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NEW RECORDS AND SPECIES OF ALPHEIDAE (CRUSTACEA: DECAPODA) FROM VIETNAM. PART I. GENUS *SALMONEUS* HOLTHUIS, 1955

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ABSTRACT. **–** Six species of the alpheid genus *Salmoneus* Holthuis, 1955, including five new species, are reported from Nhatrang Bay, southern Vietnam. *Salmoneus nhatrangensis*, new species, *S. auroculatus*, new species, *S. falcidactylus*, new species, and *S. pusillus*, new species, were collected under rocks on sand-mud bottoms at depths of 6-40 m. *Salmoneus alpheophilus*, new species and *S rostratus* Barnard, 1962 were collected on tidal flat from burrows of *Alpheus* with gobies. The affinities of the new species to other Indo-West Pacific and Atlantic species are discussed. All species are illustrated. *Salmoneus* is preliminarily divided into seven species groups.

KEY WORDS. **–** Alpheidae, *Salmoneus*, new species, species groups, Indo-Pacific, Vietnam.

INTRODUCTION

Despite several extensive studies of alpheid shrimps in the South China Sea and the adjacent Gulf of Thailand (e.g. Banner & Banner, 1966b, 1978; Jeng & Chang, 1985; Chace, 1988; Bruce, 1990a, 1990b), the Alpheidae of the Vietnamese coast remain poorly known. Only one major review deals with the Alpheidae of this region, mainly from Nhatrang Bay and adjacent waters, based on the collections of the Oceanographic Institute of Nhatrang City (Tiwari, 1963). However, this study is of limited use being out-dated, not very extensive and containing some misidentifications. The only other studies of Vietnamese alpheids are descriptions of several new species from different localities along the coastline of Vietnam (De Man, 1898; Anker et al., 2001; Xuan, 2001). Presently, the total number of alpheid species recorded from Vietnam is about 25. This is undoubtedly an underestimate of the actual alpheid diversity of this region, as for instance, the genus *Salmoneus* Holthuis, 1955 – the focus of this study – was previously not reported from Vietnamese waters.

During an ongoing study of the biodiversity of marine invertebrates in Nhatrang Bay, Vietnam, the second author (IM) collected numerous specimens of alpheid shrimps, among them specimens of *Salmoneus*. These specimens proved to belong to six species, five of which are described herein as new. In most cases, the differences between the new species and the previously described species of *Salmoneus* are subtle, but are considered to be of specific importance. The sixth species, *S. rostratus* Barnard, 1962, is recorded for the first time from Vietnam and the South China Sea. The Vietnamese specimens of *S. rostratus* are compared to the type material from Madagascar and specimens from other localities.

MATERIAL AND METHODS

Specimens were collected by SCUBA diving, either by hand or with the aid of a suction pump, and at greater depths by means of Petersen grab, in Nhatrang Bay between September 2003 and July 2004. They were fixed in 4% buffered seawater-formalin solution for two to three days and then preserved in 70% ethanol. All drawings were made with the help of a camera lucida. Carapace length (CL) and total length (TL) are given in mm, and were measured at the midline from the tip of the rostrum to the posterior margin of the carapace and the telson, respectively. All specimens were deposited in the collections of the Zoological Museum of the Moscow State University, Moscow, Russia (ZMMU).

TAXONOMY

Salmoneus Holthuis, 1955

Salmoneus nhatrangensis, new species
(Figs. 1-3)

Material examined. – Holotype, non-ovigerous specimen (CL 3.4, TL 10.2)(ZMMU Ma 5438), South China Sea, Vietnam, Nhatrang Bay, Tre Island, on sand, under stone, depth 8-10 m, SCUBA, coll. I. Marin, 29 Sep.2003.

Description. – Carapace slightly setose, with small rounded depressions or pits, appearing somewhat granular, laterally with shallow oblique depression and slight suture starting from lateral margin proximal to base of antenna (Figs. 1, 2b). Rostrum moderately long, not reaching distal margin of first segment of antennular peduncle (Fig. 2a), broader than long at base; lateral margins distinctly convex proximally (Fig. 2a); rostral carina moderately developed, reaching slightly beyond level of eyes posteriorly (Fig. 2a). Extra-corneal teeth acute, directed towards apex of rostrum; notch between rostrum base and extra-corneal teeth deep (Fig. 2a). Pterygostomial angle rounded. Eyes without tubercle, completely covered by carapace, not visible in dorsal view, anterior portion visible in lateral view (Fig. 2b). Epistomial sclerite with small, subacute process. Ocellar beak small.

Antennular peduncle stout, second segment shorter than first and third; ventromesial carina of first segment with acute tooth; stylocerite reaching to, but not exceeding distal margin of second segment, distally subacute (Fig. 2a); lateral flagellum biramous, with shorter ramus situated at first-second segment. Antenna with basicerite bearing strong ventrolateral tooth (Fig. 2b); scaphocerite relatively broad, anterior margin of blade strongly convex, exceeding distolateral tooth; carpocerite short, reaching to about 3/4 length of scaphocerite (Fig. 2b).

Mouthparts typical for genus. Mandible with incisor process bearing seven teeth, third and fourth largest. Maxillule with bilobed palp, lower lobe with one seta, upper lobe unarmed. Second maxilliped with rounded epipod. Third maxilliped slender (Fig. 2c); lateral plate blunt, ear-shaped (Fig. 2e); ultimate segment distally tapering, bearing two subapical spines (Fig. 2d), tip subacute; arthrobranch normally developed.

First pereiopods (chelipeds) very asymmetrical, unequal (Figs. 2f, 3), carried flexed ventrally in life, mesially when preserved (Fig. 1); major cheliped robust; ischium short, without spines; merus elongate, distally widening, ventrally depressed, rounded distal lobes; carpus short, cup-shaped, constricted, distally with several more or less pronounced lobes (Fig. 3a, c); chela subcylindrical, with ratio fingers-palm about 3/5; palm proximoventrally with complex deep groove (Fig. 3b, c), dorsal surface with elongate depression (Fig. 3a); pollex proximolaterally with massive blunt lobe (Fig. 3c, d), cutting edge with 10 rounded regularly spaced, rounded teeth, tip strongly curved; dactylus with cutting edge bearing nine teeth (one apparently broken), tip strongly curved (Fig. 3d); tips crossing when fingers closed (Fig. 3a). Minor cheliped slender; ischium slightly elongate, about half length of merus; carpus slightly shorter than merus, cylindrical; chela simple, not particularly enlarged, fingers as long as palm, cutting edges unarmed (Fig. 2f).

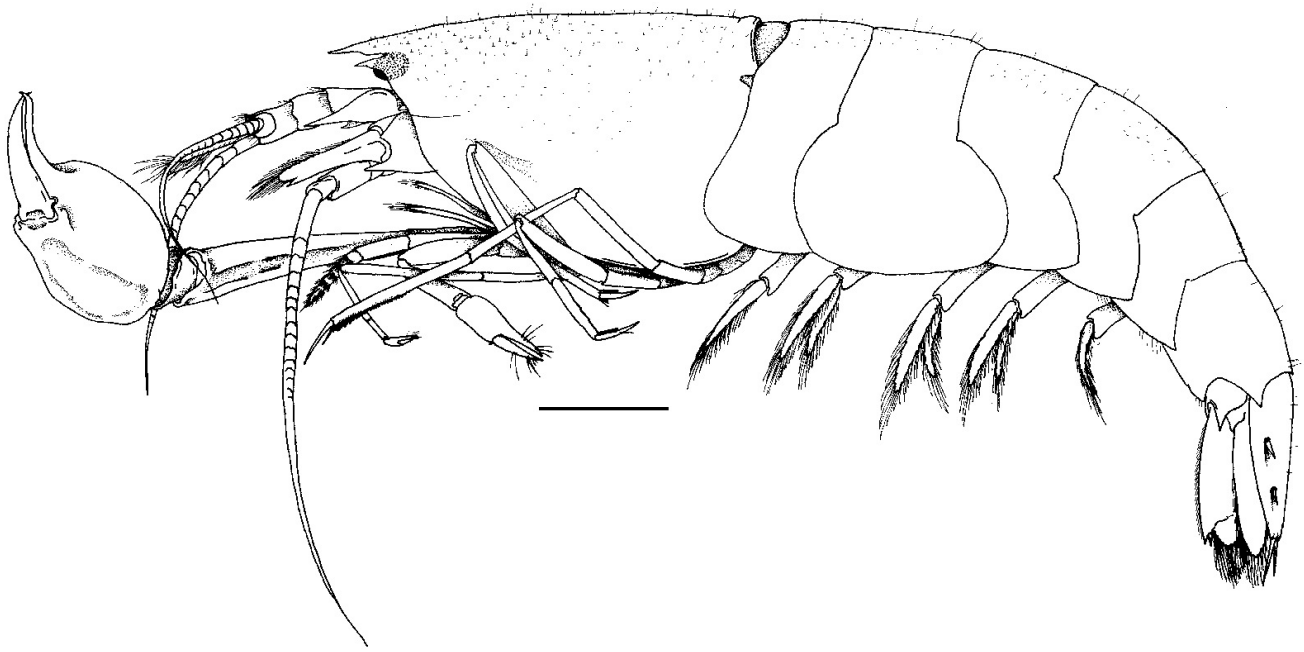

Fig. 1. *Salmoneus nhatrangensis*, new species, holotype (ZMMU Ma 5438): habitus. Scale bar = 1 mm.

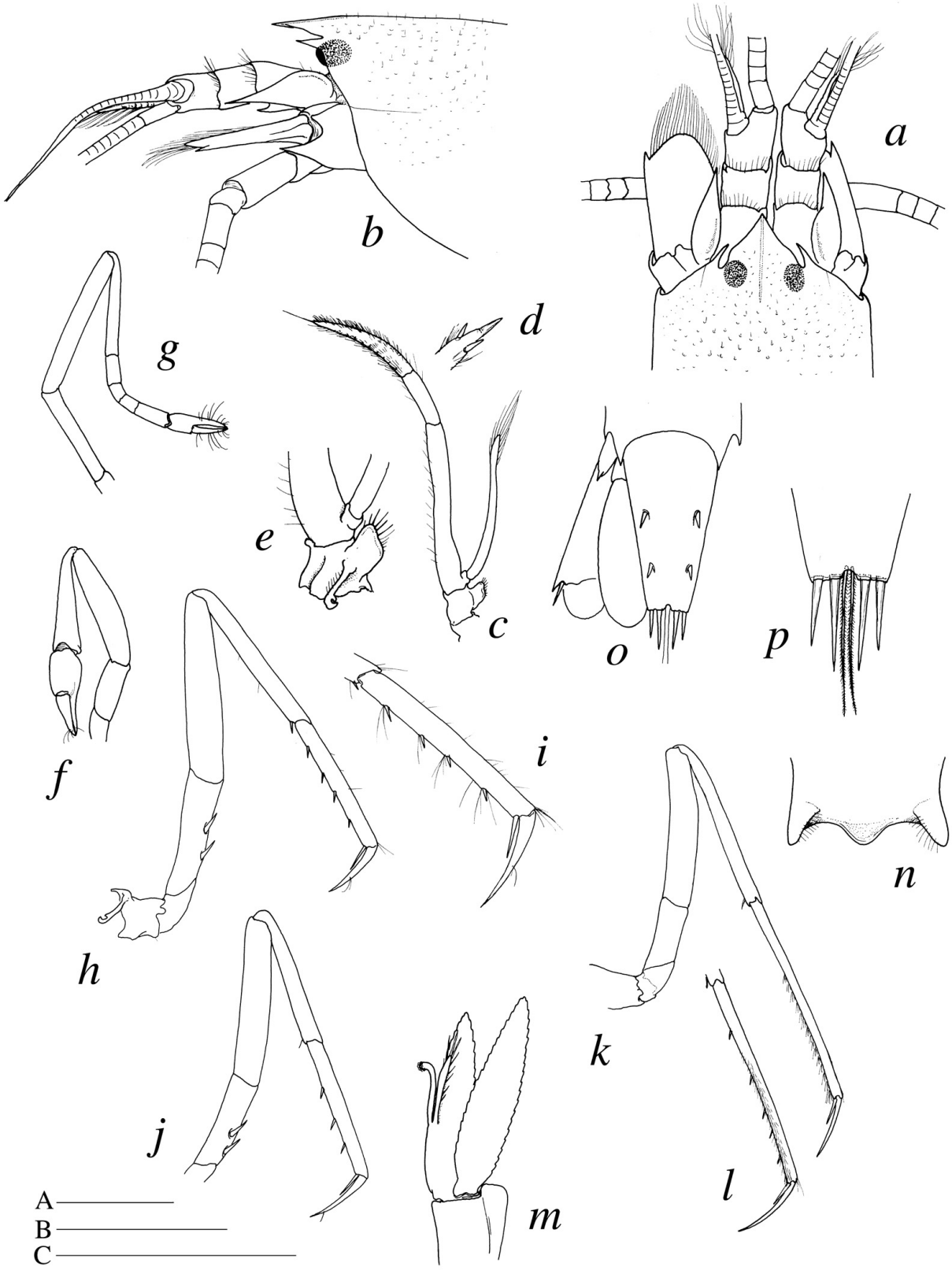

Fig. 2. *Salmoneus nhatrangensis,* new species, holotype (ZMMU Ma 5438): a, frontal region, dorsal view; b, same, lateral view; c, third maxilliped (arthrobranch not drawn); d, same, apex; e, same, coxa and proximal portion of antepenultimate segment (arthrobranch not drawn); f, left minor cheliped; g, second pereiopod; h, third pereiopod; i, same, propodus and dactylus; j, fourth pereiopod; k, fifth pereiopod; l - propodus and dactylus; m, second pleopod; n, preanal plate of sixth abdominal segment, ventral view; o, uropods and telson; p, telson, distal portion. Scale bars: A (a-c, f-h, j-l, o) = 1 mm; B (n) = 1 mm; C (e, i, m, p) = 1 mm; d = without scale bar.

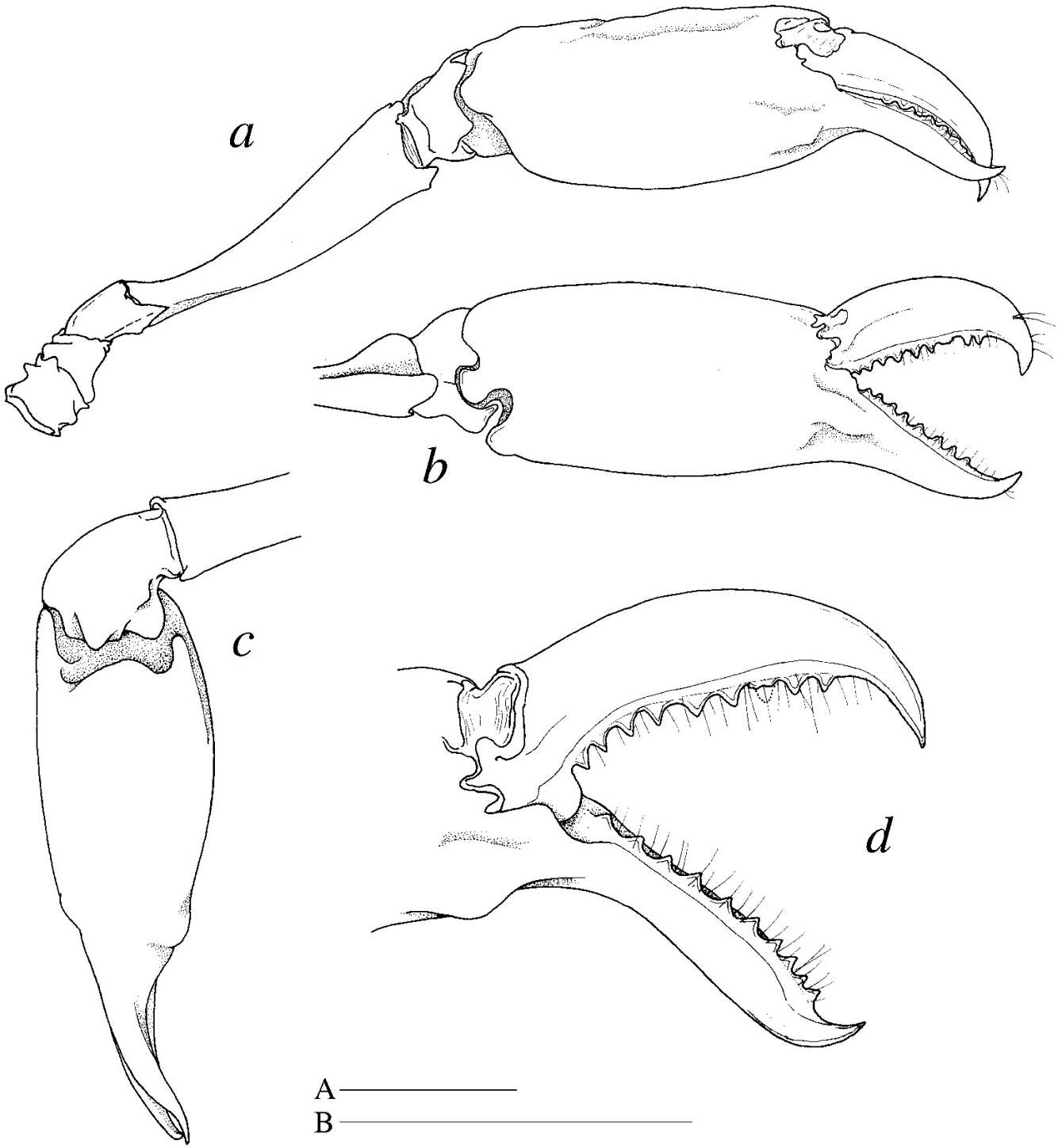

Fig. 3. *Salmoneus nhatrangensis*, new species, holotype (ZMMU Ma 5438): a, right major cheliped, mesial view; b, same, chela and carpus, lateral view; c, same, ventral view; d, same, fingers. Scale bars: A (a-c) = 1 mm; B (d) = 1 mm.

Second pereiopod slender; ischium about 3/4 length of merus; carpus with five segments with ratio approximately equal to 4/1/0.7/0.7/1.4; chela simple, fingers slightly longer than palm (Fig. 2g). Third pereiopod slender; ischium with two spines; merus about 1.7 length of ischium, about five times as long as wide at base; carpus slender, shorter than merus, with small distoventral spine; propodus slightly shorter than carpus, ventrally with four small spines and one slender distoventral spine proximal to dactylus; dactylus simple, slender, less than half length of propodus, slightly curved (Fig. 2h, i). Fourth pereiopod similar to third (Fig. 2j). Fifth pereiopod very slender; ischium unarmed; merus more than twice length of ischium, about six times as long as wide at base; carpus slender, slightly longer than merus, with distal spinule; propodus about 1.3 length of carpus, ventrally with about 15 rows of setae, five-six spines and one slender distoventral spine proximal to dactylus; dactylus simple, slender, less than 1/3 length of propodus, slightly curved (Fig. 2k, l).

Abdominal segments I-III with posteroventral margins rounded; segment IV with posteroventral margin angular; segment V with posteroventral margin acutely projecting (Fig. 1); segment VI with acute posterior projection, without articulated plate (Fig. 1); preanal plate rounded posteriorly (Fig. 2n). Second pleopod with appendix masculina slightly shorter than appendix interna, with row of slender spines along mesial margin (Fig. 2m). Telson about twice as long as wide proximally; basal width about twice width of posterior margin; dorsal surface with two pairs of spines situated at some distance from lateral margin, at about mid-length and 3/4 length of telson, respectively (Fig. 2o); posterior margin with shallow median notch bearing two setae and two pairs of spines, lateral shorter than mesial (Fig. 2p); anal tubercles absent. Uropods slightly longer than telson; sympodite with acute tooth; diaeresis sinuous; lateral spine well developed (Fig. 2o).

Gill formula typical for genus: pleurobranchs above first to fifth pereiopods; arthrobranch above third maxilliped; podobranch absent; lobed epipods on first and second maxillipeds; mastigobranchs (strap-like epipods) on third maxilliped and first to fourth pereiopods; sets of setobranchs on first to fifth pereiopods; exopods on first to third maxillipeds.

***Colour*. –** Whitish to pale yellowish.

***Habitat.* –** The specimen was collected by hand under a medium-sized stone on muddy sand, at a depth of about 10 m, together with several specimens of another alpheid shrimp, *Athanas parvus* De Man, 1910. The site is a transition zone between a coral reef and a sand plain, and is a muddy sand bottom with numerous dead fungiid and branching corals, coral rubble and stones, all partly covered by mud and sand.

***Etymology.* –** *Salmoneus nhatrangensis*, new species, is named after the type locality, Nhatrang Bay, Vietnam.

***Remarks.* –** The new species appears to have affinities with several species characterized by the fingers of the major cheliped armed with numerous small teeth, the merus of the major cheliped not inflated and ventrally not excavated, the eyes dorsally concealed by the orbital hoods and the carapace lacking strong mediodorsal carina. These are *S. serratidigitus* (Coutière, 1896), *S. latirostris* (Coutière, 1896), *S. sibogae* (De Man, 1910), *S. hilarulus* (De Man 1910), *S. mauiensis* (Edmondson, 1930), *S. babai* Miyake & Miya, 1966 in the Indo-Pacific, and *S. teres* Manning & Chace, 1990, *S. setosus* Manning & Chace, 1990 and *S. arubae* (Schmitt, 1936) in the Atlantic.

The new species can be separated from the problematical *S. serratidigitus*, as described by Coutière (1896, 1899), and redescribed by Banner & Banner (1981), by several features. It differs from *S. serratidigitus* in the shape of the rostrum, being much shorter and broader, with lateral margins proximally convex (vs. longer, more slender, not convex proximolaterally in *S. serratidigitus*); and the orbital teeth being directed mesially towards the rostrum (vs. directed anteriorly in *S. serratidigitus*). In *S. nhatrangensis*, new species, the stylocerite does not reach the distal margin of the second segment of the antennular peduncle, while in *S. serratidigitus,* the stylocerite clearly exceeds this margin. The minor cheliped of *S. nhatrangensis*, new species, is shorter and more robust compared to that of *S. serratidigitus*. The major cheliped is similar although there is a small difference in the number of teeth on the cutting edges of the fingers: 9-10 in *S. nhatrangensis*, new species, and 12-13 in *S. serratidigitus*. The live colour of *S. serratidigitus* was described by Coutière (1899) as bright yellow-orange, while that of *S. nhatrangensis*, new species, was noted as whitish.

Salmoneus nhatrangensis, new species, differs from *S. sibogae*, as described and illustrated by De Man (1911, 1915) by the same morphological criteria as *S. serratidigitus*, except for the minor cheliped (unknown in *S. sibogae sensu* De Man), the number of teeth on the fingers of the major chela (9-10 in both *S. sibogae* and *S. nhatrangensis*, new species) and the colour pattern (unknown in *S. sibogae sensu* De Man). A further point of difference is the median notch on the posterior margin of the telson: broad and triangular in *S. sibogae*, but small, shallow and rounded in *S. nhatrangensis*, new species.

Salmoneus nhatrangensis, new species, appears to be most closely related to the poorly described *S. latirostris* from the Red Sea and the Gulf of Aden (Coutière, 1896, 1899), differing from the latter however, by the shorter rostrum and the shape of the extra-corneal teeth. More importantly, the colour pattern of *S. latirostris* was described as transversely banded with red and white (Coutière, 1899; Banner & Banner, 1981), while our specimen of *S. nhatrangensis*, new species, did not have red bands.

The new species can be separated from *S. hilarulus* and *S. brevirostris* (Edmondson, 1930) by the very different shape of the frontal margin (cf. De Man, 1911, 1915; Edmondson, 1930). *Salmoneus nhatrangensis*, new species, can be differentiated from *S. mauiensis* by the shape of the rostrum;

the greater number of teeth on the fingers of the major chela (6 in *S. mauiensis*, 9-10 in the new species); and the shape of the posteromedian notch on the telson (broad, conspicuous in *S. mauiensis*, small, inconspicuous in the new species). *Salmoneus nhatrangensis*, new species, cannot be confused with *S. babai*, which is characterized by the very unequal fingers on the major chela and very stout dactylus on the third to fifth pereiopods (Miyake & Miya, 1966). Furthermore, both *S. mauiensis* and *S. babai* were described as bright orange-yellow or yellow (Edmondson, 1930; Miyake & Miya, 1966).

The new species markedly differs from the first two of the afore-mentioned Atlantic species. It differs from *S. arubae* by the configuration of the frontal margin; the presence of a small, posteromedian notch on the telson; and the general shape of the major cheliped (Schmitt, 1936; Holthuis, 1990). It differs from *S. setosus* by the absence of thick, erect setae on the carapace and the abdomen; the configuration of the frontal margin; and the shape of the major cheliped (Manning & Chace, 1990). The last species, *S. teres*, surprisingly shows close affinities to *S. nhatrangensis*, new species, especially in the configuration of the telson, the frontal region, including the rostrum, and most features on the first to fifth pereiopods. However, the new species from Vietnam can be separated from *S. teres* by the presence of two strong spines on the ischium of the third pereiopod (lacking in *S. teres*); the more pronounced incisions between the rostrum and the extra-corneal teeth; the major chela bearing complex grooves near the articulation with the dactylus; and a blunt process near the pollex.

The small, rounded depressions or pits on the carapace, giving it a somewhat granulated appearance, were previously observed only in *S. arubae* (Holthuis, 1990) and *S.* aff. *sibogae* (Banner & Banner, 1982). The pits or interconnected depressions are also present in *S. teres* (R. Lemaitre, pers. comm.; A. Anker, pers. obs.), a new species close to *S. teres* from Brazil (Anker, in prep.), *S. nhatrangensis*, new species, and another new species described below. The presence or absence of these pits could prove to be a further important taxonomic character for species of the genus *Salmoneus*.

***Distribution.* –** Presently known only from the type locality, Nhatrang Bay, Vietnam.

Salmoneus auroculatus, new species
(Figs. 4-6, 7a)

***Material examined.* –** Holotype, ovigerous female (CL 3.4, TL 10.6)(ZMMU Ma 5440), South China Sea, Vietnam, Nhatrang Bay, Tre Island, depth 6-8 m, SCUBA, with suction pump, coll. I. Marin, 24 Oct.2003.

***Description.* –** Carapace slightly setose, with inconspicuous rounded depressions or pits, appearing finely granular, laterally with shallow oblique depression and slight suture starting from lateral margin proximal to base of antenna (Figs. 4, 5b). Rostrum moderately long, overreaching distal margin of first segment of antennular peduncle (Fig. 5a), longer than broad at base; lateral margins slightly concave (Fig. 5a); rostral carina well developed, reaching beyond 3/4 of carapace length (Figs. 4, 5a). Extra-corneal teeth acute, directed anteriorly; margin between rostrum base and extra-corneal teeth broadly concave (Fig. 5a). Pterygostomial angle rounded. Eyes without tubercle, completely covered by carapace, not visible in dorsal and lateral view (Fig. 5b). Epistomial sclerite with small, rounded process. Ocellar beak slightly protruding between eyes.

Antennular peduncle stout, second segment approximately equal to first and third segments; ventromesial carina of first segment with acute tooth; stylocerite reaching to, but not exceeding distal margin of second segment, distally acute (Fig. 5a); lateral flagellum biramous, with shorter ramus situated at second segment. Antenna with basicerite bearing strong ventrolateral tooth (Fig. 5b); scaphocerite relatively broad, anterior margin of blade convex, only slightly exceeding distolateral tooth; carpocerite short, reaching to about 3/4 length of scaphocerite (Fig. 5b).

Mouthparts typical for genus. Mandible with incisor process bearing eight teeth, with third and fourth largest. Maxillule with bilobed palp, lower lobe with one seta, upper lobe non-setose. Second maxilliped with rounded epipod. Third maxilliped slender (Fig. 5c); lateral plate oval, ear-shaped (Fig. 5e); ultimate segment distally with one apical and one subapical spines (Fig. 5d); arthrobranch normally developed.

First pereiopods (chelipeds) very asymmetrical, unequal (Fig. 6), carried flexed ventrally in life, mesially when preserved (Fig. 4); major cheliped robust (cf. Fig 7a); ischium slightly elongate, without spines; merus slender, elongate, distally not widening, with feebly marked rounded lobes, ventrally flattened; carpus somewhat elongate, vase-shaped, ventrally depressed, distally with two pronounced lobes (Fig. 6b); chela subcylindrical, with palm slightly longer than fingers; palm proximoventrally with deep groove, continuing by oblique groove across lateral to dorsal surface (Fig. 6b), dorsal surface with slight, elongate depression (Fig. 6a), distolateral surface with feeble groove, extending to pollex; pollex with cutting edge bearing 11 rounded-triangular, regularly spaced teeth, tip curved; dactylus with cutting edge bearing nine teeth, distal 1/6 unarmed, tip curved (Fig. 6c). Minor cheliped slender; ischium elongate, equal in length to merus; carpus equal in length to merus, subcylindrical, ventrally flattened, distally widening; chela simple, not particularly enlarged, fingers slightly shorter than palm, cutting edges unarmed (Fig. 6d).

Second pereiopod slender; ischium about 5/6 length of merus; carpus with five segments having ratio of approximately 4.5/1/0.6/0.6/1.2; chela simple, fingers equal to palm (Fig. 5f). Third pereiopod slender; ischium with three spines; merus about 1.4 length of ischium, about 5.5 times as long as wide at base; carpus slender, shorter than merus, with small distoventral spinule (broken); propodus slightly longer than carpus, ventrally with four small spines and one slender distoventral spine proximal to dactylus; dactylus simple, slender, less than half length of propodus, slightly curved (Fig.

5g). Fourth pereiopod similar to third. Fifth pereiopod slender; ischium unarmed; merus 2.5 times length of ischium, about five times as long as wide at base; carpus slender, slightly longer than merus, with small distal spinule; propodus about 1.3 length of carpus, ventrally with numerous rows of small setae, five small ventral spines and one inconspicuous distoventral spine proximal to dactylus; dactylus simple, slender, less than 1/3 length of propodus, slightly curved (Fig. 5h).

Abdominal segments I-III with posteroventral margins rounded or rounded-angular; segments IV and V with posteroventral angle acutely projecting (Fig. 4); segment VI with acute posterior projection, without articulated plate (Fig. 4); preanal plate rounded posteriorly (Fig. 5k). Second pleopod with appendix masculina longer than appendix interna, with slender spines along mesial margin (Fig. 5i, j). Telson about twice as long as wide proximally; basal width about 2.3 times width of posterior margin; dorsal surface with two pairs of spines situated at some distance from lateral margin, at mid-length and 3/4 length of telson, respectively (Fig. 5l); posterior margin with deep, U-shaped median notch bearing two very long, fine setae and two pairs of spines, lateral shorter than mesial (Fig. 5m); anal tubercles absent. Uropods slightly longer than telson; sympodite with acute tooth; diaeresis slightly sinuous; lateral spine well developed (Fig. 5l). Gill formula typical for genus: see under *S. nhatrangensis*, new species.

***Colour*. –** Semitransparent white, corneas conspicuously golden-yellow (Fig. 7a).

***Habitat*. –** The specimen was collected with a suction pump beneath a boulder in a transition zone between coral reef and sand plain. The biotope is characterized by dead fungiid and branching corals, coral rubble and stones partly covered by sand and mud. Other alpheids collected at this location were *S. nhatrangensis*, new species, and *Athanas parvus*.

Etymology. – *Salmoneus auroculatus*, new species, received its name (aurum – gold, oculus – eye) from the strikingly golden colour of the cornea (Fig. 7a).

Remarks. – *Salmoneus auroculatus*, new species, must first be first contrasted to species with a well-marked mediodorsal carina, extending to or beyond the mid-length of the carapace: *S. tricristatus* Banner, 1959, *S. cristatus* (Coutière, 1897) and *S. brevirostris*. *Salmoneus auroculatus*, new species, can be easily separated from *S. tricristatus* by the absence of the two strong dorsolateral carinae on the carapace (cf. Banner, 1959; Miya, 1972; Banner & Banner, 1973). It also differs markedly from *S. cristatus* by the shape of the rostrum and extra-corneal teeth, and the much deeper posteromedian notch on the telson (cf. Coutière, 1897, 1899; Holthuis, 1958; Banner & Banner, 1966b; Anker, 2003b). This new species can be distinguished from *S. brevirostris* by the absence of a slight carina on each orbital hood, posterior to the extra-corneal tooth, and the presence of three spines on the ischium of the third pereiopod (vs. unarmed ischium in *S. brevirostris*, cf. Banner, 1953). Furthermore, these three species have different colour patterns: *S. tricristatus* is semitransparent, with posterior portion of the carapace appearing reddish due to the presence of numerous red chromatophores (A. Anker, pers. obs.); *S. cristatus* is semitransparent, with bright transverse red bands across the carapace and the abdomen (Coutière, 1899; Banner & Banner, 1981); *S. brevirostris* is uniformly bright yellow-orange (Edmondson, 1930; Banner & Banner, 1983).

The other closely related Indo-Pacific and Atlantic species, characterized by the fingers of the major cheliped armed with numerous small teeth, the merus of the major cheliped not inflated and ventrally not excavated, the eyes dorsally concealed by the orbital hoods and the carapace lacking strong mediodorsal carina, are *S. serratidigitus*, *S. sibogae*, *S. hilarulus*, *S. brevirostris*, *S. mauiensis*, *S. babai* and *S. nhatrangensis*, new species, in the Indo-Pacific, and *S. teres*,

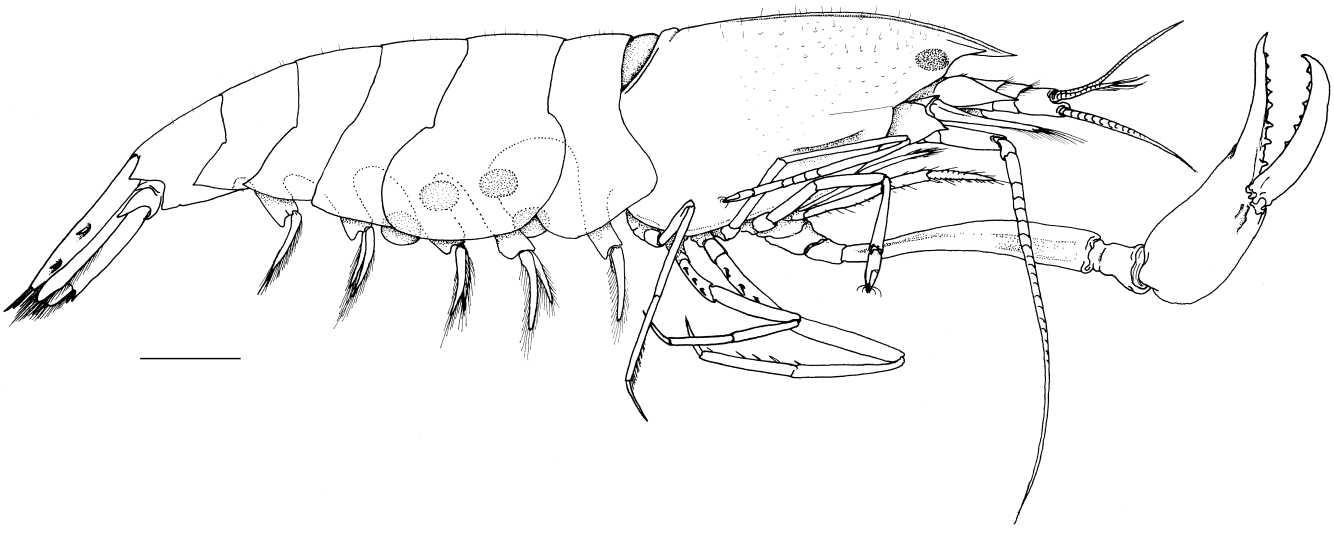

Fig. 4. *Salmoneus auroculatus*, new species, holotype (ZMMU Ma 5440): habitus. Scale bar = 1 mm.

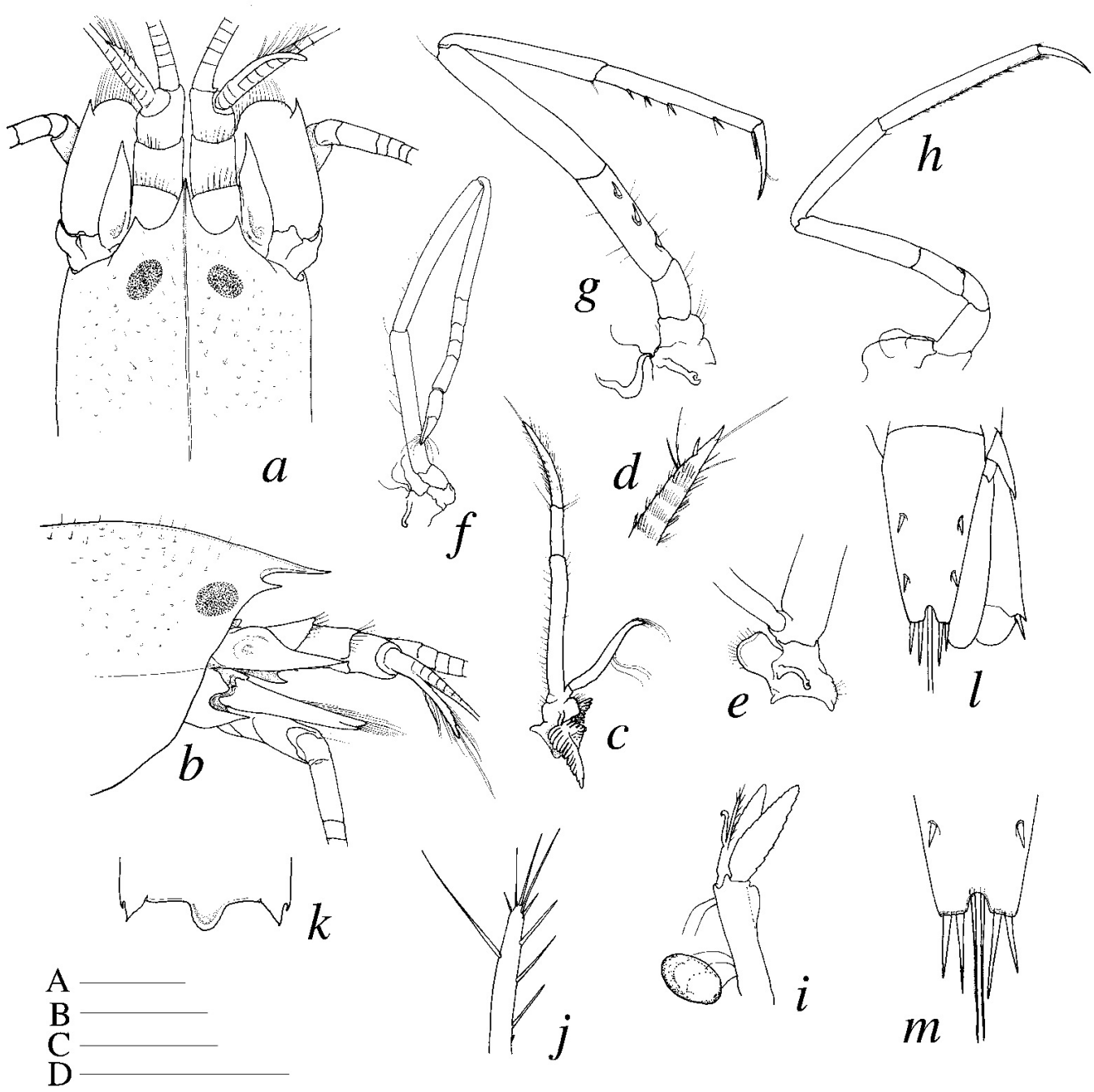

Fig. 5. *Salmoneus auroculatus*, new species, holotype (ZMMU Ma 5440): a, frontal region, dorsal view; b, same, lateral view; c, third maxilliped; d, same, apex; e, same, coxa and proximal portion of antepenultimate segment, arthrobranch not drawn; f, second pereiopod; g, third pereiopod; h, fifth pereiopod; i, second pleopod; j, appendix masculina; k, preanal plate of sixth abdominal segment, ventral view; l, uropods and telson; m, telson, distal portion. Scale bars: A (a, b, f, i, l) = 1 mm; B (c) = 1 mm; C (f-h, k) = 1 mm; D (d, e, j, m) = 1 mm.

S. setosus and *S. arubae* in the Atlantic. However, in none of these species, the mediodorsal carina, if present, extends far beyond the eyes (cf. Coutière, 1896, 1899; De Man, 1911, 1915; Edmondson, 1930; Schmitt, 1936; Banner, 1953; Banner & Banner, 1981, 1982; Manning & Chace, 1990).

Among the above-mentioned species, *S. serratidigitus*, *S. sibogae*, *S. hilarulus*, *S. brevirostris* and *S. mauiensis* appear to be particularly close to *S. auroculatus*, new species, especially in the configuration of the frontal margin and most features of the major cheliped. As already mentioned, *S. auroculatus*, new species, can be separated from these species by the presence of a well marked rostral carina continued by a mediodorsal carina, the latter reaching beyond the 3/4 length of the carapace (Figs. 4, 5a). *Salmoneus auroculatus*, new species, differs more specifically from *S. serratidigitus* and *S. sibogae* (cf. Coutière, 1899; De Man, 1911, 1915; Banner & Banner, 1981) by the shorter rostrum; the shorter stylocerite (not reaching distal margin of the second segment of the antennular peduncle in *S. auroculatus*, new species, vs. exceeding this margin in *S. serratidigitus*); and the longer carpus of the major cheliped. It differs from *S. hilarulus* by the shorter rostrum and more slender minor cheliped; and from *S. mauiensis* by the shorter rostrum; the shape and extension of the posteromedian notch on the telson; and the presence of spine on the ischium of the third pereiopod.

Salmoneus auroculatus, new species, differs from the above-described *S. nhatrangensis*, new species, by the presence of a strong mediodorsal carina; the shape of the orbital teeth and the rostrum; the more elongated, vase-shaped carpus of the major cheliped; the much more developed posteromedian notch on the telson; and the proportions of the articles of the minor cheliped. *Salmoneus babai* is more distantly related to *S. auroculatus*, new species, and can be distinguished from it by the same features as from *S. nhatrangensis*, new species (see above), and also by the much less pronounced rostro-mediodorsal carina.

Salmoneus auroculatus, new species, differs in several important characters from the above-mentioned Atlantic species, for instance, from *S. arubae* by the presence of a deep posteromedian notch on the telson and the shape of the major chela; from *S. setosus* by the absence of thick, erect setae on the carapace and abdomen and the presence of a deep posteromedian notch on the telson; and from *S. teres* by the shape of the frontal margin and the much less developed posteromedian notch on the telson (cf. Schmitt, 1936; Holthuis, 1990; Manning & Chace, 1990). Noteworthy, like the above-described *S. nhatrangensis*, new species, *S. auroculatus*, new species, possesses small, inconspicuous pits on the carapace, a character shared with *S. arubae, S. teres* and an undescribed species from the western Atlantic (Anker, in prep.).

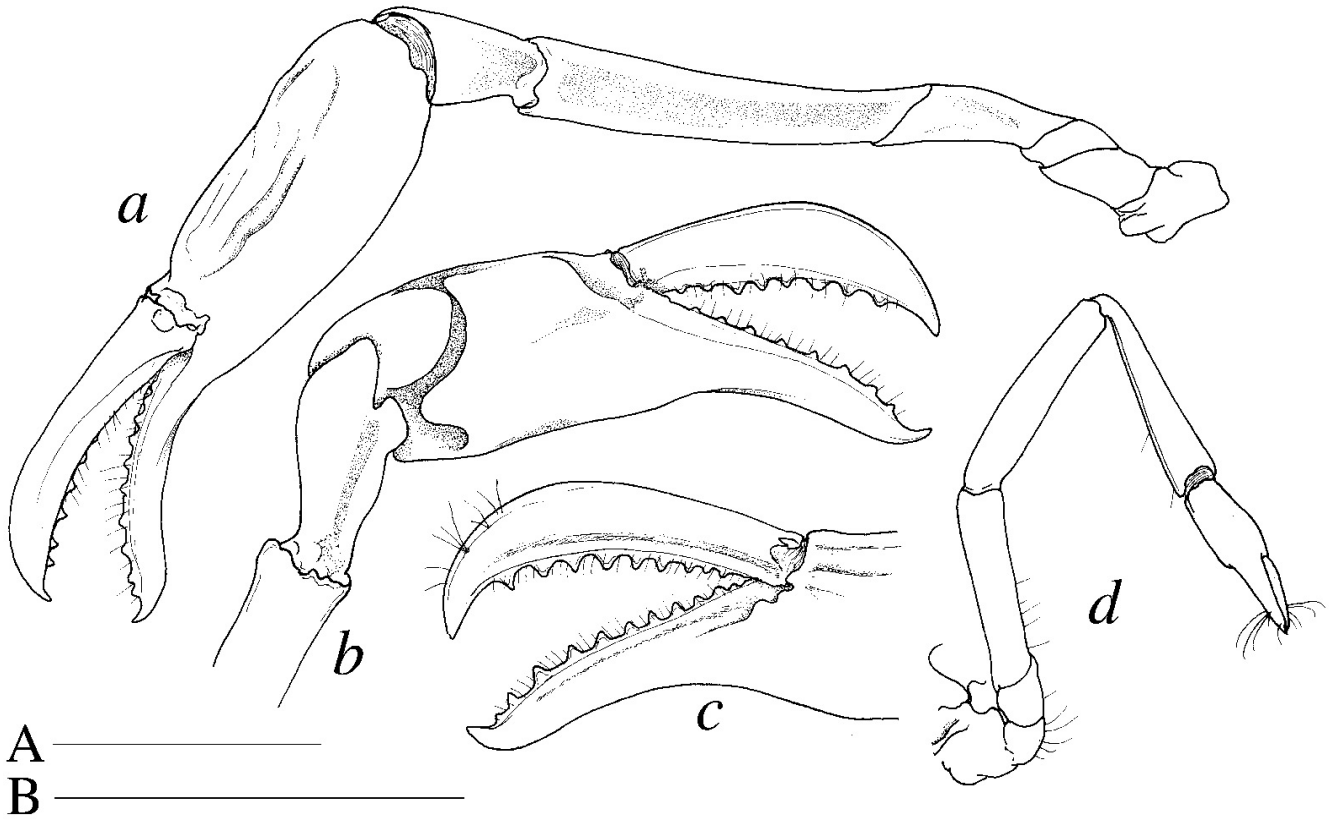

Fig. 6. *Salmoneus auroculatus*, new species, holotype (ZMMU Ma 5440): a, left major cheliped, ventromesial view; b, same, chela and carpus, lateral view; c, same, fingers, mesial view; d, right minor cheliped. Scale bars: A (d) = 1 mm; B (a-c) = 1mm.

Distribution. – Presently known only from the type locality, Nhatrang Bay, Vietnam.

Salmoneus falcidactylus, new species
(Figs. 8, 9)

Material examined. – Holotype, non ovigerous specimen (CL 1.9, TL 5.9)(ZMMU Ma 5439), South China Sea; Vietnam, Nhatrang Bay, station Nr 6, about 2 km SW off Mung Island, on muddy bottom, depth 40 m, coll. O. Savinkin, I. Marin & A. Beliaev, 17 Oct.2003.

Description. – Carapace non-setose, glabrous (Figs. 8, 9c), laterally with shallow oblique depressions. Rostrum elongate, reaching distal 3/4 of second segment of antennular peduncle (Fig. 9a), longer than broad at base; lateral margins shallowly concave (Fig. 9b); rostral carina absent. Extra-corneal teeth acute, directed toward rostrum; concavity between rostrum base and extra-corneal teeth deep, U-shaped (Fig. 9a, b). Pterygostomial angle slightly protruding, rounded. Eyes without tubercle, only partly covered by carapace, extreme anterior portion visible in dorsal and lateral view (Fig. 9a, c). Epistomial sclerite with small subacute process. Ocellar beak inconspicuous.

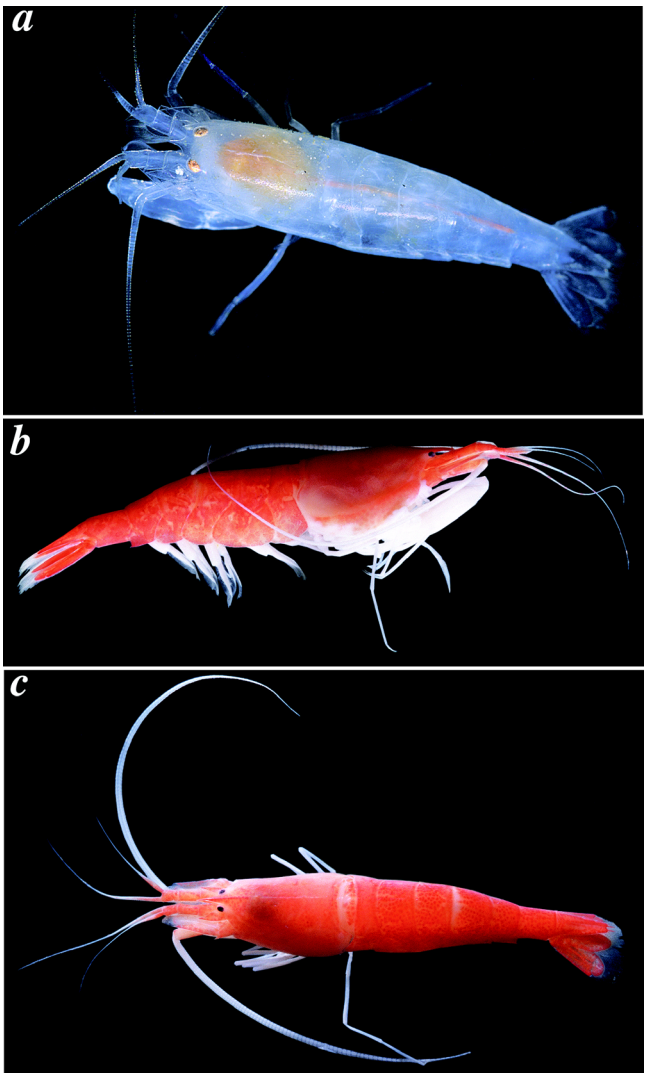

Fig. 7. Colour patterns of two species of *Salmoneus* from Nhatrang Bay, Vietnam: a, *Salmoneus auroculatus*, new species, holotype (ZMMU Ma 5440); b, c, *S. rostratus* Barnard, 1962, non-ovigerous specimen (ZMMU Na 5466). Photographs by O. Savinkin.

Antennular peduncle not particularly stout; second segment shorter than first, but longer than third; ventromesial carina of first segment with acute tooth; stylocerite reaching slightly beyond mid-length of second segment, distally acute (Fig. 9a, c); lateral flagellum biramous, with shorter ramus situated at second segment. Antenna with basicerite bearing strong ventrolateral tooth (Fig. 9c); scaphocerite moderately broad, anterior margin of blade convex, not exceeding distolateral tooth; carpocerite very short, reaching to about 2/3 length of scaphocerite (Fig. 9c).

Mouthparts not dissected (to avoid damage of single, fragile specimen). Third maxilliped slender; ultimate segment distally tapering; arthrobranch present.

First pereiopods (chelipeds) very asymmetrical, unequal (Fig. 9d, g), carried flexed ventrally in life, mesially when preserved (Fig. 8); major cheliped slender; ischium elongate, without spines; merus slender, elongate, distally not widening, with small rounded lobes, ventrally flattened; carpus somewhat elongate, vase-shaped, ventrally constricted, distally with two pronounced lobes (Fig. 9e); chela subcylindrical, with palm 3/4 length of fingers; palm proximoventrally with deep groove or constriction (Fig. 9e), dorsal and lateral surface with longitudinal ridges and depressions (Fig. 9d), ventral surface slightly flattened (Fig. 9e); pollex with cutting edge armed with at least 20 very small, subtriangular, regularly spaced teeth, tip acute and strongly curved; dactylus with cutting edge bearing about 20 teeth, tip acute and strongly curved (Fig. 9f). Minor cheliped slender; ischium elongate, equal in length to merus; carpus slightly shorter than merus, subcylindrical, distally widening; chela simple, not particularly enlarged, fingers slightly shorter than palm, cutting edges unarmed (Fig. 9g).

Second pereiopod slender; ischium about 5/6 length of merus; carpus with five segments having ratio of approximately 5.2/1/1/1/1.5; chela simple, fingers almost equal to palm (Fig. 9h). Third pereiopod slender; ischium with two spines; merus about 1.5 times of ischium, about 11 times as long as wide at base; carpus slender, shorter than merus, unarmed; propodus longer than carpus, ventrally unarmed except for two slender distal spines; dactylus simple, extremely slender, about 0.8 length of propodus, strongly curved, sickle-shaped (Fig. 9i). Fourth pereiopod similar to third. Fifth pereiopod slender; ischium unarmed; merus twice as long as ischium, about 10 times as long as wide at base; carpus slender, shorter than merus, with small distal spinule; propodus subequal to carpus, ventrally unarmed, rows of setae absent; dactylus simple, slender, about 0.8 length of propodus, strongly curved, sickle-shaped (Fig. 9j).

Abdominal segments I-IV with posteroventral angles rounded; segment V with posteroventral angle acutely projecting (Fig. 8); segment VI with strong, acute posterior projection, without articulated plate (Fig. 8); preanal plate

truncate posteriorly (Fig. 9m). Second pleopod with appendix masculina longer than appendix interna, with two slender apical spines, almost reaching distal margin of endopod (Fig. 9k, l). Telson about 2.3 times as long as wide proximally; basal width about twice width of posterior margin; dorsal surface with two pairs of spines situated at some distance from lateral margin, at mid-length and about 3/4 length of telson, respectively (Fig. 9n); posterior margin with very shallow median notch bearing two long, fine setae and two pairs of spines, lateral much shorter than mesial (Fig. 9o); anal tubercles absent. Uropods slightly longer than telson; sympodite with acute tooth; diaeresis not conspicuous; lateral spine well developed, slender, reaching to distal margin of exopod (Fig. 9 n). Gill formula typical for genus: see under *S. nhatrangensis*, new species.

***Colour*. –** Semitransparent white.

***Habitat.* –** The specimen was collected on a muddy bottom together with a specimen of the alpheid shrimp *Thuylamea camelus* Xuan, 2001, several specimens of the ogyridid shrimp *Ogyrides* cf. *orientalis* (Stimpson, 1860), as well as some possibly juvenile unidentified mudshrimps (Upogebiidae).

***Etymology*. –** The sickle-shaped form of the dactylus on the walking legs of *S. falcidactylus*, new species, was the origin of its name.

***Remarks.* –** The very small size of the present specimen of *S. falcidactylus*, new species, would suggest that it could be juvenile. However, the presence of a well developed, elongated appendix masculina (Fig. 9k) leaves no doubt that the specimen is at least a subadult individual. As this specimen is also complete, and could not be assigned to any described species of *Salmoneus*, it is considered as a representative of a new species.

Salmoneus falcidactylus, new species, is closely related to other species characterized by the elongated rostrum; dorsally partly exposed eyes; elongated, slender dactyli on the third to fifth pereiopods; and the major chela bearing numerous small teeth on the cutting edges of both fingers, viz. *S. gracilipes* Miya, 1972, *S. colinorum* De Grave, 2004, *S. seticheles* Anker, 2003, *S. cavicolus* Felder & Manning, 1986, *S. pusillus*, new species (see below), and possibly *S. tafaongae* Banner & Banner, 1966 (chelipeds unknown). The new species can be separated from all these species by the extremely elongated, slender dactylus on the walking legs; and the much greater number of teeth (about 20) on the cutting edges of the fingers of the major chela; more specifically from *S. gracilipes* by the presence of two instead of three spines on the ischium of the third pereiopod, the shorter stylocerite (reaching to about mid-length of the second segment of the antennular peduncle in *S. falcidactylus*, new species vs. reaching to the distal margin of this segment in *S. gracilipes*), the less pronounced posteromedian notch on the telson, and the absence of the rostral carina (cf. Miya, 1972); from *S. seticheles* by the absence of long, flexible setae on the major chela and numerous other features (cf. Anker, 2003b); from *S. colinorum* by the carpus of the minor cheliped being subequal to the merus (vs. longer in *S. colinorum*); from both *S. colinorum* and *S. cavicolus* by the ventrally unarmed rostrum (vs. bearing a subapical tooth in *S. colinorum* and *S. cavicolus*), and the posterior margin of the telson bearing a shallow cleft (vs. straight in *S. colinorum* and *S. cavicolus*)

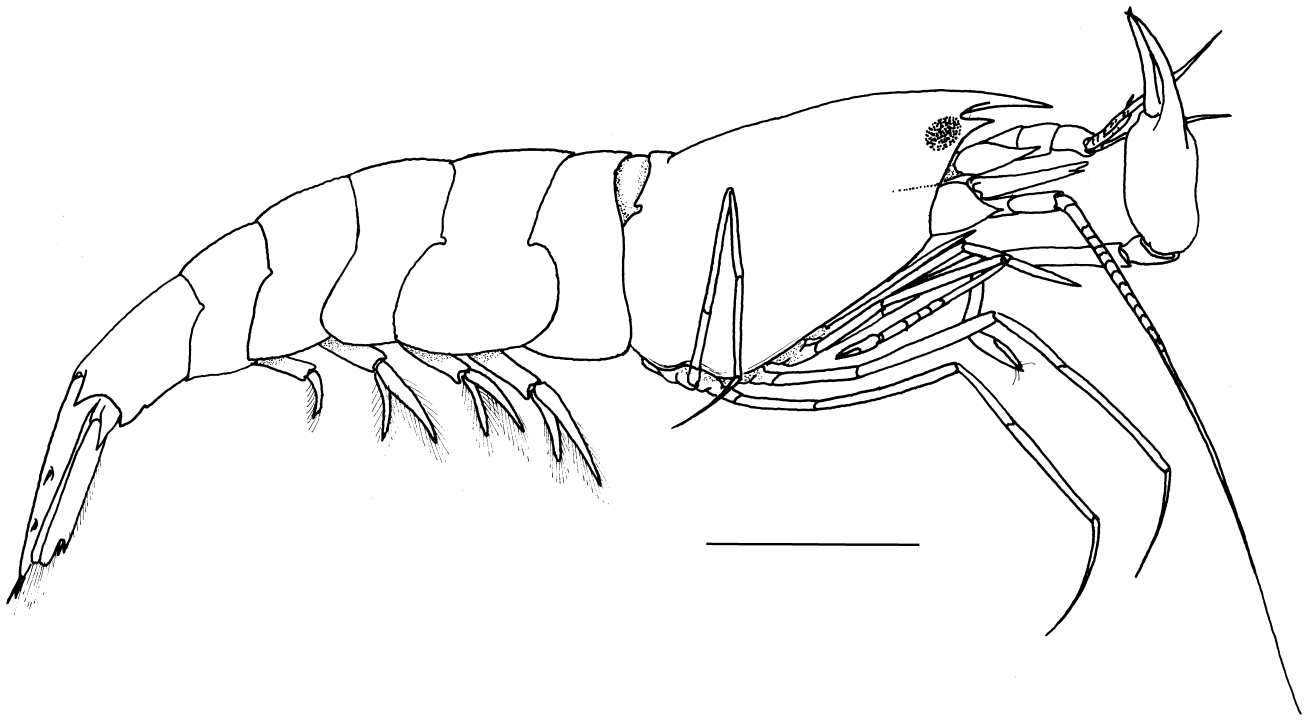

Fig. 8. *Salmoneus falcidactylus*, new species, holotype (ZMMU Ma 5439): habitus. Scale bar = 1 mm.

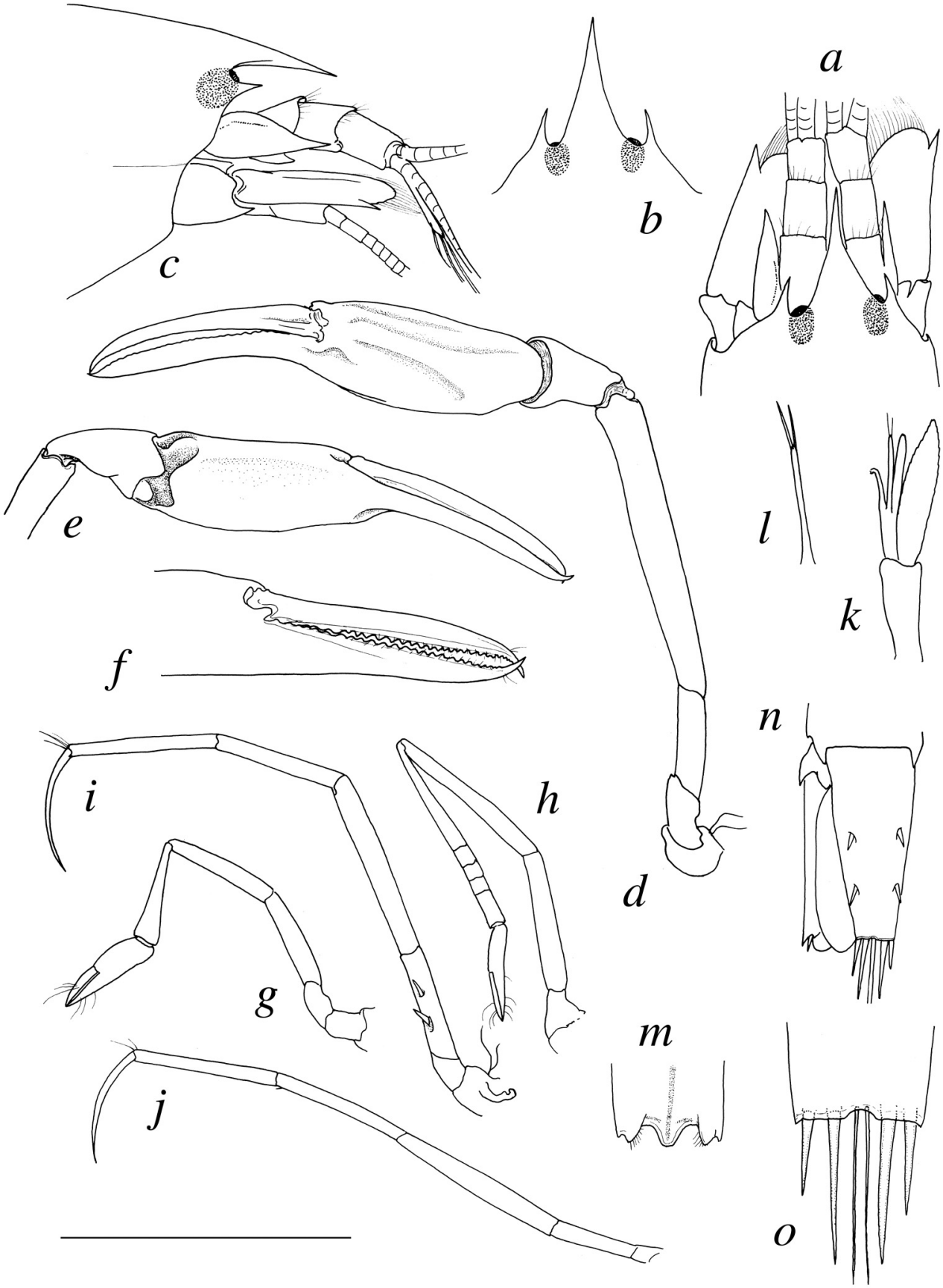

Fig. 9. *Salmoneus falcidactylus*, new species, holotype (ZMMU Ma 5439): a, frontal region, dorsal view (slightly lateral); b, same, rostrum and extra-corneal teeth; c, same, lateral view; d, left major cheliped, mesial view; e, same, chela and carpus, ventro-lateral view; f, same, fingers, lateral view; g, right minor cheliped; h, second pereiopod; i, third pereiopod; j, fifth pereiopod; k, second pleopod; l, appendix masculina; m, preanal plate of sixth abdominal segment, ventral view; n, uropods and telson; o, telson, distal portion. Scale bar: a-k, m = 1 mm; l, o = without scale bar.

(cf. Felder & Manning, 1986; De Grave, 2004); from *S. pusillus*, new species, by the absence of subapical tooth on the ventral margin of the rostrum and postrostral tubercle (see below); finally, from *S. tafaongae* by the much shorter, ventrally unarmed rostrum (vs. elongated rostrum armed with a subapical tooth in *S. tafaongae*), and the non-upturned extra-corneal teeth (vs. upturned in *S. tafaongae*) (cf. Banner & Banner, 1966a).

***Distribution.* –** Presently known only from the type locality, Nhatrang Bay, Vietnam.

Salmoneus pusillus, new species
(Figs. 10, 11)

***Material examined.* –** Holotype, ovigerous female (CL 2.7, TL 7.6) [minor cheliped lacking, specimen dissected](ZMMU Ma 5444), South China Sea, Vietnam, Nhatrang Bay, Pyramides, depth 14-16 m, on sand under boulder, SCUBA, coll. I. Marin, 12 May.2004.

Paratypes, 2 ovigerous females (CL 2.9, TL 8.2 and CL 3.0, TL 7.9) [minor cheliped of one specimen dissected, major chelipeds detached](ZMMU Ma 5445), South China Sea, Vietnam, Nhatrang Bay, bay near lighthouse, depth 15 m, slope, on sand under boulder, SCUBA, coll. I. Marin, 27 Jun.2004.

***Description.* –** Carapace sparsely setose, without pits, laterally with slight suture starting from lateral margin proximal to base of antenna (Figs. 10c), dorsally with minute postrostral tubercle (Fig. 10b, c). Rostrum relatively long, reaching to distal margin of second segment of antennular peduncle (Fig. 10c), longer than broad at base; ventral margin with more or less conspicuous subapical tooth; lateral margins slightly concave (Fig. 10b); rostral carina inconspicuous. Extra-corneal teeth acute, directed anteromesially; margin between rostrum base and extra-corneal teeth deeply incised, U-shaped (Fig. 5a). Pterygostomial angle rounded. Eyes without tubercle, partly visible in dorsal and lateral view (Fig. 10a-c), sometimes concealed (10h). Epistomial sclerite with strong acute process. Ocellar beak inconspicuous.

Antennular peduncle moderately stout, second segment shorter than visible portion of first segment, and shorter than third segment; ventromesial carina of first segment with acute tooth; stylocerite reaching to distal margin of second segment, distally acute (Fig. 10b, c); lateral flagellum biramous, with shorter ramus situated at second segment. Antenna with basicerite bearing strong ventrolateral tooth (Fig. 10c); scaphocerite subrectangular, anterior margin of blade convex, not exceeding distolateral tooth (Fig. 10b); carpocerite short, reaching to about 3/4 length of scaphocerite (Fig. 10c).

Mouthparts not dissected, appearing typical for genus in external view. Third maxilliped slender; lateral plate large, rounded; ultimate segment distally with small spinules; arthrobranch rather poorly developed.

First pereiopods (chelipeds) very asymmetrical, unequal (Fig. 10d, 11), carried flexed ventrally in life; major cheliped (Fig. 11) slender; ischium elongate, with strong ventral spine (Fig. 11a); merus slender, elongate, distally not widening, ventrally flattened; carpus vase-shaped (Fig. 11a, c), ventrally not depressed, distally with broad lobes (Fig. 11b, c); chela sub-cylindrical, with palm slightly shorter or subequal to fingers; palm proximoventrally with deep groove, rest of palmar surface smooth; pollex with cutting edge armed with 11-12 rounded-triangular, regularly spaced teeth, distal portion unarmed, tip strongly curved; dactylus with cutting edge bearing 11 teeth, most distal portion unarmed, tip curved (Fig. 11b, c). Minor cheliped slender; ischium elongate, slightly shorter than merus, armed with spine ventrally (Fig. 10d); carpus somewhat longer than merus, subcylindrical, distally slightly widening; chela simple, not particularly enlarged, fingers slightly longer than palm, cutting edges unarmed.

Second pereiopod slender; ischium about 5/6 length of merus, unarmed; carpus with five segments having ratio of approximately 5/2/1/1.2/2.2; chela simple, fingers longer than palm (Fig. 10e). Third pereiopod slender; ischium with two spines (Fig. 10f); merus slender, almost twice as long as ischium, six to seven times as long as wide at base; carpus equally slender, subequal in length to merus, with small distoventral spinule; propodus subequal to carpus, ventrally with three slender spinules and one slender distoventral spine proximal to dactylus; dactylus simple, slender, about half length of propodus, slightly curved (Fig. 10f). Fourth pereiopod generally similar to third. Fifth pereiopod with unarmed ischium; merus longer than carpus; propodus longer than carpus, ventral margin with three spinules and one slender spinule proximal to dactylus, distal half with nine rows of setae ventrolaterally; dactylus similar to that of third pereiopod.

Abdominal segments I-III with posteroventral margins rounded; segment IV with posteroventral margin angular; segments V and VI with posteroventral angles acutely projecting (Fig. 10a); segment VI with acute posterior projection near telson, without articulated plate (Fig. 10a); preanal plate rounded posteriorly. Second pleopod with slender appendix masculina, almost twice as long as appendix interna, with small spines distally. Telson about twice as long as wide proximally; basal width approximately double width of posterior margin; dorsal surface with two pairs of spines situated at some distance from lateral margin, at about mid-length and 3/4 length of telson, respectively (Fig. 10g); posterior margin straight, with two pairs of spines, lateral half length of mesial, and two long, plumose setae medially, between mesial spines (Fig. 10g); anal tubercles absent. Uropods slightly longer than telson; sympodite with acute tooth; diaeresis slightly sinuous; lateral spine small (Fig. 10a). Gill formula typical for genus: see under *S. nhatrangensis*, new species. Eggs comparatively large and few, e.g., at least 13 (diameter 0.5 x 0.8 mm) in holotype (Fig. 10a), around 16 (diameter 0.4 x 0.5 mm) in one paratype.

***Colour*. –** Semitransparent white, gonads or eggs yellow.

***Habitat*. –** All specimens were collected on sand-mud under boulders at depths of 14-16 m.

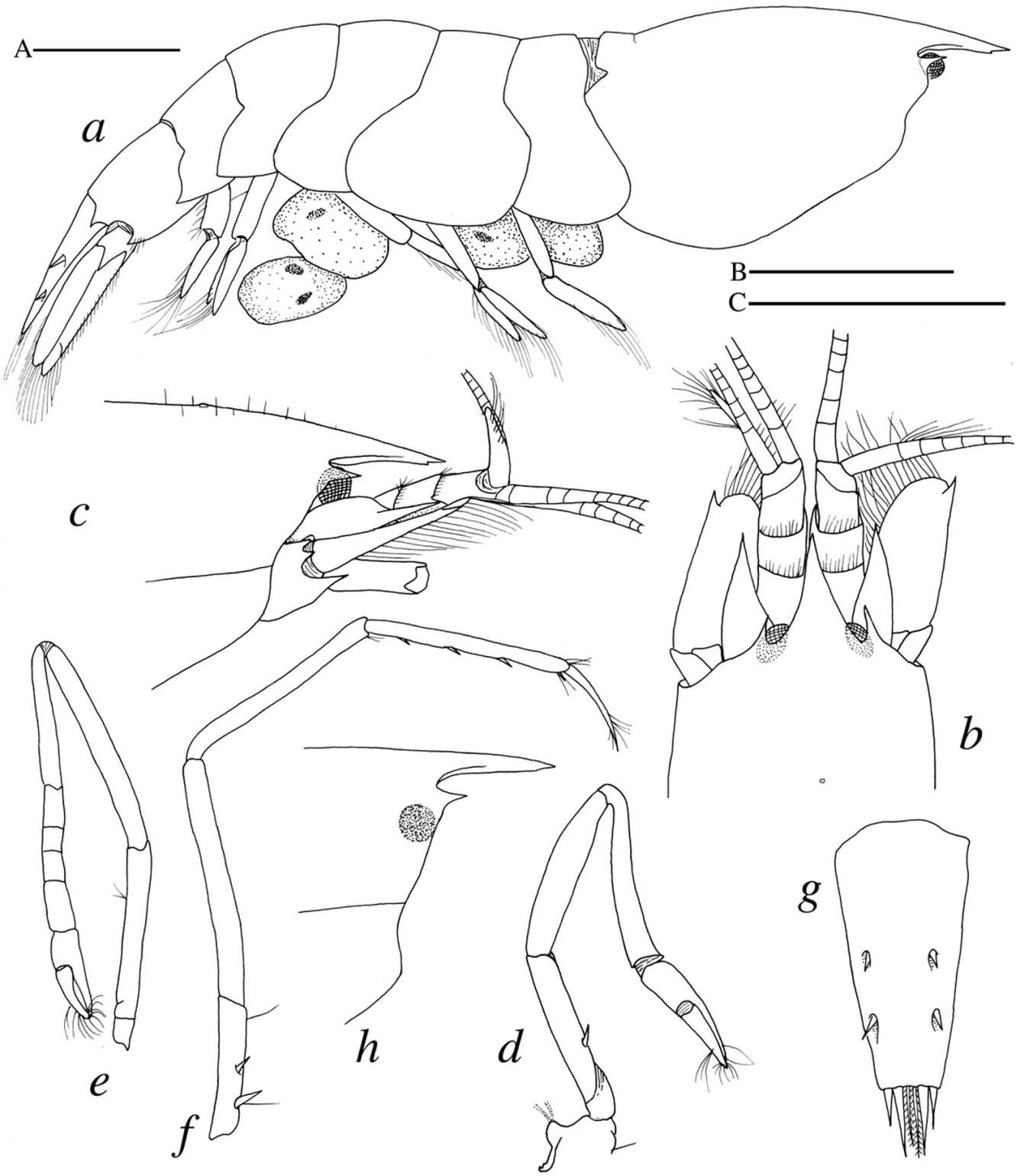

Fig. 10. *Salmoneus pusillus*, new species, holotype (ZMMU Ma 5444) (a-g), paratype (ZMMU 5445) (d, h): a, abdomen and carapace, lateral view; b, frontal region, dorsal view; c, same, lateral view; d, right minor cheliped; e, second pereiopod; f, third pereiopod; g, telson; h, anterior carapace, lateral view. Scale bars: A (a) = 1 mm; B (b, c, h) = 1 mm; C (d-g) = 1 mm. Drawings: Denis Poddoubtchenko.

***Etymology.* –** *Salmoneus pusillus*, new species, was so named (pusillus – dwarf, minute) because it is one of the smallest-sized members of the genus *Salmoneus*.

***Variation*. –** The only variation noted is the degree of development of the ventral subapcial tooth on the rostrum, and the degree of exposure of the eyes. In the holotype and one of the paratypes, the rostrum has a small subapical tooth, and the eyes are partly exposed dorsally and laterally (Fig. 10b, c), while in the second paratype, the rostrum is only slightly notched subapically, and the eyes are concealed both dorsally and laterally (Fig. 10h).

***Remarks.* –** *Salmoneus pusillus*, new species, is closely related to *S. gracilipes*, *S. colinorum*, *S. falcidactylus*, new species, *S. alpheophilus*, new species (see below), *S. cavicolus*, *S. setichelles*. In particular, it appears to be morphologically very close to *S. colinorum* and *S. falcidactylus*, new species, and must first be contrasted to these two species. *Salmoneus pusillus*, new species, may be separated from *S. colinorum* by the longer stylocerite, reaching the posterior margin of the second segment of the antennular peduncle (vs. reaching only 3/4 of this segment in *S. colinorum*); the presence of a minute postrostral tubercle (absent in *S. colinorum*); the stouter minor cheliped; and the ischium of both chelipeds armed with a strong spine (vs. unarmed in *S. colinorum*) (cf. De Grave, 2004). A further possible difference between *S. pusillus*, new species and *S. colinorum* is the size of eggs relative to the body: very large in the first species, much smaller in the second (compare Fig. 10a and De Grave, 2004, fig. 1A).

Salmoneus pusillus, new species differs from *S. falcidactylus*, new species, by the less elongated dactylus of the third to fifth pereiopods; the longer stylocerite, reaching the posterior margin of the second segment of the antennular peduncle (vs. reaching only about 1/2 of this segment in *S. falcidactylus*, new species); the somewhat stouter antennular peduncle; the ischium of both chelipeds armed with a robust spine (vs. unarmed in *S. falcidactylus*, new species); the rostrum armed with a small subapical tooth ventrally (vs. unarmed in *S. falcidactylus*, new species); and the posterior margin of the telson straight, without cleft, as in *S. falcidactylus*, new species (cf. Figs. 9 and 10-11). Three of the afore-mentioned features, viz. the straight posterior margin of the telson, the cheliped ischium armed with a spine, and the presence of the ventral subapical tooth on the rostrum, separate *S. pusillus*, new species, from *S. gracilipes*. The ischium of the third pereiopod

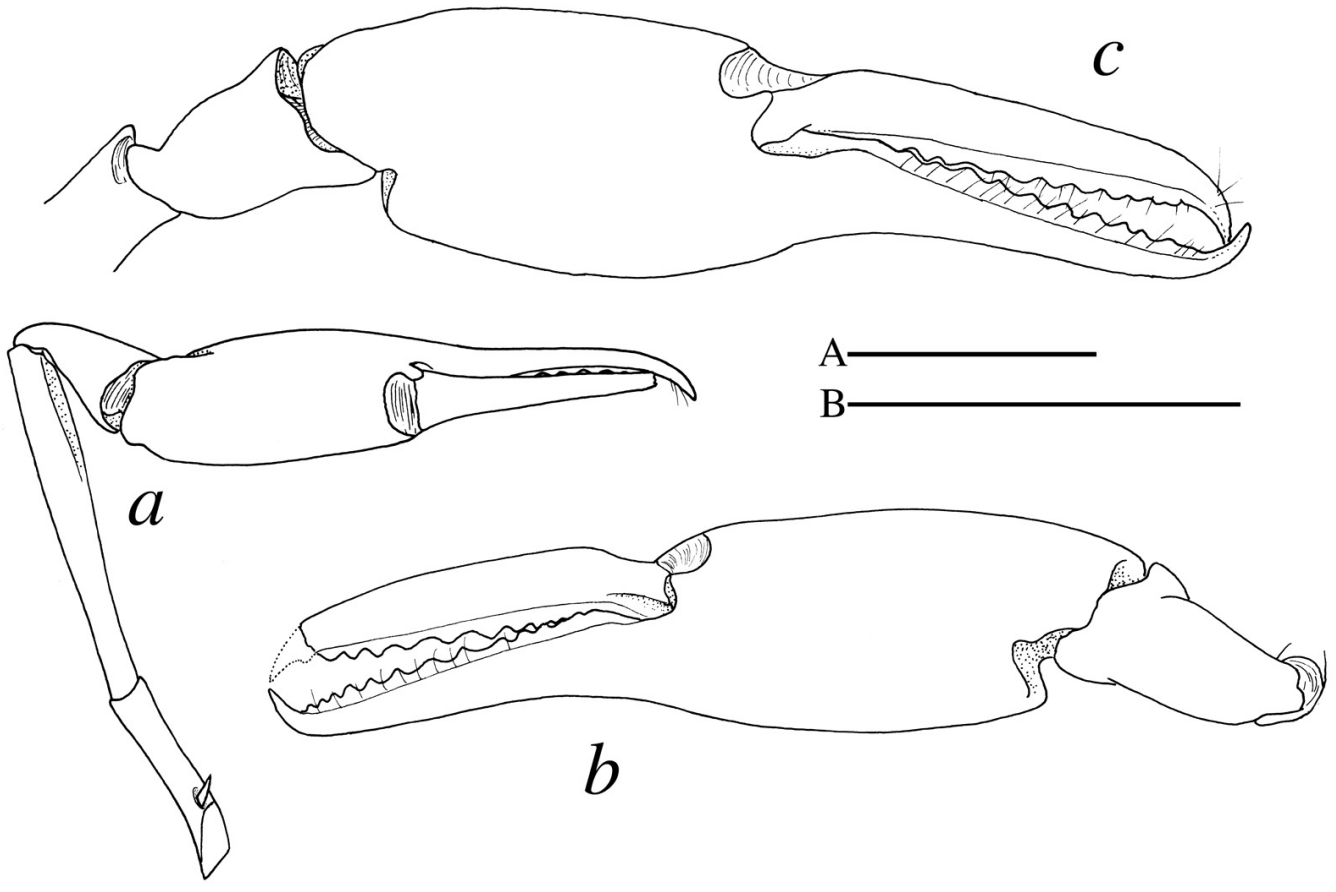

Fig. 11. *Salmoneus pusillus*, new species, holotype (ZMMU Ma 5444) (a, b), paratype (ZMMU Ma 5445) (c): a, left major cheliped, ventro-lateral view; b, same, chela and carpus, tip of dactylus broken; c, left (?) major cheliped, chela and carpus. Scale bars: A (a) = 1 mm; B (b, c) = 1 mm. Drawings: Denis Poddoubtchenko.

is armed with three spines in *S. gracilipes* (cf. Miya, 1972), and only two in *S. pusillus*, new species. Further, *S. gracilipes* was collected intertidally, while all specimens of the new species were collected from subtidal depths (14-16 m). The status of the ovigerous specimen from Majuro Atoll reported as *S. gracilipes* by Miya (1984) remains unknown. This specimen markedly differs from *S. gracilipes sensu* Miya, 1972 and most likely represents *S. colinorum*.

Salmoneus pusillus, new species, shares the presence of a subapical ventral tooth on the rostrum and a spine on the cheliped ischium with two other species, *S. alpheophilus*, new species, and *S. cavicolus*. However, it can be separated from *S. alpheophilus*, new species, by the differently shaped major chela; the unarmed ischium of the second pereiopod (vs. armed with spines in *S. alpheophilus*, new species); the straight posterior margin of the telson (vs. with a shallow cleft in *S. alpheophilus*, new species); the eyestalk without tubercle (vs. with anteromesial tubercle in *S. alpheophilus*, new species); and also by the smaller size (maximum TL 8.2 mm vs. 13.0 mm); and from *S. cavicolus* by the broader rostrum and much stouter segments of the antennular peduncle (cf. Felder & Manning, 1986). Furthermore, *S. alpheophilus*, new species, and *S. cavicolus* both appear to be infaunal shrimps, dwelling mostly in burrows of other crustaceans (Felder & Manning, 1986; see also below), while all three specimens of *S. pusillus*, new species, were found free-living on sand-mud, dwelling under large boulders. *Salmoneus pusillus*, new species, is only distantly related to *S. seticheles*, differing from this species by numerous features, including the absence of a row of long, flexible setae on the major chela, characteristic of *S. seticheles* (cf. Anker, 2003b).

***Distribution*. –** Presently known only from the type locality, Nhatrang Bay, Vietnam.

Salmoneus alpheophilus, new species
(Figs. 12, 13)

***Material examined.* –** Holotype, ovigerous female (CL 3.9, TL 10.8)(ZMMU Ma 5446), South China Sea, Vietnam, Nhatrang Bay, Tre Island, Dam Bay, 12°10'20"N 109°15'30"E, tidal sand-mud flat, low tide, in burrow of goby-associated *Alpheus* sp., bait suction (yabby) pump, coll. I. Marin, 4 Jun.2004.

Paratypes: 1 post-ovigerous female (CL 4.5, TL 13.3)(ZMMU Ma 5447) [dissected], same data as for holotype, from the same burrow; 1 non ovigerous specimen (CL 4.5, TL 13.0)(ZMMU Ma 5448) [major cheliped lacking], same data as for holotype, from a different burrow.

***Description.* –** Carapace setose (Fig. 12a, e), without pits, laterally with slight suture starting from lateral margin proximal to base of antenna (Figs. 12c), dorsally with small postrostral tubercle (Fig. 12b, c). Rostrum long, slender, reaching to about 3/4 of second segment of antennular peduncle (Fig. 12b), much longer than broad at base; ventral margin with conspicuous subapical tooth (Fig. 12c-e); lateral margins slightly concave (Fig. 12b); rostral carina feebly developed. Extra-corneal teeth relatively small, acute, directed anteriorly or anteromesially; margin between rostrum base and extra-corneal teeth broadly U-shaped (Fig. 12b). Pterygostomial angle rounded. Eyes with small anteromesial tubercle, largely exposed in dorsal and lateral view (Fig. 12a-e, j, k). Epistomial sclerite with strong acute process. Ocellar beak inconspicuous, situated well below and between eyes.

Antennular peduncle stout, second segment slightly shorter than visible portion of first segment, subequal to third segment; ventromesial carina of first segment with acute tooth as illustrated (Fig. 12f); stylocerite reaching between half and 2/3 length of second segment, distally acute (Fig. 12b, c); lateral flagellum biramous, with shorter ramus situated at third segment (Fig. 12c). Antenna with basicerite bearing medium-sized ventrolateral tooth (Fig. 12c); scaphocerite oval, broad, anterior margin of blade convex, slightly exceeding distolateral tooth (Fig. 12b); carpocerite short, reaching slightly beyond half length of scaphocerite (Fig. 12c).

Mouthparts not dissected, appearing typical for genus in external view. Third maxilliped slender (Fig. 13g); lateral plate rounded (Fig. 13h); ultimate segment distally tapering, with two small subapical spines and one apical spine (Fig. 13i); arthrobranch well-developed (Fig. 13h).

First pereiopods (chelipeds) very asymmetrical, unequal (Figs. 13a, d), carried flexed ventrally in life, mesially when preserved (Fig. 12a); major cheliped (Fig. 13a-c) with ischium slightly elongate, armed with strong ventral spine (Fig. 13a); merus slender, elongate, distally slightly widening, ventrally depressed; carpus cup-shaped (Fig. 13a, b), ventrally with deep grooves, distally with lobes (Fig. 13b, c); chela somewhat swollen, subcylindrical; palm longer than fingers, proximoventrally with deep complex groove (Fig. 13b), continuing as notch on mesial surface (Fig. 13a, c), rest of palmar surface smooth; pollex with cutting edge bearing 14 rounded-triangular, regularly spaced teeth, distal portion unarmed, tip strongly curved; dactylus with cutting edge bearing 13 teeth, most distal portion unarmed, tip curved (Fig. 13c). Minor cheliped slender; ischium elongate, shorter than merus, armed with spine ventrally; carpus subequal to merus, subcylindrical, distally slightly widening; chela simple, not enlarged, fingers about as long as palm, cutting edges unarmed (Fig. 13d).

Second pereiopod slender; ischium about 5/6 length of merus, armed with two spines ventrally (Fig. 13e); carpus with five segments having ratio of approximately 7/2/1/1.5/2.5; chela simple, fingers as long as palm (Fig. 13e). Third pereiopod slender; ischium with two spines (Fig. 12f); merus slender, 1.3 times length of ischium, six times as long as wide at base; carpus more slender and shorter than merus, with small ventral spine distally; propodus slightly longer than carpus, ventrally with three slender spinules and one slender distoventral spine proximal to dactylus; dactylus simple, slender, about half length of propodus, slightly curved (Fig. 12f). Fourth pereiopod generally similar to third (Fig. 12a). Fifth pereiopod slender, ischium unarmed; merus slightly longer than carpus; propodus longer than carpus, ventral margin with several slender spinules, distal 3/5 with at least 13 rows of

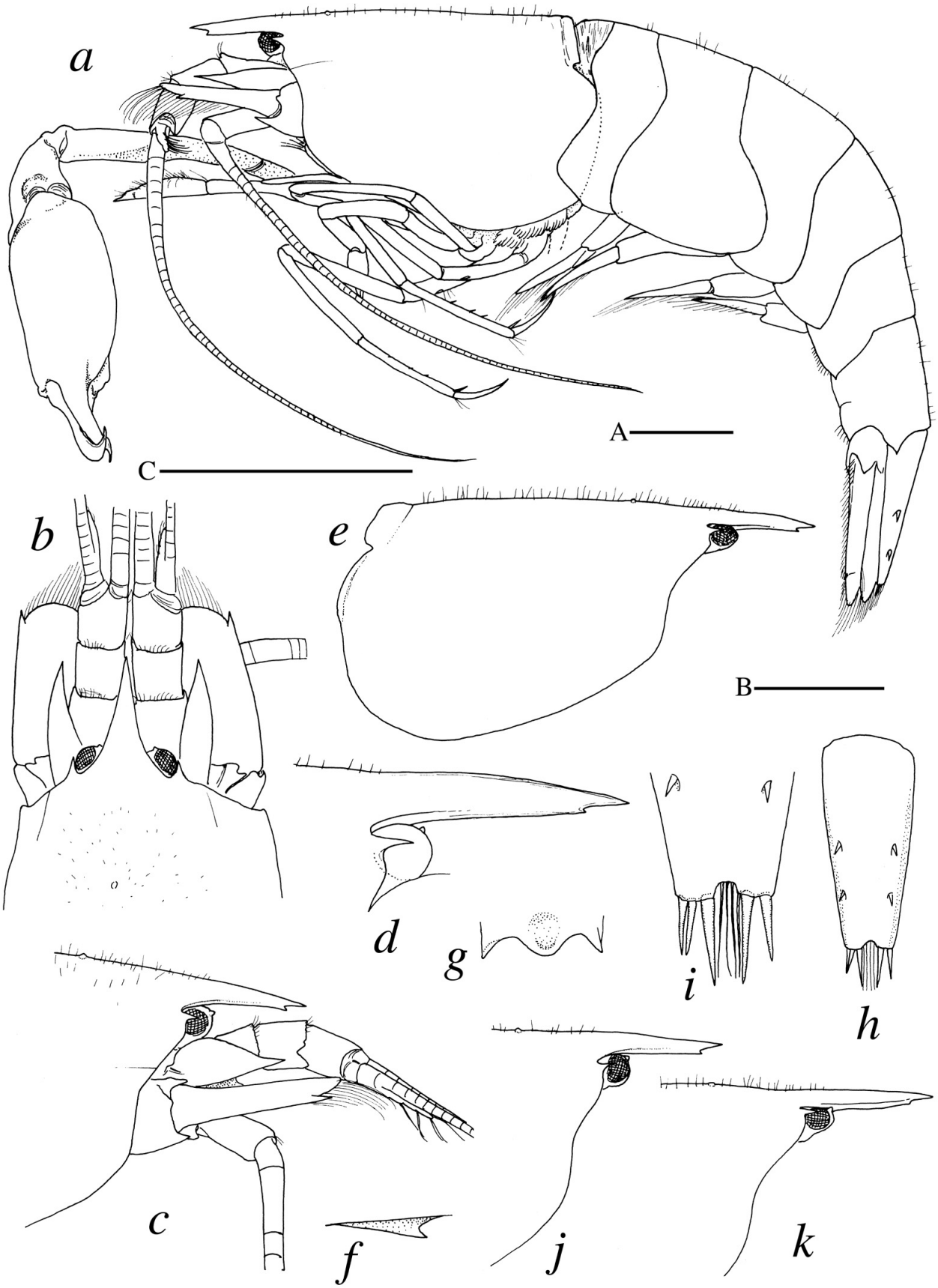

Fig. 12. *Salmoneus alpheophilus*, new species, paratype (ZMMU Ma 5447) (a-i), holotype (ZMMU Ma 5446) (j), paratype ZMMU Ma 5448 (k): a, habitus; b, frontal region, dorsal view; c, same, lateral view; d, same, detail of rostrum and eye; e, carapace, lateral view; f, tooth on ventromesial carina of first segment of antennule; g, sixth abdominal somite, preanal plate, ventral view; h, telson; i, same, detail of posterior margin; j, k, anterior carapace, lateral view. Scale bars: A (a, e) = 1 mm; B (b, c, g, h, j, k) = 1 mm; C (f, d, i) = 1 mm.

setae ventrolaterally; dactylus similar to that of third pereiopod, slightly expanded proximally.

Abdominal segments I-III with posteroventral margins rounded; segment IV with posteroventral margin angular; segments V and VI with posteroventral angles acutely projecting (Fig. 12a); segment VI with acute posterior projection near telson, without articulated plate (Fig. 12a); preanal plate rounded posteriorly (Fig. 12g). Second pleopod with appendix masculina shorter than appendix interna, bearing slender spines on tip and along lateral margins (Fig. 13j). Telson more than twice as long as wide proximally; basal width less than twice width of posterior margin; dorsal surface with two pairs of spines situated at some distance from lateral margin, at about mid-length and 3/4 telson length, respectively (Fig. 12h); posterior margin with shallow U-shaped median cleft furnished with four long plumose setae and two pairs of spines, lateral slightly shorter than mesial (Fig. 12i); anal tubercles absent. Uropods slightly longer than telson (Fig. 12a); sympodite with acute tooth; diaeresis simple, slightly sinuous; lateral spine small. Gill formula typical for genus: see under *S. nhatrangensis*, new species. Ovigerous female with six remaining eggs (diameter 0.8 x 0.5 mm).

Colour. – White-semitransparent, eggs or gonads bright yellow.

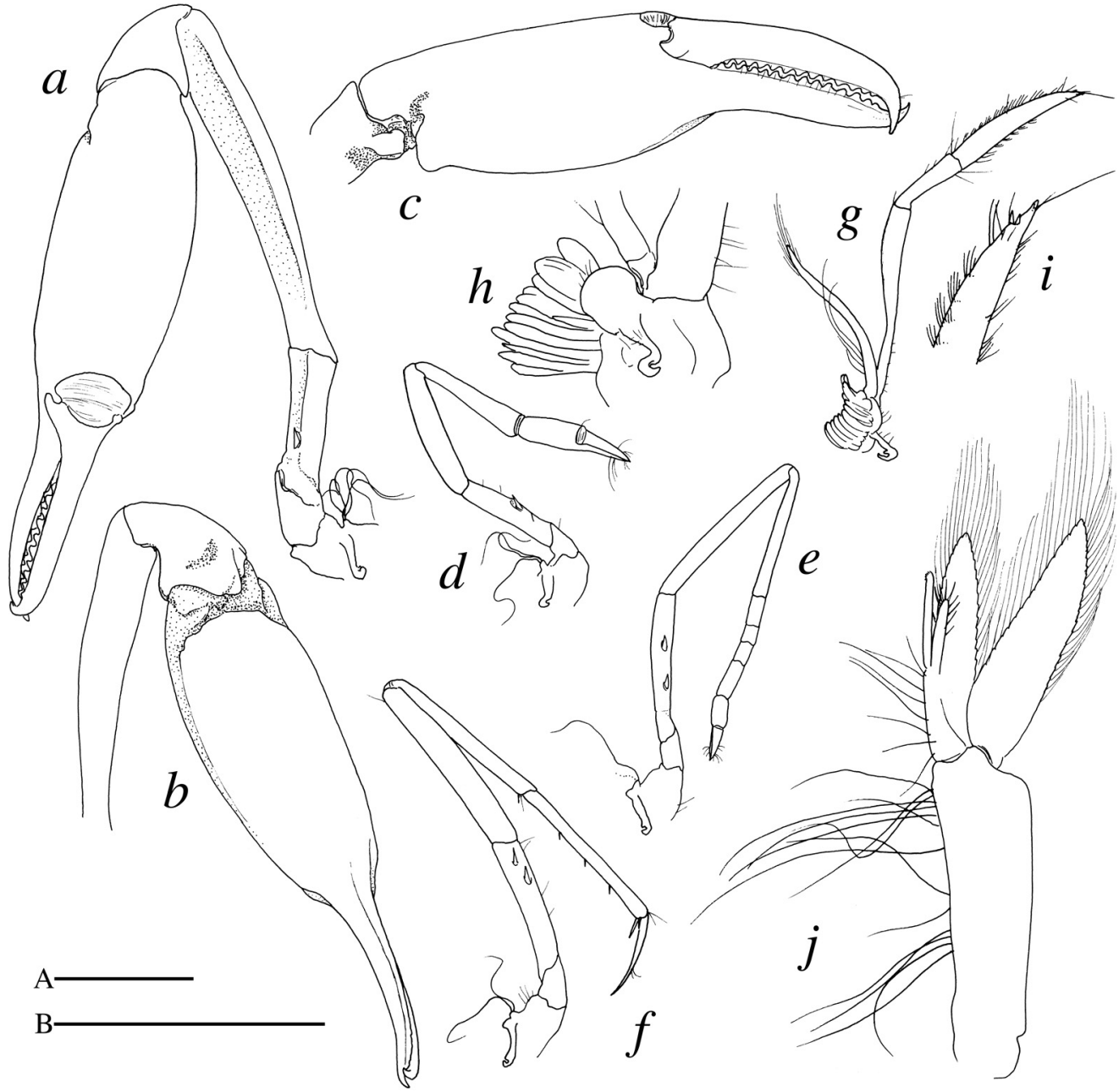

Fig. 13. *Salmoneus alpheophilus*, new species, paratype (ZMMU Ma 5447): a, left major cheliped, ventrolateral view; b, same, chela, carpus and distal merus, ventromesial view; c, chela, mesial view; d, right minor cheliped; e, second pereiopod; f, third pereiopod; g, third maxilliped; h, same, basal portion; i, same, distal ultimate segment; j, second pleopod. Scale bars: A (a-g) = 1 mm; B (h, i, j) = 1 mm.

***Habitat*. –** Intertidal sand-mud flats, fringed with mangroves, in burrows of *Alpheus* species (*A*. cf. *rapacida* De Man, 1909, *A*. sp. aff. *bellulus* Miya & Miyake, 1969 and *Alpheus* sp.) associated with gobies (*Cryptocentrus* cf. *leptocephalus* Bleeker, 1876 and *Cryptocentrus* sp.). *Salmoneus alpheophilus*, new species, probably live as facultative commensals in these burrows, similar to *S. rostratus* Barnard, 1962 (see below).

***Etymology*. –** The specific name ("*Alpheus*-loving") is the reference to the habits of *S. alpheophilus*, new species, to dwell in burrows of *Alpheus* species.

***Variation*. –** Slight variation exists in the shape and length of the rostrum (see Fig. 12c, j, k).

***Remarks*. –** *Salmoneus alpheophilus*, new species, appears to be related to *S. gracilipes*, *S. colinorum*, *S. falcidactylus*, new species, *S. pusillus*, new species (see above), *S. seticheles*, *S. cavicolus*, and possibly the problematic *S. tafaongae*. However, the unique combination of several morphological features enables a separation of *S. alpheophilus*, new species, from all these species. For instance, it may be distinguished from *S. gracilipes*, *S. colinorum* and *S. falcidactylus*, new species, by the presence of a robust spine on the ischium of both chelipeds and two spines on the ischium of the second pereiopod (cf. Miya, 1972, 1984; De Grave, 2004; see also above); from *S. seticheles* by the absence of long flexible setae on the major chela (cf. Anker, 2003b); and from *S. tafaongae* by the much shorter rostrum (cf. Banner & Banner, 1966a). For distinction between *S. pusillus*, new species, and *S. alpheophilus*, new species, see under the former species.

Salmoneus alpheophilus, new species, shares many features with the western Atlantic *S. cavicolus*, e.g. the general shape of the rostrum, the presence of a small tubercle on the anteromesial margin of the eyestalk, and a spine on the ischia of the first and second pereiopods (cf. Felder & Manning, 1986). However, *S. alpheophilus*, new species differs from *S. cavicolus* by the much stouter second segment of the antennular peduncle, almost as long as wide (vs. much longer than wide in *S. cavicolus*), and the posterior margin of the telson bearing a small rounded median cleft (vs. straight in *S. cavicolus*) (cf. Felder & Manning, 1986).

***Distribution*. –** Presently known only from the type locality, Nhatrang Bay, Vietnam.

Salmoneus rostratus Barnard, 1962
(Fig. 7b, c, 14)

Salmoneus rostratus Barnard, 1962: 240, Fig. 1; Kensley, 1974: 74; Banner & Banner, 1981: 52, 53; Banner & Banner, 1983: 88; Carvacho, 1989: 255; De Grave & Wilkins, 1997: 633, Fig. 1; Anker, 2003a: 287, Fig. 3c, d.

Material examined. – 1 ovigerous female (CL 6.4, TL 18.3), 1 non-ovigerous specimen (CL 6.3, TL 18.5)(ZMMU Ma 5449) [dissected], South China Sea, Vietnam, Nhatrang Bay, Tre I., Dam Bay, 12°10'20"N 109°15'30"E, tidal sand-mud flat, extreme low tide, in burrow of goby-associated *Alpheus* species, bait suction (yabby) pump, coll. I. Marin, 4 Jun.2004; 2 ovigerous females (CL 6.8, TL 18.9 and CL 6.5, TL 18.3)(ZMMU Ma 5450), same collection data as for previous specimens, from a different burrow; 2 ovigerous females (CL 5.8, TL 17.0 and CL 6.5, TL 18.2)(ZMMU Ma 5451), South China Sea, Vietnam, Nhatrang Bay, Tre I., Dam Bay, 12°10'20"N 109°15'30"E, tidal sand-mud flat, in burrow of goby-associated *Alpheus* species, bait suction (yabby) pump, coll. I. Marin, 17 Jun.2004; 1 ovigerous female (CL 7.2, TL 19.6), 1 non-ovigerous specimen (CL 5.6, TL 16.3)(ZMMU Ma 5452), same collection data as for previous specimens, from a different burrow.

Additional material examined. – 1 ovigerous female (CL and TL not measured)(MNHN-Na 4587), Nosy-Bé, Madagascar, intertidal, coll. B. Opic, 7 Sep.1974, det. Banner 28 Oct.1980.

***Description*. –** For detailed description see Barnard (1962) and De Grave & Wilkins (1997).

***Colour*. –** Carapace, abdomen, telson, and uropods maroon-red; antennae and antennules brilliant white; pereiopods translucent with red tinge (De Grave & Wilkins, 1997) (Fig. 7b, c).

***Habitat*. –** Intertidal sand-mud flat, fringed with mangroves, in burrows of *Alpheus* species (*A*. cf. *rapacida*, *A*. sp. aff. *bellulus* and *Alpheus* sp.) associated with gobies (*Cryptocentrus* cf. *leptocephalus* Bleeker, 1876, and *Cryptocentrus* sp.). A burrow was usually inhabited by a pair of *S. rostratus*, either two ovigerous specimens or one ovigerous and one non-ovigerous specimen. Some burrows also contained amphinomid polychaete worms. The association of *S. rostratus* with goby-associated burrowing *Alpheus* was also noted in previous reports (De Grave & Wilkins, 1997; Anker, 2003a), although in Hansa Bay, Papua New Guinea, the specimens were collected in deeper water, precisely at about 11 m (De Grave & Wilkins, 1997).

***Remarks*. –** The present specimens of *S. rostratus* agree well with material reported from Papua New Guinea (De Grave & Wilkins, 1997) and Phuket, Thailand (Anker, 2003a). On the other hand, specimens from the western Pacific (Vietnam, Papua New Guinea) and northeastern Indian Ocean (Phuket) show clear differences with the type material from Madagascar. Some of these differences were already pointed out by De Grave & Wilkins (1997). For instance, the rostrum of most specimens from Nhatrang Bay reaches only to the distal margin of the first segment of the antennular peduncle (Fig. 14a, b), whereas it reaches to the middle of the second segment in the holotype (Barnard, 1962, Fig. 1a) and to 1/4 length of the second segment in the ovigerous female from Nosy-Bé (MNHN-Na 4587) (Fig. 15a). Barnard (1962) did not mention or illustrate the conspicuous postrostral tubercle on the carapace (Fig. 14b) and the three strong spines on the ischium of the third pereiopod (Fig. 14h), but De Grave & Wilkins (1997) examined the type series and confirmed that both features are present in the types. The postrostral tubercle is conspicuous in the MNHN specimen (Fig. 15b), although much less so compared to the Vietnamese specimens (Fig. 14b). The shape and length of the stylocerite appear to be slightly different. In the specimens from Nhatrang Bay, the stylocerite is distally much more slender, slightly

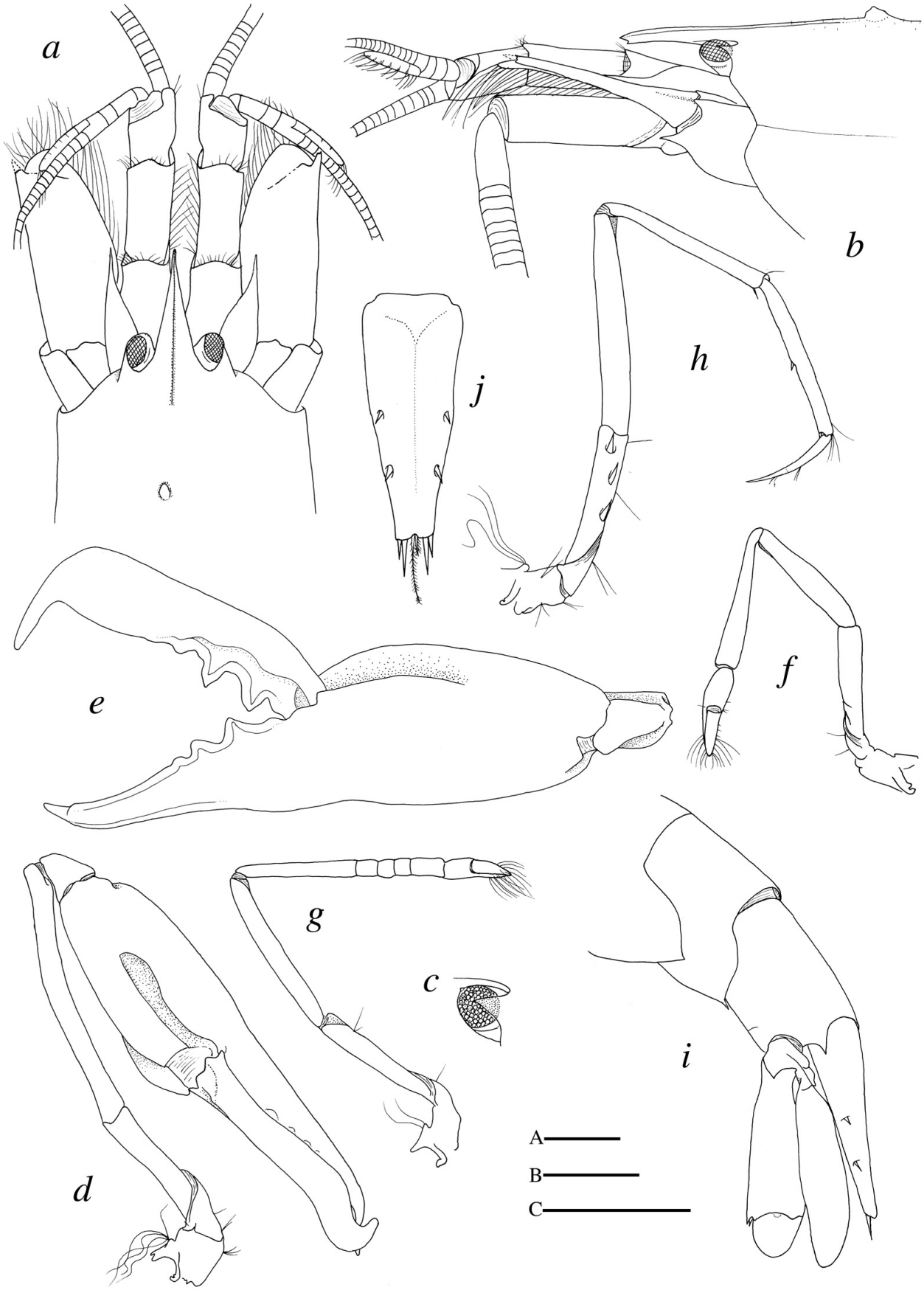

Fig. 14. *Salmoneus rostratus* Barnard, 1962, non-ovigerous specimen from Nhatrang Bay, Vietnam (ZMMU Ma 5449): a, frontal region, dorsal view; b, same, lateral view; c, detail of eye; d, right major cheliped, lateral view; e, same, chela, mesial view; f, left minor cheliped; g, second pereiopod; h, third pereiopod; i, abdomen, posterior somites and tail fan, lateral view (setae omitted); j, telson. Scale bars: A (f) = 1 mm; B (a, b, d, e, g-j) = 1 mm; C (c) = 1 mm. Drawings: Denis Poddoubtchenko.

overreaching the distal margin of the first segment of the antennular peduncle (Fig. 14a), like in the MNHN specimen (Fig. 15a), while in Barnard's type, the stylocerite is stouter and is only reaching the distal margin of the first segment (Barnard, 1962, Fig. 1a). Furthermore, in the Nhatrang Bay specimens, the telson is narrower and less tapering (Fig. 14j) compared to that of the type (*idem*., Fig. 1d). Although these differences appear to be slight, they should be taken into account when more material of *S. rostratus* becomes available, and eventually closely related species are recognized. This is particularly true for the development of the postrostral tubercle, which is hard to overlook when fully developed as in the present specimens (Fig. 14b). The armature of the major chela fingers, as well as most other features, are very similar among the specimens from Nhatrang (Fig. 14), Nosy-Bé (Barnard, 1962; see also Fig. 15), Phuket (Anker, 2003a) and Hansa Bay (De Grave & Wilkins, 1997).

Distribution. – Madagascar: Nosy-Bé (Barnard, 1962; Banner & Banner, 1983); Thailand: Phuket (Anker, 2003a); Papua New Guinea: Hansa Bay (De Grave & Wilkins, 1997); Vietnam: Nhatrang Bay (present study).

DISCUSSION

The description of five new species from Vietnam raises the number of the described species of *Salmoneus* in the Indo-Pacific to 21, and the world total to 29. The genus was formerly divided in two species groups, the small eastern Atlantic *S. jarli* (Holthuis, 1951) group and the large, heterogenous, worldwide *S. serratidigitus* group (e.g. Dworschak et al., 2000). Here we propose to subdivide *Salmoneus* into seven species groups. Some of these groups are presumably monophyletic, but others may be not.

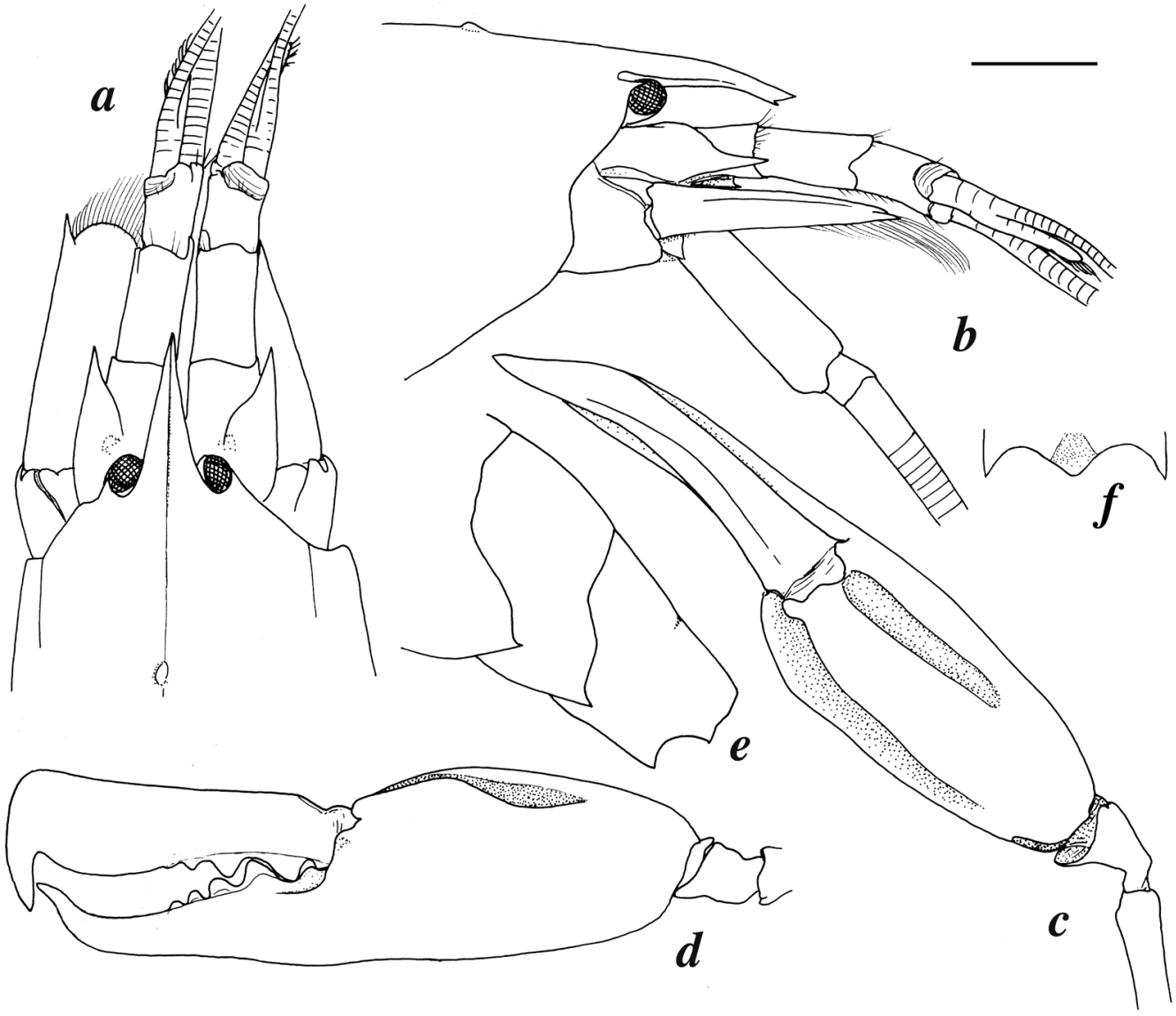

Fig. 15. *Salmoneus rostratus* Barnard, 1962, ovigerous female from Nosy-Bé, Madagascar (MNHN-Na 4587): a, frontal region, dorsal view; b, same, lateral view, ventral view tooth of basicerite probably broken); c, d, major cheliped; e, posterior abdominal somites; f, sixth abdominal somite, preanal plate. Scale bar = 1 mm.

Therefore, they should be used only as first-step taxonomic groupings, similar to the species groups commonly used in *Alpheus* Fabricius, 1798 and *Synalpheus* Bate, 1888. We hope that a future phylogenetic analysis of the genus *Salmoneus* will help to better define these groups, perhaps retain some of them and abandon others.

The first species group, the *S. jarli* group, is defined mainly by the relative size of the chelipeds. This group includes four eastern Atlantic species, *S. jarli* (Holthuis, 1951), *S. sketi* Fransen, 1991, *S. erasimorum* Dworschak, Anker & Abed-Navandi, 2000 and *S. caboverdensis* Dworschak, Anker & Abed-Navandi, 2000, and three undescribed species: two in the Indo-West Pacific and one in the western Atlantic (A. Anker, pers. obs.). All these species have a shorter, but stouter ("major") cheliped, and a longer, but usually more slender ("minor") cheliped (Holthuis, 1951; Fransen, 1991; Dworschak et al., 2000). *Salmoneus jarli* is unique within the group and the genus in that the major cheliped lacks armature consisting of regularly spaced teeth. At least four species of the *S. jarli* group appear to live commensally in burrows of thalassinideans (Dworschak et al., 2000; A. Anker, pers. obs.), while *S. sketi* inhabits marine caves (Fransen, 1991). The colour patterns are known for *S. sketi*, *S. caboverdensis*, *S. erasimorum* and two undescribed species, ranging from translucent or creamy white to greenish yellow (Fransen, 1991; Dworschak et al., 2000; A. Anker, pers. obs.). *Deioneus sandizelli* Dworschak, Anker & Abed-Navandi, 2000 appears to have some affinities to this group (Dworschak et al., 2000).

The second species group, the *S. rostratus* group, is distinctive in that all species have a relatively slender rostrum, sometimes with a small, subapical tooth on the ventral margin; elongated, robust carpocerite of the antenna; dorsally partly exposed eyes; slender dactyli on the third to fifth pereiopods; major cheliped with slender merus and rather massive chela with fingers that are armed proximally with a few large teeth, and distally either with gradually smaller teeth or without teeth. This group includes three Indo-West Pacific species, *S. rostratus*, *S. singaporensis* Anker, 2003 and *S. bruni* Banner & Banner, 1966 (Barnard, 1962; Banner & Banner, 1966b; De Grave & Wilkins, 1997; Anker, 2003a). All but *S. bruni* have a postrostral tubercle (very conspicuous in *S. rostratus*), a small tubercle on the anterior margin of the eyestalks, and a small, subapical, ventral tooth on the rostrum. The colour pattern is known only for *S. rostratus* (see above), which is one of the most colourful members of *Salmoneus*.

The third species group, the *S. gracilipes* group, is undoubtedly closely related to the *S. rostratus* group. It includes species with relatively long, slender rostrum, sometimes with a small, subdistal tooth on its ventral margin; dorsally partly exposed eyes; slender dactyli on the third to fifth pereiopods; and the major chela armed with small teeth on the entire or almost entire length of the cutting edges. In some species, the carapace bears a small postrostral tubercle. The ischium of the first and sometimes second pereiopods may bear a strong spine on the ventral margin. The *S. gracilipes* group includes: *S. gracilipes*, *S. colinorum*, *S. alpheophilus*, new species, *S. pusillus*, new species, *S. falcidactylus*, new species, *S. seticheles*, and at least one undescribed species in the Indo-West Pacific (Miya, 1972, 1984; Anker, 2003b; De Grave, 2004; A. Anker, pers. obs.; present study); and *S. cavicolus* and four undescribed species in the western Atlantic (A. Anker, pers. obs,). This group may also include *S. tafaongae* described on the basis of a mutilated specimen from Samoa (Banner & Banner, 1966a; Anker, 2003a, 2003b; see also above). *Salmoneus seticheles* is unique within the genus in having a fringe of long setae on the major chela and the presence in some individuals of the so-called "subminor" cheliped, armed with large teeth, instead of the typical minor cheliped (Anker, 2003b). The colour of *S. gracilipes* was described as "entirely transparent; the cornea is dull reddish orange" (Miya, 1972). At least four other species of this group, viz. *S. alpheophilus*, new species, *S. falcidactylus*, new species, *S. pusillus*, new species (see above), and *S. cavicolus* are also semitransparent; however, one undescribed form has brownish bands across the abdomen (D. Felder, pers. comm.).

The fourth species group, the *S. babai* group, includes only *S. babai* from the Ryukyu Islands. This species is markedly different from the other species of *Salmoneus* by the stout dactyli on the third to fifth pereiopods and the configuration of the fingers of the major chela, with the pollex being much shorter than the hawk-shaped (distally strongly curved) dactylus (Miyake & Miya, 1966). The colour of *S. babai* was noted as "uniformly bright yellow" (Miya, 1972).

The fifth species group, the *S. cristatus* group, includes four Indo-West Pacific species having a strong mediodorsal carina, sometimes extending to the posterior half of the carapace; dorsally concealed eyes; and the major chela with fingers bearing small teeth on the entire or almost entire length of the cutting edges. These are *S. cristatus*, *S. tricristatus*, *S. brevirostris* and *S. auroculatus*, new species (Holthuis, 1958; Banner, 1959; Banner & Banner, 1966a, 1973, 1981; Miya, 1972; Anker, 2003b; present study). In *S. tricristatus*, the mediodorsal carina is paralleled by two other strong carinae on each side of the carapace and several less marked ridges, while in *S. brevirostris* there are two slight carinae on the orbital hoods. The colour patterns are very different among these four species: whitish with red bands across the carapace and abdomen in *S. cristatus* (Coutière, 1899; Holthuis, 1958); whitish with red chromatophores on the posterior portion of the carapace in *S. tricristatus* (A. Anker, pers. obs.); bright orange yellow in *S. brevirostris* (Edmondson, 1930; Banner & Banner, 1983); and whitish-semitransparent in *S. auroculatus*, new species (Fig. 7). This group may also include an undescribed western Atlantic species presently known from a few incomplete specimens (e.g., Schmitt, 1924, as "*Jousseaumea trigona*", A. Anker, pers. obs.).

The sixth group, the *S. ortmanni* (Rankin, 1898) group, is defined by the dorsally covered eyes and the major cheliped with a strongly inflated, ventrally excavated merus, and with ventrally depressed palm of the chela. This group includes the western Atlantic *S. ortmanni* and possibly two undescribed species currently confused with *S. ortmanni* (A. Anker, pers.

obs.), one in the western Atlantic (Carvacho, 1979; Christoffersen, 1982), and another in the tropical eastern Pacific (Ríos & Carvacho, 1983; Ríos, 1989; Wicksten, 1993). The colour pattern of *S. ortmanni* and *S. aff. ortmanni* is uniform bright yellow-orange (A. Anker, pers. obs.).

The seventh species group, the *S. serratidigitus* group, includes all the remaining Indo-Pacific and Atlantic species. This group is characterized by the dorsally covered eyes; the major chela with fingers bearing small teeth on the entire or almost entire length of the cutting edges; and the carapace lacking strong carinae. It includes *S. serratidigitus*, *S. sibogae*, *S. latirostris*, *S. mauiensis*, *S. hilarulus*, *S. nhatrangensis*, new species, and several undescribed species in the Indo-West Pacific (Coutière, 1896, 1899; De Man, 1911; Edmondson, 1930; Banner, 1953; Banner & Banner, 1981; present study; A. Anker, pers. obs.); *S. arubae*, *S. setosus*, *S. teres* and several undescribed species in the western and central Atlantic (Schmitt, 1936; Manning & Chace, 1990; Holthuis, 1990; A. Anker, pers. obs.); and an undescribed species in the eastern Atlantic (Grippa, 2002). All these species are morphologically very close and difficult to discriminate (see above). Two of them, *S. latirostris* and *S. sibogae*, were considered as synonyms of the variable *S. serratidigitus* (Banner & Banner, 1981). Anker (2003b) did not accept Banner's view of *S. serratidigitus* as a single, highly variable species, and suggested to treat both *S. latirostris* and *S. sibogae* as valid species. Furthermore, several specimens were obviously misidentified. For instance, some specimens from Madagascar identified as *S. serratidigitus* by Banner & Banner (1983) actually represent an undescribed species from the *S. gracilipes* group, closely related to *S. colinorum* and *S. alpheophilus*, new species (A. Anker, pers. obs.). All records of *S. serratidigitus* from the tropical eastern Pacific, e.g. Gulf of California and Galapagos (Wicksten, 1983, 1993; Hickman & Zimmermann, 2000) could refer to a closely related species, remaining to be described. We also believe that the two very different Australian specimens reported as *S. sibogae* (Banner & Banner, 1982) were misidentified, and represent actually two different, most probably undescribed species. The record of *S. mauiensis* from Mindanao, Philippines (Banner & Banner, 1978) is also questionable, at least judging from the shape of the major chela, which is markedly different from that in Hawaiian specimens; it is more likely that the Mindanao specimen probably belongs to a further undescribed species. The colour patterns are known for *S. serratidigitus* (bright orange-yellow, *S. sibogae* (bright yellow to muddy white, eggs red), *S.* aff. *sibogae* (whitish translucent), *S. latirostris* (red-white banded) *S. mauiensis* (orange-yellow) *S. nhatrangensis*, new species (whitish), and *S.* cf. *teres* (pale whitish) (Coutière, 1899; Edmondson, 1930; Banner & Banner, 1968, 1981, 1982; Kamezaki et al., 1988; A. Anker, pers. obs.; present study). The *S. serratidigitus* group may also include other species, such as *S. babai*, *S. auroculatus*, new species, and *S. brevirostris*, here tentatively placed in other groups. In view of numerous (at least 12) species remaining to be described, a species key would not particularly be useful at this stage. For the most recent key to the *Salmoneus* species see Anker (2003b).

It is worth noting that the specimens of *Salmoneus* cannot be sexed if they are not ovigerous, as both sexes have a well-developed appendix masculina (Carvacho, 1989; A. Anker, pers. obs.). The gonopods are tiny and barely visible even under the dissecting microscope. The only way to determine the sex of a non-ovigerous specimen of *Salmoneus* is to dissect the gonad, and to find male/female gonoducts ending in male or female gonopores situated near the base of coxae on the fifth or third pereiopods, respectively. Whether *Salmoneus* species are hermaphroditic or not remains unknown. Often specimens are collected in pairs where both individuals are simultaneously egg-bearing (as in the case of *S. pusillus*, new species, and *S. rostratus*, see above) suggesting that some unusual sex phenomenon may exist in most if not all species of this interesting genus.

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