Springtails (Collembola) in meadows, pastures and road verges in Central Finland

Atte Komonen* & Saana Kataja-aho

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Understanding of species distribution, abundance and habitat affinities is crucial for red-list assessment, conservation and habitat management. In Central Finland, we studied Collembola in three habitat types, namely non-grazed meadows, pastures and road verges using pitfall traps. Altogether, 9,630 Collembola individuals were recorded. These belonged to 12 families, 34 genera and 60 species. The number of specimens was clearly higher in meadows than in pastures or road verges. The number of species, however, was higher in meadows and road verges (40 and 39 species, respectively) than in pastures (33 species). The overall species number is comparable to other large-scale sampling schemes in similar habitats. We recorded a few abundant species (*Spatulosminthurus flaviceps*, *Sminthurus viridis* and *Sminthurus nigromaculatus*) that have been previously recorded from very different biotopes. In conclusion, biodiversity inventories of soil fauna, as well as other biota, should also include marginal habitats, which often host peculiar communities.

*A. Komonen, University of Jyväskylä, Department of Biological and Environmental Science, P.O. Box 35, FI-40014 University of Jyväskylä, Finland; *Corresponding author's e-mail: atte.komonen@jyu.fi*
S. Kataja-aho, University of Jyväskylä, Natural History Museum, P.O. Box 35, FI-40014 University of Jyväskylä, Finland; E-mail: saana.kataja-aho@jyu.fi

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1. Introduction

Understanding of species distribution, abundance and habitat affinities in different environments is crucial for red-list assessment, conservation and habitat management. Unfortunately, such information is lacking for many invertebrate groups. In Finland, forest soil fauna has been rather well-studied, partly due to its importance and sensitivity to silviculture (Huhta *et al.* 1967, 1986, Siira-Pietikäinen *et al.* 2001, Huhta & Räty 2005, Kataja-aho *et al.* 2016). At the same time, the knowledge of soil fauna in non-forested habitats is insufficient and geographically limited (Pommeresche & Løes 2014); for example, very little is known about soil fauna in traditional rural biotopes, such as pastures and meadows (Huhta *et al.* 2010).

Springtails (Collembola) are an important component of soil meso- and macrofauna, because they influence soil decomposition processes (Rusek 1975, Petersen 1994, Hopkin 1997). Springtails can be abundant and diverse even in highly modified and disturbed habitats such as agricultural fields (Lagerlöf & Andrén 1991, Bitzer *et al.* 2005, Pommeresche & Løes

Table 1. Study site characteristics and total number of individuals and species. Collembola were sampled in 2014 mainly from 26th–30th of May to 18th–22nd of June (= first period). If specimens were identified also from the second period (18th–22nd of June to 7th–11th of July), the pooled numbers of individuals and species for both periods are given in parentheses. Vegetation height is the average of five study plots.

Habitat Sites	Area (ha)	pH	Soil fractions	Vegetation height (cm)	Indiv.	Species
Meadows						
Peurala	0.1	5.16	coarse silt	42	128 (277)	11 (17)
Kirkonmäki	0.3	4.98	fine sand	39	103	10
Syysniemi	0.4	4.62	coarse silt	29	380	10
Vaaru	0.4	4.33	medium silt	33	182	10
Vuorela	0.5	4.60	coarse silt	38	369	15
Liehu	0.5	4.16	coarse silt	36	287	15
Riihimäki	0.9	4.61	medium silt	33	485	11
Karhukorpi	1.0	4.62	fine sand	22	1,256	15
Vaateri	1.1*	4.67	coarse silt	33	309	12
Hettee	2.0	4.45	fine sand	22	256	8
Mäentalo	11.9*	4.93	fine silt	39	101 (136)	7 (7)
Harju	32.5*	4.39	medium silt	24	78	8
Pastures with cattle						
Pekkanen	1.7	4.27	fine sand	30	314	7
Ohramaa	5.2	4.16	coarse silt	30	213	7
Aatula	6.1	3.73	medium silt	15	114	6
Kivijärvi	7.6	4.70	coarse silt	10	193	9
Pasture with sheep/cattle						
Haapalehto	8.6	4.28	coarse silt	14	75 (174)	6 (9)
Pastures with sheep						
Vaateri	1.1*	5.18	coarse silt	39	352	9
Mäentalo	11.9*	4.65	fine silt	33	137 (146)	17 (17)
Harju	32.5*	4.07	medium silt	22	217	7
Pastures with horses						
Koivulahti	1.1	4.24	fine sand	15	174	7
Huusko	2.6	3.96	coarse silt	12	524	13
Nuuttila	3.1	4.70	coarse silt	20	301	13
Suuruspää	6.0	4.98	fine silt	21	52	7
Road verges						
Myllypohja	na	5.41	coarse sand	23	39 (235)	7 (17)
Multia	na	5.45	coarse sand	8	460	15
Petäjävesi	na	5.65	coarse sand	10	45	8
Muurame	na	5.99	fine sand	35	13	3
Paateri	na	5.66	coarse sand	19	5	2
Rotkola	na	4.75	coarse sand	20	578	22
Klemettilä	na	5.09	coarse sand	31	49	1
Valospohja	na	4.63	coarse sand	27	106	11
Tammikoski	na	5.14	coarse sand	42	21	2
Jukola	na	4.65	coarse sand	11	553	14
Havulankangas	na	5.22	coarse sand	21	280 (386)	18 (20)
Norola	na	5.43	fine sand	23	287	12

* Pooled area for meadows and pastures in a given farm. na: Not applicable.

2014). However, different vegetation types (Huhta *et al.* 2005) and soil disturbances (Kataja-aho *et al.* 2016), as well as different levels of soil compaction (Larsen *et al.* 2004), pollution or nutrient loads (Lagerlöf & Andrén 1991, Song *et al.* 2016) can affect composition, structure and small scale spatial heterogeneity of collembolan communities.

Many environmental factors are likely to vary among meadows, pastures and road verges. For example, animal tramping affects soil compaction, whereas grazing and excretions affect vegetation and soil chemistry (Oldén 2016). Road salt and traffic pollution can influence biota on road verges (Viard *et al.* 2004, Owojori *et al.* 2009). The response of Collembola on environmental variation can vary among euedaphic and epedaphic species; euedaphic species are subsurface-active, whereas epedaphic species are surface-active (Eisenbeis & Wichard 1987).

Traditional rural biotopes have high conservation value, with many rare and threatened plant and invertebrate species. Their soil fauna, however, is much more poorly known. We studied surface-active Collembola in non-grazed meadows, pastures and road verges in Central Finland to better understand biodiversity in these valuable habitats, as well as gain more information about the distribution, abundance and habitat affinity of Collembola.

2. Materials and methods

2.1. Study sites

This study was conducted in southern and middle boreal vegetation zone in Central Finland. Twelve meadows, pastures and road verges each were selected for the study (n_{tot} = 36 sites, Table 1). The list of potential meadows and pastures was obtained from the Centre for Economic Development, Transport and the Environment of Central Finland (ELY Centre). All the selected sites were mesic or dry meadows, and had been managed by grazing (pastures) or hand-mowing (meadows) for years. Pastures were a few hectares in size with varying, but generally low intensity, grazing pressure. Meadows had been hand-mowed once annually, and they had not been treated with animal manure or artificial fertilizers. The most common (occurred in most sites) plant species in meadows and pastures were *Veronica chamaedrys*, *Agrostis capillaris*, *Alchemilla* sp., *Festuca rubra*, *Fragaria vesca*, *Hypericum maculatum*, *Poa pratensis*, *Ranunculus acris*, *Rumex acetosa* and *Taraxacum* spp.; these were almost equally common in both habitat types.

Road verges were selected as close to the pastures and meadows as possible. All selected roads were tarmacked and belonged to Finnish road category "Local road" or bigger, which ensured at least 3 m wide verges. The selected roads were all constructed decades ago, there were no signs of recent renovations, and they were outside urban areas. The selected verges were adjacent to a forest, or to a ruderal area in two cases. In Finland, road verges are mowed with machinery 1–2 times yearly; after machine mowing vegetation is generally taller than in hand-mowed pastures. The most common plant species in road verges were *Achillea millefolium*, *Festuca rubra*, *Taraxacum* spp., *Epilobium angustifolium*, *Hieracium umbellatum*, *Hieracium vulgata* group, *Trifolium repens*, *Anthriscus sylvestris*, *Betula pubescens* and *Cerastium fontanum*.

2.2. Sampling

At each pasture and meadow, we established a random 50 m transect that ran through the center of the site. In road verges, transects ran along the road and at least one meter from the edge of the asphalt. Along transects, five 2 × 2 m plots were placed at 10 m intervals. At two predetermined corners of these plots, we placed one pitfall trap, i.e. there were 10 pitfall traps in each site. All pitfall traps were covered by a plywood roof to exclude rain water; roofs were some 2 cm from the ground. The pitfall traps were filled with saltwater for preserving the material and soap to reduce surface tension. The pitfall traps were set up 26th–30th of May 2014. They were emptied twice: 18th–22nd of June and 7–11th of July; all traps were catching equal time periods.

Pitfall traps sample surface-active invertebrates (see Gudleifsson & Bjarnadottir 2008 for a study on Collembola). Due to limited resources, not all Collembola were separated from the pitfall material: from each pitfall at least a hundred different looking specimens were separated for identification and all these were identified to the species if possible. Thus, the data do not warrant statistical comparisons and abundances should be only used to disentangle anecdotal and true habitat affinities. Collembola were identified with, and the nomenclature follows, Fjellberg (1998, 2007). Juvenile collembolans (n = 45) were only identified to genus or family.

Table 2. Numbers of Collembola individuals from pitfall traps from meadows, pastures and road verges recorded during the first period. If specimens were identified from two periods (for periods, see Table 1), the first number indicates the 1st period; pooled numbers of individuals for both periods are given in parentheses.

Taxa	Meadow	Pasture	Road verge	Total
Arrhopalitidae				
Arrhopalites principalis		1	2	3
Arrhopalites sp.			1	1
Bourletiellidae				
Bourletiella hortensis			18	18
Deuterosminthurus bicinctus	1			1
Deuterosminthurus sp.			0 (3)	0 (3)
Heterosminthurus claviger	1		1	2
Dicyrtomidae				
Dicyrtoma fusca	2 (14)		0 (1)	2 (15)
Dicyrtomina flavescens	0 (3)			0 (3)
Dicyrtoma flavosignata	3 (10)	3		6 (13)
Dicyrtoma minuta	20 (27)	12	5 (8)	25 (47)
Dicyrtoma ornata	1		1	2
Ptenothrix atra	25		12 (13)	37 (38)
Indet	2	1		3
Entomobryidae				
Entomobrya corticalis	5	1	2 (4)	8 (10)
Entomobrya marginata	2		0 (4)	2 (6)
Entomobrya multifasciata		2	1 (2)	3 (4)
Entomobrya nicoleti		27	6	33
Entomobrya nivalis	1	7	16	24
Entomobrya superba	2			2
Entomobrya sp.	1	46 (49)	4 (6)	51 (56)
Heteromurus nitidus		27		27
Lepidocyrtus curvicollis	0 (2)		0 (3)	0 (5)
Lepidocyrtus cyaneus	7		41	48
Lepidocyrtus lignorum	2,378 (2,454)	451 (468)	959 (1,031)	3,788 (3,953)
Lepidocyrtus violaceus	21 (22)	85	87 (90)	193 (197)
Lepidocyrtus sp.		1	4	5
Orchesella bifasciata			4	4
Orchesella cincta	8			8
Orchesella flavescens	30 (31)	30	45 (49)	105 (110)
Orchesella spectabilis	3			3
Orchesella sp.	9	15 (16)		24 (25)
Indet	3	5		8
Hypogastruridae				
Ceratophysella sp.		57	57 (61)	114 (118)
Choerutinula inermis	10 (11)	11	32	53 (54)
Schoettella ununguiculata	3	1	20 (24)	24 (28)
Isotomidae				
Desoria tolya	0 (1)		0 (11)	0 (12)
Desoria sp.	6 (7)	5 (6)	1 (17)	12 (30)
Folsomia quadrioculata	2	4		6
Isotoma anglicana	32	402 (404)	50 (71)	484 (507)
Isotoma caerulea	58	214	218	490
Isotoma viridis	121 (135)	335 (338)	281 (322)	737 (795)
Isotoma sp.	35 (36)	21	35 (39)	91 (96)
Isotomurus graminis	22 (32)	225	6	253 (263)
Isotomurus italicus	1			1
Isotomurus palustris		5		5
Isotomurus sp.	13	21 (22)	1	35 (36)
Parisotoma notabilis	9		2	11
Indet	107	458	113	678

Table 2, continued

Taxa	Meadow	Pasture	Road verge	Total
Katiannidae				
Gisinianus flammeolus		3		3
Sminthurinus aureus	30		44	74
Sminthurinus niger group sp.	7	1		8
Sminthurinus reticulatus	9		1	10
Sminthurinus signatus	32		1	33
Sminthurinus sp.	5	3	14	22
Indet	6	1	1	8
Neanuridae				
Friesea mirabilis			4	4
Neanura muscorum	14	3	9	26
Pseudachorutes dubius		1		1
Pseudachorutes sp.	2			2
Indet	1			1
Onychiuridae				
Micraphorura absoloni		7	1	8
Protaphorura armata		4		4
Protaphorura sp.		1		1
Poduromorpha				
Indet		1		1
Sminthuridae				
Allacma fusca	18	5	9 (14)	32 (37)
Caprainea marginata			1	1
Sminthurus nigromaculatus			20	20
Sminthurus viridis	8 (11)	7	22 (26)	37 (44)
Sminthurus sp.			10	10
Spatulosminthurus flaviceps			32	32
Indet	2	5	6	13
Sminthurididae				
Sminthurides schoetti			2	2
Sminthurides sp.	4			4
Sphaeridia pumilis	38	5	46 (49)	89 (92)
Symphypleona				
Indet	9	14	3	26
Tomoceridae				
Pogonognathellus flavescens	798 (827)	148 (200)	213 (270)	1,159 (1,297)
Pogonognathellus longicornis	11 (18)	6	5	22 (29)
Pogonognathellus sp.	3 (4)	3 (5)		6 (9)
Tomocerus vulgaris		1		1
Total	3,979 (4,118)	2,692 (2,774)	2,479 (2,738)	9,150 (9,630)

Soil samples were taken from each of the five study plots and pooled for one composite sample to measure soil type and pH. Vegetation composition and height (cm) was measured from each of the five study plots 16th June–8th July 2014 (Table 1).

3. Results

Altogether, 9,630 Collembola individuals were recorded. These belonged to 12 families, 34 genera and 60 species (Table 2); 12% (1,164 individuals) of the specimens could not be identified to species. The number of specimens from the first sampling period (n = 9,150) was higher in meadows (n = 3,979) than in pastures (n = 2,692) or road verges (n = 2,479). All the results hereinafter concern the first sampling period to allow comparison due to equal sampling period in all sites. The number of species was higher in meadows (n = 40) and road verges (n = 39) than in pastures (n = 33). There were some differences in soil quality and vegetation: soil pH ranged from 3.73–5.99 and vegetation height 8–42 cm (Table 1). Most (78%) of the individuals were Entomobryidae or Isotomidae. The most abundant species were *Lepidocyrtus lignorum* (41% of all individuals), *Pogonognathellus flavescens* (13%) and *Isotoma viridis* (8%).

4. Discussion

The number of collembolan individuals was highest in meadows, whereas pastures and road verges had similarly lower numbers. The number of species was higher in meadows and road verges than in pastures. In all road verges soil fraction was sand, whereas in pastures and meadows soil fractions ranged from sand to fine silt. Although soil type influences collembolan densities (Gudleifsson & Bjarnadottir 2008), these differences are unlikely to explain the smaller species number in pastures, because the soil type was similar in pastures and meadows. However, the somewhat smaller species number in pastures may result from animals trampling on pitfall traps, which was commonly observed. Animals may also have caused soil compaction, which can decrease the density of collembolans (Heisler & Kaiser 1995, Larsen *et al.* 2004).

It is known that collembolan densities in pastures and hayfields are highest in late summer (Gudleifsson & Bjarnadottir 2008). Even though we did not identify all the specimens and did not sample in late summer, the overall species number is comparable to other large-scale sampling studies in similar habitats with roughly similar number of identified individuals, but different sampling methodology (cf. Huhta *et al.* 2010).

Most of the recorded individuals were Entomobryidae or Isotomidae. Indeed, epedaphic species are typified by Entomobryoidea and Symphypleona (Hopkin 1997). The most abundant species were *Lepidocyrtus lignorum*, *Pogonognathellus flavescens* and *Isotoma viridis*. These were abundant in all the three habitat types and have been recorded also earlier in great numbers from grasslands (Gudleifsson & Bjarnadottir 2008). Road verges had more Sminthuridae species than meadows and pastures, but in general there was no species that would clearly favour one habitat type over the others, *Spatulosminthurus flaviceps* being possibly an exception (see below). Five to eight unique species were recorded from each of the three habitat types, but these were mainly represented by only a few individuals. Although we did not identify all specimens, the similarity of the collembolan fauna among the three habitat types could be a real pattern. The rationale is that the dominant vascular plants were identical among the three habitat types, and vegetation composition and structure are known to affect collembolan densities and diversity (Salamon *et al.* 2004, Sabais *et al.* 2011). Overall, the species from pastures, meadows and road verges were rather different from those that are typically caught by pitfalls from forests and clearcuts. The latter usually include Entomobryidae, especially the large species, such as *Pogonognathellus* and *Orchesella* (Kataja-aho *et al.* 2016).

We recorded *S. flaviceps* (n = 32 individuals) from several road verges. Previously the species has been found only from salt meadows (Fjellberg 1998). If *S. flaviceps* really is a species that benefits from salt, then the spillover of the de-icing salt on road verges may create a suitable habitat for the species in Finland, far away from coastal areas. More generally, the importance of road verges for salt-favouring species deserves further attention.

In addition, *Sminthurus viridis* and *S. nigromaculatus* were recorded in great numbers, the former from all studied biotopes and the latter only from road verges. Although the occurrence of these species in Finland was uncertain according to Fjellberg (1998), later both of these species have been discovered from Finland (P. Vilkamaa, pers. comm.). In conclusion, our study corroborates the results by Huhta *et al.* (2010) in that many non-forested habitats host a peculiar Collembola fauna. Systematic studies in marginal or otherwise poorly studied biotopes are crucial to get a thorough understanding of species abundance, distribution and habitat affinities.

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