Effects of Afforestation with Pines on Collembola Diversity in the Limestone hills of Szárhalom (West Hungary)

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Abstract – We investigated the responses of collembolan communities to pine afforestation in an area formerly characterized by a mosaic of autochthonous downy oak woodland and steppe meadows. Study sites were selected in mixed stands of black pine and Scots pine and control samples were taken from downy oak stands and open steppe meadows. A total of 1884 Collembola specimens belonging to 66 species were collected. Three species, namely *Protaphorura pannonica* (Onychiuridae), *Tomocerus mixtus* (Tomoceridae) and *Isotoma caerulea* (Isotomidae) proved to be new to the Hungarian fauna. There are typical Collembola communities which are specific to different habitat types where species of a given composition can only or predominantly be found in that habitat, as well as some basic common species which occur in every habitat. The highest species richness (41) was found in steppe meadows, considerably lower (34) in downy oak forests, reaching the lowest value (25) in pine plantations. Although several forest species present in the oak woodland were completely missing from the pine forests, there was no significant difference between the Collembola diversities of the two forest habitats. The difference became more prominent in collembolan abundance which resulted in less than half of individuals/m^2 in pine plantations compared to the soils of downy oak forests, most likely due to the changed soil conditions, especially of humus characteristics, caused by the pine needle litter. Jaccard similarity measure indicated approximately equal similarity (0.24–0.28) for paired comparison, suggesting that a relatively constant 'basic Collembola community' determined by the soil type typical for the area is present; while dissimilarity in communities between sites are partly provided by spatial heterogeneity of open and forest habitats and by the difference of the vegetation type.

soil fauna / Collembola communities / xerophil habitats / allochthonous pine forest

Kivonat – Fenyvesítés hatása a Collembola diverzitásra a Szárhalmi-dombság területén. Kutatásunkban a fenyvesítés talajlakó ugróvillás-közösségekre gyakorolt hatását vizsgáltuk egy meszes talajú, egykoron molyhos tölgyes sztyepprét élőhelymozaikkal jellemezhető területen. A talajmintákat vegyes erdeifenyves-feketefenyves állományokból, valamint kontrollként őshonos molyhos tölgyesből és sztyepprétről gyűjtöttük. A vizsgálat során összesen 66 faj 1884 egyede került elő. Három faj, a *Protaphorura pannonica* (Onychiuridae), a *Tomocerus mixtus* (Tomoceridae) és az *Isotoma caerulea* (Isotomidae) a hazai faunára nézve újnak bizonyult. A vizsgált élőhelyek jellegzetes ugróvillás-közösségekkel jellemezhetők, amelyek az adott élőhelyre specifikus fajok mellett néhány közös, mindegyik habitatban előforduló fajt is tartalmaznak. A legnagyobb fajszámú (41) Collembola közösséget a sztyeppréteken találtuk, míg a molyhos tölgyesek fajgazdagsága alacsonyabbnak (34) bizonyult. A legkevesebb fajt (25) a telepített fenyvesekben gyűjtöttük. Bár több, a tölgyesekben előkerült erdei faj hiányzott a fenyőállományokból, a két erdei élőhely ugróvillás-közösségének diverzitása között nem mutatkozott szignifikáns eltérés. A közösségek összabundanciáját illetően már

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markánsabb különbségek adódtak: a telepített fenyvesekben a molyhos tölgyeshez viszonyítva kevesebb, mint a fele ugróvillás egyedet mutattunk ki 1 m^2-re vetítve. Ez elsősorban a fenyőtűavar lebomlást késleltető hatásának köszönhető, amely ezáltal eltérő humuszformákban is megmutatkozik. A Jaccard-féle fajazonossági index hozzávetőleg azonos (0,24–0,28) értéket mutatott mindegyik élőhelypár esetében. A specifikus eltéréseket az ugróvillás-közösségekben a nyílt és zárt élőhelyek heterogenitása, valamint a vegetációbeli különbségek is okozhatják.

talajfauna / Collembola közösségek / xerofil habitat / telepített fenyvesek

1 INTRODUCTION

The impact of tree introduction on soil Collembola has been studied less extensively (Arbea – Jordana 1985, Sousa – Da Gama 1994, Sousa et al. 1997, Pinto et al. 1997); although, this kind of conversion process often tends to reduce soil fauna community structure and biodiversity (Elmarsdottir et al. 2008). In Hungary, major land-use changes have been conversion from natural grassland and deciduous woodland to coniferous plantations, using mainly Scots pine (*Pinus sylvestris*), black pine (*Pinus nigra*) and Norway spruce (*Picea abies*). The area covered by such coniferous plantations now represents about 12% of the total forest area in Hungary (Kottek 2008).

The characteristic vegetation types for Fertőmellék Hills are oak forests and steppe meadows. The scattered presence of pine species in the Fertőmellék Hills was already documented from the 1830's, but afforestations with pines of larger tracts of land started only from the 1870's and peaked after World War II (Király 2001). Pines are non-native, the autochthony of Scots pine on schist is questionable (Király 2001). The increasing coverage of pine stands therefore induced considerable changes in landscape, and most presumably, on biodiversity.

The aim of this study was to determine the effects of pine plantations on soil condition and Collembola community composition, species richness, diversity and abundance in a xerophile area. As null hypothesis we considered that there is no difference between the Collembola communities of the pine-forested area and the control forest and meadow areas. As alternative hypothesis we supposed that Collembola community structure, species richness and abundance are different in the pine plantations compared with the autochthonous forest and meadow sites.

2 MATERIAL AND METHODS

2.1 Study area

The Fertőmellék Hills has a moderately cold – moderately dry climate, with a mean annual air temperature of 9.5–9.8 °C and a mean annual precipitation of 640–660 mm (Dövényi 2010). The study sites are situated between 47°01'39" and 47°02'43" N and 16°44' and 16°45'14" near Fertőrákos, Győr-Moson-Sopron county, Hungary.

Sampling was conducted in mixed allochthonous black pine (*Pinus nigra*) and Scots pine (*Pinus sylvestris*) forests. Autochthonous control sites were selected in both open (steppe meadows) and forest (downy oak stands) habitats.

The main characteristics of the surveyed habitats are given below.

- downy oak stands – closed thermophilous downy oak woodlands. The most dominant canopy species is *Quercus pubescens* with some *Qu. cerris*. The well-developed shrub layer is characterized by *Cornus mas, C. sanguinea, Crataegus monogyna, Ligustrum vulgare, Viburnum lantana. Melica nutans, Convallaria majalis, Hedera helix* and *Campanula trachelium* are frequent in the herb layer. Thermophilous and light-demanding species are sporadic.

- pine plantations – middle-aged mixed stands of black pine and Scots pine, with scattered trees of turkey oak (*Quercus cerris*) and European hornbeam (*Carpinus betulus*) and with a well-developed schrub layer (*Coryllus avellana, Carpinus betulus, Quercus cerris, Cornus mas, C. sanguinea*).
- steppe meadow – *Bromus erectus–Brachypodium pinnatum* xero-mesic grasslands, dry tall herb communities and forest steppe meadows. Most characteristic species are *Brachipodium pinnatum, Festuca rupicola, Carex michelii*. Colonization of the grasslands by shrubs (with *Quercus pubescens, Qu. petraea, Crataegus Monogyna, Prunus spinosa*) have already started.

2.2 Soil chemistry

Soil pH was determined by potentiometric methods in H_2O and KCl. Organic carbon, total nitrogen and calcium contents were also assayed. C/N ratio was calculated for each sampling site to find connection between Collembolan abundance and soil conditions.

2.3 Sampling design, extraction and taxonomic identification

Sampling was carried out in April 2009. From each habitat, 4 intact soil cores of 100 cm^3 were taken with 3 replications from the 0 to 5 cm layer and stored in plastic bags. Collembola were extracted from soil/litter using modified Berlese-Tullgren apparatus at room temperature (Balogh 1958) and preserved in 96% ethyl alcohol until sorting and identification. Species were counted and identified using a binocular microscope according to Gisin (1960), Stach (1960, 1963), Massoud (1967), Deharveng (1982), Fjellberg (1980, 1998), Babenko et al. (1994), Zimdars & Dunger (1994), Weiner (1996), Jordana et al. (1997), Pomorski (1998), Bretfeld (1999), Potapov (2001), Thibaud et al. (2004) and Jordana (2012). Taxonomic classification is primarily based on the most recent classification by Janssens – Christiansen (2011) and on the annotated checklist of the Hungarian Collembola fauna (Dányi – Traser 2008).

2.4 Data analysis

In addition to the recorded species richness nonparametric richness estimators (abundance-based estimators *ACE* and *Chao1* and incidence-based estimators *ICE* and *Chao2*) were evaluated using the Species Richness Estimators v2.1 module of www.eco-tools.net. Singletons and doubletons (number of species represented by one or two individuals) were also verified. On species level, the measure 'habitat amplitude' (*HA*) has been used according to the formula of Simpson (1949), which reflects the relative abundance of each Collembola species in the sampled habitats. Rank abundance curves were used to examine general trends in the Collembola dominance structure and abundance for each habitat type. Dominance structure was quantified by using community dominance index (*CDI*), which reflects how large a proportion of the total species present (in terms of numbers of individuals) is made up of the two most abundant species. Two measures of species α diversity were calculated for each habitat: the Shannon index ($H' = -\sum p_i \ln p_i$) and equitability ($J = H' / \ln S$ – where S is species richness). To compare diversity values of two assemblages a *t*-test was used to determine whether they are significantly different (Hutcheson 1970). Rényi diversity profiles (Tóthmérész 1997) were used for partial ranking of the recorded collembolan communities based on diversity. A community of higher diversity has a diversity profile consistently above the profile of a less diverse community. In case the diversity profiles cross each other, the communities are not comparable, and thus the diversity comparison carried out by using *t*-test gets overruled. Community structure comparison between the different habitats was estimated using single linkage cluster analysis based on the *Jaccard* similarity index.

3 RESULTS AND DISCUSSIONS

3.1 Soil chemistry

The basic physico-chemical parameters of the soil samples are summarized in *Table 1*. Although usually acidification is experienced in the 0–5 cm layer of pine plantations (Halbritter et al. 2007), our pine forest soil samples were close to neutral, and there was no significant differences in soil pH compared with the oak stands or meadow soils (Kruskal-Wallis test). Total calcium content was lower in the soil samples taken from the downy oak forests compared with the pine plantations and steppe meadow area. Total organic carbon content was the highest in the pine forests. The allelochemical inhibition of nitrification by monoterpenes occurring in the pine needle litter is a known fact (Paavolainen et al. 1998). Supposedly, it was one of the reasons why the total nitrogen content proved to be the lowest in this same habitat. The calculated C/N ratio was, hence, the highest in the pine forest soil, indicating a lower organic matter decomposition rate.

Table 1. Soil physico-chemical parameters of the study sites (mean ± SD)

	steppe meadow	downy oak forest	pine plantation	
pH H_2O	7.53 ± 0.12	7.37 ± 0.15	7.27 ± 0.25	ns
pH KCl	7.30 ± 0.10	7.23 ± 0.21	7.16 ± 0.35	ns
Ca (g/kg)	142.33 ± 10.59	95.67 ± 28.36	134.42 ± 51.03	* meadow-oak
N (g/kg)	5.80 ± 1.45	6.17 ± 1.99	5.77 ± 1.22	ns
C (g/kg)	104.57 ± 20.32	102.23 ± 36.28	124.23 ± 19.15	ns
C/N ratio	18.21 ± 1.48	16.51 ± 1.04	21.92 ± 4.02	ns

** $p < 0.05$; ns – non significant (Kruskal-Wallis test)*

3.2 Faunistical results

A total of 1,884 specimens representing 12 families, 38 genera and 66 species of Collembola were collected and identified (*Table 2*), 33 of them are new to the fauna of the Fertőmellék Hills (Traser 2002, Traser et al. 2006). Because of the geographical nature and climate of the area we recorded a number of typical xerothermophilic species (*Xenylla maritima, Doutnacia xerophila, Mesaphorura critica, Metaphorura affinis, Entomobrya handschini, Entomobrya multifasciata, Orchesella albofasciata*).

Three species, namely *Protaphorura pannonica* (Onychiuridae), *Tomocerus mixtus* (Tomoceridae) and *Isotoma caerulea* (Isotomidae) proved to be new to the Hungarian fauna:

Protaphorura pannonica (Haybach, 1960)

This Palearctic, euedaphic species typical for meadow habitats, was formerly known from the neighbour countries Austria, Ukraine (Deharveng – Fjellberg 2011) and Romania (Fiera 2007). A total of 5 specimens were found in the samples from the steppe meadow soils.

Tomocerus mixtus (Gisin, 1961)

The possible occurrence of this species in the Central European area has already been suggested by Gisin (1961). According to Arbea – Fjellberg (2011), this species is known from Germany (type locality), Austria, Italy, Bosnia and Herzegovina and from the former Yugoslavian countries while it is absent in the major part of Northern, Western and Eastern Europe. We found 7 specimens in the soils samples taken from the pine plantations.

Isotoma caerulea Bourlet, 1839

Up to the present time, this species has probably been confounded with *I. anglicana*, a species undoubtedly present throughout the territory of Hungary. The revision of the '*Isotoma viridis* complex' (Fjellberg 2003) made clear the difference between *I. anglicana* and *I. caerulea*, allowing us to identify the latter species for the first time in Hungary taken from the soil samples of the steppe meadows in Szárhalom.

3.3 Collembola community analysis

Average abundance and habitat amplitude of the species occurred are presented in *Table 2*, while *Table 3* shows the most important structural characteristics of the Collembola communities found in the three habitats.

Table 2 Average abundance (individuals/100 cm³) of Collembola species in the habitats studied and species habitat amplitude (HA) according to Simpson's formula

COLLEMBOLA	steppe meadow	downy oak forest	pine plantation	*HA*
Neanuridae				
Deutonura conjuncta (Stach, 1926)	0.33	–	0.33	2.00
Neanura sp.	–	–	0.33	1.00
Pratanurida sp.	0.67	–	–	1.00
Pseudachorutes dubius Krausbauer, 1898	–	–	0.33	1.00
Pseudachorutes parvulus Börner, 1901	–	1.00	1.67	1.88
Pseudachorutes pratensis Rusek, 1973	–	0.33	–	1.00
Odontellidae				
Superodontella pseudolamellifera (Stach, 1949)	–	–	1.00	1.00
Hypogastruridae				
Ceratophysella armata (Nicolet, 1841)	0.33	–	–	1.00
Ceratophysella luteospina (Stach, 1920)	0.33	1.67	3.00	2.10
Choreutinula inermis (Tullberg, 1871)	18.00	1.67	–	1.18
Hypogastrura vernalis (Carl, 1901)	1.67	–	–	1.00
Schoettella ununguiculata (Tullberg, 1869)	–	1.33	–	1.00
Willemia anophthalma Börner, 1901	–	2.00	–	1.00
Xenylla maritima Tullberg, 1869	8.33	0.67	–	1.16
Onychiuridae				
Protaphorura armata (Tullberg, 1869)	4.00	6.00	–	1.92
Protaphorura cancellata (Gisin, 1956)	2.33	–	–	1.00
Protaphorura gisini (Haybach, 1960)	5.67	–	–	1.00
Protaphorura pannonica (Haybach, 1960)	1.67	–	–	1.00
Protaphorura subarmata (Gisin, 1957)	1.33	–	–	1.00
Protaphorura subnemorata (Gisin, 1957)	–	16.33	7.67	1.77
Protaphorura tricampata (Gisin, 1956)	–	2.00	–	1.00
Tullbergiidae				
Doutnacia xerophila Rusek, 1974	11.67	9.00	2.00	2.32
Jevania weinerae Rusek, 1978	–	0.33	0.33	2.00
Mesaphorura critica Ellis, 1976	4.67	–	7.00	1.92
Mesaphorura hylophila Rusek, 1982	2.67	1.33	11.33	1.71
Mesaphorura italica (Rusek, 1971)	1.33	–	3.33	1.69
Mesaphorura krausbaueri Börner, 1901	2.67	–	5.00	1.83
Mesaphorura macrochaeta Rusek, 1976	2.00	–	5.00	1.69
Mesaphorura yosii (Rusek, 1967)	0.67	–	–	1.00
Metaphorura affinis (Börner, 1902)	1.33	–	–	1.00
Paratullbergia callipygos (Börner, 1902)	–	1.33	–	1.00
Oncopoduridae				
Oncopodura crassicornis Schoebotham, 1911	–	0.67	1.67	1.69
Tomoceridae				
Pogonognathellus flavescens (Tullberg, 1871)	–	0.33	–	1.00
Tomocerus mixtus (Gisin, 1961)	–	–	2.33	1.00

Table 2 cont. Average abundance (individuals/100 cm3) of Collembola species in the habitats studied and species habitat amplitude (HA) according to Simpson's formula

COLLEMBOLA	steppe meadow	downy oak forest	pine plantation	*HA*
Isotomidae				
Anurophorus laricis Nicolet, 1842	0.33	–	–	1.00
Coloburella cf. *zangherii* (Denis, 1924)	–	0.67	0.67	2.00
Cryptopygus bipunctatus (Axelson, 1903)	100.67	37.00	–	1.65
Folsomia manolachei Bagnall, 1939	13.33	4.00	–	1.55
Folsomia penicula Bagnall, 1939	–	67.00	–	1.00
Folsomia quadrioculata (Tullberg, 1871)	–	24.00	–	1.00
Isotoma caerulea Bourlet, 1839	0.33	–	–	1.00
Isotominella minor (Schäffer, 1896)	2.67	27.00	27.00	2.19
Isotomodes productus (Axelson, 1906)	0.33	–	–	1.00
Isotomodes sexsetosus da Gama, 1963	0.67	–	–	1.00
Parisotoma notabilis (Schäffer, 1896)	1.33	23.00	30.00	2.06
Proisotoma minuta (Tullberg, 1871)	–	1.00	–	1.00
Entomobryidae				
Entomobrya sp. juv.	1.67	1.67	–	2.00
Entomobrya handschini Stach, 1922	1.33	–	–	1.00
Entomobrya multifasciata (Tullberg, 1871)	–	–	0.33	1.00
Entomobrya muscorum (Nicolet, 1842)	–	0.33	–	1.00
Heteromurus nitidus (Templeton, 1835)	–	0.33	–	1.00
Lepidocyrtus cf. *flexicollis* Gisin, 1965	0.33	–	–	1.00
Lepidocyrtus lanuginosus (Gmelin, 1788)	16.33	–	–	1.00
Lepidocyrtus lignorum (Fabricius, 1793)	0.33	0.33	–	2.00
Lepidocyrtus paradoxus Uzel, 1890	0.33	–	–	1.00
Lepidocyrtus violaceus (Geoffroy, 1762)	–	1.00	–	1.00
Orchesella sp. juv.	–	–	0.33	1.00
Orchesella albofasciata Stach, 1960	0.67	–	–	1.00
Orchesella cincta (Linnaeus, 1758)	–	–	0.33	1.00
Pseudosinella alba (Packard, 1873)	0.33	1.67	–	1.38
Pseudosinella cf. *horaki* Rusek, 1985	4.67	20.33	10.00	2.29
Willowsia nigromaculata (Lubbock, 1873)	0.33	–	–	1.00
Neelidae				
Megalothorax minimus Willem, 1900	0.33	13.33	8.67	1.97
Katiannidae				
Sminthurinus elegans (Firch, 1863)	7.33	1.33	0.33	1.46
Sminthuridae				
Lipothrix lubbocki (Tullberg, 1822)	–	0.67	–	1.00
Sminthurus maculatus Tömösváry, 1883	2.00	–	–	1.00

Only about the 35% of the collected species occurred in more than one habitat, which means that most of the species are habitat specialists. Species with relatively high habitat amplitude were *Doutnacia xerophila*, *Isotominella minor* and *Pseudosinella* cf. *horaki* occurring with high abundance in both meadow and forest habitats.

Table 3. Estimated species richness and diversity indices of the habitats sampled

Habitat	*S*	*N*	*A*	Singletons/ Doubletons	Richness estimates		Number of presumed species	*H'*	*J*	*CDI*
					ACE/ ICE	*Chao1/ Chao2*				
steppe meadow	41	682	22733	12/4	51/81	53/55	10 – 40	2.353	0.6336	27.86
downy oak forest	34	812	27067	6/4	36/69	36/47	2 – 35	2.517	0.7139	19.48
pine plantation	25	390	13000	8/1	32/59	31/37	6 – 35	2.446	0.7599	22.18

S – total number of species; N – number of individuals; A – total abundance (individuals/m^2);
ACE, ICE, Chao1 and Chao2 – nonparametric richness estimators; H' – Shannon's diversity index;
J – equitability; CDI – community dominance index (%)

The highest overall species richness (41) was found in the steppe meadows (*Figure 1a*), while this parameter decreased in the forest habitats and reached the lowest value (25) in the pine plantation. The highest number of singletons – species represented by single individuals – also occurred in the meadow samples resulting in the highest values of non-parametric species richness estimations *Chao1* and *Chao2* which use the relative proportions of singletons and doubletons for calculating the estimated value. In all three habitats, maximum species richness was predicted by the incidence based estimator *ICE* which takes into account the frequency counts for rare species.

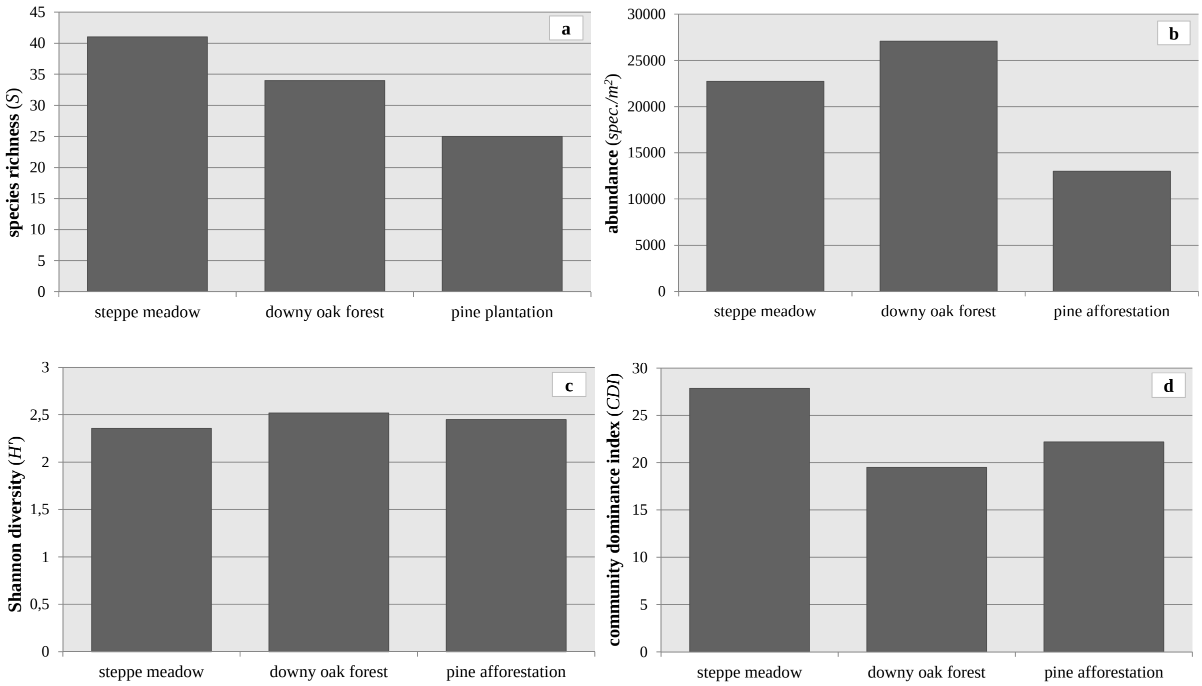

Fig. 1a-d: Species richness, abundance, Shannon diversity and community dominance index

The abundance of collembolan communities varied from 13,000 ind./m^2 to 27,067 ind./m^2 (*Figure 1b*). The most abundant communities were found in the downy oak forests while abundance was less than half in the pine plantations. This phenomenon can probably be explained by changed humus characteristics after the replacement of deciduous oak stands by pine plantations which induced a shift from mull humus towards moder humus forms. In pine plantations, the decomposition efficiency of the soil-fauna is much lower than in deciduous forests (Dunger – Voigtländer 2009). The decreased organic matter decomposition rate, well predicted by the higher C/N ratio (Lorenz et al. 2004), can therefore be reflected in low Collembola abundance, especially in early stages of pine stands.

Species diversity, measured by Shannon-Weaver index, showed the highest value in the downy oak forests (*Figure 1c*). While diversity profile of the Collembola community found in the pine plantations clearly runs under the downy oak forest's profile (*Figure 2*), Hutheson's modified *t*-test yielded no significant difference between the diversities. The diversity profile of the steppe meadow crosses both forest community profiles meaning that the steppe meadow habitat has a completely different community structure and cannot be ranked with the forest communities based solely on diversity.

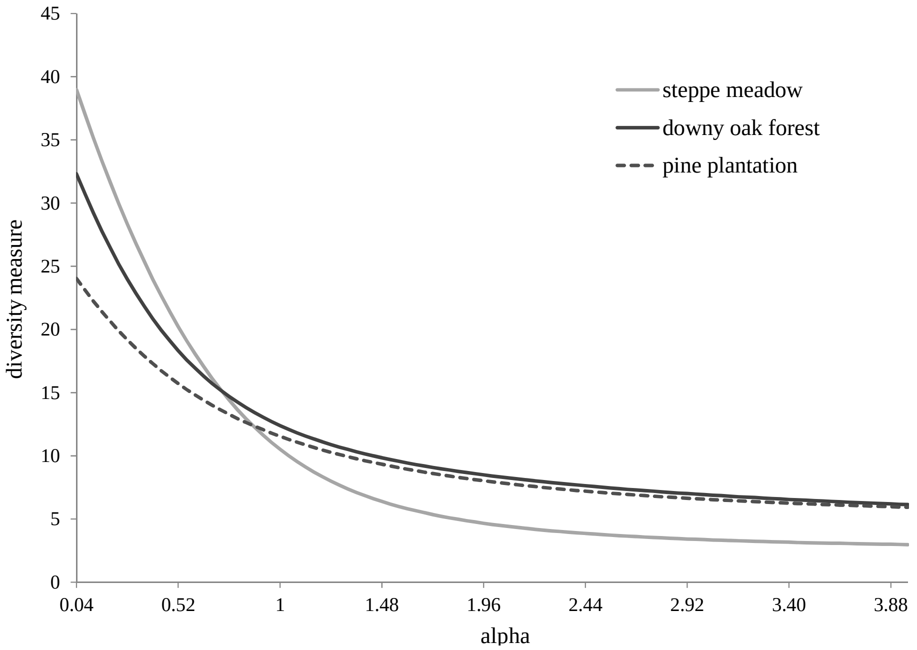

Figure 2. Diversity profiles of Collembola communities in the different habitats

Values of the community dominance index (*Figure 1d*) and the species rank abundance curves (*Figure 3*) emphasise well the differences between the dominance structures of Collembola communities found in the sampled habitats.

Dominance index was lowest (~20%) in the downy oak forest which indicates a relatively balanced dominance structure. The most dominant species was *Folsomia penicula*, a rather silvicolous, mesophil species occurring with an average of 67 ind./100 cm^3 abundance. Subdominant species were the Palaearctic, xerotolerant *Cryptopygus bipunctatus* and the ubiquist, euedaphic mesophilous *Isotomiella minor*. While most of the *Protaphorura* species are characteristic for open habitats, *P. subnemorata*, recorded also in the downy oak stands, appears to be a typical forest species (Dányi – Traser 2008).

Community dominance structure in the pine plantations shows a similar pattern. The relatively low (~22%) value of *CDI* indicates that there were no species present in extreme abundance. The most dominant species was *Parisotoma notabilis*, accounted for about 12% of the total number of individuals, one of the most ubiquist springtails of the Western Palaearctic, reaching high abundance in both natural and disturbed sites, from forests to open grasslands (Potapov 2001). *Isotomiella minor* appeared in high abundance also in the soil of the coniferous pine forests. While we found a number of common species (*Protaphorura* *subnemorata, Pseudosinella* cf. *horaki, Isotomiella minor, Parisotoma notabilis*) for both sampled forest types, it is noteworthy to mention that several species (e.g. *Cryptopygus bipunctatus, Folsomia penicula, Folsomia quadrioculata*) occurred in high abundance in the downy oak forests which on the other hand were completely missing in the pine plantations. The very same phenomenon was observed by Traser – Csóka (2001) in their comparative soil fauna study of an autochton pedunculate oak and an allochton pine plantation in South Hungary. Members of the family *Sminthuridae* were also lacking from pine plantation, while they were present in the other two habitats. There were only very few species that were found preferentially in pine plantations (*Pseudachorutes dubius, Superodontella pseudolamellifera, Tomocerina mixtus*).

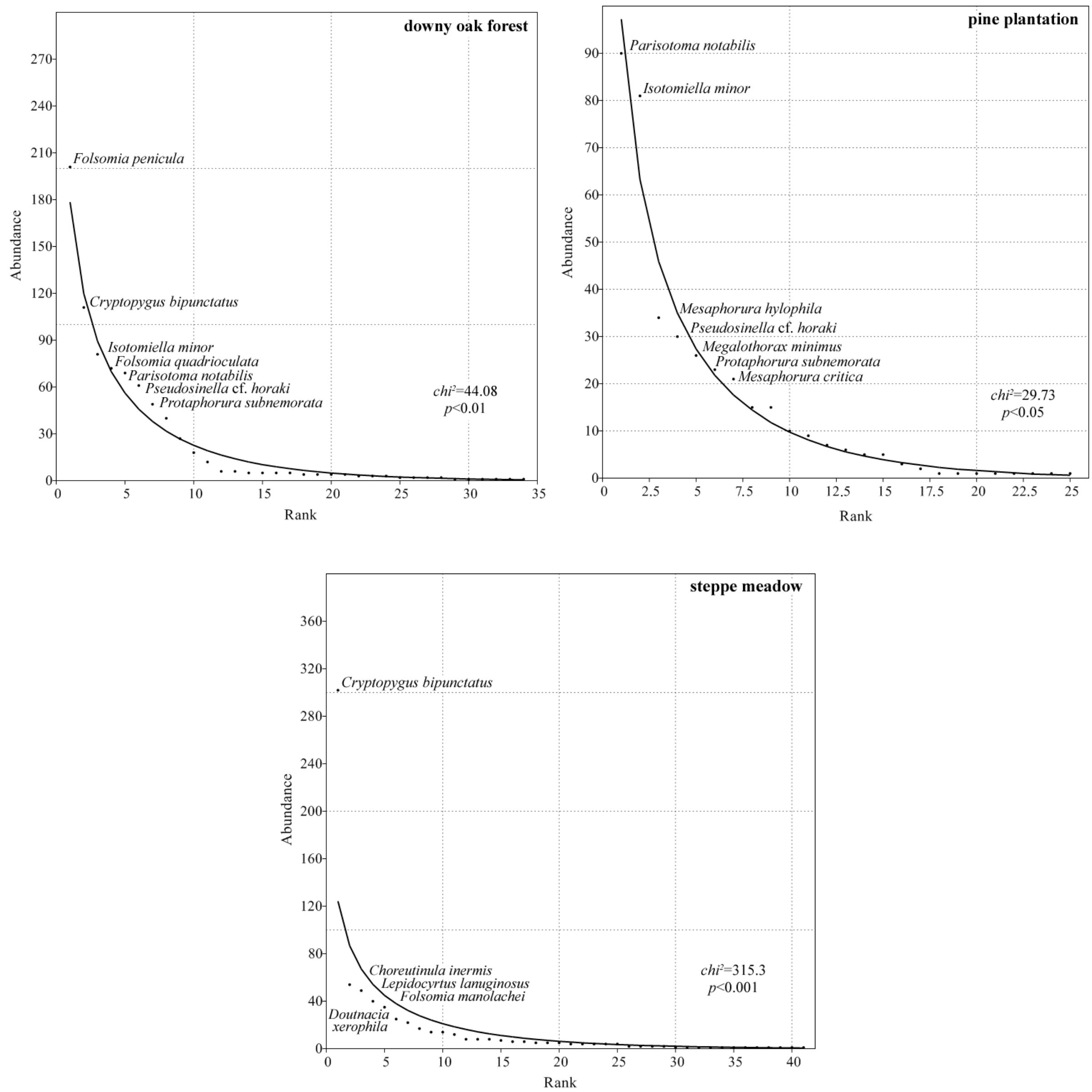

Figure 3. Rank abundance curves (log series) of Collembola communities of the habitats studied

The highest dominance index was obtained in the community found in steppe meadows. The dominance structure is therefore somewhat unbalanced and the equitability is lower mainly because of the mass occurrence of the species *Cryptopygus bipunctatus*. The community is enriched with several rare species represented by few individuals, including typical open area species such as *Hypogastrura vernalis, Protaphorura gisini* or *Metaphorura affinis.*

The agglomerative cluster analysis based on the *Jaccard* measures of similarity (*Figure 4*) shows the separation of meadow and forest habitats. The *Jaccard* similarity values computed for every paired combination are, however, very close to each other (ranging from 0.24–0.28) suggesting that there is a relatively constant 'basic community' as determined by the soil typical type for the area; while dissimilarity in communities between sites is partly provided by spatial heterogeneity of open and forest habitats and by the differences in the vegetation type.

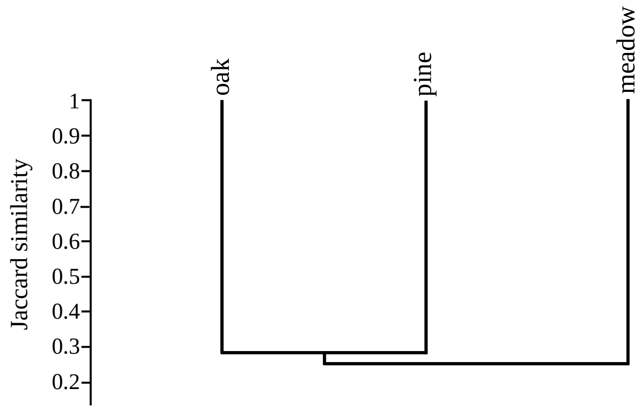

Figure 4. Dendrogram based on cluster analysis using the Jaccard index of similarity

4 CONCLUSIONS

The study area is characterized by a rich Collembola fauna. There are typical Collembola communities characteristic of the different habitat types studied, which contained specific species that appeared only or predominantly in that habitat, as well as some basic common species occurring in every habitat. Although species richness was lowest in the allochthonous pine forest, species composition still maintained a part of the richness of the autochthonous downy oak forest and even that of the steppe meadow habitat.

Notwithstanding that several forest species present in the oak woodland were completely missing from the pine forests, there was no significant difference between the Collembola diversities of the two forest habitats. The difference became more prominent in collembolan abundance which proved to be less than half of individuals/m^2 in pine plantations compared to the downy oak forest soil, and which was probably due to the changed humus characteristics caused by the pine needle litter. The shift towards the moder humus forms, the inhibition of nitrification by monoterpenes present in pine needles can lead to decreased microbial and fungal organic matter decomposition and so thus to a lower Collembola abundance.

Our results suggested that soil conditions have not yet been altered fundamentally that would have been manifested in substantially changed Collembola communities. As a concluding remark it has to be mentioned, that a conversion of pine forests to woodland of native tree species or to steppe meadows has its grounds, and would support the possibility of a quick Collembola community recovery.

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