9 plumose setae
Endopodite	3 setae	4 setae	4 setae
Basal endite	7 setae	9 setae	10 setae
Coxal endite	5 setae	5 setae	7 setae
MAXILLIPED I			
Protopodite	5 setae	6 setae	6 setae
Endopodite	Setation from 1st-5th segment 2, 2, 1, 2, 5	As in Stage I	Setation from 1st-5th segment 2, 2, 1, 2, 4
Exopodite	4 swimming setae	6 swimming setae	As in Stage II
MAXILLIPED II			
Protopodite	4 setae	4 setae	2 setae
Endopodite	5 setae on last segment	As in Stage I	As in Stage I
Exopodite	4 swimming setae	5 swimming setae	As in Stage II
Maxilliped III	Absent	Absent	As a bud
ABDOMEN			
Telson	Lateral border without a spinule	Lateral border with a small projection	Lateral border with a small spinule

Remarks. This larva has remarkable resemblance to Zoea 001 with regard to the general characteristic feature abdomen. But the absence of the median triangular lobe larger spines of carapace are some of the features which are helpful in the separation of this larva.

ZOEA 006

Figs 17-18

This larva, though was not uncommon in the samples, was not as abundant as the larvae described before. The samples contained the first two zoeal stages of this larvae.

Stage I Zoeae (Fig. 17)

Diagnosis. Carapace (Fig. 17A, B) has all three spines, dorsal spine is

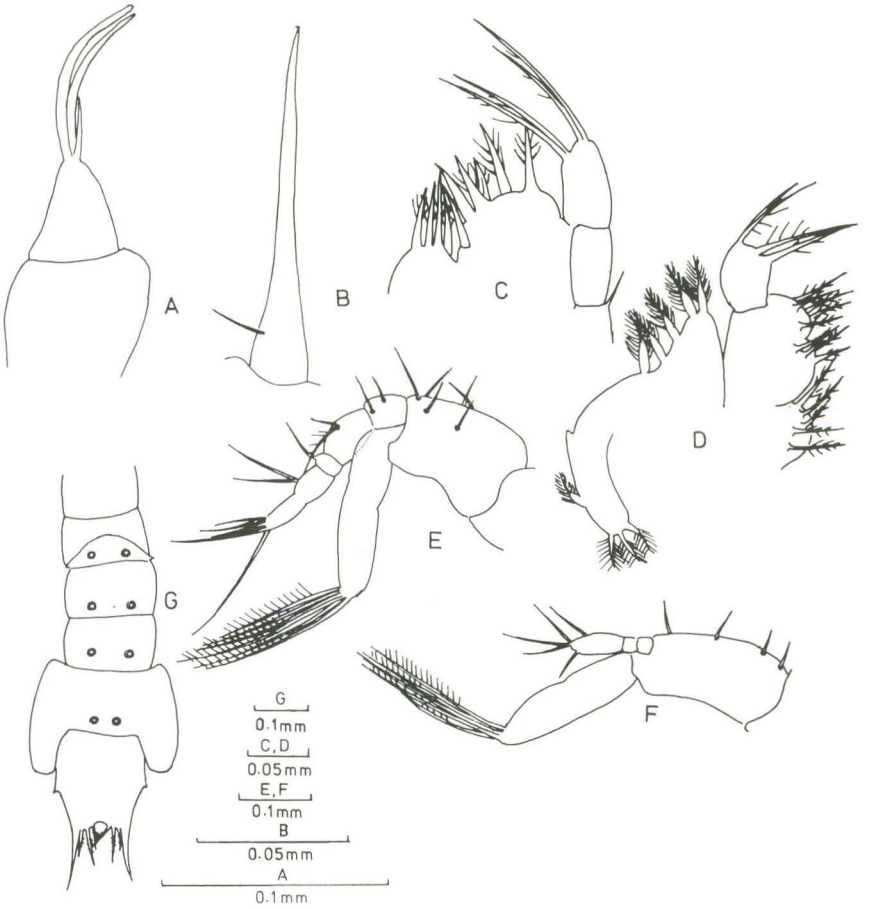

Fig. 15. Zoea 005, Stage II larva. (A) antennule; (B) antenna; (C) maxillule; (D) maxilla; (E) maxilliped I; (F) maxilliped II; (G) abdomen.

largest and lateral spine smallest and laterally directed. Eyes are sessile at this stage. Abdomen consists of five segments and telson; second segment has anteriorly turned lobe located closer to the anterior border; third segment has a small spiny projection situated almost in the middle of segment; postero-lateral borders of segments 3 to 5 are spiny, that of fifth segment largest; telson forked and its distal border has the normal three pairs of setae, a small spinule is also present on the outer border of telson almost midway between the base and tip of telson.

Antennule (Fig. 17C) is elongated and narrows to the distal end, two aesthetascs and one spinule can be seen at the distal end.

Spiny process of antenna (Fig. 17D) is provided with spicules in two rows and expodite is long but shorter than spiny process and has two setae of unequal size.

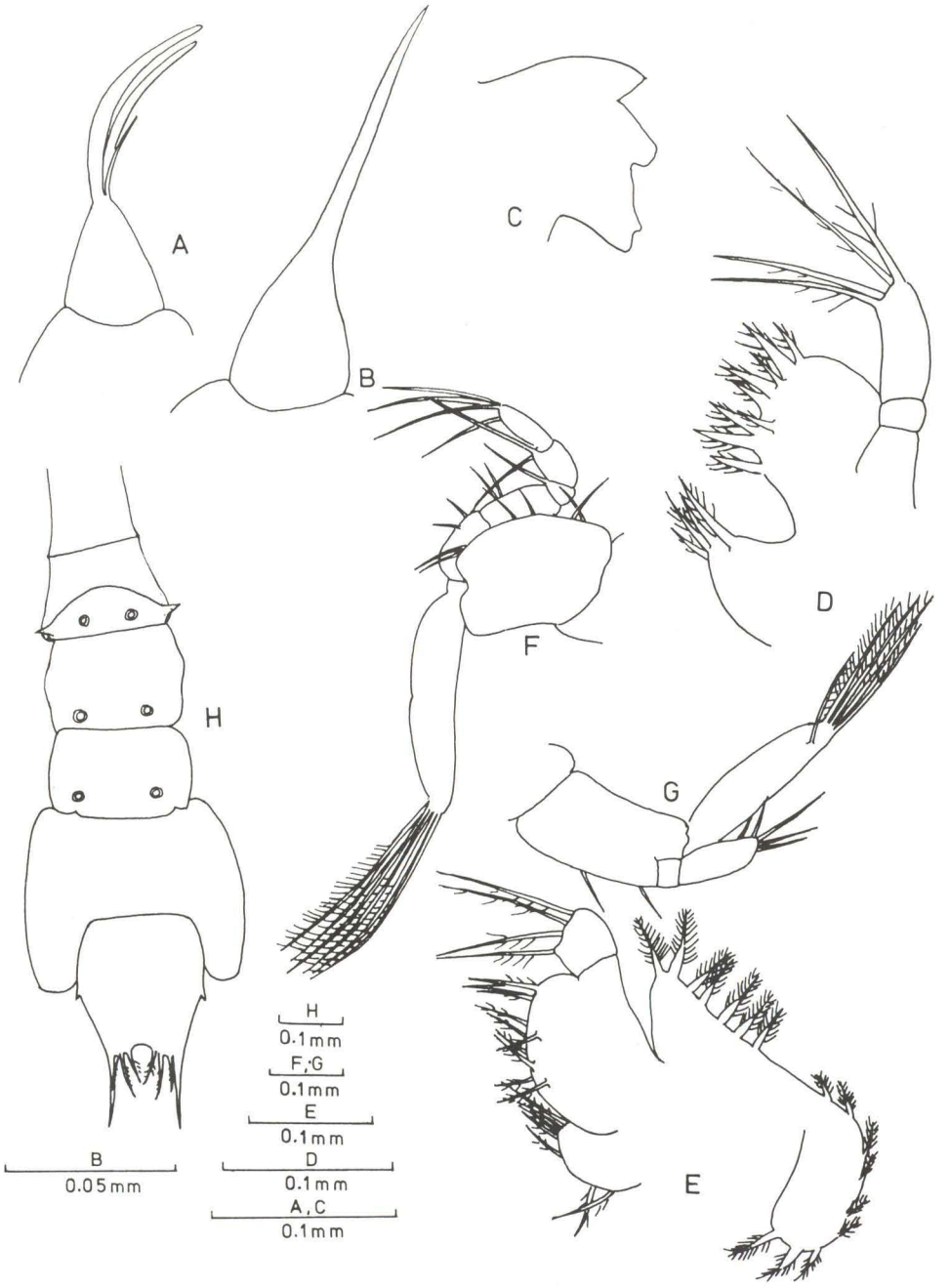

Fig. 16. Zoea 005, Stage III larva. (A) antennule; (B) antenna; (C) mandible; (D) maxillule; (E) maxilla; (F) maxilliped I; (G) maxilliped II; (H) abdomen.

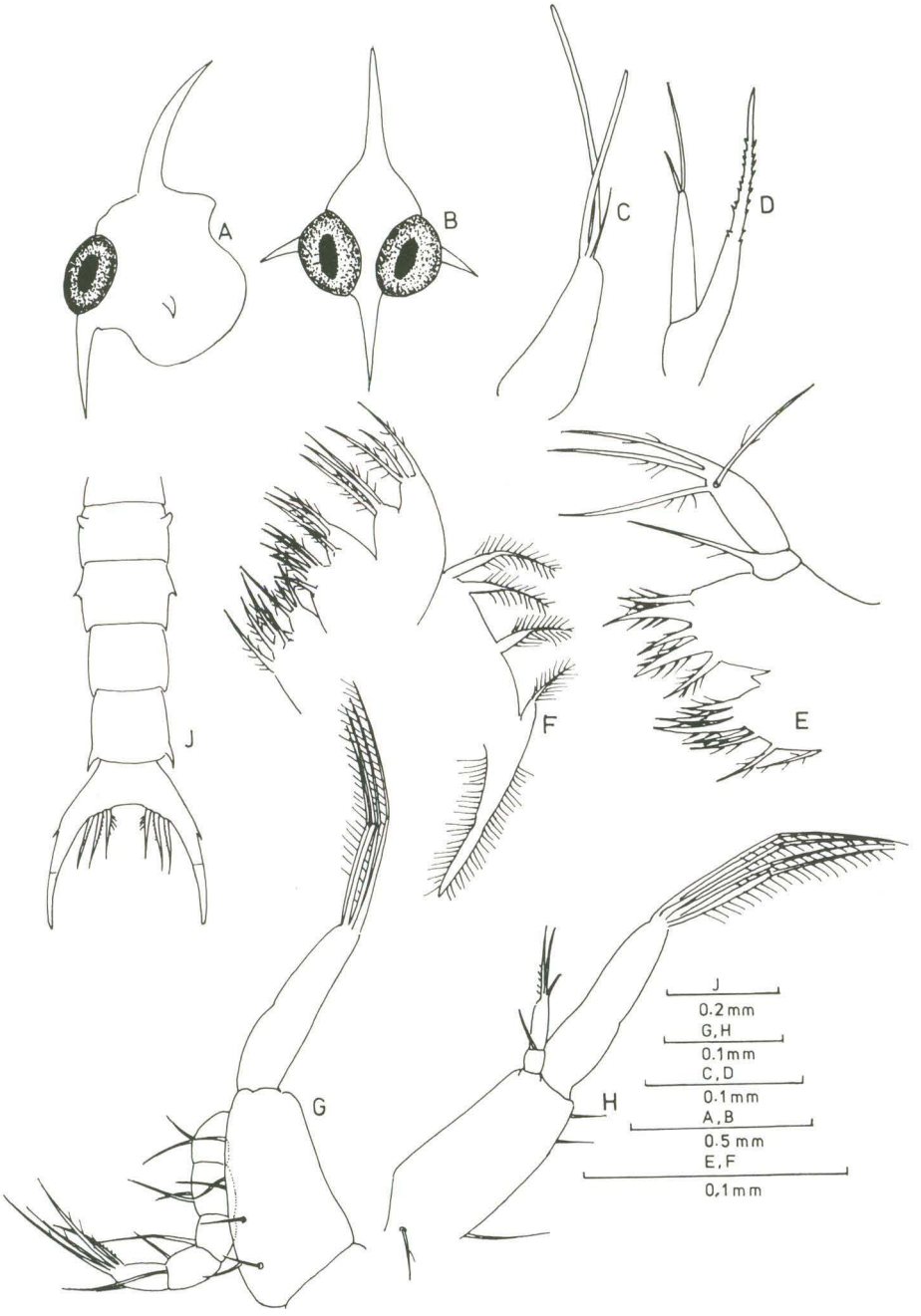

Fig. 17. Zoea 006, Stage I larva. (A,B) carapace, lateral and frontal view; (C) antennule; (D) antenna; (E) maxillule; (F) maxilla; (G) maxilliped I; (H) maxilliped II; (J) abdomen.

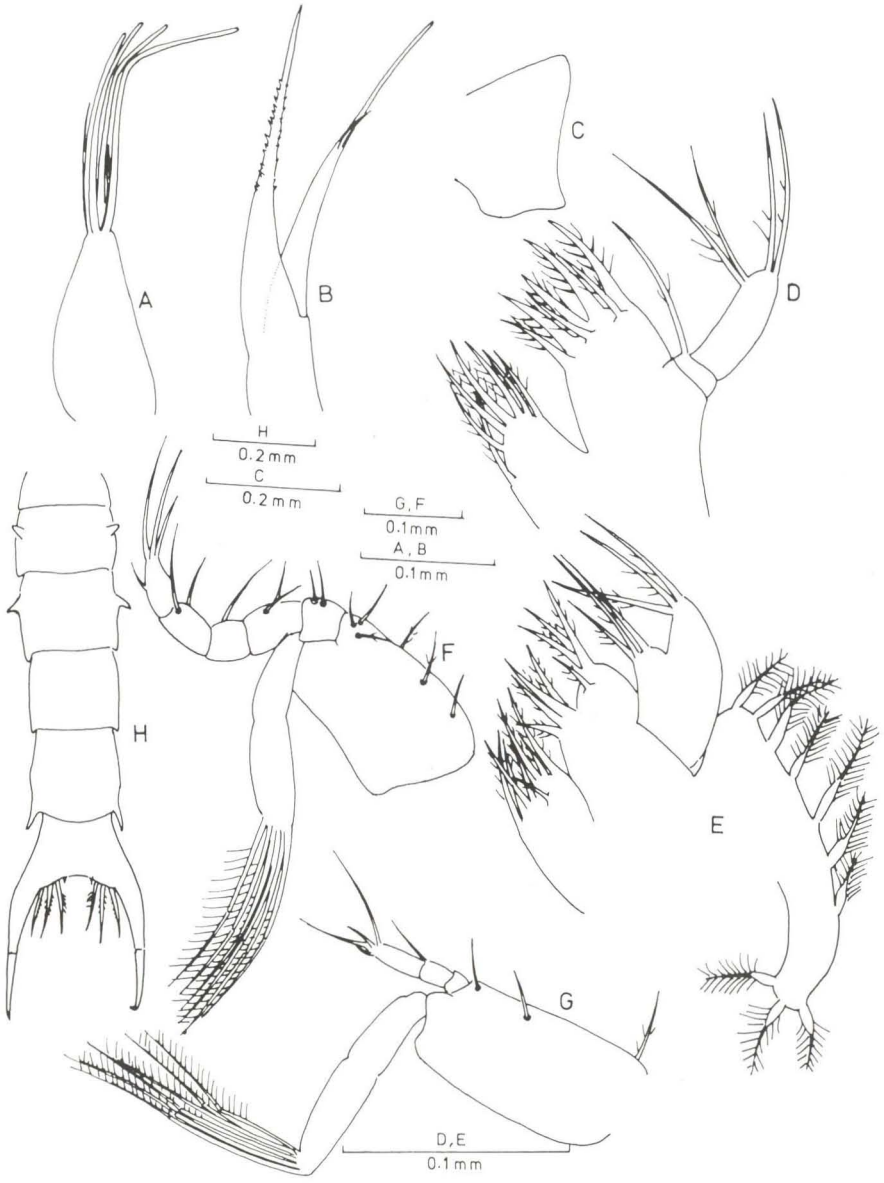

Fig. 18. Zoea 006, Stage II larva. (A) antennule; (B) antenna; (C) mandible; (D) maxillule; (E) maxilla; (F) maxilliped I; (G) maxilliped II; (H) abdomen.

Two-segmented endopodite of maxillule (Fig. 17E) has one seta on the first and four setae on the second segment; basal endite has five setae and coxal endite has seven setae.

Scaphognathite of maxilla (Fig. 17F) has four plumose setae on the lateral

margin and its posterior end is drawn into a process which is also plumose; endopodite is bilobed with six setae in two groups; basal endite is bilobed with five setae in proximal lobe and four setae in distal lobe, coxal endite also bilobed has four and three setae in proximal and distal lobes respectively.

Basipodite of maxilliped I (fig. 17G) has four to nine setae; setae on endopodite are distributed from first to fifth as follows: 2, 2, 1, 2 and five (or four when subterminal seta absent); four swimming setae are present on exopodite.

Basipodite of maxilliped II (Fig. 17H) carries four setae; endopodite is provided with one seta on second and three setae on distal segment; exopodite has four swimming setae.

Table VII. Zoea 006, comparison of morphological features of four zoeal stages.

Features	Stage I	Stage II
Length carapace (mm)	0.30	0.38
Dorsal spine	0.40	0.52
Rostral spine	0.26	0.34
Lateral spine	0.20	0.30
Telson	0.36	0.44
Antennule	1 spinule and 2 aesthetascs	2 spinule and 4 aesthetascs
Antenna	Armed spiny process and exopodite with 2 setae	As in Stage I
MAXILLULE		
Endopodite	1 seta on 1st and 4 setae on 2nd segment	As in Stage I
Basal endite	5 setae	6 setae
Coxal endite	7 setae	7 setae
MAXILLA		
Scaphognathite	4 + 1 plumose setae	7 + 3 plumose setae
Endopodite	3 + 3 setae	3 + 3 setae
Basal endite	5 + 4 setae	4 + 4 setae
Coxal endite	7 setae	8 setae
MAXILLIPED I		
Protopodite	6 setae	6 setae
Endopodite	Setation from 1st-5th segment 2, 2, 1, 2, 4	As in Stage I
MAXILLIPED II		
Protopodite	4 setae	3 setae
Endopodite	2nd segment with 1 and 3rd segment with 3 setae	2nd segment with 1 and 3rd segment with 4 setae
ABDOMEN		
Telson	With a small spinulle on outer margin	Without spinule on outer margin but with a pair of small setae in middle

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