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Intricatonura fjellbergi, a new peculiar genus and species of Neanurini (Collembola: Neanuridae: Neanurinae) from Great Smoky Mountains National Park

Adrian Smolis[1], and Ernest C. Bernard[2]*

Abstract

Intricatonura fjellbergi, gen. nov., sp. nov. (Neanuridae: Neanurinae: Neanurini) is described from temperate North America. The genus has a unique suite of autapomorphic morphological characters: reduction of labial chaetotaxy to 6 setae, division of DL tubercles on 2nd and 3rd thoracic tergites, rectangular and transverse shape of Di tubercles on abdominal segments I–IV, and absence of tubercles and ordinary De setae on abdomen I–IV. Morphologically, *Intricatonura* resembles *Vietnura* Deharveng & Bedos, a monotypic genus known from Vietnam.

Key Words: taxonomy; springtails; Tennessee

Resumen

Intricatonura fjellbergi gen. nov., sp. nov. (Neanuridae: Neanurinae: Neanurini) es descrito de la América del Norte templada. El género tiene un conjunto único de caracteres morfológicos autapomórficos: reducción del grupo de setas labial a seis setas, división de los tubérculos DL en el segundo y tercer tergitos torácicos, forma rectangular y transversal de los Di tubérculos en los segmentos abdominales I–IV y ausencia de tubérculos y de setas ordinarios en el abdomen I–IV. Morfológicamente, *Intricatonura* se asemeja a *Vietnura* Deharveng y Bedos, un género monotípico del Vietnam.

Palabras Clave: taxonomía; colémbolos; Tennessee

Great Smoky Mountains National Park (GSMNP) includes an area of ca. 2,200 square kilometers in the southern Appalachian Mountains in the states of North Carolina and Tennessee. The park is known for its extraordinarily rich species diversity. For example, there are more than 1,700 species of vascular plants including more native trees (130 species) than in all of Europe. The park is the home of 61 native mammals, 340 birds, 84 reptiles, nearly 50 amphibians, and over 50 fish species. It also hosts a diversity of invertebrates, especially arthropods. However, many groups of these small creatures are little known and understudied. To change the situation and to better understand and catalogue the biodiversity of GSMNP, in early 1990, dozens of scientists and trained volunteers participated in a large project, called the All Taxa Biodiversity Inventory (ATBI) (Sharkey 2001). For Collembola, Bernard & Felderhoff (2007) estimated a total of 220 species were present based on previous records and recent numerous collections, with many of the taxa being undescribed.

Among a world fauna of Collembola, the subfamily Neanurinae are the most species rich and defined by the characteristic arrangement and number of sensilla on the 4th antennal segment (Deharveng 1983). Additionally, most Neanurinae are characterized by strongly developed cuticular tubercles on the dorsal surface of the body. Although nearly 800 species of Neanurinae have been described, there are many geographical regions, including the southeastern USA, where the knowledge of this subfamily is still far from complete.

Analysis of rich materials of Collembola from GSMNP revealed a new species of Neanurini. This tribe includes more than 170 species belonging to 23 genera (Cassagnau 1989; Hopkin 1997, Deharveng & Bedos 2000; Deharveng et al. 2007; Smolis 2007, 2011; Mayvan et al. 2015; Bellinger et al. 2017). A new species from GSMNP exhibits unique features that easily separate it from other Neanurini and support the establishment of a new monobasic genus. Its description and taxonomic remarks are presented below.

Materials and Methods

The specimens were cleared in Nesbitt's fluid, subsequently mounted on slides in Swan's medium and studied with a Nikon Eclipse E600 (Nikon Instruments Inc., Amsterdam, the Netherlands) phase contrast microscope. Figures 1–14 were drawn with the aid of a camera lucida and prepared for publication using Adobe Photoshop CS3 (Adobe Systems Inc., San Jose, California, USA). The map (Fig. 15) was created using "Royalty free clip art maps" provided by www.freeusandworldmaps.com (accessed 21 June 2017).

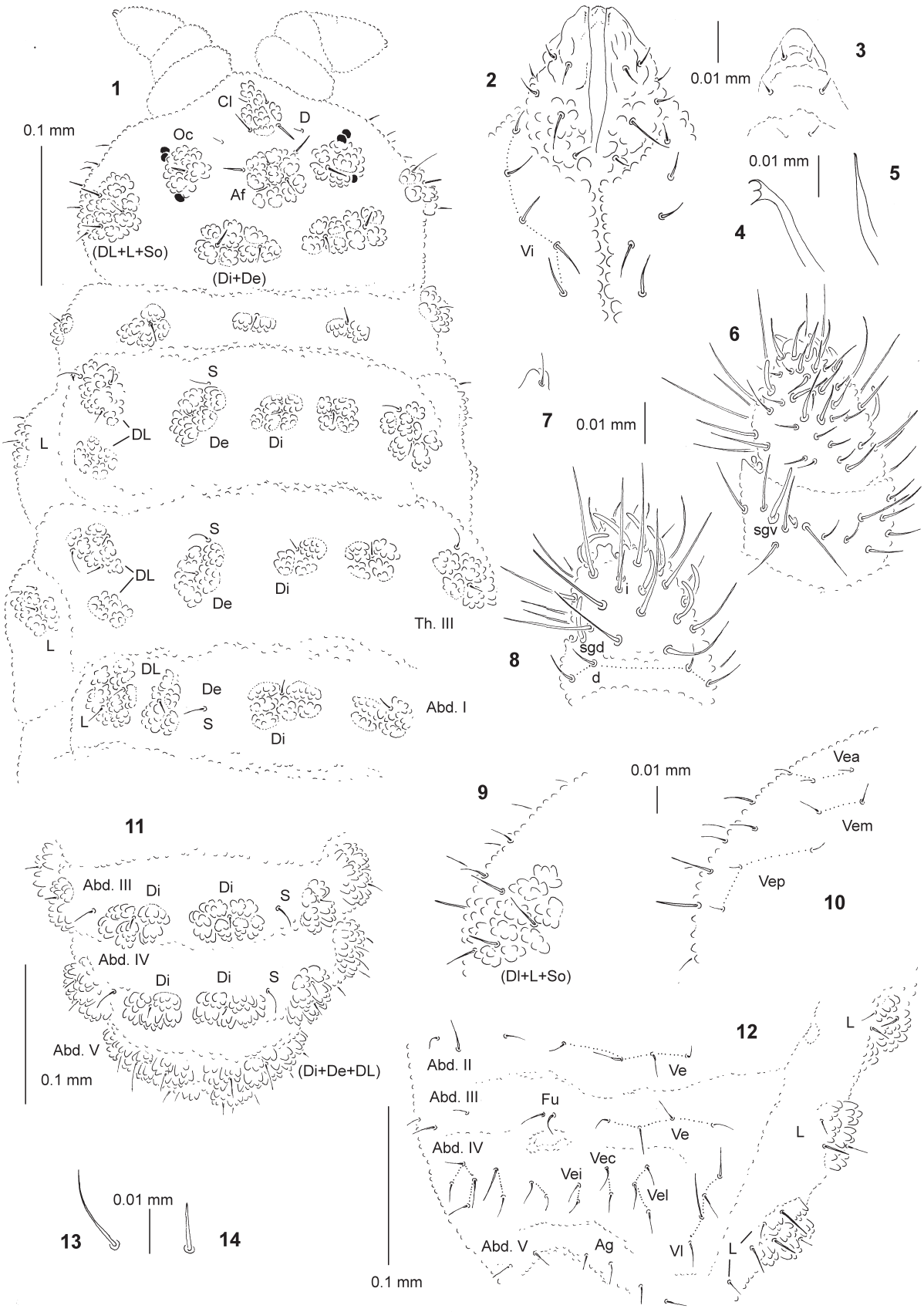
Terminology and abbreviations for the description are used following Deharveng & Weiner (1984), Smolis & Deharveng (2006), Palacios-Vargas & Simón Benito (2007), and Smolis (2008).

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Figs. 1–14. *Intricatonura fjellbergi* **sp. nov**. 1) Chaetotaxy of head, thorax and Abd. I, dorsal view of holotype; 2) Chaetotaxy of labium and Vi-group setae; 3) Labrum; 4) Mandible; 5) Maxilla; 6) Chaetotaxy of ant. III–IV, ventral view; 7) Apical vesicle, dorsal view; 8) Chaetotaxy of antennal segments III–IV, dorsal view; 9) Chaetotaxy of lateral part of head, dorsal view; 10) Chaetotaxy of lateral part of head, ventral view; 11) Chaetotaxy of Abd. III–V, dorsal view; 12) Chaetotaxy of Abd. II–V, ventral view; 13) Seta s of abdomen V; 14) seta Di1 of Abd. V.

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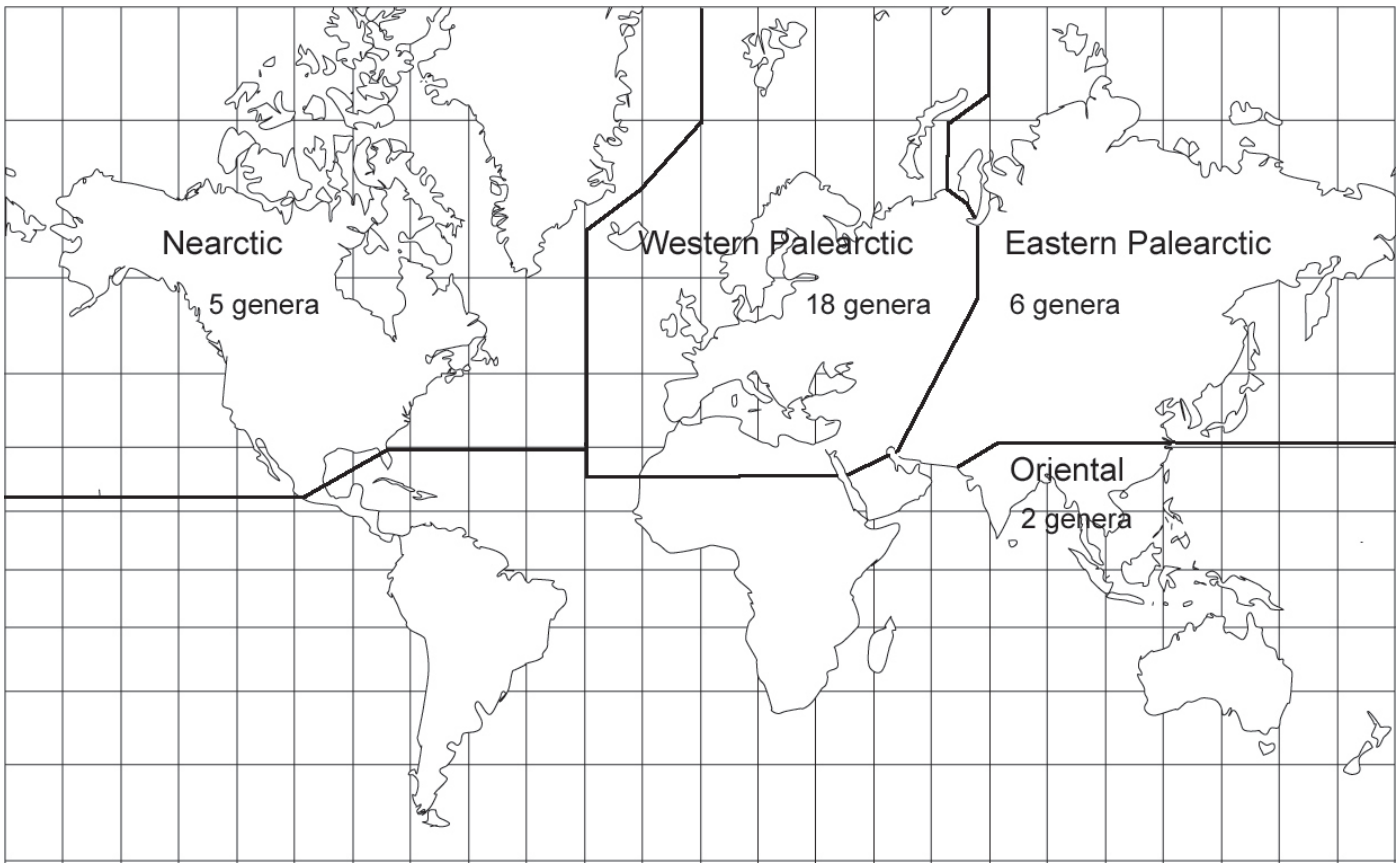


Fig. 15. Generic diversity of Neanurini and the number of genera in 4 zoogeographical regions.

Abbreviations used:

General morphology: Abd. – abdomen, Ant. – antenna, AOIII – sensory organ of antennal segment III, Th. – thorax, VT – ventral tube.

Groups of setae: Ag – antegenital, An – setae of anal lobes, ap – apical, ca – centroapical, cm – centromedial, cp – centroposterior, d – dorsal, Fu – furcal, vc – ventrocentral, Ve or ve – ventroexternal, Vea – ventroexternoanterior, Vem – ventroexternomedial, Vep – ventroexteroposterior, Vel – ventroexternolateral, Vec – ventroexternocentral, Vei – ventroexternointernal, Vi or vi – ventrointernal, Vl – ventrolateral.

Tubercles and groups of chaetae: Af – antenno–frontal, Cl – clypeal, De – dorsoexternal, Di – dorsointernal, DL – dorsolateral, L – lateral, Oc – ocular, So – subocular.

Types of setae: Ml – long macroseta, Mc – short macroseta, Mcc – very short macroseta, me – mesoseta, mi – microseta, ms – s – microseta, S – seta s, bs – S – seta on Ant. IV, miA – microsetae on Ant. IV, iv – ordinary setae on ventral Ant. IV, or – organite of Ant. IV, brs – border S – seta on Ant. IV, i – ordinary seta on Ant. IV, mo – cylindrical S – setae on Ant. IV (soies mousses), x – labial papilla x, L' – ordinary lateral seta on Abd. V.

Depositories: USNM – National Museum of Natural History, Smithsonian Institution, Washington, District of Columbia; DIBEC – Department of Invertebrate Biology, Evolution and Conservation, Institute of Environmental Biology, University of Wrocław, Poland.

Results

Family Neanuridae Börner, 1901

Subfamily Neanurinae Börner, 1901

Tribe Neanurini Salmon, 1951

Intricatonura **gen. nov.**

Type species: *Intricatonura fjellbergi* **sp. nov.**

Diagnosis. Blue hypodermic pigment present on the body. Tubercles on body well developed. Three pigmented eyes on each side of head. Mouth parts reduced, maxilla styliform, mandible thin, tridentate. Labral chaetotaxy 2/2, 2. Chaetotaxy of labium reduced with 2 basal, 2 distal, and 2 lateral setae, and without papillae x. Eight tubercles on head, with Di fused to De, and DL fused to (L + So). Chaetotaxy of tubercles Oc and (Di + De) reduced on head, with only 6 setae (Ocm, Di1 and De2) and setae Oca, Ocp, Di2 and De2 absent. Tubercle DL of Th. II–III divided into 2 components. Chaetotaxy of tubercles Di strongly reduced on Th. II–III and Abd. I–IV, with seta Di1 only. Tubercle Di of Abd. I–IV rectangle-shaped. Tubercles De on Abd. I–IV not developed. Chaetotaxy of groups De strongly reduced on Abd. I–IV, without ordinary setae. Abd. IV and V with 6 and 2 tubercles, respectively. Tubercles (Di + De + DL) on abd. V separate along midline. Cryptopygy present as Abd. VI nearly invisible from dorsal side. Tibiotarsal chaetotaxy 18, 18, 17. Claw untoothed.

The new genus constitutes a monophyletic group within Neanurini, with the following autapomorphies: reduction of labial chaetotaxy with 6 setae only, division of DL-tubercles on 2nd and 3rd thoracic tergites, presence of only 1 Di-seta on each side of Th. II–III and Abd. I–IV, rectangular and transverse shape of Di-tubercles on Abd. I–IV, and absence of tubercles and ordinary De setae on Abd. I–IV.

Some of above mentioned features, i.e., division of DL-tubercles on Th. II–III and rectangular shape of Di-tubercles on Abd. I–IV are unknown in other members of the subfamily. *Intricatonura* gen. n. re-

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Table 1. Cephalic chaetotaxy of *Intricatonura fjellbergi* **gen. nov.**, **sp. nov**.

Tubercle	Number of setae	Types of setae	Names of setae
Cephalic chaetotaxy–dorsal side			
Cl	4	Ml	F
		Mc	G
Af	6-7	Ml	B
		Mc	A, O
		me	D
Oc	1	Ml	Ocm
(Di + De)	2	Ml or Mc	Di1, De1
(DL + L + So)	11	Ml, Mc, me	not recognizable
Cephalic chaetotaxy–ventral side			
Vi	5	—	—
Vea	3	—	—
Vem	2-3	—	—
Vep	3	—	—
Labium	6, 0x	—	—

sembles most closely *Vietnura* Deharveng & Bedos, 2000, the genus created for *V. caerulea* from Vietnam (Deharveng & Bedos, 2000). Both genera share the fusion of all lateral tubercles on the head into a single mass, fusion of tubercles Di and De on head, reduction of the chaetotaxy of tubercles Di, De and Oc on the head, and presence of cryptopygy. Besides the apomorphies outlined above, they differ additionally in the number of eyes (in *Vietnura* 2, in *Intricatonura* **gen. nov.** 3), the length of dorsal macrosetae (in *Vietnura* long, at least 3 times longer than length of tubercles; in *Intricatonura* **gen. nov.** notably short, 2 or 3 times shorter than length of tubercles), the arrangement of tubercles in the central area of the head (in *Vietnura* tubercles Af and Oc fused, in *Intricatonura* **gen. nov.** separate), the number of tubercles on the penultimate abdominal tergum (in *Vietnura* 3 tubercles: 2 (De + DL) and (Di + Di), in *Intricatonura* **gen. nov.** 2 tubercles: 2 (Di + De + DL)) and the presence of seta M on the tibiotarsi (in *Vietnura* present, in *Intricatonura* **gen. nov.** absent).

Etymology. The name of the new genus is derived from the Latin combining form *intricat-* (entangled), referring to its intricate combination of characters and the common root *–nura* used for many neanurid genera.

Revised key to Neanurini genera (modified from Mayvan et al. 2015)

In order to assign the new genus within the tribe Neanurini, we modified the key published by Mayvan et al. (2015) as follows:

1. — Head with complete fusion of lateral tubercles DL, L and So. 2

1′. — Head with separation or incomplete fusion of lateral tubercles DL, L and So (e.g., only tubercles DL and L fused). 4

2. (1) Abdomen IV with tubercles Di fused . . . . . .*Monobella* Cassagnau (partim: *Monobella cassagnaui* Deharveng)

2′. — Abdomen IV with tubercles separate. 3

3. (2) Head with fusion of tubercles Af and Oc; Abdomen V with 3 tubercles: (Di + Di) and 2 (De + DL). . . . . .*Vietnura* Deharveng & Bedos

3′. — Head with separation of tubercles Af and Oc; Abdomen V with 2 tubercles: 2 (Di + De + DL) . . . . . .*Intricatonura* **gen. nov.**

Intricatonura fjellbergi **sp. nov.** (Figs. 1–14; Tables 1, 2)

HOLOTYPE 1 female USA: Tennessee, GSMNP, trail W of Clingman's Dome (35.5628°N, 83.5042°W; 1981 masl), from moss and fir litter, 7–VI–2007, A. Fjellberg (USNM).

PARATYPES 1 male and 1 female, data same as Holotype (DIBEC).

Description. Body length (without antennae): 0.7–0.9 mm (holotype: 0.9 mm). Body color diffuse greyish–blue. 3 + 3 medium-sized, pigmented eyes, on the margin of tubercle Oc (Fig. 1). Long macrosetae (Ml) notably short and thin, smooth, apically pointed (Fig. 14); short macrosetae (Mc) short and thin, pointed at apex; mesosetae short, very thin and pointed. Buccal cone short, labrum rounded, with feebly ventral sclerification (Figs. 2, 3). Chaetotaxy of antennae as in Figs. 6–8. Ant. I, II with 7, 11 ordinary setae respectively. Ant. III with 5 S-setae (AOIII) and 17 ordinary setae: 4 d, 4 vi, 4 vc and 5 ve. Ant. IV dorsally with the complete set of setae: 8 S, or, i, 12 mou and 3 brs. Apical vesicle of Ant. IV distinct and consists of 2 lobes (Fig. 7); s-setae on Ant. IV rather short and moderately thickened (Figs 6, 8). Ant. IV ventrally with complete set of setae (3 brs, 2 iv; ap: 8 bs and 5 miA; ca: 2 bs and 3 miA; cm: 3 bs and 1 miA; cp: 8 miA and 1 brs). Head tubercle (DL + L + So) with 11 setae; seta D not fused with tubercle Af; seta O present or

Table 2. Postcephalic tergal tubercle chaetotaxy of *Intricatonura fjellbergi* **gen. nov.**, **sp. nov**.

	Tubercle			
	Di	De	DL	L
Th. I	1	1	1	—
Th. II	1	1 + S	2 + S + ms	3
Th. III	1	1 + S	2 + S	3
Abd. I	1	S	1	3
Abd. II	1	S	1	3
Abd. III	1	S	1	3
Abd. IV	1	S	2	6
Abd. V		3 + S		
Abd. VI		6		

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Table 3. Distribution of genera of Neanurini in zoogeographic regions.

Region	Genera
Western Palaearctic	*Albanura* Deharveng, *Balkanura* Cassagnau, *Cansilianura* Dallai & Fanciulli, *Catalanura* Deharveng, *Caucasanura* Kuznetzova & Potapov, *Cryptonura* Cassagnau, *Deutonura* Cassagnau, *Edoughnura* Deharveng et al., *Endonura* Cassagnau, *Ghirkanura* Kuznetzova & Potapov, *Lathriopyga* Caroli, *Monobella* Cassagnau, *Neanura* MacGillivray, *Neanurella* Cassagnau, *Persanura* Mayvan et al., *Protanura* Börner, *Pumilinura* Cassagnau, *Thaumanura* Börner
Eastern Palaearctic	*Deutonura* Cassagnau, *Endonura* Cassagnau, *Metanura* Yosii, *Neanura* MacGillivray, *Kalanura* Smolis, *Tetraloba* Lee
Nearctic	*Deutonura* Cassagnau, *Endonura* Cassagnau, *Neanura* MacGillivray, *Xylanura* Smolis, *Intricatonura* **gen. nov.**
Oriental	*Neanura* MacGillivray, *Vietnura* Deharveng & Bedos

absent; seta A slightly shorter than seta B (Figs. 1, 9, 10; Table 1). S-seta formula of body 022/11111 (Figs. 1, 11; Table 2). Body S–setae slender, smooth, equal to or longer than nearby macrosetae (Figs. 1, 11, 13). Lateral (L) tubercles on Th. II and III with 3 setae (Fig. 1). Tubercle L on Abd. IV with 6 setae (1 seta not fused with tubercle, Fig. 12). Abd. VI with 6+6 setae (Table 2). Ventral chaetotaxy of abdomen as follows: ventral tube with 4+4 setae; Abd. II with 4+4 setae Ve (setae Ve1 present); Abd. III with 4+4 setae Vel, furca rudimentary with 2 mesosetae and without microsetae (Fig. 12); Abd. IV with 4+4 setae Vl, 3–4+3–4 setae Vel, 2+2 setae Vec and 2+2 setae Vei; Abd V with 3+3 setae Ag, 1+1 setae L' and 1+1 setae Vl; each anal lobes with 10–11 mesosetae and 2 microsetae. Chaetotaxy of legs from I to III as follows: tibiotarsi with 18, 18, 17 setae respectively (seta M absent); femora I, II, III with 13, 12, 11. Trochanters with 6 setae each. Coxae I, II, III with 3, 7, 8; subcoxae I, II, III with 0, 2, 2 setae, respectively. Claw relatively short, without inner denticle.

Remarks. The new species most closely resembles *Vietnura caerulea* Deharveng & Bedos, 2000, the sole species of this also monotypic genus. The differences between them are presented in the generic discussion.

Etymology. The new species is named in honor of Arne Fjellberg, eminent Norwegian collembologist and collector of the specimens.

Discussion

Within subfamily Neanurinae, the tribe Neanurini is of special interest because of its distribution and high diversity. With the exception of 2 species, *Neanura muscorum* Templeton and *Deutonura gibbosa* Porco et al. that have been become distributed worldwide presumably by human activities, all members of the tribe are exclusively found in Laurasia (Deharveng et al. 2015). The distribution of genera belonging to this tribe is provided in Table 3 and Fig. 15. Whereas Neanurini are fairly widespread and widely distributed, from western Europe to the southeastern USA, and from the Arctic to North Africa and Vietnam (e.g., Fjellberg 1985; Jordana et. al 1997; Babenko & Fjellberg 2006; Deharveng et al. 2015), almost all known genera appear to be very localized and restricted to narrow zoogeographic regions. Among 24 genera, only *Deutonura* and *Endonura* are Holarctic and reported from both the Palaearctic (Western and Eastern) and Nearctic. The other 20 taxa are restricted to 1 of 4 regions (Table 3, Fig. 15). The largest generic and species diversity of Neanurini occurs in the Western Palaearctic where currently 18 genera and 145 species are known. Thus, in this region Neanurini constitutes more than 80% of all genera and species of Neanurinae. For comparison, in areas of the eastern Palaearctic and Nearctic that are comparatively well-studied (Rusek & Marshall 1995; Deharveng & Weiner 1984), this tribe usually constitutes less than 25% of overall Neanurinae diversity. One of explanations of the observed picture and notably high generic and species richness of the tribe in the Western Palaearctic could be low diversity and, in consequence, lack or low degree of competition of other Neanurinae tribes. These tribes are represented in the mentioned zoogeographic region only by a single native species (Paranurini, Sensillanurini), a single introduced 1 (Lobellini), and a few genera with relatively small number of species (Paleonurini). In contrast to the Western Palaearctic, these tribes dominate or co-dominate, and have numerous native genera and species in the Eastern Palaearctic (Paranurini, Lobellini, Paleonurini), Oriental (Paranurini, Lobellini, Paleonurini) and Naearctic (Paranurini, Sensillanurini). It should be mentioned, however, that boreal areas of Holarctic, generally very poor in species of the subfamily, do not show the mentioned pattern in distribution of the tribe.

In spite of the apparently low diversity of Neanurini in the Nearctic, Eastern Palaearctic, Oriental and Australasian, knowledge of the tribe in these regions can be crucial in the context of its history and relationships between genera. We believe also that molecular analyses based on extensive materials of this new genus and species could help the solution of some "intricate" problems connected with its unclear systematic and taxonomic position.

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