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New Records of the *Copidognathus gibbus* Group (Acari, Halacaridae) from Korea, with Descriptions of *C. levicostatus* n. sp. and *C. vicinus*

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Abstract: Two marine halacarids, *Copidognathus levicostatus* n. sp. and *C. vicinus* Bartsch, 1997, belonging to the *C. gibbus* group, have been recorded based on both sexes from the microhabitat of intertidal and sublittoral rocks on the coast of South Korea. *Copidognathus levicostatus* n. sp. Is characterized by a combination of features, as follows: the absence of areolae with rosette pores on all dorsal and ventral plates, the presence of a short frontal process, a pair of costae with raised narrow ribs on the posterior dorsal plate, the partial fusion of the anterior epimeral plate and genitoanal plate in both sexes, and three pairs of perigenital setae in the male. The Korean specimens of *C. vicinus* Bartsch, 1997 agree well with the original description from Hong Kong, except for the lateral claws bearing a comb. This study provides detailed (re)descriptions of the morphological characteristics of the two Korean halacarid species, *C. levicostatus* n. sp. and *C. vicinus*, based on illustrations and scanning electron microscope photomicrographs. Additionally, we present a dichotomous key for known *Copidognathus* species in Korean waters, accompanied by a brief comment on their occurrence in various microhabitats, especially their habitat preferences for geniculate and non-geniculate red coralline algae.

Keywords: halacarid mite; marine; meiofauna; northwest Pacific; taxonomy; coralline algae

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1. Introduction

The genus *Copidognathus* Trouessart, 1888 in the family Halacaridae Murray, 1877 is the most diverse and representative mite within marine halacarid [1–4], comprising approximately 380 valid species known to date [5]. Among them, approximately 160 species are allocated to 13 species groups: the *bairdi*, *balakrishnani*, *curassaviensis*, *hartmanni*, *gibberipes*, *gibbus*, *lamellosus*, *oculatus*, *ornatus*, *pulcher*, *spinula*, *temaeus*, and *tricorneatus* groups; however, the remaining species have not yet been grouped definitely [6–15].

The *gibbus* group is the most species-rich group, with 50 currently recognized species, which are known from the shallow intertidal zone to the subtidal zone above 300 m depth [4,13,16,17]. Chatterjee and De Troch [17] listed 49 species of the *C. gibbus* group according to their geographical distribution, which comprised a species from the Antarctic, six species from the Atlantic and the Mediterranean, 16 species from the Indian Ocean, and 27 species from the Pacific (15 from the western and 12 species from the eastern Pacific), including the four species concurrently distributed in the other oceans. The 50th member of this species group, *C. ditadii* Pepato and Tiago, 2005, was described as coming from Brazil in the southwestern Atlantic [4].

In Korea, since Chatterjee and Chang [18] first recorded the marine halacarid mite of *Copidognathus koreanus* Chatterjee and Chang, 2003 from Yeongdeok on the eastern coast and Jeju Island, ten species of *Copidognathus* have been identified [3], of which only one species, *C. daguilarensis* Barstch, 1997, belongs to the *C. gibbus* group. During a survey of the marine halacarid fauna from the tidal to shallow subtidal habitats of the coast of South Korea, we found two halacarid species, *C. levicostatus* n. sp. and *C. vicinus* Bartsch, 1997, both belonging to the *C. gibbus* group. In this study, we provide detailed (re)descriptions of these species with illustrations and photomicrographs from a scanning electron microscope. We also present a dichotomous key to all the *Copidognathus* species recorded in Korean waters to date, along with a brief comment on their habitat preference.

2. Materials and Methods

2.1. Sampling and Preparation

Samples were collected by rinsing the invertebrate colonies (mussels, polychaete tubes, and barnacles) and geniculate red coralline algae attached to the rocks in the intertidal zone with a trowel, and non-geniculate red coralline algae in the shallow subtidal zone at a depth of 15–20 m by SCUBA from the coast of South Korea (Figure 1). Halacarids were extracted by applying an osmotic shock to the invertebrates and coralline algae with tap water for five to ten minutes, followed by filtering them through a nylon net (64 µm in pore diameter), and immediately fixing with 80% ethanol or 5% formalin solution. In the laboratory, halacarid mites were sorted under a stereomicroscope (SZX12, Olympus, Tokyo, Japan). Then, they were immersed in a 3% glycerin solution, which was evaporated at room temperature for 1–3 days, to be replaced, finally, with pure glycerin. For measurement and observation, they were mounted in a mixed liquid of glycerin-lactic acid (9:1) on temporary reverse slides [19]. All drawings were made under a differential interference contrast microscope (BX53, Olympus, Tokyo, Japan) equipped with a drawing tube. After examination, the specimen was mounted in glycerin on an H-S slide [20] and sealed with paraffin. Scale bars in figures are given in µm.

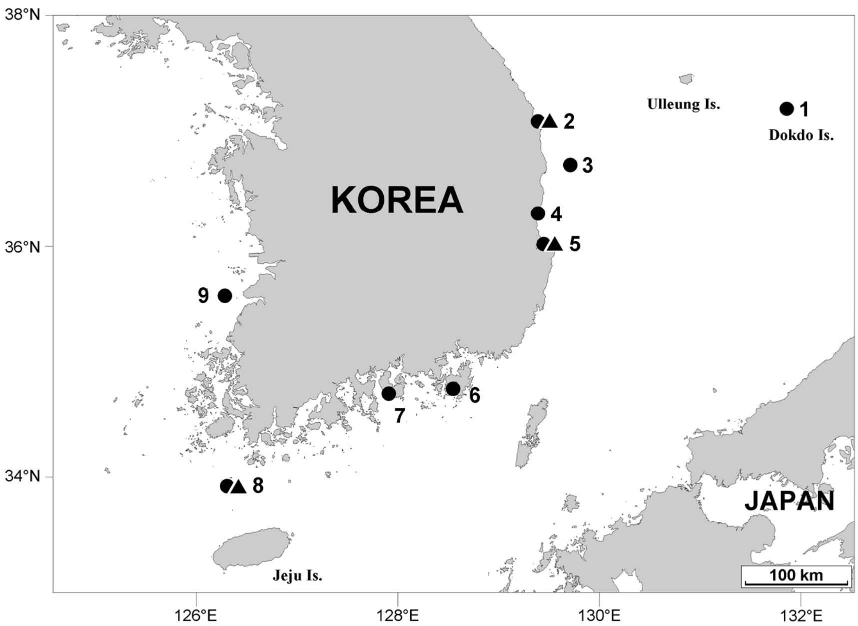

Figure 1. A map showing locations. (1) Dongdo port, Dokdo Is.; (2) Huam Rock, Uljin; (3) Wangdolcho Rock, Uljin; (4) Jangsa beach, Yeongdeok; (5) Haseondae, Pohang; (6) Deokwon beach, Geoje; (7) Wolpo beach, Namhae; (8) Sinyang port, Chuja Is.; (9) Wido beach, Wido Is., Buan (symbols as follows: • *Copidognathus levicostatus* n. sp., ▲ *Copidognathus vicinus*).

All type specimens and some additional specimens were deposited at the Honam National Institute of Biological Resources (HNIBRIV), Mokpo, Korea, and the other additional specimens were kept at the Korea Institute of Ocean Science and Technology (KIOST).

2.2. Observation for the Scanning Electron Microscope

Samples for the scanning electron microscope (SEM) were prefixed in 2.5% glutaraldehyde in 0.1 M phosphate buffer (pH 7.4) for 6 h at 4 °C, followed by post fixation in 2% OsO_4 in the same buffer for 2 h [21]. After an ethanol dehydration series of 50–100% was carried out at 10% intervals for 30 min each, the materials were freeze-dried in a cooling stage (EYELA FDU-1200, Sunileyela Co., Ltd., Seongnam, Korea), coated with gold/palladium in ion sputter (MCM-100, SEC Co., Ltd., Suwon, Korea), and then examined with a low vacuum desktop mini SEM (SNE3200M, SEC Co., Ltd., Suwon, Korea).

2.3. Terminology and Abbreviations

Terminology and abbreviations in the text and figure captions follow Bartsch [2]: AD, anterior dorsal plate; AE, anterior epimeral plate; ds, dorsal setae on idiosoma (ds-1 to 6, first to sixth dorsal setae on idiosoma); GA, genitoanal plate; glp, gland pore(s), numbered glp-1 to 3 from anterior to posterior; GO, genital opening; OC, ocular plate(s); P, palp (P-1 to 4, first to fourth palpal segment); pas, parambulacral setae; PD, posterior dorsal plate; PE, posterior epimeral plate; pgs, perigenital setae; sgs, subgenital setae.

3. Results

Systematics

Subclass: Acari Leach, 1817
Order: Trombidiformes Reuter, 1909
Suborder: Prostigmata Kramer, 1877
Superfamily: Halacaroidea Murray, 1877
Family: Halacaridae Murray, 1877
Genus: *Copidognathus* Trouessart, 1888
***Copidognathus levicostatus* n. sp.** (Figures 2–4 and 8A–E)
urn:lsid:zoobank.org:act:78586B7F-B5A9-4378-9E4C-72D6DF12BB21

Type locality. SOUTH KOREA: Gyeongsangnamdo Province, Geoje City, Dongbu-myeon, Gabae-ri, Deokwon beach (34°46′40″ N, 128°34′43″ E), geniculate red coralline algae on the rocks in the intertidal zone, 0–1 m depth, 14 March 2021, C.Y. Chang and J.H. Shin *leg*.

Type specimen. Holotype: ♀(HNIBRIV7508) dissected and mounted on two slides, from the type locality.

Allotype: ♂(HNIBRIV7509) mounted on a slide, same data as for holotype.

Paratypes: 14♀♀(HNIBRIV106, HNIBRIV7510–7522) and 7♂♂(HNIBRIV7523–7529) mounted each on a slide, same data as for holotype.

Other material. 2♀♀1♂on a stub for SEM, same data as for holotype; 2♂♂(HNIBRIV105, HNIBRIV7501) and 2♀♀3♂♂mounted each on a slide, Buan, Wido Island, Wido beach (35°36′32″ N, 126°16′53″ E), geniculate red coralline algae, 16 November 2020, J.G. Kim and J.H. Shin *leg*.; 1♀(HNIBRIV107), 1♂(HNIBRIV7502) and 2♀♀mounted each on a slide, Jeju Island, Chuja Is., Sinyang port (33°56′10″ N, 126°19′28″ E), geniculate red coralline algae, 9 September 2021, J.G. Kim *leg*.; 1♂mounted on a slide, Yeongdeok, Jangsa beach (36°16′49″ N, 126°22′39″ E), invertebrate colonies and geniculate red coralline algae, 31 August 2019, J.H. Shin *leg*.; 1♂preserved in 90% ethanol, Uljin, Hujeong, Huam Rock (37°04′28″ N, 129°25′03″ E), non-geniculate red coralline algae, 9 August 2022, H.S. Rho *leg*.; 1♀preserved in 90% ethanol, Uljin, Hupo, Wangdolcho Rock (36°42′15″ N, 129°43′47″ E), non-geniculate red coralline algae, 25 August 2022, H.S. Rho *leg*.; 1♀2♂♂preserved in 90% ethanol, Dokdo Island, Dongdo port (37°14′18″ N, 131°52′08″ E), non-geniculate red coralline algae, 30 August 2022, H.S. Rho *leg*.; 1♀preserved in 90% ethanol, Pohang, Yeongil Bay, Haseondae (36°00′59″ N, 129°28′58″ E), invertebrate colonies and geniculate red coralline algae, 21 April 2019, J.H. Shin *leg*.; 1♂preserved in 90% ethanol, Namhae, Wolpo beach (34°45′43″ N, 127°54′17″ E), geniculate red coralline algae, 4 July 2020, J.G. Kim and J.H. Shin *leg*.

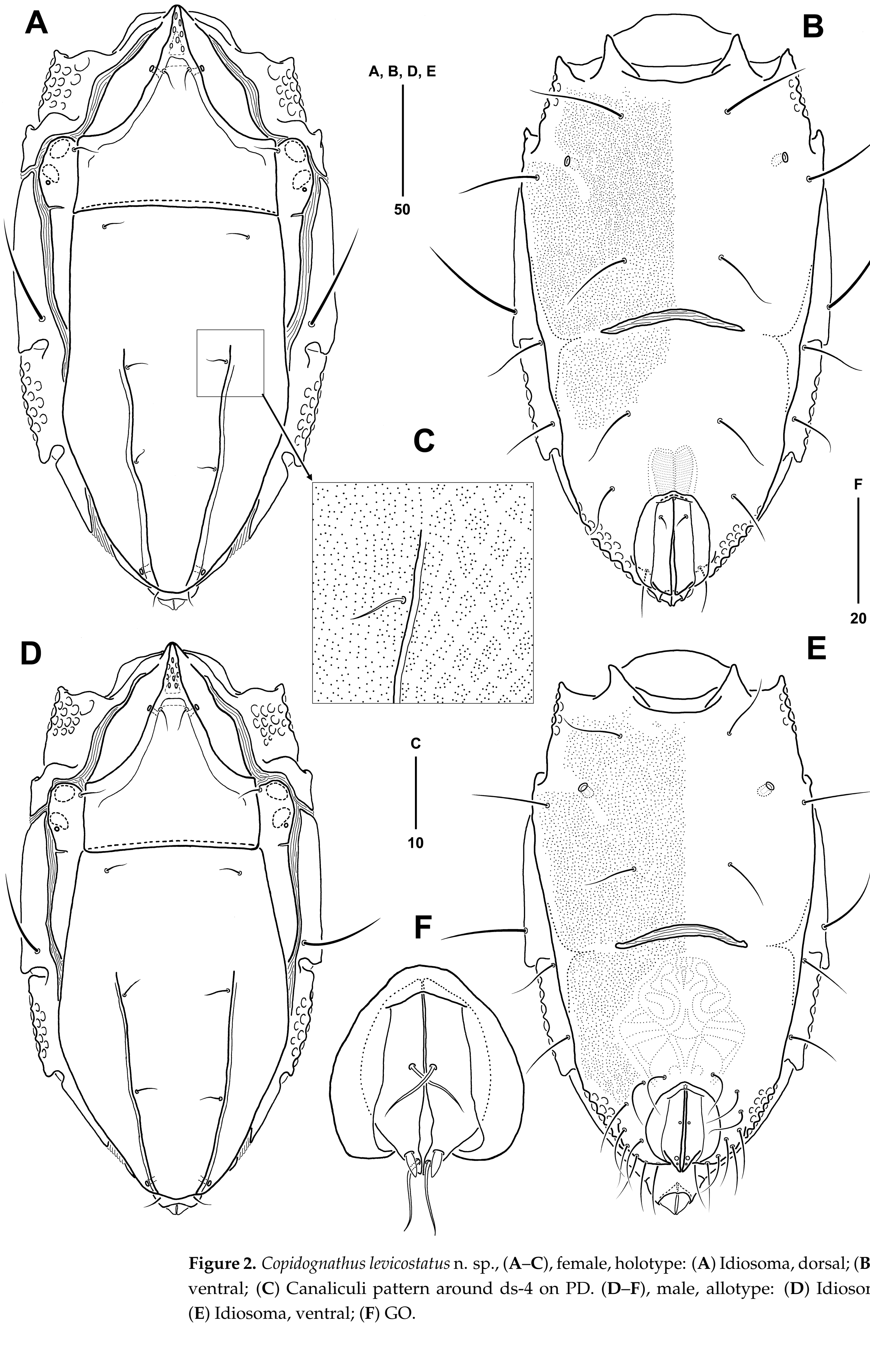

Figure 2. *Copidognathus levicostatus* n. sp., (**A**–**C**), female, holotype: (**A**) Idiosoma, dorsal; (**B**) Idiosoma, ventral; (**C**) Canaliculi pattern around ds-4 on PD. (**D**–**F**), male, allotype: (**D**) Idiosoma, dorsal; (**E**) Idiosoma, ventral; (**F**) GO.

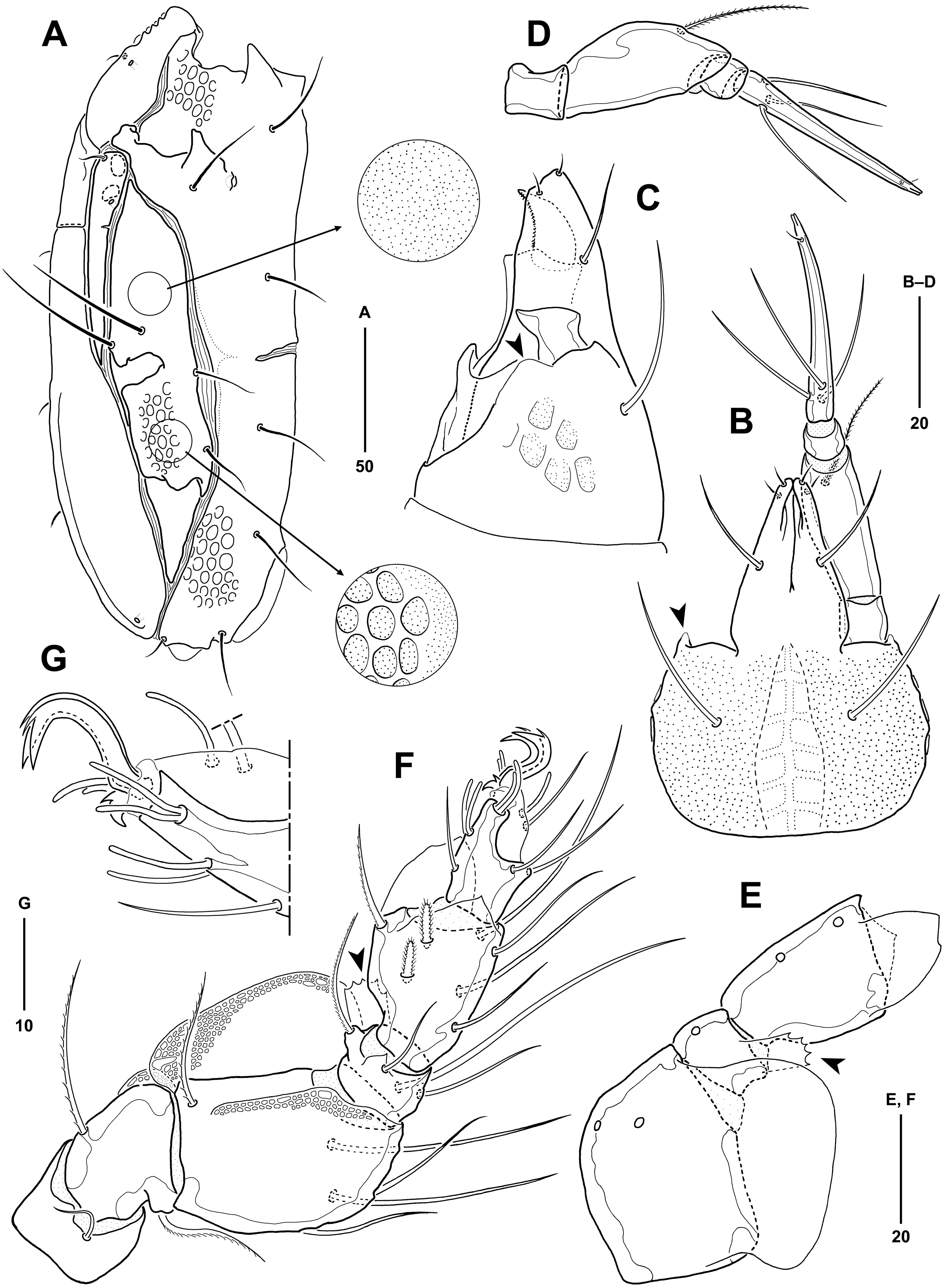

Figure 3. *Copidognathus levicostatus* n. sp., female, holotype. (**A**) Idiosoma, lateral; (**B**) Gnathosoma, ventral; (**C**) Gnathosoma, lateral; (**D**) Palp, lateral; (**E**) Ventrolateral lamellae on telofemur to tibia of leg I, lateral; (**F**) Leg I, ventromedial; (**G**) Tip of tarsus I, ventromedial.

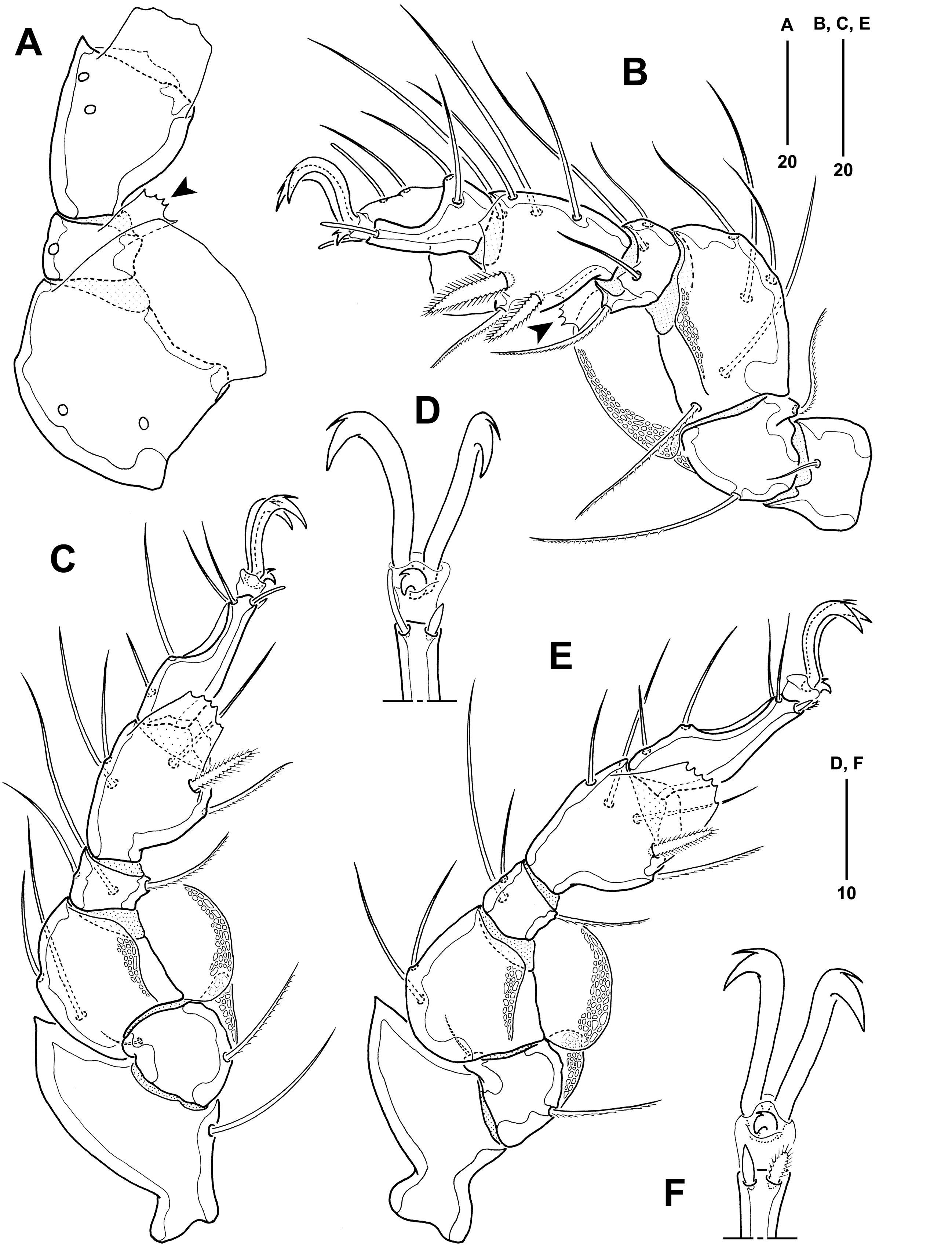

Figure 4. *Copidognathus levicostatus* n. sp., female, holotype. (**A**) Ventrolateral lamellae on telofemur to tibia of leg II, lateral; (**B**) Leg II, ventromedial; (**C**) Leg III, ventromedial; (**D**) Tip of tarsus III, ventral; (**E**) Leg IV, ventromedial; (**F**) Tip of tarsus IV, ventral.

Description of female (holotype). Idiosoma (Figures 2A and 8A,B) 263 μm long (245–274 μm, mean = 261 μm, n = 20), 139 μm wide (125–163 μm, mean = 144 μm, n = 20); length to width ratio about 1.89. All dorsal plates (AD, OC, and PD) well-developed, adjacent to each other, but not fused to each other; dorsal plates covered with punctate pores, without areolae of distinct rosette pores.

AD (Figures 2A and 8C) 85 μm long, including short frontal process protruding forward (79–89 μm, mean = 85 μm, n = 20), 0.32 times as long as idiosoma, 80 μm wide (74–83 μm, mean = 80 μm, n = 20), length to width ratio about 1.06; gradually narrowing forward at anterior two-thirds, forming raised gable-like area, nearly parallel on both sides at next one-third; with 5–8 tiny pores distributed from level of glp-1 to tip of frontal process; posterior margin of AD nearly straight; a pair of glp-1 located on slope of anterior raised gable-like area of AD at level of ds-1; with a transverse internal bar slightly ahead of glp-1.

OC (Figures 2A and 3A) elongate, narrowing posteriorly, 85 μm long (81–92 μm, mean = 88 μm, n = 20), 17 μm wide (12–21 μm, mean = 18 μm, n = 20), length to width ratio about 4.83, and located between leg II and leg III; posterior edge almost reach insertion of leg III; with two corneae, front cornea slightly larger than rear one; glp-2 located behind rear cornea laterally; pore canaliculus positioned at level of anterior third of OC.

PD (Figures 2A and 8D) 164 μm long (159–172 μm, mean = 164 μm, n = 20), 0.62 times as long as idiosoma, 89 μm wide (88–112 μm, mean = 100 μm, n = 20), length to width ratio about 1.84; gradually narrowing in posterior third of PD; on posterior part, a pair of raised narrow ribs extending forward to anterior third of PD; canaliculi forming several faint lines along ribs medially, and faint reticular patterns at anterior, mid-dorsal, and lateral surfaces of PD, of which lateral sides more distinct (Figures 2C and 8D); glp-3 situated at posterior margin of PD.

Six pairs of dorsal setae (Figure 2A) short; ds-1 located on anterior raised gable-like AD at level of glp-1; ds-2 on anterior corner of OC; 3 pairs of ds (ds-3 to ds-5) situated at PD, ds-3 below anterior margin of PD, ds-4 and ds-5 each issuing along raised rib at anterior 43% and 66% of PD, respectively; ds-4 closer to ds-5 than ds-3; ds-6 (adanal seta) located between PD and anal sclerite.

All ventral plates (Figure 2B) covered with surfaces uniformly punctuated, similar to AD, forming net-like patterns more obscure than on lateral PD; AE and GA partly separated at medial part by membranous integument, while remaining lateral regions incompletely fused at surfaces only.

AE (Figure 2B) 101 μm long (95–105 μm, mean = 99 μm, n = 20), 130 μm wide (123–141 μm, mean = 133 μm, n = 20), length to width ratio about 0.78; with a pair of epimeral pores and three pairs of ventral setae; epimera I well-developed, with medial epimeral process more protruding and sharper than lateral one; with about fourteen to eighteen large pits on dorsolateral surface of epimera I (Figures 2A and 8C); epimera II smaller than epimera I.

GA (Figure 2B) 127 μm long (116–133 μm, mean = 125 μm, n = 20), 92 μm wide (92–108 μm, mean = 102 μm, n = 20), length to width ratio about 1.38; gradually narrowing posteriorly, with several large pits along posterolateral margin (Figures 2B and 3A); with three pairs of pgs, of which foremost pgs located at about anterior 34% of GA, second one at almost same level of anterior GO, last pgs behind posterior margin of GO. GO (Figure 2B) elliptical, 42 μm long, 29 μm wide, about 0.33 times as long as GA; with a pair of small sgs situated on about anterior sixth of genital sclerite. Ovipositor present internally, its anterior tip not reaching to level of foremost pgs.

PE (Figure 2A,B and Figure 3A) separated completely to OC, PE, AE and GA, with four setae in total, consisting of two strong setae dorsally and dorsolaterally, and two slender setae along ventral margin; formers, 40–48 μm long, about 1.63 times longer than the latters; ornamented with canaliculi densely, accompanied by about 16–20 large foveae between levels of legs III and IV.

Gnathosoma (Figure 3B,C) 71 μm long (67–73 μm, mean = 70 μm, n = 20), 51 μm wide (49–54 μm, mean = 51 μm, n = 20), consisting of rostrum anteriorly and gnathosomal base posteriorly; small lamellae located at dorsolateral corner of gnathosomal base (indicated by arrowhead in Figure 3B,C); rostrum 36 μm long, half of gnathosoma, narrowing apically and its tip reaching end of P-2; with four pairs of rostral setae: two pairs of short rostral setae (protorostral and deutorostral setae) issuing near tip of rostrum, and two pairs of long maxillary setae (tritorostral and basirostral setae), tritorostral seta on half of rostrum and basirostral one at level of anterior third of gnathosomal base, respectively; gnathosomal base ornamented densely with canaliculi on ventral surface and slightly faint, 5–6 large pores on lateral side. Palp (Figure 3B,D) consisting of four segments, 7, 28, 6, and 40 μm long, respectively; P-1 and P-3 without setae; P-2 with one dorsal bipectinate seta subdistally; P-4 slender and the longest, 1.43 times longer than P-2, with three long proximal and one short distal setae, and its terminal bifurcated. Tectum (Figure 3C) represented by low crista dorsally. Chelicera (Figure 3C) 53 μm long, 11 μm wide, with quadrangular shaped base and movable digit terminally; appendage 17 μm long, dorsal margin with row of minute teeth.

Chaetotaxy of legs (Figures 3F and 4B,C,E) as follows: trochanters 1-1-1-0; basifemora 2-2-2-2; telofemora 5-5-2-2; genua 4-4-3-3; tibiae 7-7-5-5; tarsi (excluding pas) 7-4-4-4; delicately pectinate setae exist on basifemora (2-2-1-1), telofemora (1-1-0-0), genua (1-1-1-1) and tibiae (1-1-1-1); bipectinate spiniform setae present on only tibiae I–IV as 2-2-1-1, which of distal one on tibia II the largest. Trochanters III and IV protruded outer distally, forming a large, curved triangular projection (Figures 4C,E and 8B). Basifemora of all legs with small lateral lamella with reticulate pattern; ventrolateral lamellae of basifemora III and IV larger and more distinct than those of basifemora I and II. Telofemora I–IV with well-developed lamellae ventrolaterally and ventromedially, both sculptured with reticulate pattern irregularly; ventrolateral lamellae much larger than medial ones with their distal margins extended roundly, reaching slightly beyond proceeding segment (genu). Genua I and II each with small triangular lamella ventromedially and subrectangular lamellae ventrolaterally, the latter armed with four to six teeth on its distal edge (indicated by arrowhead in Figures 3E,F, 4A,B and 8E); genua III and IV without lamellae. All tibiae each with two lamellae ventrolaterally and ventromedially; in tibiae I–II, ventrolateral lamellae subrectangular, prominent and much larger than triangular ventromedial ones, its end extending to middle of each tarsus; in tibiae III–IV, ventrolateral lamellae smaller than ventromedial ones, ventromedial lamellae armed with three to six and three to eight teeth on distal edge, respectively, with its distal edge reaching to proximal third of tarsus. Tarsi I–IV 26, 28, 33, and 35 μm long, respectively, measured in ventral sides; tarsi I–II with well-developed claw fossa, bearing one solenidion and three dorsal setae; tarsi III–IV slender, 1.26 times longer than tarsi I–II, with four dorsal setae; tarsus I (Figure 3F,G) with one ventromedial seta, two ventral eupathids, and four pas consisting of paired doublet eupathids on each side; tarsus II (Figure 4B) with a pair of singlet eupathid pas; tarsus III (Figure 4C,D) with one normal eupathid and one small lanceolate pas ventrally; tarsus IV (Figure 4E,F) with two short pas consisting of one lanceolate and one bipectinate pas ventrally; one median and a pair of lateral claws on all tarsi, each claw with one accessory process subdistally.

Male. Idiosoma (Figure 2D) 262 μm long (242–271 μm, mean = 258 μm, n = 15), 150 μm wide (138–166 μm, mean = 149 μm, n = 15). Similar to female, except for genital area. GA (Figure 2E) 130 μm long and 108 μm wide (length to width ratio 1.20); surrounded by 18–20 pgs. GO (Figure 2E,F) 39 μm long, 35 μm wide, about 1/3 as long as GA; with three pairs of sgs; foremost sgs long, filiform, located at anterior 0.41 level of genital sclerite; second one short spiniform near posterior margin; last sgs long, filiform, situated at posterior edge, adjacent to second sgs; distance between anterior margin of GA and that of GO 73 μm, about 1.87 times as long as GO. Spermatocytes extending to level of leg III; width about half as broad as GA.

Etymology. The proposed specific name is taken from the Latin '*levis (laevis)*' meaning "smooth" and '*costa*' meaning 'rib', which refers to the narrow, smooth rib-like costae without the rosette pores on the posterior dorsal plate.

***Copidognathus vicinus* Bartsch, 1997** (Figures 5, 6, 7 and 8F)

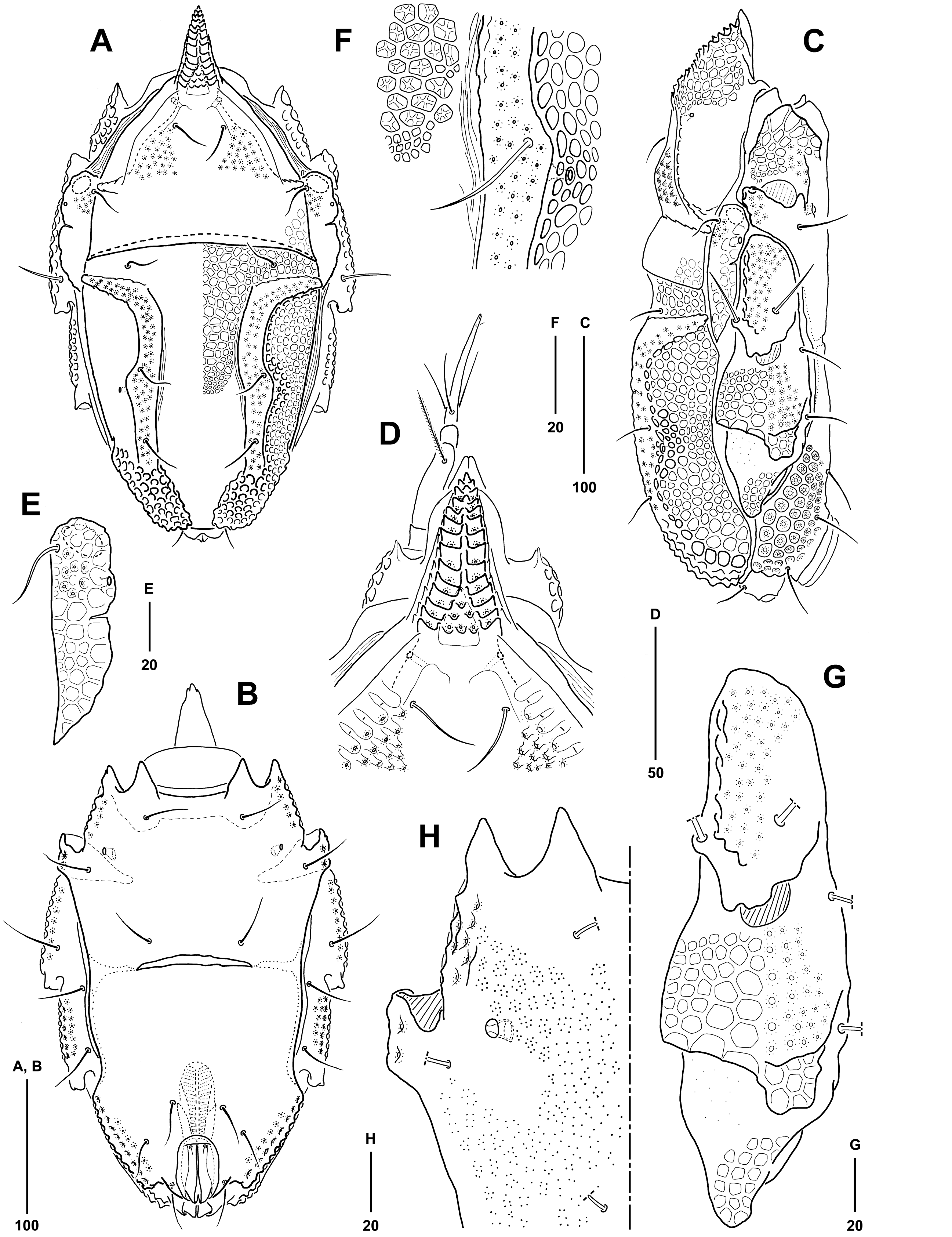

Figure 5. *Copidognathus vicinus* Bartsch, 1997, female. (**A**) Idiosoma, dorsal; (**B**) Idiosoma, ventral; (**C**) Idiosoma, lateral; (**D**) Anterior part of AD and gnathosoma, dorsal; (**E**) OC; (**F**) Ornamentation and rosette pores near ds-4 on PD, dorsal; (**G**) PE, lateral; (**H**) Anterior part of AE, ventral.

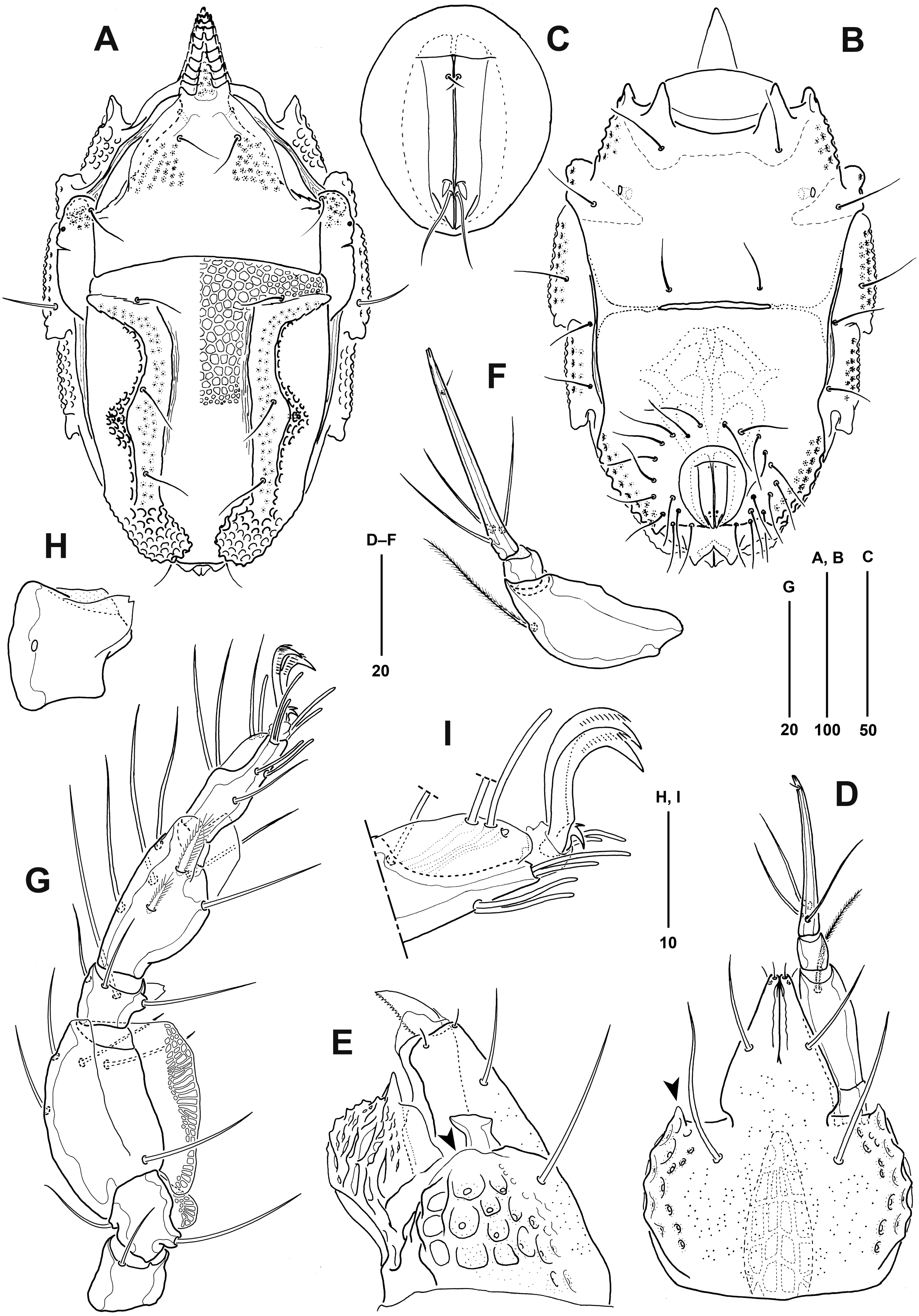

Figure 6. *Copidognathus vicinus* Bartsch, 1997, (**A**–**C**), male: (**A**) Idiosoma, dorsal; (**B**) Idiosoma, ventral; (**C**) GO. (**D**–**I**), female: (**D**) Gnathosoma, ventral; (**E**) Gnathosoma, lateral; (**F**) Palp (P-2 to P-4), lateral; (**G**) Leg I, ventromedial; (**H**) Ventrolateral lamella on genu I, ventrolateral; (**I**) Tip of tarsus I, ventrolateral.

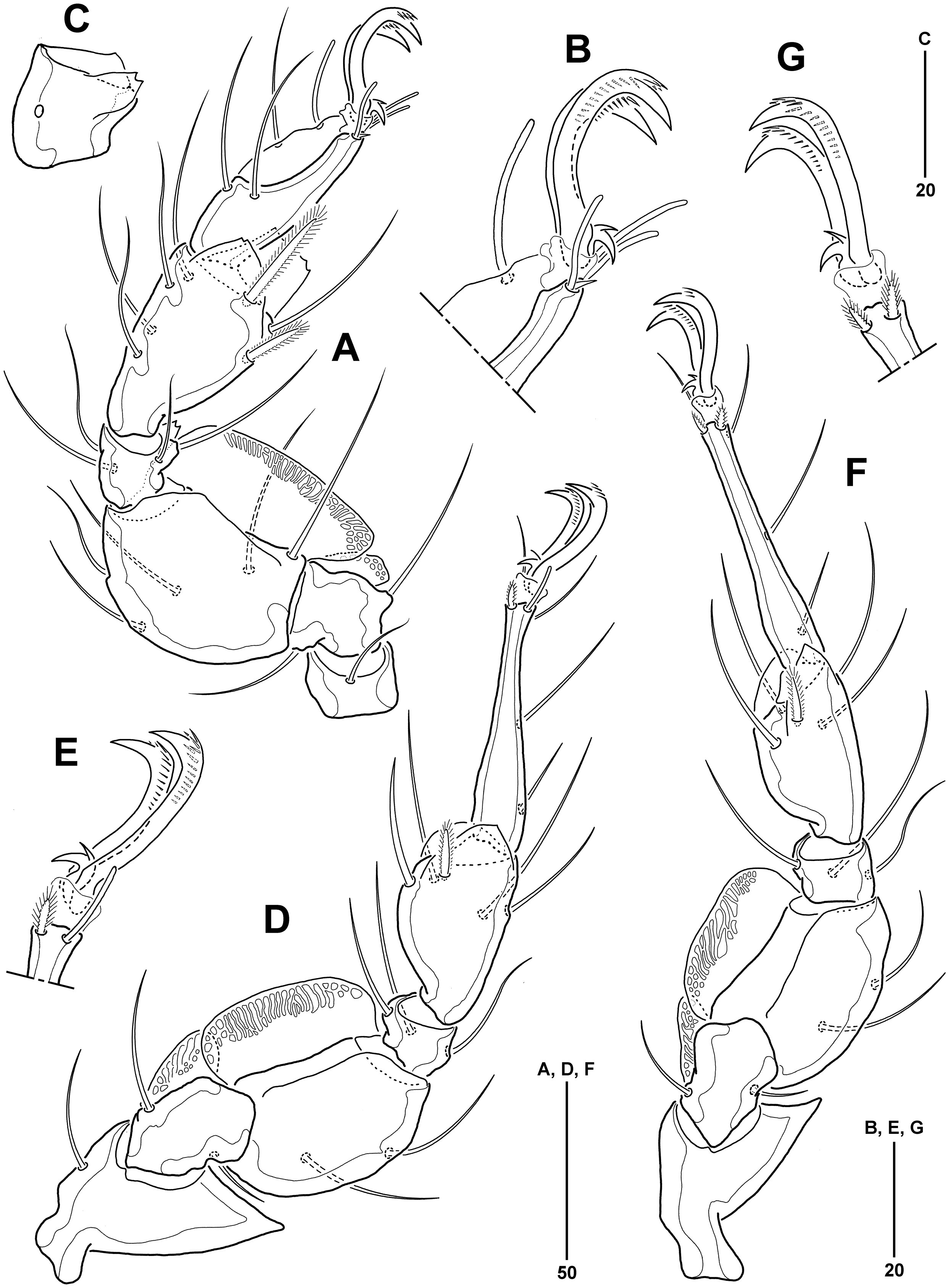

Figure 7. *Copidognathus vicinus* Bartsch, 1997, female. (**A**) Leg II, ventromedial; (**B**) Tip of tarsus II, ventromedial; (**C**) Ventrolateral lamella on genu II, ventrolateral; (**D**) Leg III, ventromedial; (**E**) Tip of tarsus III, ventromedial; (**F**) Leg IV, ventromedial; (**G**) Tip of tarsus IV, ventromedial.

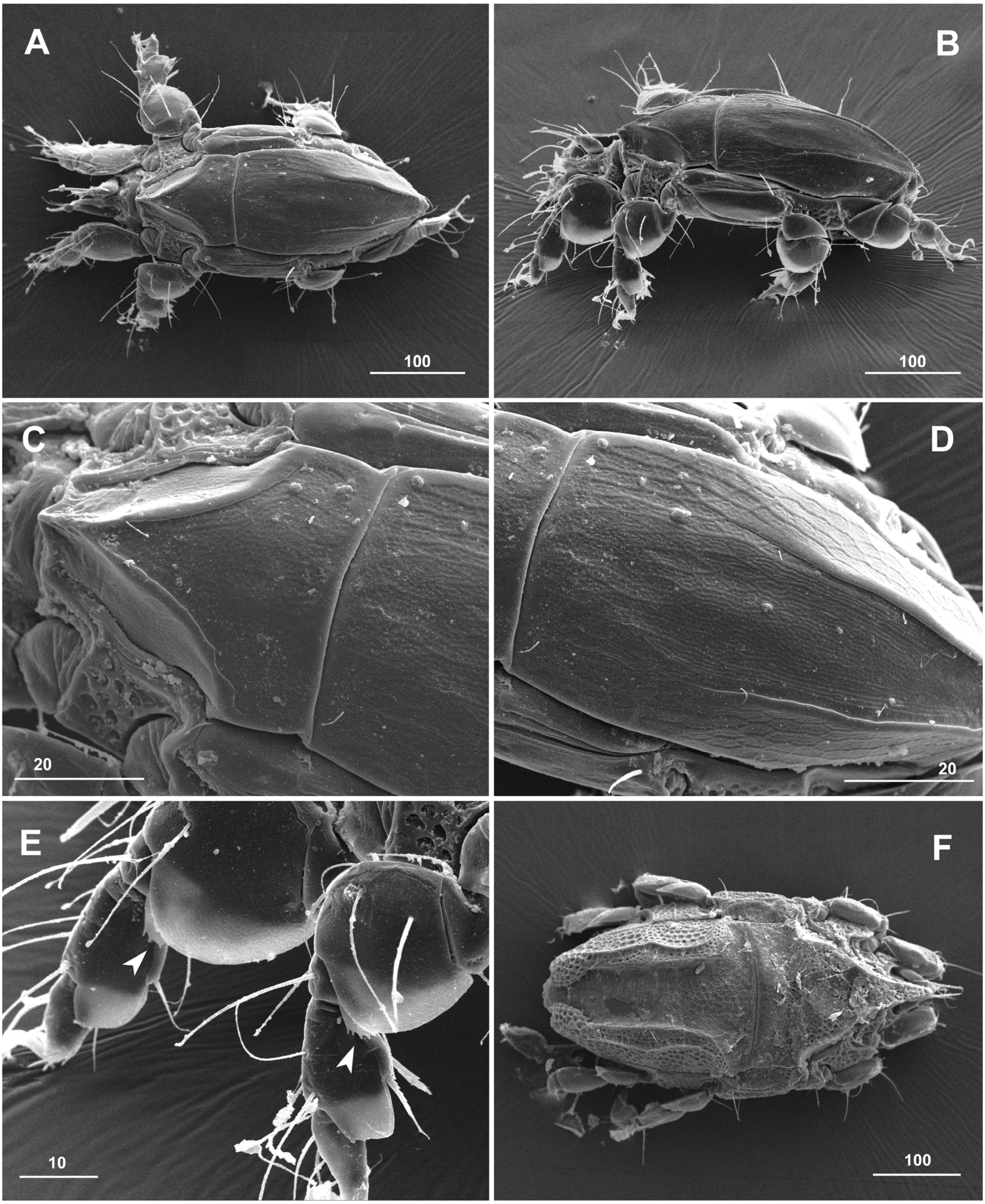

Figure 8. *Copidognathus levicostatus* n. sp., (**A**–**E**), female, SEM photographs: (**A**) Idiosoma, dorsal; (**B**) Idiosoma, lateral; (**C**) AD, dorsal; (**D**) PD, dorsal; (**E**) Legs I and II, lateral (arrowheads indicate the teeth on the distal edge of ventrolateral lamellae of genua I and II). *Copidognathus vicinus* Bartsch, 1997, female, SEM photographs. (**F**) Idiosoma, dorsal.

Copidognathus vicinus Bartsch, 1997: 70–73, Figures 4 and 5.

Type locality. Holotype (♀) Hong Kong, Telegraph Bay, Shell sand and gravel, 10.5 m depth; deposited in the Zoological Institute and Zoological Museum, Hamburg [13].

Material examined. 1♀(HNIBRIV109), 1♂(HNIBRIV7507) and 2♀♀3♂♂mounted each on a slide, Pohang, Yeongil Bay, Haseondae (36°00′59″ N, 129°28′58″ E), invertebrate colonies and geniculate red coralline algae, 21 January 2019, J.H. Shin *leg*.; 1♀1♂on a stub for SEM, same data as for preceding; 4♀♀(HNIBRIV108, HNIBRIV7503–7505), 1♂(HNIBRIV7506) and 3♀♀2♂♂mounted each on a slide, Jeju Island, Chuja Is., Sinyang port (33°56′10″ N, 126°19′28″ E), geniculate red coralline algae, 9 September 2021, J.G. Kim *leg*.; 1♀3♂♂preserved in 90% ethanol, Uljin, Hujeong, Huam Rock (37°04′28″ N, 129°25′03″ E), non-geniculate coralline red algae, 9 August 2022, H.S. Rho *leg*.

Description of female. Idiosoma (Figures 5A and 8F) 400 µm long (363–400 µm, mean = 380 µm, n = 10), 228 µm wide (206–238 µm, mean = 218 µm, n = 10), length to width ratio about 1.67–1.82; AD, PD and OC separated but contiguous each other; posterior AD adjacent to anterior PD, and OC to both posterolateral AD and anterolateral PD.

AD (Figure 5A) 177 µm long (157–177 µm, mean = 163 µm, n = 10), including frontal process, 0.44 times as long as idiosoma, 155 µm wide (137–155 µm, mean = 148 µm, n = 10). Frontal process well-developed, extending far beyond gnathosomal base; dorsal surface forming deep sculptured layers, each with rosette pore comprising large ostium and several canaliculi (Figure 5D). Anterior AD, posterior to frontal process, raised triangular shaped with narrow lamellae along lateral margin; triangular areola present in each side comprising 22–25 rosette pores. Posterior third of AD ornamented with faintly reticulated pattern, when observed under high magnification; posterior margin of AD nearly straight. A pair of glp-1 located on raised slope in anterior AD; with transverse cuticular bar internally at level of glp-1.

OC (Figure 5A,C,E) 92 µm long (82–94 µm, mean = 88 µm, n = 10), 27 µm wide (23–29 µm, mean = 26 µm, n = 10), 0.23 times as long as idiosoma, gradually narrowing posteriorly, extending to about anterior 1/5 of PD; large cornea positioned at most anterior part of OC; posterior to cornea, glp-2 located near lateral margin, followed by pore canaliculus; with 7–9 rosette pores grouped at anteromedial corner behind cornea; with remaining surface delicately and irregularly reticulated.

PD (Figure 5A,C) 212 µm long (177–219 µm, mean = 203 µm, n = 10), 171 µm wide (149–171 µm, mean = 158 µm, n = 10), 0.53 times as long as idiosoma. A pair of distinct costae, anterior part bending anterolaterally towards OC, posterior part slightly exceeding beyond ds-5; each costa comprising two to three rows of rosette pores. Dorsal surface anterior to costae and anterior half between costae ornamented with irregularly polygonal panels, forming loosely reticulate arrangement; polygonal panels growing larger anteriorly, meanwhile smaller posteriorly and spaced densely (Figure 5A,F). Deep and large foveae outstanding posterior and lateral to costae (Figures 5A and 8F). Glp-3 located at level of 0.53 of PD, lateral to the widest part of costa.

Dorsal setae (Figure 5A,C): ds-1 located at anterior half of AD; ds-2 at anterior corner of OC; ds-3 anterior to curved costa of PD; ds-4 and ds-5 on costa of PD, inserted at levels of 0.47 and 0.69 of PD length, respectively; ds-6 on adanal plate.

Ventral plates (Figure 5B) not completely separated between AE and GA, medially separated by striated membranous cuticle; ventral surface covered with pits of canaliculi densely, except for vicinities of epimera I and epimera II smooth (dotted area in Figure 5B).

AE (Figure 5B) 112 µm long (101–121 µm, mean = 111 µm, n = 10), 201 µm wide (192–210 µm, mean = 198 µm, n = 10), length to width ratio about 0.56. With three pairs of ventral setae; a pair of epimeral pores situated on 0.33 level of AE, about 6 µm wide opening; medial and lateral epimera I developed, almost same to each other in size; epimera II slightly protruded outward; seven to nine rosette pores running along lateral margins of epimera I and II (Figure 5B,H).

GA (Figure 5B) 183 µm long (167–183 µm, mean = 173 µm, n = 10), 157 µm wide (148–163 µm, mean = 154 µm, n = 10), length to width ratio about 1.17. With three pairs of pgs, foremost pgs located at 0.54 level of GA, second one near anterior tip of GO, last pgs situated behind posterior margin of GO; four to five rows of foveae arranging along posterolateral margins of GA, each fovea with a rosette pore (Figure 5B). GO (Figure 5B) elliptical, 48 µm long, 31 µm wide, about 0.26 times as long as GA; with one sgs issuing on anteriormost of genital sclerite; distance between anterior margins of GA and GO 125 µm, about 2.60 times as long as GO. Ovipositor extending to anterior 38% of GA.

PE (Figure 5C,G) with one dorsal and three ventral setae; anterior PE (ahead of trochanter III insertion) with rosette pores (Figure 5C,G); posterior PE (between insertions of trochanter III and IV) with foveae dorsally and rosette pores ventrally (Figure 5G).

Gnathosoma (Figure 6D,E) 82 µm long (78–86 µm, mean = 82 µm, n = 10), 72 µm wide (64–76 µm, mean = 70 µm, n = 10). Gnathosomal base with pits of canaliculi scattered sparsely on ventral surface, with 15–17 foveae laterally (10–12 of which with rosette pore); lamellae protruding on dorsolateral corner of gnathosomal base (indicated by arrowhead in Figure 6D,E); both protorostral and deutorostral setae minute, issuing from anterior tip of rostrum; basirostral seta located at anterior fourth of gnathosomal base, tritorostral seta at anterior half of rostrum. Rostrum 38 µm long, 0.46 times as long as gnathosoma, reaching to distal margin of P-2. Palp (Figure 6D,F) composed of four segments; P-1 to P-4 12, 33, 8, and 47 µm long, respectively; P-1 and P-3 lacking setae; P-2 with one dorsal bipectinate seta subdistally; P-4 slender and longest, about 1.42 times as long as P-2, with one short distal and three long proximal setae. Tectum (Figure 6E) well-developed crest-shaped process, not reaching rostral tip. Chelicera (Figure 6E) 42 µm long, 11 µm wide; inserted between rostrum and tectum; base quadrangular-shaped, its anterior end reaching to distal end of rostrum; forming movable digit terminally (18 µm long), with row of minute teeth along dorsal margin.

Chaetotaxy of legs (Figures 6G and 7A,D,F): trochanters 1-1-1-0; basifemora 2-2-2-2; telofemora 5-5-2-2; genua 4-4-3-3; tibiae 7-7-5-5; tarsi (excluding pas) 8-4-4-4; spiniform setae on tibiae I–IV 2-2-1-1. Trochanters III and IV with well-developed triangular projections (Figure 7D,F). All basifemora, telofemora, and tibiae having lamellae; basifemur with one lamella ventrolaterally; telofemur and tibia with two lamellae ventrolaterally and ventromedially; ventrolateral lamellae of basifemora and telofemora delicately reticulated; ventrolateral lamellae of telofemora outstanding developed. Genua I–II having small ventrolateral lamella, with bicuspid tip (Figures 6H and 7C). Tibiae G and Figure 7A,D,F) with two lamellae distally, of which ventrolateral lamellae were higher than the ventromedial one in tibiae I–II, meanwhile, both triangular and similar in lengths in tibiae III–IV. Tarsi I–IV 41, 41, 50, and 54 µm long, respectively (measured in ventral surface, excluding lamellae); tarsi III and IV about 1.26 times longer than tarsi I and II; tarsus I slightly shorter than tibia I; tarsus II nearly as long as tibia II; tarsi III–IV slender, 1.35 and 1.42 times longer than tibiae III–IV, respectively. Tarsus I (Figure 6G,I) with one famulus, one solenidion, three dorsal, one ventromedial setae, and two ventral eupathids and a pair of doublet pas; tarsus II (Figure 7A,B) with one solenidion, three dorsal setae, and a pair of doublet eupathid pas; ventromedial pas consisting of one eupathid and one short proeupathid; tarsus III (Figure 7D,E) with four dorsal setae, one short bipectinate pas, and one long eupathid pas; tarsus IV (Figure 7F,G) with four dorsal setae and two short bipectinate pas; all tarsi with one median claw and a pair of lateral claws; median claw bearing one accessory process; lateral claw furnished with comb of thirteen to fifteen spinules on subdistal surface.

Male. Idiosoma (Figure 6A) 380 µm long (361–399 µm, mean = 381 µm, n = 7), 221 µm wide (208–229 µm, mean = 217 µm, n = 7), length to width ratio 1.72, slightly wider than females. Almost similar to female, except for sexual dimorphism in genital area. GA (Figure 6B) 173 µm long and 159 µm wide, with 21–24 pgs around GO; GO (Figure 6B,C) 56 µm long, 45 µm wide, about 0.32 times of GA; distance from anterior edge of GA to anterior tip of GO 91 µm long, about 1.62 times that of GO; 3 pairs of sgs (Figure 6C), foremost sgs short, located at anterior genital sclerite, second and third sgs spiniform and long filiform, respectively, adjacent to each other on posterior genital sclerite. Anterior end of spermatocytes extends to level of leg III.

Distribution. Hong Kong [13], Korea.

4. Discussion

4.1. Systematic Account

There is no doubt that both *Copidognathus levicostatus* n. sp. and *C. vicinus* Bartsch, 1997 from South Korea belong to the *C. gibbus* group, based on their morphological features. These features comprise an acute triangular protrusion on trochanters III and IV dorsally, small lamellae on all basifemora ventrolaterally, well-developed lamellae on all telofemora ventrolaterally, articular lamellae on tibiae laterally, a large fossa membrane on tarsi I and II, and slender tarsi III and IV with very a small or absent fossa membrane [4,13,15,22,23].

Five species within the *C. gibbus* group share similar characteristics with the present new species from Korea, including a short forehead spine in AD and the absence of rosette-pores-areolae on all dorsal plates, including costae on PD: *C. remipes* (Trouessart, 1894) from northern Europe and the Mediterranean Sea [6,16,24], *C. felicis* Newell, 1971 and *C. subgibbus* Newell, 1971 from Chile [15], *C. mactanus* Bartsch, 1985 from the Philippines [25], and *C. strigellus* Bartsch, 1994 from Australia and Hong Kong [13,22]. However, *C. remipes*, *C. subgibbus*, and *C. mactanus* are markedly different from the new species in that they show entire separation between AE and GA in both sexes (whereas AE and GA are not completely separated, and confluent on both sides in the new species), and have four pairs of pgs in the male (against three pairs in the new species). Furthermore, the latter two species, *C. subgibbus* and *C. mactanus*, are clearly distinguished from the new species by the absence of a transverse internal bar in AD.

Copidognathus remipes, which is most similar to the new species in having a pair of costae on the PD, was originally recorded as '*Halacarus gibbus* var. *remipes* Trouessart, 1894' and insufficiently described. Later, it was redescribed in both sexes from the coast of Brittany, France, and Helgoland, Germany, by Bartsch [6], but a few detailed characteristics of the species remained uncertain. Nonetheless, *C. remipes* differs from the new species by the posterior edge of OC exceeding beyond the insertion of leg III (see [6], Abb 34; versus not reaching in the new species), telofemur II with four setae (see [6], Abb 38; versus five setae in the new species), and the anterior two pairs of pgs of the female located far from the anterior end of GO (see [6], Abb 44; versus only an anteriormost pair of pgs in the new species).

Copidognathus felicis was described based on only a single female at a depth of 160–170 m off the submarine slope of San Felix Island, Chile [15]. Its AE is partially fused with the GA laterally, as in the new species. However, *C. felicis* is clearly distinguished from the new species by lacking a proximodorsal seta on tarsus IV and a pair of raised ribs on PD, and by having a small GO, about 1/4 times as long as the GA (versus about 1/3 times as long as the GA in the new species).

Copidognathus strigellus is clearly discernible from the new species by the delicate panels on dorsal plates, forming striae; the absence of raised costae on PD (versus a pair of raised ribs on PD in the new species); a transverse internal bar in AD; a similar length between P-2 and P-4 (while P-4 is 1.43 times longer than P-2 in the new species); and the location of the bipectinate dorsal seta on the P-2 near the middle of the segment (versus situated at about a distal third of the segment in the new species). Furthermore, *C. strigellus* shows a sexual dimorphism of different pattern between the ventral plates (AE and GA). In the female (from Australia, described by [22]), AE and GA are completely separated from each other, meanwhile in the male (from Hong Kong, described by [13]) they are partially fused except for the central part.

Copidognathus vicinus Bartsch, 1997, another member of the *C. gibbus* group, was described for both sexes from Telegraph Bay, Hong Kong [13]. It is characterized from other members of the *C. gibbus* group by a combination of characteristics, as follows: the dorsal plates separated from one another; a well-developed frontal spine exceeding far beyond the gnathosomal base; the lamellae along the lateral margins of the raised triangular area in the AD; a pair of triangular porose areolae with rosette pores at the lateral AD; a pair of curved costae with two to three rows of rosette pores on the PD; a pair of cornea in the OC; and a spatulate ventrolateral lamella on the genua I–II.

The Korean specimens of *C. vicinus* coincide well with the original description, except for a minor morphological discrepancy that all lateral claws have a comb row of 13–15 spinules on the subdistal surface (versus showing very delicate pecten on the lateral claws of legs II–III only, in the Hong Kong specimens).

4.2. A Brief Comment on Habitat Preference

Previous studies on the *C. gibbus* group [2–4,17] have reported that *Copidognathus* inhabits various habitats, including interstitial spaces in sediments, in and on macroinvertebrate colonies such as bryozoans, mussels, polychaetes and barnacles, as well as epifloral beds such as seagrasses and coralline algae, ranging from the intertidal to subtidal zones. In Korea, since the first record of a marine halacarid, *C. koreanus* Chatterjee and Chang, 2003, 12 species of *Copoidognathus* have been recorded, including *C. levicostatus* n. sp. and *C. vicinus*. The Korean halacarid mites are commonly and frequently found in geniculate red coralline algae, mostly on intertidal rocks.

During our faunal study of marine halacarid mites in Korea, we confirmed the presence of ten species of *Copidognathus* halacarids, including *C. levicostatus* n. sp. and a new record from Korea (*C. vicinus*), from nine collection sites in Korea (Figure 1). We surveyed their microhabitat preferences, including subtidal non-geniculate red coralline algae, at each location (Table 1).

Table 1. Occurrences of the ten *Copidognathus* species from nine locations in this study (+, occurrence).

Locations	1	2	3	4	5	6	7	8	9
Habitats	**Non-Geniculate Red Coralline Algae**			**Mixture of Invertebrate Colonies with Geniculate Red Coralline Algae**		**Geniculate Red Coralline Algae**			
Species									
Copidognathus cerberoideus						+	+		
Copidognathus daguliarensis	+	+	+		+	+	+	+	
Copidognathus fistulosus				+					
Copidognathus jejuensis	+	+				+			+
Copidognathus koreanus	+	+		+	+				
Copidognathus laevisetosus				+	+				
Copidognathus polyporus					+	+	+	+	+
Copidognathus quadriporosus		+		+	+			+	
Copidognathus vicinus		+			+	+		+	
Copidognathus levicostatus n. sp.	+	+	+	+	+	+	+	+	+

We found that *C. levicostatus* n. sp. was the most frequently occurring species, present at all nine sites and inhabiting a wide range of microhabitat types, such as the mixture of invertebrate colonies (e.g., mussels [*Mytilisepta virgata* (Wiegmann, 1837)], polychaete tubes and cirripeds) and both non-geniculate and geniculate red coralline algae. In contrast, *C. fistulosus* was the rarest species, occurring at only one location. *Copidognathus vicinus*, although it was found in all three habitat categories, was not as frequently found as *C. levicostatus* n. sp., co-occurring with *C. levicostatus* n. sp. at four locations.

All ten species were found among geniculate red coralline algae (locations 6–9) in the intertidal zone and/or in a mixture of invertebrate colonies with geniculate red coralline algae (locations 4 and 5). Among them, six species (*C. daguilarensis*, *C. koreanus*, *C. jejuensis* Chatterjee and Chang, 2004, *C. quadriporosus* Chatterjee and Chang, 2006, *C. vicinus* and *C. levicostatus* n. sp.) inhabited both non-geniculate red coralline algae in the subtidal zone and geniculate red coralline algae in the intertidal zone. Meanwhile, the remaining four species (*C. cerberoideus* Bartsch, 1990, *C. fistulosus* Chatterjee and Chang, 2005, *C. laevisetosus* Chatterjee, Lee and Chang, 2004 and *C. polyporus* Bartsch, 1990) were not found among non-geniculate red coralline algae (locations 1–3). These collection data suggested the possibility of microhabitat preferences between geniculate and non-geniculate red coralline algae. Further extensive and elaborate collection of the species among non-geniculate red coralline algae in the subtidal zone is necessary to clarify whether genuine microhabitat preferences between the two types of red coralline algae exist.

4.3. Key to the Species of Copidognathus Hitherto Recorded in Korean Waters

Below is a dichotomous key for all known *Copidognathus* species, including two newly recorded species in Korea.

1. Trochanters III and IV with a triangular protrusion dorsally ———— 2 (*gibbus* group)
   Trochanters III and IV without a triangular protrusion dorsally ————————— 4
2. PD with rosette pores on costae; tectum with a large crest-shaped process ——— 3
   PD without rosette pores on costae; tectum with a small crista ——— *C. levicostatus* n. sp.
3. AD with a long frontal process extending beyond the gnathosomal base; PD with a pair of costae, each with two to three rosette pores wide ———————— *C. vicinus*
   AD with a short frontal process; PD with a pair of costae, each with one rosette pore wide —————————————————————————— *C. daguilarensis*
4. Genua I and II with two setae ———————————————— *C. cerberoideus*
   Genua I and II with four setae —————————————————————————— 5
5. AD with inverted "Y"-shaped areolae ——————— *C. tetrachachis* (*pulcher* group)
   AD without inverted "Y"-shaped areolae —————————————————————— 6
6. PD with a pair of costae; AE with four areolae ————————– *C. quadriporosus*
   PD with two pairs of costae; AE without areolae ———————————————— 7
7. AD with two areolae; ds-3 on the membranous cuticle between AD and PD ——— 8
   AD with three areolae; ds-3 on the anterior part of PD ———————————— 11
8. Tibia I with one bipectinate seta —————————————————— *C. curtus*
   Tibia I without the bipectinate setae ————————————————————— 9
9. Tibia I with one thicker and spiniform ventral-most seta; tibia II without the bipectinate setae —————————————————————————— *C. laevisetosus*
   Tibia I without the spiniform setae; tibia II with one bipectinate seta —————— 10
10. Tibia III with one bipectinate seta; PD with glp-3 ————————— *C. fistulosus*
    Tibia III without the bipectinate setae; PD without glp-3 ——————— *C. koreanus*
11. All AE covered with pores; tibiae I and II with two ventrolateral dentate lamellae; tarsus IV with three dorsal setae ————————————————— *C. jejuensis*
    AE covered with pores, except for smooth "Y"-shaped part; tibiae I and II without the ventrolateral dentate lamellae; tarsus IV with four dorsal setae on ——————————————————————————————————————— *C. polyporus*

5. Conclusions

We discovered two halacarid species from red coralline algae and various invertebrate colonies on intertidal and sublittoral rocks at nine locations along the coast of South Korea. We taxonomically classified them as a new species (*Copidognathus levicostatus* n. sp.) and a new record from Korea (*C. vicinus* Bartsch, 1997), both belonging to the *C. gibbus* group. We provided detailed descriptions and systematic comparisons with related species, based on morphological characters examined under a differential interference microscope and scanning electron microscope. Additionally, we made out a key to all known *Copidognathus* species in Korea. Our study reveals that the species diversity of the genus *Copidognathus* is higher than that of any other halacarid genera in Korean waters. Moreover, our collection data suggest the possibility of microhabitat preferences between geniculate and non-geniculate red coralline algae, with the latter representing an unknown microhabitat for halacarid mites in Korea.

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