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Contribution to the knowledge of Galumnidae (Acari: Oribatida) in the Oriental region

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Abstract

We found two species of galumnid mites from Babeldaob Island of the Palau Republic, which is an island located in the western Pacific Ocean. In the present work, we describe *Trichogalumna ekaterinae* **sp. nov.**, which is clearly different from other known species of *Trichogalumna* in the specific structure of sensillus, reduced number of notogastral porose areas, and smaller body size. A supplementary description of another species, *Galumna flabellifera*, which is recorded for the first time in Palau, is given. Furthermore, we discuss aspects of the distribution, diversity and habitat ecology of species belonging to these genera in the Oriental region.

Key words: *Galumna*, *Trichogalumna*, new species, biogeography, habitat ecology

Introduction

The large-winged mite family Galumnidae Jacot, 1925 is one of the species-richest groups of oribatid mites with a worldwide distribution, and presently comprises 43 genera (including 15 subgenera) with over 600 species (Subías 2004, online version 2019; Ermilov & Klimov 2017). Members of this family are abundant in the litter or upper layer of forest soil as well as in pasture soil of open habitats; in particular, they are very diverse in the tropical soil, litter and arboreal habitats of rain forests (Norton & Behan-Pelletier 2009). The feeding habits of galumnid species are diverse, they mostly feed on organic debris, green algae, fungal hyphae and spores (Woodring 1965; Schneider *et al*. 2004). A few species feed on plant tissues, while some others are obligate coprophages on fecal materials (Wallwork 1958). Some galumnid species also have been observed to prey on nematodes and hence they may contribute to their control (Rockett & Woodring 1966; Walter *et al*. 1988). A rather large number of galumnid species play an important role in the life cycle of cestode tapeworms of the family Anoplocephalidae, serving as their intermediate hosts in both natural conditions and experimental infections (Stunkard 1937; Sengbusch 1977; Denegri 1993).

Due to the early contributions by Aoki, Hammer, Mahunka and other authors (e.g. Aoki 1964, 1965, 1982; Hammer 1968, 1971, 1972, 1973; Mahunka 1978, 1987, 1989, 1995, 2008), and recent extensive studies by Ermilov and his colleagues (e.g. Ermilov & Anichkin 2010, 2011, 2014; Ermilov *et al*. 2014, 2015; Ermilov & Corpuz-Raros 2015*a*, *b*, 2016), the Galumnidae became one of the well-known groups in the Oriental region (over 170 spp.). However, the oribatid mite faunas of many individual islands, like Palau, have not been studied yet, therefore, there is a great possibility for more species of Galumnidae to occur in this region.

Among Galumnidae, *Trichogalumna* is one of the smaller genera and was proposed by Balogh (1960) with *Pilogalumna lunai* Balogh, 1958 as type species. Currently the genus comprises 33 named species, which are distributed in the Palaearctic, Ethiopean, Oriental, Neotropical and Australian regions. The other genus studied here, *Galumna* was established by Heyden (1826) with *Notaspis alatus* Hermann, 1804 as type species, and is the largest genus with more than 200 known species, which collectively have a cosmopolitan distribution (Subías 2004).

In the present work, we describe one recently discovered species of the genus *Trichogalumna* Balogh, 1960, and provide a supplementary description of another species of *Galumna* Heyden, 1826. Furthermore, we discuss the distribution, diversity and habitat ecology of species belonging to these genera in the Oriental region.

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We dedicate this work in memory of our esteemed colleague and friend, Dr. Ekaterina A. Sidorchuk, who recently passed away due to unexpected tragic accident. She had exceptional abilities and experiences in discovering fossil mites and interpreting their evolution, and was one of the scientists who led to the development of modern palaeoacarology.

Materials and methods

The present material was collected from Babeldaob Island, which is the largest island of Palau, an island country (officially the Republic of Palau) located in the western Pacific Ocean. The country contains approximately 340 islands, forming the western chain of the Caroline Islands in Micronesia, and has an area of 466 km^2. Palau has a tropical rainforest climate with an annual mean temperature of 28°C, and rainfall is heavy throughout the year, averaging 3800 mm of annual precipitation (Cole *et al*. 1987; Crombie & Pregill 1999). Partly elevated limestone and partly volcanic in origin, the Babeldaob has 331 km^2 of area, which makes up over 70% of the land area of the entire Republic of Palau. Babeldaob's eastern coast has many sandy beaches, in particular north from Melekeok to Ngaraard, and the island's western coast has a shoreline with many mangrove forests (Crombie & Pregill 1999; Endress & Chinea 2001).

The collection locality and habitat data for each species are given in the respective "material examined" section. All mites were extracted from samples by means of modified Berlese funnel extraction.

Specimens were mounted in lactic acid on temporary cavity slides for measurement and illustration. The body length of adults was measured in lateral view, from the tip of the rostrum to the posterior edge of the ventral plate. Notogastral width of adults refers to the maximum width in dorsal aspect. Lengths of body setae were measured in lateral aspect. Drawings were made with a drawing tube using a transmission light microscope "Nikon, Optiphoto II".

The morphological terminology used in this paper is mostly based on that developed by Grandjean (1966), Norton & Behan-Pelletier (2009), Ermilov & Klimov (2017).

Results

Family Galumnidae Jacot, 1925
Genus *Trichogalumna* Balogh, 1960
Type species *Pilogalumna lunai* Balogh, 1958

Trichogalumna ekaterinae sp. nov.

(Fig. 1)

Diagnosis. Small species, body length 253–262 µm, width of notogaster 173–182 µm; rostrum widely rounded in dorsal view, but protruding in lateral view; rostral, lamellar and interlamellar setae medium long, thin, smooth; sensillus with thin, long stalk and widely lanceolate head with small, pointed tip; anterior margin of notogaster not developed; notogastral setae well developed; three pairs of porose areas (*Aa*, A_1 and A_3).

Measurements. Holotype (female): body length of 253 µm, width of notogaster 176 µm; paratypes (three females): 256–262 (259) µm, width of notogaster 173–182 (178) µm.

Integument (Figs. 1A). Body color yellowish brown to dark brown. Body surface nearly smooth, with microgranules on prodorsum and pteromorph.

Prodorsum (Fig. 1A, B, C, E). Rostrum widely rounded in dorsal view, but protruding in lateral view; inner rostral tooth (*irt*) of rostrum distinct (Fig. 1B). Tutorial (*S*) and lamellar (*L*) ridges distinct, nearly parallel, curving backwards. Rostral (*ro*) and lamellar (*le*) setae 30–32 µm in length, interlamellar seta (*in*) ~22 µm long, setiform, thin, smooth. Sensillus (*ss*) having thin stalk and large, asymmetrically dilated, almost semicircular head with small, pointed tip. Dorsosejugal porose area (*Ad*) oval, located posterolaterad to seta *in*. Exobothridial seta and porose area *Al* not evident.

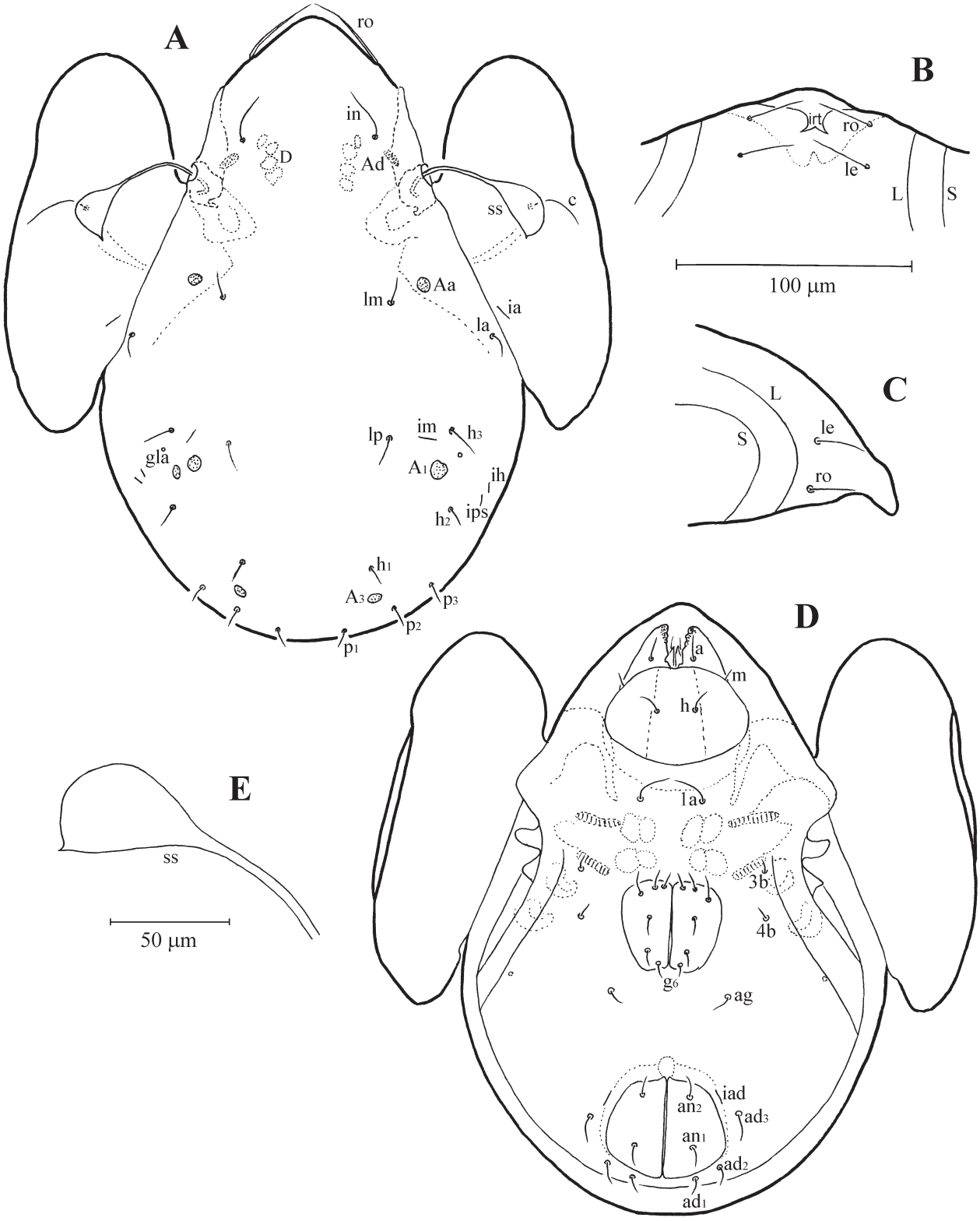

FIGURE 1. Adult of *Trichogalumna ekaterinae* **sp. nov.**, holotype. A—Dorsal view of body, B—Rostrum, dorso-frontal view, C—Anterior part of prodorsum, lateral view, D—Ventral view of body, legs not shown, E—Sensillus, lateral view. A, B, C and D to same scale.

Notogaster (Fig. 1A). Anterior margin of notogaster not developed. Dorsophragma (*D*) elongated longitudinally. Notogastral setae 18–32 µm long, thin, smooth. Three pairs of notogastral porose areas, *Aa*, A_1 and A_3 circular to oval in shape (in holotype, left A_1 was divided into two parts); A_1 located anterior to seta h_2; A_3 situated posterior

to seta h_1. Notogastral lyrifissures (*ia*, *im*, *ih*, *ips* and *ip*) and opisthonotal gland opening (*gla*) well developed; *ip* visible in posterior view.

Gnathosoma (Fig. 1D). Morphology of subcapitulum, palp and chelicera typical for genus (e.g. see Ermilov & Corpuz-Raros 2016). Subcapitular setae short, setiform, smooth. Palp setation: 0-2-1-3-9+1ω; axillary saccules distinct, elongated. Cheliceral setae setiform, barbed, *cha* longer than *chb*; Trägårdh's organ elongate triangular, rounded distally.

Epimeral region (Fig. 1D). Only three pairs of epimeral setae (*1a, 3b, 4b*) distinct, thin, smooth; seta *1a* ~21 μm long, *3b* and *4b* ~11 μm long. Discidium broadly conical; pedotectum I rounded, pedotectum II scale-like, subtriangular in ventral view. Circumpedal carina well developed.

Ano-genital region (Fig. 1D). All ano-genital setae medium long (12-18 μm), thin, smooth; g_1, g_2 and g_3 inserted on anterior margin of genital plate, g_4, g_5 arranged longitudinally, g_6 inserted on posterior margin of genital plate. Adanal setae ad_1 and ad_2 inserted posterior to anal plates; ad_3 inserted in paraanal position; lyrifissure *iad* situated anterolateral to anal aperture. Postanal porose area (*Ap*) oval, transversely oriented, visible only in posterior view.

Legs. Morphology of leg segments, setae and solenidia typical for *Trichogalumna* (e.g. Ermilov *et al*. 2011). Claws smooth dorsally. Famulus short, with slight distal expansion. Formulas of leg setation: I (1-4-3-4-20), II (1-4-3-4-15), III (1-2-1-3-15), IV (1-2-2-3-12); formula of solenidia: I (1-2-2); II (1-2–2), III (0-1-1), IV (0-1-0).

Material examined. Holotype (female) and three paratypes (females): Raelkelat, Island of Babeldaob, Republic of Palau, from moss sample growing on bark of fallen tree in a secondary forest, 7°28'59"N, 134°29'32"E, coll. S. Shimano, 17 December 2017.

Type depository. Holotype and all paratypes are deposited in NSMT—the National Museum of Nature and Science, Tsukuba, Japan (Zhang 2018).

Etymology. This species is named in honor of our esteemed colleague and friend Dr. Ekaterina A. Sidorchuk, who made a great contribution to the knowledge of mite diversity in Baltic amber inclusions.

Remarks. *Trichogalumna seminuda* Balogh, 1960 known from Angola, *Trichogalumna arborea* Ohkubo, 1984 from Japan, *Trichogalumna vietnamica* Mahunka, 1987 from Vietnam, *Trichogalumna africana* Ermilov, Sidorchuk & Rybalov, 2011 from Ethiopia, and a semicosmopolitan species, *Trichogalumna nipponica* (Aoki, 1966) (see Balogh 1960; Aoki 1966; Ohkubo 1984; Mahunka 1987; Ermilov *et al*. 2011) are similar to *Trichogalumna ekaterinae* **sp. nov.** in the morphology of asymmetrically dilated sensillus. However, all these known species have clearly developed four pairs of porose areas (*vs*. A_1 absent in the new species), and a much larger body size (body sizes more than 350 × 240 μm *vs*. 259 × 178 μm). Additionally, *T. seminuda* differs from the present new species by the very long interlamellar seta extending beyond the rostrum, and distinctly barbed rostral setae. The other African species, *T. africana* is different from the present new species in the relatively slender sensillus with a small notch behind the tip of the sensillar head. The Japanese species, *T. arborea* differs from the new species in the well-developed transverse bands on the notogaster and ano-genital region, as well as in the finely wrinkled and granulated structure of the humeral region. The Oriental species, *T. vietnamica* can easily be distinguished from *T. ekaterinae* **sp. nov.** by the long, barbed rostral seta. The semicosmopolitan species, *T. nipponica* has a much slender, distally barbed lanceolate sensillus rather than the largely dilated, smooth sensillus shown in the present new species.

It should be noted here that the holotype of *Trichogalumna ekaterinae* **sp. nov.** has the left porose area A_1 divided into two parts, which seems to be an abnormal character. Klimov & Ermilov (2017) studied the evolutionary dynamics of gain and loss of the notogastral porose areas of Galumnoidea Jacot, 1925 with respect to the various modifications of their properties, such as shape and position. These authors concluded that patterns of expression of porose areas in abnormal individuals and rare species suggest that this may be a complex, non-Mendelian character, encoded by several genes (i.e. a polygenic trait). They also proposed that the loss of porose areas is not likely to be down-regulated by a third gene.

Genus *Galumna* Heyden, 1826
Type species: *Notaspis alatus* Hermann, 1804

Galumna flabellifera Hammer, 1958

(Fig. 2)

Galumna flabellifera Hammer, 1958, p. 93, fig. 116; Aoki 1964, p. 659, figs. 18–22; 1982, p. 186, fig. 8d; Mahunka 1978, p. 334, figs. 57–58; Al-Assiuty *et al*. 1985, p. 284, figs. 3 & 4.

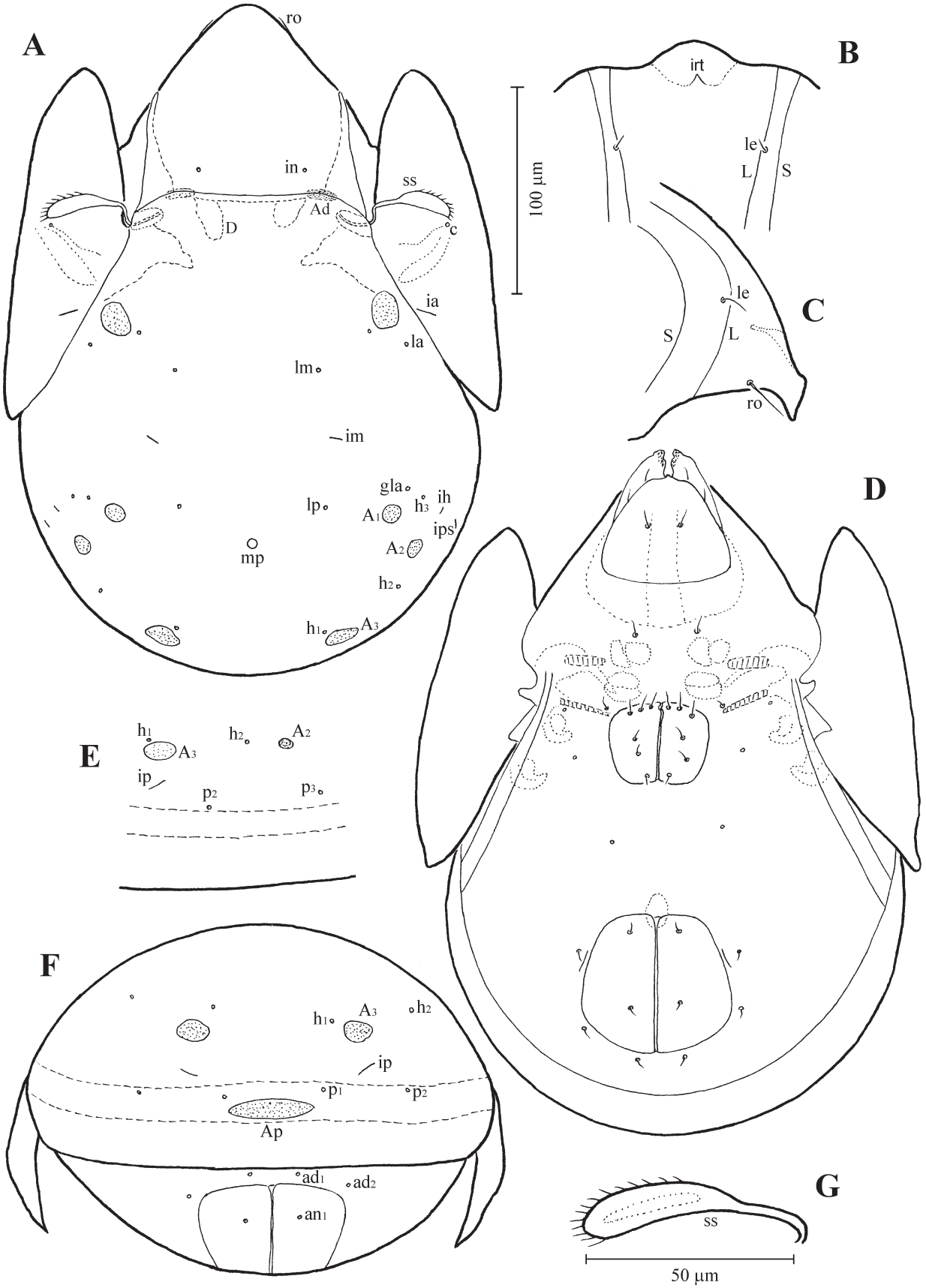

FIGURE 2. Adult of *Galumna flabellifera* Hammer, 1958. A—Dorsal view of body, legs not shown; B—Rostrum, dorso-frontal view, C—Anterior part of prodorsum, lateral view, D—Ventral view of body, legs not shown, E—Posterior part of notogaster, dorso-lateral view; F—Posterior view of notogaster; G—Sensillus, lateral view. A, B, C, D, E and F to same scale.

Galumna flabellifera orientalis Aoki, 1965, p. 187, figs. 97–100.
Galumna nuda Engelbrecht, 1972, p. 246, figs. 12–22.
Pergalumna pyri Elbadry & Nasr, 1975, p. 145.

Supplementary description. Body color dark brown; body covered by cerotegumental granules or small tubercles. Body length 307 μm, width of notogaster 211 μm; length of notogaster 224 μm. Rostrum rounded dorsally, but distinctly protruded in lateral view; inner rostral tooth (*irt*) of rostrum distinct (Fig. 2B). Lamellar (*L*) and sublamellar (*S*) ridges parallel, curving backwards (Fig. 2C). Rostral seta (*ro*) ~24 μm, lamellar seta (*le*) ~11 μm, both setae thin, smooth; interlamellar (*in*) and notogastral setae (*c*, *la*, *lm*, *lp*, h_1-h_3, p_1-p_3) represented by their alveoli. Sensillus relatively short, clavate, unilaterally barbed (Fig. 2G). Porose area *Ad* oval; exobothridial seta and porose area *Al* not evident. Anterior margin of notogaster almost straight, very slightly concave. Dorsophragma (*D*) slightly elongated longitudinally. Four pairs of notogastral porose areas, *Aa*, A_1, A_2 irregular round to oval, A_3 elongate oval; median pore (*mp*) well developed. All lyrifissures (*ia*, *im*, *ip*, *ih*, *ips*) and opisthonotal gland opening (*gla*) distinctly developed (Fig. 2A, E). Morphology of subcapitulum, palps and chelicerae typical for *Galumna* (e.g. see Ermilov & Corpuz-Raros 2016). Epimeral setae *1a*, *3a* well developed, *3b*, *4b* represented by their alveoli; other setae not evident. Discidium (*dis*) subtriangular. Circumpedal carina (*cp*) long, anteriorly extending beyond level of pedotectum II. Six pairs of genital (g_1–g_6), two pairs of anal (an_1, an_2) and three pairs of adanal (ad_1–ad_3) setae thin, smooth, 8–14 μm in length; seta *ag* represented by its alveolus. Adanal lyrifissure (*iad*) located close and parallel to anal aperture at level of ad_3 (Fig. 2D). Postanal porose area (*Ap*) elongate oval (Fig. 2F). Legs tridactylous, setation typical for family (e.g. see Ermilov & Corpuz-Raros 2016).

Material examined. One specimen (female): Raelkelat, Island of Babeldaob, Republic of Palau, from moss sample growing in a secondary forest, 7°28’59”N, 134°29’32”E, coll. S. Shimano, 17 December 2017.

Distribution. Initially, this species was described by Hammer (1958) from Bolivia, and later it was reported from Pacific and Indian islands, such as Laysan, Tahiti, Fiji and Mauritius (Aoki 1964; Hammer 1971, 1972; Mahunka 1978), as well as Thailand (Aoki 1965), South Africa (Engelbrecht 1972), and several other areas of the tropical and subtropical regions (Al-Assiuty 1985; Ermilov & Anichkin 2010; Ermilov & Tolstikov 2015*a*, *b*). It is an inhabitant of the roots of grasses, mosses, soil and litter of the grasslands and various forests, seashore habitats, cliff sides and swampy marshes.

Remarks. The characters of the present material correspond well with those of the materials studied by Hammer (1958), Aoki (1964, 1982), Mahunka (1978) and Al-Assiuty *et al*. (1985). This is a morphologically quite variable species, and therefore, has been reported under several synonyms. This species is recorded for the first time from Palau.

Aoki (1965) described a subspecies, *G. flabellifera orientalis* from Thailand, but later he considered the differences mentioned by him as not sufficient for the subspecific segregation and therefore, synonymized *G. flabellifera orientalis* with the nominal subspecies (Aoki 1982). In both lists by Subías (2004; online version 2019), and in Ermilov & Klimov (2017), this subspecies was listed as a valid taxon, which should be eliminated in their next update.

This species acts as an intermediate host of anoplocephalid tapeworms in sheep pastures (Bayoumi *et al*. 1981; Balakrishnan & Haq 1984).

Discussion

The family Galumnidae is among the most diverse in oribatid mites, representatives of which are widespread, occurring in all continents and biogeographical regions, and inhabiting various habitats, especially tropical rainforests. Currently, there are 21 genera of galumnid mites with 172 species in the Oriental region, of which only four genera, namely *Allogalumna*, *Galumna*, *Pergalumna* and *Trichogalumna* are most species rich representing more than three quarters of total species (136 spp.). Ermilov & Starý (2017) presented an identification key to *Galumna*-species in the Oriental region, whereas Hagino *et al*. (2017) provided a key to the world species of *Trichogalumna*. Therefore, we discuss the distribution and habitat ecology of species belonging to these two genera recorded in the Oriental region, as follows.

One of two genera studied here, *Trichogalumna* has little diversity in the Oriental region, where only eight species have been recorded. Most species of this genus seem to be relatively rare, and according to present data,

T. nipponica, which is considered a semicosmopolitan species known from the Palaearctic (Aoki 1966; Fujikawa 1981; Golosova *et al*. 1983; Pan'kov *et al*. 1997; Aoki *et al*. 1997; Wang *et al*. 2003; Chen *et al*. 2010; Ryabinin 2015), Oriental (Ermilov *et al*. 2012, 2014; Ermilov & Martens 2014; Ermilov & Corpus-Raros 2016), Afrotropical (Ermilov 2012) and Neotropical regions (Ermilov *et al*. 2013; Ermilov 2019), has the widest distribution. However, Norton & Ermilov (2017) questioned the reality of this purportedly wide distribution. They studied some materials of *T. nipponica* found outside Japan, and revealed that this species is very similar to *Trichogalumna curva* (Ewing, 1907) in its morphological characters except the cuticle structure (surface texture) of the notogastral porose areas. Therefore, these authors doubt the non-Japanese records of *T. nipponica*, and future morphological studies should include reexamination of findings of this species outside Japan.

Another common species is *T. seminuda*, which has a rather wide distribution in the Afrotropical and Oriental regions (Balogh 1960; Engelbrecht 1972). The remaining species of *Trichogalumna* reported from the Oriental region seem to be confined to small areas, and are found rarely in the western (*Trichogalumna chitralensis* Hammer, 1977), but mostly in the eastern parts of this region (*Trichogalumna interlamellaris* Ermilov & Corpuz-Raros, 2016, *Trichogalumna longipilosa* (Mahunka, 1996), *Trichogalumna subnuda* Balogh & Mahunka, 1967, *T. vietnamica*). Some of these species are only known from their type localities (see Balogh & Mahunka 1967; Hammer 1977; Mahunka 1987, 1996; Ermilov & Corpuz-Raros 2016). In our opinion, however, there is a great chance of finding these species in other areas, especially on individual islands of the western Pacific Ocean, where oribatid mite faunas are largely unknown.

Concerning *Galumna* in the Oriental region, relatively few species (*Galumna alata* (Hermann, 1804), *Galumna calva* Starý, 1996, *Galumna chujoi* Aoki, 1966, *Galumna discifera* Balogh, 1960, *Galumna flabellifera* Hammer, 1958, *Galumna lanceata* (Oudemans, 1900), *Galumna microfissum* Hammer, 1968, *Galumna triquetra* Aoki, 1965, *Galumna virginiensis* Jacot, 1929) have wide geographical ranges stretching over two or more biogeographic realms. Most other species of *Galumna* have restricted distributions in certain areas. For instance, 14 and 13 species out of the 51 *Galumna* species reported from the Oriental region have been found before in Vietnam and India, respectively.

As for their habitat ecology, all *Galumna* and *Trichogalumna* species from the Oriental region are typical inhabitants of soils of different types of vegetation including grasses, bushes, tree stands, mosses growing on rocks, and litter of various forest types. It is well known that some species of Galumnidae are abundantly found and numerically dominant in arboreal habitats, and sampling frequently yields new taxa that appear restricted to this specific environment (Behan-Pelletier & Winchester 1998; Behan-Pelletier & Walter 2000; Walter 2004; Lindo *et al*. 2008).

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