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The alpheid shrimp genus *Potamalpheops* Powell, 1979, (Crustacea: Decapoda: Caridea: Alpheidae) from Southeast Asia, with descriptions of three new species

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The present study describes three new species, viz. *Potamalpheops amnicus*, n. sp., from Johore [Peninsular Malaysia], Singapore and Pulau Bintan [Indonesia], *Potamalpheops miyai* n. sp., from Pulau Bintan [Indonesia], and *Potamalpheops tigger* n. sp., from Singapore. One of these, *P. amnicus*, is a true freshwater species while the other two are mangrove-dwellers. This represents the first record of *Potamalpheops* from Southeast Asia. The genus has previously also been reported from Central America, West Africa, Northern Australia and New Caledonia. A key to the Southeast Asian species of *Potamalpheops* is provided.

KEYWORDS: Crustacea, Decapoda, Alpheidae, *Potamalpheops*, freshwater, mangrove, Southeast Asia.

Introduction

The genus *Potamalpheops* was erected by Powell (1979) for three West African species found in the Gulf of Guinea region, namely *P. pylorus* Powell, 1979, and two other species previously described under the genus *Alpheopsis* Coutière, 1896, namely, *P. haugi* (Coutière, 1906) and *P. monodi* (Sollaud, 1932). *Potamalpheops stygicola* (Hobbs, 1973), a cave-dwelling species from Oaxaca, Mexico was originally described as a species of *Alpheopsis* but later transferred to *Potamalpheops* after several key characters diagnostic to the genus were noted (Hobbs, 1973, 1983). Subsequently three more species were discovered from the Indo-West Pacific region, namely *P. hanleyi* Bruce, 1991, and *P. darwiniensis* Bruce, 1993, from Darwin, Australia and *P. pininsulae* Bruce & Iliffe, 1992, from the Isle of Pines, New Caledonia. One more distinct species is known from West Africa but is as yet undescribed (Powell, 1979; Bruce, 1993).

In this present study, three new species of *Potamalpheops* from Southeast Asia are reported, making this the first record of the genus from the region. Several of the recently named species (e.g. *P. stygicola, P. pininsulae, P. darwiniensis* and *P. tigger* n. sp.), although clearly belonging to the genus, differ from Powell's original genus description (1979) in certain minor aspects. Thus the generic definition of the genus *Potamalpheops* given in the present study has been updated and modified after Powell (1979) in order to accommodate all the existing species.

Material and methods

Material examined for the present study was obtained from recent collections made in the following localities: Central Catchment Area, Sungei Buloh mangroves and Lim Chu Kang mangroves [Singapore]; Sungei Tementang and Sungei Selangi [Kota Tinggi, Johore, Peninsular Malaysia]; and Sungei Lagoi [Pulau Bintan, Riau Archipelago, Indonesia]. Further details on these localities are given under the *Material examined* and *Ecology* sections for each species. The material including type specimens is deposited in the Zoological Reference Collection (ZRC), Department of Zoology, National University of Singapore; the Natural History Museum, [formerly the British Museum of Natural History (BMNH)], London, and the Nationaal Naturhistorisch Museum [formerly the Rijksmuseum van Natuurlijke Historie (RMNH)], Leiden.

The following abbreviations are used in the text: tl (total length) and cl (carapace length). The total length is measured from the tip of the rostrum to the distal margin of the telson. The carapace length is measured from the tip of the rostrum to the dorsal posterior margin of the carapace in lateral view. Antennular peduncle segment lengths are measured through the middle of the dorsally visible portions. To avoid error caused by inconsistent positioning of the dorsally exposed eyes in preserved specimens, the length of the proximal segments also include the portions not dorsally visible (that are concealed by the eyes). Therefore, the proximal segment length is measured dorsally from the distal margin to the posterior margin of the orbitals. All measurements are in millimetres. Important Malay words used in the text that should be noted are 'Sungei' (stream or river), 'Pulau' (island) and 'Kampung' (village).

Systematic account

Family **ALPHEIDAE** Rafinesque, 1815

Genus ***Potamalpheops*** Powell, 1979

Potamalpheops Powell, 1979: 117.

Type species. By original designation, *Potamalpheops pylorus* Powell, 1979.

Gender. Masculine.

Diagnosis. Small-sized shrimp. Rostrum acute, of variable shape dorsally, from broadly triangular to slender, of variable length, from very short, hardly reaching base of antennular peduncle, to relatively longer, distinctly exceeding proximal segment of antennular peduncle, reaching about midway of intermediate segment. Carapace with extra-corneal tooth well developed and acute, rarely weakly developed and blunt, inferior orbital angle feebly produced and usually broadly rounded, with distinct cardiac notch on posterior margin. Sixth abdominal pleurite with articulated triangular plate. Posterior telson margin wholly or partly broadly convex with one or two pairs of robust lateral spines. Antennular peduncle with intermediate segment at least as long as dorsally visible portion of proximal segment. Scaphocerite of antenna with variable lateral spine ranging from distinctly not reaching to distinctly exceeding distal margin of lamella. Eyes usually totally or partially exposed dorsally by anterior margin of carapace, with or without anteromedial setae. First pereiopods with chelae smooth, subequal, relatively large and robust or small and slender, carried either flexed or extended. Second pereiopod with five-segmented carpus. Third to fifth pereiopods with robust movable spines on merus, dactyli simple. Exopod of uropod with lateral part of diaeresis produced as a dorsal toothed lamella.

Distribution. West Africa (Cameroons, Gabon, Nigeria, Senegal, Sierra Leone); Central America (Mexico); Indo-West Pacific (northern Australia and New Caledonia) and Southeast Asia (Indonesia, Peninsular Malaysia, Singapore) (Fig 7).

Remarks. *Potamalpheops* bears a close superficial resemblance to *Alpheopsis* Coutière, 1896, *Athanas* Leach, 1814, and *Neoalpheopsis* A. H. Banner, 1953. The toothed lamella or flange of the diaeresis on the uropodal exopod and the presence of movable spines on the meri of the third to fifth pereiopods, however, clearly separates *Potamalpheops* from these genera. In addition, species which possess dorsally exposed eyes and anteromedial setae on the eyes are also easily distinguished, as these are absent in the abovementioned closely related genera. *Potamalpheops* is further differentiated from *Neoalpheopsis* by its convex posterior margin of the telson (Powell, 1979).

Key to Southeast Asian Species of *Potamalpheops*

The Southeast Asian species of *Potamalpheops* can be separated by the following artificial key:

1 Rostrum very slender, relatively long, reaching at least distal margin of proximal segment of antennular peduncle; stylocerite slender, long, distinctly exceeding distal margin of proximal segment of antennular peduncle, reaching or exceeding distal margin of intermediate segment . . . . ***Potamalpheops tigger*** n. sp.

– Rostrum broadly triangular to slightly slender, short, not reaching distal margin of proximal segment of antennular peduncle; stylocerite suboval, just reaching to or hardly exceeding distal margin of proximal segment of antennular peduncle, never reaching distal margin of intermediate segment 2

2 Eyes with anteromedial setae, cornea size not exceeding 0·1 of carapace length; distal margin of proximal segment of antennular peduncle minutely dentate; broadly convex portion of posterior margin of telson occupying >0·5 of posterior margin width, with 17–19 long plumose setae; uropodal exopod with single fixed tooth lateral to large movable spine on the diaeresis; with curved toothed flange of diaeresis; appendix masculina with five short, robust distal spines . . . . ***Potamalpheops amnicus*** n. sp.

– Eyes lacking anteromedial setae, cornea size not <0·1 of carapace length; distal margin of proximal segment of antennular peduncle distinctly dentate; broadly convex portion of posterior margin of telson occupying <0·5 of posterior margin width, with 10 to 13 long plumose setae; uropodal exopod with two fixed teeth lateral to large movable spine on diaeresis; with straight toothed flange of diaeresis; appendix masculina with five long, slender distal spines . . . . ***Potamalpheops miyai*** n. sp.

Potamalpheops amnicus n. sp.
(Figs 1, 2)

Material examined

Holotype: 1♂ (ZRC 1996·9), 1°51′46·5″N 104°00′31·0″E, Sungei Selangi, Kota Tinggi, Johore, coll. P. K. L. Ng *et al.*, 5 June 1995.

Paratypes: 4♂♂, 4♀♀ (ZRC 1996·10), same data as holotype. 2♂♂, 2♀♀ (BMNH), same data. 2♂♂, 1♀ (RMNH), 1°52′0·81″N 103°55′49·2″E, Sungei Tementang, Kota Tinggi, Johore, coll. D. C. J. Yeo and Y. Y. Goh, 31 July 1995. 1♂, 2♀♀ (ZRC 1996·11), 1°52′0·81″N 103°55′49·2″E, Sungei Tementang, Kota Tinggi, Johore, coll. P. K. L. Ng *et al.*, 5 June 1995. 2♂♂, 3♀♀ (ZRC 1996·12), Sime Road, upstream of

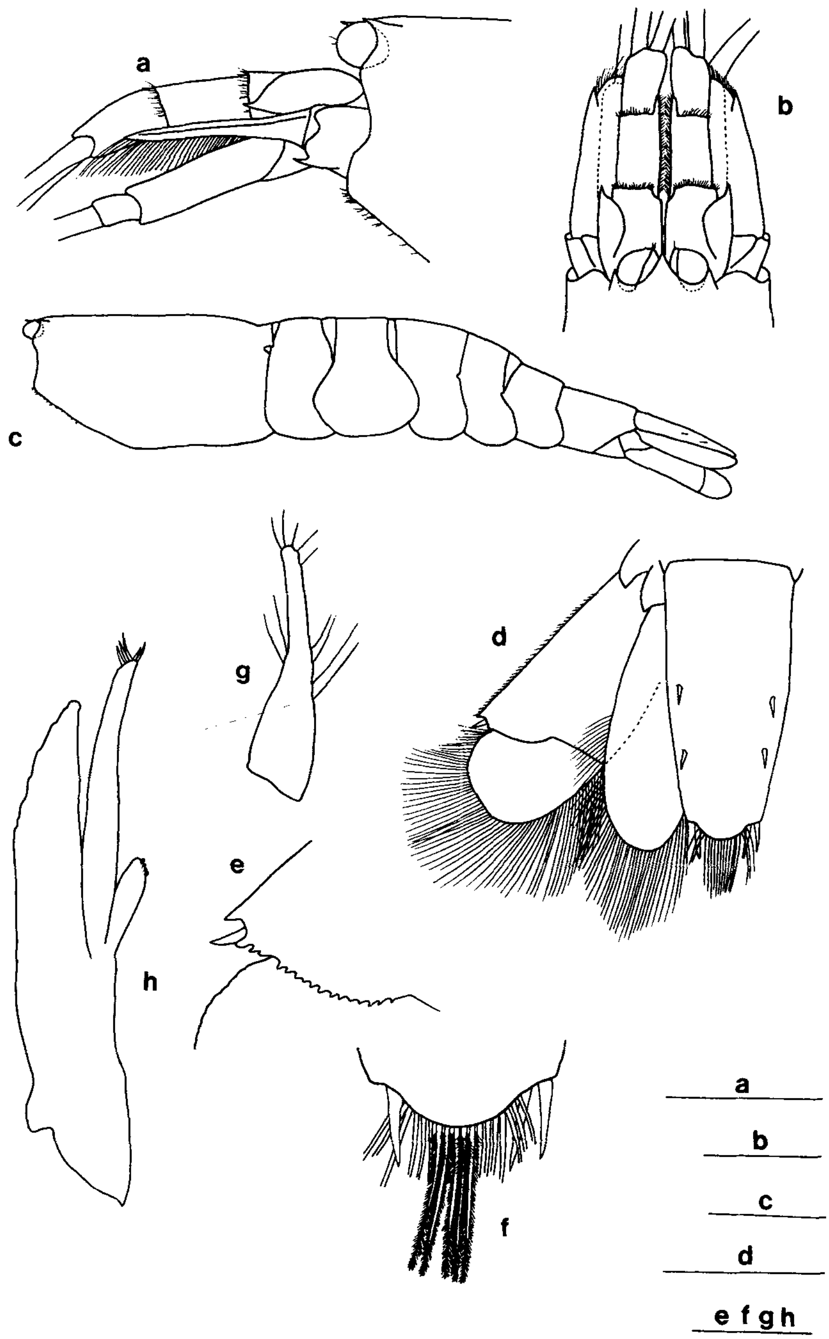

FIG. 1. *Potamalpheops amnicus* n. sp. Paratype male (cl 4·2 mm, tl *ca* 12·3 mm) (ZRC 1996.10), Sungei Selangi, Kota Tinggi, Johore, Peninsular Malaysia: (a) lateral view of anterior carapace; (b) dorsal view of anterior carapace; (c) lateral view of carapace and abdomen; (d) uropod and telson; (e) diaeresis on distal end of uropodal exopod; (f) posterior margin and spines of telson; (g) endopod of left first pleopod; (h) appendix masculina and appendix interna on endopod of left second pleopod. Pinnae of plumose setae of scaphocerite, uropod and telson, and plumose setae of second pleopod not drawn in. Scales = 1·0 mm in (a) 1·0 mm in (b) 2·0 mm in (c) 1·0 mm in (d) 0·3 mm in (e–h).

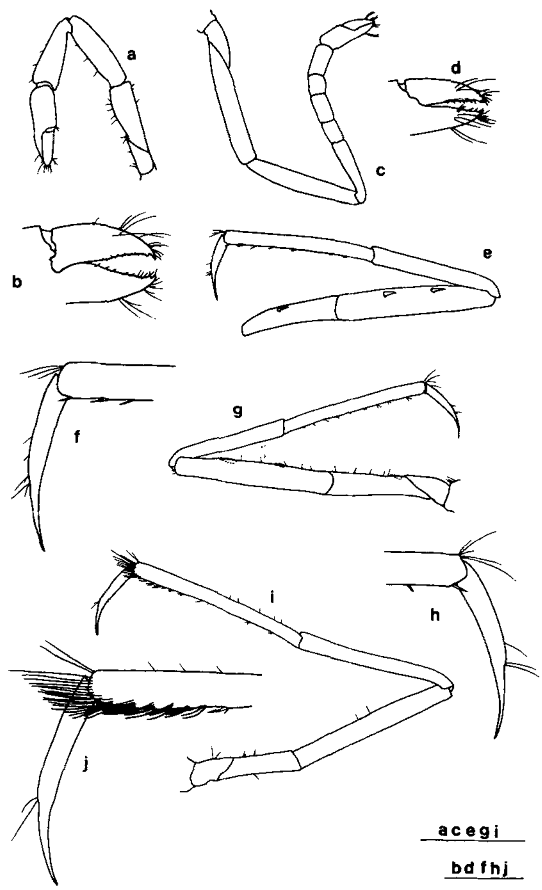

FIG. 2. *Potamalpheops amnicus* n. sp. Paratype male (cl 4·2 mm, tl *ca* 12·3 mm) (ZRC 1996.10), Sungei Selangi, Kota Tinggi, Johore, Peninsular Malaysia: (a) left first pereiopod; (b) fingers of chela of left first pereiopod; (c) left second pereiopod; (d) fingers of chela of left second pereiopod; (e) left third pereiopod; (f) propodus and dactylus of left third pereiopod; (g) left fourth pereiopod; (h) propodus and dactylus of left fourth pereiopod; (i) left fifth pereiopod; (j) propodus and dactylus of left fifth pereiopod. Scales = 1·0 mm in (a, c, e, g, i); 0·3 mm in (b, d, f, h, j).

bridge, downstream of siltation pond, Central Catchment Area, Singapore, coll. D. C. J. Yeo and H. H. Tan, 21 June 1995. 3♀♀ (ZRC 1996·13), Sime Road, upstream of bridge, downstream of siltation pond, Central Catchment Area, Singapore, coll. P. K. L. Ng *et al.*, February 1995. 1♀ (RMNH), same data. 1♀ (ZRC 1996·14), Sime Road, upstream of bridge, downstream of siltation pond, Central Catchment Area, Singapore, coll. T. M. Leong, 30 December 1994. 1♀ (ZRC 1996·15), 1°10′0·0″N 104°23′10·6″E, reservoir outlet to Sungei Lagoi, Pulau Bintan, coll. D. C. J. Yeo and Y. Y. Goh, 26 July 1995.

Description of paratype. Small-sized alpheid shrimp, subcylindrical, slightly compressed body form.

Rostrum (Fig. 1 a, b) very short, reaching distal margin of cornea and base of dorsally visible portion of proximal segment of antennular peduncle, broadly triangular in dorsal view, dorsal and ventral carina obsolete, unarmed, lateral carina weakly developed, expanded posteriorly to conceal small portion of posterior part of cornea.

Carapace (Fig. 1 a) glabrous, smooth; anterior margin leaving cornea of eyes mostly exposed dorsally and laterally, extra-corneal tooth well developed, acute, reaching about midpoint of cornea, inferior orbital angle weakly produced, rounded, pterygostomial angle feebly produced, rounded, sparsely setose; cardiac notch distinct.

Abdomen (Fig. 1 c) glabrous, smooth; sixth segment about 1·6× length of fifth, 1·3× longer than deep, compressed, posterior lateral angle acute, posteroventral angle with articulated triangular plate; pleura of first two segments broadly rounded, third and fourth subrectangular, fifth subacute with posteroventral angle rounded. Telson (Fig. 1d, f) about 1·4 × length of sixth segment, 2·3 × longer than anterior width, lateral margins subparallel proximally, slightly convergent distally, with two pairs of dorsal spines about 0·06 of telson length, anterior pair at 0·4 of telson length, posterior pair at 0·7 of telson length; posterior margin about 0·5 of anterior width, with two pairs of subequal, robust lateral spines (one missing from left side), about 2 × longer than dorsal spine length, central broadly convex portion occupying about 0·7 of posterior margin width, with about 18 long plumose setae, with numerous small spiniform setae dorsally.

Antennule (Fig. 1 b) with peduncle about 0·5 of carapace length, distinctly exceeding scaphocerite and carpocerite; proximal segment about 2 × longer than broad, distal margin minutely dentate and sparsely setose, with distally acute ventromedial carina; stylocerite suboval, with terminal distal spine just exceeding anterior margin of proximal segment; intermediate segment subcylindrical, about 0·8 × proximal segment length, 2 × longer than wide, with long plumose ventromedial setae, distal margin entire and sparsely setose; distal segment about 0·6 × proximal segment length, distal margin entire; upper flagellum biramous, proximal 18 to 20 segments fused, shorter ramus with 2 or 3 free segments, with about 19 groups of aesthetascs, longer ramus slender, tip missing; lower flagellum slender, about 1·6 × carapace length.

Antenna (Fig. 1 a, b) with basicerite stout, with acute ventrolateral tooth, reaching about midway of proximal segment of antennular peduncle, carpocerite subcylindrical, not exceeding antennular peduncle and scaphocerite, about 4·3 × longer than wide, flagellum about 3·8 × carapace length, proximal segments not thickened; scaphocerite not exceeding anterior margin of distal segment of antennular peduncle, 2·2 × longer than wide, broadly rounded distally, lateral margin straight, with acute distolateral tooth not exceeding anterior margin of lamella.

Eyes (Fig. 1 a, b) mostly exposed dorsally and laterally and slightly concealed posteriorly by anterior and lateral margins of carapace, cornea about 0·07 × of carapace length, sparsely setose on distomedial margin.

First pereiopods (Fig. 2 a, b) small, subequal, similar; chela small, about 0·2 of carapace length, 2·7 × longer than broad, palm 1·3 × longer than broad, smooth, dactylus about 4 × longer than proximal breadth, 0·5 of chela length, tapering, tip with two distal teeth, sparsely setose, cutting edge entire, fixed finger similar; carpus elongated, expanded distally, about 0·8 of chela length, 1·5 × length of palm of chela, 3 × longer than distal width; merus 4 × longer than central width, subequal to chela length; ischium 3·5 × longer than central width, subequal in length to carpus, 0·9 of chela length; basis normal; coxa robust.

Second pereiopods (Fig. 2 c) slender; chela small, about 0·1 of carapace length, about 2·5 × longer than broad; palm as long as broad; dactylus 0·6 of chela length, tip with two small distal teeth (Fig. 2 d), with cutting edge entire, sparsely setose; fixed finger 0·6 of chela length, tip with three small distal teeth, cutting edge entire, sparsely setose; carpus about 3·2 × chela length, 1·5 × merus length, 5-segmented, articles in approximate ratio of 10 : 3·3 : 5 : 3·3 : 5 (rounded off to nearest integer to facilitate comparison giving a ratio of 10 : 3 : 5 : 3 : 5); merus 0·7 of carpus length, 5·5 × longer than broad, unarmed; ischium 1·1 × as long as merus, 6 × longer than broad, basis normal, coxa robust.

Third pereiopods (Fig. 2e, f) extending beyond antennular peduncle, dactylus simple, with feebly demarcated unguis, sparsely setose, 0·4 × propodus length, 6·7 × longer than proximal width; propodus about 2·5 × longer than dactylus, 15 × as long as broad, with a pair of distoventral spines, six ventral spines, sparsely setose; carpus about 0·9 of propodus length, 6·5 × longer than distal width, unarmed; merus subequal to propodus, 5 × as long as broad, with 2 robust ventrolateral spines at 0·4 and 0·7 of merus; ischium about 0·6 of merus, 4·5 × longer than distal width, with single robust ventrolateral spine at 0·6 of ischium; basis normal, coxa robust. Fourth pereiopods (Fig. 2g, h) similar to third pereiopods; dactylus simple, with feebly demarcated unguis, sparsely setose, 0·4 × propodus length, 7·5 × longer than proximal width; propodus about 2·3 × longer than dactylus, 14 × longer than broad, with a pair of distoventral spines, with nine (two missing) ventral spines, sparsely setose; carpus about 0·9 of propodus length, 6 × longer than distal width, unarmed; merus about 1·1 times propodus, 7·5 × as long as broad, with two robust ventrolateral spines at 0·4 and 0·7 of merus; ischium about 0·6 of merus, 4·5 × longer than distal width, with one robust ventrolateral spine at 0·7 of ischium; basis normal; coxa robust. Fifth pereiopods (Fig. 2i, j) similar to third and fourth pereiopods but more slender; dactylus simple, with feebly demarcated unguis, sparsely setose, 0·4 × propodus length, 8 × longer than proximal width; propodus about 2·3 × longer than dactylus, 18 × as long as broad, with four ventral spines, with about eight ventrolateral transverse rows of serrulate setae, increasing in size and number distally; carpus about 0·8 of propodus length, 7·5 × longer than distal width, unarmed; merus 0·9 of propodus length, 8 × as long as broad, unarmed; ischium about 0·5 of merus, 4 × longer than distal width, unarmed; basis normal; coxa robust.

Pleopods normal; endopod of first pleopod (Fig. 1g) 3 × longer than basal breadth, distally tapered, with five small spiniform setae distally, two slightly longer setae laterally, four medially; endopod of second pleopod (Fig. 1h) relatively robust, 6 × longer than broad, with appendices at about 0·5 of endopod; appendix masculina subcylindrical, 7·8 × longer than wide, with five short simple spines distally, several longer simple spines laterally; appendix interna about 0·3 of appendix masculina length, with distal cincinnuli, inserted just posterior to appendix masculina, about 3·3 × as long as broad.

Uropod (Fig. 1d) protopod with subacute distolateral lobe, rami reaching posterior margin of telson; exopod 2 × longer than wide, lateral margin straight, with ventral submarginal setal fringe, distolateral angle produced as a single acute distal tooth, with single larger movable spine medially, diaeresis (Fig. 1e) well developed with broadly curved dentate dorsal flange laterally, extending about 0·5 of breadth, with about 17 small blunt teeth, distal lobe broadly rounded, with long plumose marginal setae and short spiniform marginal setae; endopod about 0·9 × exopod length, 2·5 × as long as broad.

Measurements. Carapace length 4·2 mm, total length *ca* 12·3 mm.

Variation. The holotype (ZRC 1996.9) (carapace length 3·4 mm; total length *ca* 9 mm) is slightly smaller than the described paratype (ZRC 1996.10) (carapace length

4·2 mm, total length *ca* 12·3 mm). The holotype differs from the paratype by: (i) a weaker, less produced pterygostomial angle of the carapace; (ii) stylocerite just reaching distal margin of proximal segment of antennular peduncle (versus slightly exceeding); (iii) lateral spine of scaphocerite just reaching the distal margin of the lamella (versus not reaching); (iv) 19 long plumose setae on the posterior telson margin instead of 18; (v) more robust antennular peduncle (proximal segment 1·8 × as long as broad versus 2 × ; distal segment as long a broad versus 1·7 ×); (vi) about 14 teeth on the dorsal flange of the diaeresis (versus 17 teeth).

The following variation was also noted in the other specimens examined:

Abdomen. The telson length ranges from 2·1 × to 2·5 × the anterior telson width. The position of the dorsal spines on the telson is variable, with the anterior pair positioned at 0·3–0·4 of the telson length and the posterior pair positioned between 0·5 and 0·7 of the telson length. The posterior telson width varies slightly in relation to the anterior width (0·6–0·7 ×). The long plumose setae on the posterior telson margin varies in number from 17 to 19.

Antennules. The antennular peduncle length with respect to the carapace length ranges from 0·4 to 0·5, with the antennular peduncle exceeding the distal margin of the scaphocerite sometimes barely and sometimes distinctly. The intermediate segment of the antennular peduncle varies in length in relation to the proximal segment (0·6 to 0·9 ×). The robustness of the intermediate segment also varies from 1·5 × longer than broad to 2 × longer than broad. The distal segment varies in length with respect to the proximal segment (0·3–0·6 ×).

Antennae. The lateral tooth of the scaphocerite varies from distinctly not reaching to barely reaching the anterior margin of the lamella.

Eyes. The cornea size varies in relation to the carapace length (0·06–0·09 ×).

First pereiopods. The slenderness of the palm of the chela varies from 1 to 2 × as long as broad. The relation of the movable as well as fixed finger length to the chela length is relatively constant (0·4–0·6 ×). The relative length of the carpus ranges from 1·5 to 1·6 × the palm length of the chela. The slenderness of the carpus also varies (2·3 to 3 × as long as distal width). The merus also shows variation (2·7–3 × as long as central width).

Second pereiopods. Slenderness of chela ranges from 2·5 to 3·5 × as long as broad. The carpus varies from 9·4 to 16·3 × as long as broad. The range of the carpus length with respect to the chela is 2·6–3·2 ×. The ratio of carpus articles in relation to the first carpus article also shows some variation giving an average ratio of about 10 : 2·8 : 4 : 3·3 : 5·6 (expressed to nearest integer for clarity and easy comparison gives a ratio of 10 : 3 : 4 : 3 : 6). The merus slenderness is rather variable, ranging from 5·5 × as long as broad to 10 ×. The ischium shows variation as well, from 6 × as long as broad to 10 ×.

Third pereiopods. The dactylus varies in slenderness from 6·7 to 8·6 × as long as proximal width and in relative length (0·4–0·5 × propodus length). There is variation in the slenderness of the propodus (12–18 × longer than broad) and in the ventral spine count (about 6–8 spines). The carpus ranges from 5 to 7 × its distal width and the distoventral spine may or may not be present. The merus is 5–7 × as long as broad with movable spines at 0·3–0·4 and 0·6–0·7 of its length.

Fourth pereiopods. The number of ventral spines of the propodus ranges from 5 to 9. The small distoventral spine on the carpus is sometimes absent. The more distal of the two movable spines on the merus is positioned at 0·3–0·4 of the merus while the more proximal spine is at 0·7–0·9 of the merus. The single ischial spine is found at 0·6–0·7 of the ischium.

Fifth pereiopods. There may be 4–5 ventromedial spines and 7–9 ventrolateral rows of serrulate setae on the propodus. The merus spines are rarely absent. When present, the distal merus spine is positioned at 0·3–0·4 of the merus while the proximal spine is positioned at 0·6–0·8 of the merus.

Second pleopods. In males, the length of the appendix masculina with respect to the endopod ranges from about 0·5–0·6 ×. The slenderness of the appendix masculina varies from 7·8 to 10 × as long as broad. Distal spines of appendix masculina about 0·07–0·08 of appendix masculina.

Uropods. Proportions vary in the exopod (1·9–2·3 × as long as broad) and endopod (2–2·5 × as long as broad). The number of teeth on the dorsal flange of the diaeresis varies from about 12–17.

It should be noted that the number of dorsal flange teeth of the diaeresis tends to be lesser in small adults and especially so in juveniles where the number falls below that of the abovementioned range. This also applies to the number of spines on the propods of the ambulatory appendages. The numbers of spines and teeth probably increase with age and size, reaching a maximum when the individual reaches adulthood. The juveniles also have generally shorter and more slender appendages than adults. The range of variations discussed here refers to adults.

Etymology. *Amnicus*, Latin for 'of a stream', alluding to the freshwater stream habitat of the species.

Colour. In live animals, the carapace and abdomen, including the telson and uropods, ranges from being very light transluscent grey to light reddish-brown. The antennular peduncles vary from light to dark reddish-brown. The antennae, pereiopods and pleopods are light translucent grey with a light pinkish to light reddish-brown tinge. The dark red gastric mass is visible through the transluscent carapace dorsally and laterally. Dorsally to dorsolaterally, there are narrow transverse dark reddish-brown bands on the posterior edge of the carapace and each abdominal segment. The telson and uropods are narrowly fringed with dark reddish-brown. Apart from being lighter and less intense, aquaria kept specimens generally retain their natural colour patterns.

Ecology. The type locality of *Potamalpheops amnicus* is the same as that of *Alpheus cyanoteles* Yeo and Ng, 1996, namely the Sedili drainage in Kota Tinggi, Johor, Peninsular Malaysia, where specimens were collected from acid water forest streams (see Yeo and Ng, 1996, for a description of the habitat and a list of syntopic organisms from the above area). Specimens of *P. amnicus* were obtained from vertical muddy banks with overhangs held in place by exposed as well as submerged root systems. These shrimp have a strong tendency to cling to submerged vegetation making them difficult to collect without severely disturbing the bank. Dislodged specimens are more easily caught by scraping a tray net along the bottom from the middle of the stream towards the bank.

Specimens from Singapore were collected from a stream in the Central Catchment Area. The banks of the stretch of stream where specimens were collected are similar to the type found in the Sedili drainage where specimens were obtained. The stream flows between two reservoirs (Upper Pierce and MacRitchie reservoirs) that have no connections to the sea. The water in the stream is obviously freshwater and free of any tidal influence. Syntopic organisms include fish like *Puntius lateristriga, Rasbora elegans* (Cyprinidae) and *Dermogenys pusilla* (Hemirhamphidae) and decapod Crustacea like *Caridina temasek*, *Macrobrachium malayanum* and *Parathelphusa maculata* (personal observation). Interestingly, there is a high likelihood that these

Table 1. Differences between *Potamalpheops monodi* (Sollaud, 1932), and *P. amnicus* n. sp.

Character	*Potamalpheops monodi*†	*Potamalpheops amnicus*
Rostrum	More slender and acute dorsally. Dorsally carinate.	Broadly triangular dorsally. Dorsal carina absent or feebly developed.
	Exposed laterally or rarely concealed by eyes.	Concealed by eyes laterally.
Carapace	Extracorneal tooth more ventrally positioned, not aligned but lower than rostrum in lateral view.	Extracorneal tooth more dorsally positioned, horizontally aligned with rostrum in lateral view.
Antennular peduncle	Intermediate segment more slender (about 3·5 × longer than broad).	Intermediate segment more robust (about 1·5–2 × longer than broad).
	Intermediate segment longer (about subequal to proximal segment).	Intermediate segment shorter (about 0·6–0·9 × longer than proximal segment).
	Distolateral margin of proximal segment entire.	Distolateral margin of proximal segment minutely dentate.
Antenna	Lateral spine of scaphocerite exceeding distal margin of lamella.	Lateral spine of scaphocerite reaching distal margin of lamella.
Second pereiopod	Slender (carpus about 32 × as long as broad; merus about 10 × as long as broad; ischium 10·5 × as long as broad).	Robust (carbus about 9·4–16·3 × as long as broad; merus about 5·5–10 × as long as broad; ischium 6–10 × as long as broad).
	Carpus proportionately longer (about 4·8 × longer than chela).	Carpus proportionately shorter (about 2·6–3·2 × longer than chela).
	Carpus articles relatively long (ratio of carpus articles 10:5:6:5:6).	Carpus articles relatively short (ratio of carpus articles 10:3:4:3:6).
Second pleopod	Appendix masculina relatively short (about 0·3 of endopod length).	Appendix masculina relatively long (about 0·5–0·6 of endopod length).
	Appendix masculina robust (about 5 × as long as broad).	Appendix masculina slender (about 7·8–10 × as long as broad).
	Appendix masculina with five long distal spines (about 0·5 of appendix masculina length).	Appendix masculina with five short distal spines (about 0·7–0·08 of appendix masculina length).
Exopod of uropod	Dorsal toothed flange of diaeresis straight.	Dorsal toothed flange of diaeresis broadly curved.
	Lateral margin terminating in small acute fixed tooth with another similar tooth immediately medial to it and lateral to large movable spine.	Lateral margin terminating in small acute fixed tooth with large movable spine immediately medial to it.
Eggs	Numerous and small, about 0·5 × 0·42 mm.	Relatively few and large, about 1·2 × 0·9 mm.

†Data from descriptions and figures by Powell (1979), Gordon (1956) and Sollaud (1932).

shrimps originated from unintentional introductions from Peninsular Malaysia (D. H. Murphy, personal communication). This is because the Sedili drainage in Kota Tinggi, Johore, is one of the water sources for Singapore with water from there being transported via pipeline to the Upper Pierce Reservoir. The Sedili drainage is where *P. amnicus* is found in far greater abundance than in Singapore (personal observations). It is therefore entirely possible for the shrimps to enter Singapore via the pipeline and become established in certain areas suitable to their habitat preference like the present stretch of stream.

A single specimen was collected from Pulau Bintan (Riau Archipelago), Indonesia. The stream from which it was collected is unshaded and flowing, with a pH of 7·3, with sand to clay substratum. This appears to be part of a highly degraded freshwater swamp forest as shown by the presence of typical freshwater swamp forest fish fauna (e.g. *Rasbora heteromorpha, Luciocephalus pulcher, Parakysis longirostris*) in pockets of slow-flowing to stagnant water (pH 5·9) adjacent to the main stream (H.H.Tan, personal communication; personal observation). Canalization of the stream as a reservoir outlet has facilitated the inland penetration of typical brackish water or tidal freshwater fish (e.g. *Dermogenys* cf. *pusilla*) and decapod crustaceans (e.g. *Macrobrachium equidens*) (H.H.Tan, personal communication; personal observation). However, the specimen of *P. amnicus* is probably part of a remnant freshwater population and not an invader from downstream brackish waters.

The eggs of *P. amnicus* are relatively few, suboval and large (*ca* $1{\cdot}2 \times 0{\cdot}9$ mm). Some larvae were obtained from ovigerous female specimens kept in aquaria and were of the highly abbreviated developmental type (Chong and Khoo, 1987).

Potamalpheops amnicus is a true freshwater prawn in that it can certainly complete its development entirely in freshwater. The fact that the only stream from which specimens (including ovigerous females and juveniles) have been taken in Singapore flows from one reservoir to another and that both reservoirs have no connections to the sea confirms that the development of *P. amnicus* is independent of the sea. Furthermore, it has the common feature of many freshwater decapod Crustacea of bearing few, large eggs that hatch out to larvae with highly abbreviated development. In addition, the larvae are typically benthic (personal observation), behaving like the larvae of true freshwater *Macrobrachium* shrimps with highly abbreviated development (Chong and Khoo, 1987). Within the genus *Potamalpheops*, only *P. amnicus* and *P. haugi* are found in freshwaters above the tidal limit. The only other true freshwater member of the family Alpheidae is *Alpheus cyanoteles* Yeo and Ng, 1996, from Peninsular Malaysia (Yeo and Ng, 1996).

Remarks. Potamalpheops amnicus belongs to the group of *Potamalpheops* with two pairs of posterior telson spines (Bruce, 1991, 1993; Bruce and Iliffe, 1992). This group includes the African species, *P. monodi*; the Central American species, *P. stygicola*; the Indo-West Pacific species, *P. hanleyi, P. pininsulae* and *P. darwiniensis* and the southeast Asian species, *P. tigger* n. sp., and *P. miyai* n. sp.. *P. amnicus* most closely resembles *P. monodi*. The adults of the two species can be distinguished by differences in the rostrum, carapace, antennular peduncle, antenna, second pereiopod, second pleopod, exopod of uropod and eggs (see Table 1 for comparison). These characters are less reliable for separating juveniles.

Potamalpheops amnicus is easily separated from the rest of the southeast Asian and Indo-West Pacific species of *Potamalpheops* by its overall more elongated, more slender and streamlined appearance with distinctly smaller eyes. Closer examination of specimens would allow for confirmation of the identity of *P. amnicus* by two

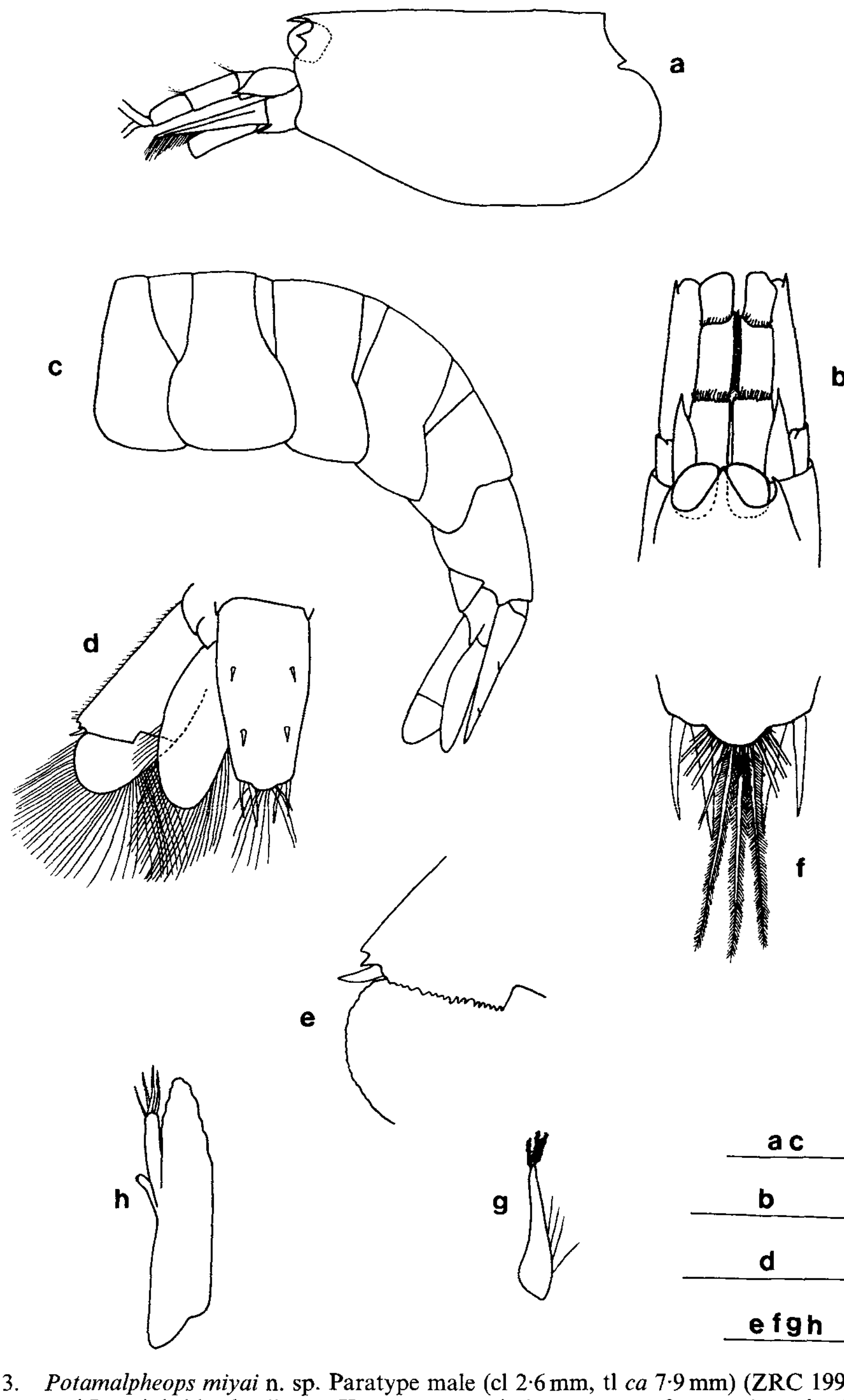

FIG. 3. *Potamalpheops miyai* n. sp. Paratype male (cl 2·6 mm, tl *ca* 7·9 mm) (ZRC 1996.42), Sungei Lagoi, bridge leading to Kampung Lagoi, downstream of reservoir outlet, Pulau Bintan, Indonesia: (a) lateral view of carapace; (b) dorsal view of anterior carapace; (c) abdomen; (d) uropod and telson; (e) diaeresis on distal end of uropodal exopod; (f) posterior margin and spines of telson; (g) endopod of left first pleopod; (h) appendix masculina and appendix interna on endopod of left second pleopod. Pinnae of plumose setae of scaphocerite, uropod and telson, and plumose setae of second pleopod not drawn in. Scales = 1·0 mm in (a, c); 1·0 mm in (b); 1·0 mm in (d); 0·3 mm in (e–h).

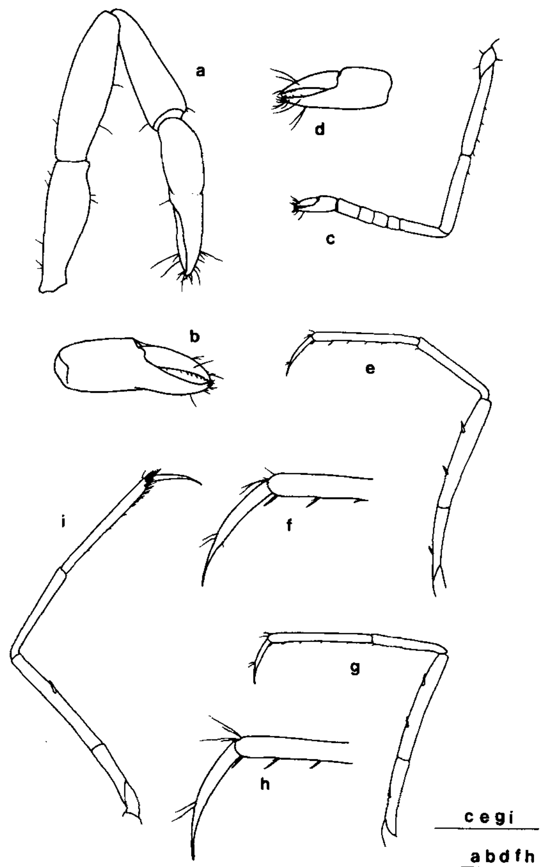

FIG. 4. *Potamalpheops miyai* n. sp. a–h, Paratype male (cl 2·6 mm, tl *ca* 7·9 mm) (ZRC 1996.42), Sungei Lagoi, bridge leading to Kampung Lagoi, downstream of reservoir outlet, Pulau Bintan, Indonesia. i, Paratype male (cl 2·7 mm, tl *ca* 8·7 mm) (ZRC 1996.245), same locality: (a) left first pereiopod; (b) chela of left first pereiopod; (c) left second pereiopod; (d) chela of left second pereiopod; (e) left third pereiopod; (f) propodus and dactylus of left third pereiopod; (g) left fourth pereiopod; (h) propodus and dactylus of left fourth pereiopod; (i) left fifth pereiopod. Scales = 1·0 mm in (c, e, g, i); 0·3 mm in (a, b, d, f, h, j).

diagnostic characters: (i) the broadly curved toothed dorsal flange of diaeresis (Fig. 1 e) (versus straight toothed flange) and (ii) the short, robust distal spines on the appendix masculina of the pleopodal endopod (Fig. 1 h) (versus long, slender distal spines).

Distribution. Kota Tinggi, Johore, Peninsular Malaysia. Central Catchment Area, Singapore. Sungei Lagoi, Pulau Bintan, Riau Archipelago, Indonesia.

Potamalpheops miyai, n. sp.
(Figs 3, 4)

Material examined.

HOLOTYPE: 1♂ (ZRC 1996·16), Sungei Lagoi, bridge leading to Kampung Lagoi, downstream of reservoir outlet, Pulau Bintan, Indonesia, coll. H. H. Tan, 27 June 1995.

PARATYPES: 2♂♂, 11♀♀ (ZRC 1996·42), same data as holotype. 1♂ (ZRC 1996·245), same data. 1♂, 2♀♀ (BMNH), same data. 1♂, 2♀♀ (RMNH), same data.

Description of paratype. Small-sized alpheid shrimp, subcylindrical, slightly compressed body form.

Rostrum (Fig. 3 a, b) very short, reaching distal margin of cornea and base of dorsally visible portion of proximal segment of antennular peduncle, broadly triangular in dorsal view, dorsal carina obsolete, ventral carina very slightly developed, unarmed, lateral carina weakly developed, expanded posteriorly to conceal posterior part of cornea.

Carapace (Fig. 3 a) glabrous, smooth; anterior margin leaving cornea of eyes largely exposed dorsally and partially exposed laterally, extra-corneal tooth well developed, acute, reaching about midpoint of cornea, inferior orbital angle weakly produced, rounded, pterygostomial angle feebly produced, rounded, sparsely setose; ventral margin sparsely setose; cardiac notch distinct.

Abdomen (Fig. 3 c) glabrous, smooth; sixth segment about 1·3 × length of fifth, 1·3 × longer than deep, compressed, posterior lateral angle subacute, posteroventral angle with articulated triangular plate; pleura of first two segments broadly rounded, third and fourth subrectangular, fifth obtuse with posteroventral angle rounded. Telson (Fig. 3 d, f) about 1·1 × length of sixth segment, 2·2 × longer than anterior width, lateral margins subparallel proximally, slightly convergent distally, with two pairs of dorsal spines about 0·08 of telson length, anterior pair at about 0·4 of telson length, posterior pair at about 0·6 of telson length; posterior margin about 0·6 of anterior width, with two pairs of subequal, robust lateral spines, about 2·2 × longer than dorsal spines length, central broadly rounded portion occupying 0·3 of posterior margin width, with about 10 long plumose setae, and numerous small spiniform setae dorsally.

Antennule (Fig. 3 b) with peduncle about 0·6 of carapace length, distinctly exceeding scaphocerite and carpocerite; proximal segment about 3·5 × longer than broad, distal margin distinctly dentate and sparsely setose, with distally acute ventromedial carina; stylocerite suboval, with terminal distal spine just exceeding anterior margin of proximal segment; intermediate segment subcylindrical, about 0·7 × proximal segment length, 2·5 × longer than wide, with long plumose ventromedial setae, distal margin entire and sparsely setose; distal segment 0·4 of proximal segment length, distal margin entire; upper flagellum biramous, broken; lower flagellum broken.

Antenna (Fig. 3 b) with basicerite stout, with acute ventrolateral tooth, not reaching distal margin of proximal segment of antennular peduncle, carpocerite subcylindrical, not reaching distal margin of distal segment of antennular peduncle, not exceeding scaphocerite, about 3 × longer than wide, flagellum missing; scaphocerite reaching anterior margin of distal segment of antennular peduncle, 2·5 × longer than wide, broadly rounded distally, lateral margin straight, with acute distolateral tooth slightly exceeding anterior margin of lamella.

Eyes (Fig. 3 a, b) mostly exposed dorsally and partially exposed laterally, slightly concealed posteriorly by anterior and lateral margins of carapace, cornea about 0·2 × of carapace length.

First pereiopods (Fig. 4 a, b) small, subequal, similar; chela small, about 0·2 of carapace length, 3 × longer than broad, palm 1·5 × longer than broad, smooth, dactylus about 4·3 × longer than proximal breadth, 0·5 of chela length, tapering, tip with two distal teeth, sparsely setose, cutting edge entire, fixed finger similar;

carpus elongated, expanded distally, about 0·7 of chela length, 1·3 times length of palm of chela, 4 × longer than distal width; merus 3 × longer than central width, subequal to chela length; ischium 2·5× longer than central width, 0·8 of chela length; basis normal; coxa robust.

Second pereiopods (Fig. 4 c) slender; chela (Fig. 4 d) small, about 2 × longer than broad; palm as long as broad; dactylus 0·3 of chela length, tip with two small distal teeth, with cutting edge entire, sparsely setose; fixed finger similar; carpus about 2·5 × chela length, 1·3 × merus length, 5-segmented, articles in approximate ratio of 10 : 2 : 2 : 2 : 4; merus 0·8 of carpus length, 8 × longer than broad, unarmed; ischium 1·1 × as long as merus, 9 × longer than broad, basis normal, coxa robust.

Third pereiopods (Fig. 4 e, f) extending beyond antennular peduncle, dactylus simple, with feebly demarcated unguis, sparsely setose, 0·5 × propodus length, 10 × longer than proximal width; propodus about 2 × longer than dactylus, 12·5 × as long as broad, with a pair of distoventral spines, with five ventral spines, sparsely setose; carpus about 0·8 of propodus length, 8 × longer than distal width, with a single small distoventral spine; merus 1·1 × length of propodus, 5·5 × as long as broad, with two robust ventrolateral spines at 0·4 and 0·7 of merus; ischium about 0·6 of merus, 7 × longer than distal width, with single robust ventrolateral spine at 0·6 of ischium; basis normal, coxa robust. Fourth pereiopods (Fig. 4 g, h) similar to third pereiopods; dactylus simple, with feebly demarcated unguis, sparsely setose, 0·5 × propodus length, 10 times longer than proximal width; propodus about 2 × longer than dactylus, 12·5 × longer than broad, with a pair of distoventral spines, with four ventral spines, sparsely setose; carpus about 0·7 of propodus length, 7·8 × longer than distal width, with a single small spine distoventrally; merus about 1·1 × propodus, 11 × as long as broad, with two robust ventrolateral spines at 0·4 and 0·7 of merus; ischium about 0·6 of merus, 7 × longer than distal width, with one robust ventrolateral spine at 0·6 of ischium; basis normal; coxa robust. Fifth pereiopods missing.

Pleopods normal; endopod of first pleopod (Fig. 3 g) 3 × longer than basal breadth, tapering distally, with three spiniform setae distally, four medially; endopod of second pleopod (Fig. 3 h) 6 × longer than broad, with appendices at about 0·5 of endopod; appendix masculina subcylindrical, 6·7 × longer than wide, with four long simple spines distally; appendix interna about 0·5 of appendix masculina length, with distal cincinnuli, inserted just posterior to appendix masculina, about 5 × as long as broad.

Uropod (Fig. 3 d) protopod with acute distolateral lobe, rami exceeding posterior margin of telson; exopod 2·4 × longer than wide, lateral margin straight, with ventral submarginal setal fringe, distolateral angle produced as a small acute distal tooth, diaeresis (Fig. 3 e) well developed, with straight dentate dorsal flange laterally, extending about 0·6 of breadth, with single stout movable lateral spine, flanked by stout acute tooth laterally, dorsal flange with about 17 small blunt teeth, distal lobe broadly rounded, with long plumose marginal setae, with short spiniform marginal setae; endopod about 0·8 × exopod length, 2·5 × as long as broad.

Measurements. Carapace length 2·6 mm, total length *ca* 7·9 mm.

Variation. The holotype (ZRC 1996·16) (carapace length 3·0 mm; total length *ca* 9·0 mm) is larger than the described paratype (ZRC 1996·42) (carapace length 2·6mm, total length *ca* 7·9 mm). The holotype differs from the paratype in having: (i) a slightly more slender rostrum; (ii) 12 long plumose setae on the posterior telson margin instead of 10; (iii) a more robust telson (about 2 × longer than anterior width versus 2·2 ×); (iv) one lateral telson spine broken; (v) more robust antennular peduncles

(0·4 × of carapace length versus 0·6 of carapace length); (vi) about 18 teeth on the dorsal flange of the diaeresis (versus about 17 teeth).

The following variation was also noted in the other specimens examined:

Rostrum. The dorsal shape of the rostrum varies from broadly triangular to slightly slender.

Abdomen. The telson length ranges from 1·1 to 1·5 × of the 6th segment and 2–2·4 × of the anterior telson width. The dorsal spine length in relation to telson length varies from 0·08 to 0·09. The posterior telson width varies in relation to the anterior width (0·6 to 0·7 ×). The length of the posterior telson spines is between 2·2 and 3 × the dorsal spine length. The long plumose setae on the posterior telson margin varies in number from 10 to 13.

Antennules. The antennular peduncle length with respect to the carapace length ranges from 0·4 to 0·6. The stylocerite just reaches or exceeds the distal margin of the proximal segment. The slenderness of the proximal segment varies between 2·3 and 3·5 × as long as broad. The intermediate segment of the antennular peduncle is shorter than the proximal to varying degrees (0·7–0·9 ×) and also varies in slenderness (2–3 × as long as broad). The distal segment also varies with respect to the proximal segment (0·3–0·5 ×). The robustness of the distal segment varies between 1 and 1·5 × as long as broad.

Eyes. Cornea size varies little in relation to the carapace length (0·1–0·2 ×).

First pereiopods. The chela varies from 3 to 4 × as long as broad. The slenderness of the palm of the chela varies from 1·5 to 2 × as long as broad. The relative length of the carpus ranges from 1·3 to 1·7 × the palm length of the chela. The carpus also varies in slenderness (2–4 × longer than distal width). The merus length to palm length ratio is 1·5–2. The slenderness of the merus also ranges from 2·5 to 5 × as long as the central width.

Second pereiopods. The carpus length in relation to the chela is 2–2·5. The ratio of carpus articles in relation to the first carpus article also shows some variation giving an average ratio of about 10 : 2·2 : 2·2 : 2·2 : 4·9 (expressed to nearest integer for clarity and easy comparison gives a ratio of 10 : 2 : 2 : 2 : 5).

Third pereiopods. Ranges of relative proportions used in comparisons are as follows: dactylus (7·1–10 × as long as proximal width), propodus (11·1–12·5 × as long as broad), carpus (7–9 × longer than distal width). The number of ventral spines of the propodus ranges from 6 to 7.

Fourth pereiopods. The number of ventral spines of the propodus ranges from 4 to 7. The small distoventral spine on the carpus is sometimes absent. The more distal of the two movable spines on the merus is positioned at 0·3–0·4 of the merus, the more proximal at 0·7–0·8 of the merus.

Fifth pereiopods. With similar proportions to the third and fourth pereiopods (Fig. 4i). The number of ventromedial spines of the propodus varies from 2 to 5. There may be 7–9 rows of ventrolateral serrulate spines on the propodus. The positions of the merus spines vary, with the distal spine being located at 0·3–0·5 of the merus and the more proximal spine located at 0·5 to 0·7 of the merus. The proximal spine is sometimes absent. The ischial spine is usually absent.

Second pleopods. In males, the length of the appendix masculina with respect to the appendix interna ranges from 2 to 3 ×.

Uropods. Proportions vary in the exopod (2–2·4 × as long as broad) and endopod (2·2–2·5 × as long as broad). The number of teeth on the dorsal flange of the diaeresis varies from about 14 to 23.

As in the case of *Potamalpheops amnicus*, n. sp., the number of dorsal flange teeth of the diaeresis as well as spines on ambulatory appendage propods tends to be fewer in small adults and juveniles (where the number falls below that of the abovementioned range). The proportions of appendage segments also differs between adults and juveniles. Variations here are for adult specimens.

Etymology. The species is named after Professor Yasuhiko Miya, who first noted the presence of the genus *Potamalpheops* in this region and brought it to our attention.

Colour. The live animals are dark and striped over a background of dark purplish to purplish-grey. The stripes are due to the presence on the posterior-lateral margin of the carapace as well as of the abdominal segments of even darker, greyish to purplish-grey bands of varying thickness (H. H. Tan, personal communication).

Ecology. Specimens of *Potamalpheops miyai* were collected from isolated pools in mangrove mud left behind by receding tidal waters. The area is part of an inland riverine mangrove habitat with typical vegetation including *Rhizophora* sp., *Pandanus* sp. and *Hibiscus tiliaceus*. Fish collected together with the *P. miyai* specimens include *Brachygobius kabiliensis*, *Mugilogobius chulae*, *Ophiocara porocephala* and *Gobiopterus* sp. Also collected were other decapod crustaceans such as *Episesarma* cf. *singaporensis*, *Varuna yui*, *Neosesarma* sp., *Alpheus euphrosyne* and *Macrobrachium equidens* (H. H. Tan, personal communication). The above clearly indicates the tidal and brackish nature of the habitat. However, *Channa lucius* as well as *Caridina* sp. were also obtained from that site (H. H. Tan, personal communication), suggesting that the area is part of the transition zone from freshwater to brackish water.

The live specimens of *P. miyai* when out of water tended to wriggle about on their sides in amphipod fashion rather than crawl about on their legs or jump about (H. H. Tan, personal communication).

Remarks. *Potamalpheops miyai* is similar to all other known species of Southeast Asian (*P. amnicus* n. sp. and *P. tigger* n. sp.) and Indo-West Pacific (*P. darwiniensis*, *P. pininsulae* and *P. hanleyi*) *Potamalpheops* in having two pairs of posterior telson spines. The African species, *P. monodi* and the Central American species, *P. stygicola* also belong to this group (Bruce, 1991, 1993; Bruce and Iliffe, 1992). The two remaining species from Africa, *P. haugi* and *P. pylorus* have only one pair of posterior telson spines. *Potamalpheops miyai* appears to be most closely related with *P. hanleyi*. *P. miyai* can be distinguished from *P. hanleyi* by its generally longer and more slender appendages (antennular peduncles and first to fourth pereiopods) as well as by differences in the carapace (see Table 2 for comparison). These characters are useful primarily for adult specimens.

Potamalpheops miyai is easily separated from the other species of Southeast Asian and Indo-West Pacific *Potamalpheops* by: (i) the distinctly dentate distal margin of the proximal antennular peduncle segment (Fig. 3 b) and (ii) the presence of a pair of robust outer teeth on the diaeresis lateral to the movable spine (with the more lateral of the two being an extension of the distolateral angle of the lateral margin of the exopod) (Fig. 3 e).

Distribution. This species has so far only been recorded from its type locality, Sungei Lagoi in Pulau Bintan, Riau Archipelago, Indonesia.

Table 2. Differences between *Potamalpheops hanleyi* Bruce, 1991, and *P. miyai* n. sp.

Character	*Potamalpheops hanleyi*†	*Potamalpheops miyai*
Carapace	Inferior orbital angle slightly more produced and less broadly rounded.	Inferior orbital angle more broadly rounded.
	Ventral margin non-setose.	Ventral margin sparsely setose.
Antennular peduncle	Intermediate segment without ventromedial setae.	Intermediate segment with long plumose ventromedial setae.
	Intermediate segment robust (about as long as broad).	Intermediate segment slender (about 2–3 × as long as broad).
	Intermediate segment relatively short (ratio of isl/psl 0·5)	Intermediate segment relatively long (ratio of isl/psl 0·7–0·9).
First pereiopod	Carpus robust (about 1·8× longer than distal width).	Carpus slender (about 2–4 × longer than distal width).
	Carpus relatively short (subequal to palm).	Carpus relatively long (about 1·3–1·7 × length of palm).
	Merus robust (about 2·3 × longer than central width).	Merus slender (about 2·5–5 × longer than central width).
	Merus relatively short (about 1·2 × length of palm).	Merus relatively long (about 1·5–2 × length of palm).
Second pereiopod	First article of carpus relatively short (ratio of carpus articles 10:5:5:5:7·5).	First article of carpus relatively long (ratio of carpus articles 10:2:2:2:5).
Third pereiopod	Relatively short (reaching about end of antennular peduncle).	Relatively long (distinctly exceeding antennular peduncle).
	Dactylus slender (about 4 × longer than proximal width).	Dactylus more slender (about 7·1 to 10 × longer than proximal width).
	Propodus robust (about 9 × as long as broad).	Propodus slender (about 11·1–12·5 × as long as broad).
	Propodus relatively short (about 0·3 of carapace length).	Propodus relatively long (about 0·4 of carapace length).
	Propodus with seven ventral spines.	Propodus with 5–6 ventral spines.
	Carpus robust (about 3·4 × longer than distal width).	Carpus slender (about 7–9 × longer than distal width).
	Carpus relatively short (about 0·5 × propodus length).	Carpus relatively long (about 0·8 × propodus length).
Fourth pereiopod	Ischium unarmed.	Ischium with a single movable spine.

†Data from description and figures by Bruce (1991).

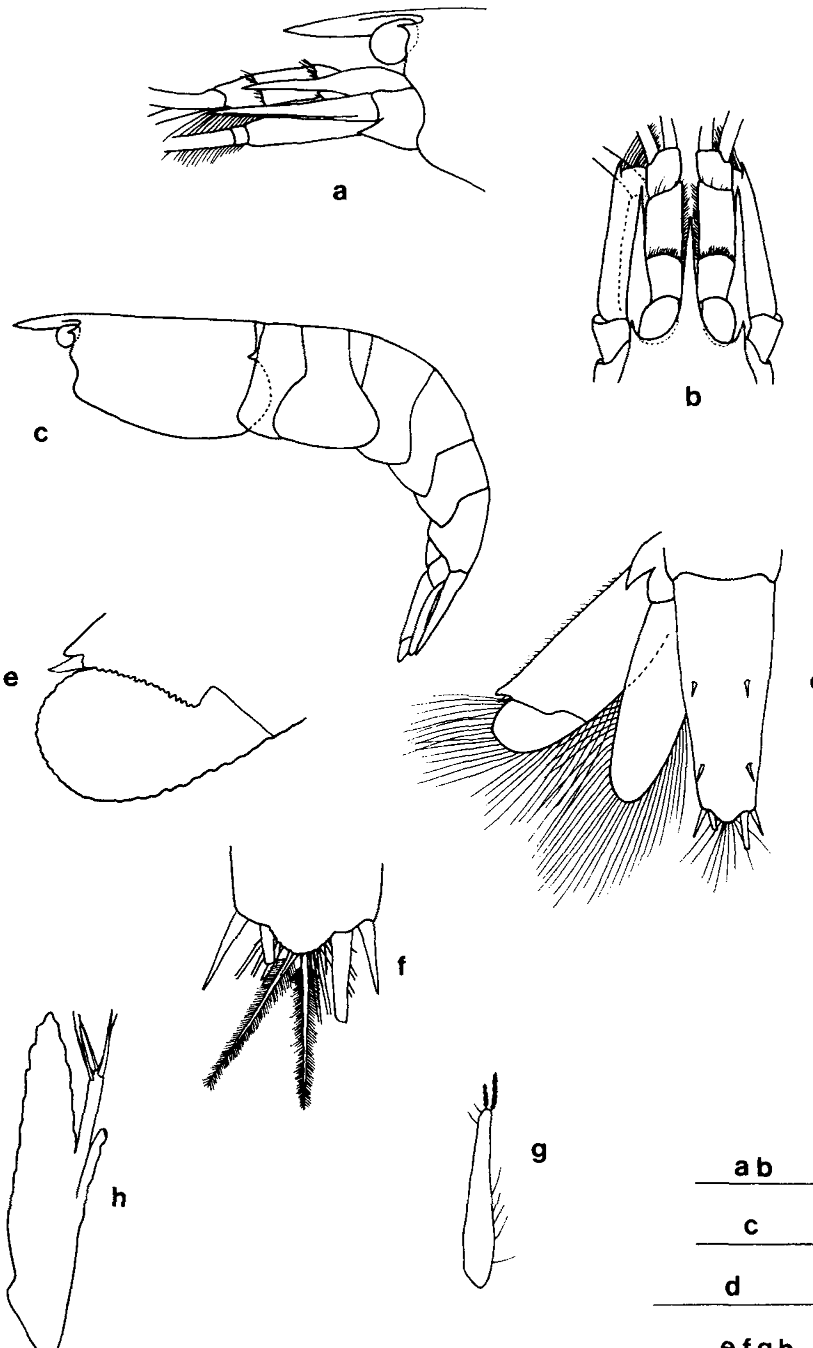

FIG. 5. *Potamalpheops tigger* n. sp. Paratype male (cl 3·9 mm, tl *ca* 12 mm) (ZRC 1996.7), Sungei Buloh mangroves, Singapore: (a) lateral view of anterior carapace; (b) dorsal view of anterior carapace; (c) lateral view of carapace and abdomen; (d) uropod and telson; (e) diaeresis on distal end of uropodal exopod; (f) posterior margin and spines of telson; (g) endopod of right first pleopod; (h) appendix masculina and appendix interna on endopod of right second pleopod. Pinnae of plumose setae of scaphocerite, uropod and telson, and plumose setae of second pleopod not drawn in. Scales = 1·0 mm in (a, b); 2·0 mm in (c); 1·0 mm in (d); 0·3 mm in (e–h).

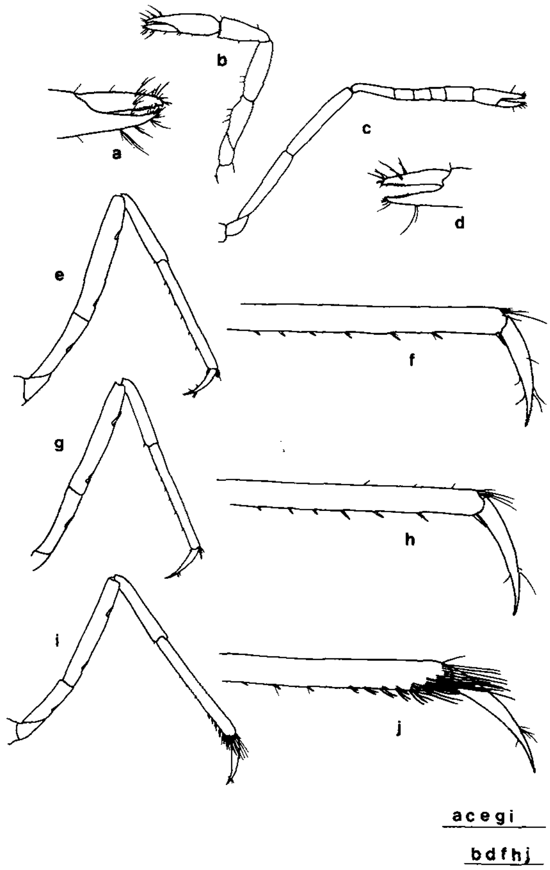

FIG. 6. *Potamalpheops tigger* n. sp. Paratype male (cl 3·9 mm, tl *ca* 12 mm) (ZRC 1996.7), Sungei Buloh mangroves, Singapore: (a) right first pereiopod; (b) fingers of chela of right first pereiopod; (c) right second pereiopod; (d) fingers of chela of right second pereiopod; (e) right third pereiopod; (f) propodus and dactylus of right third pereiopod; (g) right fourth pereiopod; (h) propodus and dactylus of right fourth pereiopod; (i) right fifth pereiopod; (j) propodus and dactylus of right fifth pereiopod. Scales = 1·0 mm in (a, c, e, g, i); 0·3mm in (b, d, f, h, j).

Potamalpheops tigger, n. sp.
(Figs 5, 6)

Material examined

HOLOTYPE: 1♂ (ZRC 1996·6), Sungei Buloh mangrove, Singapore, coll. P. K. L. Ng *et al.*, 5 August 1995.

PARATYPES: 15♂♂, 18♀♀ (ZRC 1996.7), same data as holotype. 3♂♂, 3♀♀ (BMNH), same data. 2♀♀ (RMNH), same data. 1♂, 2♀♀ (RMNH), Sungei Buloh mangroves, Singapore, coll. P. K. L. Ng *et al.*, 14 January 1994. 1♂, 1♀ (ZRC 1996.8), Lim Chu Kang mangroves, Singapore, coll. P. K. L. Ng *et al.*, 18 September 1995.

Description of Paratype. Small sized alpheid shrimp, subcylindrical body form, body slightly laterally compressed.

Rostrum (Fig. 5 a, b) long, distinctly exceeding anterior margin of dorsally visible portion of proximal segment of antennular peduncle, reaching about 0·6 of intermediate segment of antennular peduncle, about 0·3 of carapace length, slender and acutely tapering in dorsal view, dorsal carina obsolete, ventral carina very weakly developed, unarmed, lateral carina weakly developed, slightly expanded posteriorly, concealing small portion of cornea posteriorly.

Carapace (Fig. 5 a) glabrous, smooth; anterolateral region concealing very little of posterior portion of cornea, leaving most of cornea exposed, extra-corneal tooth well developed, inferior orbital angle feebly produced, rounded, pterygostomial angle produced, bluntly rounded; cardiac notch distinct.

Abdomen (Fig. 5 c) glabrous, smooth; sixth segment about 1·8 × length of fifth, 1·6 × longer than deep, compressed, posterior lateral angle subacute, posteroventral angle with articulated triangular plate; pleura of first three segments broadly rounded, fourth subrectangular, fifth subacute, posteroventral angle subacute. Telson (Fig. 5 d, f) about 1·1 × length of sixth segment, 2·5 × longer than anterior width, lateral margins subparallel proximally, slightly convergent distally, with two pairs of dorsal spines about 0·07 of telson length, anterior pair at 0·4 of telson length, posterior pair at 0·7 of telson length; posterior margin about 0·5 of anterior width, with two pairs of unequal robust lateral spines, lateral pair about 2 × length of dorsal spines, medial pair (tips broken) about 3 × longer than dorsal spines, about 0·2 × telson length, strongly convex central portion of posterior margin occupying about 0·5 of posterior margin width, with nine long plumose setae, with numerous small spiniform setae dorsally.

Antennule (Fig. 5 b) with peduncle robust, about 0·4 of carapace length, distinctly exceeding scaphocerite and carpocerite; proximal segment 2·3 × as long as broad, distal margin minutely dentate and sparsely setose, with well developed distally acute ventromedial carina; stylocerite slender, acute, distinctly exceeding anterior margin of intermediate segment; intermediate segment subcylindrical, about 0·7 × proximal segment length, 1·7 × longer than wide, distal margin minutely dentate and sparsely setose, with long plumose ventromedial setae; distal segment as long as broad, about 0·4 of proximal segment length, non-setose; upper flagellum biramous, proximal 12 segments fused, with about 15 groups of aesthetascs, longer ramus slender, tip missing; lower flagellum slender, slightly exceeding upper flagellum, tip missing.

Antenna (Fig. 5 b) with basicerite stout, with well developed, acute ventrolateral tooth, reaching about 0·5 of proximal segment of antennular peduncle, carpocerite subcylindrical, distinctly shorter than antennular peduncle, reaching distal margin of intermediate segment, about 2·7 × longer than wide, flagellum slender, about 1·9 × carapace length, tip broken, proximal segments not thickened; scaphocerite not exceeding anterior margin of distal segment of antennular peduncle, 2 × longer than central width, broadly rounded distally, lateral margin straight, with acute distolateral tooth slightly exceeding anterior margin of lamella.

Eyes (Fig. 5 a, b) mostly exposed dorsally and laterally, with oval oblique cornea, cornea with dorsal longitudinal diameter about 0·1 × of carapace length.

First pereiopods (Fig. 6 a, b) small, subequal, similar; chela small, about 0·2 of carapace length, 3·5 × longer than broad, palm 2 × longer than broad, smooth, dactylus about 3·8 × longer than proximal breadth, 0·4 of chela length, tapering, tip with two distal teeth, sparsely setose, cutting edge entire, fixed finger similar, with small, weakly developed tooth near distal tip; carpus elongated, conical-shaped, about 0·7 of chela length, 1·3 × length of palm of chela, 2·5 × longer than distal width; merus 3 × longer than central width, 0·9 of chela length; ischium 2·5 × longer than central width, subequal in length to carpus, 0·7 of chela length; basis normal; coxa robust.

Second pereiopods (Fig. 6 c) slender; chela small, about 0·1 of carapace length, about 5 × longer than broad; palm 3 × longer than broad; dactylus 0·4 of chela length, tip with two distal teeth (Fig. 6 d), with cutting edge entire, sparsely setose; fixed finger 0·4 of chela length, tip with two distal teeth, with cutting edge entire, sparsely setose; carpus about 2·4 × chela length, 1·3 × merus length, 5-segmented, articles in approximate ratio of 10 : 5 : 5 : 2·5 : 7·5 (rounded off to nearest integer to facilitate comparison giving a ratio of 10 : 5 : 5 : 3 : 8); merus 0·8 of carpus length, 9 × longer than broad, unarmed; ischium 0·9 × as long as merus, 8 times longer than broad, basis normal, coxa robust.

Third pereiopods (Fig. 6 e, f) exceeding antennular peduncle, with dactylus simple, curved, without distinct unguis, sparsely setose, 0·3 × propodus length, 5·7 × longer than proximal width; propodus about 3 × longer than dactylus, 0·3 × of carapace length, 13·3 × as long as broad, with a pair of distoventral spines, with 6 small ventral spines, sparsely setose; carpus about 0·7 of propodus length, 8 × longer than distal width, with a single small distoventral spine; merus subequal to propodus, 6 × as long as broad, with two robust ventrolateral spines at 0·3 and 0·9 of merus length; ischium about 0·7 of merus, 4 × longer than distal width, with single robust spine ventrolaterally at 0·5 of ischium length; basis normal, coxa robust. Fourth pereiopods (Fig. 6 g, h) with dactylus simple, curved, without distinct unguis, sparsely setose, 0·5 × propodus length, 6·3 × longer than proximal width; propodus about 2·2 × longer than dactylus, 11 × as long as broad, with a pair of distoventral spines, with six small ventral spines, sparsely setose; carpus about 0·6 of propodus length, 7 × longer than distal width, with a single small distoventral spine; merus 1·1 × of propodus, 6 × as long as broad, with two robust ventrolateral spines at 0·3 and 0·8 of length; ischium about 0·6 of merus, 3·5 × longer than distal width, with single robust ventrolateral spine at 0·5 of ischium length; basis normal, coxa robust. Fifth pereiopods (Fig. 6 i, j) with dactylus simple, curved, without distinct unguis, sparsely setose, 0·4 × propodus length, 6·3 × longer than proximal width; propodus about 2·4 × longer than dactylus, 12 × as long as broad, with three small ventral spines, with about 8 ventrolateral transverse rows of serrulate setae, increasing in number and size distally; carpus about 0·7 of propodus length, 8 × longer than distal width, unarmed; merus 0·9 × of propodus, 11 × as long as broad, with two robust ventrolateral spines at 0·3 and 0·8 of length; ischium about 0·5 of merus, 3 × longer than distal width, with single robust ventrolateral spine at 0·5 of ischium length; basis normal, coxa robust.

Pleopods normal; endopod of first pleopod (Fig. 5 g) tapering distally, 5·7 × longer than basal breadth, with four long plumose setae distally and several medially and laterally; endopod of second pleopod (Fig. 5 h) robust, 4 × longer than broad, with appendices at 0·5 of endopod; appendix masculina subcylindrical, 10 × longer than wide, with five long terminal spines; appendix interna with distal cincinnuli, inserted just posterior to appendix masculina, about 10 × as long as broad, 0·7 × appendix masculina length..

Uropod (Fig. 5 d) protopod with acute distolateral lobe, rami reaching posterior margin of telson; exopod 2·8 × longer than wide, lateral margin straight, with ventral submarginal setal fringe, distolateral angle produced as a single acute distal tooth, with single larger movable spine medially, diaeresis (Fig. 5 e) well developed with straight dentate dorsal flange laterally, extending about 0·6 of breadth, with about 18 small blunt teeth, distal lobe broadly rounded, with long plumose marginal setae, with short spiniform marginal setae; endopod about 0·9 × exopod length, 3·3 × as long as broad.

Measurements. Carapace length 3·9 mm, total length *ca* 12 mm.

Variation. The holotype (ZRC 1996.6) (carapace length 4·2 mm; total length *ca* 12·7 mm) is slightly larger than the described paratype (ZRC 1996.7) (carapace length 3·9 mm, total length *ca* 12 mm). The holotype differs from the paratype in having: (i) 12 long plumose setae on the posterior telson margin instead of nine; (ii) shorter dorsal telson spines (0·05 relative to the telson length versus 0·07 ×); (iii) intact lateral telson spines; (iv) more robust antennular peduncles (proximal segment 2 × as long as broad versus 2·3 ×; intermediate segment 1·5 × as long as broad versus 1·7 ×); (v) about 23 teeth on the dorsal flange of the diaeresis (versus 18 teeth).

The following variation was also noted in the other specimens examined:

Rostrum. The rostral length in relation to the antennular peduncle is variable, with the rostrum reaching about 0·3–0·6 of the intermediate segment. Rostra just exceeding the distal margin of the proximal segment are rare.

Abdomen. The telson length ranges from 1·1 to 1·4 × of the 6th segment and 2–2·7 × of the anterior telson width. The dorsal spine length in relation to telson length varies from 0·06 to 0·07. The posterior telson width varies in relation to the anterior width (0·6–0·9 ×). The length of the lateral pair of posterior telson spines is between 1 and 5 × dorsal spine length while the medial pair varies between 2 and 7 × dorsal spine length. The length of the medial pair with respect to the telson length varies between 0·2 and 0·4. The long plumose setae on the posterior telson margin varies in number from 9 to 14.

Antennules. The antennular peduncle length with respect to the carapace length ranges from 0·3 to 0·5, with the antennular peduncle exceeding the distal margin of the scaphocerite sometimes barely and sometimes distinctly. The stylocerite rarely fails to reach the distal margin of the intermediate segment and usually just reaches or exceeds it. The intermediate segment of the antennular peduncle is shorter than the proximal to varying degrees (0·3–0·5 ×). The distal segment also varies with respect to the proximal segment (0·4 to 0·5 ×). The robustness of the distal segment varies between 1 and 1·3 × as long as broad.

Antennae. The lateral tooth of the scaphocerite varies from barely reaching to just exceeding the anterior margin of the lamella.

Eyes. The cornea size varies in relation to the carapace length (0·08–0·2 ×).

First pereiopods. The slenderness of the palm of the chela varies from 1 to 2 × as long as broad. The relation of the movable as well as fixed finger length to the chela length is relatively constant (0·4–0·5 ×). The relative length of the carpus ranges from 1·3 to 1·5 × the palm length of the chela. The merus length to chela length ratio is 0·8–0·9. The slenderness of the merus also shows variation (2·7–3 × as long as central width).

Second pereiopods. The carpus length in relation to the chela and merus is 2·4–2·8 and 1·3–1·6 respectively. The ratio of carpus articles in relation to the first carpus article also shows some variation giving an average ratio of about 10 :4 ·3 : 3·9 : 3·3 : 6·7 (expressed to nearest integer for clarity and easy comparison gives a ratio of 10 : 4 : 4 : 3 : 7).

Third pereiopods. Ranges of relative proportions used in comparisons are as follows: propodus (10 to 15 × as long as broad) (0·1–0·3 × of carapace length), carpus (5–8 times longer than distal width), merus (5·7–7 × longer than broad). The number of ventral spines of the propodus ranges from 6 to 7.

Fourth pereiopods. The number of ventral spines of the propodus ranges from 5 to 7. The small distoventral spine on the carpus is sometimes absent. The more distal of the two movable spines on the merus is positioned at 0·3–0·4 of the merus. The ischial spine may be present or absent.

Fifth pereiopods. The number of ventromedial spines of the propodus varies from 3 to 6. There may be 5–8 rows of ventrolateral serrulate spines on the propodus. The positions of the merus spines vary, with the distal spine being located at 0·3–0·5 of the merus and the more proximal spine located at 0·8–0·9 of the merus. The proximal spine is sometimes absent. The ischial spine is rarely absent.

Second pleopods. In males, the length of the appendix masculina with respect to the appendix interna ranges from 1·5–2 times.

Uropods. Proportions vary in the exopod (2·3–3 × as long as broad) and endopod (2·3–3·5 × as long as broad). The number of teeth on the dorsal flange of the diaeresis varies from about 17 to 24.

As in the case of the previous two species, the range of variations given here refers to adult specimens.

Colour. The posterior margin of the carapace has a dark purplish-grey band of varying width over a transluscent grey background. Clearly visible beneath the carapace, is the dark yellowish-brown to greenish gastric mass. The antennular peduncle is grey to dark grey in colour. The first, second and ambulatory pereiopods as well as the pleopods are overall transluscent grey. Like the carapace, the posterior margin of the transluscent grey abdominal segments possess dorsolateral bands of dark purplish-grey that vary in width, sometimes appearing as narrow marginal bands, other times covering almost the entire segment dorsally. This banding gives live specimens a distinctive bold striped appearance. The telson and uropods range from light to dark-purplish grey. Specimens kept in aquaria tend to lose the natural colouration, becoming almost totally transluscent or retaining the banding pattern as faint, thin lines.

Etymology. The species is named after the imaginary character of Tigger, A. A. Milne's portrayal of a tiger in 'Winnie the Pooh'. Alluding to the bold striped appearance of freshly caught live specimens. Used as a noun in apposition.

Ecology. Potamalpheops tigger specimens were found in mangroves on the northwest coast of Singapore during low tide under or within driftwood of fallen rotting logs and planks. Most of this driftwood, although within the littoral zone, was several metres away from the shallow main creek draining towards the sea but retained adequate moisture to provide a relatively humid microhabitat for the prawns. This observation was supported by the absence of the prawns from driftwood that was too high up or too dry. The waters of these mangrove areas are typically polyhaline (Johnson, 1965), with the salinity reaching that of seawater during high tides. The pH and conductivity of the water in the channel at low tide is 7·1 and about 1·7 millisiemens respectively. Syntopic species of alpheids include *Alpheus euphrosyne* and *A. microrhynchus*. The vegetation is a mixture of typical mangrove species including *Rhizophora* sp., *Avicennia* sp. and *Acanthus* sp.

The specimens of *P. tigger* rapidly scurry into the crevices of the driftwood or jump away when exposed. They appear to be accustomed to extended periods out of water (low tides) as shown by their strong ability and tendency to crawl over exposed surfaces and jump. This differs from some other members of the genus which never jump but move around on their sides in amphipod fashion or remain still when out of water, like *P. monodi* (Powell, 1976) and *P. amnicus*.

Table 3. Differences between *Potamalpheops pininsulae* Bruce and Iliffe, 1992, and *P. tigger* n. sp.

Character	*Potamalpheops pininsulae* †	*Potamalpheops tigger*
Rostrum	Relatively short (reaching about distal margin of proximal segment of antennular peduncle).	Relatively long (well exceeding distal margin of proximal segment of antennular peduncle, reaching about 0·3–0·6 of intermediate segment).
	Ventral margin usually with single small acute tooth, rarely unarmed.	Ventral margin unarmed.
Antennular peduncle	Distodorsal margin of proximal segment dentate with about eight acute teeth, smallest medially, largest laterally.	Distodorsal margin of proximal segment minutely dentate with subequal teeth.
	Stylocerite short, not reaching distal margin of intermediate segment or carpocerite.	Stylocerite elongated, distinctly exceeding distal margin of intermediate segment or carpocerite.
	Distodorsal margin of intermediate segment entire.	Distodorsal margin of intermediate segment minutely dentate.
	Distal segment $1{\cdot}5 \times$ as long as broad.	Distal segment more robust ($1-1{\cdot}3 \times$ as long as broad).
Second pereiopod	Carpus relatively long ($3 \times$ length of chela).	Carpus relatively short ($2{\cdot}4 \times$ length of chela).
	Second, third and fifth article relatively short (carpus article ratio 10 : 3 : 3 : 3 : 5).	Second, third and fifth article relatively more elongated (carpus article ratio 10 : 4 : 4 : 3 : 7).
Third pereiopod	Propodus long and slender ($27 \times$ as long as broad; $0{\cdot}5 \times$ of carapace length).	Propodus short and robust ($10-15 \times$ as long as broad; $0{\cdot}1-0{\cdot}3 \times$ of carapace length).
	Propodus with 10 ventral spines.	Propodus with 6–7 ventral spines.
	Carpus slender ($8{\cdot}5 \times$ longer than distal width).	Carpus robust ($5-8 \times$ longer than distal width).
	Merus slender ($8{\cdot}5 \times$ longer than broad).	Merus robust ($5{\cdot}7-7 \times$ as long as broad).
Second pleopod	Appendix masculina with five spines distally and seven spines laterally.	Appendix masculina with five spines distally.
Exopod of uropod	Dentate dorsal flange of exopod with about 32 teeth.	Dentate dorsal flange of exopod with about 17–24 teeth.
Telson	Lateral spines of posterior margin relatively short (lateral and medial pair subequal to dorsal spines; medial pair 0·13 of telson length).	Lateral spines of posterior margin relatively long (lateral pair $1-5 \times$ longer than dorsal spines; medial pair $2-7 \times$ longer than dorsal spines; medial pair 0·2 to 0·4 of telson length).
Eggs	Few, about 12, and large, about $1{\cdot}0 \times 0{\cdot}8$ mm.	Numerous and small, about $0{\cdot}4 \times 0{\cdot}3$ mm.

†Data after description and figures by Bruce and Iliffe (1992).

The eggs of *P. tigger* are numerous, suboval and relatively small with length of about 0·4mm and breadth about 0·3 mm.

Remarks. The genus *Potamalpheops* can be separated into two groups based on the number of lateral spines on the posterior margin of the rostrum (Bruce, 1991, 1993; Bruce and Iliffe, 1992). The larger group, consisting of species with two pairs of lateral spines on the telson includes *Potamalpheops monodi*, *P. stygicola*, *P. hanleyi*, *P. pininsulae*, *P. darwiniensis*, *P. amnicus* n. sp., and *P. miyai* n. sp.. *Potamalpheops haugi* and *P. pylorus* form the other group, both having a single pair of lateral spines on the telson. *Potamalpheops tigger* belongs to the former group and most closely resembles *P. pinisulae* because of the presence of a long rostrum, which is absent in other species. Several characters can be used to distinguish between the two species. The most obvious being the proportionately much longer stylocerite and rostrum of *P. tigger*. The other differences are seen in the rostrum, antennular peduncle, second pereiopod, third pereiopod, second pleopod, exopod of uropod and eggs (see Table 3 for summary of differences). However, these differences are more consistent and reliable in adults than in juveniles (see *Variation*) and are therefore more useful when applied to the former.

Among the remaining species, *P. tigger* appears to be most closely related to *P. hanleyi*. Apart from the longer, more slender rostrum, *P. tigger* can also be differentiated from *P. hanleyi* by the following: (i) a relatively longer intermediate segment of antennular peduncle (0·7 × proximal segment length versus 0·5 ×); (ii) distodorsal margin of intermediate segment of antennular peduncle minutely dentate (versus entire); (iii) appendix masculina with five distal spines (versus four distal spines); (iv) convex central portion of posterior margin of telson occupying about 0·5 of posterior margin (versus about 0·33 of posterior margin). *Potamalpheops tigger* can be immediately separated from all the other species of the genus by its much longer rostrum and stylocerite.

Distribution. *Potamalpheops tigger* has so far been recorded from two sites in Singapore, namely Sungei Buloh mangroves and Lim Chu Kang mangroves.

Discussion

The disjunct distribution [West Africa, Indo-West Pacific and Central America] of the members of this genus may reflect an ancient worldwide distribution which has fragmented (Bruce, 1991) (Fig. 7). Bruce (1991) suggested that the present species of *Potamalpheops* may have originated from a widespread marine group that became restricted over time to isolated populations in various refugia (e.g. mangroves, freshwater drainages, subterranean waters) that provide suitable niches and advantages like reduced competition or better nutrient supply. Bruce (1993) speculated: 'It seems likely that additional specimens or species of these shrimps, which are so far known only from very shallow coastal or fresh waters, will be found in due course, and will link the eastern distribution of the Indo-West Pacific species with those of the West African species'. This link has indeed been found with the discovery of *P. amnicus* from Peninsular Malaysia, Singapore, and Indonesia [Pulau Bintan, Riau Archipelago], *P. tigger* from Singapore and *P. miyai* from Indonesia [Pulau Bintan, Riau Archipelago], giving rise to a distribution spanning four continents. The occurrence of these new species increases the range of the genus and lends further support to the theory that the genus came from a widely distributed original stock while at the same time raising doubts as to whether the genus distribution is as disjunct as previously thought. In order to better understand the possible origins of

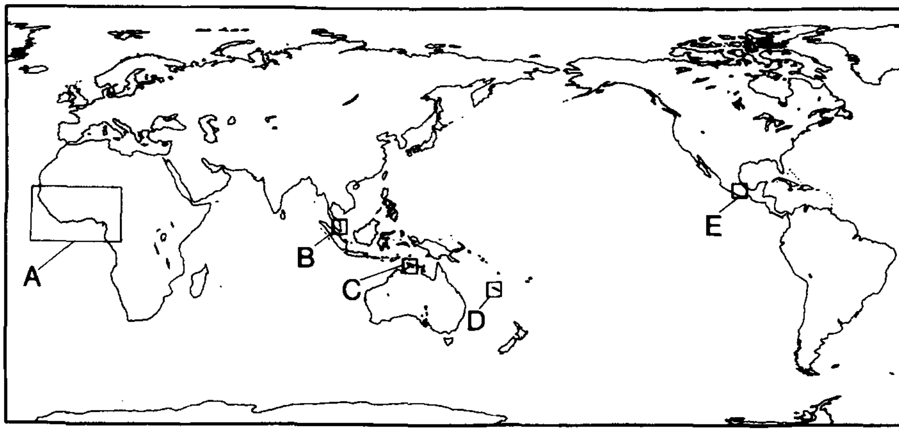

FIG. 7. Map showing worldwide distribution of *Potamalpheops* species: (A) Central West Africa: *P. haugi, P. monodi, P. pylorus*; (B) southeast Asia: *P. amnicus, P. miyai, P. tigger*; (C) Northern Australia: *P. darwiniensis, P. hanleyi*; (D) New Caledonia: *P. pininsulae*; E. Central America: *P. stygicola.*

the genus and to get a more complete picture of its worldwide distribution, it is necessary to obtain more specimens from coastal brackish waters and freshwaters which may lead to discovery of more new species or new records. It may also be necessary to review major collections from such areas because there is a high likelihood that specimens of *Potamalpheops* may have been collected but mistaken for similar-sized, closely related genera like *Athanas* or *Alpheopsis* as was the case with *A. stygicola* (Hobbs, 1973, 1983).

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