TWO NEW SPECIES AND A NEW RECORD OF *SPATULAPHORUS* (ACARI: PYGMEPHORIDAE) PHORETIC ON SCARAB BEETLES (COLEOPTERA: SCARABAEIDAE) FROM FRENCH GUIANA

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ABSTRACT: Two new species, *Spatulaphorus dignus* sp.n. and *S. porosus* sp.n. (Acari: Pygmephoridae), collected from scarab beetles *Oxysternon durantoni* and *Coprophanaeus jasius*, respectively, are described from French Guiana. *Spatulaphorus brasiliensis* Khaustov and Frolov, collected from the beetle *Dichotomius borreus*, is recorded from French Guiana for the first time. A key to the world species of the genus *Spatulaphorus* is also provided.

KEY WORDS: Heterostigmata, systematics, morphology, key, phoresy.

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INTRODUCTION

Pygmephoroid mites (Acari: Heterostigmata: Pygmephoroidae) have phoretic relationships with a wide range of scarab beetles (Coleoptera: Scarabaeoidea), mostly with dung beetles of the families Geotrupidae and Scarabaeidae (Khaustov and Frolov 2019). Representatives of at least five genera of the family Pygmephoridae are associated with dung beetles: *Geotrupophorus* Mahunka, 1970; *Pygmephorellus* Cross and Moser, 1971; *Pseudopygmephorellus* Khaustov, 2008; *Pediculaster* Vitzthum, 1931; and *Spatulaphorus* Rack, 1993 (Dastych and Rack 1993; Dastych *et al.* 1997; Khaustov 2005, 2007a, b; Rahiminejad *et al.* 2011; Khaustov and Trach 2012, 2018; Katlav *et al.* 2015a, b; Khaustov and Frolov 2017, 2018, 2019; Sobhi *et al.* 2017). The genus *Spatulaphorus* includes 14 described species (Khaustov and Frolov 2018), all of which are associated with dung beetles of the genera *Copris* Geoffroy, *Onitis* Fabricius, *Catharsius* Hope, *Gymnopleurus* Illiger (Scarabaeidae), *Geotrupes* Latreille and *Enoplotrupes* Lucas (Geotrupidae) in Europe, Asia, South America and Africa (Khaustov and Trach 2012; Khaustov and Frolov 2017, 2018; Sobhi *et al.* 2017; Khaustov and Trach 2018). Only one species of *Spatulaphorus* (*S. brasiliensis*) has been recorded in the Neotropical region. However, *Pygmephorellus imbricatipes* Mahunka, 1980, described from specimens in the Berlese collection and collected from *Phaneus* sp. (Scarabaeidae) in Argentina, may be a member of *Spatulaphorus* (Khaustov and Trach 2012; Khaustov and Frolov 2017) because of the leg chaetotaxy, illustrated in the original description of this species. Previously, mites of the genus *Spatulaphorus* have never been recorded from French Guiana.

Recently, we had the opportunity to examine phoretic mites of dung beetles of the tribes Phanaeini and Dichotomiini, collected in French Guiana by Olivier Montreuil (National Museum of Natural History, Paris, France). The specimens of *Oxysternon durantoni* Arnaud and *Coprophanaeus jasius* (Olivier) (Pahaneini) bore two new species of *Spatulaphorus*. On *Dichotomius borreus* (Olivier) (Dichotomiini), we found *S. brasiliensis*, which has previously been described from Brazil from another species of *Dichotomius*.

The aim of this paper is to describe two new species of *Spatulaphorus* and to present a new record of *S. brasiliensis* from French Guiana.

MATERIALS AND METHODS

The mites were collected from preserved beetles, housed in the private collection of Olivier Montreuil. The mites were recovered from under the elytra of the beetles. The collected mites were preserved in 70–80% ethanol and later cleared in lactic acid and mounted in Hoyer's medium. Mite morphology was studied using a Carl Zeiss AxioImager A2 compound microscope equipped with phase contrast and DIC illuminations. Photomicrographs were taken with an AxioCam ICc5 (most micrographs) and Hitachi KP-HD20A (Fig. 6) digital cameras.

The terminology of the idiosoma and legs follows Lindquist (1986); the nomenclature of subcapitular setae and the designation of cheliceral setae follow Grandjean (1944, 1947), respectively. The taxonomic system of Pygmephoroidae follows Khaustov (2004, 2008). All measurements are given in micrometers (μm) for the holotype and five paratypes (in parentheses). For leg chaetotaxy, the number of solenidia is given in parentheses.

Fig. 1. *Spatulaphorus dignus* sp.n., female: A—dorsum of body, B—venter of body. Legs omitted.

SYSTEMATICS

Family **Pygmephoridae** Cross, 1965

Genus ***Spatulaphorus*** Rack, 1993

Type species: *Spatulaphorus camerikae* Dasytch and Rack, 1993, by original designation.

***Spatulaphorus dignus* sp.n.**

(Figs. 1–6)

Description. *Female* (Figs. 1–6). Body well sclerotized. Length of idiosoma 210 (205–240), width 120 (120–140).

Gnathosoma (Fig. 6A). Gnathosomal capsule, excluding palps, subrectangular, length 21 (20–23), width 22 (21–23). Dorsum with one pair of needle-like cheliceral setae (*cha*) 5 (4–5). Dorsal median

apodeme present, but poorly developed. Postpalpal setae (*pp*) 2 (2) spine-like, situated laterad setae *cha*. Ventral gnathosoma with one pair of smooth, pointed subcapitular setae *m* 6 (6–7) and round pits *n* situated posteriad *m*. Palps with smooth and weakly blunt-tipped setae *dFe* 3 (3) and *dGe* 6 (6–7) dorsolaterally. Palps ventrally each with mushroom-like accessory setigenous structure (*ass*) and tiny solenidium. Palps terminated with small blunt-tipped tibial claw and tiny eupathidium-like seta (Fig. 6A). Pharyngeal pump 2 poorly visible, oval with weak transverse striation (Fig. 6B); pharyngeal pumps 1 and 3 not visible.

Idiosomal dorsum (Figs. 1A, 4A, 5A, C, E). All dorsal shields with numerous tiny, barely discernible puncta (Figs. 5A, C, E). Prodorsal shield

Fig. 2. *Spatulaphorus dignus* sp.n., female: A—left leg I, dorsal aspect, B—left leg II, dorsal aspect.

with three pairs of setae ($v1$, $v2$, $sc2$), one pair of weakly barbed capitate trichobothria ($sc1$) and one pair of round stigmata (Fig. 5A). Stigmata associated with well developed tracheal trunks. All dorsal idiosomal setae blunt-tipped; setae $v2$ and $h2$ smooth, other dorsal setae barbed; setae e with one or two barbs. Cupuli ia on tergite D, im on tergite EF and ih on tergite H large, round. Lengths of dorsal setae: $v1$ 22 (22–24), $v2$ 11 (11–13), $sc2$ 48 (47–54), $c1$ 41 (39–46), $c2$ 45 (44–48), d 47 (44–49), e 19 (19–21), f 48 (48–55), $h1$ 47 (45–49), $h2$ 12 (12–13). Distances between setae: $v1$ – $v1$ 25 (25–27), $v2$ – $v2$ 38 (38–42), $sc2$ – $sc2$ 36 (36–41), $c1$ – $c1$ 45 (45–49), $c1$ – $c2$ 18 (18–22), d – d 61 (61–67), e – f 7 (7–8), f – f 55 (55–61), $h1$ – $h1$ 43 (43–47), $h1$ – $h2$ 8 (8–10).

Idiosomal venter (Figs. 1B, 4B, 5B, D, F). All ventral plates with numerous tiny puncta. Setae $1b$ and $ps1$ – 2 pointed; other ventral setae with slightly rounded tips. Setae $1b$ with a few barbs; setae $ps3$ usually with one barb, sometimes smooth; other ventral setae smooth. Bases of setae ps_3 situated distinctly anteriad bases of setae $ps1$ – 2 . Apodemes

1 ($ap1$) and apodemes 2 ($ap2$) well developed and joined with thick prosternal apodeme ($appr$); sejugal apodeme ($apsej$) developed only laterally; apodemes 3 ($ap3$) weak, not reaching poststernal apodeme ($appo$); apodemes 4 ($ap4$) well developed, exceeding beyond bases of setae $3b$. Apodemes 5 ($ap5$) well developed, joined with $appo$ and reaching beyond setae $4a$. Anterior genital sclerite (ags) small, cup-like; posterior genital sclerite (pgs) small, oval, with lateral processes. Posterior margins of posterior sternal plate weakly concave in middle part. Posterior margin of aggenital plate rounded. Lengths of ventral setae: $1a$ 9 (8–11), $1b$ 12 (12–14), $1c$ 12 (12–17), $2a$ 12 (12–14), $2c$ 8 (8–9), $3a$ 11 (13–14), $3b$ 11 (11–13), $3c$ 14 (14–15), $4a$ 10 (10–13), $4b$ 18 (18–19), $4c$ 13 (13–15), $ps1$ 11 (11–13), $ps2$ 12 (12–13), $ps3$ 13 (13–15).

Legs (Figs. 2, 3, 6C). Leg I (Figs. 2A, 6C) slightly thicker than leg II. Setal formula: 1–4–2–17(4). Tibiotarsus enlarged, with large claw. Setae (u) consolidated into a horn-like structure opposing to claw (Fig. 6C). Tarsal claw blunt-tipped. Seta d of femur spatulate, with short subterminal projec-

Fig. 3. *Spatulaphorus dignus* sp.n., female: A—right leg III, dorsal aspect, B—right leg IV, dorsal aspect.

tion. Setae l' of femur and k of tibiotarsus smooth; other leg setae (except eupathidia p' , p'' , tc' , tc'' , ft' , ft'') sparsely barbed. Setae l' , l'' of femur and (l) of genu blunt-ended; other leg setae (except eupathidia) pointed. Lengths of solenidia ωl 10 (10), $\omega 2$ 4 (4–5), ϕl 7 (7–8), $\phi 2$ 5 (5); solenidion ϕl thick, clavate, ωl digitiform; other solenidia weakly clavate. Leg II (Fig. 2B). Setal formula: 1–3–1–4–6(1). Tarsus with thickened basally claws and flipper-like empodium. Solenidion ω 6 (6) weakly clavate, solenidion ϕ absent. All setae barbed; seta tc' of tarsus spiniform, blunt-tipped; setae d , l' , v'' of femur and l' of genu blunt-tipped;

other leg setae pointed. Leg III (Fig. 3A). Femur divided into basi- and telofemur. Setal formula: 1–2–1–4–6. Claws and empodium of same shape as on tarsus II. All setae barbed; setae v' of trochanter, d , v' of femur and l' of genu blunt-tipped, other leg setae pointed; solenidion ϕ absent. Leg IV (Fig. 3B). Femur divided into basi- and telofemur. Setal formula: 1–2–0–4–6. Claws simple, empodium round, stalked. All setae barbed; setae v' of trochanter, d of femur, v'' of tibia and pl'' of tarsus blunt-tipped, other leg setae pointed; solenidion ϕ absent.

Male unknown.

Fig. 4. DIC micrographs of *Spatulaphorus dignus* sp.n., female: A—general view dorsally, B—general view ventrally

Type material. Female holotype, slide ZISP T-Pygm-007, French Guiana, St. Georges, 3. II.2018, O. Montreuil leg., on beetle *Oxysternon durantoni*; paratypes: 13 females, same data.

Type deposition. The holotype and four paratypes are deposited in the collection of the Zoological Institute of the Russian Academy of Sciences (RAS), Saint Petersburg, Russia; other paratypes are deposited in the collection of the Tyumen State University Museum of Zoology, Tyumen, Russia.

Differential diagnosis. The new species is most similar to *S. brasiliensis* Khaustov and Frolov, 2017, described from Brazil (Khaustov and Frolov 2017), in: the similar lengths and shapes of dorsal and ventral setae; absence of foliate setae on tarsi I–IV; the characteristic position of setae *ps3* distinctly anteriad *ps1*–2; absence of spiniform setae on tarsus III. The new species differs from *S. brasiliensis* in: barbed setae *e* (vs. smooth in *S. brasiliensis*), having spiniform seta *tc'* on tarsus II (vs. not modified in *S. brasiliensis*), absence of big puncta on idiosomal tergites (vs. idiosomal tergites with big puncta in *S. brasiliensis*), much longer and thicker seta *pl''* on tarsus IV.

Etymology. The name of the new species is derived from Latin *dignus* meaning *dignified*.

***Spatulaphorus porosus* sp.n.**

(Figs. 7–11)

Description. *Female* (Figs. 7–11). Body well sclerotized. Length of idiosoma 235 (215–245), width 125 (110–130).

Gnathosoma. As in *S. dignus* sp.n., except shorter, weakly blunt-tipped setae *m* 3(3–5). Length of gnathosoma 20 (19–22), width 21 (20–23). Lengths of setae: *cha* 5 (5–6), *pp* 2 (2), *dFe* 3 (3), *dGe* 7 (6–7).

Idiosomal dorsum (Figs. 7A, 10A, 11A, C, E) in general very similar to *S. dignus* sp.n. All dorsal shields with big pore-like puncta (Figs. 11A, C, E). All dorsal idiosomal setae blunt-tipped; setae *v2* smooth, other dorsal setae barbed; setae *h2* with one or two barbs. Lengths of dorsal setae: *v1* 30 (28–32), *v2* 12 (12–14), *sc2* 44 (47–60), *c1* 48 (47–52), *c2* 51 (51–57), *d* 54 (51–59), *e* 21 (21–23), *f* 53 (53–60), *h1* 50 (50–59), *h2* 12 (12–13). Distances between setae: *v1*–*v1* 22 (21–23), *v2*–*v2* 34 (31–37), *sc2*–*sc2* 37 (34–40), *c1*–*c1* 39 (38–44), *c1*–*c2* 24 (22–24), *d*–*d* 56 (52–62), *e*–*f* 8 (8–9), *f*–*f* 53 (49–58), *h1*–*h1* 42 (38–45), *h1*–*h2* 10 (10–11).

Idiosomal venter (Figs. 7B, 10B, 11B, D, F) in general very similar to *S. dignus* sp.n. All ventral plates with numerous tiny puncta, aggenital plate

Fig. 5. DIC micrographs of *Spatulaphorus dignus* sp.n., female: A—prosoma, dorsal aspect, B—prosoma, ventral aspect, C—metapodosoma, dorsal aspect, D—metapodosoma, ventral aspect, E—opisthosoma, dorsal aspect, F—opisthosoma, ventral aspect.

and anterolateral parts of coxal fields I and II with some big puncta (Figs. 11B, D, F). Lengths of ventral setae: *1a* 11 (11–12), *1b* 20 (19–21), *1c* 12 (12–14), *2a* 12 (12–14), *2c* 11 (10–12), *3a* 12

(12–16), *3b* 12 (12–13), *3c* 16 (15–16), *4a* 12 (12–13), *4b* 19 (19–22), *4c* 14 (14–16), *ps1* 14 (13–14), *ps2* 14 (14–16), *ps3* 17 (17–19).

Fig. 6. DIC micrographs of *Spatulaphorus dignus* sp.n., female: A—gnathosoma, ventral aspect, B—pharyngeal pump 2, C—tibiotarsus I, ventral aspect; cl—tibial claw, eup—eupathid-like seta.

Legs (Figs. 8, 9). Leg setation as in *S. dignus* sp.n. Leg I (Fig. 8A) as in *S. dignus* sp.n., except pointed setae v'' of femur and l' of genu. Lengths of solenidia $\omega 1$ 9 (9), $\omega 2$ 5 (5–6), $\phi 1$ 8 (8), $\phi 2$ 5 (5–6). Leg II (Fig. 8B) as in *S. dignus* sp.n., except pointed seta l' on genu. Solenidium ω 7 (7) weakly clavate. Legs III (Fig. 9A) and IV (Fig. 9B) as in *S. dignus* sp.n.

Male unknown.

Type material. Female holotype, slide ZISP T-Pygm-008, French Guiana, St. Georges, 3. II.2018, O. Montreuil leg., on beetle *Coprophanaeus jasius*; paratypes: 14 females, same data.

Type deposition. The holotype and four paratypes are deposited in the collection of the Zoo-

Fig. 7. *Spatulaphorus porosus* sp.n., female: A—dorsum of body, B—venter of body. Legs omitted.

logical Institute of RAS, Saint Petersburg, Russia; other paratypes are deposited in the collection of the Tyumen State University Museum of Zoology, Tyumen, Russia.

Differential diagnosis. The new species is very similar to *S. dignus* sp.n. The new species differs from *S. dignus* sp.n. in having big pore-like puncta on dorsal idiosomal tergites, aggenital plate, and coxal fields I and II (vs. big puncta absent in *S. dignus*) and in having a clearly longer setae *1b* (19–21) (vs. 12–14 in *S. dignus*).

Etymology. The name of the new species is derived from Greek πόρος meaning *pore* and refers to big pore-like puncta on idiosomal sclerites.

***Spatulaphorus brasiliensis* Khaustov and Frolov, 2017**

Spatulaphorus brasiliensis Khaustov and Frolov, 2017: 513.

This species was described from Brazil (Khaustov and Frolov 2017) from the scarab beetle *Dichotomius podalirius*. This is the first record of *S. brasiliensis* from French Guiana. *Dichotomius borreus* is a new phoretic host for *S. brasiliensis*.

Material examined. Seventeen females, French Guiana, St. Georges, 3.II.2018, O. Montreuil leg., on beetle *Dichotomius borreus*.

Fig. 8. *Spatulaphorus porosus* sp.n., female: A—right leg I, dorsal aspect, B—right leg II, dorsal aspect.

**KEY TO WORLD SPECIES
OF SPATULAPHORUS
(based on Khaustov and Frolov 2018)**

1. Genu I with two setae 2
— Genu I with one seta *S. copridis* Khaustov, 2007 (Crimea, Iran)
2. Tarsi II and III each with spiniform setae *pl''* and *tc'* 3
— Tarsi II and III without spiniform setae, or only *pl''* or *tc'* spiniform 5
3. Setae *sc2* foliate ... *S. vladimiri* Khaustov, 2005 (Ukraine, Crimea, Iran)
— Setae *sc2* not modified, setiform 4
4. Setae *c2* foliate, blunt-tipped
..... *S. venustus* Khaustov and Trach, 2012 (Ukraine)
— Setae *c2* not modified, pointed
..... *S. altaicus* Khaustov and Trach, 2018 (Russia: Altai)
5. At least setae (*pv*) on tarsus II foliate distally ... 6

- Setae (*pv*) on tarsus II not foliate distally 10
6. Tibiotarsus I with large, hook-like claw and a distinct counterpart opposite to the claw base 7
— Tibiotarsus I with a small, almost straight claw, and no counterpart *S. foliatus* Dastych and Rack, 1993 (Botswana)
7. Tarsi II and III with setae *tc'* not modified 8
— Tarsi II and III with setae *tc'* spiniform
..... *S. langi* Dastych and Rack, 1993 (Vietnam)
8. Setae *ps₃* subequal to or shorter than *ps1*, 2 9
— Setae *ps3* distinctly longer than *ps1*, 2
..... *S. luriei* Dastych, Rack and Camerik, 1997 (South Africa)
9. Setae (*pv*) on tarsus III foliate, setae *ps1*, 2 distinctly barbed
..... *S. enoplotruporum* Khaustov and Frolov, 2018 (Thailand)
— Setae (*pv*) on tarsus III not foliate, setae *ps1*, 2 smooth *S. camerikae* Dastych and Rack, 1993 (Botswana)

Fig. 9. *Spatulaphorus porosus* sp.n., female: A—right leg III, dorsal aspect, B—right leg IV, dorsal aspect.

10. Tarsi II and III with setae *pl''* not modified 11
 — Tarsi II and III with setae *pl''* spiniform
 .. *S. gorganica* Rahiminejad and Hajiqanbar, 2011
 (Iran, Crimea)
 11. Apodemes 4 long, exceeding beyond setae *3b* .. 12
 — Apodemes 4 vestigial
 S. geotruporum Khaustov, 2005
 (Ukraine)
 12. Setae *ps3* situated on the same transverse level
 with *ps1–2* 13
 — Setae *ps3* situated distinctly anteriad *ps1–2* 14

13. Setae *e* more than two times longer than *h2*, setae
ps3 and *ps1–2* subequal .. *S. geotrupi* (Mahunka, 1970)
 (Hungary)
 — Setae *e* and *h2* subequal; setae *ps3* more than
 two times longer than *ps1–2*
 S. gymnopleuri Sobhi and Hajiqanbar, 2017
 (Iran)
 14. Seta *tc'* on tarsus II spiniform 15
 — Seta *tc'* on tarsus II not modified
 S. brasiliensis Khaustov and Frolov, 2017
 (Brazil)

Fig. 10. DIC micrographs of *Spatulaphorus porosus* sp.n., female: A—general view dorsally, B—general view ventrally

15. Idiosomal tergites with big puncta (Fig. 7A)..
..... *S. porosus* sp.n.
— Idiosomal tergites only with tiny puncta
(Fig. 1A)..... *S. dignus* sp.n.

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Fig. 11. DIC micrographs of *Spatulaphorus porosus* sp.n., female: A—prosoma, dorsal aspect, B—prosoma, ventral aspect, C—metapodosoma, dorsal aspect, D—metapodosoma, ventral aspect, E—opisthosoma, dorsal aspect, F—opisthosoma, ventral aspect.

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