Ceratophysella species from mushrooms in China (Collembola, Hypogastruridae)

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Academic editor: L. Deharveng | Received 27 October 2018 | Accepted 21 January 2019 | Published 5 February 2019

Citation: Weiner WM, Xie Z, Li Y, Sun X (2019) Ceratophysella species from mushrooms in China (Collembola, Hypogastruridae). ZooKeys 822: 67–77. https://doi.org/10.3897/zookeys.822.30880

Abstract
Four species of the genus Ceratophysella living on mushrooms are reported from China, including a new species, Ceratophysella skarzynskii Weiner & Sun, sp. n., which is described from alpine mushrooms. The new species belongs to the Ceratophysella group of species with a dorsal chaetotaxy of type B and differs from the other species in a combination of characters. Ceratophysella skarzynskii sp. n. is distinguished by its small body size (maximum length 1.09 mm), number of peg-like s-chaetae (30–32) in the ventral sensory file, the trilobed apical vesicle of antennal segment IV, five modified chaetae on dens, and serrated dorsal chaetae. A key to the Chinese species of the genus has been provided.

Keywords
Ceratophysella skarzynskii sp. n., key, new species, taxonomy
Introduction

The genus *Ceratophysella* Börner, 1932 is distributed worldwide, having more than 130 species (Bellinger et al. 1996–2018). The main diagnostic characters for the genus are the pigmented body, 8 + 8 ocelli, body chaetae mostly differentiated into micro- and macrochaetae, an eversible integumental sac usually present between antennal segments III and IV, the ventral side of antennal segment IV with a sensory file often well-developed of short, erect, curved, and flattened at tips s-chaetae, unguiculus with broad basal lamella, furca well developed, mucro usually boat-like with a spoon-like apex and distinct lamella, and anal spines usually long and curved.

Until now, fourteen species of the genus *Ceratophysella* have been reported from China (Zhao 1992, Shen 1993, Liu et al. 1998, Zhao et al. 1997, Jia et al. 2010). As a common group of Collembola living on mushrooms, species have often caused significant economic damage in China (Wei 2002; Zhu 2012). Within a large collection of the mushroom Collembola in China, three known species, *C. communis* (Folsom, 1898), *C. denticulata* (Bagnall, 1941), *C. liguladorsi* (Lee, 1974), and the new species described here, *C. skarzynskii* sp. n., are reported in the present paper.

Materials and methods

Specimens were collected by hand using a brush and stored in ethanol; they were then cleared in lactic acid and KOH, and mounted in Marc André II medium. Drawings and measurements were made using a phase contrast microscope LEICA DM2500 equipped with a camera lucida.

Mushroom species were determined by the third author, Yu Li.

Abbreviations used in the descriptions:

- **Abd.** abdominal segments,
- **Ant.** antennal segments,
- **av** apical vesicle
- **AIIIO** sensory organ of Ant. III,
- **l.p.** lateral processus on labial palp,
- **ms** s-microsetae (ms) (microsensillum),
- **or** subapical organite
- **PAO** postantennal organ,
- **S** sensillum,
- **s-chaetae** sensorial chaetae on Th. and Abd.
- **Th.** thoracic segments,
- **VT** ventral tube,
- **IGA-CAS** Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences;
- **ISEA-PAS** Institute of Systematics and Evolution of Animals, Polish Academy of Sciences.

Terminology for the descriptions follows that given in Fjellberg (1984, 1999), Babenko et al. (1994), and Thibaud et al. (2004).
Taxonomy

*Ceratophysella skarzynskii* Weiner & Sun, sp. n.
http://zoobank.org/BA3F1CD5-D62C-4AFA-8450-26FB928994CA
Figs 1–3, Table 1

**Type material.** **Holotype:** preadult male, China: Jilin: Changbai Mountains, alt. 2000 m, on *Russula* sp., leg. Xin Sun, 29 July 2015. **Paratypes:** 10 females and one juvenile, the same data as holotype. Type material: the holotype and 8 paratypes are housed in IGA-CAS, China, two paratypes in ISEA-PAS, Poland.

**Diagnosis.** Dorsal chaetotaxy of type B with serrated chaetae. Maximal length 1.09 mm. Antennal segment IV with bi- or trilobed apical vesicle and ventral sensory file with 30–32 peg-like s-chaetae. Dens with seven chaetae, five of them modified.

**Description.** Body length 0.9–1.09 mm (holotype: 1.07 mm). Body colour violet or blue in alive specimens, grey or grey-black in alcohol, ventrally pale. Granulation rather coarse, 10–14 granules between chaetae *p* on Abd. V (Yosii’s parameter).

**Antennae.** Ant. IV with bilobed or trilobed apical vesicle (av), subapical organite (or), dorso-lateral microsensillum (ms), seven cylindrical, subequal sensilla (dorsal S0, S1–4, dorsolateral S7–8), ca. 30 small, peg-like sensilla and one subcylindrical sensillum in ventral sensory file (sensory rasp) (Fig. 2A, B). Ant. III-organ with two long (external) and two short (internal) curved sensilla (Fig. 2A). Microsensillum on ant. III present. Eversible sac between Ant. III–IV present (Fig. 2B). Ant. I with seven chaetae, Ant. II with 13 chaetae.

**Head.** Ocelli 8 + 8. Postantennal organ 1.5 times as large as single ocellus with four lobes of which the anterior pair is larger than the posterior pair (Fig. 2C). Accessory boss present (Fig. 2C).

**Labrum** with 5, 5, 4 chaetae, four prelabrals present. Head of maxilla of the *C. armata*-type. Maxillary outer lobe with two sublobal hairs. Labium of the *C. armata*-type, with five papillae (A–E) and six proximal chaetae. Guard chaetae *a* 1, *b* 1–2, *d* 2, *e* 2 and lateral processus (l.p.) as accessory papillae with short terminal sensillum. Guards *b* 3–4, *d* 3–4, and *e* 1–6 with long sensilla. Dorsal guards *b* 3–4, *d* 3–4, and *e* 5 distally expanded and flattened.

**Chaetotaxy.** Differentiation of dorsal chaetae into micro-/meso- and macrochaetae quite distinct (Figs 1A, 1B, 2D, 3C). Arrangement of chaetae on head typical for the genus, spine-like chaetae absent. Cephalic chaetae *d* 2, 4, *v* 2, *p* 3,4, *g* 1, 5, *l* 0,1, *l* 11 as macrochaetae. Dorsal chaetotaxy of B type (sensu Gisin 1947, Bourgeois and Cassagnau 1972, and Babenko et al. 1994) (Fig. 1B). Chaetae of medium length, pointed and serrated. Th. I with macrochaetae *p* 4, without *p* 2. Th. II–III with macrochaetae *p* 2 (shifted forward), *p* 5,6, *m* 5, chaetae *m* 4 and *m* 5 (Th. II with *m* 4 and microsensillum ms), chaeta *p* 4, *m* 6 as sensorial chaetae *s*, chaetae *a* 2 as long as *a* 1. Abd. I–III with macrochaetae *p* 2,6, sensorial chaetae *s* = *p* 5. Abd. IV with macrochaetae *p* 1,3,6, s-chaetae as *p* 4. Abd. V with macrochaetae *p* 1,5, 4 + 4 a-chaetae inside two macrochaetae *p* 5 (*a* 2,2 absent, chaeta *a* 5

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straight above $p_5$) (Figs 1B, 3C). Body s-chaetae relatively long, but shorter than macrochaetae, only on Abd. V as long as macrochaetae $p_{1,5}$ (Figs 1A, B, 3C).

**Tibiotarsi** I, II, III with 19, 19, 18 chaetae respectively, including one acuminate tenent hair A, each, femora with 13, 13, 12 chaetae, trochanters with 7, 7, 7 chaetae, coxae with 3, 7, 8 chaetae, subcoxae II with 0, 3, 3 chaetae, subcoxaeI with 1, 2, 3 chaetae. Claws with inner tooth and two pairs of lateral teeth. Empodial appendage with broad basal lamella and apical filament reaching slightly below inner tooth (ratio empodial filament: inner edge of claw = 0.47) (Fig. 3A). Ventral tube with 4 + 4 chaetae.

**Retinaculum** with 4 + 4 teeth. Furca well developed. Ratio dens + mucro: inner edge of claw III = 2.11: 1, ratio dens: mucro = 1.79: 1. Cuticular skeleton of furca well visible. Dens with uniform granulation and seven dorsal chaetae of which five are modified, two strongly thickened and three moderately so; basal macrochaeta longer than others chaetae, shorter than dens (3/5 of its length). Mucro boat-like with clear outer lamella (Fig. 3B, D).

**Anal spines** as long as inner edge of claw III slightly curved, situated on basal papillae, colourless (Figs 1B, 3C).
**Etymology.** The species is cordially dedicated to our colleague and friend Dr Dariusz Skarżyński, a prominent Polish specialist in Hypogastruridae, Collembola.

**Remarks.** The new species belongs to the *armata*-group of species, group B ( Abd. tergum IV with $p_1$ as macrochaeta) and subgroup B2 ( Abd. tergum IV without chaeta $p_3$) (Bourgeois and Cassagnau 1972). Among the species which could belong to this subgroup, *C. skarzynskii* is most similar to four species: *C. denisana* (Yosii, 1956), *C. empodialis* Babenko, 1994, *C. longispina* (Tullberg, 1876) and *C. scotica* (Carpenter & Evans, 1899) after authors and Babenko et al. (1994).

**Table 1.** Morphological characters for *C. skarzynski* sp. nov. and similar species: *C. denisana* Yosii, 1954 (Yosii 1956), *C. empodialis* Babenko, 1994, *C. longispina* (Tullberg, 1876) and *C. scotica* (Carpenter & Evans, 1899) after authors and Babenko et al. (1994).

| Species/characters | *C. denisana* | *C. skarzynskii* | *C. empodialis* | *C. longispina* | *C. scotica* |
|--------------------|--------------|-----------------|-----------------|-----------------|-------------|
| Maximal body size (mm) | 1.20 | 1.09 | 1.80 | 2.00 | 2.00 |
| Yosii’ parameter | 14–16 (20) | 10–14 | 8–13 | 12–16 | 13–15 |
| Ant.IV: apical vesicle | trilobed | trilobed | simple/slightly bilobed | simple/slightly bilobed | simple |
| Ant.IV: number of peg-like chaetae in ventral file | >50 | 30–32 | 20 | max. 15 | 15–20 |
| Maxillar palp: number of sublobal hairs | 2 | 2 | 2 | 2 | 1 |
| Dorsal chaetae | smooth | serrated | rather smooth | serrated | rather smooth |
| Th.II–III: length of chaetae $s = p_4/p_1$ | $p_1 > p_3$ | $p_1 > p_3$ | $p_1 > p_3$ | $p_1 = p_3$ | $p_1 = p_3$ |
| Abd. V: chaetae $s = p_2/p_1$ | $p_2 = p_1$ | $p_2 = p_1$ | $p_2 < p_1$ | $p_2 = p_1$ | $p_2 < p_1$ |
| Tibiotarsial tenent hair | ? | pointed | pointed | ? | pointed |
| Empodial appendage : inner edge of claw | $±1\frac{1}{2}$ | $±1\frac{1}{2}$ | $±1\frac{1}{4}$ | $±1\frac{1}{2}$ | $±1$ |
| Empodial basal lamella : inner edge of claw | 1/4 | 1/5 | 1/5 | ? | 1/5 |
| Lateral teeth of claw | basal 3 pairs | 2 pairs | 2 pairs | 2 pairs | 2 pairs |
| Chaetae on dens: total number/nume of modified chaetae | 7/5 | 7/5 | 7/2 | 7(8)/2 | 7/2 |

**Ceratophysella communis** (Folsom, 1898)

*Acorutes communis* Folsom, 1898: 52.

Syn: *Hypogastrura yuasai* Yosii, 1954: Yosii 1960.

**Studied material.** China: Henan: Zhengzhou, on *Pleurotus ostreatus*, 7 specimens on slides and 20 in alcohol, leg. Xin Sun, 05 Dec 2014; China: Henan: Zhumadian, on
Figure 2. *Ceratophysella skarzynskii* sp. n. **A** ant. III and IV dorsal **B** ant. III and IV dorsal **C** PAO and eyes **D** macro-, microchaetae and s-chaeta. Scale bars: 0.01 mm.

*Pleurotus ostreatus*, 9 specimens on slides and 50 in alcohol, leg. Zhijing Xie, 10 Nov 2017; China: Zhejiang: Pinghu, on *Pleurotus ostreatus*, 13 specimens on slides and 100 in alcohol, leg. Xin Sun, 07 Dec 2014; China: Sichuan: Qingchuan, on *Morchella esculenta*, 4 specimens on slides and 30 in alcohol, leg. Zhijing Xie, 19 Mar 2017.

*Ceratophysella denticulata* (Bagnall, 1941)

*Achorutes denticulatus* Bagnall, 1941: 218.  
Syn: *Achorutes armata* var. nov. *cuspidate* Axelton, 1905: Thibaud et al. 2004.
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*Achorutes distinguendus* Bagnall, 1941: Thibaud et al. 2004.

*Hypogastrura (Ceratophysella) exilis* Yosii, 1956: Yosii 1965.

*Hypogastrura (Ceratophysella) afghanistanensis* Stach, 1963: Thibaud et al. 2004.

**Studied material.** China: Tibet: Lasa, on *Ganoderma* sp., 9 specimens on slides, leg. Weiping Xiong, 27 Mar 2015.

*Ceratophysella liguladorsi* (Lee, 1974)

*Hypogastrura liguladorsi* Lee, 1974: 95.

**Studied material.** China: Zhejiang: Wuyi, on *Lentinus* sp., 11 specimens on slides and 80 in alcohol, leg. Xin Sun, 09 Dec 2014.

Figure 3. *Ceratophysella skarzynskii* sp. n. **A** tibiotarsus and claw III **B** dens and mucro **C** abd. V and VI **D** set of dens chaetae. Scale bars: 0.01 mm.
Key to the Chinese species of *Ceratophysella*

In 2007 Wu and Yin proposed a key to the six species of the genus *Ceratophysella* known from China. Jia et al. (2010) proposed a list of 14 Chinese species of *Ceratophysella*. The present key includes 15 species. Some of the species are not sufficiently described, but the available characters given in the descriptions are sufficient to include them in the key. The characters for *C. adexilis* have been verified on type material, and for *C. communis* on fresh material from the type locality (Tokyo).

1 Abd. IV with p1 chaeta shorter than p2 chaeta (A-type) ................................................. 2
   – Abd. IV with p1 chaeta longer than p2 chaeta (B-type) ................................................. 9
2 Dens with 6 chaetae ........................................................................................................... 3
   – Dens with 7 chaetae ......................................................................................................... 5
3 Unguiculus as long as 1/2–1 of internal edge of claw ......................................................... 4
   – Unguiculus very short, as long as 1/3, claw without teeth. *C. zhangi* (Zhao, 1998)*
4 Labial palp with 4 papillae (papilla C absent), macrochaetae rather short, Th. II
   with p4 = s longer than macrochaeta p5 .......................................................... *C. succinea* (Gisin, 1949)
   – Labial palp with 5 papillae (papillae A–E present), macrochaetae long, Th. II with
   p4 = shorter than macrochaeta p5 .......... *C. taiguensis* Jia, Skarżyński & Li, 2010
5 Body chaetae smooth ........................................................................................................ 6
   – Body chaetae serrated ..................................................................................................... 8
6 Dens with thickened chaetae ............................................................................................. 7
   – Dens without thickened chaetae ..................................................................................... *C. yinae* (Yue & Fu, 2000)
7 Four internal chaetae on dens thickened, Ant. IV with 8 dorsal sensilla ................
   ................................................................................................................................. *C. baichengensis* Wu & Yin, 2007
   – Two internal chaetae on dens thickened, Ant. IV with 7 dorsal sensilla ..............
   ................................................................................................................................. *C. adexilis* Stach, 1964
8 Abd. V tergum with chaeta a2′ present, Ant. IV with simple apical vesicle, Abd. IV
   tergum with p5=s equal to ½ macrochaetae .............................................................. *C. denticulata* (Bagnall, 1941)
   – Abd. V tergum without chaeta a2, Ant. IV with bi- or trilobed apical vesicle, Abd
   IV with chaeta p5=s equal to ¼ macrochaetae .......... *C. communis* (Folsom, 1898)
9 Abd. V tergum with cuticular projection or medial spines ............................................ 10
   – Abd. V tergum without such projection or spines ..................................................... 11
10 Abd. V tergum with medial cuticular projection, dens with 7 normal chaetae,
   ventral sensory file (sensory rasp) with ca. 40 peg-like sensilla .................................
   ................................................................................................................................. *C. liguladorsi* (Lee, 1974)
   – Abd. V tergum with chaetae p1 modified in spines, dens with 7 chaetae among
   which two modified, central sensory file (sensory rasp) with ca. 25–35 peg-like
   sensilla .................................................. *C. duplicispinosa* (Yosii, 1954)
11 Head with chaetae d5 and sd5 modified into spines ....................................................... 12
   – Head without chaetae modified into spines ............................................................. 13

* following the description in Tamura and Zhao 2008
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12 Length of unguiculus as 1/3 of inner edge of claw, tibiotarsi with A1 (tenten hair) short (= ½ of inner edge of claw) .................................................................

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C. xiaoi (Tamura, 1998) (in: Tamura and Zhao 1998)
– Length of unguiculus as 1/2 of inner edge of claw, tibiotarsi with A1 (tenten hair) long (= length of inner edge of claw) ....C. anshanensis (Wu & Xie, 2007)

13 Head without a pair of cornea-like convexity ................................................. 14
– Head with a pair of cornea-like convexity .....................C. sinensis Stach, 1964

14 Dens with thickened chaetae, tibiotarsi with prolonged chaeta A1 as pointed
tenent hair, claws with one internal tooth and two pairs of lateral teeth ............

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C. skarzynskii sp. n.
– Dens without thickened chaetae, tibiotarsi without prolonged chaeta A1, claws
without internal and lateral teeth ......................C. flectochaeta Lin & Xia, 1983

Acknowledgements

We would like to express our thanks to Dariusz Skarżyński, Anatoly Babenko, and Louis Deharveng for their valuable and helpful advice. We are also grateful to Taizo Nakamori for collecting C. communis specimens in the type locality. The present study was mainly supported by funding from the National Basic Research Program of China (No. 2016YFA0602303-1), the National Natural Science Foundation of China (No.: 41571052, 41430857, 41811530086), the Science and Technology Development Plan Project of Jilin Province (No. 20160520051JH), the Postdoctoral Science Foundation of China (No. 2015M570281), the funding provided by the Alexander von Humboldt Foundation, the Youth Innovation Promotion Association, CAS, and the academic exchange program between Chinese and Polish Academies of Sciences.

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