

Description of *Orthoprotella bicornis*, new species, and *Paraprotella teluksuang*, new species (Crustacea: Amphipoda) from Johor, Malaysia with special reference to unusual sexual bias towards females in *Paraprotella*

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Abstract. Two new species of caprellidean amphipods, *Orthoprotella bicornis*, new species, and *Paraprotella teluksuang*, new species, were discovered in shallow water coral reef and seagrass bed habitats in the Taman Laut Sultan Iskandar, Johor, South China Sea, off the east coast of Peninsular Malaysia. *Orthoprotella bicornis*, new species, is distinguished from other existing *Orthoprotella* species by the presence of several projections on the anterodistal margin of peduncle article 3 on antenna 1, head with 1 pair of dorsal projections, and propodus of pereopod 7 with a pair of grasping spine. *Paraprotella teluksuang*, new species, is close to *P. saltatrix* Takeuchi & Guerra-García, 2002, but differs in its lack of a suture between head and pereonite 1, single dorsal projection on head, 1 dorsodistal projection on pereonite 1 and paired mid-dorsal projections on pereonite 2. Keys to the species of *Orthoprotella* and *Paraprotella* are provided. *Paraprotella teluksuang*, new species, shows unusual sexual bias towards females, which is apparent in the absence of male specimens among the 360 individuals collected. This suggests that *P. teluksuang*, new species, is either a parthenogenetic species or is influenced by the presence of high environmental stress and/or parasitic infection.

Key words. Amphipoda, Taman Laut Sultan Iskandar, Johor, Malaysia, new species, *Orthoprotella*, *Paraprotella*, taxonomy, sexual bias

INTRODUCTION

The Taman Laut Sultan Iskandar, Johor (TLSI) is situated 15–65 km from Mersing, off the North-east coast of the Johor State, Malaysia in the South China Sea. The TLSI is surrounded by coral reefs (see Harborne et al., 2000; Maritime Institute of Malaysia, 2006; Affendi & Rosman, 2011) and tropical sea grass communities (see Japar Sidik & Muta Harah, 2003; Japar Sidik et al., 2006; Azman et al., 2008; Japar Sidik & Muta Harah, 2011). Faunal surveys on Amphipoda in shallow coral reef habitats within the TLSI have resulted in the discovery of one new species from the family Maeridae Krapp-Schickel, 2008 (Lim et al., 2010), two new species from the family Urothoidae Bousfield, 1978 (Azman & Melvin, 2011) of the suborder Gammaridea; and one new genus and species from the family Phtisicidae Vassilenko, 1968 of the suborder Caprellidea (Lim et al., 2012). A series of continuous faunal surveys

has led to the further discovery of two new species from *Orthoprotella* Mayer, 1903 and *Paraprotella* Mayer, 1903 of the Caprellidea. Both genera were separated from the genus *Protella* Dana, 1853 by Mayer (1903), and are morphologically closely related to each other.

Species of the genus *Orthoprotella* are distributed from tropical regions of the Indo-Pacific to temperate regions of the southern hemisphere. Among the 11 known species of *Orthoprotella*, *Orthoprotella bicornis*, new species, from TLSI is most similar to *O. australis* (Haswell, 1880), originally recorded from New South Wales, Australia. It differs in its antenna 1 peduncle article 3, gnathopod 2 propodus proximal projection and abdominal region; uropod 1 distal margin without fine setae and uropod 2 ramus vestigial (uropod 1 distal margin with fine setae; uropod 2 degenerated into 1 seta in *O. australis*).

The genus *Paraprotella* has been recorded from tropical to temperate regions of the Indo-Pacific and comprises three species thus far. *Paraprotella teluksuang*, new species, from TLSI differs from *P. saltatrix* Takeuchi & Guerra-García, 2002, recorded from Phuket Island, Thailand in the lack of a distinct suture between head and pereonite 1 and lack of a dorsodistal projection on pereonite 2. Among the 360 specimens collected in this study, no male individuals of *P. teluksuang*, new species, were identified, indicating a biased sex ratio towards females in *P. teluksuang*, new species, which is also found in *P. saltatrix*.

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MATERIAL AND METHODS

Materials described here were obtained from two localities, Kampung Sebirah and the Mahkota artificial reef, Teluk Suang, Pulau Tinggi, TLSI. Collecting was done in various habitats including seagrasses through SCUBA diving or snorkelling. Epifaunal organisms were washed out in a tray by adding formalin. Caprellids were hand-picked from these formalin-washed samples for identification and preserved in 4 % formalin in seawater. Dissected mouthparts and appendages were stored on semi-permanent slides mounted on glycerol. The familial classification of this study follows Takeuchi (1993). All materials are deposited at the Universiti Kebangsaan Malaysia Muzium Zoologi (UKMMZ), Malaysia. The following abbreviations are used on the figures: A, antenna; ABD (L), abdomen lateral view; ABD (V), abdomen ventral view; G, gnathopod; LL, lower lip; MD, mandible; MX, maxilla; MXP, maxilliped; P, pereopod; UL, upper lip; R, right; L, left; ♂, male; ♀, female.

TAXONOMY

Family Caprellidae Leach, 1814

Genus *Orthoprotella* Mayer, 1903

Orthoprotella bicornis, new species

(Figs. 1–5)

Material examined. Holotype: Male, 8.37 mm, UKMMZ-1502, Kampung Sebirah, Pulau Tinggi, TLSI, Johor, 02°18.490'N, 104°05.575'E; seagrass bed, SCUBA diving, 3 April 2009, depth 4.0 m; coll. Azman, B.A.R., Gan, S.Y., Lim, J.H.C., Chew, M.W.H., Shamsul, B. & Yoshida, T. Paratypes: 1 female, UKMMZ-1503; 3 males, 4 females, 7 premature males, 4 premature females, 28 juveniles, UKMMZ-1504; 3 males, 4 females, 6 premature males, 3 premature females, 28 juveniles, UKMMZ-1505; 2 males, 4 females, 6 premature males, 3 premature females, 28 juveniles; UKMMZ-1506; same station data.

Type locality. Kampung Sebirah, Pulau Tinggi, TLSI, Johor, Malaysia.

Description. Male. Body length 8.37 mm. UKMMZ-1502 (Fig. 1). Head/pereonite 1 concave along dorsal margin, showing slight suture; head with a pair of mid-dorsal projections; eye large, distinctive. Head length 0.57 mm; pereonite 1 length 0.48 mm; pereonite 2 length 1.34 mm, with 1 small anterolateral triangular projection, 1 lateral projection above the insertion of gnathopod 2, 1 lateroventral triangular projection and 1 rounded dorsodistal projection; pereonite 3 length 1.73 mm, with 1 small anterolateral triangular projection; pereonite 4 length 1.62 mm; pereonite 5 length 1.76 mm, longest; pereonites 6 and 7 partially fused (dorsal suture oblique), combined length 0.87 mm. Antenna 1, 0.9× body length; peduncular article 2 longest; peduncular article 3 with several small projections on anterodistal margin; flagellum 0.5× peduncular length, with 16 articles, proximal article composed of 3 articles (Fig. 1: A1). Antenna 2 slender;

0.4× the length of antenna 1; peduncle with several feeble setae; flagellum 0.2× of peduncular length, with 2 articles (Fig. 1: A2).

Mouthparts. Upper lip notched, forming rounded quadrilateral projections (Fig. 2: UL). Lower lip finely setose on inner and outer lobes (Fig 2: LL). Mandible right incisor with 5 teeth; lacinia mobilis with 2 distinct teeth and 3 small teeth; followed by 3 bundled setae; molar flake present; palp article 2 with 8 lateral setae; palp article 3 with setal formula 1-18-4-1 [Fig. 2: MD (R)]; left incisor with 5 teeth; lacinia mobilis with 5 teeth, followed by 3 bundled setae; palp article 2 with 8 lateral setae; palp article 3 with setal formula 1-19-4-1 [Fig. 2: MD (L)]. Maxilla 1 outer plate with 7 stout apical setal-teeth; palp distal margin with 5 triangular projections, with 7 setae and a row of 3 slender setae (Fig. 2: MX1). Maxilla 2 inner plate triangular with about 8 apical setae; outer plate subrectangular with 12 apical setae (Fig. 2: MX2). Maxilliped basal endite (inner plate) quadrilateral with 2 small teeth-like setae and 4 plumose setae on distal margin; ischial endite (outer plate) oval, 2.5× length of inner plate, inner margin blade-like, with many fine setae, with 2 setae on inner margin and 3 setae on outer margin; palp article 2 setose on inner margin; palp article 3 with small triangular distal projection and 10 distal setae; palp article 4 (dactylus) falcate (Fig. 2: MXP).

Pereon. Gnathopod 1 basis shorter than ischium, merus and carpus combined (0.7×); ischium 0.3× basis; merus subrectangular with several setae at ventrodistal corner; carpus subtriangular, with setae at distal and ventrodistal margin; propodus subtriangular, with 4 rows of submarginal setae (each row with 2–3 setae), palm begins 1/5 along posterior margin, with serriform teeth along entire margin, proximally with 1 robust seta; dactylus falcate, inner margin serrated, scarcely setose (Fig. 1: G1). Gnathopod 2 begins 1/3 along anterior margin of pereonite; basis length 5× width, 0.8× pereonite 2, distally with triangular projection with 1 seta near distal margin; carpus 0.2× propodus length; propodus subovate, large, length 2× width, dorsodistally with a small triangular projection, palm proximal projection with 1 robust (grasping) seta, and 2 smaller tooth-like setae apically, margin of palm heavily setose, proximal half of palm convex, mid-palmar projection with one seta followed by a deep sinus and a triangular projection, palm with serriform teeth between grasping proximal projection and mid-palmar projection; dactylus falcate, with fine setae along inner and outer margins (Fig. 1: G2).

Gill 3 length 0.4× of pereonite 3, oval. Pereopod 3 oval, 2-articulate, article 1 with 7 distal setae and 4 lateral setae; article 2 tiny, conical, with 1 apical plumose seta (Fig. 3: P3). Gill 4 length 0.4× pereonite 4, oval. Pereopod 4 oval, 2-articulate, subequal in length to pereopod 3, article 1 with 7 distal setae and 5 lateral setae; article 2 tiny, conical, with 1 apical plumose seta (Fig. 3: P4). Pereopods 5–7 well-developed, progressively robust. Pereopod 5 carpus longest; propodus with 1 pair of grasping spine near proximal end of palm; dactylus falcate (Fig. 3: P5). Pereopod 6 merus and carpus subequal in length; propodus with a pair of grasping

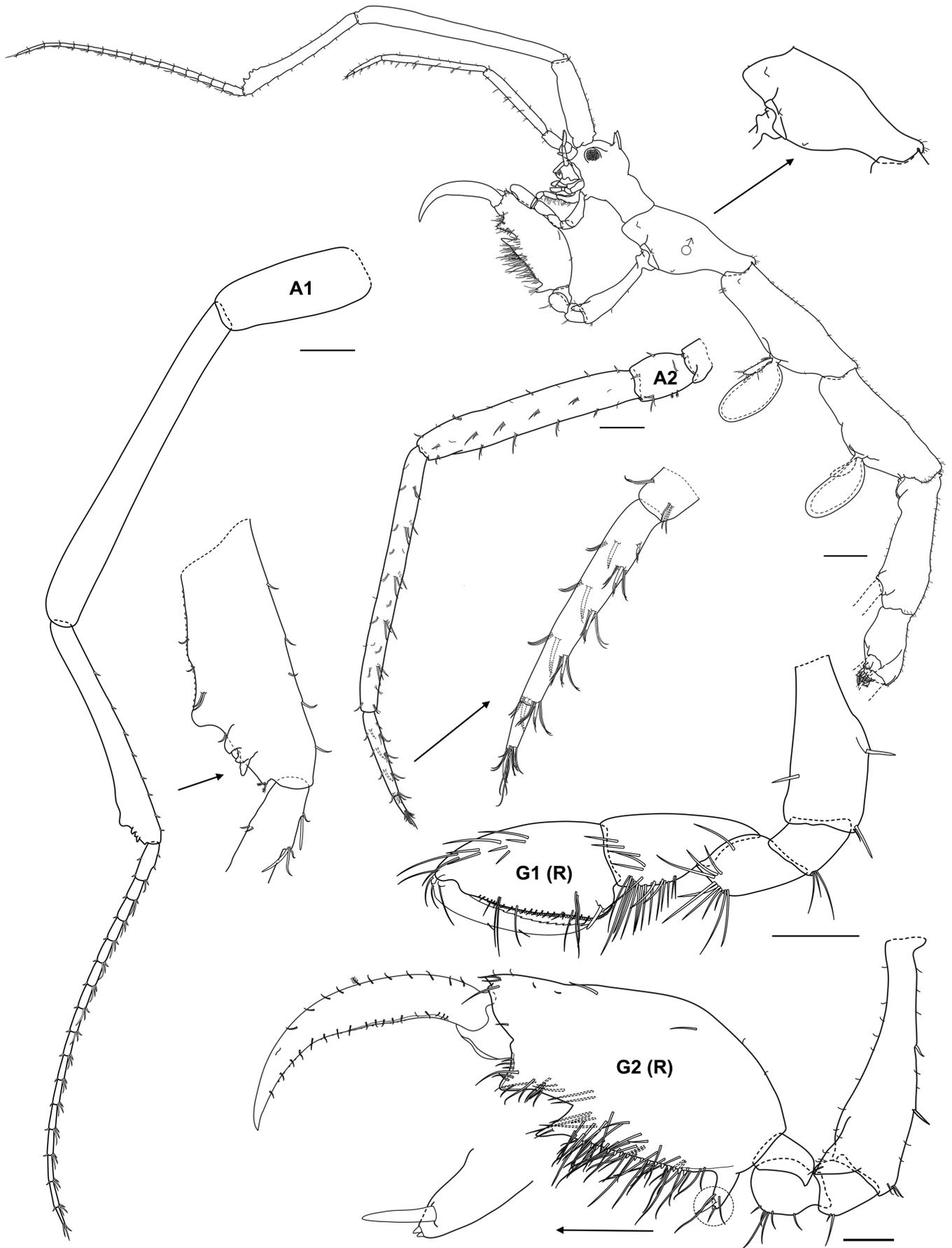


Fig. 1. *Orthoprotella bicornis*, new species, male holotype, 8.37 mm, UKMMZ-1502, Kampung Sebirah, Pulau Tinggi, TLSI. Scale bars A1, A2 and G2 = 0.2 mm; G1 = 0.1 mm; whole body = 0.5 mm.

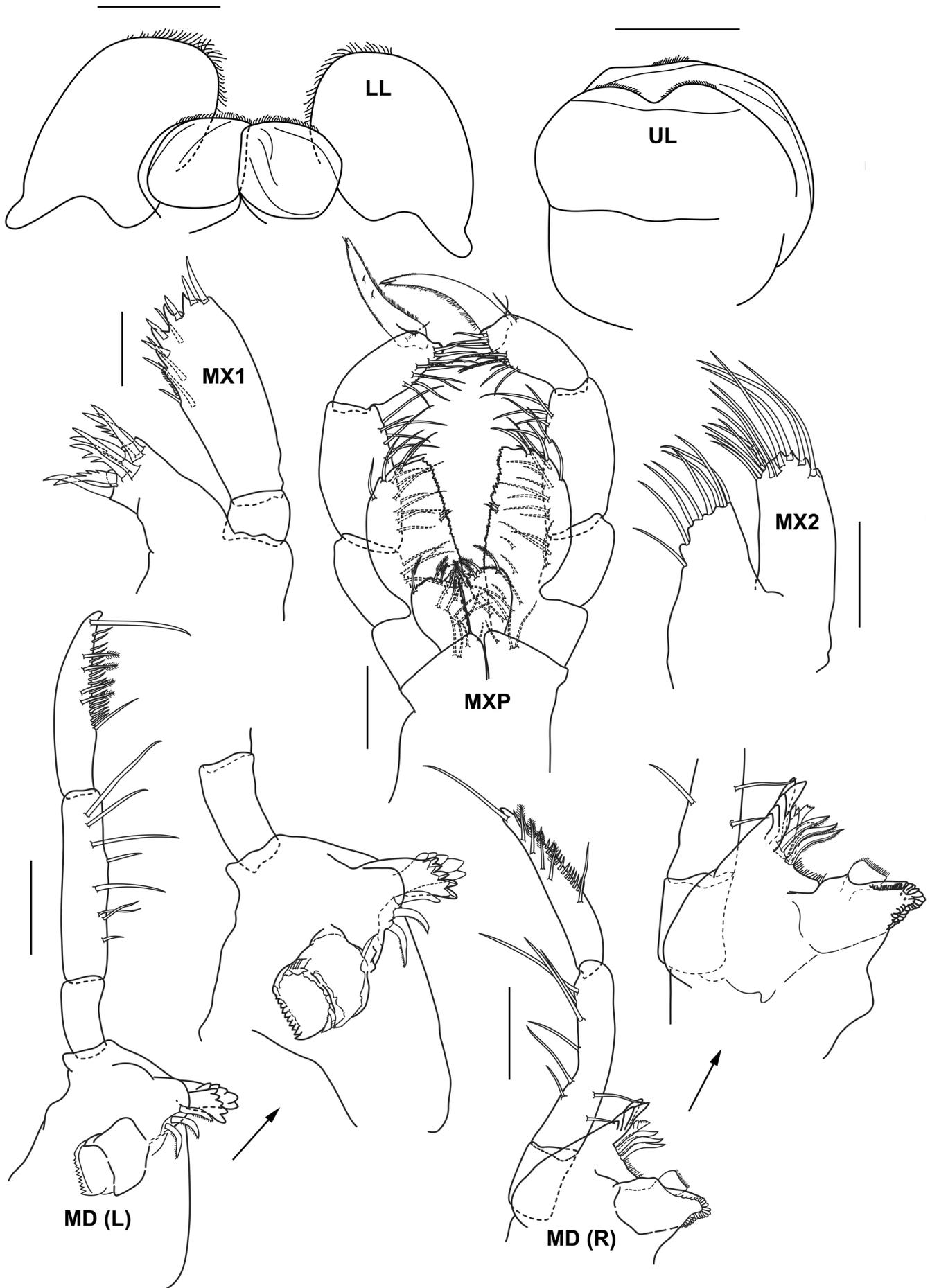


Fig. 2. *Orthoprotella bicornis*, new species, male holotype, 8.37 mm, UKMMZ-1502, Kampung Sebirah, Pulau Tinggi, TLSI. Scale bars MD (R), MD (L) and MXP = 0.1 mm; MX1, MX2, LL and UL = 0.05 mm.

spine; dactylus falcate (Fig. 3: P4). Pereopod 7 merus and carpus subequal in length; propodus longest with a pair of grasping spine; dactylus falcate (Fig. 3: P7).

Pleon. Penes large, situated medially, Uropods 2 uniramous pairs. Uropod 1 biarticulate, peduncle with 8 setae on outer margin and 2 setae on inner margin; ramus slender, 1.4× the length of peduncle, with 2 marginal setae and 1 apical seta. 2 setae present between penes and uropod 1. Uropod 2 ramus vestigial. Telson with 1 pair of normal setae and 1 pair of plumose setae (Fig. 3: ABD).

Female. Body length 6.16 mm. UKMMZ-1503 (Fig. 4). Head length 0.43 mm, and pereonite 1 length 0.25 mm; head and pereonite 1 fused, with slight suture along dorsal margin (between head and pereonite 1). Pereonite 2 length 1.20 mm, with rounded dorsodistal projection, knob-like with fine setae. Pereonite 3 length 1.23 mm, with small dorsodistal projection. Pereonite 4 length 1.12 mm, distolaterally with a plate-like projection. Pereonite 5 length 1.25 mm, dorsally smooth. Pereonites 6 and 7 partially fused, combined length 0.68 mm. Antenna 1 length subequal with body length; peduncular article 2 longest, 2.8× article 1; peduncular article 3 without distal projections; flagellum 0.8× peduncular length, 15 articles, proximal article composed of 3 articles (Fig. 4: A1). Antenna 2, 0.6× the length of antenna 1; flagellum 0.15× peduncular length with 2 articles, proximal article 0.3× distal article (Fig. 4: A2).

Pereon. Gnathopod 1 basis shorter than ischium, merus and carpus combined (0.8×)(Fig. 4: G1). Gnathopod 2 begins 1/5 along anterior margin of pereonite; basis longer than ischium, merus and carpus combined (1.6×), length 5.5× width, 0.8× pereonite 2; carpus subequal in length with ischium, subtriangular; propodus subovate (Fig. 4: G2).

Gill 3 length 0.6× of pereonite 3. Pereopod 3 length 0.4× gill, oval, article 1 with 8 distal setae and 2 lateral setae. Oostegite 3 length 1.2× width, setose along entire outer margin (Fig. 5: G1). Gill 4 length 0.7× pereonite 4, oval. Pereopod 4 length 0.4× gill, article 1 with 6 distal setae and 4 lateral setae. Oostegite 4 length 1.0× width, sparsely setose along entire outer margin (Fig. 5: G2). Pereopods 5–7, progressively robust (Figs. 5: P5–7). Pereopod 5 carpus longest, slender; propodus with a pair of grasping spine near proximal end of palm (Fig. 5: P5).

Pleon. Uropod 1 absent in females. Uropod 2 ramus vestigial, degenerated into 2 setae [Fig. 5: ABD (V) and ABD (L)].

Remarks. Among the genera in the family Caprellidae, the genus *Orthoprotella* is distinguishable from its closest relative, the genus *Protella* Dana, 1852 (see Takeuchi et al., 2014) in terms of its uropod 1 ramus lacking a knob-like appendage (present in species of the genus *Protella*).

Orthoprotella bicornis, new species, is unique in several distinctive characteristics; namely 1) dorsal and lateral projections (head with 1 paired projections; pereonite 2 with 1 small anterolateral triangular projection, 1 lateral projection

above the insertion of gnathopod 2, 1 lateroventral triangular projection and 1 rounded dorsodistal projection; pereonite 3 with 1 small anterolateral triangular projection and 1 round dorsodistal projection); 2) antenna 1 peduncular article 3 with several distal projections (not present in females); 3) gnathopod 2 propodus with a small dorsodistal triangular projection; and 4) gnathopod 2 propodus proximal projection equipped with 1 robust seta (grasping spine) and 2 smaller tooth-like structures.

Species of *Orthoprotella* have a wide range of dorsal projections; therefore, observations of its dorsal and lateral body projections can be used to easily distinguish one species from another. Among the 11 recorded species of *Orthoprotella* (Haswell, 1880; Barnard, 1916; Guiler, 1954; Quitete, 1975; Mori, 1996; Arimoto, 1981; Guerra-García, 2004, 2006; Guerra-García & Takeuchi, 2004; Takeuchi & Lowry, 2007), the status of two species, *O. melloi* Quitete, 1975 and *O. hamata* Arimoto, 1981, is unclear due to their limited descriptions and insufficient figures. According to Laubitz (1991), *O. hamata* could be synonymous with *Monoliropus falcimanus* Mayer, 1904, but further examination of specimens is needed. Due to their unresolved taxonomy, these two species are considered nomina dubia and omitted from comparisons below.

The remaining nine species can be further divided into two groups based on the presence or absence of dorsal projections on the body. The first group consists of four species, which are dorsally smooth (this includes *O. mayeri* Barnard, 1916; *O. tasmaniensis* Guiler, 1954; *O. pearce* Guerra-García, 2006; and *O. berentsae* Takeuchi & Lowry, 2007). The second group consists of five species, which are equipped with dorsal projections (*O. gordonii* Guiler, 1954; *O. australis* (Haswell, 1880); *O. spinigera* Mori, 1996; *O. nana* Guerra-García, 2004; and *O. tuberculata* Guerra-García & Takeuchi, 2004).

Orthoprotella bicornis, new species, belongs to the second group (based on paired dorsal projections on its head and a single dorsodistal projection on pereonites 2) and appears most similar to *O. australis* (Haswell, 1880) recorded from New South Wales, Australia. Descriptions and figures of mouthparts were not provided in Haswell's (1880) original record. Mayer (1903) illustrates the whole body (lateral and dorsal view), maxilliped, mandibular palp and abdomen of mature and premature male. *Orthoprotella bicornis*, new species, is similar to *O. australis* (Haswell, 1880) in the following characteristics: 1) antenna 1 length almost as long as body length; 2) gnathopod 1 with propodus subtriangular in shape; 3) gnathopod 2 propodus longer than head and pereonite 1 and suboval in shape; and 4) palmar margin of gnathopod 2 marginally setaceous. The abdomen of *O. australis* from Mayer (1903) shows close similarity with the present specimen in the distinct peduncle of uropod 1. However, *O. bicornis*, new species, differs from *O. australis* in 1) the presence of several small projections on the anterodistal margin of antenna 1 peduncle article 3 (not stated in *O. australis*); 2) the shape of pereopods 3 and 4 oval, and expanded medially (pereopods 3 and 4 slender,

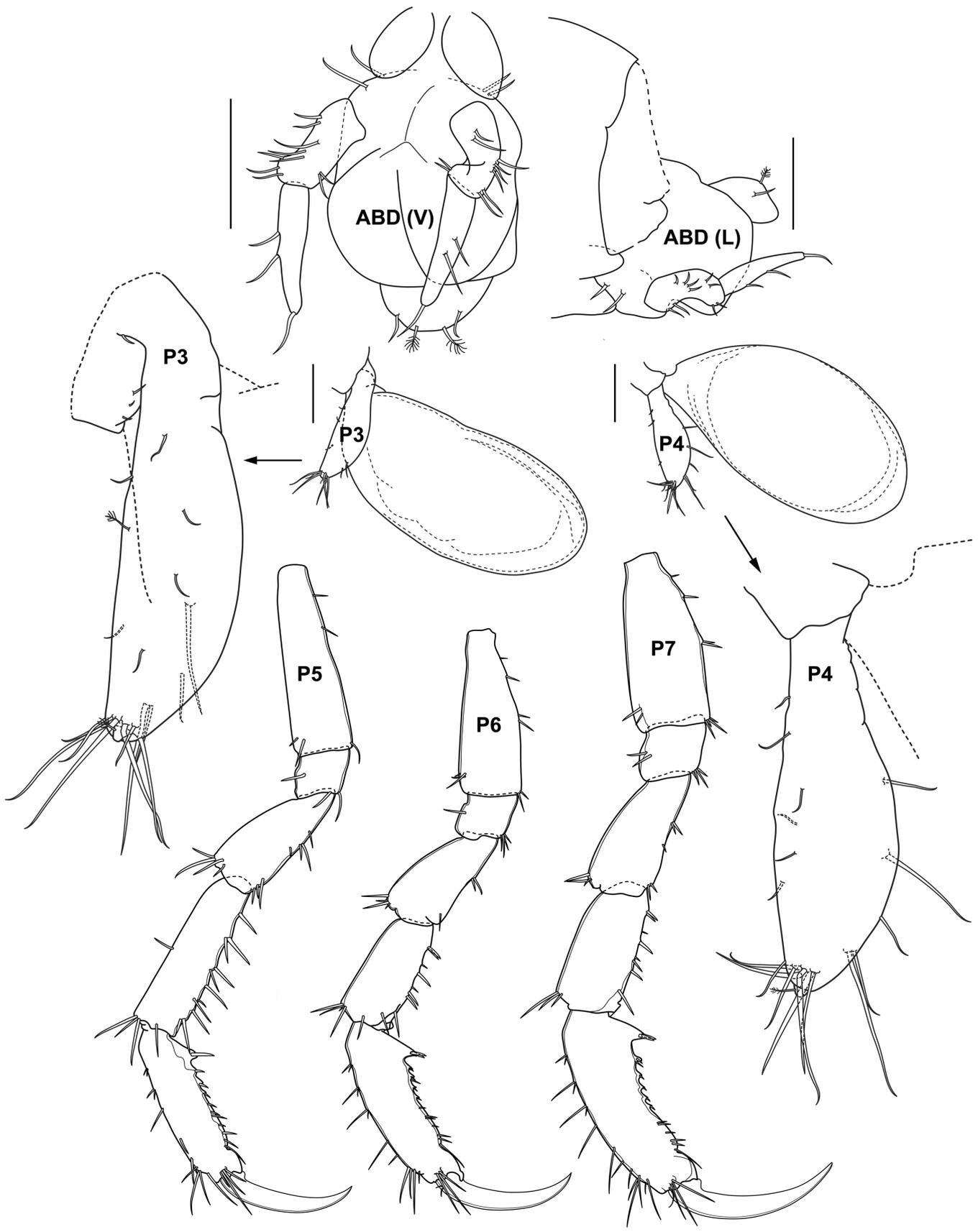


Fig. 3. *Orthoprotella bicornis*, new species, male holotype, 8.37 mm, UKMMZ-1502, Kampung Sebirah, Pulau Tinggi, TLSI. Scale bars ABD (L), ABD (V) = 0.1 mm; P3, P4, P5, P6 and P7 = 0.2 mm.

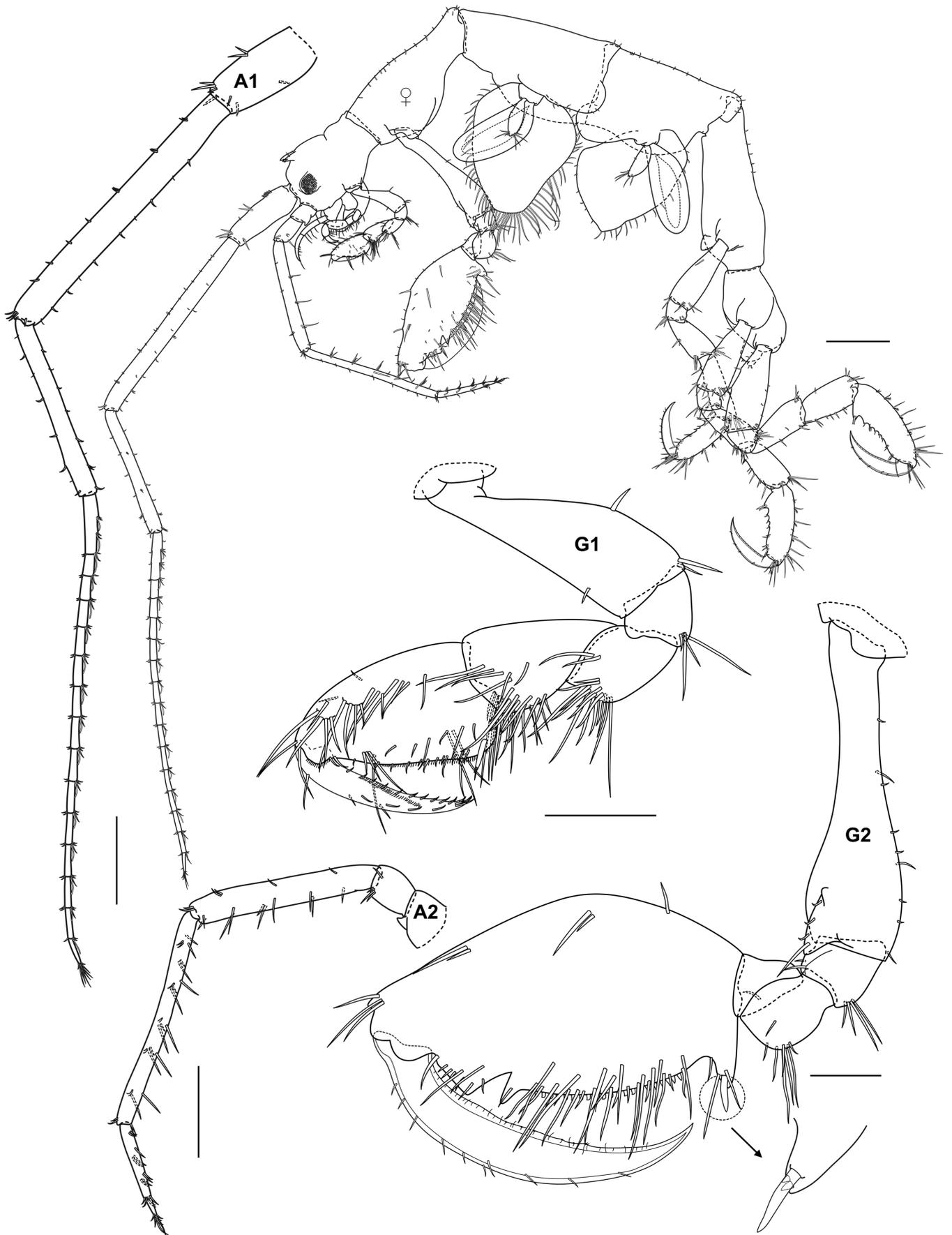


Fig. 4. *Orthoprotella bicornis*, new species, female paratype, 6.16 mm, UKMMZ-1503, Kampung Sebirah, Pulau Tinggi, TLSI. Scale bars A1, A2 and whole body = 0.5 mm; G1 and G2 = 0.2 mm.

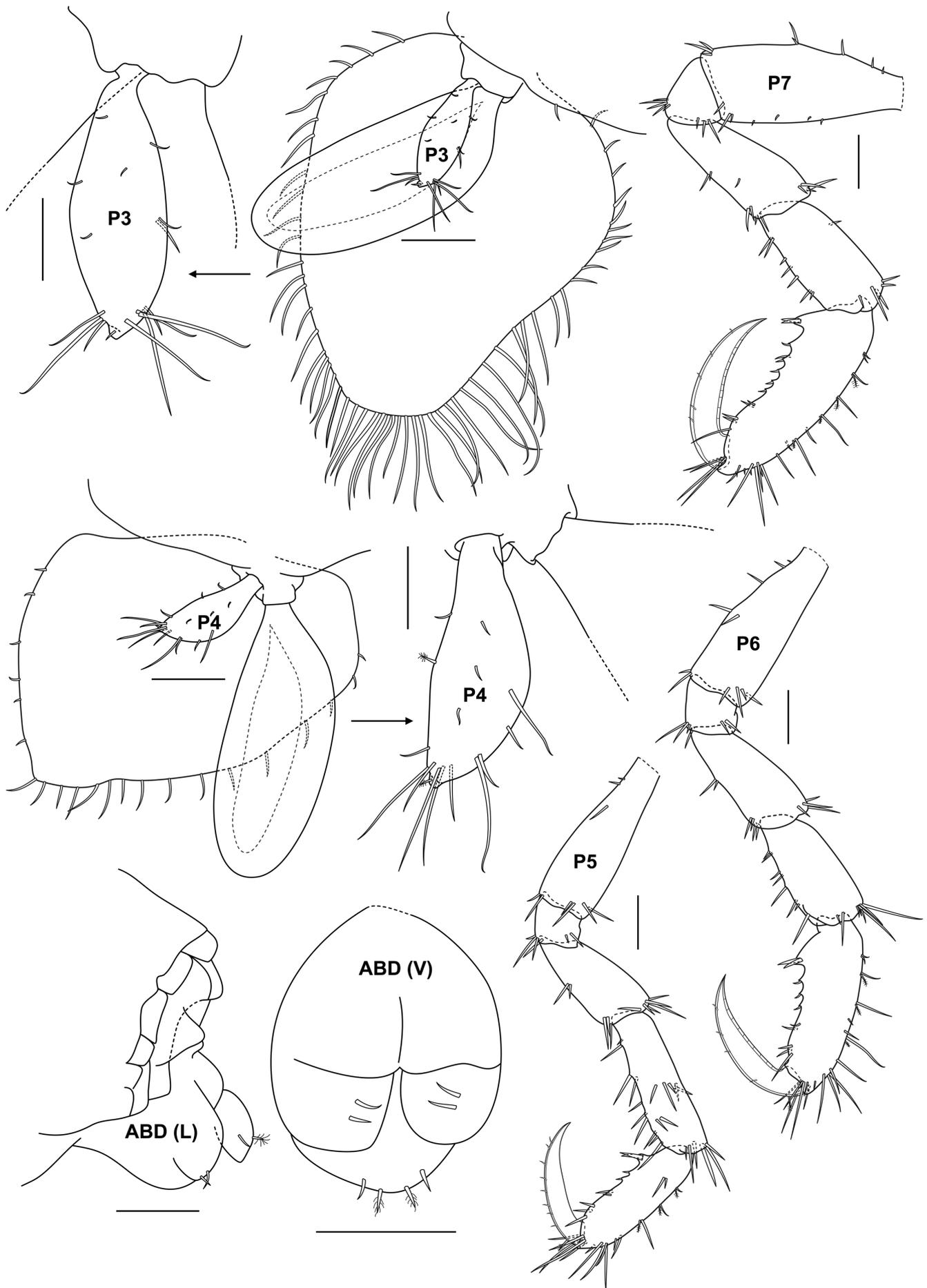


Fig. 5. *Orthoprotella bicornis*, new species, female paratype, 6.16 mm, UKMMZ-1503, Kampung Sebirah, Pulau Tinggi, TLSI. Scale bars ABD (L) and ABD (V) = 0.1 mm; P3, P4, P5, P6 and P7 = 0.2 mm.

not expanded medially in *O. australis*); 3) the pereopod 7 propodus proximal projection with 1 pair of grasping spines (proximal projection equipped with several robust setae in *O. australis*); 4) the distal region of uropod 1 peduncle lacking fine setae (present in *O. australis*); and 5) ramus of uropod 2 lacking setae (1 seta in *O. australis*).

The second group is distinct in the number of dorsal projections on the body. *Orthoprotella tuberculata* Guerra-García & Takeuchi, 2004 has numerous dorsal projections from head to pereonite 5; *O. nana* Guerra-García, 2004 is dorsally smooth with a small dorsal hump on its head. *Orthoprotella nana* is close to *O. mayeri* Barnard, 1916 but differs in body length as well as the absence of an anterolateral projection on pereonites 2 and 3 (present in *O. mayeri*).

Etymology. This species was named based on the two prominent projections on the head.

Distribution. Currently known only from Johor, Malaysia.

Key to the species in the genus *Orthoprotella*

(*Orthoprotella melloi* Quitete, 1975 and *O. hamata* Arimoto, 1981 are omitted from this key.)

- Body dorsally smooth GROUP 1
- Body provided with dorsal projection GROUP 2

GROUP 1

1. Pereonites 2–3 with 1 anterolateral projection 2
 - Pereonites 2–3 without anterolateral projection *Orthoprotella tasmaniensis* Guiler, 1954
2. Pereonite 4 with 1 anterolateral projection 3
 - Pereonite 4 without anterolateral projection *O. mayeri* Barnard, 1916
3. Pereopods 3 and 4 with 1 article
 - Pereopods 3 and 4 with more than 1 article (2-articulate) *O. pearce* Guerra-García, 2006
 - Pereopods 3 and 4 with more than 1 article (2-articulate) *O. berentsae* Takeuchi & Lowry, 2007

GROUP 2

1. Head with 1 large dorsal projection or 1 small dorsal hump 2
 - Head with 1 pair of dorsal projections 4
2. Body very small (length < 3 mm); Antenna 1 short, about 2/3 whole body length *O. nana* Guerra-García, 2004
 - Body large (length > 10 mm); Antenna 1 long, about 5/6 whole body length 3
3. Pereonite 1 without dorsal projection
 - Pereonite 1 without dorsal projection *O. gordonii* Guiler, 1954
 - Pereonite 1 with 1 acute dorsal projection *O. tuberculata* Guerra-García & Takeuchi, 2004
4. Pereonites 2–3 with 1 pair of anteriorly curved mid-dorsal projections *O. spinigera* Mori, 1996
 - Pereonites 2–3 without mid-dorsal projections 5
5. Antenna 1 peduncular article 3 provided with several projections anterodistally *O. bicornis*, new species
 - Antenna 1 peduncular article 3 without projections anterodistally *O. australis* (Haswell, 1880)

Genus *Paraprotella* Mayer, 1903

***Paraprotella teluksuang*, new species**

(Figs. 6–8)

Material examined. Holotype: female, 7.9 mm, UKMMZ-1511, Mahkota artificial reef, Teluk Suang, Pulau Tinggi, 02°17.637'N, 104°05.817'E, hydroids, SCUBA diving, 10.7 m, Azman, B.A.R., Lim, J.H.C., Melvin, C.W.H., Gan, S.Y. & Shamsul, B., 9 June 2009. Paratypes: 14 mature females, 8 premature females and 103 immature females, UKMMZ-1513, Mahkota artificial reef, Teluk Suang, Pulau Tinggi, 02°17.637'N, 104°05.817'E, SCUBA diving, 10.7 m, Azman, B.A.R., Lim, J.H.C., Melvin, C.W.H., Gan, S.Y. & Shamsul, B., 9 June 2009; 15 mature females, 8 premature females and 104 immature females, UKMMZ-1514, same station data; 1 mature female, 4 premature females and 101 immature females, UKMMZ-1515, Pulau Mentinggi, 02°16.408'N, 104°06.958'E, SCUBA diving, 6.6 m, Azman, B.A.R., Lim, J.H.C., Melvin, C.W.H., Gan, S.Y. & Shamsul, B., 10 June 2009, 1 immature female, UKMMZ-1516, Pulau Pemanggil, 02°35.847'N, 104°18.971'E, SCUBA diving, 16.3 m, Azman, B.A.R., Lim, J.H.C., Melvin, C.W.H., Gan, S.Y., Khoo, M.L. & Shamsul, B., 5 August 2009.

Type locality. Mahkota artificial reef, Teluk Suang, Pulau Tinggi, TLI, Johor, Malaysia.

Description. Female: Holotype, 7.9 mm. UKMMZ-1512 (Fig. 6). Head length 0.80 mm, and pereonite 1 length 0.70 mm; Head and pereonite 1 completely fused, suture absent; Head with an unpaired anterodorsally curved projection. Pereonite 1 with an unpaired dorsodistal projection. Pereonite 2 length 1.23 mm, with a pair of mid-dorsal projections. Pereonite 3 length 1.4 mm, with an anterolateral projection provided with a few small setae, distolaterally with a plate-like projection and an obtuse mid-dorsal hump. Pereonite 4 subequal with pereonite 2, 1.2 mm, with a weak mid-dorsal hump. Pereonite 5 longest, length 1.57 mm. Pereonite 6 length 0.6 mm. Pereonite 7 shortest, length 0.4 mm. Antenna 1 incomplete, at least 0.6× body length, peduncular article 1 with 2 plumose setae and tuft of fine setae at distal margin; article 2 longest, about 2.2× longer than article 1; article 3 longer than article 1, about 0.5× the length of article 2; flagellum about 1.1× peduncular length with more than 14 articles, proximal article composed of 2 articles (Fig. 6: A1). Antenna 2 about 0.4× antenna 1; flagellum 0.1× peduncular length, with 2 articles; proximal article 2.3× distal article (Fig. 6: A2).

Mouthparts. Upper lip symmetrical, slightly depressed medially, smooth, with no fine setae at apical margin (Fig. 7: UL). Lower lip well developed, inner lobes separated into 4 lobes, without fine setae (Fig. 7: LL). Mandible left incisor with 5 teeth; lacinia mobilis with 5 teeth, followed by 3 bundled setae; molar well developed [Fig. 7: MD (R)]. Mandible right incisor with 5 teeth; lacinia mobilis serrated, with many small teeth, followed by 2 bundled setae; molar well developed; palp for left and right similar, 3-articulate; article 2 with marginal and facial setae; article 3 with setal

formula 2-6-1 [Fig. 7: MD (L)]. Maxilla 1 outer lobe with 6 stout apical setal-teeth, two of which are pectinate; palp biarticulate; distal article 3× longer than proximal article, provided with 4 apical setae and 1 facial seta (Fig. 7: MX1). Maxilla 2 inner plate medially expanded with 5 slender setae apically; outer plate subrectangular, more slender than inner plate, with 6 apical setae (Fig. 7: MX2). Maxilliped basal endite (inner plate) subrectangular, with 2 simple setae and 2 plumose setae at distal margin; ischial endite (outer plate) 3× the length of inner plate, not extending beyond article 2 of palp, with 2 simple setae distally and 3 facial setae; palp

4-articulate, article 2 longest with 6 setae on inner margin; article 3 subequal in length with article 1, provided with 8 setae on inner distal corner and 1 seta on outer corner; palp article 4 (dactylus) falcate with row of setules along inner margin and 2 small setae at tip (Fig. 7: MXP).

Pereon. Gnathopod 1 basis, shorter than ischium, merus and carpus combined, with 4 setae on posterodistal corner and 1 seta on anterodistal corner; ischium shortest; merus and carpus subtriangular; carpus 0.6× shorter than basis, anterior margin setaceous; propodus short and mitten-like, 1.2× longer

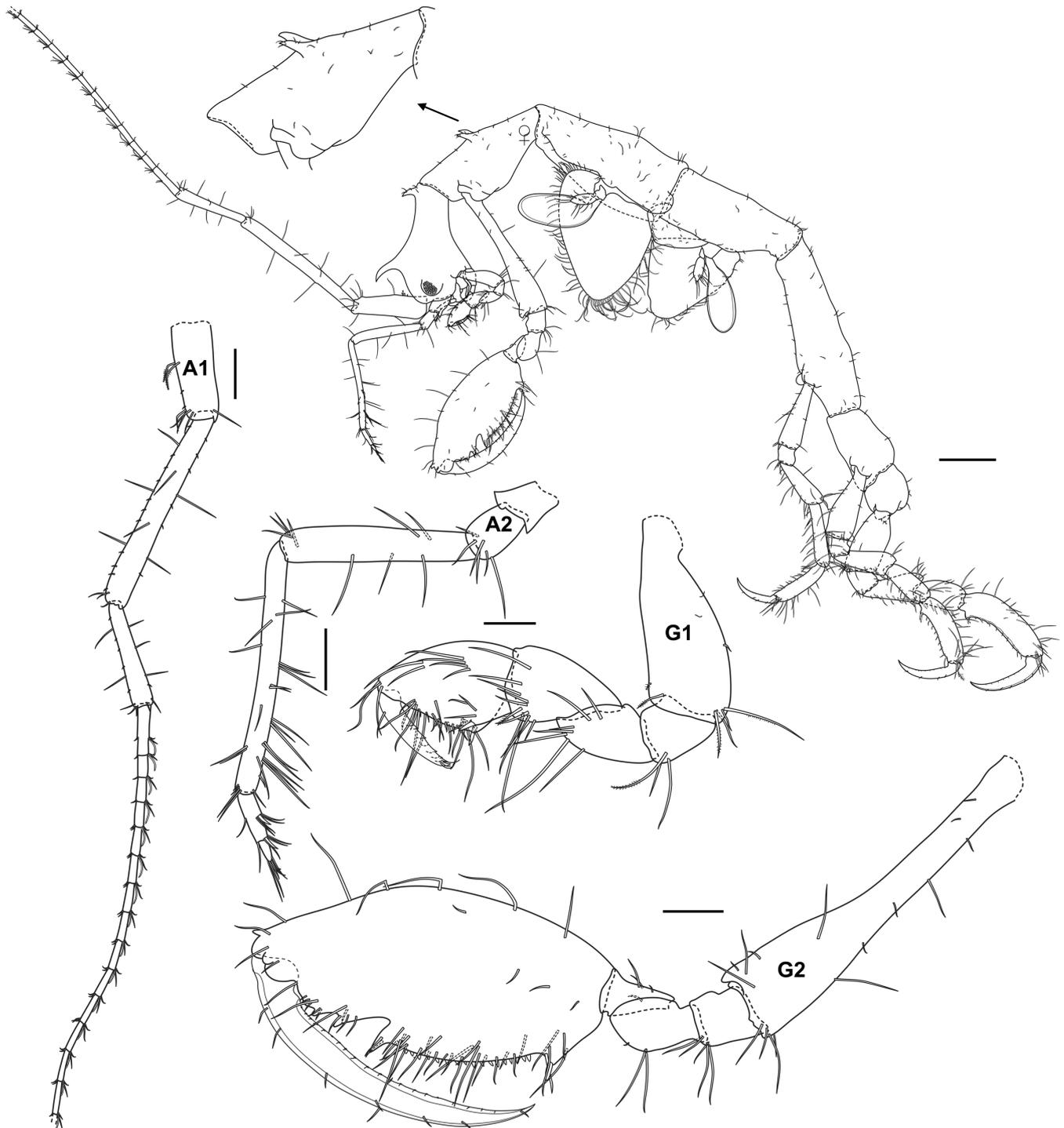


Fig. 6. *Paraprotella teluksuang*, new species, female holotype, 7.90 mm, UKMMZ-1511, Mahkota artificial reef, Teluk Suang, Pulau Tinggi, TLSI. Scale bars A1 = 0.3 mm; A2 and G2 = 0.2 mm; G1 = 0.1 mm; whole body = 0.5 mm

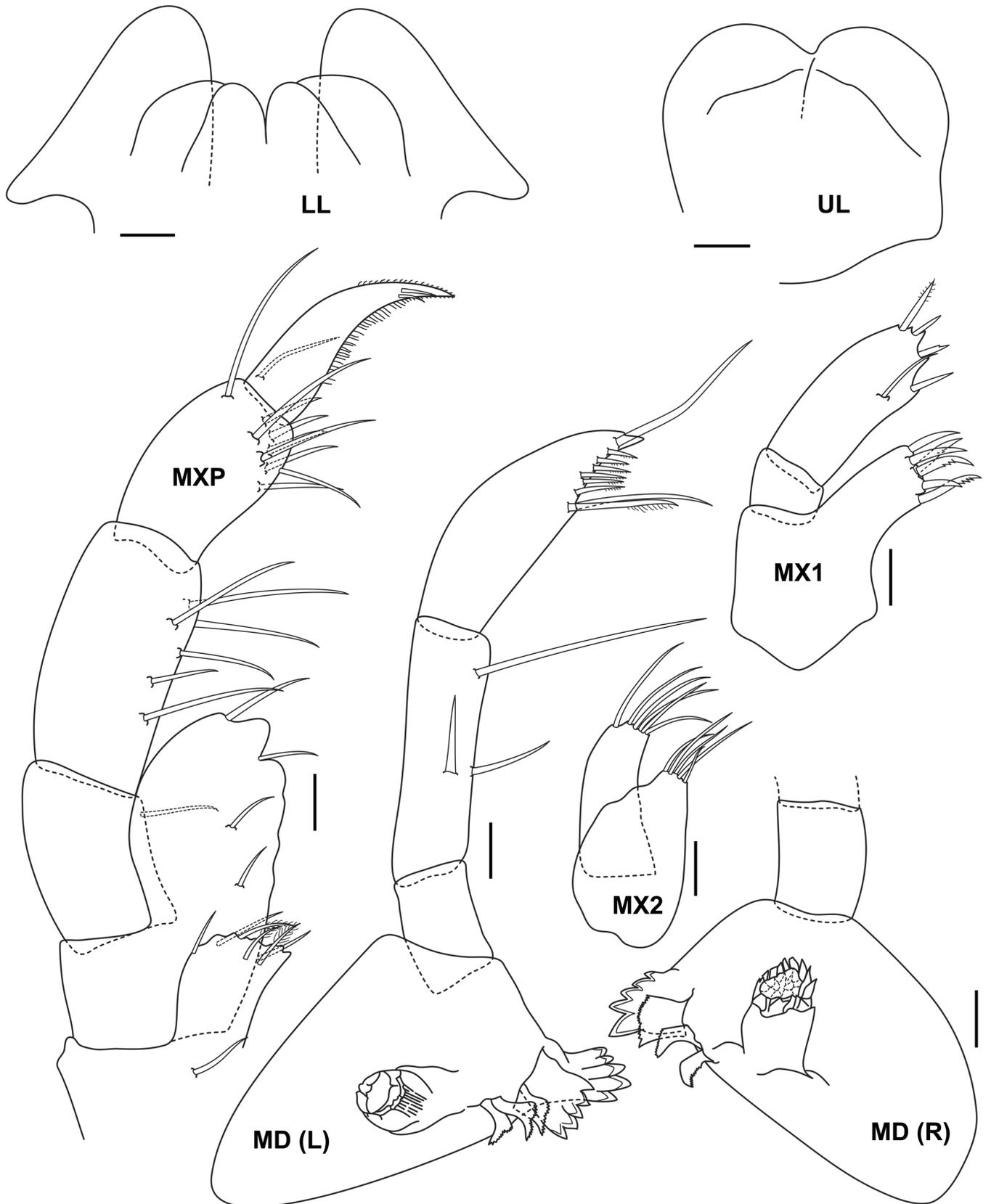


Fig. 7. *Paraprotella teluksuang*, new species, female holotype, 7.90 mm, UKMMZ-1511, Mahkota artificial reef, Teluk Suang, Pulau Tinggi, TLSI. Scale bars = 0.025 mm

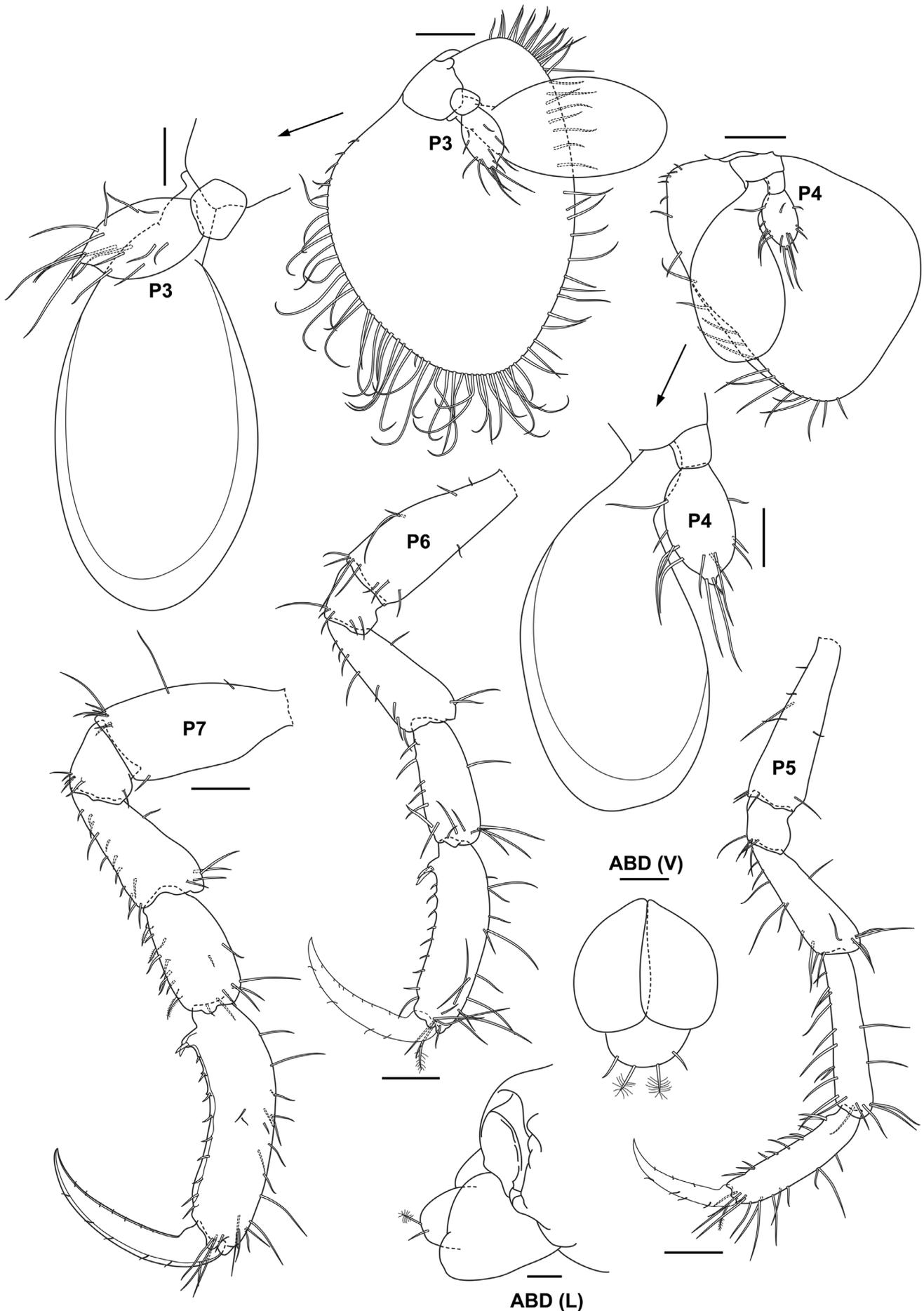


Fig. 8. *Paraprotella teluksuang*, new species, female holotype, 7.90 mm, UKMMZ-1511, Mahkota artificial reef, Teluk Suang, Pulau Tinggi, TLSI. Scale bars ABD (L), ABD (V), P3 magnified and P4 magnified = 0.1 mm; P3, P4, P5, P6 and P7 = 0.2 mm

than carpus, convex on dorsal margin, with 2 rows of facial setae, palm begins 1/4 along posterior margin with 1 pair of proximal robust setae; dactylus slightly curved, pectinate along inner margin with a few fine setae at tip (Fig. 6: G1). Gnathopod 2 begins 1/5 along anterior margin of pereonite 2, basis subequal with length of pereonite 2, anterodistal corner with acute triangular projection; ischium as long as wide with posterodistal setae; merus subovate, very scarcely setose; carpus subtriangular; propodus longest, 1.1× the length of basis, oblique, palm sinuous, with proximal grasping spine, mid palmar projection with 1 seta followed by a deep sinus and two small triangular projections; palm with serriformed teeth between proximal projection and mid palmar projection; dactylus length subequal with basis, falcate, with fine setae along entire outer margin (Fig. 6: G2). Gill 3 length 0.5× pereonite 3, oval. Pereopod 3 about 0.4× the length of its gill, 3 articulate, article 2 subovate, covered in short and long setae, article 3 vestigial, with 1 terminal plumose seta (Fig. 8 P3). Gill 4 length 0.5× pereonite 4, oval, shorter than gill 3 (0.9× shorter). Pereopod 4 about 0.4× the length of its gill, slightly shorter than pereopod 3 (0.9× shorter), 3 articulate, article one subrectangular, article 2 subovate covered in short and long setae, article 3 vestigial with 1 terminal seta (Fig. 8: P4). Pereopods 5–7 well developed, progressively robust, carpus decreasing in length from pereopods 5–7, length of propodus increases significantly from pereopods 5–7. Pereopod 5 slender, equipped with long setae, basis longest, rectilinear; carpus length 4.7× width, subequal in length with ischium and merus combined, 0.9× length of basis; propodus shorter than carpus (0.9× shorter), palm with a pair of proximal grasping spines followed by several marginal setae, outer margin with several long and short setae; dactylus falcate, scarcely setose, proximally with 1 plumose seta (Fig. 8: P5). Pereopod 6 basis wider but subequal in length with pereopod 5 basis; merus slightly pronounced posterodistally; carpus length 2.5× width, 0.7× the length of basis, 0.8× shorter and 1.5× wider than pereopod 5 carpus, more setose on inner margin; propodus longest, longer than carpus (1.4× longer), palm with a pair of proximal grasping spines followed by several short marginal setae, outer margin with several long and short setae; dactylus falcate, fitting onto palm, with 1 plumose proximal seta (Fig. 8: P6). Pereopod 7 equipped with finer and shorter marginal setae throughout articles, basis length about 2× width; merus pronounced posterodistally; carpus length 1.8× width, 0.7× the length of basis, subequal in length with merus, subequal in length and 1.3× wider than pereopod 5 carpus; propodus longest, subequal in length with merus and carpus combined, 2× longer than carpus, palm with a pair of proximal grasping spines followed by several short marginal setae, outer margin with several long and short setae; dactylus falcate (Fig. 8: P7).

Pleon. Uropod 2 vestigial. Telson with a pair of normal setae and a pair of plumose setae [Fig. 8: ABD (V) and ABD (L)].

Remarks. The genus *Paraprotella* is unique in having 3-articulate pereopods 3 and 4. This genus was established by Mayer in 1903 based on *P. prima* Mayer, 1903 (from Japan, Thailand and Singapore) and *P. secunda* Mayer, 1903

(from Japan) (Mayer, 1903; Arimoto, 1976). Takeuchi & Guerra-García (2002) later added another species, *P. saltatrix*, from Phuket, Thailand, bringing the total to three species. No male specimens were collected in the present material; this phenomenon is also observed in *P. saltatrix* (Takeuchi & Guerra-García, 2002).

Paraprotella teluksuang, new species, shares several similar characteristics with *P. saltatrix* such as head and pereonites 1–4 lacking lateral projections, mandibular palp article 3 with setal formula of 2 (long setae near proximal end)–x (number of short setae)–1 (long seta near apical end) and the more robust structure of pereopods 3 and 4, with article 2 longer than article 1 and article 3 minute.

Paraprotella teluksuang, new species, differs from *P. saltatrix* based on the following characteristics: 1) lack of a distinct suture between head and pereonite 1 (present in *P. saltatrix*); 2) lack of a dorsodistal projection on pereonite 2 (present in *P. saltatrix*); 3) pereonites 3 and 4 with very slight mid-dorsal round projections, almost unnoticeable on pereonite 4 (with shallow mid-dorsal projections in *P. saltatrix*); 4) specimens of the present material are more robust in body somites; 5) *P. teluksuang*, new species, having 2 rows of facial setae on gnathopod 1; and 6) vestigial uropod and telson with 1 normal seta and 1 plumose seta (uropod in *P. saltatrix* with 1 seta; uropod in *P. prima* 1-articulate and uniramous; unknown for *P. secunda*).

Paraprotella prima and *P. secunda* described in Mayer (1903) are equipped with more projections on the pereonites particularly the female specimens; compared with *P. teluksuang*, new species, and *P. saltatrix*. *Paraprotella prima* Mayer, 1903 has distinct lateral triangular projections on pereonites 1 to 4 which are absent in *P. teluksuang*, new species, *P. secunda* and *P. saltatrix*. The large lateral projections are present on pereonite 6 of *P. secunda*, small tubercles in *P. prima* but absent in *P. teluksuang*, new species, and *P. saltatrix*. *P. prima* is armed with 1 projection on dorsal margin of pereonite 1, 1 dorsodistal projection and 1 pair of acute spines mid-dorsally on pereonite 2 while *P. secunda* is armed with only 1 projection/spine on pereonites 1 and 2. The latter 4 species, have long antenna 1, usually more than half of total body length.

In *P. secunda* Mayer, 1903, identification was based on 2 premature individuals (1 premature male and female). Pereopods 5 to 7 of both individuals were also detached. No illustrations were provided and only description of whole body, antenna 1 and gnathopod 2 were included. Based on these 2 individuals, the male individual of *P. secunda* shows similar characteristics with the female of *P. prima* in pereonites 3 with a pair of mid-dorsal spines. *P. secunda* also has a tooth at distal end of pereonite 3 (absent in *P. teluksuang*, new species, *P. prima* and *P. saltatrix*). Following descriptions of Mayer (1903) and Arimoto (1976), it is clear that *P. teluksuang*, new species, differs from *P. prima* Mayer, 1903 and *P. secunda* Mayer, 1903 in terms of dorsal and lateral projections, setal formula of the mandibular palp (2-x-1) instead of 1-x-y-1, and the abdomen.

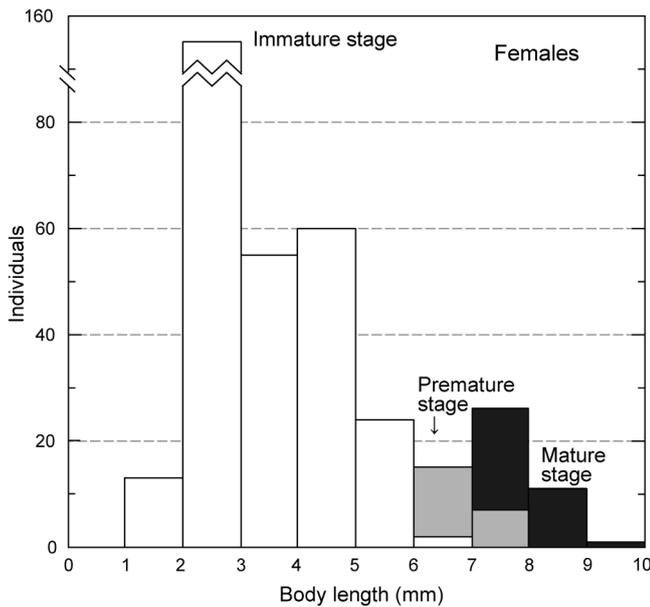


Fig. 9. Size distribution of body length (mm) in *Paraprotella teluksuang*, new species, collected from three stations, Mahkota artificial reef, Teluk Suang, Pulau Tinggi; Pulau Mentinggi and Pulau Pemanggil, TLSI, Malaysia.

Etymology. This species was named after the type locality, Teluk Suang. The name is treated as a Latin noun in apposition.

Distribution. Currently only known from TLSI, Johor, Malaysia.

Key to the species in the genus *Paraprotella*

1. Head with single pair of anteriorly-curved mid-dorsal projections2
- Head with 1 large anteriorly-curved mid-dorsal projection...3
2. Pereonite 3 without mid-dorsal projections, 1 anterolateral projection present; Pereonite 6 without ventrolateral projection.....*Paraprotella prima* Mayer, 1903
- Pereonite 3 with 1 pair of mid-dorsal projections, anterolateral projection absent; Pereonite 6 with 1 large ventrolateral projection.....*Paraprotella secunda* Mayer, 1903
3. Pereonite 2 with 1 dorsodistal projection; Pereonite 3 without anterolateral projection.....*Paraprotella saltatrix* Takeuchi & Guerra-García, 2002
- Pereonite 2 without dorsodistal projection; Pereonite 3 with 1 anterolateral projection.....*Paraprotella teluksuang*, new species

DISCUSSION

Paraprotella teluksuang, new species, was collected from three localities, 1) Mahkota artificial reef, Teluk Suang, Pulau Tinggi (02°17.637'N, 104°05.817'E, 10.7 m, 9 June 2009); 2) Pulau Mentinggi (02°16.408'N, 104°06.958'E, 6.6 m, 10 June 2009); and 3) Pulau Pemanggil (02°35.847'N, 104°18.971'E, 16.3 m, 5 August 2009), which resulted in a total of 360 individuals. Collections of *Paraprotella teluksuang*, new species, showed unusual sexual bias towards females, with only females having been observed among all individuals collected. Specimen body length ranged

from 1.49 mm to 9.14 mm (Fig. 9). The growth of females in caprellidean amphipods is divided into three stages, 'immature', 'premature' and 'mature'. In the immature stage, oostegites are smaller in size compared to the corresponding gills while in the premature stage its oostegites are larger than the gills and leaf-like in shape. The final mature stage can be identified from the large oostegites or brood pouch expanding downwards and marginally lined with long setae to circulate water into and out of the brood pouch containing eggs (Takeuchi & Hirano, 1991). Individuals in the range of 6.11–7.25 mm (n= 20) in body length are premature females, and those larger than 7.25 mm (n= 31) are all mature females (Fig. 9). This is the second report of female biased population. The first report was by Takeuchi & Guerra-García (2002) on *Paraprotella saltatrix* from Phuket Island, Thailand, where specimens collected from two localities contained only female individuals.

Parthenogenesis is uncommon in macrobenthic Amphipoda with only a few subjective reports from several species; *Corophium bonelli* Milne Edwards, 1830 (see Crawford 1937; Moore 1981; Myers et al., 1989) and the cavernicolous amphipod *Stygobromus* such as *S. spinatus* (Holsinger, 1967), *S. pseudospinosus* Holsinger, 1978 and *S. albapinus* Taylor & Holsinger, 2010 to mention a few (see Culver & Holsinger, 1969; Holsinger, 1978; Taylor & Holsinger, 2010). Parthenogenesis is considered a means of sustaining lineage and population expansion. Asexual reproduction such as this is also known to occur in certain favorable food and environmental circumstances (Schön et al., 2009).

Sex ratio distortions caused by feminising microsporidians have previously been reported in amphipods such as in *Gammarus duebeni* Liljeborg, 1852 and *Echinogammarus marinus* (Leach, 1815) (Bulnheim, 1978; Dunn et al., 1993; Terry et al., 1998; Ironside et al., 2003; Ford et al., 2004; Rodgers-Gray et al., 2004). Microsporidian parasites such as *Nosema granulosis* Terry et al., 1999 living on *G. duebeni*, have been known to feminise its host, causing genetic males to develop as phenotypic females (Terry et al., 1998, 1999). These parasites prevent the development of the androgenic gland and as a result, inhibit the production of AGH, an important hormone for male sexual differentiation (Rodgers-Gray et al., 2004). Ford et al. (2004) found an increased occurrence of intersexuality in the marine/estuarine amphipod, *E. marinus*, at polluted sites of East Scotland. They mentioned that some of the prominent causes of intersex include; parasitism, possibly increased via immunosuppression of the host, parasite function induced by pollution, and pollution directly causing the intersexuality of this amphipod. Several anthropogenic chemicals have also been reported to disrupt sexual development of marine invertebrates (see Depledge & Billingham, 1999). For example, tributyltin (TBT), a well-known endocrine disruptor that causes "imposex" (i.e., superimposition of male genital organs on females) in gastropods at extremely low environmental concentrations. As of 2004, about 150 species of gastropods worldwide were reported to be affected by imposex (see Horiguchi et al., 2006). The occurrence of imposex in *Nucella lapillus*

(Linnaeus, 1758), a dog-whelk on the north Atlantic coasts, was caused by TBT concentrations of $< 2.4 \text{ ng TBT L}^{-1}$ (Gibbs & Bryan, 1996).

It is still unclear if the biased sex ratio in *P. teluksuang*, new species, and *P. saltatrix* is temporary due to changes in environmental factors or if it is just a natural attribute for survival. Further studies are crucial to determine the reasons for this occurrence (if it is truly parthenogenesis, or otherwise) in these two closely related *Paraprotella* species; *P. teluksuang*, new species, and *P. saltatrix*, distributed in Malaysia and Thailand. Possible future studies may include rearing newly hatched juveniles for more than one generation and/or molecular analysis based on microsatellite DNA and/or mitochondrial DNA analysis to clarify the parental relationship of *Paraprotella*.

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