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Collembolan guild structure as an indicator of tree plantation conditions in urban areas

Abstract. The structure of soil collembolan communities was investigated in lime plantations along the gradient of their simplification from natural forests to single trees in urban areas. In comparison with forests, the species composition of *Collembola* is significantly higher under urban conditions due to the appearance of meadow, compost and ruderal forms. Thus, collembolan communities with "unnatural" combinations of these ecological groups are forming and these can sometimes be rather stable. The extended spectrum of ecological groups among *Collembola* can be considered as an indicator of the process of the tree stands' degradation in urban conditions in comparison with their natural analogues.

INTRODUCTION

Collembola or springtails, a group of small (0.3–5.0 mm) soil arthropods, play a conspicuous part in organic matter decomposition taking part in regulating the mineralization-humification balance in soils. At the same time, it is one of a few groups of animals which can well tolerate an urban environment (STERZYŃSKA 1987, SCHAEFER 1989). First of all, the soil partly protects them from anthropogenic impacts. On the other hand, according to JOOSE and VERHOEF (1987), springtails are relatively resistant to the action of toxic substances owing to frequent moults and the ability to avoid contaminated substrates.

Thus, *Collembola* may be used as a model group to study the limits of the stability of the population and the principles of community formation under urbanization pressures. Our previous investigations in natural forest biotopes showed that this group can be considered as an indicator of forest conditions (KUZNETZOVA 1989).

MATERIALS AND METHODS

Communities of soil springtails were studied in lime plantations of Moscow and Moscow Region in 1988–1992. These plantations are considered here along the gradient of their simplification induced by the urban environment: natural forests, forest parks and botanical gardens/small parks, boulevards and rows of trees along the streets/single trees surrounded by asphalt. All the studied plots were without evident human trampling.

Soil samples, arranged in transects between trees, were taken to a depth of 10 cm. Springtails were extracted using Tullgren-type equipment. In total, 640 soil samples were taken, and more than 12,000 specimens belonging to 70 species were identified.

Species with a relative abundance of more than 10% of the total numbers of *Collembola* in sampling were considered as dominant, and with an abundance of more than 3% as mass ones. I use also the term "potential dominants" proposed by CHERNOVA and KUZNETZOVA (1990) for species that can predominate in a certain type of plant association. Species diversity was estimated using the Shannon index ($H' = \Sigma p_i \log_2 p_i$). Species with a significant positive correlation of their numbers (at $p = 0.05$, Pearson coefficient) were regarded as correlation pleiads (method proposed by TERENTJEV 1959), outlining species closely interrelated within the given biotope.

Collembola communities were investigated in 15 biotopes, viz. **natural lime forests** (*Tilietum pilosae-caricosum*) in different Districts of Moscow Region: (1)[1] Leninsky, (2) Podolsky, (3) Lyuberetzky, (4) Istrinsky; **forest-parks** of Moscow: (5) Kuskovo, (6) Neskuchny Sad, (7) Botanic Garden of Moscow University; **boulevards**: (8) Raketny bl., (9) Kibalchicha str; **small parks**: (10) Bauman garden, (11) Kremlin embankment; **rows of trees along the streets**: (12) near chemical plant in Kuskovo, (13) Kr. Kazanetz str.; **single trees surrounded by asphalt**: (14) Zubovsky bl., (15) U Poryvaeva str.

As a rule, the sampling was carried out in each biotope once or twice during the study. In addition, in biotope (11) samples were taken at monthly intervals and in biotope (15) at yearly intervals.

COLLEMBOLAN COMMUNITIES IN NATURAL FORESTS

In natural lime forests, the main characteristics of the structure of *Collembola* communities have not very high values (Tab. 1). The group of potential dominants is very distinct: *Isotoma notabilis*, *Isotomiella minor*, *Folsomia quadrioculata*, *Protaphorua subarmata*, *Megalothorax minimus*, *Lepidocyrtus lignorum*, *Pseudachorutes parvulus*. As a rule, in natural lime forests only two ecological groups of *Collembola*, viz. **eurytopic** and **forest** species are observed (Fig. 1). The majority of synecological features of collembolan populations in natural coniferous forests varies strongly during a year, average annual indices are rather stable in successive years (KUZNETZOVA, BABENKO 1984). I believe that this conclusion is true for the investigated lime forests too.

I realize that the structure of natural springtail communities is only partly characterized here but believe that these very features of collembolan populations to a large degree distinguish natural forests from urban plantations.

1 These figures are used below as biotope numbers.

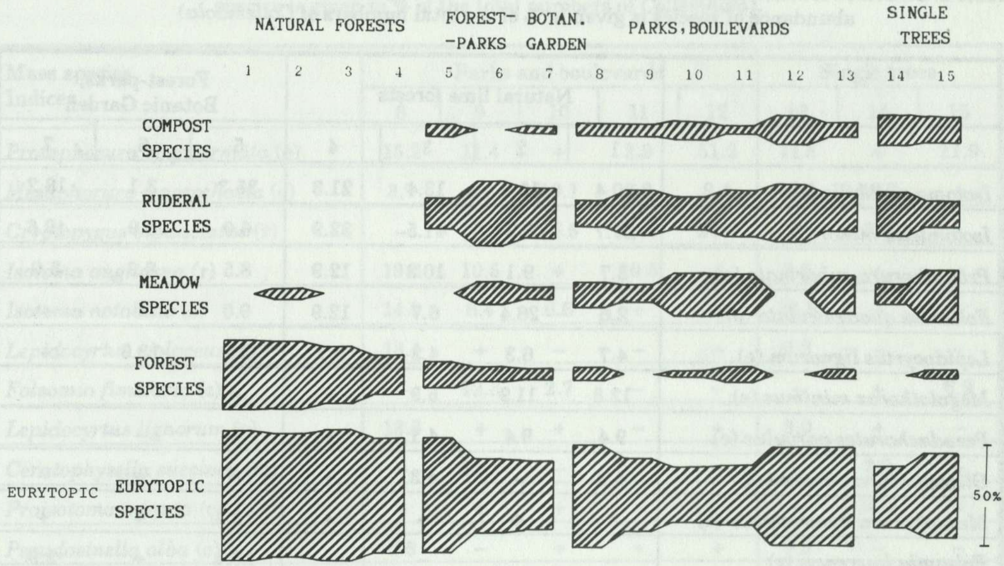

Fig.1. Species richness of different ecological groups of *Collembola* (in % of the total species numbers in a biotope) in some types of lime plantations.

COLLEMBOLAN COMMUNITIES IN URBAN LIME PLANTATIONS

As a whole, collembolan populations in forest-parks and the Botanic Garden are similar to those in natural forests. There are many common species numerous in both types of stand (Tab. 1). Most of them belong to the eurytopic group. Nevertheless, species richness in the forest group declines as well as their abundance in communities (except the Botanic Garden with its very old plantations). In distinction from meadow and compost forms, ruderal species are usual in forest-parks and sometimes can even predominate, e. g. *Onychiurus* sp. *gr. fimetarius* (Fig. 1). Correlation pleiads are rather complicated, especially in Botanic Garden (Fig. 2). Collembolan density can be much higher than in natural soils, exceeding 50 thous. ind/m^2.

In small parks and other biotopes of this category the level of total springtail density is low (Tab. 2). Collembolan communities there can be considered as ruderal (with predominance of *Isotoma anglicana*, *Cryptopygus bipunctatus*, *Folsomia lawrencei*, etc.) or as meadow ones. The latter are characterized by the presence of some specific forms, viz. *Ceratophysella succinea*, *Pseudachorutes parvulus*, *Isotomodes productus*, species of *Stenaphorura*, *Metaphorura*, *Neotullbergia*, *Neonaphorura*, although they are not always numerous. The eurytopic group is also diverse and abundant there, but forest species are rare (Fig. 1).

The list of potential dominants under single trees surrounded by asphalt includes a great number of *Collembola* species, but in separate plots a few dominants usually occur. Compost species (*Hypogastrura* spp., *Lepidocyrtus cyaneus*, *Proisotoma minu-*

Table 1. Structure of collembolan communities in natural and slightly disturbed lime plantations (relative abundance of species is given in % of the total numbers of *Collembola*)

	Natural lime forests				Forest-parks, Botanic Garden		
	1	2	3	4	5	6	7
Isotoma notabilis (e)	30.4	15.7	13.4	21.3	35.3	3.1	18.2
Isotomiella minor (f)	27.7	8.2	41.5	32.9	6.0	3.9	49.6
Protaphorura subarmata (e)	3.7	9.1	10.3	12.9	8.5	8.9	3.0
Folsomia quadrioculata (e)	2.6	26.4	6.7	12.9	9.0	+	+
Lepidocyrtus lignorum (e)	4.7	6.3	4.3	9.7	3.2	13.0	+
Megalothorax minimus (e)	12.8	11.9	5.9	+	+	–	–
Pseudachorutes parvulus (e)	9.4	9.4	4.1	+	–	–	–
Oligaphorura absoloni (f)	4.2	–	4.3	+	–	–	–
Mesaphorura macrochaeta (e)	+	+	+	+	12.4	+	+
Folsomia lawrencei (r)	–	–	–	–	16.4	+	2.9
Isotoma anglicana (r)	–	–	–	–	+	7.2	–
Onychiurus sp. gr. fimetarius (r)	–	–	–	–	+	47.0	–
Number of individuals	382	318	491	155	1058	483	917
Number of samples	20	20	20	20	20	20	20
Size of sample (cm^2)	8	10	8	10	10	10	10
Density (thous.ind/m^2)	27.3	15.9	35.1	15.5	52.9	26.8	50.9
Mean density (ind//sample)X±m	19.1± ±3.8	15.9± ±3.9	24.6± ±3.5	15.5± ±2.3	52.9± ±8.4	24.2± ±4.9	45.9± ±10.8
Number of species	14	19	21	15	19	16	25
H'(bit)	2.68	3.16	2.83	2.65	2.94	2.56	2.57
Ecological forms: e – eurytopic, f – forest, r – ruderal							
+ – less than 3% of total abundance							

ta, Folsomia fimetaria) are the most typical for such biotopes (Tab. 2, Fig. 1). The total density of *Collembola* varies widely, but its average level is usually rather high (about 20 thous. ind/m^2), possibly due to the protection given by a lattice cover. Springtail populations can be quite specific even under neighbouring trees sampled at the same time. For example, in June 1992, four different dominants were found under four successive trees in biotope 15 (Fig. 3). In such a plantation, the community of *Collembola*, probably due to the "island effect", consists of several micropopulations forming a complicated mosaic with local predomination of compost, ruderal and eurytopic forms.

Table 2. Structure of Collembolan communities in lime plantations in Moscow (relative abundance of species is given in % of the total numbers of *Collembola*).

Mass species Indices	Parks and boulevards					Single trees		
	8	9	10	11	12	13	14	15
Protaphorura sp.gr.armata (e)	15.2	11.4	+	3.9	51.2	11.8	+	11.9
Mesaphorura macrochaeta (e)	3.7	4.1	19.1	6.8	8.4	21.4	46.8	+
Cryptopygus bipunctatus (r)	–	13.2	26.5	20.6	27.0	+	3.3	–
Isotoma anglicana (r)	19.8	10.5	+	30.5	+	3.6	+	+
Isotoma notabilis (e)	14.9	6.4	6.6	+	+	38.8	+	+
Lepidocyrtus violaceus (e)	13.4	+	–	–	–	6.2	–	–
Folsomia fimetaria (c)	–	12.3	2.7	–	–	–	+	6.9
Lepidocyrtus lignorum (e)	13.8	+	+	–	+	3.0	+	–
Ceratophysella succinea (m)	–	24.5	–	–	–	–	3.0	+
Proisotoma minuta (c)	+	+	+	–	5.0	–	30.3	+
Pseudosinella alba (e)	8.6	–	+	+	+	9.9	–	–
Folsomia lawrencei (r)	–	+	4.7	+	–	–	4.5	+–
Sphaeridia pumilis (e)	+	+	–	4.8	+	+	–	5.4
Hypogasrura assimilis (c)	–	–	–	–	+	–	+	47.0
Lepidocyrtus cyaneus (c)	–	–	–	–	–	–	–	15.3
Ceratophysella denticulata (c)	–	–	11.7	–	–	–	–	–
Sminthurinus elegans (m)	+	+	–	10.6	–	–	–	–
Sminthurinus aureus (e)	+	+	9.3	+	–	–	–	–
Isotomiella minor (f)	+	+	+	9.0	–	+	–	–
Friesea mirabilis (e)	–	+	+	+	–	+	+	5.8
Pseudachorutes parvulus (e)	–	+	–	–	2.7	–	–	–
Onychiurus sp. gr. fime-tarius (r)	–	–	3.9	–	+	–	+	+
Number of individuals	268	220	257	311	559	304	333	744
Number of samples	15	15	20	20	20	20	20	15
Size of a sample (cm^2)	25	25	10	8	10	10	10	25
Density (thous.ind/m^2)	7.1	5.9	12.9	18.3	31.1	16.0	19.5	22.9
Mean density (ind/ /sample X±m)	19.1± ±5.1	14.7± ±3.1	12.9± ±2.8	15.6± ±1.6	28.0± ±6.7	16.0± ±3.7	17.5± ±4.4	57.2± ±17.2
Number of species	17	19	24	19	13	16	18	19
H'(bit)	2.97	3.46	3.42	3.08	2.02	2.61	2.23	2.46
Ecological forms: e – eurytopic, f – forest, r – ruderal, m – medow, c – compost, + – less than 3% of total abundance								
biotope 11: data for May 1992; biotope 15: data for 1988								

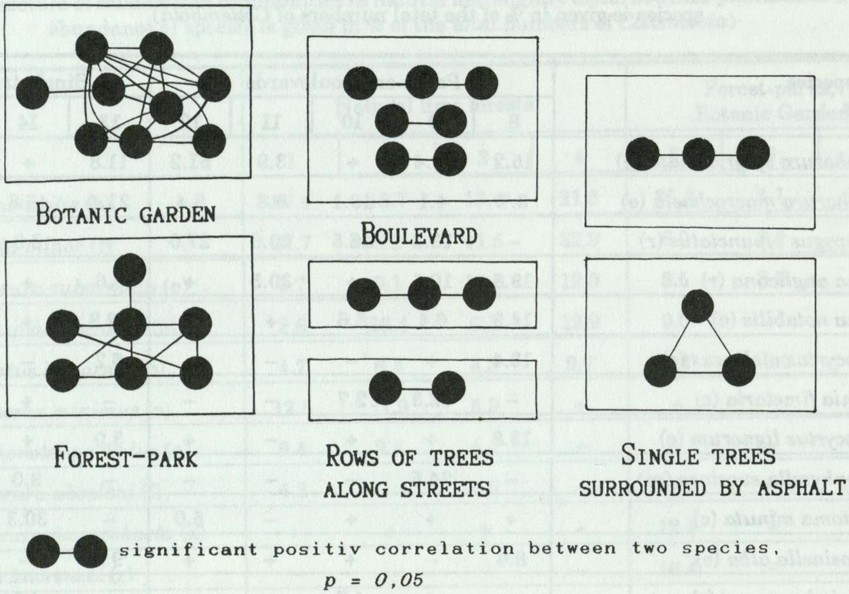

Fig. 2. Correlation pleiads of *Collembola* in urban lime stands.

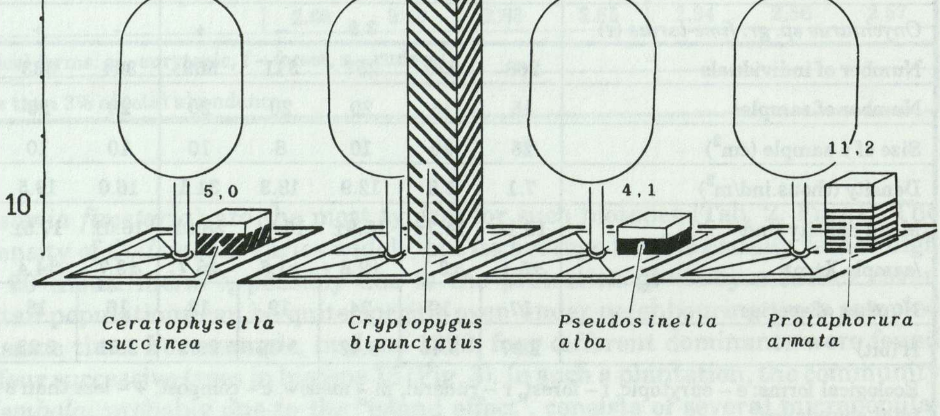

Fig. 3. Dominant species of springtails under single lime trees surrounded by asphalt.

The high level of the Shannon index of *Collembola* communities registered sometimes in urban areas of Moscow District (up to 3.5 bit) might be just a result of the extreme lability of species structure in a permanently disturbed environment. Analogous conclusions were made by ANDRÉ and LEBRUN (1982) in their study of the corticolous complex of microarthropods in the urban district of Charleroi (Belgium). Therefore, in anthropogenic conditions this index can hardly be considered as an indicator of the state of the community.

Correlation pleiads in urban areas are usually very simple (Fig. 2). As for the natural environment, the most simple structure of such pleiads is characteristic of poor conditions or young forest associations (KUZNETZOVA 1987). Their simplification in urban tree plantations might be connected with the weakening of a tree stand influence on a habitat.

A DYNAMIC ASPECT OF COMMUNITY STRUCTURE UNDER URBAN CONDITIONS

The presence of non-typical (for natural forest) ecological groups of *Collembola* in the same community of an urban stand raises a question about the principles of their coexistence. Monthly sampling in a small park in the very centre of Moscow (biotope 11) showed a temporal differentiation of these groups (Fig. 4). **Meadow** species of *Collembola* were found mainly in spring and summer, density peaks of **forest** forms are recorded in winter, whereas **"ruderal"** and **eurytopic** species were abundant throughout the year. A rather stable springtail population is forming there. In this case, the stability manifests itself in the sense of resistance, i.e. in an ability to avoid changes (BEGON et al. 1986). This can reveal itself in two ways:

– Although some changes in ecological composition have been observed in this biotope, the group of dominant species was the same over the whole sampling period.

– No sharp fluctuations in total springtail abundance were recorded in this biotope.

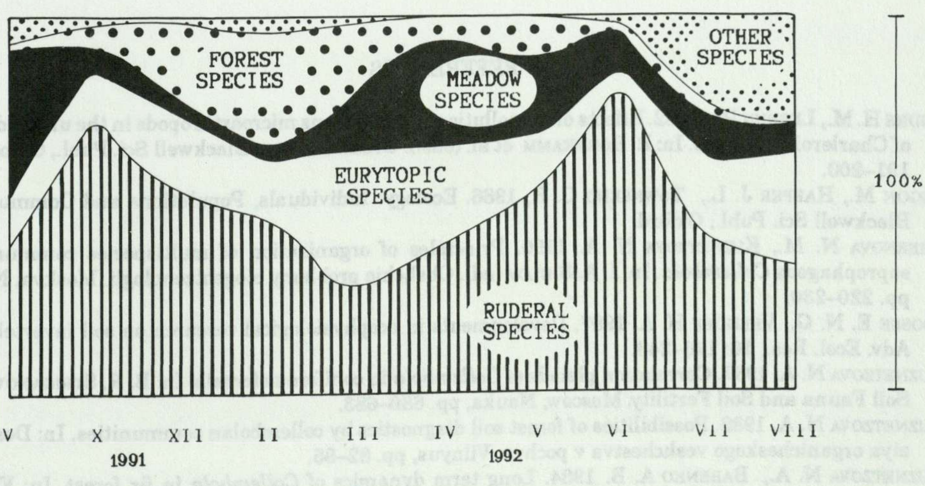

Fig. 4. Seasonal changes in relative densities of Collembolan ecological groups in a small park.

However, in extremely simplified plantations (for example, under a single tree surrounded by asphalt) very labile communities of springtails are formed. Regular changes of dominant species were recorded there. At first, compost forms such as *Hypogasrura assimilis* and *Lepidocyrtus cyaneus* predominated (Tab. 2: biotope 15). During the next year the eurytopic *Mesaphorura macrochaeta* was the most abundant, being replaced by the ruderal *Cryptopygus bipunctatus* in the last year of sampling. In such extreme conditions the strategy of survival of *Collembola* populations is rapid response to environmental changes, especially to the appearance of organic waste.

CONCLUSION

The ability to form a broad spectrum of community types with different combinations of ecological groups gives a *Collembola* population high adaptive possibilities in relation to the environment. In most cases collembolan communities with such ecological structures are not found in nature. In urban soil *Collembola* demonstrate different types of community organisation: from relatively stable to extremely labile. As a result, their densities are usually relatively high and, I suppose, this allows the functional activity of this group to be preserved in urban soil. The extended spectrum of ecological groups of springtails should be considered as an indicator of the level to which lime stands have degraded under urban conditions in comparison with their natural analogues.

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