



Description of a new species of *Willemia* (Collembola: Hypogastruridae) from Panama with key to *Willemia* species occurring in the Americas

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Abstract

Willemia panamaensis sp. nov. from Panama is described and illustrated. It is characterised by the presence of sensilla I (S2) and i1 (S9) on antennal segment IV, nine vesicles in the postantennal organ, and having dorsal setae and sensilla on abdominal segments V and VI twice as long than on segments I and II. A dichotomous key to species recorded from the Americas is provided. Reference is given to the DNA barcoding sequences of the new species.

Key words: *Buddenbrocki* group, Barro Colorado Island, soil fauna, tropical rainforest, key

Introduction

Börner (1901) erected the genus *Willemia* and its type species, *W. anophthalma*, for members of the Hypogastruridae family characterised by a complete lack of eyes, pigment and furcula (Jordana *et al.* 1997). There are 46 species of *Willemia* recorded worldwide (Zon *et al.* 2015), but few have a cosmopolitan distribution. A phylogenetic study of *Willemia*, by D'Haese and Thibaud (2011) resulted in the genus being divided into four groups: *anophthalma*, *persimilis* Bonet, *denisi* Mills and *buddenbrocki* Hüther. The last group is characterised (D'Haese & Weiner 1998) by the presence of two globular sensilla in a depression in the antennal cuticle of segment IV and by lacking cephalic seta a0 (Zon *et al.* 2015).

In the Americas, 14 species have been recorded, among which *Willemia brevispina* Hüther, 1962 and *W. biddenbrocki* Hüther, 1959 are widely distributed and probably cosmopolitan. *Willemia brevispina* has been recorded from Brazil, Nicaragua and Mexico, but not from Panama and the *W. biddenbrocki*-group has only been documented for South America by *W. australis* by Salazar *et al.* (2017). In the Americas the Collembola of Panama are poorly known (Palacios-Vargas 1992) with only 19 species recorded (Castaño-Meneses & Palacios-Vargas 2011; Palacios-Vargas 1992, 2007). The present contribution is part of a larger project to document and monitor the soil fauna of Barro Colorado Island, Panama, using morphological and molecular data (Smithsonian 2019) with a focus on springtails, ants and termites.

Many morphologically well-defined springtails are considered to have broad geographical ranges by occurring on different continents, but recent molecular work has revealed high genetic diversity within species (Cicconardi *et al.* 2013). Consequently, to detect more precisely diversity in Panama, we analysed the molecular composition of voucher specimens following Porco *et al.* (2010). The results will allow us to characterise soil diversity in more detail, enable comparisons with members of other genera, and so assess more species richness fully (Porco *et al.* 2012).

MATERIAL AND METHODOLOGY

Specimens were extracted from soil samples taken on Barro Colorado Island (La Chorrera District) during the

months of March, April, December, 2017 and January of 2018. One hundred soil cores were obtained from the top 10cms of soil near the permanent ForestGEO forest dynamics plot, which has been described in detail in Anderson-Teixeira *et al.* (2014).

Samples were extracted for six days in Berlese/Tullgren funnels at the Smithsonian Tropical Research Institute in Panama, preserved in 96% ethanol and sorted at the Laboratorio de Ecología y Sistemática de Microartrópodos, Faculty of Sciences, Universidad Nacional Autónoma de México. Eight specimens were prepared under cover slips in Hoyer's solution, were studied under a contrast phase microscope Carl Zeiss mod. 465270-9906 and drawn with the aid of a camera lucida.

Abbreviations: Abd.—Abdominal segment; Ant.—antennal segment; PAO—postantennal organ; S.g.d.—dorsal guard seta; S.g.v.—ventral guard seta; Tita—tibiotarsus, tibiotarsi; Th.—thorax segment; LESM—Laboratorio de Ecología y Sistemática de Microartrópodos, UNAM, Mexico. Ant. IV sensillary designation used in this contribution follows proposal of Bu *et al.* (2012), and in parenthesis, that proposed by D'Haese (2003).

Description of new species.

Willemia panamaensis sp. nov.

(Figs. 1–13)

Type locality: Panama, Barro Colorado Island. Holotype (♀), Distrito de La Chorrera: Barro Colorado Island; ex soil (9°05'02.6"N, 79°39'48.2"W); 14.iii.2017, 4.iv.2017, Y. Lopez *et al.* Coll. Paratypes (♀♀) and juveniles, with same data as holotype. All the material is deposited at LESM.

Type material: Holotype (♀) (Figs 1–13) body length 435 µm, paratypes (5 ♀♀, 2 juveniles), length (n=8) 408.3 µm, (range 324–510 µm).

Diagnosis: Ant. IV with four subcylindrical sensilla, one microsensillum *v* close to *e2* and *e3*; PAO with nine vesicles; Tibiotarsi I–III with 12 setae; no tenent hairs; sensilla on Abd I–IV are in *p4* position and *p2* on Abd V; Abd. II–III with sensillum lanceolate.

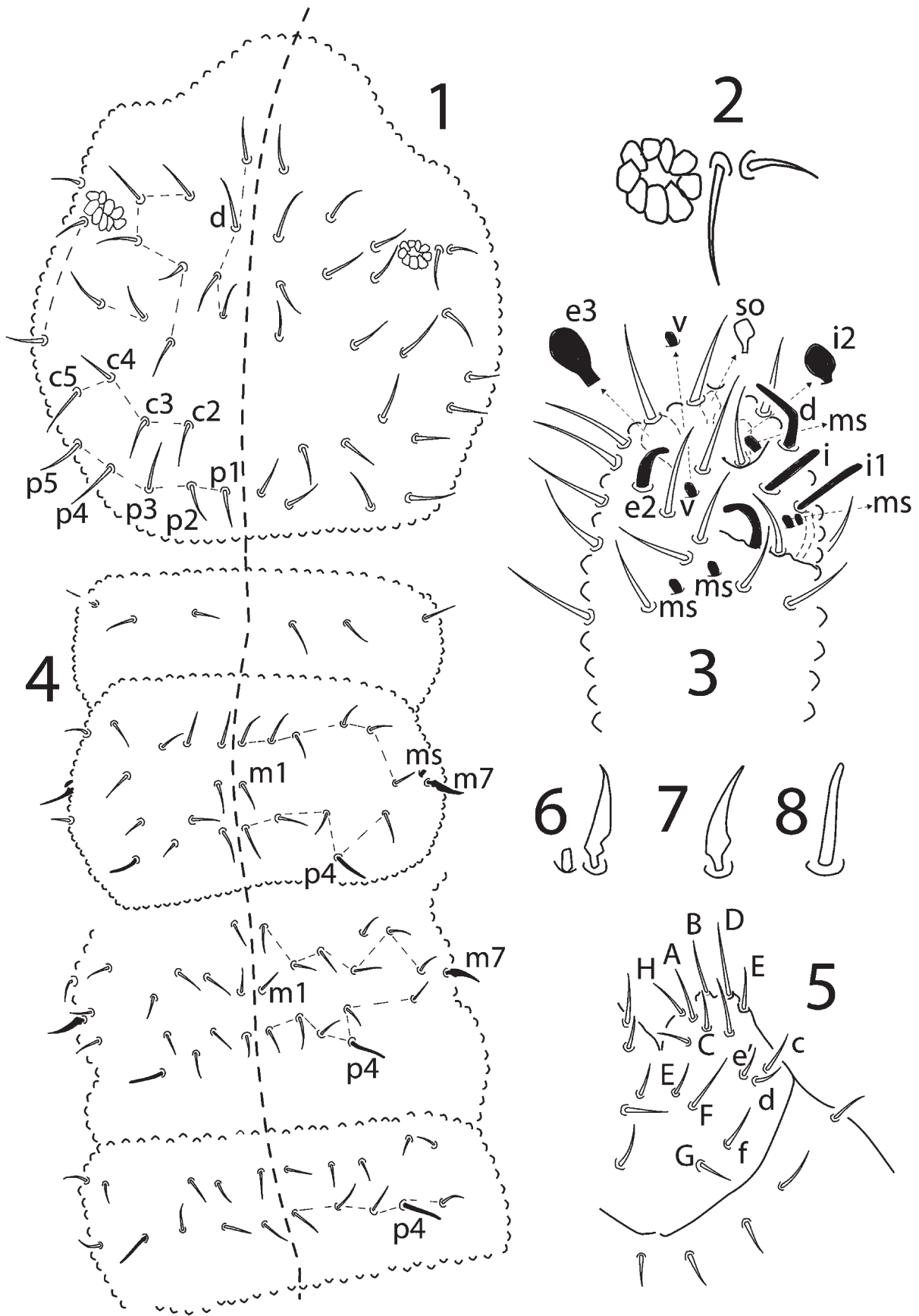
Description: Colour whitish, tegumentary grainules fine and regularly distributed. Antenna (56.8 µ). Ant. I with 6 setae; Ant. II with 11 setae; Ant. III organ with two microsensilla (*ms*), and one guard sensillum (*S*) at each side, S.g.d. longer than S.g.v., sinuose and curved; S.g.v. short and straight; one additional microsensillum is present. Ant. IV with six sensilla: two globular (*e3(S4)*, *i2(S7)*), two internal (*i(S2)*, *i1(S9)*), one dorsal (*d(S8)*) and one external (*e2(S1)*); apical vesicle simple (*SO*), one microsensillum close to *d*, and other microsensillum *v* close to *e2* and *e3* (Fig. 3). Postantennal organ (PAO) with nine vesicles (Fig. 2). Head lacking setae *a0* and *c1* (Fig1). Labrum with 2 setae. Labium with ABCD proximal setae, 4 basomedial (*E*, *F*, *G* and *f*) and 3 basolateral (*c*, *d*, *e'*) (Fig. 5). Dorsal chaetotaxy as in Figs 1, 4 and 9, most setae short and thin, increasing in length from anterior to posterior part of body; sensillary formula from Th. II to Abd. V as 022/111110; *m7* sensilla on thoracic segments cylindrical (Fig. 8) and *p4* lanceolate (Fig 7); Th. II with a microsensillum close to *m7* (Fig 6), Th. III lacking microsensillum (Fig. 4); sensilla on Abd. II–IV are in *p4* position (Fig. 9) and *p2* on Abd. V (Fig. 9). Abd. I with cylindrical sensillum; Abd. II–III with sensillum lanceolate (Fig. 11), Abd. IV and V, lanceolate-cylindric (Fig. 12). Setae *m1*, 2 and 3 lacking on Abd. IV (Fig. 9). Ventral chaetotaxy of abdomen as in Fig. 10.

Tibiotarsi I–III (Fig. 13) with 12 setae each, and two pretarsal, no tenent hairs, unguis without tooth; unguiculus absent. Ventral tube with 4+4 setae (Fig. 10), two small anal spines (Fig. 9), female genital plate with 3+3 pregenital setae, 3 circumgenital and 2 eugenital; male unknown. Anal valves with 10 setae each and 2 hr setae (Fig. 10).

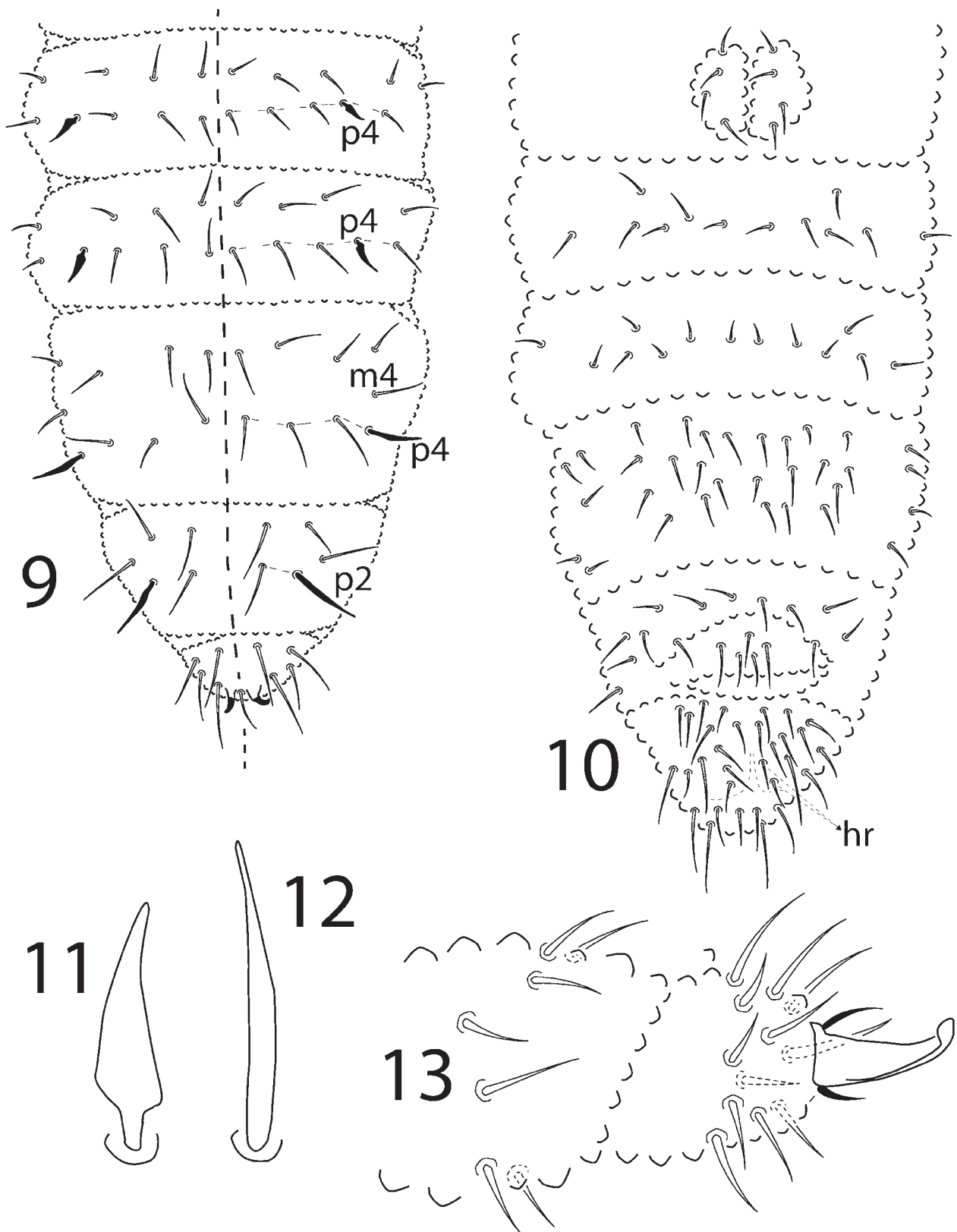
Variation. One specimen has 8+8 vesicles in PAO, while all others have 9 + 9. Two paratypes are lacking seta *m3* on Th. II and one specimen has 11 setae on Tita. III.

Etymology. The species is named after the country in which it was collected.

Remarks. *Willemia panamaensis* sp. nov. is close to *W. brevispina* Hüther, 1962. The main differences are as follows. In the new species Ant. IV has four sensilla (*d*, *e2*, *i* and *i1*) and microsensillum *v* is close to *e2* and *e3*, Ant. III organ has one *ms* at mid-region of the organ, and is not lateral as in *W. brevispina*; abdominal setae and sensilla are twice as long on the distal segments of the new species than on *W. brevispina*. The two species share a similar number of vesicles in PAO. We list other differences in Table 1.



FIGURES 1–8. *Willemia panamaensis* sp. nov. 1, dorsal chaetotaxy of head; 2, postantennal organ; 3, Ant. III and IV in dorsal view; 4, dorsal chaetotaxy of thorax and Abd. I; 5, labium right half; 6, lanceolate sensillum and microsensillum of Th. II; 7, lanceolate sensillum of Th. III; 8, cylindrical sensillum of Abd. I.



FIGURES 9–3. *Willemia panamaensis* sp. nov. 9, dorsal Abd. II–VI; 10, ventral Abd. I–VI; 11, lanceolate sensillum from Abd. II–III; 12, subcylindrical sensillum from Abd. IV–V; 13, femur and Tita III.

Similar characters are: shape of apical vesicle on Ant. IV; two globular sensilla (e3(S4), i2(S7)); c1 seta on head absent; 3+3 setae on thorax I; tibiotarsi I–III with 12 setae each; Abd. V with sensillum position at p2; a3 setae on abdominal sternite II absent; a3 seta on abdominal sternite IV present; m1 setae on abdominal sternite IV.

TABLE 1. Main morphological differences between the *Willemia budenbrocki* species group in the Americas.

Character	<i>W. panamaensis</i>	<i>W. brevispina</i>	<i>W. budenbrocki</i>
Ant. IV subcylindrical sensilla	4	2	4
PAO vesicles	9	7–10	12–13
Tita I–III setae	12	12	11
Seta a3 on Abd. II	-	-	+
Unguiculus	-	+	?

The new species was collected in tropical rainforest soil from Barro Colorado Island, Panamá, during the dry season. No males were collected. Five specimens were sequenced for the standard COI-5P marker (“DNA barcode”, Ratnasingham & Hebert 2013) at the Canadian Centre for DNA Barcoding. DNA was successfully recovered from two specimens, sequences BCICL047-19 (length 624bp) and BCICL048-19 (655bp), which were deposited in the project BCICL of the Barcode of Life Data System (<http://www.barcodinglife.org/index.php>).

Identification key to species of the genus *Willemia* in the Americas

1	Seta a0 present on the head	2
—	Seta a0 absent on the head	18
2	Anal spines present (usually 2, sometimes 1)	3
—	Anal spines absent	14
3	Seta m3' present on the abdominal tergum V	<i>W. bellingeri</i> Palacios-Vargas & Vázquez, 1998
—	Seta m3' absent on the abdominal tergum V	4
4	Setae a1 on abdominal sternum IV present	5
—	Setae a1 on abdominal sternum IV absent	11
5	Abdominal tergum V with seta p2 absent	6
—	Abdominal tergum V with seta p2 present	7
6	Postantennal organ with 10 to 11 vesicles; tibiotarsi I with 10–11 setae	<i>W. psammophila</i> Palacios-Vargas & Thibaud, 2001
—	Postantennal organ with 8 vesicles; tibiotarsi I with 15 setae	<i>W. iztacihuatlensis</i> García-Gómez & Cutz-Pool, 2008
7	Setae m1 present on abdominal tergum IV	8
—	Setae m1 absent on abdominal tergum IV	10
8	Setae m3 present on abdominal terga II and III; 2 hr setae on anal lobes	<i>W. anophthalma</i> Börner, 1901
—	Setae m3 absent on abdominal terga II and III; 3 hr setae on anal lobes	9
9	S-seta i1 (S9) present on antennal segment IV; 2 prelabral setae	<i>W. similis</i> Mills, 1934
—	S-seta i1 absent (it is not differentiated from ordinary setae) on antennal segment IV; 4 prelabral setae	<i>W. chistianseni</i> D'Haese, 1998
10	S-setae e2 (S1) and i (S2) present on antennal segment IV	<i>W. dubia</i> Christiansen & Bellinger, 1980
—	S-setae e2 and i absent (e2 and I not differentiated from ordinary setae) on antennal segment IV	<i>W. scandinavica</i> Stach, 1949
11	Postantennal organ with 4 or 5 vesicles	<i>W. intermedia</i> Mills, 1934
—	Postantennal organ with 7 vesicles or more	12
12	S—setae e3 (S4) and i2 (S7) on antennal segment IV not globular; tibiotarsi I, II, and III with 14, 14, and 13 setae, respectively	<i>W. persimilis</i> Bonet, 1945
—	S—setae e3 and i2 on antennal segment IV globular	13
13	Setae a2 absent on abdominal terga II and III; setae m1 and m3 absent on abdominal tergum IV	<i>W. bulbosa</i> Bonet, 1945
—	Setae a2 present on abdominal terga II and III; setae m1 and m3 present on abdominal tergum IV	<i>W. subbulbosa</i> Thibaud, 1994
14	S-setae on antennal segment IV all thick and subcylindrical	15
—	S-setae on antennal segment IV not thick and subcylindrical	16
15	Postantennal organ vesicles with numerous secondary tubercles	<i>W. granulata</i> Fjellberg, 1985
—	Postantennal organ vesicles smooth	<i>W. acantha</i> Bonet, 1945
16	Setae a2 absent on abdominal terga II and III; s-seta e2 (S1) present on antennal segment IV and some s-setae candle flame-shaped	<i>W. denisi</i> Mills, 1934
—	Setae a2 present on abdominal terga II and III; s-setae e2 and I (S2) absent on antennal segment IV (i.e., S1 and S2 not differentiated from ordinary setae)	17
17	Postantennal organ vesicles with numerous secondary tubercles	<i>W. arida</i> Fjellberg, 1991
—	Postantennal organ vesicles simple	<i>W. fjellbergi</i> Potapov, 1994
18	S-setae e3 (S4) and i2 (S7) of antennal segment IV both small, not placed in cavity, and not covered by tegumental fold	19
—	S-setae e3 and i2 of antennal segment IV both large, globular, placed in cavity, and covered in part by tegumental fold—budenbrocki-group	21

19	Anal spines present	W. arenicola Palacios-Vargas & Vázquez, 1988
—	Anal spines absent	20
20	Postantennal organ with 15 vesicles or more	W. meybholae Palacios-Vargas, 1987
—	Postantennal organ with 4 to 5 vesicles	W. zeppelini D'Haese & Thibaud, 2011
21	Tibiotarsi I and II with 11 setae; tibiotarsi III with 10 or 11 setae	W. budenbrocki Hüther, 1959
—	All tibiotarsi with 12 setae	22
22	Antennal segment IV with two subcylindrical s-setae	W. brevispina Hüther, 1962
—	Antennal segment IV with four subcylindrical s-setae	W. panamaensis sp. nov.

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