Morphology in Collembola systematics: the potential and limitations

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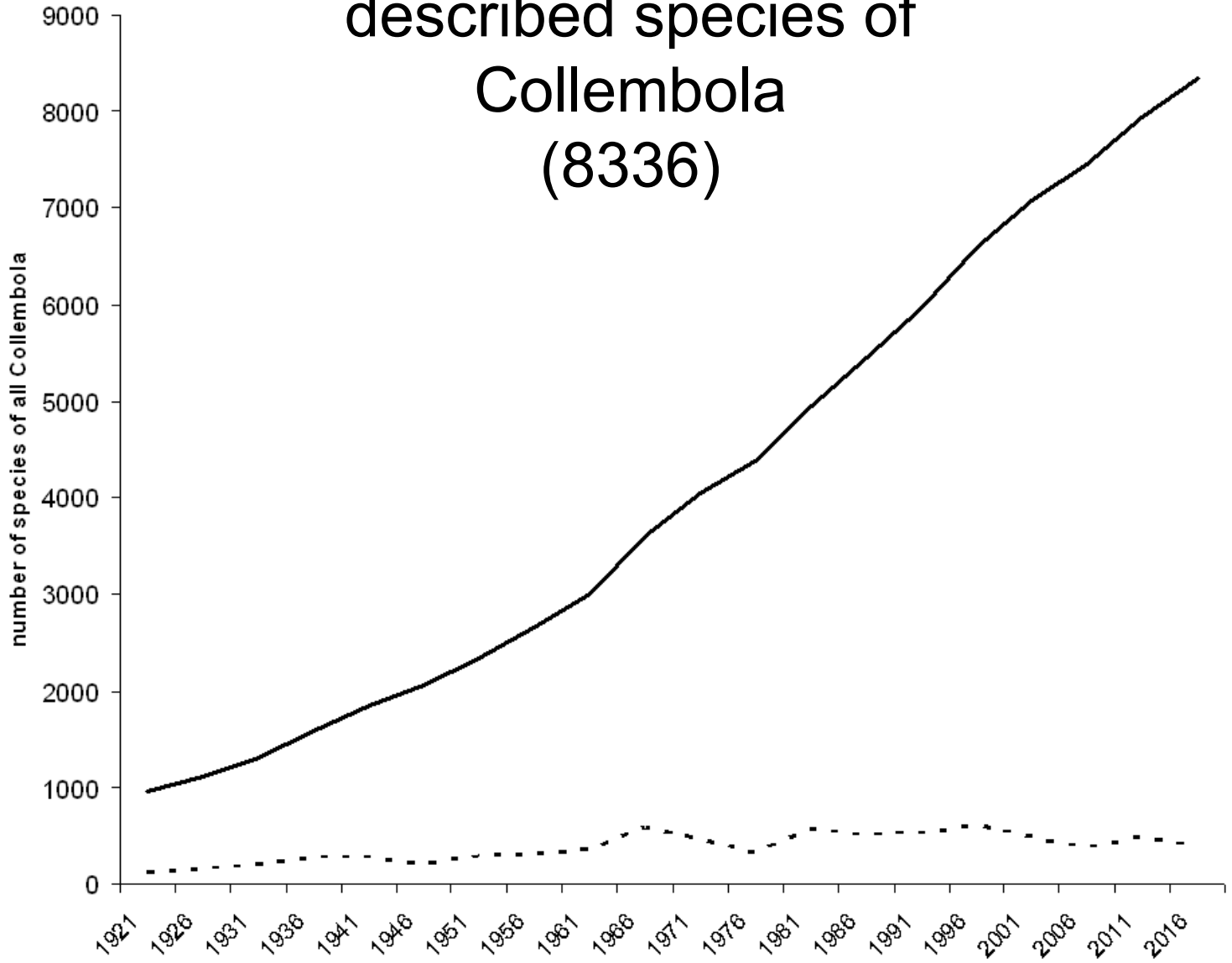
- geography of routine taxonomy
- re-estimation of widely accepted morphological characters and phenotypic plasticity (limitations)
- the characters newly introduced and new insight into systematics of higher taxa (potential)

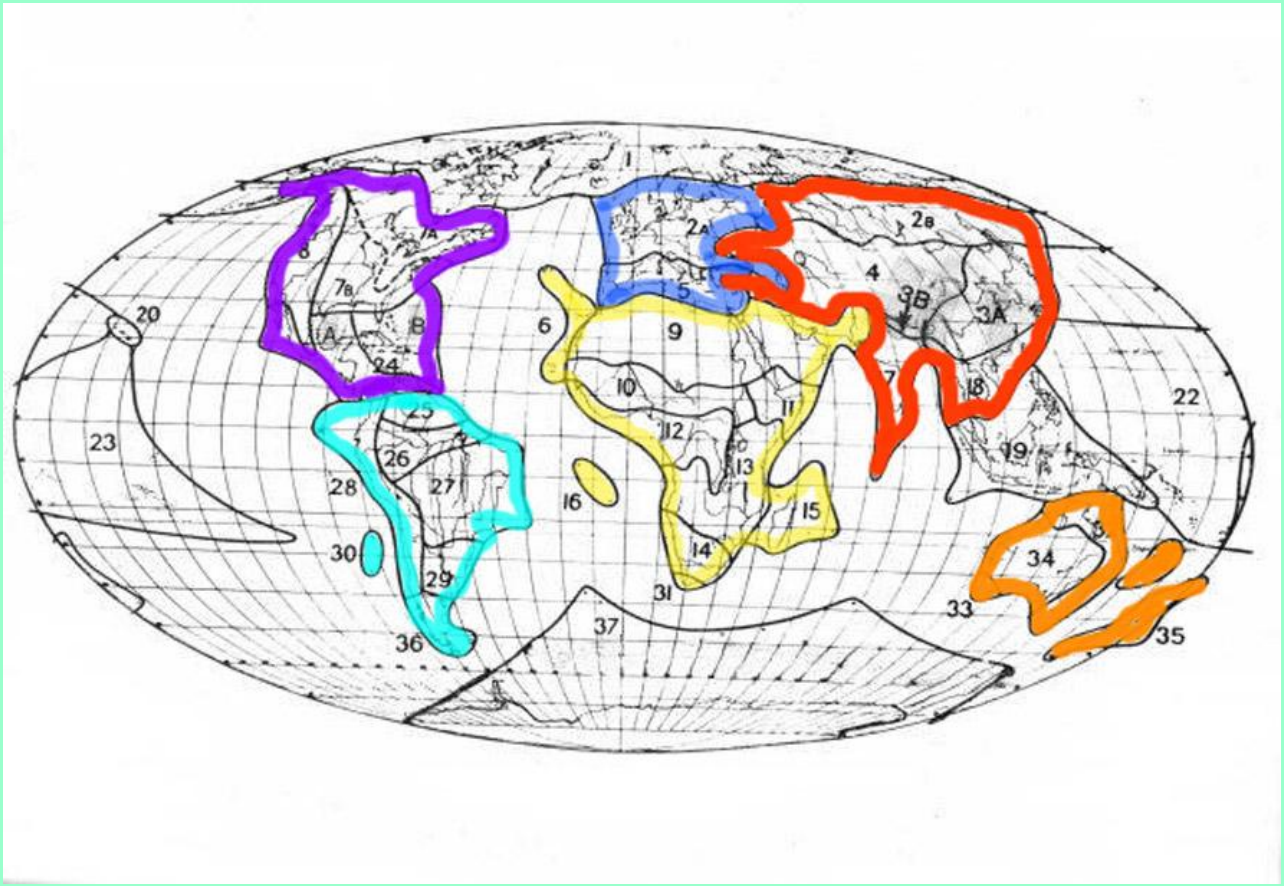
our contribution to global diversity of springtails

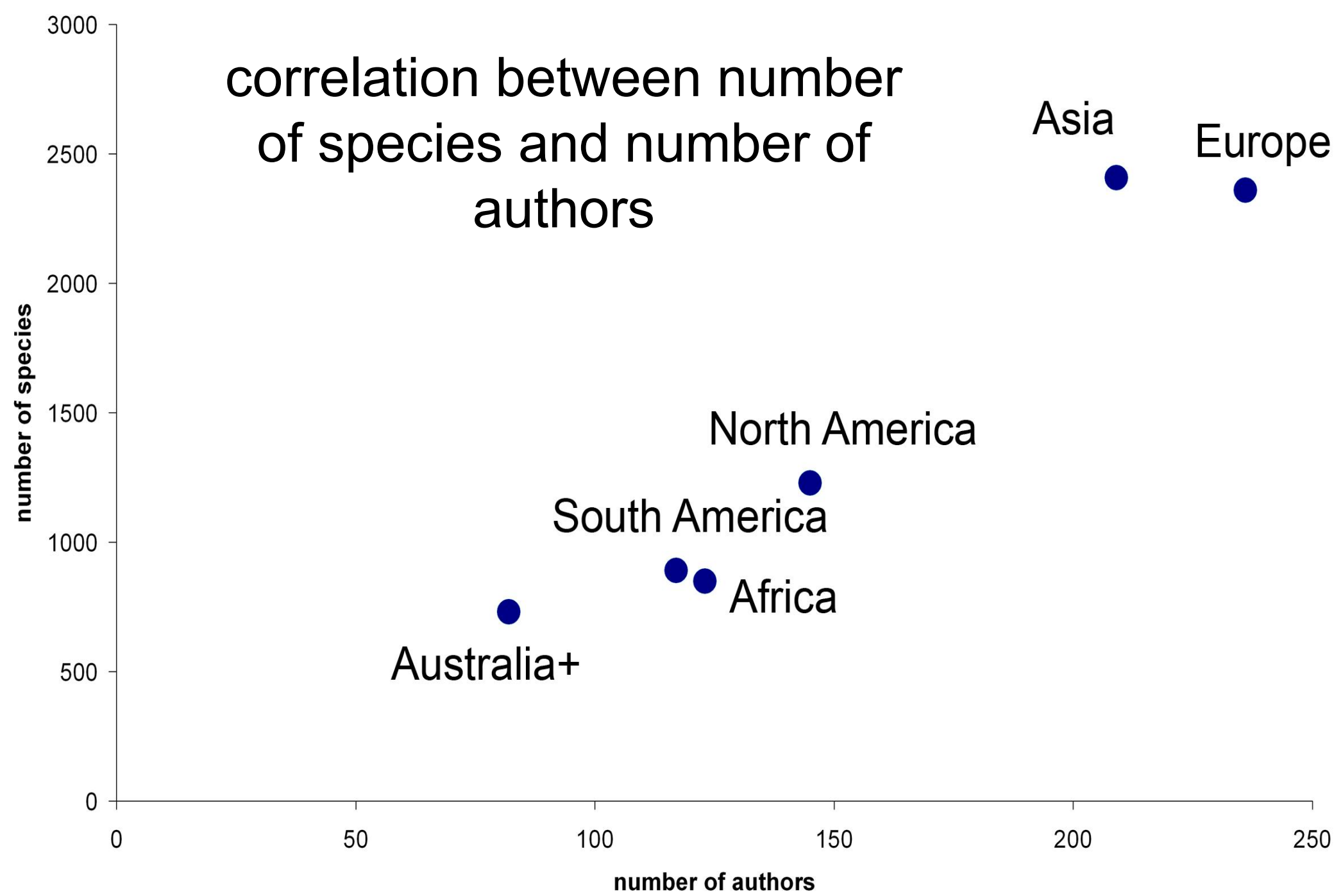
based on data from
http://www.collembola.org

the whole number of described species of Collembola (8336)

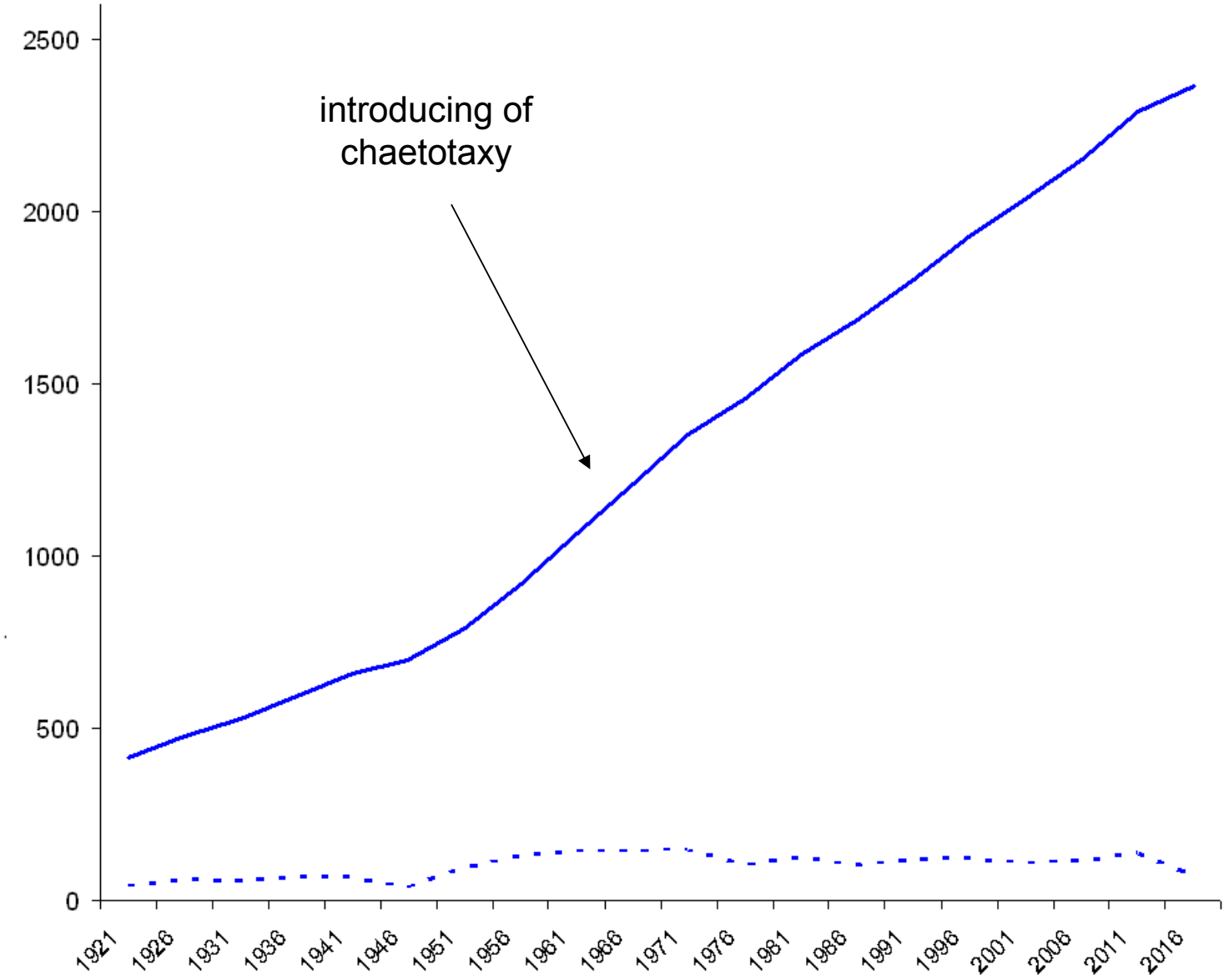


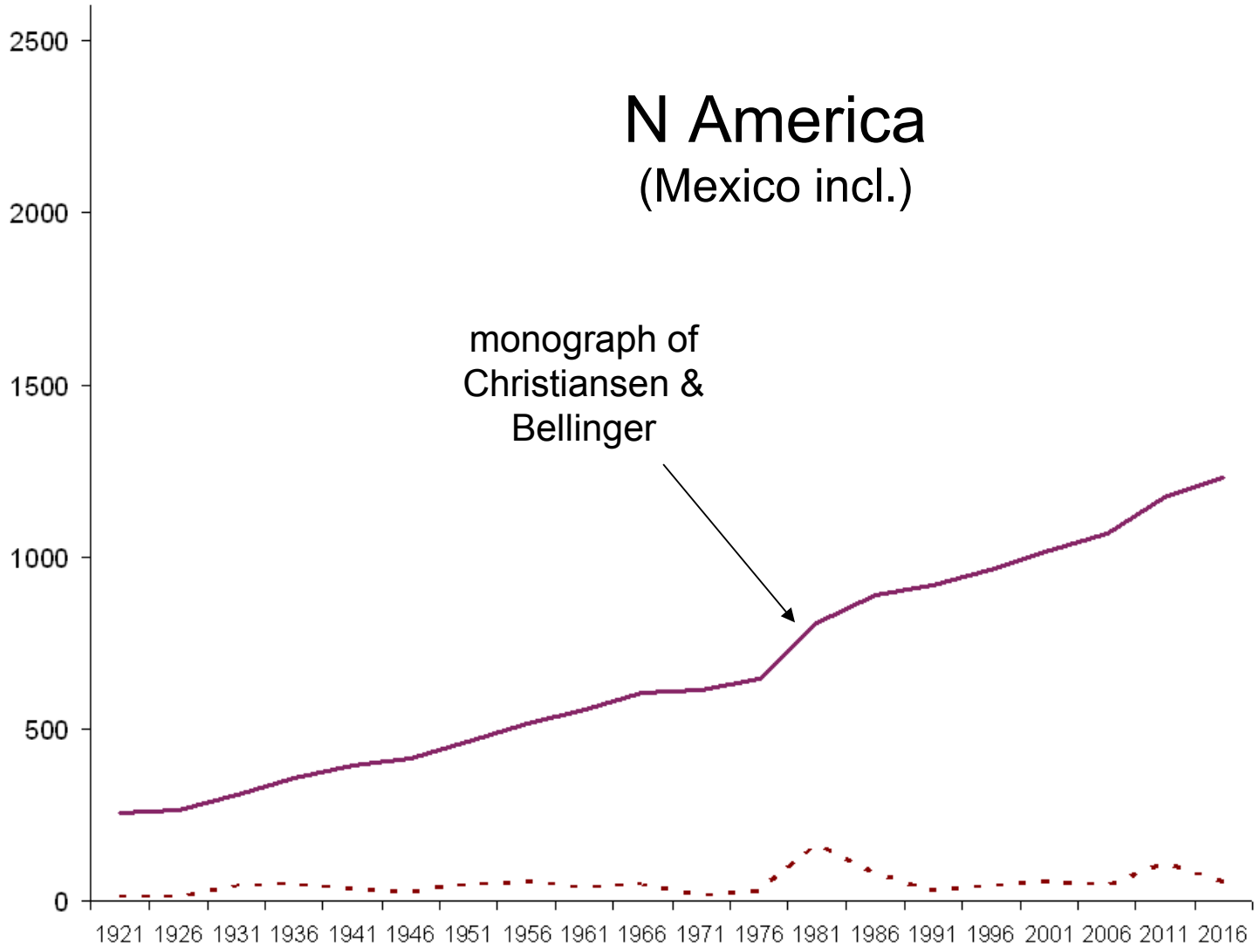
regions analyzed

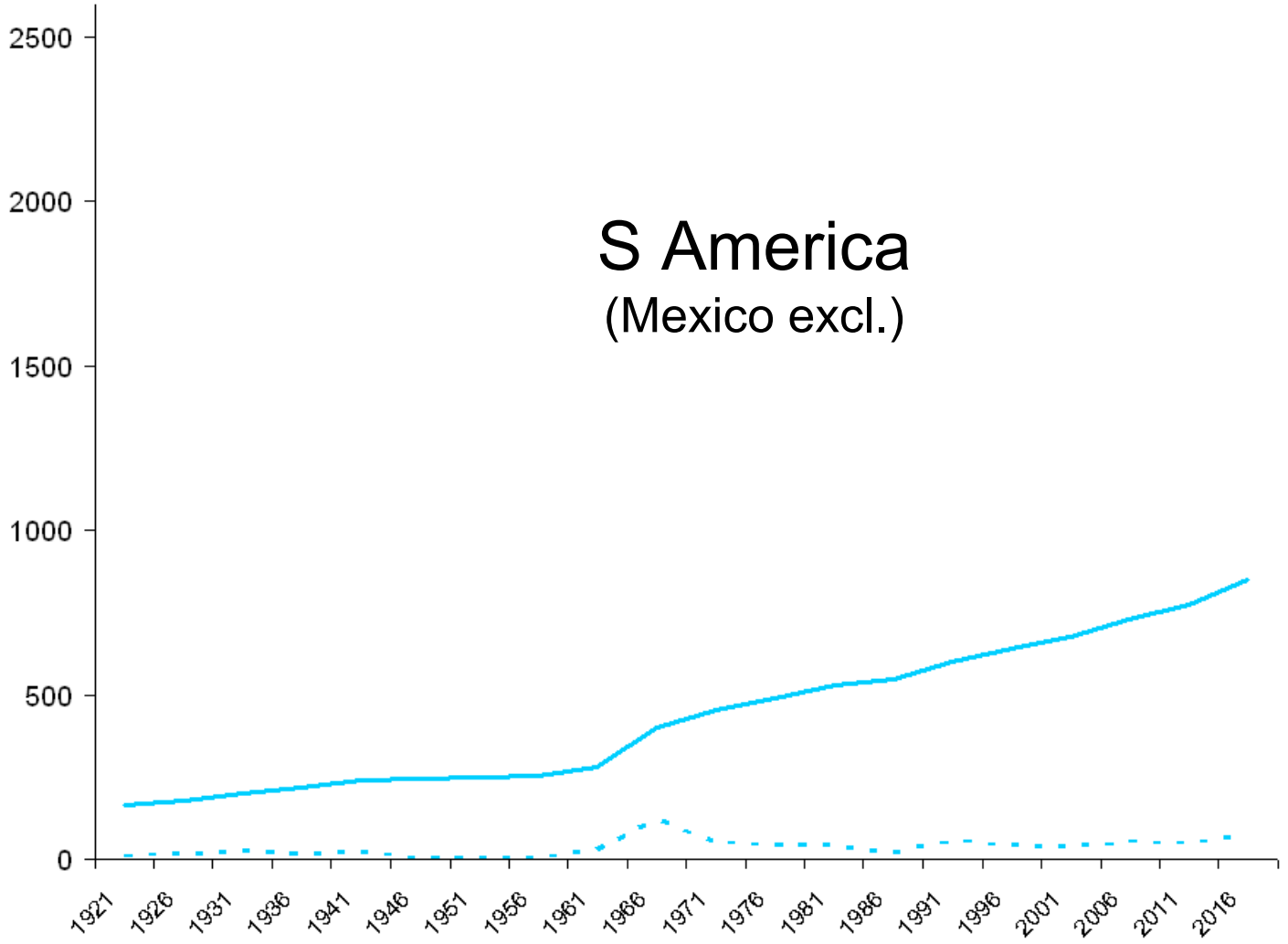



correlation between number of species and number of authors
Asia
Europe
North America
South America
Africa
Australia+
number of species
number of authors
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250

number of described and recorded species in Europe




N America
(Mexico incl.)
monograph of
Christiansen &
Bellinger
2500
2000
1500
1000
500
0
1921 1926 1931 1936 1941 1946 1951 1956 1961 1966 1971 1976 1981 1986 1991 1996 2001 2006 2011 2016


S America
(Mexico excl.)
2500
2000
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1921
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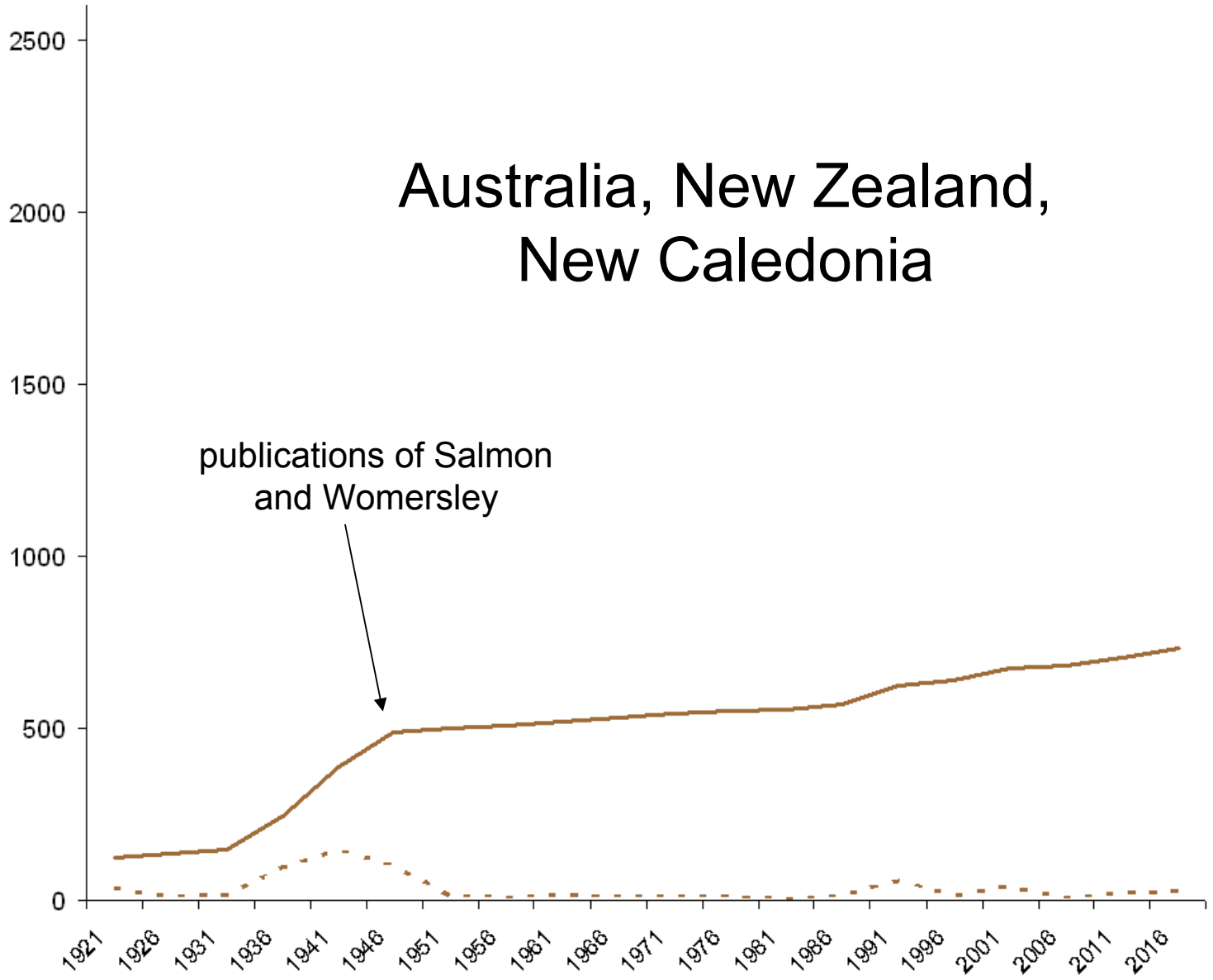
2016


Australia, New Zealand,
New Caledonia
publications of Salmon
and Womersley
2500
2000
1500
1000
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0
1921
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1941
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1971
1976
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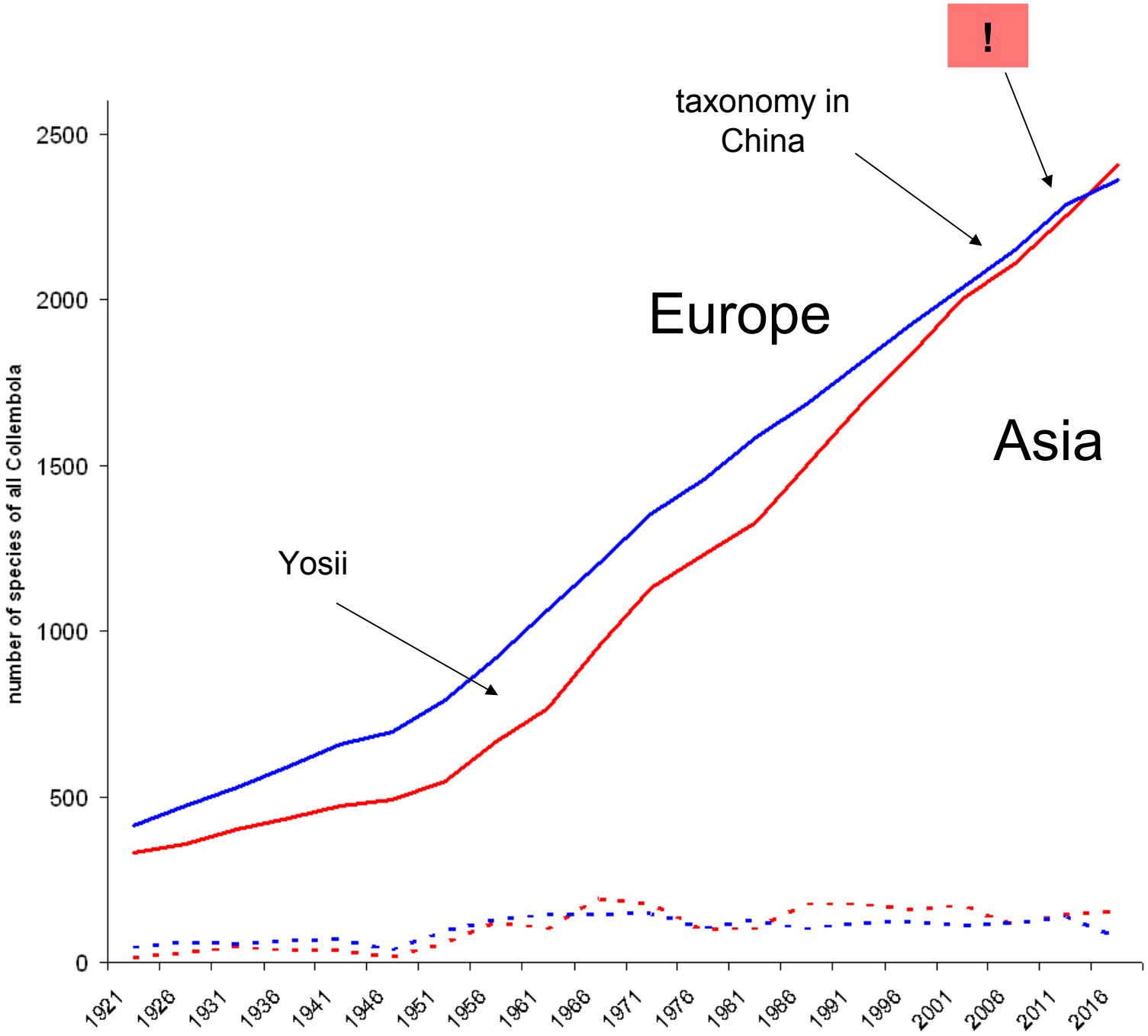
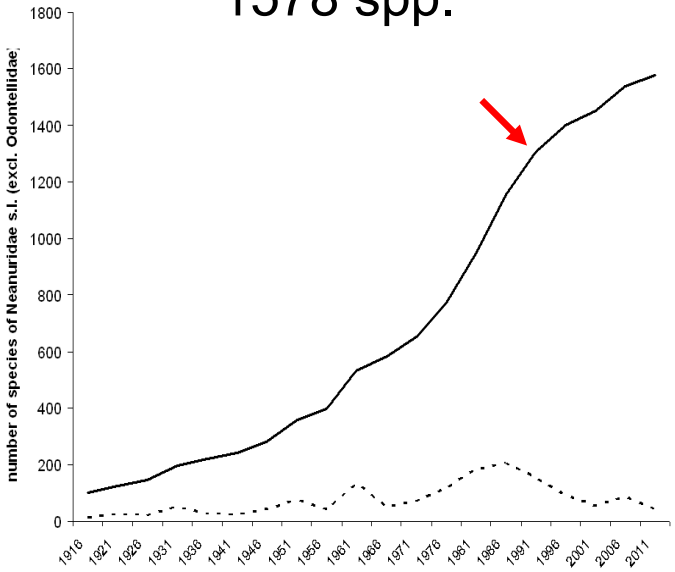
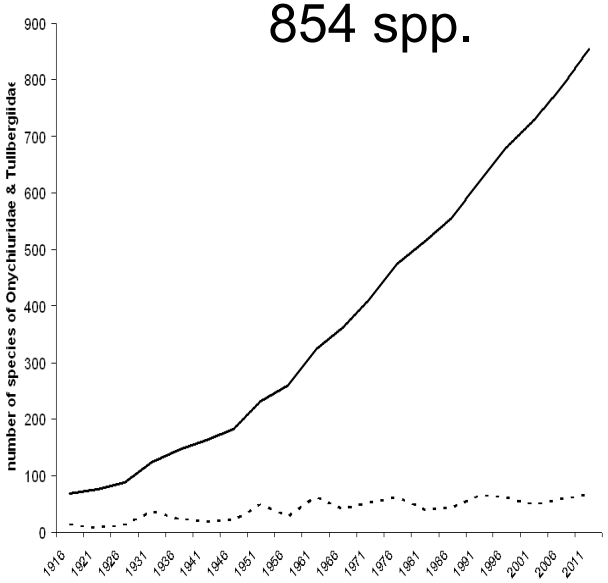
1996
2001
2006
2011
2016


!
taxonomy in China
Europe
Asia
Yosii
number of species of all Collembola
2500
2000
1500
1000
500
0
1921
1926
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

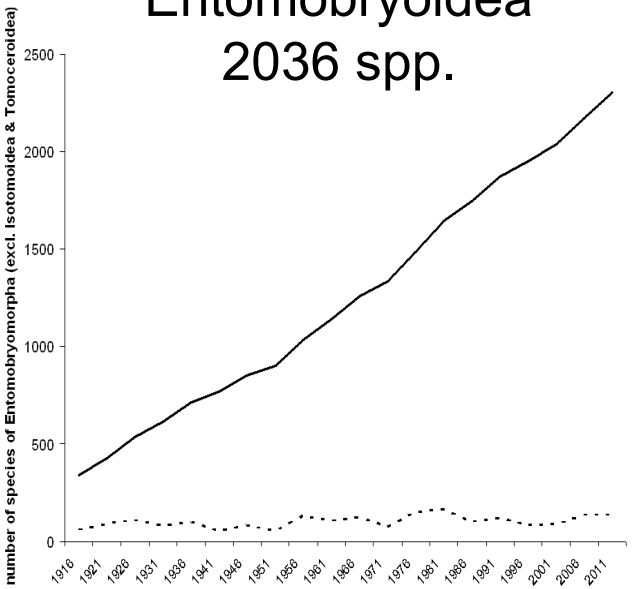
Neanuridae s.l.
1578 spp.



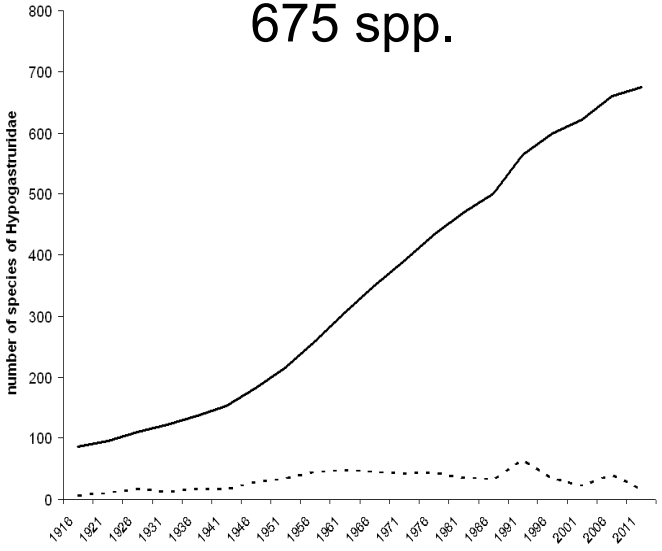
Onychiuroidea
854 spp.



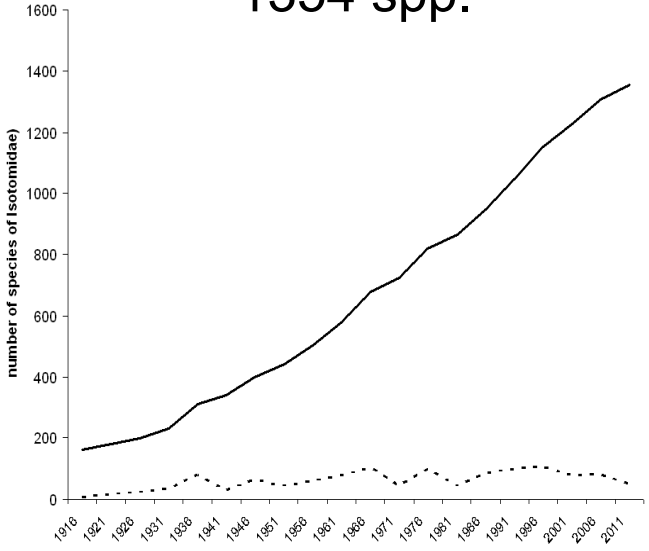
Entomobryoidea
2036 spp.



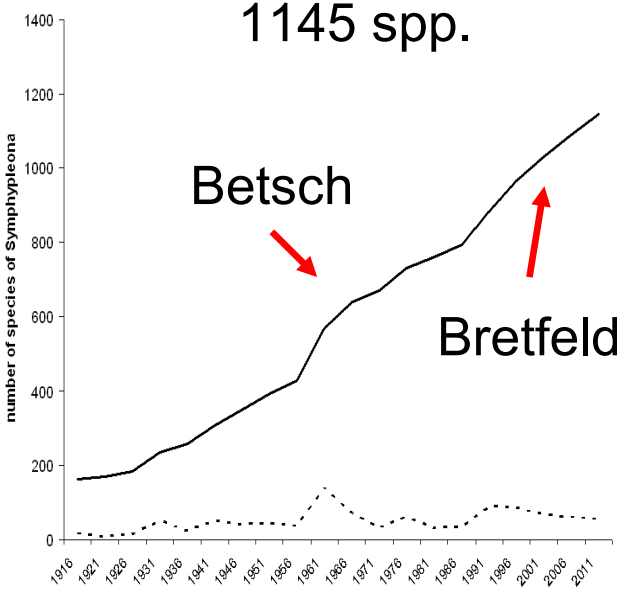
Hypogastruridae
675 spp.



Isotomidae
1354 spp.



Symphypleona
1145 spp.



taxa with "explosive" taxonomy

Tomoceridae (174 spp.)

number of species of Tomoceridae

descriptions in China

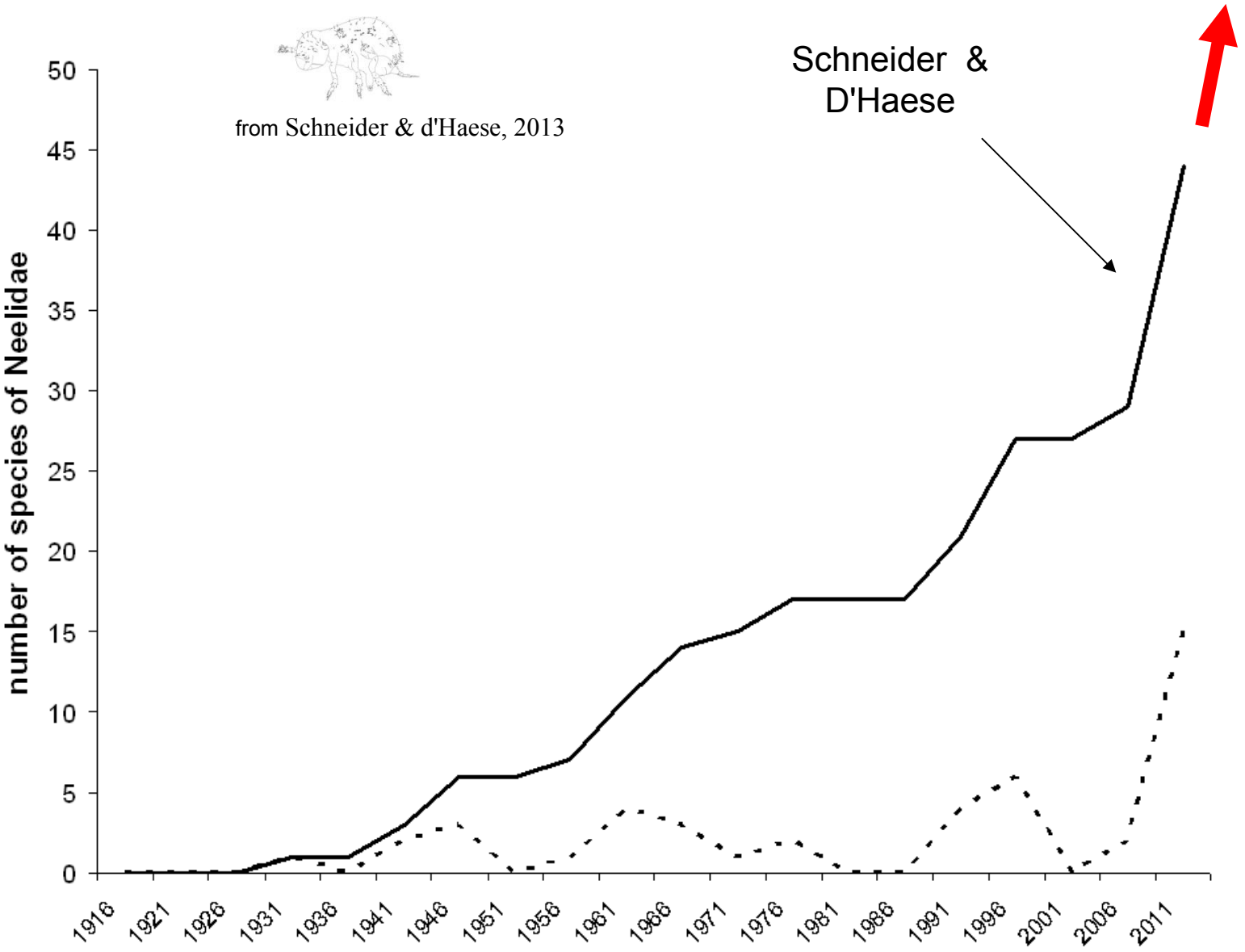
Yosii (Asia)

0 20 40 60 80 100 120 140 160 180 200

1916 1921 1926 1931 1936 1941 1946 1951 1956 1961 1966 1971 1976 1981 1986 1991 1996 2001 2006 2011

Neelidae (44 spp.)

from Schneider & d'Haese, 2013



Entomobrya (270 spp.)

REBIRTH:
Jordana's taxonomical system

Stach (Europe and Asia) and Christiansen (America)

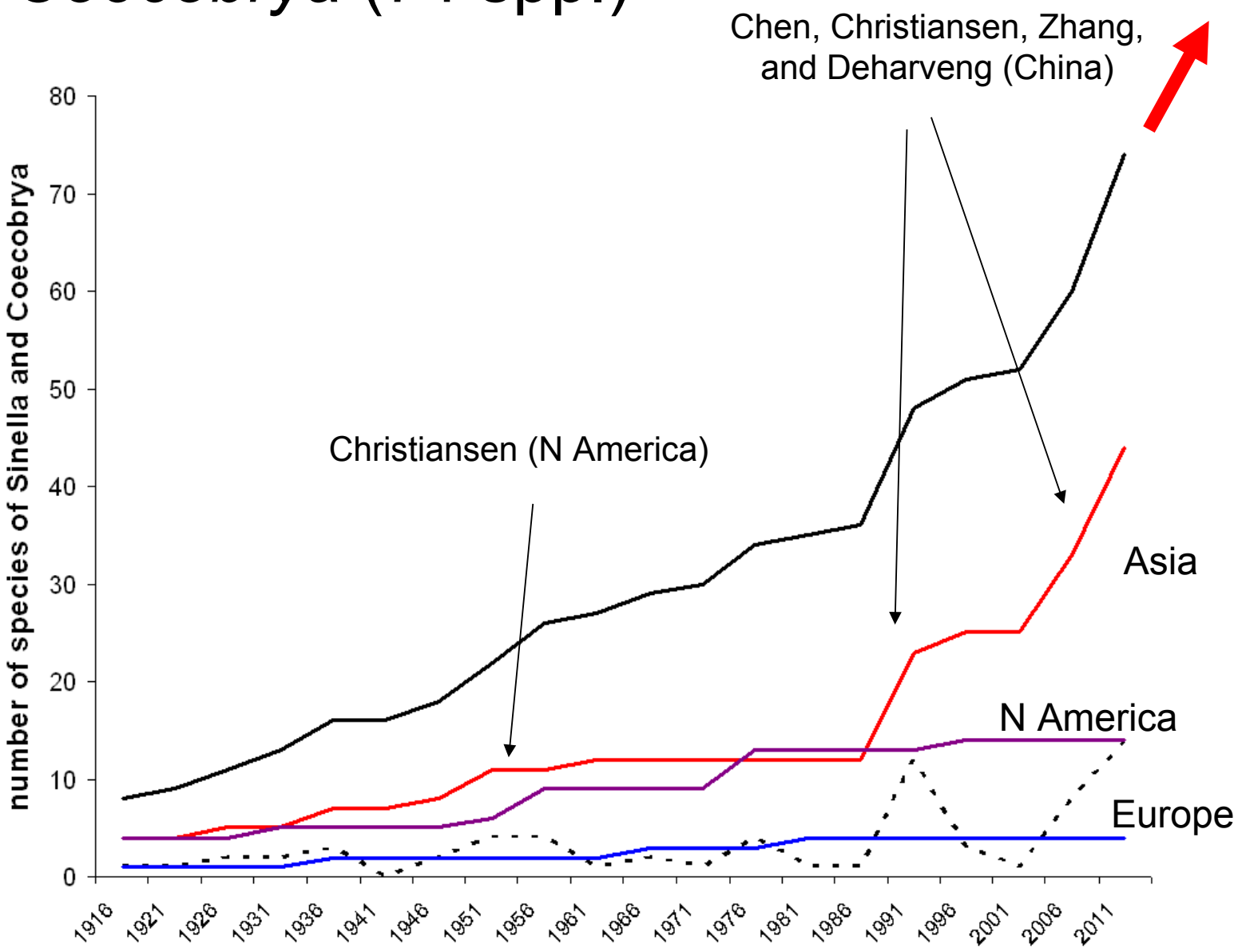
Salmon

number of species of Entomobrya

300
250
200
150
100
50
0

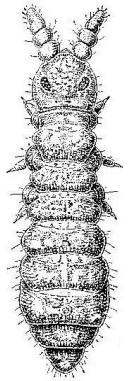
1916 1921 1926 1931 1936 1941 1946 1951 1956 1961 1966 1971 1976 1981 1986 1991 1996 2001 2006 2011

Sinella and Coecobrya (74 spp.)

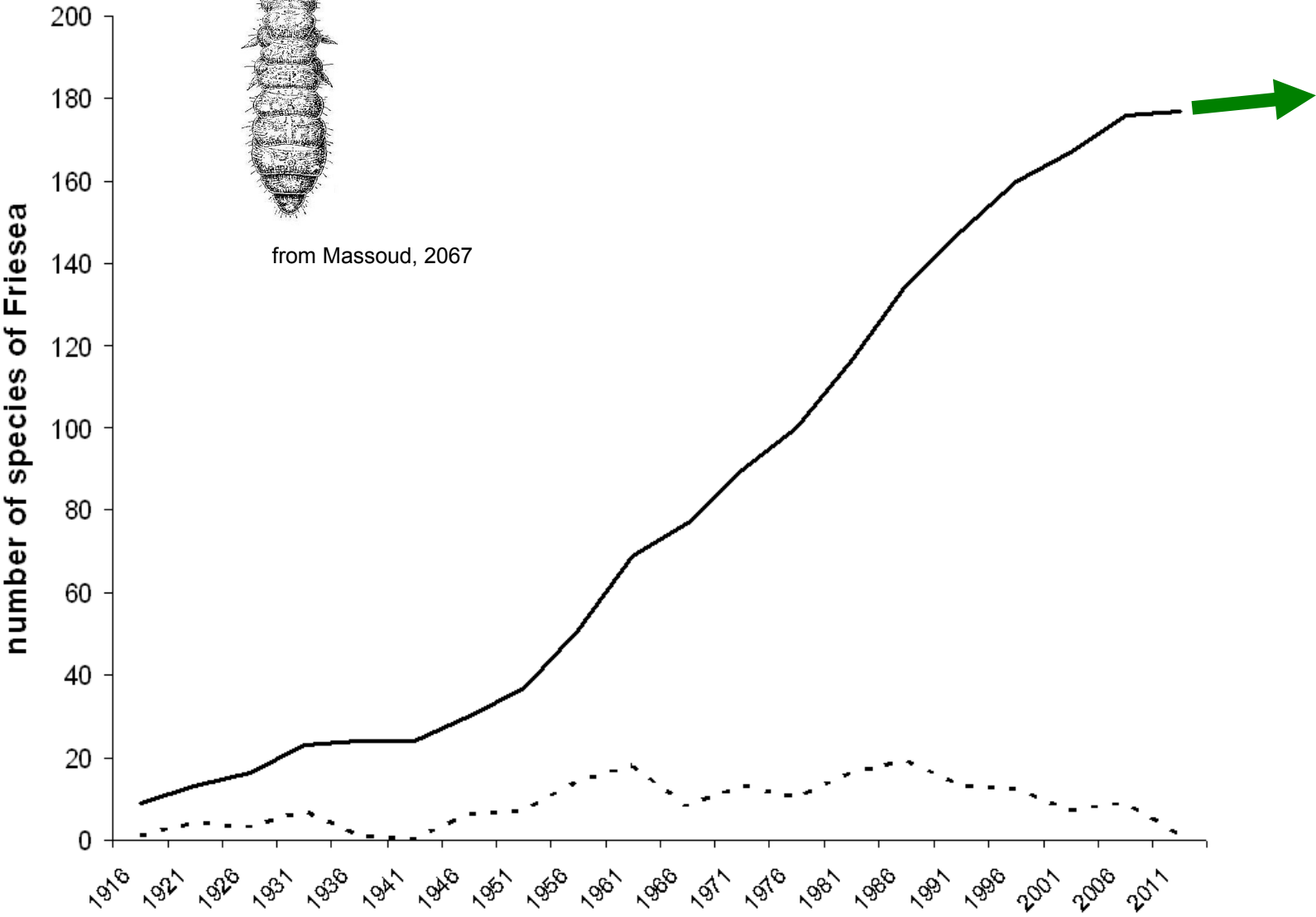


taxa which almost found their final size ?

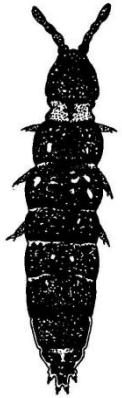
Friesea (177 spp.)



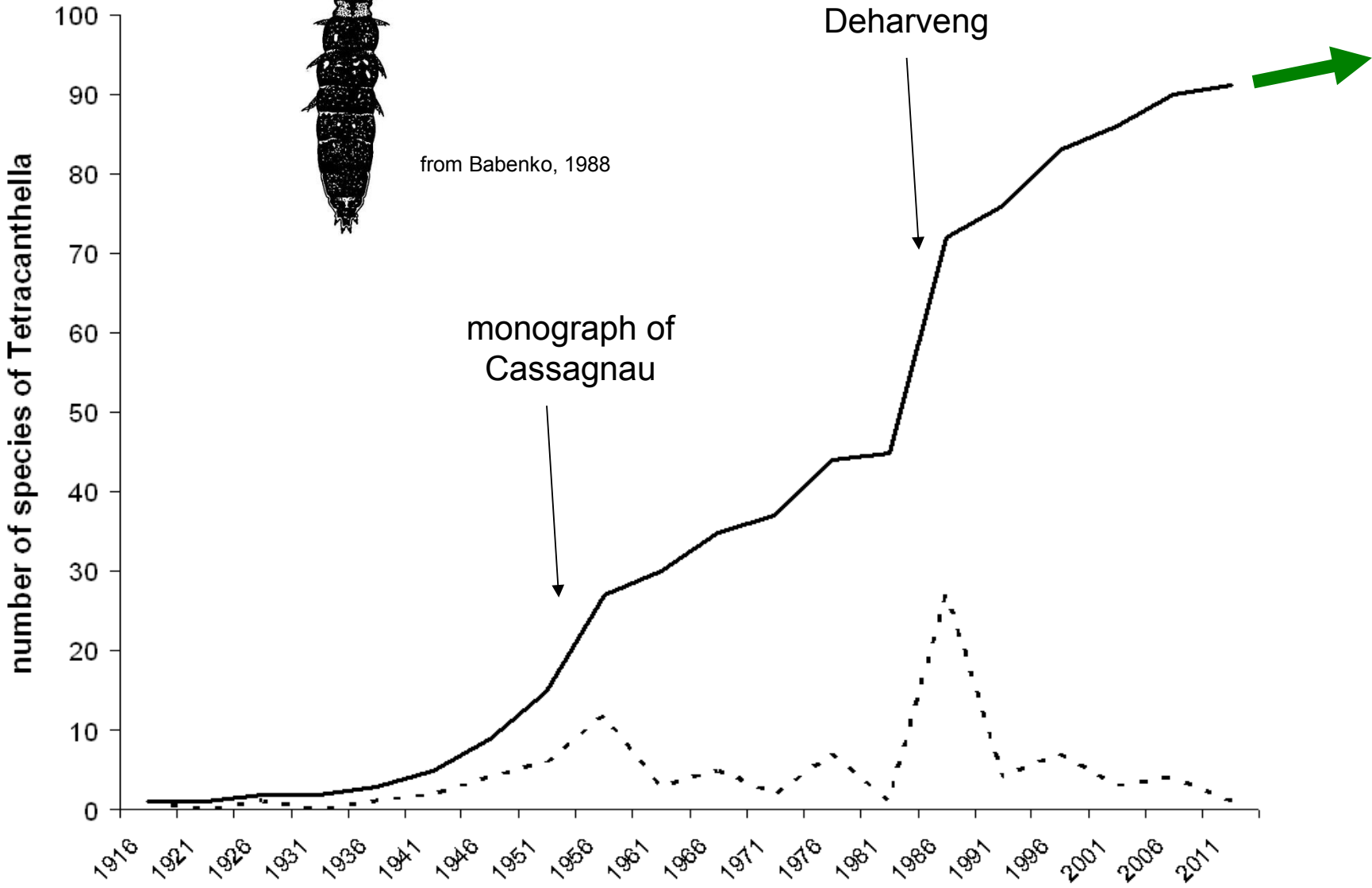
from Massoud, 2067



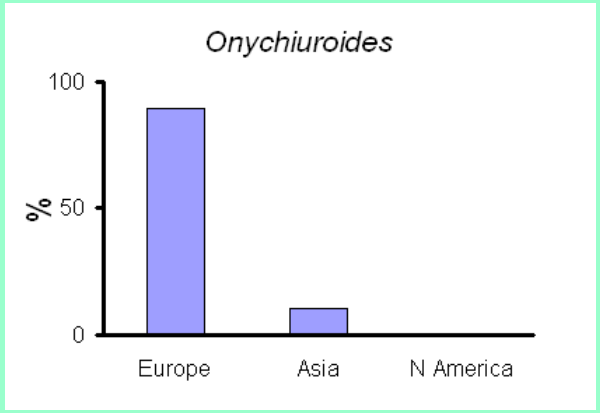
Tetracanthella (91 spp.)

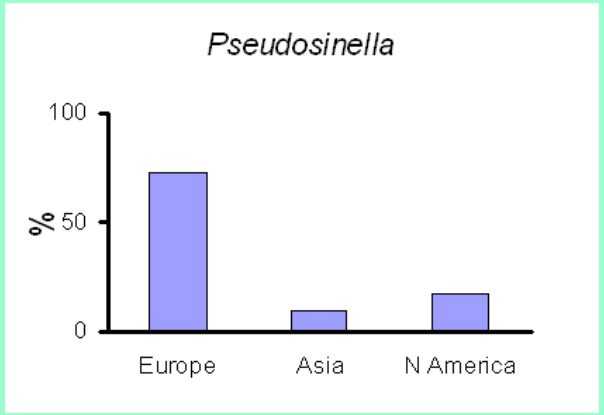


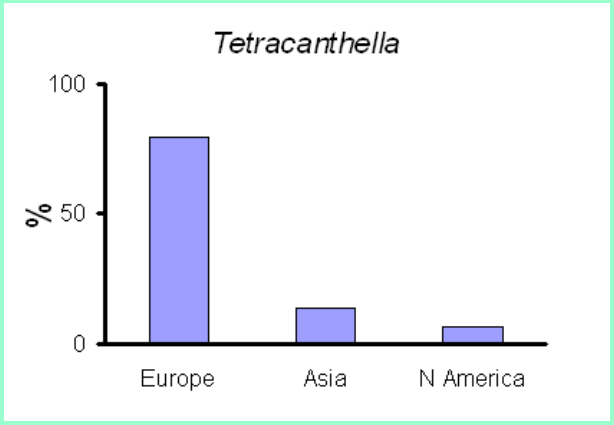
from Babenko, 1988



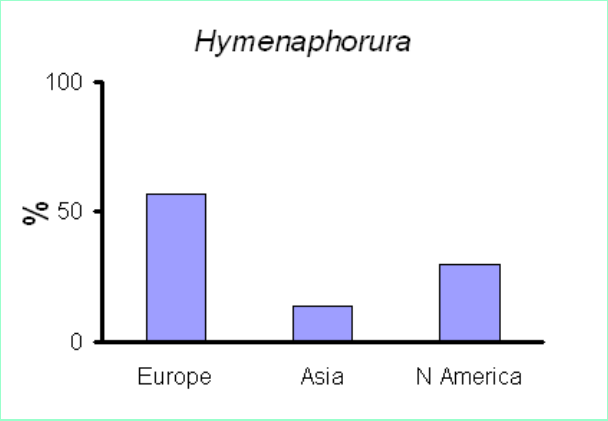
Taxonomy of East and West: Overview of distributions of higher taxa on large biogeographical scale

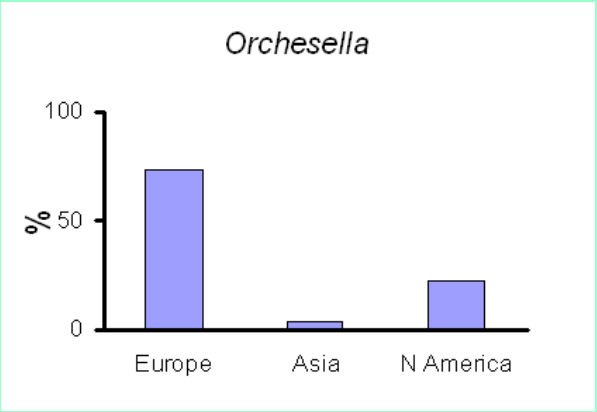




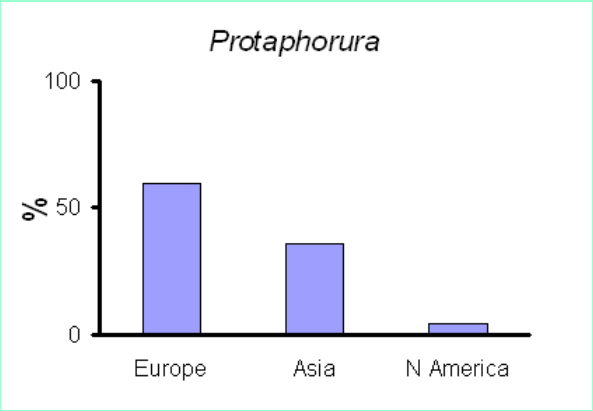


genera with European distribution

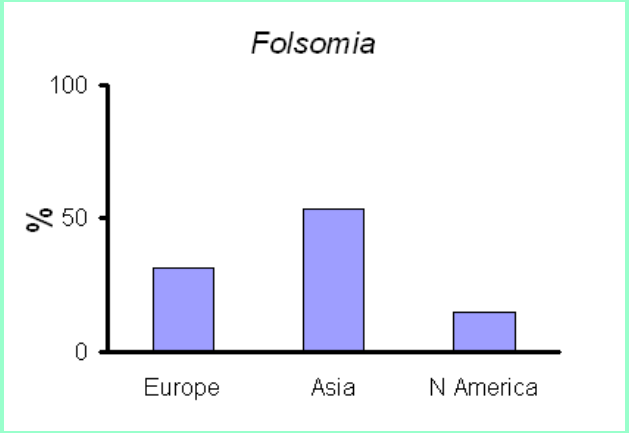


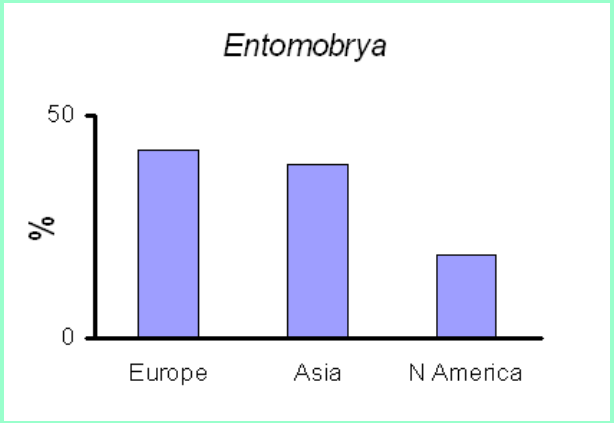


genera with Euro-American distribution

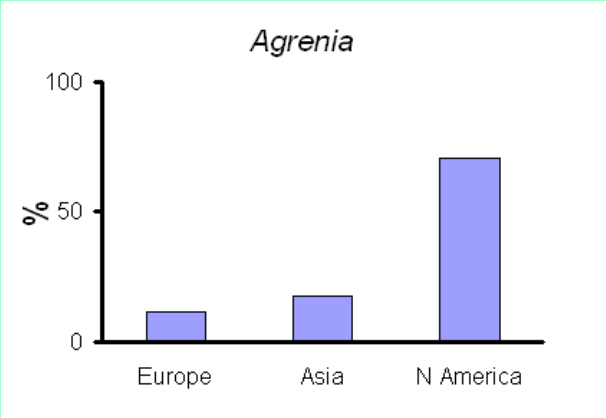


genera with Palearctic distribution

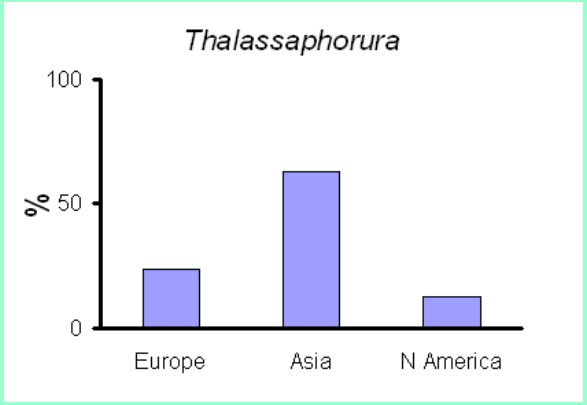


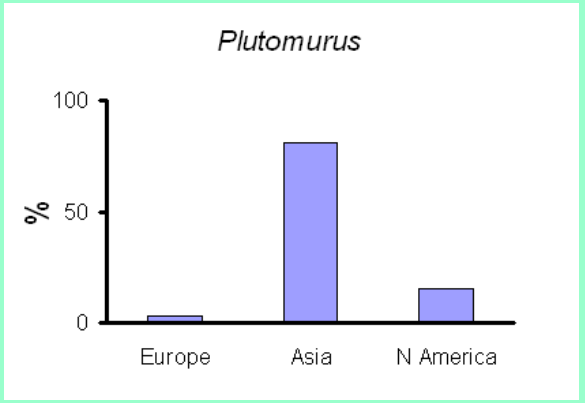


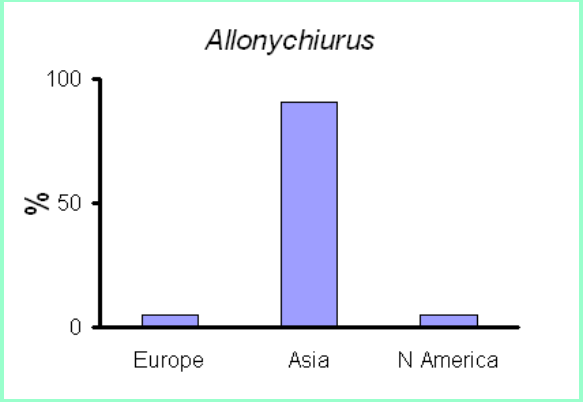
genera with Holarctic distribution

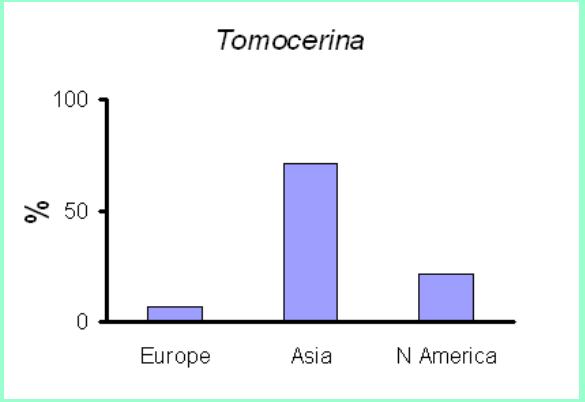


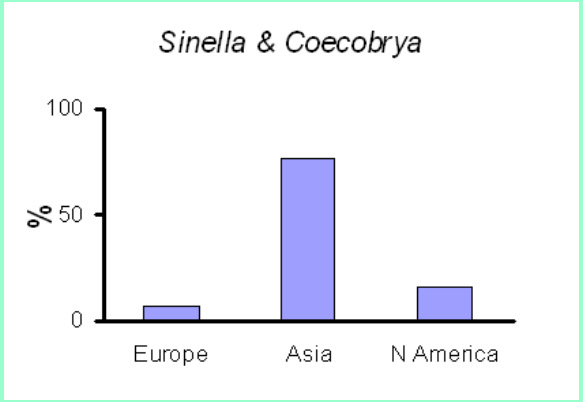
genera with Nearctic distribution

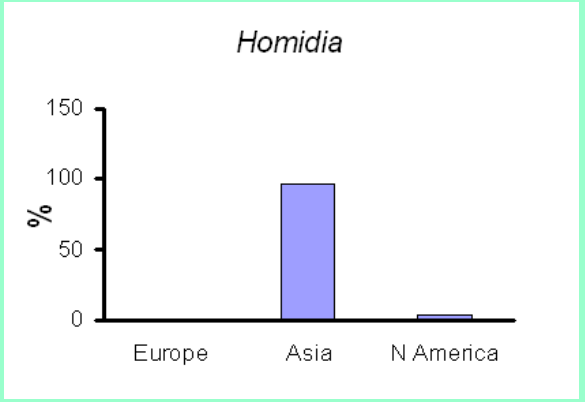












genera with
Asiatic distribution

Limitations of morphological taxonomy:

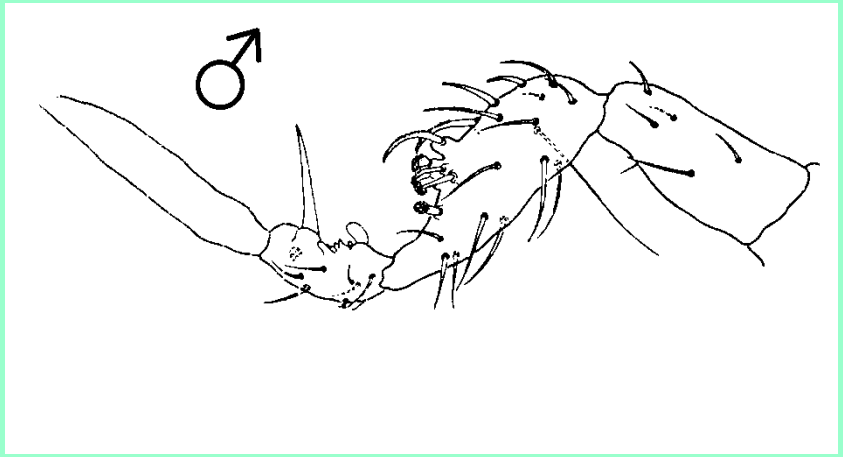
- value of strong sexual dimorphism and epitoky
- colour pattern
- mobile forms

Limitation of morphological taxonomy:

value of strong sexual dimorphism and epitoky

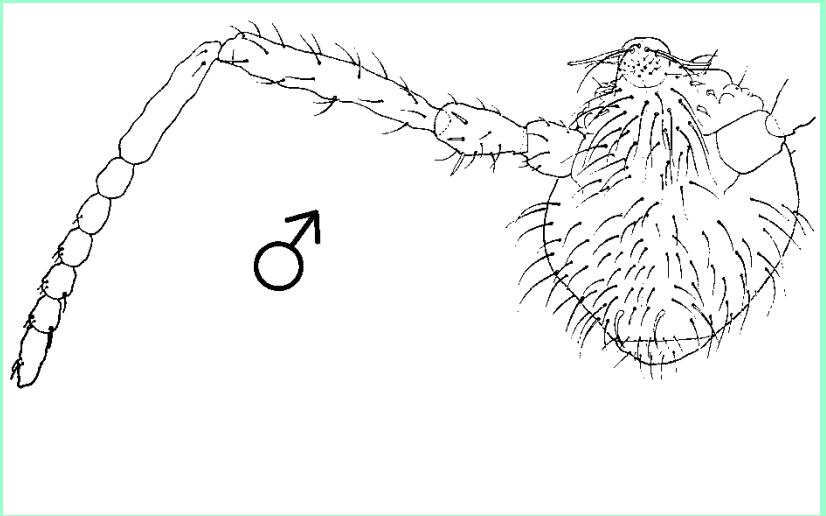
Symphypleona:

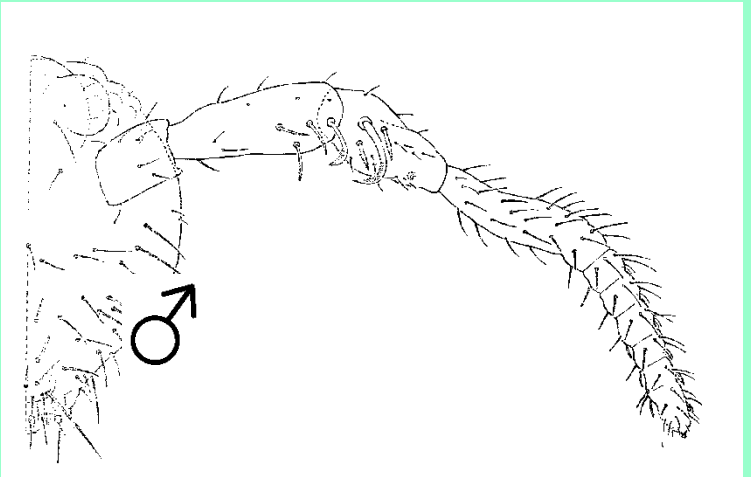
males of “dimorphic” genera (from Betsch, 1980)



Sminthurides

Bourletides



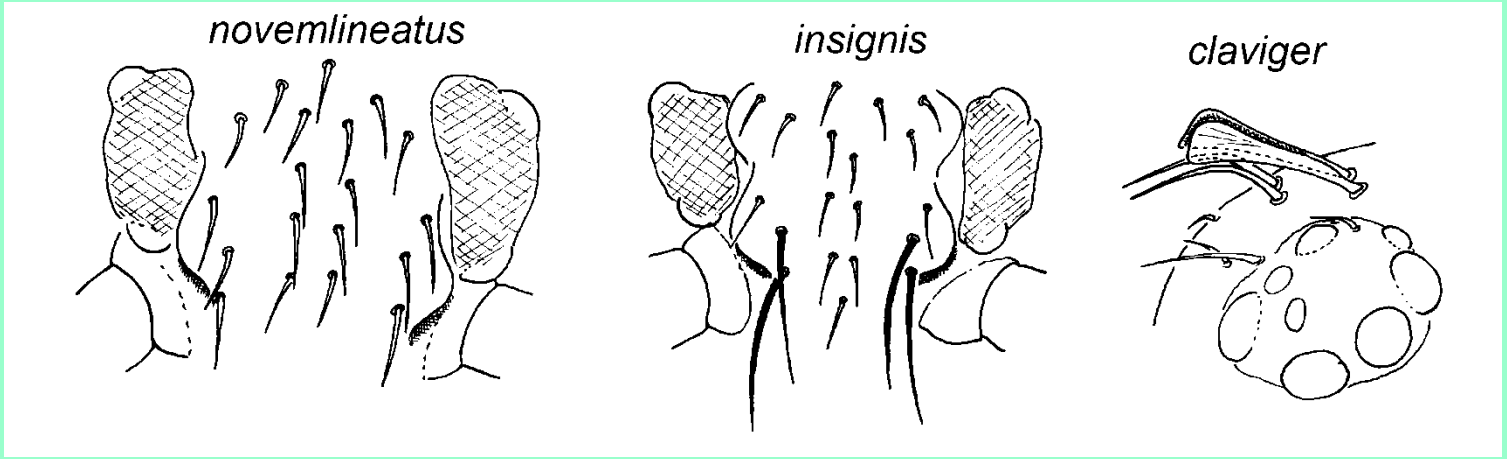


Bovicornia

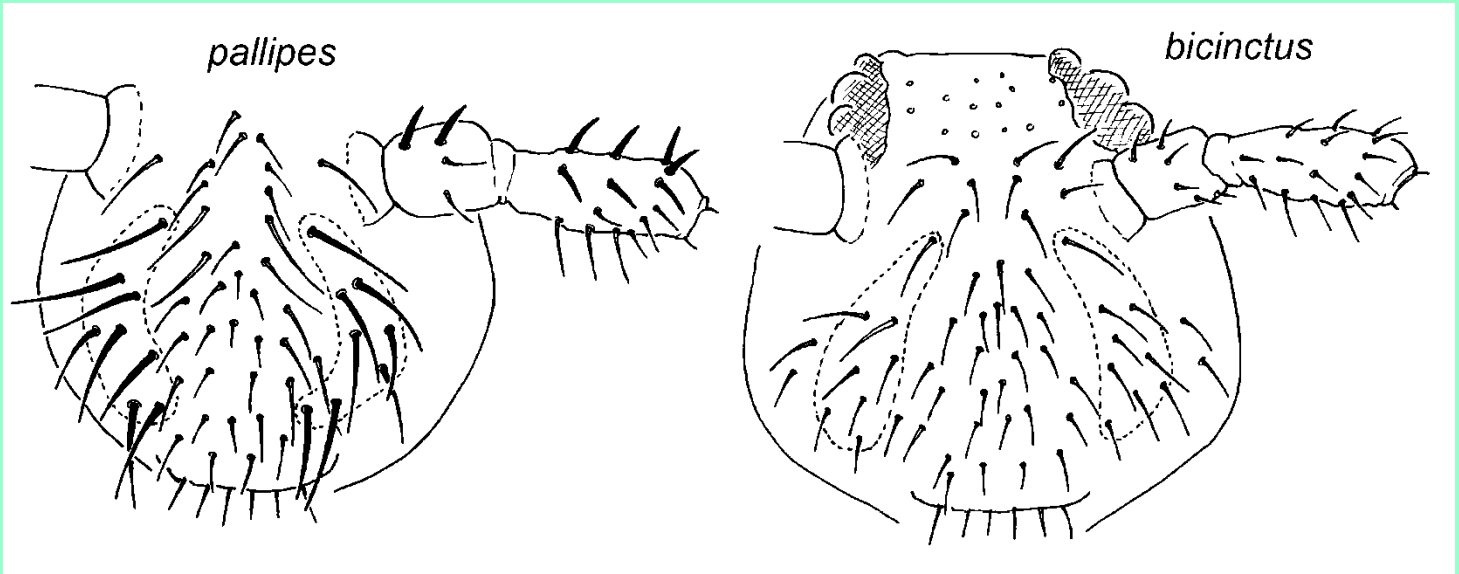
males of species of "non dimorphic" genera

(from Fjellberg, 2007)

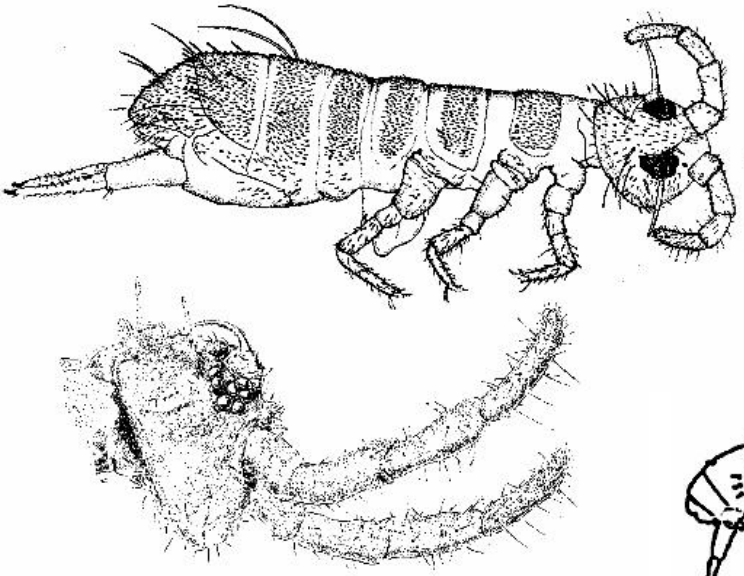
Heterosminthurus



Deuterosminthurus



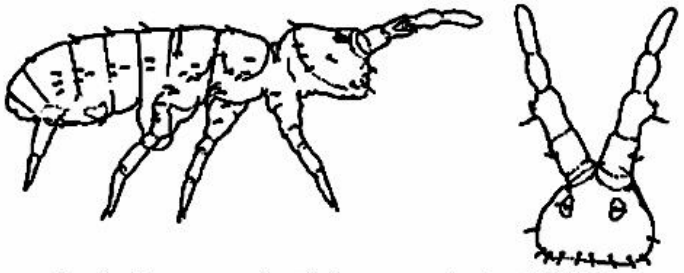
Isotomidae: modified males



Rhodanella minos Denis, 1928
(Delamare-Debbouttvile et al., 1969)

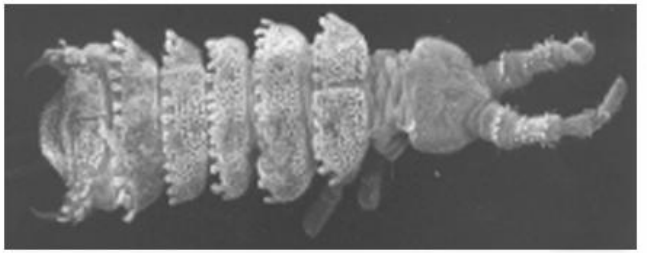
Rhodanella

Jestella siva Najt, 1977 (Najt, 1977)



Jestella armata Potapov et al., 2005
(Potapov et al., 2005)

Jestella



Guthriella muskegis Börner, 1906
(Palacios-Vargas et Castaño-Meneses, 2009)

Guthriella

Dimorphotoma porcella Ellis, 1976
(Schulz, 2010)

Ephemerotoma

separate “dimorphic” genera

Isotomidae: modified males

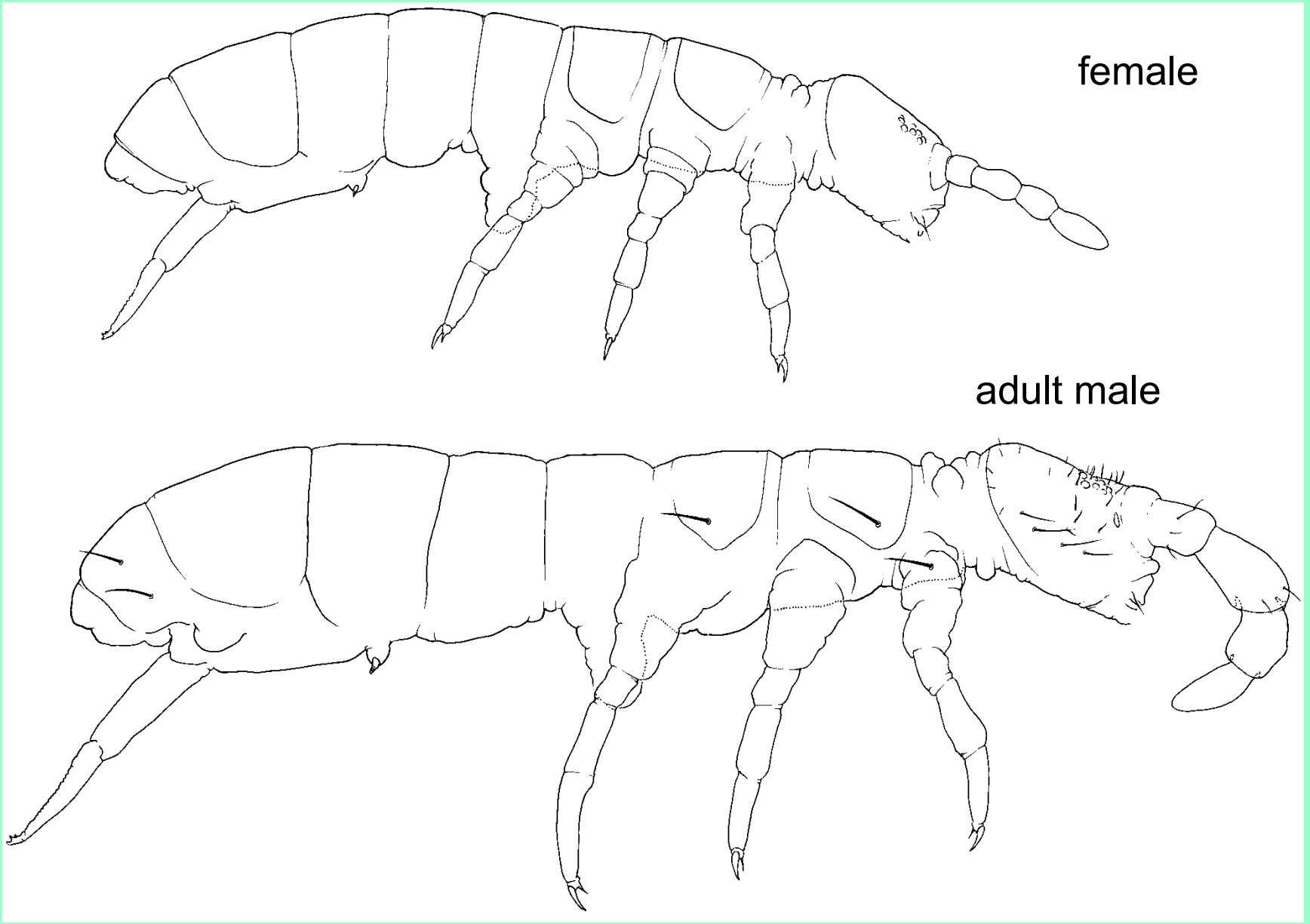
Vertagopus reuteri Schott, 1893
(Fjellberg, 1982)

Archisotoma pulchela
Moniez, 1890 (Fjellberg, 2007)

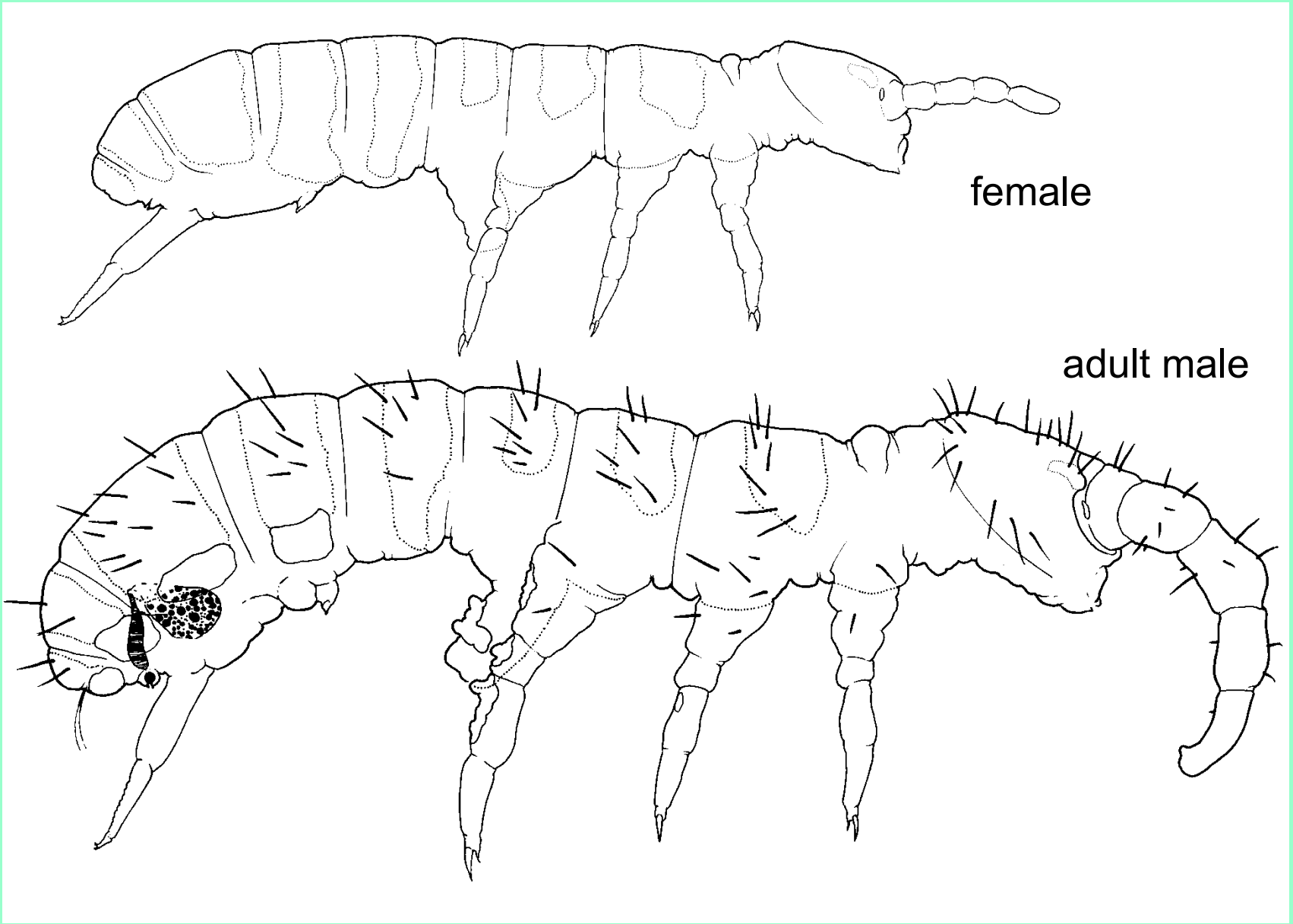
Vertagopus

Archisotoma

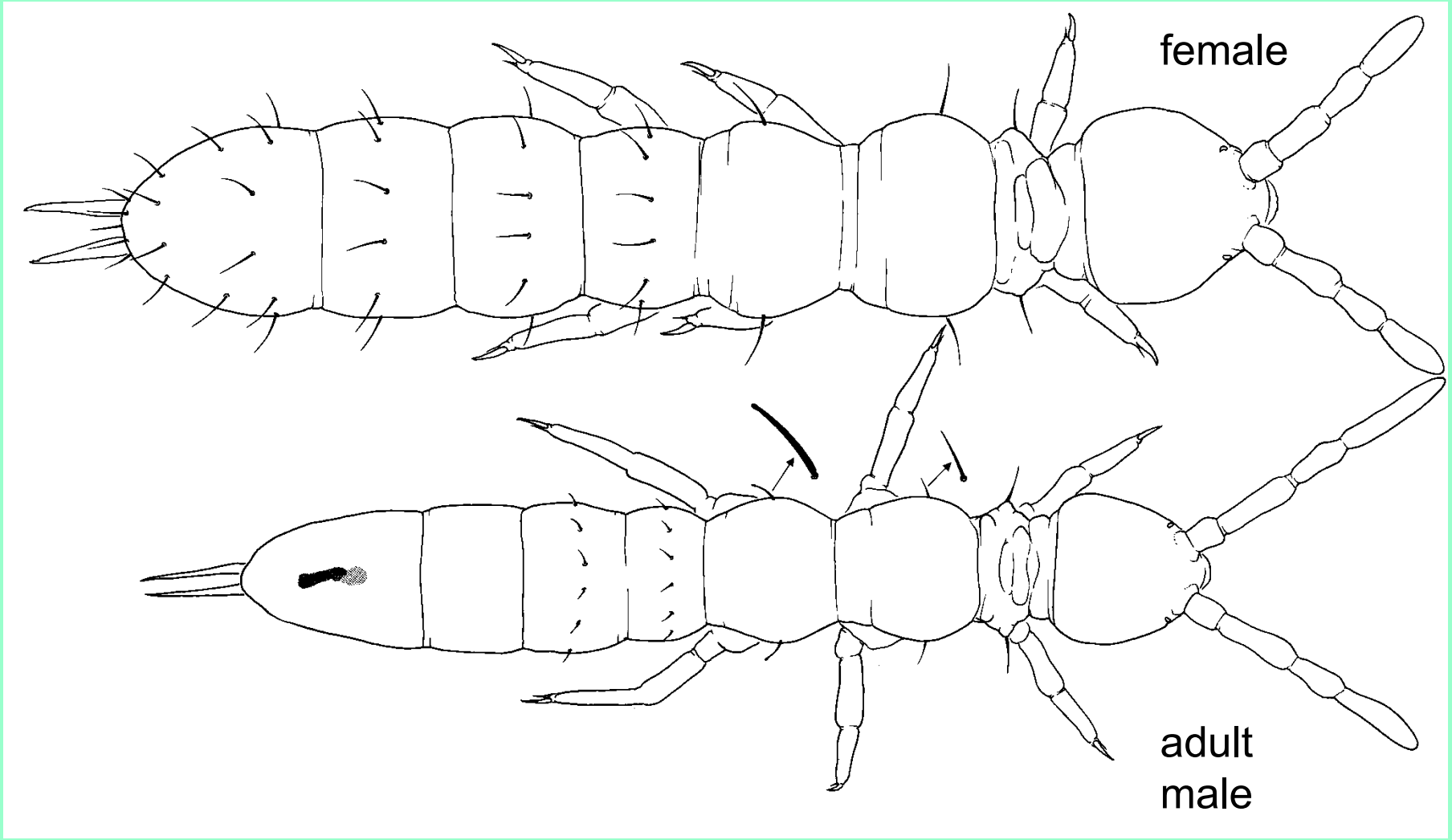
males of some species of
"not dimorphic" genera



Ephemerotoma huadongensis (Chen, 1985) Asia: Shanghai

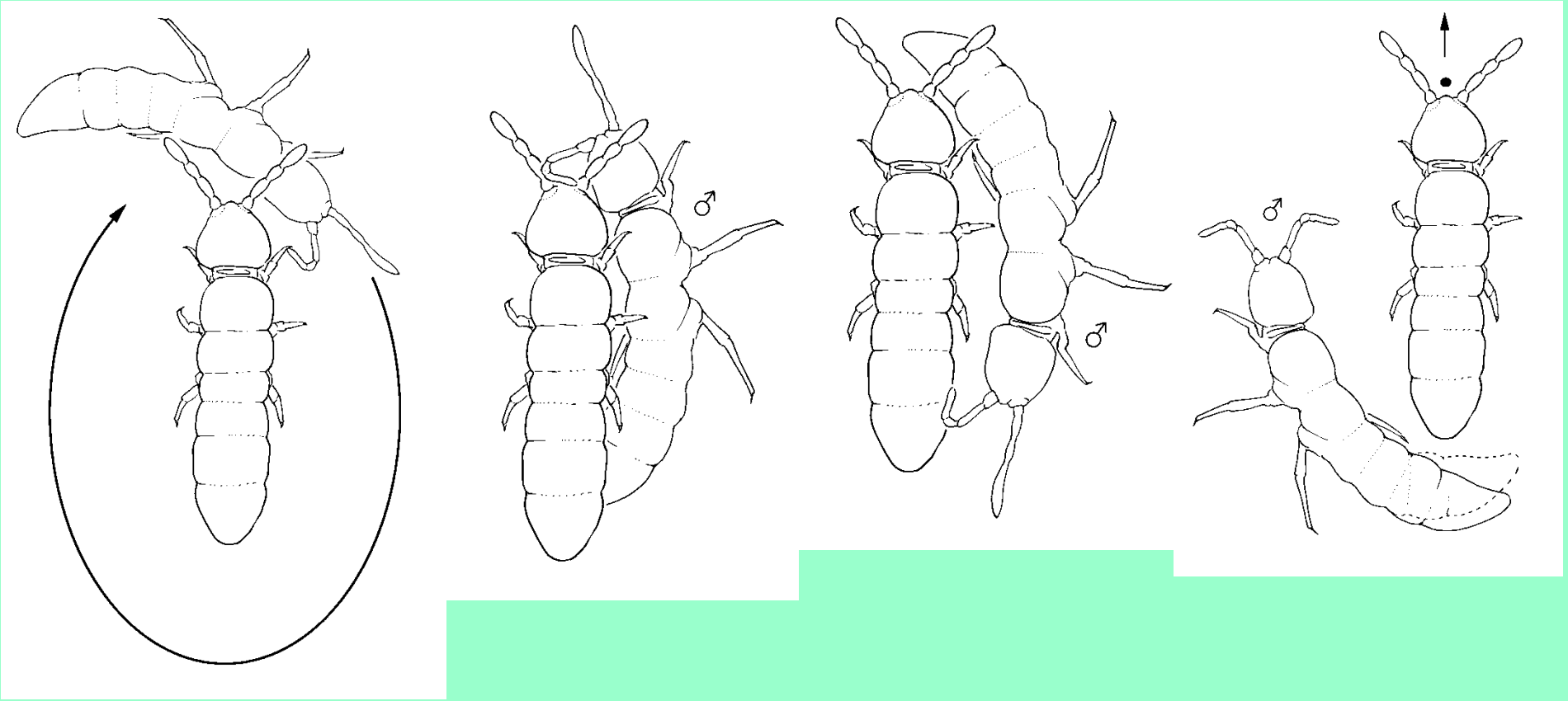


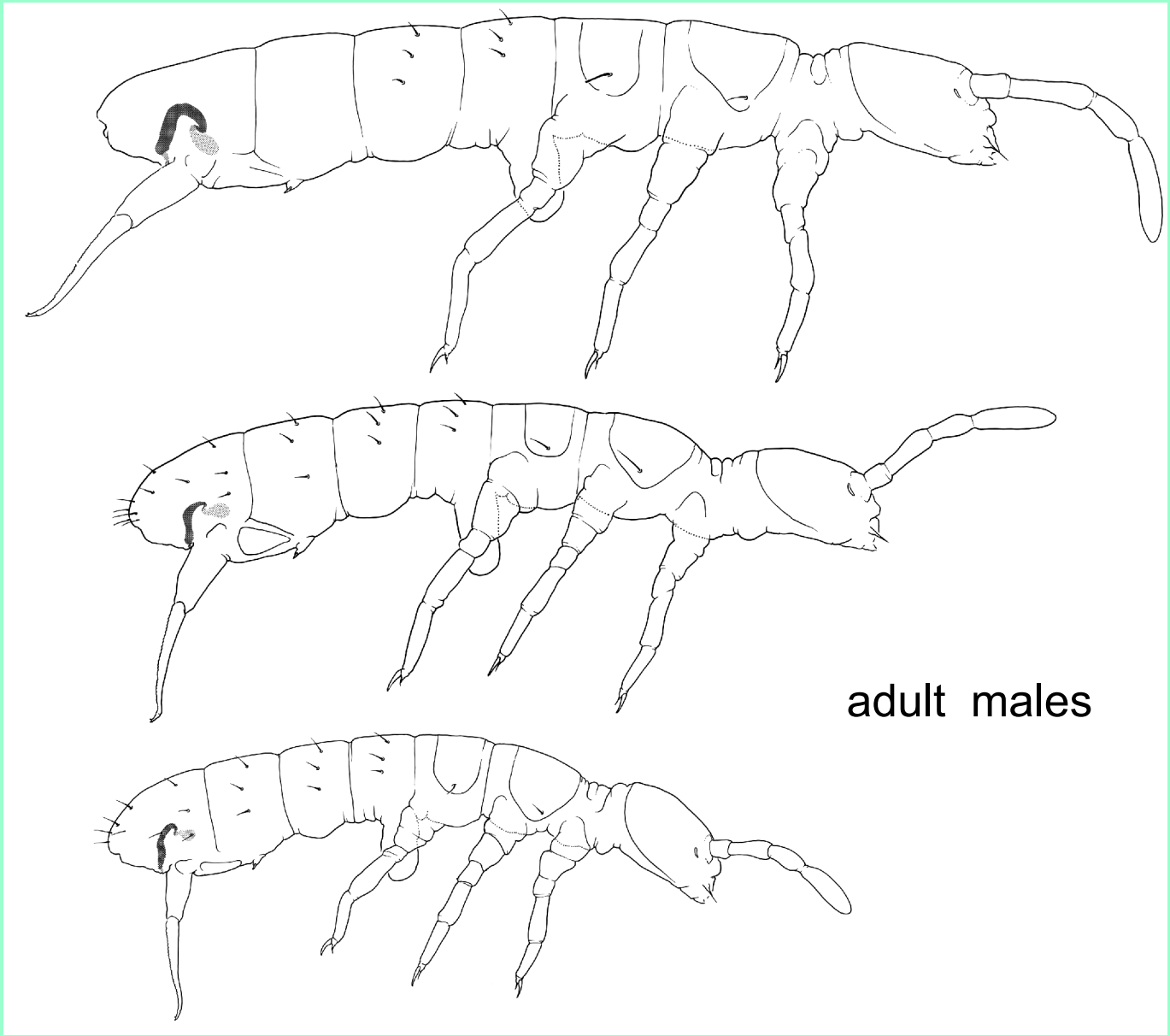
Scutisotoma stepposa (Martynova, 1975) Asia, Eastern Siberia



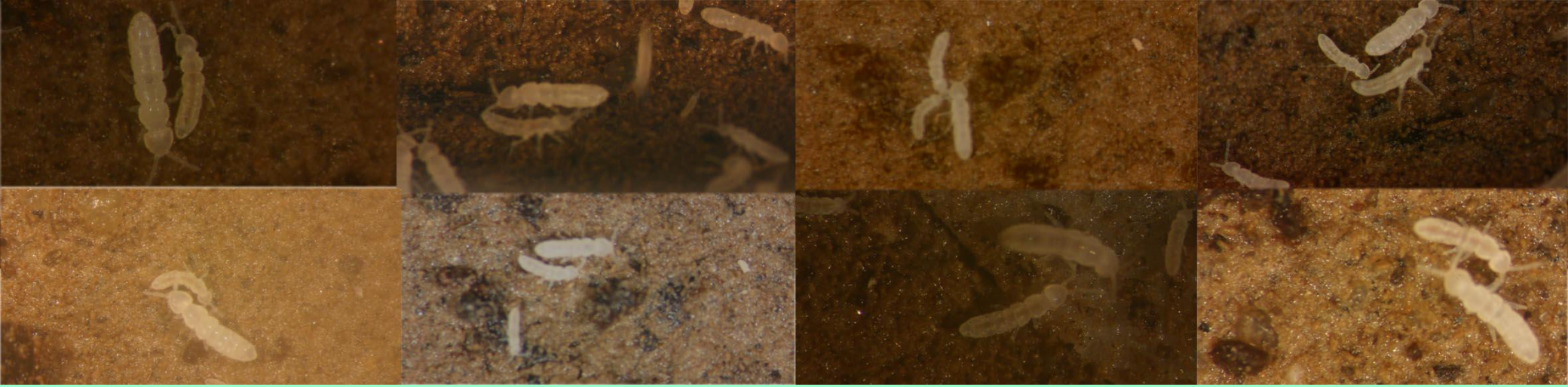
Folsomia candida Willem, 1902 Asia, Shanghai laboratory population (unpubl.)

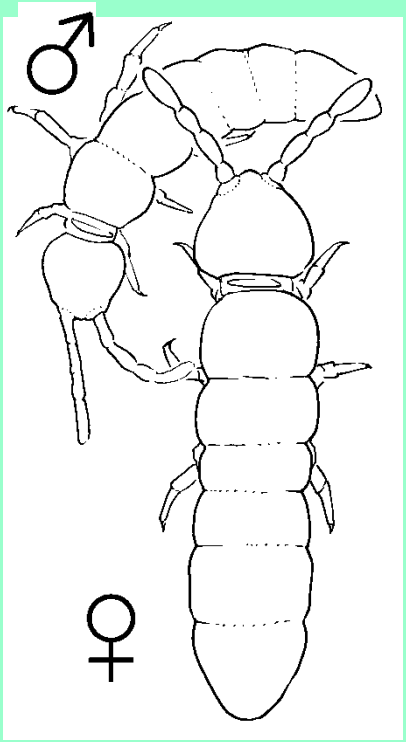
courtship in *F. candida* (Shanghai laboratory population, unpubl.)

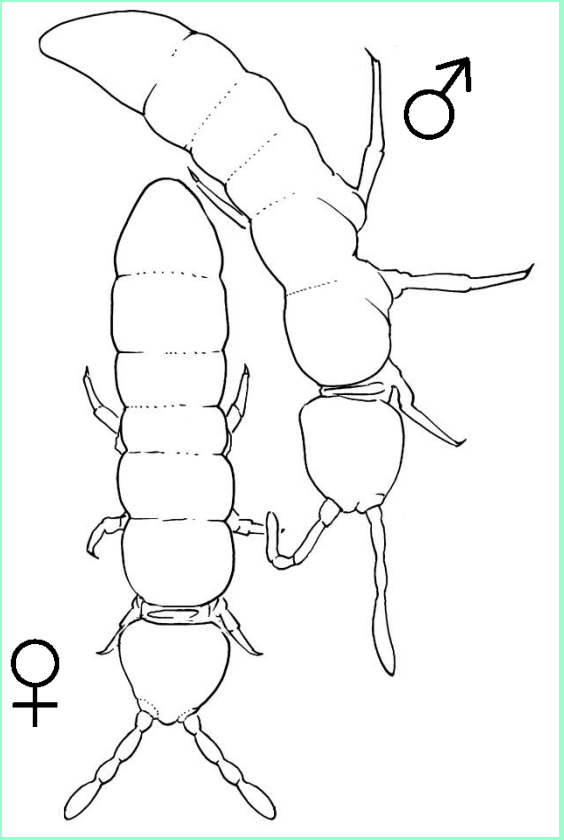


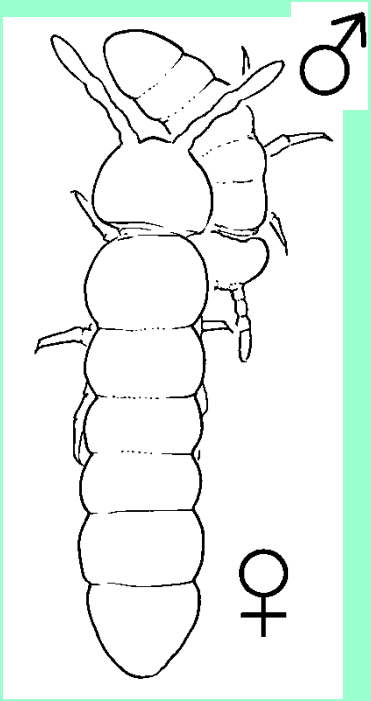


Folsomia candida Willem, 1902 Asia, Shanghai laboratory population (unpubl.)

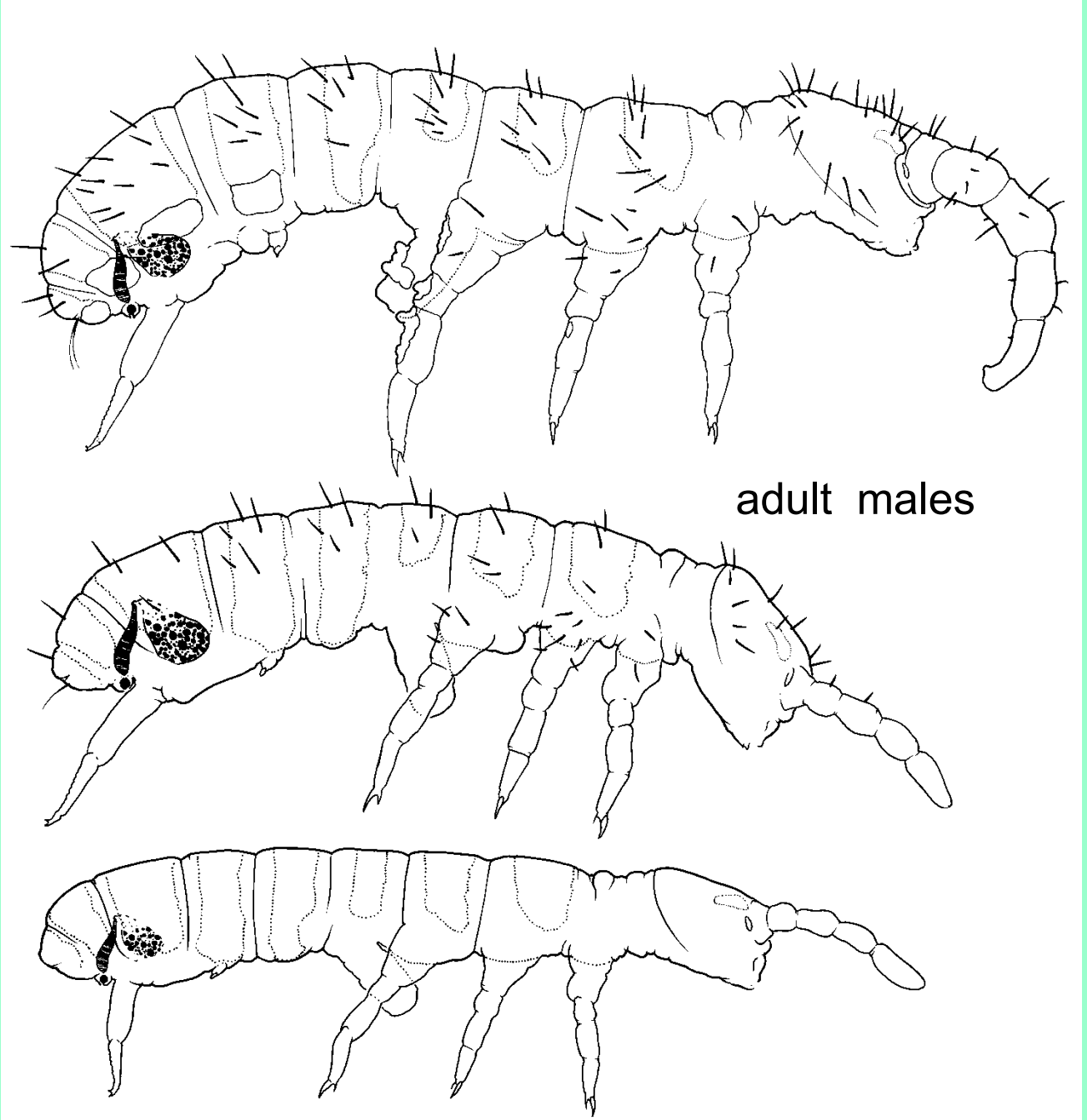






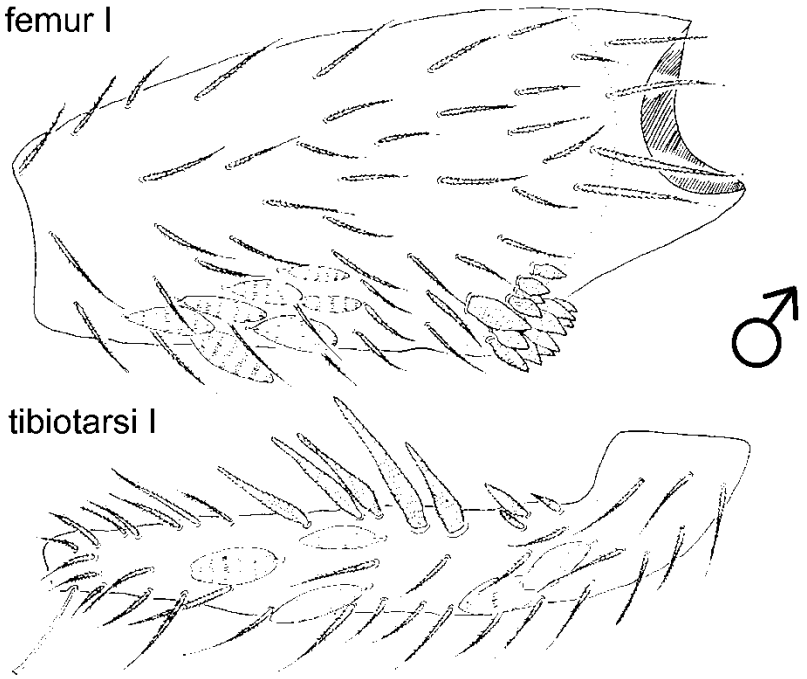


Folsomia candida Willem, 1902 Asia, Shanghai laboratory population (unpubl.)

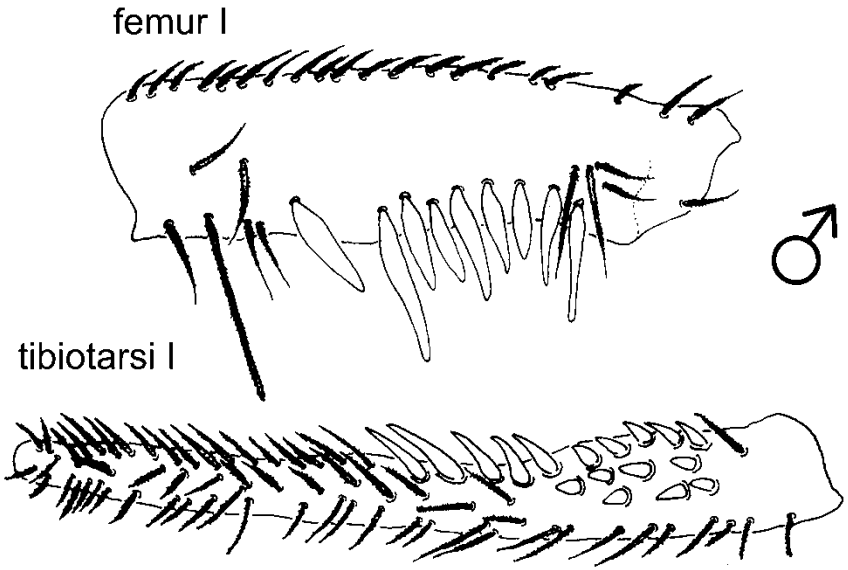


Scutisotoma stepposa
(Martynova, 1975)
Asia, Eastern Siberia

Entomobryidae:
"dimorphic" genera

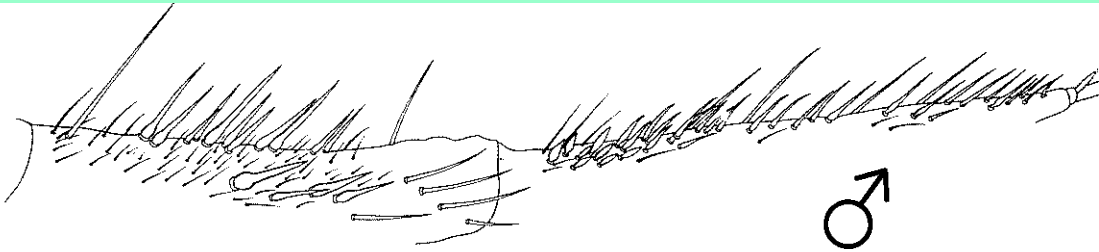


"dimorphic" genus:
1-st pair of legs in *Tyrannoseira*
(from Bellini & Zeppelini, 2011)



non "dimorphic" genus:
Seira mantis
(from Zeppelini & Bellini, 2006)

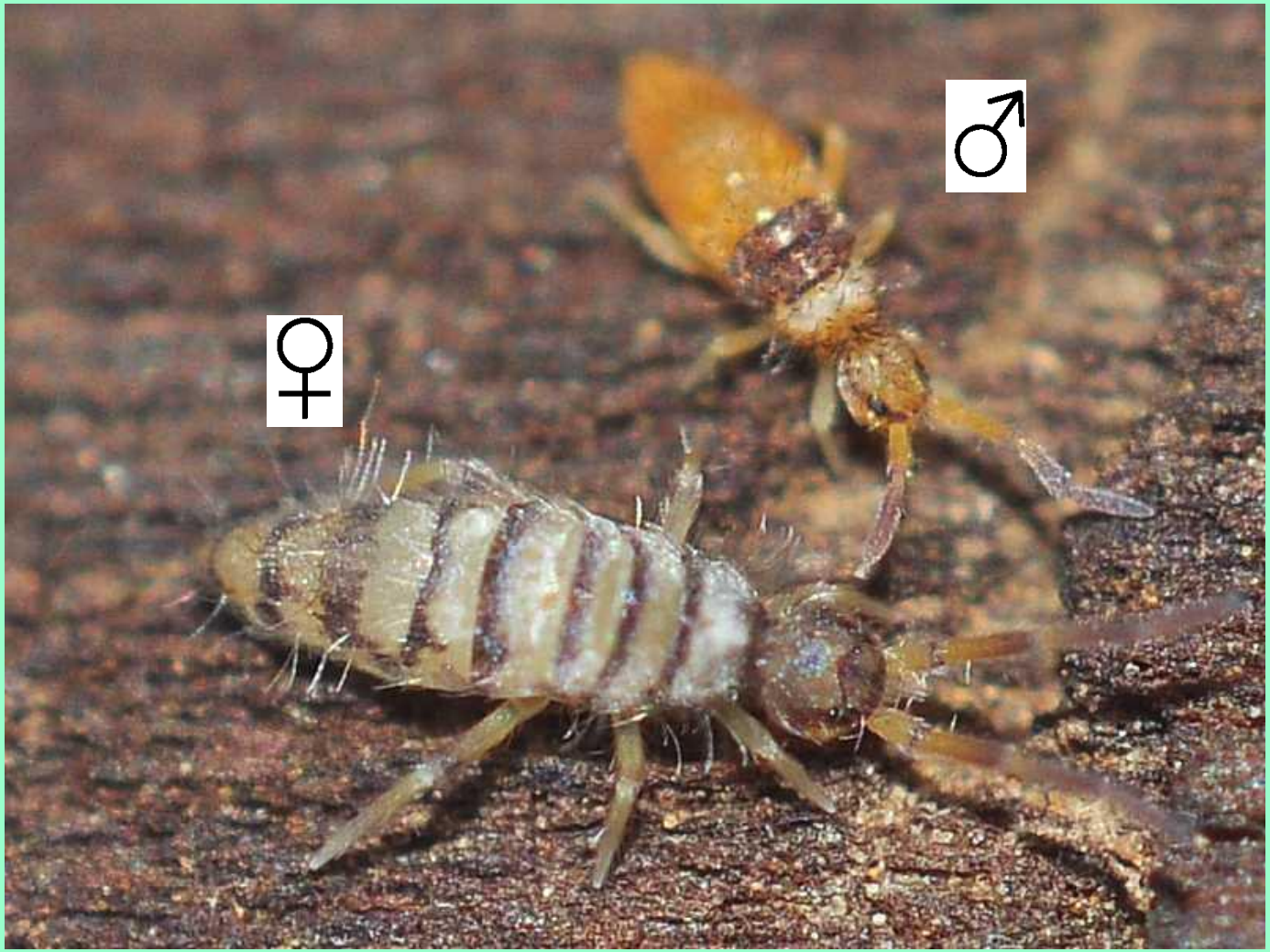
Seira domestica
(from Gisin & Gama, 1962)



Limitation of morphological taxonomy:

colour pattern

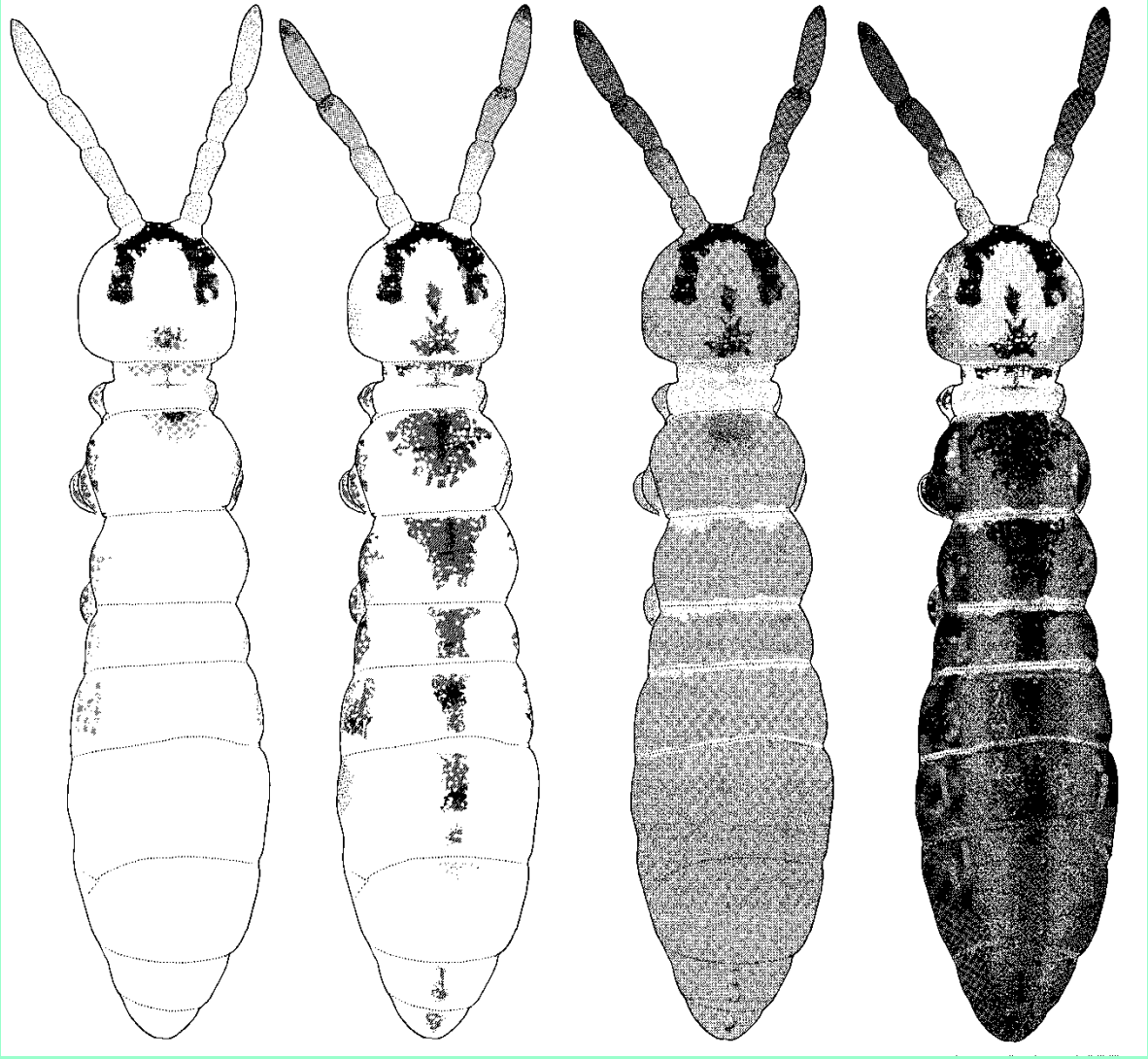
dimorphism of *Entomobrya atrocincta*: Ramel, Baquero, Jordana, 2008)
from http://www.collembola.org



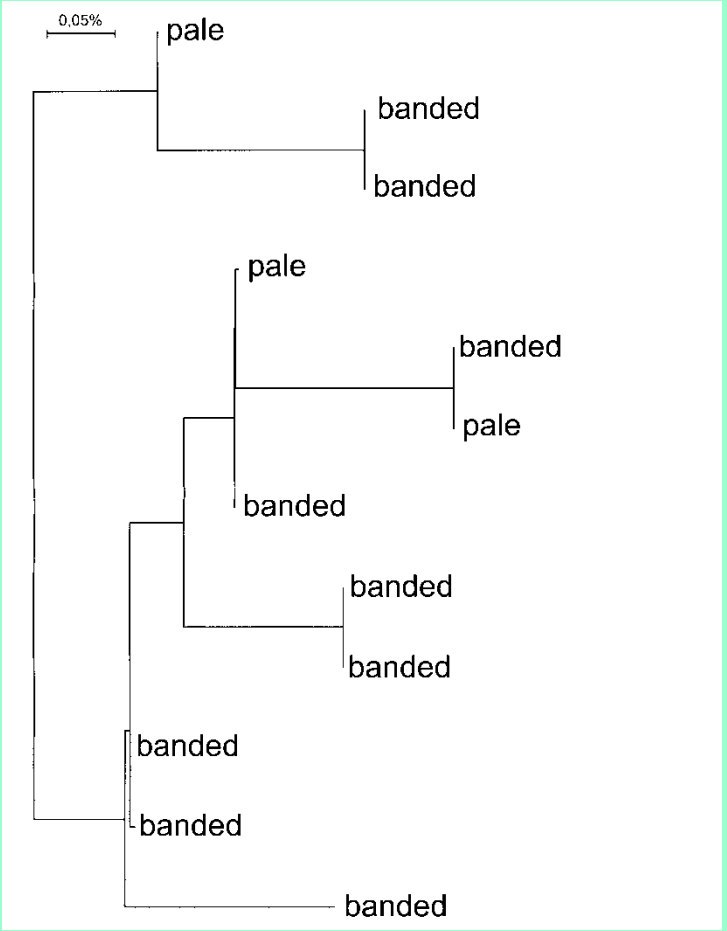
Isotomurus sp.nov. Asia: Kunashir Isl. (unpubl.)

by Deharveng (unpubl.)

Isotomurus sp.nov. Asia: Kunashir Isl. (unpubl.)

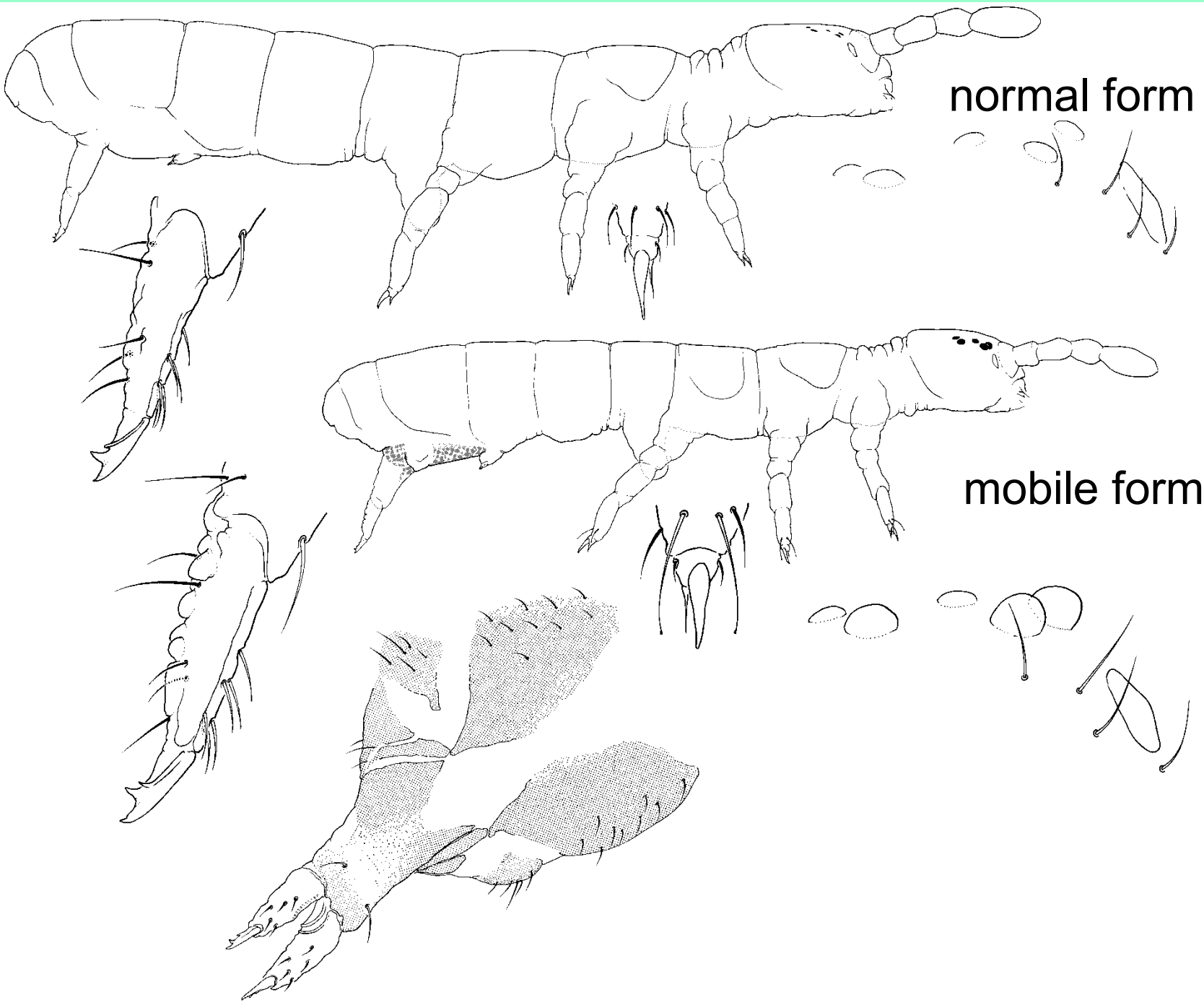


barcoding (COI)



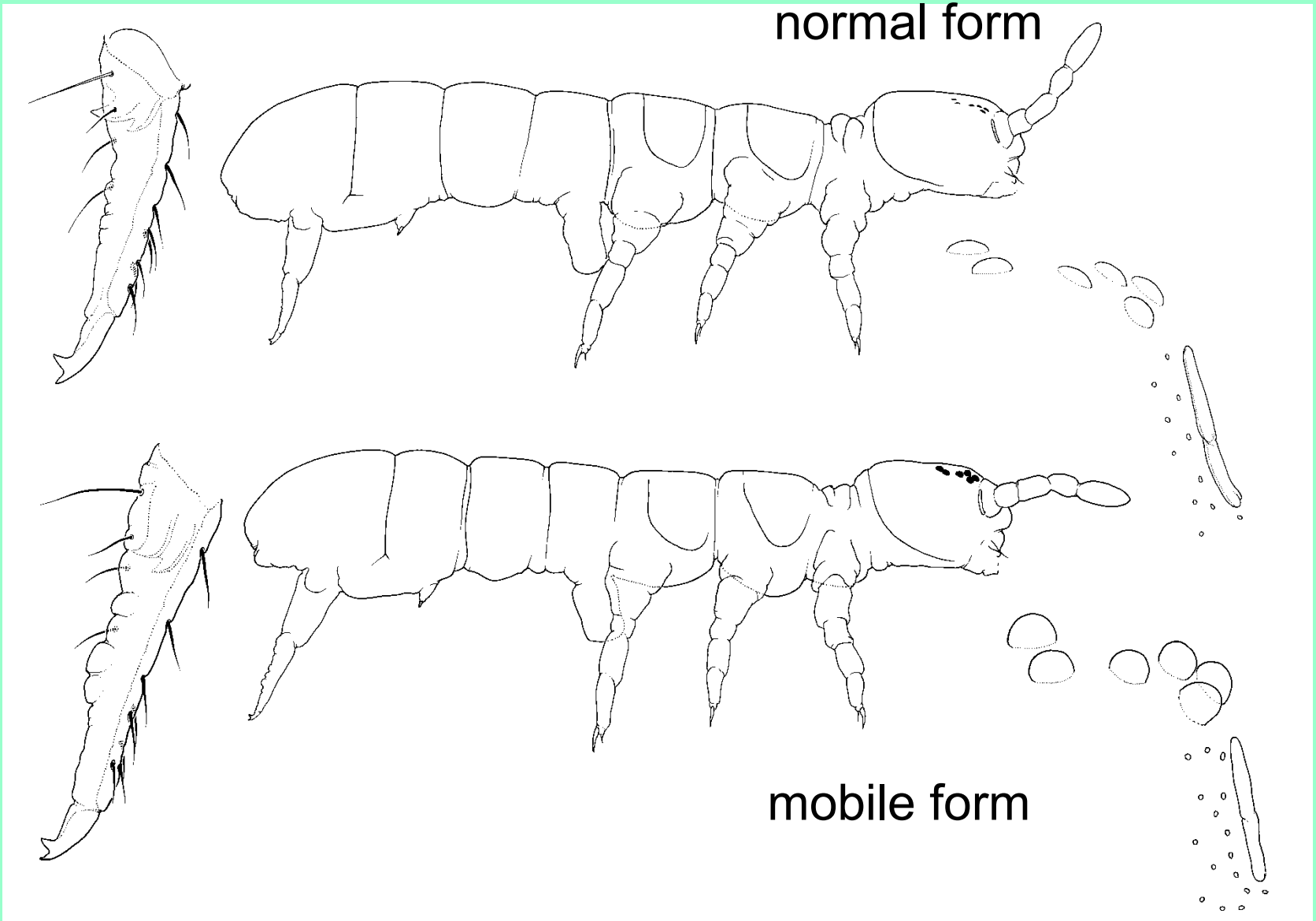
Limitation of morphological taxonomy:

mobile forms – effect of current conditions

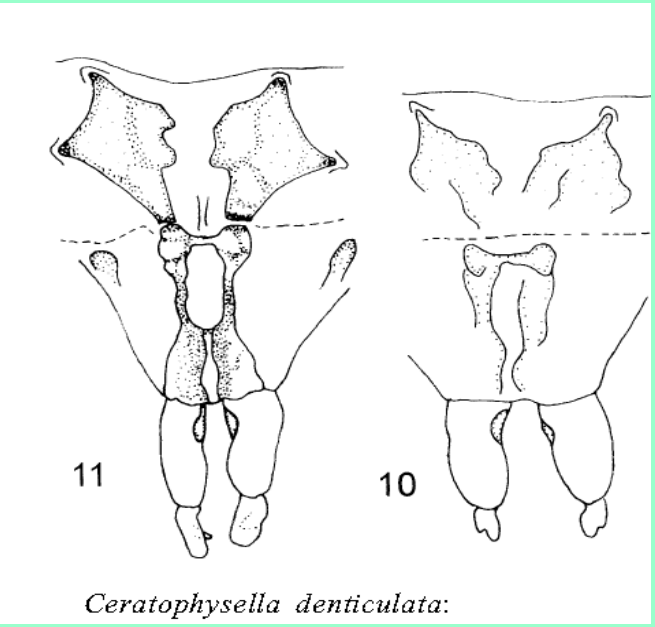


Proisotoma minima

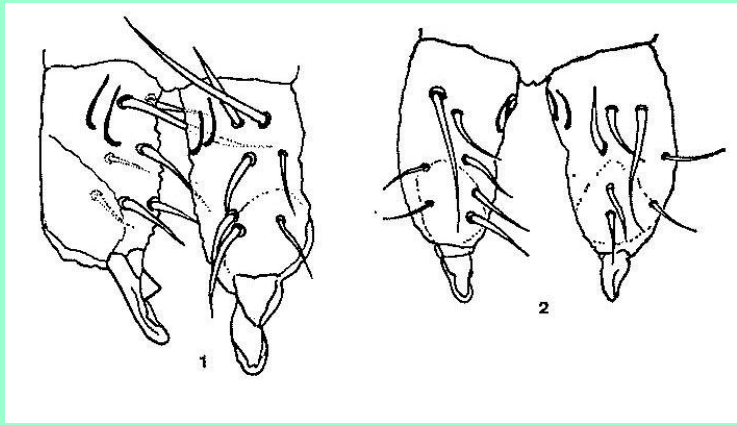
\+ *P.dualis*
P. dottrensi



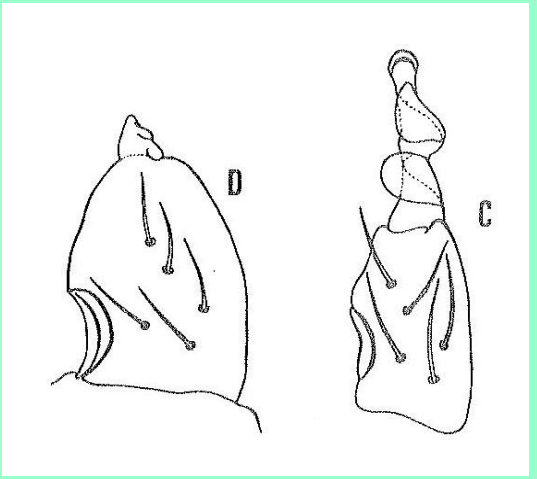
Folsomia sp.nov. (Asia, Far East of Russia, unpubl.)



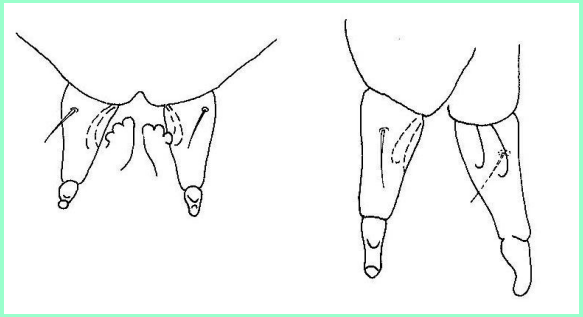
from Skarzynki (2000)



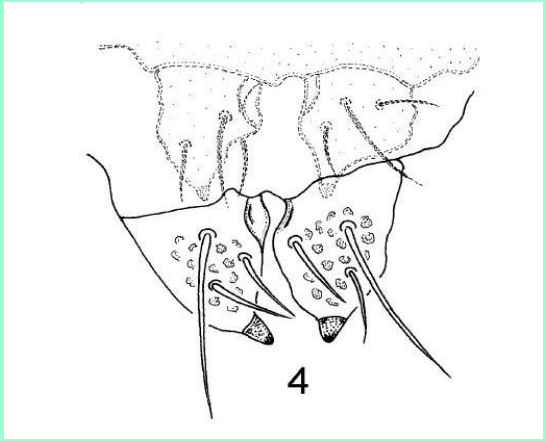
from Bourgeois (1981)



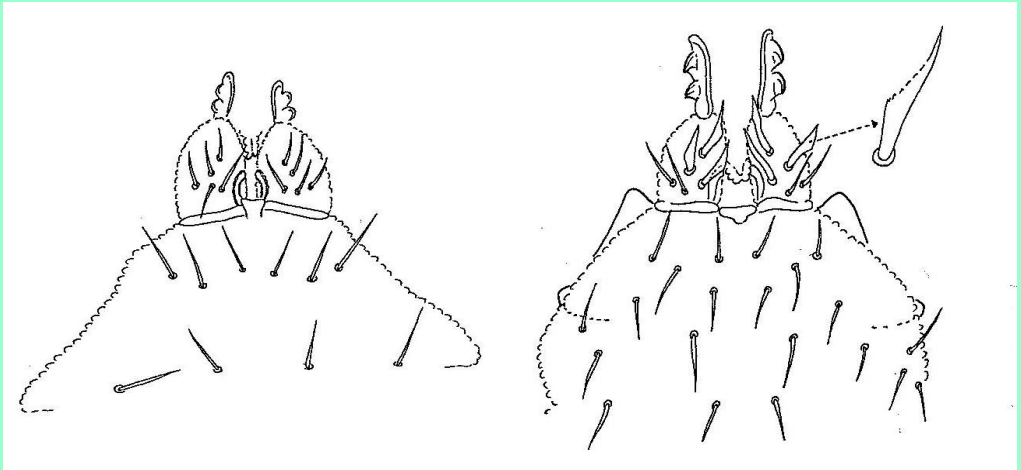
Odontella nana
from Arbea (1988)



Xenylla franzi
from Luciañez et Simon (1992)



from Skarzynki (2001)

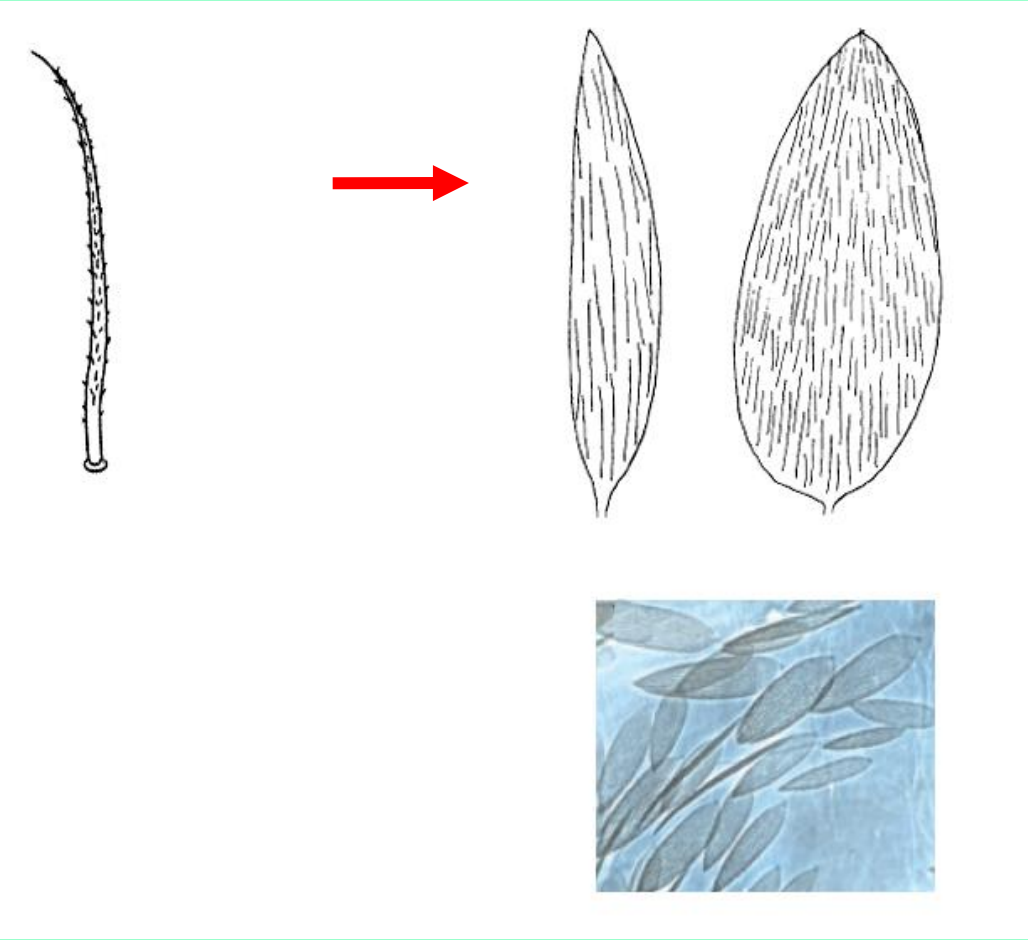


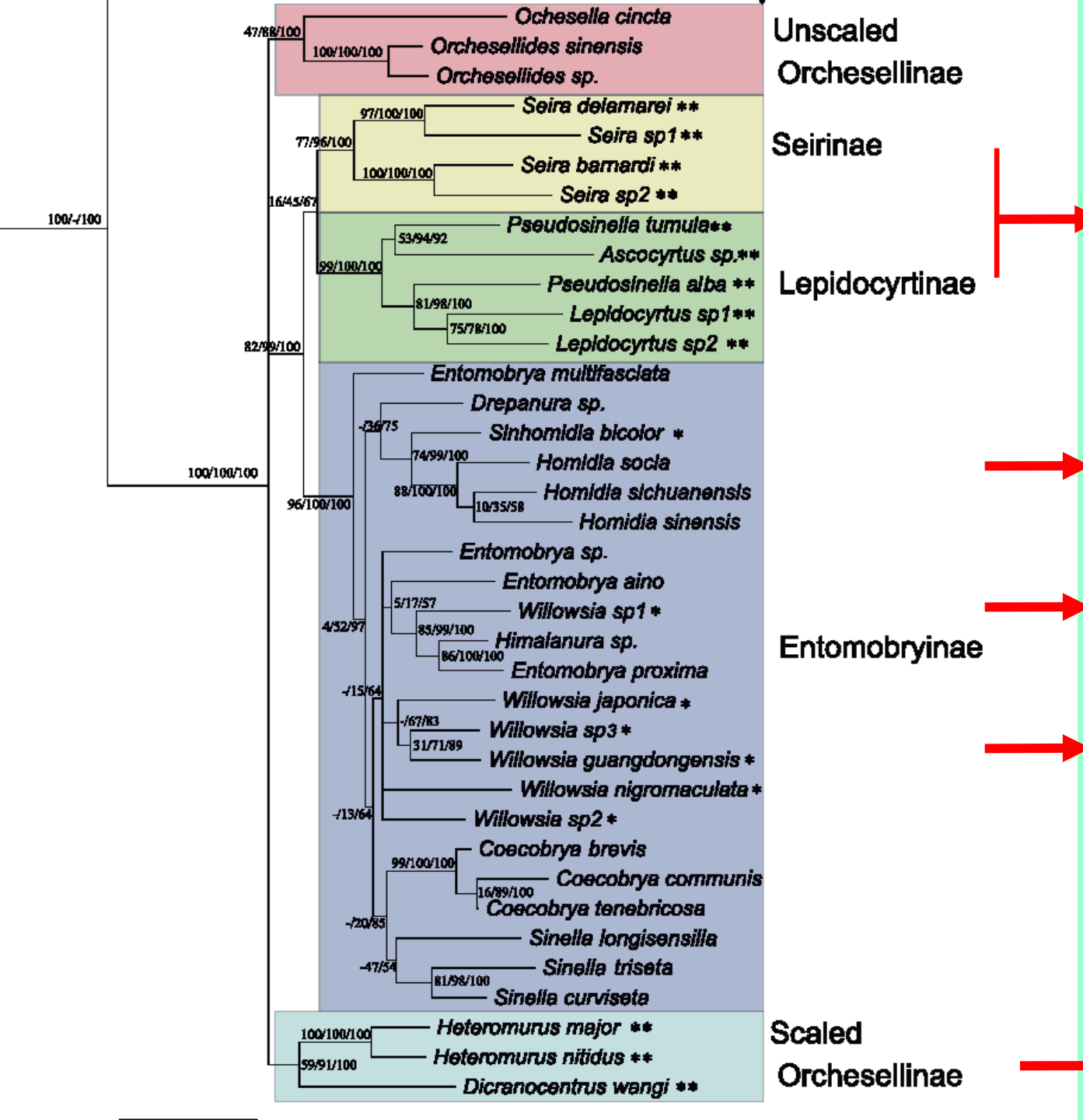
Odontella lamellifera
from Cassagnau et Lauga-Reyrel (1992)

Potential of morphological taxonomy:

- the characters newly introduced or re-estimated
- taxonomy of particular taxa

1. Re-estimation of value of body scales in Entomobryidae





Re-estimation of body scales in Entomobryidae

Phylogeny based on three DNA fragments (from Zhang, Chen, Dong, Deharveng, Stevens, Huang, Zhu, 2014)

2. Scale patterns in Tomoceridae

Pogonognathellus bidentatus

P. elongatus

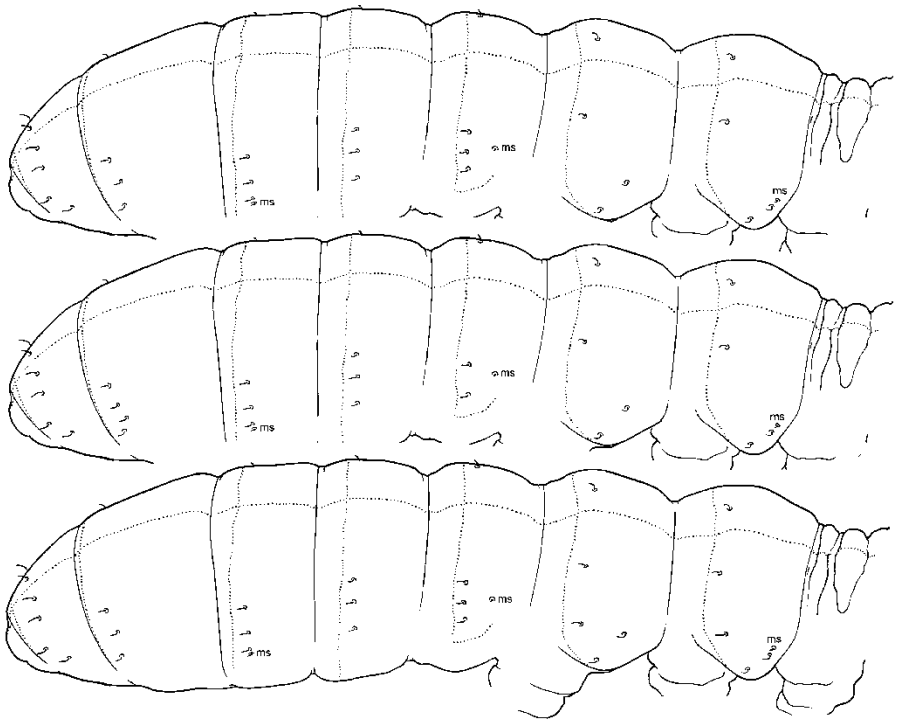
P. nigritus

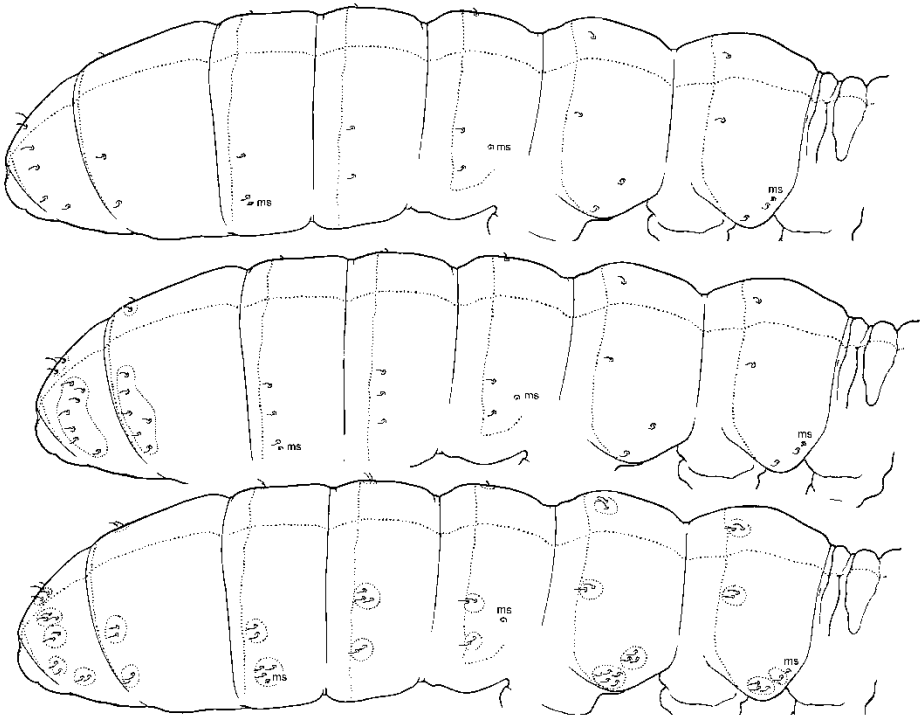
from Felderhoff, Bernard and Moulton (2010)

3. S-chaetotaxy of Entomobryidae

S-chaetotaxy of Isotomidae

Subisotoma





from Potapov et al. (2009)

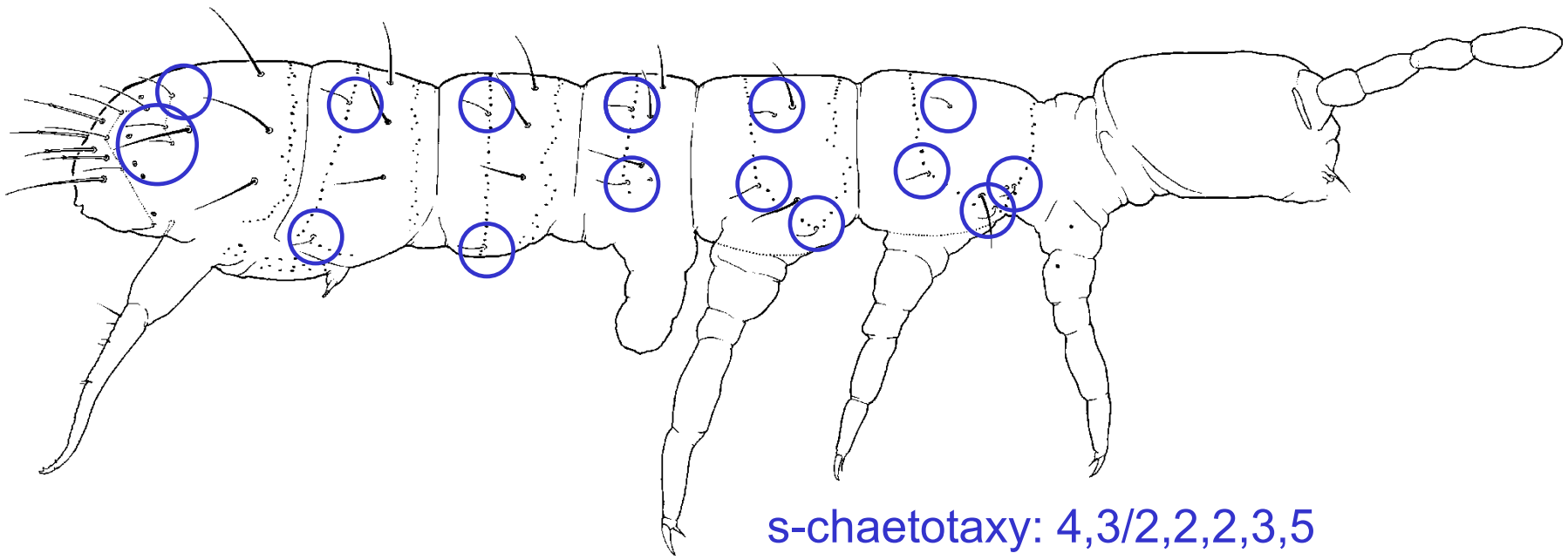
ms-chaetotaxy: 1,0/1,0,1

S-chaetotaxy of Isotomidae

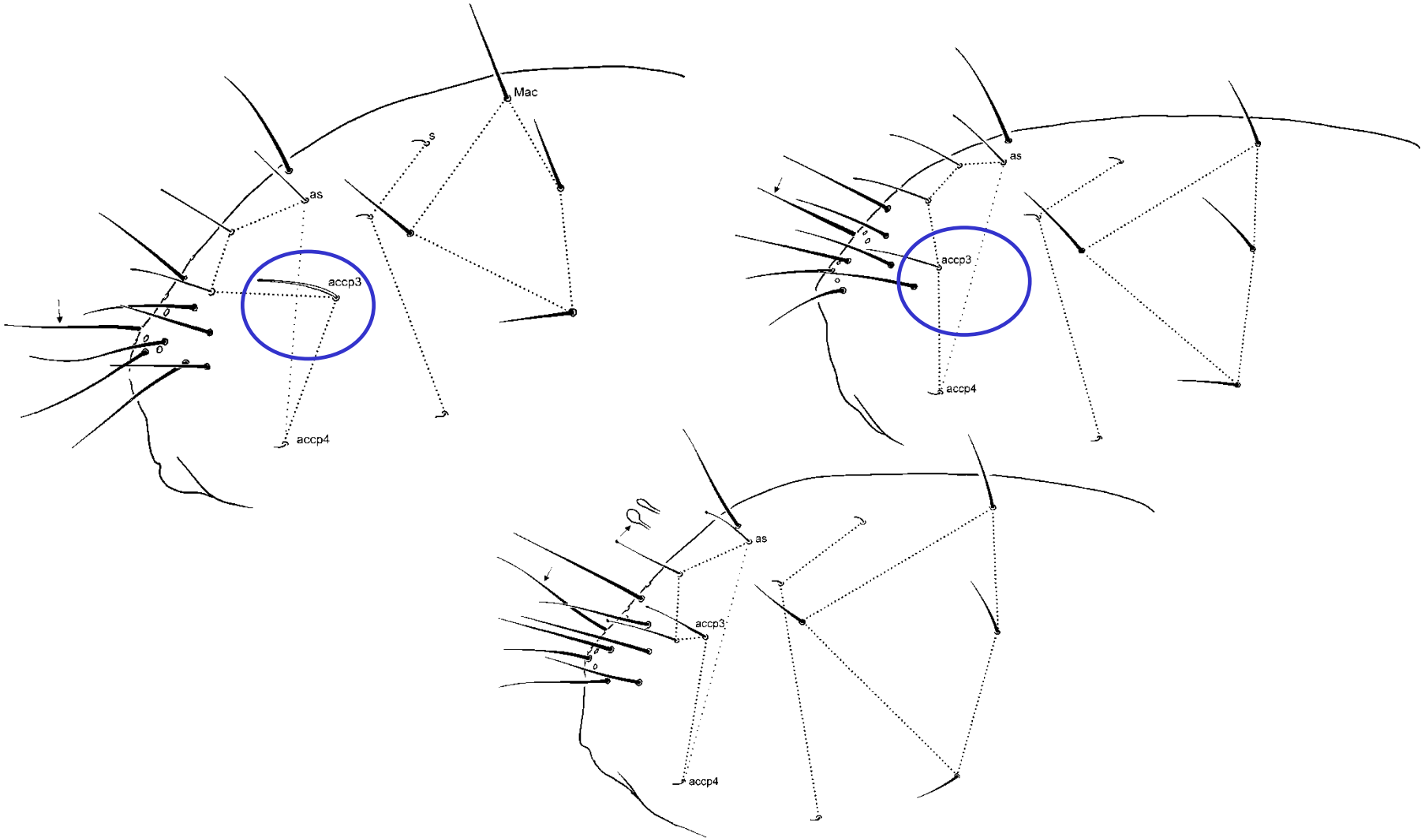
varies considerably: *Subisotoma, Desoria, Parisotoma, Pachyotoma, Isotopenola.*

varies slightly: *Anurophorus, Vertagopus, Isotoma, Isotomiella, Metisotoma, Isotomurus.*

stable within a genus: *Folsomia*, *Cryptopygus* s.str., *Scutisotoma*, *Tetracanthella, Isotomodes, Folsomides, Proisotoma,*



S-chaetotaxy of Abd. IV-V in *Folsomia octooculata*



S-chaetotaxy of Entomobryidae

ms-chaetotaxy: 1,0/1,0,0-1

from Zhang & Deharveng (2014)

Species	Th. II		Th. III	Abd. I		Abd. II	Abd. III		Abd. IV	Abd. V
	sens	ms	sens	sens	ms	sens	sens	ms	sens	sens
Bessoniella procera Deharveng & Thibaud 1989	1	0	1	0	0	2	4	0	3	3
Corynothrix borealis Tullberg, 1876	2	1	2	1	1	>3	>4	1	–	9
Orchesella cincta (Linnaeus, 1758)	2	1	2	1	1	6	8	1	>53	10
Orchesella flavescens (Bourlet, 1939)*	2	1	2	1	1	5	5	1	–	–
Orchesella sp.	2	1	2	1	1	6	6	1	>38	9
Orcheselides boraoi Bonet, 1930	2	1	2	1	1	7	8	1	20	6
Heteromurus major (Moniez, 1889)	2	1	2	1	1	3	3	1	–	3
Heteromurus nitidus (Templeton, 1839)*	2	1	2	1	1	3	3	1		3
Dicranocentrus chenae Ma, Chen & Soto-Adames, 2006	2	1	2	1	1	3	3	1	–	4
Dicranocentrus wangi Ma & Chen, 2007	2	1	2	1	1	3	3	1	>30	4
Dicranocentrus liuae Xu & Zhang, 2014	2	1	2	1	1	3	3	1	–	4
Entomobrya nivalis (Linnaeus, 1758)	?	1	?	1	1	?	?	1	13	3
Entomobrya huangi Chen & Ma, 1998	2	1	2	1	1	2	2	1	7	3
Entomobrya koreana Yosii, 1965	2	1	2	1	1	2	2	1	–	3
Entomobrya proxima Folsom, 1924	2	1	2	1	1	2	2	1	10	3
Entomobrya aino Matsumura & Ishida, 1931	2	1	2	1	1	2	2	1	–	3
Entomobrya multifasciata Tullberg, 1871	2	1	2	1	1	2	2	1	–	3
Entomobrya sp.	2	1	2	1	1	2	2	1	–	3
Entomobryoides myrmecophila (Reuter, 1886)*	2	1	2	1	1	2	2	1	–	3
Homidia cingula Börner, 1906	2	1	2	1	1	2	2	1	>60	3
Szeptyckiella lii Zhang, Bedos & Deharveng, 2014	2	1	2	1	1	2	2	1	–	3
Lepidosira vicina Yoshii, 1989	2	1	2	1	1	2	2	1	≈17	3
Acanthocyrtus spincsus (Schött, 1917)	2	1	2	1	1	2	2	1	–	3
Seira bamardi (Womersley, 1934)	1	1	1	0	1	2	2	1	3	3
Seira delamarei Jacquemart, 1980	1	1	1	0	1	2	2	1	11	3
Seira oligoseta Lee & Park, 1989	1	1	1	0	1	2	2	1	–	3
Seira dowlingi Wray, 1953†	1	1	1	0	1	2	2	1	11	3
Seira sp1	1	1	1	0	1	2	2	1	–	3
Seira sp2	1	1	1	0	1	2	2	1	–	3
Seira sp3	1	1	1	0	1	2	2	1	–	3
Lepidocyrtus cyaneus Tullberg, 1871	1	1	1	0	1	1	1	1	8	3
Lepidocyrtus curvicollis (Bourlet, 1839)	1	1	1	0	1	1	1	1	4	3
Lepidocyrtus cf. *lanuginosus* (Gmelin, 1788)‡	1	1	1	0	1	1	1	1	4	3
Lepidocyrtus absens Zhang, Chatterjee & Chen, 2009	1	1	1	0	1	1	1	0	8	2
Lepidocyrtus felipei Wang, Chen & Christiansen, 2003	1	1	1	0	1	1	1	1	5	3
Lepidocyrtus sp1	1	1	1	0	1	1	1	1	–	3
Lepidocyrtus sp2	1	1	1	0	1	1	1	1	–	3
Lepidocyrtus sp3	1	1	1	0	1	1	1	1	4	3
Pseudosinella alba (Packard, 1873)	1	1	1	0	1	1	1	1	3	3
Pseudosinella decipiens Denis, 1924§	1	1	1	0	1	1	1	1	5	3
Pseudosinella sexoculata Schött, 1902	1	1	1	0	1	1	1	1	–	3
Pseudosinella tumula Wang, Chen & Christiansen, 2002	1	1	1	0	1	1	1	1	–	3
Pseudosinella mutabilis Wang, Chen & Christianser, 2003	1	1	1	0	1	1	1	1	–	3
Pseudosinella sp.	1	1	1	0	1	1	1	0	6	3
Acrocyrtus zhujiensis Xu, Pan & Zhang 2013	1	1	1	0	1	1	1	1	5	3
Acrocyrtus finis Xu, Pan & Zhang 2013	1	1	1	0	1	1	1	1	5	3
Ascocyrtus sp1	1	1	1	0	1	1	1	1	7	3
Ascocyrtus sp2	1	1	1	0	1	1	1	1	6	3
Rambutsinella honchongensis Deharveng & Bedos, 1996	1	1	1	0	1	1	1	1	–	1
Rambutsinella grinnellia (Wang, Chen & Christiansen, 2004) n. comb.	1	1	1	0	1	1	1	1	–	1
Rambutsinella sp.	1	1	1	0	1	1	1	1	4	1

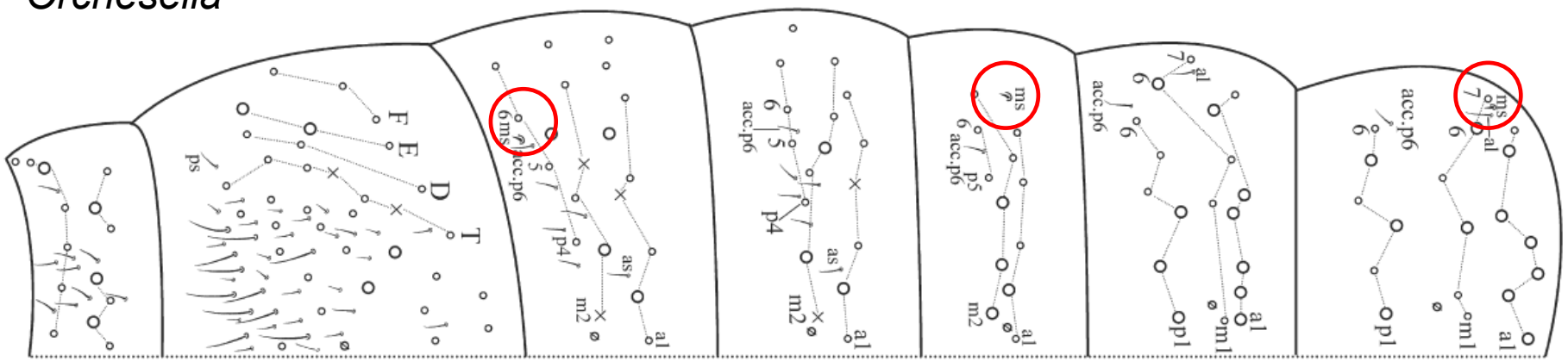
S-chaetotaxy of Entomobryidae

s-chaetotaxy:
1-2,1-2/
0-1,1-2(>2), 1-2(>2), 4->60,1-10

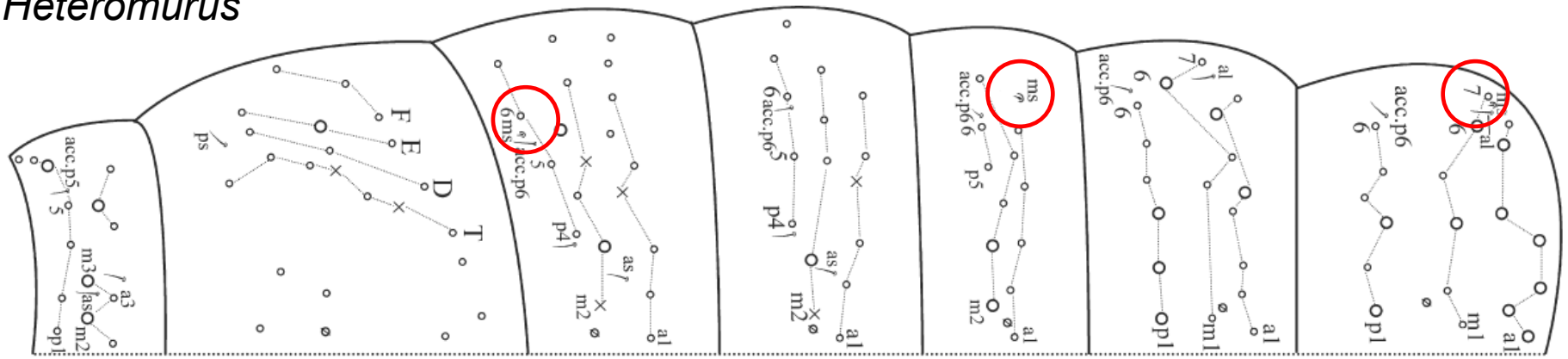
from Zhang & Deharveng (2014)

Species	Th. II		Th. III	Abd. I		Abd. II	Abd. III		Abd. IV	Abd. V
	sens	ms	sens	sens	ms	sens	sens	ms	sens	sens
Bessoniella procera Deharveng & Thibaud 1989	1	0	1	0	0	2	4	0	3	3
Corynothrix borealis Tullberg, 1876	2	1	2	1	1	>3	>4	1	–	9
Orchesella cincta (Linnaeus, 1758)	2	1	2	1	1	6	8	1	>53	10
Orchesella flavescens (Bourlet, 1939)*	2	1	2	1	1	5	5	1	–	–
Orchesella sp.	2	1	2	1	1	6	6	1	>38	9
Orcheselides boraoi Bonet, 1930	2	1	2	1	1	7	8	1	20	6
Heteromurus major (Moniez, 1889)	2	1	2	1	1	3	3	1	–	3
Heteromurus nitidus (Templeton, 1839)*	2	1	2	1	1	3	3	1		3
Dicranocentrus chenae Ma, Chen & Soto-Adames, 2006	2	1	2	1	1	3	3	1	–	4
Dicranocentrus wangi Ma & Chen, 2007	2	1	2	1	1	3	3	1	>30	4
Dicranocentrus liuae Xu & Zhang, 2014	2	1	2	1	1	3	3	1	–	4
Entomobrya nivalis (Linnaeus, 1758)	?	1	?	1	1	?	?	1	13	3
Entomobrya huangi Chen & Ma, 1998	2	1	2	1	1	2	2	1	7	3
Entomobrya koreana Yosii, 1965	2	1	2	1	1	2	2	1	–	3
Entomobrya proxima Folsom, 1924	2	1	2	1	1	2	2	1	10	3
Entomobrya aino Matsumura & Ishida, 1931	2	1	2	1	1	2	2	1	–	3
Entomobrya multifasciata Tullberg, 1871	2	1	2	1	1	2	2	1	–	3
Entomobrya sp.	2	1	2	1	1	2	2	1	–	3
Entomobryoides myrmecophila (Reuter, 1886)*	2	1	2	1	1	2	2	1	–	3
Homidia cingula Börner, 1906	2	1	2	1	1	2	2	1	>60	3
Szeptyckiella lii Zhang, Bedos & Deharveng, 2014	2	1	2	1	1	2	2	1	–	3
Lepidosira vicina Yoshii, 1989	2	1	2	1	1	2	2	1	≈17	3
Acanthocyrtus spincsus (Schött, 1917)	2	1	2	1	1	2	2	1	–	3
Seira bamardi (Womersley, 1934)	1	1	1	0	1	2	2	1	3	3
Seira delamarei Jacquemart, 1980	1	1	1	0	1	2	2	1	11	3
Seira oligoseta Lee & Park, 1989	1	1	1	0	1	2	2	1	–	3
Seira dowlingi Wray, 1953†	1	1	1	0	1	2	2	1	11	3
Seira sp1	1	1	1	0	1	2	2	1	–	3
Seira sp2	1	1	1	0	1	2	2	1	–	3
Seira sp3	1	1	1	0	1	2	2	1	–	3
Lepidocyrtus cyaneus Tullberg, 1871	1	1	1	0	1	1	1	1	8	3
Lepidocyrtus curvicollis (Bourlet, 1839)	1	1	1	0	1	1	1	1	4	3
Lepidocyrtus cf. *lanuginosus* (Gmelin, 1788)‡	1	1	1	0	1	1	1	1	4	3
Lepidocyrtus absens Zhang, Chatterjee & Chen, 2009	1	1	1	0	1	1	1	0	8	2
Lepidocyrtus felipei Wang, Chen & Christiansen, 2003	1	1	1	0	1	1	1	1	5	3
Lepidocyrtus sp1	1	1	1	0	1	1	1	1	–	3
Lepidocyrtus sp2	1	1	1	0	1	1	1	1	–	3
Lepidocyrtus sp3	1	1	1	0	1	1	1	1	4	3
Pseudosinella alba (Packard, 1873)	1	1	1	0	1	1	1	1	3	3
Pseudosinella decipiens Denis, 1924§	1	1	1	0	1	1	1	1	5	3
Pseudosinella sexoculata Schött, 1902	1	1	1	0	1	1	1	1	–	3
Pseudosinella tumula Wang, Chen & Christiansen, 2002	1	1	1	0	1	1	1	1	–	3
Pseudosinella mutabilis Wang, Chen & Christianser, 2003	1	1	1	0	1	1	1	1	–	3
Pseudosinella sp.	1	1	1	0	1	1	1	0	6	3
Acrocyrtus zhujiensis Xu, Pan & Zhang 2013	1	1	1	0	1	1	1	1	5	3
Acrocyrtus finis Xu, Pan & Zhang 2013	1	1	1	0	1	1	1	1	5	3
Ascocyrtus sp1	1	1	1	0	1	1	1	1	7	3
Ascocyrtus sp2	1	1	1	0	1	1	1	1	6	3
Rambutsinella honchongensis Deharveng & Bedos, 1996	1	1	1	0	1	1	1	1	–	1
Rambutsinella grinnellia (Wang, Chen & Christiansen, 2004) n. comb.	1	1	1	0	1	1	1	1	–	1
Rambutsinella sp.	1	1	1	0	1	1	1	1	4	1

Orchesella



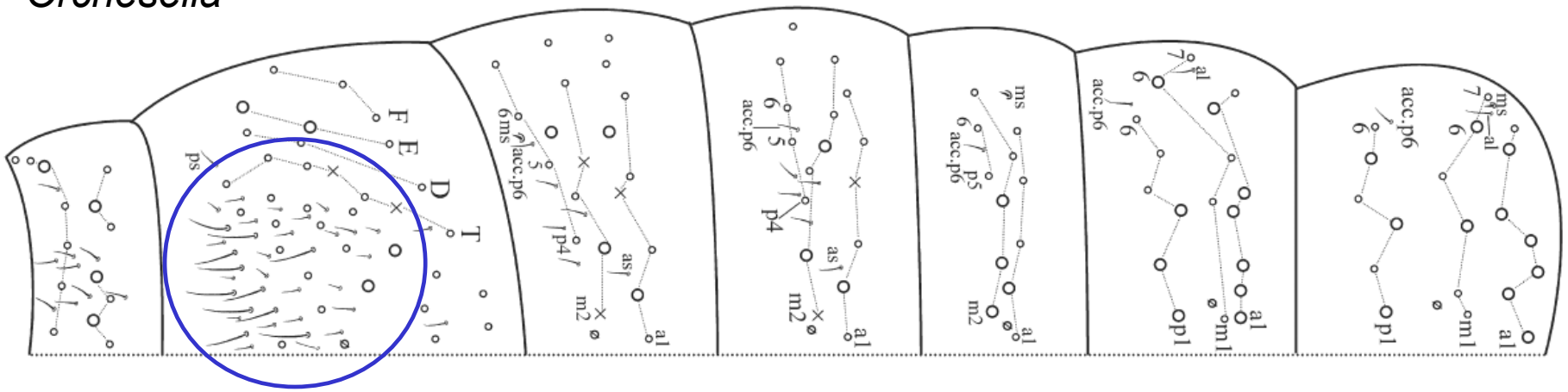
Heteromurus



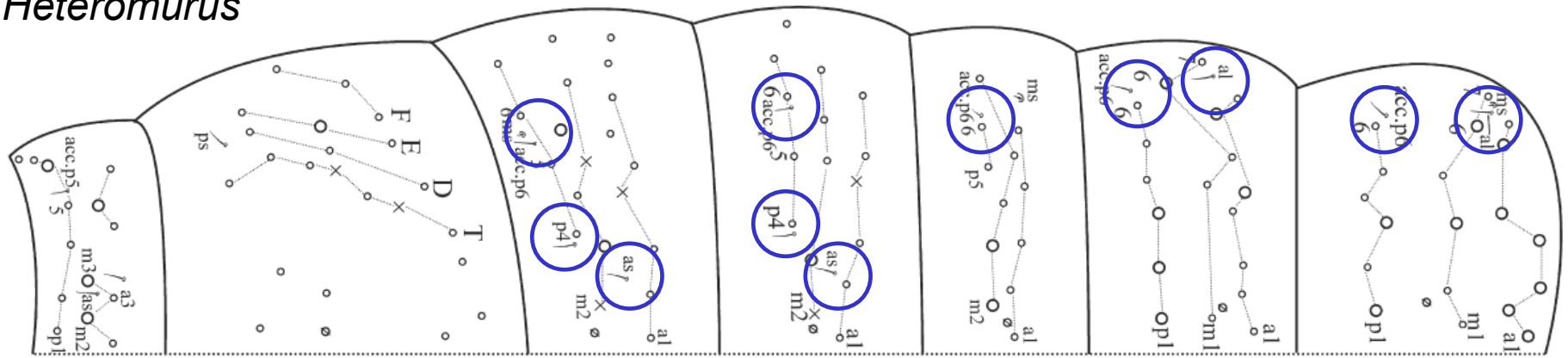
ms-chaetotaxy: 1,0/1,0,1

from Zhang & Deharveng (2014)

Orchesella



Heteromurus



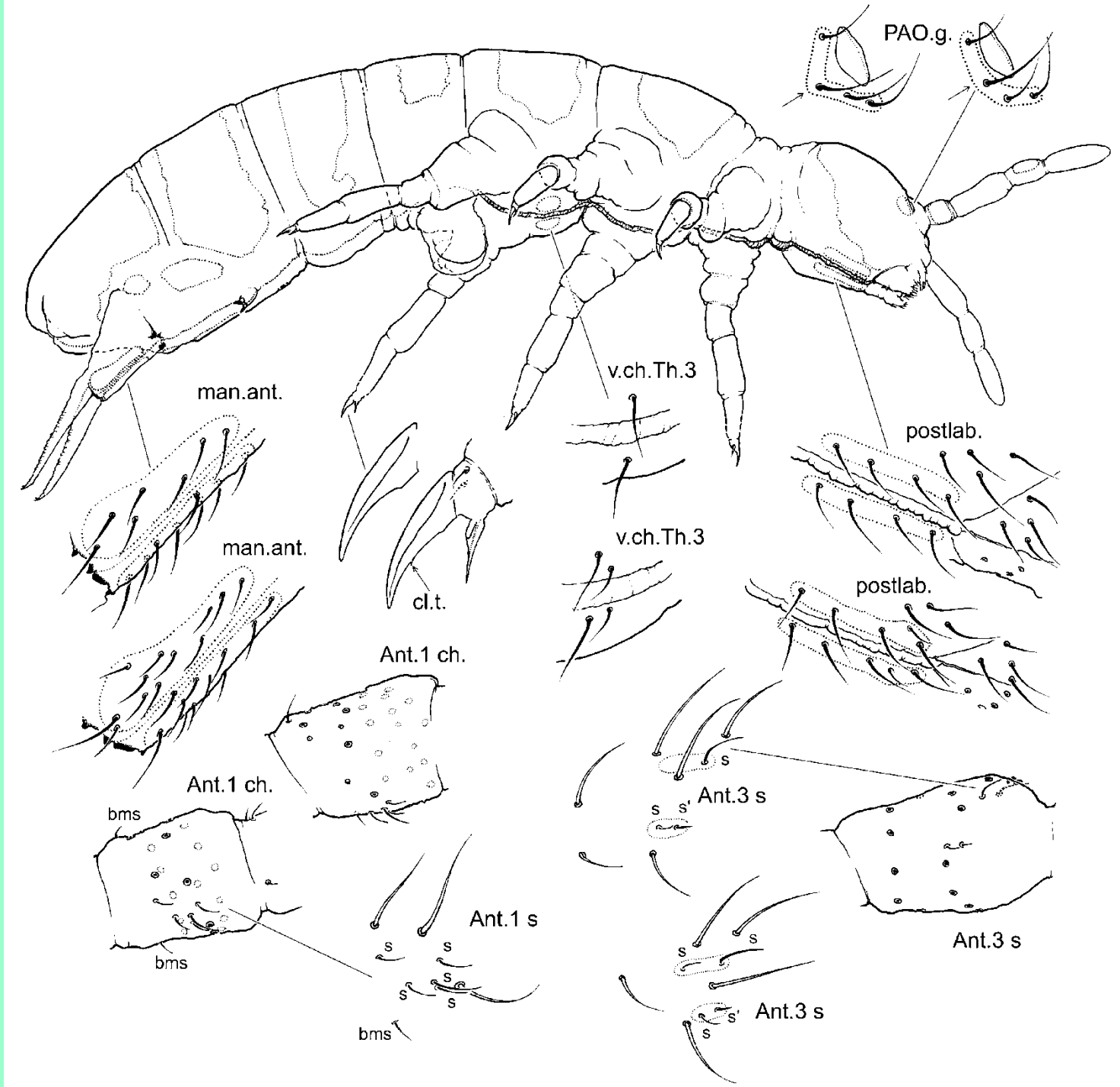
s-chaetotaxy: 2,2/1,3,3, …, …

from Zhang & Deharveng (2014)

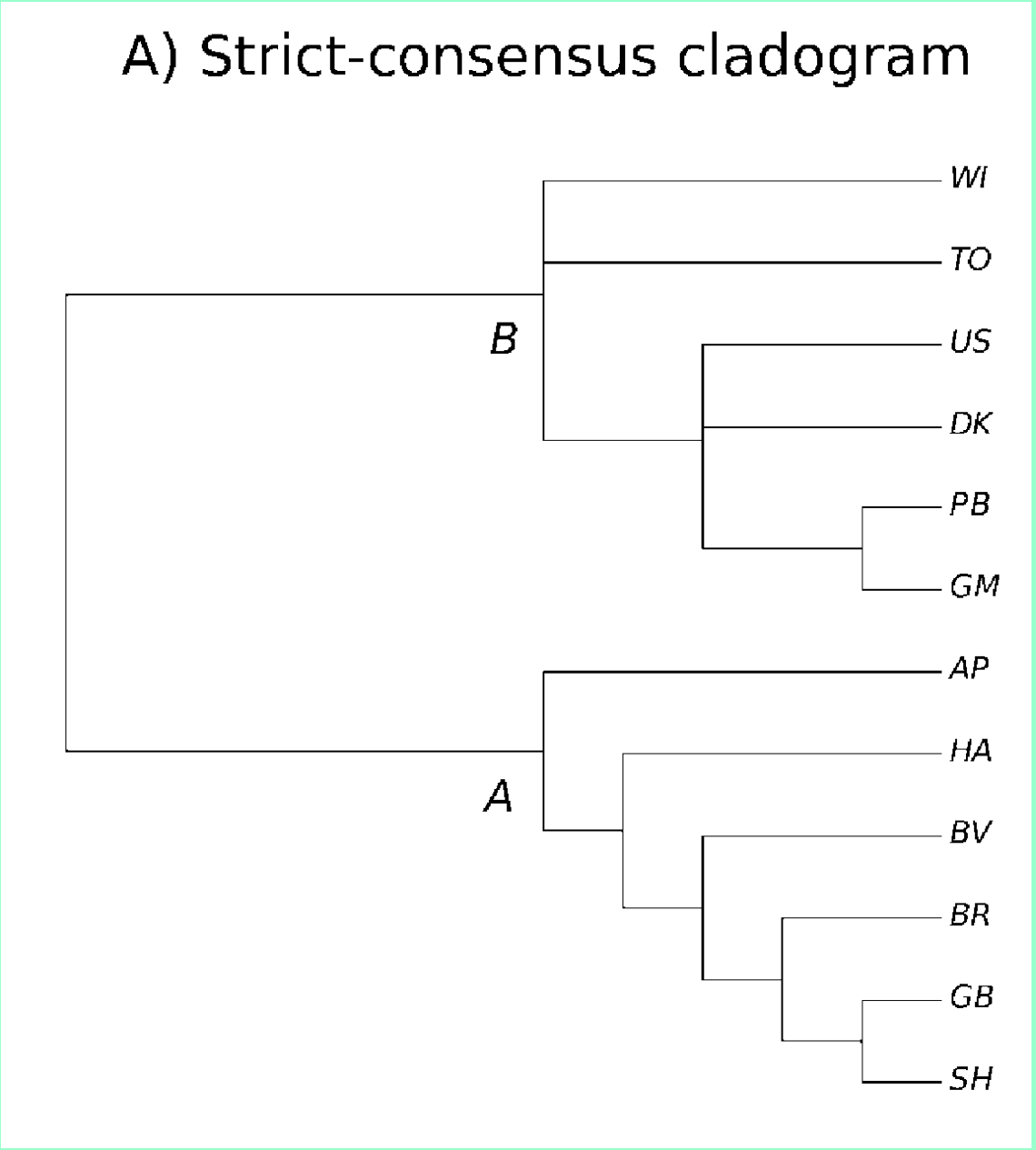
4. Morphology at intra-specific level

Morphological characters in discrimination between strains of *F.candida*

from Tully & Potapov (2015)



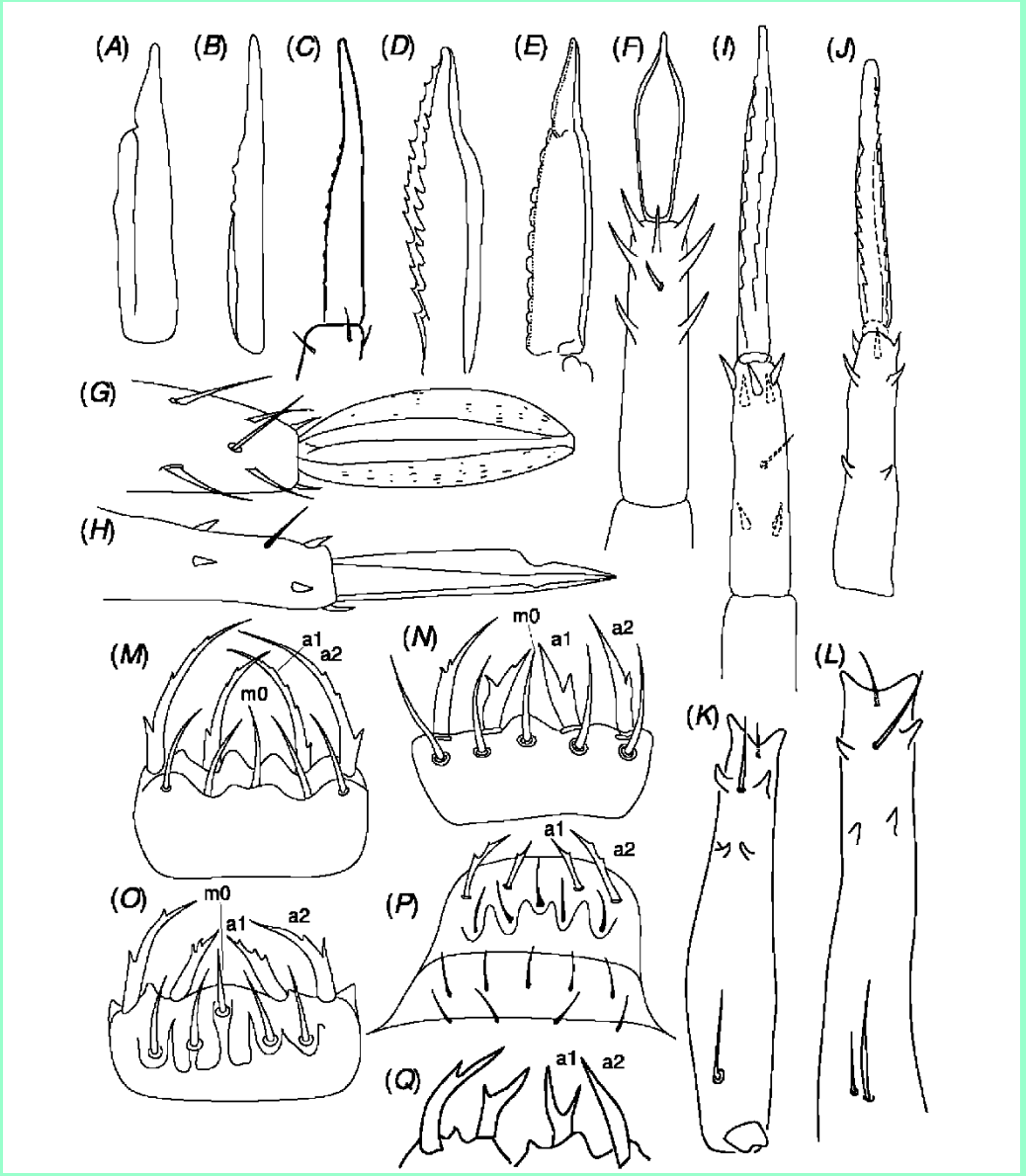
“Phylogeny” of strains of *F.candida*



from Tully & Potapov (2015)

particular taxa

Revision of *Megalothorax* (Schneider & D'Haese, 2013)



from Schneider & D'Haese (2013)

Our ongoing tasks in morphological taxonomy:

- description of diversity (faunas, lists of species, catalogues, new species descriptions)

- introducing new characters and careful re-estimation of known morphological characters

- closer connection to molecular taxonomy

Thank you