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A NEW SPECIES OF FRESHWATER SNAPPING SHRIMP, *ALPHEUS CYANOTELES* (DECAPODA: CARIDEA: ALPHEIDAE) FROM PENINSULAR MALAYSIA AND A REDESCRIPTION OF *ALPHEUS PALUDICOLA* KEMP, 1915

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ABSTRACT. - A new species of freshwater snapping shrimp, *Alpheus cyanoteles* (Decapoda: Caridea: Alpheidae) is described from Peninsular Malaysia. A comparison is made with its nearest congener, *Alpheus paludicola* Kemp, 1915. A lectotype is designated for *Alpheus paludicola* and an illustrated redescription is also provided.

INTRODUCTION

In the course of sampling freshwater streams of the Kota Tinggi district of Johor, Peninsular Malaysia in June to July 1995, a good series of a medium-sized snapping shrimp of the genus *Alpheus* was obtained. The waters of this drainage are permanent freshwaters, making this species the only true freshwater member of the genus *Alpheus*. This species clearly belongs to the *A. edwardsi* group as defined by Banner & Banner (1966) (modified from De Man, 1911) and closely resembles *Alpheus paludicola* Kemp, 1915. Johnson (1965, 1966) referred to snapping shrimp from the same above area as *A. paludicola* (mispelled as *Alpheus paludosus*). Tweedie (1938) also reported an alpheid shrimp from the same area which was not identified. Upon comparing with type material of *A. paludicola* loaned from the Natural History Museum, London, the present specimens showed a number of consistently different characters from *A. paludicola* s. str.

In this paper, the shrimp, *Alpheus cyanoteles*, new species, is described and figured. A lectotype is designated for *A. paludicola* to facilitate comparative work and a redescription with illustrations based on the lectotype and paralectotype is also provided. Brief comparisons are also made with two other closely related species of the *A. edwardsi* group from mangroves in Southeast Asia, namely *Alpheus euphrosyne* De Man, 1897, and *Alpheus microrhynchus* De Man, 1898, with variations in the latter species noted for comparative purposes. An identification key to the above species is provided.

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MATERIALS AND METHODS

The following abbreviations are used: tl (total length), cl (carapace length), chl (chela length), chb (chela breadth), mfl (movable finger length), mfb (movable finger breadth), ffl (fixed finger length), ffb (fixed finger breadth), isl (intermediate segment length), psl (proximal segment length), dl (dactylus length of third pereiopod), pl (propodus length of third pereiopod), ml (merus length of third pereiopod), ail (appendix interna length) and aml (appendix masculina length). The total length is measured from the tip of the rostrum to the distal margin of the telson. Carapace length is measured from the anterior margin of the orbital hood to the dorsal posterior margin of the carapace in lateral view. Antennular peduncle segment lengths are measured through the midline of the dorsally visible portions. Measurements of the chelae used in the descriptions are shown in Fig. 1. Measurements of total length or carapace length of large specimens were made using dial callipers.

Measurements of small parts were made from scales obtained directly with the aid of an objective micrometer set. All measurements are in millimetres. Types are deposited in the Natural History Museum, [formerly the British Museum of Natural History] (BMNH), London; Nationaal Naturhistorisch Museum [formerly the Rijksmuseum van Natuurlijke Historie] (RMNH), Leiden; and the Zoological Reference Collection (ZRC), Department of Zoology, National University of Singapore.

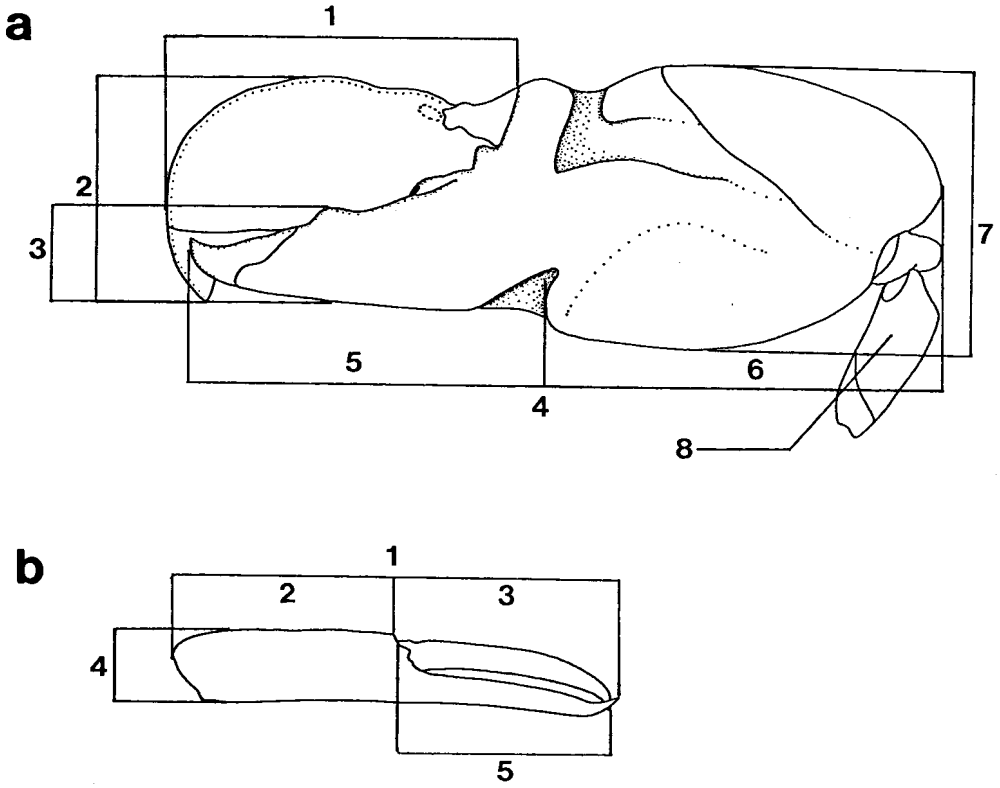

Fig. 1. a. Schematic drawing of modified/large chela of *Alpheus* species with the measurements used in the present study. 1: movable finger length; 2: movable finger breadth; 3: fixed finger breadth; 4: chela length; 5: fixed finger length; 6: palm length; 7: chela breadth; 8: merus (the ischium is fused to the merus in the first pereiopod of *Alpheus* species and the whole article is referred to as "merus"). b. Schematic drawing of non-modified chela of first pereiopod of *Alpheus* species and the measurements used. 1: chela length; 2: palm length; 3: fixed finger length; 4: chela breadth; 5: movable finger length.

SYSTEMATICS

FAMILY ALPHEIDAE RAFINESQUE, 1815

Alpheus Fabricius, 1798

Alpheus paludicola Kemp, 1915
(Figs. 2, 3)

Alpheus paludicola Kemp, 1915: 303-306, fig. 33, pl. 13: fig. 11-13; ? Kemp, 1918: 273.

Material examined. - Lectotype - 1 male (BMNH 1919.11.1.1), Outer Channel, Lake Chilka, Orissa, India, coll. S.Kemp, 1914.

Paralectotype - 1 male (BMNH 1919.11.1.2), same data as lectotype.

Description of Lectotype. - Subcylindrical body form, body slightly laterally compressed. Rostrum (figs. 2a, c) without setae, very short, barely exceeding anterior margin of orbital hood, reaching over about 0.1 of dorsally visible portion of proximal segment of antennular peduncle, broadly triangular in dorsal view, dorsal carina obsolete, ventral carina very weakly developed, unarmed, lateral carina confluent with anterior margin of orbital hoods.

Carapace (fig. 2a) glabrous, smooth; orbital hood margin (fig. 2c) totally concealing eyes dorsally and laterally, anterior margin slightly convex dorsally, orbitorostral grooves almost absent, inferior orbital angle feebly produced, rounded, pterygostomial angle slightly produced, blunt; cardiac notch distinct.

Abdomen (fig. 2b) glabrous, smooth; sixth segment about 1.1 times length of fifth, 1.2 times longer than deep, compressed, posterior lateral angle acute, posteroventral angle rounded; pleura of first three segments bluntly triangular, fourth broadly rounded, fifth subrectangular, posteroventral angle rounded. Telson (fig. 3b) about 1.3 times length of sixth segment, 1.5 times 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 0.5 of telson length, posterior pair at 0.7 of telson length; posterior margin about 0.6 of anterior width, strongly convex, with numerous long plumose setae, with numerous small spines dorsally, with lateral spines missing.

Antennule (fig. 2c) with peduncle robust, about 0.4 of carapace length, not exceeding scaphocerite and carpocerite; proximal segment about 1.8 times longer than width, distal margin entire and setose; stylocerite oval, not exceeding anterior margin of proximal segment; intermediate segment subcylindrical, subequal to proximal segment, about 1.1 times proximal segment length, 2.5 times longer than wide, distal margin entire and sparsely setose; distal segment about 0.1 of proximal segment length, non-setose; upper flagellum biramous, proximal 27 segments fused, with about 10 groups of aesthetascs, longer ramus slender, tip missing; lower flagellum slender, slightly exceeding upper flagellum, tip missing.

Antenna (fig. 2c) with basicerite stout, with feebly developed, blunt ventrolateral tooth, carpocerite subcylindrical, distinctly exceeding antennular peduncle and scaphocerite, about 8.3 times longer than wide, flagellum with tip missing, about 1.3 times carapace length, proximal segments not thickened; scaphocerite reaching anterior margin of distal segment of antennular peduncle, 1.8 times longer than wide, suboval, lateral margin slightly concave, with acute distolateral tooth not exceeding anterior margin of lamella.

Eyes (figs. 2a, c) entirely concealed by anterior and lateral margins of orbital hood, cornea about 0.07 times of carapace length.

Mandible (fig. 3f) with corpus robust; palp 2-segmented, distal segment suboval, compressed, about 1.5 times longer than broad, with several short plumose setae on distal margin, proximal segment subconical, about 1.9 times longer than anterior width, anterior width 2.9 times greater than posterior width, with three plumose setae at anterior medial angle; molar process subcylindrical, obliquely truncate distally, exterior surface densely microspinulate distally with scoop-shaped process fringed with small tooth-like spines; incisor process robust, with 6 acute distal teeth, with several rows of smaller teeth posteriorly. Maxillula (fig. 3g) with bilobed palp (badly damaged), distal lobe larger than proximal lobe; upper lacinia normal, with lower distal margin bearing 2 rows of about 8 short simple spines and with spiniform setae proximally; lower lacinia slender (badly damaged), with 3 to 4 stout spines distally, with numerous spiniform setae distally. Maxilla (fig. 3h) with short, stout palp, with single distal plumose seta, basal endite broad, with some indication of division into 2 lobes, with numerous short setulose setae medially, coxal endite narrower than basal endite, sparsely setose; scaphognathite with anterior lobe about 1.4 times longer than broad (posterior lobe missing). First maxilliped (fig. 3i) with slender, unsegmented palp, about 0.5 times exopod length, with 4 plumose setae distally, several shorter setulose setae medially; basal endite simple, setose along medial margin; exopod tapering distally, curving medially, with several plumose setae distally, caridean lobe narrow, extending midway up exopod, with numerous marginal plumose setae, epipod large, simple. Second maxilliped (fig. 3j) with normal endopod, dactylar segment narrow with numerous spines and spiniform setae medially; propodal segment bluntly produced distally with numerous spines and spiniform setae distally; exopod curved medially, with plumose setae distally; epipod large, subrectangular. Third maxilliped (fig. 3k) with robust endopod reaching anterior end of carpocerite; ischiomerus fused to basis, combined segment about 4.1 times longer than broad, subcylindrical, sparsely setose laterally and medially; penultimate segment about 3.1 times longer than broad, subcylindrical, 0.4 times of combined segment length, sparsely setose laterally and medially; distal segment tapering distally, about 6.7 times longer than proximal width, 0.7 of combined segment length, medial aspect with about 20 transverse rows of serrulate spines, of increasing size distally, laterally sparsely setose; exopod slightly exceeding combined segment of endopod, with numerous plumose setae distally, with several serrulate setae laterally; coxa sparsely setose, with rounded distolateral plate.

Large chela (figs. 2d, e) robust, about 2.4 times longer than broad, laterally compressed, carried with inner face dorsal and outer face ventral, fingers open obliquely. Palm 1.5 times longer than broad, sculptured on both outer and inner face; transverse groove of superior margin with anterior edge straight dorsally, with posterior edge rounded dorsally, posterior edge obtuse to floor of groove, groove continuous with quadrangular shaped depression on upper edge of outer face and with triangular shaped depression on upper edge of inner face; inferior margin with strong, rounded shoulder ventrally at base of fixed finger opposite dactylar articulation, distal depressed area continuing on lower edge of outer face as triangular groove to about 0.2 of breadth of palm, continuing on lower edge of inner face as deeper triangular groove to about 0.5 of breadth of palm, transverse ridge at base of fixed finger posteriorly delimiting the triangular groove on lower edge of inner face continues posteriorly almost parallel to inferior margin and terminating with it but separated from it by infero-internal groove extending almost entire length of palm; inner face with central transverse ridge terminated proximally by curved groove running to carpal articulation, with distal large shallow depression delimited posteriorly by this transverse ridge and anteriorly by

other transverse ridge at base of fixed finger. Dactylus compact, about 1.1 times longer than broad, 0.3 of chela length, laterally compressed, slightly overlapping distal end of fixed finger, molar process moderately well-developed, outer margin sparsely setose. Fixed finger compact, broad, with inner margin of both inner and outer face strongly angled distal to socket for housing dactylus tooth, about 0.4 of chela length, 3.4 times longer than breadth at angle (outer face) distal to socket, outer margin sparsely setose. Carpus small, rounded, cup-shaped, about 0.3 of merus length. Merus unarmed, robust, 2.7 times longer than broad, 0.3 of chela length, slightly expanding distally.

Small chela (fig. 2f) about 5.2 times longer than broad. Palm subcylindrical, 2.6 times longer than broad, sculpturing much less pronounced than large chela, superior margin with weak, shallow transverse groove posterior to base of dactylus insertion, inferior margin with very faint transverse ridge, outer and inner face with faint longitudinal groove running next to superior margin. Dactylus 'balaeniceps-shaped', broadened with widest point midway, narrowing to curved, acute tip distally, lateral margins fringed with spiniform setae which meet over superior surface proximal to tip, about 0.5 of chela length. Fixed finger with laterally fringing spiniform setae in proximal half, slightly crossing tip of dactylus, 0.5 of chela length. Carpus subconical, about 0.3 of merus length. Merus unarmed, more slender than in large cheliped, about 3.4 times longer than broad, 0.4 of chela length.

Second pereiopods (fig. 2g) slender; chela (fig. 2h) small, about 3.3 times longer than broad; palm 1.3 times longer than broad; dactylus with cutting edge entire, 0.6 of chela length; fixed finger with cutting edge entire, 0.6 of chela length; carpus 5-segmented, about 3.2 times chela length, articles in approximate ratio of 10:6:2.5:2.5:4 (rounded off to nearest integer to facilitate comparison giving a ratio of 10:6:3:3:4); merus 0.6 of carpus length, 6.3 times longer than broad, unarmed; ischium 1.1 times as long as merus, 6.7 times longer than broad.

Third pereiopods (figs. 2i, j) relatively robust; dactylus simple, subspatulate, 0.5 times propodus length, 5.5 times longer than proximal width; propodus about 2.0 times longer than dactylus, 8.0 times as long as broad, with a pair of distoventral spines, with 2 ventral spines in proximal half, sparsely setose; carpus about 0.7 of propodus length, 4 times longer than distal width, unarmed; merus about 1.2 times propodus, 5.6 times as long as broad, unarmed; ischium about 0.4 of merus, 2.5 times longer than distal width, with single movable spine ventrolaterally; basis normal, coxa robust. Fourth pereiopods similar in proportions to third pereiopods. Fifth pereiopods (fig. 3a) similar in proportions to third and fourth pereiopods, more slender; propodus with about 10 ventrolateral transverse rows of serrulate setae, increasing in number and size distally.

Pleopods normal; endopod of first pleopod (fig. 3d) slender, 5 times longer than wide, curved, with long plumose setae distally, medially and laterally; endopod of second pleopod (fig. 3e) 7 times longer than broad, with appendices at 0.3 of endopod; appendix masculina subcylindrical, 7.5 times longer than wide, with 4 long terminal spines; appendix interna long and slender, with distal cincinnuli, inserted just posterior to appendix masculina, about 12.5 times as long as broad, 1.7 times appendix masculina length.

Uropod (fig. 3b) protopod with acute distolateral lobe, rami exceeding posterior margin of telson; exopod 1.3 times longer than wide, lateral margin convex, with ventral submarginal setal fringe, distolateral angle subrectangular, with single stout movable spine medially, diaeresis straight, entire, distal lobe broadly rounded, with long plumose marginal setae,

with short spiniform marginal setae; endopod about 0.8 times exopod length, 1.4 times as long as broad.

Measurements. - Carapace length 5.5 mm, total length about 18 mm.

Paralectotype. - The paralectotype (carapace length 5.2 mm; total length about 14 mm) is smaller than the lectotype (carapace length 5.5 mm; total length about 18 mm). Slight variation between the two specimens examined is observed in the rostrum, eye, carapace, antennules, antennae, large chelae, ambulatory pereiopods, uropods and telson. The paralectotype has a slightly longer rostrum (about 0.2 of proximal segment of antennular peduncle versus 0.1 in the lectotype). The cornea of the paralectotype (0.06 of carapace length) is smaller than that of the lectotype (0.07 of carapace length). In the carapace, the anterior margin of the orbital hood is straight versus slightly convex in the lectotype and the inferior orbital angle indistinct. The proximal and intermediate segments of the antennular peduncle of the paralectotype (1.6 times and 2.3 times as long as broad respectively) are slightly less slender than in the lectotype (1.8 times and 2.5 times as long as broad respectively). In addition, the stylocerite of the paralectotype terminates in a small distal spine which is missing in the lectotype. The distolateral tooth of scaphocerite (of the antenna) distinctly exceeds the anterior margin of the lamella in the paralectotype while not doing so in the lectotype. The dactylus of the large chela is slightly less broad in the paralectotype (1.3 times longer than broad, 0.4 of chela length) than in the lectotype (1.1 times as long as broad, 0.3 of chela length). The fixed finger of the large chela is also less broad (2.6 times longer than broad) in the paralectotype than in lectotype. Kemp (1915) stated that this species, like many others of the *A. edwardsi* group exhibits sexual dimorphism in that the males possess 'balaeniceps-type' small chela while the females have normal small chelae. Most of the ambulatory pereiopods examined had already dropped off and could not be assigned with certainty to either specimen - these legs showed variation in propodus ventral spine number, having from 1 to 3 spines. The exopod of the uropod is 1.2 times longer than broad in the paralectotype and 1.3 times longer than broad in the lectotype. The lateral spine of exopod is also missing in the paralectotype. The endopod of the uropod is slightly more slender in the paralectotype (1.5 times as long as broad) than in the lectotype (1.4 times as long as broad). In the telson (fig. 3c), the paralectotype has 2 unequal pairs of slender, slightly curved, posterolateral spines which are missing in the lectotype, the lateral pair being about 0.5 times length of the dorsal spines and the medial pair about subequal in length to the dorsal spines. The paralectotype is similar to the lectotype in other aspects.

Colour.- Based on Kemp's (1915) observations, the shrimps were overall translucent with a brownish red rostrum. The antennular peduncles and lateral margins of the scaphocerite were similarly tinged with reddish brown. At the posterior edge of the carapace and of each abdominal segment was a transverse brownish to bluish-green band. The telson and uropods were dusky.

Ecology. - As only preserved specimens were used for this redescription, this section will be based on the original observations of live material and records made by Kemp (1915). *Alpheus paludicola* was listed as one of several species that appeared to be confined to estuarine tracts or lagoons of variable salinity, that communicated directly with the sea. The species was common and widely distributed in Lake Chilka, being obtained from 21 different collecting stations. Specimens were always obtained from the soft, muddy bottom in about 1 to 4 m of water. Although the waters of Lake Chilka experience seasonal fluctuations in salinity, specimens were obtainable throughout the year indicating that the species is able to

tolerate large changes in salinity.

Remarks. - *Alpheus paludicola* was first described by Kemp (1915) from specimens from Lake Chilka, Orissa, India. No holotype was designated. In the course of examining *A. paludicola* syntypes from BMNH, it was found that Kemp's description was inadequate for modern standards in certain respects. Thus the need for this illustrated and more detailed redescription, and the designation of a lectotype.

The present specimens agree with the description given by Kemp (1915) in most aspects. There are, however, some differences which are discussed below. Kemp's (1915: 303) description states that the terminal spine of the stylocerite "does not reach the end of the segment" (proximal antennular peduncle segment). However, the stylocerite does reach the level of the anterior margin of the proximal segment of the antennular peduncle in the present specimens. The merus of the large chelipeds of the present specimens (small males) is about 2.7 times longer than broad, while the original description gave the proportions as 2 times in large males, 2.4 times in younger males and 2.7 times in adult females. The "very fine granulation" in the large chela noted by Kemp (1915: 304, pl 13: figs. 12, 13) is not visible. The sculpturing on the palm of the small chela described by Kemp (1915: 304, fig. 33b) is hardly obvious and almost indistinguishable. Unlike the original description in which the propodus of the third pereiopod is said to "bear long setae but no spines", the present specimens do have small spines on the propodus varying in number from 1 to 3. Finally, the uropods distinctly exceed the distal margin of the telson, contrary to Kemp's description which states that "the telson reaches as far as the uropods".

The diagnostic characters of *A. paludicola* however, remain unchanged following this redescription and those used by Kemp (1915) are still applicable for distinguishing it from its close relatives. *Alpheus paludicola* belongs to the *A. edwardsi* group (sensu De Man, 1911; Banner & Banner, 1966), its closest relatives being *Alpheus euphrosyne* De Man, 1897, and *A. microrhynchus* De Man, 1898. *Alpheus paludicola* can be distinguished from both *A. euphrosyne* and *A. microrhynchus* by the following combination of characters: i) rostrum much shorter, reaching not more than 0.2 of proximal segment of the antennular peduncle versus rostrum relatively longer in relation to proximal segment of the antennular peduncle (0.4 to 0.5 in *A. euphrosyne*; 0.2 to 0.5 in *A. microrhynchus*); ii) rostrum broadly triangular in dorsal view versus rostrum more slender and acutely tapering in dorsal view; iii) more robust large chela (ratio of chl/chb 2.4) with relatively more robust fingers (ratio of mfl/mfb 1.1 to 1.3, ffl/ffb 2.6 to 3.4) versus more slender large chela (ratio of chl/chb 2.4 to 2.5 in *A. euphrosyne*; 2.5 to 2.7 in *A. microrhynchus*) with relatively more slender fingers (ratio of mfl/mfb 1.6 to 1.8, ffl/ffb 3.8 to 4.5 in *A. euphrosyne*; mfl/mfb 1.5 to 1.7, ffl/ffb 3.3 to 3.8 in *A. microrhynchus*) (figs. 8a, d). It should be noted, however, that the two features of the rostrum mentioned above are less reliable when used for differentiating *A. paludicola* from *A. microrhynchus* as the latter species has a highly variable rostrum length (from 0.2 to 0.5 times the length of the proximal segment of the antennular peduncle) and shape (broadly triangular to slender) (figs. 8b, c), with some variants having rostra almost identical to the former species. *Alpheus paludicola* can be further differentiated from *A. euphrosyne* by the presence on the inner face of the palm of the large chela of a transverse ridge midway along the length of the palm and a large shallow depressed area distal to it, bound anteriorly by a shorter transverse groove at the base of fixed finger (versus absence of these characters) as well as by its much larger eggs of about 1.4 mm in diameter (Kemp, 1915) (versus 0.5 mm in diameter). The ratio of carpal articles of the second pereiopod in *A. paludicola* (10:6:2:2:4) differs only slightly from that of *A. euphrosyne* (10:6:2:2:3) (see Banner & Banner, 1966)

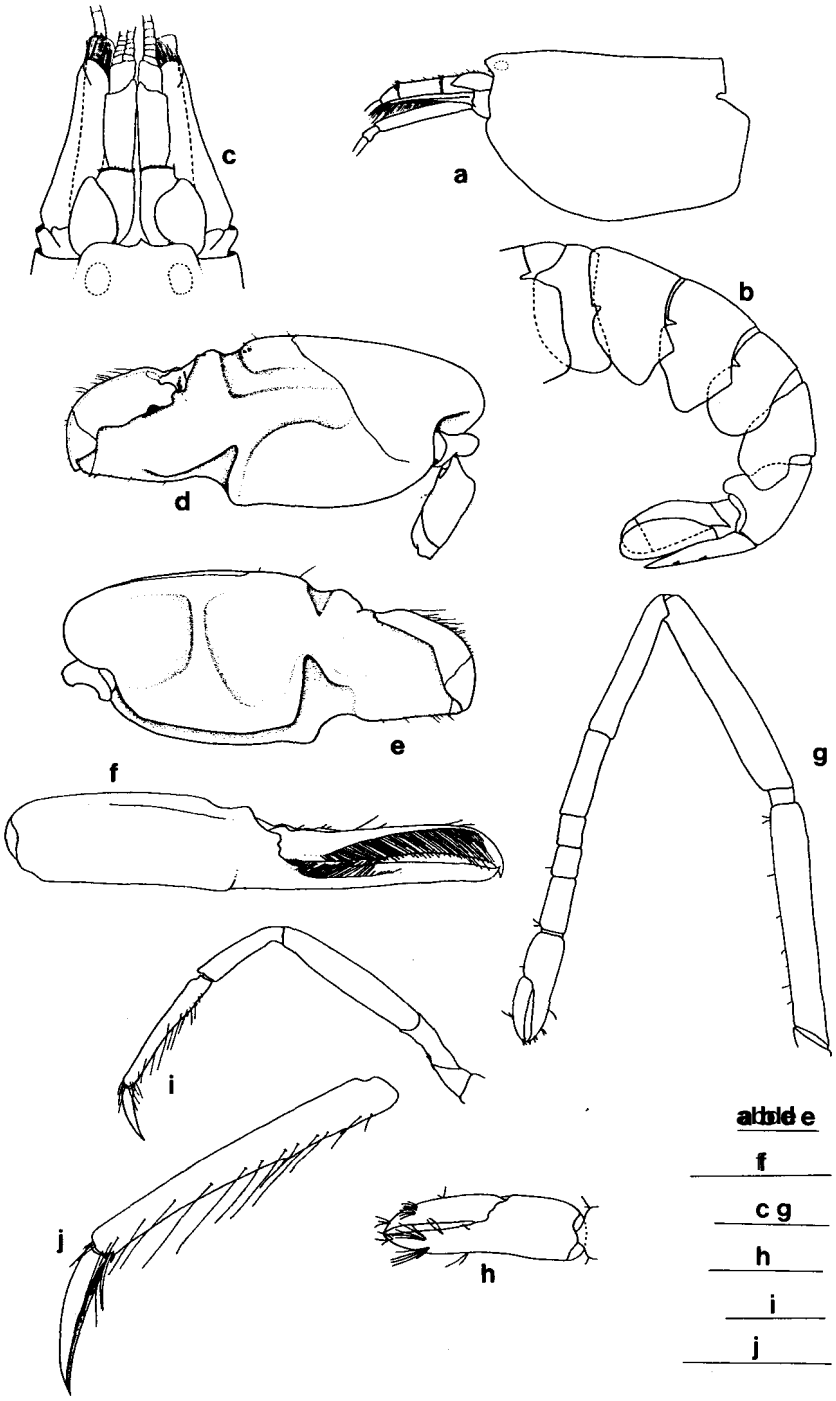

Fig. 2. *Alpheus palludicola* Kemp, 1915. Lectotype male (cl 5.5 mm, tl about 18 mm) (BMNH 1919.11.111), Lake Chilka, Orissa, India. a: lateral view of carapace; b: abdomen; c: dorsal view of anterior carapace; d: outer face of large chela of left first pereiopod; e: inner face of large chela of left first pereiopod; f: balaeniceps-type small chela of right first pereiopod; g: right second pereiopod; h: chela of right second pereiopod; i: right third pereiopod; j: propodus and dactylus of right third pereiopod. Pinnae of plumose setae of scaphocerite not drawn in. Scales = 2.0 mm in a, b, d, e; 2.0 mm in f; 1.0 mm in c, g; 0.5 mm in h; 2.0 mm in i; 1.0 mm in j.

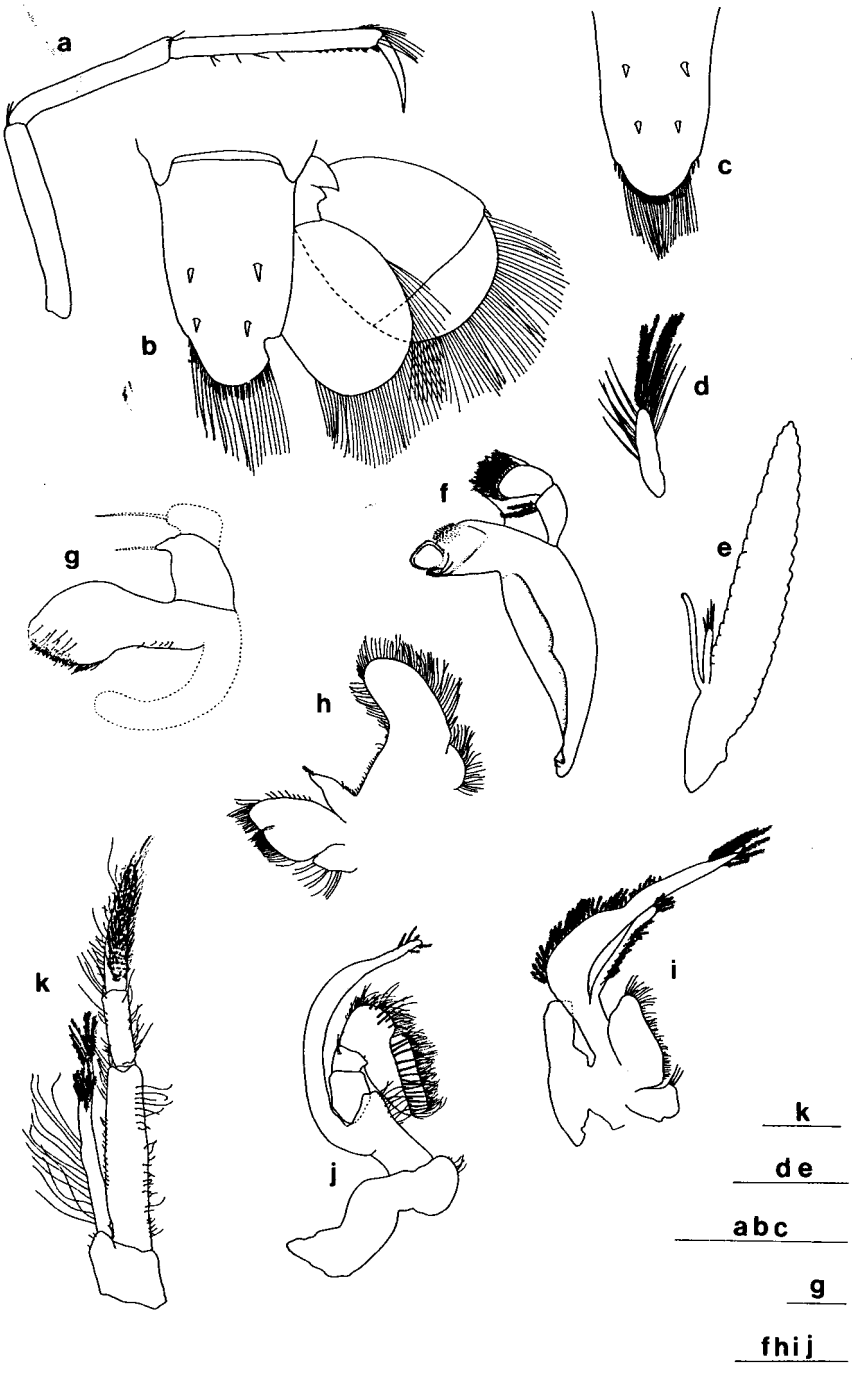

Fig. 3. *Alpheus paludicola* Kemp, 1915. a, b, d - k, Lectotype male (cl 5.5 mm, tl about 18 mm) (BMNH 1919.11.1.1), Lake Chilka, Orissa, India. c, Paralectotype male (cl 5.2 mm; tl about 14 mm) (BMNH 1919.11.1.2), same locality. a: right fifth pereiopod; b: uropod and telson; c: telson; d: endopod of right first pleopod; e: appendix masculina and appendix interna on endopod of right second pleopod; f: right mandible; g: right maxillule; h: left maxilla; i: right first maxilliped; j: right second maxilliped; k: right third maxilliped. Pinnae of plumose setae of telson and uropod, plumose setae of second pleopod and short spiniform marginal setae of uropod not drawn in. Scales = 1.0 mm in k; 0.5 mm in d, e; 2.0 mm in a - c, 0.3 mm in g; 1.0 mm in f, h - j.

and should be used only as a supporting diagnostic feature. *Alpheus paludicola* can be further distinguished from *A. microrhynchus* by the presence of a superior margin notch and a very feeble inferior margin notch in the small chela (versus absence of notches in margins of small chela). In addition, the length of the second carpal article in relation to the first in *A. paludicola* is almost double that in *A. microrhynchus*, as reflected in the ratio of carpal articles of the second pereiopod of 10:6:2:2:4 in the former species versus 10:3:1:1:2 in the latter species (see Banner & Banner, 1966). *Alpheus microrhynchus* is also a larger species than *A. paludicola*. The largest specimen of *A. microrhynchus* examined was a female (ZRC 1979.441) of total length 81.6 mm versus the lectotype of *A. paludicola* (BMNH 1919.11.1.1) total length 18 mm and the maximum size of 22 mm reported by Kemp (1915: 305). Kemp (1915) had also used the presence of a transverse ridge on the inner face of the palm of the large chela and conical shape of the third pereiopod dactylus to differentiate *A. paludicola* from *A. microrhynchus*. However, examination of several specimens of the latter species from the ZRC showed the ridge to be present (fig. 8a) and the dactylus to be subconical to subspatulate. In all other aspects, these specimens matched the description of *A. microrhynchus* given by Banner & Banner (1966) and De Man (1898).

Alpheus paludicola has been reported from Tale Sap in southern Thailand (Kemp, in Annandale, 1918) and from Johor, Peninsular Malaysia as *A. paludosus* (Johnson, 1965, 1966). However, the specimens from the former locality may not be *A. paludicola* s. str. and their true identity is debatable while those from the latter area belong to a new species (see ***Remarks*** under *Alpheus cyanoteles*, new species).

Distribution. - Lake Chilka, Orissa, India; (?) Tale Sap, Thailand (see fig. 9).

Alpheus cyanoteles, new species
(Figs. 4 - 7)

Alpheus paludosus (sic) - Johnson, 1965: 9; 1966: 430; Powell, 1979: 117; Lovett, 1981: 67 (not *Alpheus paludicola* Kemp, 1915).
Alpheus paludicola - Banner & Banner, 1966: 135.

Material examined. - Holotype - 1 male (ZRC 1996.1), Sungei Tementang, Kota Tinggi, Johore, 1°52'0.81"N 103°55'49.2"E, coll. P.K.L.Ng et al., 5 Jun.1995.

Paratypes - 8 males, 7 females (ZRC 1996.2), same data as holotype.- 3 males, 3 females (ZRC 1996.3), same locality data as holotype, coll. D.C.J.Yeo et al., 31 Jul.1995.- 3 males, 5 females (ZRC 1996.4), Sungei Selangi, Kota Tinggi, Johore, 1°51'46.5"N 104°00'31.0"E, coll. P.K.L.Ng et al., 5 Jun.1995.- 1 female (ZRC 1996.58), same data as holotype.- 3 males, 4 females (BMNH), Sungei Selangi, Kota Tinggi, Johore, 1°51'46.5"N 104°00'31.0"E, coll. D.C.J.Yeo et al., 31 Jul.1995.- 1 female (ZRC 1979.4415), Sungei Semalok, big stream at 9 3/4 mile Kota Tinggi-Mawai Road, Johore, coll. D.S.Johnson, 5 May.1960.- 1 female (ZRC 1992.8382), Johore, Mawai-Sedili Road, coll. P.K.L.Ng, 14 Aug.1991.- 2 males (ZRC 1992.8383-8384), Johore, stream along Mawai-Tanjung Sedili Road, freshwater above tidal influence, coll. P.K.L.Ng, 14 Aug.1991.- 1 male (ZRC 1992.8385), Malaysia, Johore, Sedili area, no data on collector and date .- 2 males 2 females (RMNH), Malaysia, Johore, Kota Tinggi, Sungei Tementang, coll. A.Y.H.Lim, H.H.Tan & S.H.Tan, 24 Feb.1995.- 2 males (RMNH), Sungei Tementang, Kota Tinggi, Johore, P.K.L.Ng et al., 7 Sep.1995.

Others - 2 females (ZRC 1996.5), Sungei Selangi, Kota Tinggi, Johore, coll. P.K.L.Ng et al., 1994.- 1 male, 1 female (ZRC 1996.46), no data.

Description of paratype. - Subcylindrical body form.
Rostrum (figs. 5a, b) without setae, short, distinctly exceeding anterior margin of orbital

hood, about 0.3 of dorsally visible portion of proximal segment of antennular peduncle, acutely tapered in dorsal view, dorsal carina obsolete, ventral carina very weakly developed, unarmed, lateral carina obsolete.

Carapace (fig. 5b) glabrous, smooth; orbital hood margin totally concealing eyes dorsally and laterally, anterior margin slightly convex dorsally, orbitorostral grooves slight, inferior orbital angle indistinct, pterygostomial angle not produced, rounded; cardiac notch distinct. Abdomen (fig. 5c) glabrous, smooth; sixth segment about 1.1 times length of fifth, 1.2 times longer than deep, compressed, posterior lateral angle acute, posteroventral angle blunt; pleura of first four segments broadly rounded, fifth subrectangular, posteroventral angle rounded. Telson (figs. 5j) about 1.2 times length of sixth segment, 1.3 times 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 0.5 of telson length, posterior pair at 0.8 of telson length; posterior margin broad, about 0.7 of anterior width, with small, subequal, spines laterally, 4 on left side, 2 on right side, about 0.3 of dorsal spines length, broadly convex, with numerous long plumose setae, with numerous small spines dorsally. Antennule (fig. 5a) with peduncle robust, about 0.3 of carapace length, not exceeding scaphocerite and carpocerite; proximal segment about 1.2 times longer than width, distal margin entire and sparsely setose; stylocerite oval-shaped, with terminal distal spine not exceeding anterior margin of proximal segment; intermediate segment subcylindrical, distinctly longer than proximal segment, about 1.4 times proximal segment length, 1.9 times longer than wide, distal margin entire and sparsely setose; distal segment about 0.6 of proximal segment length, distal margin entire and sparsely setose; upper flagellum biramous, proximal 28 segments fused, shorter ramus with 1 free segment, with about 16 groups of aesthetascs, longer ramus slender, tip missing; lower flagellum slender, about 1.1 times carapace length. Antenna (fig. 5a) with basicerite robust, with acute ventrolateral tooth, not reaching midway of proximal segment of antennular peduncle, carpocerite subcylindrical, distinctly exceeding antennular peduncle and scaphocerite, about 5.5 times longer than wide, flagellum, about 2.4 times carapace length, proximal segments not thickened; scaphocerite not exceeding anterior margin of distal segment of antennular peduncle, 1.9 times longer than wide, suboval, lateral margin straight, with acute distolateral tooth not exceeding anterior margin of lamella. Eyes (figs. 5a, b) entirely concealed by anterior and lateral margins of orbital hood, cornea about 0.04 times of carapace length.

Mandible (fig. 7a) with corpus robust; palp 2-segmented, distal segment suboval, compressed, about 1.5 times longer than broad, with several short plumose setae on distal margin, proximal segment subcylindrical; molar process subcylindrical, truncate distally, exterior surface densely microspinulate distally with scoop-shaped process with fringe of small tooth-like spines; incisor process robust, with 10 acute distal teeth. Maxillula (fig. 7b) with bilobed palp, distal lobe larger than proximal lobe, proximal lobe with long, slender, simple seta distally; upper lacinia normal, with lower distal margin bearing about 2 rows of 10 to 12 stout, simple spines and with numerous submarginal spiniform setae; lower lacinia slender, curved, with about 4 stout spines distally, with numerous spiniform setae distally. Maxilla (fig. 7c) with short, stout palp, with single distal plumose seta, basal endite broad, weakly bilobed, with numerous short, stout, setulose setae medially, coxal endite weakly developed, sparsely setose; scaphognathite normal, about 5.6 times as long as broad, with posterior lobe about 3.9 times longer than broad, with anterior lobe about 1.4 times longer than broad. First maxilliped (fig. 7d) with slender, 2-segmented palp, about 0.5 times exopod length, distal segment subcylindrical, tapering distally, about 4 times longer than broad, 0.4 of proximal segment length, with single plumose seta distally, proximal segment slender,

curved about 8.6 times longer than broad, with shorter setulose setae medially; basal endite simple, setose along medial margin; exopod well developed, with numerous plumose setae distally, caridean lobe narrow, extending midway up exopod, with numerous marginal plumose setae, epipod large, simple. Second maxilliped (fig. 7e) with normal endopod, dactylar segment narrow, with 3 large spines distomedially, with numerous small spines and spiniform setae medially; propodal segment bluntly produced distally with numerous spines and spiniform setae distally; exopod curved, with plumose setae distally; epipod large, subrectangular. Third maxilliped (fig. 7f) with robust endopod not exceeding anterior end of carpocerite; ischiomerus fused to basis, combined segment, subcylindrical, about 4.3 times longer than broad, sparsely setose laterally and medially; penultimate segment about 4.4 times longer than broad, subcylindrical, 0.4 of combined segment length, sparsely setose laterally and medially; distal segment tapering distally, about 8.9 times longer than broad, 0.7 of combined segment length, medial aspect with numerous rows of serrulate spines, of increasing size distally, laterally sparsely setose; exopod exceeding combined segment of endopod, with numerous plumose setae distally, with several serrulate setae distally; coxa sparsely setose, with rounded distolateral plate.

Large chela (figs. 5d, e) robust, about 2.6 times longer than broad, laterally compressed, carried with inner face dorsal and outer face ventral, fingers open obliquely. Palm 1.3 times longer than broad, sculptured on both outer and inner face; transverse groove of superior margin linking quadrangular shaped depressed area on upper edge of outer face and with triangular shaped depressed area on upper edge of inner face, with anterior edge of groove straight dorsally, with posterior edge rounded dorsally, posterior edge obtuse to floor of groove; inferior margin with strong, rounded shoulder ventrally near base of fixed finger opposite dactylar articulation, with depressed area distally, continuing on lower edge of outer face as triangular groove to about 0.2 of breadth of palm, continuing on lower edge of inner face as deeper triangular groove to about 0.5 of breadth of palm, transverse ridge at base of fixed finger posterior to and delimiting inner face lower edge triangular groove continues posteriorly almost parallel to inferior margin terminating with it but separated from it by infero-internal groove extending almost entire length of palm; inner face with central transverse ridge bound proximally by curved groove running to carpal articulation, with distal large shallow depression delimited posteriorly by this transverse ridge and anteriorly by other transverse ridge at base of fixed finger. Dactylus with tip broken, elongated, about 1.9 times longer than broad, 0.4 of chela length, laterally compressed, slightly overlapping distal end of fixed finger, molar process well-developed, outer margin sparsely setose. Fixed finger elongated, broad, with inner margin of both inner and outer face slightly produced in blunt angle distal to socket for housing dactylus tooth, about 0.5 of chela length, 4.1 times as longer than breadth at angle (outer face) distal to socket for housing dactylus tooth, outer margin sparsely setose. Carpus small, rounded, cup-shaped, about 0.2 of merus length. Merus unarmed, robust, 2.7 times longer than broad, 0.3 of chela length, slightly expanding distally. Small chela (fig. 5f) about 5 times longer than broad. Palm subcylindrical, 2.6 times longer than broad, sculpturing much less pronounced than large chela, superior margin with shallow transverse groove posterior to base of dactylus insertion, inferior margin with very weak transverse ridge, outer and inner face with longitudinal groove running next to superior margin. Dactylus 'balaeniceps-shaped', broadened with widest point midway, narrowing to curved, acute tip distally, lateral margins fringed with spiniform setae which meet over superior surface proximal to tip, about 0.4 of chela length. Fixed finger with sparse laterally fringing spiniform setae, slightly crossing tip of dactylus, 0.5 of chela length. Carpus subconical, about 0.3 of merus length. Merus unarmed, more slender than in large cheliped, about 3.6 times longer than broad, 0.4 of chela length.

Second pereiopods (fig. 5h) slender; chela (fig. 5i) small, about 3.2 times longer than broad; palm 1.2 times as long as broad; dactylus with cutting edge entire, 0.6 of chela length; fixed finger with cutting edge entire, 0.6 of chela length; carpus 5-segmented, about 4.3 times chela length, articles in approximate ratio of 10:3.5:1.5:1.5:2.5; merus slender, 9.2 times longer than broad, 0.7 of carpus length, unarmed; ischium slender, 8 times longer than broad, 0.9 times as long as merus; basis normal; coxa robust.

Third pereiopods (figs. 6a, b) relatively robust; dactylus simple, subspatulate, 0.3 times propodus length, 3 times longer than proximal width; propodus about 2.9 times longer than dactylus, 7.2 times as long as broad, with a pair of distoventral spines, with 8 ventral spines, sparsely setose; carpus about 0.7 of propodus length, 4.6 times longer than distal width, unarmed; merus about 1.4 times propodus, 6.6 times as long as broad, unarmed; ischium about 0.4 of merus, 2.4 times longer than distal width; basis normal, coxa robust. Fourth pereiopods (figs. 6c, d) similar to third pereiopods; dactylus simple, subspatulate, 0.3 times propodus length, 3.7 times longer than proximal width; propodus about 3.7 times longer than dactylus, 8.2 times longer than broad, with a pair of distoventral spines, with 8 ventral spines, sparsely setose; carpus about 0.7 of propodus length, 4.7 times longer than distal width, unarmed; merus about 1.2 times propodus, 6 times as long as broad, unarmed; ischium about 0.4 of merus, 3 times longer than distal width; basis normal, coxa robust. Fifth pereiopods (figs. 6e, f) similar to third and fourth pereiopods but more slender; dactylus simple, subspatulate, 0.4 times propodus length, 5 times longer than proximal width; propodus about 2.7 times longer than dactylus, 10 times as long as broad, with a pair of distoventral spines, with 3 ventromedial spines, with 1 distal ventromedial spine, with several ventrolateral transverse rows of serrulate setae, increasing in size and number distally; carpus about 0.9 of propodus length, 6.8 times longer than distal width, unarmed; merus about subequal to propodus length, 5.7 times as long as broad, unarmed; ischium about 0.6 of merus, 4.4 times longer than distal width; basis normal, coxa robust.

Pleopods normal; endopod of first pleopod (fig. 6g) slender, 7 times longer than wide, curved, with long plumose setae distally and medially and laterally; endopod of second pleopod (fig. 6h) 5.7 times longer than broad, with appendices at about 0.3 of endopod; appendix masculina subcylindrical, 8.8 times longer than wide, with 5 long spines distally; appendix interna subequal in length to appendix masculina, with distal cincinnuli, inserted just posterior to appendix masculina, about 8.8 times as long as broad.

Uropod (fig. 5j) protopod with acute distolateral lobe, rami exceeding posterior margin of telson; exopod 1.3 times longer than wide, lateral margin convex, with submarginal setal fringe ventrally, diaeresis straight, entire, with stout movable lateral spine, flanked by small acute fixed tooth medially, with small acute tooth laterally; distal lobe broadly rounded, with numerous long plumose marginal setae, with short spiniform marginal setae; endopod about 0.9 times exopod length, 1.4 times as long as broad.

Measurements. - Carapace length 11.4 mm, total length about 31.1 mm.

Variation. - The holotype (ZRC 1996.1) (carapace length 13.7 mm; total length about 35.7 mm) (fig. 4) is larger than the described paratype (ZRC 1996.2) (carapace length 11.4 mm, total length about 31.1 mm). Deviations from the paratype description observed in the holotype are primarily in the antennular peduncle and the large chela. The antennular peduncle of the holotype slightly exceeds the carpocerite and scaphocerite (while not exceeding in the paratype). In addition, the antennular peduncle segments also show slight differences: i) the

proximal segment is more robust in the holotype than in the paratype (1.1 times as long as broad versus 1.2 times); ii) intermediate segment is relatively longer (ratio of isl/psl 1.7 versus 1.4); iii) the intermediate segment is more slender (2.2 times as long as broad versus 1.9 times). The large chela of the holotype (2.5 times as long as broad) is slightly less slender than that of the paratype (2.6 times as long as broad). The fingers of the large chela of the holotype are correspondingly slightly more robust (ratio of mfl/mfb 1.4 versus 1.9 ; ratio of ffl/ffb 3.9 versus 4.1).

Within the series of specimens examined, variation in the following parts was also noted: Rostrum. - The rostral length relative to the proximal segment of the antennular peduncle varies from about 0.3 to 0.5.

Carapace.- The anterior margin of the orbital hood rarely conceals the eye partially in the lateral view and from the dorsal view, varies from convex to slightly convex, rarely straight. The inferior orbital angle ranges from being very weak, not produced to being indistinct and obsolete.

Abdomen.- The telson length in proportion to the 6th segment and its own anterior width ranges from 1.1 to 1.3 and 1 to 1.5 respectively. The dorsal spine length in relation to telson length varies from 0.06 to 0.1. The posterior telson width varies in relation to the anterior width (0.6 to 0.8 times). The paratype described is unusual in having 4 lateral spines on the left side of the posterior margin of the telson (fig. 5j). All other specimens have 2 pairs of unequal lateral spines on the posterior margin (fig. 5k). The smaller lateral pair being subequal (0.1 to 0.8 of dorsal spine) and the longer medial pair being subequal (0.2 to 0.5 of dorsal spine).

Antennules.- The intermediate segment of the antennular peduncle is distinctly longer than the proximal to varying degrees (1.3 to 2 times) while the distal segment also varies with respect to the proximal segment (0.6 to 1 times).

Antennae.- The ventrolateral tooth of the basicerite is usually acute and stout, reaching or nearly reaching about half of the proximal segment of the antennular peduncle. It rarely exists as a slight acute projection. The carpocerite ranges from slightly shorter than the antennular peduncle to being about subequal to or slightly exceeding it. The scaphocerite length is also variable in relation to the antennular peduncle (from slightly shorter than to just exceeding). In the scaphocerite, the lateral tooth varies from not exceeding the anterior margin of the lamella to distinctly exceeding.

Eyes.- The cornea size varies with respect to the carapace length (0.04 to 0.08 times).

First pereiopods.- The slenderness of the large chela varies from 2.5 to 3 times as long as broad. The relation of the dactylus length to the chela length varies little (0.4 to 0.5 times). The dactylus also varies in breadth (1.4 to 2 times as long as wide). There is also little variation in the fixed finger length in proportion to the chela length (0.4 - 0.5 times). The fixed finger also varies in broadness (3.4 to 4.1 times as long as wide). In the small chela, the length with respect to breadth ranges between 4.9 to 6.4 times. There is sexual dimorphism exhibited with the dactylus of males being 'balaeniceps-shaped' while that of females being normal (fig. 5g). The subequal fingers of the small chela vary from 0.4 to 0.5 times of the chela length. In general, the more slender chelae and fingers for both large and small chelae are found in females and small males, however this is not always the case. The

sculpturing on the palm of the large chela varies in intensity from individual to individual but the pattern remaining the same. In the small chela, sculpturing on the palm ranges from being absent to faint.

Second pereiopods.- The merus length in relation to the carpus length varies from 0.6 to 0.8 times. The ratio of carpus articles in relation to the first carpus article also shows some variation giving an average ratio of about 10:4:1.7:1.7:2.8 (expressed to nearest integer for clarity and easy comparison gives a ratio of 10:4:2:2:3).

Third pereiopods.- The range of relative proportions used are as follows: dactylus (0.3 to 0.4 times of propodus), propodus (2.6 to 3.1 times longer than dactylus), carpus (0.7 to 0.8 times of propodus), merus (1.3 to 1.5 times longer than propodus), ischium (0.4 to 0.6 times of merus). The number of ventral spines of the propodus ranges from 6 to 8.

Fourth pereiopods.- The number of ventral spines of the propodus ranges from 6 to 8.

Fifth pereiopods.- The number of ventromedial spines of the propodus varies from 2 to 3.

Second pleopods.- The position of the appendix interna (and appendix masculina in males) varies from being inserted at 0.2 to 0.3 of the endopod. In males, the length of the appendix interna with respect to the appendix masculina ranges from 1 to 1.3 times.

Uropods.- Proportions vary in the exopod (1.2 to 1.4 times as long as broad) and endopod (1.1 to 1.6 times as long as broad). The length of the endopod with respect to the exopod ranges between 0.8 to 0.9 times .

Etymology. - *Cyanoteles*, latinized from the Greek words *kyanos* meaning dark blue and *telos* meaning end, referring to the bluish colouration of the telson and uropods. Used as a collective noun in apposition.

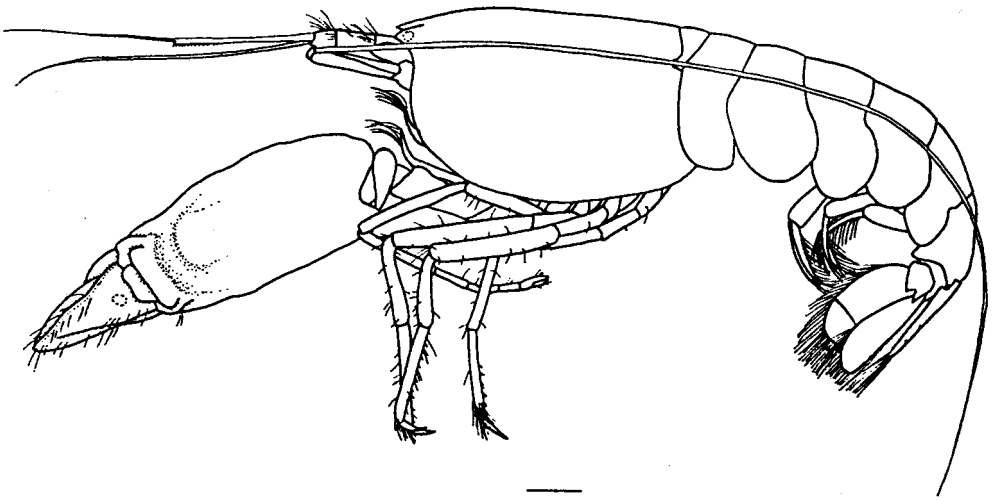

Fig. 4. *Alpheus cyanoteles*, new species. Holotype male (ZRC 1996.1) (cl13.7 mm; tl about 35.7 mm). Scale = 1.0 mm.

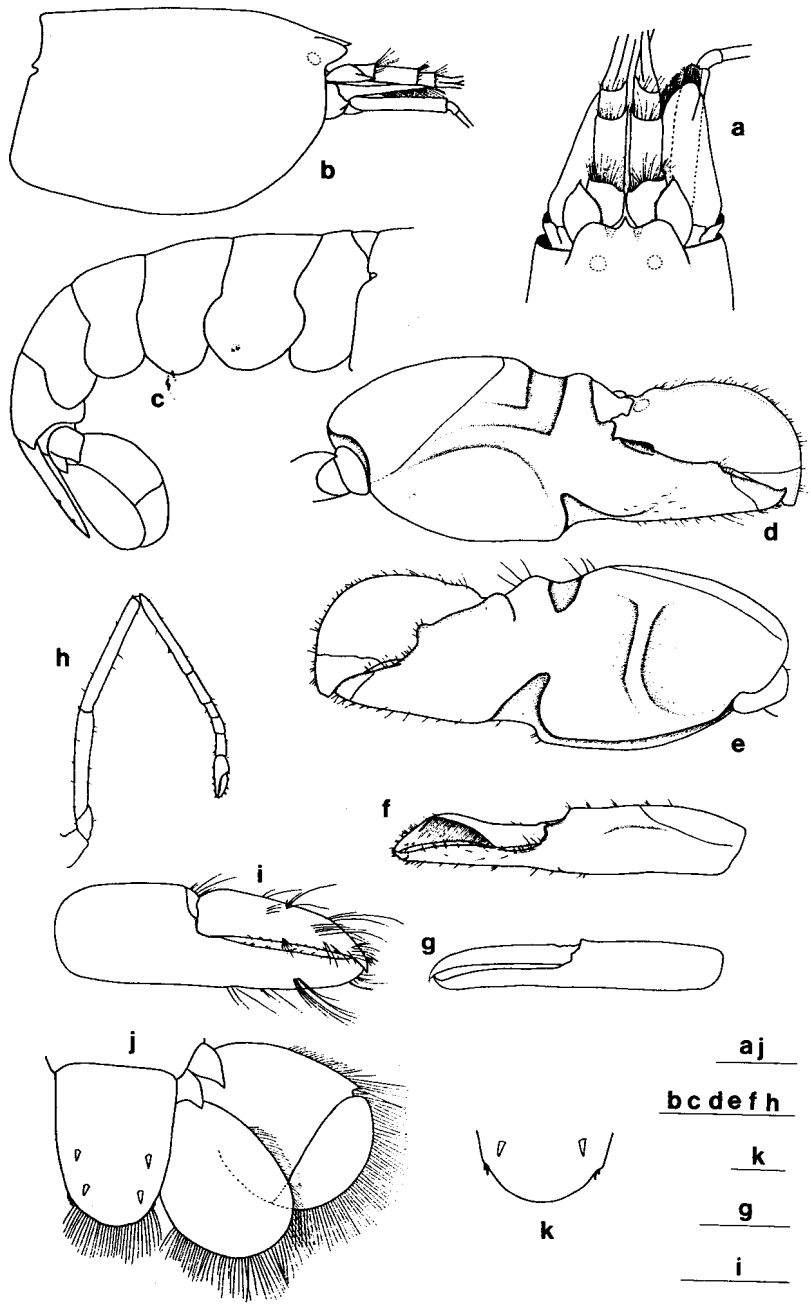

Fig. 5. *Alpheus cyanoteles*, new species. a - f, h, i, Paratype male (cl 11.4 mm, tl about 31.1 mm) (ZRC 1996.2), Sungei Tementang, Kota Tinggi, Johore, Peninsular Malaysia. g, Paratype female (cl 15.1 mm, tl about 46.2 mm) (ZRC 1996.58), same locality. k, Paratype male (cl 6.6 mm, tl about 18.8 mm) (RMNH), same locality. a: dorsal view of anterior carapace; b: lateral view of carapace; c: abdomen; d: outer face of large chela of right first pereiopod; e: inner face of large chela of right first pereiopod; f: balaeniceps-type small chela of left first pereiopod; g: small chela of left first pereiopod; h: right second pereiopod; i: chela of right second pereiopod; j uropod and telson; k: posterior margin of telson. Pinnae of plumose setae, short spines of telson posterior margin and short spiniform marginal setae of uropod not drawn in. Scales = 2.0 mm in a, j; 5.0 mm in b - f, h; 0.5 mm in k; 5.0 mm in g; 0.5 mm in i.

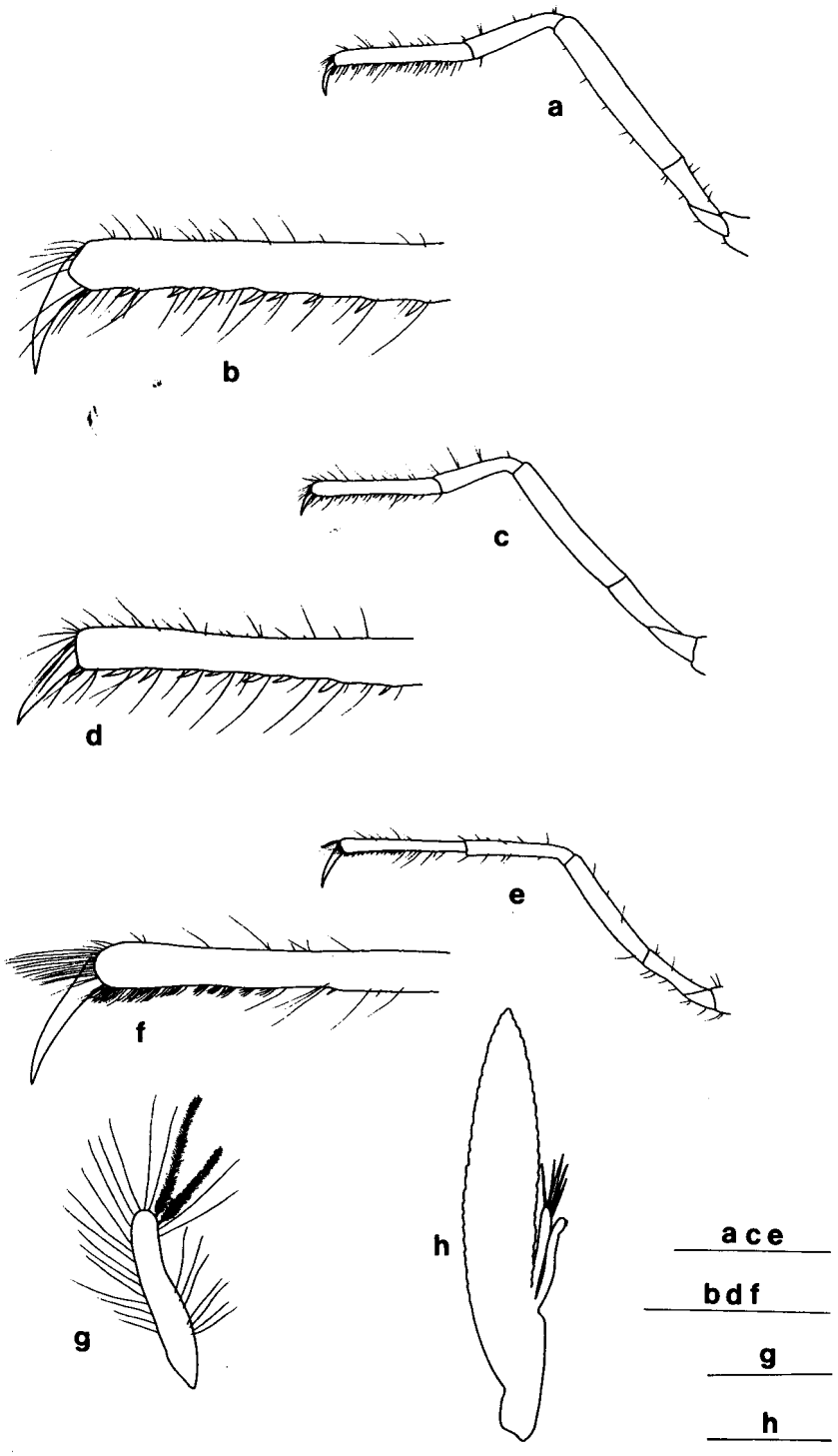

Fig. 6. *Alpheus cyanoteles*, new species. Paratype male (cl 11.4 mm, tl about 31.1 mm) (ZRC 1996.2), Sungei Tementang, Kota Tinggi, Johore, Peninsular Malaysia. a: right third pereiopod; b: propodus and dactylus of right third pereiopod; c: right fourth pereiopod; d: propodus and dactylus of right fourth pereiopod; e. right fifth pereiopod; f: propodus and dactylus of right fifth pereiopod; g: endopod of right first pleopod; h: appendix masculina and appendix interna on endopod of right second pleopod. Plumose setae of second pleopod not drawn in. Scales = 5.0 mm in a, c, e; 2.0 mm in b, d, f; 1.0 mm in g; 2.0 mm in h.

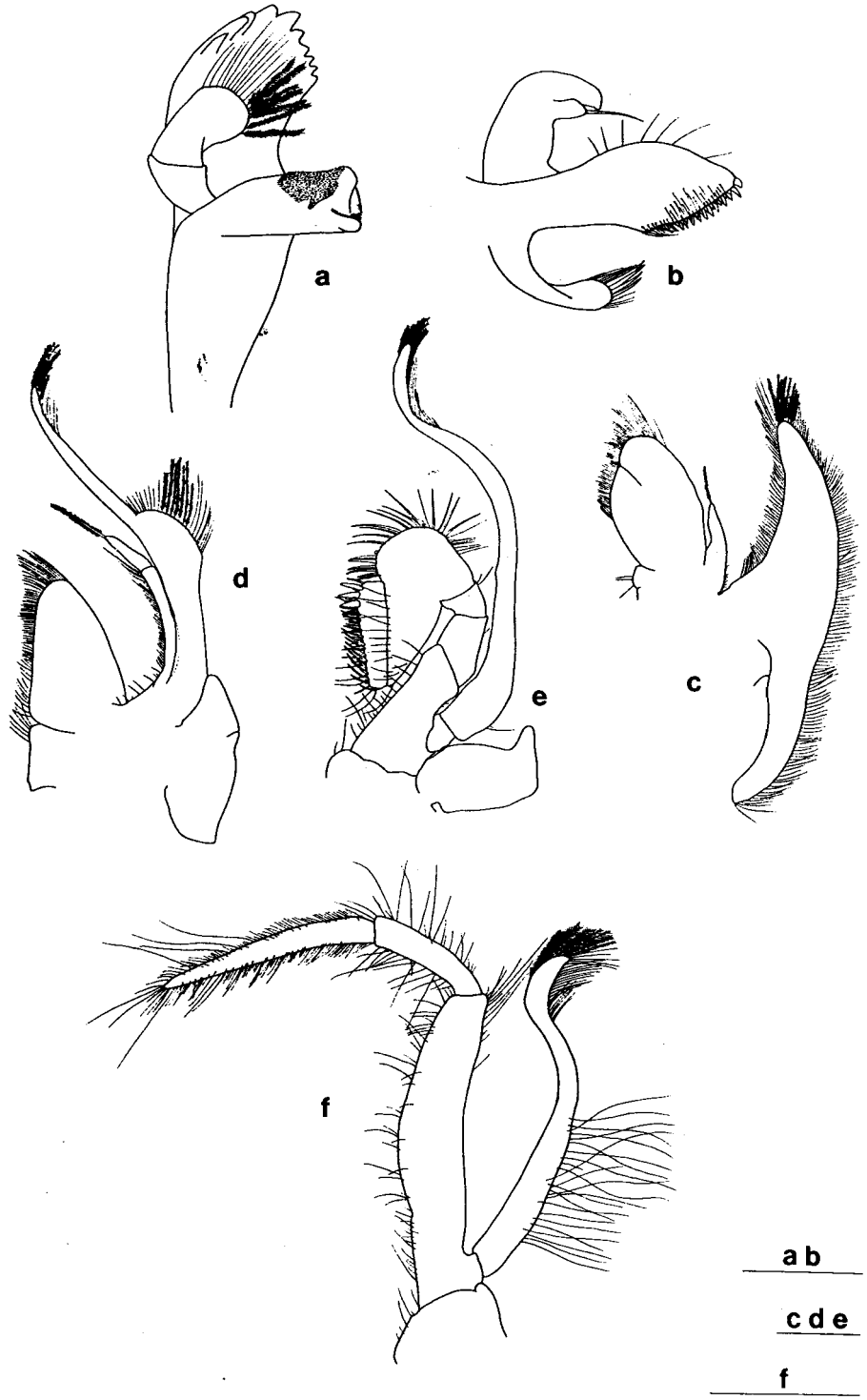

Fig. 7. ***Alpheus cyanoteles***, new species. Paratype male (cl 14.4 mm, tl about 31.1 mm) (ZRC 1996.2), Sungei Tementang, Kota Tinggi, Johore, Peninsular Malaysia. a: left mandible; b: right maxillule; c: right maxilla; d: right first maxilliped; e: right second maxilliped; f: right third maxilliped. Scales = 2.0 mm in a, b; 1.0 mm in c - e; 2.0 mm in f.

Colour. - The carapace and most of the abdomen of live specimens is a dark transluscent grey. Dorsally, there are transverse bands of dark blue on the posterior edge of the carapace and each abdominal segment. The telson is dark blue in the posterior half. The uropod is generally blue to dark blue, especially in the distal lobes of the endopod and exopod. The antennules and antennae are light translucent grey with a light bluish tinge. The fingers of the large chela, except for pinkish fingertips, are dark bluish gradually becoming a lighter greyish blue posteriorly in the palm. The small chela is grey with light bluish fingers and the remaining pereiopods and pleopods are light greyish and transluscent. Aquarium kept specimens retain their natural colouration (pers. observ.).

Ecology. - *Alpheus cyanoteles* is a true freshwater shrimp, found in freshwater streams, above tidal influence, in the Kota Tinggi drainage of Johor, Peninsular Malaysia (see fig. 9). These forest streams are well-shaded and have a sand and clay substrate with clear, flowing water of variable depth (40 - 100 cm). The pH and conductivity of the water is about 4.7 (Sungei Tementang) to 5.8 (Sungei Selangi) and not more than 24 microsiemens respectively. Syntopic organisms include the shrimps *Caridina* sp., *Macrobrachium malayanum*, *Macrobrachium platycheles* (see Ou & Yeo, 1995), *Macrobrachium trompi* and *Potamalpheops* sp. (pers. observ.); fishes include: *Cyclocheilichthys apogon, Osteocheilus hasselti, O. microcephalus, Rasbora bankanensis, R. cephalotaenia, R. elegans, R. heteromorpha, R. trilineata, Puntius binotatus* (Cyprinidae), *Homaloptera tweediei, Nemacheilus selangoricus,* (Balitoridae), *Lepidocephalichthys tomaculum, Pangio kuhlii* (Cobitidae), *Hemibagrus hoeveni, Leiocassis fuscus, L. stenomus, Mystus singaringam* (Bagridae), *Krytopterus macrocephalus, Silurichthys* sp., *Wallago leerii* (Siluridae), *Parakysis verrucosus* (Akysidae), *Glyptothorax* cf. *major* (Sisoridae), *Hemirhamphodon pogonognathus* (Hemiramphidae), *Phenacostethus smithi* (Phallostethidae), *Doryichthys martensi* (Syngnathidae), *Monopterus albus* (Synbranchidae), *Nandus nebulosus* (Nandidae), *Pristolepis grooti* (Pristolepididae), *Brachygobius xanthomelas, Pseudogobiopsis siamensis* (Gobiidae), *Luciocephalus pulcher* (Luciocephalidae), *Betta pugnax, B. tomi, Trichopsis vittata* (Belontiidae), *Channa gachua, C. lucius* (Channidae); and the freshwater crab, *Parathelphusa maculata.* (H.H.Tan, pers. comm.; pers. observ.). Most specimens of *A. cyanoteles* were obtained from below vertical muddy banks with overhangs held in place by vegetation and root systems. It is likely that these shrimp have a preference for building their burrows along the stream bottom, at or near the base of the submerged part of such sheltered banks as many specimens were collected by scooping a tray net deep down to the bottom and then upwards against the vertical bank.

The eggs of *A. cyanoteles* are relatively few and large (about 1.5 mm in diameter). Some larvae were obtained from ovigerous female specimens kept in aquaria and these were of the highly abbreviated type (see Chong & Khoo, 1987).

Referring to *A. cyanoteles* as *A. paludicola*, Johnson (1965, 1966) regarded *A. paludicola* primarily as a prawn inhabiting lower salinity brackish waters . In his review of brackish water prawns of Malaya, Johnson (1965) referred to *A. paludicola* as a characteristic species of oligohaline waters, together with other prawns like *Caridina gracilirostris, C. propinqua, C. tonkinensis* and *C. thambipillaii.* Johnson (1966) again made reference to *A. paludicola* in a discussion on factors influencing distribution of freshwater prawns in Malaya, citing it as an example of a species characteristic of oligohaline waters being able to survive in true freshwaters or "soft, acid waters near the sea". Thus it would appear that the habitat occupied by *A. cyanoteles* ranges from freshwater to oligohaline brackish water. In the present study, only freshwater habitats in Kota Tinggi, Johore [Peninsular Malaysia] were sampled and no

detailed surveys further downstream (i.e closer to the sea) were conducted. As such no specimens from brackish waters were obtained for examination. Furthermore, there has been rapid development of the area since Johnson (1965, 1966) collected specimens of this species in the 1960s or earlier, making it almost impossible to be sure if recent collections in the same area are from the original sites sampled by Johnson. However, from the present large sample size including ovigerous females obtained from freshwaters, it is clear that *A. cyanoteles* is an established freshwater inhabitant and not merely a brackish water prawn able to tolerate low salinities. That it can tolerate brackish waters is also interesting but secondary to the present contention that it can survive wholly in freshwater. Banner & Banner (1966) mentioned *A. paludicola* and Powell (1979) and Lovett (1981) mentioned "*A. paludosus*" (sic) in discussions on freshwater alpheids based on Johnson (1965, 1966).

Remarks. - *Alpheus cyanoteles* belongs to the *A. edwardsi* group (sensu De Man, 1911; Banner & Banner, 1966) and is related to *Alpheus paludicola* Kemp, 1915, *Alpheus euphrosyne* De Man, 1897 and *Alpheus microrhynchus* De Man, 1898. Its closest congener is *A. paludicola* with which it has been mistaken for in the past. *A. cyanoteles* can be distinguished from *A. paludicola* mainly by characters in the rostrum (figs. 2c, 5a), antennule (figs. 2c, 5a), antenna (figs. 2a, c, 5a, b), large chela (figs. 2d, e, 5d, e), second pereiopod (figs. 2g, 5h), third pereiopod (figs. 2i, j, 6a, b), fifth pereiopod (figs. 3a, 6e), second pleopod (figs. 3e, 6h), exopod of uropod (figs. 3b, 5j), telson (figs. 3b, c, 5j) and first maxilliped (figs. 3i, 7d) (See table 1 for comparison). In addition, some other consistent but less reliable differences are noted between the two species. Firstly, *A. cyanoteles* is a larger species than *A. paludicola*. The largest specimen examined from the former species was an ovigerous female of total length 46.2 mm from Sungei Tementang (ZRC 1996.58), compared to the lectotype of *A. paludicola* (BM 1919.11.1.1) total length 18 mm. Kemp (1915: 305) reported that "...large specimens ...reach a length of about 22 mm", which are still smaller than large specimens of *A. cyanoteles*. With regards to the carapace, the anterior margin of the orbital hood tends to be convex dorsally in *A. cyanoteles* versus straight in *A. paludicola*. The inferior orbital and pterygostomial angles of the anterior margin of the carapace are indistinct or very weak, rounded and never produced in *A. cyanoteles* while in *A. paludicola*, these angles are almost always feebly produced. In terms of live colouration, the telson and uropods in *A. paludicola* are dusky (Kemp, 1915) while in *A. cyanoteles*, they are blue to dark blue. The habitat of *A. cyanoteles* differs from that of *A. paludicola*. The streams in Kota Tinggi from which *A. cyanoteles* specimens were collected from are true freshwater forest streams while Lake Chilka, being a coastal lake with direct connection to the sea, has polyhaline waters, spatially and seasonally varying in salinity from almost that of freshwater to that of the adjacent Bay of Bengal. *Alpheus cyanoteles* and *A. paludicola* are also not sympatric, with the latter being reported only from the type locality, Lake Chilka, Orissa, India (Kemp, 1915) and from Tale Sap, southern Thailand (Kemp, 1918).

The specimens of *Alpheus paludicola* reported from Tale Sap in southern Thailand, a coastal lake similar to Lake Chilka in the type locality, Orissa, by Kemp (Kemp in Annandale, 1918:273) were described by him as follows: "The only difference I am able to detect between specimens collected by Dr. Annandale in Lower Siam and those originally described from Chilka Lake in Orissa is that the rostrum is very slender and rather longer, extending considerably beyond the end of the orbital hoods. In the form of the chelae and in all other particulars there is precise agreement. The eggs are 1.3 or 1.4 mm in diameter.

According to Dr. Annandale's notes the specimens differed somewhat in colour from those observed in the Chilka Lake, the transverse bands of pigment on the abdomen are

missing. They were transluscent, without definite markings, but tinged, owing to the presence of scattered chromatophores, with reddish brown. The eyes were black and the palm and fingers of both chelae were deeply tinged with blue, especially on the dorsal surface. The eggs were pale green.

The specimens were obtained in the Tale Sap, in the channel connecting the upper and lower lakes at a depth of $3^1/_2$ to 8 metres. They were found in a shallow layer of dense mud overlying a coarse sandy bottom and occurred in company with *Upogebia heterocheir*. The specific gravity of the water in the channel was variable according to the state of the tide, but probably does not rise much above 1.004." No data for size of specimens or number of specimens were provided.

Determining the true identity of these specimens from the above description alone is a problem as there are several pieces of apparently conflicting information. In the form of the rostrum being "very slender and rather longer, extending considerably beyond the end of the orbital hoods" (Kemp, 1918: 273), the specimens do not match *A. paludicola*. The use of the terms "very slender" and "extending considerably" by Kemp are probably in comparison with the very short rostrum of *A. paludicola* s. str. specimens from Lake Chilka and are probably comparable to the rostra of *A. cyanoteles* or *A. microrhynchus*. The large-sized eggs (1.3 to 1.4 mm in diameter) are characteristic of *A. paludicola* and *A. cyanoteles*. The habitat of Tale Sap (where the specimens were collected) is slightly brackish, unlike that of the freshwater streams of Kota Tinggi where *A. cyanoteles* has been collected. The brackish habitat does agree with that of Lake Chilka from which *A. paludicola* has been obtained. This is further supported by the presence of *Upogebia heterocheir*, a brackish to marine water inhabitant (Kemp, 1915). In live colouration, the description given does not match either *A. paludicola* or *A. cyanoteles* but agrees well with the live colouration of *A. microrhynchus* which is also found from brackish waters (pers. observ.). The actual specimens (deposited in the Indian Museum) could not be obtained for examination in this present study. Based on the available information, four possible hypotheses on the identity of the Tale Sap specimens are put forward: these specimens could represent an extreme variant of *A. paludicola* or an extreme variant of *A. cyanoteles* or mistakenly identified *A. microrhynchus* or a new species. Unfortunately, the egg size of *A. microrhynchus* is not known. If it were, it might be useful in this case as a diagnostic character to either discount or include *A. microrhynchus* as a possible identity for the specimens. It is important however, that these original specimens be obtained and examined to determine their true identity. Until this is done, the specimens should tentatively be assigned to *A. paludicola* Kemp, 1915, and the distribution of the species should include Tale Sap in southern Thailand (see fig. 9).

Johnson (1965, 1966) referred to a snapping shrimp from brackish to freshwaters from Malaya, specifically "...in the Sedili basin of South Johore..." (Johnson, 1965: 9) as *A. paludicola* (mis-spelled *A. paludosus*). One of Johnson's specimens from the above area labelled as *A. paludosus* (ZRC 1979.4415) was examined and has been confirmed to be a specimen of *A. cyanoteles*. In addition, the area mentioned above is also the type locality of *A. cyanoteles*. Therefore, Johnson (1965, 1966) was actually referring to *A. cyanoteles*.

Alpheus cyanoteles can be differentiated from *A. euphrosyne* and *A. microrhynchus* by: i) absence of a movable spine on the ischium of the third pereiopods (versus presence of spine); ii) different proportions in carpus of second pereiopod, 10:4:2:2:3 in *A. cyanoteles* versus 10:6:2:2:3 in *A. euphrosyne* (see Banner & Banner, 1966) and 10:3:1:1:2 in *A. microrhynchus* (see Banner & Banner, 1966). Other differences between *A. cyanoteles* and

A. euphrosyne include the presence of a distinctive transverse ridge running midway through the inner face of the palm of the large chela in *A. cyanoteles* (versus absence of such a ridge), the absence of a distal tooth on the inferior margin of merus of the large cheliped of the former (usually present in the latter) and the fact that the eggs of the former (1.5 mm in diameter) are much larger than those of the latter (0.5 mm in diameter). *Alpheus cyanoteles* can be further distinguished from *A. microrhynchus* by its generally smaller size. The largest *A. cyanoteles* specimen examined being an ovigerous female (ZRC 1996.58) of total length 46.2 mm while the largest *A. microrhynchus* specimen examined was a female (ZRC 1979.441) of total length 81.6 mm. In terms of habitat, *A. cyanoteles* differs from the two in that it is found (including ovigerous females) in true freshwater habitat while *A. euphrosyne* and *A. microrhynchus* inhabit brackish to oligohaline waters of estuarine and mangrove habitats. There are also differences in live colouration. The dark blue banding pattern of the abdomen together with the dark blue uropods and telson would clearly separate live specimens of *A. cyanoteles* from *A. euphrosyne* and *A. microrhynchus*.

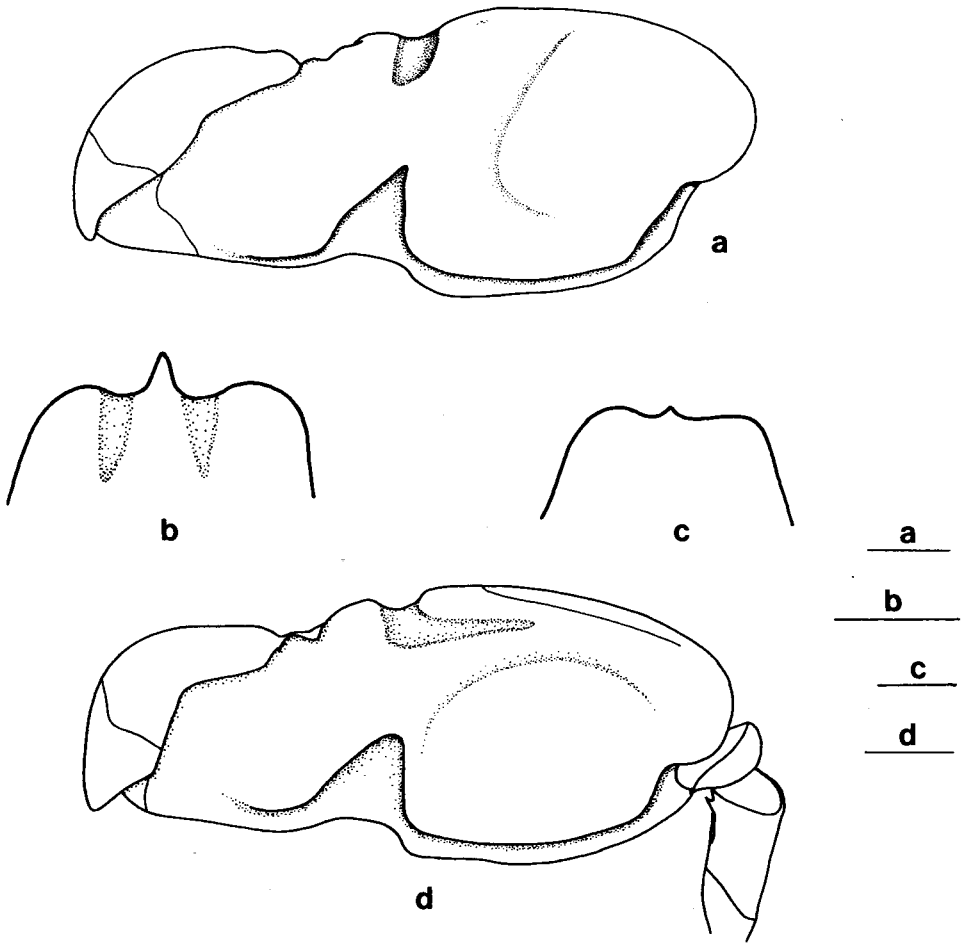

Fig. 8. *Alpheus microrhynchus* De Man, 1898. a, b, (ZRC 1979.441) (cl 28.1 mm, tl 81.6 mm), Jurong prawn pond, Singapore. c, (ZRC 1992.8064) (cl 11.9 mm, tl 33.8 mm), Sungei Buloh swamps, Singapore. *Alpheus euphrosyne* De Man, 1897. d, (ZRC 1979.438) (cl 10.2 mm, tl 32.1 mm), Port Sweetenham (Port Klang), Selangor, Malaysia. a: inner face of right first pereiopod; b: dorsal view of orbital hood and rostrum; c: dorsal view of orbital hood and rostrum; d: inner face of right first pereiopod. Scales = 5.0 mm in a; 3.0 mm in b; 1.0 mm in c; 2.0 mm in d.

Distribution. - *Alpheus cyanoteles* has so far been recorded only from its type locality in the Kota Tinggi area, Johor, Peninsular Malaysia (see fig. 9).

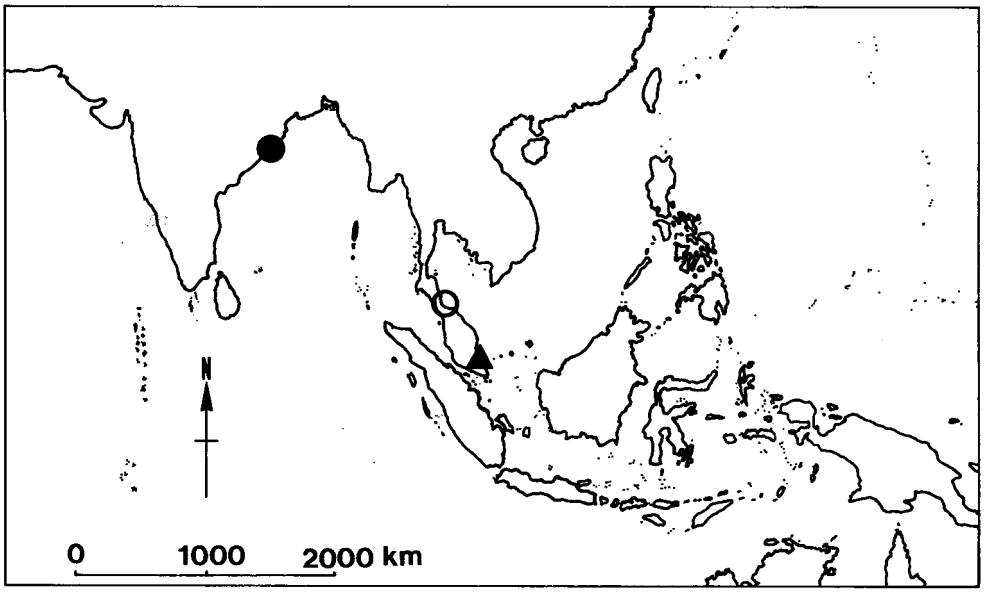

Fig. 9. Map showing distribution of *Alpheus paludicola* and *A. cyanoteles*. ▲: *A. cyanoteles*; ○: (?) *A. paludicola*; ●: *A. paludicola*.

GENERAL DISCUSSION

Caridean freshwater shrimps are known almost exclusively from the families Palaemonidae and Atyidae. There are however, a small number of freshwater shrimps from the family Alpheidae in the genera *Potamalpheops* and *Alpheus*. *Potamalpheops haugi* (Coutière, 1906) is found in the Niger Delta area and Gabon in West Africa, restricted to whitewater rivers above the tidal limit (Powell, 1979). *Potamalpheops monodi* (Sollaud, 1932) is a tidal freshwater prawn found in a wide range of salinities, ranging from mesohaline to oligohaline to almost pure freshwater, in Cameroons, Senegal, Sierra Leone, and the Niger Delta in West Africa (Powell, 1979, 1976). *Potamalpheops stygicola* (Hobbs, 1973) is a troglobitic prawn found in freshwater caves in Oaxaca, Mexico (Hobbs, 1973, 1983). A fourth freshwater *Potamalpheops* shrimp is a new species found in freshwater forest streams in Singapore, Peninsular Malaysia and Indonesia [Pulau Bintan, Riau Archipelago] above the tidal limit (pers. observ.). *Alpheus cyanoteles* is only the fifth freshwater alpheid as well as the only true freshwater member of the genus *Alpheus* to be reported. Recent collections from acid water forest streams in Kota Tinggi, Johor [Peninsular Malaysia] over a period of 12 months included several ovigerous females, thus providing an excellent sample size. This shows that the species, having established breeding populations in soft, acidic, true freshwater streams well above the tidal limits, can thrive in a wholly freshwater habitat. Very indicative of the nature of its habitat are the syntopic fish and decapod crustacean fauna collected (see ***Ecology*** section under *Alpheus cyanoteles*, new species) as well as the presence of the aquatic plants *Cryptocoryne* sp. and *Blyxa* sp. (pers. observ.). *Alpheus cyanoteles* is almost certainly able to complete its life cycle wholly in such freshwaters. This conclusion is based on the large series of *A. cyanoteles* specimens collected, which includes numerous ovigerous females and juveniles from the freshwater streams of Kota Tinggi, Johore. In addition , the large eggs, highly abbreviated larval development and benthic or non-pelagic larval behaviour

(pers. observ.) of the species are typical of many freshwater prawn species, for example, *Macrobrachium pilimanus* (De Man, 1879) (see Chong & Khoo, 1987). It is important however to note that *A. cyanoteles* has been reported to occur in oligohaline brackish waters as well (Johnson, 1965, 1966). However, the main point to note here is the fact that freshwater populations of this shrimp survive well, reproduce normally and most probably complete their development entirely in freshwater.

Within the genus *Alpheus*, in addition to *A. cyanoteles*, *A. paludicola* Kemp, 1915, has also been reported from freshwaters (Kemp, 1915). However, it is more a brackish water species with high tolerance of low salinity or even freshwater conditions that prevail seasonally in its habitat, that of a coastal lake with direct connection to the sea (Kemp, 1915), than a true freshwater prawn. Another brackish water species, *A. microrhynchus* De Man, 1897 has been recorded from freshwaters in Thailand: "klongs or canals of Bangkok about 15 miles from the river mouth where they are reported to be plentiful during the rainy season" (Banner & Banner, 1966: 135). These probably penetrated upstream during the rainy season from among the large numbers in the brackish waters of the river mouth and would seem unlikely to have established a breeding population there. It seems unlikely that *A. microrhynchus* can be a true freshwater prawn as it is known from this region primarily as a mangrove species inhabiting brackish and mangrove waters (Johnson, 1965, 1969; Tan & Ng, 1988; pers. observ.). Several other species of *Alpheus* besides *A. paludicola* and *A. microrhynchus* have been reported from estuaries, mangrove swamps or coastal lakes, tolerating waters of very low salinity or even seasonal freshwaters. One example is *Alpheus pontederiae* Rochebrune, 1883, from West Africa which has been reported from brackish waters (L.B.Holthuis, pers. comm.). From Southeast Asia, Banner & Banner (1966) report five alpheid shrimp species (all from the genus *Alpheus*) in addition to *A. microrhynchus*, as occurring in brackish waters, namely, *Alpheus crassimanus, A. euphrosyne, A. malabaricus malabaricus, A. malabaricus songkla* and *A. rapax*. However, *A. euphrosyne* is an obligate mangrove species while the rest are estuarine species and all are not known to penetrate freshwaters.

KEY TO *ALPHEUS* SPECIES FOUND IN FRESHWATERS AND MANGROVES OF SOUTHEAST ASIA

1. Large chela without distinct transverse ridge running midway through inner face of palm, merus of first pereiopods usually with distal tooth on inferior margin ..... *A. euphrosyne euphrosyne*
- Large chela with distinct transverse ridge running midway through inner face of palm, merus of first pereiopods unarmed 2

2. First article of carpus of second pereiopod proportionately long (carpus article ratio 10:3:1:1:2); large species (tl up to 81.6 mm); found primarily in mangroves ..... *A. microrhynchus*
- First article of carpus of second pereiopod proportionately shorter (carpus article ratio 10:4:2:2:3 or 10:6:2:2:3); smaller species (tl not exceeding 46.2 mm); found in freshwater to brackish water but not in mangroves 3

3. Rostrum short (reaching up to 0.2 of proximal segment of antennular peduncle) and broadly triangular in shape dorsally; ventrolateral tooth of basicerite feebly developed and blunt or absent; large chela compact (ratio of chl/chb 2.4), fingers robust (ratio of mfl/mfb 1.1 to 1.3; ffl/ffb 2.6 to 3.4); second pereiopod carpus article ratio 10:6:3:3:4; propodus of third pereiopod with 1 to 3 ventral spines; appendix interna much longer than appendix masculina in males (ratio of ail/aml 1.7); movable lateral spine of uropodal exopod not flanked by fixed teeth; telson more slender and tapered in appearance (posterior margin width about 0.5 to 0.6 of anterior margin width); palp of first maxilliped unsegmented ..... *A. paludicola*

- Rostrum longer (reaching up to 0.3 to 0.5 of proximal segment of antennular peduncle) and slender, acutely tapering in shape dorsally; ventrolateral tooth of basicerite well-developed and acute; large chela more slender (ratio of chl/chb 2.5 to 3.0), fingers more slender (ratio of mfl/mfb 1.4 to 2.0; ffl/ffb 3.4 to 4.1); second pereiopod carpus article ratio 10:4:2:2:3; propodus of third pereiopod with 6 to 8 ventral spines; appendix interna equal to or slightly longer than appendix masculina in males (ratio of ail/aml 1.0 to 1.3); movable lateral spine of uropodal exopod flanked medially and laterally by fixed teeth; telson broader and less tapered in appearance (posterior margin width about 0.6 to 0.8 of anterior margin width); palp of first maxilliped 2-segmented ..... *A. cyanoteles*, new species

Table 1. Differences between *Alpheus paludicola* Kemp, 1915, and *A. cyanoteles*, new species.

Character	*Alpheus paludicola*	*Alpheus cyanoteles*
Rostrum	Very short (reaching up to 0.2 of proximal segment of antennular peduncle).	Relatively longer (reaching 0.3 to 0.5 of proximal segment of antennular peduncle).
	Broadly triangular in shape dorsally.	Slender and acutely tapering shape dorsally.
Antennular peduncle	Intermediate segment almost equal to or slightly longer than proximal segment (ratio of isl/psl 1.1).	Intermediate segment distinctly longer than proximal segment (ratio of isl/psl 1.3 to 2.0).
Antenna	If present, ventrolateral tooth is feebly developed and blunt.	With well developed, acute, stout ventrolateral tooth.
	Scaphocerite with lateral margin slightly concave.	Scaphocerite with lateral margin straight.
Large chela	Chela more compact (ratio of chl/chb 2.4).	Chela more elongated (ratio of chl/chb 2.5 to 3.0).
	Fingers relatively shorter (ratio of mfl/chl 0.3 to 0.4; ffl/chl 0.4).	Fingers relatively longer (ratio of mfl/chl 0.4 to 0.5; ffl/chl 0.4 to 0.5).
	Fingers more robust (ratio of mfl/mfb 1.1 to 1.3; ffl/ffb 2.6 to 3.4).	Fingers more slender (ratio of mfl/mfb 1.4 to 2.0; ffl/ffb 3.4 to 4.1).
Second pereiopod	First article of 5-segmented carpus shorter (carpus article ratio 10:6:3:3:4).	First article of 5-segmented carpus more elongated (carpus article ratio 10:4:2:2:3).
Third pereiopod	More slender, with relatively longer propodus (ratio of ml/pl 1.2).	More stout, with relatively shorter propodus (ratio of ml/pl 1.3 to 1.5).
	Propodus with 1 to 3 ventral spines.	Propodus with 6 to 8 ventral spines.
Second pleopod	Appendix interna much longer than appendix masculina in males (ratio of ail/aml 1.7).	Appendix interna equal to or slightly longer than appendix masculina in males (ratio of ail/aml 1.0 to 1.3).
Uropod	Movable lateral spine of exopod not flanked by fixed teeth; distolateral angle of lateral margin subrectangular.	Movable lateral spine of exopod flanked by short fixed tooth medially (projection of diaeresis) and laterally (projection of distolateral angle of lateral margin).
Telson	More slender and tapered in appearance, with posterior margin width about 0.5 to 0.6 of anterior margin width.	Broader and less tapered in appearance, with posterior margin width about 0.6 to 0.8 of anterior margin width.
First maxilliped	Palp unsegmented.	Palp 2-segmented.

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