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MORPHOLOGY OF JUVENILE INSTARS OF *FURCORIBULA FURCILLATA* AND *ZYGORIBATULA EXILIS* (ACARI, ORIBATIDA)

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ABSTRACT: The morphology of juvenile instars of the oribatid mites *Furcoribula furcillata* (Nordenskiöld, 1901) (Astegistidae) and *Zygoribatula exilis* (Nicolet, 1855) (Oribatulidae) is described and illustrated. All instars are from moss on trees (*Quercur robur*). Those of *F. furcillata* are the first to be described for Astegistidae, and are characterized by the following traits: body cuticle smooth; rostrum rounded except for medial mucro; prodorsal setae setiform; dorsal gastronotic region with pigmented, well-bordered sclerite; larva with 12 pairs and nymphs with 15 pairs of setiform gastronotic setae; larva with two pairs of paraproctal setae; tarsi II only with one solenidion. The juvenile instars of *Zygoribatula exilis* are similar morphologically to those of other species of *Zygoribatula*, and this genus can be included among those in which species are difficult to distinguish based on juvenile characteristics alone.

KEY WORDS: oribatid mites, *Furcoribula furcillata*, *Zygoribatula exilis*, morphology, juvenile instars.

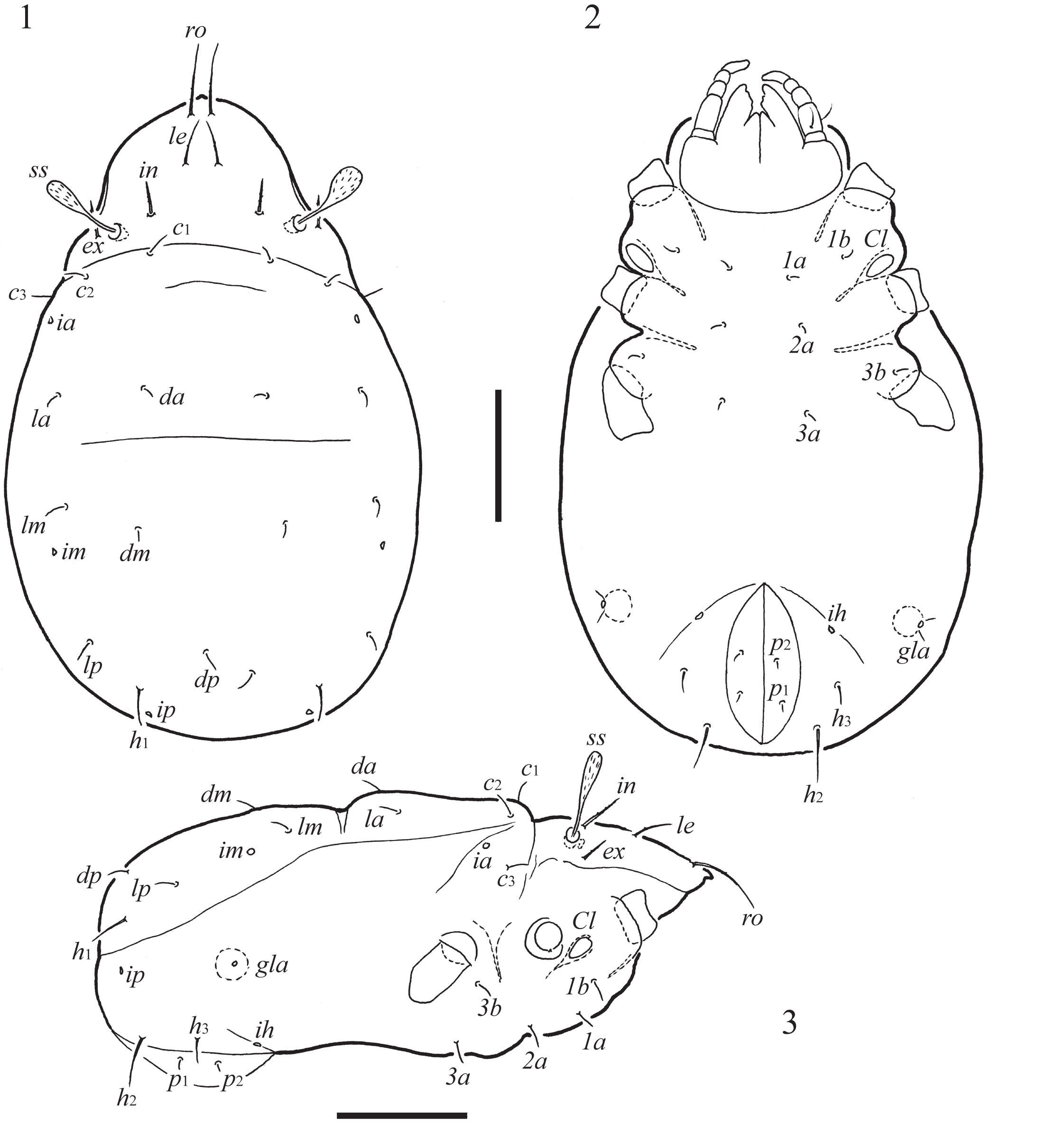
INTRODUCTION

Furcoribula furcillata (Nordenskiöld, 1901) (Gustavioidea, Astegistidae) and *Zygoribatula exilis* (Nicolet, 1855) (Oripodoidea, Oribatulidae) are well know from the adult instar and have been redescribed and illustrated by several authors, including, for example, Willmann (1931), Bulanova-Zakhvatkina (1975), Krivolutskiy (1975) and Weigmann (2006). Both these species are distributed in the Holarctic region and often are recorded together as representatives of arboreal fauna (in particular, in the Central European part of Russia; Ermilov 2004; Ermilov and Chistyakov 2007). Despite their wide distribution and frequent citations in the literature, the juvenile instars of these species have remained unknown. The purpose of the present work is to describe and illustrate the morphology of juvenile instars of *F. furcillata* and *Z. exilis* based on material collected from moss on trees.

The oribatid mite family Astegistidae includes 10 genera and more than 50 species, which collectively occur worldwide, except in Antarctica. At present, the juvenile instars of no astegistid mite has been studied, so our data comprise the first such complete treatment for any member of this family.

The family Oribatulidae includes 19 genera and more than 200 species, which collectively also have a worldwide distribution. Grandjean (1953) listed several generic characteristics of juvenile instars in this family, but at present, those of only a few species have been studied, and these often briefly. Michael (1880) briefly described and illustrated a nymph of *Phauloppia lucorum* (Koch, 1841) and, and later he (1888) briefly described and illustrated a nymph of *Oribatula tibialis* (Nicolet, 1855)[1], *Lucoppia burrowsi* (Michael, 1890) (without illustration) and again described a nymph of *Ph. lucorum*. Grandjean (1933) described and illustrated the juvenile instars of *Zygoribatula exarata* (Berlese, 1916), and later (1958) he also described and illustrated the anogenital region of the larva and palp of instars of *O. tibialis*. Tuxen (1943) briefly described and illustrated the nymph of the latter species. Hammer (1958) briefly described and illustrated the nymph of two oribatulid species, *Paraphauloppia altimontana* (Hammer, 1958) and *Pa. altimontanoides* (Hammer, 1958). Travé (1961) briefly described the juvenile instars of *Oribatula exsudans* Travé, 1961 and *Ph. rauschenensis* Sellnick, 1928. Feider et al. (1970) described and illustrated the all juvenile instars of *Zygoribatula mariehammerae* Feider, Vasiliu et Călugăr, 1970. Wallwork and Weems (1984) briefly described the nymphs and illustrated the deutonymph of *Jornadia larreae* Wallwork and Weems, 1984. Steiner (1989) presented lengths of a few morphometric characters (in particular: body, prodorsal and gastronotic setae) of *O. tibialis*, *Ph. lucorum*, *Z. frisiae* (Oudemans, 1900), *Z. glabra* (Michael, 1890) and also *Z.exilis*, but the latter were not illustrated or fully described. Seniczak and Seniczak (2012) described and illustrated the juvenile instars of *O. tibialis*, *Ph. lucorum* and *L. burrowsi*.

[1] Michael (1888) described and illustrated a nymph of this species, wrongly believing that it represented *Zygoribatula exilis* (this is clear from examining his Plate 28, Figs. 1, 6 — see morphology of lamellae and translamella)



Figs. 1–3. *Furcoribula furcillata*, larva: 1 — dorsal view; 2 — ventral view, legs (except trochanters) and hypostomal setae not shown; 3 — lateral view, legs (except trochanters) and gnathosoma not shown. Scale bar 50 µm.

MATERIALS AND METHODS

Specimens of *Furcoribula furcillata* and *Zygoribatula exilis* were collected by V.B. Kolesnikov in the Central European part of Russia: 51º53'S, 39º16'E, Voronezh region, Ramonskiy district, Aydarovo village, mosses on *Quercus robur* in mixed forest, collected during June and July 2011. The field-collected material of *F. furcillata* included: 15 larvae, 11 protonymphs, 6 deutonymphs, 1 tritonymph. The field-collected material of *Z. exilis* included: 12 larvae, 18 protonymphs, 43 deutonymphs, 48 tritonymphs.

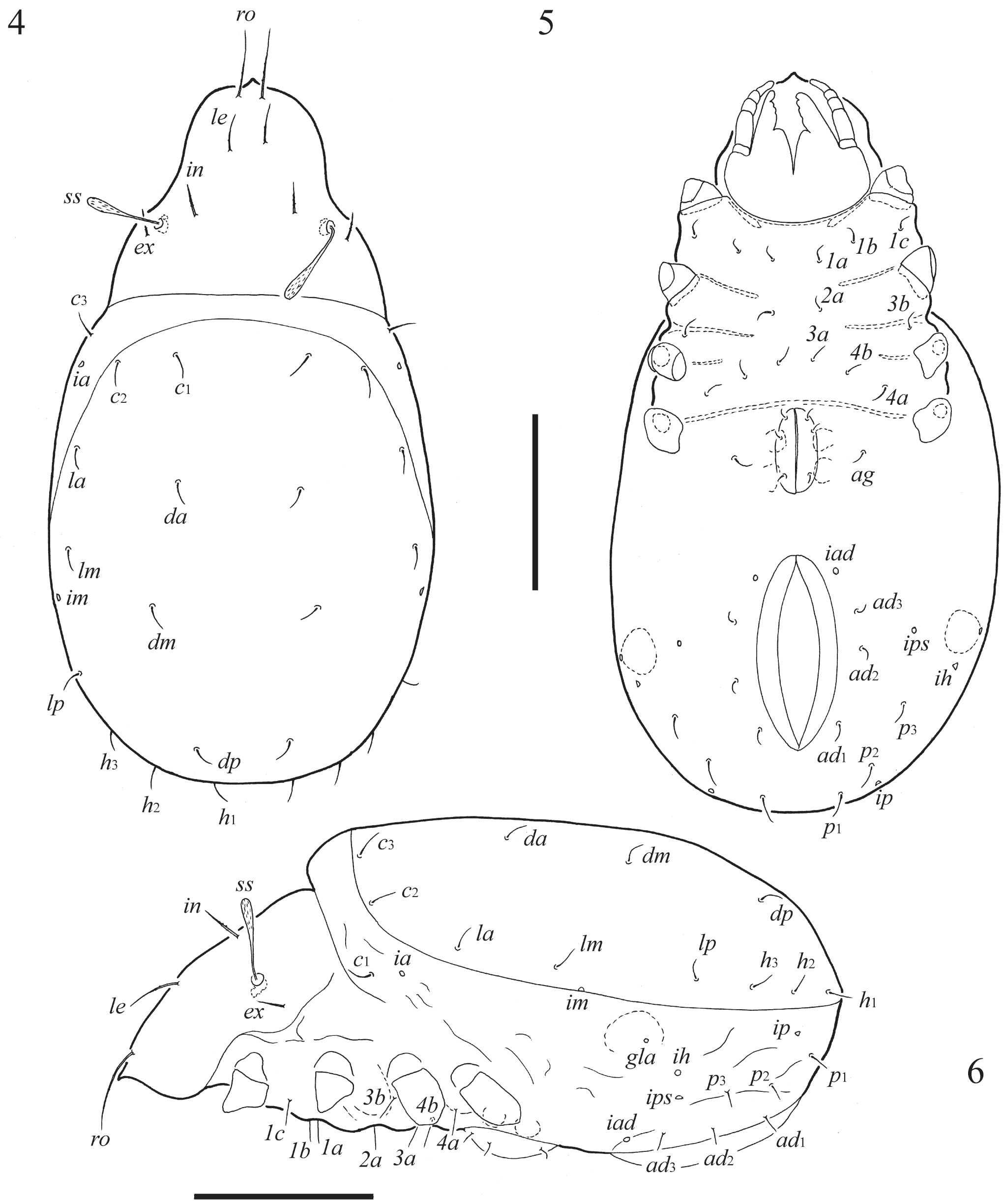
Specimens were studied and illustrated in lactic acid, mounted on temporary cavity slides for the duration of the study. All body measurements are presented in micrometers. Body length was measured in lateral view. Notogastral width refers to the maximum width in dorsal aspect.

Terminology used in this paper follows that of F. Grandjean (see Travé and Vachon 1975 for many references).

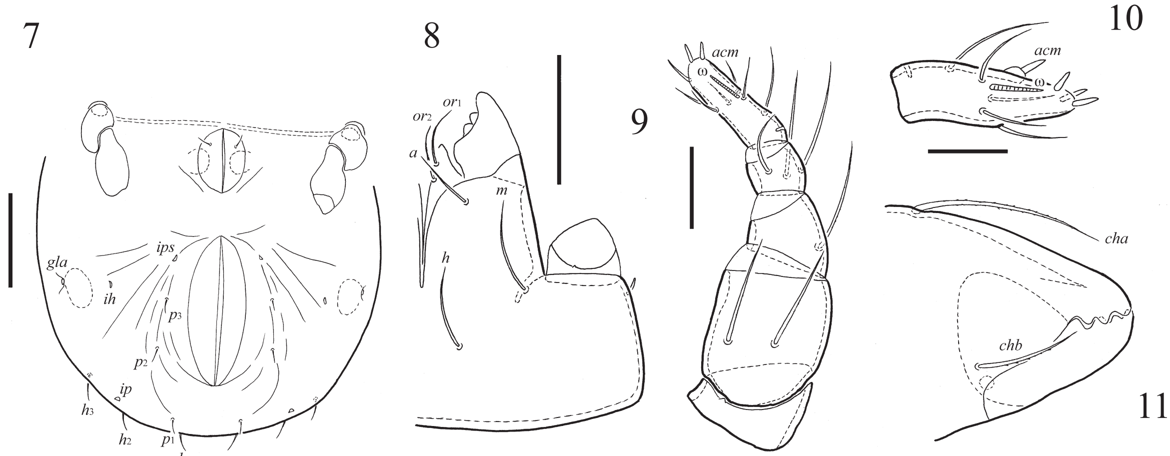
RESULTS

Morphology of juvenile instars of *Furcoribula furcillata* (Nordenskiöld, 1901)

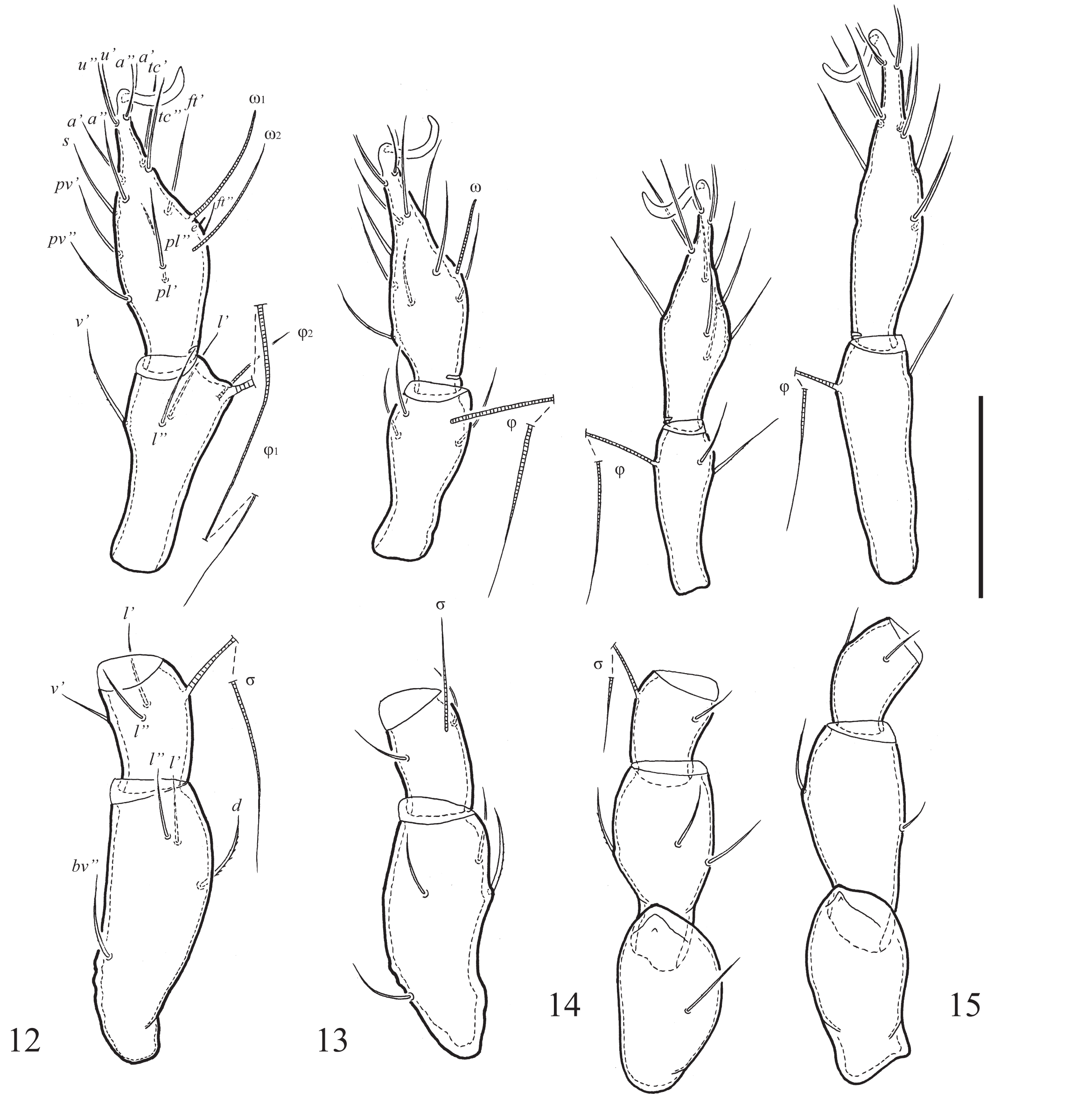
Dimensions. Length: larva 246–266 (n=4), protonymph 332–365 (n=4), deutonymph 398–431 (n=4), tritonymph 498 (n=1). Width: larva 139–159 (n=4), protonymph 189–215 (n=4), deutonymph 232–249 (n=5), tritonymph 265 (n=1).



Figs. 4–6. *Furcoribula furcillata*, deutonymph: 4 — dorsal view; 5 — ventral view, legs (except trochanters) and hypostomal setae not shown; 6 — lateral view, legs (except trochanters) and gnathosoma not shown. Scale bar 100 μm.



Figs. 7–11. *Furcoribula furcillata*, juvenile instars: 7 — anogenital region of protonymph; 8 — left half of subcapitulum of larva; 9 — palp of larva; 10 — palptarsus of deutonymph; 11 — anterior part of chelicera of larva. Scale bar (7) 50 μm, scale bar (8, 10) 20 μm, scale bar (9, 11) 10 μm.



Figs. 12–15. *Furcoribula furcillata*, legs of deutonymph: 12 — leg I, without trochanter, left, antiaxial view; 13 — leg II, without trochanter, left, antiaxial view; 14 — leg III, left, antiaxial view; 15 — leg IV, left, antiaxial view. Scale bar 50 μm.

Table 1. Comparison of prodorsal setae measurements of *Furcoribula furcillata* during ontogeny

Character	Larva	Protonymph	Deutonymph	Tritonymph
	n=4	n=4	n=4	n=1
Length of rostral seta	32–41	45–49	49–53	53
Length of lamellar seta	18–22	All 28	36–41	45
Length of interlamellar seta	18–22	All 24	28–32	36
Length of sensillus	36–41	49–53	49–57	57
Length of exobothridial seta	14–16	16–18	22–24	26

Integument. Body cuticle colorless to yellowish. Legs and subcapitulum more sclerotized, yellow-brownish in nymphs. Dorsal gastronotic well-bordered sclerite of larvae colourless or yellowish. Dorsal gastronotic well-bordered sclerite of nymphs more pigmented than lateral and ventral sides of body, yellow to slightly brownish. Body cuticle smooth, only with several lateral folds.

Prodorsum (Figs. 1, 3, 4, 6). Relatively short, about 1/2 length of gastronotic region. Rostrum generally rounded in dorsal view but with sharp medial mucro. Rostral (*ro*) and lamellar (*le*) setae

Table 2. Setal and solenidial counts on legs of *Furcoribula furcillata* during ontogeny*

	Formula of setae	Formula of solenidia
Leg I		
Larva	0–2–2–3–16	1–1–1
Protonymph	0–2–2–3–16	1–1–2
Deutonymph	0–4–3–3–16	1–2–2
Tritonymph	1–5–3–4–18	1–2–2
Leg II		
Larva	0–2–2–2–13	1–1–1
Protonymph	0–2–2–2–13	1–1–1
Deutonymph	0–4–2–3–13	1–1–1
Tritonymph	1–5–3–4–15	1–1–1
Leg III		
Larva	0–2–1–1–13	1–1–0
Protonymph	0–2–1–1–13	1–1–0
Deutonymph	1–3–1–2–13	1–1–0
Tritonymph	2–3–2–3–15	1–1–0
Leg IV		
Protonymph	0–0–0–0–7	0–0–0
Deutonymph	0–2–2–1–12	0–1–0
Tritonymph	1–2–2–2–12	0–1–0

*Formula for leg setae in sequence trochanter–femur–genu–tibia–tarsus (famulus included), formula for solenidia in sequence genu–tibia–tarsus.

Table 3. Development of leg setation of *Furcoribula furcillata* during ontogeny*

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

*Roman letters refer to normal setae (*e* — famulus), Greek letters refer to solenidia. One apostrophe (′) marks setae on anterior and double apostrophe (″) setae on posterior side of the given leg segment. Parentheses refer to a pair of setae. Setae are listed only for the instar in which they first appear.

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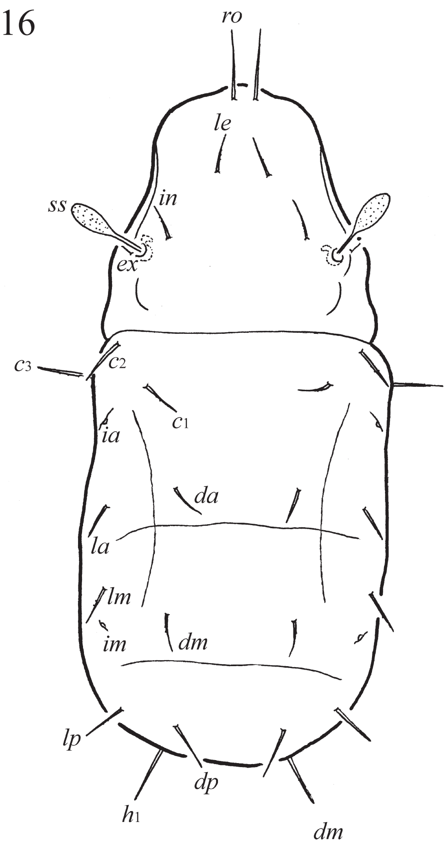

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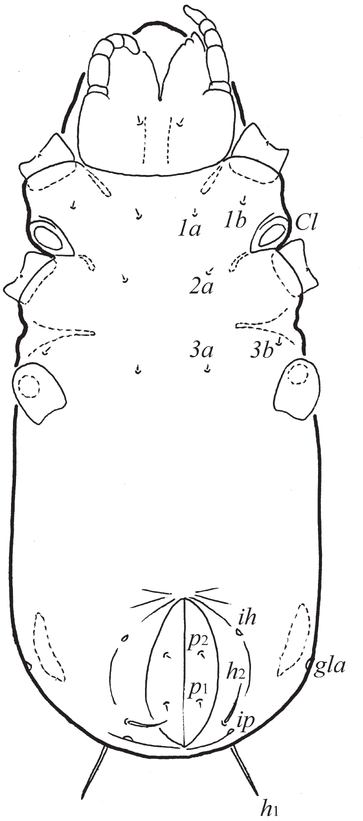

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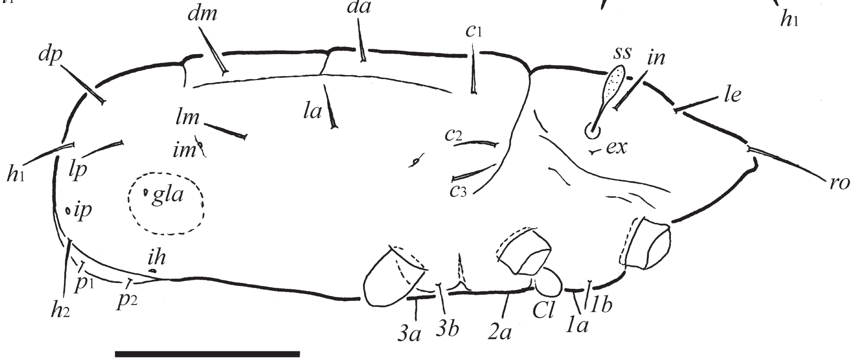


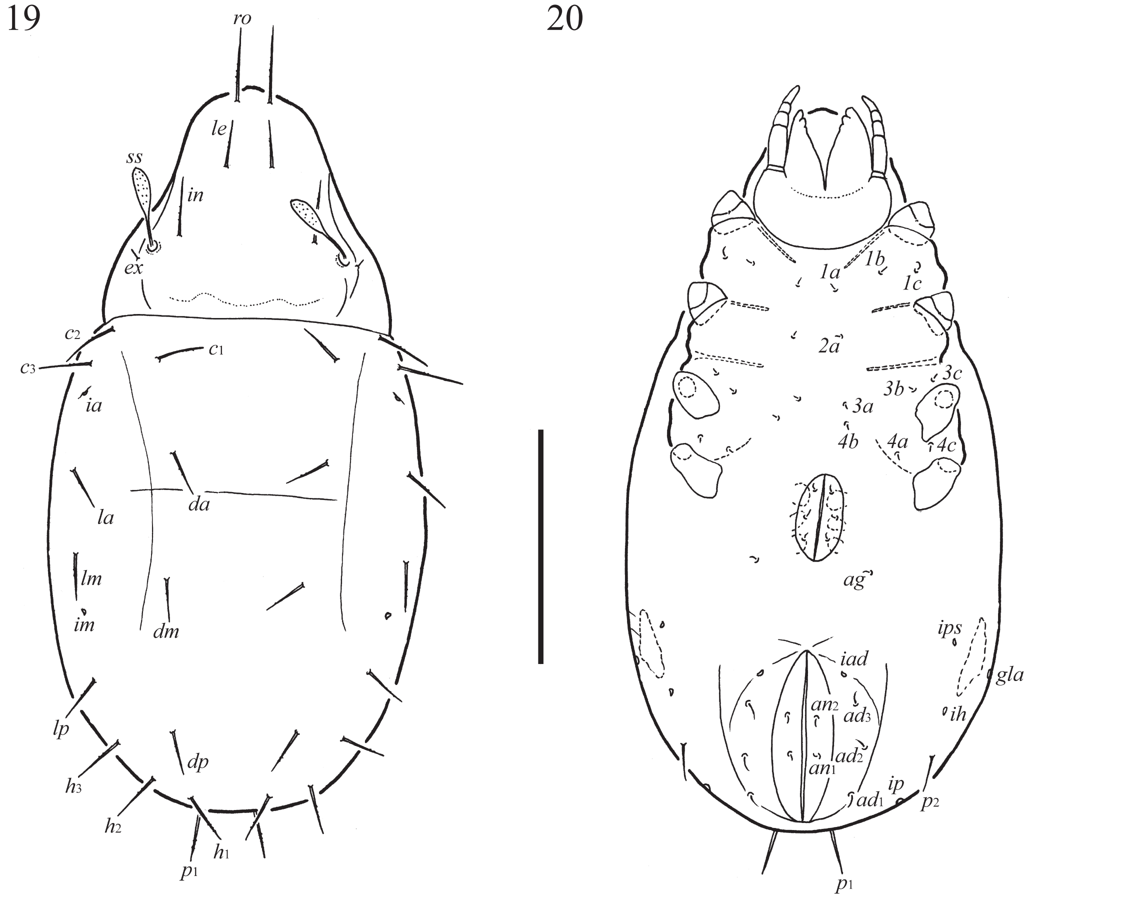
Figs. 16–18. *Zygoribatula exilis*, larva: 16 — dorsal view; 17 — ventral view, legs (except trochanters) and hypostomal setae (except h) not shown; 18 — lateral view, legs (except trochanters) and gnathosoma not shown. Scale bar 50 µm.

setiform, thin, slightly barbed, set on small tubercles. Interlamellar (*in*) and exobothridial (*ex*) setae straight, slightly barbed, set on small tubercles. Sensilli (*ss*) clavate, head with minute barbs. Relative length of prodorsal setae: *ss* ≈ *ro* > *le* > *in* ≈ *ex*. Prodorsal setae measurements of juvenile instars compared in Table 1.

Gastronotic region (Figs. 1, 3, 4, 6). Dorsal gastronotic region with pigmented, well-bordered sclerite in all juvenile instars. Larva with 12 pairs of gastronotic setae, nymphs with 15 pairs; most inserted on sclerite (except c_3, h_1–h_3 – in larva; c_3, p_1–p_3 – in nymphs). All gastronotic setae relatively short, setiform and smooth, set on small tubercles. Setae h_1 and h_2 longer than others in larva; setae similar in length in nymphs. Distinct simple transverse linear groove present posterior to setae *da* and *la* in larva, best seen in lateral view; groove absent from nymphs. Cupules *ia*, *im* and *ip* clearly visible. Only *im* located on sclerite.

Anogenital region (Figs. 2, 5, 7). Ontogenetic genital, aggenital, adanal, anal formulae (larva to tritonymph): 0–1–3–5, 0–0–1–1, 0–0–3–3, 0–0–0–2, respectively. All setae setiform and smooth. Larva with two pairs of paraproctal setae. Cupules *ih*, *ips*, *iad* and opisthonotal gland openings (*gla*) clearly visible, appearing in normal ontogenetic pattern.

Epimeral region (Figs. 3, 6). Apodemal line IV complete in nymphs, more or less horizontal. Setal formulae for epimera: larva 3–1–2 (larval seta *1c* scale-like, covering tip of retracted Cla-



Figs. 19–20. *Zygoribatula exilis*, tritonymph: 19 — dorsal view; 20 — ventral view, legs (except trochanters) and hypostomal setae not shown. Scale bar 100 μm.

parède's organ); protonymph 3–1–2–1; deutonymph 3–1–2–2; tritonymph 3–1–3–3. Epimeral setae similar in length, setiform and smooth.

Gnathosoma (Figs. 8–11). Subcapitulum little wider than long. All hypostomal setae setiform and smooth; *h* and *m* little longer than *a*. Lateral lips with two pairs setiform and smooth adoral setae (or_1, or_2). Palp setal formula: 0–2–1–3–9+1ω in all juvenile instars. Palpal solenidion ω rod-like, pressed to surface of tarsus; solenidion and eupathidium *acm* distinctly separated, not forming double horn. Cheliceral setae long, setiform and barbed; *cha* longer than *chb*.

Legs (Figs. 12–15). Ontogeny of leg setae and solenidia given in Tables 2 and 3. Leg setae setiform and slightly barbed. Tarsi II with only one solenidion. Solenidion ω_1 on tarsi I and ω on tarsi II slightly thickened, blunt-ended; other solenidia setiform. Famulus short, blunt-ended.

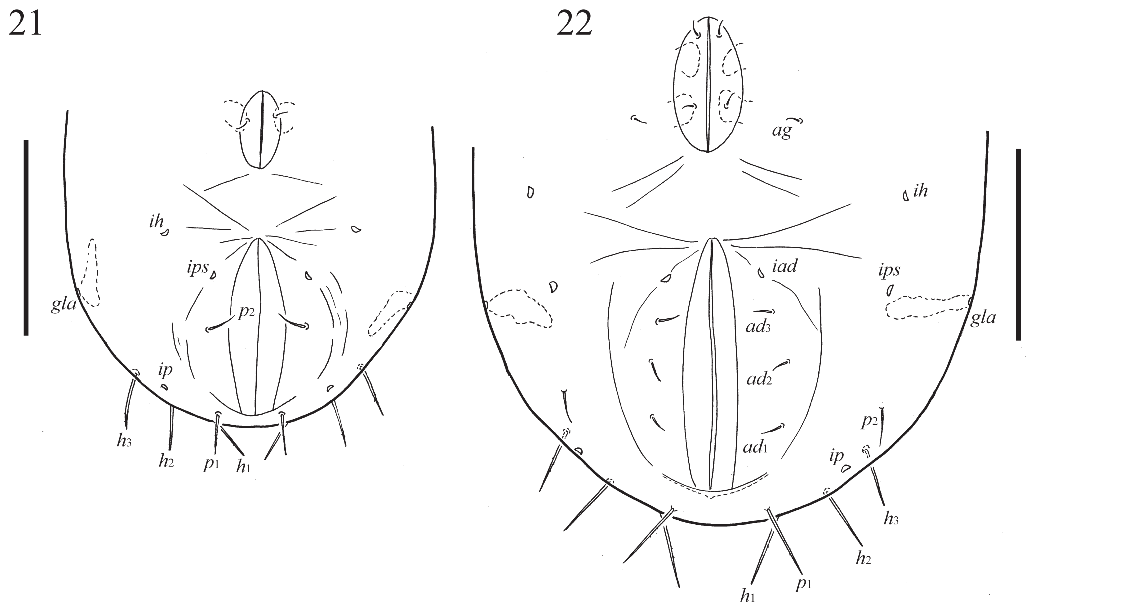
Morphology of juvenile instars of *Zygoribatula exilis* (Nicolet, 1855)

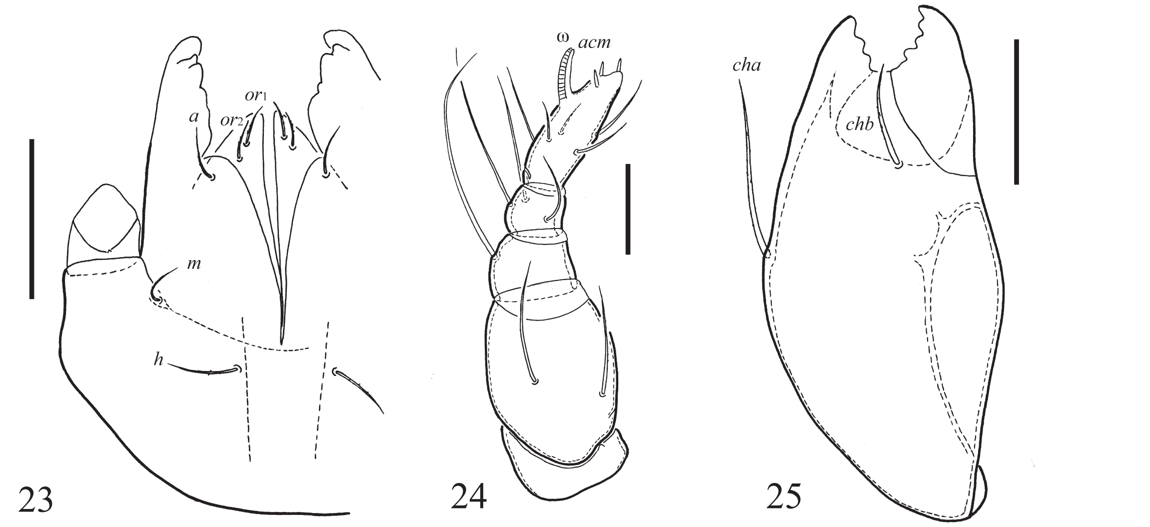
Dimensions. Length: larva 188–200 (n=6), protonymph 229–237 (n=6), deutonymph 266–299 (n=6), tritonymph 311–336 (n=6). Width: larva 82–94 (n=6), protonymph 86–114 (n=6), deutonymph 118–143 (n=6), tritonymph 143–159 (n=6).

Integument. General body cuticle colorless. Legs more sclerotized, yellow-brownish in nymphs. Dorsal gastronotic setae set on very small excentrosclerites, hovewer these excentrosclerites often poorly visible even under high magnification. Body cuticle smooth, only with several folds in lateral and anogenital regions. A longitudinal fold between c_1, *da*, *dm* and c_3, *la*, *lm* strongly developed.

Prodorsum (Figs. 16, 18, 19). Relatively short, about 1/2 length of gastronotic region. Rostrum rounded in dorsal view. Rostral, lamellar and interlamellar setae setiform, slightly barbed, set on small tubercles. Exobothridial setae shortest, slightly barbed. Sensilli clavate, head with minute barbs. Relative length of prodorsal setae: *ss* ≈ *ro* > *in* > *le* > *ex*. Prodorsal setae measurements of juvenile instars compared in Table 4.

Gastronotic region (Figs. 16, 18, 19). Larva with 11 pairs of gastronotic setae; nymphs with 14 pairs; all relatively short, similar in length, setiform, slightly barbed, set on small tubercles. Dis-





Figs. 21–25. *Zygoribatula exilis*, juvenile instars: 21 — anogenital region of protonymph; 22 — anogenital region of deutonymph; 23 — right half of subcapitulum of tritonymph; 24 — palp of of tritonymph; 25 — chelicera of tritonymph. Scale bar (21, 22) 50 µm, scale bar (23, 25) 20 µm, scale bar (24) 10 µm.

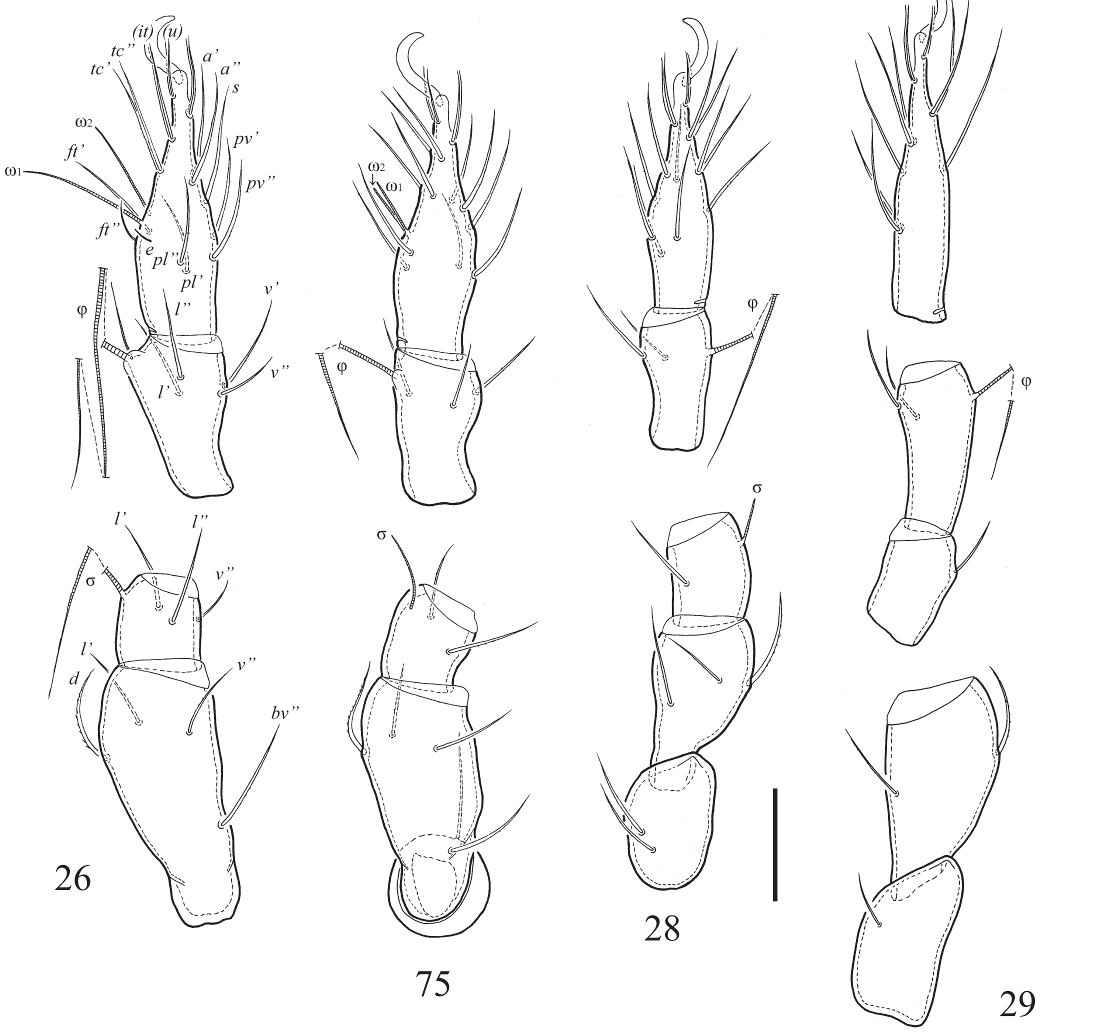
tinct simple transverse linear grooves present posterior to setae *da* and *dm* in larva, best seen in lateral view; only one linear groove (posterior to setae *da*) present in nymphs. Cupules *ia*, *im* and *ip* clearly visible.

Anogenital region (Figs. 17, 20–22). Ontogenetic genital, aggenital, adanal, anal formulae (larva to tritonymph): 0–1–2–3, 0–0–1–1, 0–0–3–3, 0–0–0–2, respectively. All setae setiform and smooth. Larva with two pairs of paraproctal setae. Cupules *ih*, *ips*, *iad* and opisthonotal gland openings clearly visible, appearing in normal ontogenetic pattern.

Epimeral region (Figs. 17, 20). Setal formulae for epimera: larva 3–1–2 (larval seta *1c* scale-like, covering tip of retracted Claparède's organ); protonymph 3–1–2–1; deutonymph 3–1–2–2; tritonymph 3–1–3–3. Epimeral setae similar in length, setiform and smooth.

Gnathosoma (Figs. 23–25). Subcapitulum nearly as long as wide. All hypostomal setae setiform and slightly barbed; *h* little longer than *m* and *a*. Lateral lips with two pairs setiform and barbed adoral setae (or_1, or_2). Palp setal formula: 0–2–1–3–9+1ω in all juvenile instars. Palpal solenidion and eupathidium *acm* separate, not forming double horn in larva, but fused to form double horn in nymphs (similar to *Oribatula tibialis*; see Grandjean, 1958). Cheliceral setae long, setiform and barbed; *cha* longer than *chb*.

Legs (Figs. 26–29). Ontogeny of leg setae and solenidia given in Tables 5 and 6. Leg setae setiform and slightly barbed. Solenidia ω_1, ω_2 on tarsi I and II, σ on genua II and III slightly thickened,



Figs. 26–29. *Zygoribatula exilis*, legs of tritonymph: 26 — leg I, without trochanter, right, antiaxial view; 27 — leg II, right, antiaxial view; 28 — leg III, right, antiaxial view; 29 — leg IV, right, antiaxial view. Scale bar 20 μm.

Table 4. Comparison of prodorsal setae measurements of *Zygoribatula exilis* during ontogeny

Character	Larva	Protonymph	Deutonymph	Tritonymph
	n=6	n=6	n=6	n=6
Length of rostral seta	24–26	28–30	32–34	36–41
Length of lamellar seta	12–14	16–18	22–24	28–30
Length of interlamellar seta	16–18	18–20	24–28	30–32
Length of sensillus	24–28	28–32	32–36	36–41
Length of exobothridial seta	6–8	All 8	10–12	10–12

blunt-ended; others solenidia setiform. Famulus short, setiform.

REMARKS

At present, juvenile instars of *Furcoribula furcillata* are the only ones studied members of Astegistidae, so morphological comparison of these juveniles to confamilials is impossible. However, the juvenile instars in the other families of Gustavioidea are known: Gustaviidae, Liacaridae, Peloppiidae (for example, Costesèque and Taberly 1961; Trávníček 1977; 1982; Ermilov, 2010, 2011; Seniczak and Seniczak 2010).

Juvenile instars of *Furcoribula furcillata* are most similar to representatives of the genus *Liacarus* Michael, 1898 and *Xenillus* Robineau-Desvoidy, 1839 (both Liacaridae) in absence of exuvial scalp in nymphs, similar body habitus, smooth body cuticle, morphology of body setae and gnathosoma. Juvenile *F. furcillata* have large morpho-

Table 5. Setal and solenidial counts on legs of *Zygoribatula exilis* during ontogeny*

	Formula of setae	Formula of solenidia
Leg I		
Larva	0–2–2–3–16	1–1–1
Protonymph	0–2–2–3–16	1–1–2
Deutonymph	0–3–2–3–16	1–2–2
Tritonymph	1–4–3–4–18	1–2–2
Leg II		
Larva	0–2–2–2–13	1–1–1
Protonymph	0–2–2–2–13	1–1–1
Deutonymph	1–3–2–2–13	1–1–2
Tritonymph	1–4–2–3–15	1–1–2
Leg III		
Larva	0–2–1–1–13	1–1–0
Protonymph	0–2–1–1–13	1–1–0
Deutonymph	1–2–1–1–13	1–1–0
Tritonymph	2–3–1–2–15	1–1–0
Leg IV		
Protonymph	0–0–0–0–7	0–0–0
Deutonymph	0–2–1–1–12	0–1–0
Tritonymph	1–2–2(1)–2–12	0–1–0

*See Table 2 for explanations of formulae

Table 6. Development of legs setation of *Zygoribatula exilis* during ontogeny*

	Trochanter	Femur	Genu	Tibia	Tarsus
Leg I					
Larva	–	*d*, *bv″*	*(l)*, σ	*(l)*, *v′*, φ_1	*(ft)*, *(tc)*, *(p)*, *(u)*, *(a)*, *s*, *(pv)*, *(pl)*, *e*, ω_1
Protonymph	–	–	–	–	ω_2
Deutonymph	–	*l′*	–	φ_2	–
Tritonymph	*v′*	*v″*	*v′*	*v″*	*(it)*
Leg II					
Larva	–	*d*, *bv”*	*(l)*, σ	*l′*, *v′*, φ	*(ft)*, *(tc)*, *(p)*, *(u)*, *(a)*, *s*, *(pv)*, ω_1
Protonymph	–	–	–	–	–
Deutonymph	–	*l′*	–	–	ω_2
Tritonymph	*v′*	*v″*	–	*v″*	*(it)*
Leg III					
Larva	–	*d*, *ev′*	*v′*, σ	*v′*, φ	*(ft)*, *(tc)*, *(p)*, *(u)*, *(a)*, *s*, *(pv)*
Protonymph	–	–	–	–	–
Deutonymph	*v′*	–	–	–	–
Tritonymph	*l′*	*l′*	–	*v″*	*(it)*
Leg IV					
Protonymph	–	–	–	–	*ft″*, *(p)*, *(u)*, *(pv)*
Deutonymph	–	*d*, *ev’*	*d*	*v’*, φ	*(tc)*, *(a)*, *s*
Tritonymph	*v′*	–	*l′* (absent in one ex.)	*v″*	–

*See Table 3 for explanations

logical differences from the other gustavioid taxa. Most important from these are:

— Juveniles of *Birsteinius* (Liacaridae): with densely granulate cerotegument on gastronotic region; nymphs with exuviae (centrodorsal gastronotic setae absent); sensilli spindle-formed; structure of interlamellar setae changes from larva to nymphs; gastronotic setae set on short apophyses.

— Juveniles of Gustaviidae: with densely granulate cerotegument on gastronotic region, larva also with reticular ornament on gastronotum; nymphs with exuviae (centrodorsal gastronotic setae absent); sensilli spindle-formed; structure of interlamellar setae changes from larva to nymphs; larva with 12 pairs of gastronotic setae; gastronotic setae set on short apophyses; subcapitulum "suctorial", palpal seta *acm* and solenidion attached in double horn, chelicerae styliform.

— Juveniles of Peloppiidae: with densely granulate cerotegument and folds on gastronotic region, centrodorsal gastronotic setae absent in nymphs; interlamellar setae short; nymphs with caudal apophyses, having setae h_1.

We would like to emphasize the fact that juvenile instars of *Furcoribula furcillata* differ from representatives of all gustavioid families (including *Liacarus* and *Xenillus*) by the presence of gastronotic pigmented, well-bordered sclerite. Only larva of *Gustavia microcephala* (possibly it is presented at all larva of the genus) has a gastronotic bordered shield, differing from that of immature *Furcoribula furcillata* by reticular ornament (Ermilov 2010).

Juvenile instars of all studied *Zygoribatula* species are similar in appearance to other known Oribatulidae (cuticle, presence of gastronotic excentrosclerites, morphology of body setae, body setal formulae). This genus can be included among those genera for which species are difficult to distinguish based on juvenile traits alone. However, juveniles of *Z. exilis* can be distinguished from those of the other two species for which all juvenile instars were previously known by gastrnotic setation. *Zygoribatula exilis* has 11 pairs of gastronotic setae in the larva and 14 pairs in nymphs; for *Z. exarata* these numbers are respectively 12 and 15 pairs, and for *Z. mariehammerae* 13 and 15 pairs).

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