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THE GENUS *CERATRIMERIA* BÖRNER, 1906 (COLLEMBOLA: NEANURIDAE, PSEUDACHORUTINAE) IN THE FAUNA OF JAPAN

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Summary. Two Japanese species, *Ceratrimeria takaoensis* (Kinoshita, 1916) and *C. yasumatsui* (Uchida, 1940), were redescribed based on fresh material, including that from the type localities and using modern morphological criteria. The main diagnostic characters of the genus *Ceratrimeria* are also discussed. In addition, nucleotide sequences of the mitochondrial cytochrome c oxidase subunit 1 and 16S ribosomal RNA genes of specimens obtained from the type localities of both congeners are analyzed allowing for their species statuses to be confirmed. Barcoded specimens are deposited in the National Museum of Nature and Science, Tsukuba, Japan and the DNA sequence data are available in the International Nucleotide Sequence Databases.

Key words: α -taxonomy, springtails, redescription, DNA sequencing, East Palaearctic.

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Резюме. На основе современных морфологических критериев переописаны два японских вида *Ceratrimeria takaoensis* (Kinoshita, 1916) и *C. yasumatsui* (Uchida, 1940). Для описаний были использованы новые материалы, собранные, в том числе, в типовых местообитаниях этих видов. Обсуждаются основные диагностические признаки рода *Ceratrimeria*, отличающие его от родственных форм. Кроме того, проанализированы нуклеотидные последовательности митохондриального гена цитохром оксидазы (CO1) и 16S рибосомной РНК особей, собранных в типовых местообитаниях обоих видов, что позволило подтвердить их видовой статус. Баркодированные особи помещены на хранение в Национальный музей природы и науки, Цукуба, Япония, а данные о последовательностях ДНК доступны в международных базах данных.

INTRODUCTION

The genus *Ceratrimeria* Börner, 1906 presently comprises 11 species and is widely distributed in the tropics and subtropics of the Old World, ranging from Japan to New Zealand (Bellinger *et al.*, 1996–2021). Initially, it was established by Carl Börner for *Schöttella maxima* Schött, 1901, known from New Guinea. The description of the latter species was not too detailed, not only because of the traditions of that time, but also because of the limited material (a single specimen) considered. Börner, when proposing a diagnosis of his new genus, significantly supplemented the description of the species based on material collected later on Java, Indonesia. Unfortunately, those additions partly contradicted Schött's original description, as did most subsequent redescriptions of this species (Schött, 1917, Handschin, 1926a). More importantly, Börner's diagnosis included a wrong statement: *Mandibeln anscheinend fehlend* (Börner, 1906: 167), *i.e.* mandibles apparently lost. All this has led to the diagnosis of the genus having been changed several times during the first half of the 20th century (Massoud, 1967) and it still remains unclear. According to the present concept of the genus, it includes species with the characteristics of the genus *Pseudachorutes* Tullberg, 1871, which have an expanded and flattened body (possessing pronounced *paratergites du 3 type*). Such a diagnosis proposed by Massoud (1967) seriously restricts the scope of the genus. For instance, Salmon (1942, 1944) listed 11 *Ceratrimeria* species for New Zealand, although only three of them are still treated as its representatives (Bellinger *et al.*, 1996–2021).

On the contrary, the Japanese species, *C. takaoensis* (Kinoshita, 1916) and *C. yasumatsui* (Uchida, 1940), both presently treated as representing the genus *Ceratrimeria*, were originally described as members of the genus *Pseudachorutes*. Nevertheless, both authors compared their new species with known species of the genus *Ceratrimeria*, rather than *Pseudachorutes*, *i.e.* with *C. maxima* and *C. pulchella* Handschin, 1926, respectively. Therefore, their transfer to the genus *Ceratrimeria*, performed by Yosii (1977) in a checklist of Japanese springtails, was apparently justified, although this was not confirmed by additional morphological studies. All contemporary views on the morphology of these species (*e.g.*, Hasegawa & Tanaka, 2013) are based on their original descriptions, which are quite old-fashioned.

It seems noteworthy that there are several genera with overlapping diagnoses listed among the subfamily Pseudachorutinae. Thus, species characterized by the presence of 8+8 ocelli, PAO and full-sized furca can be classified at least within four different genera: *Pseudachorutes*, *Ceratrimeria*, *Aethiopella* Handschin, 1942, and *Halachorutes* Arlé, 1966. A series of papers by South American authors (*e.g.* Queiroz & Fernandes, 2011; Queiroz & Zeppelini, 2017; Paz *et al.*, 2019) have recently attempted at a more clear delimitation of the Neotropical genera of Pseudachorutinae. There are also recent studies discussing this issue based on the Old World fauna (*e.g.* Zon *et al.*, 2014). Their results are pretty encouraging. However, in the case of *Ceratrimeria*, everything is complicated by the fact that almost all known descriptions of species in this genus, with the only exception (see below), are clearly outdated. This undoubtedly hinders the adequate characterization of the genus and its differences from closely related groups within Pseudachorutinae. And this accounts for objective to redescribe those two interesting Japanese species using modern standards and requirements.

We do not intend to present a new, updated diagnosis of the genus, since this obviously requires a redescription of its type species. The task of this paper is more modest, *i.e.* to find out what is in common and combines the redescribed species with congeners, additionally to their special body shape.

METHODS OF MOLECULAR ANALYSIS

Three specimens of both *C. takaoensis* and *C. yasumatsui* from the respective type localities and three specimens of *C. takaoensis* from a non-type locality were subjected to molecular analysis. Partial regions of the mitochondrial cytochrome c oxidase subunit 1 (CO1; 658 bp) and 16S ribosomal RNA (16S; 445 bp) genes were selected as primary and supporting DNA barcoding markers, respectively. The supporting marker previously used for Japanese Collembola (Aoyama *et al.*, 2015; Saitoh *et al.*, 2016; Babenko & Nakamori, 2017; Potapov *et al.* 2017; Nakamori *et al.*, 2020; Ohira *et al.*, under review) was included in this study for cases for which the primary marker was not available. To study a specimen both morphologically and molecularly, DNA was extracted as described in Aoyama *et al.* (2015), with complete specimens being boiled in buffer. The DNA barcode sequence fragments were amplified using PCR and the DNA sequences of the fragments were determined by a direct Sanger sequencing. Nested PCR was performed with extracted DNA as the first-run template and with 1/100-diluted amplicon of the first run as the second-run template, using the primers in Table 1. Each PCR mixture contained 2 μ L of DNA template, 6.25 μ L of 2 \times PCR buffer, 0.5 μ M of each primer, 0.4 mM of dNTPs, and 0.25 units of DNA polymerase (KOD ONE; Toyobo). Water was added for a total reaction volume of 12.5 μ L. The PCR conditions consisted of 98°C for 30 s; 45 cycles at 98°C for 10 s, 55°C for 5 s, and 68°C for 1 s, with a final 30-s extension at 68°C. The PCR products were cleaned using a Agencourt AMPure XP (Beckman Coulter, Inc.). The DNA was sequenced from both directions using primers M13 and M13R by FASMAC, Japan. The sequences of both genes were aligned using MUSCLE (Edgar, 2004). Uncorrected pairwise distances (p-distances) among specimens were estimated using MEGA X (Kumar *et al.*, 2018) for both genes. Barcoded specimens were deposited in the National Museum of Nature and Science, Tsukuba, Japan (institution code: NSMT) and the DNA sequence data are presently available in the International Nucleotide Sequence Databases (INSD). The DNA sequence data are available in the Barcode of Life Data System (BOLD).

Table 1. Museum voucher numbers, INSD accession numbers and BOLD process ID of specimens examined for DNA barcoding.

Species	Locality	Museum voucher No.	INSD accession No. for CO1 gene	INSD accession No. for 16S gene	BOLD process ID
<i>C. takaoensis</i>	Mt. Takao (type locality)	NSMT-Ap 580	LC638483	LC638477	TNDTD0001-21
		NSMT-Ap 581	LC638484	LC638478	TNDTD0002-21
		NSMT-Ap 582	LC638485	LC638479	TNDTD0003-21
	Chino	NSMT-Ap 583	LC638486	LC638480	TNDTD0004-21
		NSMT-Ap 584	LC638487	LC638481	TNDTD0005-21
		NSMT-Ap 585	LC638488	LC638482	TNDTD0006-21
<i>C. yasumatsui</i>	Mt. Hikosan (type locality)	NSMT-Ap 577	not available	LC638474	TNDTD0007-21
		NSMT-Ap 578	not available	LC638475	TNDTD0008-21
		NSMT-Ap 579	not available	LC638476	TNDTD0009-21

Abbreviations used in the text and figures. *Abd.*1–6 – abdominal segments; *Abds.*1–4 – abdominal sterna; *Ant.*1–4 – antennal segments; *AO* – antennal organ on *Ant.*3; *B* – anterolateral ocellus; *E*, *F*, *G*, and *f* – common set of setae on basomedial part of labium (submentum) named according to Massoud (1967); *hr* – microsetae on anal valves; *i* – microseta on *Ant.*4; *L* – tiny spinulose seta on papilla in apical part of labial palp (Massoud

1967); *ms* – microsensillum; *or* – organite on antennal tip; *PAO* – postantennal organ; *S1–S4* and *S7–S9* – dorsal and dorsolateral sensilla on *Ant.4* numbering according to D’Haese (2003); *sgv* and *sgd* – ventral and dorsal guard sensilla of *AO*, respectively; *Th.1–3* – thoracic segments; *VT* – ventral tube.

TAXONOMY

Ceratrimeria takaoensis (Kinoshita, 1916)

Figs 1–2, 11–21

Pseudachorutes takaoensis Kinoshita, 1916: 495 (type locality: Japan, Honshu, Mt. Takao).

MATERIAL EXAMINED. Topotypes (14 ex.): Japan, Honshu Island, Tokyo Prefecture, Hachioji city, Mt. Takao, 485 m alt., 35.6225° N, 139.2452° E, rotten wood, 24.VII 2017, 4 ex., T. Nakamori leg.; the same locality, 28.VIII 2019, 8 ex., A. Ohira, M. Kataoka & T. Nakamori leg.; the same locality, 25.VI 2021, 2 ex., A. Ohira & T. Nakamori leg. **Other material:** Japan, Honshu Island, Nagano Prefecture, E Chino city, Kitayama, surroundings of Mugikusa Hutte, GPS 93: 2037 m alt., 36.0544° N, 138.3326° E, humid valley forest with old *Abies* trees, litter & turf (*Lycopodium*, *Carex*, *Polytrichum*), under bark, 12.VIII 2016, 8 ex. (No 2016-46R); the same site and date, but GPS 94: 2029 m alt., 36.0540° N, 138.3318° E, 2 ex. (No 2016-50R) and 5 ex. (No 2016-51R), under *Abies* bark. All M. Potapov & N. Kuznetsova leg.

DNA BARCODE. Three specimens each from Mt. Takao (the type locality, 35.6225° N, 139.2452° E, 24.VII 2017) and Chino (36.0544° N, 138.3326° E, 12.VIII 2016) were barcoded. Museum voucher numbers and INSD accession numbers are given in Table 1. The values of p-distance between the two populations were less than 0.02 and 0.1 for the CO1 and 16S genes, respectively (Table 2).

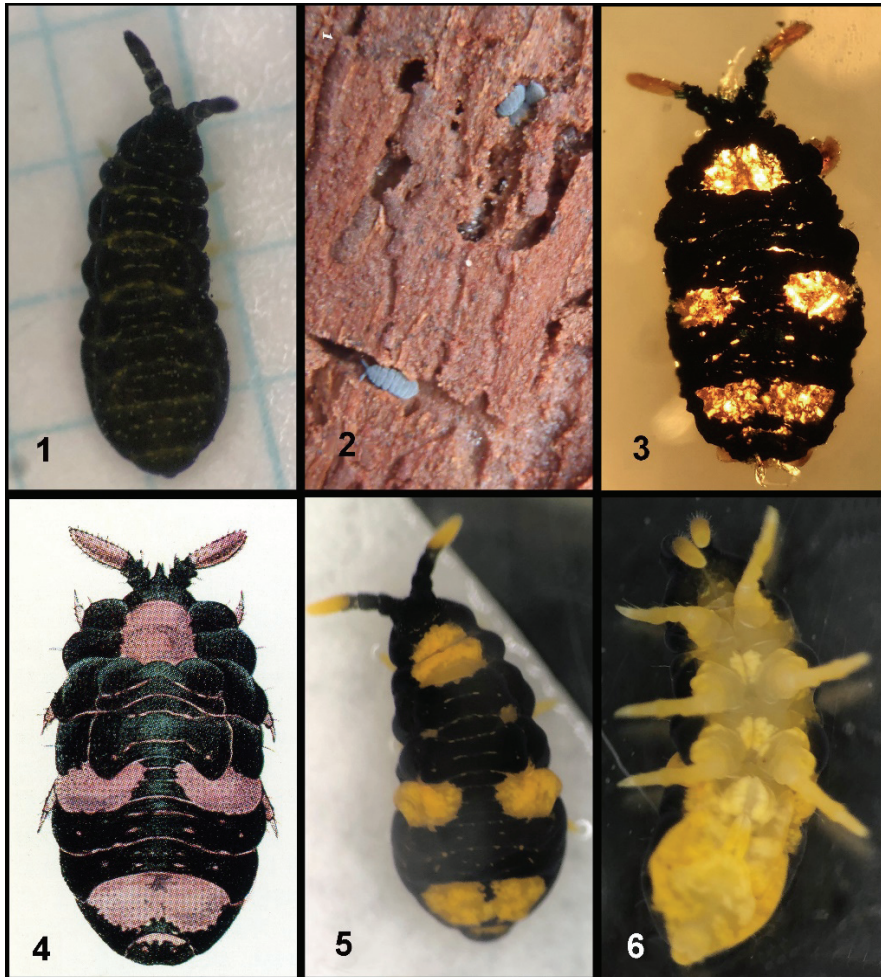
Table 2. Range of p-distances within and between groups.

Group	CO1 gene			16S gene		
	A	B	C	A	B	C
A: <i>C. takaoensis</i> (Mt. Takao)	0–0.002	0.009–0.012	-	0	0.009	0.173–0.176
B: <i>C. takaoensis</i> (Chino)	-	0–0.002	-	-	0	0.178–0.180
C: <i>C. yasumatsui</i> (Mt. Hikosan)	-	-	-	-	-	0–0.002

REDESCRIPTION. Length (without antennae) of largest available specimens 2.0–3.3 mm [not given in Kinoshita (1916)]. Body wide, 0.8–1.3 mm in the widest area in region of *Abd.2–3* (length : width = 2.5–3.0), *Abd.6* small, but clearly visible from above, *Abd.5* with rounded posterior edge. Dorsal side uniformly deep grey-blue in colour (Figs 1–2), ventral side in contrast to dorsum almost colourless. Ground colour slightly yellowish in alive specimens and white in alcohol (at least in the Mt. Takao population). Hypodermic blue pigment intense, covering entire dorsal side of body from antennae to *Abd.6*, apart from foveae and intersegmental borders, scarce pigmented spots also present on ventral side and legs. Tegumental granulations uniform and not especially strong.

Antennae about as long as head diagonal or slightly longer, ratio as 1.0–1.2 : 1 [*isometric* after Kinoshita], *Ant.3–4* usually longer than *Ant.1–2* taking together, ratio as 1.1–1.4 : 1. *Ant.3–4* fused dorsally, ventral separation well marked. *Ant.4* with a trilobed apical vesicle,

external *ms*, subapical *or* and seta *i* present; dorsal sensilla rather thin, not clearly differentiated from other dorsal setae of *Ant.4* (Fig. 15), their number unstable; ventral side of *Ant.4* with a well-developed ventral sensorial field consisting of about 100 short, pointed, truncate or slightly clavate microsetae (Fig. 16). Inner sensilla of *AO* together with dorsal guard (*sgd*) moved to middle part of *Ant.4*, inner sensilla partly covered with a cuticular fold; ventral guard (*sgv*) with *ms* in usual position in proximal part of *Ant.3-4*. *Ant.1* and *Ant.2* with 11–12 and 13–14 setae, respectively, setae on dorsal side being shorter than ventral or lateral ones.



Figs 1–6. *Ceratrimeria takaoensis* (1–2) and *C. yasumatsui* (3–6): 1 – alive specimens (N424) from the type locality (Mt. Takao); 2 – specimens under bark of *Abies* tree (Chino); 3 – type specimen (slide); 4 – general appearance after Uchida (1965, reproduced with a permission from the Hokuryu-kan, unauthorized copying prohibited); 5 – alive specimen (N322) from the type locality (Mt. Hikosan), dorsal view; 6 – the same, ventral view.

Head with 8+8 subequal ocelli. *PAO* narrowly elliptical consisting of 20–25 densely packed vesicles, located in deep rim (Fig. 17). Buccal cone elongate. Maxilla styliform with two tiny apical teeth (Fig. 14), lamellae not clearly seen. Mandible delicate, with one large basal and two smaller apical teeth (Fig. 13). Distal edge of labrum rounded with four tiny papillae, number of labral setae as follows: 4/2-3-3-4 (Fig. 19). Main part of labium with four proximal ordinary setae and distal seta *L* on tiny papilla, labial organites invisible; submentum with a usual set of four setae (*E*, *F*, *G*, and *f* in an unusual position), lateral part of labium (mentum) with (5)6 setae (Fig. 18). Perilabial area with 5 setae on each side. Head with 2+2 long setae along ventral line.

Dorsal chaetotaxy as in Figs 11–12: tergal sensilla 4–6 times longer than ordinary microsetae; their number per half tergum as follows: 22/21111. Lateral *ms* on *Th.2* present. Microsetae numerous, forming two irregular lines on most terga, excluding *Th.1* (Fig. 11). Dorsal side of head also with numerous tiny setae, two setae located laterally to ocellus *B* and *PAO* clearly longer.

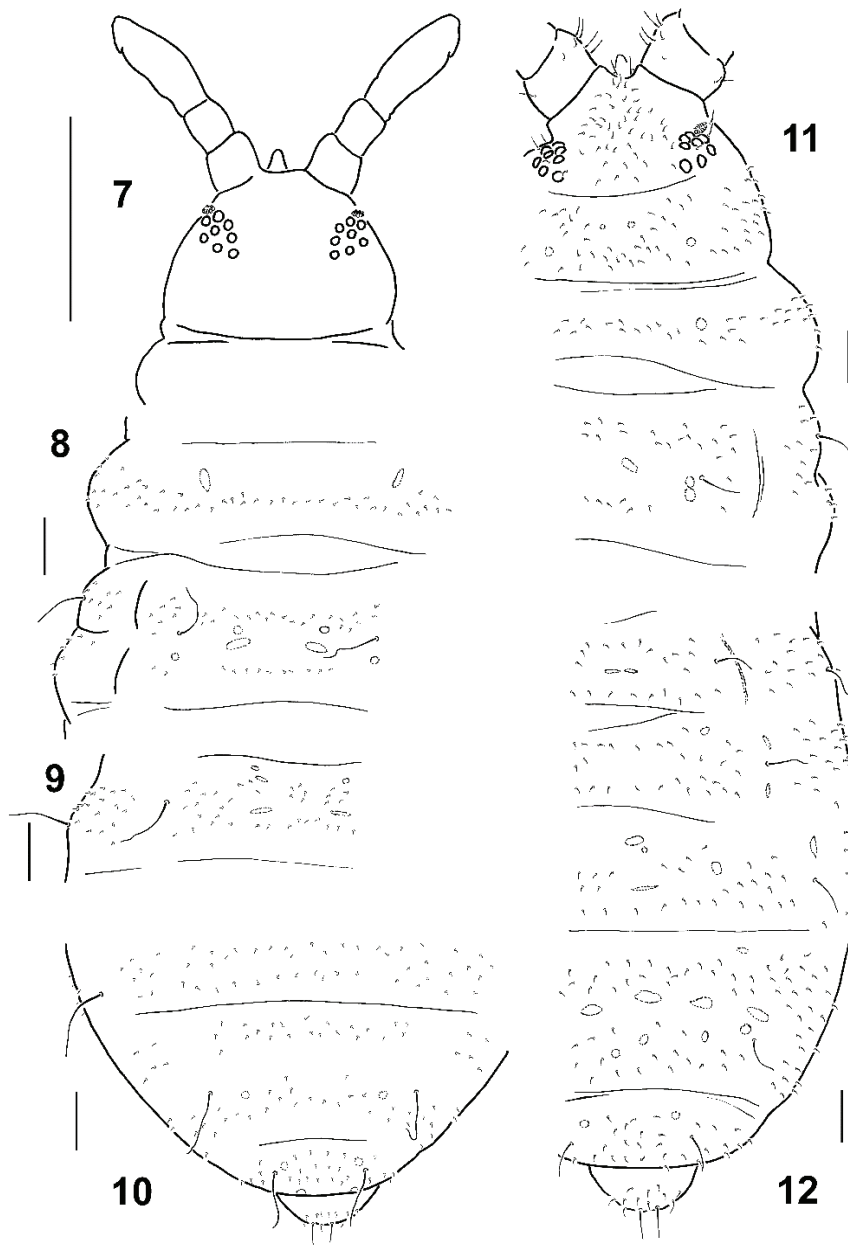
Thoracic sterna without setae. *VT* in all available specimens with 3+3 setae (two anterior and one posterior on each side). Ventral abdominal setae much longer than dorsal ones, clearly differentiated and also rather numerous. Main characteristics: sternum of *Abd.1* usually with 1+1 setae, *Abds.2* with 2–4 (usually 3) ventral setae on each side, number of ventral setae on *Abds.3–4* high and unstable (Fig. 21). Each anal valve with two setae *hr*. Tenaculum with 3+3 teeth. Furca rather long, almost reaching *VT*. Manubrium with 8+8 setae on main part, 8–9 setae around macroseta on each basolateral lobe and four basal setae in line (Fig. 21). Dorsal side of dens with six setae and uniform granulation. Mucro long and straight, about half of dens, tip slightly upturned, lateral lamellae long and subequal, basal part on dorsal side granulated (Fig. 21), ventral side with a keel reaching tip (as in Fig. 35).

Upper subcoxae of all legs covered with tiny and numerous setae similar to dorsal ones, other parts of legs with usual number of longer setae. Legs 1–3 with 0, 2, (1)2 setae on lower subcoxae, 3, 6–8, 8 setae on coxae, 6, 6, 6 on trochanters, 13, 12, 11–12 setae on femora and 19, 19, 18 setae on tibiotarsi, respectively. Unguis with a strong tooth in lower third of inner edge, a subapical pair of lateral teeth also present, one of them usually being larger. Empodial appendage absent.

REMARKS. All specimens studied are immature with only a trace of the genital orifice on the sternum of *Abd.5* (Fig. 20), and at least some of quantitative details given above should be taken with caution.

Ceratrimeria takaoensis is rather similar to *C. yasumatsui* (see redescription below), the second known Japanese species of the genus. Apart from the different colour pattern (uniform in *C. takaoensis* vs several large bright spots on dark background in *C. yasumatsui*, cf. Fig. 1 & Fig. 5), the two species differ in the number of basal teeth on the mandible (one vs two in *C. yasumatsui*) and the relative lengths of dorsal setae and sensilla (setae in *C. takaoensis* are slightly longer, but the sensilla are shorter, their ratio as length of sensilla : microsetae = 4–6 : 1 in *C. takaoensis* vs 10–12 : 1 in *C. yasumatsui*). There are also rather distinct differences in antennal structures: a lesser number of dorsal sensilla, as well as short sensilliform setae in ventral file on *Ant.4* in *C. takaoensis* (cf. Figs 23–25 & Figs 15–16). The number of setae on *Ant.2* in *C. takaoensis* is usually likewise lesser: 13–14 vs 14–15 (up to 19) in *C. yasumatsui*, but this character is probably age/size dependent.

DISTRIBUTION AND ECOLOGY. A characteristic corticolous species living under the bark on dead trunks (Fig. 2) and also in rotten wood which is still known from only two habitats located in the central part of the island of Honshu (Tokyo and Nagano prefectures).



Figs 7–12. Dorsal chaetotaxy of *Ceratrimeria yasumatsui* (7–10) and *C. takaoensis* (11–12). Scales: Fig. 7 – 1 mm, 8–12 – 0.1 mm.

***Ceratrimeria yasumatsui* (Uchida, 1940)**

Figs 3–10, 22–32

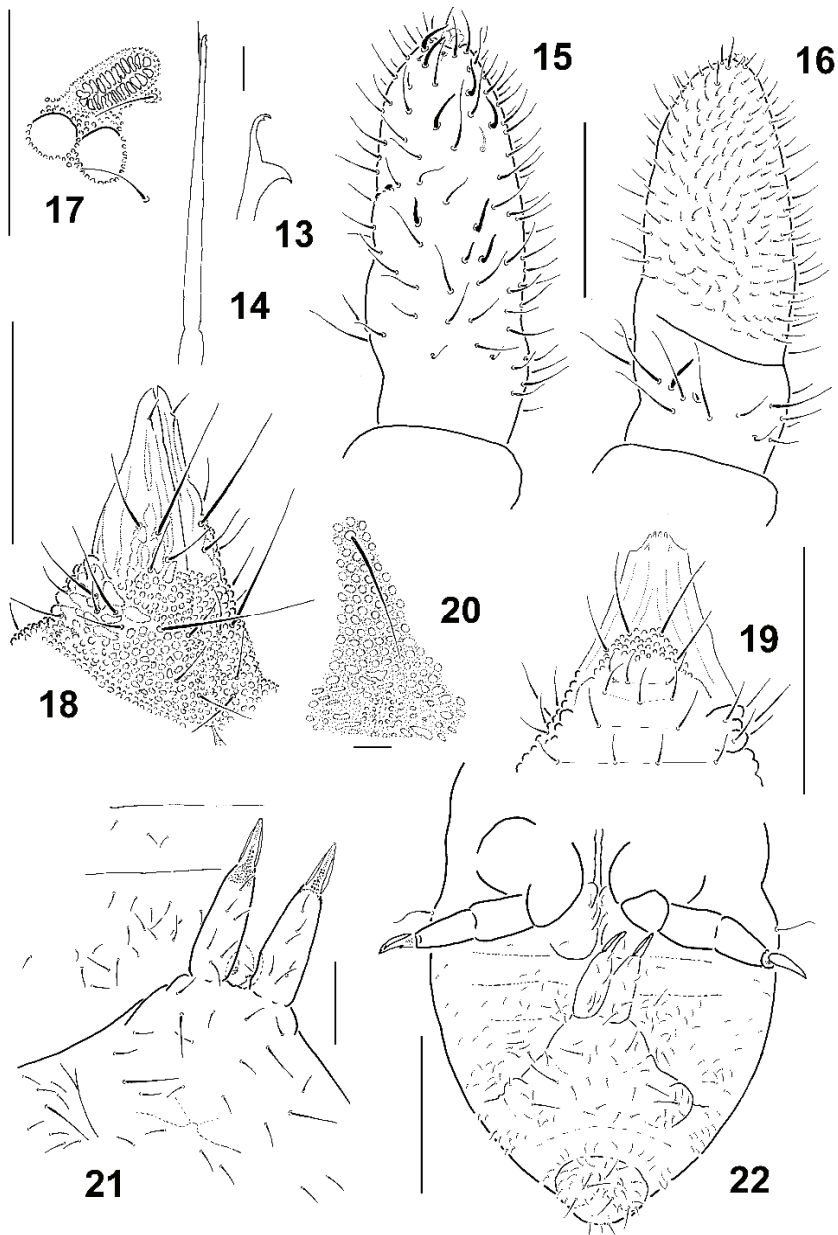
Pseudachorutes yasumatsui Uchida, 1940: 9 (type locality: Japan, Kyushu, Mt. Hikosan).

MATERIAL EXAMINED. **Cotypes** (3 ex.): Japan, Hikosan, Fukuoka Prefecture, 28.VII 1939, H. Uchida leg. (One whole and two headless specimens mounted on two slides; all kept in the Aomori Prefectural Museum, APM1618-13–14). **Topotypes**: Japan, Kyushu Island, Fukuoka Prefecture, Tagawa, Mt. Hikosan, 864 m alt., 33.4832° N, 130.9333° E rotten wood, 30.VI 2020, 7 ex., A. Ohira leg. **Other material**: Japan, Kyushu Island, Miyazaki Prefecture, Ohkawauchi, Shiiba Village, Mt. Tsunodake, Yatate, GPS 70: 1174 m alt., 32.3708° N, 131.0856° E, shadow beech forest, rotten wood, 05.VIII 2016, 1 ex. (No 2016-8); same forest, but debris and soil under rotten wood, 05.VIII 2016, 2 ex. (No 2016-9); same area, but GPS 71: 1201 m alt., 32.3648° N, 131.0865° E, *Cryptomeria* plantation, rotten wood, 05.VIII 2016, 3 ex. (No 2016-11); Miyazaki Prefecture, Kashiba, Misato-cho, foot of Mt. Sanpo-dake, along trail to waterfall, 794 m alt., 32.3541° N, 131.2101° E, evergreen forest (*Quercus*), rotten wood, 06.VIII 2016, 2 ex. (No 2016-15). All T. Nakamori, S. Saitoh, M. Potapov & N. Kuznetsova leg.

DNA BARCODE. Three specimens from Mt. Hikosan (the type locality, 33.4832° N, 130.9333° E, 30.VI 2020) were barcoded. DNA sequences of 16S gene were determined, but the CO1 gene was not successfully amplified using PCR. Museum voucher numbers and INSD accession numbers are given in Table 1. The p-distances between *C. yasumatsui* and *C. takaoensis* were greater than those noted between individuals of the same species for 16S gene (Table 2).

REDESCRIPTION. Length (without antennae) of available specimens from Miyazaki Prefecture 1.5–3.0 mm [about 2 mm after Uchida (1940)], body wide, 0.70–1.28 mm in the widest area (*Abd.2–3*), length: width = 2.1–2.3. Mounted specimens from Mt. Hikosan even larger: length 3.0–3.7 mm, width 1.4–2.1 mm. *Abd.6* small, but clearly visible from above, posterior edge of *Abd.5* rounded. Colour in alcohol deep blue with numerous small lighter spots, ocular plate bluish-black, *Ant.4* yellowish to orange. Eight more or less large colourless patches present dorsally (Figs 3–5): one medial on posterior side of head shared with *Th.1*, two smaller ones dorso-laterally at *Th.2–3* border (poorly visible in some specimens), two large patches laterally on *Abd.1*, and one medial patch covering almost all dorsal side of *Abd.4*, one small medial patch on anterior part of *Abd.5*, and one patch covering entire *Abd.6*. All these patches, as well as ventral side of body and appendages (Fig. 6), orange in alive specimens. Hypodermic blue pigment also absent from foveae and intersegmental boundaries on dorsal side of body, but usually present as sparse spots ventrally on head, body from *Th.1* to *Abd.6* and also on legs. Tegument granulations uniform and not particularly strong.

Antennae clearly longer than head diagonal (Fig. 7), ratio as 1.2–1.6 : 1, *Ant.3–4* longer than *Ant.1–2* taking together, ratio as 1.4–1.7 : 1. *Ant.3–4* fused dorsally, ventral separation well marked. *Ant.4* with a trilobed apical vesicle, external *ms*, subapical organite, seta *i* and several broaden curved sensilla present dorsally (Figs 23–24), *S9* sometimes absent, number of sensilla in *S2* position and in proximal part of *Ant.4* variable, total number of ordinary setae on *Ant.4* clearly higher than usual. Whole ventral side of *Ant.4* covered by numerous short sensilliform setae (Fig. 25). Inner sensilla of *AO* together with dorsal guard (*sgd*) moved to upper half of *Ant.4*, inner sensilla located at right angle to each other and covered by cuticular fold (Fig. 26); ventral guard (*sgv*) with *ms* in usual position in proximal part of *Ant.3–4* (Fig. 25). *Ant.1–2* with 11–12 and 14–15 (whole range 14–19) setae, respectively, setae on dorsal side being much shorter than ventral or lateral ones.



Figs 13–22. *Ceratrimeria takaoensis* (13–21) and *C. yasumatsui* (22): 13 – mandible; 14 – maxilla; 15 – *Ant.*3–4, dorsal view; 16 – the same, ventral view; 17 – *PAO* and nearest ocelli; 18 – labium; 19 – labrum; 20 – medial part of *Abds.*5; 21 – furca; 22 – ventral chaetotaxy of abdomen. Scales: Figs 22 – 1 mm, 15–16, 18–21 – 0.1 mm, 13–14, 17 – 0.01 mm.

Head with 8+8 subequal ocelli. *PAO* narrowly elliptical consisting of 20–25 densely packed vesicles, located in deep rim (Fig. 27). Buccal cone elongate. Maxilla styliform, usually with two tiny apical teeth (Fig. 31), number of lamellae uncertain. Mandible delicate, with several teeth (Fig. 30), number of subapical teeth apparently unstable. Distal edge of labrum rounded with four tiny papillae, number of labral setae usually as follows: 4/2-3-3-4 (Fig. 29) with few observed abnormalities. Main part of labium with four proximal ordinary setae and a distal seta *L* on a tiny papilla, labial organites invisible; submentum also with a usual set of four setae (*E*, *F*, *G*, and *f* in an unusual position), but mentum with 1–2 additional setae (5–6, totally) (Fig. 28). Perilabial area with 5 setae on each side, medial ones longer. Head with 2+2 long setae along ventral line.

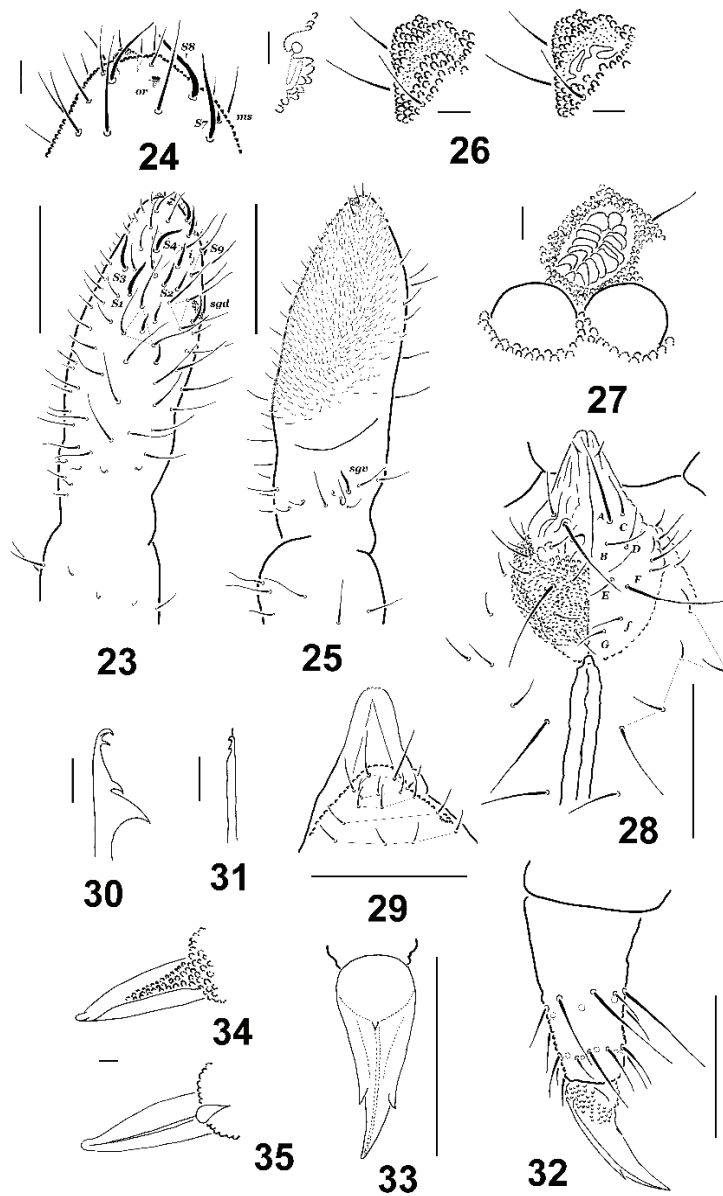
Dorsal chaetotaxy as in Figs 8–10: only long, whip-like sensilla on each tergum clearly visible, 10–12 times longer than ordinary microsetae; number of sensilla per half tergum as follows: 22/21111. *Th.2* with a lateral *ms* present. Microsetae poorly visible but very numerous, forming two irregular lines on most terga excluding *Th.1* (Figs 8–10). Dorsal side of head also with numerous tiny setae, only two setae located laterally to ocellus *B* and *PAO* longer.

Thoracic sterna without setae. *VT* in all available specimens with 3+3 setae. Ventral abdominal setae distinctly longer than dorsal ones, clearly differentiated and also numerous (Fig. 22). Main characteristics: *Abds.1* usually with 1+1 setae, *Abds.2* with 2+2 setae, number of setae on *Abds.3–4* high and unstable. Each anal valve with two setae *hr*. Tenaculum with 3+3 teeth. Furca long, reaching mid part of *VT*. Manubrium with 8+8 setae on main part, 8–9 setae around macroseta on each basolateral lobe and 4 basal setae (Fig. 22). Dorsal side of dens with six setae and uniform granulation. Mucro long and straight (mucro : dens = 0.4–0.5 : 1), lateral lamellae subequal, long and not particularly high, basal part granulated (Fig. 34), ventral side with a keel reaching tip (Fig. 35).

Upper subcoxae of all legs covered by tiny and numerous setae similar to dorsal ones, other parts of legs with a usual number of longer setae. Legs 1–3 with 0, 2, 2 setae on lower subcoxae, 3, 7, 8 setae on coxae, 6, 6, 5–6 on trochanters, 13, 11–12, 10–11 setae on femora and 19, 19, 18 setae on tibiotarsi, respectively. Unguis with a strong tooth in lower third of inner edge and a pair of lateral teeth subapically (Figs 32–33), a small tooth also present on outer side of unguis (Fig. 33). Empodial appendage absent.

REMARKS. The original description of the species (Uchida, 1940) and a colour illustration by the same author (1965) are the only existed ones. It provides only few details, namely: size, colour pattern, number of ocelli and lobes in the *PAO*, the presence of a furca and of an inner tooth on the unguis, and the relative lengths of the mucro. Some additional details are clear from the accompanying figures: the shape of the mandible (fig. E in Uchida, 1940), the presence of a trilobed apical vesicle on the apex of the antennae (fig. H) and two inner sensilla in the *AO* (fig. I). Our specimens fit this description quite well. Two smaller colourless patches at the *Th.2–3* border were not mentioned in the original description, but could be seen in the studied types. Only few inconsistencies worth mentioning were observed. The main of them are as follows: colour of patches is not *pink* or *vivid pink* as in Uchida (1940), but orange in the live specimens from Mt. Hikosan (Fig. 5), and the mucro is much longer in our specimens (~1/2 of dens vs 1/7 in the text or 1/5, according to fig. F in Uchida). We checked the type materials of *C. yasumatsui*, but unfortunately only few details could be observed. The positions of the dens and mucro allow no correct measurement to be taken, but the mucro in the type material is clearly longer than illustrated by Uchida.

No specimens studied have any traces of a genital orifice and, despite their large sizes, they all are clearly juveniles. However, the above description of most morphological characters is likely to hold for adults as well. Only some quantitative details should be taken with caution. Among them, for example, are the presence of only 3+3 setae on *VT* which is a common juvenile characteristic in the related genus *Pseudachorutes* and, apparently, a certain number of antennal sensilla and setae, which may also depend on age.



Figs 23–35. *Ceratrimeria yasumatsui*: 23 – *Ant.*3–4, dorsal side; 24 – tip of *Ant.*4; 25 – *Ant.*3–4, ventral view; 26 – inner sensilla of *AO* covered by cuticular fold; 27 – *PAO* and nearest ocelli; 28 – labium; 29 – labrum; 30 – mandible; 31 – head of maxilla; 32 – tibiotsarsus and unguis of leg 3; 33 – unguis, outer side; 34–35 – mucro, dorsal and ventral views. Scales: Figs 23, 25, 28–29, 32–33 – 0.1 mm, 24, 26–27, 30–31, 34–35 – 0.01 mm.

DISTRIBUTION AND ECOLOGY. *Ceratrimeria yasumatsui* is known from three neighboring prefectures: Fukuoka, Miyazaki and Oita (see Hasegawa & Tanaka, 2013), and appears to be widespread on the island of Kyushu. Like the previous species, it mainly inhabits cavities under bark of dead trees and also rotten wood.

DISCUSSION

Both species redescribed were originally treated as members of the genus *Pseudachorutes*, but Massoud (1967), in his key to the world fauna of this genus, omitted both due to their brief and insufficiently detailed descriptions (*d'une façon trop brève et insuffisante*, p. 168). Later, Yosii (1977), in his catalogue of Japanese Collembola, transferred them to the genus *Ceratrimeria*. Their close relationship was clear even during the initial descriptions of both species. For instance, Uchida wrote (1940: 9) that *it resembles a species of closely allied genus, Ceratrimeria pulchella Handschin from Luzon in body form and coloration...*, but differs *by the presence of mandibles*. The diagnosis of *Ceratrimeria* has since changed considerably, and the only difference remaining between this genus and the genus *Pseudachorutes* is the body shape with enlarged lateral regions of segments typical of the former genus (Massoud, 1967).

Following Massoud's key to *Ceratrimeria* both Japanese species might be identified as *C. maxima* (Schött), the type species of the genus, although three existed descriptions of the latter (Schött, 1901; Schött, 1917, Handschin, 1926a) may correspond to three different species (Massoud, 1967). The same may be true for that of Börner (1906). Unfortunately, the descriptions of almost all representative of the genus *Ceratrimeria* are out of date. The only known exception is *C. lydiae* Najt et Weiner, 1991. This species, described from New Caledonia, is fully comparable to *C. yasumatsui* and *C. takaoensis* in most important morphological characters. For example, all three species are characterized by a strong dorsal polychaetosis, a clear shift of dorsal part of *AO* to antennal apex, many sensilliform setae on the ventral side of *Ant.4*, and the elongated labium with four proximal setae. There are also many features that clearly differentiate these forms as distinct species. The most interesting one is the number of dorsal sensilla (22/21111 in *C. yasumatsui* & *C. takaoensis* vs more usual number of 22/11111 in *C. lydiae*). The presence of a pair of additional sensilla on *Abd.1* is also known for at least some Thailand (Bedos, 1994) and Indonesian species of *Ceratrimeria* (L. Deharveng, pers. comm.).

Interestingly, some of the above features shared by these three species are probably also characteristic of *C. maxima*, the type species of the genus. Thus, a shift of *AO* is clear from Tabl. XVI, fig. 3 in Schött (1901), and a probable strong polychaetosis – from fig.1 of the same table, despite its being a sketch. The ventral file covering all of the ventral side of *Ant.4* was mentioned by Börner (1906): *sehr kurze Haare ventral in der ganzen Ausdehnung des Endabschnittes*. Unfortunately, on the basis of the available descriptions, it is almost impossible to say anything definite about other species of the genus, this once again emphasizing the urgent need for updating the old descriptions concerning this interesting group with a probable South Pacific distribution pattern covering Japan, Thailand, Indonesia, India, Philippines, Papua New Guinea, Australia, New Caledonia and New Zealand (Massoud, 1967, Suhardjono, 1989; Bedos, 1994; Greenslade, 1994, 2015, etc.). If the set of features mentioned above, *i.e.* the antennae with a highly developed sensorial field on *Ant.4* and an apical displacement of *AO*, as well as the dorsal chaetotaxy with numerous tiny microsetae and very long sensilla, is indeed characteristic of *C. maxima*, then this very set of characters will probably define the genus rather well and differentiate it from most known species of *Pseudachorutes*.

We were able to spot only one species (and genus) with similar morphological characters among unrelated Pseudachorutinae, namely, *Notachorudina rapoportii* Queiros et Zeppelini, 2017. This endemic Neotropical species also shows antennae with an apically displaced *AO*

and more than 90 truncate setae in the ventral sensorial field, both thorax and abdomen pluri-chaetotic with small ordinary setae and long sensilla, as well as the labium with four setae and a distal seta *L* on papilla, but it differs clearly in having no *PAO* and a strong toothed maxilla with long fringed lamellae, as well as many other unique features. It is highly likely that among the numerous tropical species of the subfamily, other forms with a similar set of characters can be found, and additional studies are clearly needed to obtain a justified and accurate diagnosis of the genus *Ceratrimeria*.

The molecular data for the *C. takaoensis* and *C. yasumatsui* specimens from the type localities reported here enable identification of the species using DNA barcodes. Although DNA barcode data for the nomenclature type are ideal for DNA barcoding, we did not expect to sequence the nomenclature types of the two species are not expected because of DNA damage. An alternative is sequencing fresh specimens obtained from the type locality under the assumption that the molecular character has not been changed dramatically after the original description (Porco *et al.*, 2012). Here, although nucleotide sequences of the CO1 gene, a standard animal DNA barcoding marker, could not be determined for *C. yasumatsui*, the 16S gene proved efficient at discriminating these species, as shown with other species of Collembola (Nakamori *et al.*, 2020). Unfortunately, molecular data for *Ceratrimeria* and related taxa are limited at present. Further accumulation of data is needed to confirm the status of the genus using molecular traits.

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REFERENCES

- Aoyama, H., Saitoh, S., Fujii, S., Nagahama, H., Shinzato, N., Kaneko, N. & Nakamori, T. 2015. A rapid method of non-destructive DNA extraction from individual springtails (Collembola). *Applied Entomology and Zoology*, 50: 419–425.
- Arlé, R. 1966. Un nouveau collembole marin du littoral brésilien. *Revista Brasileira de Biologia*, 26 (4): 367–372.
- Babenko, A. & Nakamori, T. 2018. Two new littoral species of the genus *Anurida* Laboulbène, 1865 (Collembola, Neanuridae) from the Pacific coast of Asia. *Zootaxa*, 4425: 575–581. DOI: <https://doi.org/10.11646/zootaxa.4425.3.10>
- Bedos, A. 1994. *Les Collemboles édaphiques du massif du Doi Inthanon, Thaïlande: biodiversité et écologie en forêt tropicale*. Unpublished PhD Thesis, Université Paul Sabatier, Toulouse, France. 348 pp.
- Bellinger, P.F., Christiansen, K.A. & Janssens, F. 1996–2021. *Checklist of the Collembola of the World*. Available on: www.collembola.org (accessed 05 July 2021).
- Börner, C. 1906. Das System der Collembolen nebst Beschreibung neuer Collembolen des Hamburger Naturhistorischen Museums. *Mitteilungen Naturhistorisches Museum Hamburg*, 23: 147–188.

- D'Haese, C.A. 2003. Homology and morphology in Poduromorpha (Hexapoda, Collembola). *European Journal of Entomology*, 101: 385–407.
- Edgar, R.C. 2004. MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research*, 32: 1792–1797.
- Folmer, O., Black, M., Hoeh, W., Lutz, R. & Vrijenhoek, R. 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Molecular Marine Biology and Biotechnology*, 3: 294–297.
- Greenslade, P. 1994. Collembola. In: Houston, W.W.K. (Ed.) *Zoological Catalogue of Australia. Volume 22. Protura, Collembola, Diplura*. Melbourne: CSIRO Australia, pp. 19–138.
- Greenslade, P. 2015. Updating the New Zealand checklist of Collembola: a synonymy and new combinations. *New Zealand Journal of Zoology*, 42 (4): 259–269. DOI: <http://dx.doi.org/10.1080/03014223.2015.1070882>
- Handschin, E. 1926a. Ost-Indische Collembolen. III. Beitrag zur Collembolenfauna von Java und Sumatra. *Treubia*, 8 (3–4): 446–461.
- Handschin, E. 1926b. Collembola from the Phillipines and New Caledonia. *The Philippine Journal of Science*, 30: 235–239.
- Handschin, E. 1942. Materialien zur Revision de Collembolen. Die Gattung *Ceratrimeria* C.B. sensu Womersley. *Verhandlungen der Naturforschenden Gesellschaft in Basel*, 53: 265–284.
- Hasegawa, M. & Tanaka, S. 2013. Classification of the family Neanuridae (Hexapoda: Entognatha: Collembola) from Japan 2. Subfamilies Brachystomellinae Massoud, 1967, Odontellinae Massoud, 1967, Frieseinae Massoud, 1967 and Pseudachorutinae Massoud, 1967. *Edaphologia*, 92: 37–73. [In Japanese]
- Kinoshita, S. 1916. Three new species of Japanese Collembola. *Zoological Magazine, Tokyo (Dobutsugaku zasshi)*, 28: 494–498. [In Japanese]
- Kumar, S., Stecher, G., Li, M., Knyaz, C. & Tamura, K. 2018. MEGA X: Molecular evolutionary genetics analysis across computing platforms. *Molecular Biology and Evolution*, 35: 1547–1549.
- Massoud, Z. 1967. Monographie des Neanuridae, Collemboles Poduromorphes à pièces buccales modifiées. In: Delamare Deboutteville, C. & Rapoport, E.H. (Eds), *Biologie de l'Amérique Australe. Vol. 3*. CNRS, Paris, pp. 7–99.
- Najt, J. & Weiner, W.M. 1991. Collembola Poduromorpha épiédaphiques de la Réserve de la Rivière Bleue, Nouvelle-Calédonie. *Bulletin du Muséum national d'Histoire naturelle, Paris, Series 4*, 13A (1–2): 97–112.
- Nakamori, T. 2013. A new species of *Ceratophysella* (Collembola: Hypogastruridae) from Japan, with notes on its DNA barcode and a key to Japanese species in the genus. *Zootaxa*, 3641(4): 371–378.
- Nakamori, T., Ichisawa, K., Pham, H.N.-D. & Terashima, Y. 2020. A new species of the genus *Ceratophysella* (Collembola: Hypogastruridae) and the first record of *Ceratophysella liguladorsi* from Japan. *Edaphologia*, 106: 11–18.
- Ohira, A., Kataoka, M., Tanooka, A. & Nakamori, T. A new species of the genus *Crossodonthina* (Collembola: Neanuridae) from Japan. *Edaphologia* (under review).
- Paz, R.V. da, Queiroz, G.C. & Bellini, B.C. 2019. A new species of *Aethiopella* Handschin, 1942 (Collembola, Poduromorpha, Neanuridae) from Neotropical Region, with comments on the genus. *Zootaxa*, 4629 (1): 039–050. DOI: <https://doi.org/10.11646/zootaxa.4629.1.3>
- Porco, D., Bedos, A., Greenslade, P., Janion, C., Skarzynski, D., Stevens, M.I., Jansen van Vuuren, B. & Deharveng, L. 2012. Challenging species delimitation in Collembola: cryptic diversity among common springtails unveiled by DNA barcoding. *Invertebrate Systematics*, 26: 470–477.

- Potapov, M., Nakamori, T., Saitoh, S., Kuznetsova, N. & Babenko, A. 2017. New or little-known taxa of Anurophorinae (Collembola) with anal spines from East Asia with notes on DNA barcode. *Zootaxa*, 4318: 312–324.
- Queiroz, G.C. & Fernandes, L.H. 2011. New Brazilian species of *Furculanurida* Massoud, 1967 (Collembola: Neanuridae). *Zootaxa*, 2805: 57–64.
- Queiroz, G.C. & Zeppelini, D. 2017. Neotropical Pseudachorutinae (Hexapoda: Collembola: Neanuridae): A comparative morphological study with emphasis on endemic taxa. *Zoologischer Anzeiger*, 269: 127–154.
- Saitoh, S., Aoyama, H., Fujii, S., Sunagawa, H., Nagahama, H., Akutsu, M., Shinzato, N., Kaneko, N. & Nakamori, T. 2016. A quantitative protocol for DNA metabarcoding of springtails (Collembola). *Genome*, 59: 705–723.
- Salmon, J.T. 1942. Supplement to the Collembolan Fauna of New Zealand. The genus *Ceratrimeria* Börner in New Zealand and a new genus *Novacerus* to replace the genus *Neocerus* (pre-occupied). *Transactions and proceedings of the Royal Society of New Zealand*, 71: 254–259.
- Salmon, J.T. 1944. New genera, species and records of New Zealand Collembola, and a discussion of *Entomobrya atrocincta* Schött. *Records of the Dominion Museum, Wellington*, 1: 123–182.
- Schneider, C., Cruaud, C. & D'Haese, C.A. 2011. Unexpected diversity in Neelipleona revealed by molecular phylogeny approach (Hexapoda, Collembola). *Soil Organisms*, 83: 383–398.
- Schött, H. 1901. Apterygota von Neu-Guinea und den Sunda-Inseln, bestimmt und beschrieben. *Természetrzaji Füzetek kiadja a Magyar nemzeti Muzeum*, 24: 317–331.
- Schött, H. 1917. Results of Dr E. Mjöberg's Swedish Scientific Expeditions to Australia 1910–1913. 15. Collembola. *Arkiv för Zoologi*, 11(8): 1–60.
- Suhardjono, Y.R. 1989. Revised checklist of Collembola from Indonesia and its adjacent regions. *Acta Zoologica Asiae Orientalis*, 1: 1–22.
- Tullberg, T. 1871. Förteckning öfver Svenska Podurider. *Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar*, 28: 143–155.
- Uchida, H. 1940. A new species of Collembola: *Pseudachorutes yasumatsui* sp. nov. *Mushi*, 13: 9–10.
- Uchida, H. 1965. Collembola. In: Yasumatsu, K., Asahina, S. & Ishihara, T. (Eds), *Iconographia Insectorum Japonicorum Colore Naturali Edita* Vol. 3. pp. 13–15, plates 2–3, Hokuryu-kan, Tokyo. [In Japanese]
- Yosii, R. 1977. Critical checklist of the Japanese species of Collembola. *Contributions from the Biological Laboratory of Kyoto University*, 25: 141–70.
- Zon, S.D., Tano Y. & Deharveng, L. 2014. A new species of *Furculanurida* (Collembola: Neanuridae) from Ivory Coast, with comments on related genera. *Zootaxa*, 3878(5): 491–497. DOI: <https://doi.org/10.11646/zootaxa.3878.5.8>

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