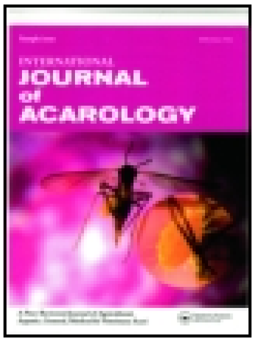

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Morphological ontogeny of *Galumna flagellata* Willmann (Acari: Oribatida: Galumnidae)

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ABSTRACT
The morphological ontogeny of *Galumna flagellata* Willmann, 1925 is described and illustrated. The juveniles of this species are light brown, with prodorsal setae of medium size or long and barbed, and bothridial seta clavate. The larva has 12 pairs of gastronotal setae, most of the medium size and barbed, of which seven (*d*-, *l*-series, h_1) are located on gastronotal shield, nymphs have 15 pairs, mostly short setae, of which 10 (*d*-, *l*-, *h*-series, p_1) are located on the gastronotal shield, setae of *c*-series are inserted on individual sclerites. In all juveniles, the typical galumnid humeral organ is absent, but a porose area is present in this location, which is unique in *Galumna*.

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KEYWORDS
Oribatid mites; juveniles; individual sclerites; leg setation; stage structure

Introduction

Galumna Heyden, 1826 *sensu stricto* is a large subgenus that comprises 198 species and seven subspecies, from which 22 are considered *species inquirendae* (Subías 2004). The diagnosis of *Galumna* has recently been given by Ermilov and Klimov (2017), with the main diagnostic characters as follows: body surface usually without strongly developed sculpture or ornamentation, sexual dimorphism in prodorsum and notogaster absent, lamellar and sublamellar lines present, rostral seta inserted close to end of the lamellar line, medial to lamellar lines or distanced from them, and lamellar seta inserted lateral to the lamellar line. Pteromorphs bilobed, partially reticulate, notogaster with 10 or 11 pairs of alveoli or microsetae, with one pair on pteromorphs, porose area *Aa* singular or divided into two parts, median pore absent or present, singular or subdivided. Leg tarsi tridactylous, leg setae not modified. Diagnosis of subgenus *Galumna sensu stricto* is the following: notogaster with porose areas, adanal lyrifissures located close and lateral to the anal aperture (Ermilov and Klimov 2017).

The morphology of juveniles of *Galumna* species has rarely been studied. Based on the catalogue of oribatid juveniles by Norton and Ermilov (2014) and paper by Ermilov et al. (2017b), all instars of three *Galumna* species and one subspecies are known, which constitute nearly 2% of all species of this genus. Some of these studies, such as Haq and Adolph (1981) (*G. flabellifera orientalis* Aoki, 1966), Sengbusch (1954) [*G. ithacensis* (Jacot, 1929)], Woodring (1965) [*G. parva* Woodring (1965), *G. louisianae* (Jacot, 1929)], only investigated the ecological and biological aspects of juveniles such as development time, cultivating and feeding behaviour, while the described morphology is very general and insufficient for comparisons. Therefore, the morphological ontogeny of all instars of the following species is known: *Galumna alata* (Hermann, 1804), *G. curvifamulus* Ermilov et al. (2017a), and *G. zachvatkini* Grishina (1982) (Grishina 1982; Seniczak et al. 2012; Ermilov et al. 2017b). The juvenile stages of *G. elimata* (C.L. Koch, 1841), *G. obvia* (Berlese, 1914) and *G. tarsipennata* Oudemans, 1914 are partially known (Norton and Ermilov 2014). The morphological ontogeny of *G. flagellata* has not been investigated.

The aim of this paper is to describe and illustrate the morphological ontogeny of *G. flagellata*, and compare it with that of congeners.

Material and methods

The juveniles and adults of *G. flagellata* used in this study for morphological investigation were collected on 30 December 2018 by S. Rodríguez-Fernández during the litterbag experiment carried out in the part of the Science's Park of Granada, Biodomo, Spain (37° 9′45.28″N, 3°36′22.13″W, 656 m a. s. l.). This park was created in 2016, with controlled climate conditions (26°C and a high level of air moisture), tropical vegetation and soil substrate composed of 50% pine bark and 50% blond peat (renewed periodically). Twenty four litterbags of the size of 20 × 15 cm, made of nylon mosquito net with 2 mm mesh, were filled with 300 cm^3 of dry and crushed prunings of common lantana (*Lantana camara* L.) (12 litterbags) and with mango (*Mangifera indica* L.) prunings (12 litterbags), and placed on the soil in Biodomo on 26 November 2018. In order to study the ecology of *G. flagellata*, samples with common lantana prunings and mango prunings were collected during four sampling events between the end of December 2018 to the end of May 2019 (i.e., after one, two, three and six months from the start of the experiment), in three replications and were extracted in Tullgren funnels during eight days. In these samples, *G. flagellata* was the only member of Galumnidae, and therefore the assumption is made that the juveniles belong to this species. We investigated the density and stage structure of the mites, and based on 50 randomly selected adults, the sex ratio, number of gravid females and carried eggs, and body length and width in μm. We measured a total body length (tip of the rostrum to the posterior edge of notogaster) in lateral aspect and body width (widest part of notogaster without pteromorphs) in dorsal aspect, and size of anal and genital openings and setae perpendicularly to their length.

The illustrations of instars are limited to the body regions of mites that show substantial differences between instars, including the dorsal, lateral aspect and some leg segments of the larva, tritonymph and adult, and ventral regions of all instars. The palp and chelicera of the adult are also illustrated. Illustrations were prepared from individuals mounted temporarily in lactic acid. In the text and figures we used the following abbreviations: rostral (*ro*), lamellar (*le*), interlamellar (*in*) and exobothridial (*ex*) setae, lamella (*La*), sublamella (*Sub*), bothridium (*bo*), bothridial seta (*bs*), dorsophragma (*D*), pleurophragma (*Pl*), sejugal porose area (*Ad*) notogastral or gastronotal setae or alveoli (*c*-, *d*-, *l*-, *h*-, *p*-series), porose areas (*Aa, A1, A2, A3*), lyrifissures or cupules (*ia, im, ip,*

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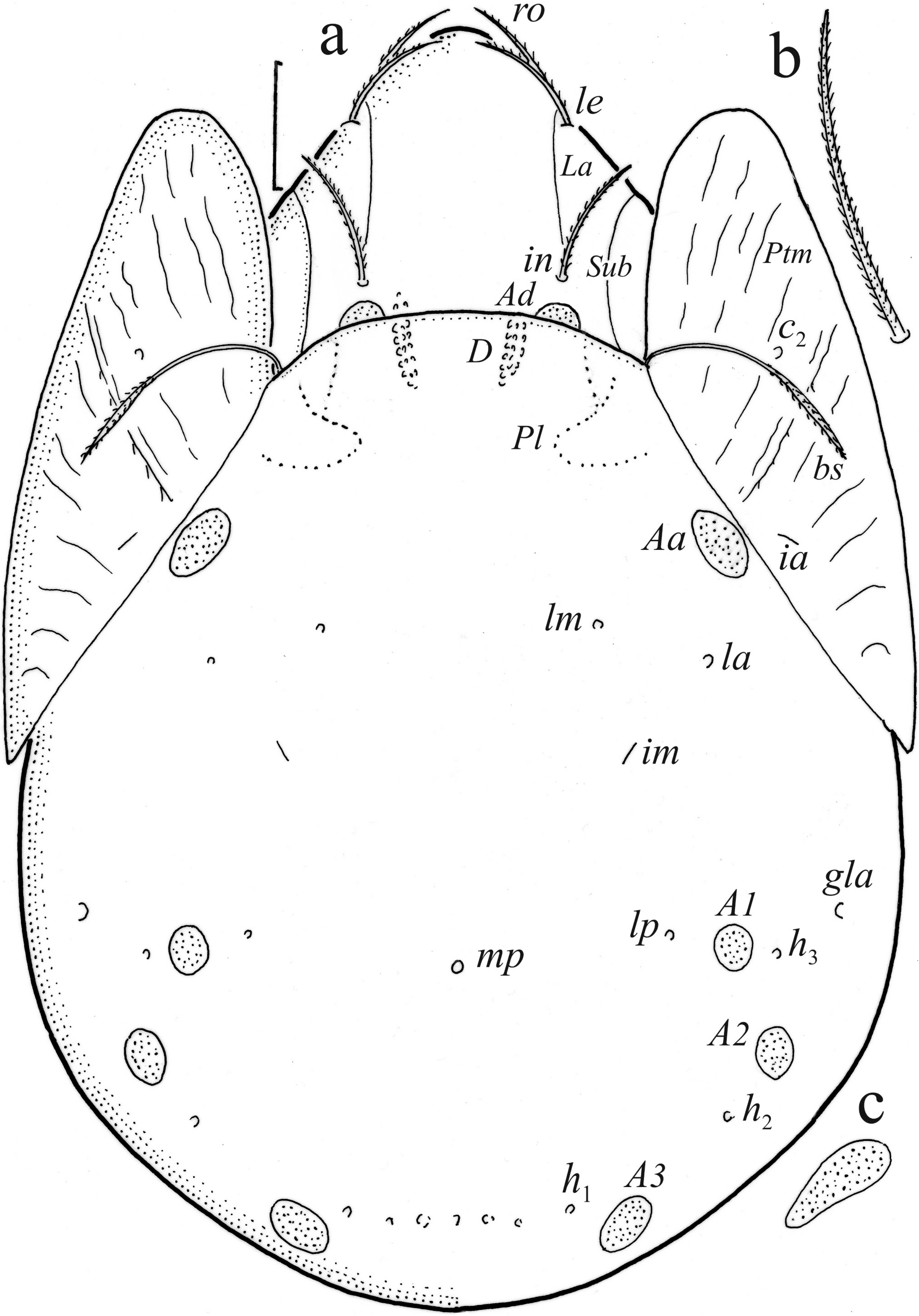

Figure 1. *Galumna flagellata*, female, a – dorsal aspect, scale bar 50 μm; b – shape of seta *in* (enlarged); c – shape of porose are *A3* in another individual.

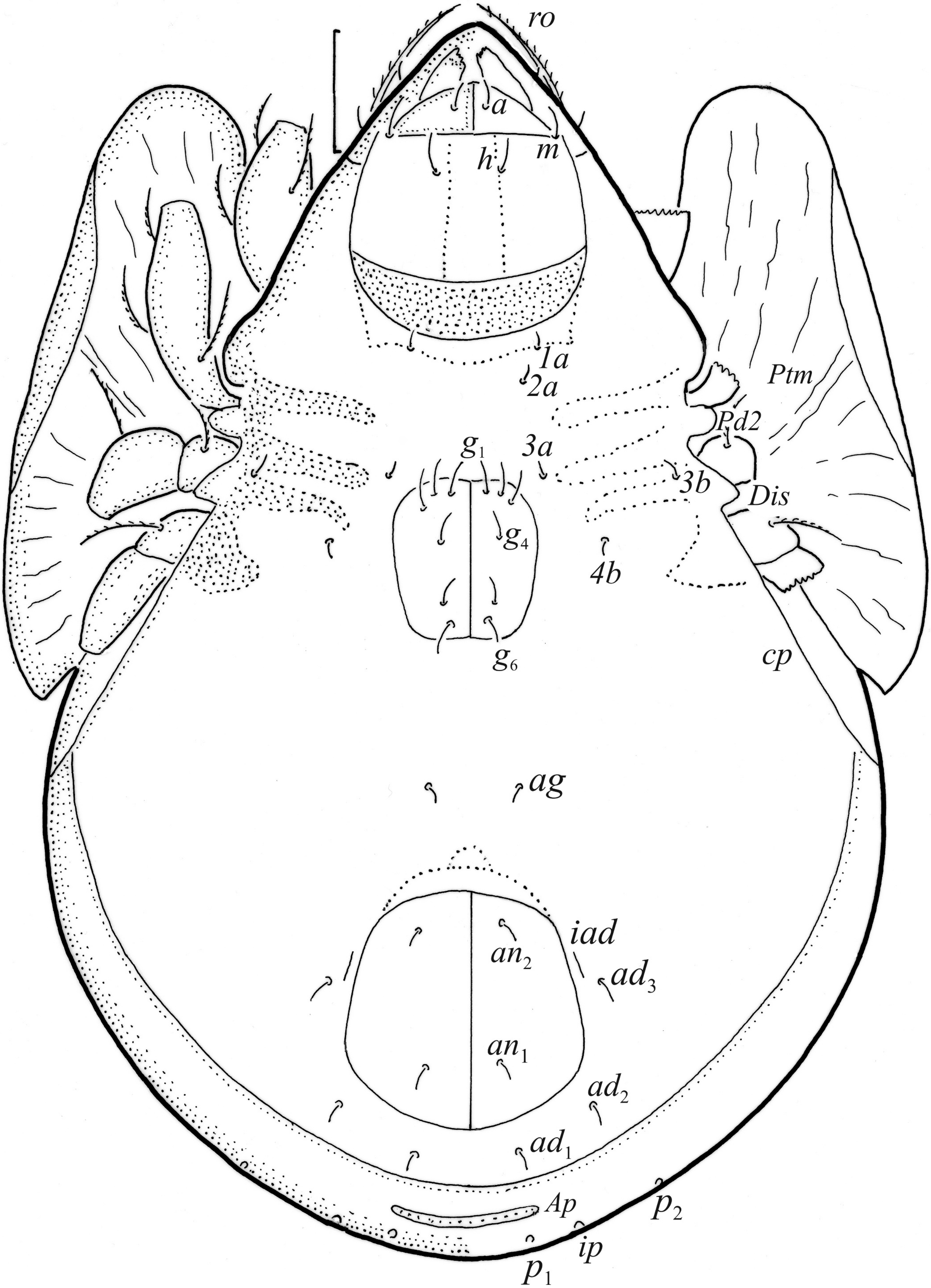

Figure 2. *Galumna flagellata*, female, ventral aspect, legs partially drawn, scale bar 50 μm.

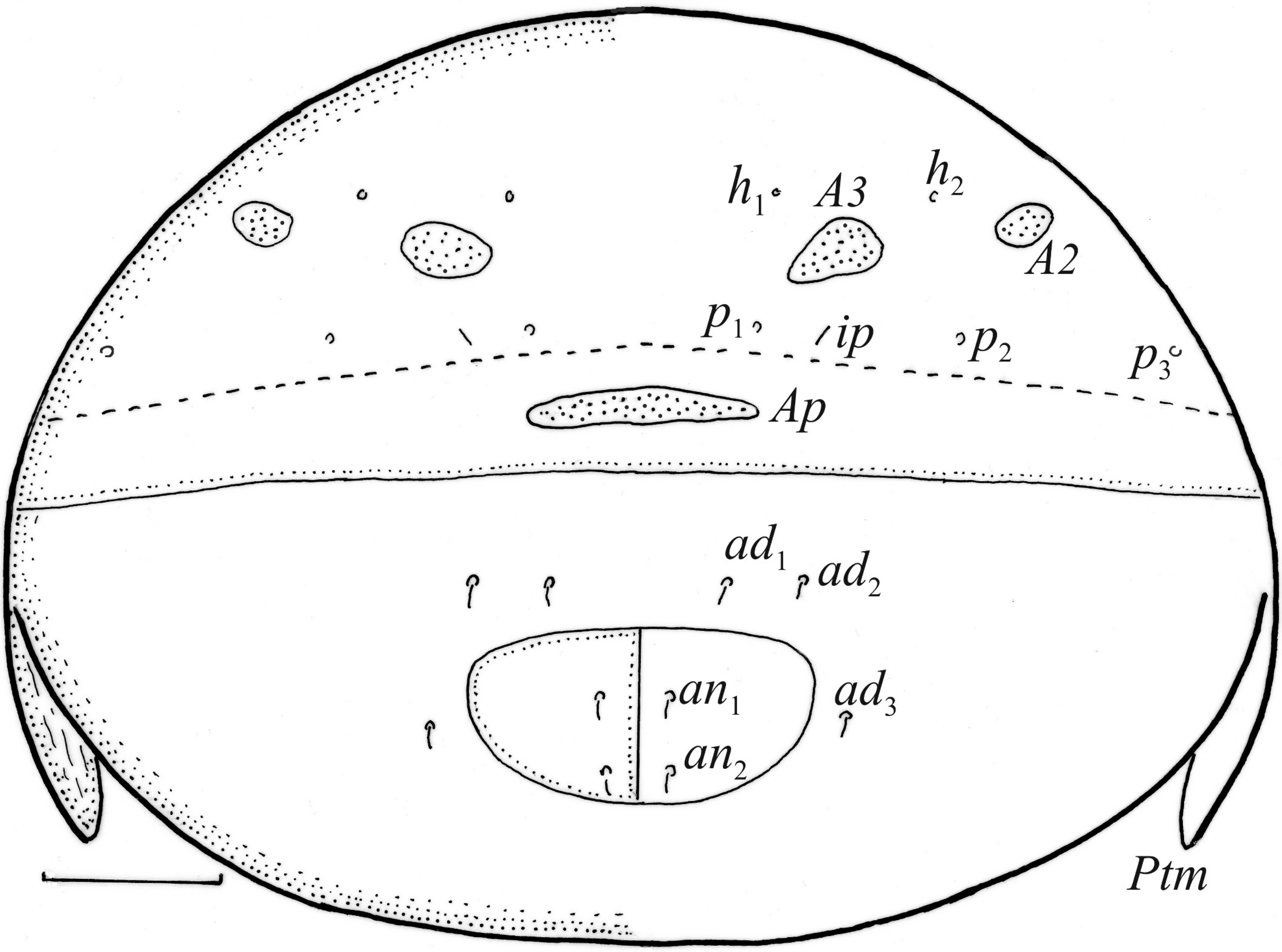

Figure 3. *Galumna flagellata*, adult, posterior aspect, scale bar 50 µm.

ih, ips, iad), opisthonotal gland opening (*gla*), pedotectum (Pd), pteromorph (*Ptm*), discidium (*Dis*), median pore (*mp*), postanal porose area (*Ap*), circumpedal carina (*cp*), subcapitular setae (*a, m, h*), cheliceral setae (*cha, chb*), palp setae (*sup, inf, l, d, cm, acm, it, vt, ul, su*) and solenidion ω, epimeral setae (*1a, 2a, 3a, 3b, 4a–c*), adanal and anal setae (*ad-, an*-series), aggenital seta (*ag*), leg solenidia (σ, φ, ω), famulus (ε) and setae (*bv, ev, d, l, ft, tc, it, p, u, a, s, pv, pl, v*). The terminology used follows that of Grandjean (1949, 1953) and Norton and Behan-Pelletier (2009). The species nomenclature follows Subías (2004, updated 2020).

For scanning electron microscopy (SEM), the mites were air-dried and coated with Au/Pd in a Polaron SC502, sputter coater and placed on Al-stubs with double-sided sticky carbontape. Observations and micrographs were made with a ZEISS Supra 55VP scanning electron microscope.

Galumna flagellata Willmann, 1925

Diagnosis

Adults dark brown, of medium size (462–540), without sexual dimorphism, and with characters of *Galumna*. Rostrum rounded, rostral setae distanced from lamellar lines. Bothridial seta fusiform, with long, narrow, barbed head. Dorsosejugal suture and postanal porose area present. Ten pairs of setal alveoli, four pairs of porose areas and median pore present on notogaster, adanal lyrifissures located close to the medial part of the anal opening.

Juveniles light brown, prodorsal setae of medium size or long and barbed, bothridial seta clavate. Larva with 12 pairs of gastronotal setae, most of the medium size and barbed, *d-*, *l*-series and h_1 located on gastronotal shield, nymphs with 15 pairs, most short, *d-*, *l-*, *h*-series and p_1 located on gastronotal shield, setae of *c*-series inserted on individual sclerites. In all juveniles, typical galumnid humeral organ absent, but porose area present in this location, which is unique in *Galumna*.

Morphology of adult

Adult (Figure 1–7) similar to that described by Willmann (1925), but see *Remarks*. Mean length (and range) of females 516.2 ± 13.6 (494–-540, n = 45) and males 481.0 ± 22.5 (462–520, n = 5), mean width (and range) of females 362.1 ± 21.9 (325–388) and males 364.0 ± 29.1 (312–377). Notogastral setae alveolar (10 pairs, including c_2 on pteromorph), porose area *Aa* larger (mean 36 × 22) than other porose areas (17 x 12), postanal porose area elongated (Figure 1–4a). Hypostomal setae short, *h* and *m* slightly longer than *a* (Figure 2). Cheliceral setae *cha* longer and thicker than *chb*, both barbed (Figure 4c), most palp setae finely barbed (Figure 4d, 7d), formula of palp setae 0–2–1–3–9(1). Leg femora relatively slim, most leg setae barbed, setae *pv* on all tarsi with longer barbs than others (Figure 5, 6b, 7a). Solenidia ω_1 and ω_2 on tarsus I of similar length, seta *ft″* short (Figure 5a, 6b–d). Formulae of leg setae [trochanter to tarsus (+ solenidia)]: I – 1–4–3(1)–4(2)–20(2); II – 1–4–3(1)–4(1)–15(2); III – 2–3–1(1)–3(1)–15; IV – 1–2–2–3(1)–12. Leg tarsi heterotridactylous.

Remarks. The adults investigated herein are smaller than those investigated by Willmann (1925) – length 550–600, width 330 and Weigmann (2006) – length 550–610, sexually not separated. In our individuals, porose areas *Aa* and *A2* are widely more separated than in Willmann (1925), but similar as in Weigmann (2006). The shape and distribution of prodorsal setae in our specimens are generally similar as in figures presented by these authors.

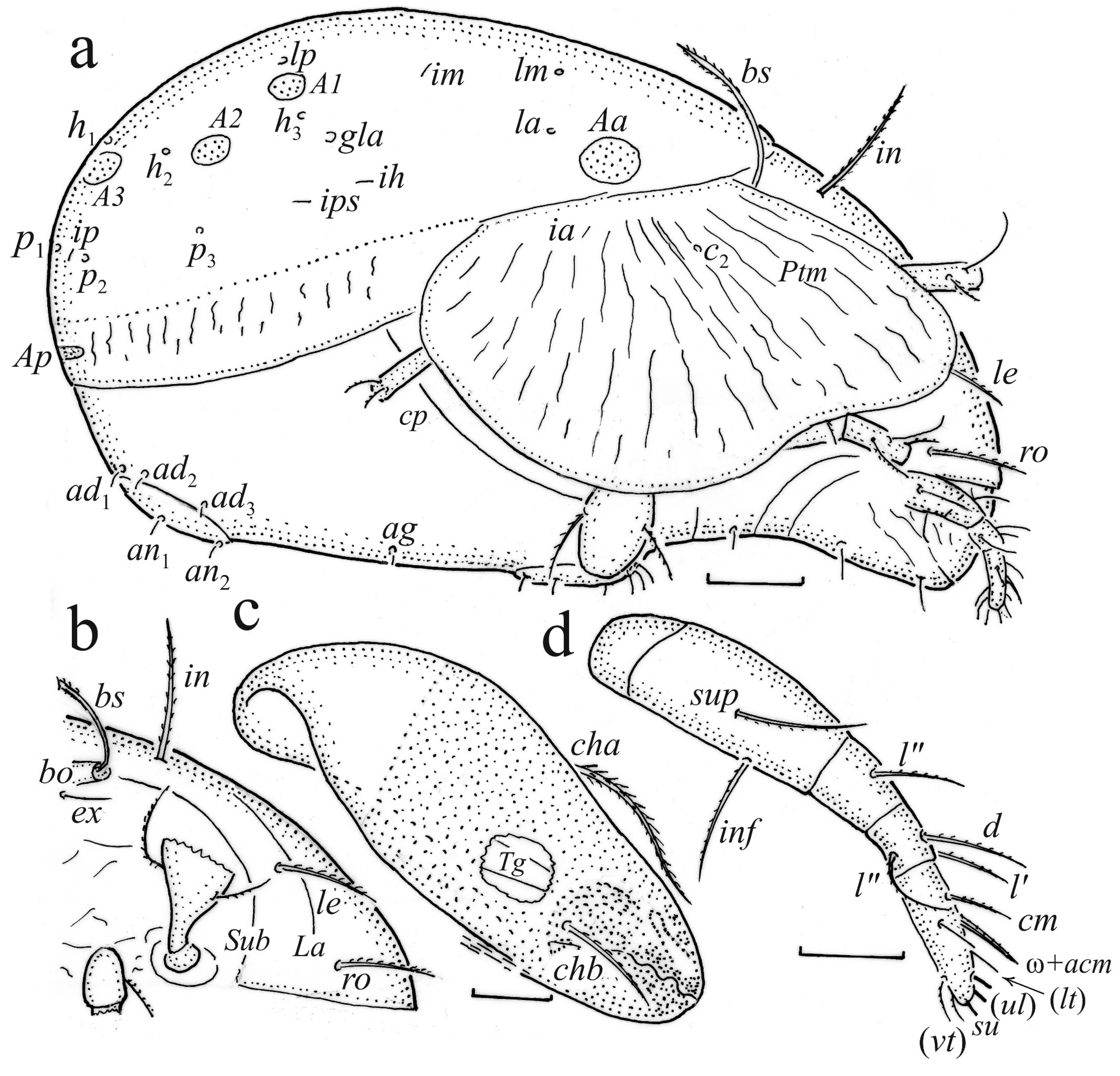

Figure 4. *Galumna flagellata*, adult, a – lateral aspect, legs partially drawn; scale bar 50 µm; b – anterior part of body, pteromorph removed, scale bar 50 µm; mouthparts, right side, scale bars 20 µm; c – chelicera (Trägårdh organ in "transparent" area); d – palp.

Description of juveniles

Larva egg-shaped in dorsal view (Figure 8, 9a), light brown. Prodorsum subtriangular, prodorsal setae of medium size (*in, ex*) or long (*ro, le*, Table 1) and barbed. Mutual distance between setal pair *le* nearly twice longer than between pair *ro*, and distance between setal pair *in* nearly three times longer than between pair *ro*; pair *le* inserted approximately midway between pairs *ro* and *in*. Opening of bothridium rounded, with anteromedial ridge, connecting bothridium with the insertion of seta *in*, and posterolateral ridge, connecting bothridium with the insertion of seta *ex*; bothridial seta clavate, with barbed head.

Gastronotum of the larva (Figure 8, 10a, 11a) with 12 pairs of setae, including h_3 inserted lateral to the medial part of anal valves; most of the medium size and barbed, except for minute h_3. Setae of *c*-series on individual microsclerites, length increasing from c_1 to c_3 (Table 1), all barbed. Gastronotal shield with seven pairs of setae (*d*-, *l*-series, h_1), setae h_2 and h_3 on unsclerotized integument. Small porose areas present, *Aa* anterior to seta *la*, *A1* anterior to seta *lm*, and *A2* posteromedial to seta *lm* (Figure 8). Cupule *ia* posterior to seta c_3, cupule *im* posterior to seta *lm*, cupule *ip* between setae h_1 and h_2, cupule *ih* lateral to the anterior part of the anal opening. Opisthonotal gland opening lateral to seta *lp*, without dark sclerotized surrounding. Typical galumnid humeral organ absent, but porose area present anterolateral to seta c_3 (Figure 11a). Paraproctal valves (segment PS) glabrous. Chelicera and palp of larva smaller than in other instars, but of similar morphology, except for absence of tarsal eupathidium *su* (Figure 12a). Legs of larva stocky, all femora with ventral keel (Figure 9, 10a, b, 12b, 13). Most leg setae barbed, some setae (*d* on all femora, *l* on all genua and tibiae, *pl″* and most *ft* and *pv* on tarsi) thicker than other leg setae.

Shape of prodorsum of protonymph, prodorsal setae, bothridium and bothridial seta as in larva, but seta *in* relatively longer, and bothridial seta slimmer than in larva. Gastronotum oval, with 15 pairs of setae because *p*-series added, and retained in subsequent nymphs (Figure 10b, 11b, 12c, d, 14a, b, 15, 16a–c). Setae of *c*-series as in larva, anterior part of gastronotum with ornamentation (Figure 11b, 15, 16a–c). In all nymphs, gastronotal shield with 10 pairs of setae (*d*-, *l*-, *h*-series, p_1), setae p_2 and p_3 inserted on unsclerotized integument; all relatively short and smooth. Four

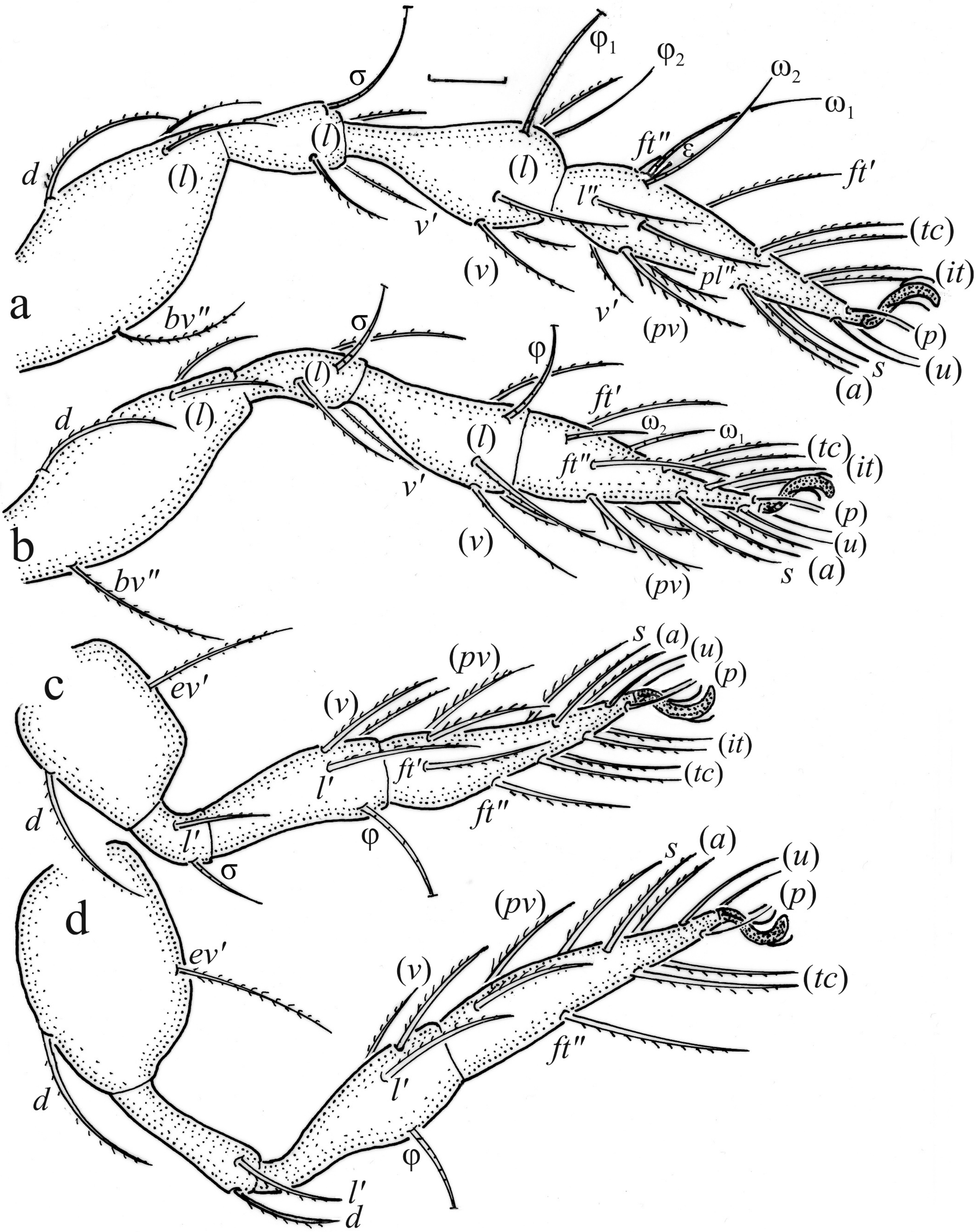

Figure 5. *Galumna flagellata*, leg segments of adult (part of femur to tarsus), right side, antiaxial aspect, scale bar 20 μm. a – Leg I, (*pl′* on tarsus not illustrated); b – leg II, c – leg III; d – leg IV.

pairs of porose areas present, *Aa* anteromedial to seta *la, A1* posteromedial to seta *lm, A2* posteromedial to seta *lp* and *A3* between setae h_1 and h_2. In protonymph, genital valves appearing on the large, porose genital shield, with one pair of genital setae inserted lateral to these valves, two pairs added in deutonymph and tritonymph each (Figure 10b, 14a, b), all short and smooth. In deutonymph, one pair of aggenital setae appearing on genital shields and three pairs of adanal setae on porose adanal shield, and remained in subsequent instars; all short and smooth. In protonymph and deutonymph, anal valves glabrous, in

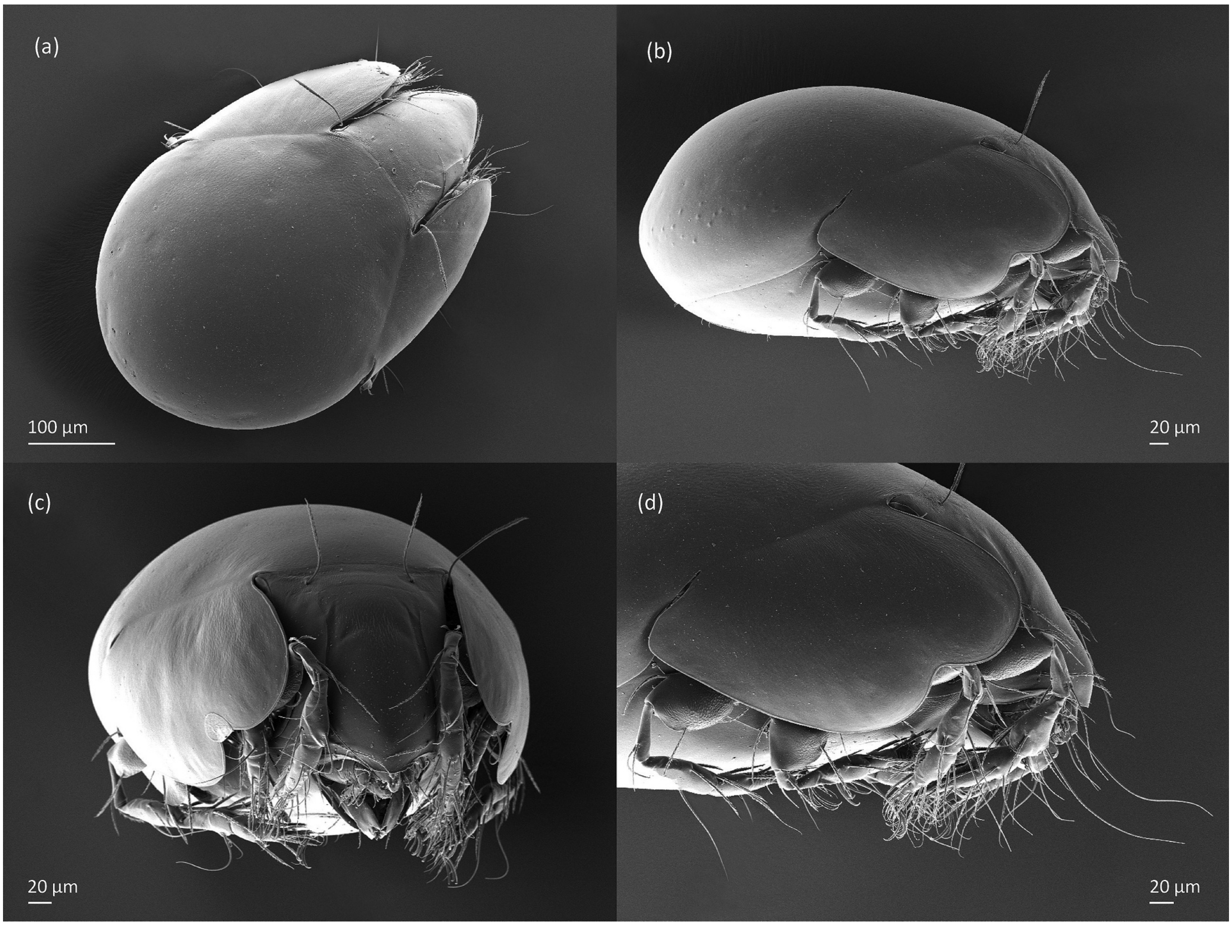

Figure 6. *Galumna flagellata*, adult, SEM micrographs. a – dorsal view; b – lateral view; c – frontal view; d – shape of pteromorph and setae, lateral view.

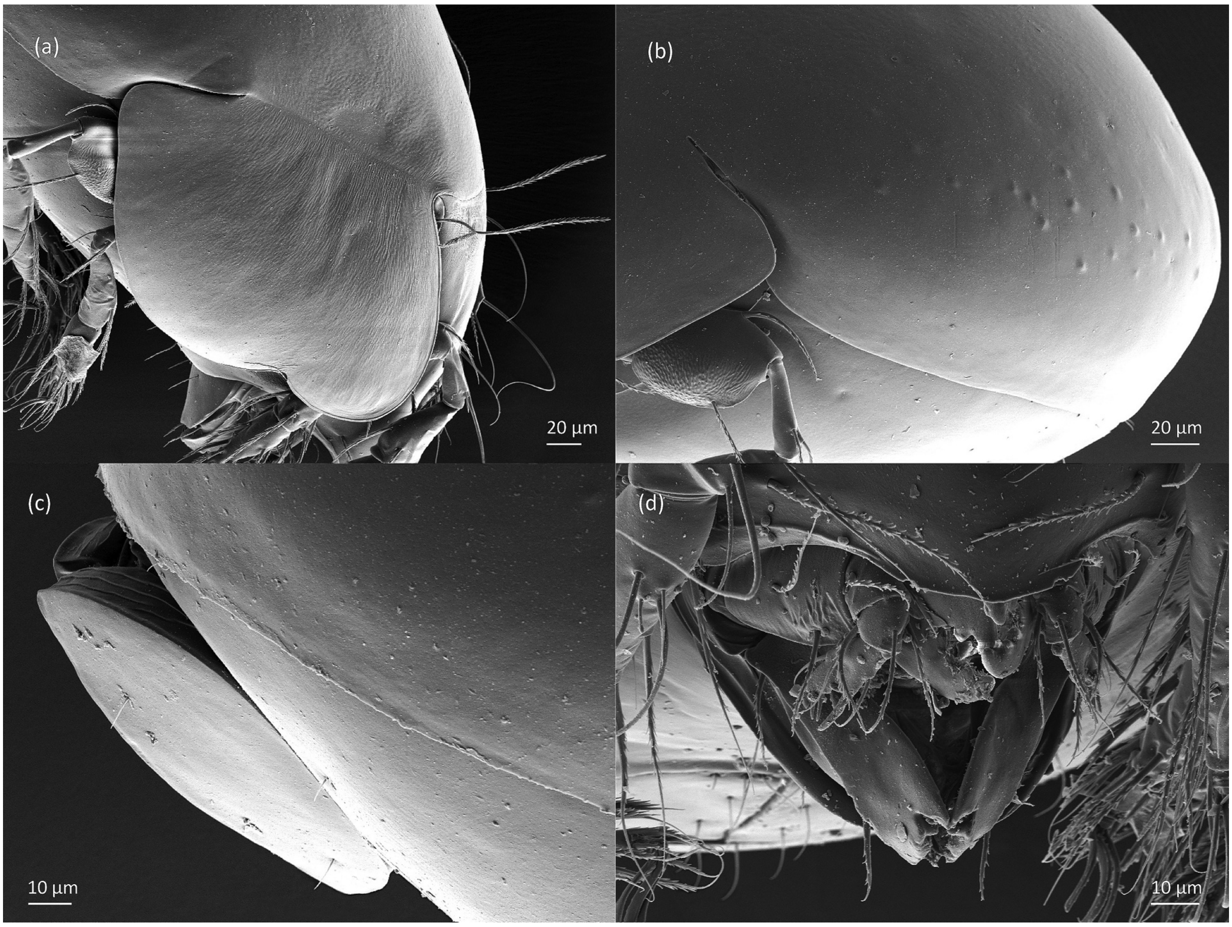

Figure 7. *Galumna flagellata*, adult, SEM micrographs. a – porose area *Aa*; b – posterior part of notogaster, lateral view; c – open anal plate, lateral view; d – mouthparts, dorsal view.

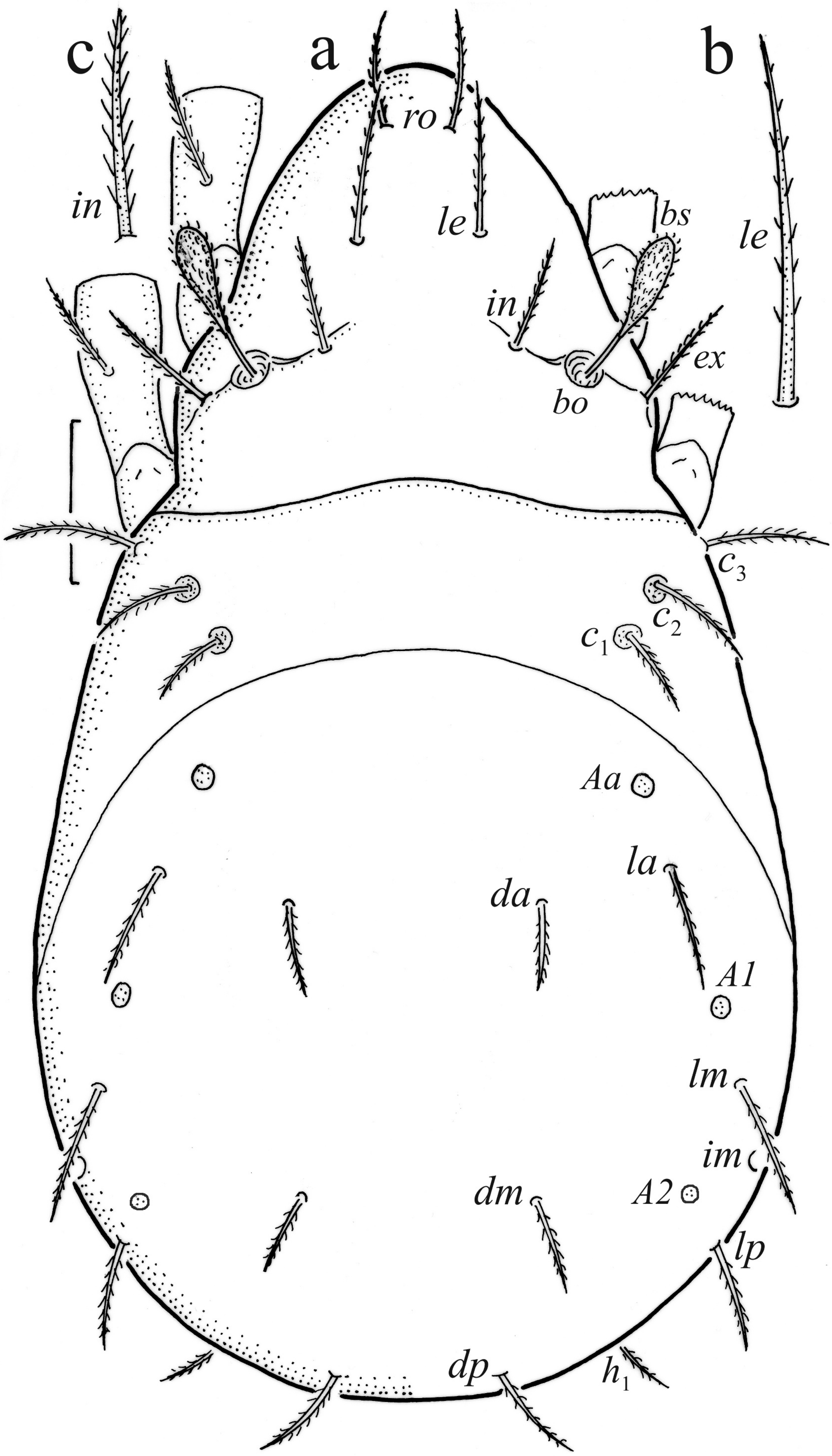

Figure 8. *Galumna flagellata*, larva, a – dorsal aspect, legs partially drawn, scale bar 20 μm; b – shape of seta *le*; c – shape of seta *in* (b, c enlarged).

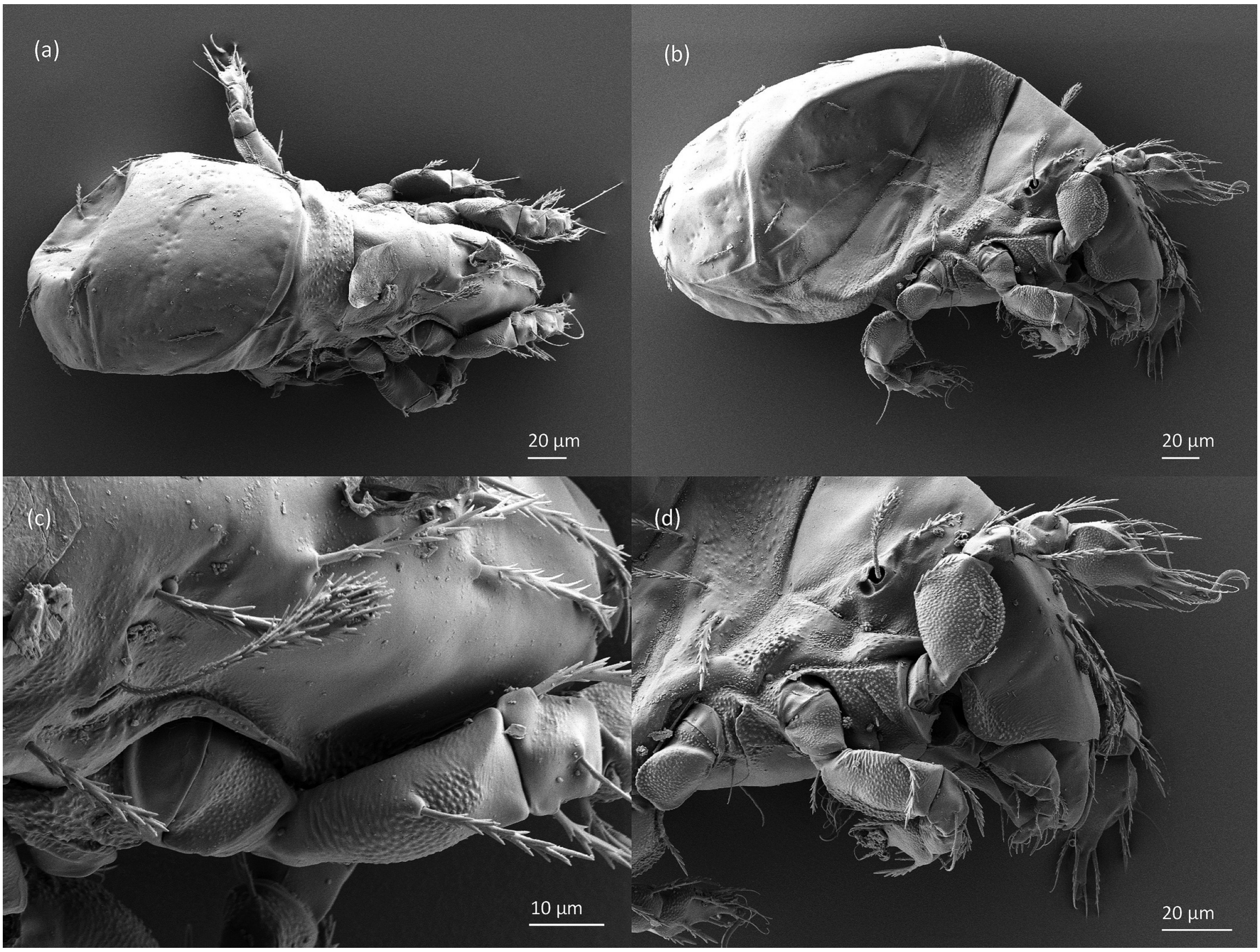

Figure 9. *Galumna flagellata*, larva, SEM micrographs. a – dorsal view, b – lateral view, c – anterior part of body, dorsolateral view, d – anterior part of body, lateral view.

Table 1. Measurements of some morphological characters of juvenile stages and adult of *Galumna flagellata* (mean measurements of 10 specimens in µm); Nd – not developed.

Morphological characters	Larva	Protonymph	Deutonymph	Tritonymph	Adult
Body length	297	345	364	455	520
Body width	160	231	241	320	345
Length of prodorsum	99	105	112	128	148
Length of: seta *ro*	40	46	56	60	74
seta *le*	37	54	59	62	60
seta *in*	29	35	47	50	72
seta *ex*	17	24	34	37	17
seta *bs*	46	50	56	63	96
seta c_1	17	17	25	33	Lost
seta c_2	29	35	39	40	0
seta c_3	33	40	45	47	Lost
seta *da*	16	3	9	11	Lost
seta *dp*	27	3	8	9	Lost
seta *la*	24	5	13	15	0
seta *lp*	23	4	10	10	0
seta h_1	20	3	9	10	0
seta h_3	2	3	8	9	0
seta p_1	Nd	3	8	9	0
genital opening	Nd	29	37	45	49
anal opening	49	75	99	101	81

tritonymph two pairs of short and smooth anal setae present. In tritonymph, cupules *ia, im* and *ip* as in larva, cupule *iad* lateral to the anterior part of anal valves, cupules *ips* and *ih* displaced lateral and anterolateral to *iad*, respectively (Figure 11b, 14b). Typical galumnid humeral organ absent, but porose area present anterolateral to seta c_3. Opisthonotal gland opening lateral to seta h_3, without dark sclerotized surrounding (Figure 11b). Legs of tritonymph stocky, all femora with ventral keel (Figure 12b, 16, 17).

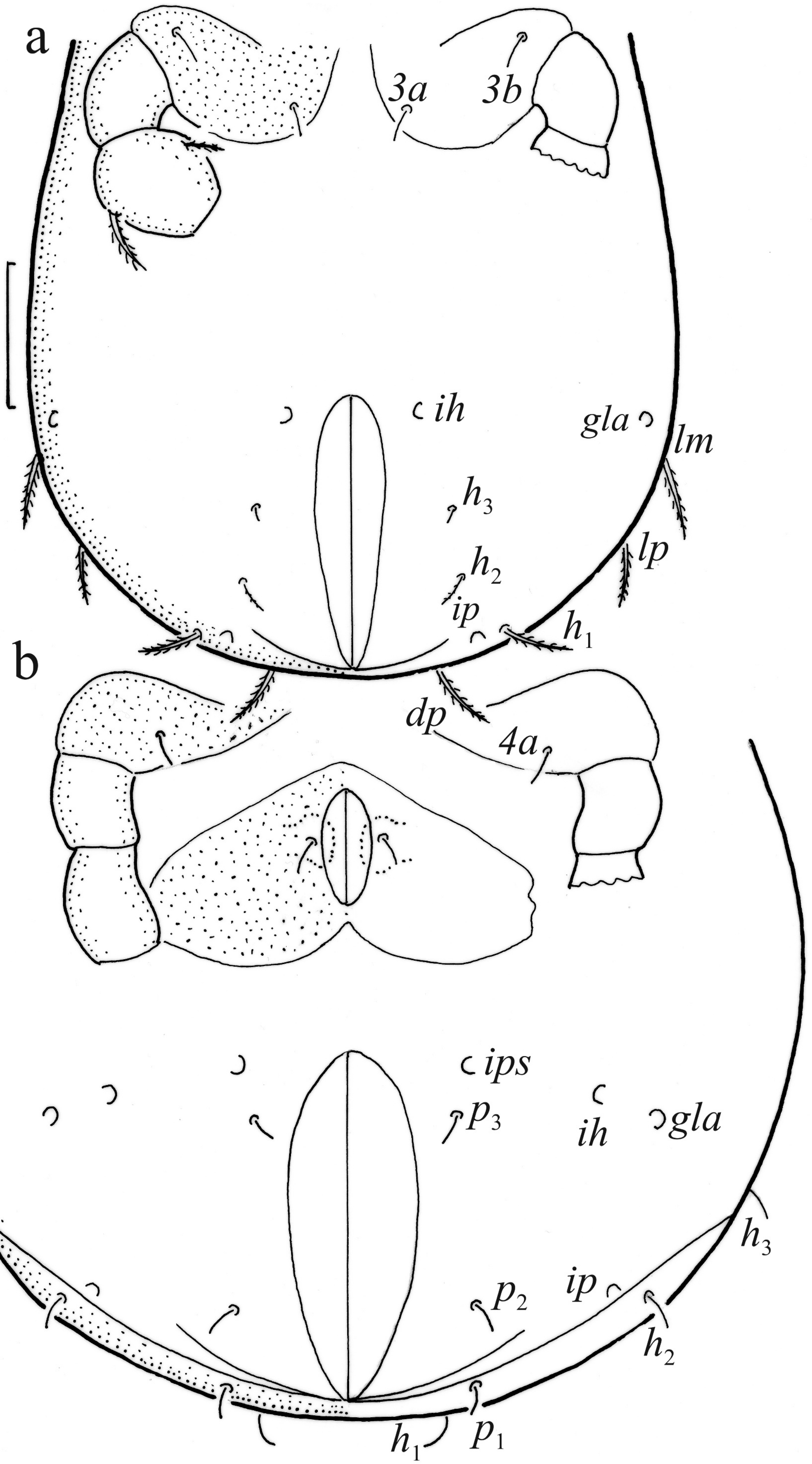

Figure 10. *Galumna flagellata*, ventral part of hysterosoma, legs partially drawn, scale bar 20 µm, a – larva, b – protonymph.

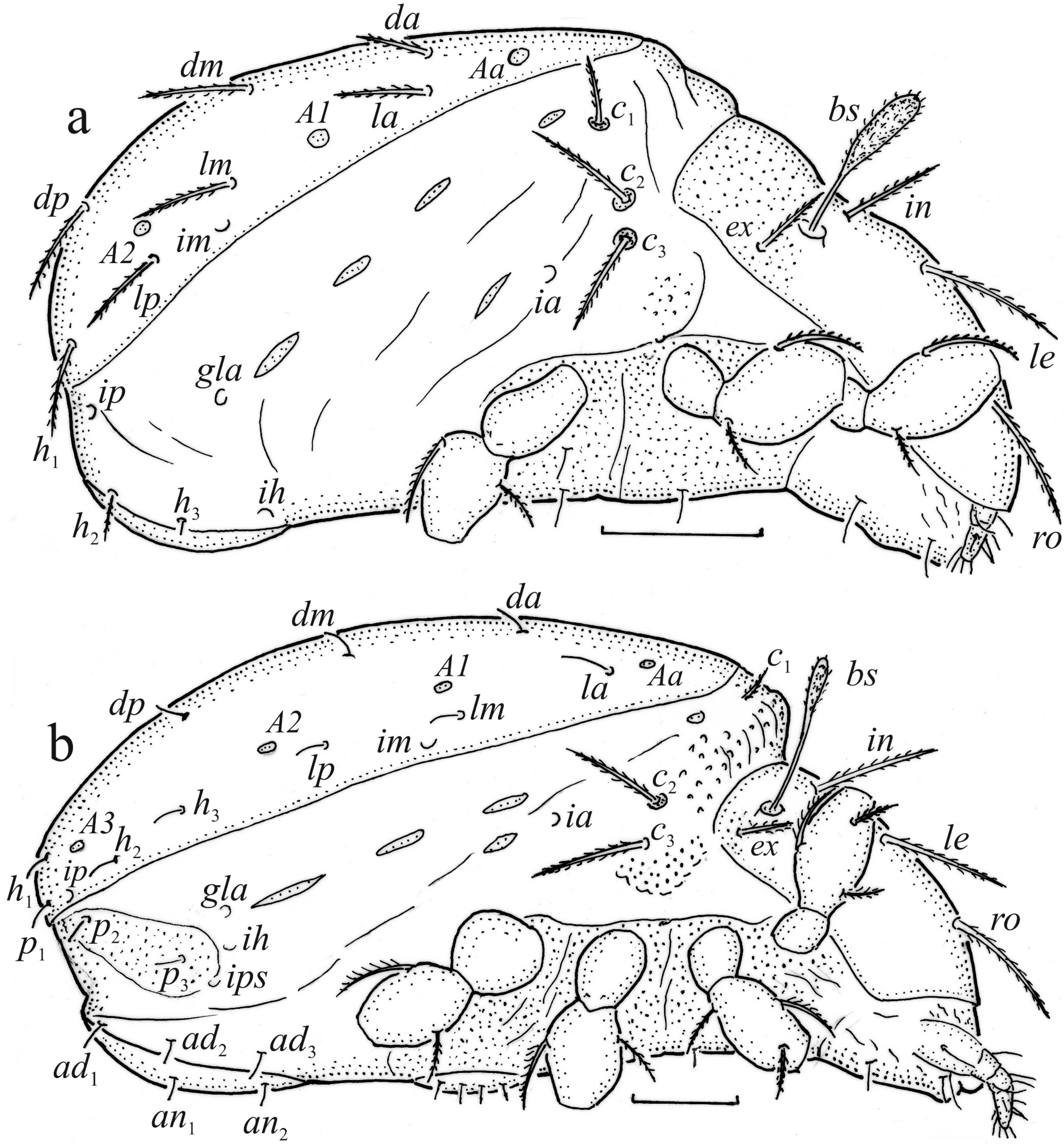

Figure 11. *Galumna flagellata*, lateral aspect, legs partially drawn, scale bars 50 µm, a – larva, b – tritonymph.

Most leg setae barbed, some setae (*d* on all femora, *l* on all genua and tibiae, *pl″*and most *pv* on tarsi and *ft* on tarsi I–III) thicker than other setae.

Summary of ontogenetic transformations

In all juveniles, the prodorsal setae *ro* and *le* are longer than *in*, whereas in the adult seta *in* is longer than *ro* and *le*. Seta *ex* is of medium size in the juveniles, and short in the adult. The bothridium is rounded in all instars, but in the adult, it is covered by anterior tectum of notogaster. In all juveniles, the bothridial seta is clavate, with barbed head, which in the larva is thicker than in the nymphs, whereas in the adult the bothridial seta is fusiform, with narrow, barbed head. The larva has 12 pairs of gastronotal setae, including h_3, the nymphs have 15 pairs (*p*-series appearing in protonymph), whereas the notogaster of adult loses all setae and alveoli of setae c_1, c_3 and of *d*-series, such that 10 pairs of alveolar setae remain. The formula of gastronotal setae in *G. flagellata* is 12–15–15–15-10 (from larva to adult), the formulas of epimeral setae are 3–1–2 (larva, including scaliform *1 c*), 3–1–2–1 (protonymph), 3–1–2–2 (deutonymph), 3–1–3–3 (tritonymph) and 1–

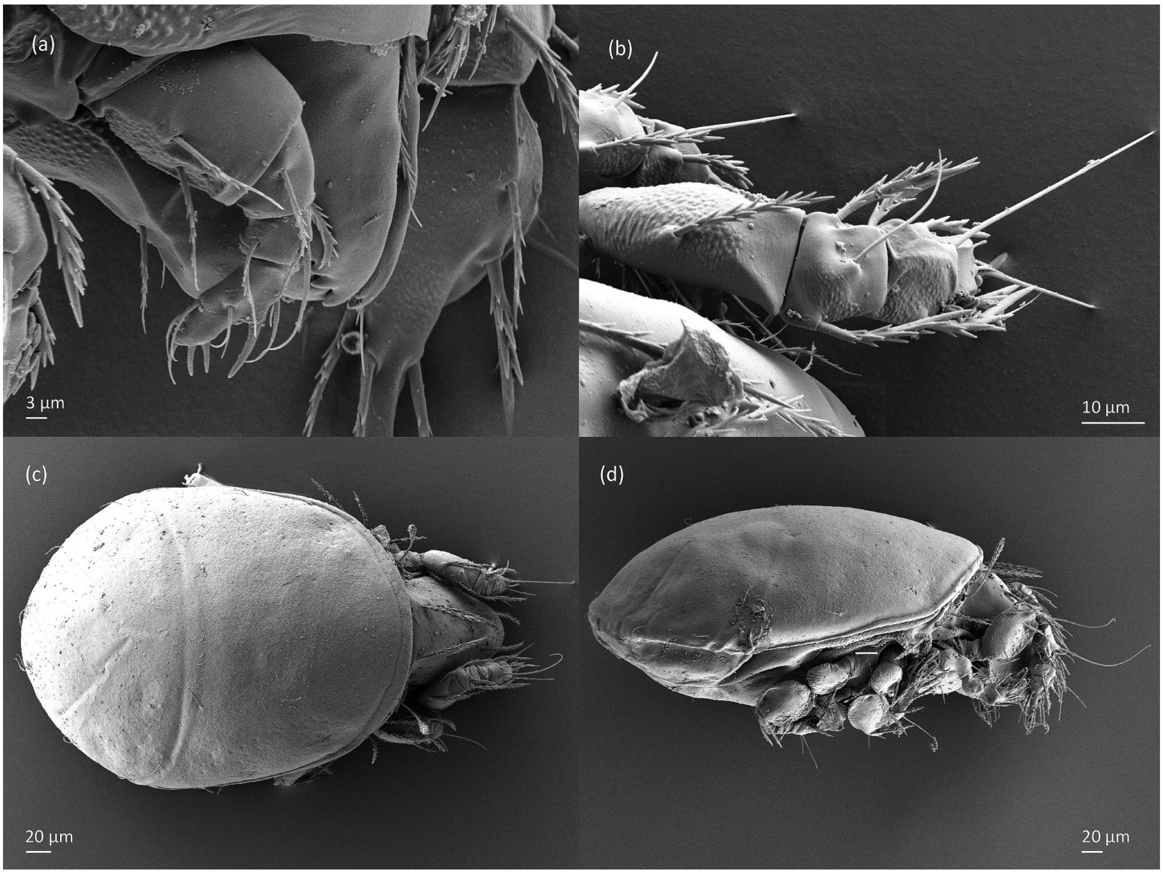

Figure 12. *Galumna flagellata*, SEM micrographs. Larva, a – mouthparts, lateral view; b – leg I, dorsal view; tritonymph, c – dorsal view, d – lateral view.

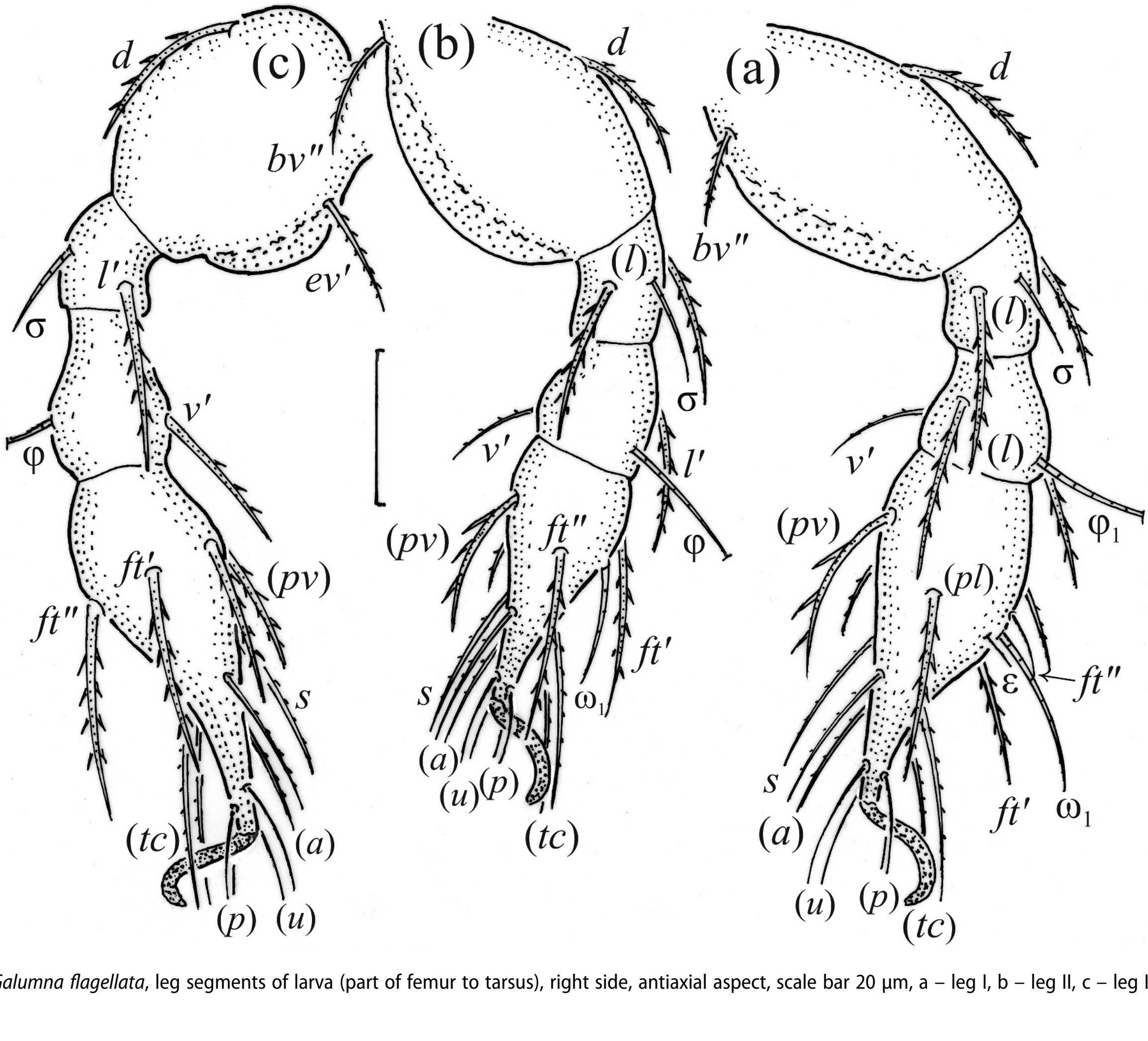

Figure 13. *Galumna flagellata*, leg segments of larva (part of femur to tarsus), right side, antiaxial aspect, scale bar 20 µm, a – leg I, b – leg II, c – leg III.

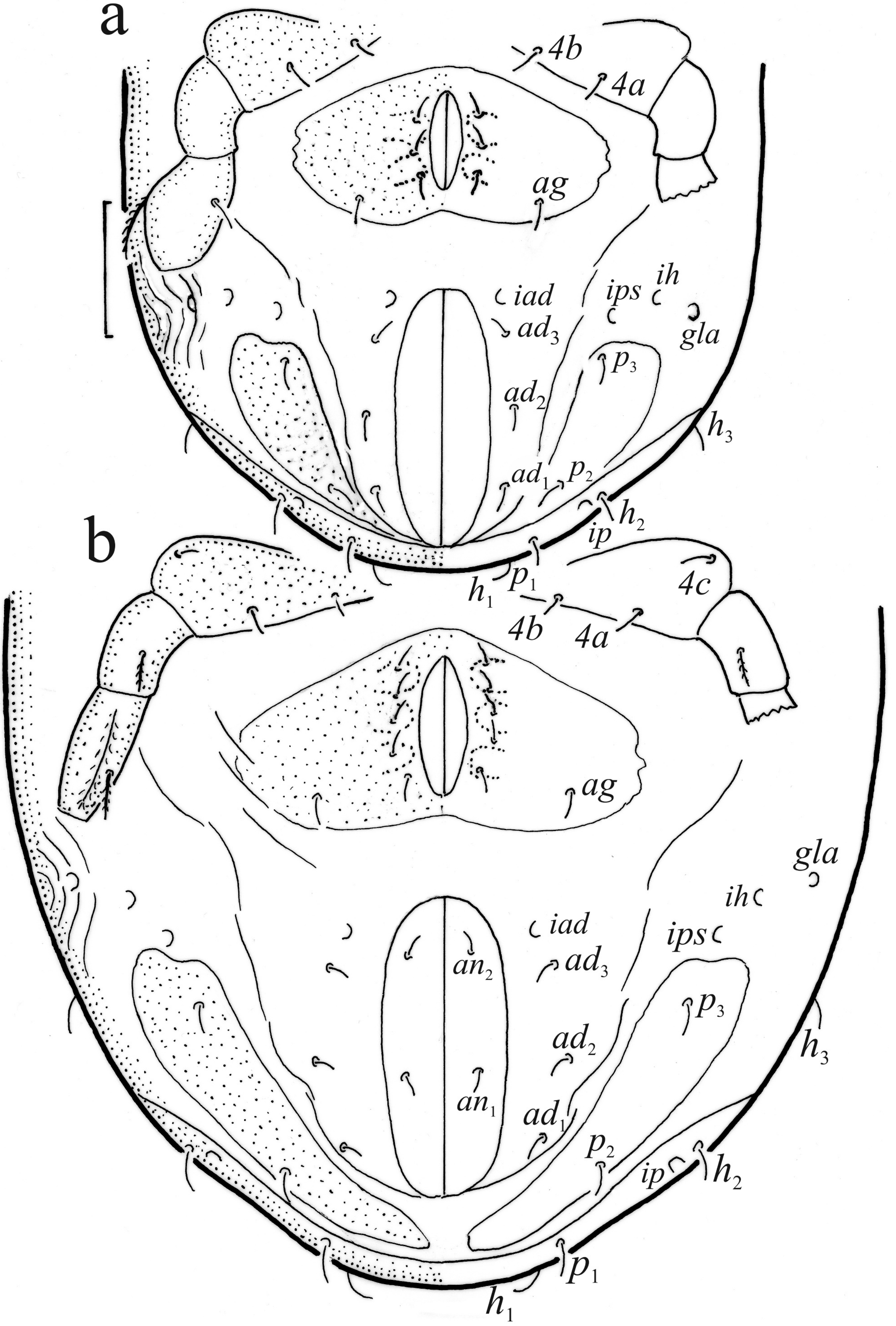

Figure 14. *Galumna flagellata*, ventral part of hysterosoma, legs partially drawn, scale bar 50 µm, a – deutonymph, b – tritonymph.

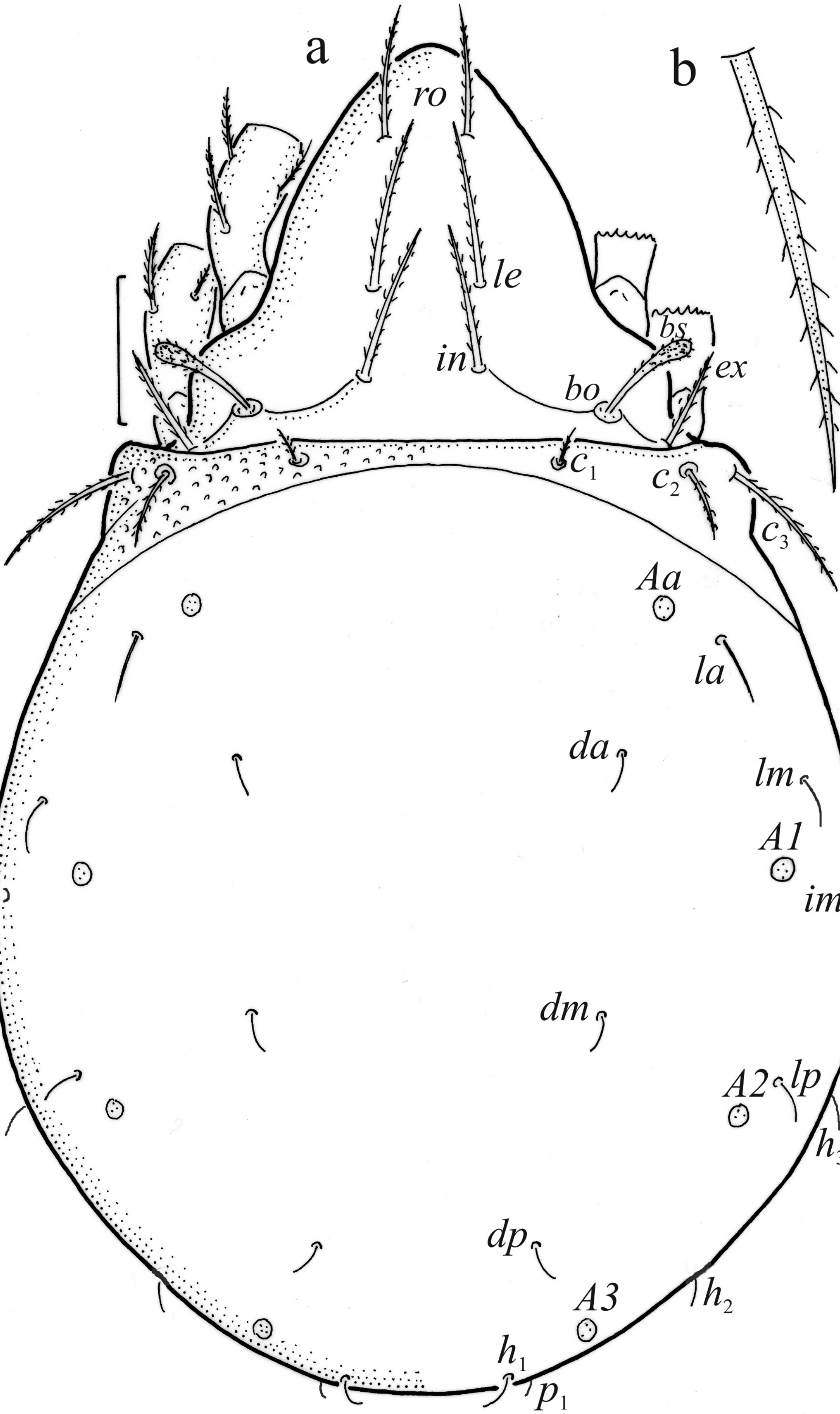

Figure 15. *Galumna flagellata*, tritonymph, a – dorsal aspect, legs partially drawn, scale bar 50 µm; b – shape of seta c_3(enlarged).

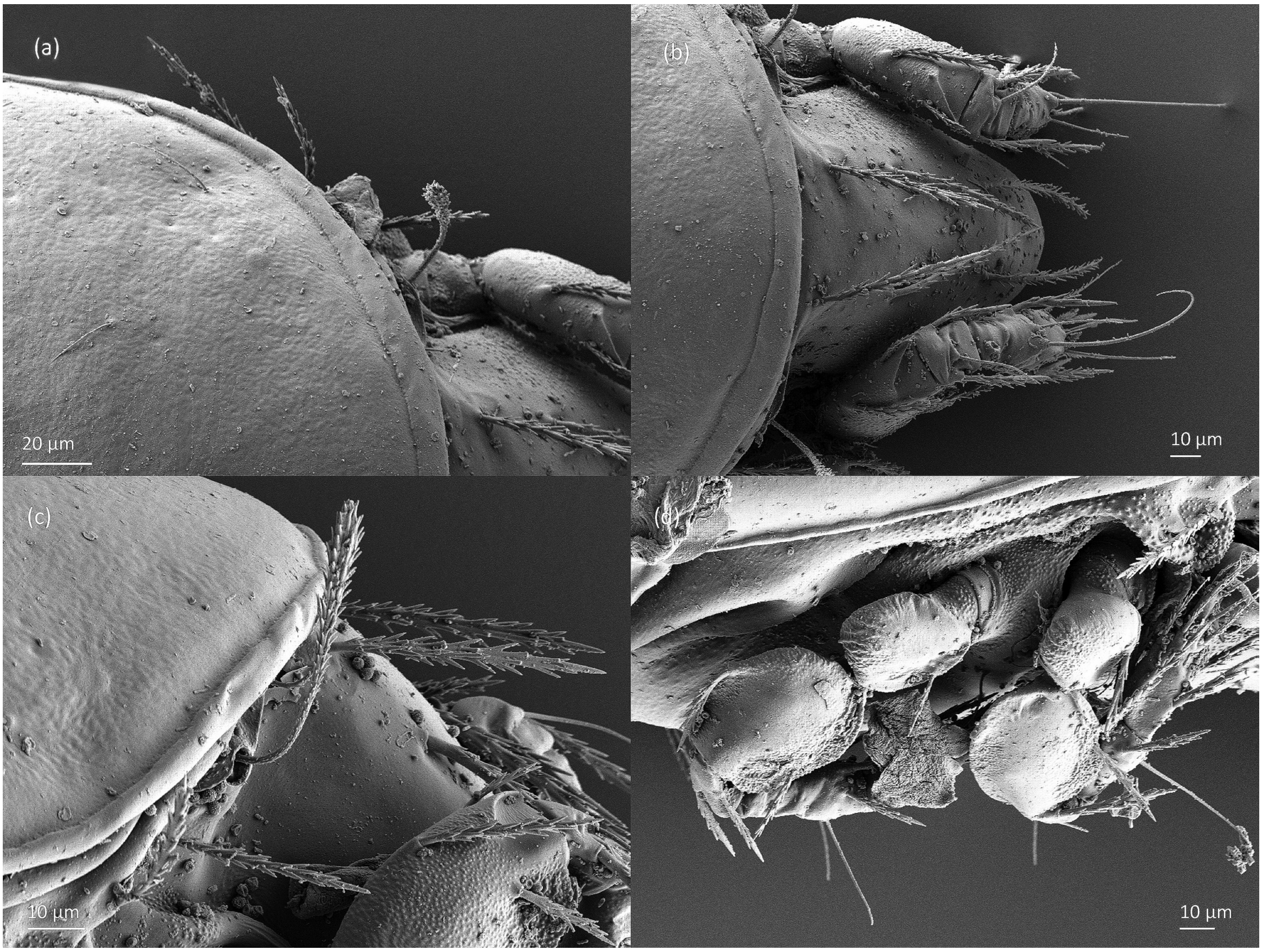

Figure 16. *Galumna flagellata*, tritonymph, SEM micrographs. a – anterior part of gastronotum, dorsal view, b – anterior part of body, dorsal view, c – anterior part of body, lateral view, d – legs III and IV, lateral view.

(0–1)–1–2–1 (adult). The formula of genital setae is 1–3–5–6 (protonymph to adult), and formula of aggenital setae is 1–1–1 (deutonymph to adult), and setal formula of segments PS–AN is 03333–0333–022. The ontogeny of leg setae and solenidia of *G. flagellata* is shown in Table 2.

Distribution, ecology and biology

Galumna flagellata has a central to southern Palearctic distribution (absent from eastern regions, Subías 2004), and is included in micro- and panphyto-phagous feeding groups (Hülsmann and Wolters 1998). The density of *G. flagellata* in terresial ecosystems is generally low (Paoletti 1988). This species prefers the litter or uppermost soil layer, and is considerably mobile and able to migrate upwards on plants (Smrž 1989).

In this study, *G. flagellata* was most abundant during the first sampling (i.e., at the end of December 2018), one month after the litterbags were placed on the soil of Biodomo. This species achieved higher mean density in common lantana prunings (61 individuals per 500 cm^3) than in mango prunings (30 individuals per 500 cm^3). A relatively high abundance of *G. flagellata* (15 individuals per 500 cm^3) was noted in mango prunings in the second sampling (i.e. at the end of January 2019), while in other samplings this species was represented by single specimens or was absent.

In the samples collected, the juveniles were more abundant (63% of all individuals) than the adults. The stage structure of this species for all samples was the following: 28 larvae, 39 protonymphs, 41 deutonymphs, 16 tritonymphs and 134 adults. In 50 randomly selected adults, the sex ratio (females to males) was 1:0.1, and 4% of females were gravid and carried one large egg (266 × 119), comprising 52% of the length of females.

Comparison of morphological ontogeny of *Galumna flagellata* with congeners and remarks

We compare the morphological ontogeny of *G. flagellata* with that of *G. alata, G. curvifamulus, G. obvia* and *G. zachvatkini* (Seniczak et al. 2012; Ermilov et al. 2017b; Grishina 1982, respectively, Table 3) to know the morphological differences between these species. Although the tritonymph of *G. obvia* is unknown, the other nymphs of this species are sufficient for this comparison. Morphology of *G. flagellata* is most similar to that of *G. zachvatkini*, and most characters concern the juveniles. The adult of *G. flagellata* differs from that of *G. zachvatkini* in sexual characters and location of lyrifissure *im*, whereas the juveniles differ in absence of typical galumnid humeral organ (*versus* present in *G. zachvatkini*), the shape of seta *in* in the tritonymph and shape of seta c_2 in the larva (Table 3). The morphology of *G. flagellata* differs most from that of *G. curvifamulus* and *G. obvia*. The adult of *G. flagellata* differs from those of *G. curvifamulus* and *G. obvia* in three morphological characters, and the juveniles differ in 10 morphological characters (Table 3). The adult of *G. flagellata* differs from that of *G. alata* in two morphological characters, and the juveniles differ in eight morphological characters. The nymphs of all species have a large, porose genital shield, whereas the presence of porose adanal shields depends on species (Table 3).

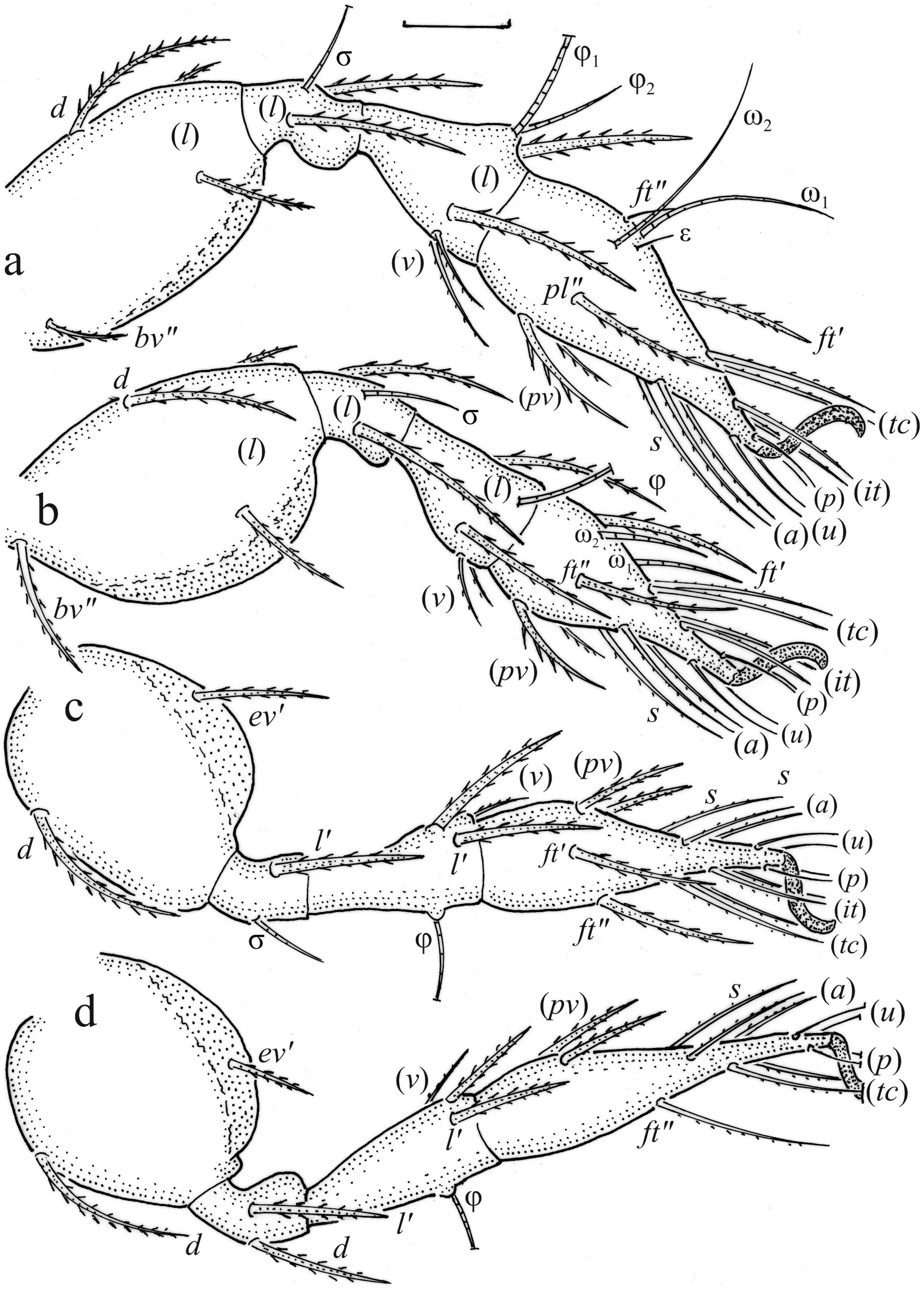

Figure 17. *Galumna flagellata*, leg segments of tritonymph (part of femur to tarsus), right side, antiaxial aspect, scale bar 10 µm, a – leg I, (*pl′* on tarsus not illustrated); b – leg II; c – leg III; d – leg IV.

Table 2. Ontogeny of leg setae (Roman letters), solenidia and famulus (Greek letters) in *Galumna flagellata*.

Leg	Trochanter	Femur	Genu	Tibia	Tarsus
Leg I					
Larva	–	*d*, *bv″*	(*l*), σ	(*l*), *v′*, $φ_1$	(*ft*), (*tc*), (*p*), (*u*), (*a*), *s*, (*pv*), (*pl*), ε, $ω_1$
Protonymph	–	–	–	–	$ω_2$
Deutonymph	–	(*l*)	–	$φ_2$	–
Tritonymph	*v′*	–	–	*v″*	(*it*)
Adult	–	–	*v′*	–	*v′*, *l″*
Leg II					
Larva	–	*d*, *bv″*	(*l*), σ	*l′*, *v′*, φ	(*ft*), (*tc*), (*p*), (*u*), (*a*), *s*, (*pv*), $ω_1$
Protonymph	–	–	–	–	–
Deutonymph	–	(*l*)	–	*l″*	$ω_2$
Tritonymph	*v′*	–	–	*v″*	(*it*)
Adult	–	–	*v′*	–	–
Leg III					
Larva	–	*d*, *ev′*	*l′*, σ	*v′*, φ	(*ft*), (*tc*), (*p*), (*u*), (*a*), *s*, (*pv*)
Protonymph	–	–	–	–	–
Deutonymph	*v′*	*l′*	–	*l′*	–
Tritonymph	*l′*	–	–	*v″*	(*it*)
Adult	–	–	–	–	–
Leg IV					
Protonymph	–	–	–	–	*ft″*, (*p*), (*u*), (*pv*)
Deutonymph	–	*d*, *ev′*	*d*	*v′*, φ	(*tc*), (*a*), *s*
Tritonymph	*v′*	–	*l′*	*l′*, *v″*	–
Adult	–	–	–	–	–

Note: structures are indicated where they are first added and are present through the rest of ontogeny; pairs of setae in parentheses, dash indicates no additions.

The juveniles of all species of Galumnidae are generally similar to one another, have most prodorsal setae of medium size or long and barbed, their gastronotum is oval or roundish, and most gastronotal setae of nymphs are short (Sengbusch 1954; Woodring 1965; Seniczak 1971/72; Seniczak and Seniczak 2007; Seniczak et al. 2012; Ermilov et al. 2013, 2017a, b, Bayartogtokh and Ermilov 2017), and usually have typical galumnid humeral organ. From these morphological characters, the most important is the absence of typical galumnid humeral organ in the juveniles of *G. flagellata*, which broadens the diagnosis of juveniles of *Galumna*. However, there are porose areas present in the place of humeral organ, which requires more investigations, also in other species of *Galumna* with unknown juveniles.

Among species of *Galumna* compared in Table 3, the ontogeny of leg setae is known in *G. flagellata* and *G. curvifamulus*. The former species differ from the latter species by the absence of seta v_1 on genua I and II of tritonymph (*versus* present in *G. curvifamulus*, Ermilov et al. 2017b), which is added in the adult. The juveniles of these species have most leg setae barbed, but femora of *G. flagellata* are thicker and have larger ventral keels than those of *G. curvifamulus*.

The juveniles of most species of Galumnidae have the typical humeral organ, which is located in the sejugal plane, above the level of leg insertions at the dorsal margin of the epimeral plate (Seniczak and Seniczak 2007; Seniczak et al. 2012; Ermilov et al. 2013, 2017a, b, Bayartogtokh and Ermilov 2017). The juveniles of

Table 3. Comparison of selected morphological characters of *Galumna flagellata, G. alata, G. curvifamulus, G. obvia* and *G. zachvatkini*; Gn – gastronotal.

Characters	*G. flagellata*	*G. alata*[3]	*G. curvifamulus*[2,3]	*G. obvia*[4]	*G. zachvatkini*[5]
Formula of Gn setae	12–15–15–15–10	11–15–15–15–10	12[6]–15–15–15–10	11–15–15–15–10	12–15–15–15–10
Adult					
Shape of *bs*	Fusiform	Fusiform	Clavate	Fusiform	Fusiform
Length of seta *in*	Long	Long	Short	Short	Long
Location of *im*	Not close to *A1*	Close to *A1*	Close to *A1*	Close to *A1*	Not close to *A1*
Median pore	Present	Absent	Present	Absent	Present
Sexual dimorphism	Indistinct	Indistinct	Indistinct	Indistinct	Distinct
Juveniles					
Shape of *bs*	Clavate	Clavate	Clavate	Fusiform	Clavate
Setae of *c*-series	On microsclerites	On microsclerites	On microsclerites	On microsclerites	?
Humeral organ	Absent	Present	Present	Present	Present
Nymphs					
Length of seta *le*	As long as *le*	As long as *le*	As long as *le*	Shorter than *le*	As long as *le*
Length of seta *in*	As long as *le*	As long as *le*	Longer than *le*	Shorter than *le*	Shorter than *le*
Length of seta c_2	Longer than c_1	Longer than c_1	Longer than c_1	As short as c_1	Longer than c_1
Length of seta c_3	As long as c_2	Shorter than c_2	Longer than c_2	Longer than c_2	As long as c_2
Most Gn setae	Short	Short	Alveolar	Short	Short
Setae of *p*-series	On *ad*-sclerite	On *ad*-sclerite	On microsclerites	On microsclerites	On *ad*-sclerite
Setae of *ad*-series	On integument	On microsclerites	On microsclerites	On integument	?
Larva					
Length of seta *le*	As long as *ro*	Shorter than *ro*	As long as *ro*	As long as *ro*	As long as *ro*
Length of seta *in*	Shorter than *le*	Longer than *le*	As long as *le*	Shorter than *le*	Shorter than *le*
Length of seta *ex*	Medium sized	Short	Short	Medium sized	Medium sized
Length of seta c_2	Longer than c_1	Longer than c_1	Longer than c_1	As short as c_1	As long as c_1
Length of seta c_3	As long as c_2	Shorter than c_2	As long as c_2	Longer than c_2	As long as c_2
Most Gn setae	Medium sized	Short	Alveolar	Short	Medium sized

[1]According to Seniczak et al. (2012), [2]adult according to Ermilov et al. (2017a), [3]juveniles according to Ermilov et al. (2017b), [4]according to Ermilov et al. (2013), [5]according to Grishina (1982), [6]including alveolar h_3.

G. flagellata lack the typical humeral organ, but have a large porose area in this place, which is unique in Galumnidae. According to Alberti et al. (1997), a humeral organ is a secretory porose organ, which is probably homologous to the humerosejugal porose organ *Ah* of adults, and has taxonomic importance (Norton and Alberti 1997). Except for the juveniles of Galumnidae, a humeral organ is also present in those of Oribatellidae, Ceratozetidae and Punctoribatidae (Norton and Behan-Pelletier 2009), but in these families, it is placed higher, near the posterolateral corner of the prodorsal shield. In the juveniles of Oribatellidae, a humeral organ is present in all species (Behan-Pelletier 2011; Behan-Pelletier and Walter 2012; Seniczak and Seniczak 2013; Seniczak et al. 2015, 2020a), except for *Oribatella reticulata* Berlese, 1916 (Seniczak et al. 2021). In the juveniles of Ceratozetidae, presence of humeral organ depends on subfamilies *sensu* Shaldybina (1972). In all species of Ceratozetinae, this organ is present (Behan-Pelletier and Eamer 2009; Seniczak et al. 2016b, 2017, 2018a), whereas in the juveniles of Sphaerozetinae this organ is generally present (summarized by Seniczak et al. 2016a), except for the larvae of *Sphaerozetes olympicus* Seniczak et al. (2016a) and *Fuscozetes coulsoni* A. and S. Seniczak, 2020 (Seniczak et al. 2016a; Seniczak and Seniczak 2020). In the juveniles of Trichoribatinae, a humeral organ is generally absent, but in some species, it is present (summarized by Seniczak et al. 2018c, 2019). In the juveniles of Punctoribatidae, a humeral organ is generally present (Behan-Pelletier et al. 2001; Behan-Pelletier and Eamer 2005, 2008; Seniczak and Seniczak 2008, 2018; Seniczak et al. 2018b, 2020b), except for *Punctoribates sellnicki* Willmann, 1928 (Seniczak and Seniczak 2008).

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References

Alberti G, Klimek A, Seniczak S. 1997. Fine structure of the humeral organ of juvenile *Edwardzetes edwardsii* (Ceratozetidae, Oribatida) compared with porose areas of the adults. Acarologia. 38:275–287.

Aoki J.1966. The large-winged mites of Japan (Acari: Cryptostigmata). Bulletin of the National Science Museum, Tokyo. 9(3):257–275.

Bayartogtokh B, Ermilov SG. 2017. Nymphal instars of two *Pergalumna* species, with remarks on morphological ontogeny of Galumnidae (Acari, Oribatida). Systematic & Applied Acarology. 22:518–540. doi: 10.11158/saa.22.4.8.

Behan-Pelletier VM. 2011. *Oribatella* (Acari, Oribatida, Oribatellidae) of eastern North America. Zootaxa. 2973:1–56.

Behan-Pelletier VM, Eamer B. 2005. *Zachvatkinibates* (Acari: oribatida: mycobatidae) of North America, with descriptions of sexually dimorphic species. The Canadian Entomologist. 137: 631–647. doi: 10.4039/n05-0.

Behan-Pelletier VM, Eamer B. 2008. Mycobatidae (Acari, Oribatida) of North America. The Canadian Entomologist. 140:73–110. doi: 10.4039/n07-027.

Behan-Pelletier VM, Eamer B. 2009. *Ceratozetes* and *cerato zetoides* (Acari: oribatida: ceratozetidae) of North America. The Canadian Entomologist. 141:246–308. doi: 10.4039/n09-023.

Behan-Pelletier VM, Eamer B, Clayton M. 2001. Mycobatidae (Acari: oribatida) of Pacific Northwest canopy habitats. The Canadian Entomologist. 133:755–776. doi: 10.4039/ent133755-6.

Behan-Pelletier VM, Walter DE. 2012. *Oribatella* (Acari, Oribatida, Oribatellidae) of Western North America. Zootaxa. 3432:1–62.

Berlese A. 1914. Acari nuovi. Manipulus IX. Redia. 10:113–150 (pls. X–XIII).

Berlese A. 1916. Centuria terza di Acari nuovi. Redia. 12:283–338.

Ermilov SG, Hugo-Coetzee EA, Khaustov AA, Theron PD. 2017a. New and interesting oribatid mites (Acari, Oribatida) near Potchefstroom (South Africa), with description of two new species. Systematic & Applied Acarology. 22: 1849–1871. doi: 10.11158/saa.22.11.6.

Ermilov SG, Hugo-Coetzee EA, Khaustov AA, Theron PD. 2017b. Juvenile instars of *Galumna curvifamulus* (Acari, Oribatida, Galumnidae). Acarina. 25:87–95.

Ermilov SG, Klimov PB. 2017. Generic revision of the large-winged mite superfamily Galumnoidea (Acari, Oribatida) of the world. Zootaxa Monograph. 4357:1–72. doi: 10.11646/zootaxa.4357.1.1.

Ermilov SG, Weigmann G, Tolstikov AV. 2013. Morphology of adult and juvenile instars of *Galumna obvia* (Acari, Oribatida, Galumnidae), with discussion of its taxonomic status. ZooKeys. 357:11–28. doi: 10.3897/zookeys.357.6404.

Grandjean F. 1949. Formules anales, gastronotiques, génitales et aggénitales du développement numériques des poils chez les Oribates. Bulletin de la Société zoologique de France. 74:201–225.

Grandjean F. 1953. Essai de classification des Oribates (Acariens). Bulletin de la Société zoologique de France. 78:421–446.

Grishina LG. 1982. A new species of the genus *Galumna* (Acariformes, Oribatei). Zoologicheskii Zhurnal. 61:146–149.

Haq MA, Adolph C. 1981. A comparative study of the duration of the life cycles of four species of oribatid mites (Acari Oribatei) from the soils of Kerala, India. Indian Journal of Acarology. 5:56–61.

Hermann JF. 1804. Memoire apterologique. Strassbourg. p. 1–144.

Hülsmann A, Wolters V. 1998. The effects of different tillage practices on soil mites, with particular reference to Oribatida. Applied Soil Ecology. 9:327–332.

Jacot AP. 1929. American Oribatid mites of the subfamily Galumninae. Bulletin of the Museum of Comparative Zoology at Harvard College, Cambridge. 69(1):1–37.

Koch CL. 1841. Deutschlands Crustaceen, Myriapoden und Arachniden. Regensburg. Bd. 31–32.

Norton RA, Behan-Pelletier VM. 2009. Suborder oribatida. Chapter 15. In: Krantz GW, Walter DE, editors. A manual of acarology. Lubbock: Texas Tech University Press. p. 430–564.

Norton RA, Alberti G. 1997. Porose integumental organs of oribatid mites (Acari, Oribatida). 3. Evolutionary and ecological aspects. Zoologica, Stuttgart. 146:115–143.

Norton RA, Ermilov SG. 2014. Catalogue and historical overview of juvenile instars of oribatid mites (Acari: oribatida). Zootaxa. 3833:1–132. doi: 10.11646/zootaxa.3833.1.1.

Paoletti MG. 1988. Soil invertebrates in cultivated and uncultivated soils in northeastern Italy. Redia. 71:501–563.

Sengbusch HG. 1954. Studies on the life history of three oribatid mites with observations on other species (Acarina - Oribatei). Annals of the Entomological Society of America. 47:646–667.

Seniczak A, Seniczak S. 2007. Morphology of juvenile stages of *Pilogalumna crassiclava* (Berlese, 1914) and *P. ornatula*

Grandjean, 1956 (Acari: oribatida: galumnidae). Annales zoologici. 57:841–850.

Seniczak A, Seniczak S. 2020. Morphological ontogeny of *Fuscozetes coulsoni* sp. nov. (Acari: oribatida: ceratozetidae) from Svalbard, Norway. Systematic & Applied Acarology. 25: 680–696. doi: 10.11158/saa.25.4.8.

Seniczak A, Seniczak S, Sgardelis S. 2016a. Morphological ontogeny of *Sphaerozetes olympicus* sp. nov. (Acari: oribatida: ceratozetidae) from Greece, with comments on *Sphaerozetes*. Systematic & Applied Acarology. 21:1040–1054. doi: 10.11158/saa.21.8.5.

Seniczak S. 1971/72. Morphology of developmental stages of *Pilogalumna tenuiclava* (Berl.) and *Pergalumna nervosa* (Berl.). Bulletin de la Societe des Amis des Sciences et des Lettres de Poznan, ser. D. 12/13:199–213.

Seniczak S, Iturrondobeitia JC, Seniczak A. 2012. The ontogeny of morphological traits in three species of Galumnidae (Acari: oribatida). International Journal of Acarology. 38:612–638. doi: 10.1080/01647954.2012.709276.

Seniczak S, Ivan O, Marquardt T, Seniczak A. 2020a. Morphological ontogeny of *Oribatella hungarica* (Acari: oribatida: oribatellidae). Zootaxa. 4857:137–159. doi: 10.11646/zootaxa.4857.1.8.

Seniczak S, Ivan O, Marquardt T, Seniczak A. 2021. Morphological ontogeny of *Oribatella reticulata* (Acari: oribatida: oribatellidae). International Journal of Acarology. in press. https://doi.org/10.1080/01647954.2021.1879259

Seniczak S, Seniczak A. 2008. Morphology of three European species of the genus *Punctoribates* Berlese, 1908 (Acari: oribatida: mycobatidae). Annales Zoologici. 58:473–485. doi: 10.3161/000345408x364328.

Seniczak S, Seniczak A. 2013. Differentiation of external morphology of *Oribatella* Banks, 1895 (Acari: oribatida: oribatellidae), in light of the ontogeny of three species. Journal of Natural History. 47:1569–1611. doi: 10.1080/00222933.2012.763056.

Seniczak S, Seniczak A. 2018. Morphological ontogeny of *Minunthozetes semirufus* (Acari, Oribatida, Punctoribatidae). Zootaxa. 4540:73–92. doi: 10.11646/zootaxa.4540.1.8.

Seniczak S, Seniczak A, Coulson SJ. 2015. Morphology, distribution and certain population parameters of the Arctic mite *Oribatella arctica* (Acari: oribatida: oribatellidae). International Journal of Acarology. 41:395–414. doi: 10.1080/01647954.2015.1048727.

Seniczak S, Seniczak A, Kaczmarek S. 2016b. Morphological ontogeny of *Ceratozetes helenae* and *Ceratozetoides cisalpinus* (Acari: oribatida: ceratozetidae). Systematic & Applied Acarology. 21:1309–1333. doi: 10.11158/saa.21.10.3.

Seniczak S, Seniczak A, Kaczmarek S. 2017. *Ceratozetes behani* sp. nov., a new cryptic ceratozetid species (Acari: oribatida: ceratozetidae) from Mongolia, its morphological ontogeny and comments on some congeners. Systematic & Applied Acarology. 22:1763–1779. doi: 10.11158/saa.22.10.15.

Seniczak S, Seniczak A, Kaczmarek S. 2018a. Morphological ontogeny of *Ceratozetes shaldybinae* (Acari, Oribatida, Ceratozetidae). Systematic & Applied Acarology. 23:581–592. doi: 10.11158/saa.23.3.13.

Seniczak S, Seniczak A, Kaczmarek S, Marquardt T. 2018b. Morphological ontogeny of *Minunthozetes pseudofusiger* (Acari, Oribatida, Punctoribatidae) and comments on *Minunthozetes* Hull. Systematic & Applied Acarology. 23:1155–1168. doi: 10.11158/saa.23.6.11.

Seniczak S, Seniczak A, Kaczmarek S, Marquardt T. 2018c. Morphological ontogeny of *Diapterobates altaicus* (Acari: oribatida: ceratozetidae), with comments on *Diapterobates* Grandjean. Systematic & Applied Acarology. 23:1656–1671. doi: 10.11158/saa.23.8.14.

Seniczak S, Seniczak A, Kaczmarek S, Marquardt T. 2019. Morphological ontogeny of *Trichoribates naltschicki* (Acari: oribatida: ceratozetidae). Zootaxa. 4717:047–064. doi: 10.11646/zootaxa.4717.1.6.

Seniczak S, Seniczak A, Kaczmarek S, Marquardt T, Sarsenova B. 2020b. Morphological ontogeny of *Zachvatkinibates latilamellatus* (Acari: oribatida: punctoribatidae), and comments on *Zachvatkinibates* Shaldybina. Zootaxa. 4857:097–116. doi: 10.11646/zootaxa.4857.1.6.

Shaldybina ES. 1972. Some morphological characters of ceratozetid moss mites (Oribatei). Ucenyje Zapiski, Gorkowskij Gosudarstwiennyj Pedagogiceskij Institut, Gorki. 130:35–66. (In Russian).

Smrž J. 1989. Reproductive biology of some soil oribatid and acaridid mites (Acari: oribatida and Acaridida). In: Tonner M, Soldan T, Bennettova B, editors. Regulation of insect reproduction. Vol. 4. Praha: Academia. p. 475–479.

Subías LS 2004, updated in 2020. Listado sistemático, sinonímico y biogeográfico de los Ácaros Oribátidos (Acariformes, Oribatida) del mundo (1758–2002). *Graellsia*, 60 (número extraordinario), 3–305. 15ª actualización, 527 pp. (accessed September 2020). doi: 10.3989/graellsia.2004.v60.iextra.218

Weigmann G. 2006. Hornmilben (Oribatida). In: Dahl F, editor. series founder, Die Tierwelt Deutschlands part 76. Keltern: Goecke & Evers. p. 1–520.

Willmann C. 1925. Neue und seltene Oribatiden. Jahresberichte des Entomologischen Vereins Bremen. 13:7–11.

Woodring JP. 1965. The biology of five species of oribatids from Louisiana. Acarologia. 7:564–576.