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# LITTORAL *WILLEMIA* (COLLEMBOLA: HYPOGASTRURIDAE) OF CHINA WITH A DESCRIPTION OF TWO NEW SPECIES AND A NEW CASE OF CONVERGENCE BETWEEN HYPOGASTRURIDAE AND ONYCHIURIDAE

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ABSTRACT

Two new species *Willemia antennomonstrum* **sp. nov.** collected in Hainan and *W. dhaesei* **sp. nov.** collected in Shandong from sand beaches of the Pacific coast of China are described. Both species belong to the *buddenbrocki* group. *Willemia antennomonstrum* **sp. nov.** shows convergence to family Onychiuridae, because it has a remarkable expanded granulated guard sensilla in sensory organ of antennal segment III. *Willemia dhaesei* **sp. nov.** differs principally from other members of the group by presenting a *m*-row of setae on abdominal segment IV. *Willemia koreana* Thibaud & Lee, 1994 (*anophthalma* group) is recorded in China for the first time; having been found at Zhejiang.

Key Words: springtail, taxonomy, Pacific coast, sensilla, chaetotaxy

RESUMEN

Se describen dos nuevas especies, *Willemia antennomonstrum* **sp. nov.** recolectada en Hainan y *W. dhaesei* **sp. nov.** recolectada en Shandong, ambas de las playas de arena de la costa Pacífica de China. Ambas especies pertenecen al grupo *buddenbrocki*; la especie nueva *W. antennomonstrum* muestra una convergencia hacia la familia Onychiuridae debido a la notable ampliación de la sensilla de guardia granulada en el órgano sensorial del segmento III de la antena. Se diferencia de la especie nueva, *W. dhaesei,* de otros miembros del grupo, principalmente, por las setas desarrolladas de la fila-*m* en el IV segmento abdominal. Se registra la especie, *W. koreana* Thibaud y Lee, 1994 (grupo *anophthalma*) por primera vez en China (Zhejiang).

Palabras clave: colémbola, nuevas especies, taxonomía, litoral, China

The genus *Willemia Börner, 1901* includes 42 species most of which live in deep layers of soil and/or sand (D'Haese 1998, 2000; D'Haese & Weiner 1998, D'Haese & Thibaud 2011). *W. anophthalma* Börner 1901 (Tamura & Zhao 2000), *W. shanghaiensis* Yue 1999, *W. wandae* Tamura & Zhao 1997, and *W. zhaoi* Tamura, Yin & Weiner 2000 were recorded inland in terrestrial biotopes of China. On the Pacific littoral of Asia, the genus was already recorded in Vietnam (Thibaud 2002, 2009) but never in China. In the course of our investigation of littoral Collembola of China, 3 species of *Willemia* have been discovered, 2 of which are described as new in present paper. One of the species possessed remarkable granulated sensilla in antennal organ III, which until now has been unknown for the family. This work is our second contribution and the second interesting discovery pertaining to Collembola of sandy and large smooth pebbled or shingly beaches of China (Potapov et al. 2011).

## MATERIALS AND METHODS

All specimens were collected by the flotation method and mounted on slides using Hoyer's solution and dried in an oven at 60 °C. Drawings were done under a microscope with a drawing tube. Our notation of setae and sensilla follows D'Haese (2000) with minor modification.

We used the following abbreviations in the descriptions: Th. – thoracic segment, Abd. – abdominal segment, Ant. – antennal segment, Man. – manubrium, MSPU – Moscow State Pedagogical University (Russia), PAO – postantennal organ, s – sensillum/a, SIPPE – Shanghai Institute of Plant Physiology and Ecology (China).

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*Willemia Antennomonstrum*
**sp. nov.** (Figs. 1-7)

Material Examined

Holotype. Female, Qizi Bay, 19°21' N 108°40'E, sand beach (No. 39), vicinity of Changhua town, Changjiang County, Hainan Province (western coast), South China, 7-IV-2011, leg. Y. Bu, C. W. Huang, M. B. Potapov and N. A. Kuznetsova. Paratypes. 4 females (No. 36, 38, 40 and 45) and 1 male (No. 39), same as holotype; 1 female (No. 13), West Island (Western part), 18°14' N 109°22'E, sandy beach, Sanya City, Hainan Province, South China, 5-IV-2011, leg. as holotype. Holotype and 5 paratypes are deposited in SIPPE, 1 paratype is deposited in MSPU. Other materials. 5 juveniles, as holotypes.

Description. Adult. Length about 0.5 mm. Tegumental granulation normal. Antennae somewhat shorter than head's diagonal dimension. Antennal segments III and IV only slightly divided. Antennal segment I and II with 6 and 11 setae, respectively (Fig. 2). Sensory organ of antennal segment III consisting of 2 expanded granulated guard sensilla curved in same direction, 2 rod-like internal sensilla set together and hidden behind a tegumental fold, and 1 ventrolateral microsensillum. Guard sensilla subequal to guard setae. Antennal segment IV with 4 subcylindrical sensilla (*el, e2, d, i1),* 2 large globular bifurcated sensilla *e3* and *i2*, hidden in a mutual cavity, external part of the cavity with microsensillum. Subapical organelle large, well-visible, pin-like, with aperture on tip, set in more exposed part of the cavity, between bifurcated sensilla. Apical vesicle simple and globular (Fig. 1).

PAO oval, with 18–19 vesicles arranged in 2 rows (Fig. 2). Seta a1 and c1 absent on the head. Mouthparts well-developed. Labral formula 2/534 (Fig. 5). Labium with 4 basomedian and 5 basolateral setae as common for the family. Labial palp unstudied in details, with 5 proximal setae, A-D papillae, and few guards. Maxillary outer lobe with simple palp and without sublobal hairs.

Dorsal chaetotaxy presented in Figs. 2, 3, 6. Half tergite formula of setae *s*: 2, 2/1, 1, 1, 1, 1 in *m7* and *p4* position on Th. II and III, in *p4* position on Abd. I-IV, and in *p2* position on Abd. V. Lateral seta *s* lanceolate on all tergites, medial sensilla on thorax slightly thickened, not lanceolate. Microsensilla *ms* on thorax II strong. Seta *m3* absent on Th. II and III, *m*-row absent on Abd. IV. Ventral chaetotaxy as in Fig. 7. Sternum of Abd. IV with only 11 setae on each side arranged in 3 rows. Sternum of Abd. II with *a*-row with 2 setae on each side *(a3* present). Ventral tube with 4 + 4 setae, 2 + 2 of which in a more lateral postion. Tibiotarsae I, II and III with 12 setae each, without tenent hairs (Fig. 4). Most setae of basic set have been lost and their homology is difficult to ascertain precisely. Claw toothless. Empodial appendage hardly visible, rudimentary. Anal spines small, as about as 2/3 of claw III.

Etymology

The new species is named after the very uncommon sensilla of its antennae.

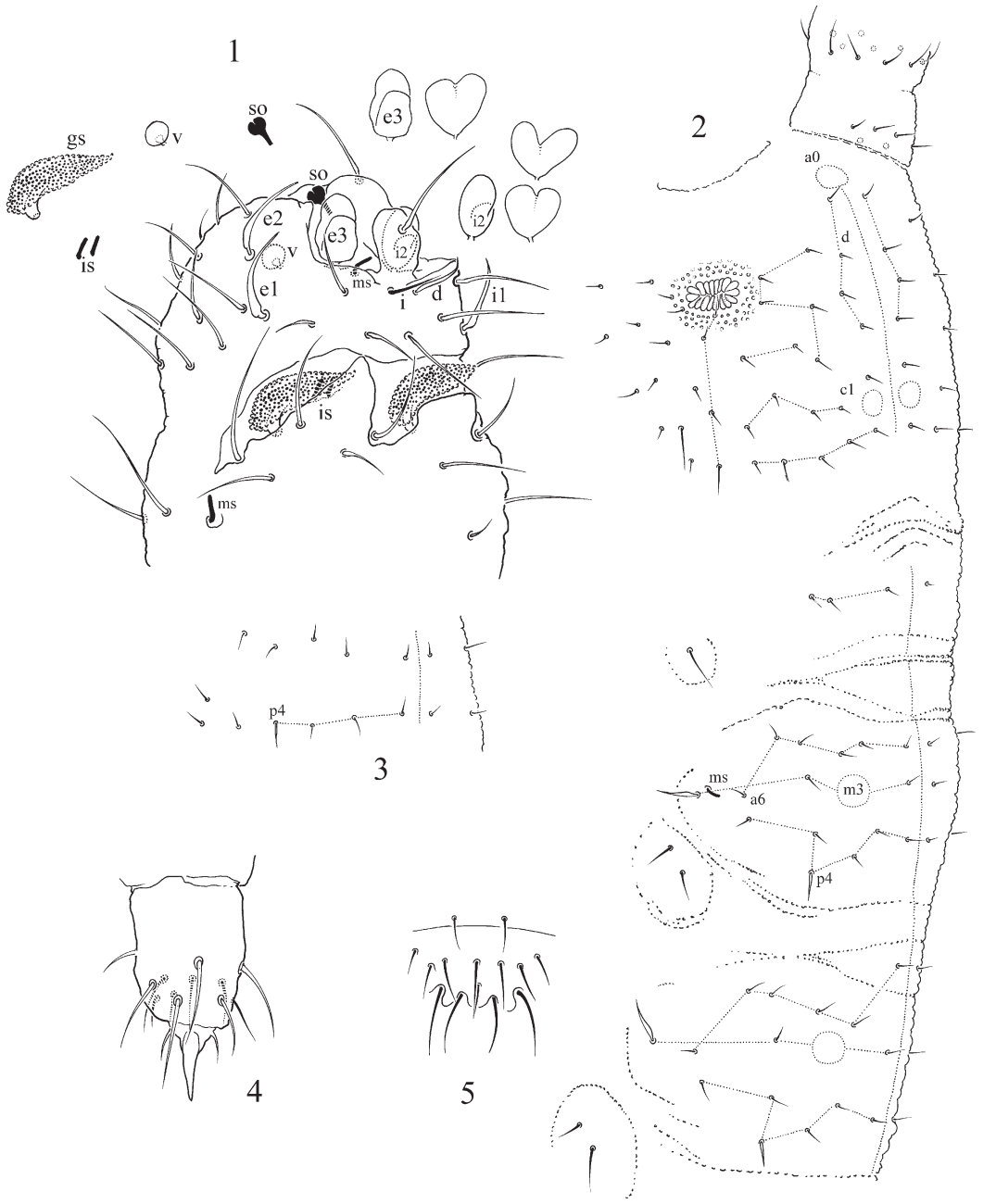
Distribution

Known only from type locality. The conditions of the locality are as for *Isotogastrura trichaetosa* (Fig. 9 in Potapov et al. 2011). *W. antennomonstrum* **sp. nov.** was collected from middle to upper part of the sand littoral.

Remarks

The large granulated sensilla of antennal organ III might suggest that this very strange species, *W. antennomonstrum*, belongs to the Tullbergiidae or the Onychiuridae. On the other hand, the absence of pseudocelli and many other traits shared with *Willemia* indicate that *W. antennomonstrum* belongs to the Hypogastruridae. Two other genera of Hypogastruridae are known, i.e., *Biscoia* Salmon, 1962 and *Acherongia* Massoud & Thibaud, 1985, which also present a complex antennal organ similar to that in the Onychiuridae. We suppose that *W. antennomonstrum* and the 2 above mentioned genera evolved independently and, therefore, this similarity does not truly indicate a phyletic relationship between these taxa. Apart from antennal organ III this species well matches the *Willemia buddenbrocki* group as defined by D'Haese & Weiner (1998). Thus on antennal segment IV, the large *e3* and *i2* sensilla are roundish and are placed in cavities and covered by a tegumental fold; antennal segment I and II present with 6 and 11 setae, respectively, and seta *a0* absent on the head. *Willemia antennomonstrum* is readily differentiated from all congeners by the broad flame-shaped granulated guard sensilla (vs. thin, tubular and smooth) in antennal organ III, bifurcated sensilla *e3* and *i2* (vs. merely globular) and large pin-shaped subapical organelle (vs. small and hardly visible) in antennal segment IV. In chaetotaxy, *W. antennomonstrum* **sp. nov.** differs in 11 setae (vs. almost always 12) on each side of sternum of Abd. IV. Other characters of the new species are more common: seta *c1* absent on head, seta *s* in the position of *p2* on Abd. V, anal spines present, short, setae *s* are lanceolate on Abd IV and V, all tibiotarsi with 12 setae. Chaetotaxy of lateral anal lobes also confirm the *buddenbrocki*-group (Fig. 7): 15 setae are calculated as 2 *i,* 2 *hr, A, a, B, b, C, c, D, d, E, F, f* (seta *e* and *z* absent).

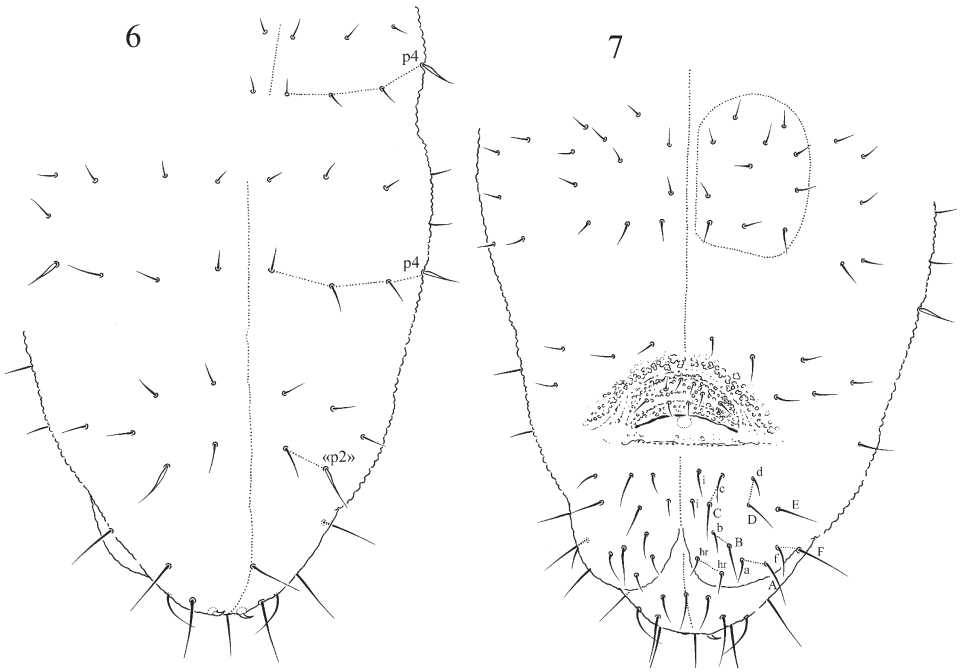
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Figs. 1-5. *Willemia antennomonstrum* **sp. nov.** 1. Ant. III and IV (outer view); 2.Chaetotaxy of Ant. I, II, head, and thorax; 3. Chaetotaxy of Abd. I; 4. Apical part of Leg III (outer view); 5. Labrum. *e1, e2, e3, d, i1, i2* = sensilla (different views and variability shown), *ms* = microsensillum, *so* = subapical organelle, *v* = apical vesicle, *gs* = guard sensillum, *is* = inner sensillum.

Recently *W. zeppelini* D'Haese & Thibaud 2011 was described from littoral of Brazil, which also has guard sensilla of antennal organ modified. However, we can easily differentiate these 2 species by following characters: much larger and granulated guard sensilla in antennal organ III in *W. antennomonstrum* **sp. nov.**, shape of sensilla *e3* and *i2* in antennal organ IV (larger and bilobed in *W. antennomonstrum* **sp. nov.** vs. only enlarged with the shape of a slightly flatted pear on *W. zeppelini*) and number of lobes in PAO (18-19 for *W. antennomonstrum* **sp. nov.** vs 4-5 for *W. zeppelini*).

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Figs. 6-7. *Willemia antennomonstrum* **sp. nov.** 6. Dorsal chaetotaxy of Abd. III-VI; 7. Ventral chaetotaxy of Abd. IV-VI.

So far, the exceptionally large guard sensilla in antennal organ III of *W. antennomonstrum* **sp. nov.** is the only known case in the family Hypogastruridae. The general appearance of such antennal organ combines rather large granulated guard sensilla (known for many Onychiuridae) and low tegumental folds (shared by Tullbergiidae and Hypogastruridae).

Using the character state definition proposed by D'Haese (2000), *W. antennomonstrum* **sp. nov.** is coded as 10032 03111 11311 11121 00122 11111 01101 11111 11011 11111 01.

### *Willemia Dhaesei* **sp. nov.**
(Figs. 8-16)

Material Examined

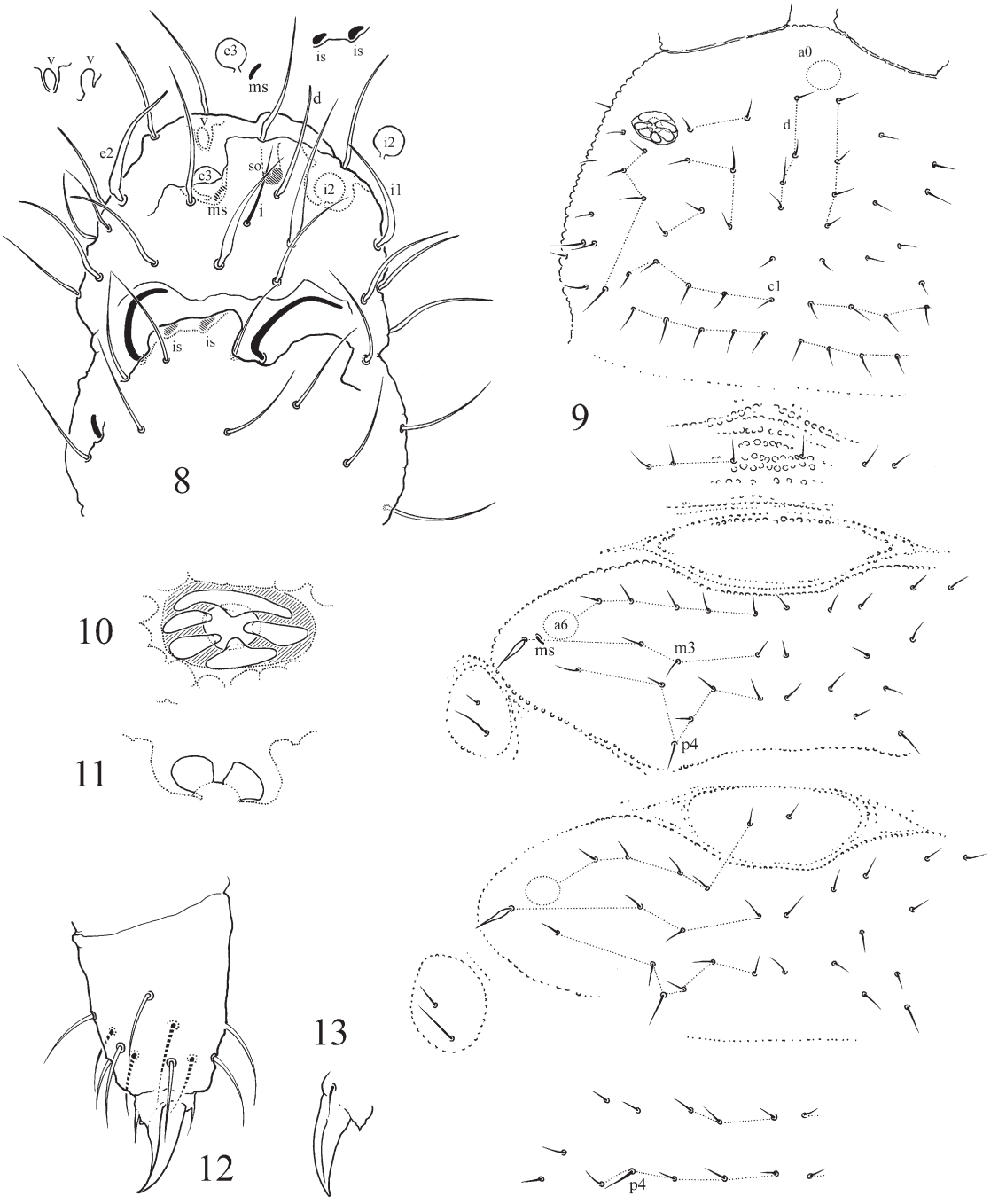
Holotype. female, Taozi Bay, 37°34' N 121°15' E, broad public beach, flotation of sand samples (No. 3), Yantai City, Shandong Province, North-East China, 20-IV-2011, leg. M. B. Potapov, Y. X. Luan and C. W. Huang. Paratypes. 3 females (No. 3, 6) and 1 male (No. 11), same as holotype. Holotype and 2 paratypes are deposited in SIPPE, 2 paratype deposited in MSPU. Other material. 1 juvenile, same as holotype (No. 3).

Description. Adult. Body length 0.4-0.5 mm. Color in alcohol white, body with short acuminate ordinary setae. Tegumental granulation normal. Antennae somewhat shorter than head's diagonal dimension. Ant. I and II with 6 and 11 setae, respectively. Antennal segments III and IV only slightly divided. Sensorial organ of Ant. III consisting of 2 long guard setae, 2 long subcylindrical sensilla, 1 ventral microsensillum, and a large integumentary fold hiding 2 internal sensilla (Fig. 8). Antennal segment IV with 3 (*e2, d, i1)* or 4 (*e1, e2, d, i1*) subcylindrical sensilla, 2 middle-sized globular sensilla *e3* and *i2*, hidden each in a separate cavity. Microsensillum set in cavity of *e3* sensillum. Sensilla *d* and *e1* (if present) hardly differentiated from ordinary seta, *i1* and *e2* subcylindrical. Two setae located near sensilla *d* flattened at basal half. Apical bulb small and oval, sometimes invisible, subapical organelle set in deep cavity, roundish (Fig. 8).

PAO roundish, hidden in hollow, with 5 to 6 tubercles, 1 or 2 of which are enlarged (Figs. 10–11). Seta *a*0 absent, *c*1 present on the head (Fig. 9). Labral formula 2/534. Postlabial setae: 3+3. Labium with 5 proximal, 4 basomedian, 5 basolateral setae, A-D papillae, and few guards (the exact number unknown).

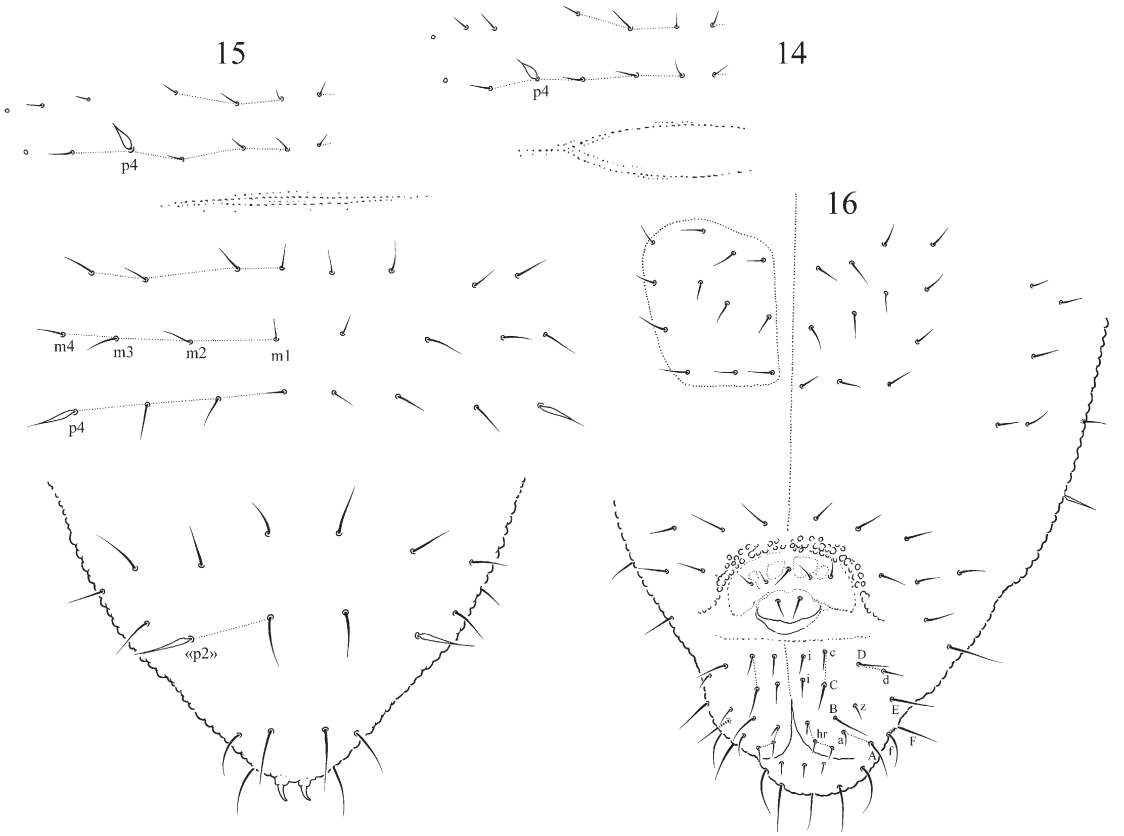
Dorsal chaetotaxy presented in Fig. 9, 14 and 15. Half tergite formula of setae *s*: 2, 2/1, 1, 1, 1, 1 in *m7* and *p4* position on Th. II and III, in *p4* position on Abd. I-IV, and in *p2* position on Abd. V. Sensilla *p*4 on Th. II-Abd. I hardly differentiated from ordinary setae. Abd. II and III with *a*2, without setea of *m*-row. Abdomen IV with completed set of *m*-row (*m1-m4*). Ventral tube with 4 + 4 setae. Ventral abdominal chaetotaxy presented in Fig. 16. Sternum

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Figs. 8-13. *Willemia dhaesei* **sp. nov.** 8. Ant. III and IV (outer view); 9. Chaetotaxy of head, thorax, and Abd. I; 10-11. Post antennal organ (PAO) (different views); 12. Apical part of Leg III (outer view; 13. Claw and empodial appendage. Abbreviations as in Figs. 1-5.

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Figs. 14-16. *Willemia dhaesei* **sp. nov.** 14 -15. Dorsal chaetotaxy of Abd. II (14) and Abd III-VI (15); 16. Ventral chaetotaxy of Abd. IV-VI.

of Abd. IV with 12 (more rarely 11) setae on each side arranged in 3 rows. Sternum of Abd. II with *a*-row with 2 setae on each side *(a3* present). Chaetotaxy of lateral anal lobes: 2 *i,* 3 *hr, A, a, B, C, c, D, d, E, F, f, z* (seta *e* and *b* absent), 16 setae altogether (Fig. 16). Asymmetries of chaetotaxy often occur. Anal spine rather long. Tibiotarsi I, II and III with 12, 12, 11 setae separately (Fig. 12). Unguis without teeth, empodial appendage vestigial (Fig. 13).

Etymology

This remarkable species is cordially dedicated to our colleague, Cyrille D'Haese, who has contributed much to the knowledge of the genus.

Distribution

Known only from type locality.

Remarks

With little doubt, the new species belongs to the *Willemia buddenbrocki* group. Among other members of the group, *W. dhaesei* **sp. nov.** is easily distinguished by the presence of *m*-row of setae on the dorsum of Abd. IV. Compared with similar congeners, the new species presents more plesiomorphic conditions in several characters: *e3* and *i2* sensilla on Ant. 4 are not very large, postantennal organ is roundish (vs. oval) and has few lobes, *m*3 on Th. II and III present (vs. absent; the loss of *m3* is one of the main apomorphies of the group). *W. dhaesei* **sp. nov.** closely resembles *W. delamarei* Prabhoo 1971 (India). These two species formally share anal spines, presence of seta *c*1 on head, and lanceolate sensilla on Abd. IV and V. Additional peculiarities of the new species are formal absence of seta *a6* on thoracic tergites (probably present in all other members of the genus, *Willemia*) and uncommon chaetotaxy of anal valves.

Using the character state definition proposed by D'Haese (2000), *W. dhaesei* **sp. nov.** is coded as 13032 03111 11?11 10101 00033 11111 01100 00111 11011 11100 01.

*Willemia Koreana* Thibaud & Lee, 1994

Material Examined

Four females, 4 males, 1 juvenile, Shengsi Island, 30°43' N, 122°30' E, sand beach (No. 2),

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Zhoushan County, Zhejiang Province, East China, 21-X-2011, Leg. Y. Bu and Y. Gao; 1 female, the same locality, 5-IV-2009, leg. M. B. Potapov, Y. X. Luan and Y. Bu.

Remarks

*Willemia koreana* belongs to the *anophthalma* group. The species is well defined due to "*p*3 position" of sensilla on Abd. V, missing seta *m*1 on Abd. IV, and empodial appendage lost. Previously *W. koreana* was known only from a sand beach in vicinities of Seoul (South Korea). Our new record makes its distribution much wider.

## Disscussion

Three species of *Willemia* were recorded from the Chinese Pacific littoral area. Compared with other regions (Mexico, Vietnam, New Caledonia) the fauna of interstitial species of *Willemia* appear to be distinct in China. Along the Pacific coast, these species possibly form the sequence: *W. dhaesei* **sp. nov.** – *W. koreana* – *W. antennomonstrum* **sp. nov.** from north to south. This geographical segregation probably reflects the climatic differences. Additional information on the presence or absence at more locations along China's Pacific coast are needed to precisely delimit these species geographically and, possibly, to provide new information concerning their ecological relationships.

## Acknowledgments

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