Folsomia najtae n. sp. (Collembola: Isotomidae) – a new species with 'mobile' forms from the Far East of Russia

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ABSTRACT
Folsomia najtae n. sp. is described from the southern part of Sikhote-Alin Range (Far East, Russia). It is characterized by 6 + 6 ommatidia, a full set of ms-chaetae on body tergites, long accp3 s-chaetae on the fifth abdominal segment, four posterior chaetae on dens, and dimorphism of juvenile specimens. The properties that define the 'mobile' form are protruding cornea of ommatidia and tuberous long dens. The closely related species *F. orientalis* Martynova, 1977 and *F. setula* Christiansen & Tucker, 1977 are redescribed basing on the material from North-East of Asia and East of North America, respectively.

KEY WORDS
Sikhote-Alin Range,
Russia,
phenotypic plasticity,
dimorphism,
springtails,
ommatidia,
new species.

RÉSUMÉ
Folsomia najtae *n. sp. (Collembola: Isotomidae) – une nouvelle espèce avec des formes « mobiles » originaire de l'Extrême Orient russe.*
Folsomia najtae n. sp. est décrite de la partie méridionale de la chaîne des Sikhote-Alin (Extrême Orient, Russie). Elle est caractérisée par 6 + 6 ommatidies, un jeu complet de ms-chaetae sur les tergites du corps, de longues soies s accp3 sur le cinquième segment abdominal, quatre soies postérieures sur la dens, et un dimorphisme chez les juvéniles. Les caractères qui définissent les formes « mobiles » sont la cornée saillante des ommatidies et la forme en tube allongé de la dens. Les espèces proches *F. orientalis* Martynova, 1977 et *F. setula* Christiansen & Tucker, 1977 sont redécrites sur du matériel originaire d'Asie du Nord-Est et de l'Est de l'Amérique du Nord, respectivement.

MOTS CLÉS
Monts Sikhote-Alin,
Russie,
plasticité phénotypique,
dimorphisme,
collembole,
ommatidia,
espèce nouvelle.

INTRODUCTION

Morphological plasticity of Collembola was repeatedly described by using terms like sex dimorphism, epitoky, ecomorphosis, and cyclomorphosis (Fjellberg 1976; Cassagnau 1990). Judith Najt made a large contribution to our knowledge on the morphological modifications related to unfavourable environmental condition, age instar and sex. Najt & Massoud (1976) and Najt & Dalens (1979) were the first to give special attention to morphological abnormalities in Collembola. It was concluded that some taxa were more vulnerable to the factors responsible for abnormal morphology. Anomalies of Collembola were classified, the epitoky and ecomorphosis were considered among distinguished groups. Subsequently these special kinds of modifications were given more attention since their functional value became more evident. Thereafter several ecomorphic forms were described (Najt 1979; 1980; 1981a, b), for example in *Folsomia nigromaculata* Najt, 1980, *Gnatisotoma bicolor* Cassagnau, 1957, *Gnathisotoma* sp., *Desoria* sp. (studied as '*Isotoma olivacea*'), *D. gersi* Najt, 1981, *D. graeca* Najt, 1981, *D. propinqua* (Axelson, 1902), *Isotoma viridis* Bourlet, 1839, *Proisotoma* (s.l.) *veca* (Wray, 1952), and *Cliforga aleghaniensis* (Wray, 1952). The published data on other 'ecomorphic species' of the family Isotomidae were summarized by Najt (1983). Four types of ecomorphic modifications were proposed to classify all known cases, based on morphological structures affected by ecomorphosis. These include chaetae, cuticle, shape of body, or a combination of these structures. Secondary sexual dimorphism and epitoky, other intriguing phenomena, were investigated, including male secondary sexual characters in several species of Brachystomellidae (Massoud & Najt 1974; Weiner & Najt 2001).The genera of Isotomidae with well developed secondary sex dimorphism were also discussed (Najt 1977). In her opinion, the characters of strong sex dimorphism were of great taxonomical value and indicated the generic status of sexually dimorphic forms.

In the genus *Folsomia* Willem, 1902, three species are known to date to be affected by ecomorphosis (Najt 1980; Takeda 1985; Culik & Najt 1986), which include *F. nigromaculata*, *F. elongata* (MacGillivray, 1896) and *F. octooculata* Handschin, 1925. In the present paper we describe a new species from the Far East of Russia displaying a phenotypic modification known in the family Isotomidae as the 'mobile' forms (Potapov & Bogomolov 2015). This type of modifications was not observed in the genus *Folsomia* until now.

MATERIAL AND METHODS

The material on which this paper is based is deposited in the Moscow State Pedagogical University, Russia (MSPU) and Muséum national d'Histoire naturelle in Paris, France (MNHN).

Abbreviations

accp	accessory p-row s-chaetae;
Abd.	abdominal segments;
alt.	altitude;
Ant.	antennal segments;
as	antero-submedial s-chaeta
bms	basal ms on antennal segments;
e-guards	supplementary chaetae for E-papilla of labium;
L1	lateral chaeta of distal row on posterior side of manubrium;
M1	medial chaeta of distal row on posterior side of manubrium;
ml1	medio-lateral chaeta of distal row on posterior side of manubrium;
ms	micro s-chaeta(e);
PAO	postantennal organ;
s	macro s-chaeta(e);
Th.	thoracic segments.

SYSTEMATICS

Family Isotomidae Schäffer, 1896
Genus *Folsomia* Willem, 1902

Folsomia najtae n. sp.
(Figs 1; 2; 3A-D)

Type material. — **Holotype**. Adult ♀. Russia, Far East, southern spurs of Sikhote-Alin Range, Ussuriysky District, Ussuriysky State Nature Reserve, Komarovskoye Forest, Turova Nipple, Khripunovsky Pass, *Pinus sibirica* (Ledeb.) Turcz forest on slope, rotten wood, 22.VII.2016, coll. N. Kuznetsova and M. Potapov. deposited in MSPU.
Paratypes. Five (adult and subadult individuals of normal form) from nearby the holotype location, Grabovaya Nipple, mixed forest on slope, rotten wood, 23.VII.2016, coll. N. Kuznetsova and M. Potapov; two (juveniles of mobile form) – from Ussuriysky District, Ussuriysky State Nature Reserve, mixed forest, litter, 05.X.2004, coll. M. Potapov.; three paratypes from Far East, Sikhote-Alin Range, Shkotovsky District, Khualaza Mt., forest, litter, 19.IX.2004, coll. L. Deharveng and A. Bedos. Seven paratypes are deposited in MSPU, three paratypes in MNHN.

Other material. — Russia, Far East, Sikhote-Alin Range, Shkotovsky District, Pidan Mt., mixed forest, rotten wood, *c.* 800 m alt., 20.IX.2004, coll. M. Potapov; *ibidem*, coniferous forest (*P. sibirica*, *Taxus* L.), 21.VII.2016, coll. M. Potapov; Far East, Lazovsky District, State Reserve of Laso, nearby Preobrazheniye, valley of Sokolovka River, mixed forest, rotten wood, 21.IX.2011, coll. M. Potapov. deposited in MSPU.

Diagnosis. — Species with eight anterior and four posterior chaetae on dens, 6+6 ommatidia, short chaetae covering, full set of ms-chaetae (1,1/1,1,1) on body tergites, long accp3 s-chaetae on Abd.V, and two s-chaetae on Ant.1.

Etymology. — The species is named in honor of Judith Najt, the famous taxonomist of Collembola.

Description

General characters

Body size from 0.8 to 1.1 mm (based on five adult ♀ and one adult ♂), with whole range probably wider since subadult ♀ of 1.4 mm seen. Colouration as in Fig. 1A. Pigment grains form transversal bands, intersegmental areas and appendages unpigmented, anterior half of body darker. Body stout, antennae short, 0.8-0.9 as long as head diagonal. Abd. IV, V and VI clearly fused. Cuticle 'smooth', granules much smaller than chaetae bases, forming a mixture of hexagonal and orthogonal pattern.

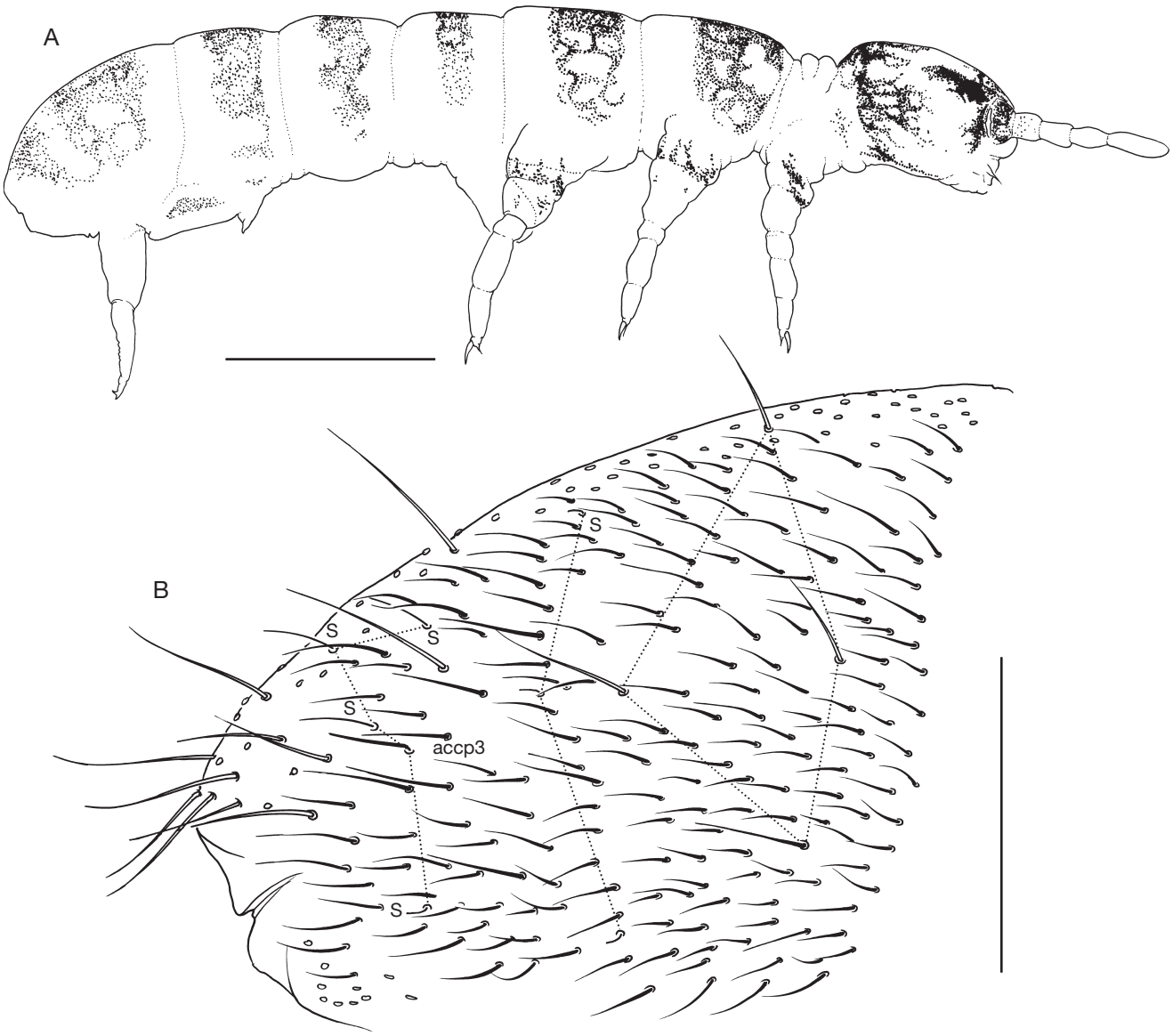

FIG. 1. — *Folsomia najtae* n. sp.: **A**, appearance of subadult ♀ of normal form (1.4 mm); **B**, Abd. IV-VI. Abbreviations: see Material and methods. Scale bars: A, 0.3 mm; B, 0.1 mm.

Head

Ocelli 6+6, size of cornea strongly variable (see the dimorphism part below). PAO narrow, constricted, longer (1.1-1.3) than width of Ant.I and 1.3-1.6 as long as inner unguis length (Figs 2E-G; 3A). Its anterior and posterior edges often with chitinized wrinkles ('setulae' or 'denticles' in use, auct.): though the variation of the character is high, from factually smooth to wrincled, even in our not so abundant material. Maxillary outer lobe with 4 sublobal hairs, maxillary palp bifurcate (few specimens found with simple palp at least on one side). Labral formula as 4/5,5,4. Labium with 5 papillae (A-E), guard e7 absent, with 3 proximal, 4 basomedian, and 5 basolateral chaetae. Ventral side of head with 4+4 postlabial chaetae. Ant.1 with 2 ventral s-chaetae (s) and 3 small basal ms-chaetae (bms), 2 dorsal and 1 ventral (Fig. 2E), normally with 13 chaetae. Ant.2 with 3 bms and a latero-distal s. Ant.3 without bms and with 6 distal s (including two lateral), without additional s-chaetae. Ant.4 with several tubular s-chaetae. Organite rather big and roundish, set together with subapical ms.

Body

S-formula 4,3/2,2,2,3,5 (s) and 1,1/1,1,1 (ms) (Fig. 3B, C). Tergal s-chaetae short, much shorter than common chaetae, longer on Abd.V. Medial s-chaetae on Th.II-Abd.III situated in mid-tergal position, on Abd.I-III between Mac1 and Mac2. Abd.V with 5 s-chaetae arranged as 3 dorsal ones (as, accp1, accp2), of middle size, almost as long as common chaetae, one dorso-lateral accp3, longer and thicker than in dorsal group, and one ventro-lateral short ('3+1+1' pattern) (Figs 1B; 3B). Common chaetae short. Macrochaetae rather short and smooth, 2,2/3,3,3 in number, medial pair hardly

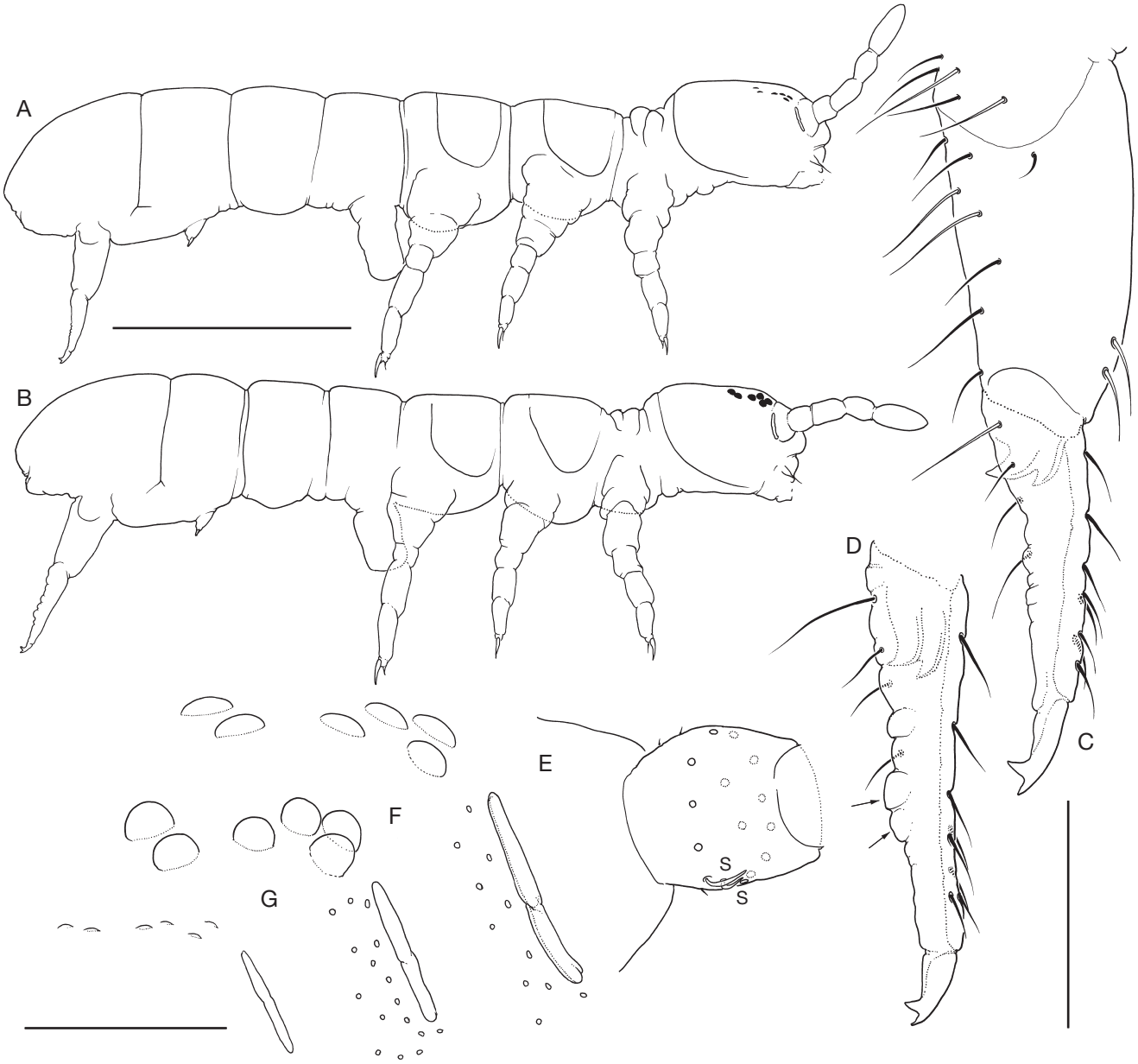

Fig. 2. — *Folsomia najtae* n. sp.: **A**, **B**, appearance of juvenile specimens of normal (**A**) and mobile (**B**) forms (both of about 0.9 mm); **C**, **D**, furca of normal (**C**) and mobile (**D**) forms; **E**, **G**, anterior half of head in normal (**E**), mobile form (**F**), and juvenile individual (**G**) of 0.6 mm length. Abbreviations: see Material and methods. Scale bars: A, B, 0.3 mm; C-G, 0.05 mm.

visible on thorax, especially on Th.II. Medial macrochaetae on Abd.V shorter than dens (0.4-0.7, see also dimorphism) and 1.6-2.1 times longer than mucro. Foil chaetae at the tip of abdomen absent. Axial chaetotaxy abundant. Thoracic sternites without ventral chaetae. Unguis with lateral teeth (Fig. 3D). Empodial appendage about half as long as inner edge of unguis. Tibiotarsi normally with 1-2 additional chaetae on Leg 1 and 2, and with several additional chaetae on Leg 3. Tibiotarsal tenent chaetae pointed. VT with 4 + 4, more rarely 3 + 4 or 3 + 3 laterodistal and 6-7 posterior chaetae, anteriorly without chaetae. Tenaculum with 4 + 4 teeth and 1-2 chaetae. Anterior furcal subcoxae with 7-12, posterior one with 2-4 chaetae. Anterior side of manubrium with two pairs of chaetae, as 2 + 2 (rarely 1 + 2 or 3 + 2) (Fig. 2C). Posterior side of manubrium with 4 + 4 (4 + 5) laterobasal, 1 + 1 apical (a1), 2 + 2 distal chaetae (M1, L1, without ml1). Lateral chaetae (l2) present or absent (Fig. 2C). Dens with 8 anterior chaetae arranged as 1,1,1,2,3. Posterior side of dens with few distinct crenulations at the middle, with 3 chaetae on proximal half and 1 at the middle. Length of dens and crenulations on its posterior side affected by dimorphism (see below). Mucro bidentate. Ratio of manubrium: dens: mucro = 3.8-4.4 : 2.8-4.6 : 1 (considering both normal and 'mobile' forms).

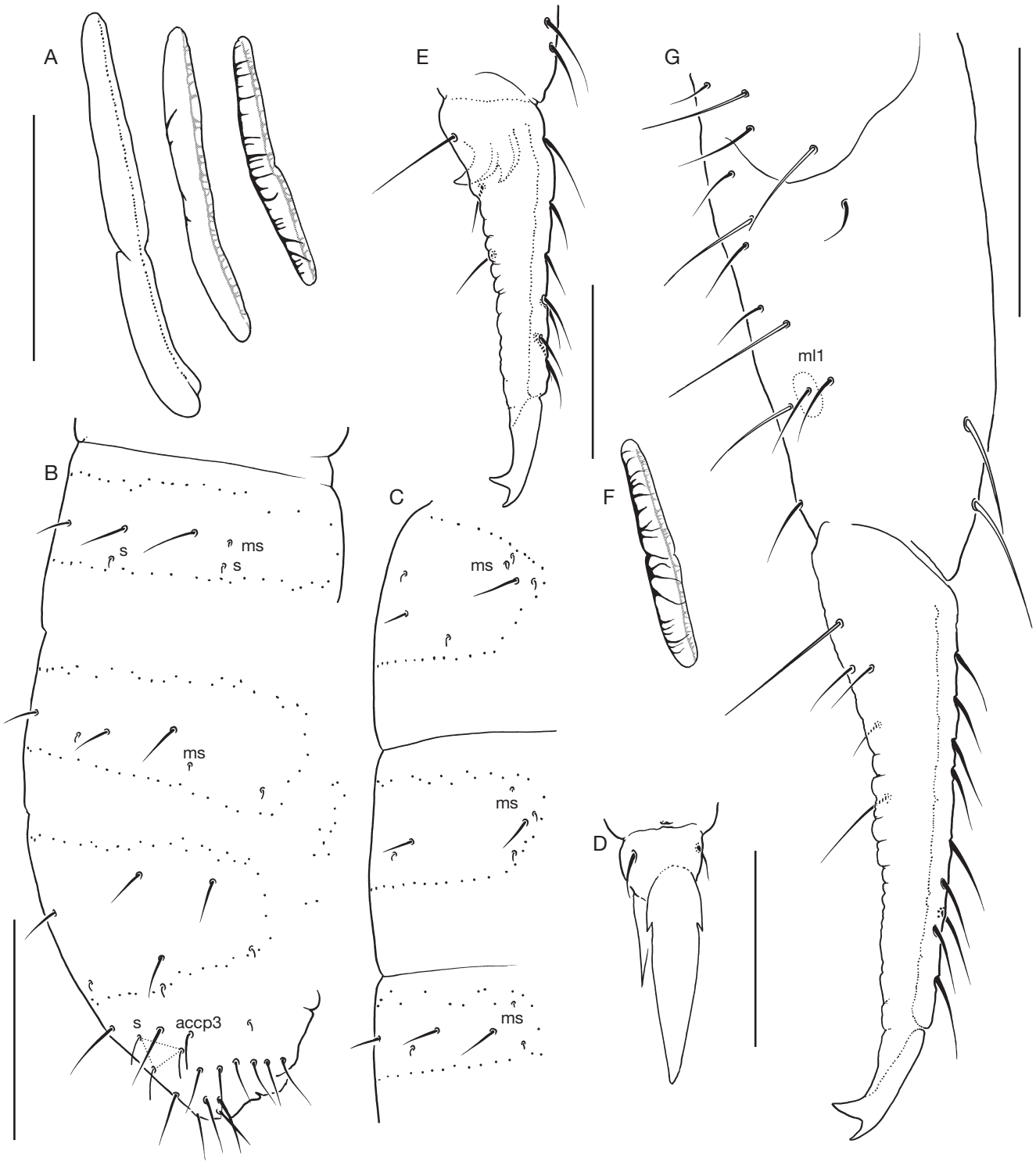

FIG. 3. — **A**-**D**, *Folsomia najtae* n. sp.: variability of PAO (**A**); s-chaetae and macrochaetae on tergites of Abd.II-VI (**B**) and Th.II,III and Abd.I (**C**), apical part of leg 3 (**D**); **E**, **F**, *F. setula* Christiansen & Tucker, 1977, dens, lateral view (**E**), PAO (**F**); **G**, *F. orientalis* Martynova, 1977 furca, lateral view. Abbreviations: see Material and methods. Scale bars: A, D-F, 0.03 mm; B, C, 0.02 mm; G, 0.05 mm.

REMARKS

F. najtae n. sp., *F. setula* (eastern areas of USA), and *F. orientalis* (North of Far East of Russia) form a compact group of species which is characterized by the presence of 6+6 ommatidia, full set of ms-chaetae on body tergites, long accp3 s-chaetae on the fifth abdominal segment (Figs 1B; 4A, B), short chaetae covering, two s-chaetae on Ant.1.

Normally *F. najtae* n. sp. does not show such a prominent PAO as in *F. setula*, but its variability prevents (Fig. 3A) reliably separating the two species with this key character. After

our study the only steady character is the number of chaetae on the posterior side of the dens: 4 (*F. najtae* n. sp.) vs 3 (*F. setula*) (see Figs 2C; 3E). Apart from this, *F. setula* has 12 common chaetae on Ant.1 (vs 13 in *F. najtae* n. sp.) but the character is not very stable in the new species. *Folsomia orientalis* has 8-10/5 chaetae on dens (Fig. 3G, vs 8/4 in *F. najtae* n. sp.) and 6-8+6-8 laterodistal chaetae on ventral tube (vs 4(3)+4(3) in *F. najtae* n. sp.), labial palp with guard e7 present (vs absent in *F. najtae* n. sp. and *F. setula*), chaetae ml1 present on the manubrium (Fig. 3G, vs absent in *F. najtae* n. sp. and *F. setula*), and basal ms present on Ant.3 (vs absent in other two species).

Ecology and distribution

The new species is known from four localities within the southern spurs of the Sikhote-Alin Mt. Range (Far East of Russia). It often inhabits rotten wood that may explain its stout body shape, large head and short antennae being usual characteristics of xylophilous species of springtails.

Folsomia setula Christiansen & Tucker, 1977
(Figs 3E, F; 4A)

Folsomia setula Christiansen & Tucker, 1977: 376.

Material. — Several juveniles, adult ♂ and ♀: USA, North Carolina, Swain, Blue Ridge Parkway, Thomas Divide, 35°31.241'N, 83°14.840'W, *c.* 3.800 ft. alt., red rotten hardwood, 29.V.2007; North Carolina, Graham, Cherohala Skyway, Unicoi Crest, 35°20.668' N, 84°02.103' W, 27.V.2007, soil under large hardwood lump. *c.* 4.600 ft. alt.; Tennessee, Monroe, Cherohala Skyway, Charles Hall Bridge, 35°20.996'N, 84°04.055'W, *c.* 3.700 ft. alt., hardwood, damp litter at seep. 27.V.2007, coll. A. Fjellberg.

Ecology and distribution. — *F. setula* is probably distributed only in the East of USA.

Redescription

Colouration from almost white (often in juveniles) to blue fumose. Body stout, antennae short. Corneas of ocelli hardly marked, their number (6 + 6) defined by form of eye pigment which often weakly developed in juveniles. PAO narrow, constricted, longer (*c.* 1.3) than width of Ant.I and 1.8-1.9 as long as inner unguis length (Fig. 3F), its anterior and posterior edges with chitinized wrinkles. Outer mouth parts as in *F. najtae* n. sp. Labial palp without guard e7 (present on one side of one individual). Ventral side of head with 4 + 4 postlabial chaetae. Ant.1 with 2 ventral s and 3 small bms, 2 dorsal and 1 ventral, with 12 (rarely 11) common chaetae. Ant.2 with 3 bms and a latero-distal s. Ant.3 without bms and with 6 distal s (including two lateral), without additional s. Ant.4 with big and roundish organite. S- and ms-formula as in *F. najtae* n. sp. Abd.V with 3 dorsal s (as, accp1, accp2) of middle size, one longer and thicker dorso-lateral accp3, and one short ventro-lateral accp4 (Fig. 4A). Common chaetae very short. Macrochaetae short and smooth, '2',2/3,3,3 in number, medial pair rudimentary on Th.II. Medial macrochaetae on Abd.V shorter than dens (0.6-0.8) and 1.8-1.9 times longer than mucro. No foil chaetae. Axial chaetotaxy abundant (9,7/6,5,5 seen in one individual). Unguis with lateral teeth. Empodial appendage about half as long as inner edge of unguis (0.5-0.6). Tibiotarsi with few additional chaetae. VT with 3-4+3-4 laterodistal and 5-6 posterior chaetae. Tenaculum with 4 + 4 teeth and 1-2 chaetae. Anterior furcal subcoxae with 5-7, posterior one with 3-4 chaetae. Anterior side of manubrium with two pairs of chaetae (rarely 1 + 2). Posterior side of manubrium with 4 + 4 laterobasal, 1 + 1 apical (a1), 2 + 2 distal chaetae (M1, L1, without ml1), and 4 + 4 central chaetae. Lateral chaetae (l2) present. Dens with 7-8 anterior and 3 posterior chaetae, basal chaeta larger (Fig. 3E). Ratio of manubrium: dens: mucro = 3.5-3.7 : 2.6-3.0 : 1.

Remark

After Christiansen & Bellinger (1998), *F. setula* is recorded from Illinois and Kentucky and can be easily separated from the related species by a striking PAO with prominent inner 'setulae' (Fig. 3F). Our material from neighboring states (North Carolina and Tennessee) fits well to the available descriptions (Grow & Christiansen 1976; Christiansen & Tucker 1977) and therefore makes the detailed comparison between *F. setula* and *F. najtae* n. sp. possible (see the Remark part to *F. najtae* n. sp.).

Folsomia orientalis Martynova, 1977
(Figs 3G; 4B)

Folsomia orientalis Martynova, 1977: 121.

Material. — Several adult and subadult ♂ and ♀: Russia, Far East, Kamchatka, Elizovsky District, Malki, 53°19.316' N, 157°33.013' E *c.* 260 m alt., coniferous (*Pinus pumila* (Pall.) Regel) and birch (*Betula ermanii* Cham.) forests, litter and rotten wood, 26.VI.2012, coll. N. Kuznetsova and M. Potapov. Holotype and one paratype: Far East, Magadan Region, Snezhnaya Valley, coll. D. Berman.

Ecology and distribution. — *F. orientalis* is recorded from Magadan region and Kamchatka (NE Asia).

Redescription

Colouration bluish grey, irregular. Body of normal shape. 6 + 6 corneas of ocelli well visible, arranged in two groups (4 anterior and 2 posterior). PAO narrow, constricted, longer (1.5-1.6) than width of Ant.I and 1.6-1.9 as long as inner unguis length, without chitinized wrinkles. Outer mouth parts as in *F. najtae* n. sp. while guard e7 present. Ventral side of head with 4-5+4-5 postlabial chaetae. Ant.1 with 2 ventral s and 3 small bms, with 13 common chaetae. Ant.2 with 3 bms and a latero-distal s. Ant.3 with bms and with 6 distal s (including two lateral), without additional s. Ant.4 with big and roundish organite. S- and ms-formula as in *F. najtae* n. sp. Abd.V with 3 dorsal s (as, accp1, accp2) of middle size, one dorso-lateral accp3 longer and slightly thicker that other s, and one short ventro-lateral accp4 (Fig. 4B), s-chaetae on other segments of body short. Common chaetae short. Macrochaetae short and smooth, 2,2/3,3,3 in number, medial pair on Th.II short while well visible. Medial macrochaetae on Abd.V shorter

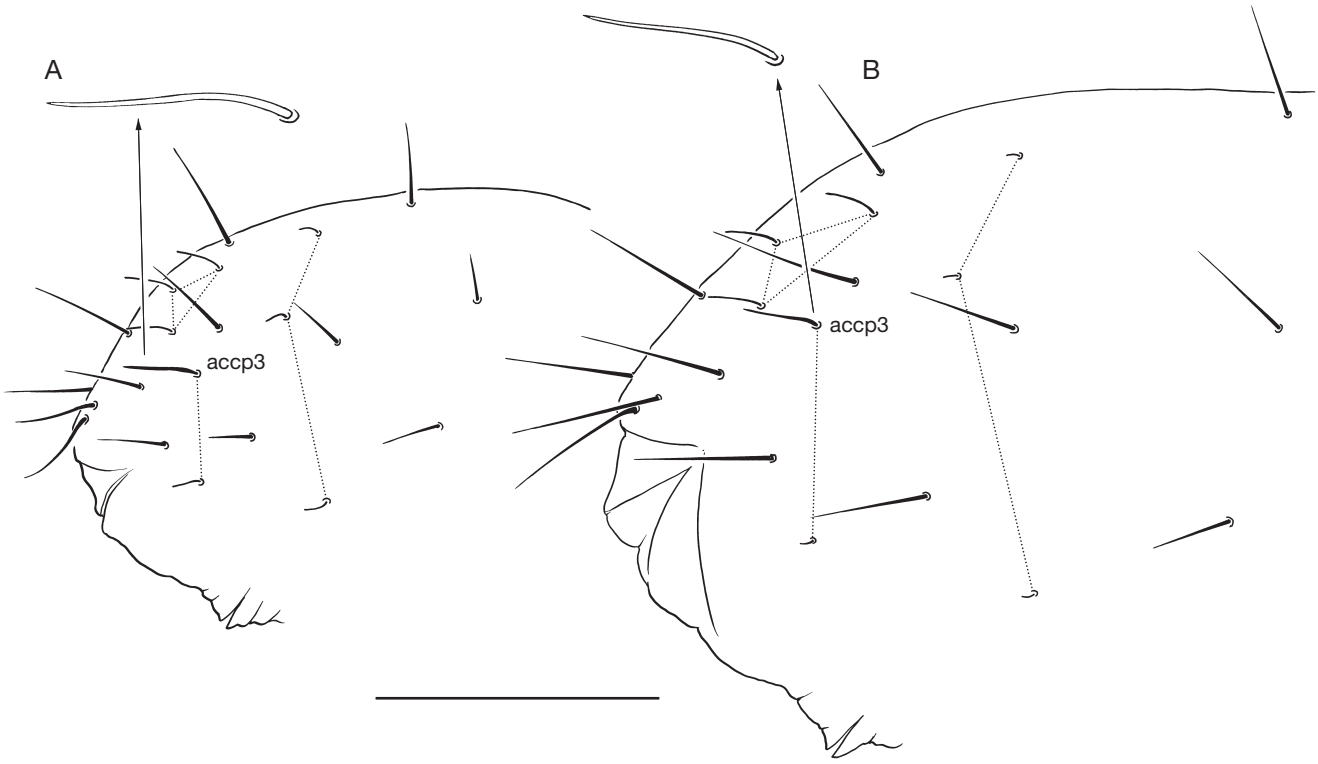

Fig. 4. — s-chaetae and macrochaetae on Abd. IV-VI of *F. setula* Christiansen & Tucker, 1977 (**A**) and *F. orientalis* Martynova, 1977 (**B**). Abbreviation: see Material and methods. Scale bar: 0.1 mm.

than dens (0.5-0.6) and 1.9-2.1 times longer than mucro. No foil chaetae. Axial chaetotaxy abundant. Unguis with lateral teeth. Empodial appendage about half as long as inner edge of unguis. Tibiotarsi with several additional chaetae. VT with 6-8+6-8 laterodistal and more than 10 posterior chaetae. In some specimens posterior side with an additional group of few chaetae at base of VT. Tenaculum with 4 + 4 teeth and normally 2-3 chaetae (4 in holotype). Anterior furcal subcoxae with 9-12, posterior one with 5-6 chaetae. Anterior side of manubrium with two pairs of chaetae. Posterior side of manubrium with 5-6+5-6 laterobasal, 1 + 1 apical (a1), 3 + 3 distal chaetae (M1, L1, ml1), and 7 + 7 central chaetae. Lateral chaetae (l2) present. Dens with 9 (more rarely 8 or 10) anterior and 5 posterior chaetae (Fig. 3G). Ratio of manubrium: dens: mucro = 3.9-4.3 : 3.4-3.7 : 1.

Remark

It is the largest and the most polychaetotic species among the three forms under consideration. For more detail comparison see the Remarks part to *F. najtae* n. sp.

DIMORPHISM

The new species displays dimorphism appearing in normal and 'mobile' forms (Fig. 2A, B). The latter forms were present only in autumn samples and only in two of the seven studied populations, occurring together with normal forms. Modified specimens have larger ocelli and longer dens armed with tubercles (Fig. 2F vs 2E, G; Fig. 2D vs 2C). The dens is 2.0-2.6 times longer than the macrochaetae on Abd.V in mobile forms compared with 1.5-2.0 in normal forms. Other characters, such as tenent hairs on tibiotarsi, skeleton of furcal apparatus and the length of chaetae on the body, are not affected. Along the whole age row of available specimens (from 0.5 to 1.4 mm), only specimens of the size ranging from 0.8 to 1.0 mm are affected by dimorphism. Mobile forms occur among both juvenile females and males. The size of the ocelli is probably age dependent even within normal specimens: younger individuals may have hardly developed cornea, which are almost invisible and marked only by pigmentation and weak swellings at the associated positions of the eye spot (Fig. 2G).

A similar dimorphism can also occur in populations of *F. setula.* According to Christiansen & Bellinger (1998) "specimens from Illinois had shorter setae and better developed eyes than those from Kentucky", while the variability of the number of ocelli was also mentioned (4-6). Our material from the North America display only normal forms without clearly marked ocelli, so that their exact number was impossible to ascertain. The studied populations of *F. orientalis* also consisted of normal specimens only. A similar dimorphism was previously described in four species of *Proisotoma* s.str. (Potapov & Bogomolov 2015) in which more morphological characters are affected, while protruding eyes and tuberculated dens are shared by mobile forms of both groups. Colonization of temporary substrata (rotten wood and similar sites) is possibly a common trait of the species displaying 'mobile' dimorphism.

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