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Article *in* Turkish Journal of Zoology · March 2019

DOI: 10.3906/zoo-1809-20

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Research Article

Turk J Zool
(2019) 43: 171-184

doi:10.3906/zoo-1809-20

A new species of the genus *Echinolaophonte* Nicholls, 1941 (Copepoda, Harpacticoida, Laophontidae) from the Aegean Sea coast of Turkey

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Received: 17.09.2018 • **Accepted/Published Online:** 03.01.2019 • **Final Version:** 01.03.2019

Abstract: During the ongoing partial taxonomic revision of the genus *Echinolaophonte* on the basis of populations previously collected from various shores of the Turkish coasts, a new species of *Echinolaophonte* was discovered and named *Echinolaophonte mordoganensis* **sp. nov.** The new species is morphologically most closely related to *E. minuta* and *E. veniliae*. The new species can easily be distinguished from its congeners by the combination of the following features: i) the shape of the rostrum, ii) having 2 ornamented setae instead of 1 on the syncoxa of the maxilliped, and iii) pattern difference in the P1–P4 setal formula in both male and female. The phylogenetic position of the new species in the genus has also been briefly discussed.

Key words: Meiofauna, taxonomy, interstitial, Laophontidae, *Echinolaophonte*

1. Introduction

The genus *Echinolaophonte* Nicholls, 1941 of the family Laophontidae Scott T., 1904 includes benthic harpacticoids that are strictly marine and encompasses 14 valid species/subspecies (Fuentes-Reinés and Suàrez-Morales, 2017). It was erected by Nicholls in 1941 with 4 species (*Laophonte brevispinosa* Sars, 1908; *Laophonte mirabilis* Gurney, 1927; *Laophonte horrida* Norman, 1876; and *Laophonte armiger* Gurney, 1927) by designating the type species as *Echinolaophonte horrida* (Norman, 1876), which had been previously assigned to the genus *Laophonte* Philippi, 1840. When Nicholls (1941) established *Echinolaophonte*, he pointed out that the genus can be separated from the other laophontid genera with the combination of the following characters: i) morphology of dorsal process on cephalothorax; ii) absence of the endopod at maxillule; iii) P2–P4 setal formula; iv) typical P5; v) dorsolaterally paired spines on each body somite except for the last 1 or 2 somites; and vi) endopod of male P4 extremely reduced. Lang (1948) unwarily transferred the *horrida*-group of the genus *Laophonte* to the genus *Onychocamptus* Daday, 1903, but Lang (1965) then accepted the genus *Echinolaophonte* when he realized his mistake.

The detailed morphological comparison and examinations of previously collected materials from various shores of the Turkish coasts in terms of intra- and interpopulational morphological variations revealed an *Echinolaophonte* species new to science. The aim of this study is to provide a full description of this new species in detail and discuss the relationships of the new species with its congeners in order to contribute to the unfamiliar phylogeny and taxonomy of the genus, as well as to the family Laophontidae.

2. Materials and methods

The type materials were collected according to the Karaman–Chauppuis method (Delamare Deboutteville, 1954) from the intertidal zone of the beaches of İzmir Province, Aegean Sea, Turkey. The substrate of all sampling beaches including the type locality is mixed, mostly pebbles and some cobbles with differing amounts of coarse/fine sand in the interstices between pebbles and cobbles (the other details of the sampling stations are given below). Specimens were dissected and mounted on slides in lactophenol medium under an Olympus SZX-16 stereo microscope (Olympus, Tokyo, Japan). Sketches of the body and appendages were made with an Olympus BX 53 differential interference contrast microscope using a drawing tube. Final figures were created from the sketches and SEM micrographs with Adobe Photoshop CC software with the aid of a Wacom Intuos Pro M graphics tablet (Wacom, Kazo, Japan). Kaymak and Karaytuğ

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(2014) were followed for preparing the species for SEM. A field emission scanning electron microscope (Supra 55; Carl Zeiss, Oberkochen, Germany) located in Mersin University's Advanced Technology Education Research and Application Center (MEITAM) was used for SEM examinations. All materials were deposited at the Zoology Museum of Adıyaman University (ZMADYU). Huys et al. (1996) were followed for the terminology used in the text. The scale bars in figures and SEM micrographs are given in µm. Abbreviations used in the text are ae for aesthetasc and P1–P6 for swimming legs 1–6.

3. Results

3.1. Systematics

Order Harpacticoida Sars, 1903
Family Laophontidae Scott T., 1904
Genus *Echinolaophonte* Nicholls, 1941
Echinolaophonte mordoganensis **sp. nov**. (Figures 1–9)

3.2. Material examined

Type material: Holotype ♀ (ZMADYU 2012/185), dissected on 7 slides, allotype ♂ (ZMADYU 2012/186), dissected on 7 slides, collected at Küçükbahçe Beach, Mordoğan, İzmir, Turkey (38°33′26.8″N, 26°22′13.8″E), 27.10.2012.

Paratypes: 152 ♀♀ (7 ovigerous, 35 copepodids) (ZMADYU 2012/187) and 99 ♂♂ (ZMADYU 2012/188) in ethanol. 3 ♀♀ (ZMADYU 2012/189) and 2 ♂♂ (ZMADYU 2012/190); each specimen dissected on 7 slides. 4 ♀♀and 4 ♂♂ specimens from these samples were critical point-dried for SEM.

Other paratype materials examined: 8 ♀♀ (ZMADYU 2012/191) and 2 ♂♂ (ZMADYU 2012/192), Özdere Beach, Ortamahalle, İzmir, Turkey (38°02′40.3″N, 27°03′14.1″E), 26.10.2012. 1 ♀ (ZMADYU 2012/193), Denizgiren Beach, İzmir, Turkey (38°34′02.7″N, 26°21′45.4″E), 27.10.2012. Coll. Serdar SÖNMEZ.

3.3. Etymology

The specific name refers to the Mordoğan district where the type specimens were collected.

3.4. Description

Female: Body length, from the tip of rostrum to distal edge of the caudal rami, 445 µm, gradually narrowing from cephalothorax to caudal rami (Figures 1a and 1b). Dorsal body surface ornamented with folds forming polygonal cell-like structures (Figure 2b), distal margin of the somites with tooth-like protrusions and hyaline fringes (Figure 2c). Cephalothorax rectangular, with numerous tube sensilla, few pores, and numerous small setules on the dorsal surface (Figure 2a). Squared dorsal process on cephalothorax ornamented with numerous spinules as in Figure 2a, bearing strong spiniform extensions distally (Figure 2d). All somites except the penultimate somite with 2 strong spiniform processes and spinules arising from a pedestal on both sides at the midline of dorsal surface (Figures 1c, 1d, and 2e).

Pseudo-operculum (Figure 7a) variable, with different numbers of strong spikes (twin, triple, or quadruple) and spinules arising from a pedestal on the outside of the protrusions. Anal operculum convex, difficult to observe, and ornamented with a thin set of setules at the distal edge (Figure 4e).

Caudal rami (Figures 4f, 7a, 7b) almost cylindrical, twice the width of its length, with 7 elements: seta I located dorsolaterally, short and naked; setae II and III located near outer distal corner, seta II about 2.5 times longer than seta I, naked; seta III slightly longer than seta II and naked; seta IV located at outer terminal; seta V located at the inner terminal, longer and thicker than seta IV; seta VI located in the inner subdistal corner, about as long as seta II, naked; seta VII located distally on dorsal surface, naked, and 3-articulated at base.

Rostrum (Figure 3a) with a small notch in the middle of the distal edge, bears a ventral tube pore and 2 sensorial setae in the proximal portion, almost reaching to the middle of the first segment of the antennule.

Antennule (Figures 3a, 4a) 6-segmented, ornamented with folds forming a polygonal cell-like pattern (Figure 4a), fourth segment with an aesthetasc fused basally to 2 naked setae, arising from a pedestal. Last segment with an acrothek consisting of 1 short aesthetasc fused to 2 short and naked setae. Setal formula: 1-[1], 2-[8], 3-[6], 4-[2+ae], 5-[1], 6-[8 + acrothek].

Antenna (Figures 3b, 4d) with coxa, allobasis, free unisegmented endopod and exopod. Allobasis length 3× the width, ornamented with a row of spines on the inner edge, and bearing a short spinulose seta at inner margin. Exopod unisegmented and with 4 pinnate setae. Endopod slightly shorter than the allobasis, ornamented with 2 transverse rows of spinules and a row of course spinules; bears a strong pinnate seta and 2 naked setae laterally, with 2 naked spines on the apical edge, 3 geniculate setae, and with a thin seta basally connected to outermost geniculate seta.

Mandible (Figures 3c–3f). Gnathobase cutting edge (Figure 3d) surrounded by numerous sharp teeth and 1 pinnate seta on the dorsal edge. Palp (Figures 3e, 3f) small, exopod and endopod reduced and fused to basis, with 3 pinnate and 2 naked setae.

Maxillule (Figure 3g). Arthrite well developed, ornamented with short rows of spinules on anterior and posterior surface; with 1 naked seta laterally, 4 naked spines and 1 pinnate spine, and 1 pinnate seta apically. Coxa ornamented with few spinules at outer distal corner; coxal endite slightly elongated and fused to coxa at base, bears 1 bare and 1 bipinnate spiniform setae. Basal endite

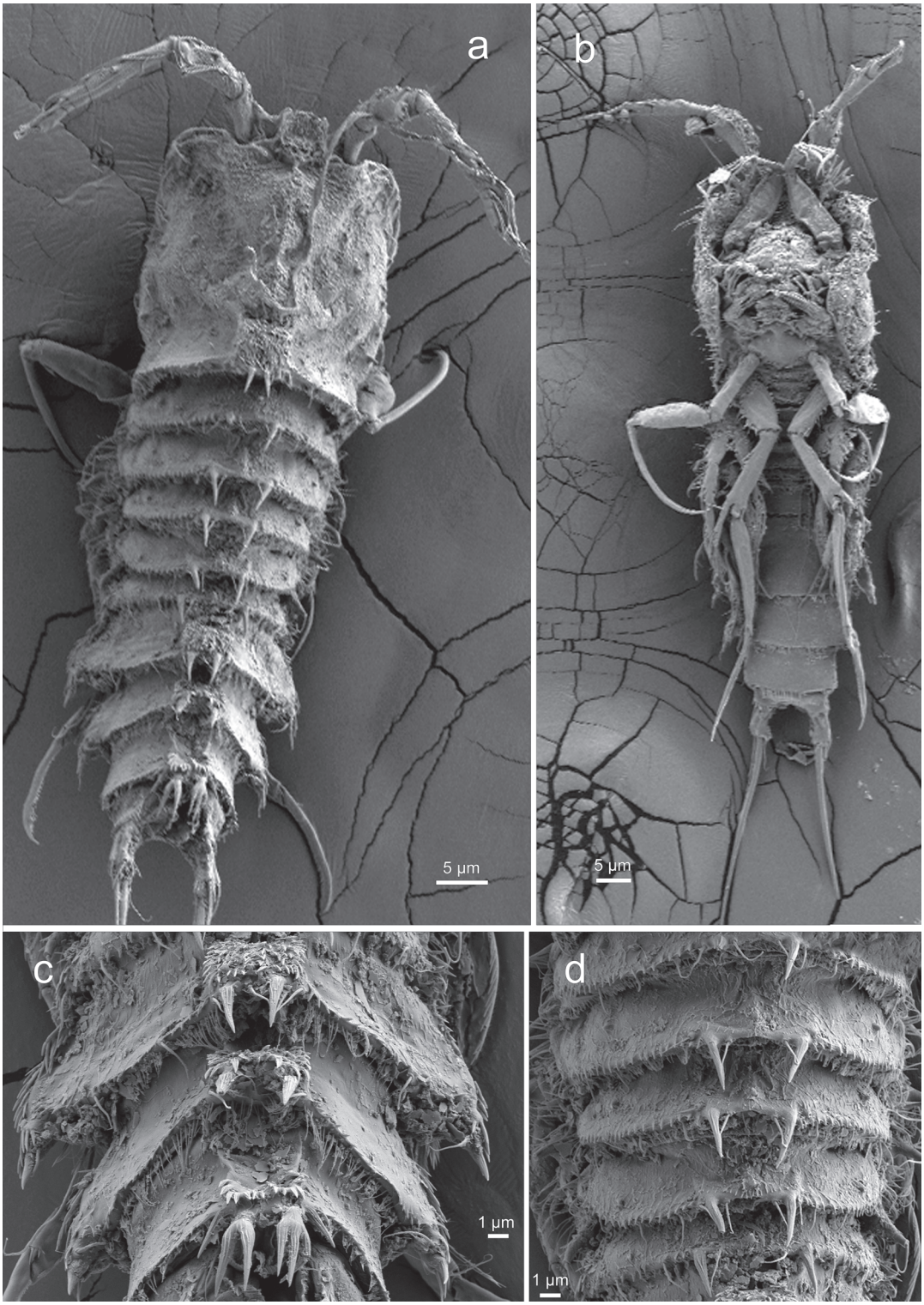

Figure 1. *Echinolaophonte mordoganensis* **sp. nov.**, SEM micrographs, ♀: a) habitus, dorsal; b) habitus, ventral; c) somites 7–9, dorsal; d) somites 2–6, dorsal.

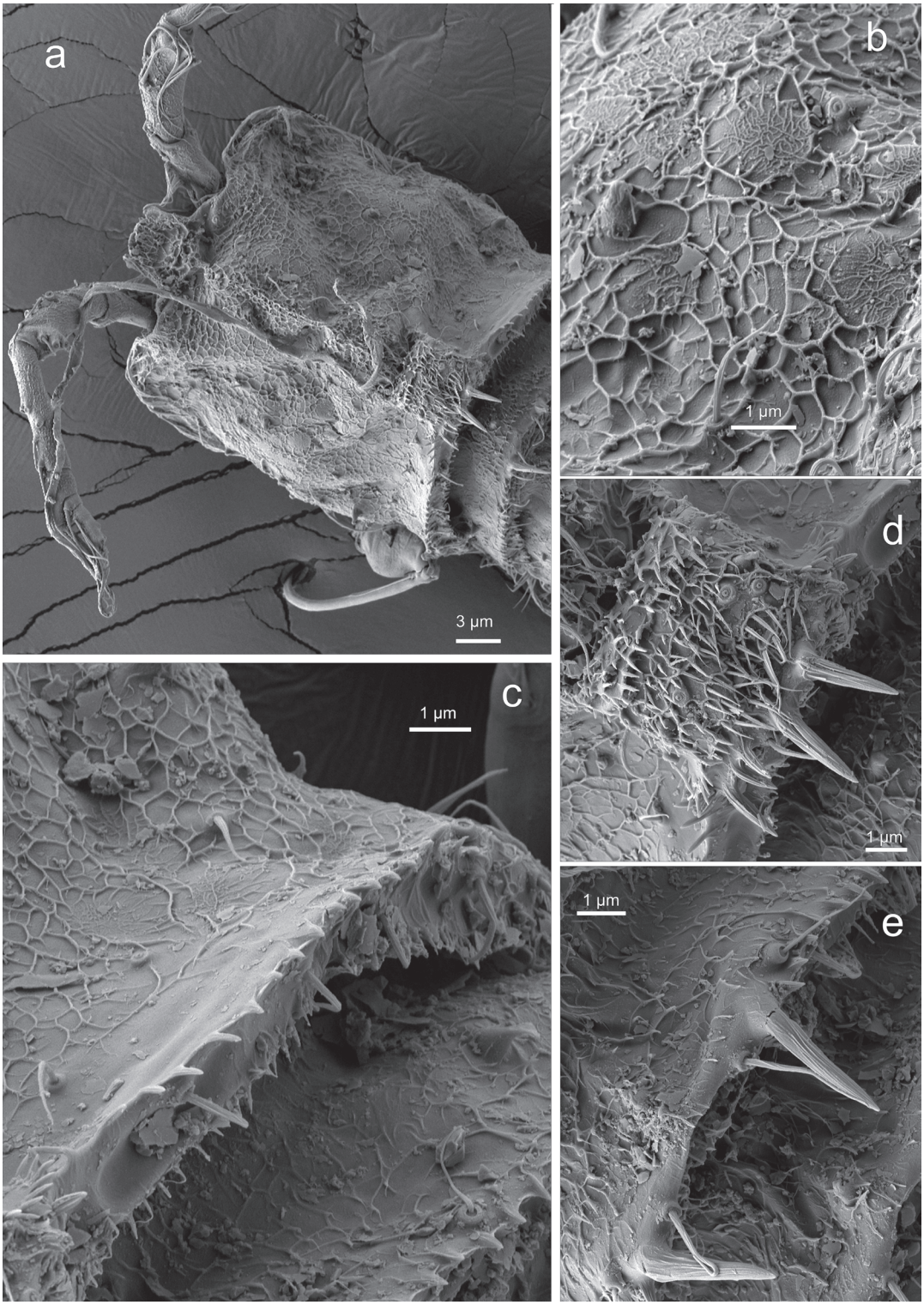

Figure 2. *Echinolaophonte mordoganensis* **sp. nov.**, SEM micrographs, ♀: a) cephalothorax, dorsal; b) folds form polygonal cell-like pattern on body; c) hyaline fringes on the distal margin; d) dorsal process of the cephalothorax; e) spiniform process of the third somite.

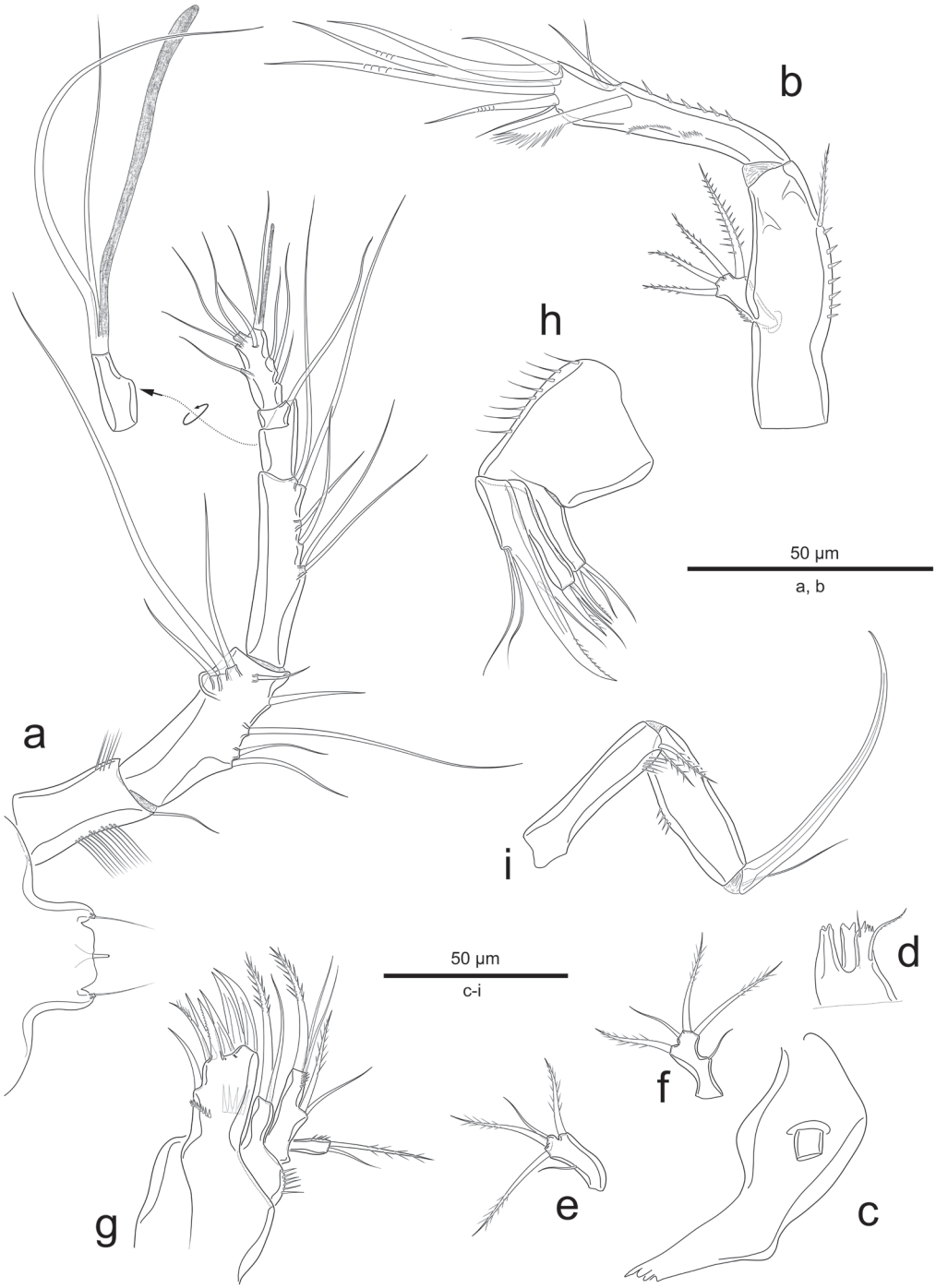

Figure 3. *Echinolaophonte mordoganensis* **sp. nov.**, ♀, holotype: a) antennule and rostrum; b) antenna; c) mandible; d) cutting edge of the mandibular gnathobase, e–f; mandibular palp; e) posterior; f) anterior; g) maxillule, h) maxilla; i) maxilliped.

and endopod fused to basis; basal endite cylindrical, bears 2 bare setae and 1 strong bipinnate spine apically; endopod bears 1 short naked and 1 relatively thicker bipinnate setae. Free exopod unisegmented, slightly elongated, bears 1 short bare seta and 1 relatively longer bipinnate seta.

Maxilla (Figure 3h). Syncoxa ornamented with long spinules at outer margin, bears 2 endites. Proximal endite with 2 naked setae and 1 distally unipinnate seta; distal endite with 2 naked setae and 1 unipinnate spine. Allobasis transformed into a strong, distally unipinnate,

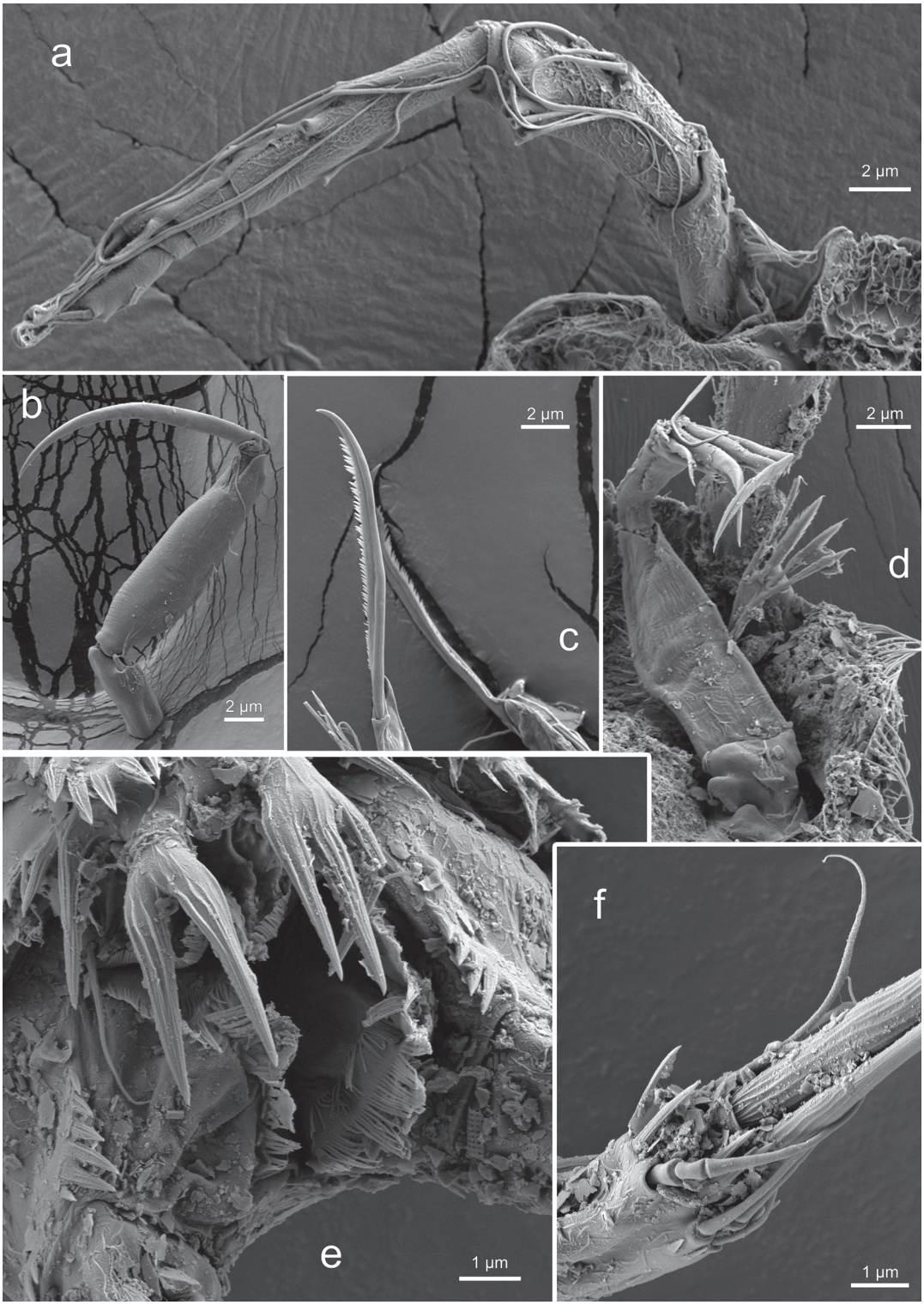

Figure 4. *Echinolaophonte mordoganensis* **sp. nov.**, SEM micrographs, ♀: a) antennule; b) maxilliped; c) P1 endopod claw; d) antenna; e) dorsal process of the penultimate somite; f) caudal rami.

Figure 5. *Echinolaophonte mordoganensis* **sp. nov.**, holotype, ♀: a) P1; b) P2; c) P3; d) P4.

slightly curved claw, bears a naked seta at posterior surface; endopod reduced, represented by 2 closely set naked setae.

Maxilliped (Figure 3i). Syncoxa narrow and elongated, about 5× longer than wide, with a row of spinules near outer distal corner and with 2 short bipinnate setae at outer distal corner. Basis elongated, about 3× longer than wide and slightly shorter than syncoxa, ornamented with a very short row of spinules at the midline of outer margin.

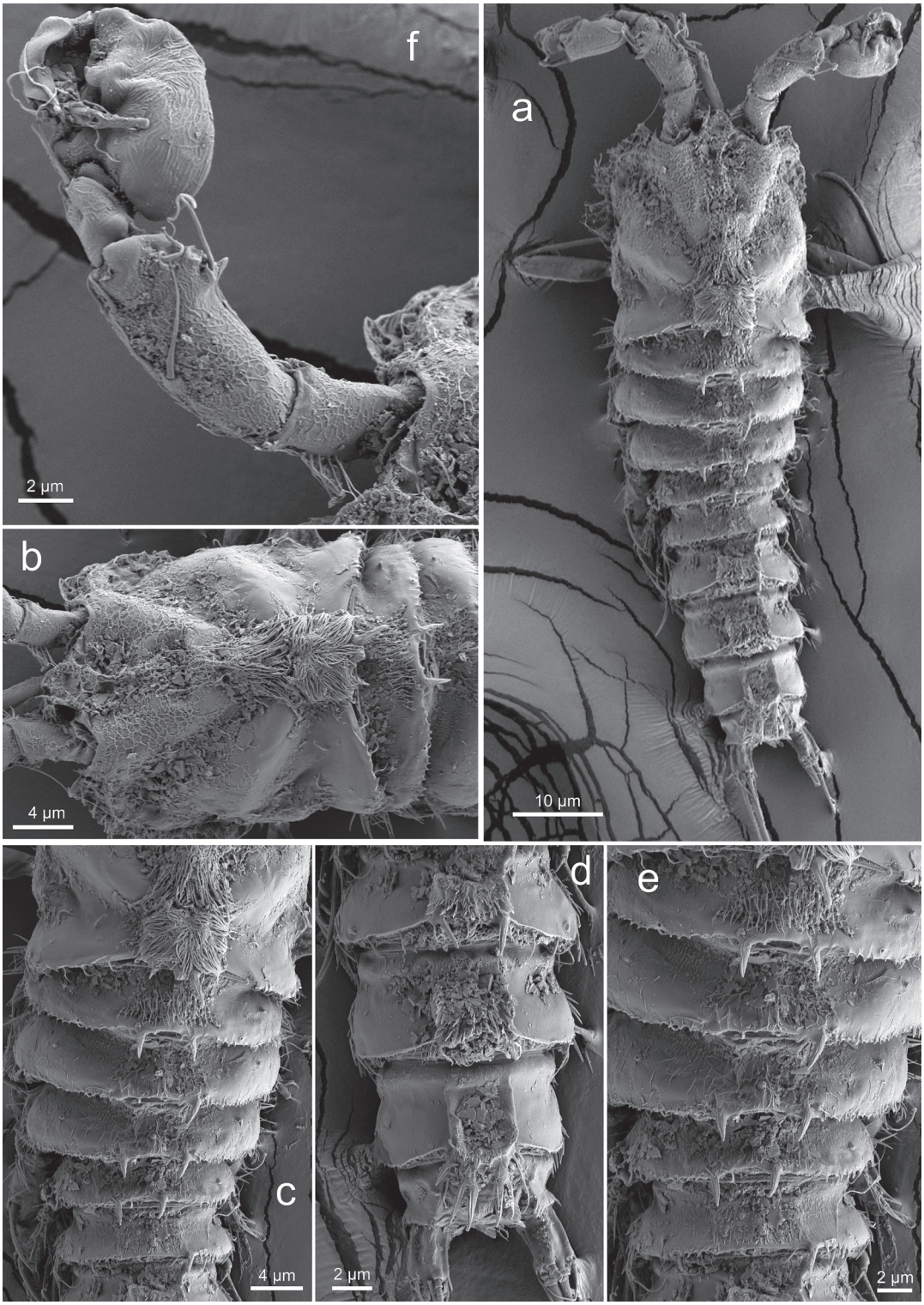

Figure 6. *Echinolaophonte mordoganensis* **sp. nov.**, SEM micrographs, ♂: a) habitus, dorsal; b) cephalothorax; c) somites 1–6, dorsal; d) somites 8–11, dorsal; e) somite 2–6, dorsal; f) antennule.

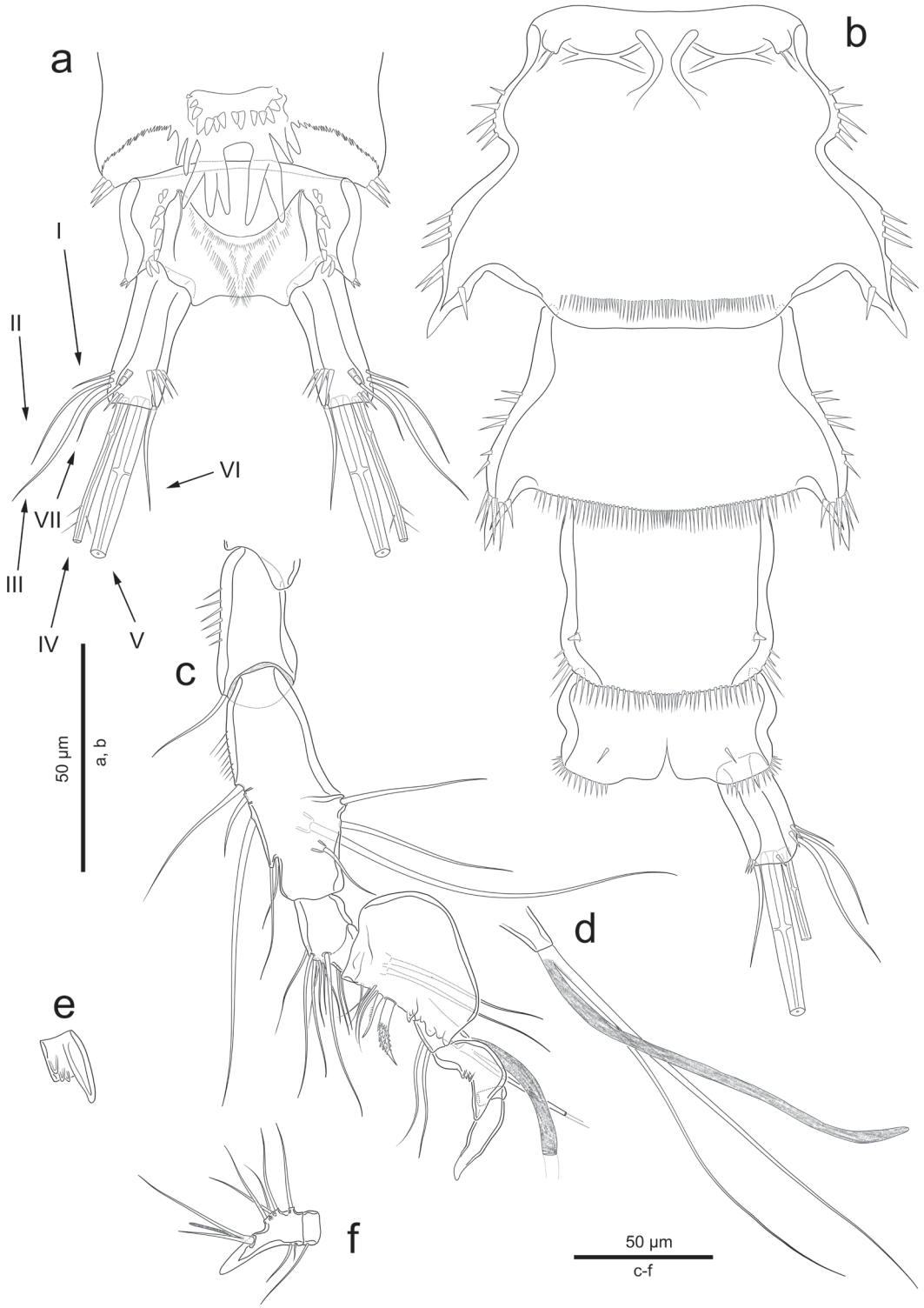

Figure 7. *Echinolaophonte mordoganensis* **sp. nov.**, a–b) holotype ♀; c–f) allotype ♂, antennule: a), penultimate somite, anal somite, and caudal rami, dorsal; b) urosome, ventral; c) antennule; d) distal part of the fifth segment; e) 3-dimensional spinous process of the sixth segment; f) seventh and eighth segments.

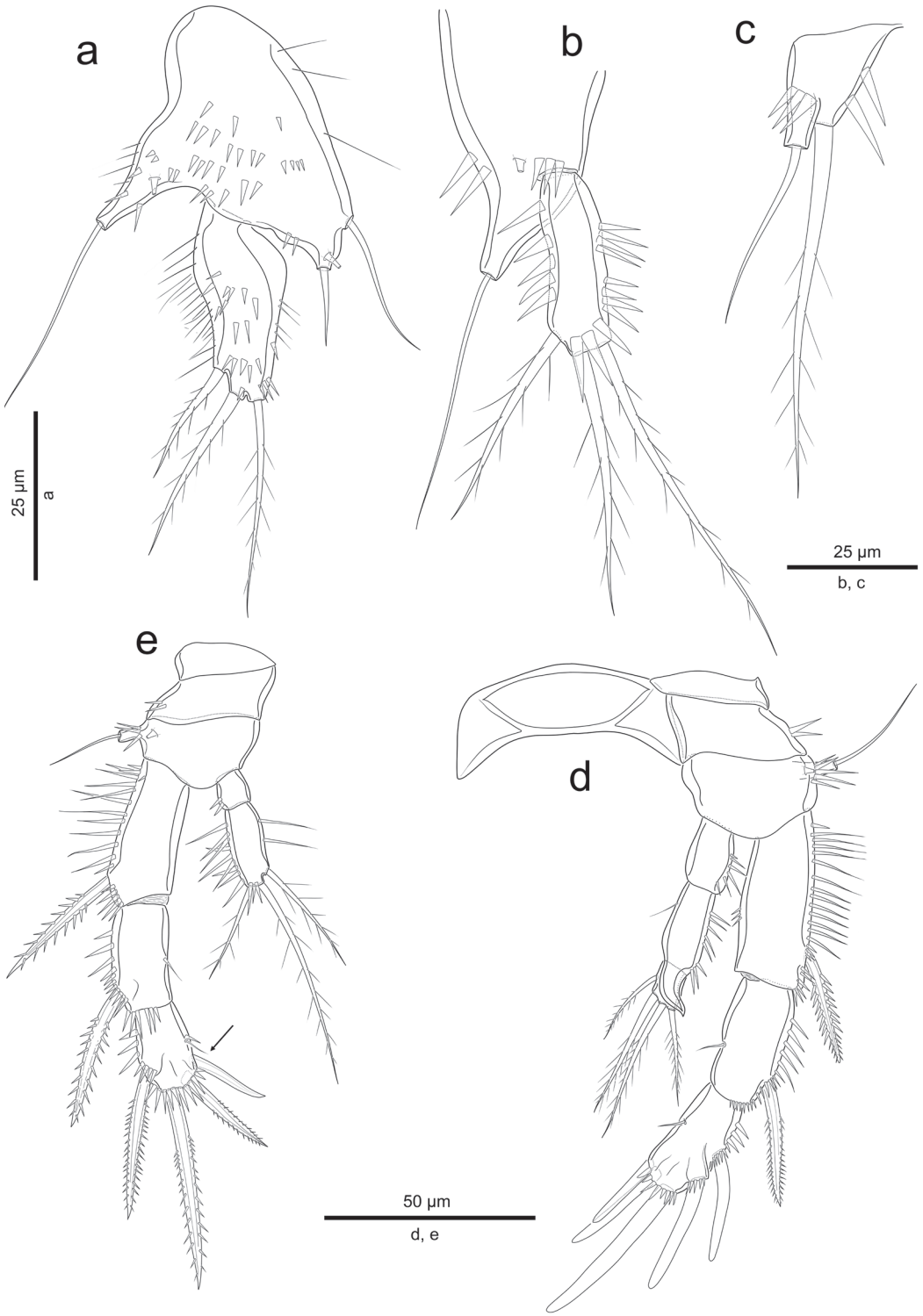

Figure 8. *Echinolaophonte mordoganensis* **sp. nov.**, a) ♀, holotype; b–e) ♂, allotype; a) P5; b) P5; c) P6; d) P3; e) P4.

Endopod transformed into a very long, curved, naked, strong claw, bears an accessory seta near base of posterior surface (Figure 4b).

P1 (Figure 5a) coxa elongated, 2× longer than wide and with spinules on the lateral margins, bears a tube pore near outer distal corner. Basis narrow and elongated

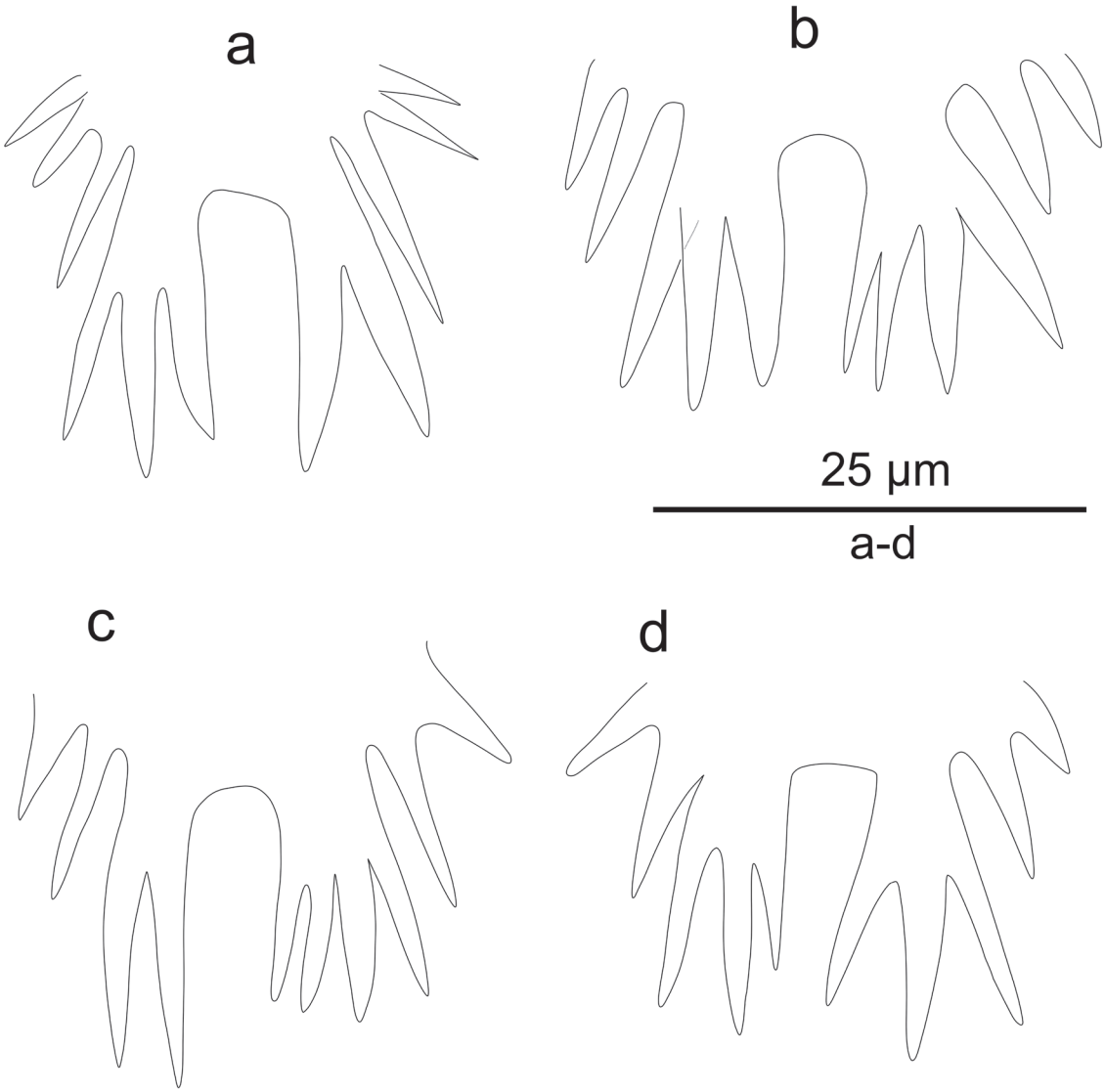

Figure 9. *Echinolaophonte mordoganensis* **sp. nov.**, a ♂, b–d ♀, variation of pseudo-operculum on paratypes.

slightly longer than coxa; bears 1 short plumose inner seta and 1 short plumose outer seta located at distal corner. Exopod 2-segmented, reaching about one-third of endopod segment; first segment short, with a plumose seta at inner margin; second segment slightly elongated, bears 3 plumose setae laterally and 1 naked and 1 spinulose setae apically. Endopod 2-segmented, prehensile; first segment elongated, about 7× longer than wide at the midline of anterior surface, naked; second segment short, bears a very long and serrate claw (Figure 4c) terminally and a minute seta at outer distal corner, ornamented with short spinules at the distal half of inner margin.

P2–P4 (Figure 5b–5d). Coxa ornamented with thin spinules at outer lateral margin. Basis with very long, strong, thick, and plumose spiniform seta (P2) or with a relatively short and naked seta (P3–P4) arising from an outer distal pedestal, with a tube pore on anterior surface. Exopod 3-segmented, first segment slightly elongated, bears a pinnate spine at outer distal corner, ornamented with setules at outer margin; second segment with a plumose seta at the inner margin and with a pinnate spine at outer distal corner; third segment slightly elongated; inner margin naked (P2) or armed with a short plumose seta (P3–P4), bears a spinulose seta and a strong spine (P2, P3) or with 2 spinulose setae (P4) distally, with 2 (P2, P4) or 3 (P3) outer spines. Endopod 2-segmented, extends to about the end of the second segment of exopod (P2, P3) or two-thirds of first exopod segment (P4); first segment elongated (P2), slightly elongated (P3) or very short (P4), unarmed, inner margin ornamented with setules (P2, P3) or naked (P4); distal segment slightly elongated, with 3 (P2), 4 (P3), or 2 (P4) plumose setae.

P5 (Figure 8a). Baseoendopod and exopod distinct; outer basal seta naked; endopodal lobe bears 2 naked setae at the inner margin, anterior surface ornamented with coarse spinules as figured, bears a tube pore set closely to the base of outermost seta at anterior surface. Exopod slightly elongated, about 1.5× longer than wide; bears coarse spinules on two-thirds distal part of anterior surface; ornamented with long setules at outer margin and with a few short spinules at inner margin, with 3 plumose setae.

P6 (Figure 7b) reduced to a very small and squarish plate, located on each side of ventral surface of genital, double somite with 2 minute setae.

Male*:* Antennule, dorsal process in cephalothorax, body ornamentation, P3, P4, P5, and P6 sexually dimorphic. Body (Figure 6a) length from tip of rostrum to posterior margin of caudal rami 410 µm. Dorsal process on cephalothorax and dorsal midline of the first prosomite different from that of female, ornamented with numerous long surface spinules on body somites. Folds form polygonal cell-like pattern on the body surface limited at the top of the cephalothorax and antennule (Figures 8b, 8c). Cephalothorax rectangular, with numerous tube sensillum on the dorsal surface, and numerous small setules on the distal sides. In the midline of the dorsal part of all somites except for the penultimate somite, 2 strong spiniform structures and spinules arising from a pedestal on both sides (Figures 8d, 8e).

Antennule (Figures 7c–7f). Eight-segmented subchirocer with geniculation between fifth and sixth segment; aesthetasc arises from the fourth and eighth segments. Antennule surface ornamented with folds forming polygonal cell-like pattern (Figure 8f). Fifth segment swollen, bears 1 pinnate seta and 1 strong ornamented seta. Sixth segment with 3-dimensional spinous process as in Figure 7e. Eighth segment with acrothek comprising 2 thin setae and an aesthetasc, distal margin with triangular extension. Setal formula: 1-[1], 2-[9], 3-[8], 4-[2], 5-[8 + 1 pinnate + 1 modified + (2 + ae)], 6-[4 spinous processes], 7-[1], 8-[7 + acrothek].

P3 (Figure 8d). Exopod segments and all spines more elongated and robust than the female. Second segment of exopod with a minute seta on inner edge. All exp-3 setae naked. Endopod 3-segmented, extending to one-third of second exopod segment; second segment longer than the first and has a strong apophysis fold bending outward. Third segment the shortest, with 2 plumose setae at the inner edge and 2 pinnate spines apically.

P4 (Figure 8e). More robust than in the female, exopod segments with a row of setules on the outer edge, second segment of exopod with a short straight seta on inner edge. The third segment of exopod bears 3 pinnate setae, 1 naked robust seta, and 1 minute seta (arrowed in Figure 8e). Endopod extends to half of the exopod second segment; 2-segmented, second segment 3× longer than the first, bears long spinules on the inner and outer edges, and with 3 plumose setae.

P5 (Figure 8b). Baseoendopod and exopod distinct; endopodal part of baseoendopod reduced and unarmed, bears a tube pore on anterior surface, outer basal seta long and naked. Exopod narrow and slightly elongated, ornamented with coarse spinules near inner, outer, and apical margins; bears 3 well-developed plumose setae.

P6 (Figure 8c). Baseoendopod and exopod fused, ornamented with a few coarse spinules; bears a naked outer basal seta and a well-developed relatively longer plumose seta.

Variability: Pseudo-operculum of the female and male can bear different numbers of strong spikes (twin, triple, or quadruple) (Figures 9a–9d).

4. Discussion

Lang (1965) was the first to attempt to discuss the phylogenetic relationships between the species of the genus *Echinolaophonte*. Lang defined 2 evolutionary lineages according to the armature of the terminal segments of P2–P4 exopods and the structure of the male P3 endopod. In the first lineage, the terminal segment of the P2–P4 exopod is armed with 3-3-2 outer spines, respectively, and the male P3 endopod is sexually dimorphic (with 3 segments, the second segment with an apophysis); in the second lineage, terminal segments of P2–P4 exopods are armed with 2-3-2 outer spines, respectively; the male P3 is not sexually dimorphic (same as female). After the discovery of *E. tetracheir* Mielke, 1981, which has 2-3-2 outer spines at the distal segments of the exopod of P2–P4 (as in the second lineage) but does not have a sexually dimorphic P3 endopod (as in the first lineage), Cottarelli and Forniz (1991) and Cottarelli et al. (1992) described 2 new species of the genus (*E. minuta* Cottarelli & Forniz, 1991 and *E. veniliae* Cottarelli et al., 1992) which share characters of the 2 evolutionary lineages of Lang (1965), but they rejected Lang's (1965) approach of using the number of spines as an evolutionary trend within the genus *Echinolaophonte* and created 2 provisional groups: i) the *horrida*-group, which accommodates the *Echinolaophonte* species with a sexually dimorphic P3 endopod in the male, including the species *E. horrida*, *E. brevispinosa* (Sars, 1908), *E. oshoroensis* Itô, 1969, *E. veniliae*, and *E. minuta*; ii) the *armiger*-group, which accommodates the *Echinolaophonte* species with a male P3 endopod as in the female, including the species *E. tetracheir*, *E. hystrix* (Brian, 1928), *E. armiger* (Gurney, 1927), *E. armiger* f. *briani* Lang, 1965, and *E. villabonae* Fuentes-Reinés & Suárez-Morales, 2017. However, the statuses of *E. mirabilis* Gurney (1927), *E. longantennata* Apostolov, 1990, and *E. gladiator* (Vervoort, 1964) are still unclear due to absence of male specimens. On the other

hand, *E. tropica* Ummerkutty, 1970 cannot be included in any of the lineages since its original description does not include a figure for the male P3; the only information about the male P3 is the statement by Ummerkutty (1970): "endopod of third leg of usual structure". Wells and Rao (1987) reported *E. tropica* from India and described the male's P3 endopod as similar to that of the female, but later Wells (2007) stated in his checklist that the male of *E. tropica* has apophysis on the P3 endopod.

E. mordoganensis **sp. nov.** described herein clearly belongs to the *horrida*-group since it has a sexually dimorphic 3-segmented P3 endopod with an apophysis arising from the distal part of the second endopodal segment anteriorly. The new species, together with *E. minuta* and *E. veniliae* in the *horrida*-group, constitute a monophyletic group on the basis of the following synapomorphies: i) exopod outer spin number (2-3-2) on P2–P4; ii) 2 setae on ♀ P4 endopod-2; iii) shape of the dorsal spiny process; iv) P5 setal formula; v) ♂ P3 endopod-2 with an apophysis; vi) same ornamentation on pseudo-operculum. On the other hand, the new species can be differentiated from *E. minuta* and *E. veniliae* by the combination of the following features: i) longer body length (*E. mordoganensis* **sp. nov**., 445 µm; *E. minuta*, 370 µm; *E. veniliae*, 300 µm); ii) having 2 ornamented setae on the maxilliped syncoxa instead of 1; iii) having 6 setae on P3 exopod-3 instead of 5; iv) having 5 setae at ♂ P4 exopod-3 instead of 4; v) ♂ P2 exp-2 with an inner seta instead of none (see Table).

E. horrida, *E. brevispinosa*, and *E. oshoroensis* are more similar to each other in the *horrida*-group. These 3 species can also be defined as a monophyletic group by the following synapomorphies: i) distal segments of P2–P4 exopod with 3-3-2 outer spines respectively; ii) bulb-shaped, large rostrum; iii) ♀ baseoendopod of P5 with 4 setae; iv) ♀ P4 enp-2 with 3 setae.

It is worth mentioning that the new species was collected from interstitial habitats of sandy beaches. The substrate of all sampling beaches including the type locality is mixed, mostly pebbles and some cobbles with differing amounts of mud and coarse/fine sand in the interstices. The dense covering of muddy particles on the individuals may also support the idea that the individuals live on/in interstices between the pebbles and cobbles. Adaptations to an interstitial lifestyle in the family Laophontidae are not unusual since several genera have been reported from such habitats (Gheerardyn et al., 2007). However, the new species does not have the typical vermiform body shape, which is one of the main adaptations to interstitial habitats, but the presence and the adaptations of the new species in sand grains can be explained by the presence of a dorsal spiny process on the cephalothorax, paired dorsal spines on body somites, the spikes on the pseudo-operculum, and an elongated and slender maxilliped and P1, which may help individuals to hold onto sand grains (Gheerardyn et al., 2007). Such attachment structures may play a role in the movement and anchoring of the animals in their interstitial habitat. P2–P4 are also much smaller in size than P1, which may be another adaptation for fitting into spaces between pebbles and cobbles. Unfortunately, no further ecological data were obtained from the sampling localities to make a further assessment on the adaptation of the new species to the interstitial habitat.

Table. Swimming leg setal formulae of *horrida*-group species of *Echinolaophonte*.

Species		P2		P3		P4		P5	
		Exopod	Endopod	Exopod	Endopod	Exopod	Endopod	Exopod	Baseoendopod
E. mordoganensis	♀	0.1.022	0.120	0.1.123	0.220	0.1.122	0.020	3	2
	♂	0.1.022	0.120	0.1.123	0.0 + apophysis.220	0.1.122	0.120	3	0
E. minuta	♀	0.0.022	0.120	0.1.023	0.220	0.1.022	0.020	3	2
	♂	0.0.022	0.120	0.1.023	0. 0 + apophysis.220	0.1.022	0.120	3	0
E. veniliae	♀	0.1.022	0.120	0.1.023	0.220	0.1.022	0.020	3	2
	♂	0.0.022	0.120	0.0.023	0. 0 + apophysis.220	0.1.022	0.010	3	0
E. horrida	♀	0.1.123	0.120	0.1.223	0.220	0.1.222	0.120	3	4
	♂	0.1.123	0.120	0.1.223	0.0 + apophysis.220	0.1.222	0.120	3	0
E. brevispinosa	♀	0.1.123	0.120	0.1.223	0.220	0.1.222	0.120	3	4
	♂	0.1.123	0.120	0.1.223	0.0 + apophysis.220	0.1.222	0.120	3	0
E. oshoroensis	♀	0.0.023	0.120	0.1.223	0.220	0.1.222	0.120	3	4
	♂	0.0.023	0.120	0.1.223	0.0 + apophysis.220	0.1.222	0.120	3	0

Nomenclatural acts

This work and the nomenclatural acts it contains have been registered in ZooBank. The ZooBank Life Science Identifier (LSID) for this publication is: http://zoobank.org/urn:lsid:zoobank.org:pub:E871B30A-3C10-458B-B747-4A04C6AE1970

Acknowledgments

This study was funded by the Mersin University Research Fund (grant number 2017-2-TP3-2610). This is part of the PhD thesis of Seher Kuru, supervised by Drs Süphan Karaytuğ and Serdar Sönmez.

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