

REDESCRIPTION OF *GAEOLAE LAPS DEBILIS* (MA) (ACARI: MESOSTIGMATA: LAELAPIDAE), WITH A KEY TO WORLD SPECIES OF *GAEOLAE LAPS* WITH SETAE *ST1* OFF STERNAL SHIELD

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ABSTRACT: Ma (1996) described *Gaeolaelaps debilis* as a new species from China, being just one female collected from the nest of Daurian ground squirrel, *Spermophilus dauricus* Brandt (Rodentia: Sciuridae), in the Jilin Province. Then he presented a supplementary description of this species, based on female and deutonymph specimens collected from soil in same province from China (Ma 2004); but they both lack some of the most important details concerning leg chaetotaxy and do not provide enough information for accurate and consistent species identification. In this paper, we redescribe the adult female of *G. debilis* (Ma, 1996) based on the newly collected specimens from new localities in China, Iran and the Russian Far East. Our work includes the first description of the male of this species. Moreover, a key to the species of *Gaeolaelaps* with setae *st1* off sternal shield is presented.

KEY WORDS: Phoretic mites, Gamasina, Dermanysoidea, Hypoaspidae, taxonomy, Palearctic region.

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INTRODUCTION

Within the Hypoaspidae subfamily (Laelapidae family), *Gaeolaelaps* is one of the largest genera. Although it is better known as a group of predatory mites found in soil and litter (Bregetova 1977; Karg 1993; Beaulieu 2009), sometimes, *Gaeolaelaps* are recovered from vertebrate (Tenorio 1982) or arthropod nests (Rosario 1981; Strong and Halliday 1994; Fain *et al.* 1995; Trach 2012, 2016). A few species of this genus have been collected in association with ants (Zeman 1982; Beaulieu 2009; Walter and Moser 2010; Joharchi *et al.* 2019d, e). More recently, species of *Gaeolaelaps* have been recorded from beetles. For example, Sklyar (2012) described *G. dubininae* in association with *Amara majuscula* (Chaudoir) (Coleoptera: Carabidae). Trach (2012, 2016) described *G. carabidophilus* associated with *Stenolophus mixtus* (Herbst), *G. khaustovi* associated with *Bembidion* sp. (Coleoptera, Carabidae), as well as *Gaeolaelaps heteroceri* and *G. sevastianovi* associated with heterocerid beetles. Joharchi and Babaeian (2014) described *G. saboorii* from under the elytra of *Acinopus* sp. in Iran. Trach and Joharchi (2018), in their review of Laelapidae mites in association with scarab beetles in Ukraine, recorded *Gaeolaelaps rhizotrogi* (Mašan) on *Amphimallon solstitiale* (L.) (Coleoptera, Scarabaeidae) for the first time in this country. Finally, Saeidi *et al.* (2019) described *Gaeolaelaps scarites* Joharchi and Saeidi recovered from under the elytra of *Scarites* (*Parallemorphus*) *terricola* Bonelli (Coleoptera: Carabidae) in Iran.

During the survey of free-living and insect-associated species of laelapid mites in China, Iran and Russia, a series of female and male specimens identified as *G. debilis* (Ma, 1996) were collected from different habitats. Ma (1996, 2004) considered *G. debilis* as a member of very broadly conceived genus *Hypoaspis sensu lato*. Subsequently, Beaulieu (2009) treated this species as a member of *Gaeolaelaps*. The descriptions provided by Ma (1996, 2004) lack some of the most important details concerning leg chaetotaxy and do not provide enough information for accurate and consistent species identification. Therefore, *Gaeolaelaps debilis* has never been fully described. Towards this aim, we herein provide additional morphological characters to complement the previous descriptions (Ma 1996, 2004) of *G. debilis* on the basis of adult females, collected from the following contexts: soil in Shanghai, China (close to type locality in the Jilin Province, China); the nest of *Formica* sp., in the vicinity of Khabarovsk (Russian Far East); and under the elytra of *Cetonia* sp. (Scarabaeidae) in the Yazd Province, Iran. Our work also includes the first description of the male of this species.

Moreover, we provide a world key to the species of *Gaeolaelaps* with setae *st1* off sternal shield.

MATERIALS AND METHODS

The host beetles were collected by hand, using light traps, after which they were transferred into vials containing 70% ethyl alcohol. The host ants were collected from a forest nest using an aspirator and

placed in vials with 70% ethanol. Thereafter, alcohol sediments from the vials were inspected for detached phoretic mites. The mites were extracted from soil samples using Berlese–Tullgren funnels. The mites were cleared in a lactic acid solution and mounted in Hoyer's medium (Walter and Krantz 2009).

The line drawings and examinations of the specimens were performed using the Zeiss Axio Imager A2 and the Leica DM 2500 compound microscopes, equipped with differential interference contrast and phase contrast optical systems, attached to the AxioCam ICc 5 and ICC50 HD cameras, respectively. The figures were elaborated with Adobe Photoshop CS2 software, based on line drawings. The images and morphological measurements were taken with the help of ZEN 2012 (v. 8.0) and Leica Application Suite (LAS) (v. 4.2, Live and Interactive Measurements modules) software. The photomicrographs were taken with an AxioCam 506 camera (Carl Zeiss, Germany).

The measurements of structures are expressed as ranges (minimum–maximum) in micrometers (μm). The length and width of the dorsal shield were taken from the anterior to posterior margins along the midline, and at the level of *r3*, respectively. The length and width of the sternal shield were measured at the maximum length and at the broadest points (at level of endopodal between coxae II and III), respectively. The length of the genital shield was measured along the midline from the anterior margin of the hyaline extension to the posterior margin of the shield, and its width where maximal, posteriorly to genital setae *st5*. The leg length was measured from the base of the coxa to the apex of the tarsus (excluding the pre-tarsus). The nomenclature used for the dorsal idiosomal chaetotaxy follows that of Lindquist and Evans (1965). The notations for leg and palp setae follow those of Evans (1963a, b). Other anatomical structures mostly follow Evans and Till (1979). Notations for the idiosomal pore-like structures (gland pores and poroids/lyrifissures) and for the peritrematal shield follow mostly Athias-Henriot (1971, 1975). The notations for the pore-like structures on the sternal shield and for the peritrematal shield region also follow modifications and additions by Johnston and Moraza (1991), adapted by Kazemi *et al.* (2014).

SYSTEMATICS

Family Laelapidae

Genus *Gaeolaelaps* Evans and Till, 1966

Hypoaspis (*Gaeolaelaps*) Evans and Till 1966: 159.

Type species: *Laelaps aculeifer* Canestrini, 1884, by original designation.

Diagnosis. The concept of *Gaeolaelaps* used here is based on that of Beaulieu (2009) with modifications by Kazemi *et al.* (2014).

Gaeolaelaps debilis (Ma, 1996)

(Figs. 1–4)

Hypoaspis debilis Ma, 1996: 51.

Hypoaspis debilis.—Ma 2004: 83, Ren and Guo 2008: 329.

Gaeolaelaps debilis.—Beaulieu 2009: 37, Kazemi *et al.* 2014: 504, Moreira 2014: 247, Yan *et al.* 2018: 261.

Diagnosis (female). Dorsal shield oval-shaped, with weak reticulation, more distinct in opisthonotal and lateral regions, bearing 39 pairs of setae (21–31), 22 pairs of podonotal and 17 pairs of opisthonotal setae, including two pairs of *Zx* setae, two supernumerary setae *Jx* present between *J*-series. All setae relatively short, never reaching base of next posterior setae, except *j1*, *J5*, *Z5*. Presternal area lightly sclerotized, with a few transverse curved lines, sternal shield smooth almost throughout, except a longitudinally lateral part between *iv1* and *st3* faintly reticulated with curved lines, bearing two pairs of smooth pointed setae, *st1* off shield, on poorly sclerotized cuticle, anterior margin slightly convex, ratio of shield length/width (at broadest level) ≈ 0.81 . Genital shield elongated, ratio of length/width (at broadest level) ≈ 2.2 , surface without any distinct reticulation, almost completely smooth. Anal shield longer than wide, with length/width ratio (at broadest level) ≈ 1.16 , gland pores *gv3* located on soft opisthogastric cuticle close to shield. Peritremes long, reaching to slightly beyond mid-level of coxae I. Palp tarsal apotele two-tined, fixed digit of chelicera with six teeth. Tarsus IV without elongate setae.

Redescription. *Female* (n=11 specimens).

Dorsal idiosoma (Figs. 1A, 2A). Dorsal shield oval-shaped, 539–575 long, 288–315 wide, covering entire idiosoma, with weak reticulation, more distinct in opisthonotal and lateral regions. Shield bearing 39 pairs of setae, 22 pairs of podonotal and 17 pairs of opisthonotal setae, including two pairs of *Zx* setae, two supernumerary setae *Jx* present between *J*-series. All setae relatively short (21–31), never reaching base of next posterior setae, except *j1*, *J5* (30–32), *Z5* (44–46). Shield with 21 pairs of discernible pore-like structures, including 16 poroids (*id1*, *id2*, *id4*, *id5*, *idm1*–*idm6*, *idx*, *is1*, *idl1*,

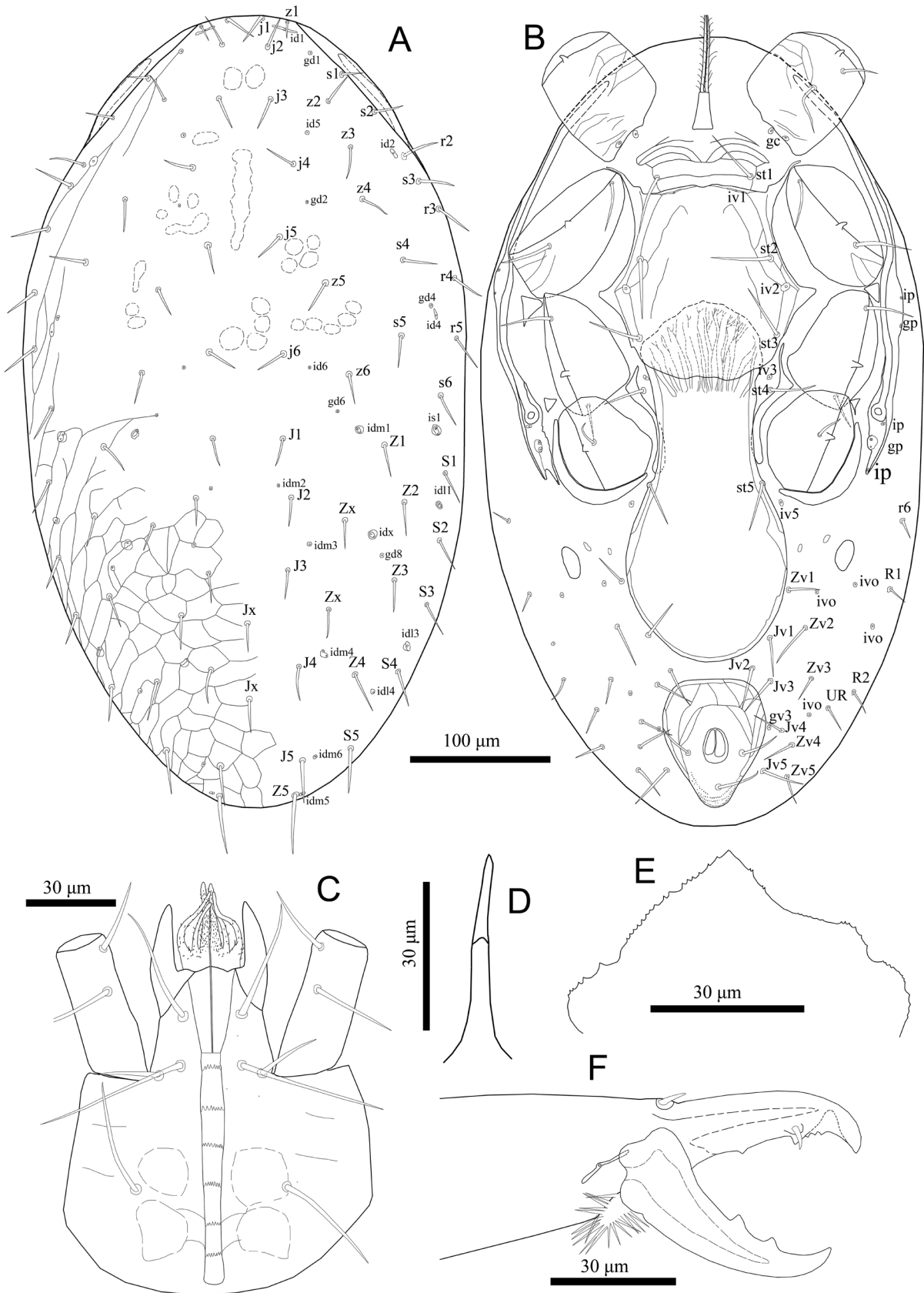


Fig. 1. *Gaeolaelaps debilis* (Ma, 1996), female. A—dorsal idiosoma; B—ventral idiosoma; C—subcapitulum; D—supralabral process; E—epistome; F—chelicera.

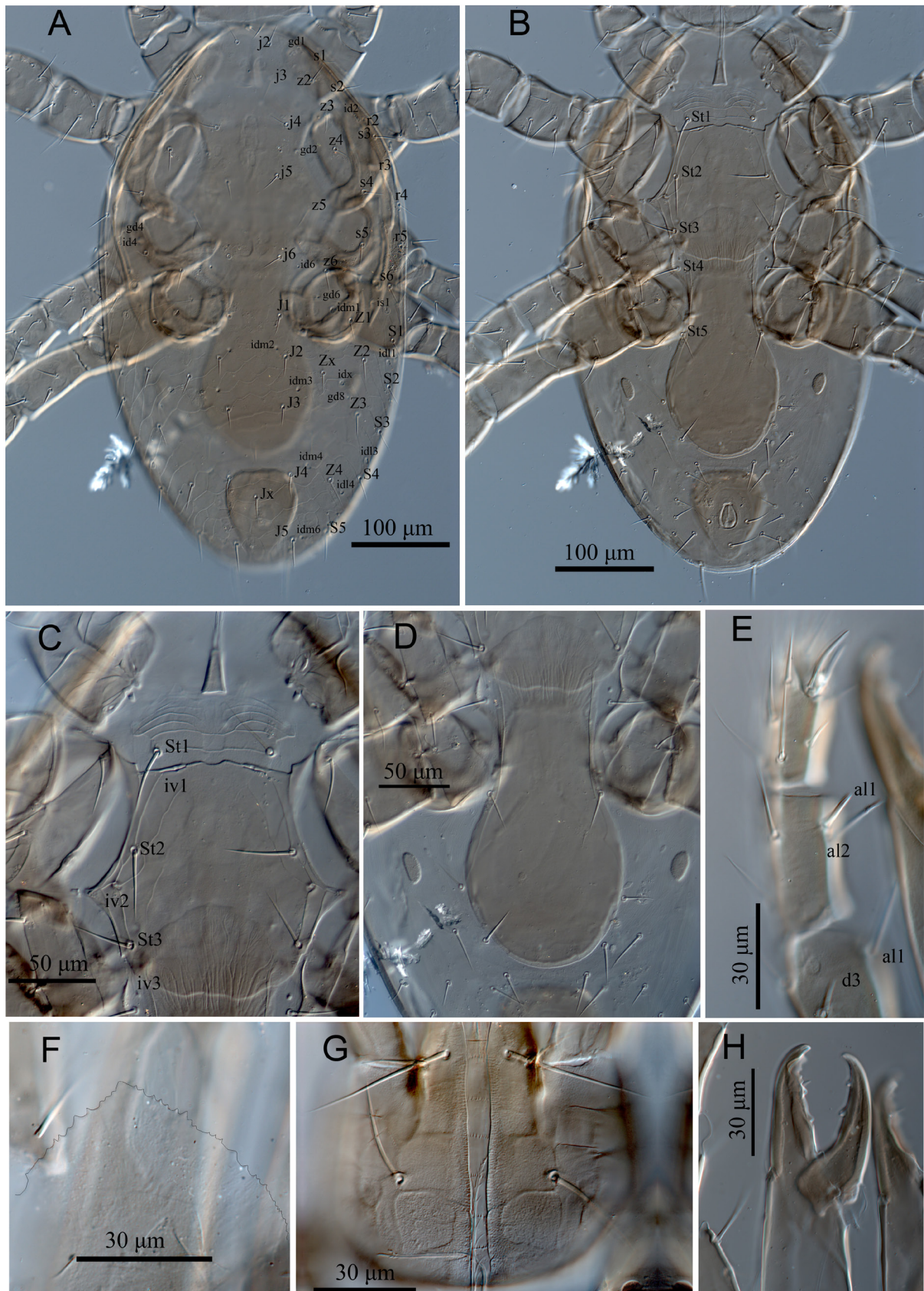


Fig. 2. DIC micrographs of *Gaeolaelaps debilis* (Ma, 1996), female. A—idiosoma in dorsal view; B—idiosoma in ventral view; C—sternal shield; D—genital shield and opisthogastric area; E—distal portion of palp, with a focus on apotele; F—epistome; G—hypostome; H—chelicera.

Redescription of *Gaeolaelaps debilis*

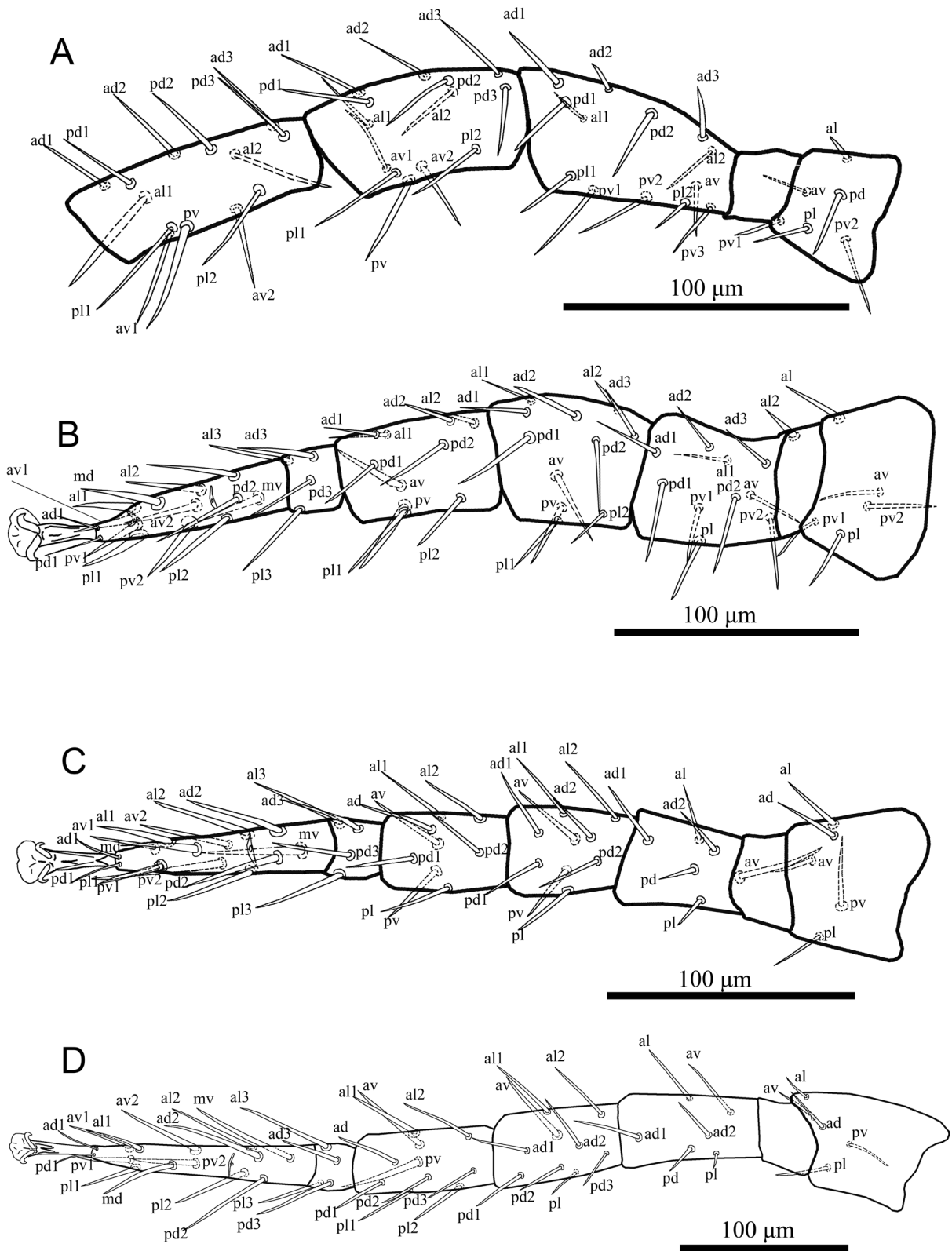


Fig. 3. *Gaeolaelaps debilis* (Ma, 1996), female. A—leg I (trochanter-tibia); B—leg II; C—leg III; D—leg IV.

idl3, *idl4*) and five gland openings (*gd1*–*2*, *gd4*, *gd5*, *gd8*) (Figs. 1A, 2A).

Ventral idiosoma (Figs. 1B, 2B–D). Tritosternum with paired pilose laciniae (74–77), columnar

base 26–28×13–16 wide; presternal area lightly sclerotized, with a few transverse curved lines. Sternal shield (length 126–136) narrowest between coxae II (95–102), widest (158–167), with anterior

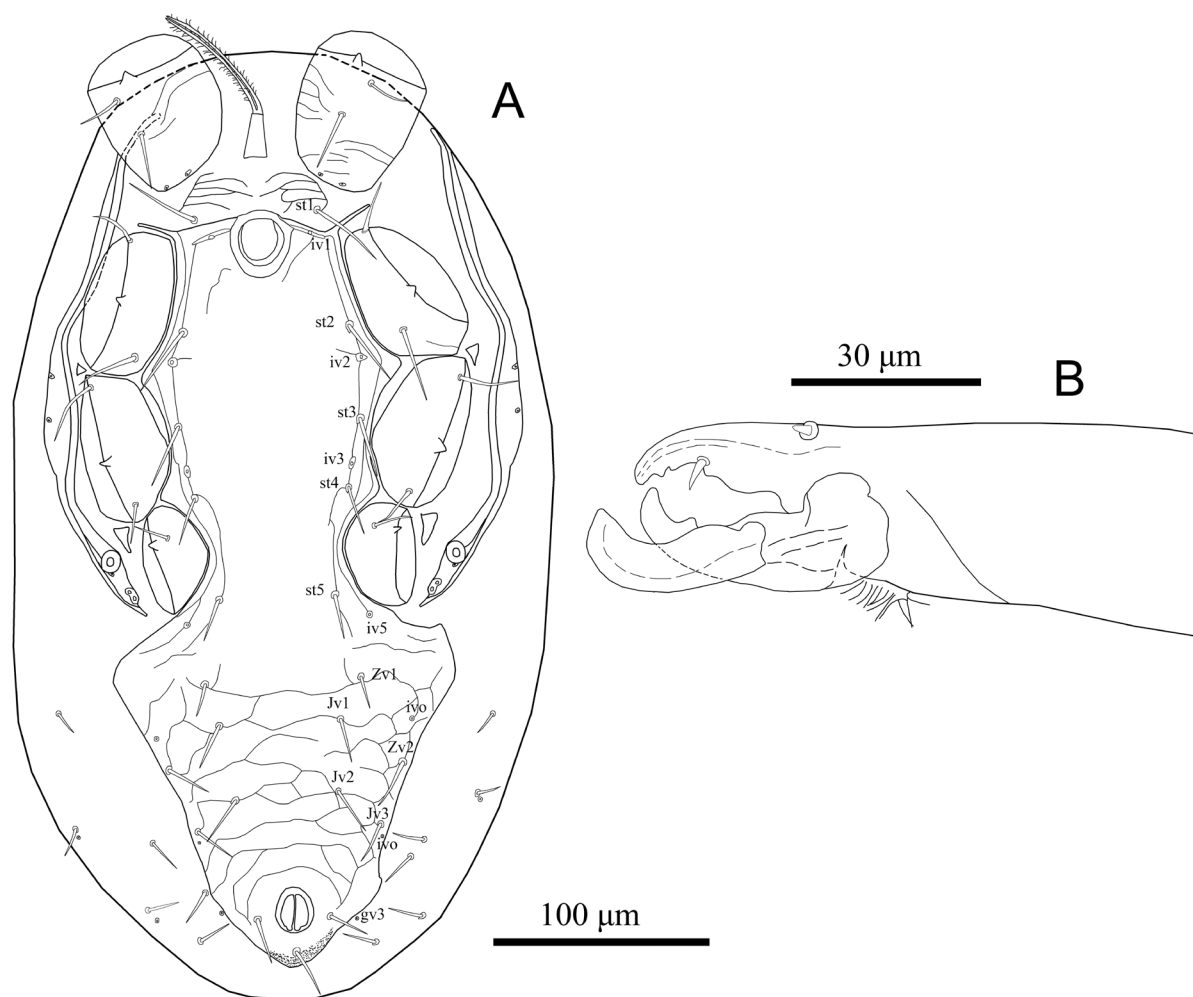


Fig. 4. *Gaeolaelaps debilis* (Ma, 1996), male. A—dorsal idiosoma; B—chelicera.

margin slightly convex, anterolateral corners of shield extending between acetabula I–II; shield bearing two pairs of smooth setae (*st2* 40–42, *st3* 38–40), *st1* (42–44) off shield, on poorly sclerotized cuticle (Fig. 2 B, C), setae not reaching base of next setae, one pair of lyrifissures adjacent to setae *st1*, and a pair of poroids between *st2* and *st3*; sternal shield smooth almost throughout, except a longitudinally lateral part between *iv1* and *st3* faintly reticulated with some curved lines. Metasternal setae *st4* (33–36) and metasternal poroids located on soft integument; metasternal platelets absent. Endopodal plates II/III completely fused to sternal shield, endopodal plates III/IV elongate, narrow, and curved. Genital shield elongated, slightly expanded laterally past level of setae *st5*, length 245–263, maximum width 108–118, posterior margin rounded, without any distinct reticulation, almost completely smooth (Fig. 2D); bearing a pair of simple setae *st5* (28–30); paragenital poroids *iv5* located on soft cuticle lateral to shield near seta *st5*

(Fig. 2D), clearly separated from anal shield, the distance midline between posterior margin of genital shield and anterior margin of anal shield nearly as long as anal opening. Anal shield subtriangular, rounded anteriorly, longer than wide, length 85–93, width 75–80, anterior half lineate-reticulate, para-anal setae (27–29) shorter than post-anal seta (30–32), cribrum small, with 3–4 irregular rows of spicules, mostly limited to region posterior to post-anal seta, pair of anterior arms reaching about to midlevel of distance between post-anal and para-anal setae; gland pores *gv3* located on soft opisthogastric cuticle close to shield. Soft opisthogastric cuticle with two pairs of small, oval paragenital platelets between *st5* and *ZV1* and pair of oval metapodal plates (22–24 long × 8–13 wide), 14 pairs of smooth setae (19–33) (*Jv1*–*Jv5*, *Zv1*–*Zv5*, *R1*, *R2*, *UR*, *r6*), five pairs of poroids (*iv5* and four pairs of *ivo*) and gland pores *gv3*. Two small and subtriangular exopodal platelets between coxae II–III and III–IV present; parapodal platelets

strip-like (Fig. 1B). Peritreme extending anteriorly to slightly beyond mid-level of coxa I; peritrematal shield narrow, fused to dorsal shield near setae *sl*, bearing one pair of gland pores (*gp*) near external margin of shield at level of anterior edge of coxae III and one pair of poroids (*ip*) at level of posterior edge of coxae II, free from exopodal shields; post-stigmatic region with a longitudinal line from stigmata to shield apex, and with two lyrifissures *ip* and a gland pore *gp* (Fig. 1B).

Gnathosoma (Figs. 1C–F and 2E–H). Epistome subtriangular, more or less pointed apically, anterior margin finely denticulate (Figs. 1E, 2F). Hypostomal groove with six rows of denticles, each row with 7–13 denticles, with smooth anterior and posterior transverse lines (Figs. 1C, 2G). Hypostome with four pairs of setae, internal posterior hypostomal setae *h3* (50–52), *h1* (42–44), *h2* (22–24), palpcoxal *pc* (38–40) (Figs. 1C, 2G). Internal malae fringed, slightly longer than corniculi, with a pair of long median projections and two additional pairs of thinner, shorter lateral projections, the inner pair shortest (Fig. 1C). Corniculi robust and horn-like, extending slightly beyond palptrochanter. Supralabral process with a narrow and undivided projection (Fig. 1D). Chaetotaxy of palps: trochanter 2, femur 5, genu 6, tibia 14, tarsus 15, all setae smooth and needle-like except *all*, *al2* on palp genu thickened and *all* apically spatulate, palp tarsal apotele two-tined (Fig. 2E). Fixed digit of chelicera with an offset and most distal tooth (gabelzhan), followed by 4–5 variously sized teeth, a setaceous pilus dentilis, dorsal cheliceral seta prostrate, arthrodial membrane with a rounded flap and normal filaments; cheliceral lyrifissures distinct, movable digit with two teeth (Figs. 1F, 2H).

Legs (Fig. 3A–D). Legs II (377–406) and III, (329–382) short, I (497–504) and IV (540–548) longer. Chaetotaxy normal for free-living Laelapidae: Leg I (Fig. 3A): coxa 0-0/1, 0/1-0, trochanter 1-0/1, 1/2-1 (*pd* slightly thickened), femur 2-3/1, 2/3-2 (*pd2* slightly thickened), genu 2-3/2, 3/1-2, tibia 2-3/2, 3/1-2 (*pv* and *pl1* slightly thickened). Leg II (Fig. 3B): coxa 0-0/1, 0/1-0, trochanter 1-0/1, 0/2-1, femur 2-3/1, 2/2-1 (*al2* thickened), genu 2-3/1, 2/1-2 (all ventral setae thickened), tibia 2-2/1, 2/1-2 (all ventral setae thickened). Leg III (Fig. 3C): coxa 0-0/1, 0/1-0, trochanter 1-1/1, 0/1-1, femur 1-2/1, 1/0-1, genu 2-2/1, 2/1-1 (all ventral setae slightly thickened), tibia: 2-1/1, 2/1-1 (all ventral setae slightly thickened). Leg IV (Fig. 3D):

coxa 0-0/1, 0/0-0, trochanter 1-1/1, 0/1-1, femur 1-2/1, 1/0-1 (*ad1* longest), genu 2-2/1, 3/0-1 (*av* slightly thickened), tibia 2-1/1, 3/1-2 (all ventral setae thickened). Tarsi II–IV with 18 setae (3-3/2, 3/2-3 + *mv*, *md*); tarsus II–IV with some spine-like ventral and lateral setae (Fig. 3B–D), and tarsus IV without elongate setae. All pretarsi with well-developed paired claws, rounded pulvilli and normal ambulacral stalk.

Description. *Male* (n=3 specimens)

Dorsal idiosoma. Dorsal shield (445–450) long, (220–228) wide; ornamentation and chaetotaxy as in female.

Ventral idiosoma (Fig. 4A). Sternal, genital, endopodal, ventral and anal shields fused into holovenral shield, weakly reticulate, distinctly posteriorly to *Zv1* level, bearing *st2–5*, *st1* off shield, on poorly sclerotized cuticle, five pairs of opisthogastric setae (*Jv1–Jv3*, *Zv2*, *Zv3*) in addition to circumanal setae; gland pores *gv3* on soft opisthogastric cuticle, close to para-anal setae, gland pore *gv2* behind coxa IV not discerned; cribrum with 3–4 irregular rows of spicules, anterior arms reaching about to mid-level of distance between post-anal and para-anal setae (Fig. 4A). Soft opisthogastric cuticle with six pairs of smooth setae, two pairs of poroids and gland pores *gv3*.

Gnathosoma. Epistome and subcapitulum similar to female. Fixed digit with two various size of teeth, a setaceous pilus dentilis. Movable digit of chelicera with one median tooth, spermatodactyl relatively stout (0.65× as long as movable digit) and curved dorsally, with bluntly pointed tip; dorsal seta conspicuous, markedly reduced, fringed hyaline arthrodial process at base of movable digit (Fig. 4B). Palps similar to those of female.

Legs. Chaetotaxy as in female.

Specimens examined and deposition: China, five females, three males, Shanghai, Gongqing Forest Park, 31°19'N, 121°32'E, 28 May 2017, O. Joharchi coll., from soil—deposited in the collection of the Tyumen State University Museum of Zoology, Tyumen, Russia; Iran, two females, Yazd Province, Manshad Village, 31°30'N, 54°13'E, 19 May 2016, P. Kafi coll., under the elytra of *Cetonia* sp. (Scarabaeidae)—deposited in the Acarological Collection, Faculty of Agriculture, Shiraz Branch, Islamic Azad University; Russia, four females, vicinity of Khabarovsk, 48°14'N 135°01'E, 15 August 2018, A. A. Khaustov coll., in the nest of *Formica* sp.—deposited in the collection of the Tyumen State University Museum of Zoology, Tyumen, Russia.

Remarks. Although the diagnosis above is based primarily on specimens from Shanghai, China (close to the type locality in Daan, Jilin Province, China), it is supplemented by comparisons with the specimens collected from Iran and the Russian Far East, as well as with the descriptions provided by Ma (1996, 2004). Although our efforts to view type material were unsuccessful, our specimens are in perfect agreement with the incomplete descriptions and illustrations by Ma (1996, 2004). *Gaeolaelaps debilis* has the unusual character state of setae *st1* off sternal shield. Sternal shield in *Gaeolaelaps* usually bears three pairs of setae, rarely setae *st1* off shield in the presternal region. This occurs only in eight species of *Gaeolaelaps* (Beaulieu 2009; Kazemi *et al.* 2014; Joharchi *et al.* 2019a–c). However, seta *st1* being off the sternal shield in the presternal region can be difficult to discern. In particular, in some of the aforementioned species, seta *st1* could be borne on paired anterior extensions of the shield, as in *G. jondishapouri* (e.g., Kazemi *et al.* 2014). The following key is based on direct examination of specimens, except for *G. krantzi*, *G. franzi* and *G. genitotortus*, in which cases we have relied on previously published descriptions and illustrations.

Key to species of *Gaeolaelaps* with setae *st1* off sternal shield

1. Peritreme long (reaches at least to anterior level of coxa I), palp tarsal apotele two-tined..... 2
— Peritreme short (barely reaching anterior margin of coxa II), palp tarsal apotele three-tined.....
.. *G. lankaensis* Joharchi, Khaustov and Ermilov, 2019
2. Dorsal shield with 37 or 39 pairs of setae..... 3
— Dorsal shield with 40 pairs of setae
..... *G. krantzi* (Arutunian, 1993)
3. Dorsal shield with 39 pairs of setae 4
— Dorsal shield with 37 pairs of setae
..... *G. genitotortus* (Sklyar, 2012)
4. Dorsal setae short, never reaching base of next posterior setae 5
— Dorsal setae long, reaching well past base of next posterior setae *G. cubaensis* Joharchi, Halliday, Tolstikov and Trach, 2019
5. Sternal setae (*st2* and *st3*) long enough to reach to the base of the next, anterior ends of endopodal plates III/IV narrowly fused or contiguous to posterolateral angles of sternal shield, surface of sternal and genital shields reticulated
..... *G. franzi* (Van Aswegen and Loots, 1970)
— Sternal setae (*st2* and *st3*) shorter, not reach to the base of the next, anterior ends of endopodal

plates III/IV obviously free from sternal shield, surface of sternal and genital shields smooth almost throughout 6
6. Dorsal shield obviously narrowing from level of setae *r3*, progressively tapering, genital shield not extending close to anal shield, the distance midline between posterior margin of genital shield and anterior margin of anal shield more than twice as long as anal opening *G. aculeiferoides* (Teng, 1982)
— Dorsal shield oval-shaped, genital shield extending close to anal shield, the distance midline between posterior margin of genital shield and anterior margin of anal shield nearly as long as anal opening..... 7
7. Size of body small (390 long, 180 wide) and leg I longer than idiosoma, anal shield nearly wider than long, post-stigmatic section elongated, slender and defectively developed after stigma.....
..... *G. minor* (Costa, 1968)
— Size of body much larger (539–575 long, 288–315 wide) and leg I shorter than idiosoma, anal shield longer than wide, post-stigmatic section well developed after stigma *G. debilis* (Ma, 1996)

Gaeolaelaps debilis was originally described from Daan, Jilin Province, China on the basis of only one female specimen collected from the nest of *Spermophilus dauricus* Brandt (Rodentia: Sciuridae) (Ma 1996). Then he collected this species from soil in the same province in China (Ma 2004). In our study, a few *G. debilis* specimens have been collected from the nest of *Formica* sp. in the Russian Far East, as well as from under the elytra of *Cetonina* sp. in Iran. All the examined phoretic individuals were adult females; no males or immatures were collected. The collected specimens of *G. debilis* have normal morphology, like other free-living *Gaeolaelaps* species (e.g., dentate chelicerae; sclerotized, horn-like corniculi, etc.), and none of the phoretic individuals were swollen, which points to it being unlikely that *G. debilis* is parasitic.

It is not possible to draw any firm conclusions about *G. debilis*'s host specificity but its normal morphology suggests that it may have a mutualistic symbiosis relationship with its hosts. In particular, this mite may feed on other small invertebrates, such as immature stages of Astigmata mites living in ant colonies, in microhabitats created by beetles, or in the nests of rodents. In the soil, *G. debilis* is probably a predator of small soil invertebrates, like other representatives of the *Gaeolaelaps* genus. We stress that further experimental work is needed to establish the true role of this mite in

relation to its insect and rodent hosts, as well as to the soil ecosystem.

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