



## Records of species of the hippolytid genus *Lebbeus* White, 1847 (Crustacea: Decapoda: Caridea) from hydrothermal vents in the Pacific Ocean, with descriptions of three new species

TOMOYUKI KOMAI<sup>1</sup>, SHINJI TSUCHIDA<sup>2</sup> & MICHEL SEGONZAC<sup>3</sup>

<sup>1</sup>Natural History Museum and Institute, Chiba, 955-2 Aoba-cho, Chuo-ku, Chiba, 260-8682 Japan. E-mail: komai@chiba-muse.or.jp

<sup>2</sup>Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka, 237-0061 Japan.

E-mail: tsuchidas@jamstec.go.jp

<sup>3</sup>Muséum national d'Histoire naturelle, Département Milieux et Peuplements Aquatiques, 61 rue Buffon, 75005 Paris, France.

E-mail: segonzac@mnhn.fr

### Abstract

Five species of the hippolytid shrimp genus *Lebbeus* White, 1847 are reported from various deep-water hydrothermal vent sites in the Pacific Ocean: *L. laurentae* Wicksten, 2010 from the East Pacific Rise 13°N; *L. wera* Ahyong, 2009 from the Brothers Seamount, Kermadec Ridge, New Zealand; *L. pacmanus* **sp. nov.** from the Manus Basin, Bismarck Sea; *L. shinkaiiae* **sp. nov.** from the Okinawa Trough, Japan; and *L. thermophilus* **sp. nov.** from the Manus and Lau basins, south-western Pacific. *Lebbeus laurentae* is fully redescribed because the original and subsequent descriptions are not totally detailed. Differentiating characters among the three new species and close allies are discussed. Previous records of *Lebbeus* species from hydrothermal vents are reviewed.

**Key words:** Crustacea, Decapoda, Caridea, Hippolytidae, *Lebbeus*, new species, hydrothermal vents, Pacific Ocean

### Introduction

The hippolytid shrimp genus *Lebbeus* White, 1847 is currently represented by 57 species (De Grave & Fransen 2011), many of which are distributed in the high latitudinal areas in the North Pacific. *Lebbeus* is the sole representative of Hippolytidae with species inhabiting chemosynthetic habitats, although the identities of the recorded species are not always clear (Martin & Haney 2005). Martin & Haney (2005) summarized information on species of the genus recorded from hydrothermal vents, and listed four species: *Lebbeus bidentatus* (?) Zarenkov, 1976 from the southern East Pacific Rise (EPR), *L. 'carinatus'* de Saint Laurent, 1984 from the East Pacific Rise at 13°N, *L. washingtonianus* (Rathbun, 1902) from the Okinawa Trough, Japan and *Lebbeus* sp. A from the Lau Basin, south-western Pacific. The problem of the homonymy between *L. carinatus* Zarenkov, 1976 and *L. carinatus* de Saint Laurent, 1984 had long been recognized (e.g. de Saint Laurent 1997). The specific identity of *L. washingtonianus* from the Okinawa Trough has been questioned (e.g., Komai *et al.* 2004; Martin & Haney 2005). Komai (2006) published an account on *L. carinatus* sensu de Saint Laurent, 1984, but the name was erroneously referred to Zarenkov (1976). Ahyong (2009) described a new species, *L. wera*, from the Brothers Caldera, southern Kermadec Ridge, New Zealand. Komai & Collins (2009) reported on the occurrence of two species of *Lebbeus* from the Manus Basin, Bismarck Sea, one of them was described as new, *L. manus*, though the second remained undescribed. Wicksten (2010) finally gave a new replacement name *L. laurentae* for *L. carinatus* de Saint Laurent, 1984, and redescribed this species based on the syntypes.

This study deals with collections made by cruises to various hydrothermal vent sites in the Pacific Ocean. Five species have been identified, including three new species: *Lebbeus laurentae* from EPR 13°N, *L. wera* from the Brothers Seamount, Kermadec Ridge, *L. pacmanus* **sp. nov.** from the Manus Basin, *L. shinkaiiae* **sp. nov.** from the Okinawa Trough (previously referred to *L. washingtonianus*) and *L. thermophilus* **sp. nov.** from the Manus and Lau basins. Based on the present results, previous hydrothermal vent records of species of *Lebbeus* are reviewed.

## Material and methods

Material studied here was collected during French, American and Japanese cruises in the Pacific Ocean: HOT 96 (EPR-13°N, chief scientist F. Gaill), HOPE 99 (EPR-13°N, chief scientist F. Lallier), BIOLAU (Lau Basin, chief scientist A.-M. Alayse), PHARE (EPR-13°N, chief scientist N. Le Bris), 2007 WAVE MERCURY (Manus Basin, chief scientist C. L. Van Dover), and various Japanese cruises carried out by RV *Yokosuka*/DS *Shinkai 6500* and RV *Natsushima*/DS *Shinkai 2000* or ROV *Hyper-Dolphin* of JAMSTEC. Specimens were sampled by using a suction sampler (slurp gun) or baited traps installed on various submersibles, e.g., DS *Cyana*, *Nautile*, *Shinkai 2000*, *Shinkai 6500*, ROV *Hyper-Dolphin*, *Jason II*, *TST212-Canyon Offshore*, and *Victor 6000*. The specimens are deposited in the Japan Agency for Marine Science and Technology (JAMSTEC), Muséum national d'Histoire naturelle, Paris (MNHN), the National Museum of Nature and Science, Tokyo (NSMT), and the Natural History Museum and Institute, Chiba (CBM).

## Taxonomy

### Family Hippolytidae

#### Genus *Lebbeus* White, 1847

##### *Lebbeus laurentae* Wicksten, 2010

(Figs 1–4, 18)

*Lebbeus carinatus* de Saint Laurent, 1984: 356; de Saint Laurent 1997: 197, unnumbered fig.; Martin and Haney 2005: 470; Komai 2006: 431, figs. 1–3. Not *Lebbeus carinatus* Zarenkov, 1976.

*Lebbeus laurentae* Wicksten, 2010: 196, figs. 1–4.

**Material examined.** Syntypes: BIOCARYSE, DS *Cyana*, site Parigo/Pogosud, 12°49'N, 103°57'W, 2630 m, 2 females (cl 13.5, 19.4 mm), 1 male (cl 12.0 mm), 6–30 March 1984, MNHN-Na 14973.

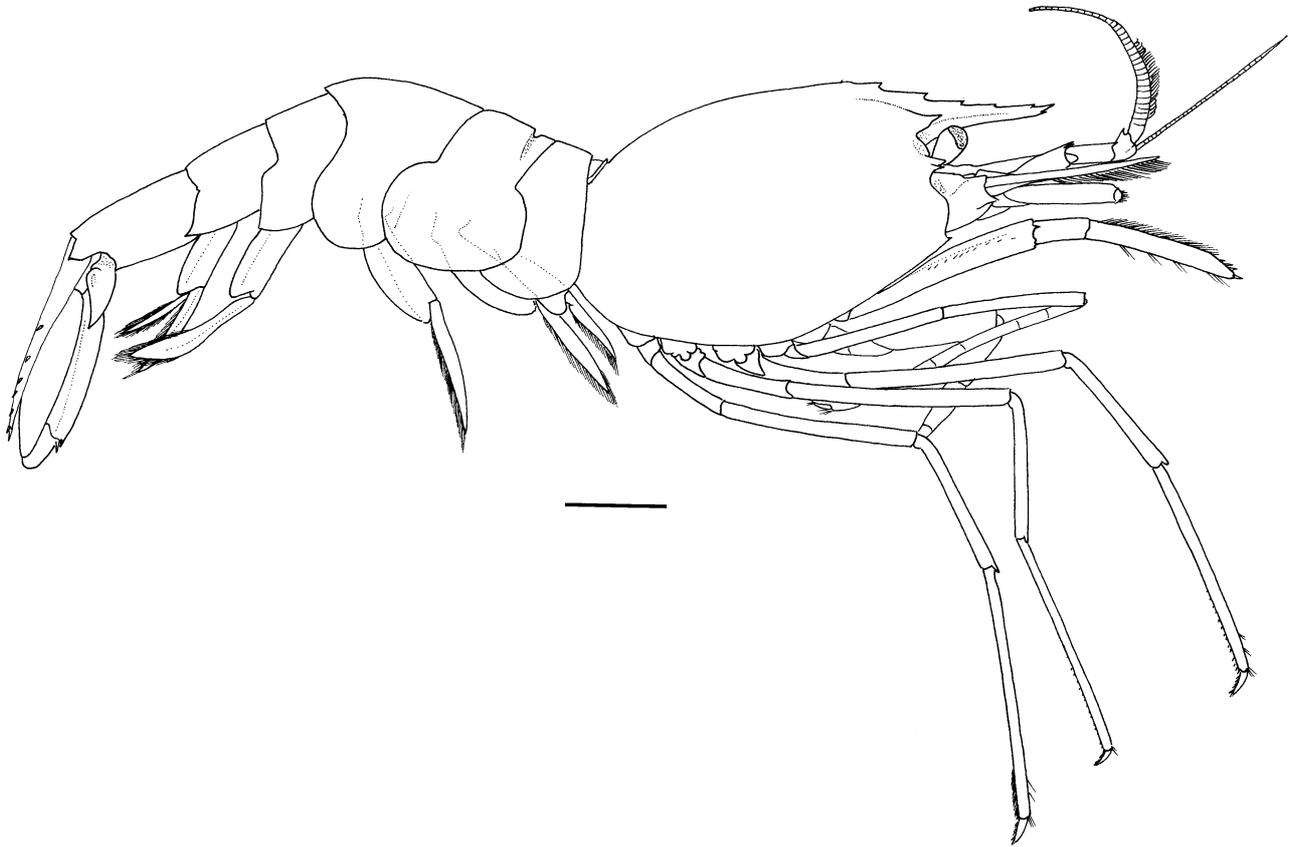
HOT 96 (RV *L'Atalante*/DS *Nautile*), dive #1063, EPR 13°N, site Genesis, 12°50'N, 103.54'W, 2640 m, 15 February 1996, slurp gun, 2 males (cl 9.9, 11.4 mm), 1 juvenile (cl 5.6 mm), MNHN-IU-2011-5721. HOPE 99 (RV *L'Atalante*/DS *Nautile*), dive #1361, EPR 13°N, site Genesis, 12°50'N, 103.54'W, 2640 m, 17 April 1999, slurp gun, 5 females (cl 8.2–14.9 mm), MNHN-IU-2011-5722; dive #1370, same site, 1 May 1999, 1 male (cl 10.1 mm), 6 females (cl 7.8–14.8 mm), 2 juveniles (cl 4.9, 7.4 mm), MNHN-IU.2011-5723; same dive, 1 male (cl. 11.1 mm), CBM-ZC 10658; dive #1381, same site, 12 May 1999, slurp gun, 1 male (cl 12.8 mm), 1 female (16.2 mm), MNHN-IU-2011-5724; dive #1384, same site, 1 female (damaged), 1 juvenile (cl 7.8 mm), CBM-ZC 10659; dive #1385, same site, 16 May 1999, slurp gun, 2 males (cl 10.0, 12.7 mm), 5 females (cl 8.7–17.1 mm), 1 juvenile (cl 5.9 mm), CBM-ZC 10660; dive #1388, site Elsa, 12°48'N, 103°56'W, 2632 m, 19 May 1999, slurp gun, 3 females (cl 7.8–14.6 mm), 1 juvenile (damaged), MNHN-IU-2011-5725; dive #1389, site Genesis, 20 May 1999, slurp gun, 2 females (cl 13.0, 14.3 mm), MNHN-IU-2011-5726. PHARE, dive #164-16, EPR 13°N, site Actinoir, 12°48.77'N, 103°56.50'W, 2618 m, 25 May 1999, baited trap, 1 female (cl 14.6 mm), 1 male (cl 10.0 mm), MNHN-IU-2011-5727.

**Redescription.** *Females.* Body (Fig. 1) moderately stout for genus; integument soft, surface glabrous.

Rostrum (Fig. 2A, B) straight, directed forward, reaching to or slightly overreaching distal margin of first segment of antennular peduncle, 0.3–0.5 times carapace length; dorsal margin armed with 2–6 small teeth, including 1–4 teeth on rostrum proper and 1–3 postrostral teeth; ventral margin armed with 1–3 tiny teeth in distal 0.2, ventral lamina poorly developed. Carapace (Figs 1, 2A, B) with low but distinct postrostral carina extending at least to midlength (usually to two-thirds) of carapace, sloping toward rostral base; posteriormost postrostral tooth arising at 0.1–0.2 of carapace length; dorsal margin in lateral view convex; supraorbital tooth moderately strong, arising at level of rostral base, not reaching tip of suborbital lobe or antennal tooth; orbital region depressed, orbital margin with convexity, base of eyestalk set between this convexity and suborbital lobe; distinct U-shaped notch present inferior to base of supraorbital tooth; suborbital lobe well developed, triangular, reaching tip of antennal tooth; anterolateral margin between antennal and pterygostomial teeth strongly sinuous, with deep excavation

below antennal tooth.

Abdomen (Fig. 1) dorsally rounded. Second somite with deep transverse groove on tergum, posteriorly forming low but distinct ridge. Pleura of anterior three somites broadly rounded; fourth pleuron usually with small posteroventral tooth; fifth pleuron with moderately strong posteroventral tooth. Sixth somite about 1.4 times longer than fifth somite and 1.8 times longer than deep, bearing small posteroventral tooth; posterolateral process terminating in small sharp tooth. Telson (Fig. 2C) 1.5–1.6 times longer than sixth somite, tapering posteriorly to convex posterior margin, bearing 3–7 (usually 4–6) dorsolateral spines on each side; posterior margin with 2 pairs of lateral spines (mesial pair longer) and 5 or 6 median spiniform setulose setae (Fig. 2D).



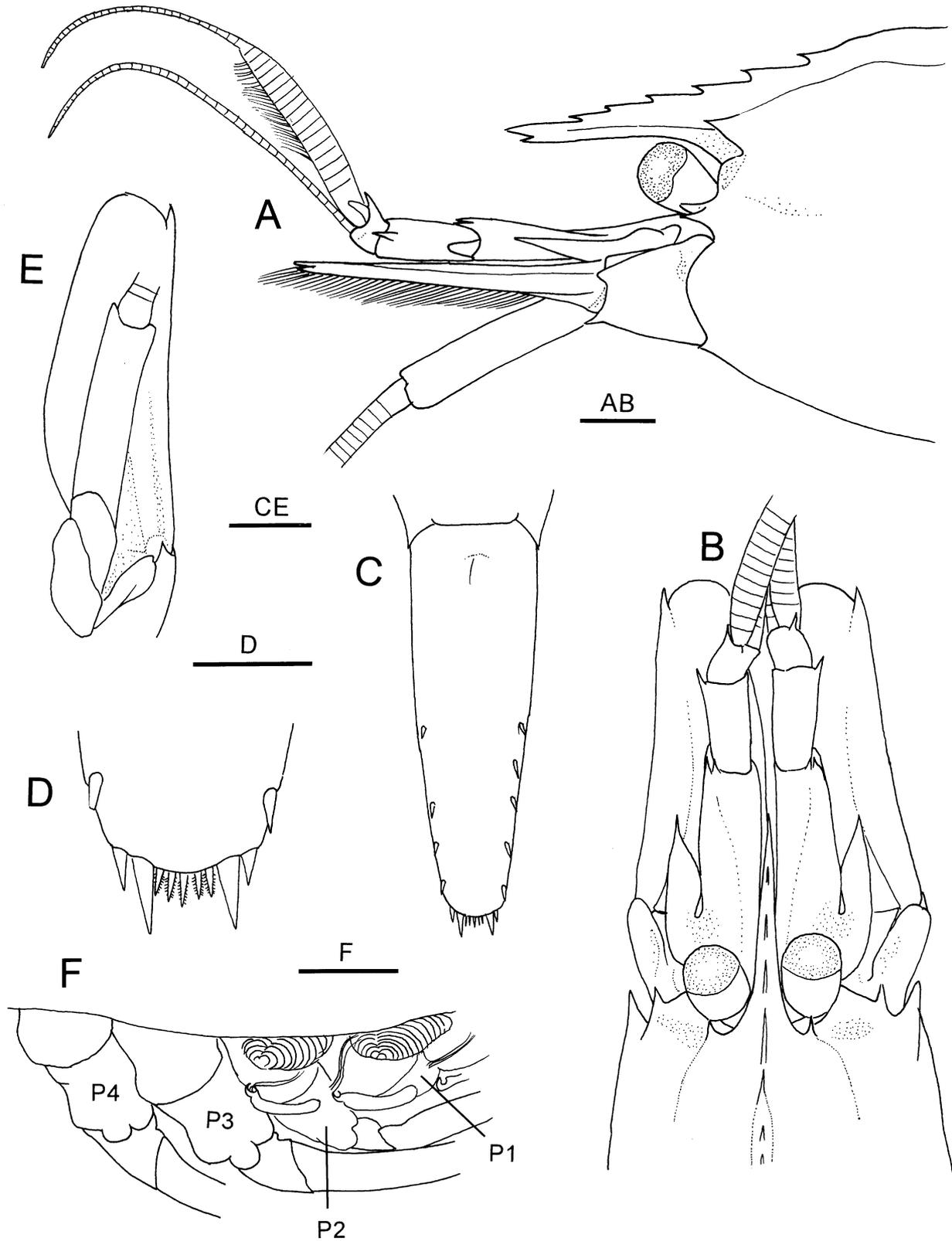
**FIGURE 1.** *Lebbeus laurentae* Wicksten, 2010, female (cl 15.9 mm), HOPE 99, dive 1361, EPR 13°N, MNHN-IU-2011-5722, entire animal in lateral view. Scale bar: 5 mm.

Eye (Fig. 2A, B) very small for genus, subpyriform with stalk slightly narrowing proximally; cornea not dilated, its maximum diameter less than 0.1 of carapace length; ocellus absent.

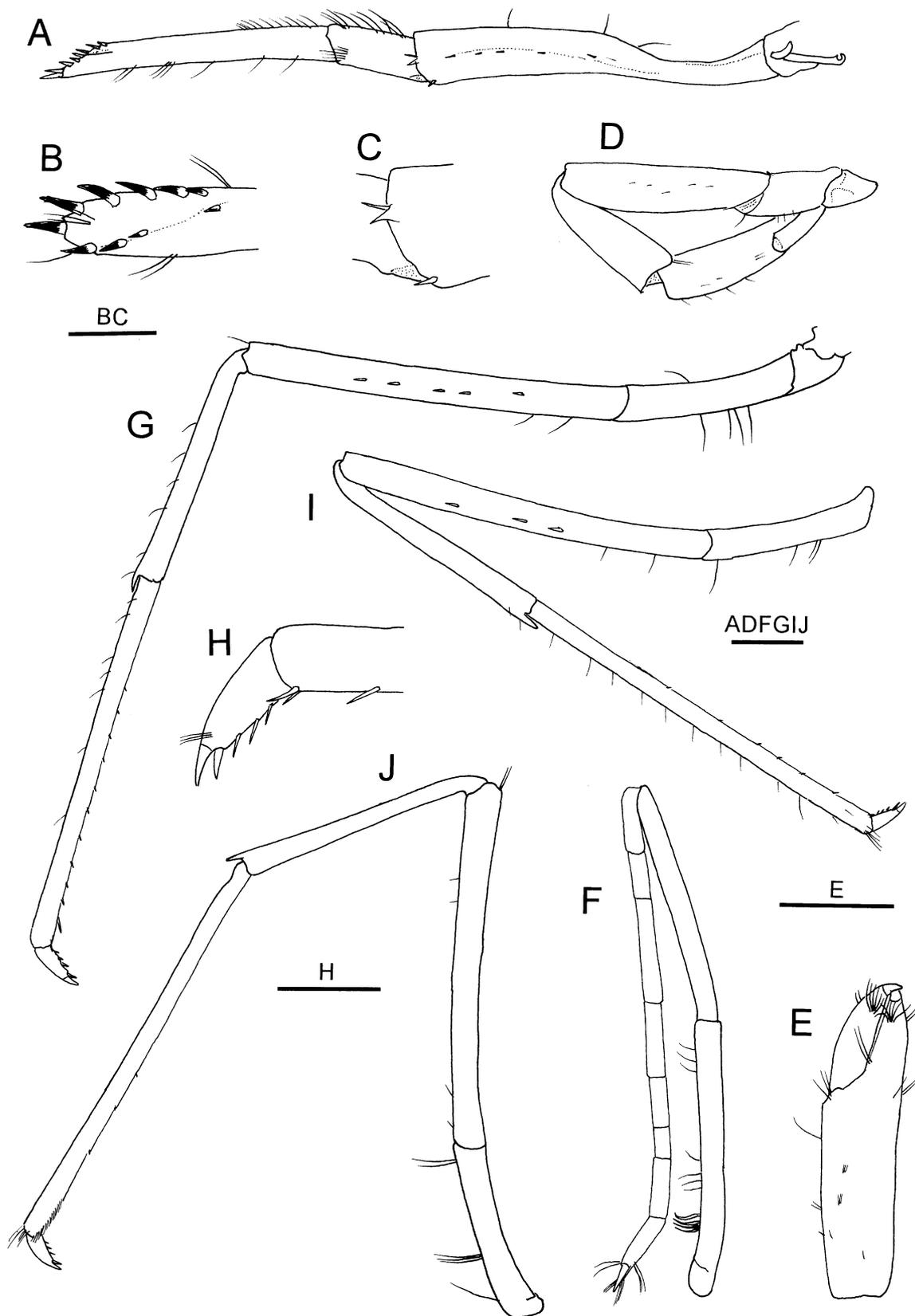
Antennular peduncle (Fig. 2A, B) not reaching base of distolateral tooth of antennal scale. First segment much longer than distal two segments combined, slightly overreaching midlength of antennal scale, dorsodistal margin armed with 2–4 slender teeth; stylocerite far falling short of distal margin of first peduncular segment, sharply pointed, mesial margin sinuous. Second segment 0.4–0.5 length of first segment, with 1 moderately large dorsolateral distal tooth. Third segment less than half as long as second segment, bearing 1 small dorsodistal tooth. Lateral flagellum with thickened aesthetasc-bearing portion about 0.4 times as long as carapace.

Antenna (Fig. 2A, B, E) with basicerite bearing relatively small ventrolateral tooth; carpocerite reaching distal 0.2–0.3 of antennal scale. Antennal scale about 0.6 times as long as carapace and 2.8–3.0 times longer than wide; lateral margin nearly straight or very slightly concave; distolateral tooth not reaching rounded distal margin of lamella.

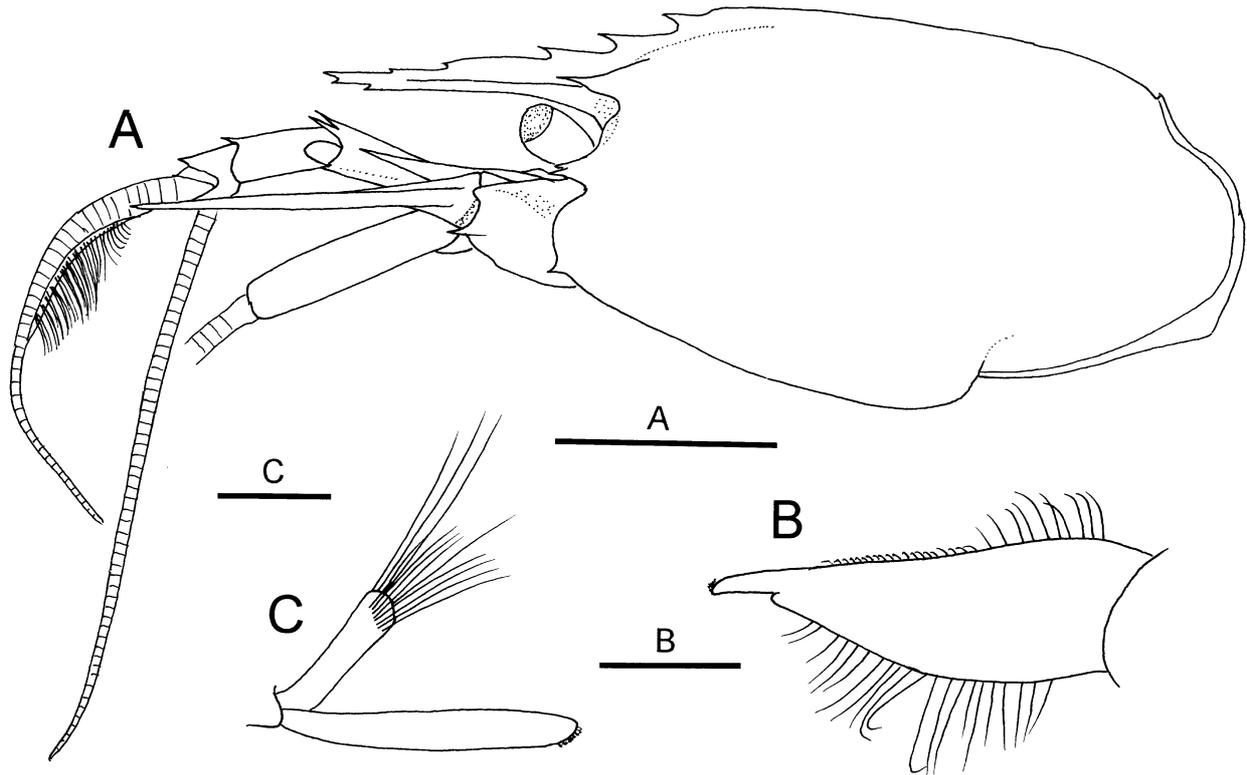
Mouthparts similar to those of other species of the genus. Third maxilliped (Fig. 3A) overreaching antennal scale by half length of ultimate segment; ultimate segment 3.0–3.5 times longer than penultimate segment, tapering distally, with short row of darkly pigmented corneous spines distomesially (Fig. 3B); antepenultimate segment shorter than distal two segments combined, armed with 1 small tooth on distolateral margin and 1 minute spine at ventrolateral distal angle (Fig. 3C); lateral surface with row of minute spiniform setae on blunt dorsolateral ridge.



**FIGURE 2.** *Lebbeus laurentae* Wicksten, 2010, female (cl 15.7 mm), HOPE 99, dive 1385, EPR 13°N, CBM-ZC 10660. A, anterior part of carapace and cephalic appendages, lateral view; B, same, dorsal view; C, telson, dorsal view; D, posterior part of telson, dorsal view; E, left antennal peduncle and scale, ventral view; F, coxae of first to fourth pereopods, showing absence of epipod on third pereopod. Scale bars: 2 mm for A–C, E, F; 1 mm for D.



**FIGURE 3.** *Lebbeus laurentae* Wicksten, 2010, female (cl 15.7 mm), HOPE 99, dive 1385, EPR 13°N, CBM-ZC 10660, left thoracic appendages. A, third maxilliped, lateral view; B, same, distal part of ultimate segment, dorsal (extensor) view; C, same, distal part of antepenultimate segment, lateral view; D, first pereopod, lateral view; E, same, chela, extensor view; F, second pereopod, lateral view; G, third pereopod, lateral view; H, same, dactylus, lateral view; I, fourth pereopod, lateral view; J, fifth pereopod, lateral view. Scale bars: 2 mm for A, D–G, I, J; 1 mm for B, C, E, H.



**FIGURE 4.** *Lebbeus laurentae* Wicksten, 2010, male (cl 12.7 mm), HOPE 99, dive 1385, EPR 13°N. CBM-ZC 10660, A, carapace and cephalic appendages, lateral view; B, endopod of left first pleopod, dorsal (anterior) view; C, appendices interna and masculina of left second pleopod, mesial view. Scale bars: 5 mm for A; 1 mm for B; 0.5 mm for C.

Strap-like, terminally hooked epipods present on third maxilliped to second pereopod, corresponding seto-branches present on first to third pereopod (Fig. 2F).

First pereopod (Fig. 3D) moderately stout, reaching distal margin of antennal scale; dactylus about 0.6 times as long as palm, terminating in 2 darkly pigmented corneous claws; fixed finger terminating in single corneous claw (Fig. 3E). Second pereopod (Fig. 3F) overreaching antennal scale by 0.7–0.8 length of carpus; carpus divided into 7 articles. Third to fifth pereopods relatively long and slender, similar and slightly decreasing in length posteriorly. Third pereopod (Fig. 3G) overreaching antennal scale by 0.3 length of carpus; dactylus (Fig. 3H) 0.14–0.16 times as long as propodus, moderately stout (about 3.0 times longer than deep), terminating in acute, darkly pigmented unguis, armed with 4 darkly pigmented accessory spinules on flexor margin, distalmost accessory spinule subterminal, distinctly larger than others, making tip of dactylus appearing biunguiculate; carpus about 0.6 times as long as propodus; merus armed with 3–7 ventrolateral spines (ventrolateral distal spine usually absent). Fourth pereopod (Fig. 3I) overreaching antennal scale by full length of propodus; merus with 1–4 (usually 2 or 3) ventrolateral spines. Fifth pereopod (Fig. 3J) overreaching distal margin of antennal scale by 0.5–0.7 length of propodus; merus usually unarmed, but rarely with 1 lateral spine.

**Males.** Generally similar to females except for sexually dimorphic characters. Antennular peduncle (Fig. 4A) reaching distal margin of antennal scale; flagella thicker, outer flagellum slightly longer than carapace, aesthetasc-bearing portion occupying about half-length of entire flagellum, about half-length of carapace; inner flagellum distinctly longer than outer flagellum, about 1.2–2.0 times longer than carapace. Endopod of first pleopod with minute lobe just lateral to base of terminally located appendix interna (Fig. 4B). Second pleopod with appendix masculina relatively stout, about half-length of appendix interna, bearing about 15 stiff setae terminally (Fig. 4C).

**Coloration in life.** Carapace reddish, rostrum translucent; abdomen translucent. Cornea light gray. Antennae and pereopods translucent.

**Distribution.** Known only from hydrothermal vents on EPR 13°N; at depths of 2618–2640 m.

**Ecology.** *Lebbeus laurentae* was seen in several active vent sites (Parigo, Elsa, Genesis, and Actinoir) which

were composed of black smokers (maximum fluid temperature 360°C) surrounded by fluid emission at 5–12°C temperature. Video recordings show that shrimps live among clusters of giant tube worms *Riftia pachyptila* Jones, 1981. Associated fauna includes the zoarcid fish *Thermarces cerberus* Rosenblatt & Cohen, 1986, the bythograeid crab *Bythograea thermydron* Williams, 1980 and the cephalopod *Vulcanoctopus hydrothermalis* González, Guerra, Pascual & Briand, 1998 (González *et al.* 1998). *Lebbeus laurentae* was not seen in clusters of Pompei worms *Alvinella pompejana* Desbruyères & Laubier, 1980, where the temperature generally exceeds 15°C, and it is suggested that this species prefers lower temperature of less than 15°C. Individuals were sometimes seen at some meters away from the bases of active chimneys, composed of basaltic substrate, together with serpulid worms, and a squat lobster *Munidopsis recta* Baba, 2005. The density of the shrimps is estimated at 1–3 individuals /m<sup>2</sup> in the clusters of *Riftia pachyptila*. The diet of some individuals was composed of unidentified organic matter (M. Segonzac, unpublished data).

**Remarks.** Intrageneric grouping within *Lebbeus* according to the number of pereopodal epipods was first discussed by Rathbun (1904) and has been followed by many authors (e.g., Holthuis 1947; Butler 1980; Wicksten 1990; Hayashi 1992; Komai *et al.* 2004; Chang *et al.* 2010). Although phylogenetic significance of the division remains unclear, the number of pereopodal epipods remains useful for discrimination of species in this morphologically disparate and species-rich genus. *Lebbeus laurentae* belongs to the species group characterized by the presence of epipods on the first and second pereopods. This group contains 17 known species (Komai *et al.* 2004; Jensen 2006; Chang *et al.* 2010). Within this group, *L. laurentae* is unique in the presence of a deep notch inferior to the base of the supraorbital tooth and the substantially reduced eye (the width of the cornea is less than 0.1 times of the carapace length). It is rather similar to the following 13 species, all placed in a group characterized by the presence of epipods on the first to third pereopods: *L. antarcticus* Hale, 1941, *L. carinatus* Zarenkov, 1976, *L. cristatus* Ahyong, 2010, *L. formosus* Chang, Komai & Chan, 2010, *L. kuboii* Hayashi, 1992, *L. microceros* (Krøyer, 1841), *L. pacmanus* **sp. nov.**, *L. polyacanthus* Komai, Hayashi & Kohtsuka, 2004, *L. shinkaiiae* **sp. nov.**, *L. similior* Komai & Komatsu, 2009, *L. thermophilus* **sp. nov.**, *L. washingtonianus*, and *L. wera*. Shared characters are: rostrum falling short of distal margin of first segment of antennular peduncle, bearing more than three dorsal and one or more ventral teeth; deep notch present inferior to base of supraorbital tooth; anterolateral margin of carapace between antennal and pterygostomial teeth strongly sinuous with deep concavity just below antennal tooth; and first segment of antennular peduncle armed with more than one teeth on dorsodistal margin. Other than the absence of an epipod on the third pereopod, the lack of a ventral lamina on the rostrum and the substantially reduced eyes distinguishes *L. laurentae* from the other 13 species.

This species had long been known as *Lebbeus carinatus*, although some workers (e.g., de Saint Laurent 1997; Komai *et al.* 2004; Martin & Haney 2005) pointed out that this name was a junior homonym of Zarenkov's (1976) *L. carinatus*. Komai's (2006) account of this species was erroneously attributed to Zarenkov (1976), although this error was corrected in the corrigendum. Wicksten (2010) finally proposed a new replacement name *L. laurentae*. Because of the lack of some diagnostic details in the redescription and inaccuracies in the figures given by Wicksten (2010), we here present a detailed redescription and drawings to better understand the morphology of this species.

### ***Lebbeus wera* Ahyong, 2009**

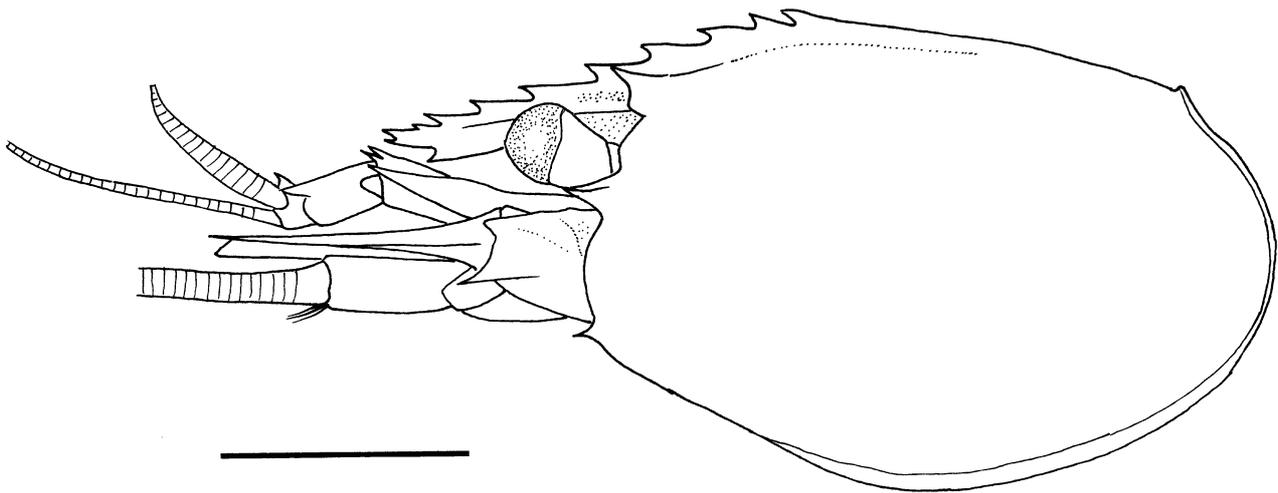
(Fig. 5)

*Lebbeus wera* Ahyong, 2009: 786, figs 5–7; 2010: 346, fig. 3B.

**Material examined.** RV *Yokosuka/DS Shinkai 6500*, YK04-09 cruise, dive #854, Brothers Seamount, Kermadec Arc, 34°52.723'S, 179°04.304'E, 1336 m, 1 November 2004, 1 female (cl 11.4 mm), JAMSTEC 056641.

**Distribution.** Known only from Brothers Seamount, Kermadec Arc, New Zealand, 1208–1336 m.

**Remarks.** The present specimen agrees very well with the detailed original description by Ahyong (2009).



**FIGURE 5.** *Lebbeus wera* Ah Yong, 2009, female (cl 11.4 mm), DS *Shinkai 6500*, dive #854, Brothers Caldera, Kermadec Ridge, JAMSTEC 056641, carapace and cephalic appendages in lateral view. Scale bar: 5 mm.

***Lebbeus pacmanus* sp. nov.**

(Figs 6–9)

**Material examined.** Holotype: RV *Natsuhima*/DS *Shinkai 2000*, NT99-15 cruise, dive #1150, PACMANUS, Manus Basin, Bismarck Sea, 03°43.267'S, 151°40.480'E, 1662 m, 7 November 1999, female (cl 13.9 mm), NSMT-Cr 21983 (ex-JAMSTEC 019523).

Paratype: Same data as holotype, male (cl 11.2 mm), JAMSTEC 019524.

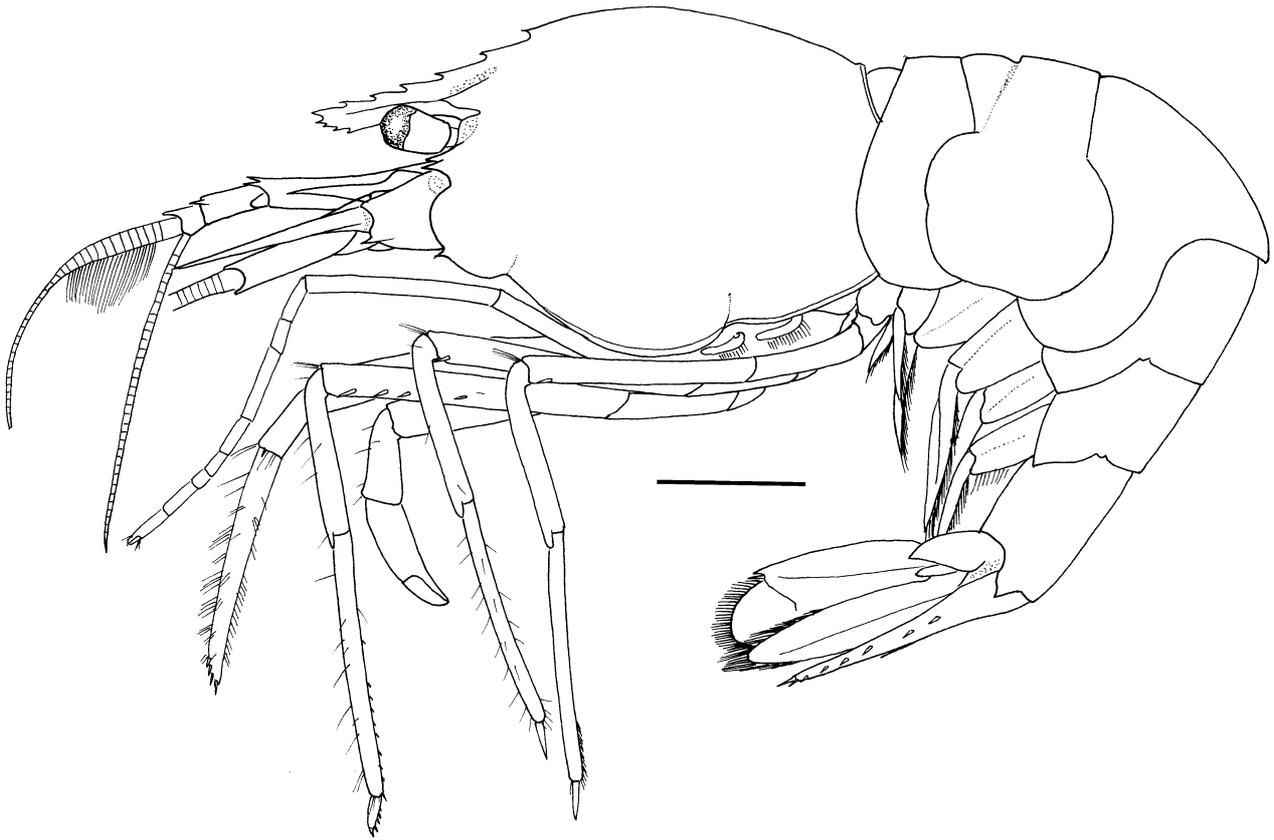
**Description.** *Female holotype.* Body (Fig. 6) moderately robust for genus; integument moderately firm, surface glabrous.

Rostrum (Figs. 6, 7A, B) straight, directed forward, reaching about distal one-third of first segment of antennular peduncle, 0.4 times carapace length; dorsal margin armed with 6 small teeth, including 4 teeth on rostrum proper and 2 postrostral teeth, ventral margin armed with 4 small teeth in distal 0.2, ventral lamina little developed. Carapace (Figs. 1, 7A, B) with low postrostral median carina extending slightly beyond midlength of carapace; posteriormost postrostral tooth arising at about 0.1 of carapace length; dorsal margin in lateral view gently convex; supraorbital tooth moderately strong, directed forward, gradually tapering distally, arising level of posterior margin of orbit, not reaching tip of antennal tooth; orbital region depressed, orbital margin with convexity, base of eyestalk set between this convexity and suborbital lobe; deep U-shaped notch present inferior to base of supraorbital tooth; suborbital lobe well developed, triangular, reaching tip of antennal tooth; anterolateral margin between antennal and pterygostomial teeth strongly sinuous with deep excavation below antennal tooth.

Abdomen (Fig. 6) dorsally rounded. Second somite with sharply defined, deep transverse groove on tergum. Pleura of anterior three somites broadly rounded; fourth pleuron with tiny posteroventral denticle; fifth pleuron with moderately strong posteroventral tooth. Sixth somite about 1.5 times longer than fifth somite and 1.7 times longer than high, bearing small posteroventral tooth; posterolateral process terminating in small tooth. Telson (Fig. 7C) 2.0 times longer than sixth somite, tapering to slightly convex posterior margin, bearing 5 (right) or 6 (left) dorsolateral spines; posterior margin with 2 pairs of lateral spines (mesial pair longer) and 3 spiniform setulose setae (Fig. 7C).

Eye (Fig. 7A, B) subcylindrical with stalk slightly narrowing proximally; cornea not dilated, its maximum width about 0.1 of carapace length; ocellus absent.

Antennular peduncle (Fig. 7A, B) reaching nearly to distal margin of antennal scale. First segment distinctly longer than distal two segments combined, slightly overreaching midlength of antennal scale, dorsodistal margin armed with 2 or 3 slender teeth; stylocerite far falling short of distolateral margin of first peduncular segment, sharply pointed, mesial margin sinuous. Second segment about 0.4 length of first segment, with 1 strong dorsolateral distal tooth. Third segment less than half as long as second segment, bearing 1 small dorsodistal tooth. Lateral flagellum with thickened aesthetasc-bearing portion about 0.3 times as long as carapace.



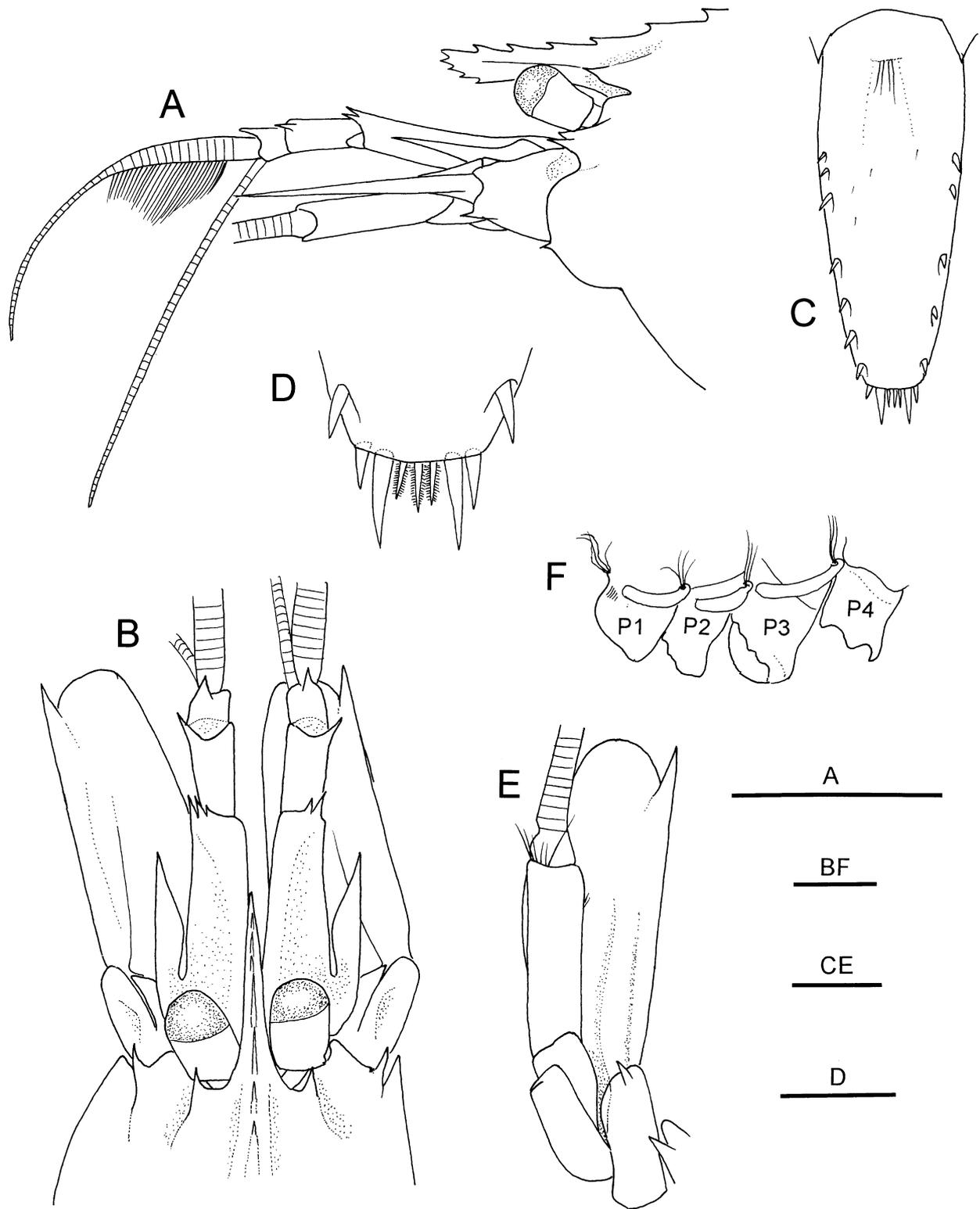
**FIGURE 6.** *Lebbeus pacmanus* sp. nov., holotype, female (cl 13.9 mm), DS *Shinkai 2000*, dive #1150, Pacmanus, Manus Basin, NSMT-Cr 21983, entire animal in lateral view. Scale bar: 5 mm.

Antenna (Fig. 7A, E) with basicerite bearing moderately small ventrolateral tooth; carpocerite reaching about distal 0.2 of antennal scale. Antennal scale 0.5–0.6 times as long as carapace and 2.5 times longer than wide; lateral margin nearly straight; distolateral tooth reaching rounded distal margin of lamella.

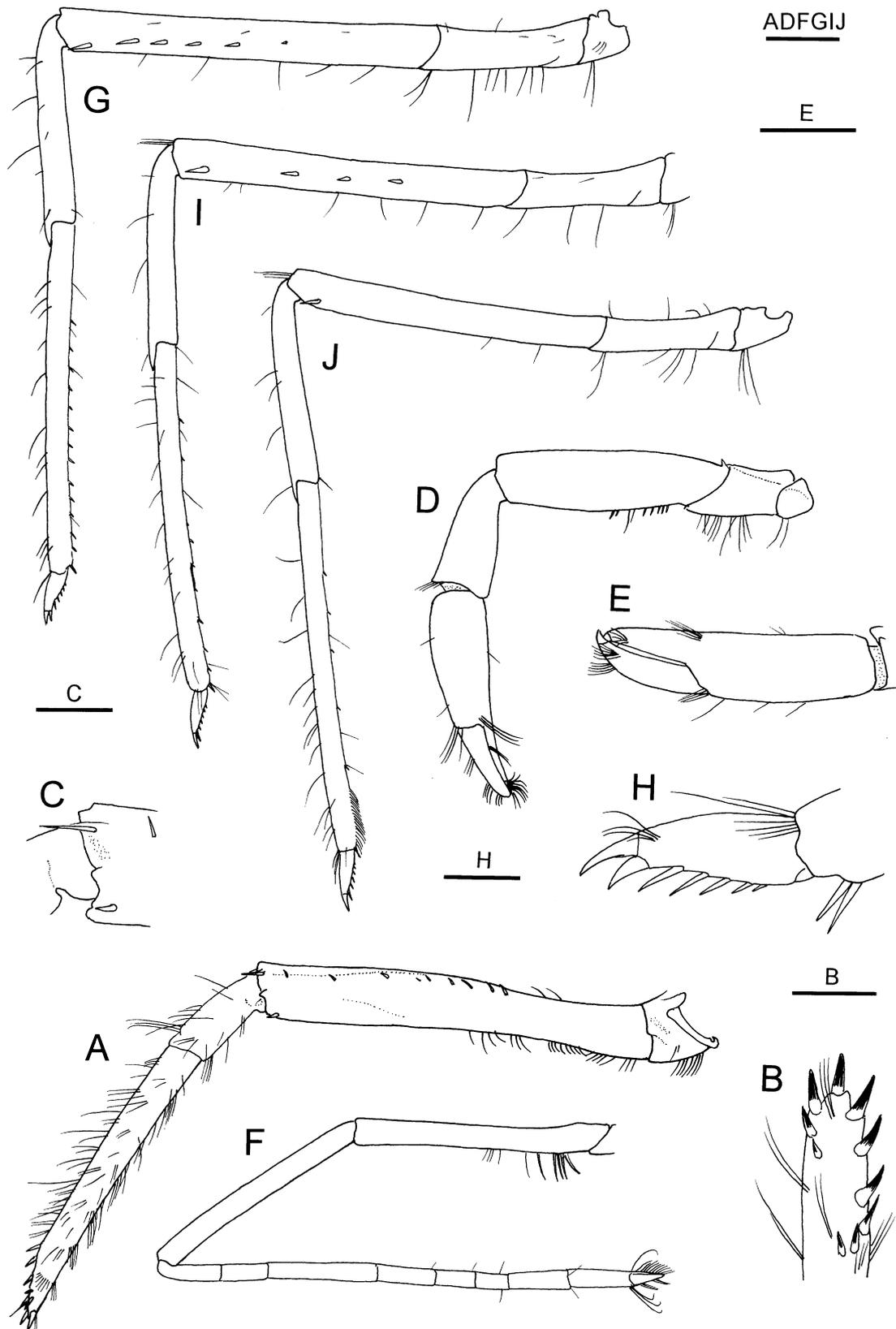
Mouthparts similar to those of other species of the genus. Third maxilliped (Fig. 8A) overreaching antennal scale by 0.9 length of ultimate segment; ultimate segment 2.8 times longer than penultimate segment, tapering distally, with short row of darkly pigmented corneous spines distomesially (Fig. 8B); antepenultimate segment subequal in length to two distal segments combined, armed with 1 small tooth and 1 long spiniform seta on distolateral margin and 1 spinule at ventrolateral distal angle (Fig. 8C); lateral surface with row of spiniform setae on blunt ridge adjacent to dorsal margin.

Strap-like, terminally hooked epipods present on third maxilliped to third pereopod, corresponding seto-branches present on first to fourth pereopod (Fig. 7F).

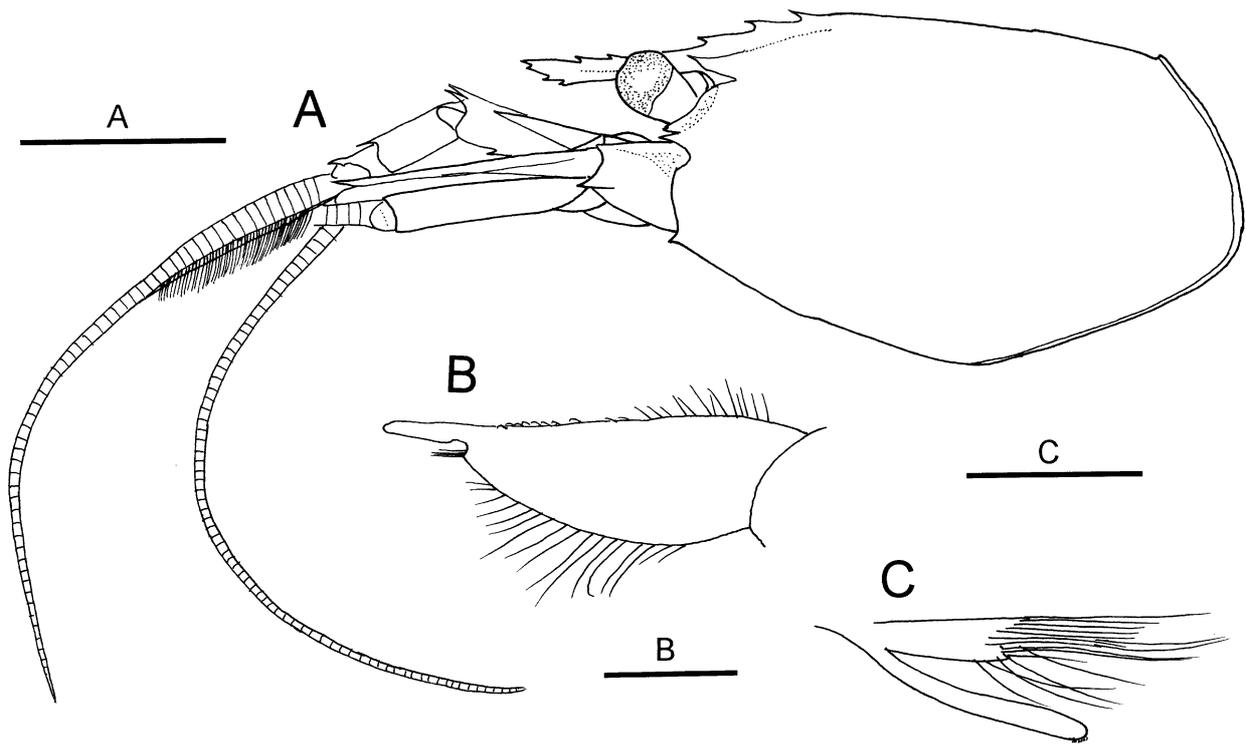
First pereopod (Fig. 8D) moderately stout, overreaching antennal scale by half length of dactylus; dactylus (Fig. 8E) about 0.7 times as long as palm, terminating in 2 darkly pigmented corneous claws; fixed finger terminating in single corneous claw. Second pereopod (Fig. 8F) overreaching antennal scale by about 0.7 length of carpus; dactylus terminating in 2 small corneous claws; carpus divided into 7 articles. Third to fifth pereopods moderately long and slender, similar in shape and subequal in length. Third pereopod (Fig. 8G) overreaching antennal scale by full length of propodus; dactylus (Fig. 8H) about 0.2 times as long as propodus, moderately stout (about 3.0 times longer than deep), terminating in acute, darkly pigmented unguis, armed with 6 darkly pigmented accessory spinules on flexor margin, distalmost accessory spinule subterminal, distinctly larger than others, making tip of dactylus appearing biunguiculate; carpus about 0.6 times as long as propodus; merus armed with 6 ventrolateral spines in distal half. Fourth pereopod (Fig. 8I) overreaching antennal scale by 0.7 length of propodus; merus with 4 ventrolateral spines. Fifth pereopod (Fig. 8J) overreaching distal margin of antennal scale by 0.3 length of propodus; merus with 1 spine at ventrolateral distal angle.



**FIGURE 7.** *Lebbeus pacmanus* sp. nov., holotype, female (cl 13.9 mm), DS *Shinkai 2000*, dive #1150, Pacmanus, Manus Basin, NSMT-Cr 21983. A, anterior part of carapace and cephalic appendages, lateral view; B, same, dorsal view; C, telson, dorsal view; D, posterior part of telson, dorsal view; E, left antennal peduncle and scale, ventral view; F, coxae of first to fourth pereopods, showing presence of epipods on first to third pereopod. Scale bars: 5 mm for A; 2 mm for B, C, E, F; 1 mm for D.



**FIGURE 8.** *Lebbeus pacmanus* sp. nov., holotype, female (cl 13.9 mm), DS *Shinkai* 2000, dive #1150, Pacmanus, Manus Basin, NSMT-Cr 21983. Left thoracic appendages. A, third maxilliped, lateral view; B, same, distal part of ultimate segment, dorsal (extensor) view; C, same, distal part of antepenultimate segment, lateral view; D, first pereopod, lateral view; E, same, chela, extensor view; F, second pereopod, lateral view; G, third pereopod, lateral view; H, same, dactylus, lateral view; I, fourth pereopod, lateral view; J, fifth pereopod, lateral view. Scale bars: 2 mm for A, D–F, G, I, J; 1 mm for B, C; 0.5 mm for H.



**FIGURE 9.** *Lebbeus pacmanus* sp. nov., paratype, male (cl 11.2 mm), DS *Shinkai 2000*, dive #1150, Pacmanus, Manus Basin, JAMSTEC 019524. A, carapace and cephalic appendages, lateral view; B, endopod of left first pleopod, dorsal (anterior) view; C, appendices interna and masculina of left second pleopod, mesial view. Scale bars: 5 mm for A; 1 mm for B; 0.5 mm for C.

*Male paratype.* Rostrum (Fig. 9A) more slender than in female, not reaching distal margin of first segment of antennular peduncle, 0.4 times as long as carapace; dorsal margin armed with 6 small teeth, including 3 on rostrum and 3 on carapace; ventral margin with 3 tiny teeth in distal 0.2. Carapace (Fig. 9A) with postrostral median ridge extending to midlength; dorsal margin in lateral view slightly convex with peak at posteriormost tooth of rostral series. Fourth abdominal pleuron with small but distinct posteroventral tooth. Telson with 6 pairs of dorsolateral spines; posterior margin with 4 spiniform setulose setae flanked by 2 pairs of lateral spines. Corneal width about 0.14 of carapace length (Fig. 9A). Antennular flagella (Fig. 9A) thicker and more elongate than in female, distinctly longer than carapace; outer flagellum with aestheasc-bearing portion occupying about 0.4 length of total length, about half-length of carapace. Third to fifth pereopods more slender than in female. Endopod of first pleopod (Fig. 9B) with poorly defined lobe just lateral to base of terminally located appendix interna. Second pleopod with appendix masculina shorter than appendix interna, bearing about 15 stiff setae (Fig. 9C).

**Coloration in life.** Not known.

**Distribution.** Known only from the PACMANUS site on the Manus Basin, at a depth of 1662 m.

**Etymology.** Named after the locality where the type specimens were collected.

**Remarks.** The three new species described in this paper all belong in a species group characterized by the presence of epipods on the anterior three pereopods. Differentiations of these three new species and close allies are discussed under “Remarks” of *Lebbeus thermophilus* sp. nov.

### *Lebbeus shinkaiae* sp. nov.

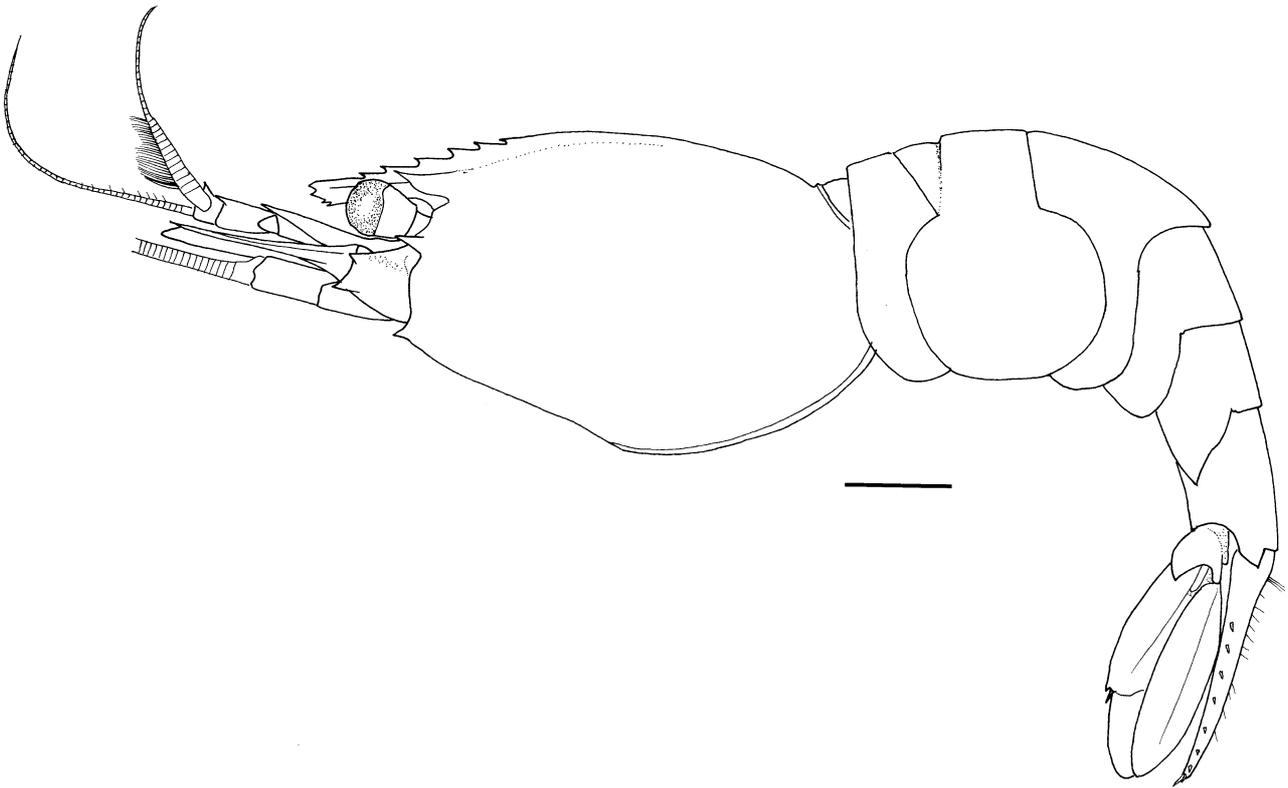
(Figs 10–13, 18)

*Lebbeus washingtonianus*: Kikuchi & Ohta 1995: 779, figs 8–12; Fujikura *et al.* 1995: 234; Watabe & Miyake 2000: 32; Komai *et al.* 2004: 121; Martin and Haney 2005: 471 (part); Hashimoto 2007: 198, unnumbered fig. Not *Lebbeus washingtonianus* (Rathbun, 1902).

**Material examined.** Holotype: DS *Shinkai* 2000, dive #1182, Hatoma Knoll, Okinawa Trough, 24°51.236'N, 123°50.600'E, 1474 m, 19 May 2000, female (cl 18.2 mm), NSMT-Cr 21982 (ex- JAMSTEC 028214).

Paratypes: DS *Shinkai* 2000, dive #1187, Hatoma Knoll, 24°51.216'N, 123°50.567'E, 1491 m, 26 May 2000, trap, 1 female (cl 13.0 mm), JAMSTEC 028210; dive #1273, Yonaguni Knoll No. 4, 24°50.912'N, 122°42.043'E, 1339 m, 24 May 2001, slurp gun, 1 male (cl 7.0 mm), 1 female (cl ca. 9.5 mm), JAMSTEC 043589–043594; ROV *Hyper-Dolphin*, dive #697, 28°23.498'N, 127°38'370'E, 691 m, 20 June 2007, 2 males (cl 7.0, 9.0 mm), 3 females (cl 6.3–13.3 mm), JAMSTEC 072424–072432; dive #700, Minami-Ensei Knoll, 28°23.347'N, 127°38.407'E, 712 m, 22 June 2007, 1 male (cl 8.0 mm), 2 females (cl 10.0, 11.6 mm), JAMSTEC 072571–072575.

**Description.** *Females.* Body (Fig. 10) moderately robust for genus; integument moderately firm, surface glabrous.



**FIGURE 10.** *Lebbeus shinkaiiae* sp. nov., holotype, female (cl 18.2 mm), DS *Shinkai* 2000, dive #1182, Hatoma Knoll, Okinawa Trough, Japan, NSMT-Cr 21982. Body (thoracic appendages and pleopods omitted) in lateral view. Scale bar: 5 mm.

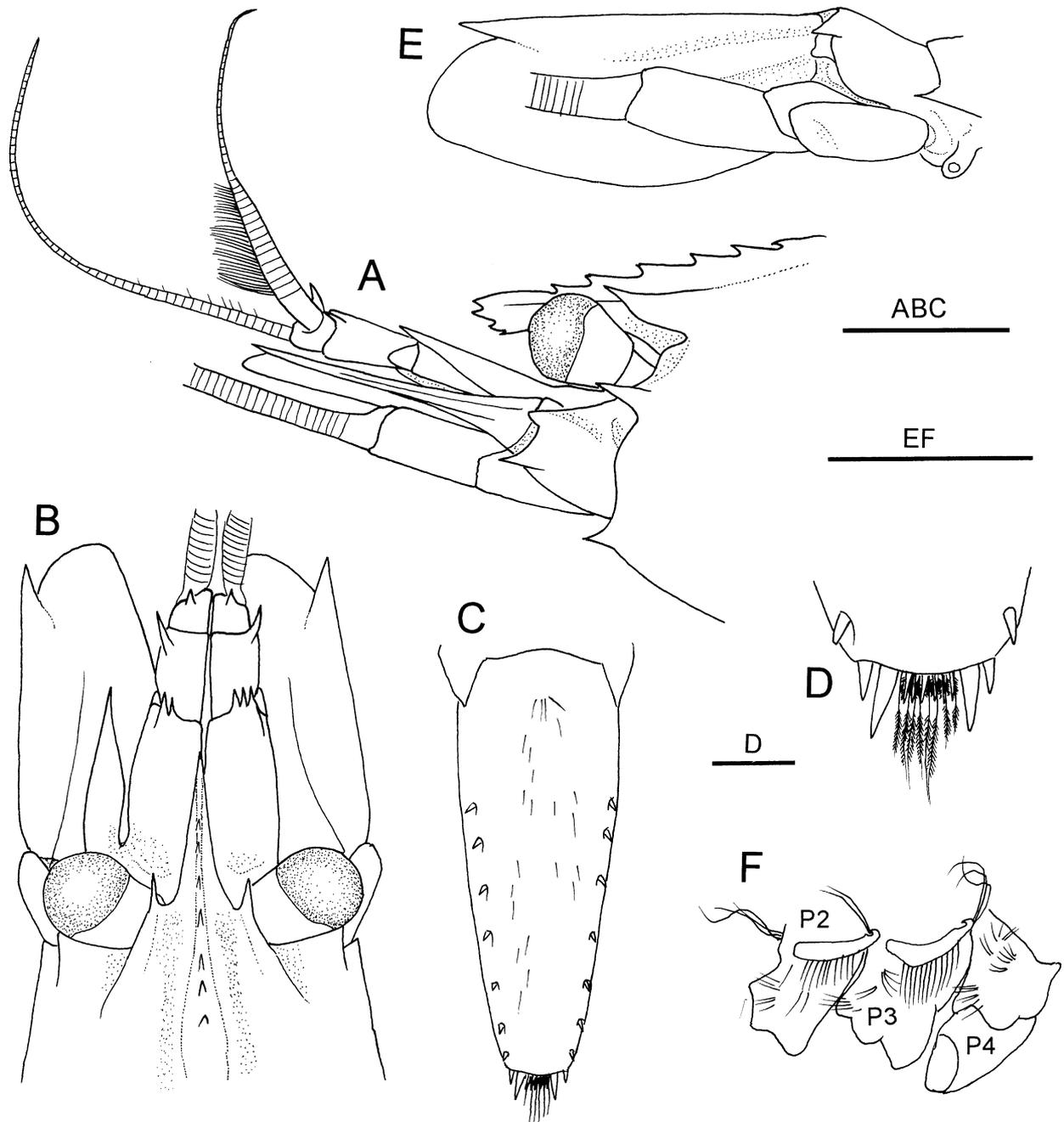
Rostrum (Figs. 10, 11A, B) straight, directed forward or slightly descending, falling short of or reaching distal margin of first segment of antennular peduncle, 0.3–0.4 times carapace length; dorsal margin armed with 6–10 teeth, including 3–5 teeth on rostrum proper and 3–5 postrostral teeth; ventral margin armed with 1–3 small teeth clustered subterminally, ventral lamina slightly developed. Carapace (Figs. 10, 11A, B) with low but distinct postrostral median carina extending to at least midlength of carapace, sloping toward rostral base; postrostral teeth relatively small, posteriormost one arising at 0.1–0.2 of carapace length; dorsal margin in lateral view gently convex; supraorbital tooth moderately strong, slightly upturned, arising anterior to level of rostral base, reaching or slightly overreaching tip of antennal tooth; orbital region depressed, orbital margin with convexity, base of eyestalk located between this convexity and suborbital lobe; deep U- or V-shaped notch present below base of supraorbital tooth; suborbital lobe well developed, triangular, reaching distal margin of antennal tooth; anterolateral margin between antennal and pterygostomial teeth strongly sinuous with shallow excavation below antennal tooth.

Abdomen (Fig. 10) dorsally rounded. Second somite with deep transverse groove, posteriorly forming low but distinct ridge. Pleura of anterior three somites broadly rounded; fourth pleuron unarmed or armed with small posteroventral tooth; fifth pleuron with moderately strong posteroventral tooth. Sixth somite about 1.6 times longer than fifth somite and 1.6 times longer than deep, bearing small posteroventral tooth; posterolateral process terminating in small tooth. Telson (Fig. 11C) 1.6–1.7 times longer than sixth somite, tapering to slightly convex poste-

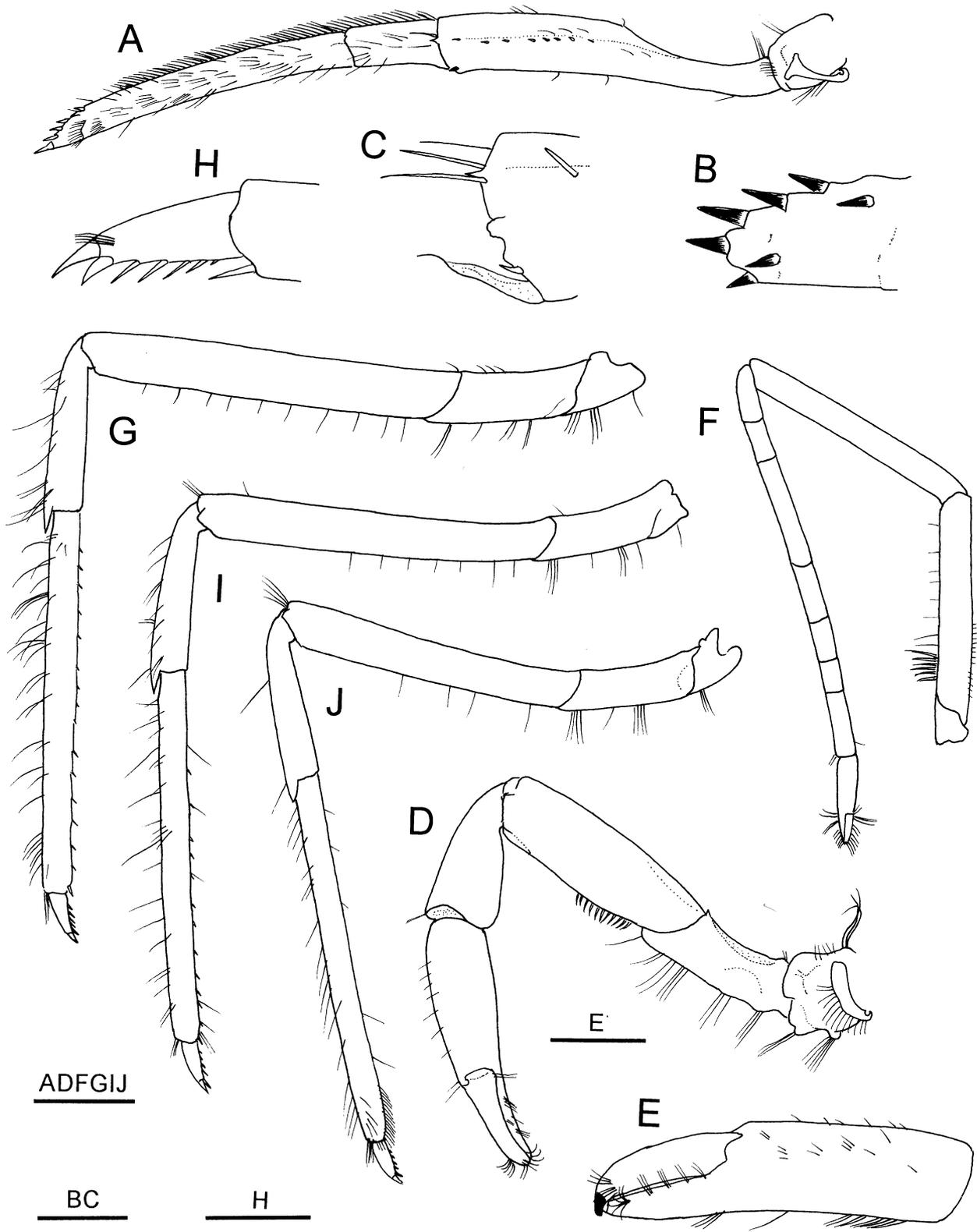
rior margin, bearing 5–7 (rarely 4) dorsolateral spines on each side; posterior margin with 2 pairs of lateral spines (mesial pair longer), 5–6 spiniform setulose setae and several longer thin plumose setae (Fig. 11D).

Eye (Fig. 11A, B) subpyriform with stalk slightly narrowing proximally; cornea not dilated, its maximum width about 0.15 of carapace length; ocellus absent.

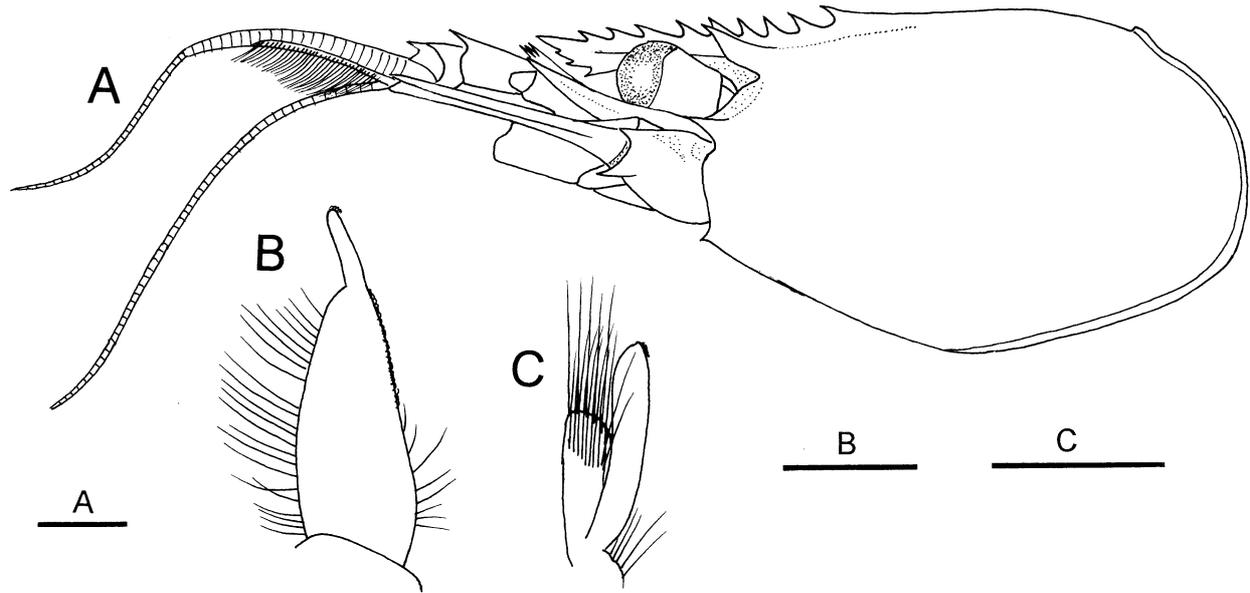
Antennular peduncle (Fig. 11A, B) reaching distal 0.2–0.3 of antennal scale. First segment distinctly longer than distal two segments combined, slightly overreaching midlength of antennal scale, dorsodistal margin armed with 1–3 small teeth; stylocerite reaching or slightly overreaching distolateral angle of first peduncular segment, sharply pointed, mesial margin sinuous. Second segment 0.4 length of first segment, with 1 large dorsolateral distal tooth. Third segment less than half as long as second segment, bearing 1 small dorsodistal tooth. Lateral flagellum with thickened aesthetasc-bearing portion about 0.3 times as long as carapace.



**FIGURE 11.** *Lebbeus shinkaiiae* sp. nov., holotype, female (cl 18.2 mm), DS *Shinkai 2000*, dive #1182, Hatoma Knoll, Okinawa Trough, Japan, NSMT-Cr 21982. A, anterior part of carapace and cephalic appendages, lateral view; B, same, dorsal view; C, telson, dorsal view; D, posterior part of telson, dorsal view; E, left antennular peduncle and scale, ventral view; F, coxae of second to fourth pereopods, showing presence of epipod on third pereopod. Scale bars: 5 mm for A–C, E, F; 1 mm for D.



**FIGURE 12.** *Lebbeus shinkaiiae* sp. nov., holotype, female (cl 18.2 mm), DS *Shinkai 2000*, dive #1182, Hatoma Knoll, Okinawa Trough, Japan, NSMT-Cr 21982. Left thoracic appendages. A, third maxilliped, lateral view; B, same, distal part of ultimate segment, dorsal (extensor) view; C, same, distal part of antepenultimate segment, lateral view; D, first pereopod, lateral view; E, same, chela, extensor view; F, second pereopod, lateral view; G, third pereopod, lateral view; H, same, dactylus, lateral view; I, fourth pereopod, lateral view; J, fifth pereopod, lateral view. Scale bars: 2 mm for A, D–F, G, I, J; 1 mm for B, C, H.



**FIGURE 13.** *Lebbeus shinkaiae* sp. nov., paratype, male (cl 9.0 mm), JAMSTEC 072424–072432. A, carapace and cephalic appendages, lateral view; B, endopod of left first pleopod, dorsal (anterior) view; C, appendices interna and masculina of left second pleopod, mesial view. Scale bars: 2 mm for A; 1 mm for B, C.

Antenna (Fig. 11A, B, E) with basicerite bearing moderately small ventrolateral tooth; carpoperite reaching midlength of antennal scale. Antennal scale about 0.5 times as long as carapace and 2.4 times longer than wide; lateral margin nearly straight; distolateral tooth not reaching rounded distal margin of lamella.

Mouthparts similar to those of other species of the genus. Third maxilliped (Fig. 12A) overreaching antennal scale by 0.6–0.7 length of ultimate segment; ultimate segment 3.6–3.7 times longer than penultimate segment, tapering distally, with short row of darkly pigmented corneous spines distomesially (Fig. 12B); antepenultimate segment shorter than distal two segments combined, armed with 1 small tooth on distolateral margin and 1 minute spinule at ventrolateral distal angle (Fig. 12C); lateral surface bluntly ridged.

Strap-like, terminally hooked epipods present on third maxilliped to third pereopod, corresponding seto-branches present on first to fourth pereopod (Fig. 11F).

First pereopod (Fig. 12D) moderately stout, reaching distal margin of antennal scale; dactylus (Fig. 12E) about 0.7 times as long as palm, terminating in 2 darkly pigmented corneous claws; fixed finger terminating in single corneous claw. Second pereopod (Fig. 12F) overreaching antennal scale by 0.4 length of carpus; dactylus terminating in 2 small corneous claws; carpus divided into 7 articles. Third to fifth pereopods moderately long and slender, similar and slightly decreasing in length posteriorly. Third pereopod (Fig. 12G) overreaching antennal scale by 0.6–0.7 length of propodus; dactylus (Fig. 12H) 0.15–0.18 times as long as propodus, moderately stout (3.0–3.2 times longer than deep), terminating in acute, darkly pigmented unguis, armed with 4 or 5 darkly pigmented accessory spinules on flexor margin, distalmost accessory spinule subterminal, distinctly larger than others, making tip of dactylus appearing biunguiculate; carpus about 0.5 times as long as propodus; merus armed with 0–5 lateral spines. Fourth pereopod (Fig. 12I) overreaching antennal scale by 0.3 length of propodus; merus with 0–5 ventrolateral spines. Fifth pereopod (Fig. 12J) overreaching distal margin of antennal scale by length of dactylus; merus unarmed or armed with 1 lateral spine.

*Males.* Carapace (Fig. 13A) with nearly straight dorsal margin in lateral view; postrostral median carina extending beyond midlength of carapace. Fourth abdominal pleuron bearing small but distinct posteroventral tooth. Antennular peduncle (Fig. 13A) reaching nearly to distal margin of antennal scale; outer antennular flagellum with thickened aesthetasc-bearing portion about 0.4 times as long as carapace; inner flagellum thin, subequal in length to carapace. Endopod of first pleopod (Fig. 13B) without lobe just lateral to base of terminally located appendix interna. Appendix masculina on second pleopod shorter than appendix interna, bearing about 15 setae in distal 0.4 (Fig. 13C).

**Coloration in life.** Entirely reddish or light yellowish brown or tan. Cornea darkly pigmented.

**Distribution.** Okinawa Trough, Japan, 691–1491 m.

**Ecology.** In the vent fields of the Hatoma Knoll, this species was abundant in deep-sea mussel beds, *Bathymodiolus platifrons* Hashimoto & Okutani, 1994. Other decapod crustaceans seen in the vent fields include the alvinocaridid shrimps *Alvinocaris longirostris* Kikuchi & Ohta, 1995 and *Shinkaicaris leurokolos* (Kikuchi & Hashimoto, 2000) and the galatheoid squat lobster *Shinkaia crosnieri* Baba & Williams, 1998. Observation of video recordings showed that individuals of *Lebbeus shinkaiae* pick some food items (probably bacterial mats) from the substrate by using the chelae of the first pereopods. It was found that they aggregate on the broken mussels for food.

**Etymology.** From the name of the deep submersible *Shinkai 2000*, which contributed substantially to biological studies of chemosynthetic communities.

### ***Lebbeus thermophilus* sp. nov.**

(Figs 14–17)

*Lebbeus* sp. aff. *washingtonianus*: Komai & Segonzac 2004: 1179.

*Lebbeus* sp. A: Martin & Haney 2005: 449, table 1.

**Material examined.** Holotype: RV *Natsushima*/DS *Shinkai 2000*, NT99-15 cruise, dive #1150, PACMANUS, Manus Basin, Bismarck Sea, 03°43.267'S, 151°40.480'E, 1662 m, 7 November 1999, female (cl 11.3 mm), NSMT-Cr 21984 (ex-JAMSTEC 019523–019525).

Paratypes: Manus Basin, Drill Ship *Hunter*/ROV TST212 *Canyon Offshore*, dive #0011, Suzette Vent Field, Binns Mound, 03°58.1168'N, 152°93.65'E, 1512 m, June 2005, 1 ovigerous female (cl 16.1 mm), MNHN-IU-2011-5720; 2007 Wave Mercury cruise, dive #36, site South Su, 03°50.97'S, 152°10.53'E, 1323 m, 16 April 2007, 4 females (cl 10.5–19.0 mm), 1 male (cl 9.8 mm), CBM-ZC 10661; dive #38, same site, 16 April 2007, 4 females (cl 9.0–18.0 mm), CBM-ZC 10662.

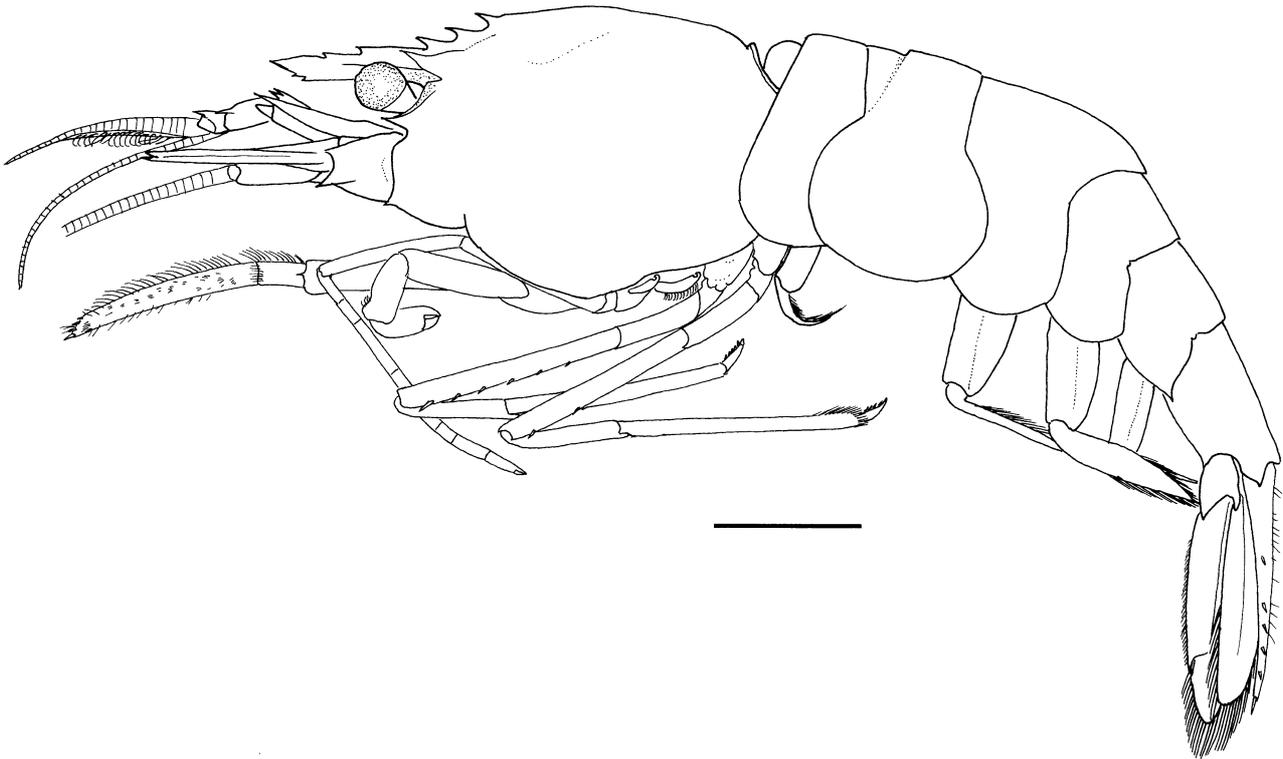
Lau Basin, BIOLAU, BL 02, site Hine Hina, 22°32'S, 176°43'W, 1842 m, 14 May 1989, baited trap, 1 female (cl 19.2 mm), MNHN-IU-2011-5140; BL 03, same site, 15 May 1989, baited trap, 16 females (cl 7.6–18.4 mm), 2 ovigerous females (cl 15.1, 15.8 mm), 2 males (cl 9.0, 9.5 mm), MNHN-IU-2011-5719; BL 06, 1 juvenile (cl 5.0 mm), MNHN-IU-2011-5145; BL 08, site Vailili, 23°13'S, 176°38'W, 1740 m, 18 May 1989, slurp gun, 4 females (cl 8.8–15.8 mm), 1 male (cl 9.5 mm), 1 juvenile (cl 5.9 mm), MNHN-IU-2011-5139; same data, 2 females (cl 13.0, 17.2 mm), MNHN-IU-2011-5141; BL 10, same site, 22 May 1989, slurp gun, 2 females (cl 13.1, 14.3 mm), MNHN-IU-2011-5142; BL 11, same site, 23 May 1989, slurp gun, 1 female (cl 7.3 mm), MNHN-IU-2011-5144; BL 12, same site, 24 May 1989, baited trap, 1 female (cl 10.7 mm), MNHN-IU-2011-5143.

**Description.** *Females.* Body (Fig. 14) moderately robust for genus; integument moderately firm, surface glabrous.

Rostrum (Figs. 14A, 15A, B) straight, directed forward, reaching or slightly falling short of distal margin of first segment of antennular peduncle, 0.4–0.5 times carapace length; dorsal rostral series consisting of 5 teeth, including 2 small teeth on rostrum proper and 2 or 3 small to moderately small postrostral teeth, ventral margin armed with 2 tiny subterminal teeth, ventral lamina slightly developed. Carapace (Figs. 14, 15A, B, 17D) with low postrostral median carina (extending to anterior 0.2–0.3 to posterodorsal margin of carapace); posteriormost postrostral tooth arising at about 0.2 of carapace length; dorsal margin in lateral view gently to strongly convex; supraorbital tooth moderately strong, slightly ascending, gradually tapering distally, located at level of posterior margin of orbit, not reaching tip of antennal tooth; orbital margin with distinct convexity posteriorly, base of eye-stalk located between this convexity and suborbital lobe; deep V-shaped notch present below base of supraorbital tooth; suborbital lobe well developed, triangular, reaching tip of antennal tooth; anterolateral margin between antennal and pterygostomial teeth strongly sinuous with relatively shallow concavity below antennal tooth.

Abdomen (Fig. 14) dorsally rounded. Second somite with distinct transverse ridge accompanied by shallow groove on tergum. Pleura of anterior three somites broadly rounded; fourth pleuron rounded or with tiny posteroventral denticle; fifth pleuron with moderately strong posteroventral tooth. Sixth somite about 1.5–1.6 times longer than fifth somite and 1.7–1.8 times longer than high, bearing tiny posteroventral tooth; posterolateral process terminating in small tooth. Telson (Fig. 15C) 1.6 times longer than sixth somite, tapering to gently convex posterior

margin, bearing 4–6 dorsolateral spines on either side; posterior margin with 2 pairs of lateral spines (mesial pair longer) and 6 spiniform setulose setae (Fig. 15D).



**FIGURE 14.** *Lebbeus thermophilus* sp. nov., holotype, female (cl 11.3 mm), DS *Shinkai 2000*, dive #1150, Pacmanus, Manus Basin, NSMT-Cr 21984, entire animal in lateral view (left third pereopod and second pleopod missing). Scale bar: 5 mm.

Eye (Fig. 15A, B) subpyriform with stalk narrowing proximally; cornea weakly dilated, slightly wider than stalk, its maximum width approximately 0.2 of carapace length; ocellus absent.

Antennular peduncle (Fig. 15A, B) reaching distal 0.2–0.3 of antennal scale. First segment distinctly longer than distal two segments combined, slightly falling short of midlength of antennal scale, dorsodistal margin armed with 2 or 3 slender teeth; stylocerite reaching or slightly overreaching distolateral margin of first peduncular segment, sharply pointed, mesial margin sinuous. Second segment about 0.4 length of first segment, with 1 strong dorsolateral distal tooth. Third segment less than half as long as second segment, bearing 1 small dorsodistal tooth. Lateral flagellum with thickened aesthetasc-bearing portion about 0.3 times as long as carapace.

Antenna (Fig. 15A, B, E) with basicerite bearing moderately small ventrolateral tooth; carpocerite reaching midlength of antennal scale. Antennal scale 0.60 times as long as carapace and 2.5 times longer than wide; lateral margin nearly straight; distolateral tooth nearly reaching rounded distal margin of lamella.

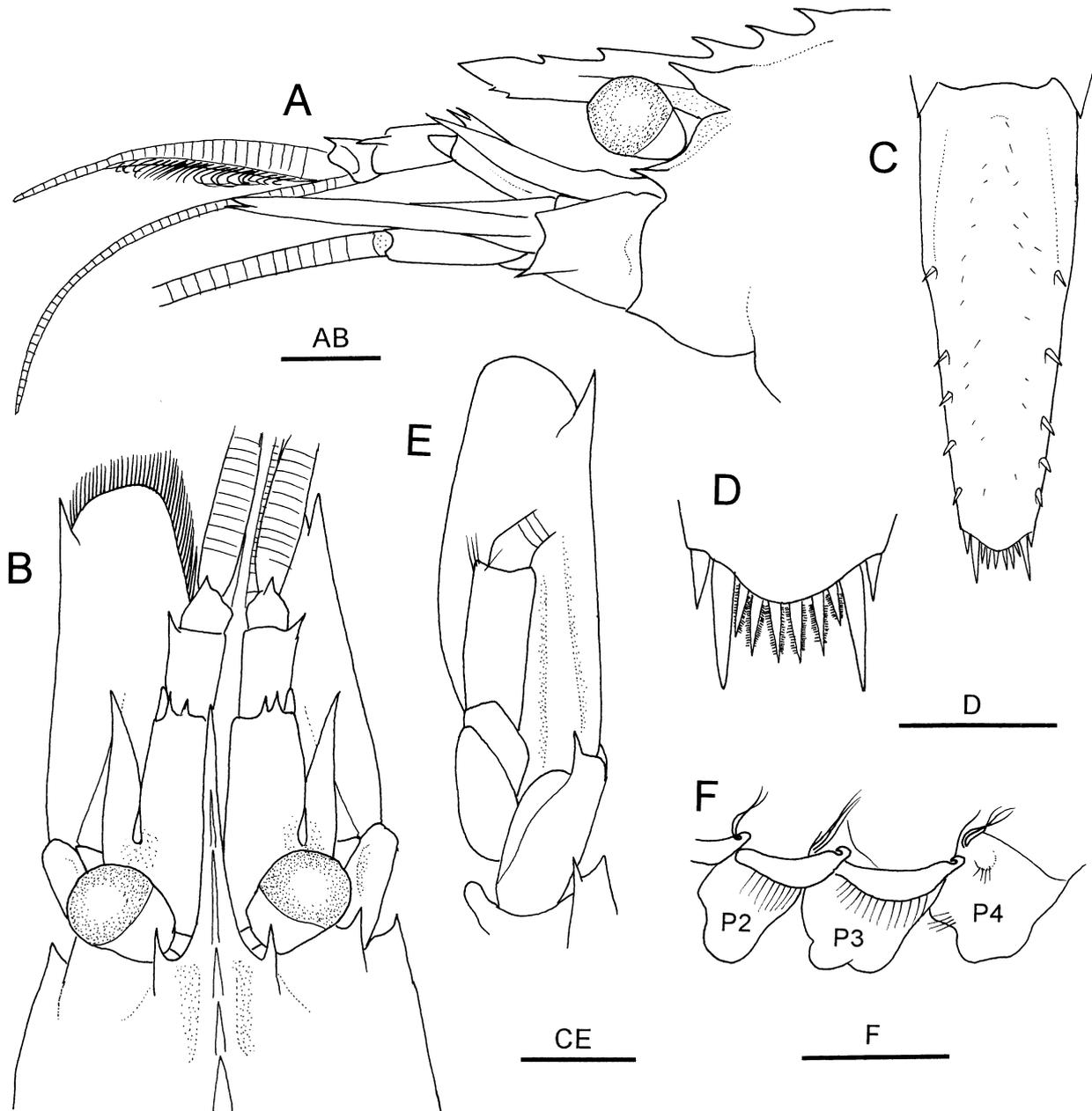
Mouthparts similar to those of other species of the genus. Third maxilliped (Fig. 16A) overreaching antennal scale by half-length of ultimate segment; ultimate segment 3.6 times longer than penultimate segment, tapering distally, with short row of darkly pigmented corneous spines distomesially (Fig. 16B); antepenultimate segment about 0.9 times as long as two distal segments combined, armed with 1 small tooth and 2 spiniform setae on distolateral margin and 1 spinule at ventrolateral distal angle (Fig. 16C); lateral surface with row of single or paired spiniform setae on blunt ridge adjacent to dorsal margin.

Strap-like, terminally hooked epipods present on third maxilliped to third pereopod, corresponding seto-branches present on first to fourth pereopod (Fig. 15F).

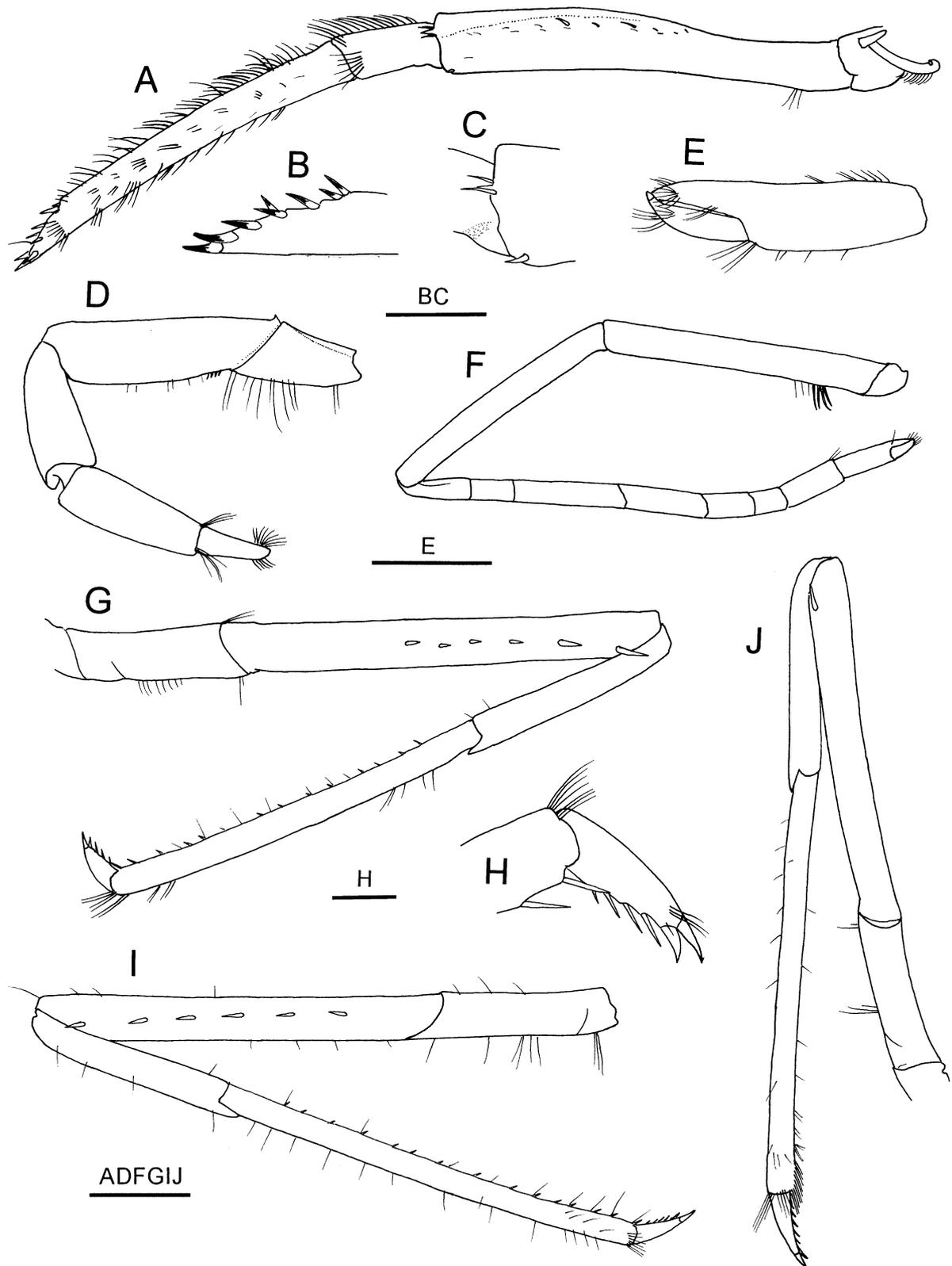
First pereopod (Fig. 16D) moderately stout, slightly overreaching midlength of antennal scale; dactylus (Fig. 16E) about 0.7 times as long as palm, terminating in 2 darkly pigmented corneous claws; fixed finger terminating in single corneous claw. Second pereopod (Fig. 16F) overreaching antennal scale by about 0.4 length of carpus; carpus divided into 7 articles. Third to fifth pereopods moderately long and slender, similar in shape and subequal in length. Third pereopod (Fig. 16G) overreaching antennal scale by about 0.8 length of propodus; dactylus (Fig. 16H) 0.20 times as long as propodus, moderately stout (about 3.9 times longer than deep), terminating in acute,

pigmented unguis, armed with 5–6 accessory spinules on flexor margin, distalmost accessory spinule subterminal, distinctly larger than others, making tip of dactylus appearing biunguiculate; carpus about 0.6 times as long as propodus; merus armed with 6 lateral spines in distal two-thirds. Fourth pereopod (Fig. 16I) overreaching antennal scale by 0.4–0.5 length of propodus; merus with 4–6 lateral spines. Fifth pereopod (Fig. 16J) overreaching distal margin of antennal scale by 0.2–0.3 length of propodus; merus with 1 spine at ventrolateral distal angle.

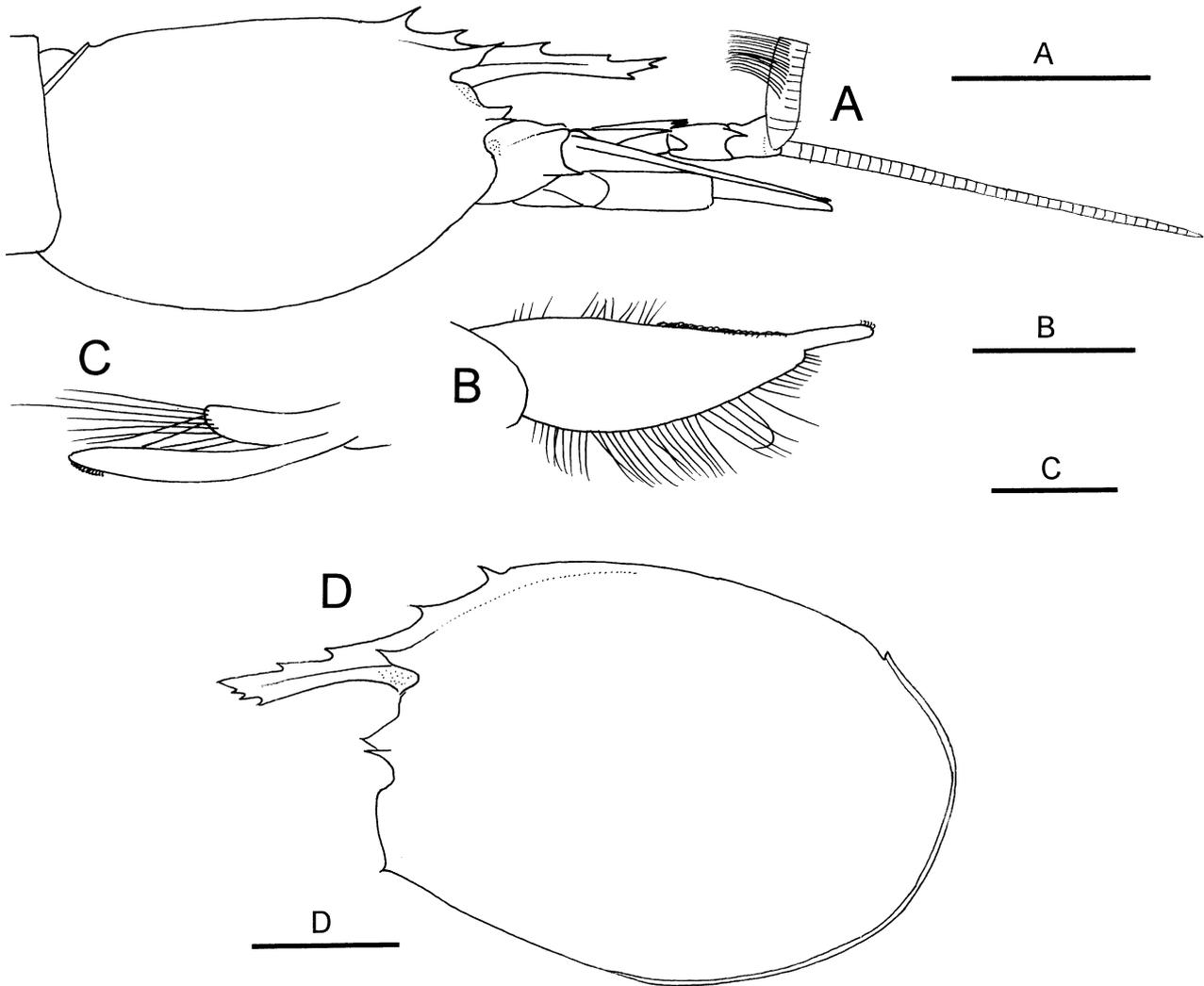
*Males.* Carapace (Fig. 17A) with nearly straight dorsal margin in lateral view; postrostral median carina extending beyond midlength of carapace. Fourth abdominal pleuron bearing small but distinct posteroventral tooth. Antennular peduncle (Fig. 17A) reaching distal 0.2 of antennal scale; outer antennular flagellum with thickened aesthetasc-bearing portion about 0.4 times as long as carapace; inner flagellum slightly longer than carapace. Endopod of first pleopod (Fig. 17B) with narrow lobe just lateral to base of terminally located appendix interna. Appendix masculina on second pleopod shorter than appendix interna, bearing about 15 stiff setae (Fig. 17C).



**FIGURE 15.** *Lebbeus thermophilus* sp. nov., holotype, female (cl 11.3 mm), DS *Shinkai 2000*, dive #1150, Pacmanus, Manus Basin, NSMT-Cr 21984. A, anterior part of carapace and cephalic appendages, lateral view; B, same, dorsal view; C, telson, dorsal view; D, posterior part of telson, dorsal view; E, left antennal peduncle and scale, ventral view; F, coxae of second to fourth pereopods, showing presence of epipod on third pereopod. Scale bars: 2 mm for A–C, E, F; 1 mm for D.



**FIGURE 16.** *Lebbeus thermophilus* sp. nov., holotype, female (cl 11.3 mm), DS *Shinkai 2000*, dive #1150, Pacmanus, Manus Basin, NSMT-Cr 21984. A, left third maxilliped, lateral view; B, distal part of ultimate segment of right third maxilliped, mesial view; C, same, distal part of antepenultimate segment, lateral view; D, left first pereopod, lateral view; E, same, chela, extensor view; F, left second pereopod, lateral view; G, right third pereopod, lateral view; H, same, dactylus, lateral view; I, left fourth pereopod, lateral view; J, left fifth pereopod, lateral view. Scale bars: 2 mm for A, D–G, I, J; 1 mm for B, C; 0.5 mm for H.



**FIGURE 17.** *Lebbeus thermophilus* sp. nov. A–C, paratype, male (cl 9.8 mm), 2007 Wave Mercury cruise, dive #36, Manus Basin, CBM-ZC 10661; D, paratype, female (cl 13.9 mm), same lot. A, carapace and cephalic appendages, lateral view (eye broken off, outer antennular flagellum damaged); B, endopod of right first pleopod; C, appendices interna and masculina of right second pleopod, mesial view; D, carapace, lateral view. Scale bars: 5 mm for A, D; 1 mm for B; 0.5 mm for C.

**Size.** Largest female cl 19.2 mm, ovigerous female cl 16.1 mm; largest male cl 9.5 mm.

**Coloration in life.** Not known.

**Distribution.** Recorded from two locations in the Southwest Pacific, Manus Basin and Lau Basin, 1512–1842 m.

**Etymology.** The species name, *thermophilus*, is the combination of the Greek, “thermos” (= hot), and “philos” (= loving), in reference to the habitat of the new species.

**Ecology.** The associated fauna of the sites in the Lau Basin where this new species occurs, i.e., Hina Hina (1842 m), Tu’i Malila (1890 m), and Vailili (1740 m), was described by Desbruyères *et al.* (1994). Video recordings taken during the BIOLAU cruise are available for this study. On the videos, this species is easily recognizable by the prominent eyes, as other shrimp fauna includes only alvinocaridids having reduced corneas. The videos show that individuals of *Lebbeus thermophilus* live among and above the molluscan beds composed of gastropods *Alviniconcha hessleri* Okutani & Ohta, 1998 and *Ifremeria nautilei* Bouchet & Warén, 1991, and mussels *Bathymodiolus brevior* Cosel, Métivier, Hashimoto, 1994, where the density of the shrimps could reach several tens of individuals/m<sup>2</sup>. The temperature of the habitat varies between 6 and 12°C (Desbruyères *et al.* 1994). Some individuals were also observed at some meters of the active sites.



**FIGURE 18.** Photographs taken in situ. A, *Lebbeus laurentae* Wicksten, 2010, one individual is seen on a tube of *Riftia pachyptila* Jones, 1981, EPR 13°N, taken during the HOPE 99 cruise (The blue color of the tubes of *R. pachyptila* is artificial, resulting from a growth experiment); B, *Lebbeus shinkaiae* **sp. nov.**, photograph taken at Hatoma Knoll, Okinawa Trough, 1493 m deep, two individuals are seen together with individuals of *Alvinocaris longirostris* Kikuchi and Ohta, 1995 and *Shinkaia crosnieri* Baba & Williams, 1998.

**Remarks.** The three new species described in this study all belong to the species group characterized by the possession of epipods on the anterior three pairs of pereopods, and are morphologically similar to the following 10 species: *L. antarcticus*, *L. carinatus*, *L. cristatus*, *L. formosus*, *L. kuboi*, *L. microceros*, *L. polyacanthus*, *L. similior*, *L. washingtonianus*, and *L. wera*. Shared characters include: rostrum not reaching distal margin of second segment of antennular peduncle, styliform rather than spiniform, bearing four or more dorsal teeth including postrostral teeth and more than one ventral teeth; distinct notch present inferior to base of supraorbital tooth; anterolateral margin of carapace between antennal and pterygostomial teeth strongly sinuous with deep concavity just below antennal tooth; first segment of antennular peduncle armed with more than one teeth on dorsodistal margin; and dactyli of third to fifth pereopods clearly biunguiculate. Differentiating characters among these species are summarized in Table 1.

In having an elongate antennular peduncle (reaching nearly to the distal margin of the antennal scale) with a relatively short stylocerite (not reaching the distal margin of the first segment of the antennular peduncle) and the relatively long antennal carpocerite distinctly overreaching the midlength of the antennal scale, *L. pacmanus* **sp. nov.** most closely resembles *L. washingtonianus*. *Lebbeus pacmanus* differs from *L. washingtonianus* in the following characters: (1) the rostrum is straight and does not reach the distal margin of the first segment of the antennular peduncle in *L. pacmanus*, rather than slightly curving dorsally and reaching the distal margin of the first segment of the antennular peduncle in *L. washingtonianus*; (2) the dorsal rostral teeth are six, including two or three postorbital in *L. pacmanus*, whereas four or five including two postrostral in *L. washingtonianus*; (3) the distolateral tooth of the antennal scale reaches the distal margin of the lamella in *L. pacmanus*, but falling short of it in *L. washingtonianus*; and (4) the first pereopod overreaches the distal margin of the antennal scale in *L. pacmanus*, rather than just reaching it in *L. washingtonianus*. In the relatively short antennular stylocerite, *L. antarcticus* and *L. similior* are also similar to *L. pacmanus* **sp. nov.** The former two species differ from *L. pacmanus* in the shorter antennular peduncle (reaching or falling short of the base of distolateral tooth of the antennal scale versus nearly reaching the distal margin of lamella of antennal scale) and the shorter distolateral tooth of the antennal scale (distinctly falling short of the lamella versus reaching it). Furthermore, *L. antarcticus* is distinguished from *L. pacmanus* in the shorter third maxilliped (slightly overreaching the distal margin of lamella of the antennal scale versus overreaching it by the 0.7–0.9 length of the ultimate segment) and more numerous meral spines on the third and fourth pereopods (eight versus six for the third pereopod, four versus six for the fourth pereopod). *Lebbeus similior* is further separated from *L. pacmanus* by the fewer dorsolateral spines on the telson (five to seven versus four).

Among the species characterized by a relatively long antennular stylocerite (reaching or slightly overreaching the dorsodistal margin of the first segment of the antennular peduncle), *L. shinkaiiae* **sp. nov.** is most similar to *L. polyacanthus* and *L. wera* in having relatively numerous dorsal rostral teeth (six or more versus less than six). However, this new species is characteristic in having the supraorbital tooth arising anterior to the rostral base and the presence of thin plumose setae in addition to the five or six spiniform setulose setae on the posterior margin of the telson. In the latter three species, the supraorbital tooth arises at the level of the rostral base or slightly posterior to it; and the posterior margin of the telson lacks thin plumose setae. *Lebbeus polyacanthus* is further distinguished from *L. shinkaiiae* by the more posteriorly arising posteriormost postrostral tooth on the carapace (at 0.1–0.2 of the carapace length versus about 0.4), the constant presence of a posteroventral tooth on the fourth abdominal pleuron, much more numerous meral spines on the third to fifth pereopods (see Table 1 for the precise counts). *Lebbeus wera* differs from *L. shinkaiiae* in the more posteriorly arising posteriormost postrostral tooth (at 0.3 of the carapace length versus 0.1–0.2).

*Lebbeus thermophilus* **sp. nov.** is very similar to *L. carinatus*, *L. cristatus*, *L. formosus*, *L. kuboi*, and *L. microceros* in having relatively few dorsal rostral teeth (five or less) and the stylocerite reaching or slightly overreaching the dorsodistal margin of the first segment of the antennular peduncle. *Lebbeus carinatus* can be distinguished from *L. thermophilus* by the shorter third maxilliped (reaching to the distal margin of the antennal scale versus overreaching it by about 0.5 length of the ultimate segment). *Lebbeus cristatus* is separated from *L. thermophilus* by the fewer meral spines on the third and fourth pereopods (two or three versus five or six for the third pereopod, four to six versus one for fourth pereopod). *Lebbeus formosus* can be separated from *L. thermophilus* by fewer dorsolateral spines on the telson (three or four versus four to six) and the smaller body size (13.7 mm in cl versus 19.2 mm). *Lebbeus kuboi* differs from *L. thermophilus* in the more elongate antennular peduncles (reaching or slightly overreaching the distal margin of the antennal scale versus far falling short of it) with a greatly elongate

TABLE 1. Comparison among the three new species of *Lebbeus* and 10 allied congeners. ND = no data.

Characters/species	<i>L. pacamanus</i> sp. nov.	<i>L. shinkaizae</i> sp. nov.	<i>L. thermophilus</i> sp. nov.
Rostrum	straight	straight	straight
Shape	6, including 2–3 postrostral	6–10, including 3–5 postrostral	5, including 2–3 postrostral
No. of dorsal teeth	about 0.1	0.1–0.2	0.1–0.2
Carapace	arising at level of rostral base, directed forward	arising anterior to rostral base, slightly ascending	arising at level of rostral base, directed forward
Position of last postrostral tooth	present	variable	variable
Supraorbital tooth			
Posteroventral tooth of fourth abdominal pleuron			
Telson			
No. of dorsolateral spines on each side	5–7	5–7	4–6
Armature of posterior margin (except 2 pairs of lateral spines)	3–4 spiniform setulose setae	5–6 spiniform setulose setae and several thin plumose setae	6 spiniform setulose setae
Antennular peduncle extension (female)	almost reaching distal margin of antennal scale	reaching level of base of distolateral tooth of antennal scale	far falling short of base of dorsolateral tooth of antennal scale
Antennular peduncle extension (male)	almost reaching distal margin of antennal scale	reaching level of base of distolateral tooth of antennal scale	ND
Extension of stylocerite	far falling short of dorsodistal margin of first segment of antennular peduncle reaching lamella	reaching to dorsodistal margin of first segment of antennular peduncle not reaching lamella	slightly overreaching dorsodistal margin of first segment of antennular peduncle not reaching lamella
Antennal scale distolateral tooth	reaching distal 0.2 of antennal scale	reaching midlength of antennal scale	reaching midlength of antennal scale
Antennal carapocerite extension			
Third maxilliped extension	overreaching antennal scale by 0.7–0.9 length of ultimate segment with tiny spiniform tooth	overreaching antennal scale by two-thirds length of ultimate segment with tiny spiniform tooth	overreaching antennal scale by half length of ultimate segment with tiny spiniform tooth
Distolateral margin of antepenultimate segment	overreaching antennal scale by half length of fingers	just reaching distal margin of antennal scale	not reaching distal margin of antennal scale
First pereopod extension	6	0–5	5–6
Third pereopod meral spines	4	0–5	4–6
Fourth pereopod meral spines	1	0–1	1
Fifth pereopod meral spines	13.9 mm	18.2 mm	19.2 mm
Maximum size (cl in mm)	Manus Basin, 1662 m	Okinawa Trough, 691–1491 m	Manus and Lau basins, 1512–1842 m
Distribution	This study	This study	This study
Source			

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TABLE 1. (continued)

	<i>L. antarcticus</i>	<i>L. carinatus</i>	<i>L. cristatus</i>	<i>L. formosanus</i>
straight 4–8, including 2 or 3 postrostral	nearly straight 4, including 2 postrostral	nearly straight 4, including 2 postrostral	nearly straight 4, including 2 postrostral	nearly straight 3–5, including 2 postrostral
0.2 arising posterior to rostral base, slightly ascending variable	ND arising at level of rostral base, directed forward present	0.2 arising at level of rostral base, ascending absent	0.2 arising at level of rostral base, directed forward variable	0.2–0.4 arising at level of rostral base, directed forward variable
3–5 6 spiniform setae	ND ND	4 7 spiniform setulose setae	3–4 6 spiniform setulose setae	3–4 6 spiniform setulose setae
reaching level of base of dorsolateral tooth of antennal scale	ND	not reaching base of distolateral tooth of antennal scale	not reaching base of distolateral tooth of antennal scale	not reaching base of distolateral tooth of antennal scale
not reaching level of base of dorsolateral tooth of antennal scale	not reaching base of distolateral tooth of antennal scale	ND	ND	ND
far falling short of dorsodistal margin of first segment of antennular peduncle not reaching lamella reaching midlength of antennal scale	reaching dorsodistal margin of first segment of antennular peduncle not reaching lamella reaching midlength of antennal scale	reaching dorsodistal margin of first segment of antennular peduncle reaching lamella slightly overreaching midlength of antennal scale	reaching dorsodistal margin of first segment of antennular peduncle reaching lamella slightly overreaching midlength of antennal scale	reaching dorsodistal margin of first segment of antennular peduncle reaching lamella reaching midlength of antennal scale
reaching slightly beyond antennal scale with tiny spiniform tooth	reaching just beyond antennal scale with tiny spiniform tooth	overreaching antennal scale by two-thirds length of ultimate segment with tiny spiniform tooth	overreaching antennal scale by one-third length of ultimate segment with tiny spiniform tooth	overreaching antennal scale by one-third length of ultimate segment with tiny spiniform tooth
overreaching antennal scale by length of fingers	slightly falling short of antennal scale	just reaching distal margin of antennal scale	just reaching distal margin of antennal scale	just reaching distal margin of antennal scale
8	ND	2–3	3–6	3–6
6	5	1	2–4	2–4
ND	ND	1	1–2	1–2
ND	8.5 mm	9.0 mm	13.7 mm	13.7 mm
Antarctic Sea, 550–640 m	off Peru, 1680–1860 m	Challenger Plateau, New Zealand, 1226–1231 m	off southern Taiwan to near Pratas Island, 635–1982m	off southern Taiwan to near Pratas Island, 635–1982m
Hale (1941); Ward (1985); Komai et al. (1996)	Fransen (1997)	Ahyong (2010)	Chang et al. (2010)	Chang et al. (2010)

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TABLE 1. (continued). Comparison among the three new species of *Lebbeus* and 10 allied congeners. ND = no data.

Characters/species	<i>L. kuboi</i>	<i>L. microceros</i>
Rostrum	slightly curving dorsally in females, nearly straight in males	nearly straight
Shape	2–5, including 2–3 postrostral	4–5, including 2 postrostral
No. of dorsal teeth	0.2–0.3	0.1–0.2
Carapace	arising at level of rostral base, directed forward	arising at level of rostral base, directed forward
Position of last postrostral tooth	present	present
Supraorbital tooth	3–7	4–5
Posteroventral tooth of fourth abdominal pleuron	6 spiniform setulose setae	2 spines
Telson	not reaching base of distolateral tooth of antennal scale	not reaching base of distolateral tooth of antennal scale
No. of dorsolateral spines on each side	reaching or slightly overreaching antennal scale by length of third segment	not reaching base of distolateral tooth of antennal scale
Armature of posterior margin (except 2 pairs of lateral spines)	reaching or slightly overreaching dorsodistal margin of first segment of antennular peduncle in females, not reaching it in males	reaching or slightly overreaching dorsodistal margin of second segment of antennular peduncle
Antennular peduncle extension (female)	reaching lamella	not reaching lamella
Antennular peduncle extension (male)	reaching midlength of antennal scale	reaching midlength of antennal scale
Extension of stylocerite	overreaching antennal scale by 0.5–0.6 length of ultimate segment	overreaching antennal scale by about half length of ultimate segment
Antennal scale distolateral tooth	with tiny spiniform tooth	with strong, curved tooth
Antennal carpoecrite extension	just reaching distal margin of antennal scale	just reaching distal margin of antennal scale
Third maxilliped extension	5–9	5
Distolateral margin of antepenultimate segment	4–10	5
First pereopod extension	1–4	3
Third pereopod meral spines	23.5 mm	14 mm
Fourth pereopod meral spines	Sea of Japan, 200–400 m	Northwestern Atlantic, 8–80 m
Fifth pereopod meral spines	Komai et al. (2004)	Squires (1990)
Maximum size (cl in mm)		
Distribution		
Source		

continued next page

TABLE 1. (continued)

<i>L. polyacanthus</i>	<i>L. similior</i>	<i>L. washingtonianus</i>	<i>L. vera</i>
nearly straight	nearly straight	slightly curving dorsally	nearly straight
6–7, including 3–4 postrostral	7, including 3 postrostral	4–5, including 2 postrostral	8–9, including 4–5 postrostral
about 0.4	0.2	about 0.2	about 0.3
arising at level of rostral base, directed forward present	arising at level of rostral base, directed forward present	arising at level of rostral base, directed present	arising slightly posterior to rostral base, present
4–6	4	4–6	6–7
4 spiniform simple setae	6 spiniform setulose setae	ND	6–7 spiniform setae
not reaching base of distolateral tooth of antennal scale	not reaching base of distolateral tooth of antennal scale	reaching nearly to base of distolateral tooth of antennal scale	not reaching base of distolateral tooth of antennal scale
ND	ND	reaching distal margin of antennal scale	not reaching base of distolateral tooth of antennal scale
reaching or slightly overreaching dorsodistal margin of first segment of antennular peduncle	slightly falling short of dorsodistal margin of first segment of antennular peduncle	far falling short of dorsodistal margin of first segment of antennular peduncle	reaching or slightly overreaching dorsodistal margin of first segment of antennular peduncle
reaching lamella	not reaching lamella	not reaching lamella	not reaching lamella
reaching midlength of antennal scale	reaching midlength of antennal scale	reaching distal 0.2 of antennal scale	slightly overreaching midlength of antennal scale
overreaching antennal scale by about half length of ultimate segment	overreaching antennal scale by 0.6 length of ultimate segment	overreaching antennal scale by about half length of ultimate segment	overreaching antennal scale by about half length of ultimate segment
with tiny spiniform tooth just reaching distal margin of antennal scale	with tiny spiniform tooth falling short of antennal scale	ND	with tiny spiniform tooth reaching distal margin of antennal scale
9–13	5	5	2–6
8–11	3	4	4–6
5–10	1	1	1–2
16.0 mm	12.4 mm	9.0 mm	15.7 mm
Sea of Japan, 250–400 m	Kashima Sea, Japan, 1196 m	British Columbia to California, 820–1808 m	Kermadec Ridge, New Zealand, 1208–1336 m
Komai et al. (2004)	Komai & Komatsu (2009)	Rathbun (1904); Butler (1980)	Ahyong (2009); this study

outer flagellum in the male and a larger body size (23.5 mm in cl versus 19.2 mm); furthermore, in *L. kuboi*, the development of epipod on the third pereopod shows individual variation (Komai *et al.* 2004), though it is constantly well-developed in *L. thermophilus*. *Lebbeus microceros* is easily distinguished from *L. thermophilus* in the different armature of the posterior margin of the telson (two spines versus three to five setulose spiniform setae) and the presence of a strong, curved distolateral tooth on the antepenultimate segment of the third maxilliped.

Wicksten & Hendrickx (1992) recorded *Lebbeus washingtonianus* from the Guaymas Basin, Mexico, where there is hydrothermal activity, but Martin & Haney (2005) noted that it was not known if specimens were found in association with such systems in the Guaymas Basin. Furthermore, the identification of the specimens used by Wicksten & Hendrickx (1992) need to be verified, concerning the presence of many species morphologically similar to *L. washingtonianus*. The previous records of *L. washingtonianus* from hydrothermal vents on the Okinawa Trough (Kikuchi & Ohta 1995; Fujikura *et al.* 1995; Hashimoto 1997; Watabe & Miyake 2000) are here all referred to *L. shinkaiae* sp. nov. The unidentified species reported from the Manus and/or Lau basins (Desbruyères *et al.* 1994; Komai & Segonzac 2004; Martin & Haney 2005; Komai & Collins 2009) is here described as new, *L. thermophilus*.

The present data suggest that the five species treated in this study are all vent-endemic. As well as the other species in the genus, each species is restricted to a rather narrow geographical area, as summarized in Table 1. It is remarkable that *Lebbeus pacmanus* sp. nov. and *L. thermophilus* sp. nov. sympatrically occur in the Manus Basin, though the latter species also occurs in the Lau Basin. Additionally, Martin & Haney (2005) reported the occurrence of *Lebbeus bidentatus*, originally described from off Chile at depth of 1680 m (Zarenkov 1976), from near a vent field on the southern portion of the EPR. Komai & Collins (2009) described a new species, *L. manus*, from a hydrothermal vent on the Manus Basin. In total, seven species are now known from hydrothermal vents.

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