RAFFLES BULLETIN OF ZOOLOGY 1992 **40**(2): 229-244

THE COMPLETE LARVAL DEVELOPMENT, INCLUDING THE FIRST CRAB STAGE OF *PILUMNUS KEMPI* DEB, 1987 (CRUSTACEA: DECAPODA: BRACHYURA: PILUMNIDAE) REARED IN THE LABORATORY

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ABSTRACT.- *Pilumnus kempi* Deb, 1987, was reared in the laboratory from the time of hatching to the first crab stage. *Pilumnus kempi* passed through two zoeal stages prior to the megalopal stage, and its first crab stage was reached in 25 to 29 days at room temperature (18° to 24°C). The larval and first crab stages are described, illustrated and compared with the larvae of *P. vespertilio* (Fabricius, 1793) (fide Lim & Tan, 1981). The comparison of the number of larval stages and morphological differences of both species supports the contention that *P. kempi* and *P. vespertilio* are distinct species despite their very similar adult appearances. As the morphology of the first crab stage of *P. vespertilio* is not known, only comparisons of zoeal and megalopal characters were made.

INTRODUCTION

Xanthoid crabs (sensu Guinot, 1978) constitute a significant part of the shallow-water brachyuran fauna throughout the world. Rice (1980) estimated that the family Xanthidae (sensu lato) contained more than 130 genera and 1000 species. Twenty-six species in 18 genera have been reported from Pakistani waters (Tirmizi & Kazmi, 1983). Of the two species of *Pilumnus* in Pakistani waters, the taxon referred to as *P. vespertilio* (Fabricius, 1793) by Tirmizi & Kazmi (1983) appears to be the more common, occurring in the intertidal zone. This is apparently the same taxon that was reported from Karachi and Tavoy as "*Pilumnus vespertilio* var." by Alcock (1898). Recently, Deb (1987) described several new Indian species of Pilumninae (= Pilumnidae), including *P. kempi* for Alcock's (1898) "*Pilumnus vespertilio* var." After examining specimens of presumed "*P. vespertilio*" from Karachi, Dr. Peter Ng determined that they were in fact, conspecific with *P. kempi*. Dr. Ng (pers. comm.) noted that the hair colour and chela granulation described by Alcock (1898: 193) as distinctive for his variety were not always reliable characters, and that the two taxa can only be effectively separated by the more setose form in *P. vespertilio*, giving it a "shaggier" appearance. *Pilumnus kempi* on the other hand, has stiffer and simpler setae. There were also no obvious differences in the structure of the male first pleopod.

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Subtle differences in adult morphology among populations of a presumably single species have frequently led carcinologists to propose distinct taxa, for example, *Carcinus mediterraneus* Holthuis & Gottlieb, 1958, for the Mediterranean population of *C. maenas* (Linneaus, 1758). Comparisons of larval morphology have been used to support such species distinctions (Rice & Ingle, 1975; Gore & Scotto, 1982). Larval development in the Xanthidae (sensu lato) are known for approximately 8% of the world's species (Martin, 1984). For Pakistani species, however, no complete descriptions of any species are available. The data is limited to the descriptions of only the first zoeal stages of 12 species (Hashmi, 1970). In this paper we describe and illustrate the zoeal, megalopal and first crab stages of *Pilumnus kempi*, and compare development in this species with that of *P. vespertilio* from Singapore as described by Lim & Tan (1981).

MATERIALS AND METHODS

Several ovigerous females of *P. kempi* were obtained beneath seaweed covered stones at Buleji during low tide (0.1 m) on November 15, 1986, and taken to the laboratory. The ovigerous females were kept in a small aquarium containing seawater of 35%. salinity at room temperature (18°-24°C). On November 29, 1986, the eggs of one female hatched. Fifty of the newly hatched larvae were segregated and placed, ten each, in five glass beakers (500 ml.), containing aged (2 weeks), filtered seawater of ambient salinity and temperature. Each beaker was examined daily for exuviae, dead individuals, and subsequent developmental stages. Surviving larvae were transferred daily to clean beakers filled with freshly filtered, aged seawater and provided newly hatched *Artemia* nauplii.

Moults, dead specimens, and larvae at each stage, were preserved in 5% formalin for further study. Temporary slides were made in a formalin-glycerin solution (1:3). The specimens were dissected under a binocular microscope (PZO MST 130,6415, Poland) and illustrated with the help of a reticule fixed in one of the eye pieces of microscope (Leitz HM-LUX3). The spent female and the remaining larvae were preserved and stored in the Marine Reference Collection Centre, Pakistan.

Measurements of each stage were made with a stage micrometer. The total length (TL) was determined by adding the carapace length (measured from the tip of rostral spine to the posterior midpoint of the carapace) and abdominal length (measured from the center of the second segment to the middle of the posterior margin of the telson).

DESCRIPTION OF LARVAE AND FIRST CRAB

Pilumnus kempi Deb, 1987

(Figs. 1-7)

Zoea I

Size. - TL = 2.5 mm - 2.6 mm (10 specimens examined).

Duration. - 2-3 days.

Carapace (Fig. 1A). - With large, slightly backwardly curved dorsal spine and small lateral and rostral spines; rostral spine one fourth length of antenna; eyes sessile.

Abdomen (Fig. 1A).- Five somites, second to fifth with pair of posterolateral spines, posterior margins of each somite with row of small spines; second somite with pair of strong, anteriorly curved projections or knobs, third somite with pair of posteriorly curved, small projections or knobs.

Telson (Fig. 1I). - Inner posterior margin of telson with 3 pairs of spines and distinct median cleft; each furca with 1 large and 2 smaller outer spines, inner margin covered with fine spinules.

Antennule (Fig. 1B). - Uniramous, with 7 terminal aesthetascs and 1 subterminal plumose seta.

Antenna (Fig. 1C).- Length of protopod and exopod nearly equal, both tapering anteriorly, distal halves each with 2 rows of spinules; 2 lateral spines, 1 large and 1 small spine at mid length of exopod, protopod with 1 small plumose seta medially; endopod about one fourth length of exopod.

Mandible (Fig. 1D). - With incisor and molar processes; palp absent.

Maxillule (Fig. 1E). - Coxal endite with 7 setae, basial endite with 5 spinulose setae and 1 papilla. Endopod 2-segmented, distal seta on proximal segment with 1 distal seta, distal segment with 4 terminal and 2 subterminal setae.

Maxilla (Fig. 1F). - Coxal and basial endites bilobed; coxal endite with 5 and 4 plumose setae on proximal and distal lobes respectively, basial endite with 4 plumose setae on both proximal and distal lobes; endopod bilobed, with 3 setae on proximal lobe and 5 on distal lobe; scaphognathite with 4 marginal setae, posterior lobe elongate, slender.

Maxilliped I (Fig. 1G). - Basipod with 11 plumose setae on medial margin; endopod 5-segmented, with setae (proximal to distal) 3,2,1,2,4+I (Roman numeral denoting dorsolateral seta); exopod with 4 natatory setae.

Maxilliped II (Fig. 1H).- Basipod with 4 plumose setae on medial margin; endopod 3-segmented, with 1,1,6 plumose setae; exopod with 4 natatory setae.

Maxilliped III. - Biramous but rudimentary.

Zoea II

Size. - TL = 2.25 mm (5 specimens examined).

Duration. - 5-6 days.

Carapace (Fig. 2A). - Slight increase in size, but no change in armature; rudimentary pereopods visible beneath carapace; eyes stalked.

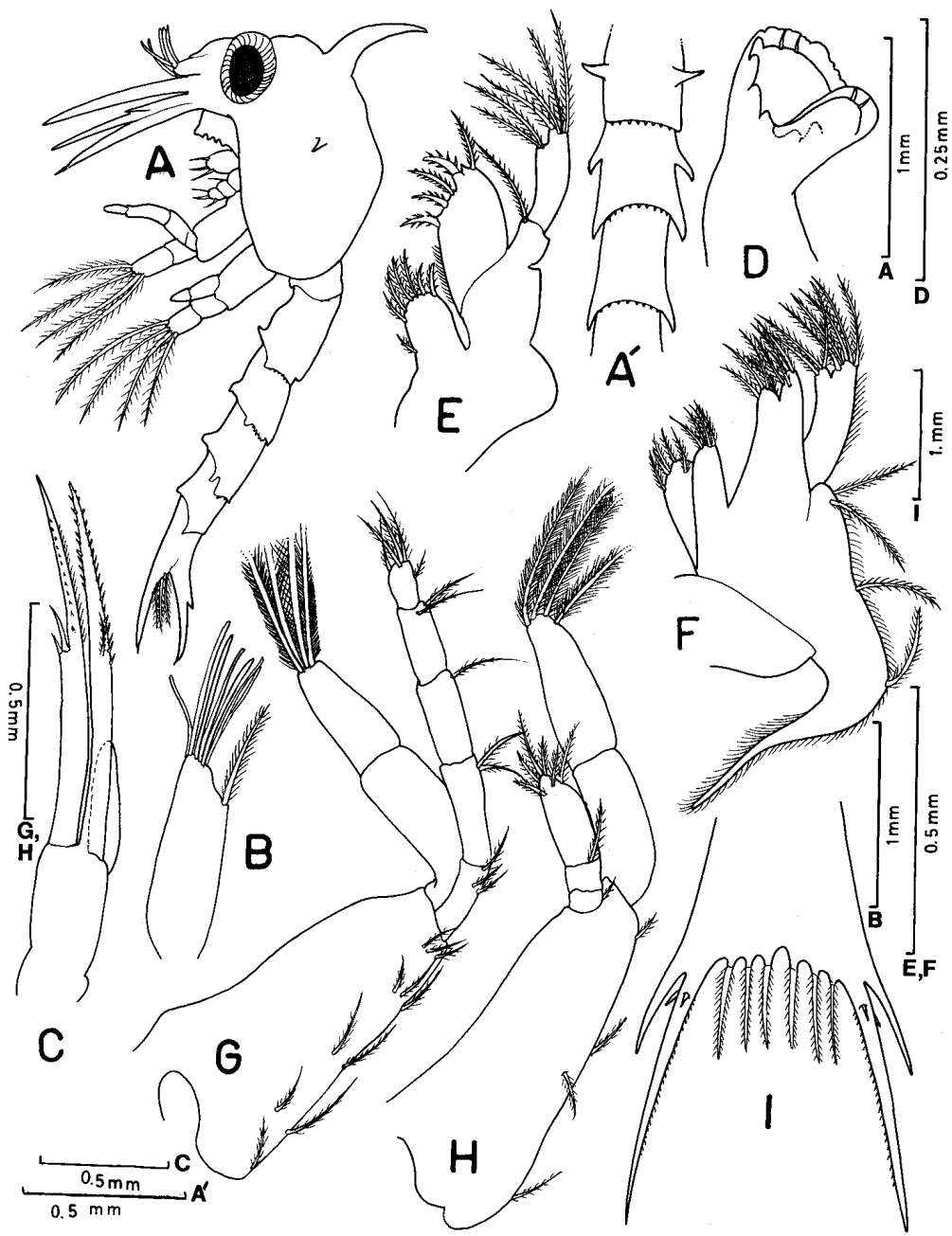

Fig. 1. *Pilumnus kempi* Deb, first zoea. A, side view; A´, dorsal view of abdomen; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, telson in dorsal view. Scales = 1mm (A, B & I); 0.5mm (A´, C, E-H); 0.25mm (D).

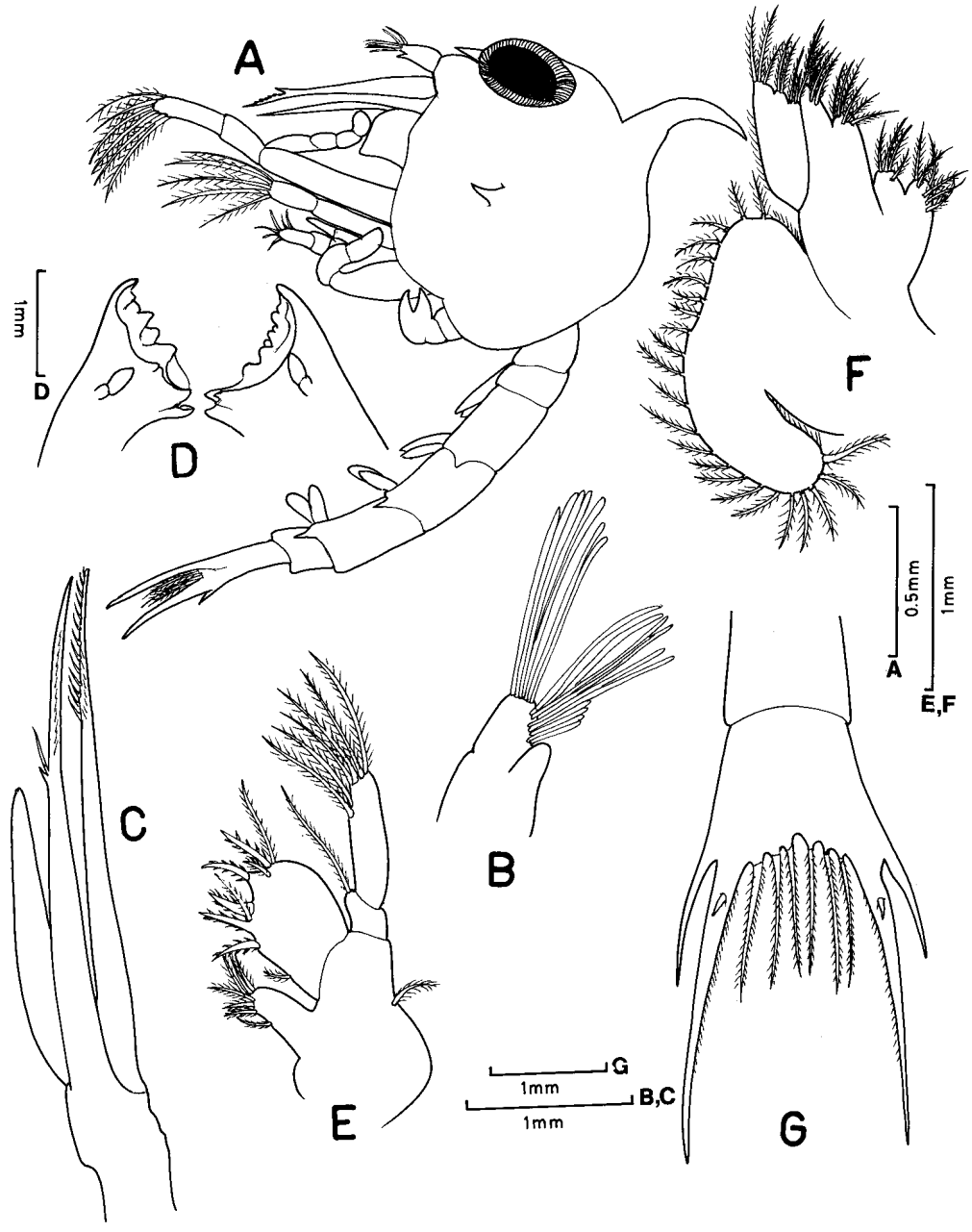

Fig. 2. *Pilumnus kempi* Deb, second zoea. A, side view; B, antennule; C, antenna; D, mandibles; E, maxillule; F, maxilla; G, telson in dorsal view. Scales = 1mm (B-G); 0.5mm (A).

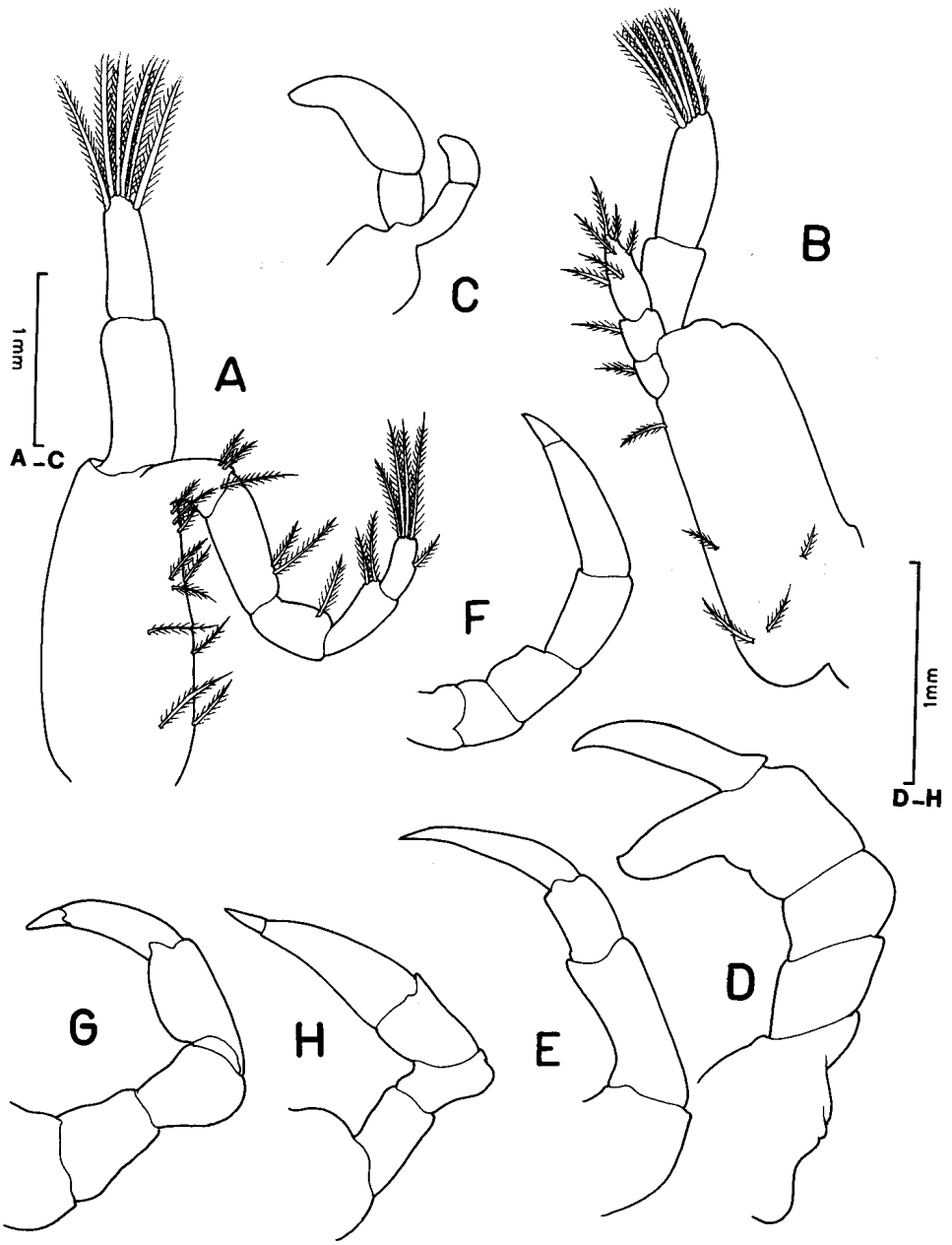

Fig. 3. *Pilumnus kempi* Deb, second zoea. A, first maxilliped; B, second maxilliped; C, third maxilliped; D-H, first to fifth pereopds. Scales = 1mm.

Abdomen. - Sixth abdominal somite distinct. Pleopod buds developed.

Telson (Fig. 2G). - Small lateral spine no longer present on either side of furca; median cleft reduced.

Antennule (Fig. 2B). - 2-segmented, biramous and globular; with 7 large terminal, 6 large and 4 small subterminal aesthetascs.

Antenna (Fig. 2C). - Endopod increased to about three fourth length of exopod; otherwise unchanged.

Mandible (Fig. 2D). - Incisor and molar processes increased in size; 2-segmented mandibular palp present. *Maxillule* (Fig. 2E).- Coxal endite as in Zoea I but with addition of 1 lateral seta; basial endite with 5 serrated and 4 plumose setae; endopod unchanged. *Maxilla* (Fig. 2F).- Coxal endite bilobed with 6 and 4 plumose setae bilobed basial endite now with 6 and 5 setae endopod unchanged; scaphognathite with 23 marginal plumose setae, posterior lobe broader.

Maxilliped I (Fig. 3A). - Basipod and endopod unchanged; exopod with 6 natatory setae.

Maxilliped II (Fig. 3B). - Basipod with 1 additional seta; endopod unchanged; exopod with 6 natatory setae.

Maxilliped III (Fig. 3C). - Still biramous, rudimentary bud.

Pereiopods I-V (Fig. 3D-H). - Cheliped bud with enlarged chela; ambulatory leg buds with 5 or 6 segments clearly delineated.

Megalopa

Size. - TL = 2.0 mm (5 specimens examined).

Duration. - 18-20 days.

Carapace (Fig. 4A) . - Longer than broad with few scattered setae and 3 tubercles in frontal region; small rostral spine and spinulate distolateral angles.

Abdomen (Fig. 4A, 5A). - Somites with rounded posterolateral angles, dorsal surfaces each with pair of small distolateral setae.

Pleopod (Fig. 4I). - Pleopods biramous developed on abdominal somites 2-5 and decreasing in size posteriorly.

Telson (Fig. 5A). - Broader than long, with pair of small setae dorsally.

Antennule (Fig. 4B). - Biramous: peduncle 3-segmented, without setation; lower flagellum with 3 terminal, 1 lateral and 1 mesial plumose setae; 2-segmented upper flagellum, proximal segment with 1 and distal segment with 2 terminal setae and each segment with 9 and 3 aesthetascs on proximal and distal segments respectively

Antenna (Fig. 4C). - Uniramus; with 3-segmented peduncle, flagellum with 9 segments; 1 small seta on each of first two segments, sixth and eighth segments with 5 and 3 setae respectively, 2 terminal setae.

Mandible (Fig. 5B). - Masticatory processes adult like; palp 3-segmented, terminal segment with marginal plumose setae.

Maxillule (Fig. 4D). - Coxal endite with 1 lateral and 1 dorsal seta, 7 plumose setae mesially; basial endite with 8 serrated spines and 7 plumose setae; endopod 2-segmented, 1 seta on proximal segment and 3 setae on distal segment.

Maxilla (Fig. 4E). - Coxal endite bilobed with 7 and 3 setae; basial endite with 4 and 5 setae; endopod narrow, no longer bilobed, naked; scaphognathite with 33 marginal plumose setae.

Maxilliped I (Fig. 4F). - Coxa with 4 marginal and 3 dorsal plumose setae; basis with 8 marginal and 2 submarginal plumose setae; endopod 2-segmented naked; exopod 2-segmented, 1 seta on distal margin of proximal segment, 4 terminal natatory setae on distal segment; epipod with 1 proxomesial seta and 6 distolateral simple plumose setae.

Maxilliped II (Fig. 4G). - Coxal and basial endites reduced and without setae; 4-segmented endopod with 1,1,5,5+I setae; exopod 2-segmented with 1 small seta on proximal segment and 5 natatory setae on distal segment; epipod uniramous bud, naked.

Maxilliped III (Fig. 4H).- Coxa and epipod fused; basis with 1 small tubercle; endopod 5-segmented, proximal segment broader than second, sparsely setose and with 4 small marginal spines; second to fifth segments with setation of 6, 3, 6, 5 respectively; exopod 2-segmented, proximal segment with 1 seta and distal segment with 5 terminal natatory setae.

Pereiopods (Fig. 5C-G). - First to fifth pereiopods with sparse covering of simple and plumose setae; cheliped also with 1 spine on mesial margin of merus; mesial margins of ischia of cheliped and pereiopods each with blunt spine.

First Crab

Size. - TL = 2.05 mm (3 specimens examined) (preserved after 6 days)

Carapace (Fig. 6A). - Somewhat squarish, flattened; eyes stout.

Abdomen (Fig. 7A). - Well developed, covered with plumose setae and tucked under the cephalothorax.

Telson (Fig.7A). - Broader than long, simple and plate-like.

Antennule (Fig. 6B). - Peduncle 3-segmented, basal segment broad; distal segment longer than penultimate segment and with 2 terminal flagella; lower flagellum 2-segmented, with 2 subterminal and 2 terminal setae; upper flagellum 5-segmented, with numerous aesthetascs.

Antenna. - Left and right dissimilar in segmentation and setation, as illustrated in figures 6C and 7B.

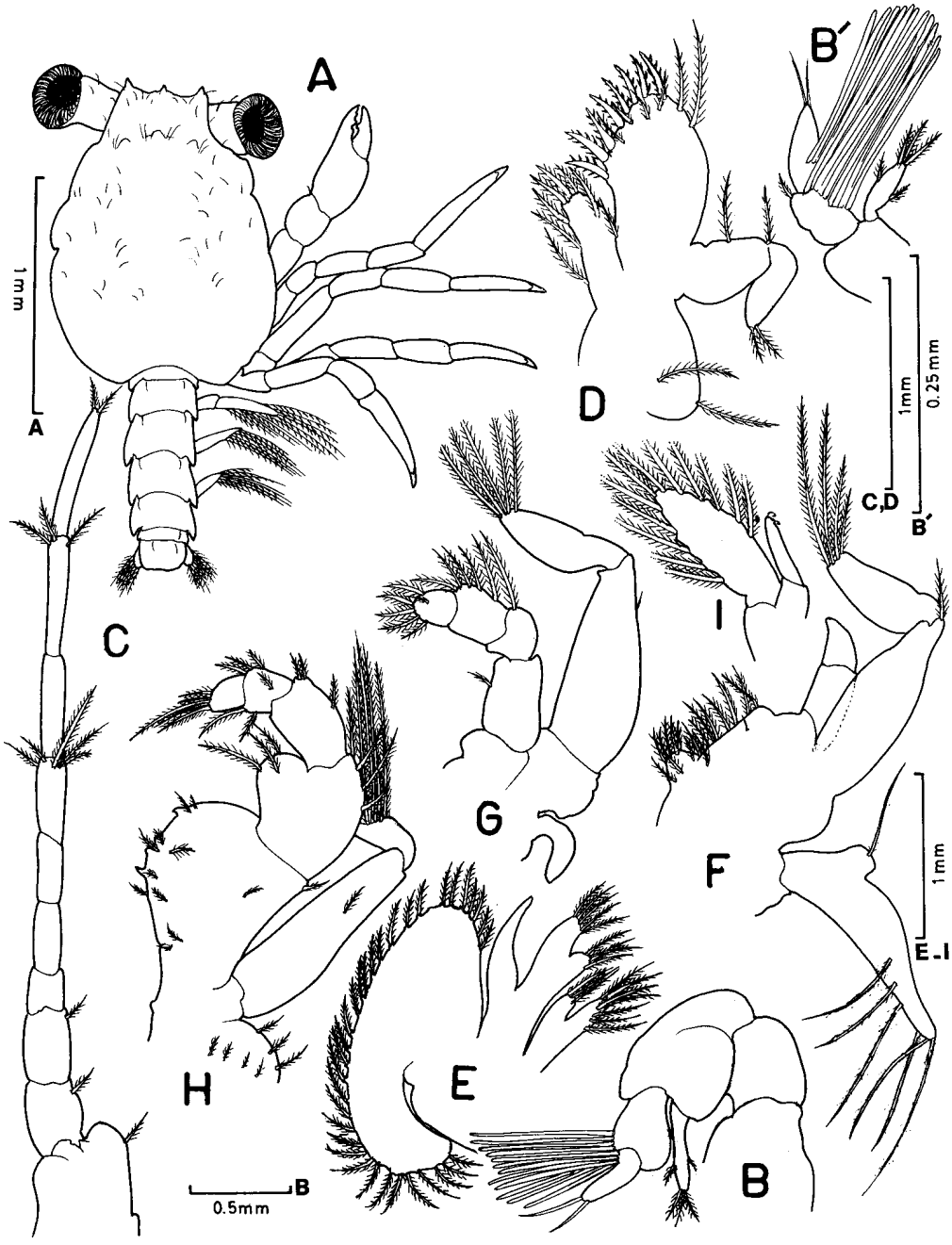

Fig. 4. *Pilumnus kempi* Deb, magalopa. A, dorsal view; B, antennule; B', tip of the antennule; C, antenna; D, maxillule; E, maxilla; F, first maxilliped; G, second maxilliped; H, third maxilliped; I, first pleopod. Scales = 1mm (A, C-I); 0.5mm (B).

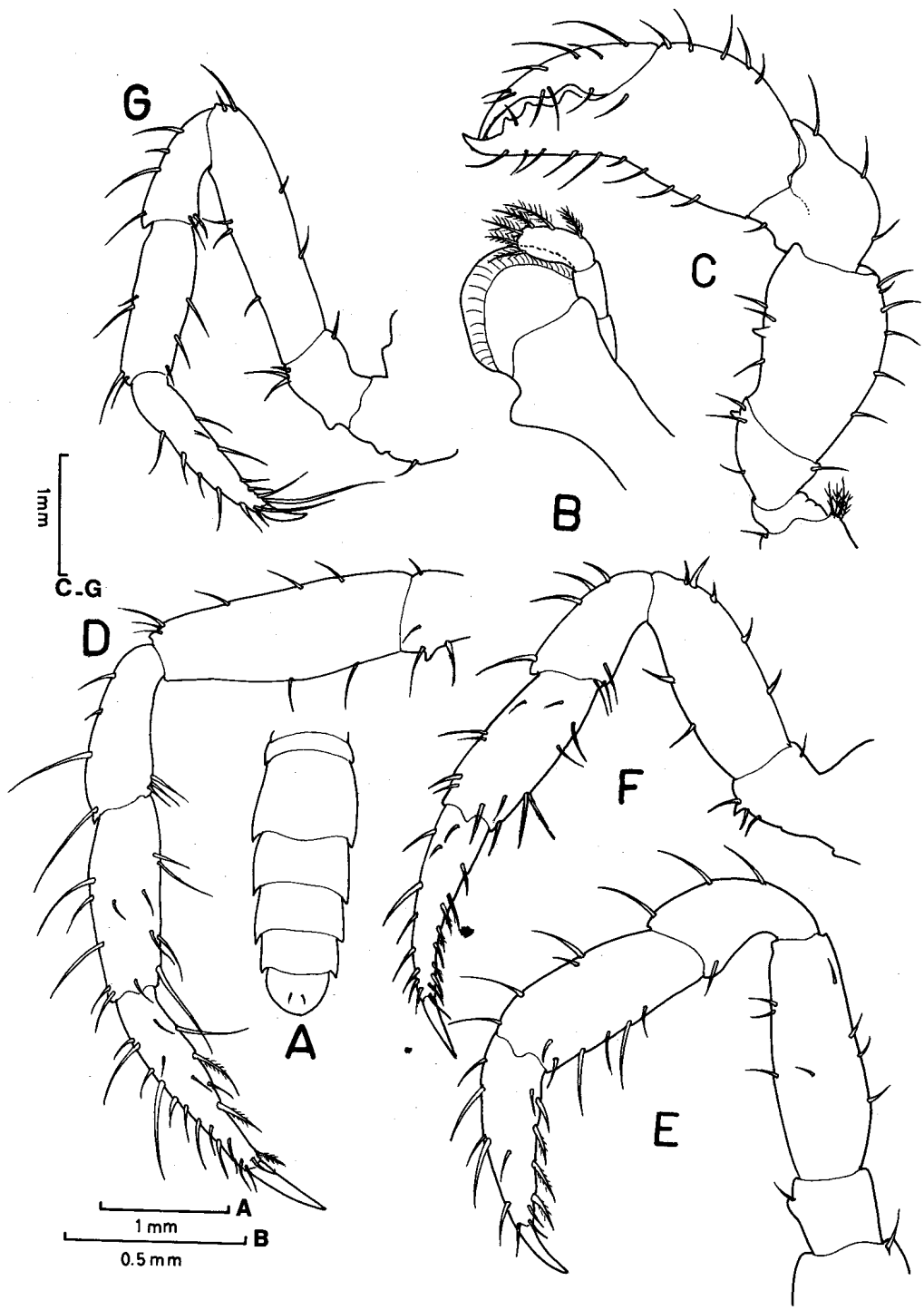

Fig. 5. *Pilumnus kempi* Deb, megalopa. A, abdomen with telson; B, mandible; C-G, first to fifth pereiopods. Scales = 1mm (A, C-G); 0.5mm (B).

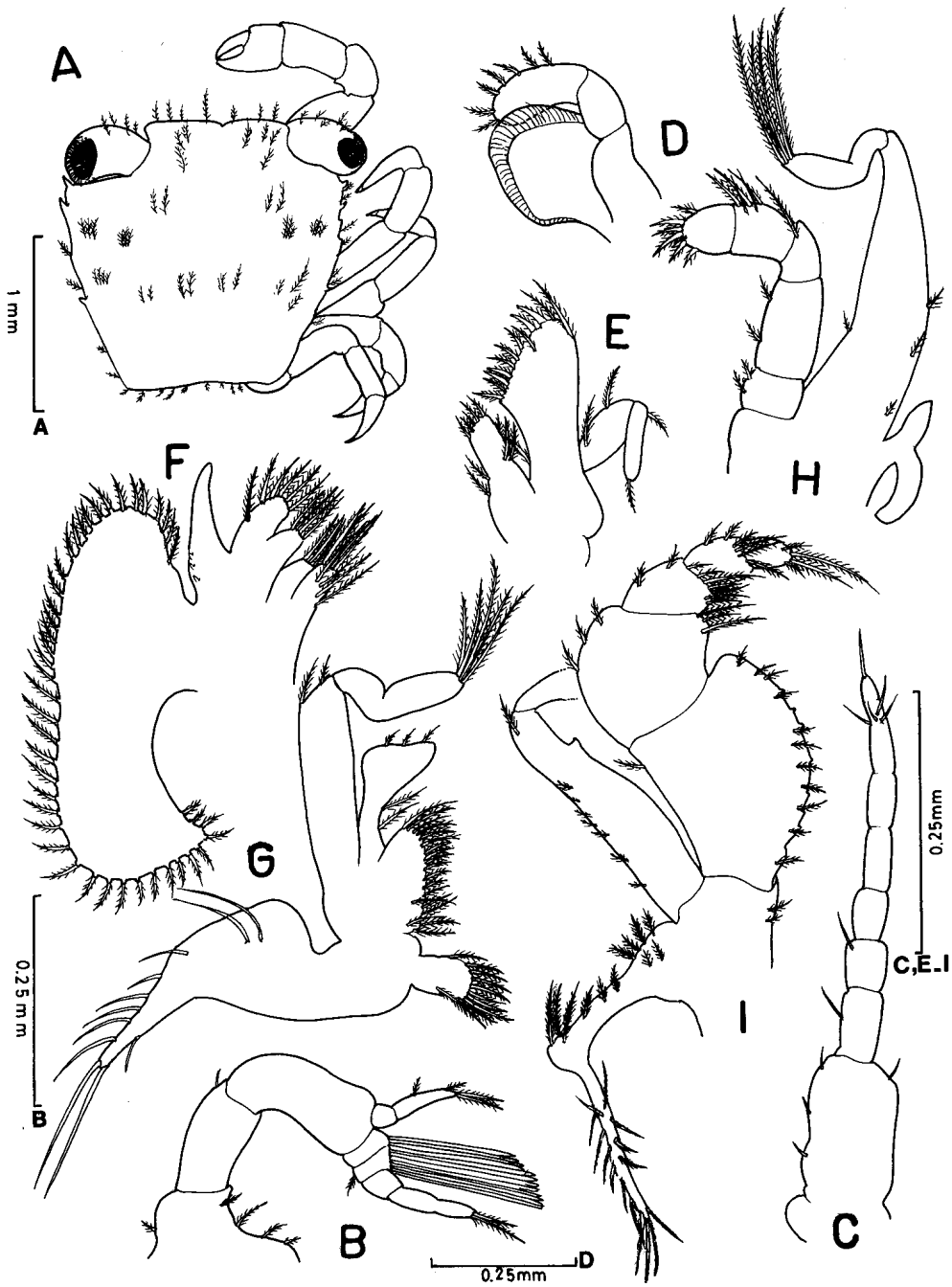

Fig. 6. *Pilumus kempi* Deb, first crab. A, dorsal view; B, antennule; C, left antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped. Scales = 0.25mm (B-I); 1mm (A).

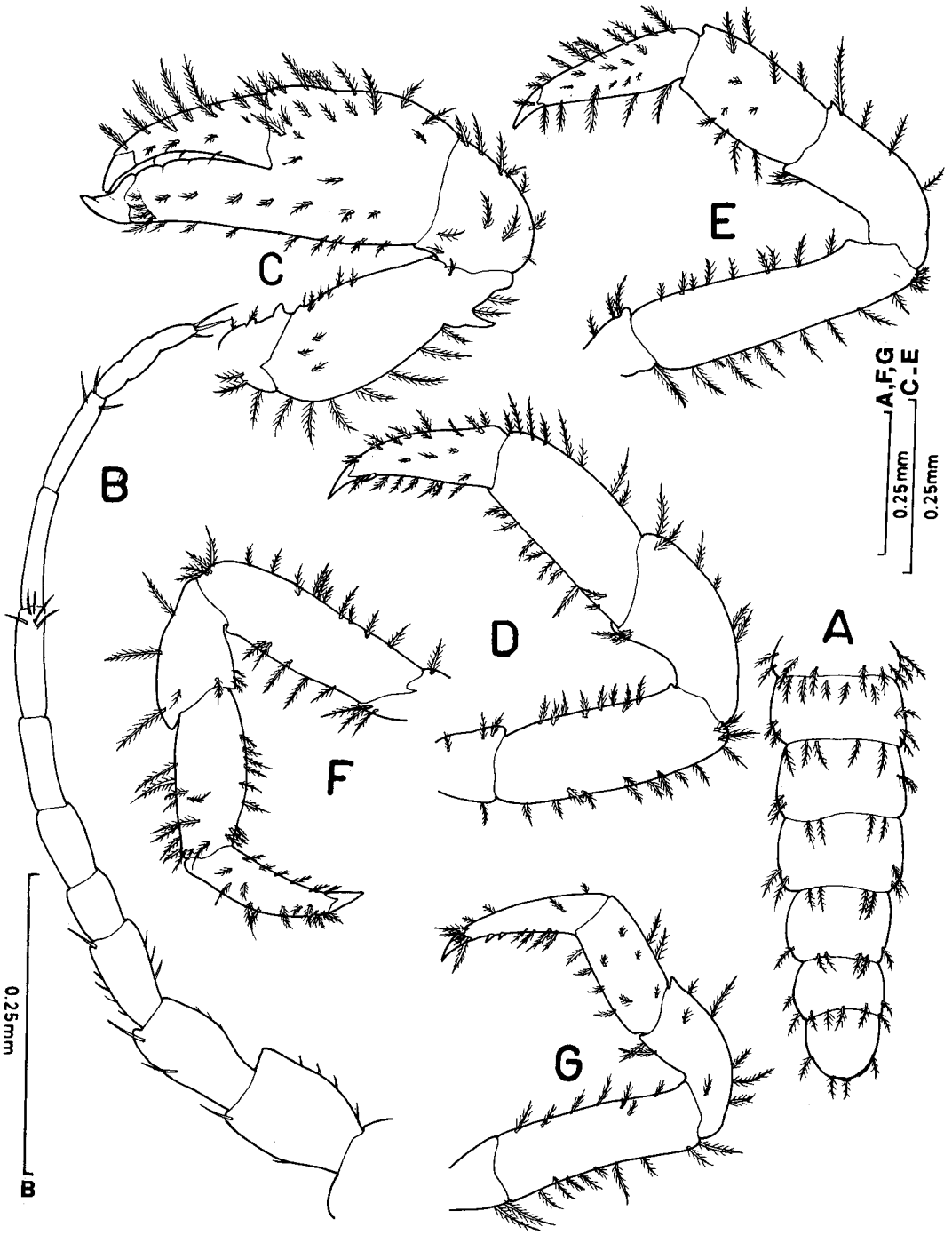

Fig. 7. *Pilumnus kempi* Deb, first crab. A, abdomen with telson; B, right antenna; C-G, first to fifth pereiopds. Scales = 0.25mm (A-G).

Mandible (Fig. 6D). - Unchanged from megalopa.

Maxillule (Fig. 6E). - Similar to that of megalopa but with fewer setae on basis.

Maxilla (Fig. 6F). - Similar to that of megalopa except in setation; coxa with plumose setae on proximal and distal lobes, bilobed basis provided with 4 setae proximally and 6 distally; scaphognathite with 45 plumose setae; endopod with 3 denticles on proximal region.

Maxilliped I (Fig. 6G). - With two broad lobes; proximal lobe with 10, and distal lobe with 19 plumose setae; exopod 2-segmented, proximal segment with 2 terminal setae, 5 terminal plumose setae on distal segment; endopod hammer-shaped, with 2 proximal and 3 distal setae on anterior margin; epipod with numerous long simple setae.

Maxilliped II (Fig. 7H). - With 5-segmented endopod, setation of 2,2,1,5,8 from proximal to distal segments; exopod 2-segmented, proximal segment with 4 setae and distal segment with 5 setae terminally; epipod small and bilobed.

Maxilliped III (Fig. 6I). - With 5-segmented endopod, setation of 11+I, 3+3, 7+2, 6, 4 (proximal to distal); exopod 2-segmented, epipod long and slender with numerous setae.

Cheliped (Fig. 7C) and *walking legs* (Fig. 7D-G). - Well developed and with plumose setae as illustrated.

Remarks.- We have observed sufficient disparities in the larval structures of *P. kempi* (present study) and *P. vespertilio* (fide Lim & Tan, 1981) to confirm the distinctness of the two taxa. The most obvious difference between the larvae of *P. kempi* and *P. vespertilio* is the number of zoeal stages, two in the former, three in the latter. Although Wear (1970) considered four zoeal stages fixed in the Xanthidae, abbreviated or advanced development (Rabalais & Gore, 1985) has been reported in several species, including *P. vestitus* Haswell where the eggs hatch as megalopae (Hale, 1931). Reasons for the abbreviated development seen in *P. kempi*, and to a lesser extent in *P. vespertilio*, are not known. Some workers have reported that the number of larval stages in some crabs (e.g. Portunidae and Menippidae) may vary, depending on food, temperature etc. These crabs, however, often have five or more larval stages under normal circumstances. For Xanthidae s. str. and Pilumnidae s. str., such variations are not known.

In addition to the number of stages, *P. kempi* and *P. vespertilio* exhibit numerous morphological differences (Tables 1, 2). For example, zoeae I of *P. kempi* have six terminal and one subterminal antennular aesthetascs; whereas that of *P. vespertilio* have only three terminal aesthetascs. This difference in aesthetasc number and position is more pronounced in zoeae II. The antennal endopod in zoea I of *P. kempi* is approximately one-third the length of the exopod and increases to approximately two-thirds in zoea II. In contrast, *P. vespertilio* zoeae have an antennal endopod only one-fourth the length of the exopod in zoea I and one-third its length in zoea II. The mandibular palp appears in zoea II in *P. kempi*, but not until zoea III in *P. vespertilio*.

Dissimilarities in the megalopae of the two speices are also apparent. Of particular note are the differences in segmentation seen in the antennules and exopods of all three pairs of maxillipeds. The upper flagellum of the antennule is 2-segmented in *P. kempi*, but 4-segmented in *P. vespertilio*. The exopods of the maxillipeds are 2-segmented in *P. kempi* and 3-segmented in *P. vesptertilio*. Differences in setation of the various appendages are also apparent.

Table 1. Comparison of features in zoeal stages of *Pilumnus kempi* Deb, 1987 (present study) and *Pilumnus vespertilio* (Fabricus, 1793) (fide Lim & Tan, 1981).

Features	Zoea I		Zoea II		Zoea III	
	P. kempi	*P. vespertilio*	*P. kempi*	*P. vespertilio*	*P. kempi*	*P. vespertilio*
Antennule						
aesthetascs terminal	6	3	7	4 (equal)	-	4
subterminal	1		10	absent	-	4
setae/hair	absent	(ocassionally) 1 or 2	absent	1 or 2	-	1
endopodal bud	absent	-	present	absent	-	present
Antenna						
endopodal bud						
length to exopod	one third	one fourth	two third	one third	-	three-fourth
Mandible						
mandibular palp	absent	absent	present	absent	-	present
Maxillule						
basial endite						
spinulated setae/papilla	5/1	5/absent	5 serrated 4 plumose	9 serrated 1 simple	-	unchanged
Maxilla						
scaphognathite marginal setae	4	4	23	14	-	24
posterior margin	long tapering finely setose	short, broad finely setose	broad	broad	-	broad
Maxilliped I						
basipod setae	11(1, 2, 2, 3, 3)	9(2, 2, 3, 2)	10(2, 2, 3, 3)	9(2, 2, 3, 2)	-	9(2, 2, 3, 2)
endopod setae	13(3, 2, 1, 2, 5)	12(2, 2, 1, 2, 5)	13(3, 2, 1, 2, 5)	12(2, 2, 1, 2, 5)	-	10(2, 1, 2, 5)
Maxilliped II						
basipod setae	4-8	4	5(2, 2, 1)	4(1, 1, 1, 1)	-	4(1, 1, 1, 1)
endopod setae	8(1, 1, 6)	8(1, 1, 6)	8(1, 1, 6)	6(1, 1, 4)	-	7(1, 3, 3, 3)
exopod natatory setae	4	4	6	6	-	8
Maxilliped III	bilobed	bilobed rudiment	bilobed	trilobed	-	trilobed
Abdomen						
posterior margin each somite	spinule present	not mentioned	spinule present	no data	-	not mentioned
Telson						
lateral spines each furca	1 large, 1 small	1 large absent	1 large	1 large	-	1 large

Table 2. Comparison between magalopae of *Pilumnus kempi* Deb (present study) and *Pilumnus vespertilio* Fabricus (fide Lim & Tan, 1981).

Features	*P. kempi*	*P. vespertilio*
Total length in mm	2.0	0.94
Rostrum shape	short, pointed	short, blunt
Lateral angles	pointed	rounded
Antennule		
penultimate segmen of peduncle	seta absent	single seta
terminal setae	3	4
sub-terminal setae	2	1
outer flagellum	2-segmented	4-segmented
aesthetascs + setae	9 on first segment	3 on each first-third segment
	3 on second segment	3+2 on fourth segment
Antennal flagellum		
setae on terminal segment	2	3
Mandibular palp		
setae on distal segment	6	4 or 5
Maxillule		
coxal endite setae	10	9
endopod setae: proximal lobe	2	1
distal lobe	2	6
Maxilla		
coxal endite, setae: distal lobe	3	4
basial endite setae: proximal lobe	4	6
distal lobe	5	7
endopod setae	absent	5+1
Maxilliped I		
epipod setae	7	4
basipod setae	10	12 or 13
endopod setae	absent	3 terminal, 2 sub-terminal
exopod	2-segmented	3-segmented
setae	1, 4	2, 0, 5
Maxilliped II		
exopod	2-segmented	3-segmented
terminal setae	5	4
setae	1, 1, 5, 6	1, 1, 5, 7
Maxilliped III		
exopod	2-segmented	3-segmented
terminal setae	5	6
endopod	5-segmented	5-segmented
setae	11, 5, 2, 6, 5	9, 8, 6, 7, 4

Acknowledgements.- The authors wish to acknowledge, with thanks, Dr. Peter K. L. Ng, Department of Zoology, National University of Singapore, for the cooperation extended to the identification of the Pakistani adults. The authors are also grateful to Dr. Patsy A. McLaughlin, Shannon Point Marine Centre, Western Washington University, for the critical review of the manuscript and for providing valuable suggestions. Thanks are also due to Dr. Quddusi B. Kazmi, Marine Reference Collection Centre, for helping us in various ways.

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