

A new asymmetrical feather mite of the genus *Michaelia* Trouessart, 1884 (Astigmata: Freyanidae) from the Neotropical Cormorant, *Phalacrocorax brasilianus* (Pelecaniformes)

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ABSTRACT — Species of the feather mite genus *Michaelia* Trouessart, 1884 are notable for striking bilateral asymmetry in males, displayed in the structure of the anterior legs (both hetero- and homeomorphs) and the opisthosomal lobes (heteromorphs). A new species of this genus, *Michaelia neotropica* Hernandez and Mironov **n. sp.**, is described from the Neotropical Cormorant *Phalacrocorax brasilianus* (Pelecaniformes: Phalacrocoracidae) from Brazil. It differs from *M. urile* (Dubinin, 1953) by having a narrower incision on the inner margins of the opisthosomal lobes anterior to setae *h1*, and relatively longer legs I with the ambulacrum reaching the midlevel of elongated tarsus II. A key to heteromorphic males of the genus *Michaelia* is provided.

KEYWORDS — *Michaelia*; feather mite; taxonomy; asymmetry; heteromorphy; low temperature scanning microscopy; LTSEM

INTRODUCTION

Most animals are bilaterally symmetrical externally with left and right sides being mirror images of each other. A few taxa of feather mites (Astigmata: Analgoidea and Pterolichoidea), however, are known for bizarre bilateral asymmetry in males (Atyeo *et al.* 1972, Gaud and Atyeo 1996), which is most noticeably expressed in the structure of legs, dorsal body setae and posterior part of the opisthosoma. Examples of asymmetry in feather mites are rare

but are observed in several distantly related groupings of both superfamilies: in one family of Analgoidea (Alloptidae: *Anisanchus* Peterson and Atyeo, 1977, *Dinalloptes* Gaud and Mouchet, 1957, and *Hyperpedaloptes* Dubinin, 1955) and in two families of Pterolichoidea (Freyanidae: *Michaelia* Trouessart, 1884, *Parafreyana* Černý, 1969, *Pavlovskiana* Dubinin, 1950, *Sulanyssus* Dubinin, 1953; and Kramerellidae: *Freyanella* Dubinin, 1953) (Peterson and Atyeo, 1977; Gaud and Mouchet, 1957; Dubinin, 1950, 1953, 1955; Černý, 1969; Gaud and Atyeo, 1996).

Reasons for the development of bilateral asymmetry in several different lineages of feather mites are still enigmatic. A common aspect of these three unrelated groups of genera is that hosts of all of them are either aquatic birds or at least birds living in aquatic habitats. Thus, cormorants (Pelecaniformes: Phalacrocoracidae) are hosts of *Dinalloptes* and *Michaelia*; ibises and spoonbills (Pelecaniformes: Threskiornithidae) host *Anisanchus*, *Hyperpedalloptes*, and *Freyanella*; boobies (Pelecaniformes: Sulidae) host *Sulanyssus*; screamers (Anseriformes: Anhimidae) host *Pavlovskiana*; and one species of duck (Anseriformes: Anatidae: *Nomonyx dominicus* (Linnaeus, 1766)) is a host of the sole species of the genus *Parafreyana*. It is necessary to note that males of other feather mite species living on those same hosts are symmetrical. Thus, ibises host a number of completely symmetrical mites of the genera *Ibidocolus* Mironov, 1998, *Ptyctalloptes* Mironov, 2002, *Spinicnemis* Mironov, 2002, and *Tauralloptes* Mironov, 2002 (Alloptidae); cormorants host mites of the genera *Plicatalloptes* Dubinin, 1955 (Alloptidae), *Scutomegninia* Dubinin, 1951 (Avenzoariidae); and *Nomonyx dominica* also host *Rectijanua oxyurae* Gaud, 1961 (Rectijanuidae).

Since the asymmetry is expressed only in males, Dubinin (1951) suggested that it may enable them to maintain a more secure hold in the slanted corridors of the feather vanes during copulation with adult females or precopulatory guarding of female nymphs. Although plausible, this hypothesis still needs to be tested. The asymmetry of feather mites is displayed to a different extent and is the expression of male polymorphism; some male individuals (referred as heteromorphs) are strongly asymmetrical, while others (referred as homeomorphs) are almost or completely symmetrical. This can be a counterargument to the hypothesis of Dubinin.

In the present paper, we describe a new *Michaelia* species with strongly pronounced asymmetry in males from the Neotropical cormorant *Phalacrocorax brasilianus* (Gmelin, 1789).

MATERIALS AND METHODS

The material was retrieved from specimens of *Phalacrocorax brasilianus* found dead trapped on fishing nets in artificial lakes. The dead specimens were kept in a freezer and sent to the laboratory of Acari of São Paulo State University (UNESP), campus of Rio Claro. Bird specimens were washed and the liquid was filtered in paper filters; the mites were collected from the filters using a dissecting microscope, cleared in 30 % lactic acid for 24 h at 50 °C, and mounted in Hoyer's medium according to the standard technique for small mites (Krantz and Walter 2009). After five days at 50 °C, the slides were sealed with varnish. Drawings and measuring of mites were made with a Leica DM3000 microscope equipped with differential interference contrast (DIC) optics and a *camera lucida*.

General morphological terms and leg chaetotaxy follow Gaud and Atyeo (1996); idiosomal chaetotaxy also follows these authors with corrections to coxal setae proposed by Norton (1998). Measuring techniques for particular structures are indicated for each sex/morph. Depositories of type material: DZUNESP-RC – Departamento de Zoologia, Universidade Estadual Paulista, Rio Claro, SP, Brazil; ZISP – Zoological Institute, Russian Academy of Sciences, Saint Petersburg, Russia; USNM – National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located at the SEL-USDA, Beltsville, Maryland, USA.

Low Temperature Scanning Electron Microscopy (LT-SEM) – Specimens were observed in the LT-SEM as described in Dowling *et al.* (2010) and Bolton *et al.* (2014). Specimens preserved in 70 % ethanol were secured to 15 cm × 30 cm copper plates using ultra smooth, round (12 mm diameter), carbon adhesive tabs (Electron Microscopy Sciences, Inc., Hatfield, PA, USA). The specimens were frozen conductively, in a Styrofoam box, by placing the plates on the surface of a pre-cooled (-196 °C) brass bar whose lower half was submerged in liquid nitrogen (LN₂). After 20-30 s, the holders containing the frozen samples were transferred to a Quorum PP2000 cryo- prep chamber (Quorum Technologies, East Sussex, UK) attached to an S-4700 field emission scanning electron microscope (Hitachi High Technologies Amer-

ica, Inc., Dallas, TX, USA). The specimens were etched inside the cryotransfer system to remove any surface contamination (condensed water vapour) by raising the temperature of the stage to -90 °C for 10–15 min. Following etching, the temperature inside the chamber was lowered below -130 °C, and the specimens were coated with a 10 nm layer of platinum using a magnetron sputter head equipped with a platinum target. The specimens were transferred to a pre-cooled (-130 °C) cryostage in the SEM for observation. An accelerating voltage of 5kV was used to view the specimens. Images were captured using a 4pi Analysis System (Durham, NC). Individual images were re-sized and placed together to produce a single figure using Adobe® Photoshop CS 5.0.

FAMILY FREYANIDAE DUBININ, 1953
 SUBFAMILY MICHAELICHINAE
 GAUD AND MOUCHET, 1959
 GENUS *Michaelia* TROU ESSART, 1884

Type species: *Freyana (Canestrinia) bihamata* Mégnin and Trouessart, 1884 (= *Dermaleichus heteropus* Michael, 1881, synonymy by Trouessart, 1884: 527), originally described from *Phalacrocorax aristotelis* (Linnaeus, 1761) (= *P. cristatus* [Gmelin, 1798]).

Males of the feather mite genus *Michaelia* are so bizarrely distorted that, when the first species "*Dermaleichus heteropus* Michael, 1881" was discovered, the author was reluctant to describe it based on a single male found, fearing it might be an abnormally distorted specimen (Michael 1881). He was only encouraged to describe the odd mite after he collected more specimens in the next year, and realized that all were identically asymmetrical. *Michaelia* species are large sized freyanids (females 600 – 750 µm, males 800 – 1090 µm in length). There are two male morphs in these mites, homeomorphs and heteromorphs; both morphs have asymmetrical anterior legs, but the opisthosomal lobes are asymmetrical only in heteromorphs. Females and immatures are absolutely symmetrical and are relatively wider and shorter than both male morphs.

All five species of *Michaelia* including a new species described herein are associated with cor-

morants (Pelecaniformes, genus *Phalacrocorax*) (Dubinin, 1953; Gaud, 1970; Gaud and Atyeo, 1982). Besides all these valid species included in the key below, Dubinin (1953) recognized three more species without formal descriptions of them (*Michaelichus americanus*, *M. javanicus* and *M. malaicus*). These species, as noted by Gaud and Atyeo (1982), are *nomina nuda*.

Taxonomic remarks — Gaud and Atyeo (1982) correctly indicated that *Michaelia* Trouessart, 1884 preceded *Michaelichus* Trouessart and Mégnin, 1885 and therefore the former genus name has priority. They also emended the spelling of the subfamily from Michaelichinae Gaud and Mouchet 1959 to Michaeliinae, which was an unjustified emendation. According to article 40.1 of the International Code of Zoological Nomenclature (ICZN), the junior synonymy of a type genus should not affect the subfamily name. Therefore, Michaelichinae Gaud and Mouchet, 1959 should be preferred over Michaeliinae Gaud and Atyeo, 1982.

Michaelia neotropica n. sp.
 Hernandes and Mironov
 (Figs. 1 – 10)

Type material — Heteromorphic male holotype (DZUNESP-RC #3213), 4 heteromorphic males, 12 homeomorphic males and 62 female paratypes from *Phalacrocorax brasiliensis* (Gmelin, 1789) (Pelecaniformes: Phalacrocoracidae), BRAZIL, São Paulo State, Pedreira, 25 August 2008, D.V. Boas-Filho col. (#390); other paratypes: 2 heteromorphic males, 12 homeomorphic males and 7 females, same host species, BRAZIL, São Paulo State, Artur Nogueira, 06 July 2010 (#744).

Depositories — Holotype heteromorphic male, 3 heteromorphs, 9 homeomorphs and 40 female paratypes at DZUNESP-RC; 1 heteromorph, 3 homeomorphs and 5 female paratypes at ZISP; 1 heteromorph, 2 homeomorphs and 5 female paratypes at USNM.

Description — Heteromorphic male (holotype, range for 4 paratypes in parentheses) — Idiosoma length from anterior end of prodorsal shield to lobar apices 1014 (1026 – 1062), widest part at level of humeral shield 421 (421 – 475). Prodorsal

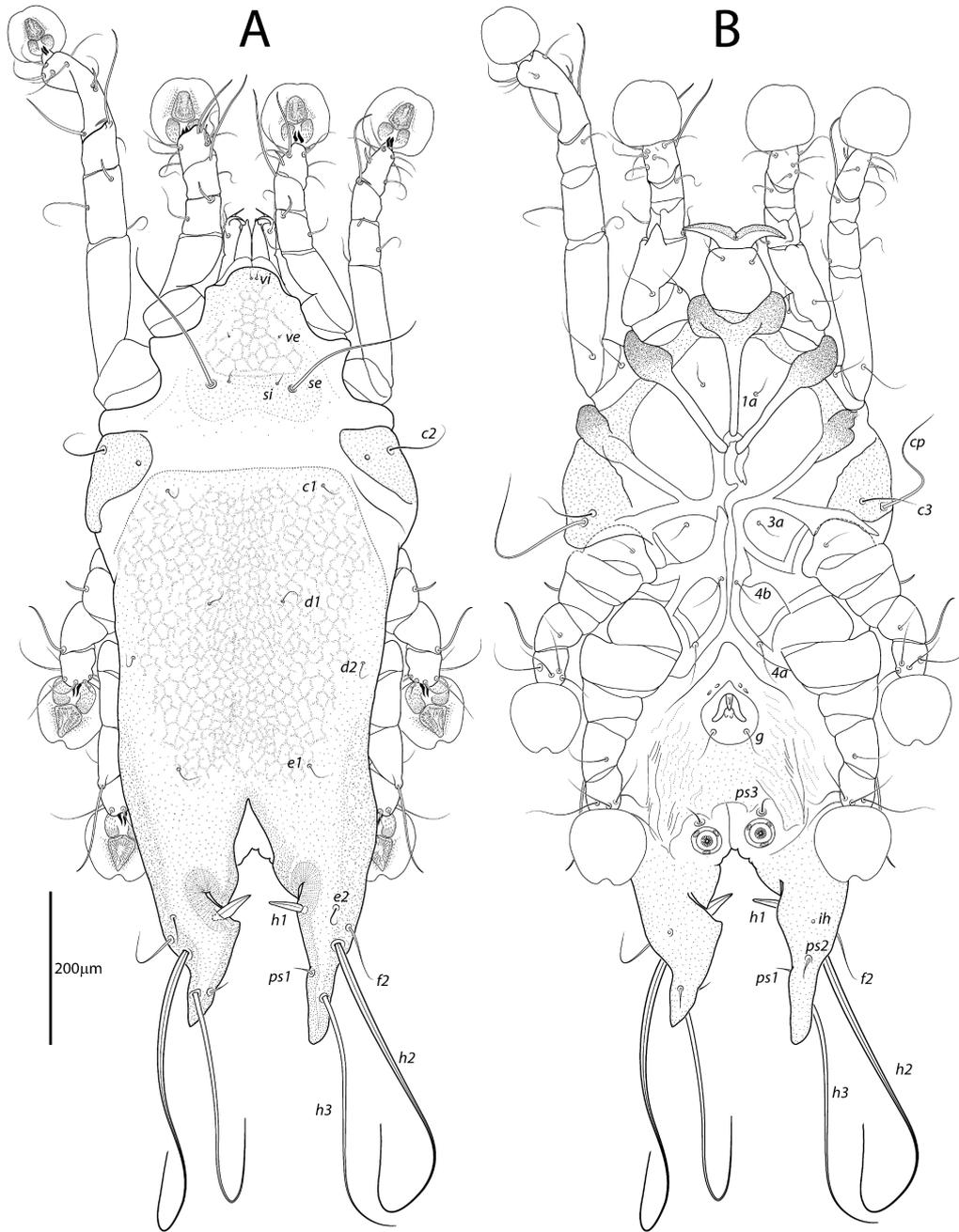


FIGURE 1: *Michaelia neotropica* n. sp., heteromorphic male: A – dorsal view, B – ventral view.

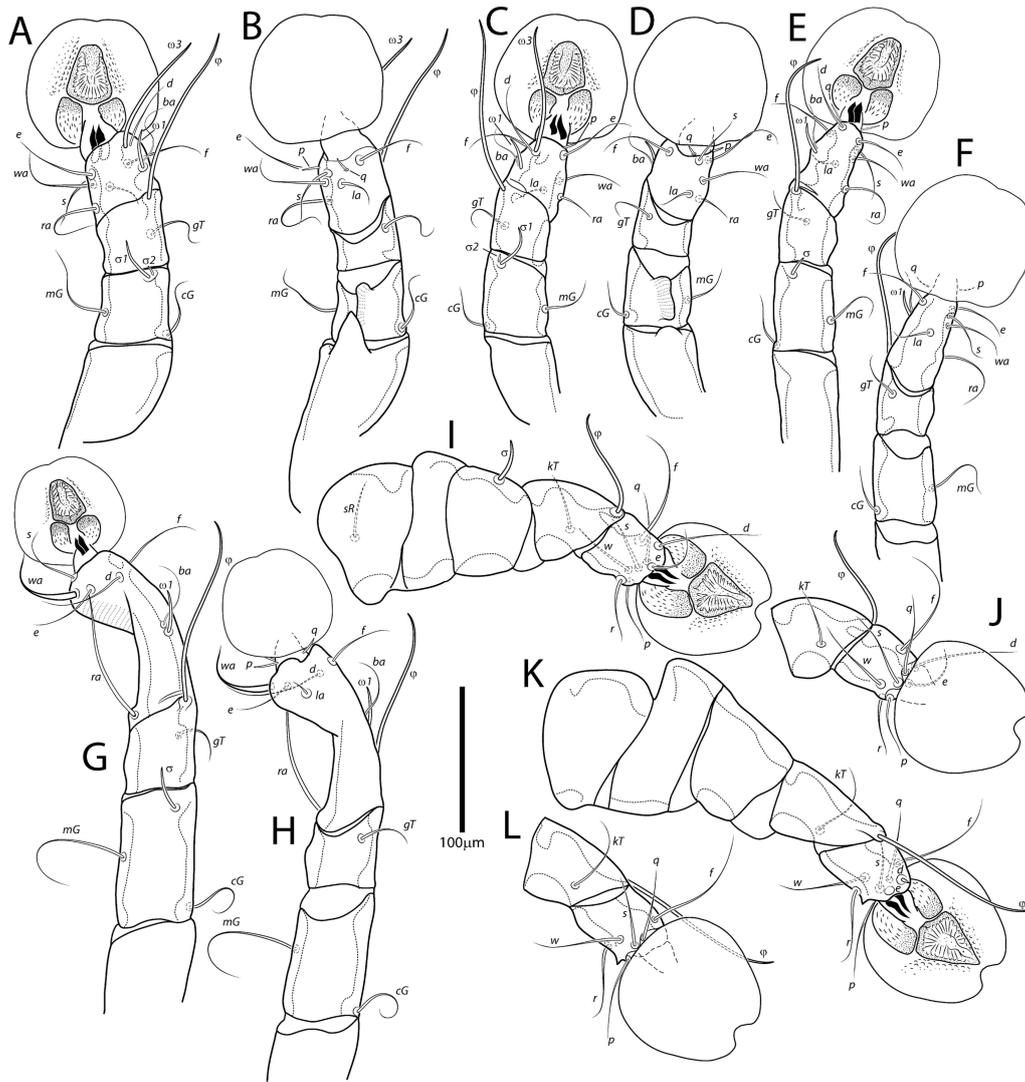


FIGURE 2: *Michaelia neotropica* n. sp., heteromorphic male legs: left leg I dorsal (A) and ventral (B), right leg I dorsal (C) and ventral (D), right leg II dorsal (E) and ventral (F), left leg II dorsal (G) and ventral (H), leg III dorsal (I), tibia and tarsus III ventral (J), leg IV dorsal (K), tibia and tarsus IV ventral (L).

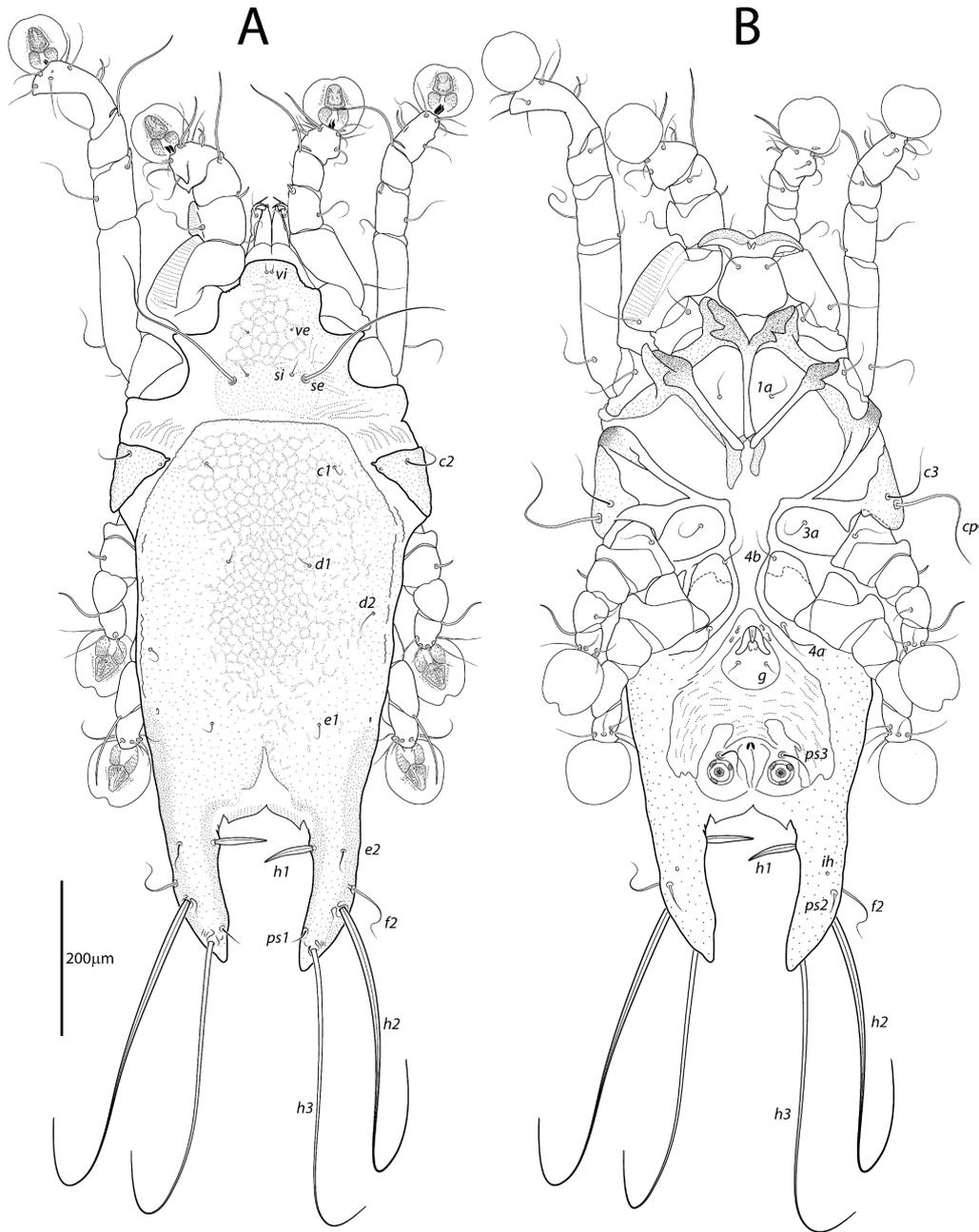


FIGURE 3: *Michaelia neotropica* n. sp., homeomorphic male: A – dorsal view, B – ventral view.

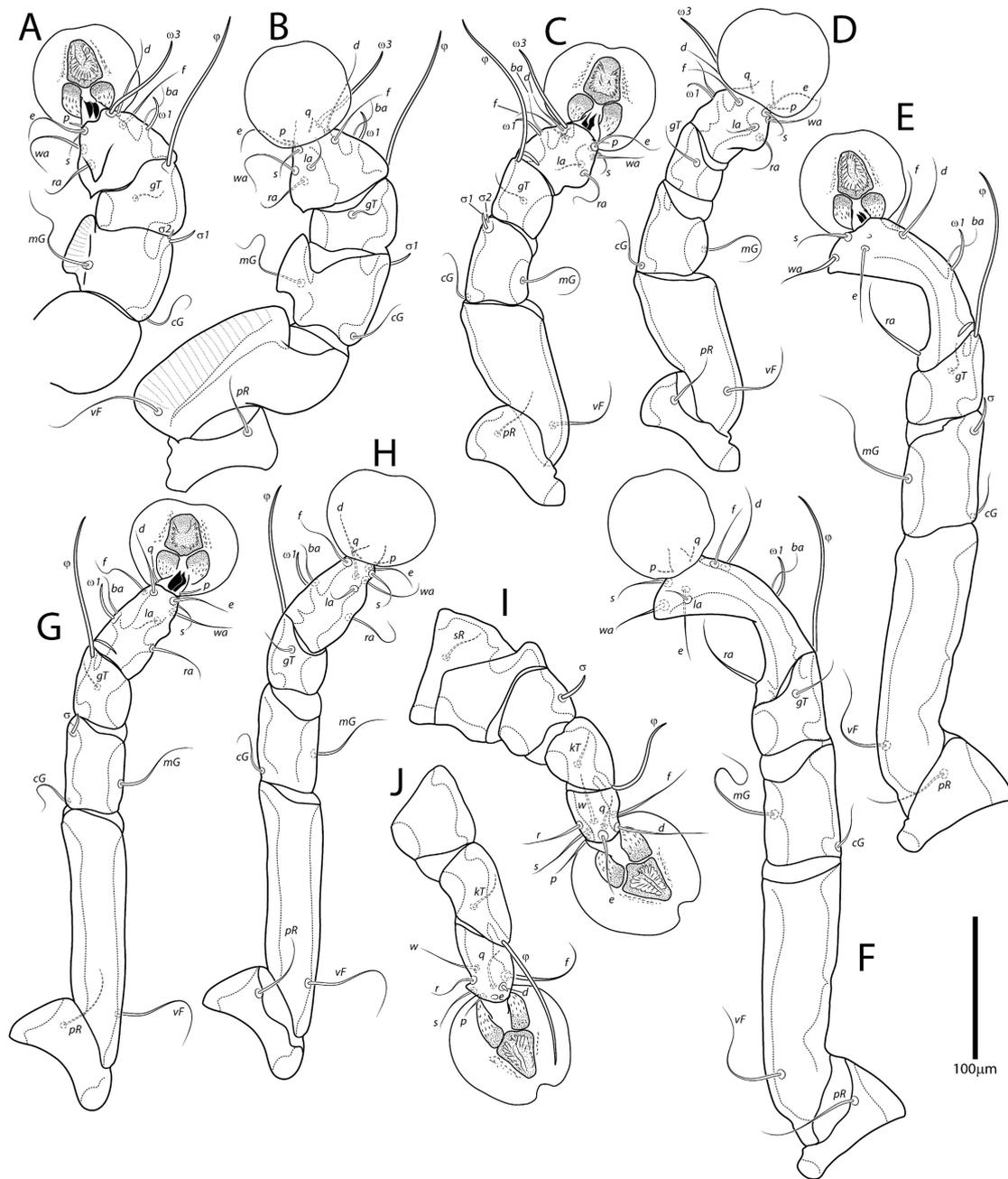


FIGURE 4: *Michaelia neotropica* n. sp., homeomorphic male legs: left leg I dorsal (A) and ventral (B), right leg I dorsal (C) and ventral (D), left leg II dorsal (E) and ventral (F), right leg II dorsal (G) and ventral (H), leg III dorsal (I), genu, tibia and tarsus of leg IV dorsal (J).

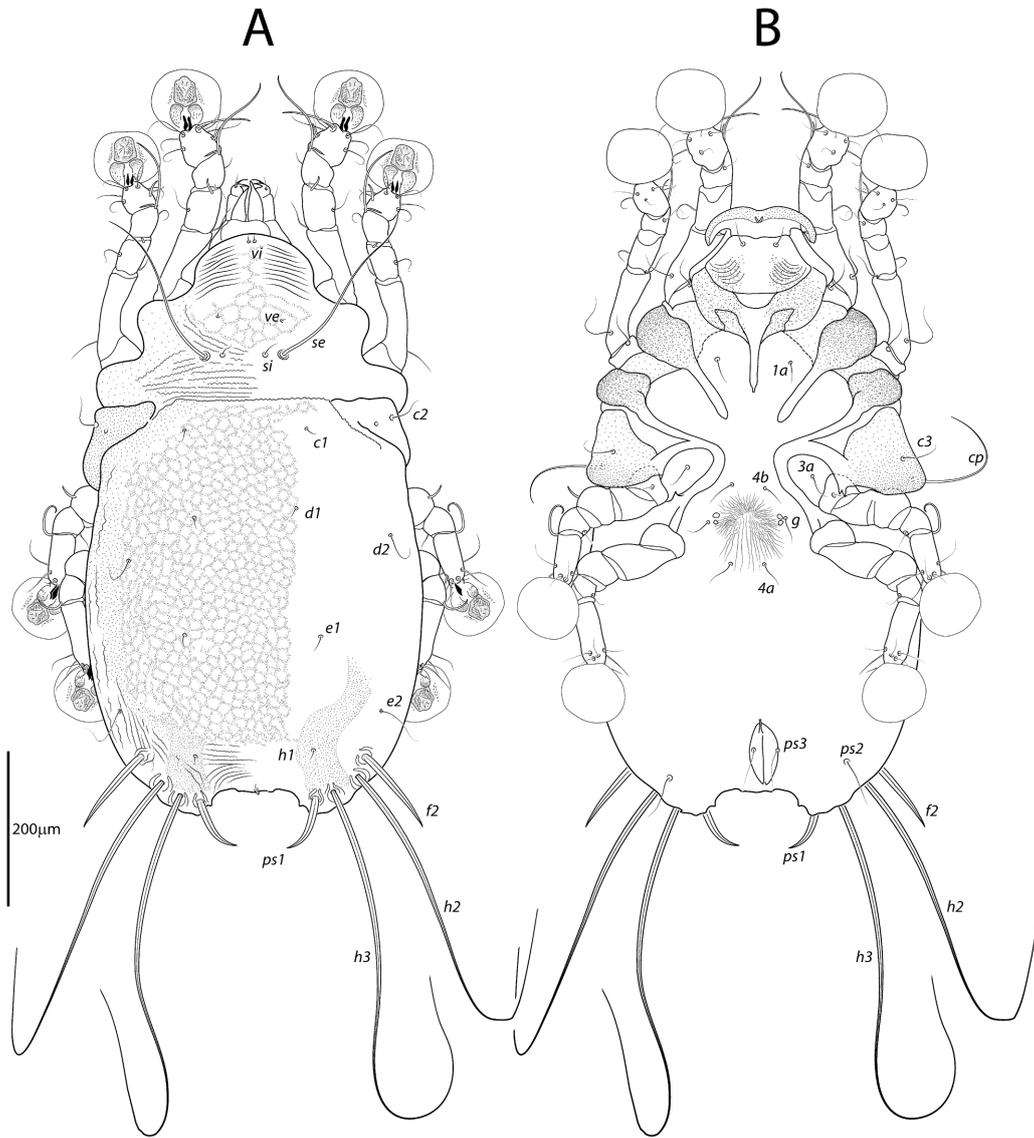


FIGURE 5: *Michaelia neotropica* n. sp., female: A – dorsal view, B – ventral view.

shield: occupying median part of prodorsum, margins poorly distinct, central part anterior to scapular setae with reticulate ornamentation. Setae *vi*, *ve* filiform, minute; setae *si* filiform, about 10 long, separated by 61 (57 – 65); setae *se* separated by 110 (107 – 114). Setae *c2* filiform, situated on humeral shields. Subhumeral setae *c3* filiform, 95 (75 – 105) long, situated ventrally on humeral shield. Hysteronotal shield: greatest length from anterior margins to lobar apices 748 (758 – 797), anterior margin rounded, poorly distinct, surface with reticulate pattern. Most dorsal setae filiform, except *h1*. Supranal concavity indistinct. Opisthosomal lobes strongly expressed, asymmetrical; length of terminal cleft from anterior angular end to tip of the longer lobe 259 (269 – 275). Lateral margins of terminal cleft with acute and slightly curved angular extensions at base and with blunt-angular extensions at midlevel; incision between basal and midlevel extension on each lobe slit-like, with margins almost touching. The lobe on the same side as longer leg II with slightly curved and shorter lobar tip. Setae *h1* lanceolate, situated at level of blunt-angular extensions of opisthosomal lobes, 52 (45 – 52) long in the longest lobe and 61 (44 – 57) long on opposite side. Distances between dorsal setae: *c1:c1* 202 (192 – 219), *c1:d1* 150 (153 – 178), *d1:d1* 97 (101 – 112), *d1:e1* 217 (221 – 278), *e1:e1* 169 (156 – 163), *ps1:ps1* 132 (127 – 153), *h1:h1* 111 (108 – 120), *h3:h3* 169 (146 – 189), *h2:h2* 199 (194 – 217).

Pseudorutellar processes directed laterally, elongated and narrowing towards the tip; two small medial spines between processes; distal half of these processes with texture of many small regularly spaced papillae resembling gecko skin or shagreen leather (Fig. 10E). Sternum and inner tips of all or almost all epimerites fused forming entire coxo-sternal network with closed coxal fields I – IV. Genital apparatus 43 (49 – 52) in length, 30 (30 – 36) in width, situated far posterior to level of trochanters IV and completely encircled by adanal shield (Fig. 9E). Anal suckers 39 (35 – 39) in diameter, distance between centers of suckers 73 (74 – 84), corolla with three distinct dark inflations.

Anterior legs I, II asymmetrical, most noticeable in legs II. Femur I co-lateral to longer leg II bear-

ing a strong apico-ventral spine (Fig. 10D); only small rounded protuberance present in corresponding part of femur I of opposing side (Fig. 2D). Both genua I with ventral longitudinal crest. Tarsus of larger leg II slightly bent and with distal margin broadened and flattened. Legs III, IV symmetrical, without crests or processes. Seta *d* of tarsus IV spine-like, only alveolus of seta *e* present. Length of two anterior pairs of legs from femur to tarsal tip (smaller/longer): I 249 (241 – 271), I 246 (265 – 283), II 329 (359 – 387), II 467 (482 – 514).

Homeomorphic male (range for 6 paratypes in parentheses) — Idiosoma length from anterior end of prodorsal shield to lobar apices 890 – 951, widest part at level of humeral shields 385 – 408. Prodorsal shield: as in heteromorphic male. Setae *vi*, *ve* filiform, minute; *si* filiform, about 10 long, separated by 57 – 61; setae *se* separated by 96 – 105. Setae *c2* filiform, situated on humeral shields. Subhumeral setae *c3* filiform, 75 – 85, situated ventrally on humeral shield. Hysteronotal shield: greatest length from anterior margins to lobar apices 652 – 696, anterior margin shaped as a trapezium [although this shape is poorly detectable in some specimens], surface as in the heteromorphic male. Most dorsal setae filiform, except *h1*. Supranal concavity indistinct. Opisthosomal lobes strongly expressed, symmetrical or almost symmetrical; inner margins of lobes almost straight; terminal cleft from anterior margin to lobar tip 207 – 234; anterior margin of cleft with pair of small acute extensions; incisions at bases of lobes small, triangular. Setae *h1* lanceolate, 60 – 77 long. Distances between dorsal setae: *c1:c1* 163 – 186, *c1:d1* 120 – 135, *d1:d1* 80 – 109, *d1:e1* 192 – 227, *e1:e1* 111 – 138, *ps1:ps1* 79 – 134, *h1:h1* 114 – 134, *h3:h3* 116 – 175, *h2:h2* 184 – 227.

Pseudorutellar processes as in heteromorph. Sternum and inner tips of epimerites II fused, enclosing coxal fields I; coxal fields II open; coxal fields III, IV closed as in heteromorphs. Genital apparatus 38 – 50 in length, 31 – 35 in width, situated slightly posterior to level of trochanters IV, completely surrounded by adanal shield. Anal suckers 35 – 38 in diameter, distance between centers of suckers 73 – 81, corolla with three distinct dark inflations.

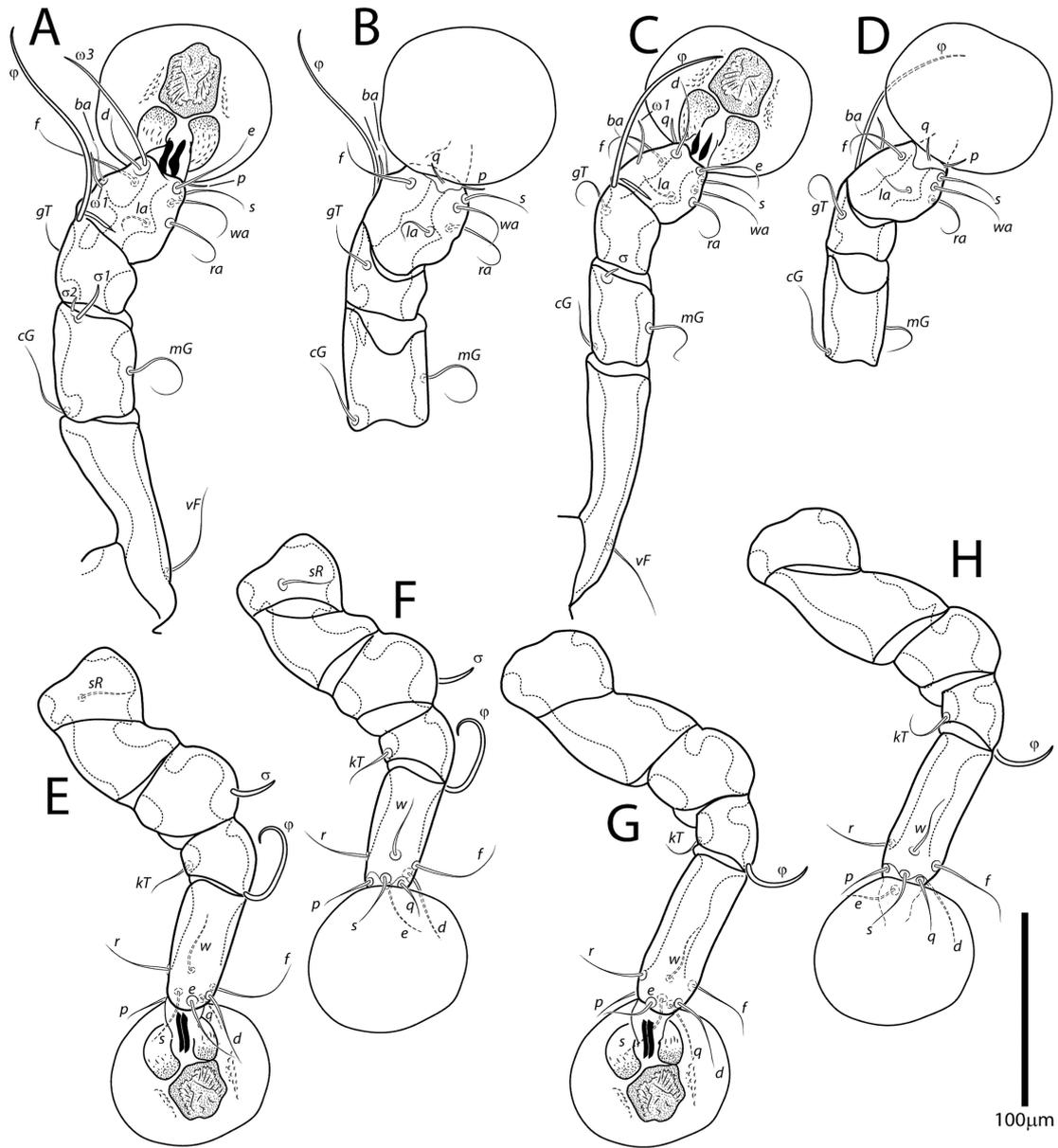


FIGURE 6: *Michaelia neotropica* n. sp., female legs: leg I dorsal (A); genu, tibia and tarsus of leg I, ventral (B); leg II dorsal (C); genu, tibia and tarsus of leg II, ventral (D); leg III dorsal (E) and ventral (F); leg IV dorsal (G) and ventral (H).

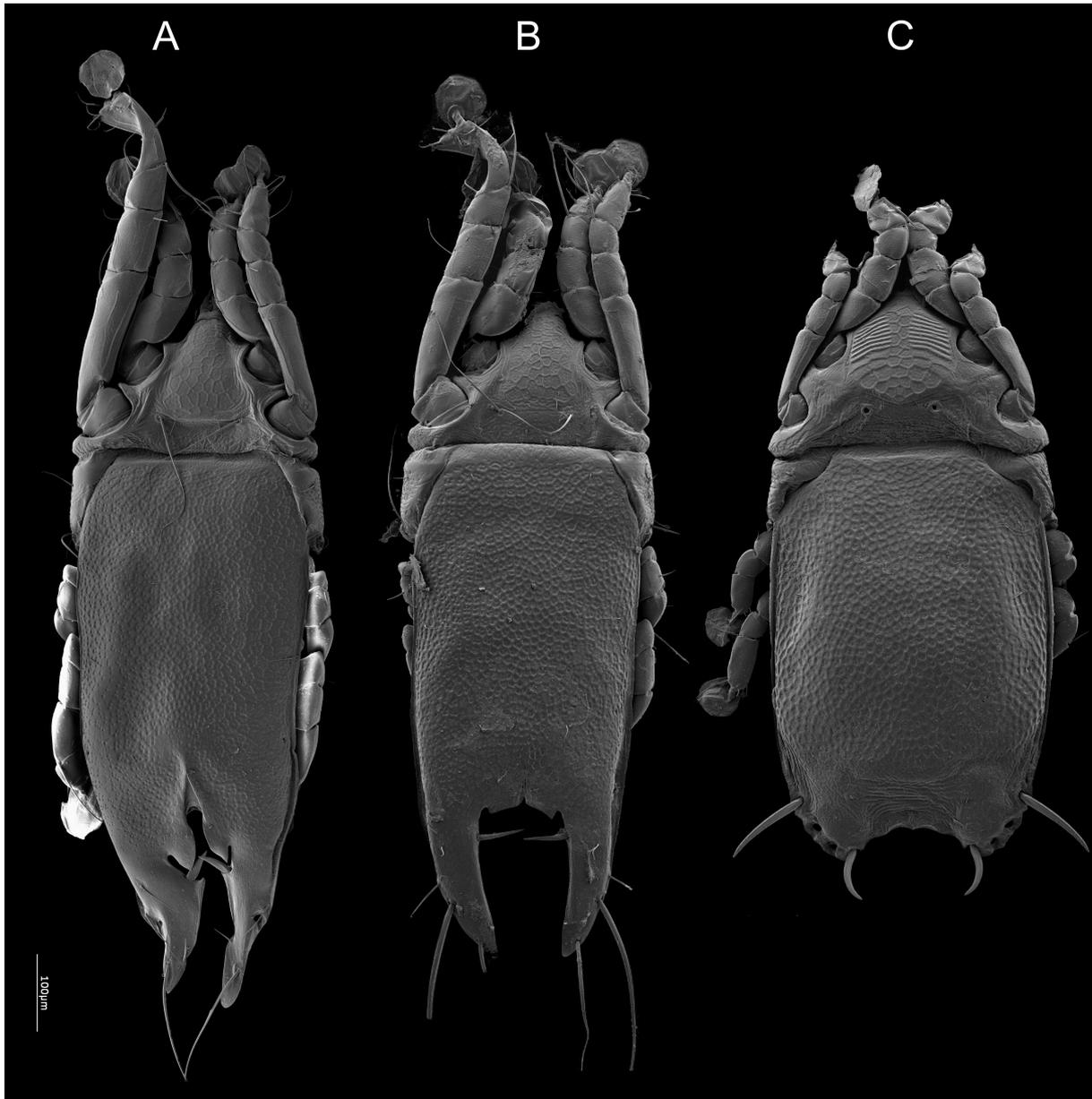


FIGURE 7: *Michaelia neotropica* n. sp., Low Temperature Scanning Microscope (LTSEM) pictures of heteromorphic male (A), homeomorphic male (B), and female (A), dorsal view.

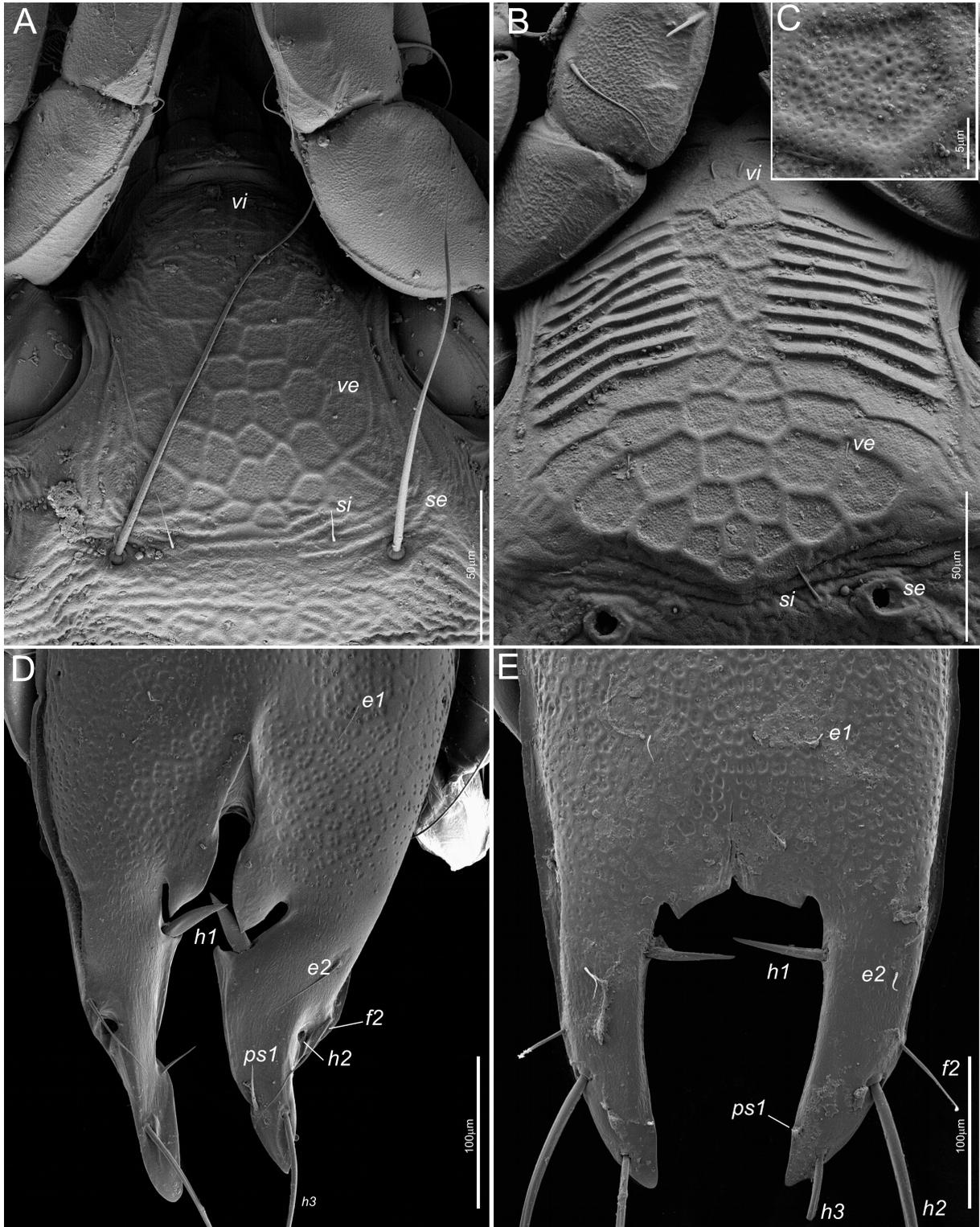


FIGURE 8: *Michaelia neotropica* n. sp., LTSEM pictures: prodorsal shield of homeomorphic male (A) and female (B), detail of female prodorsal shield (C); dorsal view of opisthosomal region of heteromorphic (D) and homeomorphic (E) males.

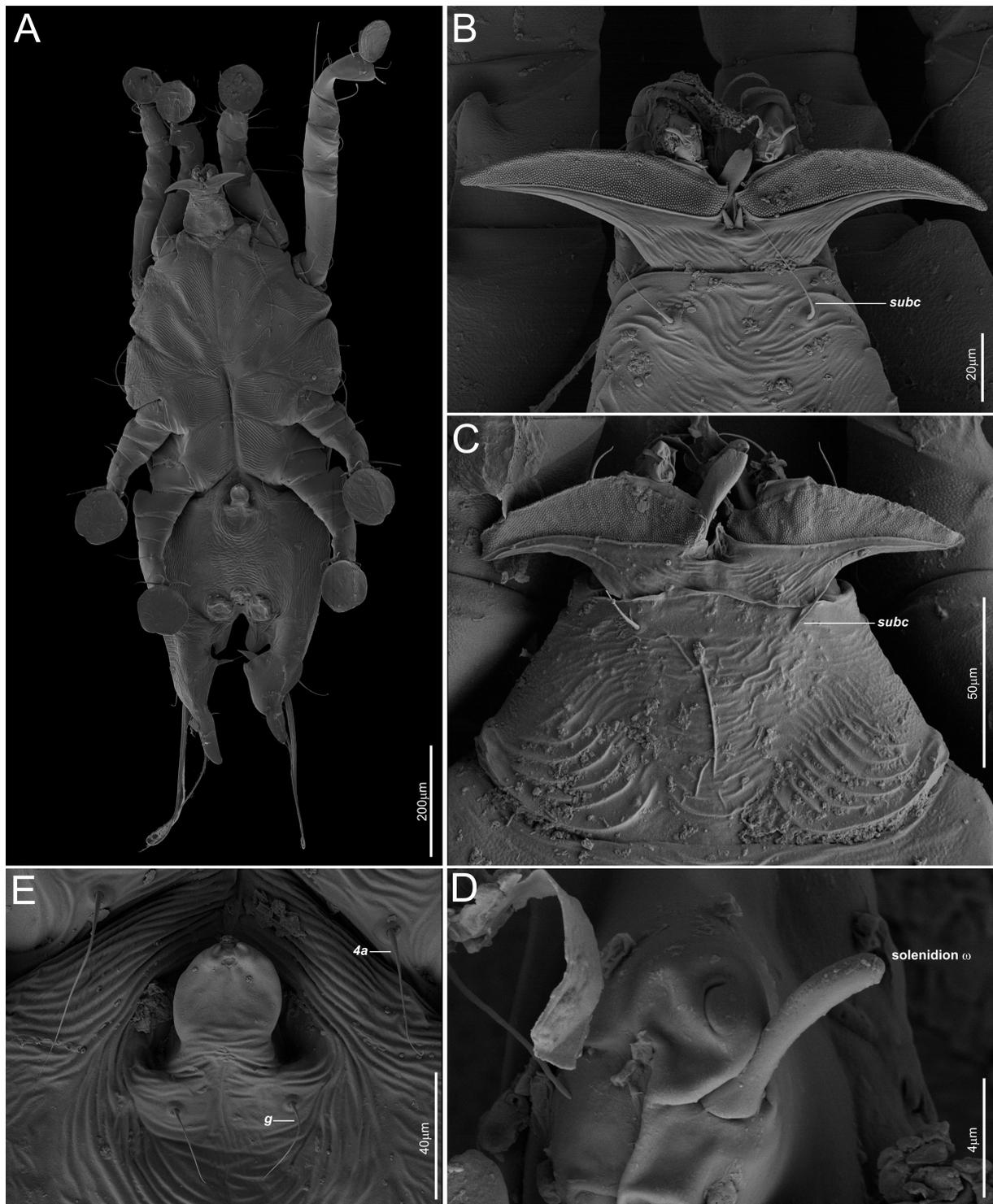


FIGURE 9: *Michaelia neotropica* n. sp., LTSEM pictures: ventral view of heteromorphic male (A), ventral views of gnathosoma of heteromorphic male (B) and female (C); external genitalia (E) and detail of palptarsus of heteromorphic male (D).

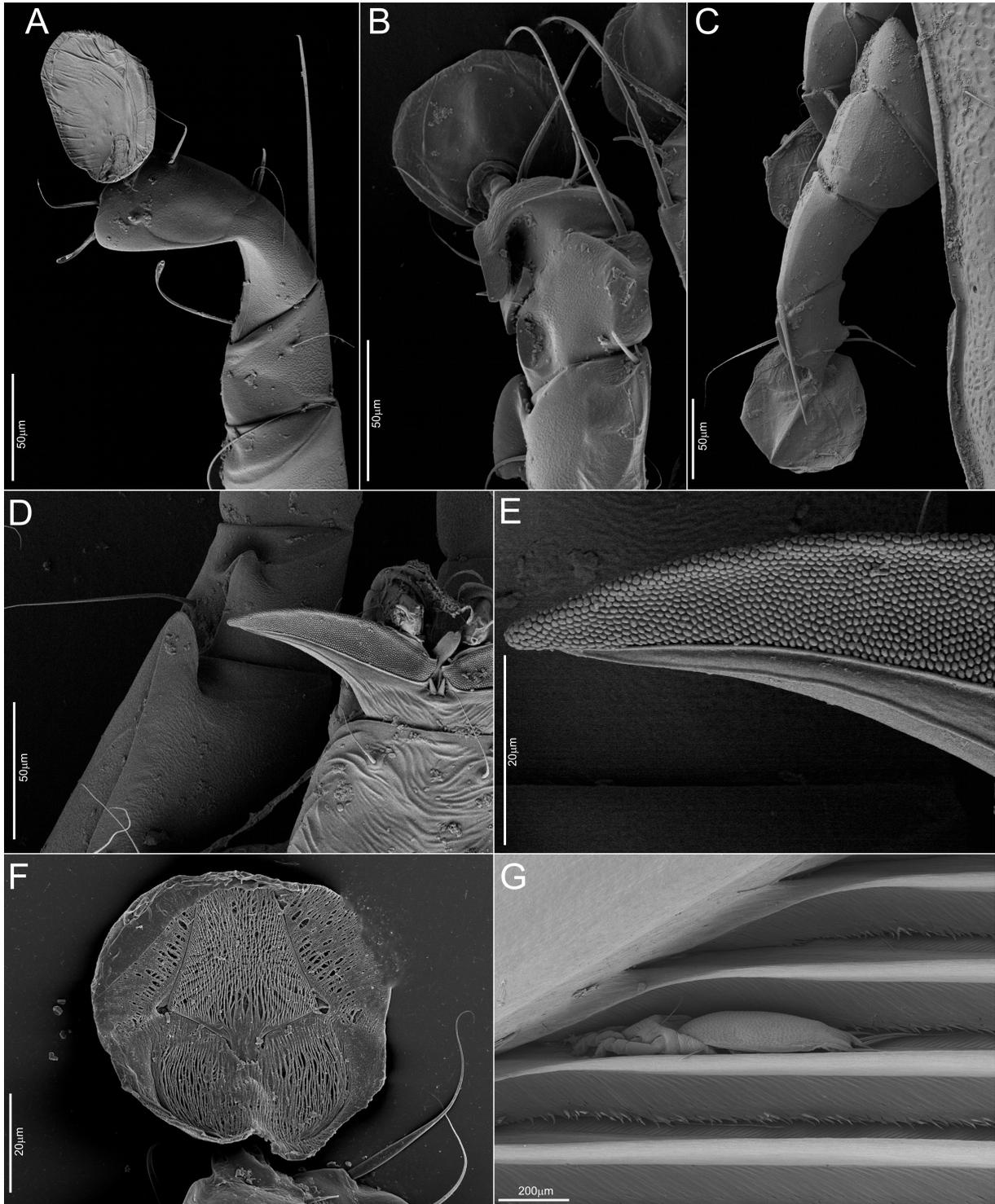


FIGURE 10: *Michaelia neotropica* n. sp., LTSEM pictures: ventral view of left tarsus II of heteromorphic male (A), dorsal view of left leg I of homeomorphic male (B), dorsal view of legs III and IV of heteromorphic male (C), ventral view of gnathosoma, femur and genu I of heteromorphic male (D), detailed view of pseudorutellar process (E), ventral view of ambulacrum II of heteromorphic male (F), lateral view of female in the feather corridor (G).

Anterior legs I, II asymmetrical. Femur and genu of larger (thicker) leg I with large ventral longitudinal crests (Fig. 4B); these crests absent on equivalent segments of the smaller leg I. Tarsus of thicker leg I broadened basally and with retrograde dorsolateral spine; tarsus of thinner leg II with rounded ventral tubercle. Legs II and posterior legs III, IV as in heteromorph. Length of anterior legs from femur to tarsal tip (the smaller leg is given first): I 246 – 250, I 250 – 273, II 329 – 346, II 420 – 458.

Female (range for 6 paratypes in parentheses) — Idiosoma length from anterior end of prodorsal shield to lobar apices 721 – 794, width at level of humeral shields 411 – 447. Prodorsal shield: covering almost all prodorsum, borders indistinct, anterior part with 8-9 pairs of transverse, gill-like striae (somewhat resembling Venetian blinds), central part with reticulate pattern. Setae *vi*, *ve* filiform, minute; setae *si* filiform, about 10 long, separated by 58 – 63; setae *se* separated by 103 – 110. Setae *c2* filiform, situated on humeral shields. Subhumeral setae *c3* filiform, situated ventrally on humeral shield. Hysteronotal shield: covering almost all hysterosoma, greatest length from anterior margins to lobar apices 503 – 558, anterior margin rounded, poorly distinct, surface with reticulate pattern. Most dorsal setae filiform, except *ps1*, *f2* lanceolate; *ps1* 82 – 94, *f2* 126 – 140 long; *h2* 472 – 609 long, *h3* 493 – 603 long. Supranal concavity indistinct. Opisthosomal lobes moderately expressed; terminal cleft from anterior end to lobar tips 28 – 42. Copulatory opening terminal, situated on small tubercle on terminal cleft margin. Setae *ps1* lanceolate, slightly curved. Distances between dorsal setae: *c1:c1* 139 – 167, *c1:d1* 105 – 119, *d1:d1* 114 – 135, *d1:e1* 158 – 173, *e1:e1* 165 – 185, *ps1:ps1* 159 – 173, *h3:h3* 212 – 224, *h2:h2* 258 – 271, *f2:f2* 294 – 323.

Pseudorutellar processes as in males. Basal part of epimerites I, II, IIa with heavily sclerotized inflations, connected to each other with wide sclerotized bridges. Coxal fields III closed. Oviporus at midlevel between trochanters III and IV. Sclerotized epigynum absent.

All legs symmetrical, without any crests or processes. Setae *d* of tarsi setiform. Length of two an-

terior pairs of legs from femur to tarsal tip: I 229 – 243, II 227 – 244.

Differential diagnosis — The new species, *Michaelia neotropica* Hernandez and Mironov **n. sp.**, is close to *M. urile* (Dubinin, 1953) by the absence of a retrograde spur on both tarsi I and a ventral spine on the femur of the smaller leg I in heteromorphic males. A spur on tarsus I is present in heteromorphic males of *M. amplosinus* (Gaud, 1970) and *M. heteropus*, and a ventral spine on femur I is present in *M. heteropus* and *M. microcarbonis* (Dubinin, 1953). Heteromorphic males of *Michaelia neotropica* differ from those of *M. urile* by having a narrower incision on opisthosomal lobes anterior to setae *h1* with its margins almost touching each other, and by the relatively longer legs I with their ambulacrum reaching the midlevel of tarsus of the elongated leg II. In heteromorphic males of *M. urile*, the lobar incisions anterior to setae *h1* are wide, rounded, about half as wide as long, and the ambulacra of tarsi I reach only the level of solenidion φ on tibia of enlarged leg II. Considering the closest species in relation to the new one being described (*Michaelia urile* vs *M. neotropica* **n. sp.**), differences between homeomorphic males are minimal, as far as it is detectable from the original descriptions. As far as we know, females are very hardly distinguishable between all species, and we prefer to avoid mentioning preliminary differences at this point.

Etymology — The specific epithet refers to the common name of the host, the Neotropical Cormorant.

Key to species of the genus *Michaelia* (heteromorphic males)

1. Inner borders of opisthosomal lobes with a pair of acute extensions anterior to bases of setae *h1* . . . 2
— Inner border of opisthosomal lobes with sinuous curvature anterior to setae *h1*
.....*M. amplosinus* (Gaud, 1970)
2. Seta *ra* of enlarged tarsus II thickened; acute anterior extension on inner margin of opisthosomal lobe counter-lateral to longer leg II surpasses beyond the base of seta *h1* of this lobe.
.....*M. microcarbonis* (Dubinin, 1953)

— Seta *ra* of enlarged tarsus II thin, filiform; no acute extensions on inner margin opisthosomal lobes reaching the base of seta *h1* 3

3. Ventral spurs present on both femora I and also on tarsus I opposite to enlarged leg II *M. heteropus* (Michael, 1881)
— Ventral spur present only on femur on enlarged leg I..... 4

4. Incisions on inner margin of opisthosomal lobe anterior to setae *h1* wide, semiovate; ambulacrum of tarsus I reaching the level of solenidion φ of enlarged tibia II..... *M. urile* (Dubinin, 1953)
— Incision on inner margins of opisthosomal lobes anterior to seta *h1* narrow, with its margins almost touching each other; ambulacrum of tarsus I reaching the midlevel of tarsus of enlarged leg II.....
..... *M. neotropica* Hernandez and Mironov **n. sp.**

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