

THE FRESHWATER AND TERRESTRIAL DECAPOD CRUSTACEA OF PULAU TIOMAN, PENINSULAR MALAYSIA

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ABSTRACT. - The freshwater and terrestrial decapod fauna of Pulau Tioman, an island off the east coast of Peninsular Malaysia, is documented and discussed. A total of 12 crab (in four families: Gecarcinidae, Grapsidae, Parathelphusidae and Potamidae) and 13 prawn species (in two families: Atyidae and Palaemonidae) are covered. Two species of crabs, *Cardisoma carnifex* (Gecarcinidae), *Pseudosesarma bocourti* (Grapsidae), and seven species of prawns, *Caridina celebensis*, *C. aff. brachydactyla* (Atyidae), *Macrobrachium idae*, *M. scabriculum*, *M. dolichodactylus* and *M. meridionalis* (Palaemonidae), constitute new records for Pulau Tioman. *Caridina celebensis*, *C. aff. brachydactyla*, *Macrobrachium scabriculum*, *M. dolichodactylus* and *M. meridionalis* are also new records for Peninsular Malaysia.

KEY WORDS. - Freshwater, terrestrial, Crustacea, Decapoda, Grapsidae, Gecarcinidae, Parathelphusidae, Potamidae, Atyidae, Palaemonidae.

INTRODUCTION

Pulau Tioman is a rugged, pear-shaped island located about 45 km east of the state of Pahang in Peninsular Malaysia. It is the third largest island in Peninsular Malaysia with a length of approximately 19 km and a maximum width of approximately 11 km. The northern third of the island is narrow and dry, mostly lacking in permanent freshwaters while the central and southern thirds make up the main bulk of the island with several sizable permanent drainages (Fig. 1).

Previously, nine species of freshwater or terrestrial crabs, viz. Grapsidae: *Geosesarma tiomanicum* Ng, 1986, *Neosarmatium indicum* (A. Milne Edwards, 1868) [as *N. punctatum*], *Tiomanium indicum* (H. Milne Edwards, 1837), *Varuna yui* Hwang & Takeda, 1986 [as *V. litterata*]; Parathelphusidae: *Parathelphusa nagasaki* Ng, 1988; and Potamidae: *Johora counsilmani* (Ng, 1985), *J. grallator* Ng, 1988, *J. punicea* (Ng, 1985), and *J. tiomanensis* (Ng & Tan, 1984), have been reported from the island (Rathbun, 1913; Tweedie, 1940, Ng, 1985, 1986, 1987, 1988; Ng & Chong, 1986; Ng & Lim, 1989; Ng & Tan, 1984). Seven freshwater prawn species have been reported, viz. Atyidae: *Atyopsis moluccensis* (De Haan,

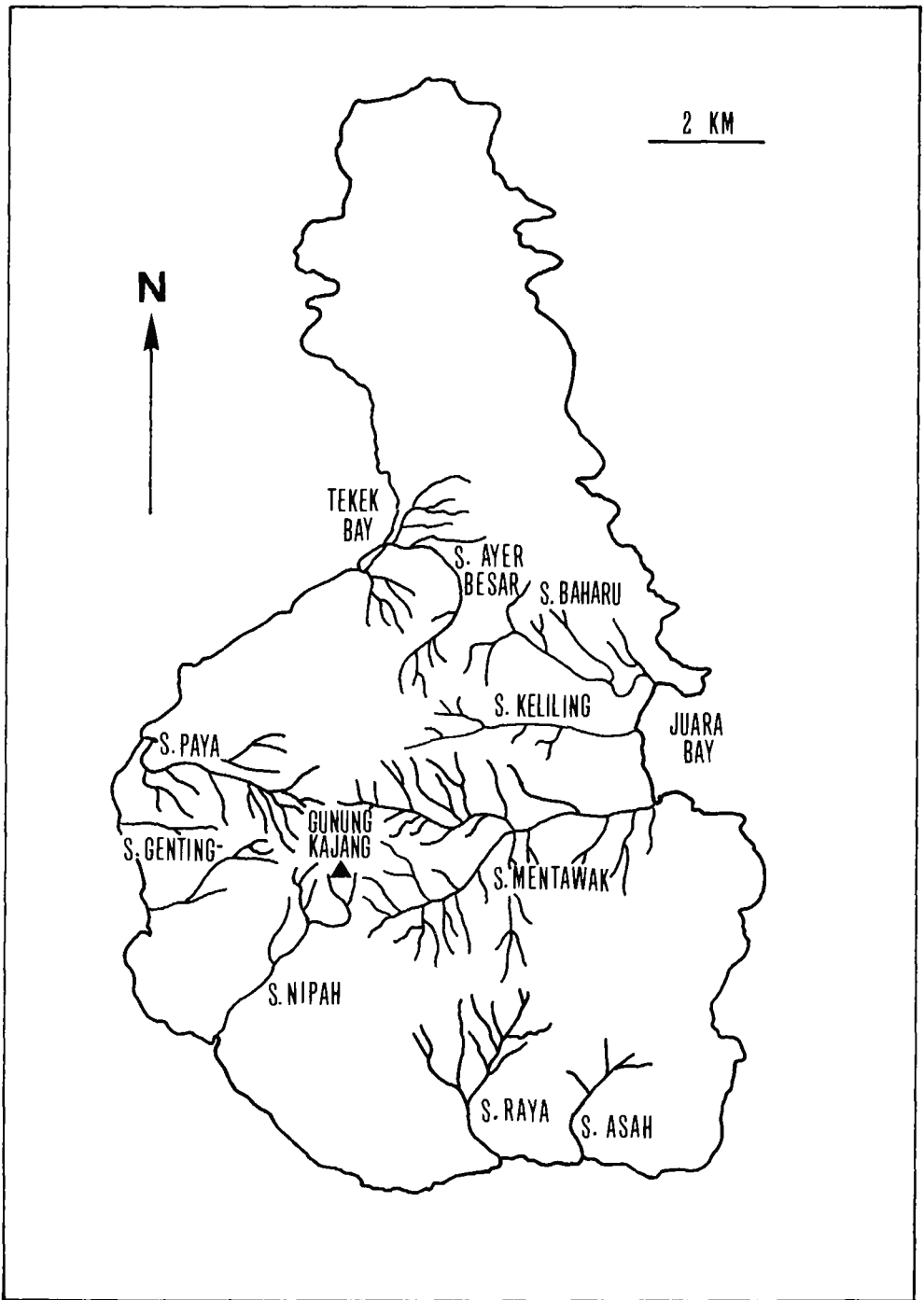


Fig. 1. Map showing major drainages on Pulau Tioman. (After Ng, 1985).

1849), *Caridina typus* H. Milne Edwards, 1837; and Palaemonidae: *Macrobrachium equidens* (Dana, 1852), *M. lar* (Fabricius, 1798), *M. latidactylus* (Thallwitz, 1891), *M. pilimanus* (De Man, 1879), and *Palaemon debilis* Dana, 1852 (Johnson, 1968; Ng, 1985; Ng & Chong, 1986). Although the freshwater decapod crustaceans of Pulau Tioman have been relatively well studied in recent years, collections were limited to only a few drainages and hardly any collections have been made in the highlands.

Extensive collections between 1995 and 1998, especially in drainages around the island, as well as from Gunung Kajang, the tallest mountain on the island (ca. 1000 m above sea level) have obtained more specimens and species. A total of 12 species of crabs from four families (Gecarcinidae, Grapsidae, Parathelphusidae and Potamidae) and 13 species of prawns from two families (Atyidae and Palaemonidae) were obtained. Of these, one crab species, *Geosesarma albomita*, is new (Yeo & Ng, 1999); while eight species, *Cardisoma carnifex* (Herbst, 1796), *Pseudosesarma bocourti* (A. Milne Edwards, 1869), *Caridina celebensis* De Man, 1892, *C. aff. brachydactyla* De Man, 1908, *Macrobrachium idae* (Heller, 1882), *M. scabriculum* (Heller, 1862), *M. dolichodactylus* (Hilgendorf, 1879), *M. meridionalis* Liang & Yan, 1983, are reported from the island for the first time. *Caridina celebensis*, *C. aff. brachydactyla*, *Macrobrachium scabriculum*, *M. dolichodactylus* and *M. meridionalis* are also new records for Peninsular Malaysia. This brings the total number of freshwater and terrestrial decapod crustaceans reported from Pulau Tioman to 25 species (12 brachyurans and 13 carideans).

The present paper reviews the freshwater and terrestrial decapod crustaceans from the island. The following abbreviations are used: G1 for male first pleopod; G2 for male second pleopod; cl for carapace length and tl for total length in prawns. The carapace length is measured from the postorbital margin to the posterior margin of the carapace; and the total length from the tip of the rostrum to the posterior margin of the telson. Measurements for the crabs are of carapace width and length respectively. Terminology used essentially follows Ng (1988) for crabs and Chace & Bruce (1993) for prawns. All measurements are in millimetres. Specimens are deposited in the Nationaal Natuurhistorisch Museum (formerly Rijksmuseum van Natuurlijke Histoire, RMNH), Leiden, The Netherlands; Natural History Museum (NHM), London, U.K.; Naturhistorisches Museum (NHMW), Wien, Austria; Shanghai Fisheries University (SFU), Shanghai, China; and Zoological Reference Collection (ZRC) of the Raffles Museum, Department of Biological Sciences, National University of Singapore. Malay words used in the text are 'Pulau' (island), 'Sungai' (river or stream), 'Gunung' (mountain) and 'Kampung' (village). For the sake of brevity, only diagnoses are given for the new records for Peninsular Malaysia.

NOTES ON THE FRESHWATERS OF PULAU TIOMAN

The freshwater drainages on Pulau Tioman are generally small and only permanent at lower altitudes of less than about 600 m; above this height, surface streams become ephemeral and running water is usually subterranean (Bullock & Medway, 1966). The streams are typically fast-flowing, over boulders and rocky substratum, creating many cascades, pools and riffles; generally slowing down and meandering over sandy substratum in the flat coastal areas and occasionally transforming directly from a steep, rocky stream into a wide, open mangal river. The drainages on the eastern half of the island flow over volcanic rocks while those on the western half flow over plutonic, granitoid rocks (Lee et al., 1977). In some areas, shallow sand bars at river mouths have partially or totally obstructed the outflow into the

sea, resulting in the formation of small coastal freshwater swamps (Bullock & Medway, 1966). The pH of the freshwaters ranges between 6.6 and 8.0 (present study).

TAXONOMY

FAMILY GECARCINIDAE DANA, 1851

Cardisoma carnifex (Herbst, 1796)

Cancer carnifex Herbst, 1796: 163, pl. 41, Fig. 1.

Gecarcinus carnifex - Desmarest, 1825: 113.

Cardisoma carnifex - Latreille, 1825: 685; Türkay, 1974: 224, pls. 1-11.

(See Türkay, 1974, for rest of synonymy).

Material examined. - 1 male (103.3 by 81.2 mm) (ZRC 1995.891), Tekek Bay, coll. P. K. L. Ng, Sep.1995. - 1 female (86.1 by 73.6 mm) (ZRC 1996.1716), Tekek Bay, Nipah vegetation, coll. P. K. L. Ng et al., 29 Jun.1996.

Remarks. - *Cardisoma carnifex* is widely distributed throughout the Indo-Pacific region (Türkay, 1974), although it is being reported from Pulau Tioman for the first time here. It has, however, been collected from Pulau Redang, Pulau Pemanggil and Pulau Seri Buat, three islands also off the east coast of Peninsular Malaysia (unpublished data). It is easily distinguished from congeners by having an asymmetrical terminal segment of the G1, produced as a small but distinct distomedial spine (versus symmetrical terminal G1 segment, without any distal spine).

Despite being terrestrial, *C. carnifex*, like other members of the Gecarcinidae, must return to the sea to release its eggs which will hatch into planktonic larvae (Johnson, 1965). This species occurs in large colonies in or at the periphery of mangrove stands (Johnson, 1965). The present specimens were collected from a highly disturbed mangal area with some remnant Nipah vegetation. The population there appears to be locally common but it is unlikely that they will survive for long as the mangrove is progressively being levelled and filled for development.

FAMILY GRAPSIDAE MACLEAY, 1838

Geosesarma albomita Yeo & Ng, 1999

Geosesarma albomita Yeo & Ng, 1999: 189, Figs. 1, 2.

Material examined. - see Yeo & Ng (1999).

Remarks. - This species has been described in detail, with comparisons being made against several congeners (see Yeo & Ng, 1999) (in this volume).

***Geosesarma tiomanicum* Ng, 1986**

Sesarma (*Sesarma*) *ocypoda* - Tweedie, 1936: 51 (part).
Sesarma (*Geosesarma*) *ocypodum* - Serène, 1968: 107 (part).
Sesarma ocypodum - Serène & Soh, 1970: 403 (part), 407 (part).
Geosesarma tiomanica Ng, 1986: 39, Fig. 7; Ng & Chong, 1986: 28.
Geosesarma tiomanicum - Ng, 1988: 136, Fig. 61; Ng & Lim, 1989: 31.
(not *Sesarma ocypoda* Nobili, 1900).

Material examined. - see Yeo & Ng (1999).

Remarks. - No further specimens of *Geosesarma tiomanicum* have been obtained since the type specimens were collected from Gunung Rokam by N. Smedly in May, 1929. A small male (ZRC 1990.9165) collected by J. A. Bullock from Gunung Kajang in 1962, was assigned to the present species by Ng & Lim (1989). It has, however, been found to be *G. albomita*, new species instead, which is closely related to *G. tiomanicum* but nevertheless can be readily differentiated by characters in the G1, carapace and ambulatory legs (see Yeo & Ng, 1999) (in this volume). The occurrence of these two highland species on separate mountains (*G. tiomanicum* on Gunung Rokam and *G. albomita* on Gunung Kajang [southwest of Gunung Rokam]) seems to suggest that they are physically separated by a habitat of lower altitude, i.e. saddle or valley.

Diagnoses as well as discussions on the affinities of this species can be found in Ng (1986, 1988), and Ng & Lim (1989). The G1 structure has been well described and figured by Ng (1986, 1988). The carapace and ambulatory legs, which have not been figured previously, have been illustrated by Yeo & Ng (1999: figs. 3A-C). To further elaborate on previous diagnoses, the following should be noted: i) the "squarish" carapace is actually slightly broader than long and ii) the presence of an acute subdistal tooth on the upper margin of the meri of the ambulatory legs.

The gender of *Geosesarma* is neuter and therefore, we follow Ng (1988) and Ng & Lim (1989) in referring to it as *G. tiomanicum* instead of *G. tiomanica* as originally named by Ng (1986).

***Neosarmatium indicum* (A. Milne Edwards, 1868)**

Metagrapsus indicus A. Milne Edwards, 1868: 174, Pl. 26, Figs. 1-5.
? *Sesarma indica* - Heller, 1865: 64 (part) (not *Sesarma indica* H. Milne Edwards, 1837).
Metagrapsus punctatus - De Man, 1880: 31.
Sarmatium indicum - Kingsley, 1880: 350; De Man, 1887: 660, 1892: 350; Tesch, 1917: 220.
Sarmatium punctatum - Tesch, 1917: 221, 1918: 115; ? Urita, 1926: 20; ? Sakai, 1934: 325.
Sesarma (*Sarmatium*) *punctata* - Tweedie, 1940: 109, 1950b: 353.
Sesarma punctata - Tweedie, 1950a: 94.
Neosarmatium punctata - Ng, 1988: 118.
Neosarmatium punctatum - Soh, 1978: 10, Pl. 3b; Ng & Chong, 1986: 26, 1 Fig.
Neosarmatium indicum - Davie, 1994: 43

(not *Sesarma punctata* A. Milne Edwards, 1873).

Material examined. - 1 male, 1 female (male 21.6 by 17.0 mm) (ZRC 1996.1721), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 3 females (largest 21.0 by 16.5 mm) (ZRC 1996.1722), Sungai Mentawak mangroves/estuarine area, coll. P. K. L. Ng et al., 27 Jun.1996. - 2 males, 2 females (largest 23.1 by 18.2 mm) (ZRC 1996.1723), Sungai Ayer Besar, stream along

beginning of Tekek-Juara trail (Tekek side), coll. P. K. L. Ng et al., 29 Jun.1996. - 1 female (ZRC 1996.351), Tekek Bay (freshwater), coll. P. Ng, 22 Jun.1983.

Remarks. - *Neosarmatium indicum* was reported from Pulau Tioman as *Sesarma* (*Sarmatium*) *punctata* (see Tweedie, 1940) and as *N. punctatum* (see Ng & Chong, 1986). *Neosarmatium indicum* has often been mistaken for *Neosarmatium punctatum* (A. Milne Edwards, 1873), but Davie (1994) noted two easily observable external differences between the two species: i) presence of a protruding basal shelf on the fixed finger of the male chela and ii) absence of a strong tubercular vertical ridge on the inner face of the chela palm. In addition, the distribution of *N. punctatum* is restricted to New Caledonia (Davie, 1994) and Taiwan (Ng et al., 1996), whereas the distribution of *N. indicum* is much wider, including Pulau Tioman [Peninsular Malaysia]. The present specimens possess the above characters, agreeing well with Davie's (1994) descriptions as well as with specimens in the ZRC which were collected separately by Michael Tweedie as well as by the second author. Live specimens are dark purplish-brown in colour with bright red chelae (Ng & Chong, 1986).

This species can be found in habitats ranging from estuaries to mangrove to almost pure freshwaters beyond tidal influence. They burrow down more than one metre into soft, clayey substrates, with the burrow openings located above the water level, and have been observed some distance away from the nearest water, indicative of their terrestrial nature (Ng et al., 1996). The inflated carapace is also indicative of terrestrial habits (Ng & Chong, 1986).

***Pseudosesarma bocourti* (A. Milne Edwards, 1869)**

Sesarma bocourti A. Milne Edwards, 1869: 28.

Sesarma (*Sesarma*) *bocourti* - Tesch, 1917: 135; Tweedie, 1940: 109.

Pseudosesarma bocourti - Serène & Soh, 1970: 400; Ng, 1995a: 200, Fig. 14.

(See Tesch, 1917, for rest of synonymy).

Material examined. - 1 male (16.2 by 14.1 mm) (ZRC 1998.850), Sungai Keliling, coll. P. K. L. Ng et al., 26 Jun.1997. - 1 male (18.5 by 16.3) (ZRC 1998.851), Sungai Paya, coll. P. K. L. Ng et al., 25 Jun.1997. - (4 males, 3 females (largest male 18.6 by 16.9 mm) (ZRC 1996.1724), Sungai Ayer Besar, stream along beginning of Tekek-Juara trail (Tekek side), coll. P. K. L. Ng et al., 29 Jun.1996. - 10 males, 16 females (largest male 17.3 by 15.0 mm) (ZRC 1996.1725), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 1 male (17.4 by 15.5 mm) (ZRC 1996.1726), Kampung Genting, Sungai Genting, coll. P. K. L. Ng et al., 15 Sep.1995.

Remarks. - This species is widely distributed throughout Southeast Asia (Tesch, 1917; Tweedie, 1940). Ng (1995a), referring to differences in the male abdomen proportions and chelae structure of some specimens, questioned the conspecificity of all the specimens attributed to this species from Malaysia, Borneo and Sumatra. Until the type material is re-examined, such differences should be regarded as infraspecific variation. The present specimens, however, agree rather well when compared with *P. bocourti* material in the ZRC collected by Michael Tweedie from Johore [Peninsular Malaysia] and by the second author from Pahang [Peninsular Malaysia] and Sarawak [Borneo] (see Ng, 1995a, for illustrations of carapace and gonopods).

Tan & Ng (1994: 82), in an annotated checklist of mangrove crabs, categorized *Pseudosesarma bocourti* a "obligate mangal species". Thus it is worth noting that the habitats from which the present specimens were obtained, range from true mangal areas to what

appear to be tidal freshwaters beyond the inland limits of the mangroves (Ng, 1995a; pers. obs.).

***Tiomanium indicum* (H. Milne Edwards, 1837)**

(Fig. 2)

Sesarma indica H. Milne Edwards, 1837: 74; Tweedie, 1950: 340 (not *Neosarmatium indicum* (A. Milne Edwards, 1868)).

Sesarma tiomanense Rathbun, 1913: 355, pl. 31 figs. 1-3.

Sesarma (*Sesarma*) *indicum* - Tesch, 1917: 159; Serène, 1968: 105.

Sesarma (*Sesarma*) *tiomanensis* - Tesch, 1917: 207; Serène, 1968: 105; Tweedie, 1936: 51.

Tiomanium indicum - Serène & Soh, 1970: 398, 406, pl. 5 figs. C, D.

(see Tesch, 1917: 159 for rest of synonymy).

Material examined. - 1 male (43.7 by 33.9 mm) (ZRC 1998.852), sandy beach near coast behind Mastura Chalet, Tekek Bay, coll. D. C. J. Yeo et al., 24 Jun. 1997.

Remarks. - *Tiomanium indicum* was originally described from Java and has been reported from Indian Seas, Sumatra, Nias, Natunas, Labuan, Pulau Tioman, Singapore, Peninsular Malaysia and New Guinea. Tweedie (1950: 340) synonymised *Sesarma tiomanense* Rathbun, 1913, under *S. indica*, commenting that the "... characters adduced by Rathbun to distinguish *S. tiomanense* from this species do not suggest that the single specimen described from Tioman Island differs specifically from those described by De Man and Tesch". This action was followed by Serène (1968). In the ZRC, we have specimens from various parts of Singapore, Malaysia (Pulau Babi Besar, Johor and Labuan) and Natunas.

Serène & Soh (1970) transferred this species to its own monotypic genus on the basis of its convex and high carapace as well as various antenna, orbital, chela and male abdomen characters. The present specimen from Pulau Tioman agrees very well with what is known about this species. Figures are provided here of its male abdomen and G1.

In their original publication, Serène & Soh (1970) used two different spellings for the genus name. In the key to genera (p. 391), list of species (p. 406) and captions to the figures (p. 408), Serène & Soh (1970) spelt the genus name as "*Tiomanium*". In the actual diagnosis and discussion of the genus (p. 398), however, they spelt the name as "*Tiomanum*" instead. On the basis of the number of times the first spelling was used and the way he named most of his new genera and subgenera, we believe that "*Tiomanum*" represents a typographical mistake. *Tiomanium* should thus be regarded as the correct spelling for the name. In any case, Sakai (1976: 659) and Davie (1994: 43) used the spelling *Tiomanium* when he referred briefly to this species when discussing *Neosarmatium indicum* (A. Milne Edwards, 1868).

In life, *Tiomanium tiomanense* is greyish-white, and inhabits sandy-muddy areas behind coastal mangroves. They dig relatively deep burrows and come out at night to forage.

***Varuna yui* Hwang & Takeda, 1986**

Varuna yui Hwang & Takeda, 1986: 11, Figs. 1-2; Tan & Ng, 1994: 77.

Varuna litterata - Ng & Chong, 1986: 26, 1 Fig.; Ng, 1988: 116, Figs. 2C, 52 (not *Cancer litteratus* Fabricius, 1798).

Material examined. - 1 female (13.1 by 12.3 mm) (ZRC 1996.1727), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 1 male (9.3 by 8.6 mm) (ZRC 1996.1728), pool between Keliling and Mentawak, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 2 males, 4 females (largest male 19.2 by 18.1 mm) (ZRC 1996.1729), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 3 females (ZRC 1989.2806-2808), stream behind Idrus Inn, Pulau Tioman, Pahang, coll. P. Ng, 1 Jul.1986. - 1 female (1989.2183), on sargassum floating between Pulau Tulai and Tekek Bay, Pulau Tioman, Pahang, coll. P. Ng, 26 Jun.1987.

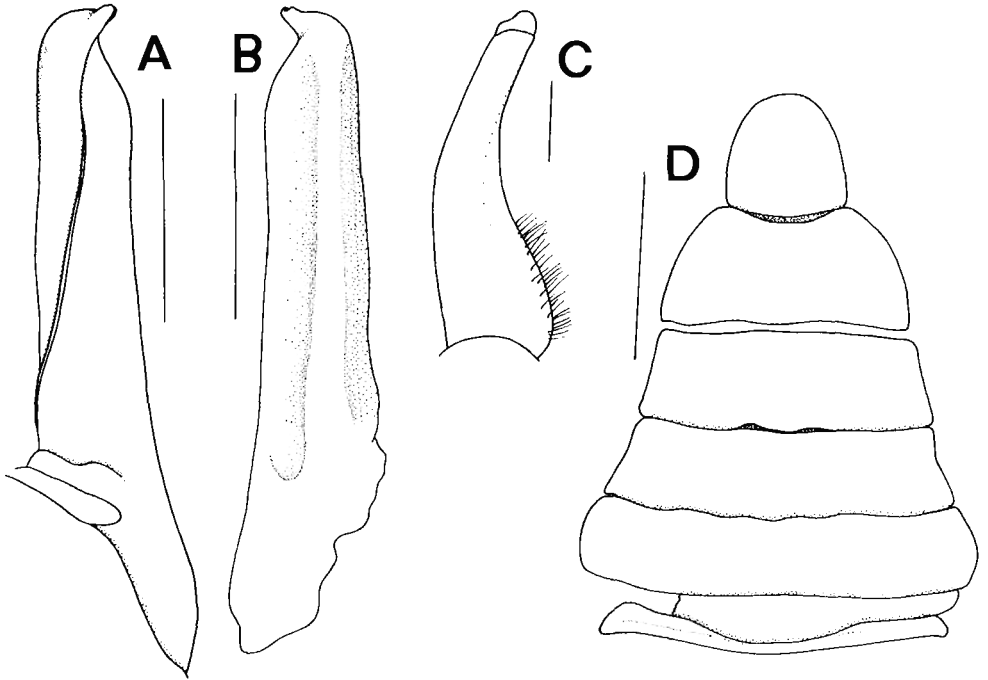


Fig. 2. *Tiomanium indicum* (H. Milne Edwards, 1837). Male (43.7 by 33.9 mm)(ZRC 1998.852), Tekek Bay. A, B: left G1; C: left G2; D: abdomen; E: overall dorsal view. Scales: A-D = 1.0 mm.

Remarks. - *Varuna yui* closely resembles *V. litterata* (Fabricius, 1798), in all the external non-sexual characters. It can, however, be clearly distinguished by its curved G1 in which the larger of two terminal lobes is further divided by a deep median cleft (versus straight G1 in which there is no dividing cleft in the larger of two terminal lobes) (see Hwang & Takeda, 1986). Ng & Chong (1986) reported *V. litterata* from Pulau Tioman, but specimens collected from there as well as from other parts of the Sundaic region have been reexamined by Peter Davie and the second author and found to be *V. yui* instead of *V. litterata* (unpublished data; Tan & Ng, 1994). Similarly, the specimens and illustrations in Ng (1988) are in fact, of *V. yui* and not *V. litterata*. The respective distributions of the two species seems to indicate that *V. yui* prefers continental shelf waters while *V. litterata* prefers more oceanic areas (Tan & Ng, 1994).

Varuna yui does not burrow but leads a relatively pelagic lifestyle. To this end, its flattened ambulatory legs lined with dense setae appear well adapted for aiding in swimming (Ng & Chong, 1986).

FAMILY PARATHELPHUSIDAE ALCOCK, 1910

Parathelphusa nagasaki Ng, 1988

(Fig. 3)

Parathelphusa nagasaki Ng, 1988: 100, Fig. 46; Ng & Lim, 1989: 29.

Material examined. - Holotype - male (29.5 by 23.0 mm) (ZRC 1989.3049), amongst forest leaf litter, probably in vicinity of Gunung Kajang, Pulau Tioman, Pahang, ca. 2°50'42.0"N 104°09'1.4"E, coll. J. A. Bullock, Apr. 1962. Paratypes - 3 males, 2 females (ZRC 1989.3050-3054), same data as holotype.

Remarks. - *Parathelphusa nagasaki* has been described and discussed in detail by Ng (1988) and Ng & Lim (1989). It is an unusual record for the island because several of its carapace and G1 characters ally it more to Bornean species of *Parathelphusa* than to the geographically closer *Parathelphusa maculata* De Man, 1879, which it superficially resembles (Ng, 1988; Ng & Lim, 1989). Despite numerous collections of the decapod fauna on the island, this

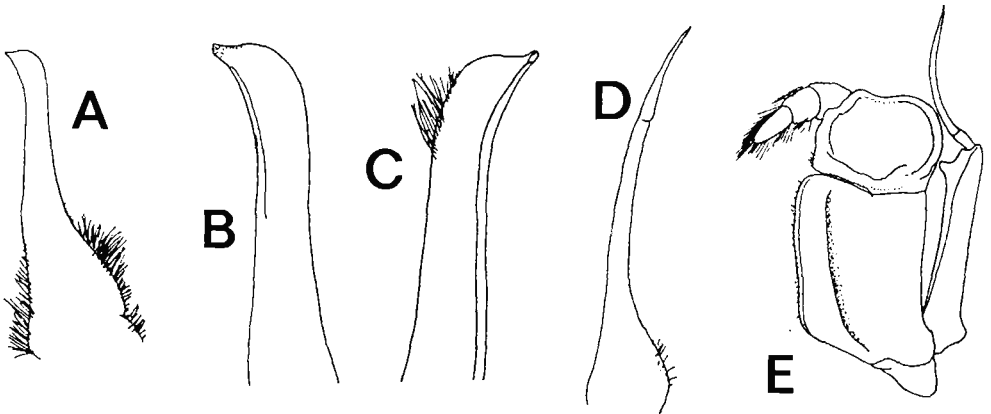


Fig. 3. *Parathelphusa nagasaki* Ng, 1988. Holotype male (29.5 by 23.0 mm)(ZRC 1989.3049), Gunung Kajang. A: ventral view of left G1; B: ventral view of distal portion of left G1; C: dorsal view of distal portion of left G1; D: left G2; E: left third maxilliped. (After Ng, 1988).

species has not been found since the type specimens were collected by J. A. Bullock in 1962 in the vicinity of Gunung Kajang (see Ng & Lim, 1989). It is possible that the least well-surveyed drainage during our recent trips there, the Sungai Mentawak drainage which originates from the Gunung Kajang, may be the key to rediscovering this species.

FAMILY POTAMIDAE ORTMANN, 1896

Johora counsilmani (Ng, 1985)

(Fig. 4)

Stoliczia (Johora) tiomanensis counsilmani Ng, 1985: 152, Figs. 3, 4; Ng & Lim, 1989: 28.

Johora tiomanensis counsilmani - Ng & Chong, 1986: 27, 1 Fig.; Ng, 1987: 37, 1988: 48, Figs. 7, 21.

Material examined. - Holotype - male (43.0 by 31.9 mm) (ZRC 1984.6798), Sungai Ayer Besar, western Pulau Tioman, Pahang, West Malaysia, 2°52'39"N, 104°11'48"E, ca. 300m asl., coll. P. K. L. Ng, 20 Jun.1984. Paratypes - 2 males, 2 females (largest female 28.1 by 23.7 mm) (ZRC 1984.6799-6802), same data as holotype. Others - 1 male, 1 female (male 24.4 by 19.1 mm) (ZRC 1996.1736), Sungai Ayer Besar, stream along Tekek-Juara trail, coll. P. K. L. Ng et al., 24-25 Jun.1996. - 10 males, 8 females, 2 juveniles (largest male 25.0 by 20.5 mm) (ZRC 1996.1737), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 7 males, 2 females, 1 juvenile (largest male 39.1 by 31.0 mm) (ZRC 1996.1738), Sungai Ayer Besar waterfall, on Tekek-Juara trail, coll. P. K. L. Ng et al., 16 Sep.1995. - 1 male (27.9 by 22.0 mm) (ZRC 1996.1739), Sungai Baharu, Tekek, along Tekek-Juara trail, coll. P. K. L. Ng et al., 26 Jun.1996. - 1 female (ZRC 1985.1994), stream behind Tanjung Said, along Merlin-Tekek road, western Pulau Tioman, Pahang, 2°52'57.0"N 104°10'8.0"E, coll. S. S. C. Chong, 27 Jun.1985. - 1 male, 1 female (ZRC 1985.1995-1996), rocky stream along Tekek to Juara path, central Pulau Tioman, Pahang., 2°52'16.0"N 104°12'0.0"E, coll. S. S. C. Chong, 26 Jun.1985. - 1 male, 1 female (ZRC 1985.1997-1998), stream near Juara, eastern Pulau Tioman, Pahang, 2°51'13.0"N 104°12'48.0"E, coll. S. S. C. Chong, 26 Jun.1985. - 3 males (ZRC 1989.2140-2142), from rock seepage near stream, enroute to Juara Bay, eastern Pulau Tioman, Pahang., 2°52'16.0"N 104°12'0.0"E. coll. S. S. C. Chong, 29 Jun.1986. - 2 males, 4 females, 3 juveniles (ZRC 1989.3040-4048), rocky area along path to Juara Bay, eastern Pulau Tioman, Pahang, 2°52'0.0"N 104°12'35.0"E, coll. S. S. C. Chong, 29 Jun.1986. - 1 male, 1 female (ZRC 1989.2205-2206), waterfall along Tekek-Juara path, Pulau Tioman, Pahang, 2°52'39.0"N 104°11'48.0"E, coll. S. S. C. Chong, 29 Jun.1986. - 1 female (ZRC 1989.2147), stream, trail to Juara, Pulau Tioman, coll. J. B. Sigurdsson, 25 Jun.1985. - 1 female (ZRC 1989.2795), waterfall along trail to Juara Bay, Pulau Tioman, coll. J. J. Counsilman, 25 Jun.1985. - 1 male, 1 female (ZRC 1989.3056-3057), waterfall along Tekek to Juara path, Pulau Tioman, coll. S. S. C. Chong, 29 Jun.1986.

Remarks. - *Johora counsilmani* was first described and discussed in detail by Ng (1985) as a subspecies of *Stoliczia (Johora) tiomanensis* Ng & Tan, 1984, based on differences in the G1 structure. There is no doubt that the two forms are very closely related, having almost identical external characters (Ng, 1985, 1988). However, the good series of specimens of both *J. tiomanensis* and *J. counsilmani* presently available, shows the diagnostic characters in the G1 structure of the two species to be consistently distinct and reliable albeit with more variation observed than previously known. Furthermore, no specimens with intermediate G1 structure between the two taxa that would indicate possible infra-specific hybridization have been found. Therefore, *J. counsilmani* and *J. tiomanensis* are here regarded as distinct, good species.

The G1 of *Johora counsilmani* differs from that of *J. tiomanensis* in the following aspects: i) the distal cleft on the outer margin of the subterminal segment is much broader and the corners are more rounded or convex (versus narrower cleft with angular corners); ii) terminal segment relatively shorter, less sharp distally and bent more obliquely (versus relatively

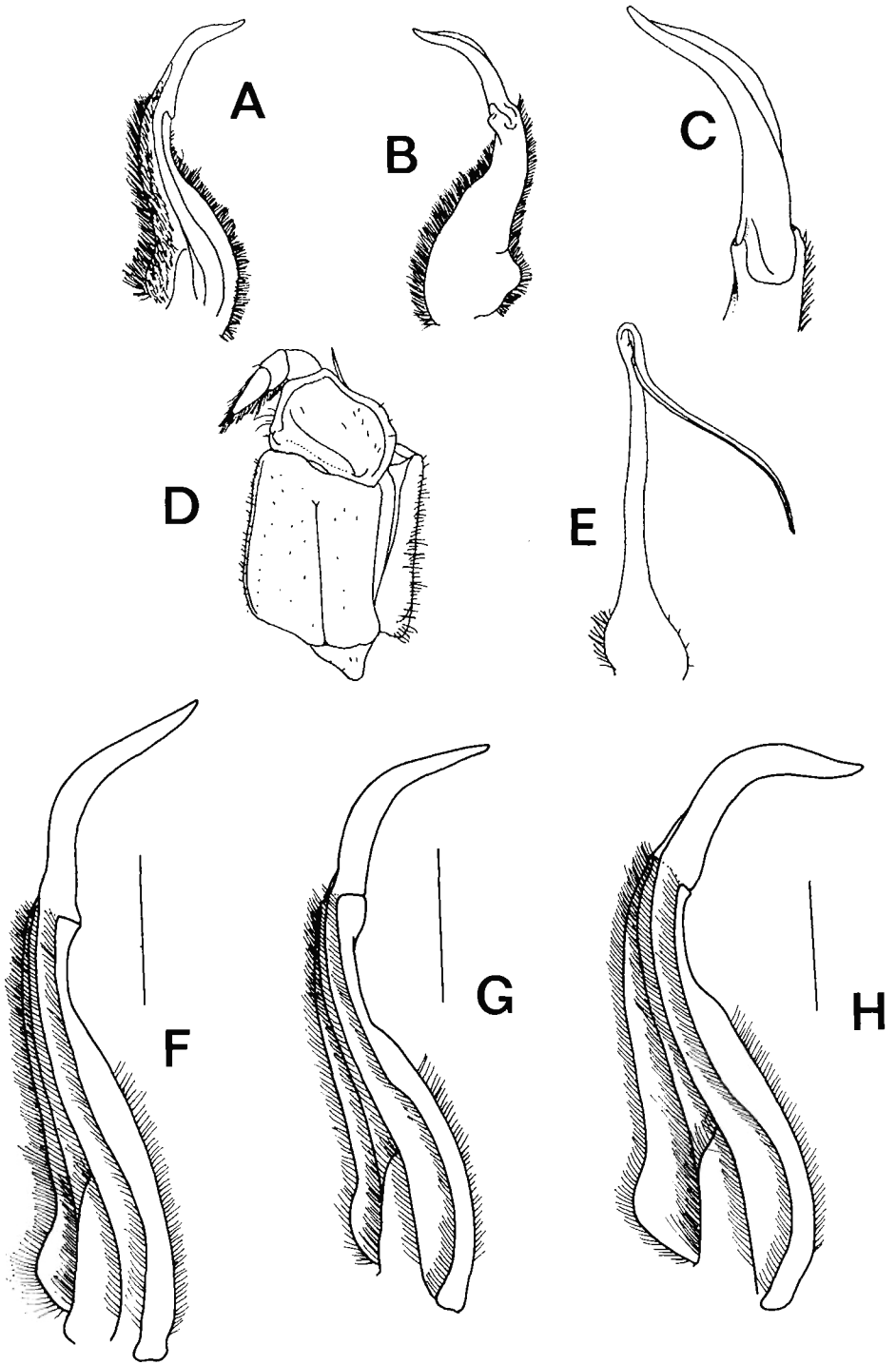


Fig. 4. *Johora councilmani* Ng, 1985. A-E, Holotype male (43.0 by 31.9 mm)(ZRC 1984.6798), Sungai Ayer Besar; F, male (27.3 by 21.6 mm)(ZRC 1996.1738), Sungai Ayer Besar waterfall; G, male (23.2 by 18.3 mm) (ZRC 1996.1737), Sungai Keliling; H, male (27.9 by 22.0 mm)(ZRC 1996.1739), Sungai Baharu, Juara. A: ventral view of left G1; B: dorsal view of left G1; C: dorsal view of terminal segment of left G1; D: left third maxilliped; E: left G2; F-H: ventral view of left G1. Scales: F-H = 2.0 mm. (A-E, after Ng, 1988).

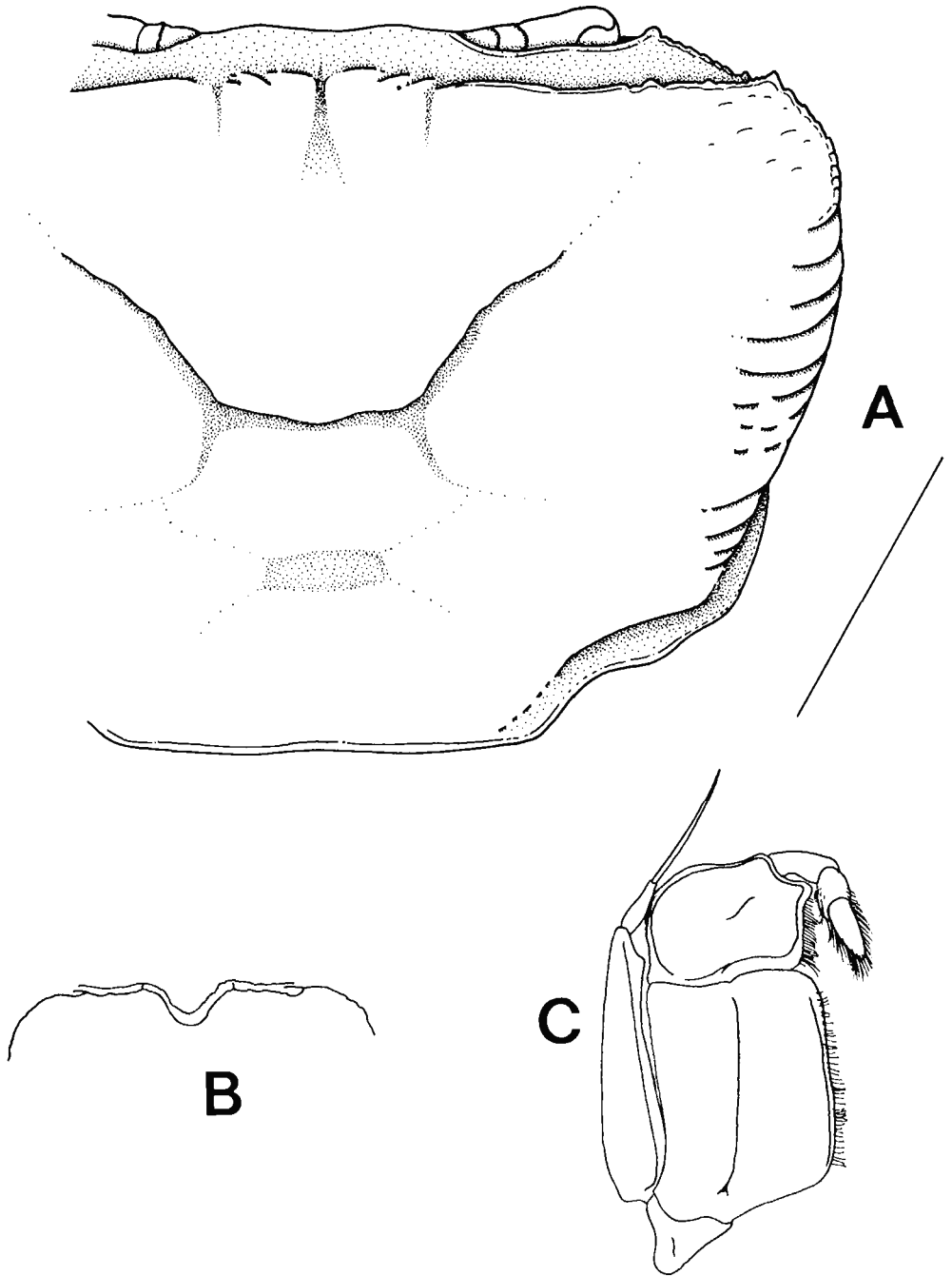


Fig. 5. *Johora grallator* Ng, 1988. Holotype female (33.1 by 23.5 mm)(ZRC 1989.2691), Ulu Lalang, Gunung Kajang, 2600 ft (792 m) asl. A: carapace; B: posterior margin of epistome; C: right third maxilliped. Scale: A = 10.0 mm. (B, C, after Ng, 1988).

longer, sharper distally and bent more horizontally); and iii) ventral fold of terminal segment broader and expanded along middle to distal portion to form dorsally visible flap-like structure, ie, dorsal flap (versus ventral fold narrower and only slightly expanded along proximal portion) (Figs. 4A-C). These differences occur together in most cases, however, specimens are sometimes found in which only one or two of these features are obvious. The variation observed in the G1 includes specimens with the terminal segment bent more to the horizontal, giving the entire G1 the appearance of being more strongly curved; specimens with slightly narrower dorsal flap and sharper or more tapered distal tip, giving the terminal segment a more slender appearance and specimens in which the distal tip is straight instead of upcurved (Figs. 4F-H). One unusual specimen that was examined had no locality data but is tentatively identified as *J. counsilmani* as the terminal segment of the G1 is clearly of that species. It should be noted however, that the distal outer margin cleft on the subterminal segment of the G1 is of the narrow *J. tiomanensis* type. In addition, the face of this specimen was relatively more hairy than any of the other specimens of *J. counsilmani* or *J. tiomanensis* examined.

Johora counsilmani, like *J. tiomanensis*, is a fully aquatic species, a habit indicated by the flatness of its carapace. Ng (1988) noted that *J. counsilmani* occupies the central portion of Pulau Tioman. In the present study, specimens examined were collected from Sungai Ayer Besar, Sungai Baharu and Sungai Keliling drainages (Fig. 1).

***Johora grillator* Ng, 1988**

(Fig. 5)

Johora grillator Ng, 1988: 52, Fig. 23; Ng & Lim, 1989: 28.

Material examined. - Holotype - female (33.1 by 23.5 mm) (ZRC 1989.2691), in insect trap baited with coconut, Ulu Lalang, Gunung Kajang, 2600 ft (792 m) asl., Pulau Tioman, Pahang, ca. 2°51'23"N 104°09'37"E, coll. J. A. Bullock, 18 Jun.1962. Others - 2 juvenile males (ZRC 1996.1730), Gunung Kajang, under rock in dry cave, coll. T. H. T. Tan et al., 27 Jun.1996.

Remarks. - *Johora grillator* was described from a single female specimen, the distinct non-sexual external characters being sufficient for distinguishing it from its congeners (Ng, 1988; Ng & Lim, 1989). The collection of two juvenile male specimens from the type locality [Gunung Kajang] during our June 1996 expedition confirms the presence of the species there. Unfortunately, due to the immaturity of these specimens, the adult G1 structure still cannot be determined. Based on the long ambulatory legs and laterally swollen carapace, Ng (1988) speculated that *J. grillator* probably has semiterrestrial tendencies, being active at night, foraging in areas relatively far from permanent water. Ng & Lim (1989) also pointed out the probable similar habits that *J. grillator* has to some members of the Philippine gecarcinucid genus *Archipelothelphusa* Bott, 1969, which it closely resembles. The discovery of the two juveniles in a dry cave during the present study lends further support to this view. The live colouration of this species is overall light orange.

***Johora punicea* (Ng, 1985)**

(Fig. 6)

Stoliczia (Johora) punicea Ng, 1985: 156, Figs. 5, 6; Ng & Lim, 1989: 28.

Johora punicea - Ng & Chong, 1986: 27, 1 Fig.; Ng, 1987: 38, Ng, 1988: 50, Fig. 22, Pl. 1D.

Material examined. - Holotype - male (19.7 by 15.5 mm) (ZRC 1984.6803), under rocks on slope adjacent to Sungai Besar, western Pulau Tioman, Pahang, 2°52'39.0"N 104°11'48.0"E, ca. 300m asl., coll. P. K. L. Ng, 20 Jun.1984. Paratypes - 2 males, 2 females (ZRC 1984.6804-6808), same data as holotype except for 1 female (ZRC 1984.6808) found under rocks in shallow water. Others - 1 female (17.6 by 13.4 mm) (ZRC 1998.853), Sungai Salang, coll. H. H. Tan et al., 25 Jun.1997. - 5 males, 2 females (largest male 17.1 by 12.9 mm) (ZRC 1996.1731), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 1 male (16.2 by 12.2 mm) (ZRC 1996.1732), Sungai Ayer Besar, stream along Tekek-Juara trail, coll. P. K. L. Ng et al., 24-25 Jun.1996. - 3 males, 4 females, 2 juveniles (largest male 16.2 by 12.1 mm) (ZRC 1996.1733), Kampung Paya, Sungai Paya, 2°47'11.9"N 10°07'11.6"E, coll. P. K. L. Ng et al., 16 Sep.1995. - 12 males, 5 females (largest male 20.6 by 15.4 mm) (ZRC 1996.1734), Sungai Ayer Besar waterfall, on Tekek-Juara trail, coll. P. K. L. Ng et al., 16 Sep.1995. - 21 males, 2 females (largest male 24.6 by 18.0 mm) (ZRC 1996.1735), Sungai Baharu, Tekek, along Tekek-Juara trail, coll. P. K. L. Ng et al., 26 Jun.1996. - 1 female (24.7 by 18.1 mm) (ZRC 1985.2002), highland, Pulau Tioman, Pahang, coll. D. S. Johnson, 1960. - 5 males, 4 females (ZRC 1989.2208-2216), beside clear freshwater stream, 800-1200ft asl., Pulau Tioman, Pahang, coll. not known, 28 May-3 Jun.1958.

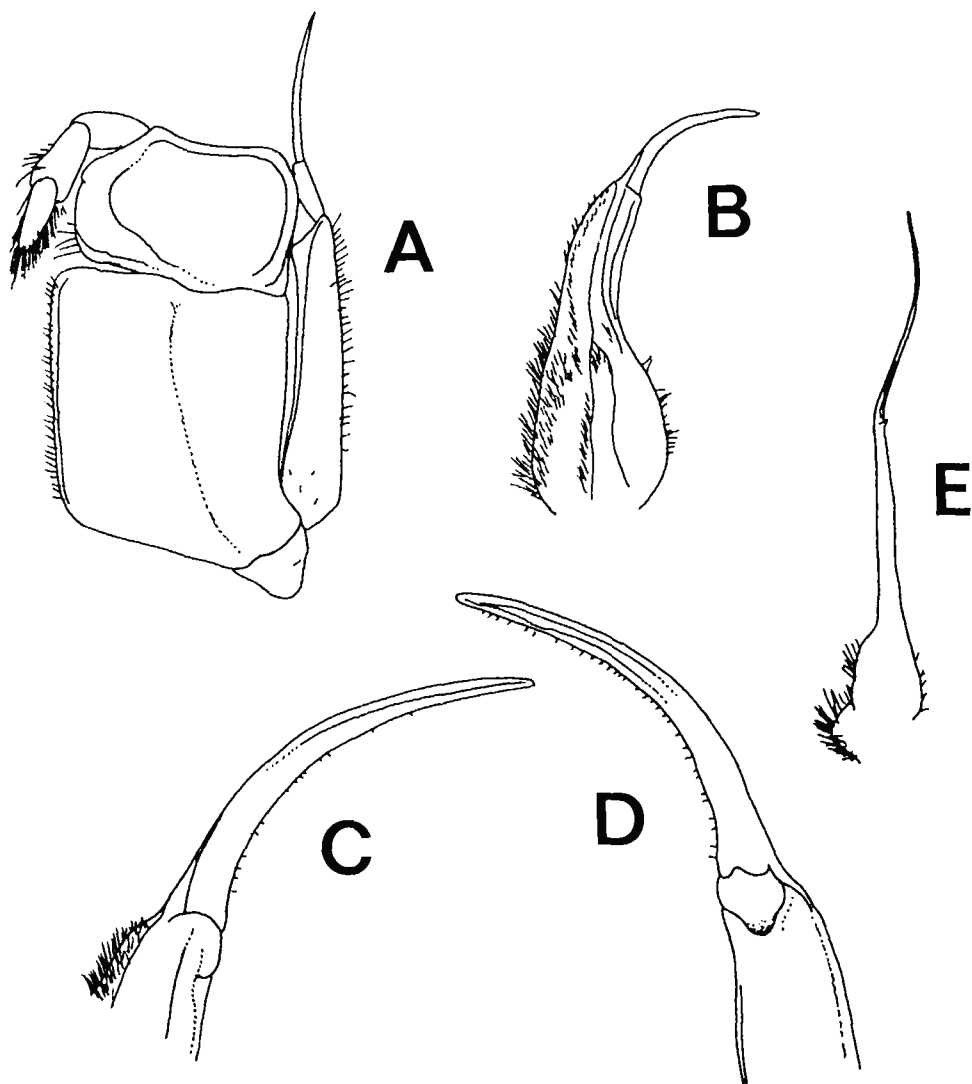


Fig. 6. *Johora punicea* Ng, 1985. Holotype male (19.7 by 15.5 mm)(ZRC 1984.6803), Sungai Besar. A: left third maxilliped; B: ventral view of left G1; C: ventral view of terminal segment of left G1; D: dorsal view of terminal segment of left G1; E: left G2. (After Ng, 1988).

Remarks. - *Johora punicea* is most closely related to *J. tiomanensis*, but can easily be separated by several differences in external carapace morphology, leg proportions and GI structure (see Ng, 1985). In addition, its purplish-reddish colouration (see Ng & Chong, 1986: 31) immediately distinguish this species from all other potamids on the island. *Johora punicea* is a semi-terrestrial species, often found under rocks in damp areas near or adjacent to streams (Ng, 1988; pers. obs.). The relatively long ambulatory legs and swollen carapace are probably adaptations to its semi-terrestrial lifestyle (Ng, 1988). The species was previously only known from and near the type locality of the Sungai Ayer Besar waterfall. Its occurrence in Sungai Salang (northwestern part of island), Sungai Baharu, Sungai Keliling and Sungai Paya area thus extends its distribution considerably.

***Johora tiomanensis* (Ng & Tan, 1984)**

(Fig. 7)

Stoliczia (Johora) tiomanensis Ng & Tan, 1984: 167, Figs. 1-4; Ng & Lim, 1989: 28.

Stoliczia (Johora) tiomanensis tiomanensis - Ng, 1985: 151, Fig. 2.

Johora tiomanensis tiomanensis - Ng & Chong, 1986: 26, 2 Figs.; Ng, 1987: 36, 1988: 46, Figs. 2A, 20.

Material examined. - Holotype - male (39.0 by 32.0 mm) (ZRC 1983.7.19.1), Sungai Genting, western Pulau Tioman, Pahang, 2°50'08"N 104°08'32"E, ca. 120 m asl., coll. P. K. L. Ng, Apr.1983. Paratypes - 1 male, 2 females (ZRC 1983.7.19.2-4), same data as holotype. Others - 1 male (27.5 by 21.6 mm) (ZRC 1998.854), Sungai Keliling, coll. H. H. Tan et al., 26 Jun.1997. - 2 males, 1 female (largest 29.9 by 23.4 mm) (ZRC 1998.855), Sungai Asah, coll. T. H. T. Tan & K. Lim, 24 Jun.1997. - 1 female, 1 juvenile (larger 30.8 by 24.6 mm) (ZRC 1998.856), Sungai Paya, coll. P. K. L. Ng et al., 25 Jun.1997. - 1 female, 1 juvenile (larger 31.5 by 25.1 mm) (ZRC 1998.857), Sungai Nipah, coll. H. H. Tan, 24 Jun.1997. - 2 males, 2 females (largest male 26.8 by 21.4 mm) (ZRC 1996.1740), Sungai Raya, Kampung Mukut, coll. P. K. L. Ng et al., 26 Jun.1996. - 1 female (ZRC 1996.1741), Kampung Paya, Sungai Pasal upstream (ca. 15 minutes walk from start of trail to Sungai Paya), coll. H. H. Tan et al., 17 Sep.1995. - 2 males (largest 51.5 by 39.5 mm) (ZRC 1996.1742), Gunung Kajang, coll. T. H. T. Tan et al., 26 Jun.1996. - 14 males, 7 females (largest male 37.0 by 29.4 mm) (ZRC 1996.1743), Kampung Paya, Sungai Paya, 2°47'11.9"N 104°07'11.6"E, coll. P. K. L. Ng et al., 16 Sep.1995. - 1 male (38.6 by 29.6 mm) (ZRC 1996.1744), Sungai Nipah, coll. D. C. J. Yeo et al., 28 Jun.1996. - 3 males, 1 female (largest male 44.2 by 33.4 mm) (ZRC 1996.1745), Sungai Paya upstream, near base of Bukit Paya, coll. H. H. Tan et al., 17 Sep.1995. - 1 male, 2 females (largest female 41.2 by 31.7 mm) (ZRC 1996.1746), Kampung Genting, Sungai Genting, 2°45'36.7"N 104°07'21.5"E, coll. P. K. L. Ng et al., 15 Sep.1995. - 2 males, 1 juvenile (largest male 44.7 by 33.9 mm) (ZRC 1996.1747), Gunung Kajang, Sungai English, ca. 1000ft asl., coll. H. H. Tan et al., 18 Sep.1995. - 2 males, 3 females (largest male 42.0 by 32.0 mm) (ZRC 1996.1748), Kampung Paya, Sungai Paya, 2°47'11.9"N 104°07'11.6"E, coll. H. H. Tan et al., 18 Sep.1995. - 12 males, 3 females, 2 juveniles (largest male 38.4 by 29.9 mm) (ZRC 1996.1749), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 6 males, 10 females, 2 juveniles (largest male 35.6 by 27.2 mm) (ZRC 1996.1750), Gunung Kajang, Sungai Ayer Surin, ca. 800ft asl., coll. H. H. Tan et al., 18 Sep.1995. - 1 male, 2 females, 3 juveniles (largest female 32.9 by 25.9 mm) (ZRC 1996.1751), Sungai Asah, coll. P. K. L. Ng et al., 26 Jun.1996. - 2 males (ZRC 1985.2169-2170), Mukut waterfalls, near second jetty, southern Pulau Tioman, Pahang, 2°46'35.0"N 104°12'19.0"E, coll. S. S. C. Chong, 27 Jun.1985. - 2 males, 2 females, 3 juveniles (ZRC 1989.2899-2905), Mukut waterfalls, southern Pulau Tioman, Pahang, 2°46'35.0"N 104°12'19.0"E, coll. S. S. C. Chong, 28 Jun.1986. - 1 male (ZRC 1989.2012), Mukut falls, Pulau Tioman, coll. S. S. C. Chong, Jun.1986.

Remarks. - This species has been described and discussed in some detail by Ng & Tan (1984) and Ng (1985, 1987, 1988). In the present study, *Johora tiomanensis* is recognized as a distinct species from *J. counsilmani* (see Remarks under *Johora counsilmani*). The GI structures of the specimens examined were more variable than expected. These variations include: i) GI with terminal segment bent less horizontally and more obliquely; ii) GIs with

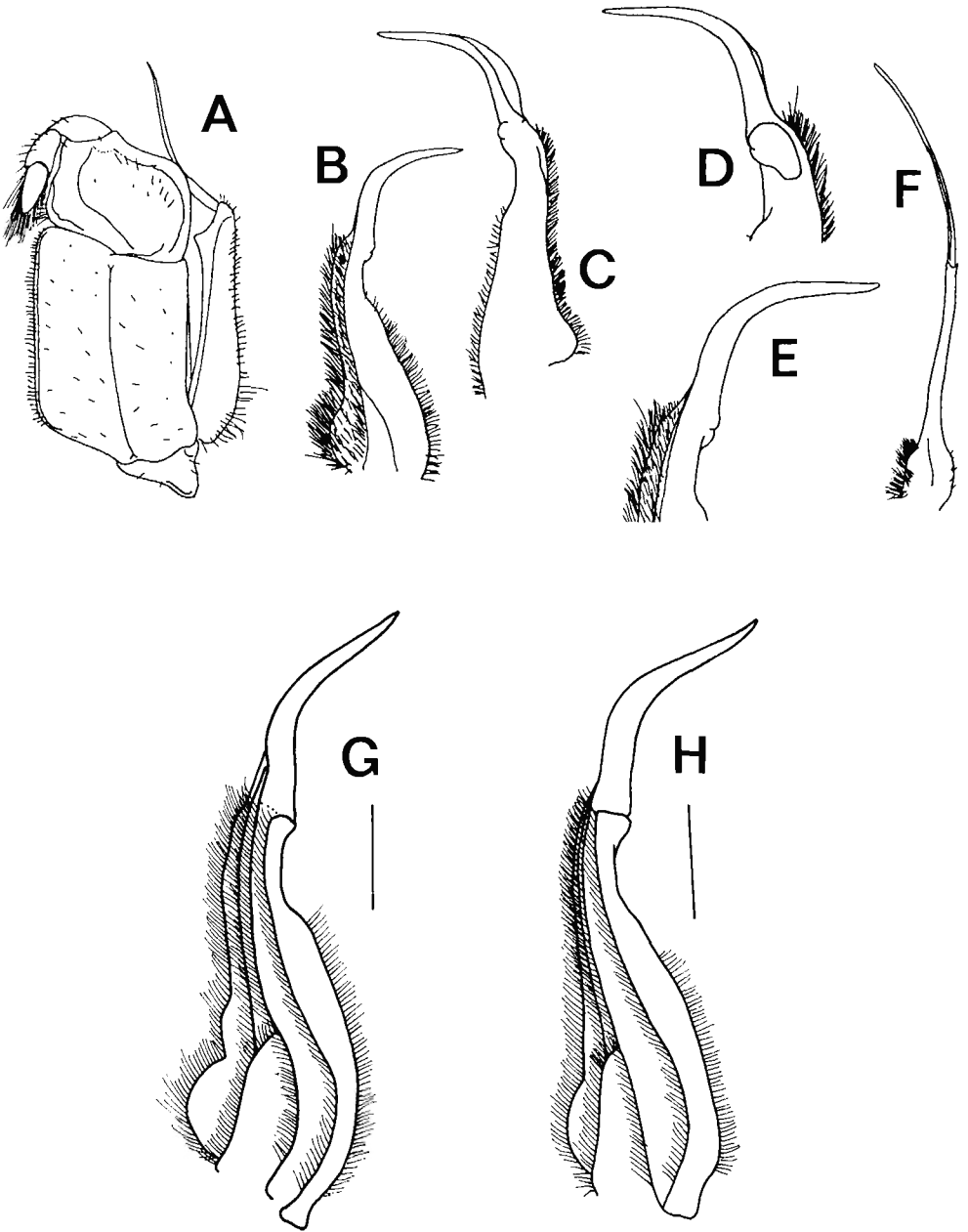


Fig. 7. *Johora tiomanensis* Ng & Tan, 1984. A-B, D-F, holotype male (39.0 by 32.0 mm)(ZRC 1983.7.19.1), Sungai Genting; C, paratype male (47.0 by 37.0 mm)(ZRC 1983.7.19.3), same locality; G, male (38.9 by 31.1 mm)(ZRC 1996.1743), Sungai Paya, Kampung Paya; H, male (36.0 by 28.0 mm)(ZRC 1996.1749), Sungai Paya, Kampung Paya. A: left third maxilliped; B: ventral view of left G1; C: dorsal view of left G1; D: dorsal view of terminal segment of left G1; E: ventral view of terminal segment of left G1; F: left G2; G-H: ventral view of left G1. Scales: G-H = 2.0 mm. (A-F, after Ng, 1988).

distal tip pointed slightly upwards instead of straight; and iii) G1s with ventral fold of terminal segment expanded slightly more, giving the terminal segment an appearance of being slightly more conical (broad proximally, narrow distally) instead of tubular or cylindrical (equal width proximally and distally) (Figs. 7G, H).

Johora tiomanensis is found in the lower part of the island and occurs frequently all major drainages south of Sungai Keliling drainage except for the Sungai Mentawak drainage (immediately south of Sungai Keliling), which has not been properly sampled beyond the brackish/mangal mouth area. However, a solitary specimen (ZRC 1998.854) (27.5 by 21.6 mm), that is clearly referable to the present species, was collected from Sungai Keliling. This shows that the distributions of *J. tiomanensis* and *J. counsilmani* actually overlap to small degree with the northernmost limit of the former coinciding with the southernmost limit of the latter (Fig. 1). It is obviously very important to properly survey the Sungai Mentawak drainage in the future as it is a relatively extensive drainage. It is highly probable that, like the other drainages originating from the Gunung Kajang vicinity (Sungai Paya, Sungai Genting, Sungai Nipah, Sungai Mukut and Sungai Raya), Sungai Mentawak would have *J. tiomanensis* occurring there as well.

FAMILY ATYIDAE DE HAAN, 1849

Atyopsis moluccensis (De Haan, 1849)

Atya moluccensis De Haan, 1849: 186, Pl. O.

Atyopsis moluccensis - Chace, 1983: 27, Figs. 16-19; Ng & Chong, 1986: 30, 1 Fig.; Ng & Chia, 1994: 644, Figs. 1, 3-10.

(See Chace, 1983, for rest of synonymy).

Material examined. - 6 males, 6 females (largest cl 19.8 mm, tl 64.4 mm), Sungai Baharu tributary, along Tekek-Juara trail, coll. O. Chia et al., 27 Jun.1997. - 5 males (largest cl 22.7 mm, tl 75.1 mm), Tekek falls, Sungai Ayer Besar, along Tekek-Juara trail, coll. O. Chia et al., 23 Jun.1997. - 3 females, 6 juveniles (largest cl 20.6 mm, tl 67.1 mm), Sungai Nipah, coll. O. Chia et al., 27 Jun.1997. - 6 males, 8 females, 7 juveniles (largest male cl 21.0 mm, tl 65.5 mm), Sungai Keliling, coll. H. H. Tan et al., 23-27 Jun.1997. - 7 males, 12 females (largest male cl 26.9 mm, tl 79.5 mm) (ZRC 1996.1776), Kampung Paya, Sungai Paya, 2°47'11.9"N 104°07'11.6"E, coll. P. K. L. Ng et al., 16 Sep.1995. - 1 male, 1 female, 1 juvenile (largest cl 21.6 mm, tl 68.0 mm) (ZRC 1996.1777), Kampung Paya, Sungai Paya, 2°47'11.9"N 104°07'11.6"E, coll. H. H. Tan et al., 18 Sep.1995. - 23 males, 26 females (largest male cl 28.0 mm, tl 84.2 mm) (ZRC 1996.1778), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 9 males, 13 females (largest male cl 25.3 mm, tl 77.2 mm) (ZRC 1996.1779), Sungai Raya, Kampung Mukut, coll. P. K. L. Ng et al., 26 Jun.1996. - 12 males, 12 females (largest male cl 28.0 mm, tl 81.6 mm) (ZRC 1996.1780), Sungai Asah, coll. P. K. L. Ng et al., 26 Jun.1996. - 12 males, 17 females (largest male cl 28.0 mm, tl 85.5 mm) (ZRC 1996.1781), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 1 male (ZRC 1998.926), second last stream before reaching Juara along Tekek-Juara path, Pulau Tioman, coll. S. S. C. Chong, 26 Jun.1985.

Remarks. - The taxonomy of *Atyopsis moluccensis* has been revised by Chace (1983: 27, Figs. 16-19). The present specimens agree well in all aspects with the diagnosis and figures of Chace (1983), except for a few specimens which only have 4 to 6 ventral serrations on the rostra. This is in contrast to Chace's (1983) diagnosis for *A. moluccensis* which states that there are 7-16 ventral rostral serrations.

Considerable colour variation occurs in this species, varying from yellowish-brown to almost black (see also Ng & Chong, 1986; Ng & Chia, 1994). The colour of the live specimens

appears to be related to the substrate of the streams from which the specimens were obtained. The majority of the lighter coloured specimens were collected from the Sungai Paya drainage which runs over granitoid rocks (see Lee et al., 1977). However, specimens collected from Sungai Raya, Sungai Asah and Sungai Keliling drainages consisted of very dark coloured and some lighter coloured individuals. This corresponds with the fact that these drainages flow over a mixture of granitoid rocks and relatively darker acid to intermediate volcanic rocks (see Lee et al., 1977). There was a good correlation between the colour of the shrimps and the substrate they were collected from. It is interesting to note that the animals retained their specific colourations for several hours after being removed from natural habitat to differently coloured backgrounds. The ecology of *Atyopsis moluccensis* has been discussed by Johnson (1961) and Ng & Chia (1994).

***Caridina celebensis* De Man, 1892**

(Figs. 8, 9)

- Caridina serratirostris* var. *celebensis* De Man, 1892: 385, pl. 23; figs. 28f-h; Bouvier, 1925: 220
Caridina serratirostris koterai Kamita, 1951: 75, figs. A-G.
Caridina serratirostris celebensis - Kamita, 1961: 74.
Caridina celebensis - Holthuis, 1978: 39, Fig. 14a-i; Hayashi, 1989: 376, figs. e, g.
Caridina leptocarpa Liang & Yan, 1988: 15, figs. 1-9; Liang & Zhou, 1993: 231.
Caridina serratirostris - Shy & Yu, 1987: 5, pl. 3d; Hung et al., 1993: 500, pl. 9e; Chace, 1997: 19, fig. 11a-r; Kubo, 1938: 92.
Caridina cf. *serratirostris* - Shy & Yu, 1998: 60.

Material examined. - 12 specimens (ZRC 1998.863), Sungai Paya, coll. P. K. L. Ng et al., 25 Jun.1997. - 7 specimens (ZRC 1996.1752), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 14 specimens (ZRC 1996.1753), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 1 specimen (ZRC 1996.1754), Kampung Paya, Sungai Pasal upstream (ca. 15 minutes walk from start of trail to Sungai Paya), coll. H. H. Tan et al., 17 Sep.1995. - 1 specimen (ZRC 1996.1755), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 2 specimens (ZRC 1996.1769), left stream at mouth of Sungai Paya, coll. O. Chia & M. J. Ng, 27 Jun.1996. - 3 specimens (1990.11854-11856), Genting Pulau Tioman, Pahang, coll. S. S. C. Chong, 28 Jun.1986. - 4 specimens (ZRC 1990.11860-11863), Mukut, Pulau Tioman, Pahang, coll. S. S. C. Chong, 28 Jun.1986. - 13 females (cl 3.4-4.0 mm) (ZRC 1998.864), Sungai Keliling, coll. Y. Cai & N. K. Ng, 10 Sep. 1998.

Diagnosis. - Rostrum horizontal, reaching to base of third segment of antennular peduncle or to end of this segment, rostral formula 7-10 (mode 8-9) + 13-18 (mode 15-16)/ 5-8 (mode 5). Antennal spine at suborbital angle. Pterygostomial margin rounded. Telson with posteromedian projection, sublateral pair of posterior spines less than half length of intermediate pairs of setae. Carpus of first pereopod 2.7-3.2 times as long as high; chela 2.4-2.5 times as long as broad, with fingers 1.2-1.6 times as long as palm. Carpus of second pereopod slender, 7.8-8.8 times as long as high, 1.5 times as long as chela; chela slender, slightly curved inwards, 3.3-3.8 times as long as broad; fingers 1.9-2.2 times as long as palm. Dactylus of third pereopod short, 1/4 as long as propodus, ending in a big claw, with 4-5 accessory spines along flexor margin. Dactylus of 5th pereopod short, 0.2 times as long as propodus, ending in a strong large claw, with 13-14 denticulate spinules along flexor margin. Endopod of male first pleopod triangular, no appendix interna. Preanal carina with a strong spine. Uropodal diaeresis with 15-16 movable denticles. Egg size 0.42-0.44 x 0.22-0.24 mm in diameter.

Remarks. - *Caridina celebensis* was originally described as a variety of *C. serratirostris* from near Palopo in the Luwu District of Celebes (Sulawesi) by De Man (1892). He separated

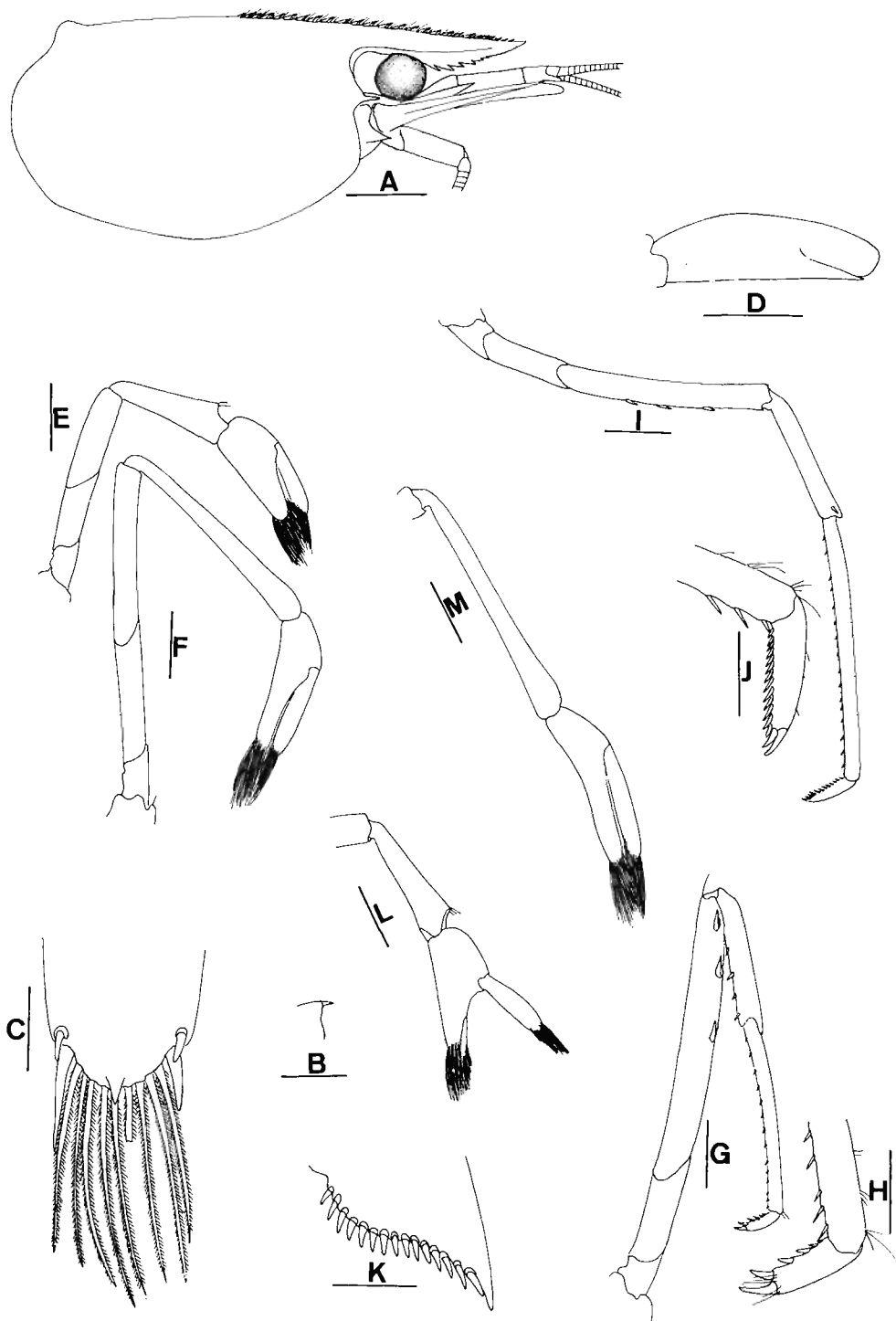


Fig. 8. *Caridina celebensis* De Man, 1892. A-K, female, (cl 3.5 mm)(ZRC 1998.864); L-M, female, (cl 4.1 mm)(ZRC 1998.864), both Sungai Keliling. A: lateral view of cephalothorax and appendages; B: pre-anal carina; C: distal portion of telson; D: scaphocerite; E: first pereiopod; F: second pereiopod; G: third pereiopod; H: dactylus of third pereiopod; I: fifth pereiopod; J: dactylus of fifth pereiopod; K: uropodal diaeresis; L: first pereiopod; M: second pereiopod. Scales: A, D = 1.0 mm; C, H, J, K = 0.2 mm; B, E-G, I, L, M = 0.5 mm.

it from the typical form (from Bangkalan and Bonea rivers in Selajar, an island south of Celebes) mainly by its short rostrum (not reaching distal end of antennular peduncle vs. distinctively beyond it), the short stylocerite (slightly reaching beyond end of basal segment of antennular peduncle vs. reaching middle of second segment of antennular peduncle or beyond) and the structure of the chelipeds (fingers of first two pereiopods slightly longer than palm vs. distinctly longer). Holthuis (1969) originally synonymised *C. serratiostris celebensis* with the nominate subspecies but subsequently (Holthuis, 1978) tentatively treated the two as separate species when his adult Sumba specimens could be readily assigned to one species or the other. Choy (1991: 355), however, stated that "... the morphological attributes which have been used to separate the two forms vary and overlap greatly for the Fijian specimens."

The specimens from Pulau Tioman have a short rostrum, with the majority reaching slightly beyond the end of the second segment of the antennular peduncle, and rarely reaching to the end of the antennular peduncle (but never beyond it)(Fig. 9). The majority of their stylocerites reach slightly beyond the end of the first segment of the antennular peduncle, and only rarely to the middle of the second segment. The fingers of the first pereiopods vary from slightly to distinctly longer than the palm (Fig. 8). The form of the chela of the second pereiopod is similar to that of the Sulawesi specimens (cf. De Man, 1892) in being relatively more slender than *C. serratiostris*, but the fingers are slightly shorter than those of De Man's specimens. All the Pulau Tioman specimens fit well with the definition of *C. serratiostris* var. *celebensis* by De Man (1892). The differences observed in the form of the chelipeds could probably be attributed to infraspecific variation. As such, we tentatively follow Holthuis (1978) in treating the two taxa as two separate species and assign the present material to *C. celebensis*.

Kubo (1938) reported *Caridina serratiostris* from Okinawa. On the basis of his drawing, the rostrum does not reach the distal end of the antennular peduncle, and the stylocerite reaches only to slightly beyond the end of the basal segment of the antennular peduncle. His material could be *C. celebensis*. Examination of two lots of fresh specimens from Okinawa (1 ovigerous female, cl 4.7 mm, ZRC, Okuma River, Okinawa, coll. 31 May 1998; 2 females, cl 4.1-4.2 mm, ZRC, Tima River, northern Okinawa, coll. 25 Apr. 1998) shows that they are clearly *C. celebensis* as presently defined.

It is also pertinent to note that Kamita (1951) described a new subspecies, *Caridina serratiostris koterai*, from Shimoko, Iwami Province in southeastern Honshu, Japan. Subsequently, he synonymised it with *C. serratiostris celebensis* (see Kamita, 1961). More localities were later reported from southern Japan (Kamita, 1961; Hayashi, 1989).

Caridina leptocarpa Liang & Yan, 1988, described from Minjiang river, Fuzhou, Fujian Province in eastern China, is most probably *C. celebensis*. According to the description and the figures by Liang & Yan (1988), the rostrum is short, not reaching to the end of the antennular peduncle, and the stylocerite reaches slightly beyond the end of the first segment of the antennular peduncle, the rostral formula is 6-10)19-28 (mode 21-24)/1-9 (mode 3-7), and the telson is identical to that in *C. celebensis*, with a posteromedian projection as well as a sublateral pair of posterior spines less than half the length of the intermediate pairs of setae. Liang & Zhou (1993) subsequently reported *C. leptocarpa* from Guangxi in southern China.

Shy & Yu (1988) and Hung et al. (1993) reported *C. serratiostris* from southern Taiwan,

providing a colour photograph of a single specimen from southern Taiwan. According to the photograph, the rostrum of the specimen is short. The Taiwanese specimen is most probably *C. celebensis* as well. Shy & Yu (1998) recorded another locality from northern Taiwan for this species under the name *Caridina* cf. *serratiostris*. This later record was based on a female specimen which is now lost (J. Y. Shy, pers. comm.)

Chace (1997) reported *C. serratiostris* from Philippines. According to his diagnosis and figures, his specimens have a "... rostrum not reaching as far as distal end of antennular peduncle." (Chace, 1997: 18). We have little doubt that his specimens are *C. celebensis* instead.

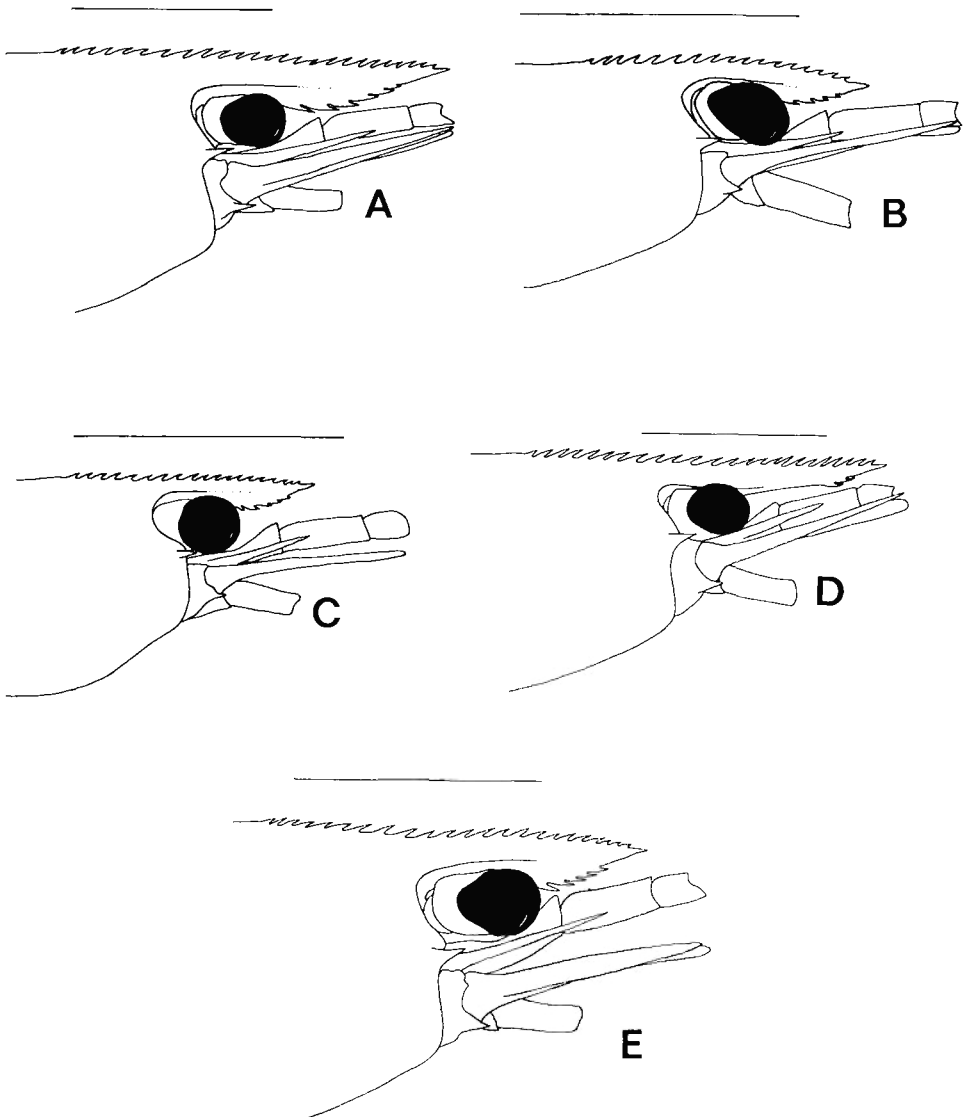


Fig. 9. *Caridina celebensis* De Man, 1892. A, female (cl 4.2 mm)(ZRC 1996.1753), Sungai Paya, Kampung Paya; B, male (cl 2.8 mm)(ZRC 1996.1769), left stream at mouth of Sungai Paya; C, male (cl 2.4 mm)(ZRC 1996.1754), Kampung Paya, Sungai Pasal upstream; D, female (cl 4.0 mm)(ZRC 1996.1752), Sungai Keliling; E, female (cl 3.9 mm)(ZRC 1996.1755), Sungai Paya, Kampung Paya. Setae not drawn in. A-E: carapace. Scales = 2.0 mm.

Kamita (1961) noted that in female shrimps, there are two forms, one reddish brown and the other purplish-brown and banded with some white lateral stripes. The male is usually coloured light red-brownish over the entire body. Liang & Yan (1988) described the colour of female specimens (as *C. leptocarpa*), noting that there are eight to nine transverse strips of purplish red or reddish brown on its rostrum and abdomen. In male specimens, the body is whitish with light red on the abdomen and indistinct purplish red stripes on the telson. Hung et al. (1993: 500) described the colour of their specimen of *C. serratirostris* as "... body reddish and covered with white patches". In Pulau Tioman, the females are of two forms, one with a black body with three transverse stripes on the third and sixth abdominal segments as well as the distal half of the telson; the other has a body reddish brown to dark, with a dorsal longitudinal band throughout its body from the tip of the rostrum to the distal end of the telson. Colour in any case, is usually not a reliable diagnostic character for many decapods.

In Pulau Tioman, *C. celebensis* was collected from many streams. The shrimps were found among weeds along edge of the stream or under leaf debris at the bottom of the stream.

***Caridina* aff. *brachydactyla* De Man, 1908**

(Figs. 10-14)

Caridina wyckii - De Man, 1892: 386, figs. 29f, g, i, ii, k, cc, dd (not *Atya wyckii* Hickson, 1888: 957).

Caridina nilotica var. *brachydactyla* De Man, 1908: 269, pl. xx, figs. 8a-c.

Caridina brachydactyla - Bouvier, 1913: 463; Holthuis, 1978: 37; Johnson, 1973: 25.

Material examined. - 28 specimens (ZRC 1998.865), Sungai Asah, coll. P. K. L. Ng et al., 24 Jun. 1997. - 4 specimens (ZRC 1998.866), Sungai Raya, coll. D. C. J. Yeo et al., 26 Jun. 1997. - 120 specimens (ZRC 1998.867), Sungai Mentawak, coll. Y. Cai, 24 Jun. 1997. - 105 specimens (ZRC 1998.868), Sungai Keliling, coll. Y. Cai et al., 27 Jun. 1997. - 53 specimens (ZRC 1998.869), Sungai Paya, coll. P. K. L. Ng et al., 25 Jun. 1997. - 50 specimens (ZRC 1998.870), Sungai Nipah, coll. Y. Cai, 24 Jun. 1997. - 65 specimens (ZRC 1998.871), Sungai Salang, coll. Y. Cai et al., 25 Jun. 1997. - 23 specimens (ZRC 1996.1756), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun. 1996. - 51 specimens (ZRC 1996.1757), Sungai Raya, Kampung Mukut, coll. P. K. L. Ng et al., 26 Jun. 1996. - 2 specimens (ZRC 1996.1758), Sungai Ayer Besar, stream along Tekek-Juara trail, coll. P. K. L. Ng et al., 24-25 Jun. 1996. - 10 specimens (ZRC 1996.1759), left stream at mouth of Sungai Paya, coll. O. Chia & M. J. Ng, 27 Jun. 1996. - 66 specimens (ZRC 1996.1760), Sungai Nipah, coll. D. C. J. Yeo et al., 28 Jun. 1996. - 125 specimens (ZRC 1996.1761), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun. 1996. - 16 specimens (ZRC 1996.1762), Kampung Paya, Sungai Pasal upstream (ca. 15 minutes walk from start of trail to Sungai Paya), coll. H. H. Tan et al., 17 Sep. 1995. - 19 specimens (ZRC 1996.1763), Kampung Genting, Sungai Ayer Raja, 2°45'36.7"N 104°07'21.5"E, coll. P. K. L. Ng et al., 15 Sep. 1995. - 10 specimens (ZRC 1996.1764), Sungai Paya upstream, near base of Bukit Paya, coll. H. H. Tan et al., 17 Sep. 1995. - 3 specimens (ZRC 1996.1765), Sungai Ayer Besar waterfall, on Tekek-Juara trail, coll. P. K. L. Ng et al., 16 Sep. 1995. - 4 specimens (ZRC 1990.11847-11850), Genting, Pulau Tioman, Pahang, coll. S. S. C. Chong, 28 Jun. 1986. - 3 specimens (ZRC 1990.11857-11859), last stream enroute to Juara, Pulau Tioman, Pahang, coll. S. S. C. Chong, 30 Jun. 1986. - 6 specimens (ZRC 1990.11864-11869), Kampung Mukut, Pulau Tioman, Pahang, coll. S. S. C. Chong, 28 Jun. 1986. - 2 specimens (ZRC 1990.11870-11871), ca. 100m asl. waterfall south of Mukut waterfall, Pulau Tioman, Pahang, coll. S. S. C. Chong, 27 Jun. 1986. 10 males (cl 2.8-3.2 mm), 27 females (cl 3.5-5.0 mm) (ZRC 1998.872) Sungai Keliling, coll. Y. Cai & N. K. Ng, 8-11 Sept. 1998.

Diagnosis. - Rostrum horizontal or slightly curved upwards along distal half, reaching to end of antennular peduncle or slightly beyond distal end of scaphocerite. Rostral formula: 2-3+16-20+1-3/8-12. Antennal spine below suborbital angle. Pterygostomian rounded. Telson with posteromedian projection, sublateral pair of posterior spines longer than intermediate pairs. Carpus of first pereiopod 1.7-2.0 times as long as high; chela 1.9-2.1 times as long

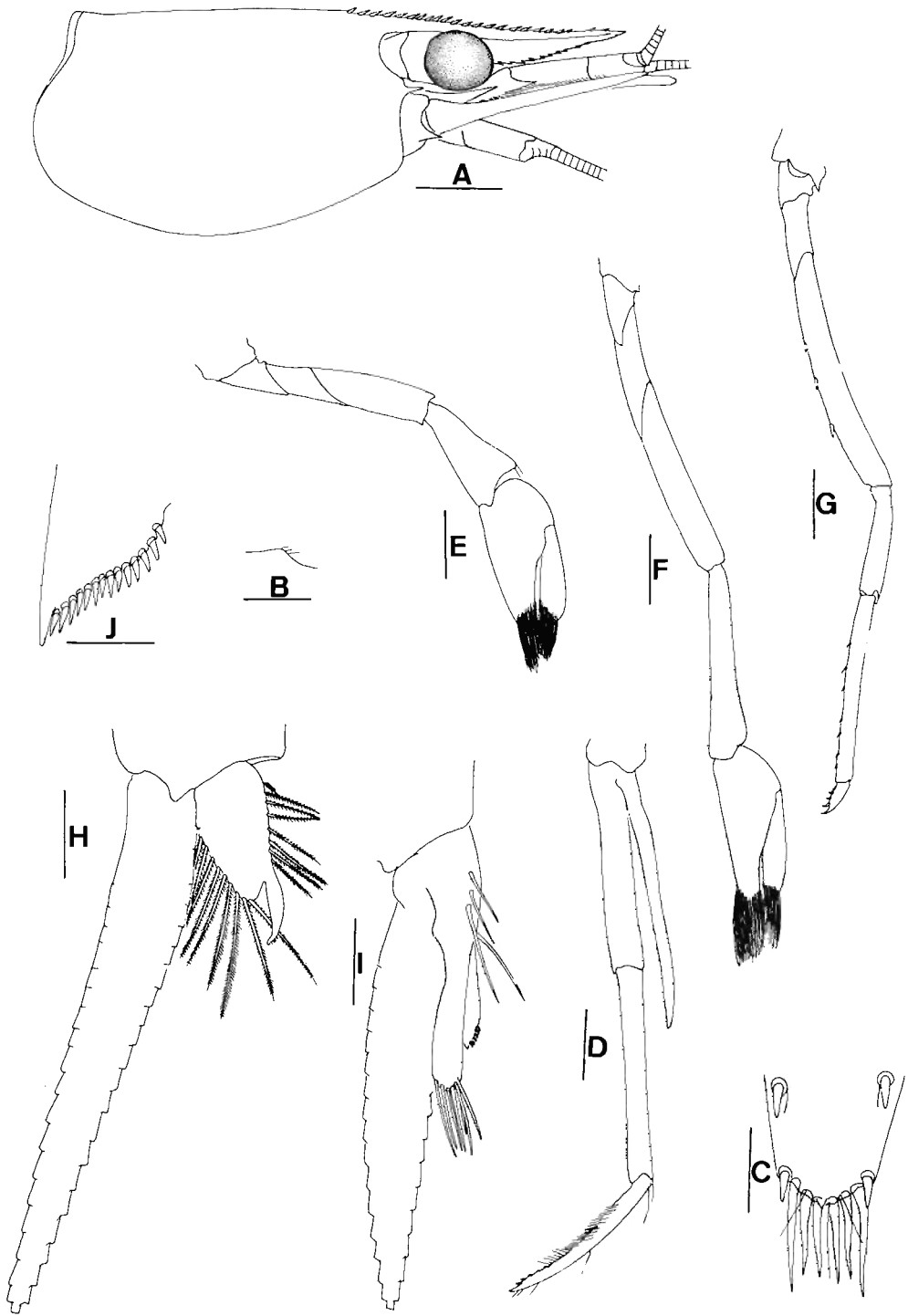


Fig. 10. *Caridina* aff. *brachydactyla* De Man, 1902. Male (cl 3.5 mm)(ZRC 1998.870), Sungai Nipah. A: lateral view of cephalothorax and appendages; B: pre-anal carina; C: distal portion of telson; D: third maxilliped; E: first pereiopod; F: second pereiopod; G: third pereiopod; H: first pleopod; I: second pleopod; J: uropodal diaeresis. Scales: A = 1.0 mm; C, H-J, = 0.2 mm; B, D-G = 0.5 mm.

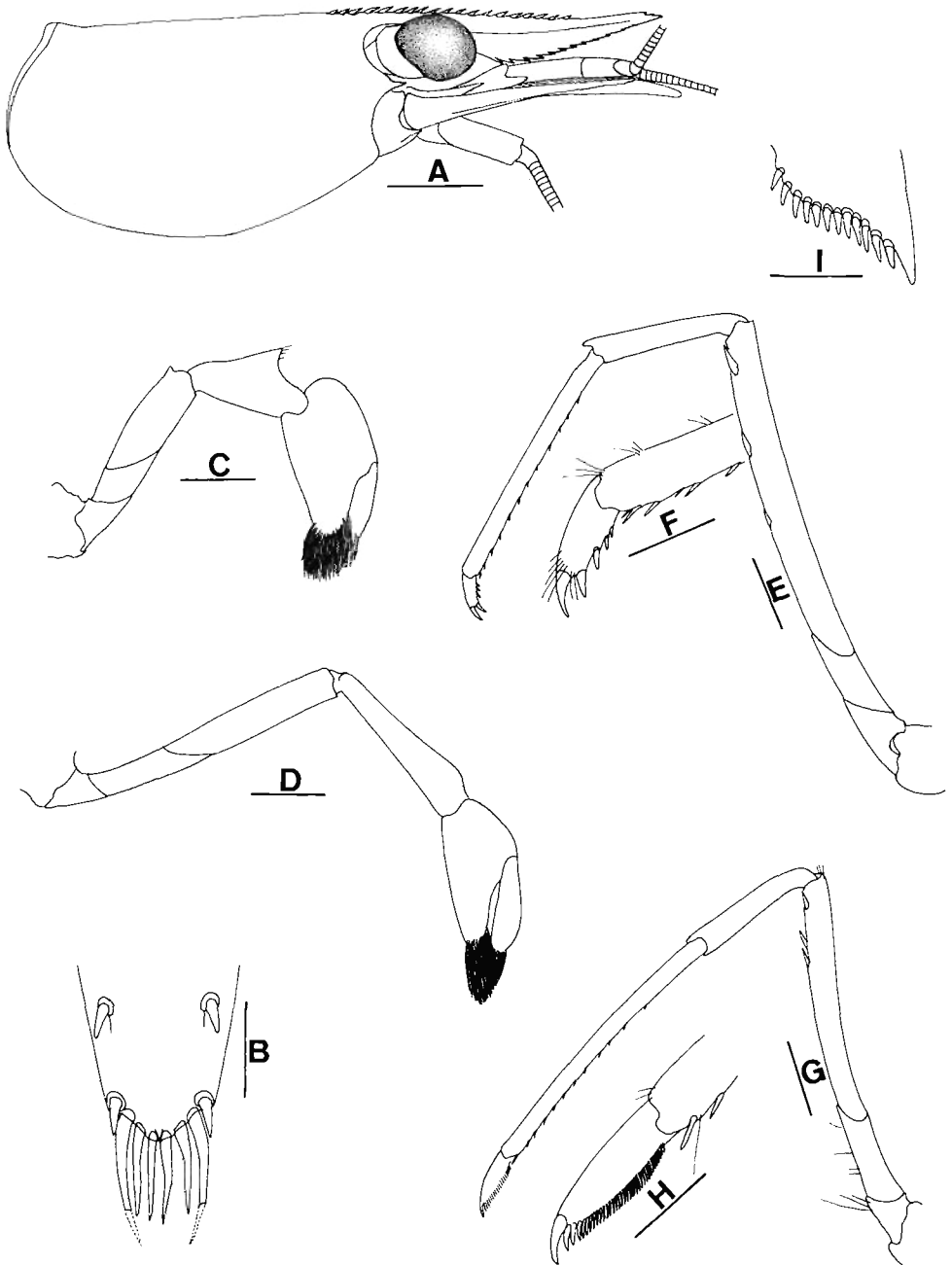


Fig. 11. *Caridina* aff. *brachydactyla* De Man, 1902. Female (cl 3.4 mm)(ZRC 1998.867), Sungai Mentawak. A: lateral view of cephalothorax and appendages; B: distal portion of telson; C: first pereiopod; D: second pereiopod; E: third pereiopod; F: dactylus of third pereiopod; G: fifth pereiopod; H: dactylus of fifth pereiopod; I: uropodal diaeresis. Scales: A = 1.0 mm; C-E, G = 0.5 mm; B, F, H, I = 0.2 mm.

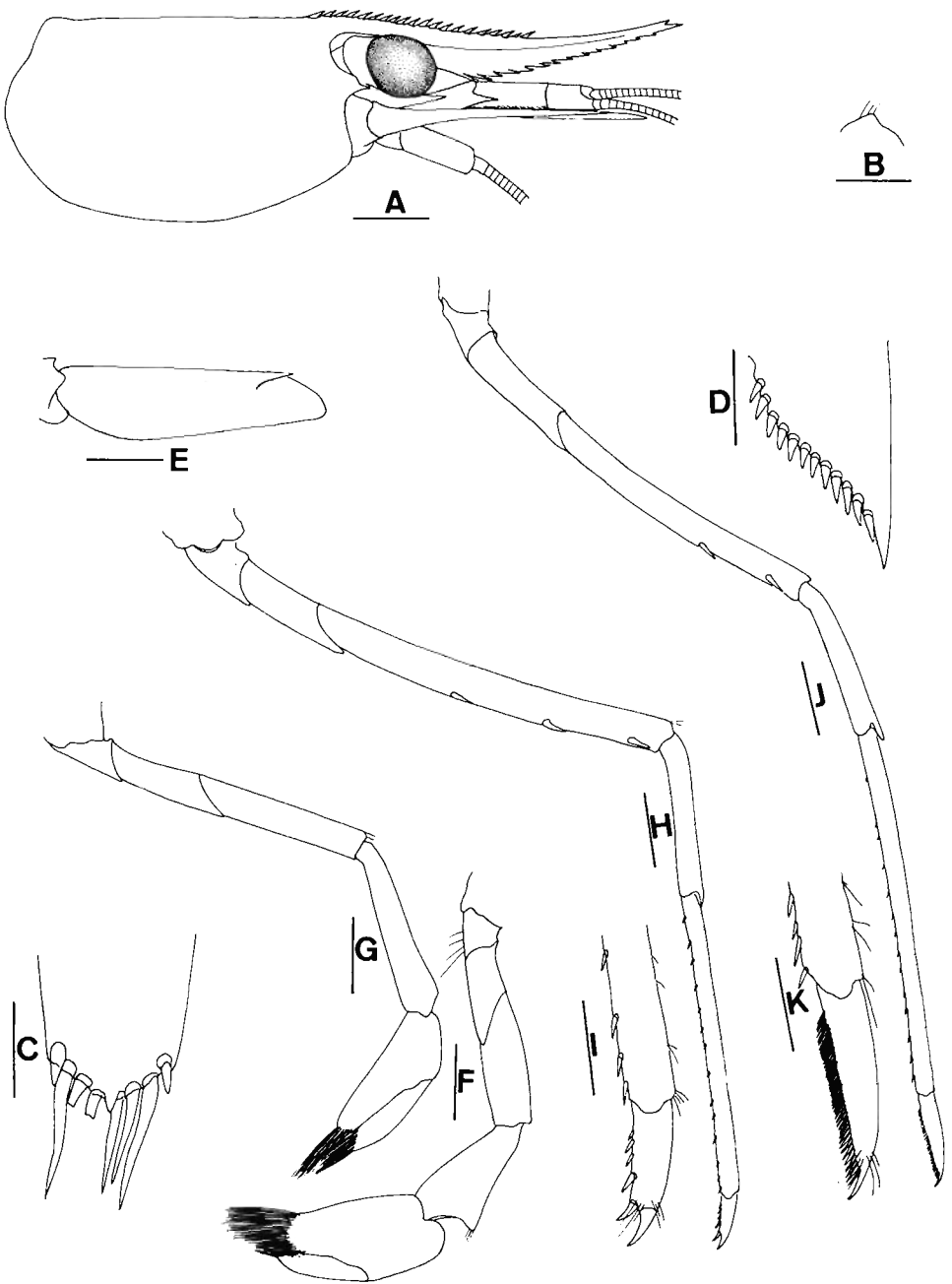


Fig. 12. *Caridina* aff. *brachydactyla* De Man, 1902. Female (cl 3.9 mm)(ZRC 1998.867), Sungai Mentawak. A: lateral view of cephalothorax and appendages; B: pre-anal carina; C: distal portion of telson; D: uropodal diaeresis; E: scaphocerite; F: first pereiopod; G: second pereiopod; H: third pereiopod; I: dactylus of third pereiopod; J: fifth pereiopod; K: dactylus of fifth pereiopod. Scales: A, E = 1.0 mm; B, F-H, J= 0.5 mm; C, D = 0.2 mm.

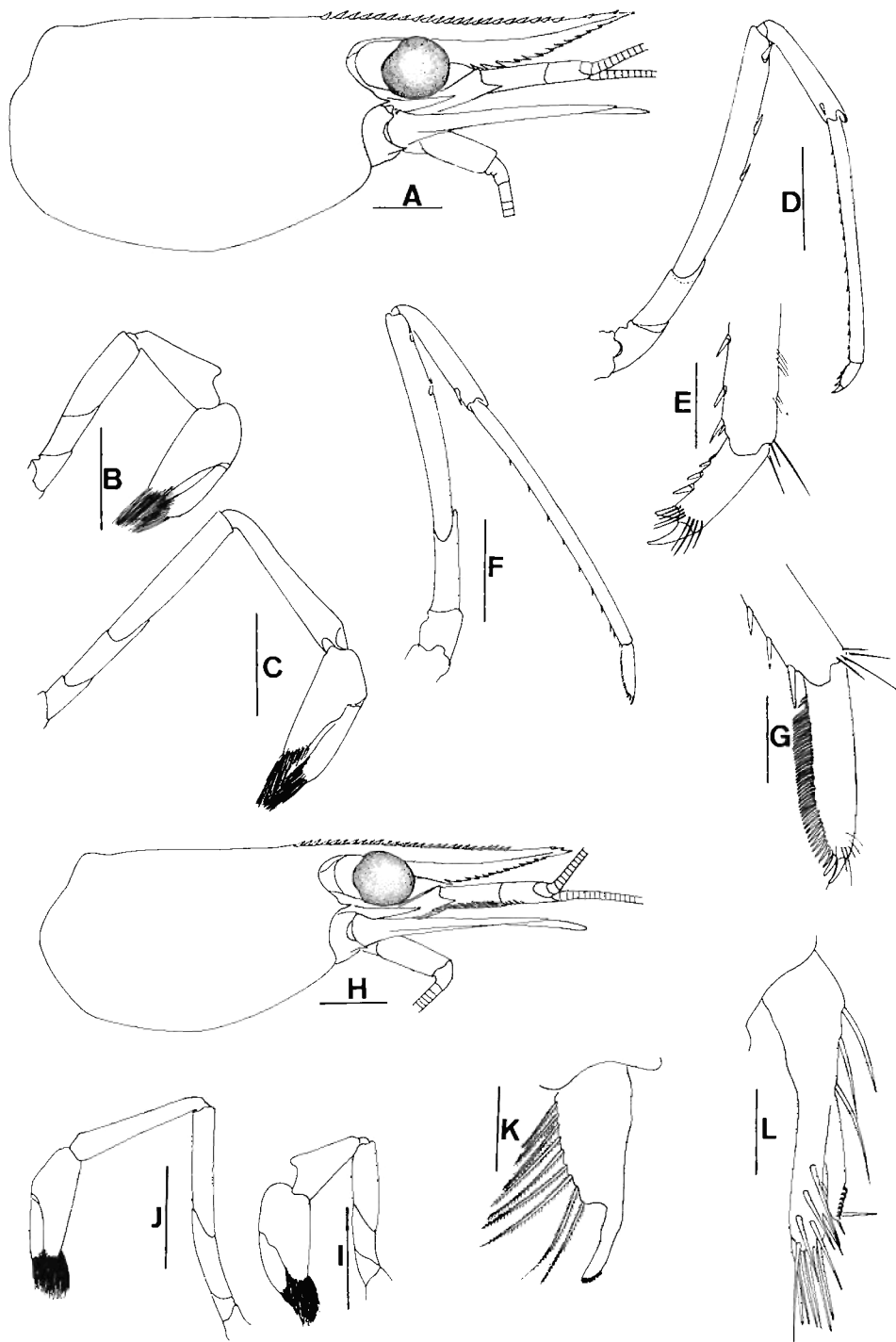


Fig. 13. *Caridina* aff. *brachydactyla* De Man, 1902. A-G, female (cl 4.5 mm)(ZRC 1998.872); H-L, male (cl 3.6 mm)(ZRC 1998.872), both Sungai Keliling. A: lateral view of cephalothorax and appendages; B: first pereiopod; C: second pereiopod; D: third pereiopod; E: dactylus of third pereiopod; F: fifth pereiopod; G: dactylus of fifth pereiopod; H: lateral cephalothorax and appendages; I: first pereiopod; J: second pereiopod; K: first pleopod; L: second pereiopod. Scales. A, H= 1.0 mm; B-D, F, I, J = 0.5 mm; E, G, K, L = 0.2 mm.

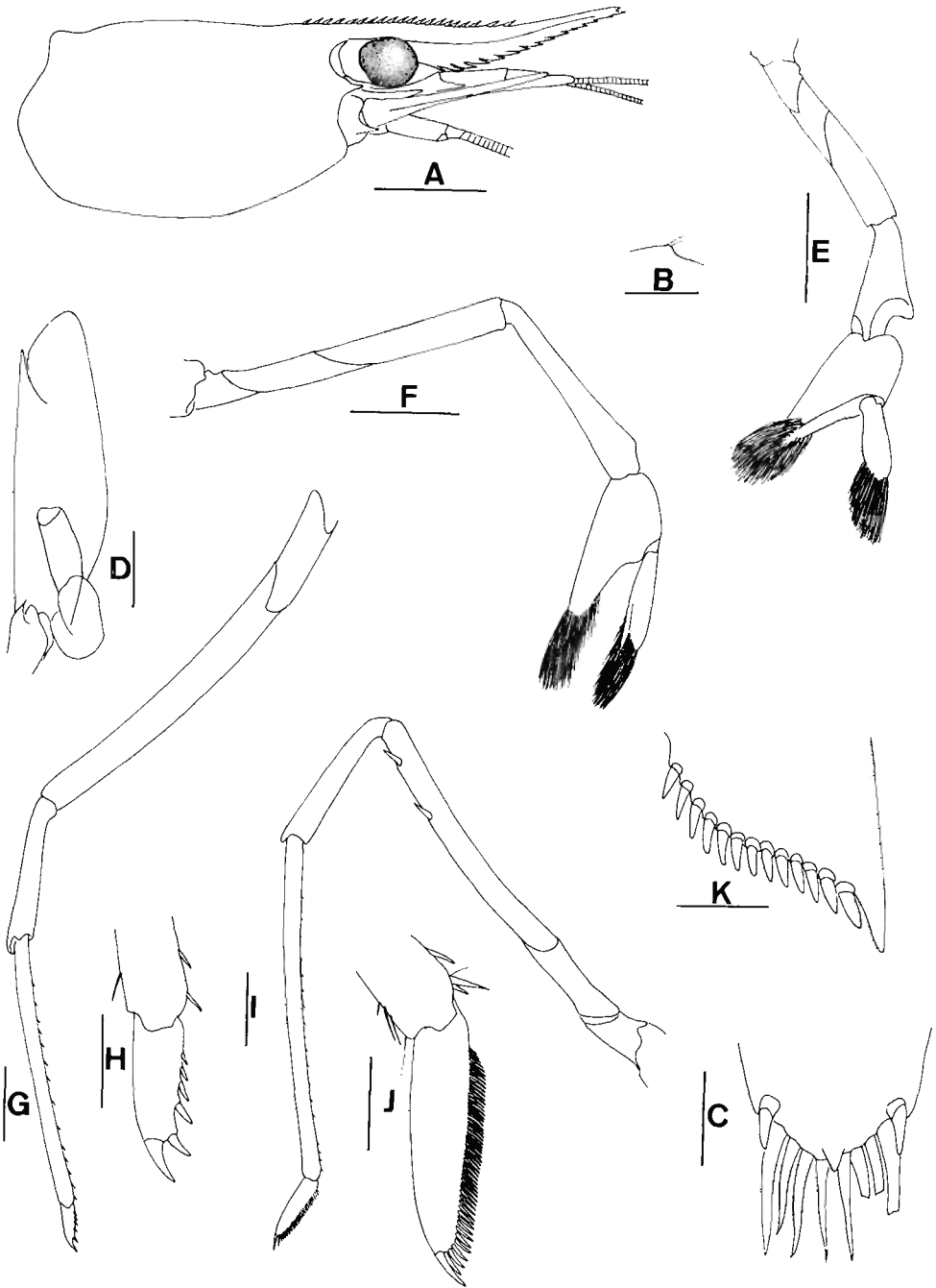


Fig. 14. *Caridina* aff. *brachydactyla* De Man, 1902. Female (cl 3.8 mm)(ZRC 1998.872), Sungai Keliling. A: lateral view of cephalothorax and appendages; B: pre-anal carina; C: distal portion of telson; D: scaphocerite; E: first pereiopod; F: second pereiopod; G: third pereiopod; H: dactylus of third pereiopod; I: fifth pereiopod; J: dactylus of fifth pereiopod; K: uropodal diaeresis. Scales: A, D = 1.0 mm; B, E-G, I = 0.5 mm; C, H, J, K = 0.2 mm.

as broad, with fingers 1.0-1.8 times as long as palm. Dactylus of third pereiopod short, 0.2 times as long as propodus, ending as large claw, with 4-5 accessory spines along flexor margin. Dactylus of fifth pereiopod short, 0.2 times as long as propodus, ending in a strong large claw, with 36-47 denticulate spinules along flexor margin. Endopod of male first pleopod triangular, with an elongate appendix at distal end. Preanal carina without spines. Uropodal diaeresis with 12-14 movable denticles. Egg size 0.38-0.42x0.20-0.25 mm in diameter.

Remarks. - Although belonging to the troublesome *C. nilotica* species complex, *C. brachydactyla* De Man, 1908, has generally been accepted as a valid taxon due to the distinctive structure of the short last three pereiopods. It has, however, been variously considered as a distinct species (Bouvier, 1905), a species with several subspecies (Kemp, 1918; Tiwari & Pillai, 1971) or as a subspecies of *C. nilotica* (cf. De Man, 1908; Bouvier, 1925).

The Pulau Tioman specimens are most similar to *C. brachydactyla* s. str. with respect to the form of rostrum, structure of the pereiopods, as well as dactylus of the last three pereiopods. It differs from *C. brachydactyla* s. str. (fide De Man, 1892), however, by having the distal spine on the posterior margin of the propodus of the third to fifth pereiopods not enlarged, and the first pereiopod having a short carpus (1.7 to 2.0 times as long as broad vs. more than 2.1 to 2.5 times), and the relatively short fingers (1.0 to 1.8 times as long as palm vs. 2.0 to 2.5 times). Considering the form of the rostrum, carpus of the first two legs and the number of spinules on the dactylus of the fifth pereiopod, the Pulau Tioman specimens are somewhat variable when considering the populations from different streams and even within one single stream (Figs. 10-14). The unarmed area on the distal part of the upper margin of the rostrum varies from less than 0.2 times (Figs. 10A, 13A) to more than 0.3 times the length of the structure (Figs. 12A, 14A). The carpus of the first pereiopod usually varies from 1.7 to 2.0 times as long as high, with that of specimens from Sungai Mentawak 1.7 to 1.8 times (Figs. 11, 12). In specimens from Sungai Keliling (Figs. 13, 14) however, the length to height ratio of the carpus is 1.8 to 2.0. Since the differences among populations overlap, they are here considered as part of the species' infraspecific variation.

On the whole, when comparing specimens from Pulau Tioman with the type description of *C. brachydactyla* (fide De Man, 1908), the differences appear to be quite significant and sufficient to possibly recognize the Tioman population as a distinct species. But in view of the substantial taxonomic problems with the *C. nilotica* species complex (Holthuis, 1965: 23; Chace, 1997: 16), we prefer to refrain from describing the present specimens as new for the time being.

For the record, *C. nilotica* (as a *Pelias*) was originally described by Roux (1833) on the basis of specimens from the Nile. Henri Milne Edwards (1837) reported the allied *C. longirostris* when he established the genus *Caridina*, giving no specific locality data. Two other members of this group, *C. grandirostris* and *C. leucosticta* from the Ryukyu Islands, were briefly described by Stimpson (1860). Hickson (1888) reported *C. wyckii* (as an *Atya*) from a lake on Sulawesi under the name *Atya wyckii*. Two more varieties, *C. nilotica* var. *gracilipes* De Man, 1892, and *C. nilotica* var. *paucipara* Weber, 1897, were subsequently described. De Man (1908) compared all his specimens related to *C. nilotica* with type material and recognized nine varieties mainly on the basis of the rostral shape, egg size and structure of the pereiopods, especially the form of the dactylus of the third and the fifth legs. Unfortunately, he did not mention Stimpson's (1860) species. Bouvier (1925: 145) subsequently recognized 14 varieties of *C. nilotica*. Following this, five more members of the *C. nilotica* group were

described, viz. *C. nilotica* var. *chauhani* Chopra & Tiwari, 1947 (India), *C. nilotica zeylanica* Arudpragsam & Coasta, 1962 (Sri Lanka), *C. subnilotica* Dang, 1975 (Vietnam), *C. acuticaudata* Dang, 1975 (Vietnam) and *C. nilotica elongapoda* Liang & Yan, 1977 (China). The identities of these taxa remain uncertain due to confusion among the known species. The validity of the two most well known species, *C. nilotica* and *C. longirostris* have been questioned by several authors. On the basis of his Madagascar material, Holthuis (1965: 23) doubtfully recognized *C. nilotica* and *C. longirostris* as distinct species, but commented on "... the confusion existing in the systematics of the *C. nilotica* group of *Caridina* ...". Chace (1997: 16) noted that there "...is even slight doubt that *C. longirostris* is distinct from *C. nilotica*, as maintained by Holthuis (1965: 21) ...".

***Caridina typus* H. Milne Edwards, 1837**

Caridina typus H. Milne Edwards, 1837: 363 (not *Caridina typus* Spence Bate, 1888); De Man, 1892: 367, pl. 21, Fig. 22; Bouvier, 1925: 249; Edmondson, 1935:10, fig. 3g-l; Kubo, 1938: 83, fig. 13; Johnson, 1960a: 179; Johnson, 1963: 27; Johnson, 1966: 418; Johnson, 1969: 110; Ng, 1985: 161; Ng, 1995a: 189, Fig. 7.

Material examined. - 136 specimens (ZRC 1998.873), Sungai Salang, coll. Y. Cai et al., 25 Jun.1997. - 12 specimens (ZRC 1998.874), Tekek falls, Sungai Ayer Besar, coll. P. K. L. Ng et al., 23 Jun.1997. - 41 specimens (ZRC 1998.876), Sungai Paya, coll. D. C. J. Yeo et al., 26 Jun.1997. - 81 specimens (ZRC 1996.1766), Sungai Ayer Besar, stream along Tekek-Juara trail, coll. P. K. L. Ng et al., 24-25 Jun.1996. - 4 specimens (ZRC 1996.1767), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 1 specimen (ZRC 1996.1768), Sungai Raya, Kampung Mukut, coll. P. K. L. Ng et al., 26 Jun.1996. - 6 specimens (ZRC 1996.1770), pool between Sungai Mentawak and Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 38 specimens (ZRC 1996.1771), Sungai Nipah, coll. D. C. J. Yeo et al., 28 Jun.1996. - 104 specimens (ZRC 1996.1772), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 59 specimens (ZRC 1996.1773), Kampung Paya, Sungai Pasal upstream (15 minutes walk from start of trail to Sungai Paya), near base of Bukit Paya, coll. H. H. Tan et al., 17 Sep.1995. - 49 specimens (ZRC 1996.1774), Kampung Genting, Sungai Ayer Raja, 2°45'36.7"N 104°07'21.5"E, coll. P. K. L. Ng et al., 15 Sep.1995. - 25 specimens (ZRC 1996.1775), Sungai Ayer Besar waterfall, on Tekek-Juara trail, coll. P. K. L. Ng et al., 16 Sep.1995. - 6 specimens (ZRC 1990.11841-11846), ca. 100m asl. waterfall stream south of Mukut waterfall, S. S. C. Chong, 27 Jun.1985. - 3 specimens (ZRC 1998.927), stream along Tekek-Juara path, Pulau Tioman, West Malaysia, coll. S. S. C. Chong, 26 Jun.1985. - 2 specimens (ZRC 1998.928), stream behind Tanjung Said, coll. A. Kamal et al., 27 Jun.1985. - 2 males, (cl 3.9-6.0 mm), 19 females (cl 4.8-6.2 mm) (ZRC 1998.875), Sungai Keliling, coll. Y. Cai & N. K. Ng, 8-11 Sep.1998.

Remarks. - *Caridina typus* is an insular or coastal freshwater species which has been reported locally from Pulau Tioman and other islands off the coast of Peninsular Malaysia (Ng, 1985; Johnson, 1960a, 1963, 1966, 1969). This species has a very wide distribution ranging from east Africa to Japan (Kubo, 1938) and as far as Polynesia (Edmondson, 1935). The rostra of the present specimens show the same kind of variation previously documented by other workers (De Man, 1892; Bouvier, 1925; Ng, 1985, 1995a). The live colouration of *C. typus* specimens that were collected in the present study show considerable variation, ranging from almost translucent overall and speckled with light green chromatophores, to a uniform bluish-green overall. Johnson (1963) commented on the mutually exclusive occurrence of this species with *Atyopsis moluccensis* (as *Atya moluccensis*), citing competition as one of the possible reasons. However, in the present study, we were able to collect the two species together on many occasions, although their specific habitats seemed to differ slightly. *Atyopsis moluccensis* was always found in parts of the stream where water flowed rapidly over large rocks or boulders, while *C. typus* was more common in areas just off the main current flow such as pools or calmer zones immediately downstream of protruding boulders.

FAMILY PALAEMONIDAE RAFINESQUE, 1815

Macrobrachium equidens (Dana, 1852)

Palaemon equidens Dana, 1852: 26.

Macrobrachium equidens - Holthuis, 1950: 162, Fig. 36; Johnson, 1973: 283; Ng & Chong, 1986: 29, 2 Figs.; Chace & Bruce, 1993: 25, Fig. 4.

(See Chace & Bruce, 1993, for rest of synonymy).

Material examined. - 6 specimens (largest cl 13.6 mm, tl 47.0 mm) (ZRC 1998.877), Sungai Keliling, coll. Y. Cai, 27 Jun.1997. - 2 specimens (largest cl 10.7 mm, tl 37.8 mm) (ZRC 1996.1782), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 4 females (largest cl 13.9 mm, tl 49.0 mm) (ZRC 1996.1783), Sungai Nipah mangroves, coll. D. C. J. Yeo et al., 28 Jun.1996. - 1 female (cl 8.3 mm, tl 29.0 mm) (ZRC 1996.1784), pool between Sungai Mentawak and Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 8 specimens (ZRC 1986.212-219), stream at Tanjong Said, along Tekek-Merlin Hotel road (second last stream before reaching hotel), Pulau Tioman, West Malaysia, coll. S. S. C. Chong, 26 Jun.1985. - 50 specimens (1979.6.22.46-95), Pulau Tioman, coll. C. Y. Chan, 1 Jul.1986. - 3 females, (cl 3.2-3.5 mm), Sungai Mentawak, coll. Y. Cai, 24 Jun. 1997.

Remarks. - *Macrobrachium equidens* was recorded from Pulau Tioman by Ng & Chong (1986). It was the only species of *Macrobrachium* obtained from mangroves which is not surprising as it is primarily an estuarine species preferring brackish waters and rarely penetrating beyond tidal freshwaters (Johnson, 1973; Ng & Chong, 1986; Chace & Bruce, 1993). It is easily separated from the other *Macrobrachium* species found on Pulau Tioman by its habitat preference. Morphologically, it is the only *Macrobrachium* species on the island with the rostrum directed upwards distally. This species has non-abbreviated larval development, producing small eggs that hatch into free-swimming larvae which are part of the marine plankton (Nguyen, 1976).

Macrobrachium idae (Heller, 1862)

Palaemon idae Heller, 1862: 416, Pl. 2, Figs. 40-41.

Macrobrachium idae - Holthuis, 1950: 142, Fig. 33; Johnson, 1961: 56, 1963: 5; Ng, 1990: 199; Naiyanetr, 1992: 18; Chace & Bruce, 1993: 27, fig.6.

Material examined. - 2 males (larger cl 12.7 mm, tl 48.0 mm), Sungai Keliling, coll. P. K. L. Ng et al., 26 Jun.1997. - 3 females (cl 12.0-18.5 mm) (ZRC 1998.878), Sungai Keliling, coll. Y. Cai & N. K. Ng, 11 Sep.1998.

Remarks. - The species is characterized by its long carpus which is distinctively longer than the chela (Holthuis, 1950; Johnson, 1963; Chace & Bruce, 1993). This, however, is only true for fully grown adult specimens. The carpus of subadult males or females is slightly shorter than, or as long as the chela. All our specimens are not fully mature, having a carpus which is slightly shorter than the chela.

The species is widely distributed in the Indo-Pacific. In Southeast Asia, *M. idae* has been reported from Thailand (Naiyanetr, 1992), Malay Peninsula (Johnson, 1961; Ng, 1990), Philippines (Chace & Bruce, 1993) and Indonesia (Holthuis, 1950). This species seems to be rare in Pulau Tioman, all the specimens were obtained from Sungai Keliling among vegetation at the edge of the stream.

***Macrobrachium meridionalis* Liang & Yan, 1983**

(Figs. 15, 16)

Macrobrachium meridionalis Liang & Yan, 1983: 213, Fig. 2; Liu et al., 1990: 115, Fig. 13.

Material examined. - Paratype - 1 female (cl 14.5) (SFU 97-367-3), Jingjiang river, Chengmai County, Hainan island, southern China. Others - 1 male (cl 24.0 mm, tl 78.6 mm) (ZRC 1996.1719), Sungai Nipah, Pulau Tioman, Peninsular Malaysia, coll. D. C. J. Yeo et al., 28 Jun.1996. - 1 female (cl 18.5 mm) (ZRC 1998.879), Sungai Keliling, Pulau Tioman, Peninsular Malaysia, coll. P. K. L. Ng et al., 26 Jun.1997. - 1 female (cl 18.8 mm) (ZRC 1998.1998.880), same locality as above, coll. P. K. L. Ng et al., 27 Jun.1997. - 1 female (cl 20.6 mm) (ZRC 1996.1720), Sungai Paya, Kampung Paya, Pulau Tioman, Peninsular Malaysia, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 1 female (cl 8.5 mm) (ZRC 1998.881), same locality as above, coll. P. K. L. Ng et al., 25 Jun. 1997.

Diagnosis. - Rostrum not exceeding antennular peduncle, with slightly elevated basal crest; rostral formula 5-7(6)+6-8(7)/3-4(3), with preorbital teeth more widely spaced apart than postorbital. Carapace smooth, glabrous; eyes about 0.1-0.2 times length of carapace; antennular peduncle about 0.4 times length of carapace; scaphocerite about 3 times as long as broad, with lateral margin straight. Second pereopods subequal in male, naked except for scattered short setae, covered with very small, rounded to sharp anteriorly directed granules, with minute anteriorly directed spines on upper margin; chela fingers slender, about half as long as palm, with 2-3 well developed teeth along proximal half, smooth cutting edge occupying distal half of length of finger; palm more than half as long as chela, with posterior oblique sulcus in lower region; carpus more than two-thirds length of palm, with distinct longitudinal sulcus on outer face; merus with indistinct longitudinal sulcus. Ambulatory legs covered with very small, rounded to sharp, anteriorly directed flattened granules, relatively slender; third pereopod propodus about 7.8 times longer than wide; carpus about 3.5 times longer than distal width; merus about 4.5 times longer than wide; fourth and fifth pereopods similar to third. Movable spine on exopod of uropod subequal to outer fixed tooth; telson narrow, lateral margins straight, sharply convergent distally.

Remarks. - The present specimens from Pulau Tioman essentially match the description of *M. meridionalis* Liang & Yan, 1983, a species previously known only from the original description from specimens obtained from Hainan Island in China. Peninsular Malaysia is thus a new record for the species.

There are some slight differences on comparing the present specimens with the paratype of the species (SFU, 97-367-3) and illustrations in Liang & Yan (1983: Fig. 2). The fingers on the chela of the second pereopods of the present Pulau Tioman specimens are relatively longer and more slender (vs. relatively shorter, more robust-looking fingers). This is probably due to allometric growth, with smaller specimens having relatively shorter, stouter fingers which lengthen and become relatively more slender as the individuals grow. This trend is also prevalent in other *Macrobrachium* species (unpublished data). The present specimens also have a very distinct sulcus running along the entire length of the carpus of the cheliped which continues onto the palm as a posterior oblique sulcus along the lower region (Fig. 16A). This feature, which occurs in both the major as well as the minor second pereopod of the present specimens, was neither noted nor illustrated by Liang & Yan (1983) for the type material. The relatively small paratype examined (cl 14.5 mm) has only one intact second pereopod (the right) and we are unable to ascertain if it is the major or minor one. In any case, this intact pereopod of the paratype does have a very faint but discernible sulcus along the length of the merus and the proximal half of the carpus only. Unlike the Pulau Tioman specimens, the anterior half of the carpus as well as the palm of the paratype shows no trace

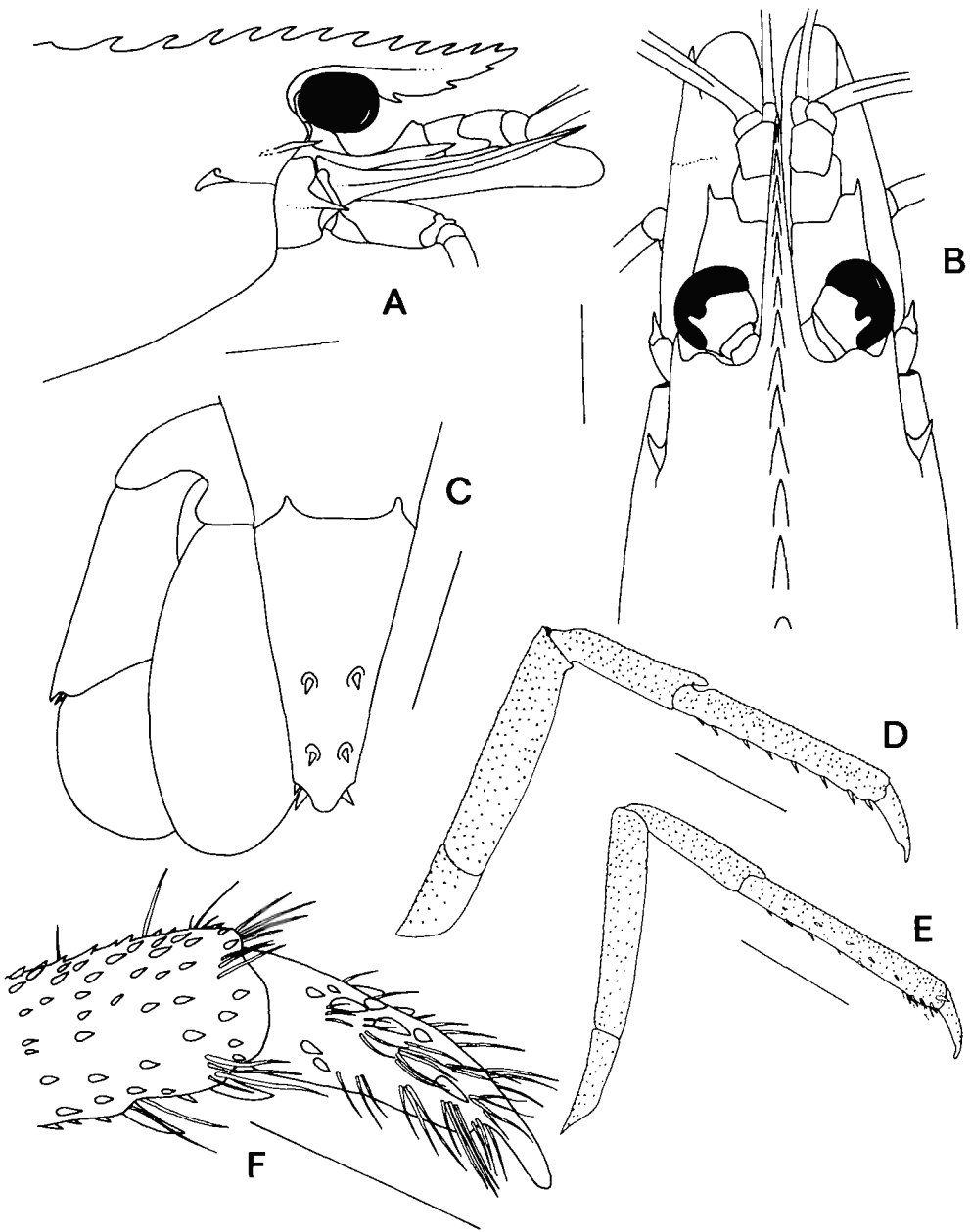


Fig. 15. *Macrobrachium meridionalis* Liang & Yan, 1983. Male (cl 24.0 mm)(ZRC 1996.1719), Sungai Nipah. A: lateral view of carapace; B: dorsal view of carapace; C: uropod and telson; D: right third pereopod; E: left fifth pereopod; F: dactylus and distal part of propodus of left third pereopod. Setae not drawn in. Scales: A-E = 5.0 mm; F = 2.0 mm.

of a sulcus. These differences are probably also size related. Apart from the second pereiopod, the number of ventral rostral teeth also varies slightly, with the present specimens having 3-4, while the type material has 2-3. It is also interesting to note that Liang & Yan (1983), who collected the type specimens themselves, commented that the live colour of *M. meridionalis* was bluish-green (like the present ones). No mention, however, was made of any yellowish joints or banding on the ambulatory legs like those seen in the present specimens from Pulau Tioman. Due to the small series of specimens available as well as the lack of similar sized comparative material with fully intact second pereiopods, it is difficult to infer much from the observed differences. All the type specimens of *M. meridionalis* are relatively smaller (largest cl 16 mm) than the larger specimens from Pulau Tioman. We thus prefer to tentatively assign the present specimens to *M. meridionalis*.

Macrobrachium meridionalis appears to be closest to *M. horstii* (De Man, 1892), and the two cannot be separated using the keys to the genus in Holthuis (1950) or Chace & Bruce (1993). However, comparisons with specimens of *M. horstii* from Luzon, Philippines (5 specimens (RMNH)(Fig. 17A-E), coll. B. Gindelberger, 14-15 Aug. 1981], show that adult specimens of *M. meridionalis* can readily be differentiated. The most striking difference is the relative slenderness of the ambulatory legs of *M. meridionalis* (e.g. third pereiopod: propodus 7.8 times longer than wide vs. 5.6 times; carpus 3.5 times longer than distal width vs. 2.5; and merus 4.5 times longer than wide vs. 3.6). In addition, the present specimens of *M. meridionalis* from Pulau Tioman can also be distinguished from *M. horstii* by the

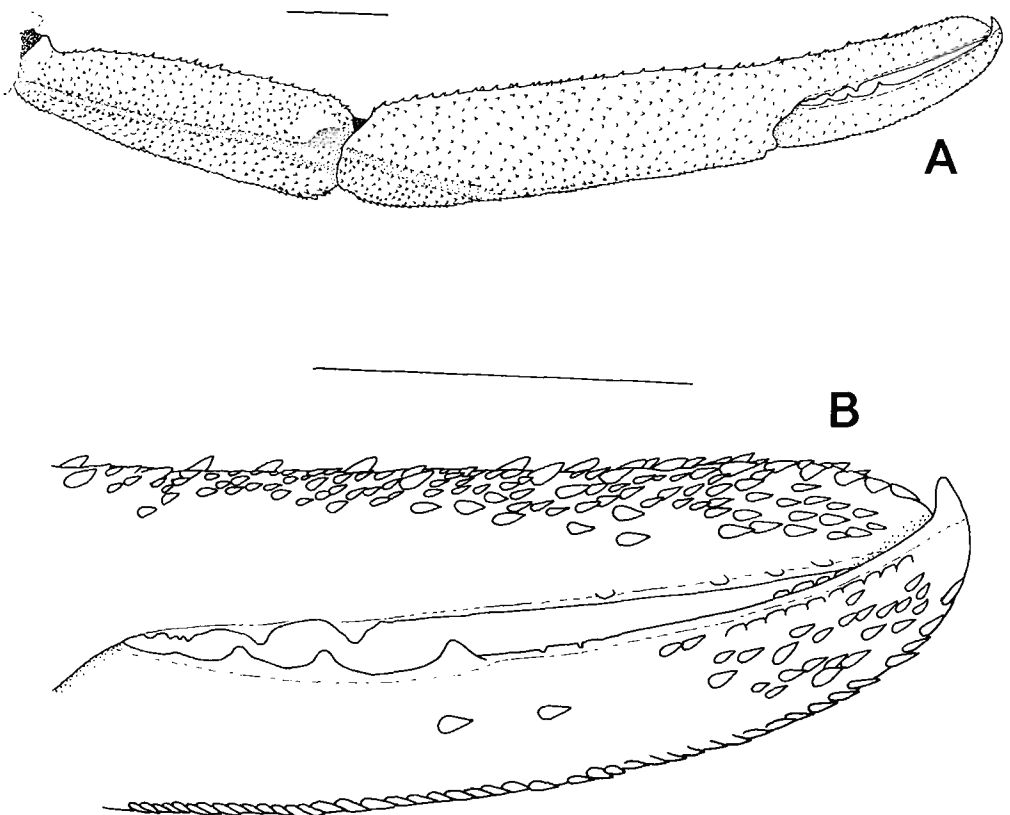


Fig. 16. *Macrobrachium meridionalis* Liang & Yan, 1983. Male (cl 24.0 mm)(ZRC 1996.1719), Sungai Nipah. A: major (right) second pereiopod; B: fingers of chela of major (right) second pereiopod. B with only prominent granules drawn in, whole chela actually covered with granules. Scales = 5.0 mm.

following diagnostic characters: i) higher number of postorbital rostral teeth (5-7 vs. 4); ii) second pereiopod more slender (dactylus 5.7 times longer than broad vs 4.7; palm 4.5 times longer than broad vs. 4.0; and carpus 3.3 times longer than distal width vs. 1.5 times); iii) proportionately shorter second pereiopod carpus (palm 1.4 times length of carpus vs. 1.1 times); iv) telson more sharply tapered (proximal width 2.6 times distal width vs. 2.3 times); and v) relatively longer distal cutting edge (about 0.5 times finger length) on the second pereiopod chelal fingers (vs. very short to absent). The *M. horstii* specimens used for comparison agree very well with the descriptions of De Man (1892), Holthuis (1950) and Chace & Bruce (1993).

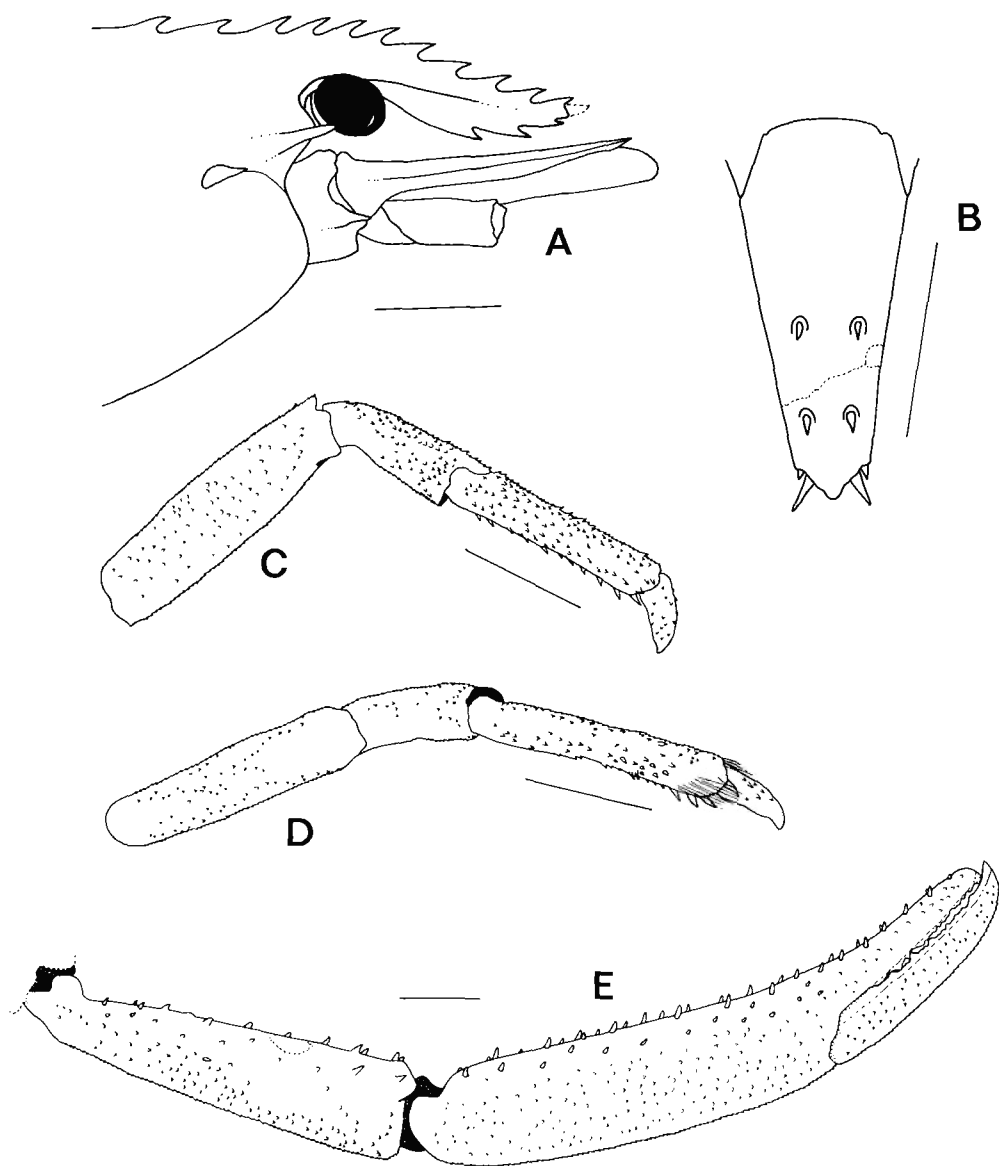


Fig. 17. *Macrobrachium horstii* De Man, 1892. Male (cl 26.2 mm)(RMNH), Cabrarian River, Luzon, Philippines. A: carapace; B: telson; C: right third pereiopod; D: right fifth pereiopod; E: major (right) second pereiopod. Scales = 5.0 mm.

The carapace of live specimens have a reddish-brown reticulate pattern on branchial area. The fingers of the chelae are dark reddish-brown with yellow tips and the ambulatory legs have reddish-brown bands and yellow joints and dactylus.

Macrobrachium meridionalis occurs in fast flowing but not torrential freshwaters, frequenting riffled stretches caused by aggregations of medium (ca. 300 mm across) rocks. Intensive sampling on separate occasions from 1995 to 1997 resulted in only five specimens being collected, indicating that the species is locally uncommon or that it is very cryptic by nature. In Pulau Tioman, the species has so far been found only in three drainages in the southern half of the island, namely Sungai Nipah, Sungai Paya and Sungai Keliling.

***Macrobrachium scabriculum* (Heller, 1862)**

(Figs. 18, 19, 20H)

Palaemon scabriculus Heller, 1862: 527; Henderson & Matthai, 1910: 296, Pls. 17-figs. 7a-c, Pls. 18-figs. 7a-p.

Macrobrachium scabriculum - Holthuis, 1950: 224 (part); Chace & Bruce, 1993: 37 (part); Johnson, 1973: 15 (part).

Material examined. - 3 male, 10 females (3 ovigerous) (largest male cl 13.0 mm) (ZRC 1998.882), Sungai Keliling, Pulau Tioman, Peninsular Malaysia, coll. P. K. L. Ng et al., 27 Jun.1997. - 1 male (cl 10.0 mm), 1 female (cl 6.9 mm) (ZRC 1998.883), same locality as above, coll. P. K. L. Ng et al. 28 Jun.1996. - 1 male (cl 9.0 mm), Sungai Keliling, coll. Y. Cai & N. K. Ng, 9 Sep.1998.

Diagnosis. - Rostrum slightly exceeding distal end of antennular peduncle, with slightly elevated basal crest; rostral formula 4-6(5)+9-11(10)/2-3(2), dorsal teeth more widely spaced apart posteriorly than anteriorly. Eyes about 0.2 times as long as carapace; antennular peduncle about 0.6 times as long as carapace; scaphocerite with lateral margin straight, about 3.0 times as long as broad. First pereiopod with entire chela exceeding distal end of scaphocerite when appressed against carapace; chela about half as long as carpus. Second pereiopod sexually dimorphic; male second pereiopods unequal; major second pereiopod slightly shorter than total length, with about one-third of carpus overreaching distal end of antennular peduncle when appressed against carapace; fingers of chela densely pubescent in proximal half, not gaping, with 11-16 uneven teeth on cutting edge, subequal to palm; palm laterally compressed, distinctly broader than distal end of carpus, covered in dense pubescence over anterior three-quarters, about 2.6 times as long as broad, 3.0 times as long as high, 1.5 times as long as carpus; carpus slightly longer than merus. Male minor second pereiopod with about half of carpus overreaching distal end of antennular peduncle when appressed against carapace, sparsely setose, with dense, minute spinules at all joints; fingers of chela distinctly longer than palm; palm not distinctly broader than carpus, shorter than carpus; carpus subequal to finger length; merus shorter than carpus, longer than palm. Female second pereiopods subequal, similar in form to minor pereiopod of male. Third pereiopod with entire dactylus overreaching antennular peduncle; propodus with about 8 spines on ventral margin, 3.5 times as long as dactylus. Fourth pereiopod similar to third. Fifth pereiopod slightly more slender than third and fourth; propodus about 4.5 times as long as dactylus. Movable spine on diaeresis of uropod shorter than outer fixed tooth. Ovigerous females with numerous small eggs, measuring about 0.45 mm by 0.65 mm.

Remarks. - *Macrobrachium scabriculum* was originally described from Ceylon (Sri Lanka) by Heller (1862). The species is characterized by the velvet on its palm and proximal part of the fingers, the stout palm which is broader than the carpus and the fingers which are

subequal to the palm. Hilgendorf (1878) described an allied species, *M. dolichodactylus* [as a *Palaemon*], from the east coast of Africa, and like *M. scabriculum*, it has a similarly setose chela, but the long second pereopod is distinctively longer than its body, its slender palm is not broader than the carpus, it has a longer carpus which is distinctively longer than the palm, and the fingers are distinctively longer than the palm. Henderson & Matthai (1910) reported both species from southern India, together with another similar new species *P. dubius*, which supposedly has relatively shorter fingers. In the same paper, Henderson & Matthai (1910: 301) suggested that the three taxa "... may all belong to one and the same species" since in some cases, the different forms are in the same river. Holthuis (1950) synonymised all three taxa and stated that he "... entirely agree with their (Henderson & Matthai, 1910) supposition and see no reason to keep the forms separated."

As part of the present study, we examined several lots of *M. scabriculum* and *M. dolichodactylus* from various parts of Southeast Asia and Sri Lanka. Most belong to *M. scabriculum*, including the types - 3 syntype males, cl 9.2-9.6 mm, 1 syntype female, cl 9.5 mm (NHMW 7705), coll. Novara 1857-59, Ceylon; 2 males, cl 11.2-13.1 mm (ZRC 1998.929), Makkola, Sri Lanka, coll. M. Kottelat & R. Pethiyagoda, 12 Apr. 1990; 2 males, cl 15.5-17.9 mm (ZRC 1998.930), Kottawa (Galle), Sri Lanka, 06°06'N 80°20'E, elevation 50 m, coll. M. M. Bahir, 17 Nov. 1995; 3 females, cl 7.0-11.2 mm (including 1 ovigerous), 1 male, cl 10.4 mm (ZRC 1998.931), bamboo forest, Kapit, Sarawak, east Malaysia, Borneo, coll. H. H. Tan, 2 Mar. 1998; 3 males, cl 7.2-10.5 mm, 2 females, cl 7.0, 11.0 mm (NHM), Tanglin, Singapore, Bedford-Lanchester Collection, coll. 1900. We also have one lot of *M.*

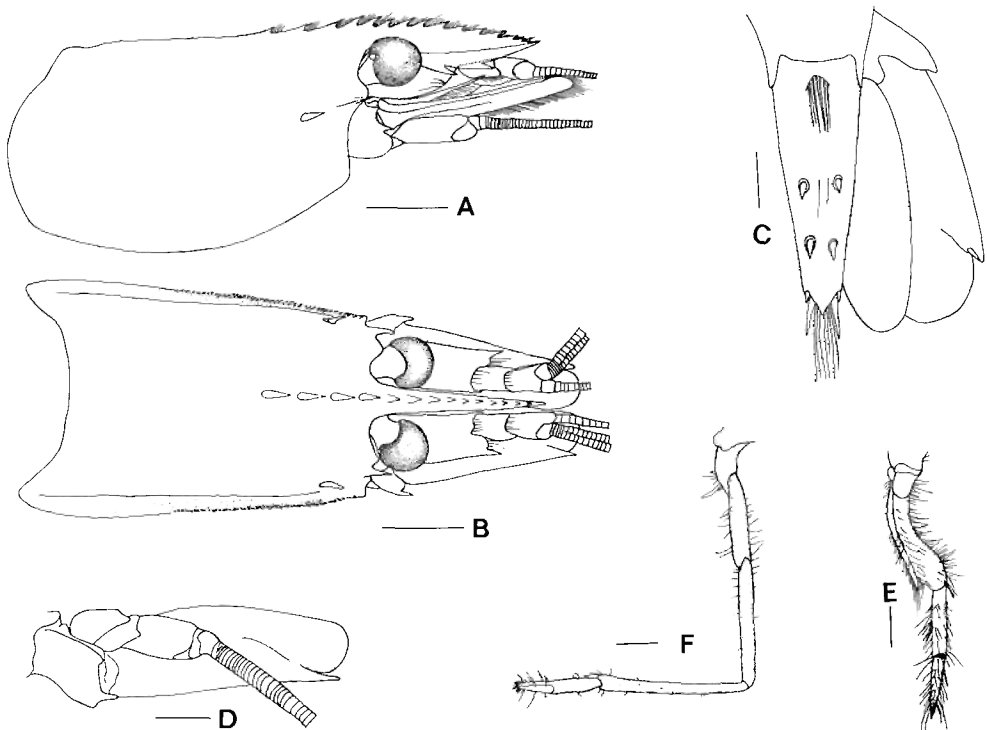


Fig. 18. *Macrobrachium scabriculum* (Heller, 1862). Male (cl 7.8 mm)(ZRC 1998.883), Sungai Keliling. A: lateral view of cephalothorax and appendages; B: dorsal view of cephalothorax and appendages; C: telson and uropod; D: left scaphocerite; E: left third maxilliped; F: right first pereopod. Scales: A, B = 2.0 mm; C = 0.5 mm; D-F = 1.0 mm.

dolichodactylus - 11 males, cl 13.4-17.2 mm, 4 females, cl 11.0-13.2 mm (ZRC 1998.932), southern Myanmar, coll. P. Yap, 29 Sep.1998.

Of 17 specimens from Pulau Tioman, 16 are clearly referable to *M. scabriculum*, while one belongs to *M. dolichodactylus*. No transition forms were found.

In present study, we found that the denticle arrangement on the cutting edges of the fingers of the major male second pereiopod is strikingly different. In *M. scabriculum*, the size of the denticles along the cutting edge gradually decreases in size (Fig. 20-H). In *M. dolichodactylus*, there is one pair of large denticles at the proximal part of the cutting edge, with all the others small, denticulate and subequal in size (Fig. 20-G). The general form of *M. dolichodactylus* is very different from *M. scabriculum*, with both species very consistent with regards to the above mentioned characters, although both species can sometimes be found from the same river. As such, we hereby treat them as two species.

With regards to *M. dubius*, Henderson & Matthai (1910: 301) stated that the "... chelipedes are much weaker than in *P. scabriculum* and *P. dolichodactylus*, while the longer chelipede is a little shorter than body ...", while the "... palm is not so strongly compressed as in *P. scabriculum* and *P. dolichodactylus* with the result that it is much longer than broad, the proportion being four to one ..." The differences do not seem substantial enough to separate it from *M. scabriculum* s. str. As no material of this taxon is available to us for the time being, we tentatively accept its synonymy with *M. scabriculum* by Holthuis (1950).

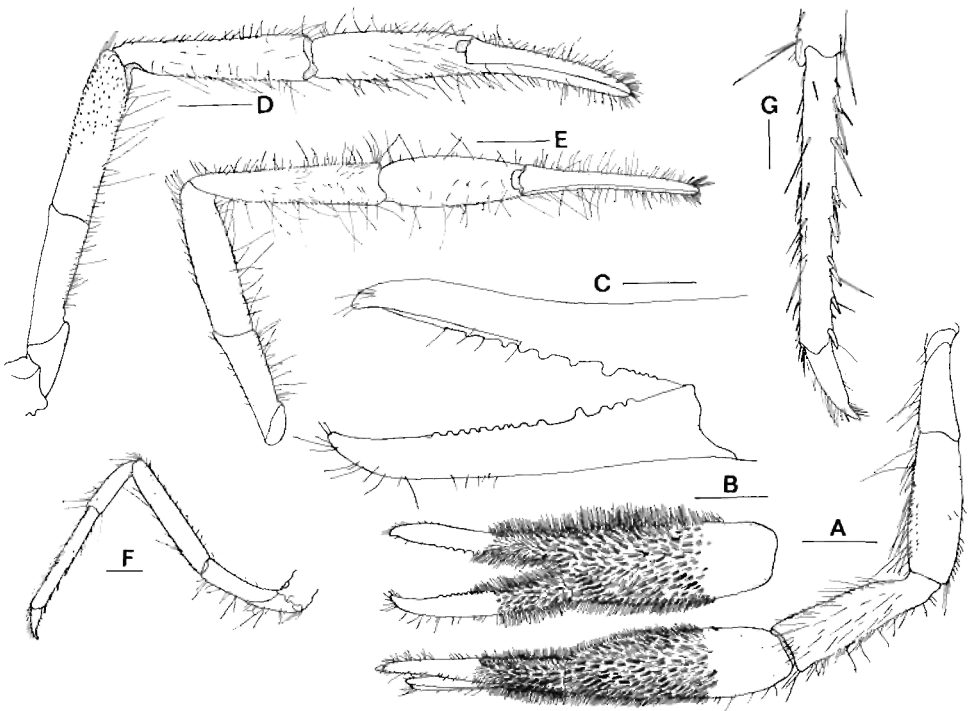


Fig. 19. *Macrobrachium scabriculum* (Heller, 1862). A-D, F-G, male (cl 7.8 mm)(ZRC 1998.883); E, female (cl 10.2 mm)(ZRC 1998.883), both Sungai Keliling. A: major (right) second pereiopod; B: chela of major (right) second pereiopod; C: fingers of chela of major right second pereiopod, denuded; D: minor (left) second pereiopod; E: right second pereiopod; F: right third pereiopod, G: propodus and dactylus of right third pereiopod. Scales: A, B, D, E = 2.0 mm; C, F = 1.0 mm; G = 0.5 mm.

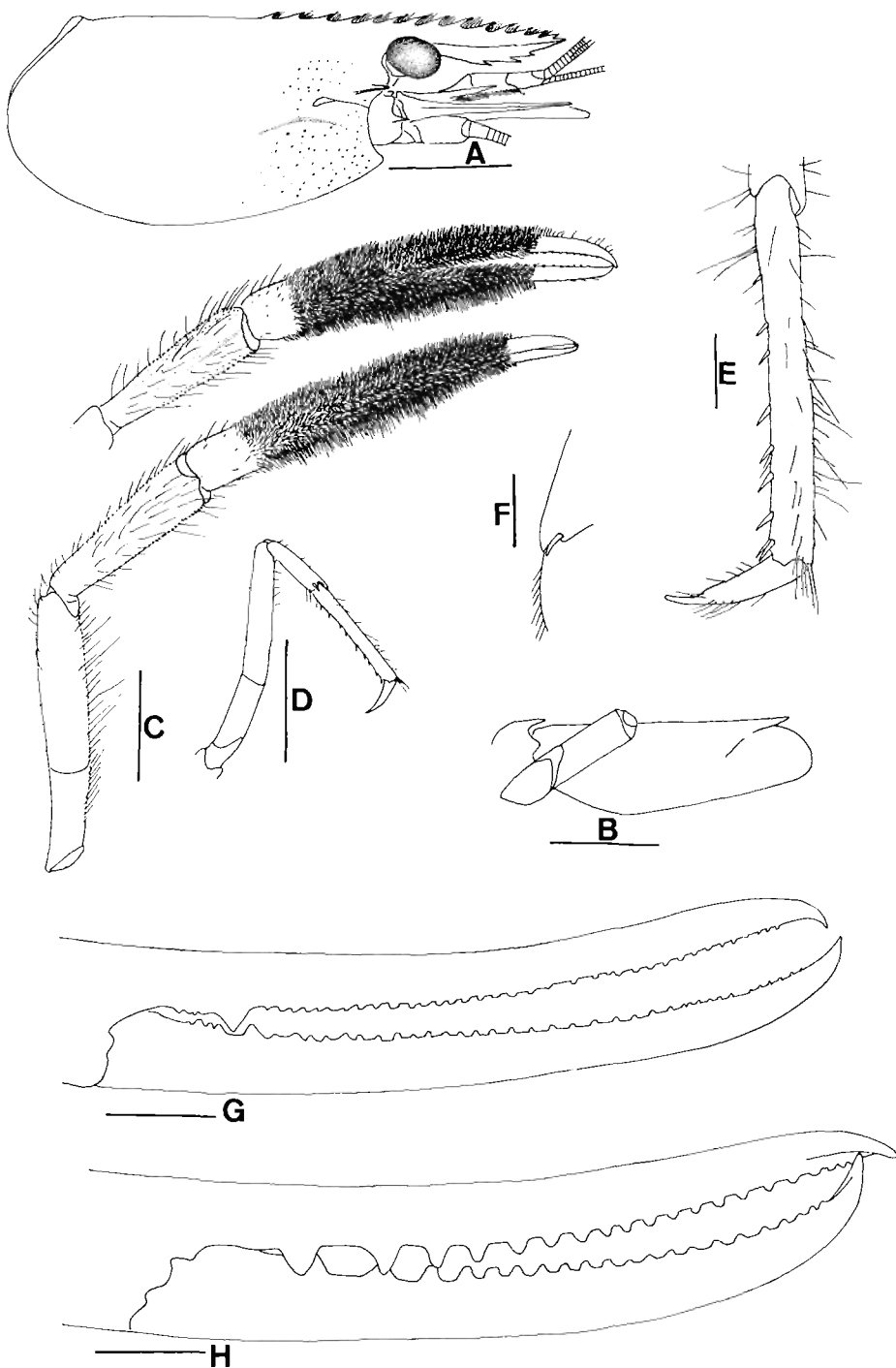


Fig. 20. *Macrobrachium dolichodactylus* (Hilgendorf, 1879). A-F, male (cl 7.8 mm)(ZRC 1998.884), Sungai Keliling; G, male (cl 16.0 mm)(ZRC 1998.932), southern Myanmar. *Macrobrachium scabriculum* (Heller, 1862), H, male (cl 17.9 mm)(ZRC 1998.930), Sri Lanka. A: lateral view of cephalothorax and appendages; B: scaphocerite; C: major (right) second pereiopod; D: third pereiopod; E: propodus and dactylus of third pereiopod; F: uropodal diaeresis; G: fingers of chela of major right second pereiopod (denuded); H: fingers of chela of major right second pereiopod (denuded). Scales: A = 5.0 mm, B-D, G = 3.0 mm; E, F = 1.0 mm.

Live specimens of *M. scabriculum* have a longitudinal pale band running along the dorsal surface from the tip of the telson to the base of the rostrum, broken by a distinct greyish streak at the fourth abdominal somite and two indistinct greyish streaks at the second and third abdominal somites. All the pereopods have pale and greyish bands.

Macrobrachium scabriculum (Heller, 1862), was collected together with *M. latidactylus* (Thallwitz, 1891) from riffled stretches of stream where water flows over aggregations of small (ca. 300 mm across) rocks. *Macrobrachium scabriculum* s. str. is distributed, with certainty, from Sri Lanka, southern India, Sarawak to Singapore and Peninsular Malaysia. On Pulau Tioman, it has so far been obtained from only a single drainage on the island, namely Sungai Keliling.

***Macrobrachium dolichodactylus* (Hilgendorf, 1879)**

(Figs. 20A-G)

Palaemon (s. s) *dolichodactylus* Hilgendorf, 1879: 840, pl. 4-fig. 18. *Palaemon dolichodactylus* - Henderson & Matthai, 1910: 300, pl. 18-fig. 8a-b.

Macrobrachium scabriculum - Holthuis, 1950: 225 (part); Chace & Bruce, 1993: 37 (part).

Material examined. - 1 male (cl 14.0 mm) (ZRC 1998.884), Sungai Keliling, Pulau Tioman, coll. Y. Cai & N. K. Ng, 10 Sep.1998.

Diagnosis. - Rostrum straight, reaching distal end of antennular peduncle, rostral formula: 4-6 (mode 5)+ 8-11 (mode 9)/2-4 (mode 2). Scaphocerite 3 times as long as broad. Male major second pereopod distinctively longer than body, about 1.5 times as long as body for fully grown specimens; merus shorter than carpus, but slightly longer than palm; carpus distinctively longer than palm, palm short, not depressed, as broad as carpus; fingers 1.5-2.0 times as long as palm, with 1 pair of strong teeth on base of fingers, with 25-37 denticles on rest of cutting edge; velvety pubescence on distal 2/3 of palm and proximal 3/4 of fingers, rest of leg with sparse stiff setae. Minor male second pereopod similar to major one in form, but short, only as long as body, with no velvety pubescence but stiff sparse setae on leg. Female second pereopods equal in length, similar in form, distinctively shorter than body. Third pereopod reaching beyond the distal end of the scaphocerite with its entire dactylus; propodus 9 times as long as broad, 2.8 times as long as dactylus. Uropodal diaeresis with 1 tooth distinctively longer than outer angle.

Remarks. - The present diagnosis of the species is based on the single specimen obtained from Pulau Tioman, together with those from Myanmar. See remarks for *M. scabriculum* for discussion.

The Pulau Tioman specimen was collected from Sungai Keliling. The shrimp was found at the centre of the stream, among water ferns which were growing on the boulder, facing the fast flowing water. The species is known from East Africa, southern India, southern Myanmar and now Peninsular Malaysia.

***Macrobrachium lar* (Fabricius, 1798)**

Palaemon lar Fabricius, 1798: 402.

Macrobrachium lar - Holthuis, 1950: 176, Fig. 37; Johnson, 1960a: 180, 1968: 220; Ng, 1985: 149; Ng & Chong, 1986: 28; Chace & Bruce, 1993: 30, Fig. 9.

(See Chace & Bruce, 1993, for rest of synonymy).

Material examined. - 1 male, 2 females (largest cl 31.7 mm, tl 100.7 mm) (ZRC 1998.885), Sungai Keliling, coll. D. C. J. Yeo et al., 27 Jun.1997. - 2 males, 2 females (largest 48.1 mm, tl 132.1 mm) (ZRC 1998.886), Sungai Asah, coll. P. K. L. Ng et al., 24 Jun.1997. - 1 male, 1 female (larger cl 20.6 mm, tl 65.8 mm) (ZRC 1998.887), Sungai Paya, coll. P. K. L. Ng et al., 25 Jun.1997. - 1 male (cl 44.0 mm, tl 125.9 mm) (ZRC 1996.1785), Sungai Raya, Kampung Mukut, coll. P. K. L. Ng et al, 26 Jun.1996. - 1 female (moult) (ZRC 1996.1786), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 1 moult (ZRC 1998.933), stream near Tekek airstrip, Pulau Tioman, coll. K. T. Kwek, 25 Jun.1985. - 1 male (ZRC 1998.934), stream, Tekek-Juara, Pulau Tioman, coll. R. E. Sharma, 1 May 1970. - 1 ovigerous female (ZRC 1998.935), Sungai Keliling, coll. 19 Apr.1968. - 3 specimens (ZRC 1986.313-315), ca. 100m asl., waterfall stream south of Mukut waterfall (wooden jetty), Pulau Tioman, coll. S. S. C. Chong, 27 Jun.1985. - 1 male (ZRC 1998.936), stream flowing into Tekek-Juara, Pulau Tioman, coll. R. E. Sharma, 1 Jun.1971.

Remarks. - *Macrobrachium lar* is the largest freshwater prawn species on Pulau Tioman (Ng & Chong, 1986) and was first reported from the island by Johnson (1968). It occurs in torrent streams where it hides in crevices between large boulders during the day and ventures out to forage at night (Ng & Chong, 1986). It is easily separated from the other prawns on the island by its large size, low number of rostral teeth and overall bluish sheen observed in living specimens.

It is a widely distributed species, ranging from East Africa to Polynesia (Johnson, 1960a; Chace & Bruce, 1993) and was considered the most abundant freshwater palaemonid species in the Indo-Pacific by Holthuis (1950). However, like other species that rely on marine transport of pelagic larvae for dispersal such as *Caridina typus* H. Milne Edwards, 1837, *M. lar* is hardly known from mainland Asia (Johnson, 1960a).

***Macrobrachium latidactylus* (Thallwitz, 1891)**

Palaemon latidactylus Thallwitz, 1891: 97.

Macrobrachium latidactylus - Holthuis, 1950: 239, Fig. 50; Johnson, 1963: 16; 1968: 220, 1969: 111; Ng & Chong, 1986: 29, 3 Figs.; Chace & Bruce, 1993: 31, Fig. 10.

(See Chace & Bruce, 1993, for rest of synonymy).

Material examined. - 35 specimens (largest cl 20.2 mm, tl 69.6 mm, ZRC), Sungai Paya, coll. P. K. L. Ng et al., 25 Jun.1997. - 28 specimens (ZRC 1998.888), Sungai Keliling, coll. Y. Cai, 28 Jun.1997. - 3 specimens (largest cl 17.7 mm, 53.4 mm) (ZRC 1998.889), Sungai Asah, coll. P. K. L. Ng et al., 24 Jun.1997. - 11 males (largest cl 15.3 mm, tl 46.2 mm) (ZRC 1996.1787), Sungai Keliling, coll. P. K. L. Ng et al., 27-28 Jun.1996. - 23 specimens (largest cl 25.0 mm, tl 69.2 mm) (ZRC 1996.1788), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 3 specimens (largest cl 19.8 mm, tl 58.7 mm) (ZRC 1996.1789), Kampung Paya, Sungai Pasal downstream on trail to Sungai Paya, coll. H. H. Tan et al., 18 Sep.1995. - 1 female (cl 14.6 mm, tl 47.6 mm) (ZRC 1996.1790), Sungai Paya upstream, near base of Bukit Paya, coll. H. H. Tan et al., 17 Sep.1995. - 6 specimens (largest cl 9.0 mm, tl 31.2 mm) (ZRC 1996.1792), left stream at mouth of Sungai Paya, coll. O. Chia & M. J. Ng, 27 Jun.1996. - 1 male (cl 13.7 mm, tl 42.6 mm) (ZRC 1996.1793), Sungai Nipah, coll. D. C. J. Yeo et al., 28 Jun.1996. - 5 specimens (largest cl 18.2 mm, tl 56.7 mm) (ZRC 1996.1794), Kampung Genting, Sungai Ayer Raja, 2°45'36.7"N 104°07'21.5"E, coll. P. K. L. Ng et al., 15 Sep.1995.

- 12 specimens (largest cl 16.9 mm, tl 53.0 mm) (ZRC 1996.1795), Sungai Raya, Kampung Mukut, coll. P. K. L. Ng et al., 26 Jun.1996. - 14 specimens (ZRC 1986.198-211), stream next to Idrus' lodging or Tekek village, Pulau Tioman, West Malaysia, coll. S. S. C. Chong, 26 Jun.1985. - 6 specimens (ZRC 1998.937), stream behind airstrip, Tekek, Pulau Tioman, coll. not known, 30 Jun.1986. - 5 specimens (ZRC 1998.938), stream behind Idrus' Inn, Tekek, Pulau Tioman, coll. not known, 29 Jun.1986. - 11 specimens (ZRC 1998.939), Kampung Genting, coll. 28 Jun.1986.

Remarks. - *Macrobrachium latidactylus* has been reported from Malaysia (including Pulau Tioman), Thailand, Taiwan, Philippines and Indonesia (Holthuis, 1950; Johnson, 1963; Chace & Bruce, 1993). On Pulau Tioman, it is fairly common in slower-flowing, lowland streams (Ng & Chong, 1986; pers. obs.).

The present specimens agree well with the descriptions and figures by Holthuis (1950) and Chace & Bruce (1993). This species is easily distinguished from other species by the large males possessing highly unequal second pereiopods in which the major chela has a laterally flattened palm with strongly curved and gaping fingers. The smaller males and females are distinguished by a combination of a high rostrum with relatively dense rostral teeth arrangement. In addition, the unmodified second pereiopod chelae appears to be pigmented (bluish) along the cutting edges of the fingers and sometimes, at intervals on the fingers, giving a banded appearance.

Macrobrachium pilimanus (De Man, 1879)

Palaemon pilimanus De Man, 1879b: 181.

Macrobrachium pilimanus - Holthuis, 1950: 214 (part); Chace & Bruce, 1993: 35 (part).

Macrobrachium pilimanus - Johnson, 1960a: 178; Johnson, 1960b: 263, Fig. 5; Johnson, 1963: 10, Figs. 2; Johnson, 1966: 418; Johnson, 1969: 111; Ng, 1985: 160; Ng, 1995a: 187, Fig. 5; Ng & Chong, 1986: 29, 2 Figs.; Chong & Khoo, 1987a: 763; Ou & Yeo, 1995: 299, Figs. 2b, d.

Material examined. - 56 specimens (largest cl 16.0 mm, tl 43.1 mm) (ZRC 1998.890), Sungai Salang, coll. Y. Cai et al., 25 Jun. 1997. - 22 specimens (largest cl 14.4 mm, tl 40.6 mm) (ZRC 1998.891), Tekek falls, Sungai Ayer Besar, coll. P. K. L. Ng et al., 23 Jun.1997. - 60 specimens (largest cl 14.3 mm, tl 39.8 mm) (ZRC 1998.892), Sungai Nipah, coll. P. K. L. Ng et al., 27 Jun.1997. - 36 specimens (largest cl 13.5 mm, tl 39.6 mm) (ZRC 1998.893), Sungai Paya, coll. P. K. L. Ng et al., 25 Jun.1997. - 12 specimens (ZRC 1998.894), Sungai Asah, coll. P. K. L. Ng et al., 24 Jun.1997. - 57 specimens (largest male 17.1 mm, tl 46.1 mm) (ZRC 1996.1796), Sungai Ayer Besar, stream along Tekek-Juara trail, coll. P. K. L. Ng et al., 24-25 Jun.1996. - 59 specimens (largest male cl 12.0 mm, tl 34.4 mm) (ZRC 1996.1797), Sungai Nipah, coll. D. C. J. Yeo et al., 28 Jun.1996. - 10 specimens (largest male cl 16.0 mm, tl 44.7 mm) (ZRC 1996.1798), Gunung Kajang, coll. T. H. T. Tan et al., 26 Jun.1996. - 1 male (cl 13.0 mm, tl 33.5 mm) (ZRC 1996.1799), Sungai Asah, coll. P. K. L. Ng et al., 26 Jun.1996. - 34 specimens (largest cl 13.6 mm, tl 39.5 mm) (ZRC 1996.1800), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun.1996. - 27 specimens (largest cl 15.4 mm, tl 44.1 mm) (ZRC 1996.1801), Kampung Paya, Sungai Pasal upstream (ca. 15 minutes walk from start of trail to Sungai Paya), coll. H. H. Tan et al., 17 Sep.1995. - 33 specimens (largest cl 16.8 mm, tl 46.2 mm) (ZRC 1996.1802), Gunung Kajang, Sungai English, ca. 1000ft asl., coll. H. H. Tan et al., 18 Sep.1995. - 20 specimens (largest cl 13.6 mm, tl 34.7 mm) (ZRC 1996.1803), Kampung Paya, Sungai Paya, 2°47'11.9"N 104°07'11.6"E, coll. P. K. L. Ng et al., 16 Sep.1995. - 10 specimens (largest cl 9.8 mm, tl 29.9 mm) (ZRC 1996.1804), Kampung Genting, Sungai Ayer Raja, 2_45'36.7"N 104_07'21.5"E, coll. P. K. L. Ng et al., 15 Sep.1995. - 2 specimens (ZRC 1996.1805), Sungai Ayer Besar waterfall, on Tekek-Juara trail, coll. P. K. L. Ng et al., 16 Sep.1995. - 9 specimens (largest cl 11.7 mm, tl 32.1 mm) (ZRC 1996.1806), Sungai Paya upstream, near base of Bukit Paya, coll. H. H. Tan et al., 17 Sep.1995. - 33 specimens (largest cl 16.6 mm, tl 47.6 mm) (ZRC 1996.1807), Gunung Kajang, Sungai Ayer Surin, ca. 800 ft asl., coll. H. H. Tan et al., 18 Sep.1995. - 31 specimens (ZRC 1985.2327-2357), stream behind Tanjong Said, Pulau Tioman, coll. A. Kamal et al., 27 Jun.1985. - 31 specimens (ZRC 1985.2358-2388), waterfall along Tekek-Juara path, Pulau Tioman, coll. S. S. C. Chong et al., 26

Jun.1985. - 37 specimens (ZRC 1985.2389-2425), first stream crossing along path from Tekek to Juara, Pulau Tioman, coll. S. S. C. Chong et al., 26 Jun.1985. - 11 specimens (ZRC 1985.2426-2436), Sungai Keliling, Telok Juara, Pulau Tioman, coll. R. E. Sharma & G. Tay, 19 Apr.1968.

Remarks. - The taxonomy of the *M. pilimanus* species complex remains difficult. Johnson (1960b, 1963) recognized *M. leptodactylus* (De Man, 1892) and *M. malayanum* (Roux, 1934) as distinct sibling species of *M. pilimanus* (De Man, 1879). Holthuis (1950, 1979), however, synonymised these taxa under *M. pilimanus* (De Man, 1879), a view tentatively shared by Ng (1985) pending a greater understanding of the variation within the group. *Macrobrachium malayanum* (Roux, 1934) s. str. was subsequently removed from the *M. pilimanus* species complex by Chong & Khoo (1987b) when it was shown to be a senior synonym of *M. geron* Holthuis, 1950. The specimens identified by Johnson (1960, 1963) as “*M. malayanum*” are in fact not conspecific with *M. malayanum* (Roux, 1934) and belong to an undescribed species of the *M. pilimanus* complex (Ng & Choy, 1990). Ng & Choy (1990) noted that among material which they examined from Java, were specimens clearly referable to both *M. leptodactylus* (De Man, 1892) as well as *M. pilimanus* s. str., and commented that the former appears to be a good species. However, Ou & Yeo (1995), after examining a good series of “*M. pilimanus*” from Bogor, Java (type locality of *M. leptodactylus*), felt that *M. leptodactylus* was possibly only a variant of Javan “*M. pilimanus*” (sensu De Man, 1892) and that Javan specimens had sufficient consistent differences from *M. pilimanus* s. str. to possibly belong to a distinct species. This means that Java had only one valid species, *M. leptodactylus*. At present, the following described species are known from this complex: *M. pilimanus* (De Man, 1879), *M. leptodactylus* (De Man, 1892), *M. ahkowi* Chong & Khoo, 1987, *M. gua* Chong, 1989, *M. forcipatum* Ng, 1995, *M. platycheles* Ou & Yeo, 1995, *M. hirsutimanus* Tiwari, 1952, *M. dienbienphuense* Dang & Nguyen, 1972, *M. longidactylus* Dai, 1984, and *M. eriocheirum* Dai, 1984 (De Man, 1879b, 1892; Johnson, 1960b, 1963; Chong & Khoo, 1987b, 1987c, 1987d; Chong, 1989; Ng, 1995b; Ou & Yeo, 1995; Tiwari, 1952; Dang & Nguyen, 1972; Dai, 1984). The last four species are from Indo-China and have long been neglected after the original descriptions.

The present specimens agree well with the descriptions and figures by De Man (1879b) and Johnson (1960a, 1963) and are clearly *M. pilimanus* s. str. No other forms from the species complex have been found on Pulau Tioman. *Macrobrachium pilimanus* is readily differentiated from other *Macrobrachium* species found on the island by its relatively short rostrum (not exceeding antennular peduncle) and the second pereopod with a rounded cup-shaped carpus and densely pubescent chelae. Live specimens are mottled dirty green and light brown in colour (Ng, 1985; Ng & Chong, 1986).

Macrobrachium pilimanus is commonly found throughout the island, inhabiting well oxygenated fast flowing to torrent streams and is the only prawn species encountered at the higher altitudes of Gunung Kajang. It appears to be active throughout the day and night unlike many other decapod crustacean species on the island, which are mostly nocturnal (pers. obs.). This species shows highly abbreviated larval development with the females bearing relatively large eggs. These hatch into well developed benthic larvae that do not travel to the sea and complete their development in fresh water (Chong & Khoo, 1987a).

Palaemon debilis Dana, 1852

Palaemon debilis Dana, 1852: 26; Ng & Chong, 1986: 30, 1 Fig; Chace & Bruce, 1993: 40.
Palaemon (Palaemon) debilis - Holthuis, 1950: 66, Fig. 13.

(See Chace & Bruce, 1993, for rest of synonymy).

Material examined. - 14 specimens (ZRC 1998.895), Sungai Paya, coll. P. K. L. Ng et al. 25 Jun. 1997. - 1 specimen (ZRC 1998.896), Sungai Keliling, coll. Y. Cai, 27 Jun. 1997. - 7 specimens (ZRC 1996.1808), left stream at mouth of Sungai Paya, coll. O. Chia & M. J. Ng, 27 Jun. 1996. - 8 specimens (ZRC 1996.1809), Sungai Nipah mangroves, coll. D. C. J. Yeo et al., 28 Jun. 1996. - 8 specimens (ZRC 1996.1819), Sungai Paya, Kampung Paya, coll. P. K. L. Ng et al., 25-27 Jun. 1996. - 25 specimens (ZRC 1998.940), Pulau Tioman (Tekek) stream, coll. C. Y. Chan, 16-17 Apr. 1970.

Remarks. - *Palaemon debilis* was reported from Pulau Tioman by Ng & Chong (1986). This species is more commonly encountered in coastal and brackish waters, however, as is the case here, it does penetrate tidal freshwaters. It has a very wide distribution, having been reported from the Red Sea, South Africa, Ryukyus Islands, Philippines, Indonesia, Hawaii and the Tuamotu Archipelago (Chace & Bruce, 1993). The genus *Palaemon* is immediately distinguished from *Macrobrachium* by its members possessing a branchiostegal spine and lacking an hepatic spine.

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