POLSKA AKADEMIA NAUK
INSTYTUT ZOOLOGII

FRAGMENTA FAUNISTICA

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Communities of *Collembola* in natural and transformed soils of the linden-oak-hornbeam sites of the Mazovian Lowland

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[With 17 Figures and 20 Tables in the text]

CONTENTS

1. Introduction 166
2. The site 168
3. Material and methods of studies on *Collembola* communities 178
4. Material analysis 182
4.1. *Collembola* communities in natural soils of linden-oak-hornbeam forests (*Tilio-Carpinetum*) 182
4.1.1. Species composition 182
4.1.2. Abundance 187
4.1.3. Dominance structure and diversity of communities 189
4.1.4. Ecological classification of species 191
4.2. *Collembola* communities in semi-natural soils of linden-oak-hornbeam meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosuretum*) 194
4.2.1. Species composition 194
4.2.2. Abundance 199
4.2.3. Dominance structure and diversity of communities 200
4.2.4. Ecological classification of species 203
4.3. *Collembola* communities in anthropogenic soils of fields and orchards 205
4.3.1. Species composition 205
4.3.2. Abundance 208
4.3.3. Dominance structure and diversity of communities 209
4.3.4. Ecological classification of species 210
4.4. *Collembola* communities in anthropogenic soils of urban greens 212
4.4.1. Species composition 212
4.4.2. Abundance 222
4.4.3. Dominance structure and diversity of communities 225
4.4.4. Ecological classification of species 229
4.5. Similarity analysis of *Collembola* communities in the studied habitats 233
5. Changes in *Collembola* communities due to anthropogenic impact 240
6. Discussion 248
7. Summary and conclusions 253
References 255
Streszczenie 260

Abstract. The work provides an ecological analysis of *Collembola* communities in natural soil of linden-oak-hornbeam forests (*Tilio-Carpinetum*), in semi-natural soil of linden-oak-hornbeam meadows (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosuretum*), in anthropogenic soil of fields and apple-tree orchard and in anthropogenic soil of urban greens. By way of comparison of *Collembola* communities in natural habitats and those subject to man's (both agricultural and urbanization), analyses and evaluation were made of the character and degree of changes proceeding in communities of *Collembola*.

In the examined soil of linden-oak-hornbeam habitats on the Mazovian Lowland there were recorded 96 *Collembola* species (including 7 new to Poland and 25 new to the region).

In effect of the carried out examinations it was found out that *Collembola* communities were dominated by euedaphic, hemiedaphic, mesophilous, eurytopic and open area species. Particular species as well as groups of species differed in their abilities and the manner reacting to habitat disturbances caused by anthropogenic factors. *Collembola* occurring in Warsaw urban greens ranked mostly among fauna, betraying peculiar urban traits resulting from a long-term effect of anthropogenic impact.

Good indicators of the degree of degradation of *Collembola* communities were: the number of species, characterists species composition and dominance structure.

1. INTRODUCTION

Linden-oak-hornbeam forests have ever occupied very fertile habitats. This type of habitat was the first to expose to the direct anthropogenic pressure. In effect of intensive management by man, agricultural in particular, the primeval and natural vegetation was replaced by semi-natural and, finally, by synanthropic one. Man-induced changes in plant associations provoke changes in soil habitats and, consequently, alternations in the composition and structure of soil zoocoenosis.

Data on *Collembola* fauna in the habitat of linden-oak-hornbeam forests of Europe and Poland as well, are duenty due to a unique occurence of these plant associations nowadays. European studies on *Collembola* in forest associations of the alliance *Carpinion* include only one paper dealing with *Collembola* of *Querceto-Carpinetum* in Yugoslavia (Živadinović, Cvijević 1967). Very inabundant are also works on *Collembola* of meadows and pastures in the habitat of linden-oak-hornbeam forest (Gisin 1943, Živadinović, Cvijević 1967, Živadinović 1976, Dunger 1975). Certain faunistic data on *Collembola* in the habitat of linden-oak-hornbeam forest in Poland can be found in Stach monographs' "The Apterygotan fauna of Poland in relation to the world fauna of this group of insects" and "The catalogue of fauna of Poland" (Stach 1964). Complementary information can be acquired from monographs dealing with *Collembola* fauna of some chosen national parks (Szeptycki 1967, Weiner 1976, 1981), zoocoenologic works by Kaczmarek (1963, 1973, 1975, 1977) conducted on the area of the Kampinoski National Park, studies aimed at evaluation of productivity of *Collembola* community in the "Las Piwnicki" linden-oak-hornbeam reserve near Toruń (Czarnecki, Kamińska 1977, Czarnecki 1978) and studies on dynamics of *Collembola* communities in crop field soil (Łosiński 1953, 1972, 1974, Czarnecki, Łosiński 1984, Trojanowski, Szeptycki 1985).

One of significant, long-range elements of anthropogenic pressure is, besides agriculture, even-intensifying process of urbanization. Changes in soil zoocoenosis induced by agricultural practices are presently well known (Tischler 1955, Edwards, Lofty 1969), as well as changes caused by pollution of soil habitat by widley emploed pesticides (Wallwork 1970, Edwards, Thompson 1973), mainly by herbicides (Curry 1970, Fratello et al. 1985, 1986) and insecticides (Butcher et al. 1971). Studies on urban zoocoenosis have been initiated only recently (Müller et al. 1975, Frankie, Koehler 1978, 1983, Schaefer, Kock 1979, Czechowski, Pisarski 1981, 1986, 1987, Czechowski et al. 1981, 1982, Bornkam et al. 1982, Klausnitzer 1987). In all these works hardly any attention has ever been paid to the effect of urbanizational pressure on soil zoocoenosis. Detailed examinations have only been carried out on *Carabidae* and *Araneidae* of urban habitats (Schaefer, Kock 1979, Klausnitzer, Lehnart 1980, Klausnitzer, Rechter 1980, 1983, Klausnitzer et al. 1980a, b, Czechowski 1982, Schaefer 1982, Klausnitzer 1983). There have been no studies on such ubiquist soil groups as *Acarina* or *Collembola*. Somewhat more through examinations were only carried out on *Oribatida* in West Berlin (Weigmann, Stratil 1979, Weigmann 1982, 1984, 1987) and on *Collembola* in the urban agglomeration of Warsaw (Sterzyńska 1981b, 1982, 1987). Moreover certain scarce data on *Apterygota* of urban habitat can be found in a typically faunistic work by Lawrence (1963), in work by Kühnelt (1982) and in the paper by Greenslade, Ireson (1986), which actually can be regarded as a key for identification the basic species occuring in urbanized habitats in Southern Australia.

Reaction of *Collembola* to stress factors of anthropogenic origin are most often considered with respect to their ecophysiological adaptation (Josse 1983); very scanty are works examining how the factors in question affect the changes in structure of the whole community of *Collembola* (Prasse 1985, Fritzlar et al. 1986).

One of the methods of zoocoenological soil diagnosis (classification of soil types in some complicated and controversial cases, defining various soil properties and direction of soil forming processes), consists in comparison of soil communities of invertebrates with regard to ecological plasticity of species and their habitat requirements (Ghilarov 1978). The question of empolyment of soil mesofauna groups as bioindicators in disturbed ecosystems and discussion on the methods of evaluation of these disturbances were presented by Weigmann (1987). Nonetheless, works focusing on comparison of *Collembola* communities from natural habitats and the ones transformed by man, are very scare (Dunger 1975, Pozo et al. 1986).

The most thoroughly studied elements of anthropogenic pressure on *Collembola* species and populations are besides the agrotechnical procedures commonly applaied in agriculture (Prasse 1978, 1985, Ulber 1979, Subgaja, Snider 1981, Fratello et al. 1985, 1986, Mallow et al. 1985) are changes in soil reaction, forest soil in particular, caused by fertilization or acid rains (Hågvar 1984, Huhta et al. 1983, 1986, Vilkamaa, Huhta 1986); silvicultural practices empolyed in forestry, such as cler-cuts (Huhta et al. 1967, 1969, Huhta, Mikkonen 1982); human trampling of forest soil (Garay, Nataf 1982, Massoud et al. 1984). The consequence of industrialization and urbanization as well as wide of application of pesticides in agriculture is, among others, accumulation of heavy metals in soil habitat. An evaluation of their effect on physiological processes and structure of *Collembola* population can be found in the works by Bengtsson et al. (1983, 1985) and Josse, Verhoeff (1983). However, little is known how urbanizational or agricultural pressure modifies the occurence of particular species and, especially, how it affects whole communities of *Collembola*.

The aim of the present paper was to examine *Collembola* communities in the habitats of linden-oak-hornbeam forest on the Mazovian Lowland, which included natural forest associations, seminatural meadow associations and homologous vicarious plant associations, such crop fields, orchards and urban greens. Apart from species identification and provide information on the occurence of soil *Collembola* in the studied habitats, a characteristic main types of *Collembola* communities functioning in natural and variously transformed habitats has been described. Moreover, an attempt was made to evaluate degradational changes in the composition and structure of *Collembola* communities from the habitats under anthropogenic pressure, mostly of urbanizational and agricultural character. Finally, the origin was traced of *Collembola* communities occuring in Warsaw urban soils.

2. THE SITE

Primarily the landscape of the Mazovian Lowland was dominated by linden-oak-hornbeam forests of the alliance *Carpinion* (Matuszkiewicz 1966), bound to very fertile, most often brown soils. Nowadays only small and scare sites of natural linden-oak-hornbeam associations of *Tilio-Carpinetum* can be found, usually enclosed under nature reserve protection. As a result of long-lasting man's activity an overwhelming part of linden-oak-hornbeam forests was destroyed, the areas having been deforested and put under agricultural use. Consequently, the Mazovian Lowland is presently dominated by replacing plant associations, such as: meadow (*Arrhenatheretum medioeuropaeum*), pasture (*Lolio-Cynosuretum*) and associations of field crops and orchards. Apart from agriculture, the other main factor affecting the form of the Mazovian Lowland landscape is urban development. The most significant is the urban agglomeration of Warsaw, where, especially in its part on the Vistula left bank, linden-oak-hornbeam (*Tilio-Carpinetum*) habitats dominate in the Mazovian Lowland, as stated on the basis of analysis of potential vegetation in the Warsaw Valley (Matuszkiewicz 1966). Presently urban greens (of parks, residental districts and streets) prevail among the replacing plant associations of Warsaw.

The studies were conducted on linden-oak-hornbeam habitats on the Mazovian Lowland, in soils of natural forest associations (*Tilio-Carpinetum*), semi-natural meadow associations (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosuretum*), in anthropogenic soils of field crops, orchards and of urban greens. A total of 25 stations was assigned for the present studies (Tab. I, Figs 1, 2).

Table I. *Characteristic of chemical composition and chemical properties of mineral-humus horizon (A_1) of the studied linden-oak-hornbeam sites on the Mazovian Lowland*

	Type of linden-oak--hornbeam forest site		Locality	No of stations	Organic matter C (%)	pH KCL 1 n	$CaCO_3$ (%)	C/N	Heavy metals (ppm)			
									Zn	Cu	Pb	Cd
I	Forest	*Tilio-Carpinetum*	Dębina	1	2.09	4.5	–	16.2	–	–	–	–
			Modrzewina	2	1.49	4.1	–	14.4	–	–	–	–
			Białołęka Dworska	3	1.94	4.1	–	16.9	–	–	–	–
				4	–	–	–	–	–	–	–	–
II	Meadow	*Arrhenatheretum medioeuropaeum*	Chylice	5	8.52	6.8	0.88	–	–	–	–	–
			Klembów	6	1.14	4.1	1.21	25.2	–	–	–	–
			Białołęka Dworska	7	5.98	5.6	–	–	–	–	–	–
		Lolio-Cynosuretum	Zbroszki	8	1.63	6.0	–	–	–	–	–	–
III		Ploughlands	Białołęka Dworska	9	–	–	–	–	–	–	–	–
			Belsk Mały n/Grójec	10	1.21	6.8	1.28	8.6	–	–	–	–
	Apple-tree orchard			11	2.06	6.0	0.48	9.6	–	–	–	–
IV	Urban greenery	Parks	Łazienki	12	3.80	6.1	0.00	15.4	248	19	32	0.32
			Cemetery of	13	4.13	6.6	0.19	13.5	92	13	12	0.18
			Soviet	14	1.93	6.4	0.54	11.5	129	18	27	–
			Soldiers	15	3.00	6.3	0.09	13.3	78	14	27	0.19
			Saxon Garden	16	–	–	–	–	66	23	64	–
		Green of housing estate	Wierzbno	17	4.29	7.0	0.98	13.8	230	20	59	0.66
				18	3.39	6.6	0.13	15.1	134	22	50	0.23
			MDM	19	2.21	7.1	1.28	12.0	195	36	73	0.38
		Streetside of green	Ujazdowskie Avenue	20	5.63	6.4	0.19	15.3	214	47	134	0.44
			Żwirki i Wigury	21	2.68	7.1	4.00	20.7	133	16	134	0.40
			Avenue	22	–	–	–	–	–	–	–	–
			Marszałkowska St.	23	6.98	7.1	1.53	15.7	250	46	155	1.18
			Woronicza St.	24	3.55	7.1	1.10	23.6	260	45	131	1.25
			Zbawiciela Square	25	7.92	7.1	1.41	16.9	–	–	–	–

2.1. Linden-oak-hornbeam forests (*Tilio-Carpinetum*)

Studies on *Collembola* communities in natural forest soils of the association *Tilio-Carpinetum* were carried out in the Dębina reserve near Klembów and Modrzewina reserve near Belsk and, moreover, for comparative purposes, also in

Forest	/*Tilio–Carpinetum*/	**1, 2, 3,**
Meadow	/*Arrhenatheretum medioeuropaeum*/	**5, 6,**
	/*Lolio–Cynosuretum*/	**8.**
Field		**10.**
Orchard		**11.**

Fig. 1. Location of the studied sites on the Mazovian Lowland; the borders of the Mazovian Lowlands were denoted after criteria assumed in the Catalogue of Fauna of Poland (Stach 1964); station numbers – see Table I, II.

a highly degraded plot of linden-oak-hornbeam forest in Białołęka Dworska. Due to it's small area, much light-penetration and trampling, the latter site resembled a suburban park rather.

Dębina reserve. Site of Special Scientific Interest. It was established in 1934 and the long-lasting protection conduced to preservation of natural character of this forest complex. The reserve area amounts to 51.2 ha. It is situated near the locality (village) of Klembów, north-west of Warsaw.

Station 1. Located in the 16d section (acc. to the arrangemant plan of forest culture in Drewnica forest inspectorate). The prevailing was weakly leached brown soil, derived from medium sands on medium loam gleyed with humus of the mull/moder type, strongly acid. The tree stand was two layered, made up of 150–180 year old oaks and 130–150 year old hornbeams, lacking small-leaved lindens, elms and ash-trees, wich were felled by local population in the time of the II World War. The tree stand was being reconditioned, undergrowth was made up mainly of hornbeams. The contributions of shrubs was varied, including hazel, rowan, hornbeam, alder buckthorn. The species occuring in the herb layer ranked among species typical of fertile linden-oak-hornbeam forests (*Polygonatum multiforum*, *Galeobdolon luteum*, *Stellaria holostea*, *Milium effusum*, *Aegopodium podagraria*, and *Anemone nemorosa*).

Modrzewina reserve. Also a Site of Special Scientific Interest. It was estabilished in 1959 in order to preserve a unique Mazovian stand of Polish larch *Larix polonica* RAC., which is a natural component of Mazovian deciduous and mixed coniferous forest. It spreads on the area of 286.6 ha. Located in Mała Wieś near Belsk, south of Warsaw.

Station 2. Located in the 152c sub-section (acc. to the arrangement plan of forest culture in Grójec forest inspectorate), on lessive soil, developed from very fine sandy soil on shallow bedding of loam (heavy loam) and with humus of the mull type. It was a relatively dry linden-oak-hornbeam forest, growing on fresh mesotrophic soils, of strongly acid reaction (Tab. I). Layered tree stand made up of oak, larch and single pine (I layer) and of hornbeam and oak (II layer). Undergrowth was composed mainly of oak and individual hornbeam and linden. Contribution of shrubs was varied, including single young oaks and hornbeams as well as coherence clusters of hazel and alder buckthorn. Species structure of herb layer, although inabundant, was typical of linden-oak-hornbeam forest. Species characteristic of plant associations were lacking, however species characteristic of order and class occured (*Asperula odorata*, *Sanicula europaea*, *Anemone nemorosa*, and *Poa nemoralis*). This was a typical linden-oak-hornbeam forest growing on fresh eutrophic soils.

Station 3. Located in 152a sub-section, on typical lessive soil of strongly acid reaction, with humus of the mull/moder type. This station was more humid than the station 2 located in the 152c sub-section, while all the other environmental parameters were nearer.

Białołęka Dworska. A suburban district of Warsaw, situated north of the city center.

Station 4. Located on the area of Białołęka Dworska. It comprised a small, 0.4 ha in area plot of typical forest association *Tilio-Carpinetum*, located on brown soil derived from alluvial loams and loose sands, surrounded by crop fields and fallow grounds. The tree stand was dominated by oak and linden, undergrowth was made up of birch, hornbeam, oak, underbush – of hornbeam and robini while in the herb layer forest species prevailed, at a relatively small contribution of anthropophytic species (Roo-Zielińska 1981).

2.2. Linden-oak-hornbeam meadows (*Arrhenatheretum medioeuropaeum, Lolio-Cynosuretum*)

One of the most characteristic repleacing communities for linden-oak-hornbeam forests *Tilio-Carpinetum* are moist meadow (*Arrhenatheretum medioeuropaeum*) and pasture associations (*Lolio-Cynosuretum*). Studies on *Collembola* communities were conducted in soil of mown meadows in Chylice, Klembów, Białołęka Dworska and of a pasture in Zbroszki.

Chylice. It is a regular, very fertile mown-grazed meadow (*Arrhenatheretum medioeuropaeum*) under intensive use. The studied meadow was located south-west of Warsaw and was owned by the Agricultural Experimental station of Agricultural Academy.

Station 5. Located on typical meadow black earth, formed from laminar alluvial deposits, medium gleyed and judging by the thickness of humus accumulation horizon, under a much advanced sodding process. High humus content (8.52), neutral soil reaction (Tab. I). A neutralizing effect on soil pH had calcium carbonate found in upper soil layers as the result of calcium fertilization. The plant community resembled meadows of the type *Arrhenatheretum medioeuropaeum* (Kotowska, Okołowicz 1989). The sward was dominated by meadow species: *Dactylis glomerata, Festuca pratensis, Taraxacum officinale, Poa pratensis.*

Klembów. A regular, little fertile mown-grazed meadow (*Arrhenatheretum medioeuropaeum*), under a fairly unintensive use. The studied meadow was located south-west of Warsaw, near the Dębina forest reserve.

Station 6. Located on leached brown pseudo-gley soil, derived from boulder clay, sanded in the top layers and betraying traces of gleying in the soil profile. In the humus accumulation horizon A_1 soil had acid reaction, the content of humus in the accumulation layer is slight (Tab. I). The herb layer was evently dominated by high productive meadow species, such as: *Poa pratensis, Dactylis glomerata, Taraxacum officinalis, Festuca rubra,* and less regulary, by *Arrhenatheretum elatius.*

Białołęka Dworska. It is a regular, very fertile mown-grazed meadow (*Arrhenatheretum medioeuropaeum*) under not very intensive use. The studied meadow was located on the outskirts of Warsaw, 15 km north of the city center, on the same location as plot of the association *Tilio-Carpinetum* described above.

Station 7. Situated on typically brown soil developed from alluvial loam on loose sands, of slightly acid reaction ($pH = 5.6$) and with considerable amount of humus in the accumulation horizon A_1 (Tab. I). The sward was dominated by species characteristic of moist meadows, there also numerously occured shrubbery species

(*Anthrisus vulgaris, Solidago serotina, Cichorium inthybus*) as well as segetal and ruderal species (*Galinsoga parviflora, Agropyron repens, Cirsium arvense*).

Zbroszki. A several-year-old, not very fertile moist meadow under pasture use, set up in place of cleared orchard. The plant community developed there was dominated by darnel (*Lolium perenne*) and may be classified as the association *Lolio-Cynosuretum*. The studied meadow was located north of Warsaw, in the environs of Pułtusk.

Station 8. Spread on typical brown soil, formed from strong medium sands on light boulder clay, gleyed on the surface layers. The soil had a slightly acid reaction and minority humus content. The meadow sward was typical of newly set grassland. Species characteristic of moist meadow occured numerously (*Dactylis glomerata, Poa pratensis, Achillea millefolium, Poa trivialis, Trifolium repens, Festuca rubra, Lolium perenne*); perennial weeds as well as segetal species were inabundant.

2.3. Crop fields, orchard

Białołęka Dworska. Ploughland assigned for tomato cultivation. Alike the station 3 and 7 the studied site was located on the suburbs of Warsaw.

Station 9. Situated on typical anthropogenic arable soil (subtype: lessive soil), derived from alluvial loam on loose sands with pseudo-gleyed horizon. The plant community accompanying the targed cultivation were root crops weeds of the class *Chenopodietea*.

Belsk Mały n/Grójec. Ploughland under barley cultivation. Situated in the same environ as the Modrzewina reserve described above.

Station 10. Marked for anthropogenic arable soil (subtype: lessive soil) formed on silty sand and silt of fluvial origin, on bulder clay of neutral reaction and low humus content (Tab. I). The plant community accompanying the target cultivation were cereal crop weeds of the class *Secalietea*.

Belsk Mały n/Grójec. Apple-tree orchard. Located similarly as the ploughland and Modrzewina reserve described above.

Station 11. Characteristic of anthropogenic soil (subtype: leached brown soil formed on silty sand and silt fluvial origin on boulder clay, slightly acid, of a relatively low humus content (Tab. I). The habitat resembled monoculture crop fields, strongly polluted with insecticides widely used in orcharing. Apart from species characteristic of moist meadows of the class *Arrhenatheretea* and ruderal species of the class *Rudero-Scalietea*, also species characteristic of trampled places of the class *Plantaginetea maioris* in the herb layer.

2.4. Urban greens

One of the ways linden-oak-hornbeam forest habitats are managed on the Mazovian Lowland, is their transformation into urban greens areas. On the basis of phytosociological analysis of the studied lawns spreadings on habitats of potential linden-oak-hornbeam forest of poor series, the composition of vegetation of Warsaw green areas was found to resemble semi-natural meadow communities of the class *Molinio-Arrhenatheretalia*, including also trample-resistant species of the class *Plantaginetea maioris*, nitrophilic species of the class *Artemisietea* and – on much dried-up lawns – species of the class *Sedo-Scleranthetea*. The soil of Warsaw green areas is as strongly degraded as the accompanying plant communities. Due to man's activity natural soil was completly altered and nowadays mechanically transformed anthropogenic soil prevails, especially on the area of old parks. Lawns in the city center and housing estates are predominantly located on heaped up anthropogenic soils i.e. humus, weakly humus and rubble type (Dobrzański et al. 1977). These are soils whose profile was altered down to 1 m depth, much dried-up, poorly aerated, much suseptible to wind erosion and blowing as the result of intensive trampling, much polluted with organic waste materials, heavy metals (lead in particular), strongly alkalized in their surface layer, highly saline – especially in case of lawns adjoining streets – which, in effect, leads to formation of halomorphic soils.

Three types of urban greens were distingushed in Warsaw: park green areas, most often confined to mechanically transformed soils and, rarely, to heaped up soils; green areas in housing estates, which actually occur in the form of large, open lawns on heaped up, anthropogenic soils or small isolated lawns in the city center on heaped up, most often rubble soils; and, finally, lawns besides the street with most transformed habitat conditions.

The material from park greens was collected in Łazienki Park, the Cemetery-Mausoleum of Soviet Soldiers and in the Saxon Garden. The material from housing estate lawns was gathered in the district of Wierzbno of a scattered settelment type and in the city center, admist the closely built up settlement of the Marszałkowska Housing District (MDM). As to the street lawns, the material was sampled in street adjoining and road dividing lawns in the following places: Ujazdowskie Avenue, Żwirki i Wigury Avenue, Marszałkowska Street, Woronicza Street and Zbawiciela Square (Fig. 2.).

2.4.1. Park greens

Łazienki Park. It is an old park, established in the 18th century in place of a forest surrounding the Ujazdowski Palace. The soil presently found on the park area ranks among mechanically transformed soils classified by Dobrzański et al. (1975) as anthropogenic brown soils or anthropogenic black earth.

Station 12. A small lawn planted with oaks (*Quercus borealis*) and thujas (*Thuja occidentalis*), 50 m off a street, with poor sward resembling plant communities of the alliance *Cynosurion*, where also species characteristic of the class *Molinio-Arrhenatheretea* occured (*Poa pratensis, Festuca rubra, Plantago lanceolata*) as well as of *Plantaginetea maioris* (*Lolium perenne*). The soil had mechanical texture of very fine sandy soil, very-fine sandy loam, strong medium sand. Fairly high content of organic matter, slightly acid soil reaction, soil much polluted with heavy metals (Tab. I).

Station 13. Open, well-insolated lawn. The plants growing there ranked among species characteristic of the class *Molinio-Arrhenatheretea* (*Poa pratensis, Festuca*

FOREST | Tilio – Carpinetum | 4
MEADOW | Arrhenatheretum - medioeuropeum | 7
FIELD 9
URBAN GREENERY:
PARKS 12, 13, 14, 15, 16
HOUSING ESTATE 17, 18, 19
STREETS 20, 21, 22, 23, 24, 25

Fig. 2. Location of the examined sites on the area of Warsaw city; station numbers – see Table I, II.

rubra) and the alliance *Cynosurion* (*Trifolium repens*). The topsoil had mechanical texture of very fine sandy loam, sandy loam, strong medium sand. The soil was much dried-up, of neutral reaction, less polluted with haevy metals than at the station 12, with fairly large organic matter content.

Cemetery-Mausoleum of Soviet Soldiers. A park set up in 1949–1950 in place of crop fields. Its soils were classified as mechanically transformed anthropogenic soils (Czarnowska et al. 1976).

Station 14. A large lawn henced on one side with *Ulmus laevis* separating from the street, planted with individual trees of various species, leafy and coniferous bushes. The species composition of the herb layer vegetation resembled pasture association of the alliance *Cynosurion*. The topsoil had mechanically composition of very fine sandy soil; soil had a slightly acid reaction and was considerably polluted with heavy metals, with low content of organic matter (Tab. I).

Station 15. A large lawn, 150 m off the street. Planted with various species of leafy and coniferous trees. Species composition of the sward resembled plant associations of the alliance *Cynosurion*. Mechanical composition of the topsoil resembled very fine sandy soil, changing in to silty loam, soil moderatly humid, of a slightly acid reaction in the upper layers, of a low organic matter content and less polluted with heavy metals than the soil of the station 14 (Tab. I).

Saxon Garden. An old park set up in 1713, devasted during the II World War and recultivated after the war in 1949–1951. Due to its location in the city center and near one of the most heavily trafficked Warsaw streets (Marszałkowska Street), it is one of the most polluted parks in Warsaw. As a result of long-lasting effect of city agglomeration, the soil of the Saxon Garden had almost entirely lost its natural features. The prevailing was heaped up anthropogenic soil (Dobrzański et al. 1977).

Station 16. An open lawn located in the center of the park, poorly insolated. Sward vegetation resembled plant associations of the alliance *Cynosurion* and *Arrhenatherion elatoris*. Mechanical composition of the topsoil approximating very fine sandy loam. Soil very strongly contamined by heavy metals.

2.4.2. Housing estate lawns

Wierzbno housing estate. A modern housing estate, built in 1964–1969 with characteristic dispersed settlement. It was erected on after-crop ploughlands. Having been strongly mixed up with building refuse (stayed after the estate construction), the soil of present housing estate lawns, resembled heaped up, rubble soils found in the city center.

Station 17. A large (7 ha) lawn, much trampled, not planted with trees or shrubs, with species composition of sward resembling the alliance *Cynosurion* with inabundant species of the class *Plantaginetea maioris*. Mechanic texture of soil: very fine sandy soil, very fine medium sand, very fine sandy loam on coarse sand, little soil humidity, slight contamination by heavy metals, neutral reaction of soil, the content of organic matter characteristic of heaped up, humus urban soils (Tab. I).

Station 18. A small, 0.8 ha in area, orderly lawn, not trampled, surrounded with apartment houses, partly planted with various species of maple trees and with vegetation of the herbaceous layer resembling the composition of the alliance *Cynosurion*. Mechanical texture of the soil – very fine sandy loam with 5–10 cm layer of very fine sandy soil of neutral reaction, except for zinc, otherwise low polluted with heavy metals, relatively a high organic matter content (Tab. I).

Marszałkowska Housing Estate (MDM). A housing estate in the city center built in 1950–1952. Urban green found in the area was confined to small lawns, completely isolated from other urban greens.

Station 19. A small lawn on the yard, grown by sod only. The dominating in the herb layer was *Lolium perenne*, i.e. the species characteristic of plant associations of the class *Plantaginetea maioris*, typical of much trampled places, of poorly aerated soil. Mechanic texture of the upper soil layer – coarse sand with debris, relatively a low organic content, soil reaction: neutral changing to alkaline downwards the soil profile. Considerable pollution with heavy metals, zinc in particular (Tab. I).

2.4.3. Street lawns

All the stations in this type of green areas were located along the street or between the roadways; some were situated near large complexes of park greens or housing estates (the Ujazdowskie Avenue, Żwirki i Wigury Avenue, Marszałkowska Street, Woronicza Street) others were totally isolated (Zbawiciela Square). Soil was anthropogenic character while vegetation was dominated by groups of species of the class *Molinio-Arrhenatheretalia* (*Poa pratensis, Festuca rubra, Achillea millefolium, Trifolium recens*) and *Plantaginetea maioris* (*Lolium perenne*).

Station 20. Ujazdowskie Avenue. A narrow lawn (28 m in width) planted with young lindens, located on the brink of the Łazienki Park. Lack of detailed phytosociological data. Mechanical composition of the upper soil layer – sandy loam, neutral soil reaction, considerable contaminated by heavy metals, a large content of organic matter (Tab. I).

Station 21. Żwirki i Wigury Avenue. A street aligning lawn near the Cemetery-Mausoleum of Soviet Soldiers, with a row of lindens (*Tilia cordata*) in the center. Vegetation of the herb layer may be classified as the plant association of the alliance *Cynosurion* (Kubicka et al. 1986). Mechanical composition of the topsoil – strong medium sand on very fine sandy soil, low soil humidity, high content of $CaCO_3$, neutral soil reaction, high contamination by heavy metals, low content of organic matter.

Station 22. Żwirki i Wigury Avenue. A road dividing lawn located near the Cemetery-Mausoleum of Soviet Soldiers, with row of lindens (*Tilia cordata*) in the center, similary as in the station 21; the herb layer limited to the lawn outskirts, lack of detailed habitat data.

Station 23. Marszałkowska Street. A large, road-dividing lawn, situated opposite the Saxon Garden, established in 1948–1950, following the reconstraction of the Marszałkowska Street. The herb layer dominated by *Festuca rubra* and *F. ovina*. Mechanical texture of soil – strong medium sand on very fine light medium sand (mixed profile), neutral soil reaction, very low soil humidity, high pollution with heavy metals, high organic content (Tab. I).

Station 24. Woronicza Street. A street adjoining lawn on the outskirts of Wierzbno housing estate, planted with young lindens; no data on species composition of the herb layer. Mechanical composition of the soil – coarse sand, very fine medium sand on sandy loam, neutral soil reaction, high soil pollution with heavy metals, fairly high organic content (Tab. I).

Station 25. Zbawiciela Square. A road dividing lawn in the city center totally isolated from other green areas, split in two by tramway rails. The herb layer dominated by species of the class *Molinio-Arrhenatheretea* (*Poa pratensis, Achillea millefolium, Bellis perennis*). Mechanical composition of soil – coarse sand, strongly penetrated by grass roots, neutral soil reaction, rich in humus and biologically moderatly active.

The description of the research station surveyed above made use of several geobotanical studies, which, in turn, were based on detailed phytosociological analysis, arrangement plants of proper forest cultures and, in certain cases, on detailed soil analyses. The studies were completed in the Institute of Zoology PAS, while conducting research on urban fauna (Nowakowski 1981, Kubicka et al. 1986), moist meadow fauna (Kotowska, Okołowicz 1989), moist forest (Kotowska, Nowakowski 1989) and while carrying out complex ecological and faunistical research on the site of the prospective housing estate in Białołęka Dworska (Bańkowska, Garbarczyk 1981, Roo-Zielińska 1981, 1982, Konecka-Betley et al. 1982).

3. MATERIAL AND METHODS OF STUDIES ON *COLLEMBOLA* COMMUNITIES

The material was sampled in 1976–1984, amounting to a total of 2305 soil samples and 23447 identified *Collembola* specimens (Tab. II).

Table II. The year of studies, number of samples and the number of *Collembola* specimens collected in the examined linden-oak-hornbeam sites on the Mazovian Lowland

Type of linden-oak-hornbeam forest site			Locality	No of stations	Date of sampling	Number of samples	Number of individuals
1	2	3	4	5	6	7	8
I	Forest	*Tilio-Carpinetum*	Dębina	1	1980	60	1753
					1981	60	1200
					1984	36	764
			Modrzewina	2	1981	60	330
					1982	59	525
				3	1981	70	850
			Białołęka Dworska	4	1976	50	235

1	2	3	4	5	6	7	8
II	Meadow	*Arrhenatheretum medioeuropaeum*	Chylice	5	1982	69	1084
					1983	99	1718
			Klembów	6	1980	49	795
					1981	70	930
			Białołęka Dworska	7	1980	70	1801
		Lolio-Cynosuretum	Zbroszki	8	1983	40	189
					1984	60	1460
III	Ploughlands		Białołęka Dworska	9	1980	70	850
			Belsk Mały n/Grójec	10	1981	69	212
	Apple-tree orchard			11	1981	69	520
					1982	40	231
					1983	20	148
IV	Urban greenery	Parks	Łazienki	12	1976	40	221
					1977	46	236
				13	1976	40	302
					1977	49	403
			Cemetery of Soviet Soldiers	14	1978	68	553
				15	1978	69	508
			Saxon Garden	16	1976	50	337
					1977	51	341
		Green of housing estate	Wierzbno	17	1976	50	81
					1977	56	317
				18	1976	44	79
					1977	51	258
			MDM	19	1976	50	248
					1977	44	378
		Streetside green	Ujazdowskie Avenue	20	1976	50	64
					1977	44	171
			Żwirki i Wigury Avenue	21	1978	66	571
				22	1978	50	845
			Marszałkowska Street	23	1976	49	120
					1977	63	300
			Woronicza Street	24	1976	49	147
					1977	37	331
			Zbawiciela Square	25	1978	69	1041
					Total	2305	23447

At every station samples were taken monthly by quantitative method since April till October, with the use of a split corer of 5.1 cm in diameter. The samples were taken to 10 cm in depth and were subsequently extracted in a Tullgren's apparatus for 3 days and preserved in 96% ethyl alcohol. Each series numbered 10 samples of joint area of 200 cm ^{2}.

3.1. Biocoenological indicator

The characteristic of *Collembola* communities took into account the biocoenological indicators:

a) abundance index A – mean monthly density in thousand individuals/m^2 (i. e. the sum of densities from particular samples was divided by the number of samples taken at a given site);

b) dominance index D – percentage ratio of abundance of a given species to the total abundance of a given community in a sampling series. According to the dominance index D the following classes were distinguished:

eudominants	> 10%
dominants	5.1–10%
subdominants	2.1– 5%
recedents	1.1– 2.0%
subrecedents	≤ 1%

c) species constancy C – the index was applied according to Tischler (1949) as a percentage ratio of the number of examined stations in which a given species was recorded to the total number of examined stations in a given habitat. The values of the constancy index C fell into the following categories:

absolutely constant species	75.1–100%
constant species	50.1– 75.0%
accessorial species	25.1– 50.0%
accidental species	< 25.0%

d) species diversity indices – Shannon and Weaver's species diversity index (1963)

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad \text{where } p_i = \frac{n_i}{N}$$

n_i = abundance of i-th species, N = total community abundance, s = number of species in the studied community. This is one of the most commonly used species diversity indices, assuming values in the interval 1; ∞.

– Pielou's evenness index

$$E = \frac{H'}{\log_2 s}$$

The index reflects community dominance structure, where $\log_2 s$ evaluates the maximal value of the H' index. The index assumes values in the interval 0; 1, the maximal value being recorded in case when all the community species are equally abundant.

– SIMPSON's species diversity index (1949)

$$M = \frac{1}{\sum_{i=1}^{s} \left(\frac{n_i}{N}\right)^2}$$

The index evaluates diversity of the group of species dominating in the community thus complementing the SHANNON-WEAVER's species diversity index (H'). Alike H' the index assumes values in the interval 0; ∞.

– the index $2^{H'}$ (acc. to RUSEK 1984a)

This is the exponential function of the SHANNON-WEAVER's index (H'). The index assumes values in the interval 1; ∞ and takes into account rare species. The advantage of $2^{H'}$ index is its compatibility to the SIMPSON's (M) and SHANNON-WEAVER's (H') indices.

3.2. Ecological classification of species

Ecological analysis of *Collembola* communities was carried out with regard to ecological plasticity and habitat selectivity considering humidity and certain soil layers. The criteria for distinguishing subsequent elements within the range of ecological plasticity were adopted according to suggestions put forward by CZECHOWSKI and MIKOŁAJCZYK (1981). Each of the two aspects was examined by means of analysis which was carried out in two variants: faunistic (percentage contribution of species representing the element under studies) and quantitative (abundance index in relation to percentage contribution of species representing the element under studies). The classification of *Collembola* species according to criteria of ecological plasticity and an account of habitat preferences of particular species were based on data coming from works by STACH (1947–1963, 1964), STERZYŃSKA (1981a, b, 1982, 1987), SZEPTYCKI (1967), WEINER (1976, 1981) and KACZMAREK (1963, 1973, 1977).

3.3. Numerical methods of community classification and ordination

Analyses which employed numerical methods (SNEATH, SOKAL 1973, GAUCH 1982, GREIG-SMITH 1983) were carried out at Biological Data Processing Center in Ceske Budejovice (Budweis), under the direction of Mr J. LEPŠA, PhD. The use was made of biological programs in Fortran language worked out by MACCUNE (1987), while estimate operations were made on IBM 370 computer.

3.3.1. The classification by clustering

Faunistic qualitative similarity. The similarity matrix (distance between particular groups) were estimated after the formula similar to the SÖRENSEN's one, i.e.

$$S = 1 - \frac{2w}{A\,B} \qquad \text{where}$$

A – the number of species in A community, B – the number of species in B community, w – the number of common species. The basis for grouping was the farthest neighbour clustering method.

Coenotic (quantitative) similarity. The similarity matrix (the distance between particular groups) was estimated on the basis of calculations of EUCLIDEAN distance:

$$E.D. = \sqrt{\sum_{i=1}^{s} \quad (x_i - y_i)^2} \qquad \text{where}$$

x_i = density of i-th species in x community, y_i = density of i species in y community, s = total number of species. The basis for grouping was WARD's method (hierarchic grouping).

3.3.2. Ordination

Technique based on reciprocal and simultaneous ordering of samples and species in three-dimensional space (HILL 1973), estimated after Detrended Correspondence Analysis DCA (HILL, GAUCH 1980), which is a transformed version of DECORANA program (HILL 1979).

3.3.3. Two-way indicator species analysis

Hierarchic ordering of the analyzed species group by means of dichotomic division of subsequently distinguishing groups of species, counted with the help of TWINSPAN classifying program (HILL 1979). The division of the studied group of species at the first level is made on the basis of a former data ordering by DCA ordination method. On the basis of the two employed scales, i.e. faunistic (qualitative) and coenotic (quantitative), the estimates were used in plotting two dendrograms. In each of these two there were marked the diagnostic ("indicatory") species appearing at successive levels of dichotomic division.

4. MATERIAL ANALYSIS

4.1. *Collembola* communities in natural soils of linden-oak-hornbeam forests (*Tilio-Carpinetum*)

4.1.1. Species composition

A total of 61 species of *Collembola* was reported from the studied linden-oak-hornbeam forests, including two species new to the fauna of Poland: *Folsomia lawrancei* and *Onychiurus naglitschi*.

Table III. Communities of *Collembola* in natural soil of linden-oak-hornbeam (*Tilio-Carpinetum*) on the Mazovian Lowland; *A* – mean monthly density in thous. ind./m^2, *D* – species dominance (%), the sign denotes density (*A*) values less than 0.005 thous. ind./m^2 and dominance (*D*) below 0.5%, S.D. – standard deviation

No	Type of linden-oak-hornbeam forest site	Forest							
	Phytosociological association	*Tilio-Carpinetum typicum*							
	Soil	weakly leached brown soil		lessive soil				brown soil	
	Locality	Dębina		Modrzewina				Białołęka Dworska	
	No of station	I–1		I–2		I–3		I–4	
	Indices	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*
1	2	3	4	5	6	7	8	9	10
1	*Folsomia quadrioculata* (TULLB.)	4.33 ±3.550	35.9	1.16 ±0.951	31.9	2.22±1.178	36.5	0.55±0.507	23.4
2	*Onychiurus armatus* (TULLB.)	0.61 ±0.745	5.1	0.21 ±0.305	5.8	0.81±0.298	13.3	0.22±0.123	9.4
3	*Isotoma notabilis* SCHÄFF.	0.81 ±0.787	6.7	0.26 ±0.257	7.4	1.00±0.606	16.4	0.05±0.055	2.1
4	*Lepidocyrtus lanuginosus* (GMEL.)	<0.005±0.007	<0.05	0.01 ±0.014	0.1	0.05±0.055	0.8	0.67±0.726	28.6
5	*Mesaphorura macrochaeta* RUSEK	1.27 ±1.604	10.6	0.24 ±0.361	6.7	0.06±0.049	0.9	0.01±0.020	0.4
6	*Friesea mirabilis* (TULLB.)	0.88 ±0.874	7.3	0.03 ±0.052	0.7	0.06±0.087	1.1	0.01±0.020	0.4
7	*Pseudosinella zygophora* (SCHILLE)	0.24 ±0.299	2.0	0.07 ±0.235	1.9	0.15±0.116	2.5	0.06±0.097	2.6
8	*Isotomiella minor* (SCHÄFF.)	1.99 ±2.399	16.6	0.95 ±0.972	26.2	1.16±0.794	19.2	– –	–
–	*Entomobryidae* spp. j.	0.29 ±0.611	2.4	0.03 ±0.069	0.9	– –	–	0.51±0.206	21.7
9	*Lepidocyrtus lignorum* (FABR.)	0.17 ±0.272	1.4	0.20 ±0.420	5.4	– –	–	0.02±0.040	0.9
10	*Pogonognathellus flavescens* (TULLB.)	0.03 ±0.050	0.2	0.23 ±0.252	6.3	0.06±0.042	0.9	– –	–
11	*Sminthurinus aureus* (LUBB.)	0.32 ±1.117	2.7	0.04 ±0.079	1.0	0.03±0.070	0.5	– –	–
12	*Onychiurus affinis* ÅGREN	0.13 ±0.300	1.1	0.01 ±0.022	0.3	0.15±0.146	2.5	– –	–
13	*Pseudosinella alba* (PACK.)	– –	–	0.01 ±0.019	0.2	0.01±0.017	0.1	0.04±0.080	1.7
14	*Stenaphorura quadrispina* BÖRN.	– –	–	0.01 ±0.030	0.3	0.04±0.086	0.7	0.03±0.060	1.3
15	*Orchesella flavescens* (BOURL.)	0.04 ±0.089	0.3	0.02 ±0.037	0.5	0.06±0.069	1.1	– –	–
16	*Proisotoma minima* (ABS.)	0.01 ±0.028	0.1	0.02 ±0.055	0.5	0.04±0.105	0.7	– –	–
17	*Mesaphorura hylophila* RUSEK	0.05 ±0.099	0.4	0.01 ±0.014	0.1	0.02±0.036	0.4	– –	–
18	*Mesaphorura critica* ELLIS	0.01 ±0.032	0.1	0.01 ±0.020	0.2	0.02±0.052	0.4	– –	–
19	*Metaphorura affinis* (BÖRN.)	0.04 ±0.103	0.4	– –	–	– –	–	0.05±0.077	2.1
20	*Entomobryides myrmecophilus* (REUT.)	– –	–	0.02 ±0.055	0.5	– –	–	0.04±0.037	1.7

Tab. III – cont.

1	2	3	4	5	6	7	8	9	10
21	*Folsomia fimetaria* (L.)	0.02 ±0.036	0.2	– –	–	– –	–	0.01±0.020	0.4
22	*Ceratophysella succinea* (Gisin)	0.20 ±0.282	1.6	0.02 ±0.077	0.6	– –	–	– –	–
23	*Megalothorax minimus* Will.	0.20 ±0.374	1.6	0.02 ±0.037	0.5	– –	–	– –	–
–	*Sminthuridae* spp. j.	0.11 ±0.100	0.9	– –	–	0.03±0.045	0.5	– –	–
24	*Mesaphorura krausbaueri* Börn.	0.01 ±0.045	0.1	– –	–	0.02±0.052	0.4	– –	–
25	*Neelus murinus* Fols.	0.01 ±0.005	0.1	0.01 ±0.022	0.4	– –	–	– –	–
26	*Lipothrix lubbocki* (Tullb.)	0.01 ±0.028	0.1	0.01 ±0.028	0.2	– –	–	– –	–
27	*Willemia intermedia* Mills	0.01 ±0.018	0.1	0.01 ±0.028	0.2	– –	–	– –	–
–	*Hypogastrura* sp.	<0.005±0.013	<0.05	0.01 ±0.019	0.2	– –	–	– –	–
28	*Sphaeridia pumilis* (Krausb.)	<0.005±0.013	<0.05	– –	–	0.01±0.035	0.2	– –	–
29	*Mesaphorura sylvatica* (Rusek)	<0.005±0.007	<0.05	0.01 ±0.028	0.2	– –	–	– –	–
30	*Proisotoma minuta* (Tullb.)	– –	–	0.01 ±0.028	0.2	0.01±0.017	0.1	– –	–
31	*Stenacidia violacea* (Reut.)	<0.005±0.013	<0.05	0.01 ±0.014	0.1	– –	–	– –	–
32	*Isotoma viridis* Bourl.	– –	–	– –	–	– –	–	0.03±0.024	1.3
33	*Isotoma hiemalis* Schött.	0.07 ±0.137	0.6	– –	–	– –	–	– –	–
34	*Isotoma tigrina* Tullb.	0.02 ±0.056	0.2	– –	–	– –	–	– –	–
35	*Ceratophysella denticulata* (Bagn.)	– –	–	– –	–	0.02±0.070	0.5	– –	–
36	*Mesaphorura yossi* (Rusek)	– –	–	– –	–	0.01±0.035	0.2	– –	–
37	*Lepidocyrtus cyaneus* Tullb.	– –	–	– –	–	– –	–	0.01±0.020	0.4
38	*Heteromurus nitidus* (Templ.)	– –	–	– –	–	– –	–	0.01±0.020	0.4
39	*Willowsia buski* (Lubb.)	– –	–	– –	–	– –	–	0.01±0.020	0.4
40	*Brachystomella parvula* (Schäff.)	– –	–	– –	–	– –	–	0.01±0.020	0.4
41	*Entomobrya quinquelineata* Börn.	– –	–	– –	–	– –	–	0.01±0.020	0.4
42	*Orchesella spectabilis* Tullb.	0.02 ±0.041	0.1	– –	–	– –	–	– –	–
43	*Neanura muscorum* (Templ.)	0.01 ±0.030	0.1	– –	–	– –	–	– –	–
–	*Karlstejnia* group *"norvegica"*	0.01 ±0.023	0.1	– –	–	– –	–	– –	–
44	*Onychiurus naglitschi* Gisin	0.01 ±0.028	0.1	– –	–	– –	–	– –	–
45	*Arrhopalites caecus* (Tullb.)	0.01 ±0.028	0.1	– –	–	– –	–	– –	–
46	*Onychiurus pseudovanderdrifti* Gisin	0.01 ±0.023	0.1	– –	–	– –	–	– –	–
47	*Willemia aspinata* Stach	0.01 ±0.015	0.1	– –	–	– –	–	– –	–
48	*Allacma fusca* (L.)	0.01 ±0.026	0.1	– –	–	– –	–	– –	–
49	*Sminthurinus niger* (Lubb.)	0.01 ±0.026	0.1	– –	–	– –	–	– –	–

50	*Microanurida pygmaea* BÖRN.	0.01	±0.017	0.1	–	–	–	–	–	–	–	–	–
51	*Isotomurus palustris* (MÜLL.)	–	–	–	0.01	±0.014	0.1	–	–	–	–	–	–
52	*Entomobrya corticalis* (NIC.)	–	–	–	0.01	±0.014	0.1	–	–	–	–	–	–
–	*Tomoceridae* spp. j.	–	–	–	–	–	–		±0.017	0.1	–	–	–
53	*Folsomides parvulus* STACH	<0.005	±0.013	<0.05	–	–	–	–	–	–	–	–	–
54	*Sminthurus wahlgreni* STACH	<0.005	±0.013	<0.05	–	–	–	–	–	–	–	–	–
55	*Lepidocyrtus ruber* SCHÖTT.	<0.005	±0.013	<0.05	–	–	–	–	–	–	–	–	–
56	*Anurida granulata* AGRELL	<0.005	±0.013	<0.05	–	–	–	–	–	–	–	–	–
–	*Hypogastruridae* spp. j.	<0.005	±0.013	<0.05	–	–	–	–	–	–	–	–	–
57	*Mesaphorura tenuisensillata* RUSEK	<0.005	±0.007	<0.05	–	–	–	–	–	–	–	–	–
58	*Folsomia lawrancei* RUSEK	<0.005	±0.007	<0.05	–	–	–	–	–	–	–	–	–
–	*Onychiurus* group *"campatus"*	<0.005	±0.007	<0.05	–	–	–	–	–	–	–	–	–
59	*Cryptopygus bipunctatus* (AXELS.)	–	–	–	<0.005	±0.014	0.1	–	–	–	–	–	–
60	*Caprainea marginata* (SCHÖTT.)	–	–	–	<0.005	±0.014	0.1	–	–	–	–	–	–
61	*Isotomodes productus* (AXELS.)	–	–	–	<0.005	±0.014	0.1	–	–	–	–	–	–
	Total	11.97		100	3.68		100	6.05		100	2.35		100

The greatest number of species was recorded in the community of the Dębina reserve, while the lowest – in the community from the suburban forest in Białołęka Dworska (Tab. III). The communities of *Collembola* in linden-oak-hornbeam forests of the Mazovian Lowland were dominated mainly by eurytopic species of a wide ecological valence, such as: *Folsomia quadrioculata, Isotomiella minor, Onychiurus armatus, Isotoma notabilis, Lepidocyrtus lanuginosus* or *Mesaphorura macrochaeta*. The studied communities included several species preferring forest habitats, among others: *Onychiurus affinis, Orchesella flavescens, Lipothrix lubbocki, Neelus murinus, Mesaphorura sylvatica*, while the most common forest species, found in all the studied communities was *Pseudosinella zygophora*.

Collembola communities of the examined linden-oak-hornbeam forests notably differed in their species composition. The community of the Dębina reserve was marked for the occurrence of species which were not to be found in communities from the other studied plots of Mazovian linden-oak-hornbeam forests. There were only the following species recorded: *Isotoma hiemalis* – species often found on snow in winter, but also recorded in forest litter, *Isotoma tigrina* – the species often confused with *I. olivacea*, abundantly reported from Pieniny beech woods (Weiner 1981), *Orchesella spectabilis* – occurring on open areas in arid and sunny places, *Neanura nuscorum* – the species most often found under detached of tree bark but also in forest litter, *Onychiurus naglitschi* – an euedaphic species for the first time recorded in Poland, reported from alfalfa crops in Germany (Pallisa 1964), *Arrhopalites caecus* – a soil species found in soil of ploughlands and poor pastures, frequently found under flower pots and in caves, *Onychiurus pseudovanderdrifti* – an euedaphic species reported from various forest communities, *Willemia aspinata* – a forest species, though acc. to Szeptycki (1967) its occurrence depends on presence of conifer needles, which condition a peculiar chemism of litter, *Allacma fusca* – an atmobiotic species found in various forest habitats, *Sminthurinus niger* – an atmobiotic species found on trunks of various trees, *Micranurida pygmaea* – a species preferring forest communities with conifer litter, *Folsomia lawrancei* – the species reported by Rusek (1984b) in soil samples with *Luzuleto pilosae-Abietum* from forest brown soil with humus of the moder type (the species is likely to have been recorded in Poland under the name *Folsomia litsteri* (Bagnall 1939).

Collembola community of the Modrzewina reserve was marked for the occurrence of the following species recorded at the station 2: *Isotomurus palustris* – a hygrophilous, eurytopic species, *Cryptopygus bipunctatus* – a species preferring open areas rather, noted as a rare species (Szeptycki 1967), *Isotomodes productus* – a xerophilous species common in open areas, ploughlands in particular, *Caprainea marginata* – an atmobiotic forest species, *Entomobrya corticalis* – an under-bark species, commonly occurring under parts of detached bark on tree trunks, but also reported from soil samples; found at the station 3: *Mesaphorura yossi* – a small soil species, eurytopic, often co-occurring with *Mesaphorura macrochaeta* in deeper layers of soil profile (Rusek 1979).

The community of *Collembola* in the forest at Białołęka Dworska was characteristic primarily for the presence of meadow species, such as: *Brachystomella* *parvula, Isotoma viridis, Lepidocyrtus cyaneus* and *Entomobrya quenquelineata*, the latter being usually found in insolated places, grown with grass and low vegetation, but also for synanthropic species, such as *Heteromurus nitidus* or xerophilous and corticophilous *Willowsia buski*, which, most probably, only incidentally was found in soil samples.

Differences in species composition of the studied forest communities reflected micro-habitat conditions, a gradual anthropogenization of the examined linden-oak-hornbeam forest plots in particular. Only the community of the Dębina reserve was marked for the presence of forest species, which were not to be found in the other communities. The community of the Modrzewina reserve included fairly less species preferring forest habitats, yet more open – formation species, frequently xerophilous and photophilous, which resulted from a lower densities of the canopy layer and a better insolation of the studied linden-oak-hornbeam plots. Quite an outstanding species make-up was observed of the *Collembola* community in the linden-oak-hornbeam forest at Białołęka Dworska. The community comprised almost no forest species at an abundance of meadow and field species, i.e. elements alien to original wooded areas, and coming from adjacent areas under cultivation as fields or meadows, thus making up for the losses in the forest fauna receding under anthropogenic pressure.

In all the studied *Collembola* communities from linden-oak-hornbeam forests the group of absolutely constant species (acc. to TISCHLER's scale 1949) consisted of 7 species, the group of constant species – 11, the group of accessorial species – 13, and the group of accidental species – 31. The group of absolutely constant species was dominated by eurytopic species (*Folsomia quadrioculata, Onychiurus armatus, Isotoma notabilis, Lepidocyrtus lanuginosus, Mesaphorura macrochaeta, Friesea mirabilis*). The only absolutely constant species preferring forest habitats was *Pseudosinella zygophora*. Eurytopic species were also numerous in the group of absolutely constant species (*Isotomiella minor, Lepidocyrtus lignorum, Pogonognathellus flavescens, Proisotoma minima, Mesaphorura hylophila*), moreover this group included species bound to open areas, i.e. fields and meadows (*Stenaphorura quadrispina, Mesaphorura critica, Pseudosinella alba*) or photophilous species bound to herbaceous vegetation (*Sminthurinus aureus*). However, contrary to their preferred habitats, field or meadow species were very inabundant in the studied forest communities. Fairly numerous were forest species (*Onychiurus affinis, Orchesella flavescens*), although a majority of them accounted merely for accessorial or canstant species. Inabundant contribution of absolutely constant and constant species to the studied forest communities pointed to a little species similarity in the studied communities, which followed mainly from a definite distinctiveness of the community from the forest at Białołęka Dworska.

4.1.2. Abundance

Mean *Collembola* density in the studied linden-oak-hornbeam forests (*Tilio-Carpinetum*) of the Mazovian Lowland to 6.01 thous. ind./m^2. The most abundant was the *Collembola* community in soil of the Dębina reserve, i.e. 11.97 thous. ind./m^2,

Table IV. Biocoenological indices characterizing *Collembola* communities in natural soil of linden-oak-hornbeam forests (*Tilio-Carpinetum*) on the Mazovian Lowland; S – number of species, A – mean monthly density in thous. ind./m^2, H', E, M, $2^{H'}$ – indices of total species diversity

Locality	No of station	Biocoenological indices					
		S	A	H' (±S.D.)	E (±S.D.)	M (±S.D.)	$2^{H'}$ (±S.D.)
Dębina	I–1	44	11.97	1.766±0.3312	0.694±0.0958	4.464±1.6220	3.492±0.0808
Modrzewina	I–2	32	3.68	1.664±0.2365	0.711±0.0843	4.074±1.1489	3.212±0.5352
	I–3	22	6.05	1.555±0.2725	0.743±0.0597	3.659±0.8225	2.991±0.5571
Białołęka Dworska	I–4	19	2.35	1.559±0.2286	0.739±0.0768	3.442±0.6908	2.984±0.4700

while the least abundant – in the suburban forest at Białołęka Dworska, i.e. 2.35 thous. ind./m^2 (Tab. IV). Such pronounced differences in abundance of *Collembola* communities from the studied linden-oak-hornbeam forest habitats are likely to result from totally different habitat conditions and various rate of anthropogenization in particular. Evidently the optimal conditions for communities of *Collembola* were found in the Dębina reserve, specific for its brown soil, weakly leached with humus of the mull/moder type, of strongly acid reaction (pH 4.5), a thick layer of A_{OL} (4 cm), of a large thickness of the A_1 (11 cm) and well shaded owing to closed canopy layer. All these habitat parameters provided optimal conditions for development of relatively abundant and stabilized *Collembola* communities. The *Collembola* community of the Modrzewina reserve was almost two times less abundant than the one from the Dębina reserve. The studied patches of linden-oak-hornbeam forest in the Modrzewina reserve were located on lessive soil, marked for a smaller organic matter content than the leached brown soil at the station in the Dębina reserve. The type of a humus formed in the two examined linden-oak-hornbeam reserves was similar to that in a majority of deciduous forests, i.e. of either mull or mull/moder type, however, litter in the Modrzewina reserve contained a large admixture of larch needles. This caused a change in litter chemism as well as in the entire soil habitat and was likely to affect abundance of *Collembola* population. In the Modrzewina reserve two stations were examined, which due to considerable micro-habitat differences, were considered as distinct patches of linden-oak-hornbeam forest. Differences in habitat properties of these two patches provoked consequently, differences in abundance of their *Collembola* communities. Station 2 was located in a relatively arid linden-oak-hornbeam forest, spreading on lessive soil, with humus of the mull type, of strongly acid reaction, the poorest A_{OL} layer (3 cm) and the smallest thickness of the A_1 – horizon A_1 (9 cm). The station in question was noted for inabundance of *Collembola* community. Station 3 in the Modrzewina reserve was more humid than station 2, also spread on typical lessive soil, with humus of the mull/moder type, yet with a relatively thick layer of litter A_{OL} – (5 cm) and a considerable thinckness of the A_1 – horizon (10 cm), which, most likely was a direct reason of a more abundant population of *Collembola* recorded in the soil of this station. On the other hand the lowest abundance of *Collembola* communities in linden-oak-hornbeam forest at Białołęka Dworska was brought about by a strong degradation of this habitat caused by anthropogenic impact. Although the herb layer was dominated by forest species, anthropophytes were inabundant, soil was moderately humid (moist) and weakly acid with a moderate nitrogen content (Roo-Zielińska 1981), nonethelase the station was marked for a lesser microhabitat diversity as compared to the linden-oak-hornbeam forest stations elsewhere. Furthermore, the surrounding ploughlands and meadows had a very strong effect on the small area of this station.

4.1.3. Dominance structure and diversity of communities

In order to state dominance structure, the use was made of dominance index (Fig. 3). The greatest share of the dominating species was recorded at the community from a more humid plot of typical linden-oak-hornbeam forest in the Modrzewina reserve (station 3), i.e. 36.5%, while the least (28.6%) – at the community from the suburban forest at Białołęka Dworska. At a majority of the examined forest stations *Folsomia quadrioculata* dominated, while the most frequent co-dominating species was *Isotomiella minor*. Only at Białołęka Dworska the community was dominated by *Lepidocyrtus lanuginosus* while *Folsomia quadrioculata* was the co-dominating species. The contribution of subrecedents to the examined forest communities ranged from 47% to 75%; it was the lowest in the much anthropogenized plot of linden-oak-hornbeam forest at Białołęka Dworska, and the greatest - at the station 2 in the Modrzewina reserve and in the Dębina reserve (Fig. 3). A considerable contribution of inabundant species attested to a properly developed dominance structure in communities of the two forest reserves, while their low share in the community at Białołęka Dworska indicated certain intercommunity disturbances under anthropogenic impact.

The communities from the reserves were marked for a small number of species occurring with a high dominance value and a large number of species of a low dominance value. The community from the forest at Białołęka Dworska was featured by a small number of species of a low dominance index value. The analysis of eveness of dominating species distribution in the studied forest communities revealed that differences in percentage contribution of the first two dominating species were high in the communities from the Dębina reserve (19.3%) and from the Modrzewina reserve station 3 (17.3%), but low in the community from the station 2 at the Modrzewina reserve (5.7%) and from the forest at Białołęka Dworska (5.2%).

Species diversity indices. The greatest values of species diversity index were recorded for the *Collembola* community at the Dębina reserve, while the lowest – for the community in the linden-oak-hornbeam forest at Białołęka Dworska (Tab. IV). Furthermore, the community of the Dębina reserve was also marked for the lowest value of Pielou's species eveness index (E) of all the linden-oak-hornbeam forest communities. The estimated low value of the E index indicated that specimen distribution of species making up the community at the Dębina reserve was

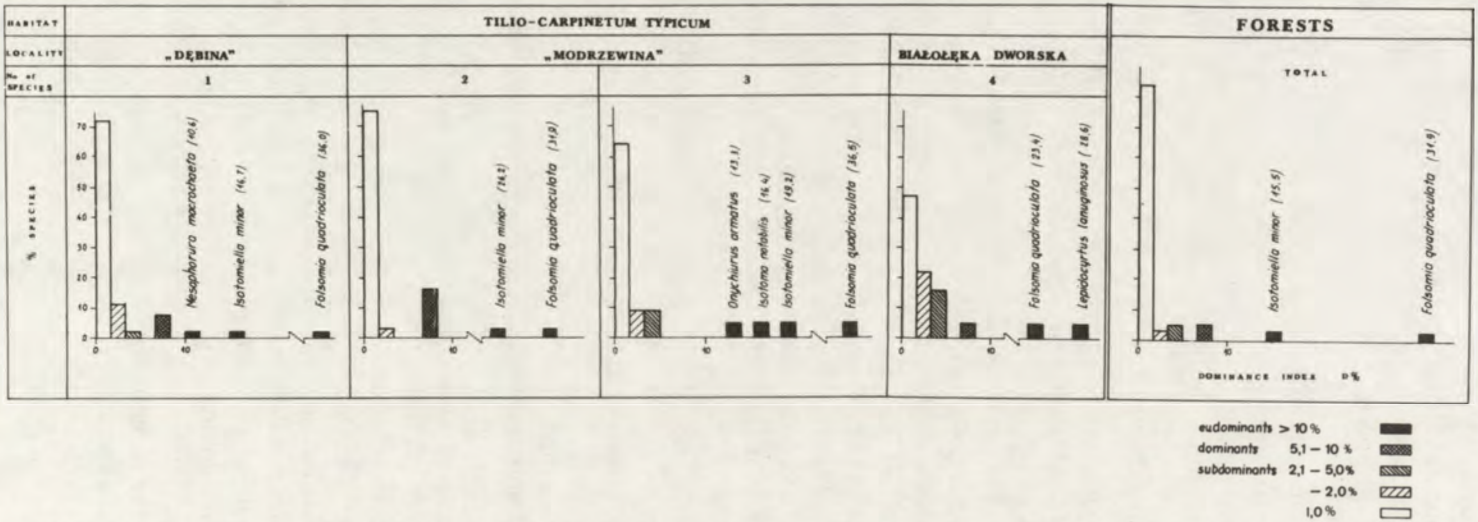

Fig. 3. Dominance structure of *Collembola* communities in natural soil of linden–oak–hornbeam forests (*Tilio–Carpinetum*) on the Mazovian Lowland; station numbers – see Table I, II.

unequeal. Marked differences in abundance of particular species composing this community, and, primarily, differences in abundance of the first and second dominant, were main reasons of low values of SHANNON-WEAVER's index, although the community in question had the greatest number of species and abundance. The analyzed species diversity indices reached values similar to those estimated for the Dębina community also for the community from the station 2 at the Modrzewina reserve. However, the latter was marked for a greater eveness of the dominance structure, i.e. for lower disproportions in relative shares of particular species, the dominating ones in particular. Definitely the lower values of species diversity indices were calculated for community at Białołęka Dworska and from the station 3 at the Modrzewina reserve. Low values of species diversity indices were caused by decrease diversity of the subrecedent species group. The species eveness index *E* indicated that spatial distribution of specimens from the species making up these communities was equal and, consequently, differences in shares of particular species were not as sharp as, e.g. in communities from the Dębina or Modrzewina reserve (station 2).

4.1.4. Ecological classification of species

Soil layer preferences

Forest communities of *Collembola* were dominated by euedaphic species dwelling to deeper layers of the soil profile (Tab. V). However, the share of soil species in the community from the forest at Białołęka Dworska was almost twice as low as in the other studied communities. A relatively low contribution of euedaphic species to *Collembola* community at Białołęka Dworska was likely to result from an intensive effect of anthropogenic factors, which had changed micro-habitat conditions of this station and its humidity and aeration in particular. Another numerous group of species recorded at communities from the studied forest soil were hemiedaphic species penetrating the litter layer A_{OL} and the ground of soil.

The share of this species was the largest in the community at Białołęka Dworska, and the lowest – in the community at the Dębina reserve, however in case of the hemiedaphone included very inabundant species, while in case of the latter – very abundant ones. The contribution of atmobiotic species, estimated on the basis of the number of species, was similar in all the examined forest communities. Obviously, occurrence of atmobiotic species in the studied communities was only incidental, as the employed sampling method aimed at collecting soil and soil-litter species. A significant group in the studied communities was made up by epigeic species of the genera *Tomocerus* NICOLET, *Orchesella* TEMPLETON, *Isotoma* BOURLET or *Hypogastrura* BOURLET, occurring in litter and on the soil surface, their share in all the studied communities being alike.

Similar tendencies were observed while analyzing abundance of species composing the distinguished community elements. Only the share of hemiedaphic species, estimated on the basis of species abundance was markedly different. The contribution of specimens of hemiedaphic species was the greatest to the communities at those forest stations where the litter layer A_{OL} was thick (the Dębina, Modrzewina reserves). At the same time these communities were noted for a considerably lower share of specimens representing epigeic species, for in natural linden-oak-hornbeam forests, contrary to the forest at Białołęka Dworska, ground cover of herbaceus plants (undergrowth) was qualitatively rich, yet of low dense vegetation due to shadiness of the forest interior.

Moisture preferences

In all the forest communities of *Collembola*, mesophilous species prevailed, their dominance being even greater while considering specimen abundance (Tab. V). The share of xerophilous and hygrophilous element was slight. A noteworthy fact, however, was a two times greater and, specimen abundance considered, almost eight times greater share of xerophilous element in the community at Białołęka Dworska as compared to other forest communities; at the same time contribution of hygrophilous species to this community was generally lower as compared to *Collembola* communities of the Dębina and Modrzewina reserves (station 2). The number as well as abundance of xero- and hygrophilous species in the studied forest communities reflected moisture requirements in the studied soils; in the forest reserves soils were moderately humid whereas at the station in Białołęka Dworska the soil was more dried up.

Ecological plasticity

The greatest share in *Collembola* communities from the studied linden-oak-hornbeam forests had eurytopic (ubiquitous) species, accounting from 31.8% in the Dębina reserve to 59.1% in the moist variant in the Modrzewina reserve (Tab. V). The most abundant species of this group were *Folsomia quadrioculata* and *Isotomiella minor*. The species were always frequent in various types of forest communities in Central Europe (Szeptycki 1967) and they are likely to have originated in these habitats. Apart from eurytopic species, *Collembola* communities were dominated by forest species. Quite exceptional in this respect was the community at Białołęka Dworska, where eurytopic species co-dominated with open area species, the contribution of forest species being very little. This attests to a strong degradation of the studied plot of linden-oak-hornbeam forest at Białołęka Dworska. Although species connected with open areas were recorded in other forest communities, yet they were relatively inabundant.

The order of the distinguished elements of ecological plasticity followed quite a different pattern while considering specimen abundance – in forest communities the dominating were the specimens of eurytopic species, while the contribution of forest species was low and amounted, on the whole, to 5%; open area species were even poorer in specimens, accounting hardly for 2%. Only in the community at Białołęka Dworska the share of open area species was relatively high, accounting for almost 9.7% of the whole community, while forest species made up barely 3.3%. Moreover a greater contribution of myrmecophilous and compost species to the community at

Table V. Percentage contribution of chosen ecological groups to *Collembola* communities in natural soil of linden-oak-hornbeam forests (*Tilio-Carpinetum*) on the Mazovian Lowland; *S* – number of species, *n* – abundance in thous. ind./m^2

Habitat			*Tilio-Carpinetum*																Forest			
Locality			Dębina				Modrzewina								Białołęka Dworska							
No of station			I–1				I–2				I–3				I–4							
Ecological groups			*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%
I	Layer preferences	atmobiotic	6	13.6	0.09	0.8	3	9.4	0.03	0.8	1	4.5	0.06	1.0	1	5.3	0.01	0.5	8	13.1	0.05	0.8
		epigeic	9	20.5	0.81	7.0	7	21.9	0.52	14.3	4	18.2	0.16	2.7	5	26.3	0.74	40.3	14	40.3	0.56	9.7
		hemiedafic	4	9.1	6.23	54.0	6	18.7	1.55	42.6	6	27.3	3.45	57.4	6	31.6	0.72	39.1	8	13.1	2.99	51.9
		euedaphic	25	56.8	4.41	38.2	14	43.7	1.51	41.5	11	50.0	2.34	38.9	5	26.3	0.32	17.4	28	45.9	2.14	37.3
		others	0	0	0	0	2	6.3	0.03	0.8	0	0	0	0	2	10.5	0.05	2.7	3	4.9	0.02	0.3
II	Moisture requirements	xerophilous	8	18.2	0.29	2.5	6	18.8	0.06	1.6	2	9.1	0.03	0.5	5	26.3	0.15	8.1	16	26.2	0.13	2.3
		mesohygrophilous	27	61.3	11.20	97.0	21	65.6	3.53	97.0	19	86.4	5.97	99.3	13	68.4	1.68	91.3	34	55.7	5.59	97.2
		hygrophilous	5	11.4	0.03	0.3	4	12.5	0.04	1.1	1	4.5	0.01	0.2	1	5.3	0.01	0.6	7	11.5	0.03	0.4
		unknown	4	9.1	0.02	0.2	1	3.1	0.01	0.3	0	0	0	0	0	0	0.	0	4	6.6	0.01	0.1
III	Ecological plasticity	eurytopic	14	31.8	10.64	92.1	14	43.8	3.40	93.3	13	59.1	5.53	92.0	7	36.8	1.53	83.2	16	26.2	5.27	91.5
		forest polytopic	13	29.6	0.55	4.8	5	15.6	0.11	3.0	4	18.2	0.38	6.3	1	5.3	0.06	3.3	15	24.6	0.28	4.9
		forest oligotopic	3	6.8	0.02	0.2	2	6.3	0.02	0.6	0	0	0	0	0	0	0	0	3	4.9	0.01	0.2
		open area polytopic	6	13.6	0.08	0.7	4	12.5	0.03	0.8	4	18.2	0.09	1.5	6	31.5	0.17	9.2	12	19.7	0.09	1.6
		open area oligotopic	5	11.4	0.22	1.9	3	9.4	0.03	0.8	0	0 8	0	0	1	5.3	0.01	0.5	7	11.5	0.06	1.0
		myrmecophilous	0	0	0.	0	1	3.1	0.02	0.6	0	0	0.	0	1	5.3	0.04	2.2	1	1.6	0.02	0.3
		corticophilous	0	0	0	0	1	3.1	0.01	0.3	0	0	0	0	1	5.3	0.01	0.5	2	3.3	<0.01	0.1
		compost	1	2.3	0.02	0.2	1	3.1	0.01	0.3	1	4.5	0.01	0.2	2	10.5	0.02	1.1	3	4.9	0.02	0.3
		unknown	2	4.5	0.01	0.1	1	3.1	0.01	0.3	0	0	0	0	0	0	0.	0	2	3.3	<0.01	0.1

this site was observed. An increased abundance of myrmecophilous species in the *Collembola* community at Białołęka Dworska was resulted in a greater density of ants in this habitat as compared to homologuous natural habitats of linden-oak-hornbeam forests as well as with a greater abundance of trophobiontic species, as, e.g. *Lassius flavus* Fabr. (Pisarski 1981).

4.2. *Collembola* communities in semi-natural soil of linden-oak-hornbeam meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosuretum*)

4.2.1. Species composition

In the studied meadow habitats, a total of 61 *Collembola* species was recorded, including one species new to the fauna of Poland – *Isotomodes armatus*. Apparently the greatest number of species was reported from the intensively used mown-grazed meadow at Chylice (40 species), while the lowest number – from the unintensively used mown-grazed meadow at Klembów (29 species) (Tab. VI).

In the soil of Mazovian linden-oak-hornbeam meadows common eurytopic (ubiquitous) species dominated in *Collembola* communities, such as: *Folsomia quadrioculata, Isotoma notabilis, Isotomiella minor, Onychiurus armatus, Mesaphorura macrochaeta,* as well as meadow species: *Isotoma viridis, Metaphorura affinis, Mesaphorura critica.* Obviously, forest species were not numerous there, their presence in the studied communities shows former history of the habitat. *Collembola* are a very conservative group, especially their euedaphic species (Dunger 1975, Rusek 1979) and they may remain in transformed habitats for over 100 years (acc. to Rusek unpublished information). The forest species which occurred in the studied meadow communities were, among others, *Onychiurus granulosus, Ceratophysella denticulata, Neanura muscorum, Caprainea marginata, Pseudosinella zygophora, Orchesella flavescens, Pseudachorutes parvulus, Folsomia lawrancei, Mesaphorura sylvatica.*

The studied meadow communities of *Collembola* differed not only in their number of species but also in their species composition. In the soil of fertile, intensively used meadow at Chylice (station 5), only the following species were recorded to occur: *Isotomodes armatus* – a soil species occurring in open areas (Naglitsch 1962, Da Gama 1963), not reported from Poland so far, *Sminthurinus niger* – an atmobiotic species, living in the vicinity of human settlements or in flower pot soil (Stach 1964), also found under bark and on tree trunks (Szeptycki 1967), *Ceratophysella succinea* – an epigeic species, most likely a xerophilous one, prefering open areas, numerously found in *Collembola* communities on lucerne crops (Trojanowski, Szeptycki 1985); *Proisotoma minima* – an eurytopic species, noted by Stach (1964) as a rare, yet widely distributed species; *Pogonognathellus flavescens* – a common species preferring moist habitats, singly recorded in soil samples (Weiner 1981). The mown-grazed meadow at Klembów, adjacent to a large forest reserve Dębina and surrounded with wooded and bushy areas on two other sides, was marked for the presence in its *Collembola* community of *Neanura muscorum*

Table VI. *Collembola* communities in semi-natural soil of linden-oak-hornbeam meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosurietum*) on the Mazovian Lowland; *A* – mean monthly density in thous. ind./m², *D* – species dominance (%); the sign denotes density (*A*) values less than 0.001 thous. ind./m² and dominance (*D*) below 0.1%

No	Type of linden-oak-hornbeam forest site	Meadow							
	Phytosociological association	*Arrhenatheretum medioeuropaeum*						*Lolio-Cynosuretum*	
	Soil	typical meadow black earth		leached brown pseudogley soil		brown soil			
	Locality	Chylice		Klembów		Białołęka Dworska		Zbroszki	
	No of station	II–5		II–6		II–7		II–8	
	Indices	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*
1	2	3	4	5	6	7	8	9	10
1	*Folsomia quadrioculata* (TULLB.)	3.36±3.735	40.4	0.03±0.048	0.3	3.21±2.364	24.8	0.18±0.429	2.7
2	*Mesaphorura macrochaeta* RUSEK	0.60±0.887	7.3	0.23±0.239	3.1	0.39±0.449	3.0	1.46±1.351	22.3
3	*Isotoma notabilis* SCHÄFF.	0.38±0.414	4.7	1.74±2.110	23.8	0.51±0.603	4.0	0.17±0.131	2.5
4	*Isotomiella minor* (SCHÄFF.)	0.13±0.306	1.6	2.10±2.276	28.8	0.01±0.035	0.1	0.11±0.106	1.6
5	*Isotoma viridis* BOURL.	0.94±1.135	11.3	0.26±0.243	3.6	0.48±0.579	3.7	0.65±0.900	10.0
6	*Onychiurus armatus* (TULLB.)	0.16±0.123	1.9	0.36±0.715	4.9	1.90±1.231	14.7	0.40±0.332	6.0
7	*Lepidocyrtus lignorum* (FABR.)	0.54±0.325	6.6	0.64±1.358	8.8	0.72±0.907	5.5	0.18±0.211	2.8
–	*Sminthuridae* spp. j.	0.08±0.244	0.9	0.21±0.558	2.9	1.66±3.813	12.9	0.04±0.087	0.5
8	*Mesaphorura critica* ELLIS	0.17±0.272	2.0	0.02±0.034	0.2	0.14±0.291	1.1	0.84±1.142	12.7
9	*Lepidocyrtus cyaneus* TULLB.	0.37±0.349	4.4	0.04±0.124	0.6	0.12±0.202	0.9	0.40±0.250	6.0
10	*Mesaphorura krausbaueri* BÖRN.	0.03±0.049	0.4	0.06±0.140	0.8	0.09±0.115	0.7	0.41±0.428	6.3
11	*Friesea mirabilis* (TULLB.)	0.30±0.506	3.6	0.06±0.154	0.8	0.04±0.032	0.3	0.05±0.104	0.8
12	*Entomobryides myrmecophilus* (REUT.)	0.07±0.101	0.8	0.24±0.377	3.3	0.04±0.052	0.3	0.01±0.018	0.2
13	*Stenaphorura quadrispina* BÖRN.	0.02±0.060	0.3	<0.01±0.014	0.1	0.16±0.225	1.3	0.13±0.165	2.0
14	*Arrhopalites caecus* (TULLB.)	0.02±0.029	0.2	0.01±0.031	0.2	0.01±0.018	0.1	<0.01±0.009	0.1
15	*Metaphorura affinis* (BÖRN.)	0.01±0.035	0.1	– –	–	2.14±3.258	16.7	0.01±0.018	0.1
16	*Sphaeridia pumilis* (KRAUSB.)	0.01±0.037	0.1	0.43±0.929	6.0	– –	–	0.71±0.798	10.8
17	*Folsomia fimetaria* (L.)	0.34±0.340	4.0	0.10±0.175	1.3	0.59±0.713	4.5	– –	–
18	*Isotomodes productus* (AXELS.)	– –	–	0.02±0.032	0.3	0.31±0.482	2.7	0.31±0.433	4.7
19	*Mesaphorura hylophila* RUSEK	– –	–	0.08±0.180	1.0	0.06±0.049	0.4	0.09±0.115	1.4

Tab. VI – cont.

1	2	3	4	5	6	7	8	9	10
20	*Cryptopygus bipunctatus* (AXELS.)	0.06±0.165	0.7	<0.01±0.014	0.1	0.04±0.069	0.3	– –	–
21	*Sminthurinus elegans* (FITCH)	0.02±0.071	0.2	<0.01±0.014	0.1	– –	–	0.05±0.122	0.8
22	*Megalothorax minimus* WILL.	0.02±0.073	0.3	0.03±0.069	0.3	– –	–	<0.01±0.009	0.1
23	*Bourletiella hortensis* (FITCH)	<0.01±0.012	<0.1	<0.01±0.014	0.1	– –	–	0.02±0.029	0.3
24	*Sminthurus viridis* (L.)	0.01±0.026	0.1	– –	–	0.01±0.018	0.1	0.01±0.018	0.1
25	*Willemia intermedia* MILLS	– –	–	<0.01±0.014	0.1	0.01±0.018	0.1	<0.01±0.009	0.1
26	*Isotomurus palustris* (MÜLL.)	0.01±0.024	0.1	0.39±0.411	5.3	– –	–	– –	–
27	*Sminthurinus aureus* (LUBB.)	0.04±0.152	0.5	– –	–	– –	–	0.15±0.171	2.3
28	*Lepidocyrtus ruber* SCHÖTT.	<0.01±0.012	<0.1	0.19±0.201	2.5	– –	–	– –	–
29	*Brachystomella parvula* (SCHÄFF.)	0.10±0.206	1.2	– –	–	0.01±0.083	0.1	– –	–
30	*Proisotoma minuta* (TULLB.)	0.04±0.176	0.5	0.02±0.056	0.3	– –	–	– –	–
31	*Pseudosinella alba* (PACK.)	– –	–	– –	–	0.01±0.018	0.1	0.05±0.077	0.8
32	*Heteromurus nitidus* (TEMPL.)	<0.01±0.012	<0.1	– –	–	– –	–	0.03±0.033	0.4
33	*Pseudosinella immaculata* (LIE PETT.)	0.01±0.035	0.1	– –	–	0.01±0.023	0.1	– –	–
34	*Metaphorura bipartita* (HANDSCH.)	<0.01±0.012	<0.1	– –	–	– –	–	0.01±0.018	0.2
35	*Onychiurus naglitschi* GISIN	– –	–	– –	–	0.01±0.018	0.1	0.01±0.018	0.1
36	*Lepidocyrtus curvicollis* BOURL.	<0.01±0.012	<0.1	<0.01±0.014	0.1	– –	–	– –	–
37	*Onychiurus granulosus* STACH	– –	–	<0.01±0.014	0.1	0.01±0.018	0.1	– –	–
38	*Hypogastrura vernalis* (CARL)	– –	–	– –	–	0.01±0.018	0.1	<0.01±0.009	0.1
–	*Entomobryidae* spp. j.	– –	–	<0.01±0.014	0.1	0.04±0.042	0.3	– –	–
39	*Isotomodes armatus* NAGLITSCH	0.28±0.668	3.5	– –	–	– –	–	– –	–
40	*Entomobrya multifasciata* (TULLB.)	0.12±0.482	1.4	– –	–	– –	–	– –	–
41	*Ceratophysella denticulata* (BAGN.)	0.02±0.042	0.2	– –	–	– –	–	– –	–
42	*Cryptopygus thermophilus* (AXELS.)	– –	–	– –	–	– –	–	0.02±0.044	0.3
43	*Sminthurus flaviceps* TULLB.	– –	–	– –	–	0.29±0.045	0.2	– –	–
44	*Lepidocyrtus paradoxus* UZEL	– –	–	– –	–	0.02±0.052	0.2	– –	–
45	*Mesaphorura yossi* (RUSEK)	– –	–	– –	–	– –	–	0.01±0.026	0.2
46	*Cyphoderus albinus* NIC.	– –	–	– –	–	– –	–	0.02±0.025	0.3
47	*Proisotoma minima* (ABS.)	0.01±0.048	0.2	– –	–	– –	–	– –	–
48	*Sminthurinus niger* (LUBB.)	0.01±0.024	0.1	– –	–	– –	–	– –	–
49	*Mesaphorura sylvatica* (RUSEK)	– –	–	– –	–	– –	–	0.01±0.018	0.1
50	*Neanura muscorum* (TEMPL.)	– –	–	0.01±0.019	0.1	– –	–	– –	–

51	*Caprainea marginata* (Schött.)	– –	–	– –	–	0.01 ± 0.035	0.1	– –	–
52	*Entomobrya nivalis* (L.)	– –	–	– –	–	0.01 ± 0.018	0.1	– –	–
53	*Pseudosinella zygophora* (Schille)	– –	–	– –	–	– –	–	0.01 ± 0.018	0.1
54	*Ceratophysella succinea* (Gisin)	$<0.01 \pm 0.012$	<0.1	– –	–	– –	–	– –	–
55	*Pogonognathellus flavescens* (Tullb.)	$<0.01 \pm 0.012$	<0.1	– –	–	– –	–	– –	–
56	*Orchesella flavescens* (Bourl.)	– –	–	– –	–	0.01 ± 0.018	0.1	– –	–
57	*Pseudachorutes parvulus* Börn.	– –	–	– –	–	0.01 ± 0.018	0.1	– –	–
58	*Orchesella spectabilis* Tullb.	– –	–	– –	–	0.01 ± 0.018	0.1	– –	–
59	*Folsomides parvulus* Stach	– –	–	– –	–	– –	–	$<0.01 \pm 0.009$	0.1
60	*Karlstejnia annae* Rusek	$<0.01 \pm 0.012$	<0.1	– –	–	– –	–	– –	–
61	*Folsomia lawrancei* Rusek	$<0.01 \pm 0.012$	<0.1	– –	–	– –	–	– –	–
–	*Karlstejnia* group *"norwegica"*	– –	–	– –	–	– –	–	$<0.01 \pm 0.009$	0.1
–	*Bourletiella* sp. j.	0.01 ± 0.024	0.1	– –	–	– –	–	– –	–
–	*Hypogastruridae* sp. j.	$<0.01 \pm 0.012$	<0.1	– –	–	– –	–	– –	–
	Total	8.33	100	7.31	100	13.10	100	6.57	100

– a species not recorded in the other studied meadow communities of *Collembola*. This sporadically found species prefers various types of forest communities rather (WEINER 1981), yet was also reported from meadows (SZEPTYCKI 1967). The community of the fertile meadow at Białołęka Dworska included exclusively the following species: *Sminthurus flaviceps* – an atmobiotic, xero- and thermophilous species (SZEPTYCKI 1967), most often found on moist meadows, yet also in forest litter (WEINER 1981), and *Lepidocyrtus paradoxus* – an atmobiotic species prefering open areas, *Caprainea marginata* – an atmobiotic species prefering forest communities, *Orchesella flavescens* – a species recorded both on meadow vegetation as well as in various forest and shrubbery associations, *Orchesella spectabilis* – a species ocurring in dry and insolated places on open areas, yet also found, very rarely, in soil samples, and *Entomobrya nivalis* – an eurytopic species, prefering, however, dried up habitats (WEINER 1981). Moreover, it was only the meadow at Białołęka Dworska where *Pseudachorutes parvulus* occured, a typical hemiedaphic species, most often found in forest litter.

In the *Collembola* community on the intensively grazed pasture at Zbroszki the following species occurred exclusively: *Cryptopygus thermophilus* – a humus species and a frequent element of synathropic fauna, *Mesaphorura yossi* – a soil species frequently co-dominating with *Mesaphorura macrochaeta* and populating deeper soil layers then (RUSEK 1979), *Cyphoderus albinus* – myrmecophilous species, *Mesaphorura sylvatica* – a species whose occurrence is limited to dry oak forests on rędzina-type soils, *Pseudosinella zygophora* – a species usually numerously found in forest litter and *Folsomides parvulus* – a species prefering dry, xerothermic habitats. The meadow at Zbroszki had been set up not long ago, in place of a cleared orchard. It spread in the habitat of linden-oak-hornbeam forest, as attested by the presence of an adjoining, well-developed mid-field of wooded area, grown with lindens, maples, oaks and ashtrees, with the herbaceous layer typical of linden-oak-hornbeam patches (KOTOWSKA, OKOŁOWICZ 1989). It affected the species composition of *Collembola* community on this meadow, which included numerous forest species.

In the studied communities of *Collembola* on the meadows of the type *Arrhenatheretum medioeuropaeum* and *Lolio-Cynosuretum*, the group of absolutely constant species (acc. to TISCHLER's scale – 1949) included 14 species, and the group of constant species – 10. The greatest share among the constant and absolutely constant species had eurytopes (*Folsomia quadrioculata, Isotoma notabilis, Mesaphorura macrochaeta, Isotomiella minor, Onychiurus armatus, Lepidocyrtus lignorum, Friesea mirabilis, Sphaeridia pumilis, Sminthurinus elegans*) as well as species characteristic of open fields and meadows (*Isotoma viridis, Mesaphorura critica, Lepidocyrtus cyaneus, Mesaphorura krausbaueri, Arrhopalites caecus, Stenaphorura quadrispina, Metaphorura affinis, Folsomia fimetaria, Isotomodes productus, Mesaphorura hylophila, Cryptopygus bipunctatus, Bourletella hortensis, Sminthurus viridis*). Fairly constant in *Collembola* communities of the studied meadows was *Entomobryides myrmecophilous*. A noteworthy fact is also a markedly constant occurrence in the studied meadow communities of *Cryptopygus bipunctatus* – a species very rarely reported from natural habitats both forest as well as meadow ones. The group of accessorial species comprised 13 species, while that of accidental ones – as many as 24 species. The numerous groups of constant and absolutely constant species in the studied meadow communities pointed to a great species similarity of their *Collembola* communities.

4.2.2. Abundance

Mean density of *Collembola* in soil of the studied meadows amounted to 8.83 thous. ind./m^2. The highest density was recorded in the soil of the very fertile, not intensively used meadow at Białołęka Dworska (13.20 thous. ind./m^2), while the least density – in the soil of little fertile meadow under pasture use at Zbroszki (6.57 thous. ind./m^2). While analyzing abundance of *Collembola* communities in soil of the studied meadows on the Mazovian Lowland it was found out that high densities of *Collembola* were recorded in fertile meadows and primarily in those with a large humus content, estimated as the content of organic matter in the humus accumulation horizon (A_1); high densities of *Collembola* were also noted to depend, to a less extent, on the manner and intensity of meadow utilization. The sites where the effect of these factors was most evident, were the meadows at Chylice and Białołęka Dworska (Tab. VII). The meadow at Chylice was markedly the most fertile of all the studied meadows, yet, at the same time, it was intensively used (fertilized with NPK, limed, mown), which, most probably, was a direct reason of a lower *Collembola* density estimated at this site. High abundance of *Collembola* community at Białołęka Dworska was caused not only by habitat fertility, yet also by a very large humus content in the humus accumulation horizon as well as the lack of regular agrotechnical practices. Furthermore, low abundance of *Collembola* communities was related to meadow habitats characteristic of their little fertility and marked for intensive processes of soil humus mineralization. The examples of such habitats were the meadow at Zbroszki and at Klembów. The meadow at Zbroszki was little fertile and marked for the lowest *Collembola* abundance. Such a low value of abundance index was caused by the least of all the studied sites humus content in the humus accumulation horizon A_1 as well by the fact that the meadow in question was relatively new, set up in place of a cleared apple-tree orchard. Greater lability of habitat conditions was, most likely, a direct reason of a decreased abundance of soil *Collembola* communities, as such places are noted for a vehement change in edaphic conditions due to greater changes in humidity of the upper soil layer, greater insolation, and an intensive leaching of nutrients, which, undoubtedly, affects the composition and abundance of *Collembola* communities. The meadow at Klembów was the least fertile, marked for an intensive process of nutrient leaching to the deeper layer of the soil profile, yet the content of organic matter in the mineral-humus horizon was greater than at the site in Zbroszki, which, most likely, brought about a greater abundance of *Collembola* community than at Zbroszki.

Table VII. Biocoenological indices characterizing *Collembola* communities in semi-natural soil of linden-oak-hornbeam meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosurietum*) on the Mazovian Lowland; S – number of species, A – mean monthly density in thous. ind./m^2, H', E, M, $2^{H'}$ – indices of total diversity

Locality	No of station	Biocoenological indices					
		S	A	H' (±S.D.)	E (±S.D.)	M (±S.D.)	$2^{H'}$ (±S.D.)
Chylice	II–5	40	8.33	1.773±0.4136	0.697±0.1418	4.568±1.9350	3.549±0.9167
Klembów	II–6	29	7.31	1.678±0.2920	0.721±0.0960	4.038±1.3749	3.265±0.6694
Białołęka Dworska	II–7	34	13.10	1.491±0.4696	0.552±0.1175	3.208±1.4200	2.950±0.8674
Zbroszki	II–8	35	6.57	1.995±0.3621	0.807±0.9425	5.882±2.0171	4.113±1.0229

4.2.3. Dominance structure and diversity of communities

In order to state dominance structure, the use was made of the dominance index (Fig. 4). The greatest contribution of the dominating species was noted to the community from the fertile, many-years' old, intensively used, mown-grazed meadow at Chylice (40.4%), where *Folsomia quadrioculata* dominated. *Folsomia quadrioculata* also dominated in the community from the fertile, rather unintensively used meadow at Białołęka Dworska, yet its contribution to the community there was almost twice as low as at Chylice (Fig. 4). The community from the meadow at Klembów was dominated by *Isotoma notabilis* (28.8%). The lowest value of the dominance index was estimated for the community from the pasture at Zbroszki, where *Mesaphorura macrochaeta* dominated (22.3%). The dominance of this small, typically soil species in the community from Zbroszki meadow seemed likely to be the effect of pronouncedly disturbed and non-stabilized habitat conditions which corne after the orchard clearing.

In the studied meadow communities the contribution of species whose dominance index was lower than 1.1% (the group of subrecedents) amounted to 58–68% and was the smallest in the community at Zbroszki and the highest – in the community from the meadow at Białołęka Dworska (Fig. 4).

In all the studied communities from the meadows there occurred few species with high dominance and numerous species with low dominance. The analysis of eveness of dominating species distribution in the studied communities showed that differences in percentage contribution of the first two dominating species were great in the communities from intensively used meadows (Chylice 29.1%), and were by far lower in soil of the remaining meadows, diminishing accordingly to a decreasing intensity of the meadow use (Zbroszki 9.6%, Białołęka Dworska 8.1%). The lowered difference (5.0%) was reckoned in the community from a fairly unintensively used meadow at Klembów. The dominance structure of *Collembola* communities from the studied meadows was pronouncedly affected by intensity of the meadow use.

Species diversity indices. The values of total species diversity index for *Collembola* communities in soil of the studied meadows were very differtifed

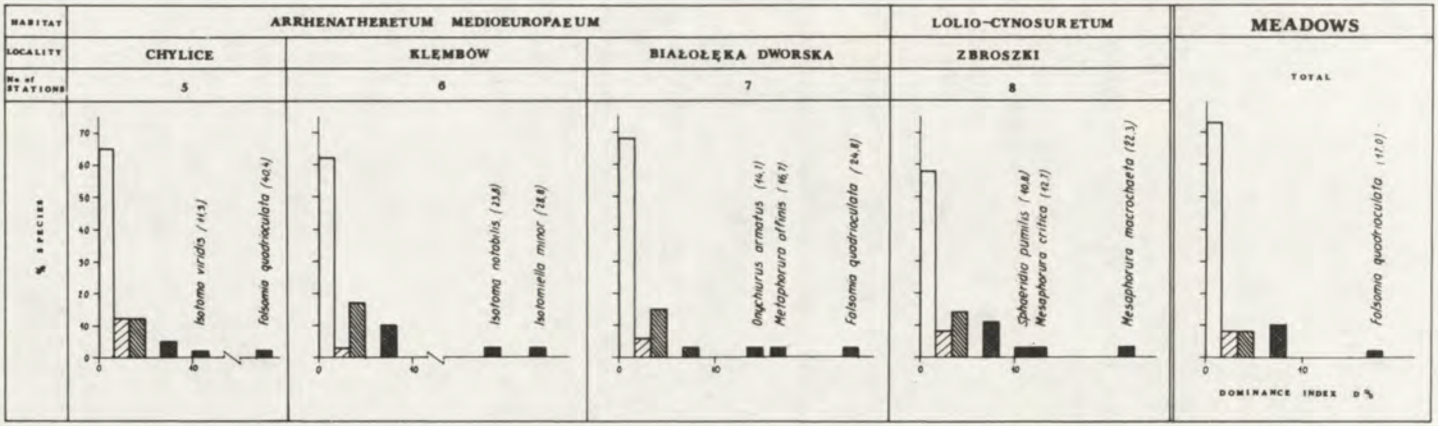

Fig. 4. Dominance structure of *Collembola* communities in semi-natural soil of linden–oak–hornbeam meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosurietum*) on the Mazovian Lowland; station numbers – see Table I, II.

(Tab. VII). The highest values of the SHANNON-WEAVER's index were estimated for the community from a many-years', low fertile meadow at Zbroszki, under pasture use, while the lowered values – for the community from a very fertile meadow at Białołęka Dworska.

The high value of the SHANNON-WEAVER's species diversity index for the community of *Collembola* from the pasture meadow at Zbroszki resulted from the fact that the many species oscillated around mean values of dominance and abundance indices. *Collembola* community at this site was marked for a relatively great number of species and the least abundance index, at the highest reduction in the contribution of the first dominant to the community. For this reason the value of PIELOU's index, reflecting eveness of specimen distribution within the species make-up of the community, was equally high. Furthermore, also diversity of the group of dominating and of the group of subreceding species, measured by the SIMPSON's and $2^{H'}$ index, were also the highest for this community. The community of Białołęka Dworska was noted for the lowest values of the SHANNON-WEAVER's and PIELOU's indices, due to great differences in density of particular species composing this community. The community was characteristic for a relatively highest abundance index, while its number of species was similar as in the community from the meadow at Zbroszki. Although the difference in contribution by the first and second dominant to the community was not high, yet the first two dominants accounted for over 41.5% of the whole community. Furthermore, the community was marked for a slight contribution of species from the group of recedents and subrecedents. The community from the intensively used meadow at Chylice was characteristic for a moderate value of the SHANNON-WEAVER's species diversity index, although it was one of the most abundant and rich in species *Collembola* communities in soil of the studied meadows. The reason for a low value of the SHANNON-WEAVER's index was a very strong dominance of *Folsomia quadrioculata*, which accounted for over 40% of the whole community, the difference between the contribution by the two first dominants amounting to 29.1%. Such a pronounced dominance of one species brought about also a decrease in the PIELOU's species eveness index value, notwithstanding a high differentiation of the groups of dominating species and subrecedents (Tab. VII). The community at Klembów was marked for a lower value of the SHANNON-WEAVER's species diversity index, as well as of the other indices, than the community from the meadow at Chylice. The community at Klembów included the lowest of all the studied meadow communities, number of species, and the specimen distribution among the occurring species was relatively equal (Tab. VII). The analyzed species diversity indices indicated that the community at Klembów included a more stabilized associations with species which did not attain very high values of the dominance index.

The pronounced differences in values of species diversity indices in communities from the studied meadows make it difficult to determine whether the difference should be attributed to habitat diversity (age, fertility, humidity, density and thickness of the sod layer) or to intensity of the applied agrotechnical procedures.

4.2.4. Ecological classification of species

Soil layer preferences

Meadow communities of *Collembola* were marked for the greatest share of euedaphic and epigeic species; only in the community from the meadow at Białołęka Dworska, atmobiotic species bound to herbaceous plants, occurred somewhat more numerously. The contribution of the group of hemiedaphic species was the highest to the communities from Zbroszki and Klembów (Tab. VIII).

Considering specimen abundance of particular species it was found out that the communities from the meadows at Klembów and Białołęka Dworska were dominated by species populating deeper layers of soil profile (euedaphic species) and by soil-litter dwellers (hemiedaphic species). The community from the pasture meadow at Zbroszki was also noted for the greatest share of specimens belonging to soil species, yet the co-dominating were epigeic species. On the other hand, the site at Chylice, marked for an advanced sodding process, had a community dominated by hemiedaphic and epigeic species. In all the meadow communities, specimens representing atmobiotic species were sporadically found, their mean contribution not exceeding 2%. Any assessment of the contribution of species bound to herbaceous layer (atmobios) should consider the fact that the employed sampling method was best fitted for soil and soil-litter species, hence the estimates of the number and abundance of species populating the herbaceous layer is rough and incomplete.

Moisture preferences

The communities of *Collembola* in soil of the studied meadows were dominated by mesophilous species, which accounted, on the average, for 55.7%, and by xerophilous species (32.8%), hygrophilous species having the least share (6.6%) (Tab. VII). The contribution of xerophilous species was the greatest to the community from the meadow at Białołęka Dworska. It was the only site, among the studied meadows, whose soil was free from any traces of gleying in the topsoil. The lowest contribution of the group of xerophilous species was marked for the community from the meadows at Klembów and Chylice. These sites had more favourable conditions for the occurrence of hygro- rather than xerophilous species, due to defective water conductivity causing slight pseudogley in the humus accumulation horizon and, consequently, increasing humidity of the topsoil. Hygrophilous species recorded in the communities of the studied meadows included: *Brachystomella parvula, Isotomurus palustris, Pogonognathellus flavescens, Sphaeridia pumilis* and *Lepidocyrtus ruber*.

While considering the specimen abundance of *Collembola* species, the prevalence of mesophilous element in the studied meadow communities was even greater, at a slight share of xerophilous species (11.9%) and almost two times slight contibution of hygrophilous species (5.5%). Out of all the studied communities from meadows, the one at Białołęka Dworska was marked for the greatest quantitative contribution of xerophilous species (25.3%). Abundance of hygrophilous species was the highest in the communities from the meadows at Klembów and Zbroszki.

Table VIII. Percentage contribution of chosen ecological groups to *Collembola* communities in semi-natural soil of linden-oak-hornbeam meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosurietum*) on the Mazovian Lowland; *S* – number of species, *n* – abundance in thous. ind./m^2

Habitat			*Arrhenatheretum medioeuropaeum*												*Lolio-Cynosuretum*				Meadow			
Locality			Chylice				Klembów				Białołęka Dworska				Zbroszki							
No of station			II–5				II–6				II–7				II–8							
Ecological groups			*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%
I	Layer preferences	atmobiotic	6	15.0	0.18	2.2	3	10.4	0.03	0.4	7	20.6	0.36	3.2	3	8.6	0.08	1.2	12	19.6	0.16	1.9
		epigeic	10	25.0	2.04	24.6	5	17.2	1.52	21.4	5	14.7	1.34	11.7	5	14.3	1.39	21.2	11	18.0	1.57	18.9
		hemiedaphic	5	12.5	4.09	49.4	5	17.2	1.86	26.1	4	11.8	3.77	33.1	7	20.0	0.51	7.8	9	14.8	2.56	30.7
		euedaphic	18	45.0	1.90	22.9	15	51.7	3.47	48.7	17	50.0	5.89	51.7	18	51.4	4.54	69.3	27	44.3	3.95	47.4
		others	1	2.5	0.07	0.9	1	3.5	0.24	3.4	1	2.9	0.04	0.3	2	5.7	0.03	0.5	2	3.3	0.10	1.1
II	Moisture requirements	xerophilous	10	25.0	0.32	3.9	7	24.1	0.30	4.2	11	32.3	2.88	25.3	10	28.6	0.46	7.0	20	32.8	0.99	11.9
		mesohygrophilous	25	62.5	7.55	91.2	18	62.1	5.80	81.5	20	58.8	8.49	74.4	22	62.9	5.37	82.0	34	55.7	6.80	81.6
		hygrophilous	4	10.0	0.13	1.5	3	10.3	1.01	14.2	1	3.0	0.01	0.1	1	2.8	0.71	10.8	4	6.6	0.47	5.5
		unknown	1	2.5	0.28	3.4	1	3.5	0.01	0.1	2	5.9	0.02	0.2	2	5.7	0.01	0.2	3	4.9	0.08	1.0
III	Ecological plasticity	eurytopic	15	37.5	5.60	67.6	12	41.3	6.10	85.7	10	29.4	7.13	62.6	13	37.1	3.57	54.4	19	31.2	5.60	67.2
		forest polytopic	2	5.0	0.03	0.4	2	6.9	0.02	0.3	4	11.9	0.04	0.3	1	2.9	0.01	0.2	8	13.1	0.03	0.3
		forest oligotopic	0	0	0	0	0	0	0	0	0	0	0	0	1	2.9	0.01	0.2	1	1.6	0.01	0.03
		open area polytopic	12	30.0	1.80	21.7	8	27.5	0.42	5.9	14	41.2	3.53	31.0	12	34.2	2.86	43.5	18	29.5	2.15	25.8
		open area oligotopic	7	17.5	0.39	4.7	3	10.4	0.21	2.9	3	8.8	0.06	0.5	4	11.4	0.03	0.5	9	14.8	0.17	2.1
		myrmecophilous	1	2.5	0.07	0.9	1	3.5	0.24	3.4	1	2.9	0.04	0.3	2	5.7	0.03	0.5	2	3.3	0.10	1.1
		corticophilous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		compost	3	7.5	0.39	4.7	2	6.9	0.12	1.7	1	2.9	0.59	5.2	1	2.9	0.03	0.5	3	4.9	0.28	3.4
		unknown	0	0	0	0	1	3.5	0.01	0.1	1	2.9	0.01	0.1	1	2.9	0.01	0.2	1	1.6	0.01	0.1

Ecological plasticity

The greatest share in *Collembola* communities from the studied linden-oak-hornbeam meadows had open area species, which accounted, on the average, for 44.3%, ranging from 37.5% in Chylice to 50.0% in Białołęka Dworska (Tab. VIII). Apart from open area species, the meadow communities of *Collembola* were dominated by eurytopic species, their contribution ranging from 29.4% in Białołęka Dworska to 41.3% in Klembów. Quite a low share had forest species – 14.7% on the average – the group being most numerously represented in the community from Białołęka Dworska (4 species). The contribution of compost species was the greatest to the community from the very intensely used meadow at Chylice.

With respect to abundance of *Collembola* species in the studied meadow communities, eurytopic species markedly dominated, accounting, on the average, for about 67.2%, while the share of open area species was almost two times lower and amounted to 27.9%. The contribution of forest species, estimated on quantitatives basis, was the highest to the community from the meadow at Klembów, located in the direct vicinity of a large forest complex (Dębina reserve). Compost and myrmecophilous species had a insignificant share among specimens of the studied meadow communities.

4.3. *Collembola* communities in anthropogenic soils of fields and orchards (cultivable crop soils)

4.3.1. Species composition

A total of 38 *Collembola* species was reported from the ploughland and apple-tree orchard soils (Tab. IX). The greatest number of species was noted in the community from a field on sandy, slightly gleyed soil at Białołęka Dworska (27 species), while the least (17 species) – in the community from a field located on a much heavier, not gleyed soil with low humus content in Belsk Mały n/Grójec.

Apart from eurytopic species such as *Isotoma notabilis, Mesaphorura macrochaeta* and *Onychiurus armatus*, the dominating in the studied agrocoenosis were the species prefering field crops, *Isotomodes productus, Cryptopygus thermophilous, Folsomia fimetaria*. Also the following compost species were more abundant: *Heteromurus nitidus, Hypogastrura assimilis, H. manubrialis* and *Proisotoma minuta*.

The community of *Collembola* from the field at Białołęka Dworska was distinguished by the presence of the following species: *Hypogastrura manubrialis* – a hemiedaphic species [regarded by Gisin (1943) as sinuzial for compost heaps and manure]; *Hypogastrura vernalis* – a species prefering dry meadows with alcalic soils; *Ceratophysella denticulata* – a species frequently found in forest habitats; *Proisotoma minuta* – a species common in humus layer and compost heaps; *Lepidocyrtus lignorum* – an eurytopic species; *Isotomiella minor* – a species very common in the studied forest soils and meadow soil on the Mazovian Lowland, yet only singly recorded from the field at Białołęka Dworska and absent in all the other communities of cultivable crop soils; *Sminthurides schöetti* – a hemiedaphic, bryophilous and hygrophilous species reported from drained meadows and re-

Table IX. *Collembola* communities in anthropogenic ploughland and orchard soil on the Mazovian Lowland; *A* – mean monthly density in thous. ind./m², *D* – species dominance (%), the sign denotes density (*A*) values less than 0.01 thous. ind./m²

No	Type of linden-oak-hornbeam forest site	Ploughlands				Apple-tree orchard	
	Phytosociological association	*Chenopodietea*		*Secalietea*		*Arrchenatheretea* *Rudero-Secalietea* *Plantaginetea maioris*	
	Soil	alluvial loam on loose sands		silty sand and silt of fluvial origin		silty sand and silt fluvial origin on boulder clay	
	Locality	Białołęka Dworska		Belsk Mały n/Grójec		Belsk Mały n/Grójec	
	No of station	III–9		III–10		III–11	
	Indices	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*
1	*Isotoma notabilis* Schäff.	0.15±0.214	2.5	0.62±0.963	40.7	0.60±0.765	17.1
2	*Onychiurus armatus* (Tullb.)	0.31±0.276	5.3	0.13±0.154	8.8	0.86±1.124	24.5
3	*Folsomia fimetaria* (L.)	1.19±1.171	19.7	0.07±0.116	4.7	0.27±0.292	7.8
4	*Cryptopygus thermophilus* (Axels.)	0.62±0.775	10.2	0.07±0.065	4.8	<0.01±0.013	0.1
5	*Mesaphorura krausbaueri* Börn.	0.06±0.094	0.9	0.10±0.167	6.6	0.12±0.153	3.5
6	*Ceratophysella succinea* (Gisin)	0.33±0.344	5.5	0.01±0.017	0.5	0.02±0.042	0.6
7	*Pseudosinella alba* (Pack.)	0.19±0.276	3.2	0.02±0.036	1.4	0.03±0.047	0.8
8	*Arrhopalites caecus* (Tullb.)	0.50±0.104	0.8	0.01±0.019	0.5	<0.01±0.013	0.1
9	*Isotomurus palustris* (Müll.)	– –	–	0.25±0.422	16.4	0.25±0.393	7.3
10	*Mesaphorura macrochaeta* Rusek	0.96±0.781	17.2	0.01±0.035	0.9	0.11±0.130	3.2
11	*Isotomodes productus* (Axels.)	1.27±1.623	20.9	– –	–	0.01±0.019	0.2
12	*Isotoma viridis* Bourl.	0.30±0.616	4.9	– –	–	0.53±0.605	15.3

13	*Mesaphorura critica* Ellis	0.05±0.089	0.8	– –	–	0.23±0.354	6.6
14	*Lepidocyrtus cyaneus* Tullb.	0.01±0.017	0.1	– –	–	0.19±0.220	5.6
15	*Mesaphorura hylophila* Rusek	0.01±0.023	0.2	– –	–	0.13±0.252	3.7
16	*Heteromurus nitidus* (Templ.)	– –	–	0.04±0.087	2.3	<0.01±0.013	0.1
17	*Folsomia quadrioculata* (Tullb.)	0.06±0.068	0.9	– –	–	0.01±0.040	0.3
18	*Willemia intermedia* Mills.	0.50±0.089	0.8	0.01±0.017	0.5	– –	–
–	*Sminthuridae* spp. j.	– –	–	0.01±0.035	0.9	0.01±0.027	0.2
19	*Megalothorax minimus* Will.	0.01±0.017	0.1	– –	–	0.01±0.040	0.3
20	*Hypogastrura assimilis* (Krausb.)	– –	–	0.09±0.170	5.8	– –	–
21	*Sminthurinus aureus* (Lubb.)	– –	–	0.06±0.140	3.7	– –	–
22	*Pseudosinella immaculata* (Lie Pett.)	0.18±0.340	2.9	– –	–	– –	–
23	*Stenaphorura quadrispina* Börn.	– –	–	– –	–	0.07±0.066	1.9
24	*Neotullbergia ramicuspis* (Gisin)	– –	–	0.01±0.017	0.5	– –	–
25	*Hypogastrura manubrialis* (Tullb.)	0.04±0.073	0.7	– –	–	– –	–
26	*Cyphoderus albinus* Nic.	0.03±0.070	0.5	– –	–	– –	–
27	*Entomobryides myrmecophilus* (Reut.)	– –	–	0.01±0.017	0.5	– –	–
28	*Friesea mirabilis* (Tullb.)	– –	–	0.01±0.017	0.5	– –	–
29	*Hypogastrura vernalis* (Carl)	0.02±0.036	0.4	– –	–	– –	–
–	*Bourletiella* sp. j.	0.02±0.052	0.4	– –	–	– –	–
30	*Onychiurus naglitschi* Gisin	– –	–	– –	–	0.02±0.023	0.4
31	*Ceratophysella denticulata* (Bagn.)	0.01±0.023	0.2	– –	–	– –	–
32	*Proisotoma minuta* (Tullb.)	0.01±0.035	0.2	– –	–	– –	–
33	*Lepidocyrtus lignorum* (Fabr.)	0.01±0.035	0.2	– –	–	– –	–
34	*Mesaphorura sylvatica* (Rusek)	– –	–	– –	–	0.01±0.018	0.2
–	*Anurida* sp.	0.01±0.023	0.2	– –	–	– –	–
35	*Metaphorura affinis* (Börn.)	0.01±0.017	0.1	– –	–	<0.01±0.013	0.1
36	*Isotomiella minor* (Schäff.)	0.01±0.017	0.1	– –	–	– –	–
37	*Sminthurides schoetti* (Axels.)	0.01±0.017	0.1	– –	–	– –	–
38	*Pseudosinella zygophora* (Schille)	– –	–	– –	–	<0.01±0.013	0.1
	Total	6.88	100	1.53	100	3.50	100

claimed swamps. The community of *Collembola* from the field at Belsk Mały n/Grójec was marked for the presence of the following species: *Hypogastrura assimilis* – a species most frequently found in compost heaps and in humus; *Sminthurinus aureus* – an eurytopic, atmobiotic species, *Neotullbergia ramicuspis* – an euedaphic species, not reported from Poland so far, found in viticultures (Gisin 1960); *Entomobryides myrmecophilus* – a myrmecophilous species; *Friesea mirabilis* – a common eurytopic species, one of few predatory species in the order *Collembola*. The community of *Collembola* from the apple-tree orchard in Belsk Mały n/Grójec was distinguished by the presence of such species as: *Pseudosinella zygophora* – a polytopic forest species; *Mesaphorura sylvatica* – a species described by Rusek (1979) in dry oak forests growing on rędzina-type soils, also reported from other studied sites in linden-oak-hornbeam habitats on the Mazovian Lowland (forests, meadows, park lawns); *Onychiurus naglitschi* – a species not reported from Poland so far, recorded in northern Germany (Palissa 1964) and *Stenaphorura quadrispina* – a sinuzial species for fertile meadows (Gisin 1943), also found in humus (Weiner 1981).

The group of absolutely constant species (acc. to Tischler's scale 1949) in the communities of *Collembola* in cultivable crop soil (of ploughlands and orchard) included only 6 species, the group of constant species – 12, the group of accessorial species – 18. The communities were characteristic for the lack of accidental species. The largest group among the constant and absolutely constant species was made up of species bound to open areas (*Folsomia fimetaria, Cryptopygus thermophilus, Mesaphorura krausbaueri, Ceratophysella succinea, Pseudosinella alba, Arrhopalites caecus, Isotomodes productus, Isotoma viridis, Mesaphorura critica, Lepidocyrtus cyaneus, Metaphorura affinis*) and eurytopic species (*Mesaphorura macrochaeta, Isotomurus palustris, Mesaphorura hylophila, Folsomia quadrioculata, Megalothorax minimus*). Fairly constant was also *Heteromurus nitidus* – a species distinctly bound to man-managed areas (found in humus soil in the vicinity of human settlements, in ploughland soil, on moist meadows) and *Willemia intermedia* – a species whose habitat preferences have not been determined yet.

4.3.2. Abundance

Mean density of *Collembola* in the studied crop field soil amounted to 3.97 thous. ind./m^2. The greatest density was recorded in the ploughland soil at Białołęka Dworska (which in its upper layer had a granulometric texture of weakly sand on gleyed alluvial loam), while the least density was estimated for the community from the field at Belsk Mały n/Grójec (with the upper soil layer being made up of fluvo-glacial sand or sand derived from surface wash-away of morraine loam with traces of periglacial weathering) (Tab. X). Most probably the reason for a greater abundance of *Collembola* community in the soil of the field at Białołęka Dworska was aeration of the upper soil layer due to the presence of weakly sand and a greater soil humidity caused by slight gleying of loamy particles.

Table X. Biocoenological indices characterizing *Collembola* communities in anthropogenic ploughland and orchard soil on the Mazovian Lowland; S – number of species, A – mean monthly density in thous. ind./m^2, H', E, M, $2^{H'}$ – indices of total species diversity

Locality	No of station	Biocoenological indices					
		S	A	H' (±S.D.)	E (±S.D.)	M (±S.D.)	$2^{H'}$ (±S.D.)
Białołęka Dworska	III–9	27	6.88	1.670±0.6296	0.775±0.1143	4.682±2.5597	3.469±1.3056
Belsk Mały n/Grójec	III–10	17	1.53	1.273±0.4818	0.753±0.1460	3.159±1.3823	2.544±0.7742
	III–11	23	3.50	1.669±0.2591	0.755±0.1048	4.294±1.5062	3.233±0.6010

Abundance of *Collembola* populations in the studied cultivable crop soils was limited by physico-chemical properties of soil and by the reduction of micro-habitats in the mineral-humus horizon caused by mixing of soil profile (in the effect of the employed agrotechnical practices) and by monoculture tilliage.

4.3.3. Dominance structure and diversity of communities

In the studied communities of *Collembola* the greatest dominant contribution was estimated for the community from the field at Belsk Mały, where *Isotoma notabilis* accounted for as much as 40.7% of the whole community, followed by the community from the apple-tree orchard at Belsk Mały (the dominating *Onychiurus armatus* contributed 24.5%); the least contribution of the first dominant was noted at the community from the field at Białołęka Dworska (the dominating *Isotomodes productus* accounted for 20.9%). An alike order was recorded while analyzing the contribution of the two first dominants in the studied communities from cultivated crop soils. The highest contribution of the two first dominants was recorded to the community from the field at Belsk Mały (57.1%), slightly lower – to the community from the apple-tree orchard (41.6%) and the least – to the community from the field at Białołęka Dworska (40.6%) (Fig. 5). The group of dominating species, comprising

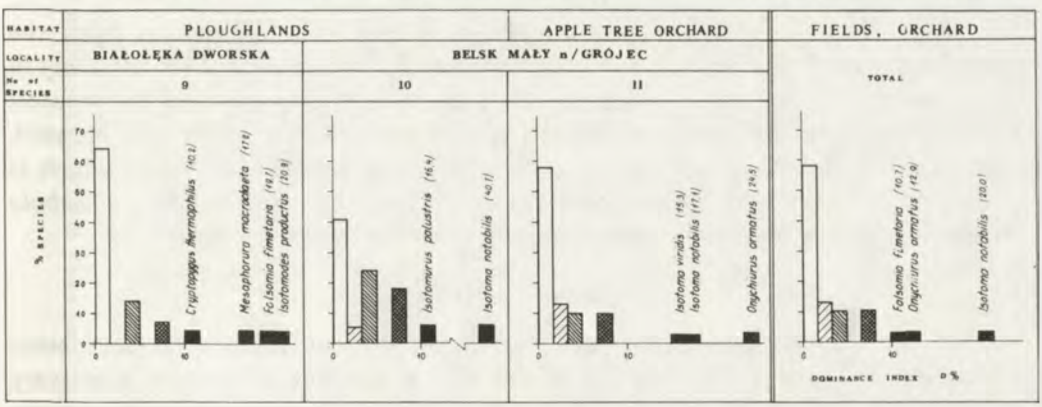

Fig. 5. Dominance structure of *Collembola* communities in anthropogenic ploughland and orchard soil on the Mazovian Lowland; station numbers – see Table I, II.

species of the dominance index exceeding 10%, was made up of totally different species at each site; also the number of species forming this group varied. Such a pronounced diversity of the dominating species group attests to a great unstability of *Collembola* communities and unstabilized habitat conditions in the studied sites.

The number of species of the dominance rate not exceeding 1.1% was much diversified in the field habitats, the group being represented by 41–64% of the species of the whole community. The lowest share of subreceding species was estimated for the community of *Collembola* in the field at Belsk Mały, while the greatest – for the community from the field at Białołęka Dworska.

All the communities of *Collembola* from crop cultivated soils were marked for a small number of species of a high dominance rate and not numerous species of a low dominance rate.

Species diversity indices. Indices of total diversity of *Collembola* communities in the studied crop field soils assumed relatively low values (Tab. X). The SHANNON-WEAVER's species diversity index (similarity as all the other species diversity indices) had the greatest value for the community from the field at Białołęka Dworska and for the community from the apple-tree orchard at Belsk Mały. The lowest value of the index in question (and of all the other indices of species diversity and species eveness) were estimated for the community from the field at Belsk Mały. Such a low value of this index followed from the fact that the contribution of dominating species was the greatest to this community (over 40%), while the difference in the percent contribution between the first and the second dominant was also the highest in this community (24.3%).

Values of species diversity indices of the studied communities from the cultivable crop field soils pointed to their strong unstability, the least stabilized being the community from the soil of the field at Belsk Mały.

4.3.4. Ecological classification of species

Soil layer preterences

The communities of *Collembola* from crop field soils as well as from the apple-tree orchard soil, were dominated by soil (euedaphic species) (Tab. XI). Only in the community from the field at Belsk Mały hemiedaphic species had the greatest quantitative share. Epigeic (litter-sward) species prefered the apple-tree orchard, which was characteristic for the presence of a well-developed sod layer, which is a refuge for epigeic and hemiedaphic fauna. None of all the studied *Collembola* communities from crop field soils included any atmobiotic species.

Moisture preferences

All the studied communities of *Collembola* in cultivable crop soils were dominated by mesophilous species (Tab. XI). Hygrophilous species were very inabundant, occuring in somewhat greater numbers only in the community from the field at Belsk Mały, where *Isotomurus palustris* was more numerously found.

Table XI. Percentage contribution of chosen ecological groups to *Collembola* communities in anthropogenic ploughland and orchard soil on the Mazovian Lowland; S – number of species, n – abundance in thous. ind./m^2

Habitat			Ploughlands								Apple-tree orchard				Ploughlands Orchard			
Locality			Białołęka Dworska				Belsk Mały n/Grójec											
No of station			III–9				III–10				III–11							
Ecological groups			S	%	n	%	S	%	n	%	S	%	n	%	S	%	n	%
I	Layer preferences	atmobiotic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		epigeic	7	25.9	0.69	10.1	3	17.6	0.32	21.1	4	17.4	0.99	28.1	9	23.7	0.67	16.8
		hemiedaphic	6	22.2	1.07	15.6	6	35.4	0.85	55.8	6	26.1	0.67	19.0	10	26.3	0.86	21.8
		euedafic	13	48.2	5.06	73.9	7	41.1	0.34	22.4	13	56.5	1.86	52.9	17	44.7	2.42	61.1
		others	1	3.7	0.03	0.4	1	5.9	0.01	0.7	0	0	0	0	2	5.3	0.01	0.3
II	Moisture requirements	xerophilous	7	25.9	2.35	34.3	5	29.4	0.06	3.9	5	21.7	0.08	2.3	9	23.7	0.83	20.9
		mesohygrophilous	18	66.7	3.99	58.3	10	58.8	1.20	78.9	16	69.5	3.17	90.1	25	65.7	2.78	70.3
		hygrophilous	1	3.7	0.01	0.1	1	5.9	0.25	16.5	1	4.4	0.25	7.1	2	5.3	0.17	4.3
		unknown	1	3.7	0.50	7.3	1	5.9	0.01	0.7	1	4.4	0.02	0.5	2	5.3	0.18	4.5
III	Ecological plasticity	eurytopic	8	29.7	1.52	22.2	6	35.4	1.08	71.0	7	30.3	1.97	56.0	11	28.9	1.53	38.4
		forest polytopic	1	3.7	0.01	0.1	0	0	0	0	1	4.4	0.01	0.3	2	5.3	0.01	0.2
		forest oligotopic	0	0	0	0	0	0	0	0	1	4.4	0.01	0.3	1	2.6	0.01	0.1
		open area polytopic	10	37.0	2.70	39.5	3	17.6	0.19	12.5	10	43.5	1.22	34.6	12	31.6	1.37	34.5
		open area oligotopic	3	11.1	0.85	12.4	3	17.6	0.03	2.0	2	8.7	0.03	0.9	4	10.5	0.30	7.7
		myrmecophilous	1	3.7	0.03	0.4	1	5.9	0.01	0.7	0	0	0	0	2	5.3	0.01	0.3
		corticophilous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		compost	3	11.1	1.24	18.1	3	17.6	0.20	13.1	2	8.7	0.28	7.9	5	13.2	0.57	14.5
		unknown	1	3.7	0.50	7.3	1	5.9	0.01	0.7	0	0	0	0	1	2.6	0.17	4.3

Ecological plasticity

The greatest share in *Collembola* communities from crop field soils had open area species and eurytopic species, the community at Białołęka Dworska being markedly dominated by open area species, while that at Belsk Mały (with respect to their abundance) – by eurytopes (Tab. XI). The community from the apple-tree orchard included the greatest number of open area species, yet with respect to abundance of particular species, eurytopic species dominated.

An interesting fact is survival (except for the field community at Belsk Mały) of scarce elements of forest fauna, although their contribution, both with respect to the number of species as well as to their abundance, to communities of *Collembola* was insignificant. The preserved elements of forest fauna included the following species: *Ceratophysella denticulata, Mesaphorura sylvatica* and *Pseudosinella zygophora*. In all the communities of *Collembola* from the crop field soils a notable share was contributed by compost species, i.e. *Heteromurus nitidus, Folsomia fimetaria, Hypogastrura assimilis, H. manubrialis, Proisotoma minuta* (the dominating being *Folsomia fimetaria*).

4.4. *Collembola* communities in anthropogenic soils of urban greens (urban soils)

4.4.1. Species composition

A total of 75 species of *Collembola* was recorded in urban greens of Warsaw. 57 species were reported from the studied parks, 46 species – from housing estate lawns and 55 species – from street lawns (Tabs XII–XIV). In the park greens, the greatest number of species was reported from the Łazienki Park, station 13 located in the park inside (37 species), while the lowest number of species (26) – also from the Łazienki Park, at the station 12 located on the park outskirts, in the vicinity of a street. In the housing estate lawns, both in loose settlement as well as in the city center in closely built up settlement, similar number of species were recorded (Tab. XIII). In the street lawns the greatest number of species was estimated in the street-adjoining lawn in Żwirki i Wigury Avenue and at the station in Woronicza Street, namely 32 species occurred there (Tab. XIV).

In the soil of the examined park lawns the most abundant were: *Isotoma viridis* – a species characteristic of open areas and *Isotoma notabilis* – an ubiquitous species. Fairly numerous were also such species as: *Cryptopygus bipunctatus, Onychiurus armatus, Sminthurinus aureus* and *Sphaeridia pumilis*. Parks are the only sites in urban greens where plytopis forest species occurred, namely, *Mesaphorura sylvatica* (Cemetery-Mausoleum of Soviet Soldiers) or *Orchesella cincta* (Łazienki Park) – the species common in natural habitats (forest ones in particular) in western Poland, and more often found in synathropic habitats in central Poland. Furthermore, it is only in parks where the following species occurred: *Sminthurinus niger* (Łazienki Park), *Entomobrya corticalis* (Łazienki Park, Cemetery-Mausoleum of Soviet Soldiers), *Cyphoderus bidenticulatus* – a myrmecophilous species found in Saxon Garden, not reported from Poland before, as well as the species prefering open habitats: *Orchesella bifasciata* (Łazienki Park, Cemetery-Mausoleum of Soviet Soldiers), *Bourletiella hortensis* (Cemetery-Mausoleum of Soviet Soldiers), *Lepidocyrtus paradoxus* (Saxson Garden – an atmobiotic species, likely to occur more abundantly in urban lawns), *Lepidocyrtus curvicollis* (Łazienki Park). Also in parks typical synanthropes were recorded to occur, namely, *Folsomia candida* (Łazienki Park) and *Seira domestica* (Cemetery-Mausoleum of Soviet Soldiers).

In housing estate lawns the most abundant were: *Isotoma notabilis* and *Sminthurinus aureus* eurytopes species. This type of green areas was also characteristic form abundance of open area polytopes, such as *Bourletiella arvalis, Isotomodes productus, Pseudosinella alba* or eurytopic *Sphaeridia pumilis*. Species whose occurrence was limited exclusively to housing estate lawns were very few; they included *Cryptopygus ponticus* and *Willemia aspinata*.

In the street lawns, similarly as in the types of urban greens discussed above, the prevailing was eurytopic *Isotoma notabilis*. Fairly abundant were also polytopes of open areas: *I. viridis, Cryptopygus bipunctatus* and eurytopic *Sminthurinus aureus*. The species exclusive for the studied street lawns included: *Entomobrya multifasciata* – a xero- and thermophilous oligotopic species of open areas, *Neotullbergia ramicuspis* – a species not reported from Poland before, found in the street-adjoining lawn in Woronicza Street and in an isolated, road dividing lawn at Zbawiciela Square; *Xenollodes ghiljarovi* – a species not reported from Poland so far, found in a street-aligning lawn in Woronicza Street, and in the isolated interline lawn at Zbawiciela Square, *Xenylla grisea* – a xerophilous species, frequently found in the vicinity of human settlements, found only in Żwirki i Wigury Avenue.

In parks the group of absolutely constant species comprised 20 species and the group of constant species – 7. Among the absolutely constant and constant species, the prevailing were *Collembola* prefering open – ground type of areas, meadows and fields (*Isotoma viridis, Lepidocyrtus cyaneus, Mesaphorura critica, Cryptopygus bipunctatus, Pseudosinella alba, Brachystomella parvula, Mesaphorura krausbaueri, Stenaphorura quadrispina, Mesaphorura hylophila*). Fairly constant were also eurytopic species (*Isotoma notabilis, Sminthurinus aureus, Onychiurus armatus, Sphaeridia pumilis, Lepidocyrtus lanuginosus, Isotomiella minor, Mesaphorura macrochaeta, Folsomia quadrioculata*) and myrmecophilous species (*Entomobryides myrmecophilus, Cyphoderus albinus*) as well as synanthropic *Pseudosinella immaculata*. The group of accessorial species was made up of 9 species ($C = 40\%$), while that of accidental species – of 21 ($C = 20\%$). An accidental element included a number of synathropic species (*Seira domestica, Sinella coeca* or *Folsomia candida*), most often found in apartments, in flower pot soil, but also in caves, as, e.g. *Sinella coeca* (Stach 1964).

Table XII. *Collembola* communities in anthropogenic urban soil of Warsaw (park lawns); *A* - mean
0.01 thous. ind./m² and

No	Type of linden-oak-hornbeam forest site			
	Phytosociological association			
	Soil	very-fine sandy soil, very-fine sandy loam, strong medium sand		
	Locality	Łazienki		
	No of station	IV–12		IV–
	Indices	*A* (±S.D.)	*D*	*A* (±S.D.)
1	2	3	4	5
1	*Isotoma viridis* BOURL.	0.13±0.144	5.1	0.15±0.197
2	*Isotoma notabilis* SCHÄFF.	0.31±0.261	11.8	0.43±0.404
–	*Sminthuridae* spp. j.	0.03±0.062	1.3	0.03±0.076
3	*Sminthurinus aureus* (LUBB.)	0.44±0.565	16.5	0.16±0.179
4	*Onychiurus armatus* (TULLB.)	0.05±0.062	2.0	0.41±0.510
5	*Sphaeridia pumilis* (KRAUSB.)	0.16±0.328	6.1	0.07±0.133
6	*Lepidocyrtus lanuginosus* (GMEL.)	0.35±0.695	13.4	0.43±1.190
7	*Isotomiella minor* (SCHÄFF.)	1.14±0.230	5.3	0.14±0.282
8	*Lepidocyrtus cyaneus* TULLB.	0.08±0.135	3.1	0.03±0.036
9	*Entomobryides myrmecophilus* (REUT.)	0.03±0.053	1.3	0.09±0.231
10	*Pseudosinella immaculata* (LIE PETT.)	0.02±0.036	0.7	0.05±0.148
11	*Mesaphorura critica* ELLIS	0.02±0.036	0.9	0.01±0.037
12	*Cryptopygus bipunctatus* (AXELS.)	0.39±0.855	14.6	0.83±1.033
13	*Pseudosinella alba* (PACK.)	0.07±0.800	2.7	0.03±0.060
14	*Mesaphorura macrochaeta* RUSEK	0.10±0.123	3.8	0.01±0.015
15	*Brachystomella parvula* (SCHÄFF.)	0.01±0.017	0.2	0.05±0.118
16	*Folsomia quadrioculata* (TULLB.)	0.01±0.016	0.2	0.13±0.201
17	*Mesaphorura krausbaueri* BÖRN.	0.07±0.113	2.5	0.02±0.060
18	*Cyphoderus albinus* NIC.	0.01±0.031	0.4	0.04±0.047
19	*Stenaphorura quadrispina* BÖRN.	– –	–	0.01±0.021
20	*Mesaphorura hylophila* RUSEK	0.02±0.028	0.9	0.01±0.023
21	*Isotomodes productus* (AXELS.)	0.08±0.178	3.2	0.14±0.139
22	*Isotomurus palustris* (MÜLL.)	– –	–	0.1 ±0.015
23	*Lepidocyrtus lignorum* (FABR.)	0.04±0.081	1.5	0.20±0.330
24	*Folsomia fimetaria* (L.)	– –	–	– –
–	*Bourletiella* sp. j.	0.02±0.047	0.6	0.06±0.139
25	*Deuterosminthurus repandus* (ÅGREN)	– –	–	– –
26	*Heteromurus nitidus* (TEMPL.)	– –	–	0.01±0.015
27	*Arrhopalites caecus* (TULLB.)	– –	–	– –
28	*Metaphorura affinis* (BÖRN.)	– –	–	0.19±0.403
29	*Friesea mirabilis* (TULLB.)	– –	–	0.09±0.164
30	*Orchesella bifasciata* (NIC.)	– –	–	0.01±0.015
–	*Entomobryidae* spp. j.	0.01±0.031	0.4	0.03±0.066
31	*Bourletiella hortensis* (FITCH)	– –	–	– –
32	*Orchesella cincta* (L.)	– –	–	0.05±0.132
33	*Mesaphorura yossi* (RUSEK)	0.01±0.016	0.2	0.01±0.017
34	*Cryptopygus thermophilus* (AXELS.)	– –	–	0.01±0.015
35	*Entomobrya corticalis* (NIC.)	0.01±0.016	0.2	– –
36	*Entomobrya marginata* (TULLB.)	– –	–	0.01±0.017

monthly density in thous. ind./m^2, *D* – species dominance (%); the sign denotes density (*A*) values less than dominance (*D*) below 0.1%

Urban greenery						
Park lawns						
	very-fine sandy soil				very-fine sandy loam	
	Cemetery of Soviet Soldiers				Saxon Garden	
13	IV–14		IV–15		IV–16	
D	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*
6	7	8	9	10	11	12
3.9	1.42±1.603	35.0	1.15±0.868	31.3	0.30±0.268	9.8
11.0	0.70±0.553	21.9	0.70±0.553	19.0	0.41±0.407	12.7
0.6	0.50±0.363	12.4	0.69±0.620	18.6	0.20±0.366	6.3
4.0	0.17±0.239	4.3	0.01±0.018	0.2	0.27±0.320	8.4
10.4	0.26±0.322	6.4	0.15±0.167	4.2	0.31±0.794	9.8
1.7	0.22±0.142	5.3	0.29±0.027	7.9	0.20±0.320	6.3
11.0	0.01±0.018	0.2	0.01±0.018	0.2	0.01±0.014	0.1
3.5	0.01±0.018	0.1	0.01±0.018	0.2	0.26±0.410	8.2
0.7	0.04±0.034	0.9	0.06±0.050	1.6	0.13±0.238	4.3
2.2	0.04±0.046	0.9	0.01±0.023	0.4	0.03±0.049	0.9
1.5	0.01±0.023	0.4	0.01±0.035	0.4	0.04±0.092	1.2
0.3	0.01±0.023	0.4	0.01±0.018	0.2	0.01±0.016	0.2
21.0	0.01±0.018	0.1	– –	–	0.28±0.357	8.7
0.7	– –	–	0.09±0.059	2.4	0.09±0.115	2.7
0.1	0.13±0.154	3.1	0.01±0.018	0.2	– –	–
1.3	– –	–	0.01±0.035	0.4	0.14±0.148	4.3
3.1	0.01±0.018	0.1	– –	–	0.05±0.129	1.7
0.6	– –	–	0.01±0.018	0.2	0.02±0.058	0.7
0.9	0.02±0.024	0.3	– –	–	0.04±0.054	1.1
0.3	0.01±0.018	0.2	0.04±0.068	1.2	0.03±0.050	0.9
0.3	0.01±0.035	0.4	– –	–	0.01±0.014	0.1
3.6	– –	–	0.01±0.018	0.2	0.09±0.195	2.7
0.1	0.03±0.058	0.6	0.30±0.436	8.2	– –	–
5.1	– –	–	– –	–	0.07±0.200	2.1
–	0.01±0.018	0.2	0.01±0.018	0.2	0.11±0.169	3.4
1.5	– –	–	– –	–	0.02±0.058	0.7
–	0.04±0.060	0.9	0.01±0.018	0.2	0.01±0.018	0.2
0.1	– –	–	0.02±0.039	0.4	0.01±0.036	0.4
–	0.01±0.023	0.4	0.01±0.018	0.2	0.01±0.020	0.3
4.7	0.07±0.084	1.6	– –	–	– –	–
2.3	– –	–	– –	–	0.01±0.014	0.1
0.1	0.05±0.117	1.2	– –	–	– –	–
0.7	– –	–	– –	–	– –	–
–	0.01±0.023	0.4	0.02±0.036	0.6	– –	–
1.2	– –	–	– –	–	0.01±0.029	0.3
0.1	– –	–	– –	–	– –	–
0.1	– –	–	0.01±0.018	0.2	– –	–
–	– –	–	0.01±0.018	0.2	– –	–
0.1	– –	–	0.01±0.018	0.2	– –	–

Tab. XII – cont.

1	2	3	4	5
37	*Hypogastrura vernalis* (CARL)	– –	–	– –
38	*Entomobrya nivalis* (L.)	– –	–	– –
39	*Megalothorax minimus* WILL.	– –	–	– –
40	*Sminthurus viridis* (L.)	– –	–	– –
41	*Proisotoma minuta* (TULLB.)	– –	–	– –
42	*Lepidocyrtus paradoxus* UZEL	– –	–	– –
43	*Willemia intermedia* MILLS.	0.01 ± 0.020	0.3	– –
–	*Paratullbergia* sp.	0.01 ± 0.031	0.4	– –
–	*Anurida* sp.	– –	–	– –
–	*Xenylla* sp.	– –	–	0.01 ± 0.037
44	*Friesea afurcata* DENIS	– –	–	0.01 ± 0.020
45	*Caprainea marginata* (SCHÖTT.)	– –	–	0.01 ± 0.017
46	*Lepidocyrtus curvicollis* BOURL.	– –	–	0.01 ± 0.019
47	*Metaphorura bipartita* (HANDSCH.)	– –	–	0.01 ± 0.019
48	*Schoettella ununguiculata* (TULLB.)	– –	–	0.01 ± 0.015
49	*Folsomia candida* (WILL.)	– –	–	0.01 ± 0.015
50	*Bourletiella arvalis* (FITCH)	0.01 ± 0.017	0.2	– –
51	*Sminthurus niger* (LUBB.)	0.01 ± 0.016	0.2	– –
52	*Ceratophysella succinea* (GISIN)	– –	–	– –
53	*Seira domestica* (NIC.)	– –	–	– –
54	*Mesaphorura sylvatica* (RUSEK)	– –	–	– –
55	*Cyphoderus bidenticulatus* (PARONA)	– –	–	– –
56	*Folsomides parvulus* STACH	– –	–	– –
57	*Sinella coeca* (SCHÖTT.)	– –	–	– –
	Total	3.65	100	4.02

In the housing estate lawns, the group of absolutely constant species was composed of 16 species, while that of constant species – of 10. Among the absolutely constant and constant species eurotypic species were most numerous (*Isotoma notabilis, Sminthurinus aureus, Sphaeridia pumilis, Onychiurus armatus, Mesaphorura macrochaeta, Mesaphorura hylophila, Folsomia quadrioculata, Isotomiella minor, Lepidocyrtus lignorum, Sminthurinus niger, Lepidocyrtus lanuginosus*). Also polytopic species of open areas were quite a lot numerous in this group (*Bouretiella arvalis, Isotomodes productus, Pseudosinella alba, Cryptopygus bipunctatus, Isotoma viridis, Mesaphorura krausbaueri, Mesaphorura critica, Metaphorura affinis, Hypogastrura vernalis, Onychiurus naglitschi*). Highly constant were compost species (*Folsomia fimetaria, Heteromurus nitidus*), myrmecophilous *Entomobryides myrmecophilus* and synanthropic *Pseudosinella immaculata*. The group of accessorial species included 19 species (C = 25%), at the lack of accidental species.

In the street greens, the group of absolutely constant species was made up of 19 species, while that of constant species – of 5. Similarly as in the park greens and housing estate lawns, the make-up of the two groups was dominated by eurytopic

6	7	8	9	10	11	12
–	0.04 ± 0.069	0.9	– –	–	– –	–
–	0.03 ± 0.058	0.8	– –	–	– –	–
–	– –	–	– –	–	0.02 ± 0.054	0.5
–	0.01 ± 0.023	0.4	– –	–	– –	–
–	– –	–	0.01 ± 0.035	0.4	– –	–
–	– –	–	– –	–	0.01 ± 0.022	0.3
–	– –	–	– –	–	– –	–
–	– –	–	– –	–	– –	–
–	– –	–	– –	–	0.01 ± 0.029	0.3
0.3	– –	–	– –	–	– –	–
0.2	– –	–	– –	–	– –	–
0.1	– –	–	– –	–	– –	–
0.2	– –	–	– –	–	– –	–
0.2	– –	–	– –	–	– –	–
0.1	– –	–	– –	–	– –	–
0.1	– –	–	– –	–	– –	–
–	– –	–	– –	–	– –	–
–	– –	–	– –	–	– –	–
–	0.01 ± 0.018	0.2	– –	–	– –	–
–	– –	–	0.01 ± 0.018	0.2	– –	–
–	– –	–	0.01 ± 0.018	0.2	– –	–
–	– –	–	– –	–	0.01 ± 0.014	0.1
–	– –	–	– –	–	0.01 ± 0.014	0.1
–	– –	–	– –	–	0.01 ± 0.014	0.1
100	3.89	100	3.70	100	3.24	100

and polytopic species of open areas, with a larger contribution of compost and myrmecophilous species. Polytopic species of open areas were represented by: *Isotoma viridis, Cryptopygus bipunctatus, Isotomodes productus, Mesaphorura critica, Lepidocyrtus cyaneus, Stenaphorura quadrispina,* while eurytopic species included: *Isotoma notabilis, Sminthurinus aureus, Onychiurus armatus, Mesaphorura macrochaeta, Folsomia quadrioculata, Sphaeridia pumilis, Lepidocyrtus lignorum, Isotomiella minor.* A constant element of the communities of *Collembola* in street-adjoining lawns were compost species: *Folsomia fimetaria,* and *Heteromurus nitidus,* myrmecophilous *Cyphoderus albinus* and *Entomobryides myrmecophilus,* and synanthropic *Pseudosinella immaculata.* The group of accessorial species included 15 species, while that of accidental ones – 17. Among the accessorial species, the highest constancy of occurrence was estimated for *Hypogastrura vernalis* – a xerophilous meadow species, occurring in alkaline soils; *Lepidocyrtus lanuginosus* – an eurytopic species, yet more rarely found than *Lepidocyrtus lignorum* and prefering light, sandy soils; *Heteromurus nitidus* – a synanthropic soil (compost) species; *Isotomurus palustris* – a hygrophilous species.

Table XIII. *Collembola* communities in anthropogenic urban soil of Warsaw (housing estate lawns); A – mean monthly density in thous. ind./m^2, D – species dominance (%), the sign denotes density (A) values less than 0.01 thous. ind./m^2 and dominance (D) below 0.1%

No	Type of linden-oak-hornbeam forest site	Urban greenery					
	Phytosociological association	Lawn of housing estate					
	Soil	very-fine sandy soil very-fine medium sand, very-fine sandy loam on coarse sand		very-fine sandy loam, very-fine sandy soil		sandy loam with debris	
	Locality	Wierzbno				MDM	
	No of station	IV–17		IV–18		IV–20	
	Indices	A (±S.D.)	D	A (±S.D.)	D	A (±S.D.)	D
1	*Isotoma notabilis* SCHÄFF.	0.38±0.732	19.4	0.20±0.249	11.0	0.50±0.780	14.6
2	*Sminthurinus aureus* (LUBB.)	0.18±0.239	8.9	0.40±0.596	22.0	0.31±0.267	9.0
3	*Bourletiella arvalis* (FITCH)	0.35±0.614	17.7	0.01±0.014	0.3	0.25±0.439	7.5
4	*Isotomodes productus* (AXELES.)	0.04±0.057	1.9	0.02±0.042	1.3	0.54±1.080	16.0
5	*Pseudosinella alba* (PACK.)	0.03±0.096	1.7	0.24±0.317	13.3	0.05±0.055	1.6
6	*Sphaeridia pumilis* (KRAUSB.)	0.17±0.354	8.5	0.11±0.129	5.9	0.07±0.092	1.9
7	*Lepidocyrtus cyaneus* TULLB.	0.02±0.055	0.8	0.20±0.476	11.0	0.11±0.233	3.2
	Sminthuridae spp. j.	0.13±0.187	6.8	0.07±0.089	4.1	0.16±0.337	4.7
8	*Cryptopygus bipunctatus* (AXELS.)	0.03±0.056	1.5	0.02±0.036	0.9	0.38±1.014	11.1
9	*Isotoma viridis* BOURL.	0.04±0.079	2.1	0.11±0.104	5.8	0.15±0.222	4.5
10	*Mesaphorura krausbaueri* BÖRN.	0.05±0.049	2.7	0.01±0.032	0.6	0.10±0.133	2.9
11	*Onychiurus armatus* (TULLB.)	0.01±0.032	0.7	0.05±0.069	2.6	0.17±0.020	5.0
	Entomobryidae spp. j.	0.07±0.141	3.8	0.03±0.096	1.7	0.05±0.119	1.4
12	*Mesaphorura macrochaeta* RUSEK	0.02±0.038	1.1	0.05±0.126	2.7	0.06±0.122	1.7
13	*Entomobryides myrmecophilus* (REUT.)	0.01±0.015	0.2	0.07±0.142	3.6	0.05±0.118	1.5
14	*Mesaphorura hylophila* RUSEK	0.02±0.049	1.2	0.02±0.064	1.4	0.01±0.023	0.3
15	*Folsomia quadrioculata* (TULLB.)	0.01±0.022	0.7	0.01±0.014	0.3	0.06±0.150	1.6
16	*Isotomiella minor* (SCHÄFF.)	0.01±0.019	0.4	0.01±0.023	0.6	0.01±0.015	0.1
17	*Willemia intermedia* MILLS	0.01±0.033	0.7	0.01±0.016	0.3	0.01±0.015	0.1
18	*Mesaphorura critica* ELLIS	0.08±0.135	4.2	0.01±0.014	0.3	– –	–

19	*Metaphorura affinis* (BÖRN.)	0.04 ± 0.099	2.1	0.04 ± 0.074	2.2	– –	–
20	*Folsomia fimetaria* (L.)	0.01 ± 0.031	0.5	– –	–	0.11 ± 0.185	3.2
21	*Pseudosinella immaculata* (LIE PETT.)	0.03 ± 0.072	1.7	– –	–	0.02 ± 0.035	0.5
22	*Lepidocyrtus lignorum* (FABR.)	– –	–	0.02 ± 0.026	1.1	0.01 ± 0.015	0.1
23	*Sminthurinus niger* (LUBB.)	< 0.01 ± 0.014	0.2	0.20 ± 0.049	1.0	– –	–
24	*Hypogastrura vernalis* (CARL)	0.01 ± 0.024	0.5	– –	–	0.03 ± 0.075	0.7
25	*Lepidocyrtus lanuginosus* (GMEL.)	0.01 ± 0.041	0.6	– –	–	0.01 ± 0.030	0.3
26	*Onychiurus naglitschi* GISIN	0.01 ± 0.031	0.5	0.01 ± 0.014	0.3	– –	–
27	*Heteromurus nitidus* (TEMPL.)	– –	–	0.01 ± 0.029	0.5	0.01 ± 0.015	0.1
	Paratullbergia sp.	– –	–	0.01 ± 0.014	0.3	0.01 ± 0.017	0.2
28	*Entomobrya marginata* (TULLB.)	0.07 ± 0.249	3.8	– –	–	– –	–
29	*Isotomurus palustris* (MÜLL.)	– –	–	– –	–	0.11 ± 0.343	3.4
30	*Hypogastrura manubrialis* (TULLB.)	– –	–	– –	–	0.07 ± 0.134	1.9
31	*Cyphoderus albinus* NIC.	– –	–	0.03 ± 0.057	1.8	– –	–
32	*Friesea mirabilis* (TULLB.)	0.03 ± 0.062	1.7	– –	–	– –	–
33	*Stenaphorura quadrispina* BÖRN.	– –	–	0.03 ± 0.053	1.6	– –	–
34	*Cryptopygus ponticus* (STACH)	0.02 ± 0.077	1.2	– –	–	– –	–
35	*Proisotoma minima* (ABS.)	0.01 ± 0.046	0.7	– –	–	– –	–
36	*Arrhopalites caecus* (TULLB.)	0.01 ± 0.041	0.6	– –	–	– –	–
37	*Cryptopygus thermophilus* (AXELS.)	0.01 ± 0.027	0.6	– –	–	– –	–
38	*Entomobrya nivalis* (L.)	0.01 ± 0.020	0.3	0.01 ± 0.018	0.3	– –	–
39	*Hypogastrura assimilis* (KRAUSB.)	– –	–	– –	–	0.02 ± 0.032	0.4
40	*Deuterosminthurus repandus* (AGREN)	– –	–	– –	–	0.01 ± 0.030	0.3
41	*Sminthurus viridis* (L.)	– –	–	0.01 ± 0.014	0.3	– –	–
42	*Caprainea marginata* (SCHÖTT)	– –	–	0.06 ± 0.016	0.3	– –	–
43	*Willemia aspinata* STACH	– –	–	0.01 ± 0.016	0.3	– –	–
44	*Pseudosinella zygophora* (SCHILLE)	– –	–	0.01 ± 0.014	0.3	– –	–
45	*Hypogastrura purpurescens* (LUBB.)	– –	–	– –	–	0.01 ± 0.015	0.1
46	*Folsomia candida* (WILL.)	– –	–	– –	–	0.01 ± 0.015	0.1
	Total	1.93	100	2.10	100	3.47	100

Table XIV. *Collembola* communities in anthropogenic urban soil of Warsaw (street lawns); *A* – mean 0.01 thous. ind./m² and

No	Type of linden-oak-hornbeam forest site				
	Phytosociological association				
	Soil	sandy loam		strong medium sand sandy	
	Locality	Ujazdowskie Avenue		Żwirki i Wi	
	No of station	IV–20		IV–21	
	Indices	*A* (±S.D.)	*D*	*A* (±S.D.)	*D*
1	2	3	4	5	6
1	*Isotoma notabilis* SCHÄFF.	0.12±0.200	8.9	1.83±1.462	29.0
2	*Sminthurinus aureus* (LUBB.)	0.51±0.716	39.5	0.23±0.239	3.7
3	*Isotoma viridis* BOURL.	0.09±0.201	6.7	1.92±0.910	30.4
4	*Cryptopygus bipunctatus* (AXELS.)	0.02±0.032	1.8	0.76±1.231	12.0
–	*Sminthuridae* spp. j.	0.23±0.501	17.8	0.29±0.546	4.6
5	*Onychiurus armatus* (TULLB.)	0.03±0.058	2.1	0.18±0.179	2.9
6	*Entomobryides myrmecophilus* (REUT.)	0.01±0.014	0.3	0.13±0.144	2.1
7	*Mesaphorura critica* ELLIS	0.05±0.143	3.8	0.02±0.024	0.2
8	*Mesaphorura macrochaeta* RUSEK	0.01±0.021	0.5	0.14±0.170	2.3
9	*Isotomodes productus* (AXELS.)	0.01±0.024	0.6	0.50±0.080	0.8
10	*Lepidocyrtus cyaneus* TULLB.	0.01±0.029	0.7	0.04±0.064	0.6
11	*Cryptopygus thermophilus* (AXELS.)	– –	–	0.02±0.024	0.2
12	*Pseudosinella alba* (PACK.)	0.01±0.014	0.3	0.13±0.128	2.1
13	*Pseudosinella immaculata* (LIE PETT.)	– –	–	0.01±0.019	0.1
14	*Folsomia quadrioculata* (TULLB.)	0.01±0.024	0.8	0.01±0.019	0.1
15	*Cyphoderus albinus* NIC.	0.02±0.038	0.9	0.03±0.027	0.5
16	*Sphaeridia pumilis* (KRAUSB.)	0.01±0.034	1.1	0.04±0.063	0.6
17	*Mesaphorura krausbaueri* BÖRN.	0.02±0.035	1.5	0.02±0.039	0.3
18	*Mesaphorura hylophila* RUSEK	0.01±0.024	0.8	0.01±0.023	0.2
19	*Metaphorura affinis* (BÖRN.)	0.03±0.086	2.4	0.02±0.052	0.3
20	*Brachystomella parvula* (SCHÄFF.)	– –	–	0.01±0.017	0.1
21	*Lepidocyrtus lignorum* (FABR.)	0.04±0.115	2.8	0.14±0.312	2.2
22	*Isotomiella minor* (SCHÄFF.)	0.01±0.016	0.4	0.02±0.052	0.3
23	*Folsomia fimetaria* (L.)	– –	–	0.50±0.122	0.8
24	*Stenaphorura quadrispina* BÖRN.	0.01±0.014	0.3	0.02±0.037	0.4
25	*Hypogastrura vernalis* (CARL)	– –	–	– –	–
–	*Entomobryidae* spp. j.	– –	–	– –	–
26	*Lepidocyrtus lanuginosus* (GMEL.)	– –	–	– –	–
27	*Heteromurus nitidus* (TEMPL.)	– –	–	0.08±0.153	1.3
–	*Bourletiella* sp. j.	0.01±0.016	0.4	– –	–
28	*Willemia intermedia* MILLS	0.01±0.014	0.3	– –	–
29	*Isotomurus palustris* (MÜLL.)	– –	–	0.02±0.037	0.4
30	*Friesea afurcata* DENIS	0.02±0.033	1.7	0.01±0.017	0.1
31	*Bourlietiella hortensis* (FITCH)	– –	–	0.02±0.039	0.3
32	*Ceratophysella succinea* (GISIN)	– –	–	– –	–
33	*Entomobrya marginata* (TULLB.)	– –	–	– –	–
34	*Deuterosminthurus repandus* (ÅGREN)	– –	–	– –	–
35	*Megalothorax minimus* WILL.	– –	–	– –	–
36	*Folsomides parvulus* STACH	0.01±0.014	0.3	– –	–

monthly density in thous. ind./m^2, D – species dominance (%); the sign denotes density (A) value less than dominance (D) below 0.1%

Urban greenery							
Street lawns							
on very-fine soil		strong medium sand on very-fine light medium sand		coarse sand, very-fine medium sand on sandy loam		coarse sand	
gury Avenue		Marszałkowska St.		Woronicza St.		Zbawiciela Square	
IV–22		IV–23		IV–24		IV–25	
A (±S.D.)	D	A (±S.D.)	D	A (±S.D.)	D	A (±S.D.)	D
7	8	9	10	11	12	13	14
1.53 ± 0.987	33.6	0.36 ± 0.407	19.2	0.09 ± 0.206	3.5	1.70 ± 1.105	22.2
0.52 ± 0.684	11.4	0.46 ± 0.504	24.9	0.06 ± 0.139	2.5	0.32 ± 0.285	4.2
0.53 ± 0.592	11.5	0.04 ± 0.064	2.1	0.06 ± 0.093	2.2	1.16 ± 1.242	15.3
0.05 ± 0.131	1.1	0.20 ± 0.221	10.8	0.23 ± 0.650	8.9	2.09 ± 2.450	27.4
0.45 ± 0.595	9.9	0.03 ± 0.055	1.5	0.20 ± 0.420	7.9	0.44 ± 0.245	5.8
0.26 ± 0.406	5.7	0.03 ± 0.062	1.8	0.36 ± 0.623	14.1	0.11 ± 0.170	0.6
0.22 ± 0.354	4.7	0.10 ± 0.175	5.4	0.16 ± 0.250	6.2	0.09 ± 0.173	1.1
0.02 ± 0.044	0.4	0.01 ± 0.023	0.5	0.13 ± 0.174	5.1	0.02 ± 0.024	0.2
0.05 ± 0.035	1.1	0.02 ± 0.055	0.9	0.02 ± 0.049	0.8	0.20 ± 0.117	2.6
0.02 ± 0.058	0.5	0.01 ± 0.030	0.7	0.02 ± 0.058	0.9	0.05 ± 0.058	0.7
– –	–	0.11 ± 0.111	6.1	0.11 ± 0.203	4.3	0.54 ± 0.713	7.0
0.33 ± 0.797	7.1	0.01 ± 0.022	0.7	0.01 ± 0.032	0.4	0.12 ± 0.169	1.6
0.02 ± 0.037	0.5	0.07 ± 0.113	3.7	0.07 ± 0.100	2.6	– –	–
0.06 ± 0.097	1.4	0.04 ± 0.084	2.0	0.03 ± 0.072	1.1	0.09 ± 0.105	1.2
– –	–	0.01 ± 0.024	0.8	0.10 ± 0.301	3.7	0.02 ± 0.040	0.3
0.05 ± 0.094	1.2	0.03 ± 0.046	1.3	– –	–	0.02 ± 0.024	1.4
0.02 ± 0.038	0.5	0.01 ± 0.028	0.5	0.06 ± 0.187	2.3	– –	–
0.01 ± 0.029	0.3	0.51 ± 0.054	2.7	0.01 ± 0.029	0.3	– –	–
– –	–	0.01 ± 0.028	0.5	0.03 ± 0.051	1.3	0.11 ± 0.152	1.5
0.02 ± 0.039	0.3	0.01 ± 0.015	0.3	0.01 ± 0.048	0.6	– –	–
0.21 ± 0.349	4.5	– –	–	0.13 ± 0.253	5.0	0.29 ± 0.444	3.8
– –	–	0.11 ± 0.353	5.8	0.01 ± 0.018	0.2	– –	–
– –	–	0.03 ± 0.069	1.3	0.22 ± 0.681	8.5	– –	–
0.01 ± 0.017	0.2	0.01 ± 0.028	0.5	– –	–	0.04 ± 0.061	0.6
0.06 ± 0.101	1.3	– –	–	– –	–	0.02 ± 0.036	0.3
0.04 ± 0.087	0.8	– –	–	0.19 ± 0.611	7.5	0.01 ± 0.018	0.2
– –	–	0.03 ± 0.092	1.5	0.09 ± 0.132	3.4	0.01 ± 0.018	0.1
0.01 ± 0.019	0.2	0.03 ± 0.069	1.4	0.03 ± 0.068	1.2	– –	–
– –	–	0.01 ± 0.020	0.5	– –	–	0.05 ± 0.055	0.3
– –	–	0.01 ± 0.015	0.3	0.03 ± 0.101	1.2	– –	–
– –	–	0.09 ± 0.021	0.5	0.01 ± 0.014	0.2	0.04 ± 0.060	0.5
0.01 ± 0.022	0.2	– –	–	– –	–	0.01 ± 0.016	0.1
– –	–	– –	–	– –	–	– –	–
0.03 ± 0.044	0.7	– –	–	– –	–	– –	–
– –	–	– –	–	0.03 ± 0.101	1.2	0.01 ± 0.018	0.1
– –	–	0.01 ± 0.020	0.5	0.01 ± 0.043	0.5	– –	–
0.02 ± 0.024	0.2	– –	–	– –	–	0.01 ± 0.012	0.2
0.01 ± 0.017	0.2	– –	–	– –	–	0.02 ± 0.024	0.2
– –	–	0.01 ± 0.015	0.3	– –	–	– –	–

Tab. XIV – cont.

1	2	3	4	5	6
37	*Sminthurinus niger* (LUBB.)	0.01 ± 0.014	0.3	– –	–
38	*Neotullbergia ramicuspis* (GISIN)	– –	–	– –	–
39	*Sminthurus viridis* (L.)	– –	–	0.01 ± 0.017	0.1
40	*Schoettella ununguiculata* (TULLB.)	0.03 ± 0.080	2.0	– –	–
41	*Metaphorura bipartita* (HANDSCH.)	– –	–	– –	–
42	*Sinella cocea* (SCHÖTT.)	– –	–	– –	–
43	*Hypogastrura assimilis* (KRAUSB.)	– –	–	– –	–
44	*Entomobrya multifasciata* (TULLB.)	– –	–	– –	–
45	*Sminthurus flaviceps* TULLB.	0.01 ± 0.021	0.5	– –	–
46	*Onychiurus granulosus* STACH	0.01 ± 0.021	0.5	– –	–
47	*Mesaphorura yossi* (RUSEK)	– –	–	– –	–
48	*Xenyllodes ghiljarovi* MARTYNOVA	– –	–	– –	–
49	*Proisotoma minuta* (TULLB.)	– –	–	0.02 ± 0.024	0.2
50	*Bourletiella arvalis* (FITCH)	– –	–	0.02 ± 0.039	0.3
51	*Arrhopalites caecus* (TULLB.)	– –	–	– –	–
52	*Xenylla grisea* AXELS.	– –	–	0.01 ± 0.017	0.1
53	*Pseudosinella zygophora* (SCHILLE)	– –	–	– –	–
54	*Friesea mirabilis* (TULLB.)	– –	–	– –	–
55	*Orchesella cincta* (L.)	– –	–	– –	–
–	*Hypogastruridae* sp. j.	– –	–	0.01 ± 0.017	0.1
–	*Anurida* sp.	– –	–	0.01 ± 0.017	0.1
	Total	1.37	100	7.25	100

4.4.2. Abundance

Mean density of *Collembola* in the studied urban lawns in Warsaw amounted to 3.76 thous. ind./m^2. The highest mean density of *Collembola* was recorded in street lawns (4.33 thous. ind./m^2) and in park greens (3.70 thous. ind./m^2), while the lowest density – in housing estate lawns (2.56 thous. ind./m^2). The most abundant communities of *Collembola* were recorded in an isolated, road dividing lawn at Zbawiciela Square (7.64 thous. ind./m^2) and in a street aligning lawn in Żwirki i Wigury Avenue (7.25 thous. ind./m^2), while the least numerous communities were stated in a lawn in Ujazdowskie Avenue (1.37 thous. ind./m^2) and in a housing estate lawn at Wierzbno (1.93 thous. ind./m^2) (Tabs XV–XVII).

Abundance of *Collembola* communities in the studied types of urban greens in Warsaw was much diversified and seemed to depend on a number of micro-habitat factors. The very type of urban greens seems to be of no significance in this respect, as both in housing estate lawns and in street lawns there were found sites with very abundant *Collembola* communities as well as others where the communites were not numerous. Furthemore, it is difficult to determine the effect of road traffic and, consequently, of pollution, especially with heavy metals. Density values were most

7	8	9	10	11	12	13	14
– –	–	– –	–	– –	–	0.01±0.018	0.1
– –	–	– –	–	0.01±0.014	0.2	0.01±0.023	0.1
0.01±0.022	0.2	– –	–	– –	–	– –	–
– –	–	– –	–	– –	–	– –	–
– –	–	– –	–	0.02±0.051	0.9	– –	–
– –	–	0.13±0.041	0.7	– –	–	– –	–
– –	–	– –	–	0.01±0.036	0.4	– –	–
– –	–	<0.01±0.014	0.3	– –	–	– –	–
– –	–	– –	–	– –	–	– –	–
– –	–	– –	–	– –	–	– –	–
– –	–	– –	–	0.01±0.036	0.4	– –	–
– –	–	– –	–	0.01±0.024	0.3	– –	–
– –	–	– –	–	– –	–	– –	–
– –	–	– –	–	– –	–	– –	–
– –	–	– –	–	– –	–	0.02±0.024	0.2
– –	–	– –	–	– –	–	– –	–
0.01±0.017	0.2	– –	–	– –	–	– –	–
– –	–	– –	–	0.01±0.014	0.2	– –	–
– –	–	– –	–	– –	–	0.01±0.018	0.1
– –	–	– –	–	– –	–	– –	–
– –	–	– –	–	– –	–	– –	–
4.58	100	2.54	100	2.58	100	7.64	100

equalized in case of communities from park lawns, while the greates differences in abundance were noted for communities from street lawns. Apart from being strongly polluted, with heavy metals in particular, soils of street lawns are exposed to more or less intensive trampling and are variously cultivated. Besides extreme for *Collembola* communities differences in abiotic conditions in soil of street lawns, also pronounced biotic differences occur there (the dense mat of vegetation laying on the soil surface, potential predators, inter-specific competition, etc.).

Table XV. Biocoenological indices characterizing *Collembola* communities in anthropogenic urban soil of Warsaw (park lawns); S – number of species, A – mean monthly density in thous. ind./m^2, H', E, M, $2^{H'}$ – indices of total species diversity

Locality	No of station	Biocoenological indices					
		S	A	H' (±S.D.)	E (±S.D.)	M (±S.D.)	$2^{H'}$ (±S.D.)
Łazienki	IV–12	26	3.65	1.823±0.2707	0.780±0.1162	4.791±1.6598	3.600±0.6675
	IV–13	37	4.02	1.827±0.6378	0.730±0.1559	5.422±3.0065	3.868±1.4457
Cemetery of Soviet Soldiers	IV–14	28	3.89	1.871±0.2883	0.749±0.0976	4.924±1.5072	3.730±0.7082
	IV–15	29	3.70	1.602±0.3308	0.764±0.0847	4.011±1.1936	3.123±0.8044
Saxon Garden	IV–16	32	3.24	2.031±0.2671	0.845±0.0728	6.197±2.1044	4.157±0.7037

Table XVI. Biocoenological indices characterizing *Collembola* communities in anthropogenic urban soil of Warsaw (housing estate lawns); S – number of species, A – mean monthly density in thous. ind./m^2, H', E, M, 2^{H} – indices of total species diversity

Locality	No of station	Biocoenological indices					
		S	A	H' (±S.D.)	E (±S.D.)	M (±S.D.)	$2^{H'}$ (±S.D.)
Wierzbno	IV–17	32	1.93	1.526±0.4068	0.792±0.1381	3.825±1.4602	2.997±0.8504
	IV–18	30	2.10	1.594±0.6171	0.779±0.1724	4.592±2.7162	3.291±1.3236
MDM	IV–19	29	3.47	1.745±0.4306	0.769±0.1515	4.844±1.9435	3.502±1.0219

Table XVII. Biocoenological indices characterizing *Collembola* communities in anthropogenic urban soil of Warsaw (street lawns); S – number of species, A – mean monthly density in thous. ind./m^2, H', E, M, 2^{H} – indices of total species diversity

Locality	No of station	Biocoenological indices					
		S	A	H' (±S.D.)	E (±S.D.)	M (±S.D.)	$2^{H'}$ (±S.D.)
Ujazdowskie Avenue	IV–20	27	1.37	1.073±0.4259	0.736±0.2012	2.581±1.0457	2.203±0.7050
Żwirki i Wigury Avenue	IV–21	32	7.25	1.620±0.2772	0.664±0.0972	3.551±0.8440	3.128±0.5479
	IV–22	27	4.58	1.544±0.3770	0.704±0.0948	3.825±1.3614	3.009±0.7086
Marszałkowska Street	IV–23	29	2.54	1.736±0.2403	0.833±0.0607	4.610±1.1606	3.376±0.5542
Woronicza Street	IV–24	32	2.58	1.610±0.4057	0.820±0.1009	4.444±1.8230	3.172±0.8516
Zbawiciela Square	IV–25	29	7.64	1.715±0.4965	0.686±0.1541	4.466±1.8743	3.467±1.0580

4.4.3. Dominance structure and diversity of communities

Park greens. The greatest contribution of the dominating species were estimated to communities from Cemetery-Mausoleum of Soviet Soldiers, a new park set up in place of crop fields, (35.0% and 31.3%), where the dominating was *Isotoma viridis*, a meadow species, which frequently is a pioneer species (Usher et al. 1982). Lower values of the dominance index were calculated for the communities from Łazienki Park (Fig. 6). At the station 13, located inside the park, *Cryptopygus bipunctatus* dominated (21%), while at the station 12, on the park outskirts – *Sminthurinus aureus* (16.5%). The lowest value of the dominance index was estimated for the community from Saxon Garden in the city center, where *Isotoma notabilis* dominated (12.7%).

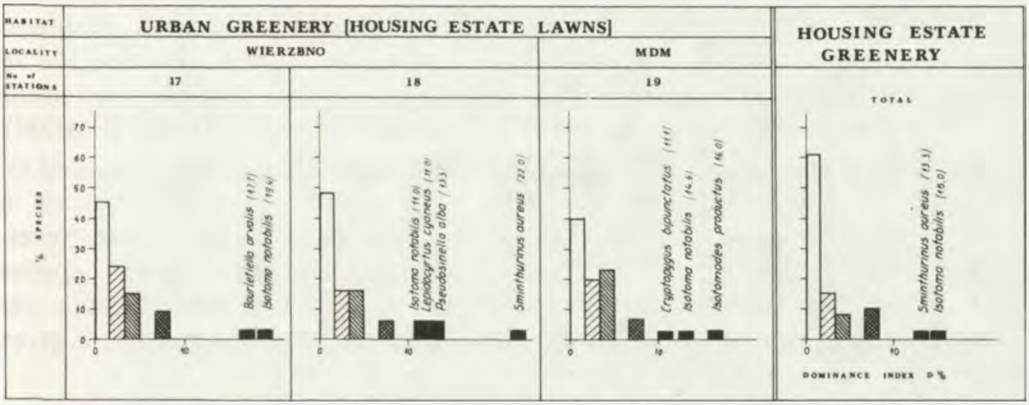

Fig. 6. Dominance structure of *Collembola* communities in anthropogenic urban soil of Warsaw (park lawns); station numbers – see Table I, II.

The contribution of the group of subrecedents, whose domination did not exceed 1.1%, differed greatly in the studied park communities. The group was represented by 36–70% of species in the community. The subreceding species had the lowest share in the community from Łazienki Park (station 12), where they accounted for 36% of the community, while the highest in Cemetery-Mausoleum of Soviet Soldiers (stations 14 and 15), accounting for 69% and 70% respectively. All the distinguished dominance groups were present in the studied park communities.

The analysis of eveness of dominating species distribution revealed that differences in percentage contribution between the two first dominants were the lowest in the community from a lawn in Łazienki Park (station 12) – 1,9% and in Saxon Garden (station 16) – 2.9%. In case of the remaining park communities, the examined differences were greater, ranging 12.3–13.1% in Cemetery-Mausoleum of Soviet Soldiers (stations 14 and 15 respectively) and amounting to 10.0% in Łazienki Park (station 13).

Housing estate lawns. The highest contribution of the dominating species was estimated for the community from Wierzbno housing estate lawns (19.4% and 22%), while the lowest – for the community from MDM housing estate in the city center, – 16% (Fig. 7). The contribution of the first and the second dominating species to communities from housing estate lawns did not exceed 37.1%. In soil of Wierzbno estate lawns typical, eurytopic species dominated, *Isotoma notabilis* (19.4%) at the station 17 and *Sminthurinus aureus* (22.0%) at the station 18, while in MDM the dominating was *Isotomodes productus* (16.0%), a typical field species.

The percentage contribution of subreceding species of dominance rate lower than 1.1% to the studied communities from housing estate lawns was not higher than 50%. This group of species accounted for 46% at station 17 (Wierzbno), 48% at station 18 (Wierzbno), and 40% at MDM.

All the studied communities from housing estate lawns were marked for a low number of species with a high dominance value and a low dominance value. While analyzing eveness of dominating species distribution it was observed that differences in percentage contribution between dominating species were the largest in soil of an orderly, small lawn at Wierzbno (8.7%), while in case of the other examined lawns they were much lower (1.7% in a large, open lawn at Wierzbno and 1.4% at MDM).

The communities from soil of the studied housing estate lawns were marked for a proper development of dominance structure, yet with a considerable decrease in percentage contribution of subreceding species to the studied communities. Nevertheless considerable diversity of species make-up of the communities, species composition of the dominating group (eudominants, dominants, subdominants) was much alike, particular species differing only in the rank they occupied in a given community.

Street lawns. The highest contribution of the dominating species was estimated for the community in Ujazdowskie Ave. (39.5%), while the lowest – the community from a lawn in Woronicza Street (14.1%). The contribution of the first and the second dominating species to communities from street lawns ranged widely from 59.4% in the street lawn soil in Żwirki i Wigury Avenue to merely 23% in the lawn in Woronicza Street (Fig. 8). In the lawn communities in Ujazdowskie Avenue and Marszałkowska Street, *Sminthurinus aureus*, an eurytopic species, dominated. The lawns in question skirt heavily trafficked streets in the city center yet they are located in the vicinity of large green areas, i.e. Łazienki Park and Saxon Garden. Similarly, lawns in Żwirki i Wigury Avenue are situated close to Cemetery-Mausoleum of Soviet Soldiers. In soil of the examined street lawns the dominating were: in the street-adjoining lawn in Żwirki i Wigury Ave. – *Isotoma viridis* (30.4%), in the road-dividing lawn – *Isotoma notabilis* (33.6%), in the street-aligning lawn in Woronicza Street – *Onychiurus armatus* (14.1%), a typically soil, eurytopic species, and in totally isolated lawn at Zbawiciela Square – *Cryptopygus bipunctatus* (27.4%).

The percentage contribution of species of lower than 1.1% dominance rate to the studied lawn communities ranged 44–67%. This group of species had the greatest

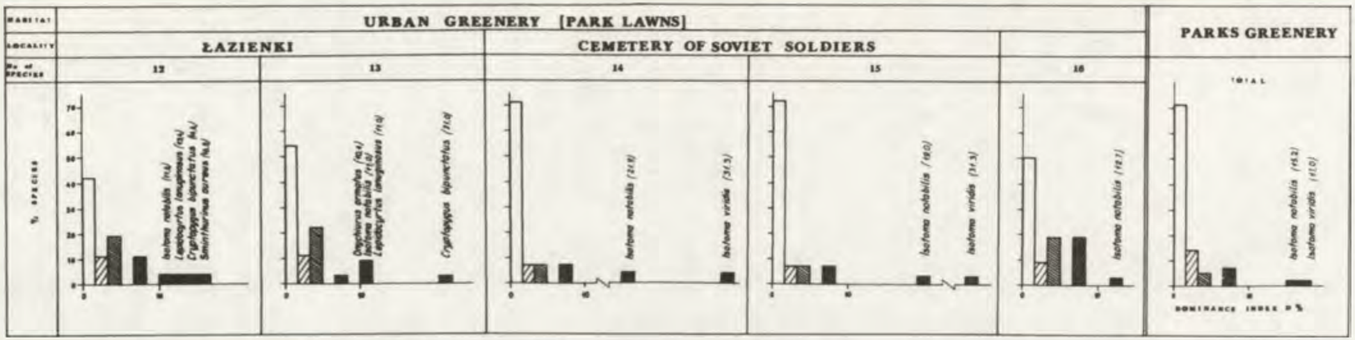

Fig. 7. Dominance structure of *Collembola* communities in anthropogenic urban soil of Warsaw (housing estate lawns); station numbers – see Table I, II.

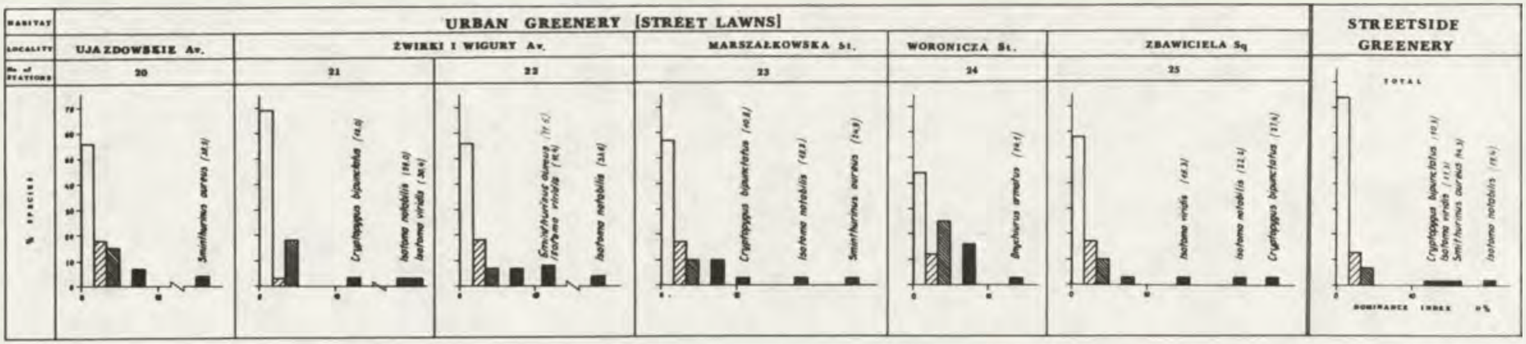

Fig. 8. Dominance structure of *Collembola* communites in anthropogenic urban soil of Warsaw (street lawns); station numbers – see Table I, II.

share in the community from an isolated road-dividing lawn at Zbawiciela Square (68%) and from a street-aligning lawn in Żwirki i Wigury Avenue (67%). The lowest percentage contribution of this group of species to *Collembola* communities was recorded in soil of a street adjoining lawn in Ujazdowskie Avenue (56%), in soil of a road-dividing lawn in Żwirki i Wigury Avenue (55%) and in soil of street-dividing lawn in Marszałkowska Street (44%).

Dominance distribution was marked for a low number of species of a high dominance rate and a good deal of species of lower dominance rate. While analyzing eveness of dominating species distribution it was found out that that differences in the percentage contribution between the dominating species were the greatest in the community from a lawn in Ujazdowskie Avenue (30.6%) and in a street-adjoining lawn in Żwirki i Wigury Avenue (21.8%). In case of the communities from the lawns situated in Marszałkowska Street, Woronicza Street and Zbawiciela Square the studied differences were slight, amounting to 5.7%, 5.2% and 5.0% respectively, while the lowest differences was noted for the community from a street-dividing lawn in Żwirki i Wigury Avenue, i.e. 1.4%.

In the studied urban soils, two types of *Collembola* communities were observed to occur, namely, in one type the prevalence of the dominating species was very large; this type of community occurred in strongly polluted soil of street lawns (Ujazdowskie Avenue, Żwirki i Wigury Avenue – station 21) as well as in newly set up parks (Cemetery-Mausoleum of Soviet Soldiers). The other type of community was marked for an inconsiderable difference in the contribution of the two first dominants (Żwirki i Wigury Avenue – station 22, MDM, Wierzbno, Saxon Garden, Łazienki Park). Moreover, the number of dominating species differed in these two types of communities. The communities of *Collembola* of old parks were noted for the presence of a numerous group of species of a dominance value exceeding 10%. In the communities from new parks or the ones in the city center as well as in a majority of communities from housing estate and street lawns, the group of dominating species was very scanty (1–2 species). The greatest variability and diversity of the dominant group was observed in *Collembola* communities from street lawns, while the lowest – in communities from park greens. Furthermore, urbanization pressure caused a marked alternation in percentage contribution of subrecedent group to the community. The share of this group of species was the highest in park communities, while the lowest – in housing estate lawn communities. Broadly speaking, *Collembola* communities from urban greens were marked for a uniformity level of species dominance (a lower disproportion in contribution of particular species to the community).

Species diversity indices. The highest values of the Shannon-Weaver's index, as well as of all the other indices of species diversity were calculated for the communities of *Collembola* from park lawns (Tab. XV–XVII). These communities had a properly developed dominance structure, a usually diversified group of dominating species and a numerous group of subreceding species. Specimen distribution into species forming a community estimated by PIELOU's index, was relatively even (the lowest value of the index amounted to 0.730). The highest value of the SHANNON-WEAVER's species diversity index was estimated for the community from Saxon Garden (2.031); this community was also noted for the highest value of the PIELOU's index (0.845). Lower values of the species diversity index were recorded only for these park communities, in which the contribution of the first and the second dominant was high, while the value of the PIELOU's index was relatively low (Fig. 6, Tab. XV).

Species diversity of *Collembola* communities in the soil of the studied housing estate lawns, estimated by means of the SHANNON-WEAVER's index, was smaller than in park communities, notwithstanding a properly developed dominance structure in the former, measured by eveness index (Tab. XV). A little diversity of these communities was caused by usually high shares of the first and the second dominant in the community, at a low contribution of the other species. Only the community from a tidy housing estate lawn at MDM in the city center, where the differences between the shares of the species forming this community were not so high, was noted for somewhat greater values of the SHANNON-WEAVER's index. The other indices of species diversity, however, were lower than in the park communities.

In soil of the studied street lawns there occurred both communities of *Collembola* which assumed high values of species diversity index as well as communities, for which the values of the examined indices were very low. The highest values of species diversity indices were estimated for the communities from well sodded and not trampled lawns in Marszałkowska Street and Zbawiciela Square. These communities were also marked for a high value of the PIELOU's eveness index (*E*). The lowest values of the species diversity index were calculated for the communities of *Collembola* from Ujazdowskie Ave. and Żwirki i Wigury Ave. The high values of species diversity index for communities of the studied street lawns were frequently not conditioned by species abundance, yet by an even contribution of particular species to the community.

The recorded great variability of values of species diversity indices in soil of the studied urban greens was brought about by a pronounced diversity of habitat conditions, which only partly was caused by varied intensity of transportation traffic pressure.

4.4.4. Ecological classification of species

Ecological structure of *Collembola* communities in Warsaw urban greens is much diversified with respect to soil layer preferences, moisture preferences and ecological plasticity.

Soil layer preferences

It was found out that in a majority of *Collembola* communities from park lawns the dominating were the species inhabit to mineral soil (euedaphic species); only in the community from Cemetery-Mausoleum of Soviet Soldiers (stations 14, 15) the highest share, with respect to quantity, had the group of epigeic (litter-sward) species (Tab. XVIII). The communities from housing estate lawns were also dominated by euedaphic species, only the community at Wierzbno (station 18) was dominated by specimens belonging to epigeic species (Tab. XIX). However, as compared to park lawn communities and considering species abundance, housing estate lawn communities were marked for a greater share of atmobiotic species and a lower share of epigeic species; the share of hemiedaphic species in the two kinds of communities was alike. In a majority of communities from street lawns a greater share of euedaphic species was noted, although not as high as in communities from park and housing estate lawns, however, in the communities from Ujazdowskie Ave. (station 20) and Żwirki i Wigury (stations 21, 22), the share of epigeic and hemiedaphic species was greater with respect to their abundance. It may be generally concluded that the share of euedaphic, epigeic and hemiedaphic species in communities from street lawns were approximately the same. Due to contribution of atmiobiotic and epigeic species, communities of street lawns resembled the ones of park lawns, however the share of hemiedaphic species in the former was much greater than in communities from park lawns.

Moisture preferences

In all types of urban greens *Collembola* communities were dominated by mesophilous species, xerophilous species were fairly numerous, while hygrophilous species receded (Tab. XVIII). With respect to abundance it was found out that in *Collembola* communities from dried up, trampled and treeless and shrubless housing estate lawns, the share of mesophilous species decreased in favour of xerophilous species. As regards housing estate lawns, the greatest abundance of xerophilous species was noted in the community from MDM (station 19). In communities of *Collembola* from park lawns, a greater share of xerophilous than hygrophilous species was noted, although as compared to the other types of urban greens, the share of hygrophilous species in these communities was the highest, and the contribution of xerophilous species – the lowest. Out of all the studied park lawn communities, the community of *Collembola* from an open, much insolated and dried up lawn in Łazienki Park (station 13) was marked for the highest share of xerophilous species (also the highest in Warsaw) and the lowest contribution of hygrophilous species (considering specimen abundance of particular species). In moderately humid soil (station 15) in Cemetery-Mausoleum of Soviet Soldiers the ratio of the examined group was inverse, i. e. the community of *Collembola* was noted for a lower share of xerophilous species and the highest contribution of the group of hygrophilous species. It was the only case of a community of *Collembola* from Warsaw urban greens, where the share of hygrophilous species was greater – and much greater at that – than the share of xerophilous species.

Table XVIII. Percentage contribution of chosen ecological groups to *Collembola* communities in anthropogenic urban soil of Warsaw (park lawns); S – number of species, n – abundance in thous. ind./m^2

Habitat			Urban greenery (park lawns)																						Parks greenery			
Locality			Łazienki								Cemetery of Soviet Soldiers								Saxon Garden							
No of station			IV–12				IV–13				IV–14				IV–15				IV–16							
Ecological groups			S	%	n	%	S	%	n	%	S	%	n	%	S	%	n	%	S	%	n	%	S	%	n	%
I	Layer preferences	atmobiotic	2	7.7	0.02	0.6	5	13.5	0.09	2.3	5	17.9	0.14	4.1	3	10.3	0.04	1.3	3	9.4	0.03	1.0	12	21.1	0.06	1.9
		epigeic	6	23.1	1.05	29.4	8	21.6	1.04	26.7	7	25.0	1.72	50.8	6	20.7	1.54	51.1	6	18.8	0.92	30.6	10	17.5	1.25	37.2
		hemiedaphic	3	11.5	0.38	10.6	7	18.9	0.71	18.3	2	7.1	0.71	20.9	5	17.2	0.83	27.6	5	15.6	0.57	18.9	8	14.0	0.64	19.0
		euedaphic	12	46.2	2.07	58.0	15	40.6	1.92	49.4	12	42.9	0.76	22.4	13	44.9	0.58	19.3	15	46.8	1.41	46.8	23	40.4	1.35	39.9
		others	3	11.5	0.05	1.4	2	5.4	0.13	3.3	2	7.1	0.06	1.8	2	6.9	0.02	0.7	3	9.4	0.08	2.7	4	7.0	0.07	2.0
II	Moisture requirements	xerophilous	6	23.1	0.59	16.5	11	29.7	1.37	35.2	10	35.7	0.32	9.4	7	24.1	0.15	5.0	9	28.1	0.57	18.9	19	33.3	0.60	17.8
		mesohygrophilous	17	65.4	2.80	78.4	22	59.5	2.38	61.2	16	57.2	2.82	83.2	19	65.5	2.26	75.1	21	65.6	2.20	73.1	33	57.9	2.49	73.8
		hygrophilous	2	7.7	0.17	4.8	4	10.8	0.14	3.6	2	7.1	0.25	7.4	3	10.4	0.60	19.9	2	6.3	0.24	8.0	4	7.0	0.28	8.3
		unknown	1	3.8	0.01	0.3	0	0	0	0	0	0	0	0	0	0	0.	0	0	0	0	0	1	1.8	0.01	0.1
III	Ecological plasticity	eurytopic	12	46.3	2.64	73.7	13	35.1	2.10	54.0	11	39.3	1.58	46.6	8	27.7	1.48	49.2	11	34.3	1.62	53.8	16	28.0	1.88	55.8
		forest polytopic	0	0	0	0	3	8.1	0.07	1.8	0	0	0	0	1	3.4	0.01	0.3	1	3.1	0.01	0.3	3	5.3	0.02	0.5
		forest oligotopic	0	0	0	0	0	0	0	0	0	0	0	0	1	3.4	0.01	0.3	0	0	0	0	1	1.8	<0.01	0.1
		open area polytopic	9	34.6	0.49	13.7	13	35.1	0.71	18.3	9	32.1	1.63	48.1	11	38.0	1.42	47.2	10	31.3	0.86	28.6	17	29.7	1.02	30.3
		open area oligotopic	1	3.8	0.39	10.9	4	10.9	0.86	22.1	5	17.9	0.11	3.2	2	6.9	0.02	0.7	4	12.5	0.31	10.3	9	15.8	0.34	10.0
		myrmecophilous	2	7.7	0.04	1.1	2	5.4	0.13	3.3	2	7.1	0.06	1.8	1	3.4	0.01	0.3	3	9.4	0.08	2.7	3	5.3	0.06	1.9
		corticophilous	1	3.8	0.01	0.3	0	0	0	0	0	0	0	0	1	3.4	0.01	0.3	0	0	0	0	1	1.8	<0.01	0.1
		compost	0	0	0	0	2	5.4	0.02	0.5	1	3.6	0.01	0.3	4	13.8	0.05	1.7	3	9.4	0.13	4.3	6	10.5	0.04	1.2
		unknown	1	3.8	0.01	0.3	0	0	0	0	0	0	0	0	0	0	0.	0	0	0	0	0	1	1.8	<0.01	0.1

Table XIX. Percentage contribution of chosen ecological groups to *Collembola* communities in anthropogenic urban soil of Warsaw (housing estate lawns); S – number of species, n – abundance in thous. ind./m^2

Habitat			Urban greenery (housing estate lawns)												Housing estate greenery			
Locality			Wierzbno								MDM							
No of station			IV–17				IV–18				IV–19							
Ecological groups			S	%	n	%	S	%	n	%	S	%	n	%	S	%	n	%
I	Layer preferences	atmobiotic	4	12.5	0.43	24.7	5	16.7	0.29	14.6	2	6.9	0.26	8.0	7	15.2	0.33	14.0
		epigeic	5	15.6	0.26	14.9	4	13.3	0.73	36.7	8	27.6	0.74	22.8	8	17.4	0.58	24.8
		hemiedaphic	6	18.8	0.48	27.6	5	16.7	0.47	23.6	6	20.7	0.71	21.8	10	21.7	0.55	23.8
		euedaphic	16	50.0	0.56	32.2	14	46.6	0.40	20.1	12	41.4	1.49	45.9	19	41.3	0.82	35.1
		others	1	3.1	0.01	0.6	2	6.7	0.10	5.0	1	3.4	0.05	1.5	2	4.4	0.05	2.3
II	Moisture requirements	xerophilous	9	28.1	0.25	14.4	7	23.3	0.43	21.6	6	20.7	1.06	32.6	11	23.9	0.58	25.0
		mesohygrophilous	19	59.4	1.28	73.6	20	66.7	1.43	71.9	19	65.5	1.99	61.2	29	63.1	1.57	67.3
		hygrophilous	1	3.1	0.17	9.7	1	3.3	0.11	5.5	3	10.4	0.19	5.9	3	6.5	0.16	6.7
		unknown	3	9.4	0.04	2.3	2	6.7	0.02	1.0	1	3.4	0.01	0.3	3	6.5	0.02	1.0
III	Ecological plasticity	eurytopic	13	40.6	0.87	50.0	11	36.7	1.08	54.3	11	37.9	1.32	40.6	15	32.6	1.09	46.9
		forest polytopic	1	3.1	0.07	4.0	3	10.0	0.08	4.0	0	0	0	0	4	8.7	0.05	2.1
		forest oligotopic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		open area polytopic	11	34.4	0.70	40.2	11	36.7	0.69	34.7	7	24.1	1.22	37.6	13	28.2	0.87	37.4
		open area oligotopic	3	9.4	0.05	2.9	1	3.3	0.02	1.0	3	10.3	0.42	12.9	4	8.7	0.17	7.0
		myrmecophilous	1	3.1	0.01	0.6	2	6.7	0.10	5.0	1	3.5	0.05	1.5	2	4.4	0.05	2.3
		corticophilous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		compost	1	3.1	0.01	0.6	1	3.3	0.01	0.5	6	20.7	0.23	7.1	6	13.0	0.08	3.6
		unknown	2	6.3	0.03	1.7	1	3.3	0.01	0.5	1	3.5	0.01	0.3	2	4.4	0.02	0.7

Table XX. Percentage contribution of chosen ecological groups to *Collembola* communities in

Habitat			Urban greenery											
Locality			Ujazdowskie Avenue				Żwirki i Wigury Avenue							
No of station			IV–20				IV–21				IV–22			
Ecological groups			*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%
I	Layer preferences	atmobiotic	2	7.4	0.02	1.8	3	9.4	0.05	0.7	3	11.1	0.06	1.5
		epigeic	5	18.5	0.68	60.2	6	18.8	2.42	34.2	6	22.2	1.32	32.0
		hemiedaphic	4	14.8	0.16	14.2	8	25.0	2.16	30.5	4	14.8	1.88	45.6
		euedaphic	14	51.9	0.24	21.2	13	40.6	2.29	32.3	12	44.5	0.59	14.3
		others	2	7.4	0.03	2.6	2	6.2	0.16	2.3	2	7.4	0.27	6.6
II	Moisture requirements	xerophilous	8	29.6	0.14	12.4	6	18.8	1.61	22.7	8	29.6	0.44	10.7
		mesohygrophilous	16	59.3	0.95	84.1	22	68.7	5.34	75.4	16	59.3	3.44	83.5
		hygrophilous	2	7.4	0.03	2.6	4	12.5	0.13	1.9	3	11.1	0.24	5.8
		unknown	1	3.7	0.01	0.9	0	0	0	0	0	0	0	0
III	Ecological plasticity	eurytopic	10	37.1	0.76	67.3	10	31.3	2.68	37.8	8	29.6	2.40	58.3
		forest polytopic	1	3.7	0.01	0.9	0	0	0	0	1	3.7	0.01	0.2
		forest oligotopic	0	0	0	0	0	0	0	0	0	0	0	0
		open area polytopic	9	33.3	0.24	21.2	15	46.9	2.83	40.0	12	44.5	1.32	32.0
		open area oligotopic	4	14.8	0.08	7.1	2	6.2	0.79	11.1	3	11.1	0.11	2.7
		myrmecophilous	2	7.4	0.03	2.6	2	6.2	0.16	2.3	2	7.4	0.27	6.6
		corticophilous	0	0	0	0	0	0	0	0	0	0	0	0
		compost	0	0	0	0	3	9.4	0.62	8.8	1	3.7	0.01	0.2
		unknown	1	3.7	0.01	0.9	0	0	0	0	0	0	0	0

Collembola communities from dried up soil of street lawns were noted for an almost equally high quantitative contribution of xerophilous species as the communities from housing estate lawns and for a decidedly lower share of hygrophilous species.

Ecological plasticity

The communities from all the sites in Warsaw were dominated by open area and eurytopic species (both with respect to the number of species as well as to their abundance); the share of any other ecological plasticity group never exceeded 10% (Tabs XVIII–XX). Generally in park lawns the most abundant were eurytopic species, in housing estate lawns the share of eurytopes and open area species was approximately the same: while in street lawns open area species were slightly more abundant that eurytopes.

Among the open area species the dominating were polytopic species, and only exceptionally abundance of oligotopic species approximated that of politopes. Housing estate lawns were marked for usually the greatest quantitative share of anthropogenic urban soil of Warsaw (street lawns); S – number of species, n – abundance in thous. ind./m^2

(street lawns)												Streetside greenery			
Marszałkowska St.				Woronicza St.				Zbawiciela Sq.							
IV-23				IV-24				IV-25							
S	%	n	%	S	%	n	%	S	%	n	%	S	%	n	%
2	6.9	0.01	0.4	1	3.1	0.01	0.4	3	10.3	0.03	0.4	9	16.4	0.03	0.7
5	517.2	0.76	30.5	9	28.2	0.63	27.9	7	24.2	2.34	32.6	11	20.0	1.36	33.6
5	17.2	0.47	18.9	5	15.6	0.28	12.4	4	13.8	1.89	26.3	10	18.2	1.14	28.2
15	51.8	1.12	45.0	16	50.0	1.18	52.2	13	44.8	2.82	39.2	23	41.8	1.38	34.0
2	6.9	0.13	5.2	1	3.1	0.16	7.1	2	6.9	0.11	1.5	2	3.6	0.14	3.5
9	31.0	0.45	18.1	9	28.2	0.74	32.7	8	27.6	2.30	32.0	15	27.2	0.95	23.4
18	62.1	1.94	77.9	18	56.2	1.30	57.6	17	58.6	4.54	63.1	33	60.0	2.92	72.2
1	3.5	0.01	0.4	2	6.2	0.19	8.4	2	6.9	0.30	4.2	4	7.3	0.15	3.7
1	3.4	0.09	3.6	3	9.4	0.03	1.3	2	6.9	0.05	0.7	3	5.5	0.03	0.7
10	34.5	1.08	43.5	12	37.5	1.00	44.2	9	31.0	2.50	34.8	15	27.2	1.74	43.0
1	3.4	0.01	0.4	1	3.1	0.01	0.4	1	3.4	0.01	0.1	4	7.3	0.01	0.2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	34.6	0.82	32.9	10	31.3	0.58	25.8	8	27.7	2.29	31.8	17	30.9	1.35	33.3
2	6.9	0.21	8.4	4	12.5	0.47	20.8	5	17.2	2.14	29.8	9	16.4	0.63	15.7
2	6.9	0.13	5.2	1	3.1	0.16	7.1	2	6.9	0.11	1.5	2	3.6	0.14	3.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	10.3	0.15	6.0	1	3.1	0.01	0.4	2	6.9	0.09	1.3	5	9.1	0.15	3.6
1	3.4	0.09	3.6	3	9.4	0.03	1.3	2	6.9	0.05	0.7	3	5.5	0.03	0.7

polytopic open area species, while park lawns – for their least contribution. The share of oligotopic open area species was distinctly the highest in communites from street lawns, and the lowest – in housing estate lawns. It is characteristic that communities from lawns in old parks (Łazienki Park, Saxon Garden) were marked for high or very high contribution of oligotopic open area species, while the communities from new park lawns (Cemetery-Mausoleum of Soviet Soldiers) – for a very low one.

4.5. Similarity analysis of *Collembola* communities in the studied habitats

Clustering. Anthropogenic pressure provoked significant changes in species composition of *Collembola* communities. It shows clearly while applying the cluster classification method for evaluating the degree of faunistic (qualitative) as well as coenotic (quantitative) similarity of *Collembola* communities in soil of the studied sites (Figs 9, 10).

As regards species composition, forest communities were noted to stand out most distinctly of all the examined *Collembola* communities. Only the community from the degraded forest at Białołęka Dworska resembled in its species composition that of park communities and of certain street lawns, both the ones situated near parks and those completely isolated. Besides communities from natural forest soil, also the community from a field at Belsk Mały was distinctively distinguishable.

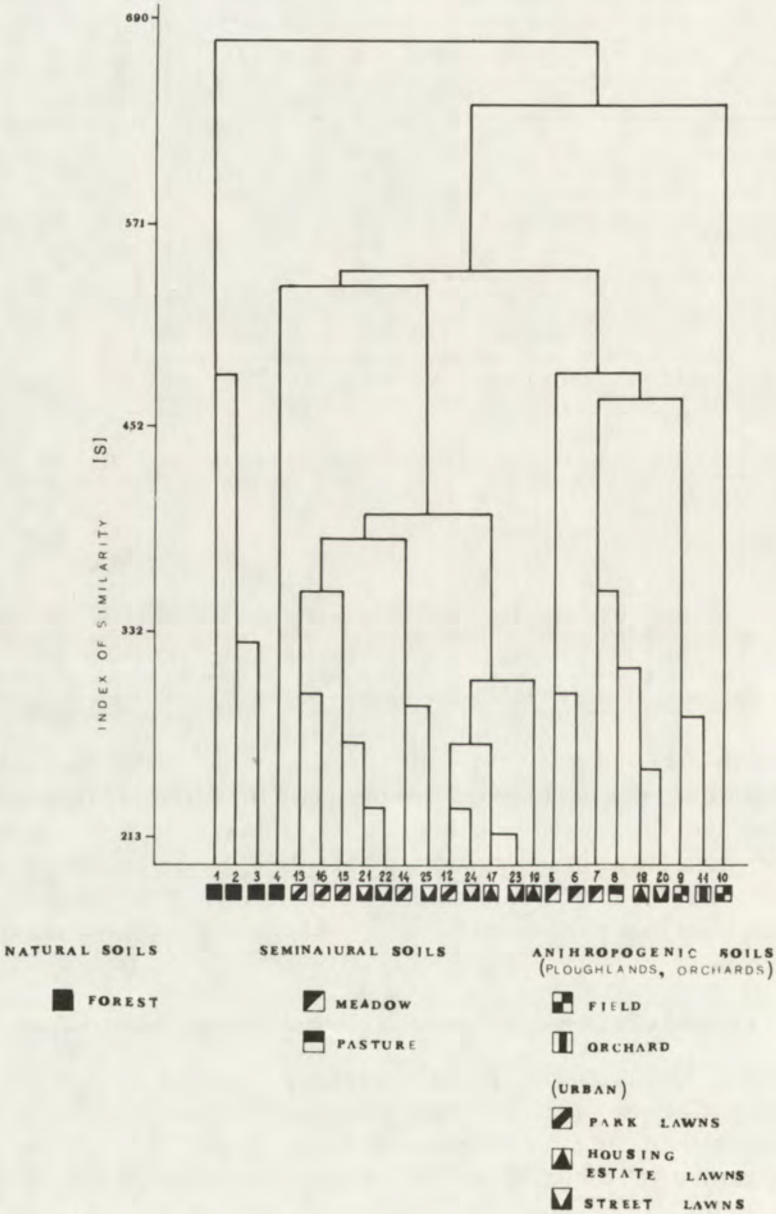

Fig. 9. Faunistic (qualitative) similarity (*S*) of *Collembola* communities in the examined sites of linden-oak-hornbeam habitats on the Mazovian Lowland; station numbers — see Table I, II.

Collembola communities from urban greens were clearly akin to the communities found in soil of open areas and meadows.

Coenotic classification, which considered not only the occurrence of species but also abundance of particular species, differed from faunistic classification, mainly in

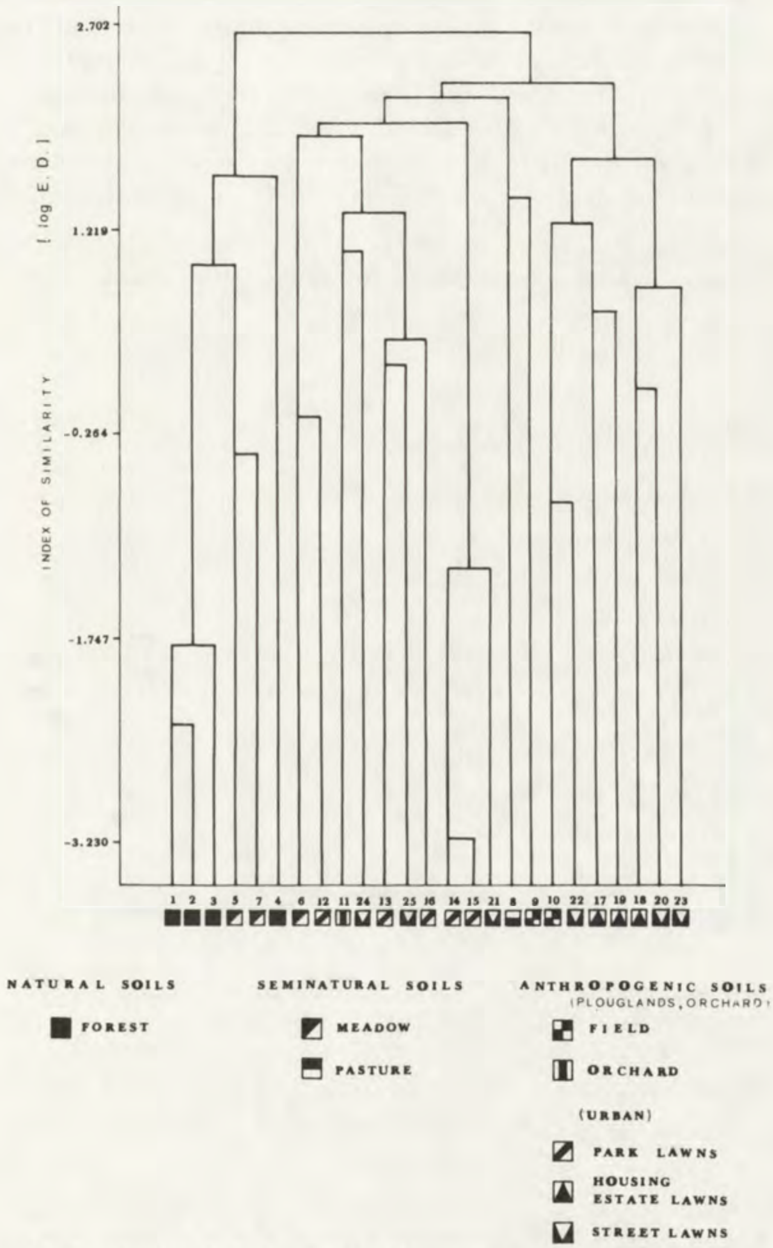

Fig. 10. Coenotic (quantitative) similarity (E. D.) of *Collembola* communities in the examined sites of linden-oak-hornbeam habitats on the Mazovian Lowland; station numbers – see Table I, II.

the fact that in case of coenotic analysis similarity between the studied communities was lower. Similarly as in the faunistic dendrogram, communities from natural forest soil formed a distinctive group completely unlike to communities from all the other habitats. Also in this case only the community from the forest at Białołęka Dworska, where the tree stand was much light-penetrated (which favoured a more abundant occurrence of photophilous or sward species), was similar to communities found in meadow soil. Urban communities were more akin to those occured in soil of open areas (especially of pastures and fields) than to forest communities.

Ordination. Position of subsequent *Collembola* communities from the studied sites was ordered on the basis of quantitative data (species abundance) and the correlated habitat variability (in this case according to intensifying anthropogenic

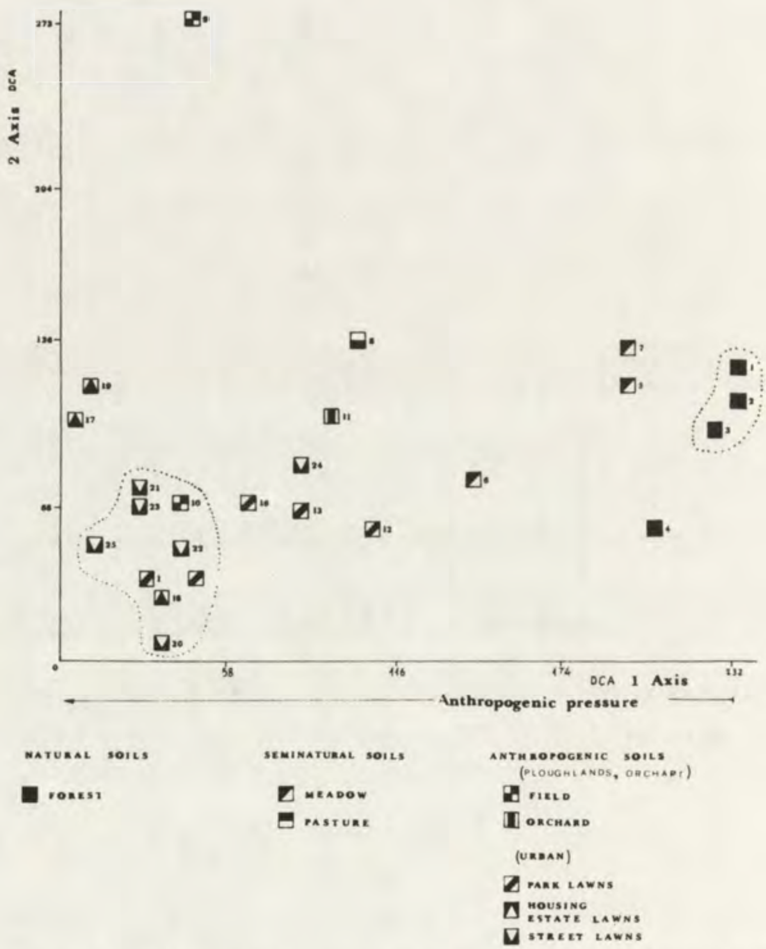

Fig. 11. Ordination (DCA) of *Collembola* communities in linden-oak-hornbeam habitats on the Mazovian Lowland in anthropogenic pressure gradient; station numbers – see Table I, II.

pressure). A very pronounced polarization was observed of *Collembola* communities within the habitat of linden-oak-hornbeam forest on the Mazovian Lowland (Fig. 11). *Collembola* communities from natural forest soil and semi-natural meadow grouped on the right side of the first axis, while on the left side of the axis communities from anthropogenic soil – both urban and of crop fields – were located. *Collembola* communities from natural forest soil occupied the most outward place on the right side of the first axis, except for the community from the forest at Białołęka Dworska, which more resembled the communities occurring in the meadow soil. Distribution of communities from meadow soil in the examined gradient was markedly more diversified than of the communities from natural forest soil. Communities from the meadow sites at Chylice and Białołęka Dworska, whose soil contained large amounts of humus, were notably alike and betrayed more freatures of natural communities than the meadow communities from soil of a low organic matter content and lesser fertility, as, e.g. in Klembów. Even more transformed community occurred in the examined pasture *Lolio-Cynosuretum* at Zbroszki, whose soil was marked for little fertility and low humus content in the A_1 humus accumulation horizon (Tab. II). Communities from the old park Łazienki, where the vegetation of its lawns is more similar to the alliance *Cynosurion* than *Arrhenatherion*, and whose soil had a considerable organic matter content, were akin to communities from soil of pasture, meadow and orchard. The left side of the first axis was distinctly occupied by communities from very much transformed urban soil. The extreme position on the axis was taken by communities from much dried-up and alkalinized soil, both in older housing estates in the city center and in modern housing estates on the outskirts of the city. A majority of communities found in ploughland soil clustered in the studied gradient, near the communities from street lawns, certain housing estate lawn soil and park lawn soil primarily under agricultural use (Cemetery-Mausoleum of Soviet Soldiers). Only the community from pseudogley soil of a crop field at Białołęka Dworska occupied the most outward position both on the first as well as on the second axis. The community was much transformed due to agricultural pressure, yet totally dissimilar to the communities occurring in usually much dried-up, urban soil (Fig. 11).

Two way indicator species analysis. Employing faunistic data, distinctively distinguishable at the first hierarchic level were communities from forest soil, with the indicatory species *Onychiurus affinis* (Fig. 12). The indicator of communities from fertile meadows of the type *Arrhenatheretum medioeuropaeum*, under variously intensive use, was hygrophilous meadow species *Lepidocyrtus ruber*. Communities from much anthropogenized habitats, i.e. urban greens, crop fields, pastures, orchard and degraded forest at Białołęka Dworska, were marked for the presence of *Isotoma viridis*, indicative for urban communities being the following species: *Sminthurinus aureus, Willemia intermedia, Stenaphorura quadrispina, Deuterosminthurinus repandus, Bourletiella hortensis* and *Folsomia fimetaria*. The characteristic species of communities from crop fields within the studied habitat of linden-oak-hornbeam forest, was a small soil species *Mesaphorura hylophila*.

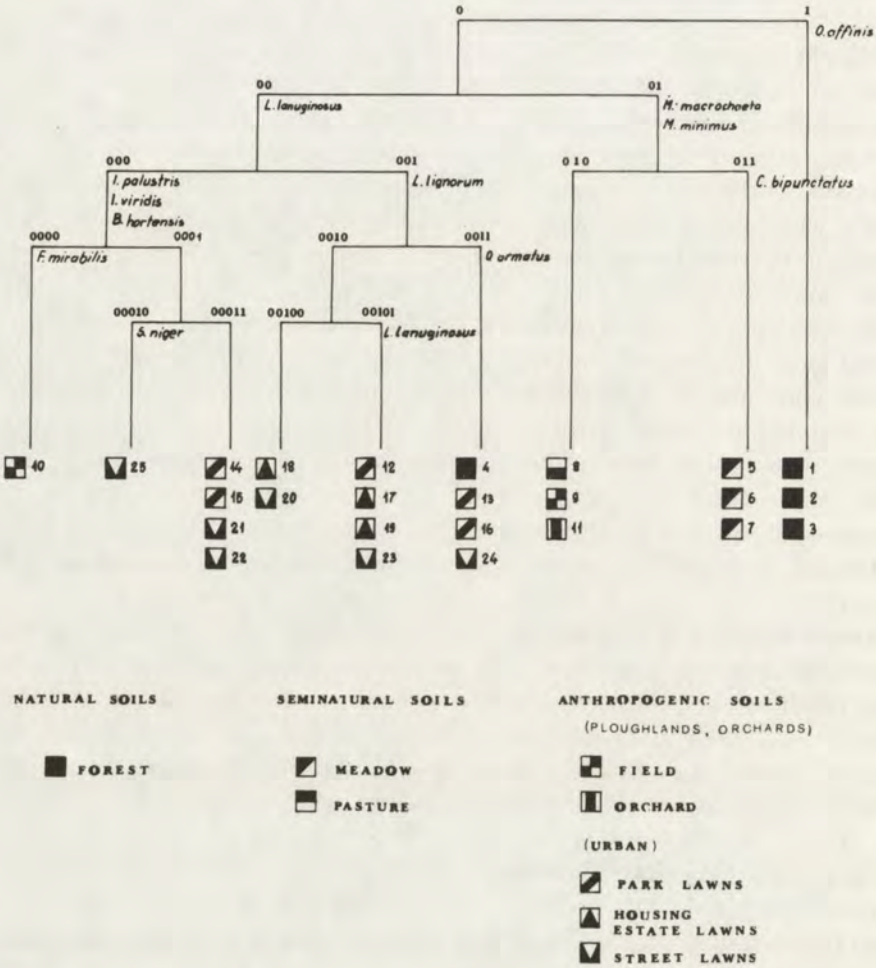

Fig. 12. Hierarchic ordering of *Collembola* communities and indicatory species distinguished, on the basis of faunistic by TWINSPAN method in the examined linden-oak-hornbeam habitats on the Mazovian Lowland; station numbers – see Table I, II.

In case of hierarchic arrangement on the basis of faunistic and coenotic data, also distinctively distinguishable at the first level were communities from natural forest soil with indicatory species *Onychiurus affinis* (Fig. 13). At the second level of hierarchization there came up communities from urban soil and crop field soil as well as communities from linden-oak-hornbeam forest at Białołęka Dworska, while the indicator of these communities was *Lepidocyrtus lanuginosus*. The species also turned up at lower levels of the hierarchic analysis, being the characteristics species of certain stations in urban greens. At the same level as *Lepidocyrtus lanuginosus*, the indicatory species for communities from intensively used soil and from agrocoenosis (crop fields, orchard), were *Mesaphorura macrochaeta* and *Megalothorax minimus*. At the third level of the arrangement, *Collembola* communities from seminatural soil of moist meadows of the type *Arrhenatheretum medioeuropaeum*, were marked for their indicative species *Cyrtopygus bipunctatus*. Co-occurrence of the species: *Isotomurus palustris, Isotoma viridis* and *Bourletiella hortensis*, was characteristic of field communities as well as of certain communities from urban greens (mostly of

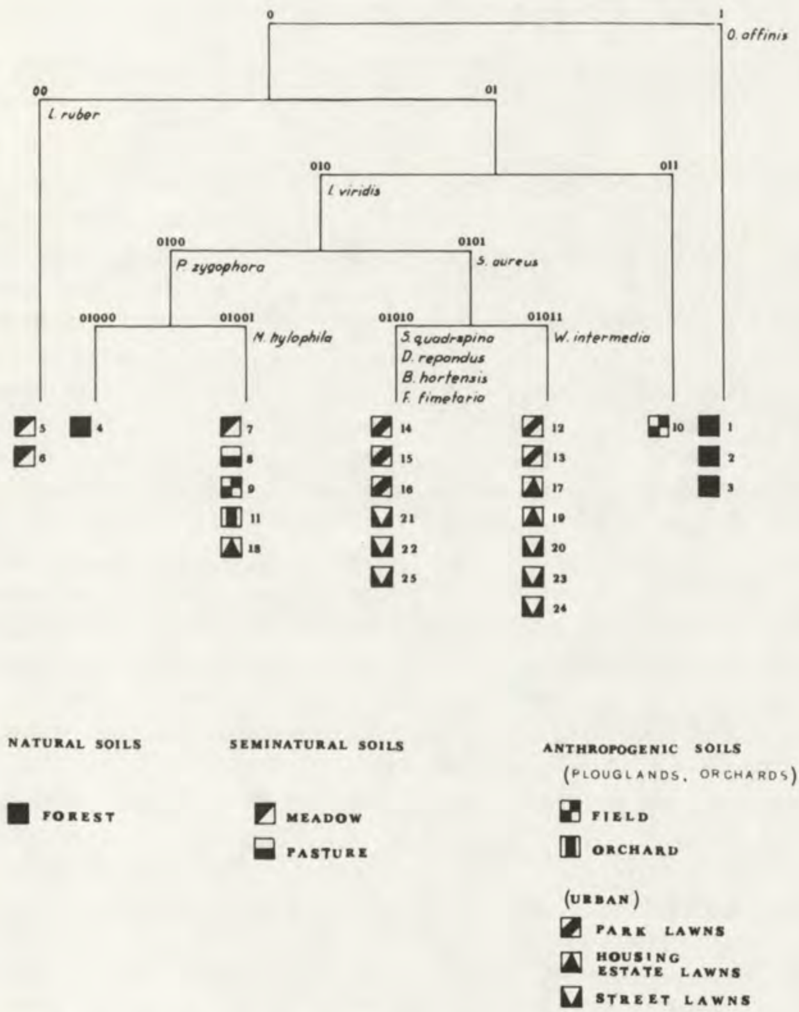

Fig. 13. Hierarchic ordering of *Collembola* communities and indicatory species distinguished, on the basis of faunistic and quantitative data, by TWINSPAN method in the examined linden-oak-hornbeam habitats on the Mazovian Lowland; station numbers – see Table I, II.

communities found in lawns set up in place of former crop fields or in entirely isolated street lawns).

On the basis of the acquired data, *Onychiurus affinis* may be considered a characteristic species of *Collembola* communities from lowland linden-oak-hornbeam forests (*Tilio-Carpinetum typicum*). Communities from transformed, anthropogenic soil (urban and crop field soil) are marked for the occurrence of two species: *Isotoma viridis* and *Lepidocyrtus lignorum*, while the presence of *Lepidocyrtus ruber* is indicative for communities from meadows of the type *Arrhenatheretum medioeuropaeum*.

5. CHANGES IN *COLLEMBOLA* COMMUNITIES DUE TO ANTHROPOGENIC IMPACT

The group of characteristics species

On the basis of dominance index and the criterion of occurrence constancy, there were distinguished species characteristic of the habitat of linden-oak-hornbeam forest and their contribution was compared in communities under diverse and variously intensive anthropogenic pressure (Fig. 14). In natural and semi-natural habitats, the dominating and constant species in *Collembola* communities was *Folsomia quadrioculata*, the species commonly regarded as eurytopes. It reacts strongly to the impact of anthropogenic pressure and is practically eliminated from the communities in ploughland soil, orchard and urban soil. Equally constant and dominating species was *Onychiurus armatus*, which, however, a lot prefered ploughland soil (of crop field habitats). *Isotoma notabilis* abounded in habitats very much transformed by man, e.g. of crop fields or urban green, or, mainly, of street lawns. *Lepidocyrtus lanuginosus* [described as "rare", bound to light, mainly sandy soils, found in forest litter and grass (Snider 1967)], was abundantly found in the studied habitats only in the anthropogenized forest at Białołęka Dworska and in park lawns. The constant eurytopic species *Mesaphorura macrochaeta* was most numerously found in communities from semi-natural meadow soil; its share in communities from urban soil was much smaller. *Friesea mirabilis*, although inabundant, was a constant species in *Collembola* communities from natural forest soil and semi-natural meadow soil; in anthropogenic ploughland and urban soil its constancy of occurrence in communities decidedly diminished. *Pseudosinella zygophora* was a constant species in forest communities, being inabundant and rare elsewhere. The absolutely constant species highly contributing to all the *Collembola* communities from urban greens was typically meadow species *Isotoma viridis;* moreover, the species was constant and abundant in semi-natural meadow soil, yet its contribution to meadow communities was pronouncedly smaller than to those from urban greens. *Lepidocyrtus lignorum* prefered meadows of all the studied habitats; it was also fairly constant in urban communities. Another constant species prefering open areas in the studied habitats of linden-oak-hornbeam forests was *Mesaphorura krausbaueri*. Myrmecophilous species (*Cyphoderus albinus* and *Entomobryides myrmecophilus*) were very constant in

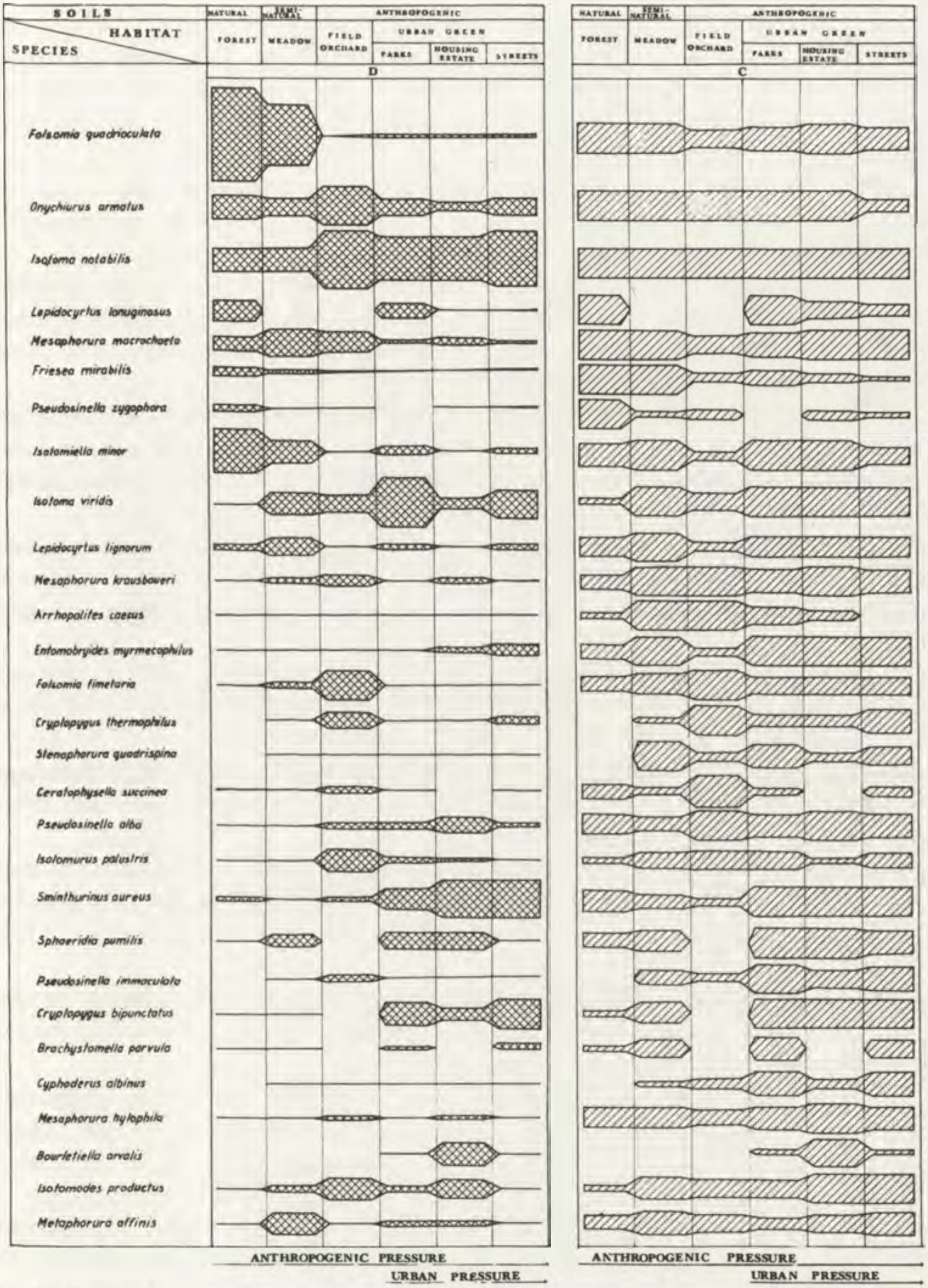

Fig. 14. Impact of anthropogenic pressure on the occurrence of *Collembola* dominating and constant species in the examined sites of linden-oak-hornbeam habitats on the Mazovian Lowland; *D* – index of species dominance; *C* – index of species constancy.

urban communities due to numerous occurrence of terricolous ant nests in Warsaw urban greens (Pisarski, Czechowski 1978). The course of changes in percentage contribution and species constancy of *Collembola* communities in the studied sites allows for distinguishing several groups of species variously reacting to anthropogenic pressure, namely.

1. Constant and dominating eurytopic species from natural forest soil and semi-natural meadow soil, increasing their contribution to communities under anthropogenic pressure: *Isotoma notabilis.*

2. Constant and usually dominating species in forest and meadow communities, whose contribution to communities from soil under strong anthropogenic pressure (urban and ploughland soil) markedly diminished: *Folsomia quadrioculata, Mesaphorura macrochaeta, Friesea mirabilis, Isotomiella minor.*

3. Inabundant species usually rather rare in communities from forest and meadow soil, which rapidly increased their dominance and constance in urban communities: *Cryptopygus bipunctatus, Sminthurinus aureus, Bourletiella arvalis, Brachystomella parvula, Entomobryodes myrmecophilus, Pseudosinella alba.*

4. Species of high constancy and a relatively high contribution only in forest communities, very inabundant and rare in the other studied habitats: *Pseudosinella zygophora* and *Lepidocyrtus lanuginosus* (the latter, however, being relatively abundant and constant in park lawns).

5. Constant and dominating species in meadow communities, which increased their abundance and remined highly constant in communities from soil under strong anthropopressure: *Isotoma viridis, Sphaeridia pumilis.*

6. Constant and dominating meadow species, which decreased their abundance in habitats influented by a strong agricultural and urbanizational pressure: *Metaphorura affinis, Lepidocyrtus lignorum.*

7. Species prefering ploughland soil, diminishing their dominance in communities from urban soil: *Onychiurus armatus, Isotomodes productus, Mesaphorura hylophila, Pseudosinella immaculata, Isotomurus palustris, Folsomia fimetaria, Mesaphorura krausbaueris.*

8. Species very inabundant in all the studied habitats, yet differing in their habitat preferences as evidenced by the constancy index: *Arrhopalites caecus, Cyphoderus albinus, Stenaphorura quadrispina.*

It is difficult to distinguish characteristic (selective) species of linden-oak-hornbeam forest (*Tilio-Carpinetum*), i.e. a climactic community in the studied habitats of linden-oak-hornbeam forest on the Mazovian Lowland, as the *Collembola* communities of the studied sites were composed mainly of eurytopic or polytopic forest species (*Folsomia quadrioculata, Isotomiella minor, Mesaphorura macrochaeta, Lepidocyrtus lanuginosus, Pseudosinella zygophora).* Nonethelless, the group of dominating and constant species of natural soil in *Tilio-Carpinetum* was observed to undergo considerable changes in habitats under strong anthropopressure. The species better adopted to anthropogenically transformed habitats were those prefering meadow plant communities, such as *Isotoma viridis, Brachystomella* *parvula, Pseudosinella alba, Cryptopygus bipunctatus.* A typically anthropophilous species is *Isotoma notabilis*, a common eurytopes species, markedly increasing its abundance in communities in anthropogenic habitats. A species sensitive to anthropogenic pressure is *Folsomia quadrioculata*, which was common in meadow and forest communities, yet receded from communities in anthropogenic habitats. Among dominating and constant species, the most characteristic of transformed urban soil were *Isotoma notabilis, Isotoma viridis, Sminthurinus aureus, Cryptopygus bipunctatus*, while of ploughland and orchard soil: *Isotoma notabilis, Onychiurus armatus* and *Folsomia fimetaria.*

Species constancy

The effect of anthropogenic pressure in the studied habitats were changes in species constancy (Fig. 15). The most transformed ("J"-shaped) course of constancy curve characterized the communities of *Collembola* from ploughland and orchard soil. A "U"-shaped course of the curve marked the community of *Collembola* from natural forest soil. A modified, more acute course of the constancy curve for the communities from forest soil in total, resulted from the fact that the analysis of forest habitats included also the community from strongly degraded forest at Białołęka Dworska. The community of *Collembola* from Białołęka Dworska was conspicuous for an entirely different species composition than the other forest communities, which caused a decrease in the number of constant species in the studied forest habitats and, consequently, strongly deviated the course of the analyzed curve. *Collembola* communities occurring in semi-natural soil of meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosuretum*) were marked for the course of

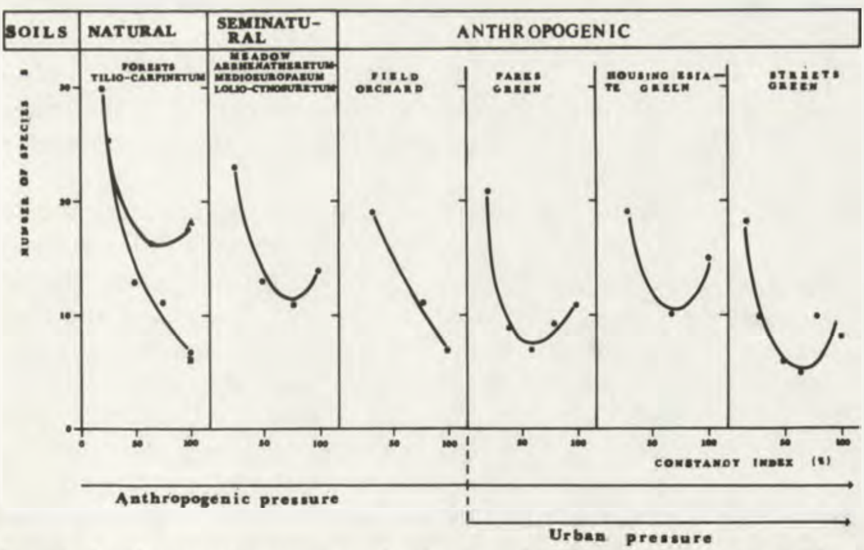

Fig. 15. Impact of anthropogenic pressure on the structure of *Collembola* communities in the examined sites of linden-oak-hornbeam habitats on the Mazovian Lowland, evaluated by species constancy index; S – number of species; C – species constancy index (%).

constancy curve similar to that featuring communities from anthropogenic soil of urban lawns, though communities from housing estate lawns lacked the group of influential species, while in those from street lawns the number of absolutely constant species distinctively tended to diminish. Nonetheless, for all these communities a "U"-shaped course of the curve was recorded, which is characteristic of all the animal communities occurring in biocoenosis that preserved natural features (Trojan 1980).

It follows from the analysis of the course of species constancy curve that the strongest effect on *Collembola* communities had agricultural pressure; less stronger was the effect of urbanizational pressure.

Biocoenological indices

Anthropogenic pressure causes structural changes in *Collembola* communities, which was reflected in the values of several basic biocoenotic indices (Fig. 16).

Comparing *Collembola* communities from natural and semi-natural habitats to those from very much anthropogenized habitats, such as ploughlands or urban greens, it was noted that agricultural pressure reduces the number of species, while urbanizational pressure increases their number. Obviously, the higher number of total *Collembola* species occurring in urban greens resulted from a great diversity of urban communities of *Collembola*; in particular types of urban greens the number of species was lower than in communities from forest or meadow soil. Such considerable diversity of *Collembola* communities in urban soil was indicative of a great variety of urban habitat conditions. As regards urban soil, the greatest number of species was estimated in soil of park and street lawns.

Strong agricultural and urbanizational pressure was accompanied by a rapid decrease in abundance of *Collembola* communities. The most abundant in all the studied habitats of linden-oak-hornbeam forest were *Collembola* communities from semi-natural soil of meadows and pastures (*Arrhenatheretum medioeuropaeum* and *Lolio-Cynosuretum*), while pronouncedly the least abundant were the communities from crop fields and orchards. Among urban habitats, the most abundant were communities from street lawn soil.

Anthropogenic pressure was not observed to affect significantly the degree of species diversity. The approximate values of species diversity indices estimated for the communities from the studied natural and anthropogenic soil, resulted from a modified dominance structure of communities from ploughland and orchard as well as urban soil. The modification consisted mainly in an overall greater eveness of contribution of particular species to the community, due, in the first place, to diminished relative abundance of dominating species, and, secondly, due to an increased abundance of several species sporadically found in natural and semi-natural habitats. In case of urban communities, the values of species diversity indices were the lower for communities from street lawns, notwithstanding the great number of species occurring there, while the highest values of these indices were calculated for communities from park lawns. It was directly related to a greater disproportion of shares of particular species in street communities, as compared to those from park lawns.

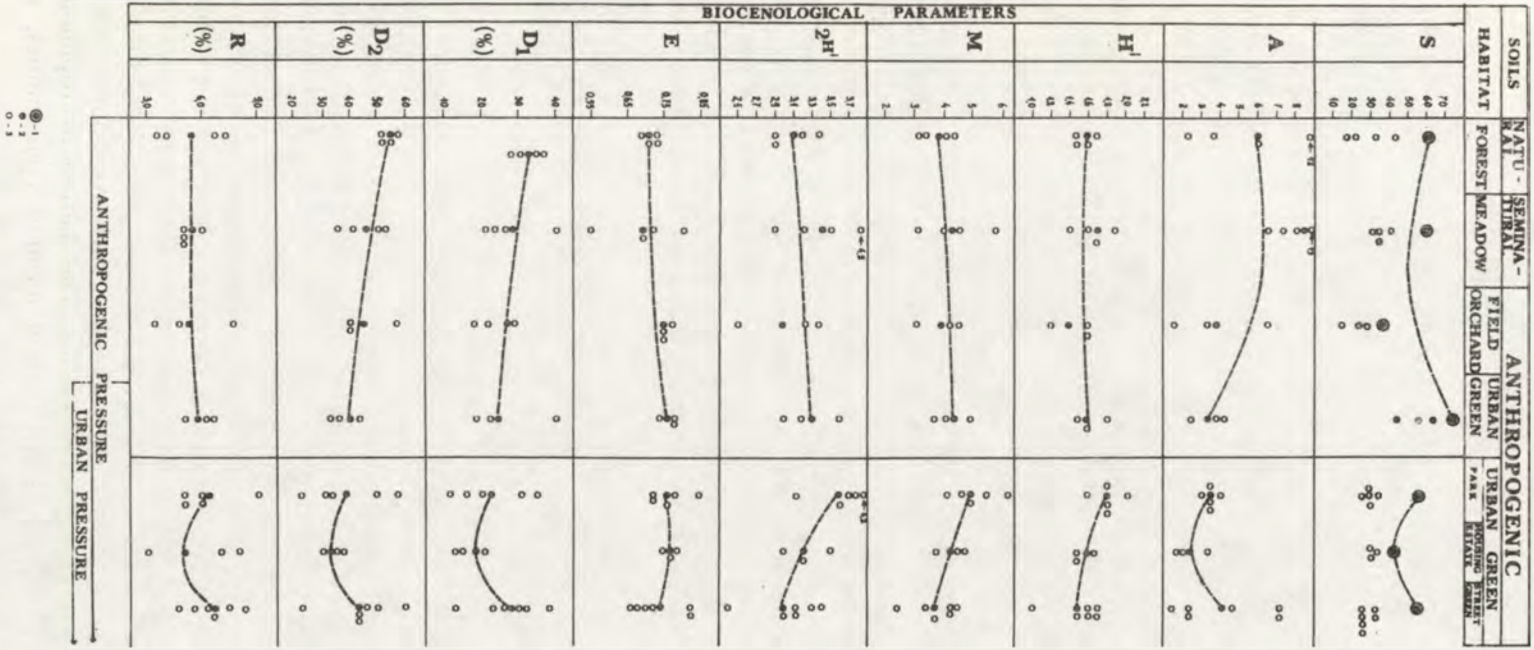

Fig. 16. Impact of anthropogenic pressure on values of chosen biocoenological indices in the examined *Collembola* communities of linden-oak-hornbeam habitats on the Mazovian Lowland; *S* – number of species; *A* – mean monthly density in thous. ind./m^2; *H* – SHANNON-WEAVER's index of species diversity; *M* – SIMPSON's species diversity index; 2^H – species diversity index after RUSEK (1984); *E* – PIELOU's eveness index; D_1, D_2 – species dominance indices (%), *R* – index of contribution of "rare" species (%).

Ecological structure

The communities of *Collembola* from various habitats of linden-oak-hornbeam forest on Mazovian Lowland differed in the contributon of species having various habitat requirements (soil layer and soil moisture preferences) as well as having diversified ecological plasticity, estimated on the basis of the number of species and their abundance (Fig. 17).

Considering the shares of the distinguished soil layer elements it was found out that with respect to abundance the dominating were euedaphic species, followed by hemiedaphic and epigeic species; the contribution of atmobiotic species to communities was slight. Atmobiotic and epigeic species were decidedly of greatest significance in communities from urban greens and, to a lower exent, in meadow communities. A greater share of these species in communities from meadows and urban greens may result not only from the presence and compactnesss of the soil layer but also from a regular sod mowing, which stimulates vertical migration of atmobios and epigeon. Clearly the smallest contributon had epigeic species to communities from soil of natural linden-oak-hornbeam forests, where the herb layer was the poorest. A compact sod layer in the linden-oak-hornbeam forest at Białołęka Dworska caused that contribution of epigeic species to the community from this habitat resembled their share in meadow communities. *Collembola* communities from natural forest habitats were marked for the greatest contribution of hemiedaphic species owing to the occurrence of thick litter layer (A_{OL}); hemiedaphic species had the lowest share in communities from crop fields and urban greens. The contribution of hemiedaphic species to communities from these two types of habitats was similar, although urban lawns were marked for the regular occurrence of fairly well developed sod layer. Scarcity of hemiedaphic species in these habitats was caused by gardening mentiones i.e. lawn mowing and remowed of the plant. The share of euedaphic species was high in ploughland and meadow communities and decidedly lower in forest and urban communities. The low number and inabundance of typically euedaphic species in urban communities was caused by a strong drying up of urban soil and its poor aeration.

In each habitat the contribution of particular moisture groups differed markedly. In all the studied habitats *Collembola* communities were dominated by mesophilous species. The greatest contribution of this group of species was noted to the communities from natural forest habitats, where the shares of the other moisture groups were insignificant *Collembola* communities from the other habitats were marked for a considerable number and specimen abundance of xerophilous and hygrophilous species. In all the studied habitats the contribution of xerophilous species was considerably greater than of hygrophilous species. Meadow communities were marked for the most levelled-out shares of hygro- and xerophilous species, while in crop field and orchard communities the ratio of the shares of xerophilous to hygrophilous species was notably the greatest (the latter were also distinguished for the highest relative share of xerophilous species and, exclusive of forest communities, the lowest contribution of hygrophilous species). The share of hygrophilous species in urban communities was similar to that in meadow communities, while the

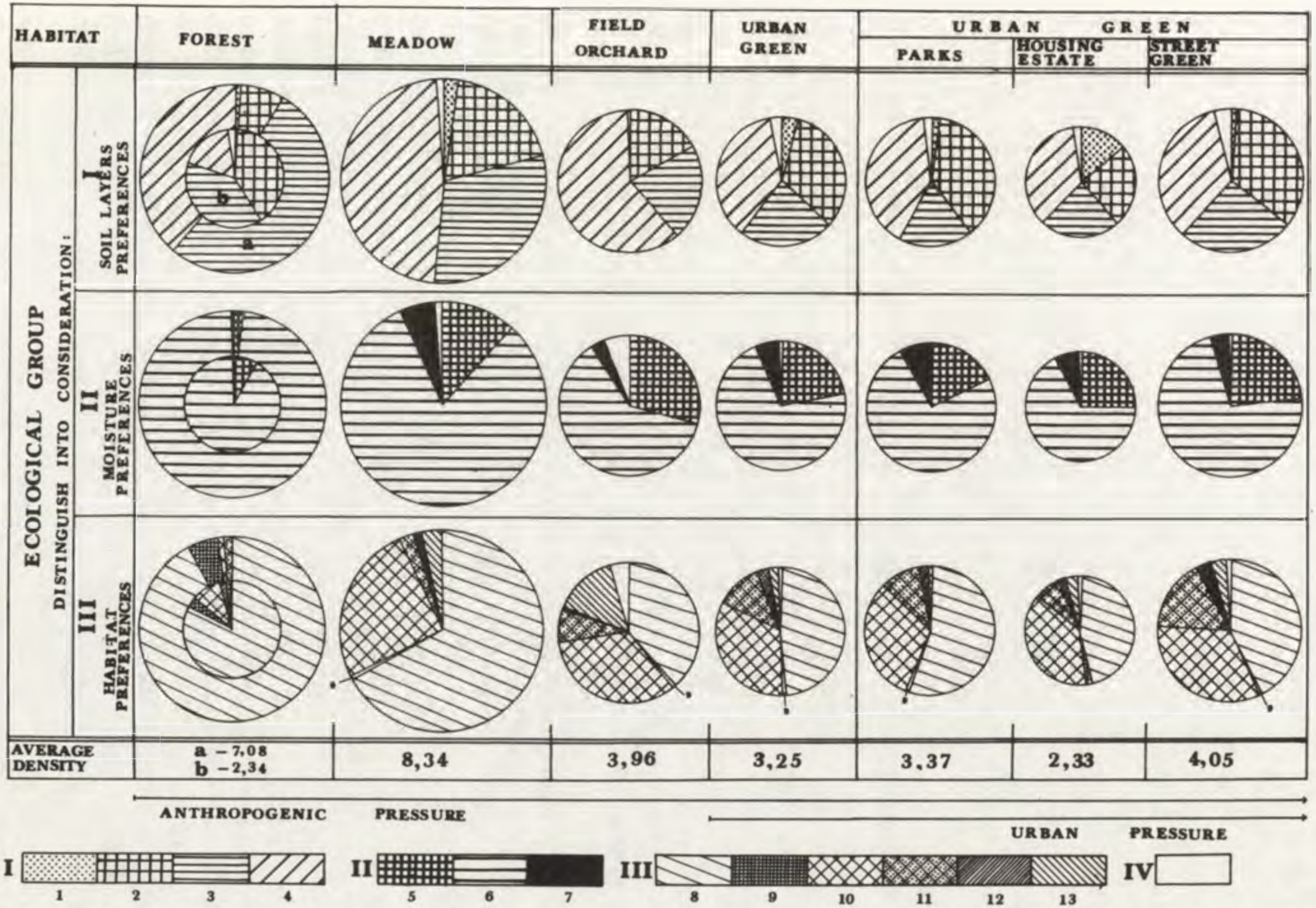

Fig. 17. Mean density and ecological structure of *Collembola* communities in the studied sites of linden-oak-hornbeam habitats on the Mazovian Lowland; percentage contribution of ecological groups; layer preferences I (1 – atmobios, 2 – epigeon, 3 – hemiedaphon, 4 – euedaphon), moisture preferences (5 – xerophilous, 6 – mesophilous, 7 – hygrophilous species), ecological plasticity (8 – eurytopes, 9 – forest polytopes, 10 – forest oligotopes, 11 – polytopes of open areas, 12 – oligotopes of open areas, 13 – myrmecophilous species, 14 – compost species), species of unknown habitat preferences IV.

contribution of xerophilous species was intermediate between that to meadow and crop field communities. In case of communities from various types of urban greens, the share of hygrophilous species was the lower in communities from dried-up soil of street lawns, while the highest – in communities from park lawns.

While analyzing the range of species tolerance of a definite biotope type it was found out that forest species highly contributed to *Collembola* communities from linden-oak-hornbeam forests *Tilio-Carpinetum typicum* (their share in communities from the other habitats was slender. Moreover, these communities were decidedly dominated by eurytopic species, yet a part of this group was constituted by eurytopes coming from forest habitats and prefering forest habitats (e.g. *Isotomiella minor, Folsomia quadrioculata*). In meadow communities, beside the dominating eurytopes, also open area species quantitatively prevailed (similarly as in case of communities from crop fields, orchard and urban greens). As compared to communities from meadows, the share of eurytopic species in communities from crop fields and orchard distinctively diminished, the share of open area species increased and the contribution of compost species was very high. The share of particular groups of species in communities from urban greens resembled that in the studied meadows, although notably greater was the contribution of oligotopic open area species to the former. Communities from urban greens (similarly as the ones from meadows) were marked for a relatively abundant participation of compost and myrmecophilous species. An increase in the share of compost species was caused by domestic waste heaped up in urban habitats, while an increase in the abundance of myrmecophilous species resulted from a greater abundance of ants building underground nests in soil of urban lawns.

It follows from the comparison of *Collembola* communities from urban greens to those from the other habitats that the ecological structure of the former resembled the most that of the communities from soil meadows of the type *Arrhenatheretum medioeuropaeum*. Moreover, attention should be paid to the community of *Collembola* from the forest at Białołęka Dworska, which betrays a number of features intermediate between forest and meadow communities. In *Collembola* communities from much anthropogenized habitats, such as crop fields or urban greens quantitative contribution of species of a wide spectrum of ecological tolerance decreased (the share of eurytopic and mesophilous species diminished), while quite abundant were species of a lower tolerance range (and increase in the share of species bound to open areas, especially of oligotopic and xerophilous species). The recorded tendencies corresponded, to some extent, to the "allocation principle" (Levins 1968 acc. to Pianka 1981). Anthropogenic pressure seems to create such conditions in which more specialized *Collembola* species may often successfully compete with less specialized species of a wide tolerance range which use up the habitat less effectively.

6. DISCUSSION

Collembola communities from the studied forest soil of linden-oak-hornbeam forest habitat on the Mazovian Lowland were qualitatively lower diversified, yet were marked for a markedly distinct species composition as compared to the other examined habitats of linden-oak-hornbeam forests. The constant dominants included *Folsomia quadrioculata* and *Isotomiella minor*, the species frequently found in various types of plant communities, yet always dominating in deciduous forests, such as beech, oak or linden-oak-hornbeam forests (Loksa 1956a, Kaczmarek 1963, 1973, 1977, Szeptycki 1967, Weiner 1976, 1981). According to hierarchic analysis the characteristic species of the studied *Collembola* communities from *Tilio-Carpinetum* was *Onychiurus affinis*, the species scarcily and rarely found by other authors, yet mainly occurring in forest habitats (Stach 1954, Nosek 1964), including linden-oak-hornbeam forests (Kaczmarek 1977). Characteristic species of *Collembola* communities from *Tilio-Carpinetum* were not previously distinguished. Szeptycki (1967) was of an opinion that *Collembola* fauna of *Tilio-Carpinetum* in the Ojcowski National Park was intermediate between that of *Corylo-Peucedanetum* and *Fagetum carpaticum*, while certain properties characteristic of the two plant communities under comparison were betrayed by *Pseudachorutes parvulus*. It seems, however, that in case of the studied linden-oak-hornbeam forests of the Mazovian Lowland, it is better to regard a whole community of *Collembola* as characteristic of this habitat in spite of the fact that a majority of species making up the community ranks among eurytopes. Loksa (1956a, b) had an alike opinion on *Collembola* communities from Hungarian oak and beech forests.

Collembola communities from the studied forest soil were not very abundant (mean 7.08 thous. ind./m^2). The reason of their scantity may be, among others, the absence of stratification and, consequently, the lack of distinctly recognizable horizons in the organic layer of soil (the studied decidous forest *Tilio-Carpinetum* had a classical for this type of plant communities mull humus), which reduces the number of the availability micro-habitats (Anderson, Hall 1977). It is a well known fact that in forests soils with humus of the mull type, the guiding role in translocation of organic substances, aeration and its decomposition perform numerously occurring there large macrosaprophages (e.g. *Lumbricidae*), while mesosaprophages, including *Collembola*, are only of secondary significance (Wallwork 1976, Swift et al. 1979). It is also another reason of the occurrence of relatively inabundant and little diversified in species *Collembola* communities in the studied associations of linden-oak--hornbeam forest. A factor impeding the occurrence of several *Collembola* species may be also the composition of leafy litter determinating its peculiar chemism.

As compared to *Collembola* communities from natural forest soil, the community from the isolated forest at Białołęka Dworska was profoundly different, due to strong anthropogenization of the studied plot of linden-oak-hornbeam forest and the imposing effect of open areas which surround it. The community resembled those which occurred in urban parks set up in place of natural linden-oak-hornbeam forest associations.

Collembola communities from semi-natural meadow soil were fairly diversified, which seemed to result from various fertility and different use of particular meadows. Communities from very fertile soil were dominated (similarly as in natural linden-oak-hornbeam forests) by *Folsomia quadrioculata* (*Isotomiella minor* being the second dominant); in the community from pasture meadow the prevailing was a typically soil species *Mesaphorura macrochaeta*, while in the communities from relatively low fertile meadows *Isotomiella minor* and *Isotoma notabilis* dominated. The species selected as characteristic of all the meadows of the type *Arrhenatheretum medioeuropaeum* was *Lepidocyrtus ruber*, i.e. a species described as typical of moist meadows (Gisin 1943, Szeptycki 1967, Weiner 1981). Abundance of meadow communities of *Collembola* (relatively high, in general) was distinctly correlated with meadow fertility and, primarily, with the content of organic matter in the humus accumulation horizon A_1 as well as with the compactness and thickness of the sod layer, and only to a lower extent – with intensity of the meadow use. The most abundant communities of *Collembola* were recorded to occur in soil of very fertile meadows, which had a large content of organic matter (humus) and were under not very intensive use. Considerable differences were noted in values of species diversity indices estimated for particular *Collembola* communities from the studied meadows. It is difficult to ascribe them explicitly either to differences in fertility, moisture, density of the sod layer or to anthropogenic factors affecting meadows.

Agricultural pressure on the studied agrocoenosis caused marked changes of degrading character in the communities of *Collembola* (e.g. considerable reduction of species-richness abundance, usually disturbed dominance structure). Species diversity indices calculated for the studied crop field and orchard communities were relatively low and pointed to a conspicuous destabilization of *Collembola* communities. A noteworthy fact is that the species appointed as characteristic of *Collembola* communities from agrocoenosis in habitats of linden-oak-hornbeam forest on the Mazovian Lowland was *Mesaphorura hylophila*, i.e. a species reported by Rusek (1982) from *Querceto-Carpinetum* on brown soil with humus of the mull type and described as a characteristic species belonging to forest euedaphon. However, in the studied habitats of *Tilio-Carpinetum* the species on question was found mainly in dried-up soil (not only of crop fields but also in urban soil). Also according to Dunger (1986) *M. hylophila* ranked among the species prefering dried-up open (mainly meadow) habitats. Great diversity of urban communities of *Collembola*, as compared to the communities from the other habitats of linden-oak-hornbeam forest, were featured in each respect. Even the communities occurring in the same category of greens were found out to differ widely, e. g. in housing estate lawns and street lawns there were stations where *Collembola* communities were highly abundant and the others where community abundance was very low. The reason of this irregularity may likely be sought in micro-habitat conditions. Hardly any effect on abundance of *Collembola* communities had road traffic and related soil pollution with heavy metals (also physiologists are of an opinion that the effect of heavy metals on reproduction and survival rate of *Collembola* populations is questionable (Bengtsson, Gunarsson, Rundgren 1983).

Urbanizational pressure and environment changes it brings cause, among others, that urban development offers favourable conditions for many *Collembola* species to widespread. In this case several zoogeographical and habitat barriers are broken down. There appear species which nowhere else were recorded, i.e. *Cyphoderus bidenticulatus, Cryptopygus ponticus, Xenyllodes ghiljarovi* and typical synanthropic species such as *Folsomia candida* and *Seira domestica*. Certain species, although occurring in comparable habitats as well, in urban greens were markedly more abundant and frequent, namely, *Cryptopygus bipunctatus, Isotoma notabilis, I. viridis, Isotomurus palustris, Sminthurinus aureus* and others. On the other hand, urban communities of *Collembola* were characteristic for the lack of such a species, common in natural and semi-natural soil as *Folsomia quadrioculata*.

Diversity of *Collembola* communities from the studied urban greens, both with respect to their species composition, abundance as well as structure, issued from great spatial heterogeneity of Warsaw greens, both as regards abiotic and biotic factors and the occurrence of numerous ecotones habitats. The habitats of urban lawns differed in the degree of their eutrophization, alkalinity, contamination (e. g. with heavy metals), fertilization, soil profile mixing, intensity of trampling, densities and thickness of sod layer, etc.. Also the previous history of a site cannot be disregarded, i.e. its age, the type of plant community or the type of soil where the lawn was set up. Undoubtedly the reaction of particular populations as well as all the communities of *Collembola* to one and the same anthropogenic factor are very diversified, depending on the character (both with respect to abiotic and biotic factors) of the habitat populated by *Collembola*. It has been confirmed by experimental studies on the effect of herbicides commonly applied in agriculture on *Collembola*. It has been ascertained that the stress effect induced by the applied herbicide on *Collembola* population depends on the properties of the soil habitat where it was introduced (Fratello et al. 1986).

Soil *Collembola* are good indicators of the degree of transformation of the edaphic system. Both species composition and structure of *Collembola* communities were subject to definite characteristic changes under the influence of diverse and variously intensive anthropogenic pressure. In the studied habitats of linden-oak-hornbeam forest on the Mazovian Lowland, two types of anthropogenic pressure affecting *Collembola* communities were analyzed, namely, agricultural and urbanizational. Agricultural pressure reduced the number of species in the studied communities of *Collembola*, whereas urbanizational pressure increased their number. This type of reaction of soil zoocoenosis may be related to biotope structure (Weigmann 1987). If pressure (disturbance) increases heterogeneity of biotope structure (develops environment mosaic), as in urban greens, than the number of species increased, whereas unification of biotope structure (crop field monoculture, orchard) causes that their number decreases. Frequently great species diversity of zoocoenosis, in urban habitats in particular, is an off-shot not only of diversity of space but also of food resources (Frankie, Ehler 1978).

Anthropogenic pressure causes changes in the number of species but also it affects qualitative species composition of *Collembola* communities. It may even lead to total retreat of certain species and their replacement by new species, frequently alien to native fauna. or to an increase in abundance of species so far reported as rare. This is a general reaction of zoocoenosis (Pisarski, Trojan 1976a, b, c, Pisarski 1981).

Collembola species are greatly diversified in their ability and manner of reacting to disturbances in abiotic environment, as well as to biotic changes, as shown by the analysis of the course of changes in species constancy and percentage share (in total *Collembola* community abundance) of the species most characteristic of the habitat of linden-oak-hornbeam forest on the Mazovian Lowland, along with growing anthropogenic pressure. On the basis of this analysis several groups of species were distinguished, variously reacting to anthropogenic pressure (chapter 4. 6.). It seems that the best bioindicator in the group of species sensitive to anthropogenic pressure is *Folsomia quadrioculata* – the constant and dominating species in communities from natural forest soil and semi-natural meadow soil eliminated from ploughland and urban soil.

Agricultural as well as urbanizational pressure causes modifications in the ecological structure of *Collembola* communities. Species bound to litter layer retreated from crop field and urban communities of *Collembola;* species bound to the sward layer are almost entirely eliminated from crop field communities, while they constantly occur in urban communities (due to frequent mowing of lawns and vertical migration of these species). Owing to trampling and poor soil aeration the number of species and total specimen abundance of typically euedaphic species was observed to decrease in communities from urban lawns. Drying up of the habitat makes hygrophilous species recede from *Collembola* communities and favours the occurrence of xerophilous species, usually of those bound to open areas.

Anthropogenic pressure, both agricultural and urbanizational, diminishes abundance of *Collembola* communities; also their dominance structure is disadvantageously affected. In agrocoenosis *Collembola* communities are marked for a very high contribution of the dominating species and a slightly share of the group of accessorial species; in urbicoenosis the contribution of species to the community is more levelled out. Changes in dominance structure bring about differences in the values of species diversity and eveness indices – field communities attain low, while urban communities – relatively high values of these indices (often exceeding those estimated for natural habitats). The growth or decrease of the values of species diversity indices for the studied *Collembola* communities is directly induced by the increase or reduction of the species number and abatement or augmentation of disproportion in the shares of particular species in the community. In anthropogenized habitats, species diversity does not allow for an explicit assessement of the state of the studied *Collembola* communities.

Collembola communities from the examined urban lawns were decidedly more similar to communities from meadows and crop fields than to those from linden-oak-hornbeam forests. All the stations in Warsaw were located on the Vistula upper terrace, within the range of potential *Tilio-Carpinetum* vegetation. It should be therefore expected that *Collembola* communities from urban greens and especially from park lawns set up in place of natural linden-oak-hornbeam forest plots (frequently with fairly well preserved soil profile) would share faunistic as well as structural features of *Collembola* communities occurring in natural linden-oak-hornbeam forests, the more so as edaphic synosium is a conservative element of soil habitat (Dunger 1975, Rusek 1979, Petersen 1980). Nonetheless, urban communities of *Collembola* have hardly any features in common with the ones found in the habitats of natural linden-oak-hornbeam forests. First of all from the species composition of urban communities of *Collembola* there have been practically eliminated forest species and the species dominating in natural linden-oak-hornbeam forests (presently of a wide ecological valence orginated down from forest habitats (*Folsomia quadrioculata* or *Isotomiella minor*). Also the structure of urban communities of *Collembola* differ greatly from that of communities in natural linden-oak-hornbeam forests (e.g. by lower values of abundance index, lower share of accessorial species, greater species diversity). The analysis carried out on a *Collembola* community in a small anthropogenic plot of linden-oak-hornbeam forest at Białołęka Dworska revealed to what type of evolution urban communities of *Collembola* were subject. The community at Białołęka Dworska preserved a number of features common with the communities from natural linden-oak-hornbeam forests, yet is also marked for certain similarity to communities from crop fields and meadows, due to an inflow of meadow and field elements from the vicinity. The recorded similarity of urban fauna to the fauna of meadows, pastures and crop fields results from the fact that a majority of species making up urban communities numbers among immigrants from meadow and field habitats presently or formerly surrounding the site, whereas differences between them arose during long lasting effect of urbanizational pressure and, to a small extent, seem also to issue from the survival of local species.

7. SUMMARY AND CONCLUSIONS

1. In the studied soil of habitats of linden-oak-hornbeam forest (*Tilio-Carpinetum*) on the Mazovian Lowland, a total of 96 *Collembola* species was recorded, including 7 species new to the fauna of Poland and 25 new to the region. With respect to the number of species and specimen abundance, the dominating were euedaphic and hemiedaphic, mesophilous, eurytopic and open area species (Fig. 17).

2. *Collembola* communities from natural soil, of linden-oak-hornbeam forests were fairly inabundant (mean 6.01 thous. ind./m^2), had a properly developed dominance structure (Fig. 3) and were marked for a considerable contribution of forest species and eurytopes prefering forest habitats. The dominants were *Folsomia quadrioculata* and *Isotomiella minor*, the characteristic species was *Onychiurus affinis*. The community from a degraded linden-oak-hornbeam forest at Białołęka Dworska markedly differed from the former, resembling in many aspects *Collembola* communities from the studied meadows. The community was dominated by *Lepidocyrtus lanuginosus* and *Folsomia quadrioculata*.

3. *Collembola* communities from semi-natural meadow soil notably varied from forest communities (e.g. by a considerably greater share of open area species, slight

contribution of forest species), yet they preserved proper dominance structure (Fig. 4). In communities from very fertile meadows *Folsomia quadrioculata* and *Isotomiella minor* dominated, in communities from relatively low fertile meadows – *Isotomiella minor* and *Isotoma notabilis*, while on the pasture meadow – *Mesaphorura macrochaeta*. The characteristic species was *Lepidocyrtus ruber*. Meadow communities were generally fairly abundant (mean 8.83 thous. ind./m^2).

4. *Collembola* communities from agrocoenosis (crop fields, orchard) were marked for a distintly impoverished species composition, inabundance (mean 3.97 thous. ind./m^2), distorted dominance structure (Fig. 5), a considerably greater contribution of xerophilous and compost species, low share of hemiedaphic species and retreat of atmobiotic species. The dominating species were *Isotoma notabilis* and *Onychiurus armatus*, the characteristic species was *Mesaphorura hylophila*.

5. *Collembola* communities from Warsaw urban soil was marked, in every aspect, for the greatest diversity due to variability of soil habitats and anthropogenic factors operating in the city. Furthemore, as compared to communities from natural or semi-natural soil, urban communities were inabundant (mean 3.76 thous. ind./m^2), yet had a greater total number of species, greater contribution of xerophilous, myrmecophilous and compost species, lower share of hemiedaphic and euedaphic species. The effect of urbanization was also noted in the occurrence of species not recorded elsewhere, including synanthropic species as well as in a significant increase in the frequency of occurrence and abundance of rare species and species inabundant in the other studied habitats (e.g. *Cryptopygus bipunctatus*) or in retreat of species common in other habitats (e.g. *Folsomia quadrioculata*). The preferential species in urban communities of *Collembola* were *Sminthurinus aureus, Willemia intermedia, Stenaphorura quadrispina, Dueterosminthurus repandus, Bourletiella hortensis* and *Folsomia fimetaria;* it was characteristic that among the dominating species the following ones occurred: *Isotomurus palustris, Isotoma viridis* and *Bourletiella hortensis*.

6. Soil *Collembola* are good indicators of the type and degree or soil transformation in linden-oak-hornbeam habitat. It was noted that particular species or groups of species differed in their ability and manner of reacting to habitat disturbances caused by anthropogenic factors (Fig. 14). Good indicators for the assessment of the degree of degradation of *Collembola* communities were the number of species, characteristic species composition and dominance structure.

7. On the basis of the conducted analysis it was ascertained that *Collembola* fauna of Warsaw urban greens was of meadow origin (forest elements being preserved only in a small part) and it may be regarded as a variant of the fauna of cultivated open areas, whereas its peculiar urban traits are the consequence of exposure to long lasting urbanizational pressure.

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STRESZCZENIE

[Tytuł: Zgrupowania *Collembola* w naturalnych i przekształconych glebach siedliska grądowego Niziny Mazowieckiej]

Pierwotnie w krajobrazie Niziny Mazowieckiej dominowały lasy grądowe związane z bardzo żyznymi, najczęściej brunatnymi glebami. Do dzisiejszych czasów przetrwały tylko nieliczne i małe fragmenty naturalnych zespołów grądowych (*Tilio-Carpinetum*). W wyniku długotrwałej działalności człowieka przeważająca część lasów grądowych została wykarczowana i zagospodarowana. W konsekwencji, na terenie Niziny Mazowieckiej aktualnie dominują zastępcze zespoły roślinne łąkowe (*Arrhenatheretum medioeuropaeum*), pastwiskowe (*Lolio-Cynosuretum*), zespoły upraw polnych, sadów oraz zieleńców miejskich. Zmiany w zespołach roślinnych wywołane presją antropogeniczną powodują istotne zmiany w środowisku glebowym. Wykształcają się gleby antropogeniczne, często silnie zdegradowane, o znacznie zmienionych właściwościach w stosunku do naturalnych gleb leśnych czy łąkowych. Dotychczasowe badania nad zoocenozami glebowymi, w tym i zgrupowaniami *Collembola*, koncentrowały się przede wszystkim wokół zjawiska sukcesji, natomiast prawie zupełnie brak jest opracowań poświęconych zmianom jakie wywołują w zgrupowaniach *Collembola* procesy degradacyjne.

Głównym celem pracy było: określenie składu gatunkowego i dostarczenie informacji o występowaniu glebowych *Collembola* w badanych środowiskach na siedlisku grądowym Niziny Mazowieckiej; opisanie głównych typów zgrupowań funkcjonujących w naturalnych i w różnym stopniu przekształconych środowiskach w obrębie badanego siedliska grądowego; określenie gatunków lub zgrupowań *Collembola* charakterystycznych dla grądowych środowisk naturalnych i zdegradowanych; ocena zmian degradacyjnych zachodzących w składzie i strukturze zgrupowań *Collembola* na drodze porównania zgrupowań *Collembola* z naturalnych środowisk grądowych i poddanych działaniu presji antropogenicznych (głównie rolniczej i urbanizacyjnej) w obrębie tego samego siedliska; próba określenia pochodzenia zgrupowań *Collembola* występujących w glebach miejskich.

Badaniami objęto 25 stanowisk w czterech podstawowych typach środowisk: w naturalnych glebach lasu grądowego (*Tilio-Carpinetum*), w seminaturalnych glebach łąk grądowych (*Arrhenatheretum medioeuropaeum* i *Lolio-Cynosuretum*), w antropogenicznych glebach pól i sadu jabłoniowego (kulturoziemnych) i w antropogenicznych glebach zieleńców miejskich (urbanoziemnych). Ze wszystkich stanowisk próby pobierano metodami ilościowymi co miesiąc (w okresie od kwietnia do października) przy użyciu

stalowego cylindra o średnicy 5,1 cm. Próby pobierano w poziomie mineralnopróchniczym (A_1) do głębokości 10 cm, następnie ekstrahowano je w aparacie Tullgrena. Materiał wykorzystany w pracy był zebrany w latach 1976–1984. W tym czasie łącznie zebrano 2305 prób glebowych; 23447 okazów *Collembola*.

W przypadku każdego z wyróżnionych środowisk scharakteryzowano występujące w nim zgrupowania *Collembola* uwzględniając ich skład gatunkowy, liczebność, strukturę dominacyjną, różnorodność gatunkową oraz strukturę ekologiczną. Do analizy zgrupowań *Collembola* wykorzystano wskaźniki biocenologiczne – liczebności, dominacji i stałości gatunkowej oraz różnorodności gatunkowej (m.in. Shannon-Weavera, Simpsona, Pielou). Klasyfikację ekologiczną gatunków przeprowadzono uwzględniając plastyczność ekologiczną oraz wybiórczość środowiskową w stosunku do wilgotności i określonych warstw gleby. W celu określenia stopnia podobieństwa między zgrupowaniami *Collembola* z badanych stanowisk zastosowano numeryczne metody klasyfikacyjne (klastrową i ordynacji); również gatunki charakterystyczne dla zgrupowań *Collembola* z poszczególnych środowisk zostały wyodrębnione przy użyciu metody klasyfikacji numerycznej (metoda klasyfikacji hierarchicznej TWINSPAN). Na drodze porównania zgrupowań *Collembola* ze środowisk naturalnych i poddanych działaniu różnej (rolniczej i urbanizacyjnej) i w różnym stopniu nasilonej presji antropogenicznej prześledzono i oceniono charakter i stopień zmian zachodzących w badanych zgrupowaniach *Collembola*, oceniono przydatność ewentualnych wskaźników stopnia degradacji zgrupowań *Collembola* oraz możliwość wykorzystania *Collembola* jako indykatorów rodzaju i stopnia przekształcenia gleb siedliska grądowego, określono pochodzenie fauny *Collembola* zieleni miejskiej Warszawy.

W badanych glebach siedliska grądowego (*Tilio-Carpinetum*) Niziny Mazowieckiej stwierdzono łącznie 96 gatunków *Collembola* (w tym jeden dotychczas nie opisany, 7 nowych dla Polski, 25 nowych dla regionu). Pod względem liczby jak i liczebności dominują gatunki euedaficzne i hemiedaficzne, mezofilne, eurytopowe i terenów otwartych.

Zgrupowania *Collembola* z naturalnych gleb lasów grądowych charakteryzują się niezbyt wysoką liczebnością (średnio 6,01 tys. osob./m^2), prawidłowo wykształconą strukturą dominacyjną oraz znacznym udziałem gatunków leśnych i eurytopów preferujących środowiska leśne. Dominantami są *Folsomia quadrioculata* i *Isotomiella minor*; gatunkiem charakterystycznym jest *Onychiurus affinis*. Znacznie od nich odbiega zgrupowanie ze zdegradowanego lasu w Białołęce Dworskiej, pod wieloma względami podobne do zgrupowań *Collembola* z badanych łąk. Dominują w nim *Lepidocyrtus lanuginosus* i *Folsomia quadrioculata*.

Zgrupowania *Collembola* z seminaturalnych gleb łąkowych wyraźnie różnią się od zgrupowań leśnych (m.in. znacznie większy udział gatunków terenów otwartych, nikły udział gatunków leśnych), lecz zachowują prawidłową strukturę. W zgrupowaniach z łąk bardzo żyznych dominuje *Folsomia quadrioculata*, w zgrupowaniach z łąk o stosunkowo niskiej żyzności – zdecydowanie *Isotoma notabilis*, na pastwisku – *Mesaphorura macrochaeta*. Gatunkiem charakterystycznym jest *Lepidocyrtus ruber*. Liczebność zgrupowań łąkowych jest wysoka (średnio 8,83 tys. osob./m^2).

Zgrupowania *Collembola* agrocenoz (pola, sad) cechują się wyraźnie zubożonym składem gatunkowym, obniżoną liczebnością (średnio 3,97 tys. osob./m^2), zniekształconą strukturą dominacyjną i ekologiczną (znacznie zwiększonym udziałem gatunków kserofilnych i kompostowych, zmniejszonym udziałem gatunków hemiedaficznych, ustąpieniem gatunków atmobiotycznych). Gatunkami dominującymi są *Isotoma notabilis* i *Onychiurus armatus*; gatunkiem charakterystycznym jest *Mesaphorura hylophila*.

Zgrupowania skoczogonków z gleb miejskich Warszawy charakteryzuje pod każdym względem największa różnorodność – jest to konsekwencją silnego zróżnicowania środowisk glebowych i czynników antropogenicznych działających w mieście. Ponadto, w porównaniu do zgrupowań z gleb naturalnych czy seminaturalnych, cechuje je niższa liczebność (średnio 3,76 tys. osob./m^2), ale sumarycznie wyższa liczba gatunków, zwiększony udział gatunków kserofilnych, myrmekofilnych i kompostowych, zmniejszony udział gatunków hemiedaficznych i euedaficznych. Skutkiem urbanizacji jest też pojawienie się gatunków poza zielenią miejską nie stwierdzonych, w tym i gatunków synantropijnych, znaczny wzrost częstości występowania i liczebności gatunków rzadkich i mało liczebnych w innych badanych środowiskach (np. *Cryptopygus bipunctatus*), ustępowanie niektórych gatunków pospolitych w innych środowiskach (np. *Folsomia quadrioculata*). Gatunkami przewodnimi miejskich zgrupowań *Collembola* są: *Sminthurinus* *aureus*, *Willemia intermedia*, *Stenaphorura quadrispina*, *Deuterosminthurus repandus*, *Bourletiella hortensis* i *Folsomia fimetaria;* wśród gatunków dominujących charakterystyczne jest występowanie *Isotomurus palustris*, *Isotoma viridis* i *Bourletiella hortensis*.

Glebowe *Collembola* są dobrymi indykatorami rodzaju i stopnia przekształcenia gleb środowiska grądowego. Stwierdzono, że poszczególne gatunki lub ich grupy różnią się możliwościami i sposobem reakcji na zakłócenia w środowisku wywołane czynnikami antropogenicznymi. Dobrymi wskaźnikami dla oceny stopnia degradacji zgrupowań *Collembola* są: liczba gatunków, charakterystyczny skład gatunkowy i struktura dominacyjna.

W wyniku przeprowadzonej analizy stwierdzono, że fauna *Collembola* zieleni miejskiej Warszawy jest w dużej mierze pochodzenia łąkowego (elementy leśne zachowały się jedynie w nieznacznym stopniu); wydaje się, że można ją traktować jako wariant fauny terenów kulturowych, a jej swoiste cechy miejskie są konsekwencją działania presji urbanizacyjnej.

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