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Two new species of *Ligia* Fabricius, 1798 (Crustacea: Isopoda: Ligiidae) from coasts of the Persian and Aden gulfs

Valiollah Khalaji-Pirbalouty · Johann-Wolfgang Wägele

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Abstract Two new species of *Ligia* are described, *L. persica* sp. nov. from the Persian Gulf and *L. yemenica* sp. nov. from the Gulf of Aden. *Ligia persica* occurs along the northern coasts of the Persian Gulf and around some Iranian islands such as Qeshm and Kish. A comparison of SEM micrographs shows that the shape and ornamentation of distal parts of the appendix masculina are reliable characters for the identification of morphologically similar *Ligia* species. They are species-specific and of great importance in the taxonomy of the genus.

Keywords Isopoda · *Ligia persica* sp. nov. · *Ligia yemenica* sp. nov. · SEM · Persian Gulf · Gulf of Aden

Abbreviations

NHCY	Natural History Collection of Yemen (specimens for present study were loaned from SMF)
SMF	Senckenberg Museum, Frankfurt am Main (Germany)
ZFMK	Zoologisches Forschungsmuseum Alexander Koenig, Bonn (Germany)
ZMH	Zoological Museum of Hamburg (Germany)
ZMB	Zoological Museum of Berlin (Germany)

Introduction

The genus *Ligia* Fabricius, 1798 has a worldwide distribution, with 36 species currently considered as valid (Schmalfuss

2003; Taiti and Ferrara 2004). Only three species have been recorded from the Red Sea and Persian Gulf coasts or from northern areas of the Indian Ocean: *L. pigmentata* Jackson, 1922 from the Red Sea and southern part of the Persian Gulf (Taiti and Ferrara 1991, 2004; Taiti et al. 2000); *L. dioscorides* Taiti & Ferrara, 2004 from Socotra Island, Yemen; and *L. exotica* Roux, 1828 from coasts of India (Joshi and Bal 1959), Pakistan (Kazmi et al. 2002) and the Red Sea (Ismail 1990; Santucci 1937). However, there is doubt about the correct identification of *L. exotica* samples from the Red Sea and of *L. pigmentata* from southern shores of the Persian Gulf. In addition, *L. italica* Fabricius, 1798 is known from the Mediterranean and Black Seas as well as from the Atlantic off northwestern Africa.

In the present paper, two new species of *Ligia* are described; *L. persica* sp. nov. and *L. yemenica* sp. nov. The material comes mainly from northern areas of the Persian Gulf. Most of the specimens examined were collected by V. Khalaji between 2006 and 2009 from the southern coasts of Iran, and the Kish and Qeshm islands. Additional specimens that were obtained from the Senckenberg Museum (Frankfurt am Main, Germany) had been collected by A. Allspach in 2005 in Hadhramaut, Yemen (Fig. 1).

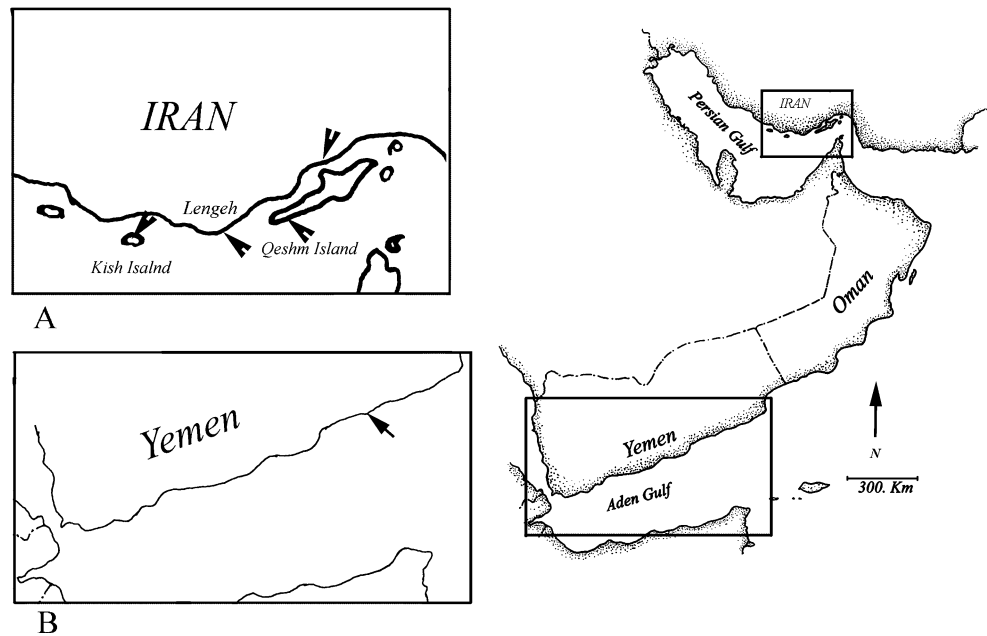
Prior to the present study, surprisingly little work was carried out on the ultrastructure of male pleopod 2 endopodites of *Ligia* species. Scanning electron microscope (SEM) studies of the sexually dimorphic pleopod 2 in the genus *Tylos* Latreille were performed by Schmalfuss and Vergara (2000). Here, we show that taxonomically important differences can be found on the male copulatory organ.

Material and methods

Appendages were dissected and fixed in stained antibacterial glycerine-gelatine (Merck). Pencil drawings were made

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Fig. 1 Locations of sampling localities. **a** *Ligia persica* sp. nov. **b** *L. yemenica* sp. nov.



using a compound microscope (Olympus BX 51) with a camera lucida; after inking all images were processed using Adobe Photoshop (version CS2). Scanning electron microscopy (SEM) objects were washed in chilled 1% sodium acetate solution for 10 min., then cleaned with ultrasound to remove sediment and debris adhering to the cuticle. Specimens were dehydrated in an ethanol series and air-dried overnight. The samples were then mounted on stubs using double adhesive carbon spots before being coated with gold in a sputter coater to 40 nm thickness. Micrographs were taken using a Hitachi S-2460N SEM.

Taxonomic section

Family *Ligiidae* Brandt & Ratzeburg, 1831

Genus *Ligia* Fabricius, 1798

Diagnosis

See Jackson (1922) and Andersson (1960).

Ligia persica sp. nov.

Etymology

The species epithet refers to the type locality in the Persian Gulf. It is to be treated as adjectival for the purposes of nomenclature.

Type material

All material was collected in Iran (Persian Gulf).

Holotype Male (ZMH-42323), about 21 mm without uropod; Kish Island, 26°34'503" N 53°57'111" E, 24.01.2006.

Paratypes One adult male 21 mm, two females up to 17 mm, four juveniles (ZMH-42324), same data as holotype; three males up to 28 mm, five females up to 19 mm (ZMH-42325), Qeshm island, southwest coast, Dustgu, 26°33' N 55°21' E, sandy and rocky shore, 07.05.2008; four males up to 13 mm, five females up to 15 mm (ZMH-42326), Bandar-e Lengeh, Pasgah, 26°38' N 55°02' E, 24.04.2008; three males up to 25 mm, one ovigerous female 19 mm, two non-ovigerous females up to 19 mm (ZMH-42327), Bandar-e Lengeh, 26°32' N 55°52' E, 01.07.2009; two males up to 17 mm, one ovigerous female 12 mm, one non-ovigerous female 12 mm (ZMH-42328), Bandar-e-Pol, 26°58' N 55°45' E, 29.06.2009.

Diagnosis

Body elongated and flattened, surface covered with minute granulations; distance between eyes shorter than eye length; pleotelson length more than half of width; uropod rami about twice as long as peduncle, and exopod shorter than endopod (excluding setae); antennule terminal article with four aesthetascs; antenna basal article 5 more than 1.5 times as long as article 4. Pereiopods 1–3 with papillar fields on inferior margin of merus and carpus. Pereiopods 1–7 carpus as long as propodus, and pereiopod 6–7 dactylus with a tuft of

long, thin setae on tergal and subdistal margins. Appendix masculina distal part dilated, with rectangular apex.

Description of male

Body (Fig. 2a) length about 2.6 times greatest width (at pereionite 4). Cephalon with large eyes, distance between eyes shorter than eye length. Pereionite 7 posterolateral angles acute, extending to middle of pleonite 3. Pleonites 1–5 of different shapes; pleonite 1 visible in dorsal view but largely concealed by pereionite 7; pleonite 4 with a subcrescentic, thin depression, pleonite 5 with an arcuate furrow.

Pleotelson length about 0.6 times greatest width, with pointed posteromedial margin; posterolateral corners acute but shorter than pleotelson apex; posterior margin (Fig. 9b) with about 17 submarginal foraminate tricorns on each side, between medial and lateral protruding points.

Antennule (Fig. 2c) basal article with one simple seta on distoventral angle; article 2 is the longest, bearing four simple setae on posterior margin and three long setae on posterodistal angle; apical article with about four aesthetascs.

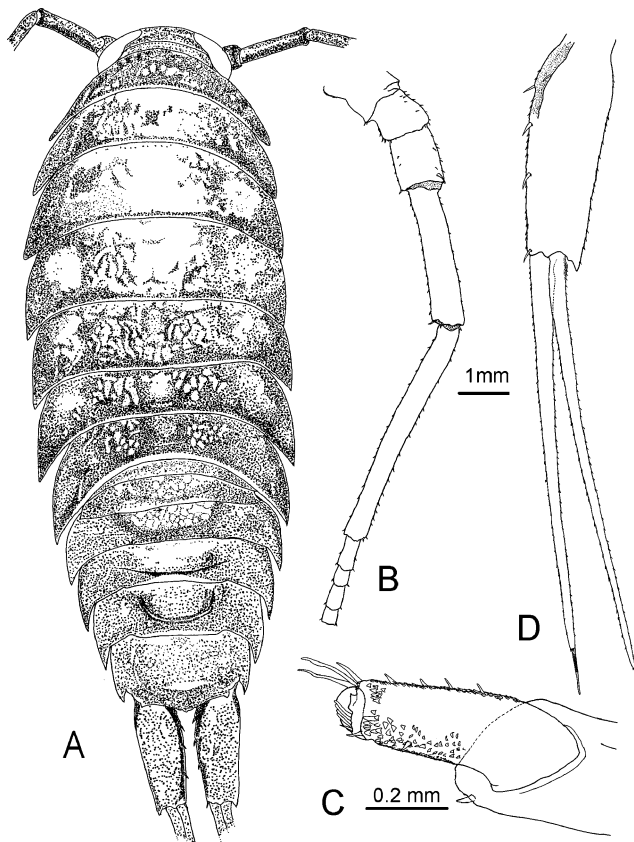


Fig. 2 *Ligia persica* sp. nov., male (holotype). a Dorsal view. b Antenna. c Antennule. d Uropod

Antenna (Fig. 2d) basal articles 2–5 increasing in length; article 5 about 1.7 times as long as article 4; flagellum extending to posterior margin of pereionite 7, with 30 articles (in Qeshm specimens extending to posterior margin of pleonite 4, with 41 articles).

Maxillule (Fig. 3a) lateral lobe apex with three simple teeth laterally and five robust setae more medially, some inferiorly serrate; mesial lobe with three stout, circumplumose setae (penicils), one robust simple seta and many scattered, fine and multipart setae on apical margin.

Maxilla (Fig. 3c) lateral and mesial lobes bearing fields with short, fine setae as illustrated.

Maxilliped (Figs. 3d and 8d, e) endite apex with two circumplumose setae (apical penicils), several robust setae and scattered short, fine setae; palp with five separate articles, basal article with one apically bifid robust seta, articles 2–4 with several bifid robust setae on distal margin, and tufts of transverse rows of slender setae on inner margins, article 5 without marginal robust seta.

Mandible (Fig. 3b) incisor with three cusps; lacinia mobilis with three cusps, spine row below lacinia with 13 serrate spines; molar process with many scattered fine setae.

Pereiopods 1–3 fringed with short cuticular scales on inferior margin of merus and carpus. Pereiopod 1 (Fig. 4a) robust, basis length about 2 times greatest width, upper margin with some short setae, ventral margin with four stout and some short, simple setae; ischium as long as merus, inferior margin with some short robust setae,

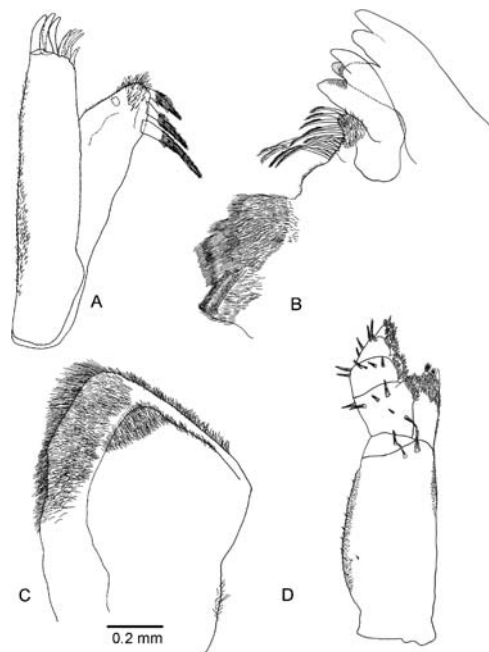


Fig. 3 *Ligia persica* sp. nov., male (holotype). a Maxillule. b Right mandible. c Maxilla. d Maxilliped

posterodistal corner with three robust setae, dorsally with five submarginal robust setae; carpus length about 2 times greatest width, with row of five robust setae on inner surface near inferior margin; propodus as long as carpus and curved, superodistal angle with one short robust seta; dactylus with five short setae on superior margin, two terminal claws.

Pereiopod 2 (Fig. 4b) basis length 2.3 times greatest width; ischium as long as merus, with four robust and some short, simple setae on superior margin; carpus length 2.3 times greatest width, with four robust and some short, simple setae on inferior margin; propodus with some short, simple setae on inferior and subinferior margins; dactylus with four short setae on superior margin.

Pereiopod 3 (Fig. 4c) similar to pereiopod 2, as figured. Pereiopod 4 (Fig. 4d) basis length 2.25 times greatest width; ischium as long as merus, with four robust setae on superodistal corner, merus with several long robust and short setae on inferior and distal margins; carpus 1.6 times as long as merus, with several long robust setae on inferior margin; propodus as long as carpus, with one robust seta on superodistal corner and five robust setae on inferior margin.

Pereiopod 5 (Fig. 5a) basis length about 2 times greatest width, with some robust setae on subdistal margin; ischium

1.4 times as long as merus; merus with several long robust and some short setae on inferior and subdistal margins; carpus as long as propodus, with some robust setae on inferior margin and superodistal corner.

Pereiopod 6 (Fig. 5b) basis length about 1.6 times greatest width, with several robust setae scattered on caudal surface; ischium caudal surface with field of regular scales (Fig. 9d, e), inferior margin with several short setae, superodistal corner with two long robust and some short setae; merus length 1.7 times greatest width, caudal surface with fields of regular scales, carpus as long as propodus; dactylus with a tuft of long, thin setae on distal outer margin.

Pereiopod 7 (Fig. 5c) with several fields of regular scales on basis, ischium, merus and carpus (not shown); basis length about 2.2 times greatest width, with several short setae on ventral and dorsal margins; ischium 1.5 times as long as merus, with one long robust seta on superodistal corner, several robust setae on inferior and distal margins; carpus as long as propodus; dactylus with a tuft of long, thin setae on outer margin.

Penes (Fig. 6d) separate, long (length about 6.3 times basal width), tapering evenly, apex with a small cleft, outer margins bearing short, fine setae in distal half.

Pleopod 2 (Fig. 6a) exopod with row of plumose setae on medial and distal margins; appendix masculina (Fig. 6b, c)

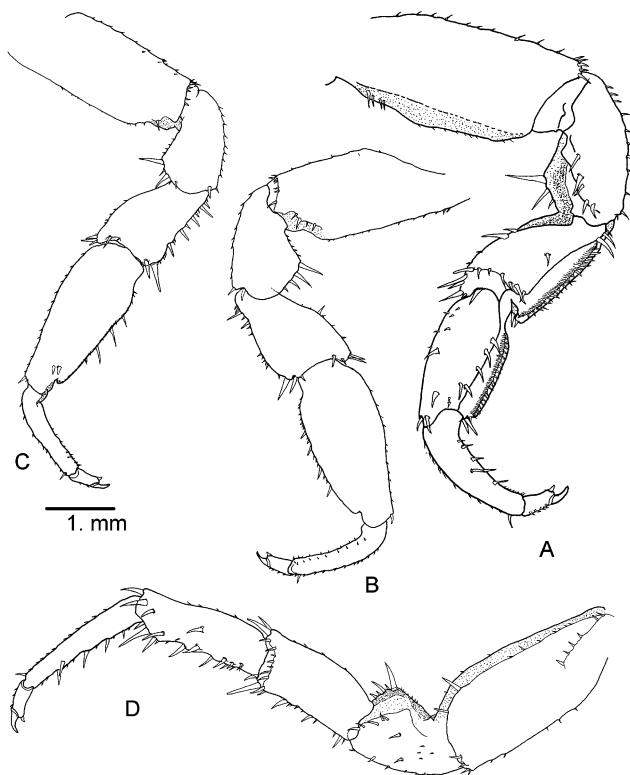


Fig. 4 *Ligia persica* sp. nov., male (holotype). **a–d** Pereiopods 1–4, respectively

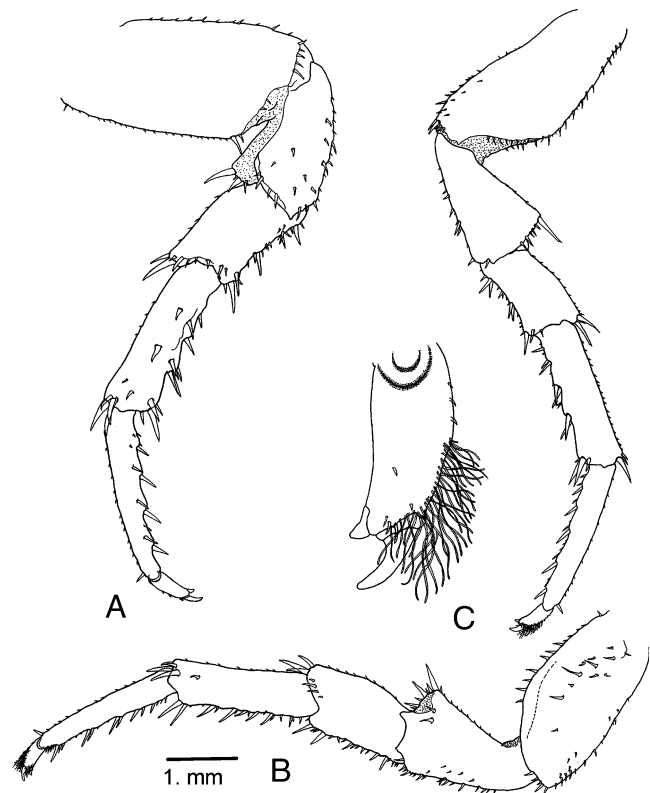


Fig. 5 *Ligia persica* sp. nov., male (holotype). **a** Pereiopod 5. **b** Pereiopod 6. **c** Pereiopod 7 and detail of dactylus

dilated in distal part, with rectangular apex, subapical convex medial margin equipped with several rows of regular robust, curved cuticular spines. Pleopods 3–5 (Fig. 7a–c) as illustrated.

Uropod (Fig. 2d) peduncle about 0.5 times as long as exopod, lateral margin bearing some short setae, distolateral angle freely extending and acute, mesial margin with 4+1 robust and some short setae; rami approximately equal in shape; endopod with a small bristle; exopod extending well beyond endopod main article.

Description of female

Similar to male except in sexual characters; body size generally smaller but relatively wider; pereopod 1 propodus (Fig. 7d, e) with one projection (two in male).

Remarks

Ligia persica sp. nov. is closely related to *L. pigmentata* Jackson, 1922, a species that has been recorded from coasts of the Red Sea to the Persian Gulf. Localities are

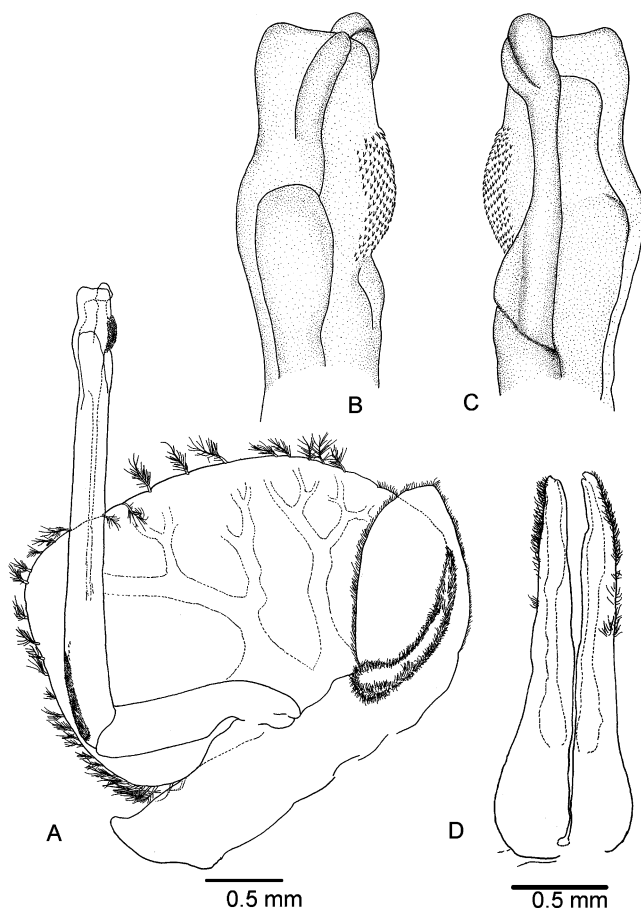


Fig. 6 *Ligia persica* sp. nov., male (holotype). **a** Pleopod 2. **b**, **c** Pleopod 2 endopod, distal part; **b** caudal surface; **c** rostral surface. **d** Penes

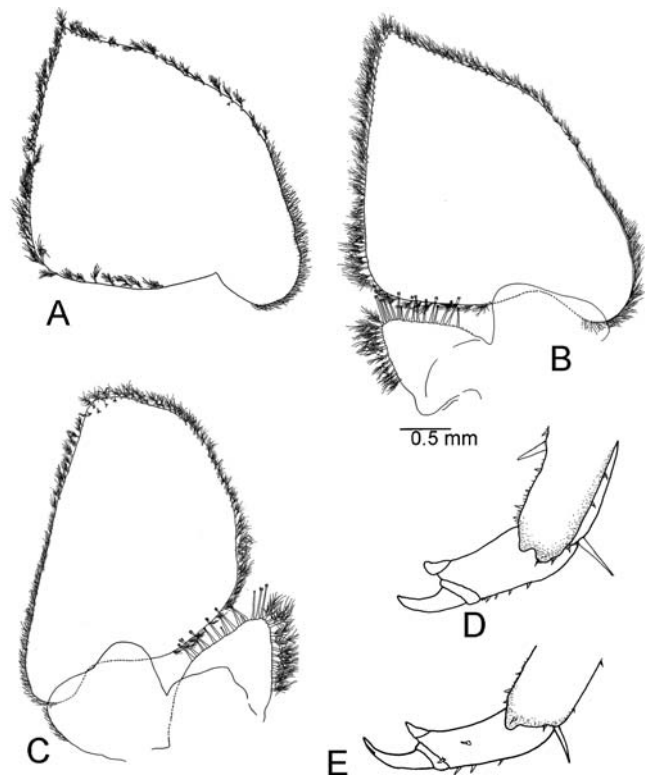


Fig. 7 *Ligia persica* sp. nov. **a–c** Male (holotype), pleopods 3–5. **d** Male (holotype), pereopod 1 dactylus. **e** Female, pereopod 1 dactylus

Suez (type locality), the Gulf of Akaba (Monod 1933), Egypt, Sudan, Djibouti, Saudi Arabia, Somalia, Yemen, Oman, and Kuwait (Taiti and Ferrara 1991, 2004; Taiti et al. 2000). Judging from syntype material of *L. pigmentata*, as well as from the descriptions and drawings in Jackson (1922), Monod (1933), and Taiti and Ferrara (1991), *L. persica* differs in the following characters: Apical part of appendix masculina rectangular and with a subapical extension medially (in *L. pigmentata*, medial process of apical part protrudes distinctly; Fig. 8a, b); different shapes, sizes, and arrangement of cuticular spines; length ratio uropod rami to peduncle is about 2 (about 1.4 in *L. pigmentata*); ratio of antenna basal articles 5 to 4 is 1.7 (1.2 in *L. pigmentata*; Fig. 8c); different shape of pleotelson and different number of marginal tricorns (Figs. 8 and 9).

Ligia persica also differs from *L. italica* Fabricius, 1798 (Mediterranean and Atlantic off northern Africa), in which the pleotelson has a rounded posteromedial margin and blunt posterolateral corners. The new species is readily distinguishable from *L. exotica* Roux, 1828 by the different shape of the pleotelson (see Fig. 18e from Tai-zih, Yun-lin, Taiwan); the distal part of the appendix masculina (see Fig. 18a, b from Taiwan) has a more protruding apical bulb in *L. exotica*, and a distinctly protruding process on the superodistal margin of the male

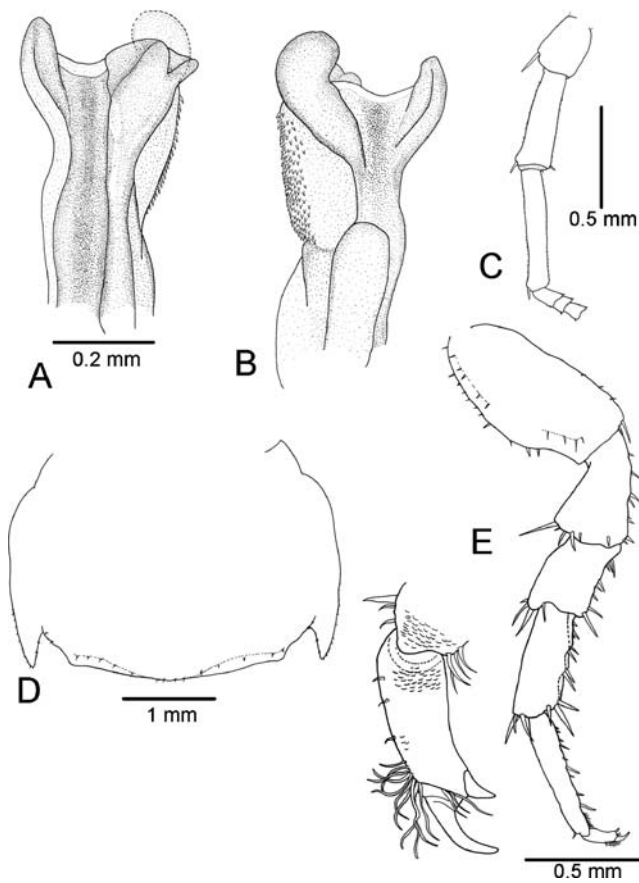


Fig. 8 *Ligia pigmentata* Jackson, male syntype. **a, b** Pleopod 2 endopod, distal part; **a** rostral surface; **b** caudal surface. **c** Antenna. **d** Pleotelson. **e** Pereiopod 7 and detail of dactylus

pereopod 1 propodus (see Fig. 18f from Kanagawa, Japan).

Ligia yemenica sp. nov.

Etymology

The species epithet refers to the type locality on the coast of Yemen. It is to be treated as adjectival for the purposes of nomenclature.

Type material

Holotype Male, about 20 mm without uropod (SMF 32257); Yemen, Hadhramaut, Al-Quran, fish landing site, 14°50'872" N 50°08'818" E, littoral zone with rockpools at low tide, leg. M. Apel, 27.05.2005.

Paratypes Data as for holotype, except as follows: five males up to 25 mm, two females up to 19 mm (SMF 35207); four males up to 25 mm, two females up to 19 mm (NHCY 79).

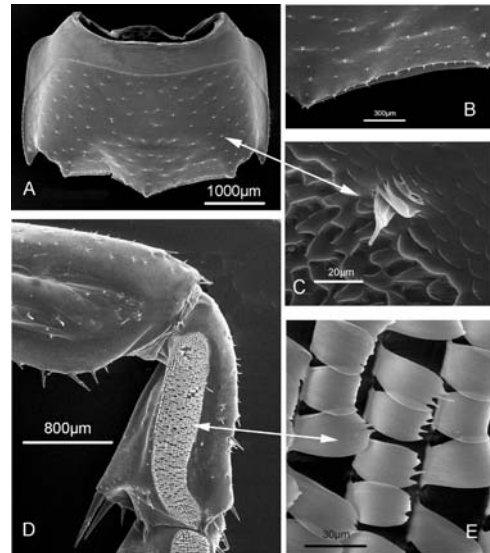


Fig. 9 *Ligia persica* sp. nov., male paratype, SEM. **a–c** Pleotelson; **b** posterior margin; **c** foraminate tricorn with protective plaques. **d, e** Pereiopod 6; **d** caudal surface; **e** rows of regular scales on ischium

Diagnosis

Distance between eyes equal to eye length. Pleotelson with slightly convex apex, margin above uropods shallowly concave. Uropodal exopod as long as endopod (without setae). Antennule terminal article with three aesthetascs. Antenna basal article 5 length less than 1.5 times article 4. Pereiopods 1–3 with setules on inferior margins of merus and carpus. Pereiopod 1–7 dactylus with secondary unguis

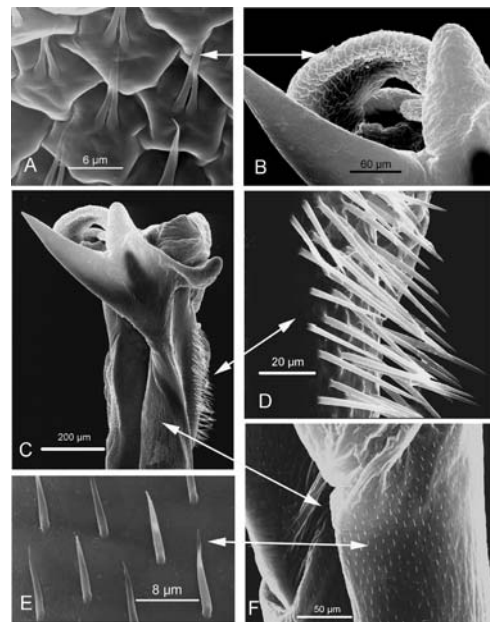


Fig. 10 *Ligia yemenica* sp. nov., paratype; appendix masculina, SEM; **a** polygon scales on semicircular part; **b** apical part; **c** distal part; **d** needle-like cuticular spines on medial margin; **e, f** rows of tiny cuticular hairs directed distally on subdistal part

long and little shorter than main unguis, pereopod 6–7 dactylus with a tuft of long, thin setae on superodistal margin. Appendix masculina with a trifurcate process rostrally, its lateral branch acute and subapical medial margin equipped with rows of needle-like cuticular spines.

Description of male

Body (Fig. 11a) length about 2.5 times greatest width. Cephalon with large eyes, distance between them equal to eye length. Pleonites 1–2 visible in dorsal view but largely concealed by pereionite 7.

Pleotelson length about 0.8 times greatest width, with broadly rounded apex, posterior margin (Fig. 16a) with dense submarginal foraminiate tricornes projecting well beyond pleotelson apex, posterolateral corners acute and subequal with posterior process.

Uropod (Fig. 11d) peduncle 0.6 times as long as exopod, lateral margin bearing some short setae, distolateral angle acute, mesial margin with five robust and some short setae; rami with approximately equal shape, endopod apex with a long bristle, exopod as long as endopod main article.

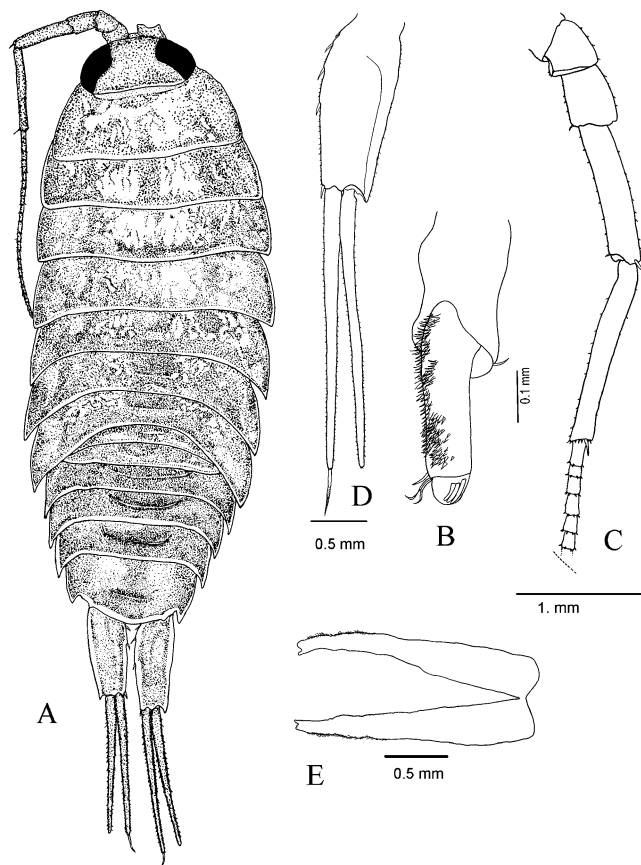


Fig. 11 *Ligia yemenica* sp. nov., male (holotype). a Dorsal view. b Antennule. c Antenna. d Uropod. e Penes

Antennule (Fig. 11b) basal article with one simple seta on distoventral angle; article 2 is the longest, with three long, simple setae on posterodistal angle; apical article with three aesthetascs.

Antenna (Fig. 11c) basal articles 1–5 increasing in length, article 5 about 1.3 times as long as article 4; flagellum extending to posterior margin of pereionite 5, with 30 articles.

Maxillule (Fig. 12a) lateral lobe with four simple teeth and three serrate robust setae; mesial lobe with three stout, circumplumose setae (penicils) on apical margin, one robust, simple seta and some scale-like setae on distal part.

Maxilla (Fig. 12d) lateral and mesial lobes bear scale-like and fine setae, as illustrated.

Maxilliped (Fig. 12c) basis with some tricornes along lateral margin, and two robust setae on distomedial corner; endite with two circumplumose setae (apical penicils), several robust setae and many fine setae on apical margin; palp with five articles, basal article with one apically bifid robust seta, articles 2–4 with several bifid robust setae and longitudinal rows of slender setae on inner margins, article

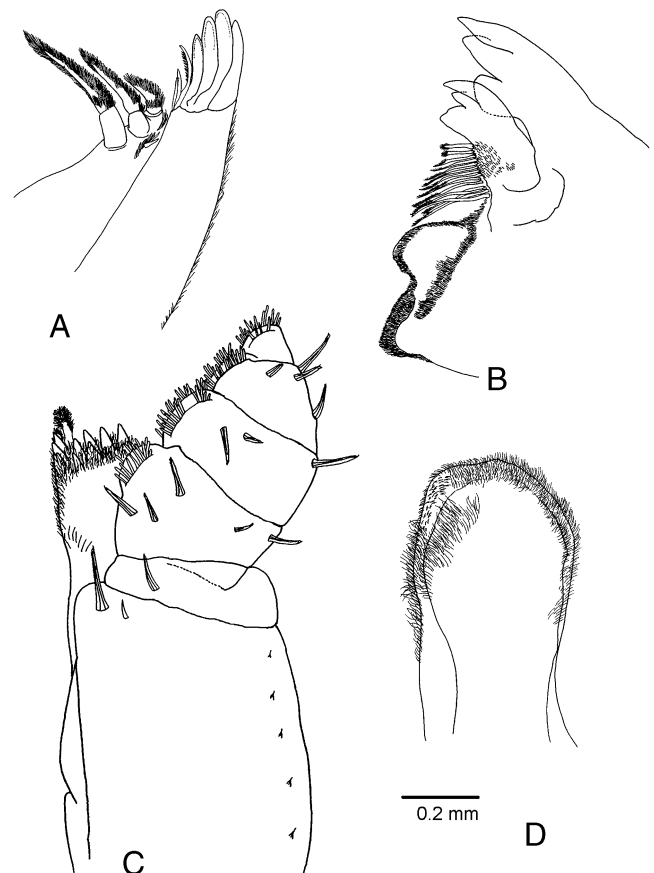


Fig. 12 *Ligia yemenica* sp. nov., male (holotype). a Maxillule. b Right mandible. c Maxilliped. d Maxilla

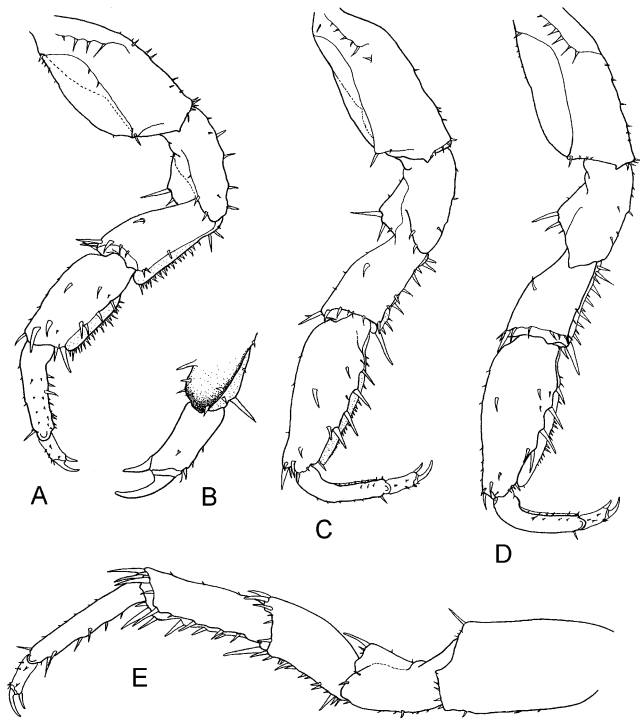


Fig. 13 *Ligia yemenica* sp. nov., male (holotype). **a, b** Pereiopod 1; **b** dactylus. **c–e** Pereiopods 2–4, respectively

5 with longitudinal rows of slender setae, without marginal robust seta.

Mandible (Fig. 12b) incisor with three cusps, lacinia mobilis with three cusps, spine row with about 12 serrate and two biserrate spines; molar process with many scattered fine setae.

Pereiopod 1 (Fig. 13a, b) basis length about 2.4 times greatest width, with some scale-like setae on caudal surface, upper margin with some short setae, ventral margin with one robust seta on ventrodistal corner; ischium as long as merus, inferior margin with four short robust setae, superodistal corner with one long and one short robust seta; merus with two long and some robust setae on distal margin; carpus length about 2 times greatest width; propodus shorter and narrower than carpus, curved, superodistal angle with one short robust seta; dactylus with three short, scale-like setae on superior margin, one on tergal surface, secondary unguis long and subequal to main unguis. Pereiopods 1–3 with short setae on inferior margins of merus and carpus.

Pereiopod 2 (Fig. 13c) basis length 2.4 times greatest width, with one robust seta on ventrodistal angle; ischium as long as merus, with two long and one short robust seta on superodistal corner; merus with two long and some short robust setae on distal margin; carpus length about 2.5 times greatest width, with four long robust setae on subinferior margin; propodus shorter than carpus and curved, superodistal angle with one short robust seta; dactylus with two

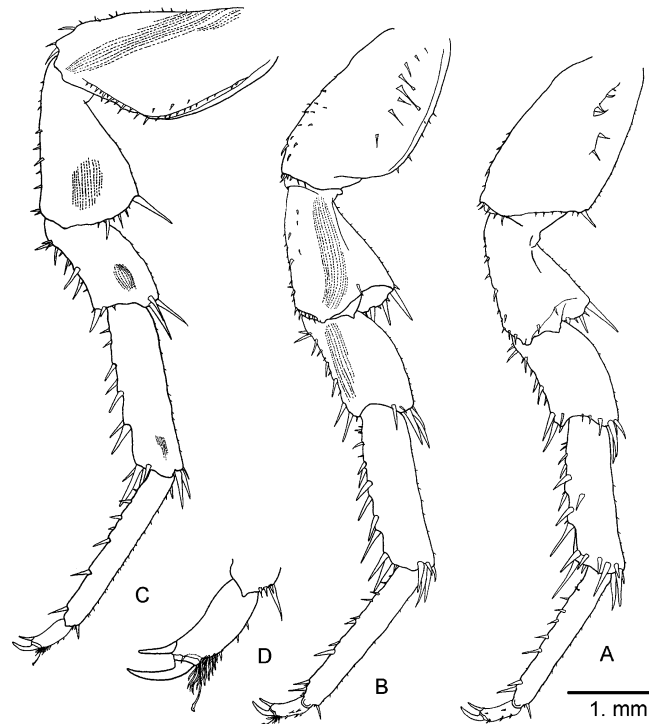


Fig. 14 *Ligia yemenica* sp. nov., male (holotype). **a** Pereiopod 5. **b** Pereiopod 6. **c, d** Pereiopod 7; **d** dactylus

short, scale-like setae on superior margin and two on tergal surface, secondary unguis long.

Pereiopod 3 (Fig. 13d) very similar to pereiopod 2, as figured.

Pereiopod 4 (Fig. 13e) basis length 2 times greatest width, with one robust seta on ventrodistal angle; ischium as long as merus, with one robust seta on superodistal

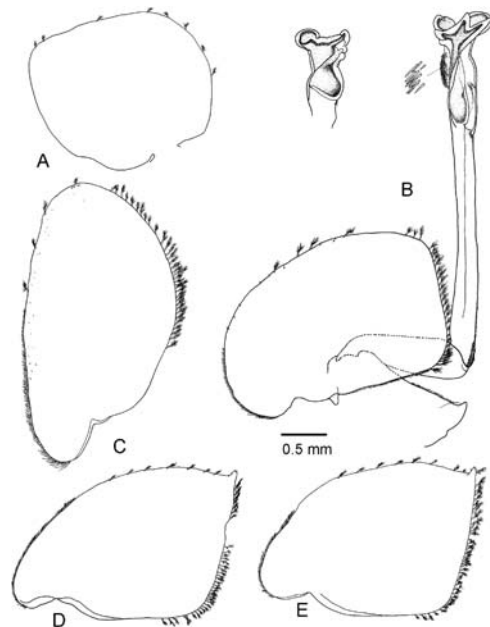


Fig. 15 *Ligia yemenica* sp. nov., male (holotype). **a** Pleopod 1 exopod. **b** Pleopod 2. **c–e** Pleopod 3–5 exopods, respectively

corner; merus with several long robust and short setae on inferior and distal margins; carpus as long as propodus, with several long robust and short setae on inferior and subdistal margins; propodus with one robust seta on superodistal corner and six robust setae on inferior margin; dactylus with five scale-like setae on superior margin and tergal surface, secondary unguis long and subequal to main unguis.

Pereiopod 5 (Fig. 14a) basis length about 1.6 times greatest width, with some scale-like setae on caudal surface, upper and distal margins with some short setae, ventrodistal corner with one robust seta; ischium as long as merus, inferior margin with some short robust setae, superodistal corner with two long and three short robust setae; merus with some long and some short robust setae on distal and inferior margins; carpus as long as propodus, with some long and some short robust setae on distal and inferior margins; propodus with one robust seta on superodistal corner and seven robust setae on inferior margin; dactylus with five scale-like setae on superior margin and dorsal surface, secondary unguis long and subequal to main unguis.

Pereiopod 6 (Fig. 14b) length about 1.8 times greatest width, with several scale-like, acute setae scattered on caudal surface; ischium length 1.4 times greatest width, caudal surface with several rows of regular scales, inferior margin with several short setae, superodistal corner with three long robust and four short setae; merus caudal surface with some rows of regular scales, inferior and distal margins with some long and some short robust setae; carpus as long as propodus, with some long and some short robust setae on superodistal corner and inferior margin; dactylus with a tuft of long, thin setae on superodistal margin and five scale-like setae on superior margin and tergal surface, secondary unguis (Fig. 16a) long and subequal to main unguis.

Pereiopod 7 (Fig. 14c, d) with fields of regular scales on basis, ischium, merus and carpus; basis length about 2 times greatest width, with several short setae on ventral and dorsal margins; ischium length about 1.6 times greatest width, with one long robust and some short setae on superodistal corner, several short robust setae on inferior margin; merus about 0.6 as long as propodus, with three long robust setae on superodistal corner; carpus as long as propodus; dactylus with a tuft of long, thin setae on superodistal margin and three scale-like setae on superior margin, secondary unguis long and subequal to main unguis.

Penes (Fig. 11e) separate, long (length about 6.2 times basal width), tapering evenly to narrowly bifurcate apex; distolateral margins bearing short, fine setae.

Pleopod 1 (Fig. 15a) exopod nearly round, with some plumose setae on distal margin (Fig. 16).

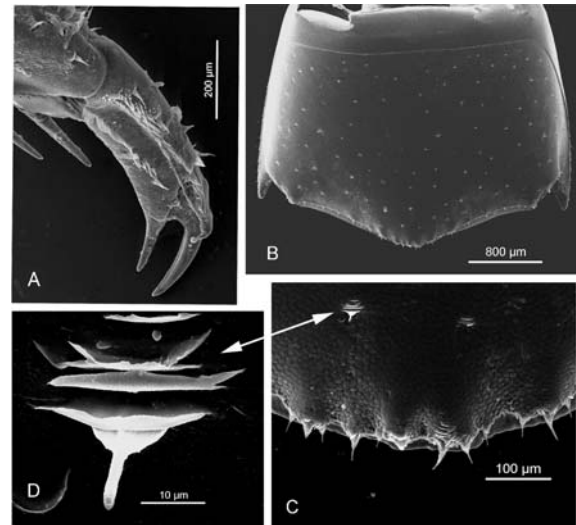


Fig. 16 *Ligia yemenica* sp. nov., paratype; SEM. **a** Dactylus of pereiopod 6; **b–d** Pleotelson; **c** posterior margin; **d** forminate tricorn with protective plaques on dorsal surface

Pleopod 2 (Fig. 15b) exopod with row of plumose setae on medial and distal margins; appendix masculina (Figs. 15b and 10a–f) distal part with trifurcate process on rostral surface, lateral branch acute, subapical medial margin nearly convex, with several rows of needle-like cuticular spines.

Pleopod 3 (Fig. 15c) exopod nearly ovate, with row of plumose setae on medial margin, some on apical margin, and row of short, fine setae on lateral margin.

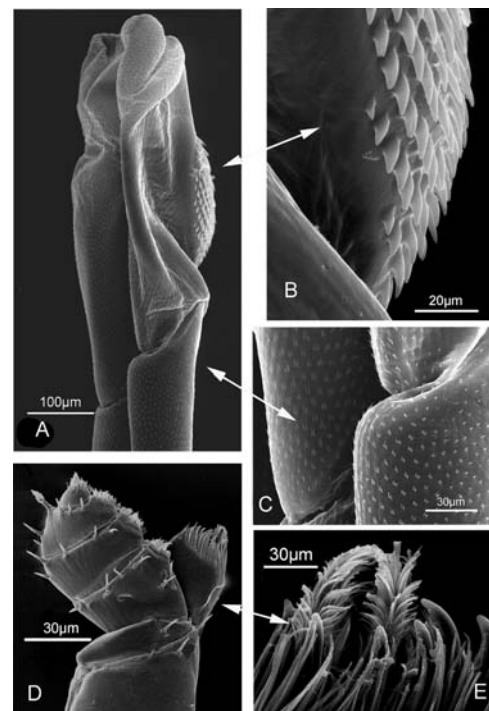


Fig. 17 *Ligia persica* sp. nov., male paratype; SEM. **a–c** Distal part of appendix masculina; **b** cuticular spines on medial margin; **c** tiny cuticular hairs on subapical parts. **d**, **e** Maxilliped; **e** endite apex

Pleopod 4 (Fig. 15d) exopod with rounded projection on apical part, medial margin with row of plumose setae, lateral margin with row of short, fine setae. Pleopod 5 (Fig. 15e) similar to pleopod 4, as illustrated.

Description of female

Similar to male, except in sexual characters, lower body size, and lower numbers of setae on pereopods and pleotelson posterior margins.

Remarks

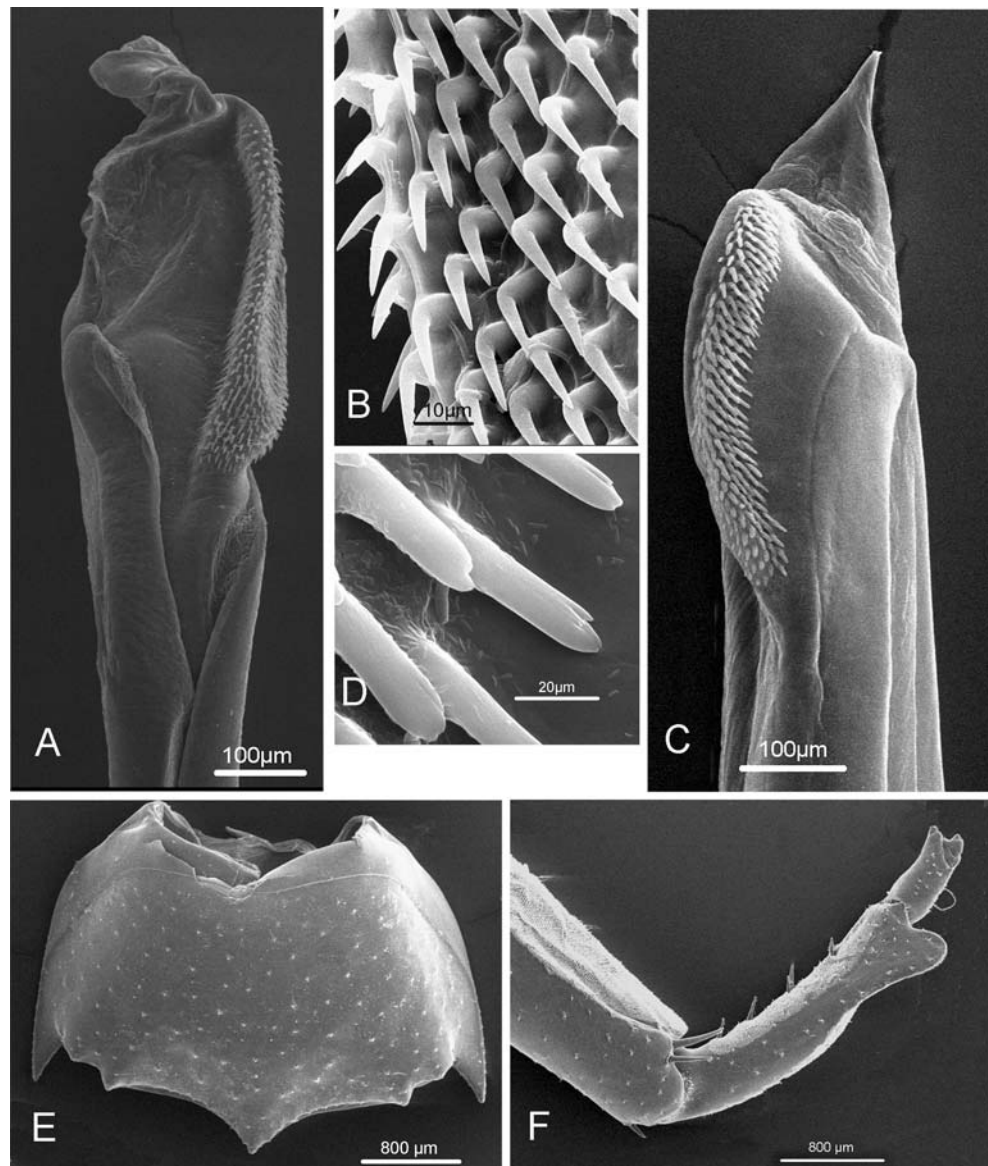
Ligia yemenica sp. nov. is distinguished easily by the shape of the appendix masculina with its unique apical trifurcate process. In other species of the genus the

apical part of the appendix masculina varies from pointed in *L. oceanica* Linné, 1767 to more acute in *L. dioscorides* Taiti & Ferrara, 2004, is enlarged with an obliquely truncate apex in *L. hawaiiensis* Dana, 1853, truncate in *L. vitiensis* Dana, 1853, flat and round in *L. exotica* Roux, 1828, and slightly bilobate in *L. pigmentata* Jackson, 1922. Moreover, the pereopod dactylus of the new species has a long secondary unguis a little shorter than the main unguis.

Ultrastructural details

The appendix masculina is a useful discriminating character at ultrastructural level that helps to distinguish morphologically similar *Ligia* species. The SEM images show useful characters of the apical part of the appendix

Fig. 18 **a, b, e, f** *Ligia exotica* Roux, male, Taiwan (**a, b, e**) and Japan (**f**); **a, b** appendix masculina, **b** cuticular spines on medial margin; **e** pleotelson; **f** pereopod 1. **c, d** *Ligia oceanica* (L.), male, Netherlands; appendix masculina, **d** cuticular spines on medial margin



masculina, including shape and ornamentation of the distal part; and the shape, density and arrangement of cuticular spines (teeth) on the medial margin. In *L. persica* the cuticular spines on the medial margin (Fig. 8b) are short, curved and arranged in regular rows. *Ligia exotica* (Fig. 18a, b) has more curved spines, longer and narrower than in *L. persica*. *Ligia oceanica* (Fig. 18c, d from The Netherlands) has robust, straight and bifid cuticular spines, and *L. yemenica* (Fig. 10c, d) has narrow, straight, and acute spines. Moreover, the ornamentation of the distal part shows species-specific patterns. In *L. persica*, cuticular hairs (with 2–5 branches) are distributed on large areas of the distal part including the apex (Fig. 17a–c). In contrast, *L. exotica* and *L. oceanica* lack cuticular hairs on the apical surface of the appendix masculina. The ornamentation pattern in *L. yemenica* is specific: The semicircular part (Fig. 10a, b) shows cuticular polygon scales bearing pairs of tiny cuticular hairs, while cuticular hairs (Fig. 10e, f) are distributed on subapical parts.

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