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THE FAUNA OF SPRINGTAILS (COLLEMBOLA) FROM THE FOREST ECOSYSTEMS OF SOUTH-EAST UKRAINE

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The Fauna of Springtails (Collembola) from the Forest Ecosystems of South-East Ukraine. Bondarenko-Borisova I. V., Sandul N. G. — The fauna of springtails (Collembola) was investigated for seven years in natural forest ecosystems of the Donetsk highland, namely in gully forests, flood-land forests and highland woods. The list of Collembola of forest habitats of the eastern Ukraine has been compiled basing on the original and literature data. It includes 115 species belonging to 52 genera and 16 families. The core of the fauna of Collembola in investigated forests is formed by such families as Entomobryidae, Onychiuridae and Isotomidae. Eight zoogeographical complexes of species were defined by the authors. The European, the Holarctic and the cosmopolitan complexes predominate in the number of species. Species richness, representation of ecological groups, life forms and Collembola hygromorphs differ in the three types of forests investigated. Most of the biotopes are characterized by the predominance of forest species, the considerable representation of eurybionts as well as meadow and steppe forms of species, the predominance of upper-litter biomorphs and a wide spectrum of hygromorphs. The ecological-faunistic peculiarities of springtails ecosystems reflect the specifics of forest microclimate in steppe and can be used for zoodiagnostics of natural and artifical forests.

Key words: Collembola, springtails, forest communities, gully forests, fauna, zoogeographical complexes, life forms, ecological groups, hygromorphs, sylvatization process, zoodiagnosis, biotops.

Фауна коллембол (Collembola) в лесных сообществах юго-востока Украины. Бондаренко-Борисова И. В., Сандул Н. Г. — В течение 7 лет изучали фауну ногохвосток в естественных лесах на Донецком кряже, а именно: в байрачных, пойменных и нагорных лесах. На основании авторских и литературных сведений составлен список коллембол лесных биотопов Левобережной Украины, включающий 115 видов из 52 родов и 16 семейств. Основу фауны исследованных лесов формируют семейства Entomobryidae, Onychiuridae и Isotomidae. Авторами выделено 8 зоогеографических видовых комплексов, среди которых преобладают (по числу видов) европейский, голарктический и космополитный. В трех исследованных вариантах лесов видовое богатство, соотношение экологических групп, жизненных форм и гигроморф коллембол отличаются. Большинству биотопов присуще долевое преобладание лесных видов и верхнеподстилочных биоморф, значительная представленность эврибионтных, луговых и степных форм, разнообразие спектра гигроморф. Эколого-фаунистические особенности сообществ ногохвосток отражают специфику лесного микроклимата и могут использоваться для зоодиагностики естественных и искусственных лесонасаждений в степной зоне.

Ключевые слова: коллемболы, ногохвостки, лесные ценозы, байрачные леса, фауна, зоогеографические комплексы, жизненные формы, экологические группы, гигроморфы, сильватизация, зоодиагностика, биотоп.

Introduction

The information about the fauna of Collembola of steppe zone of Ukraine is rather fragmentary. The investigation of nidicolous fauna of Collembola in the nature reserve "Chomutovskaya steppe" has recorded 49 species of Collembola (Мартынова, Скляр, 1973). The latter papers of A. A. Prokopenko (Прокопенко, 1988) provided information about the fauna of forest, flood plain, meadow and steppe habitats of eastern Ukrain comprizing 73 species belonging to 39 genera and 14 families (Прокопенко, 1988). I. P. Vtorov (Второв, 1988) mentioned 25 species of Collembola belonging to 7 families in his investigation of vertical distribution of microarthropods in the soil of gully forests of Dnepropetrovsk region. According to the summarizing data of M. V. Taraschuk (Таращук, 1995), 108 species of Collembola were registered in diverse habitats of eastern Ukraine (forest, steppe and flood plain biotopes).

Detailed research of representation of the forest fauna of Collembola in the steppe zone has not yet been conducted. Nevertheless, such data are of great importance for research and practice, since Collembola can serve as reliable bioindicators of abiotic (soil) and biotic onditions in forest ecosystems.

Our investigation was focused on the forests of Donetsk ridge. These forests are preserved rather well and occupy about 6% of the area, being usually located in depressions of relief (gullies and ravines) or on flood-lands. Climate should be defined as dry continental.

Material and methods

The material has been collected during 1993–2000 in central, northwest and southeast parts of Donetsk ridge (territory of Donetsk and Lugansk regions). On the whole, about 845 soil samples were collected and about 16 500 specimens of springtails were identified. In addition, more then 1000 specimens of Collembola were collected using qualitative methods (soil traps and exhauster).

Soil samples were taken with a metallic bore with cross-section of 25 cm^2 up to depth of 10 cm.

Samples of litter were taken from an area of 100 cm^2 each and extracted separately. Extraction of microarthropods was carried out in funnels of Tullgren-Berlese during 5–7 days. Collected specimens of springtails were fixed in 80% alcohol.

The list of species provided in this work is compiled according to the system given in the review "Collembola of USSR" (Определитель коллембол фауны СССР, 1988). Species identification was based on the recently published keys.

List of selected habitats

Gully forests

1. Debal'cevo — damp* gully oak-forest (Quercetum aceroso (campestrae)-aegopodiosum); soil and litter.
2. Yasinovataya — damp gully oak-forest (Quercetum aceroso (tatarici)-egopodiosum); soil and litter.
3. Donetsk — damp gully oak-forest (Quercetum aceroso (campestrae)-aegopodiosum); soil and litter.
4. Gorlovka — fresh gully oak-forest (Quercetum aceroso (tatarici)-aegopodiosum); (Quercetum aceroso (tatarici)-melicosum); soil and litter.
5. Village Proval'ye — dry gully forest; nature reserve "Provalskaya steppe": (Aceretum-quercetosum-ulmosum-chelidoniosum); soil and litter.

Flood lands forests

1. Village Dronovka, the flood-lands of the r. Severskiy Donets: (Quercetum-fraxniosum-aceriosum) and (Populetum nigrae); soil and litter.
2. Village Yampol', the flood-lands of the r. Cherniy Zherebets: (Alnetum glutinosae); soil and litter.
3. Village Stanichno-Luganskoye, the flood-lands of the r. Severskiy Donets, Lugansk state nature reserve: (Quercetum ulmosum) and (Populetum tremulae); soil and litter.

Highland forests

1. Village Bogorodichnoye, the right shore of the r. Severskiy Donets. (Quercetum aceroso (tatarici)-convallariosum) and (Pinetum (cretaceae) cotinoso-stipposum (pulcherrimae); soil and litter.

General characteristics of the springtails fauna

The material in the forests of Donetsk highland comprised 98 species of Collembola belonging to 50 genera and 15 families. The summarizing list taking into account the data of other investigators (Второв, 1988; Прокопенко, 1988) includes 115 species belonging to 52 genera and 16 families (tabl. 1). Approximately 58% of all species belong to the families Entomobryidae (30 species), Onychiuridae (19) and Isotomidae (18) (fig. 1). These three families form the core of faunistic complexes in each type of forests of the studied area. The families Hypogastruridae (9 species), Neanuridae (8), Katiannidae (8), and Sminthuridae (7) are rather rich in species. Contribution of the remaining families is rather small and does not exceed 5% of total number of species (fig. 1). Families Odontellidae, Tomoceridae and Sminthurididae as well as the monotypic family Poduridae were represented by a single species each.

The following species were recorded in Ukraine for the first time: *Xenylla uniseta* Gama, 1963, *Protaphorura furcifera* (Börner, 1901), *Pseudanurophorus quadrioculatus* Torne, 1955, *Jesenikia filiformis* Rusek, 1997, *Megalothorax incertus* Börner, 1903, and *Sminthurinus alpinus* sp. *bisetosus* (Ellis, 1976). Furthermore, *Hypogastrura* (*Ceratophysella*) *denticulata* Bagnal, 1941, *Xenylla maritima* Tullberg, 1869, *Mesaphorura hylophyla* Rusek, 1982, *M. sylvatica* Rusek, 1982, *Doutnacia xerophyla* Rusek, 1974,

* Typological division of gully forests into damp, fresh and dry ones is given after S. A. Gensiruk (Генсирук, 1975).

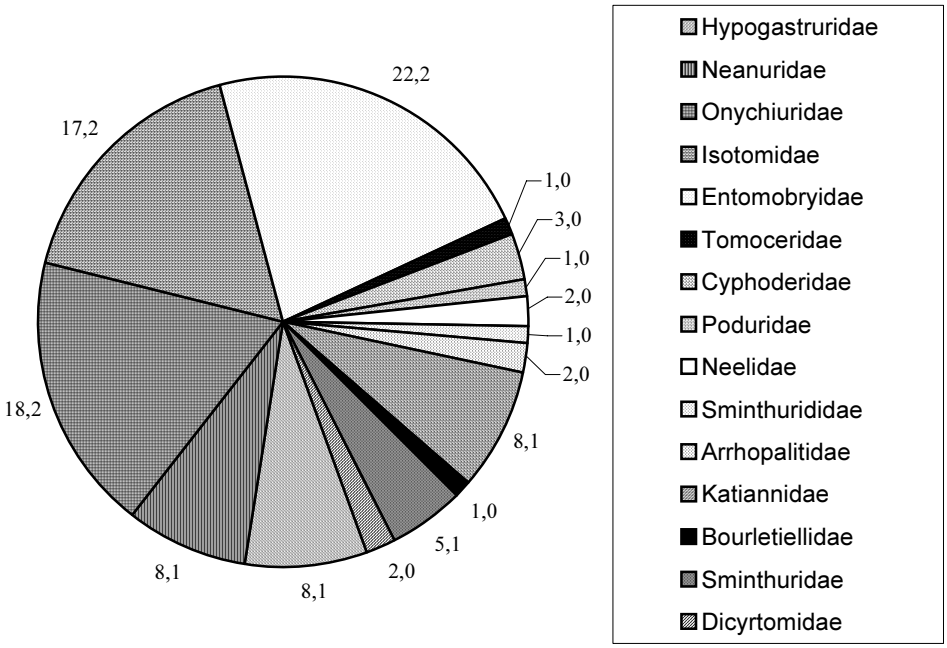

Fig. 1. Taxonomic structure of Collembola fauna in the natural forests (as a whole) of South-East Ukraine, %.

Рис. 1. Таксономическая структура коллембол фауны естественных лесов (в целом) юго-восточной Украины, %.

Pseudosinella imparipunctata Gisin, 1953, *Cyphoderus bidenticulatus* (Parona, 1888), *Arrhopalites principalis* Stach, 1945, *Sminthurinus trinotatus* (Axelson, 1905), and *S.* (*Gisinianus*) *flammeolus* (Gisin, 1957) were noted for the first time in eastern Ukraine.

Table 1. List of Collembola species in natural forests of steppe-zone of Ukraine (according to original and literature data)

Таблица 1. Видовой состав коллембол в естественных лесах степной зоны Украины (по оригинальным и литературным данным)

Species	Gully forests	Flood-lands forests	Highland forests	
			oak	pine
1	2	3	4	5
HYPOGASTRURIDAE				
Hypogastrura (*Ceratophysella*)*denticulata* Bagn., 1941 *	B	–	–	–
H. (*C.*) *succinea* Gisin, 1949	B	B	P, B	–
H. (*H.*) *assimilis* (Krausbauer, 1898)	V	–	–	–
H. (*H.*) *socialis* (Uzel, 1891)	–	B	–	–
Shoetella ununguiculata (Tullb., 1869)	–	P, B	P, B	P, B
Xenylla maritima s. l. Tullb., 1869 *	B	–	–	–
X. boerneri Axelson, 1905	B	–	–	–
X. corticalis Boerner, 1901	B	B	–	–
X. uniseta Gama, 1963 **	B	–	B	–
Willemia scandinavica s. l. Stach, 1949	B	B	B	–
ODONTELLIDAE				
Xenyllodes (*Pseudoxenyllodes*) *macrocanthus* Kuz. & Pot. 1988	–	–	P	–
NEANURIDAE				
Friesea s. str. *mirabilis* (Tullb., 1871)	B	B	–	P
Brachystomella parvula (Shaffer, 1896)	B	B	–	–
B. curvula Gisin, 1948	B	–	B	–
Pseudachorutes dubius Krausbauer, 1898	B	–	P	P
Anurida sp.	B	–	–	–
Neanura muscorum (Templ., 1835)	B	P, B	P, B	P, B

Table 1 (*continued*)

1	2	3	4	5
Endonura tetrophthalma (Stach, 1929)	B	B	B	–
Achorutes (*Lathriopyga*) *stachi* (Gisin, 1952)	–	–	–	P
ONYCHIURIDAE				
Oligaphorura uralica (Khanislamova, 1986)*	B	–	–	–
O. sp.	–	B	–	–
Protaphorura serbica Loksa & Bogojevic, 1967	B	B	B	B
P. octopunctata (Tullb., 1876)	–	–	–	P
P. aurantiaca Ridley, 1880	B	B	B	–
P. campata Gisin, 1952	B	B	B	B
P. armata (Tullb., 1869)	B	P	P, B	–
P. meridiata Gisin, 1952	B	B	B	B
P. furcifera Boerner, 1901**	B	B	–	–
Mesaphorura krausbaueri (Boerner, 1901)	V, B	P, B	B	P, B
M. macrochaeta Rusek, 1976*	B	–	B	B
M. hylophyla Rusek, 1982*	B	–	–	–
M. italica Rusek, 1971	B	–	–	–
M. sylvatica Rusek, 1982*	B	–	–	–
M. critica Rusek, 1982	B	–	–	–
Metaphorura affinis (Boerner, 1902)	V, B	P, B	–	–
Stenaphorurella quadrispina (Boerner, 1901)	V, B	–	–	–
Neonaphorura adulta (Gisin, 1944)	V, B	–	–	–
Doutnacia xerophyla Rusek, 1974*	B	–	–	–
ISOTOMIDAE				
Anurophorus laricis Nic., 1842*	B	–	–	–
Jesenikia filiformis Rusek, 1997**	B	–	–	–
Pseudonurophorus quadrioculatus Toern., 1955**	B	–	–	–
Folsomides parvulus Stach, 1922	B	–	–	–
Folsomia manolachei (Bagnall, 1939)	B	B	B	B
F. volgensis Mart., 1967	V, B	B	B	B
F. fimetaria Stach, 1947	B	B	P, B	P, B
F. candida Stach, 1947	B	–	–	–
F. quadrioculata (Tullb., 1871)	V, B	P, B	P, B	P
Isotomiella minor (Shaff., 1896)	V, B	P, B	P, B	P, B
Proisotoma minuta (Tullb., 1871)	B	–	–	–
Cryptopygus (*Isotomina*) *thermophylus* (Axels., 1900)	B	B	–	B
Pseudofolsomia acanthella Martynova, 1971	V	–	–	–
Isotoma anglicana Lubbock, 1862	B	B	B	B
I. viridis (Bourlet, 1839)	B	P, B	P	P
I. tigrina (Nicolet, 1842)	B	–	–	–
I. (*Parisotoma*) *notabilis* Shaff., 1896	V, B	P, B	P, B	P, B
Vertagopus cinereus (Nic., 1841)	B	–	–	–
ENTOMOBRYIDAE				
Heteromurus nitidus (Templeton, 1835)	B	–	P	–
Entomobrya arborea (Tullb., 1871)	B	–	–	–
E. corticalis Nicolet, 1842	–	–	–	P
E. lanuginosa Nicolet, 1842	–	–	–	P
E. nivalis (L., 1758)	B	–	–	P
E. muscorum Nicolet, 1842	–	P	P	P
E. multifasciata (Tullb., 1871)	V, B	B	B	P, B
E. marginata (Tullb., 1871)	V, B	–	–	P
E. handschini Stach, 1922	B	–	–	–
E. puncteola Uzel, 1891	–	–	P	–
Entomobryoides myrmecofila Reuter, 1886	B	B	P, B	P, B
Sinella sp.	V	–	–	–
Orchesella taurica Stach, 1960	V, B	B	B	P, B
O. cincta (L., 1758)	B	–	P, B	P, B
O. pseudobifasciata Stach, 1960	–	–	P	–
O. multifasciata Stscherb., 1898	V, B	P	P	–
Lepidocyrtus violaceus (Geoffroy, 1762)	B	–	–	–
L. lignorum (Fabricius, 1775)	B	P, B	P	B
L. paradoxus Uzel, 1891	V, B	B	–	–
L. cyaneus (Tullb., 1871)	B	P, B	P, B	P, B
L. lanuginosus (Gmelin, 1788)	V, B	–	B	B
Seira sp.	–	–	–	P
Pseudosinella octopunctata (Boerner, 1901)	B	–	B	P, B

Table 1 (*continued*)

1	2	3	4	5
P. sexoculata Schott, 1902	B	B	B	–
P. alba (Packard, 1873)	B	P, B	P, B	P, B
P. wahlgreni Boerner, 1907	B	B	B	B
P. fallax Boerner, 1903	B	–	–	–
P. imparipunctata Gisin, 1953*	B	B	–	–
Willowsia buski Lubb., 1869	B	B	P, B	B
W. nigromaculata Lubbock, 1873	V	–	P	–
TOMOCERIDAE				
Tomocerus vulgaris (Tullb., 1871)	V, B	P, B	P, B	–
CYPHODERIDAE				
Cyphoderus albinus Nic., 1842	B	–	–	–
C. sp.	–	–	B	B
C. bidenticulatus (Parona, 1888)*	B	–	–	–
PODURIDAE				
Podura aquatica L., 1758	–	B	–	–
NEELIDAE				
Megalothorax minimus (Willem, 1900)	V, B	–	–	–
M. incertus Boerner, 1903**	B	–	–	–
SMINTHURIDIDAE				
Sphaeridia pumilis (Krausbauer, 1898)	V, B	B	P, B	P, B
ARRHOPALITIDAE				
Arrhopalites caecus (Tullb., 1871)	V, B	B	B	–
A. principalis Stach, 1945*	B	–	B	–
KATIANNIDAE				
Sminthurinus bimaculatus (Axelson, 1902)	B	–	P, B	–
S. elegans (Fitch, 1863)	B	–	–	–
S. aureus (Lubbock, 1867)	B	P	–	–
S. alpinus ssp. *bisetosus* (Ellis, 1976)**	B	B	B	B
S. niger (Lubb., 1867)	B	–	P, B	–
S. trinotatus (Axelson, 1905)*	B	–	–	–
S. sp. cf. *albifrons*	B	–	–	–
S. (*Gisinianus*) *flammeolus* (Gisin, 1957)*	B	–	B	B
BOURLETIELLIDAE				
Bourletiella sp.	V	–	–	–
Deuterosminthurus repandus (Agren, 1903)	B	–	–	–
SMINTHURIDAE				
Sminthurus nigromaculatus Tullb., 1871	B	–	–	–
S. viridis (L., 1758)	–	P, B	–	P, B
S. flaviceps Tullberg, 1871	–	–	–	P
Caprainea marginata (Schoett, 1893)*	B	–	–	–
Allacma (*Podura*) *fusca* (L., 1758)	V, B	–	B	B
Lipothrix (*Sphyrotheca*) *lubbocki* (Tullberg, 1872)	–	B	B	B
DICYRTOMIDAE				
Dicyrtoma fusca Lubbock, 1873	–	–	P	–
Ptenothrix atra (L., 1758)	B	–	–	–
P. setosa (Krausbauer, 1902)	–	B	P, B	–

Legend: – — the species not recorded; B — original data; V — recorded by V. P. Vtorov (1988); P — recorded by A. A. Prokopenko (1988; 1988 a). * The species registered for the first time in East Ukraine; ** The species registered for the first time in Ukraine.

Eurytopic and forest species, e. g. *Folsomia manolachei, Isotoma notabilis, Neanura muscorum, Isotomiella minor, Lepidocyrtus lignorum, L. lanuginosus* and *Sphaeridia pumilis*, form the core of Collembola assemblages in the majority of plant communities under consideration (tabl. 2). The first two species were among dominants in all types of forest ecosystems. Such species as *P. wahlgreni, Orchesella multifasciata, S. alpinus s*sp. *bisetosus, Protaphorura serbica,* and *Folsomia volgensis* were among co-dominants in gully forests. *Isotomiella minor, Tomocerus vulgaris, Pthenothrix setosa,* and *Sminthurinus* sp. gr. *niger* were co-dominants in flood plain forests, while *F. fimetaria, O. taurica*, *Pseudosinella octopunctata* dominated in highland pine forests, and *Isotoma anglicana*, *Mesaphorura krausbaueri, Ps. alba,* and *Schoetella ununguiculata* — in highland oak-forests. The share of meadow and steppe species in the fauna under

Table 2. Relations between ecological groups of Collembola in natural forests of South-East of Ukraine (absolute number of species and a share in the general species richness)

Таблица 2. Соотношение экологических групп коллембол в естественных лесах юго-востока Украины (абсолютное число видов и доля в общем видовом богатстве)

Ecological groups	Forest associations (as a whole)		Gully forests		Flood-lands forests		Highland oak forests		Highland pine forests	
	1	2	1	2	1	2	1	2	1	2
Eurytopic	22	19.1	19	19.4	12	24.5	11	20.0	14	31.1
Forest	36	31.3	26	26.5	18	36.7	18	32.7	13	28.9
Meadow	20	17.4	15	15.3	8	16.3	10	18.2	5	11.1
Steppe	12	10.4	12	12.2	6	12.2	4	7.3	4	8.9
Compost	6	5.2	5	5.1	1	2.0	2	3.6	1	2.2
Corticicolous	5	4.3	–	–	1	2.0	3	5.5	1	2.2
Psammophilous	4	3.5	4	4.1	–	–	1	1.8	1	2.2
Myrmecophilous	3	2.6	2	2.0	1	2.0	1	1.8	2	4.4
Neyston	1	0.9	–	–	1	2.0	–	–	–	–
Ruderal	1	0.9	1	1.0	1	2.0	–	–	2	4.4
Sinantropic	1	0.9	–	–	–	–	–	–	–	–
Nidicolous	1	0.9	1	1.0	–	–	–	–	–	–
Galophilous	1	0.9	1	1.0	–	–	–	–	–	–
Uncertain	2	1.7	9	9.2	–	–	5	9.1	2	4.4
Total:	115	100	98	100	49	100	55	100	45	100

Legend (in tabl. 2–4): 1 — abs.; 2 — %.

consideration was also significant (17.4% and 10.4% of the total number of species respectively) (tabl. 2), being probably conditioned by the migration from adjoining steppe, meadow plots and agrocoenoses. *Brachystomella curvula, Neonaphorura adulta, Entomobrya arborea, Pseudosinella fallax, Ptenothrix atra* are apparently rare and were represented in our collections by a few specimens.

Such species as *Pseudosinella wahlgreni, Folsomia fimetaria, Ptenothrix setosa, Tomocerus vulgaris, Endonura tetrophthalma, L. paradoxus, Allacma fusca* et al. are characterized in literature as nemoral (Мартынова, 1967; Кузнецова, 1985) and give the nemoral aspect to the fauna under consideration.

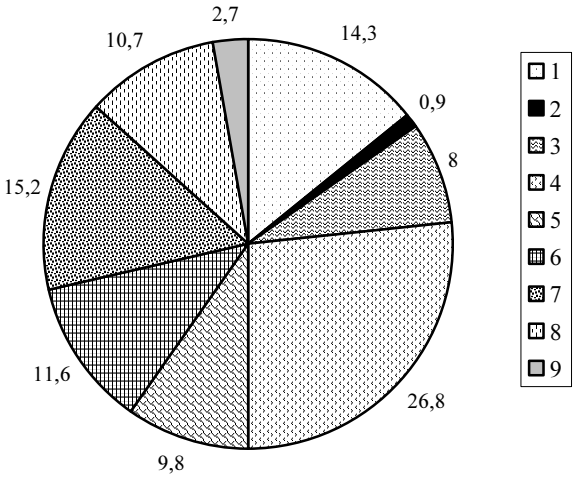

Fig. 2. Spectrum of life forms of Collembola in investigated forests, %: 1 — atmobious; 2 — neustonic; 3 — corticicolous; 4 — upper-litter; 5 — lower-litter; 6 — litter-soil; 7 — upper-soil; 8 — lower-soil; 9 — specialized species.

Рис. 2. Спектр жизненных форм коллембол в исследованных лесах, %: 1 — атмобионты;. 2 — нейстонные; 3 — кортицикольные; 4 — верхнеподстилочные; 5 — нижнеподстилочные; 6 — подстилочно-почвенные; 7 — верхнепочвенные; 8 — глубокопочвенные; 9 — специализированные.

Table 3. Relations of hygropreferendums of Collembola in natural forests of South-East Ukraine (absolute number of species and a share in the general species richness)

Таблица 3. Соотношение гигропреферендумов коллембол в естественных лесах юго-востока Украины (абсолютное число видов и доля в общем видовом богатстве)

Hygropreferendums	Forestry associations (as a whole)		Gully forests		Flood-lands forests		Highland oak forests		High pine forests	
	1	2	1	2	1	2	1	2	1	2
Mesophilous	35	30.4	31	31.6	18	36.7	17	30.9	17	37.8
Xeromesophilous	33	28.7	27	27.6	10	20.4	14	25.5	14	31.1
Xerophilous	14	12.2	12	12.2	5	10.2	6	10.9	4	8.9
Mesohygrophilous	13	11.3	10	10.2	6	12.2	8	14.5	2	4.4
Hygrophilous	4	3.5	1	1.0	2	4.1	1	1.8	1	2.2
Euriplastic	4	3.5	4	4.1	2	4.1	3	5.5	3	6.7
Uncertain	12	10.4	13	13.3	6	12.2	5	9.1	4	8.9
Total:	115	100	98	100	49	100	55	100	45	100

Analysis of hygropreferendums based on the literature data (Кузнецова, Крестьянинова, 1998; Стебаева, 1975; Стебаева, Щербаков, 1977; Чернова, Кузнецова, 1988; Ханисламова, 1988; Rusek, 1989 et al.) showed that the groups of mesophilous and xeromesophilous species were dominating in the studied forests (30.4% and 28.7% of the total number of species respectively) (tabl. 3). Contribution of xeroresistable and mesohygrophilous was approximately equal, showing considerable contrast of soil and climatic conditions in the forests of the steppe zone. While hygrophilous and mesophilous species concentrate under forest canopy in depressions of relief, the xerothermic forms find favourable conditions on the edges of forest covered with meadow-steppe vegetation.

The spectrum of life forms in investigated forests included nine biomorphs defined according to S. K Stebaeva (Стебаева, 1970), upper-litter, upper-soil and atmobious species were dominating (26.8%, 15.2% and 14.3% of the total number of species, respectively) (fig. 2). Probably, prevalence of the complex of superficially dwelling species can be explained by its resistence to low humidity and abnormally high temperatures, in comparison to the other living forms (Стебаева, 1975; Стебаева, Сухов, Щербаков, 1977). The complex of litter-soil (11.6%) and deep-soil (10.7%) forms was also well represented. The unique neustonic species — *Podura aquatica* is typical for flood plain biotopes. As mentioned above, the lower-litter *Isotoma notabilis* and the litter-soil *Folsomia manolachei* were included in the main core of dominant species in all types of forest ecosystems investigated. Belonging of dominant species to different living forms indicates clear division of ecological niches between them.

According to the original and literature (Второв, 1988) data, 97 species of Collembola belonging to 44 genera and 14 families inhabit gully forests (tabl. 1), 43 of them proved to be specific to this type of forests and were not found in other forest biotopes: *Hypogastrura* (*Ceratophysella*) *denticulata, Xenylla boerneri, Oligaphorura uralica, Mesaphorura italica, M. critica, Doutnacia xerophyla, Anurophorus laricis, Vertagopus cinerea, Jesenikia filiformis, Pseudosinella fallax, Cyphoderus bidenticulatus,* etc. Mesophilous and xeromesophilous species apparently predominated in gully forests (31.6% and 27.6% of the total number of species respectively) (tabl. 3). The share of xerothermic species was 12.2%. Considerable number of species belonged to the groups of forest inhabitants and eurybionts (tabl. 2), contribution of meadow and steppe species was markedly smaller — 15.3 and 12.2% accordingly.

The upper-litter (28% of the total number of species), soil-litter (15%) and upper-soil (15%) biomorphes were predominant in the spectrum of the life forms. According to S. E. Nadtochiy (Надточий, 1995), the high share of hemiedaphic species is a characteristic peculiarity of oak-forest ecosystems of the Middle Russian highland, but is not attributed to coniferous forests.

The fauna of flood plain forests comprises 49 species of Collembola belonging to 31 genera and 12 families, including those reported by A. A. Prokopenko (Прокопенко, 1988). However, the share of species peculiar to these habitats was rather

low. Apparently, the fauna is formed mainly by euryplastic and polytopic species, which disperse along river-beds southwards from the forest-steppe and nemoral zones. This suggestion is supported by a considerable contribution of the complex of eurybionts species (24.5% of the total number of species) alongside the prevailing forest ecological group — 36.7% (tabl. 2). Only three species found here were absent in other forest ecosystems — *Podura aquatica, Oligaphorura* sp. and *Sminthurus viridis.*

As well as in gully forests, the majority of species registered in flood plain forests belongs to mesophilous (36.7% of the total number of species) and xero-mesophilous (20.4%) groups (tabl. 3). However the complex of mesohygrophilous springtails is more represented here (12.2%). Most probably, this result can be explained by the specific hydrothermic conditions of flood plain soils.

The spectrum of life forms is characterized by the high share of the upper-litter (27.1% of the total number of species) and upper-soil (20.8%) biomorphs. The share of litter-soil species is accordingly reduced reduces at the same time (14.6%).

The highland oak-forests are inhabited by 55 species of Collembola belonging to 33 genera and 13 families (Прокопенко, 1988; original data). The specific inhabitants of highland forests were *Dicyrtoma fusca, Entomobrya puncteola, Orchesella pseudobifasciata, Willowsia nigromaculata* and *Xenyllodes macrocanthus* mentioned by A. A. Prokopenko (Прокопенко, 1988) and not found in our samples from the other types of forests on Donetsk ridge.

One third (32.7%) of the species marked in highland forests belong to the forest forms. The share of eurybiont (20%) and meadow (18.2%) species is also considerable. The part of steppe forms decreased, in comparison with gully forests and flood plain forests (tabl. 2). Mesophilous and xeromesophilous species predominate in this type of forests, as well as in the previous types. Contribution of mesohygrophilous springtails is comparatively large (14.5%), while the share of xeroresistant species is somewhat decreased — 10.9% (tabl. 3).

In spectrum of life forms, upper-litter biomorphs prevail — 24.1% of the total number of species. The part of atmobious (18.5%), lower-litter (16.7%) and upper-soil (14.8%) species is also high.

Summarizing list of Collembola in highland pine forests, including the data of A. A. Prokopenko (Прокопенко, 1988), comprises 45 species of 25 genera and 9 families. Such species as *Achorutes stachi, Protaphorura octopunctata*[*], *Entomobrya corticalis, E. lanuginosa, Seira* sp., *Sminthurinus flaviceps* mentioned by A. A. Prokopenko (Прокопенко, 1988) are peculiar for this type of habitats. They were not registered in other investigated forests.

The increasing dryness of microclimate and strained hydrothermic regime in soils under pine forests has apparently influenced upon the structure of springtails assemblages. The latter was characterized by the expressed predominance of eurybionts (31.1% of the total number of species) over the forest species (28.9%) (tabl. 2). The complex of hygrophilous and mesohygrophilous markedly declined, while mesophilous and xero-mesophilous groups were well represented (tabl. 3). The upper-litter species were prevailing among the life forms (30.1%), the shares of atmobiont, lower-litter, litter-soil and upper-soil groups were equal (14% each), the share of corticole species (7%) was comparatively high.

Zoogeographical analysis

Eight zoogeographical complexes (tabl. 4) can be distinguished in the forest fauna of Collembola of south-eastern Ukraine on the base of the literary data on species distribution (Palissa, 1964; Nosek, Vysotskaya, 1973; Fjellberg, 1998; Weiner, 1981; Catalogus fauna Austriae, 1987; Определитель коллембол фауны России и сопредельных стран..., 1994). The majority of species are widely distributed, among them the European complex is the most representative (24.3% of the total number of

[*] Probably the question is out of *Protaphorura serbica* which the author identified in the system of Palissa (1964) as *P. octopunctata.*

Table 4. Relations between zoogeographical complexes of Collembola in natural forests of South-East of Ukraine (absolute number of species and a share in the general species richness)

Таблица 4. Соотношение зоогеографических комплексов коллембол в естественных лесах юго-востока Украины (абсолютное число видов и доля в общем видовом богатстве)

Zoogeographical complexes	Forest associations (as a whole)		Gully forests		Flood-lands forests		Highland oak forests		Highland pine forests	
	1	2	1	2	1	2	1	2	1	2
European	28	24.3	21	21.4	11	22.4	12	21.8	9	20.0
Holarctic	26	22.7	23	23.4	13	26.5	14	25.5	12	26.7
Cosmopolitan	21	18.3	19	19.4	15	30.6	14	25.5	11	24.4
Palaearctic	15	13.0	12	12.2	7	14.3	5	9.1	6	13.3
Euro-Mediterranean	11	9.6	11	11.2	2	4.1	3	5.5	2	4.4
Euro-Siberian	4	3.5	2	2.0	–	–	3	5.4	1	2.2
Mediterranean	2	1.7	2	2.0	–	–	1	1.8	–	–
Uncertain	8	6.9	8	8.2	1	2.0	3	5.5	4	8.9
Total:	115	100	98	100	49	100	55	100	45	100

species). Holarctic and cosmopolitan species were also numerous (21.7% and 18.3% respectively). Less represented were species with Palaearctic (13%) and Euro-Siberian ranges (3.5%). On the whole, the share of the widely distributed species is 78.6%. Noteworthy, the share of these species in the forest-steppe zone is only 46.9% (Таращук, 1993). Probably, decreased rate of species with limited ranges in our study region is due to the more severe physical and climatic conditions of steppe zone, in particular to the "continentalisation" and a aridization of climate. The part of widely distributed species in separate types of sudied forests varied from 77.4% (gully forests) to 91.7% (flood plain forests).

The Euro-Mediterranean complex makes an essential contribution to the forest fauna of south-east of Ukraine (tabl. 4). This complex is formed by such species as *Protaphorura aurantiaca, P. meridiata, Mesaphorura critica, M. italica, Allacma fusca, Sminthurinus alpinus* sp. *bisetosus* etc.

The part of Euro-Siberian complex is comparatively low (3.5%). It is formed by such species as *Pseudachorutes dubius, Sminthurinus bimaculatus, Oligaphorura uralica*, *Pseudophopsomia acanthella.*

The record of *Jesenikia filiformis* Rusek (1997) in gully forests of Donetsk region is of some scientific interest, since it was previously known only from the mountain regions of North Moravia (Czech Republic).

Peculiar feature of the studied fauna is the presence Mediterranean species *Xenylla uniseta, Pseudosinella fallax, Entomobrya handschini* and *Cyphoderus bidenticulatus.* Probably, presence of these Mediterranean elements is explained by the complicated geological history of territory examined. According to the paleogeographical data (Атлас..., 1960), continuous development of soils and plant cover on Donetsk and Priazov heights could take place since the begining of Palaeozoic, since these territories were not flooded by ancient sea or directly influenced by glaciation. For these reasons, some investigators of the region treated it as a refugium of interglacial forest (forest-steppe) relicts of flora and fauna (Лавренко, 1938; Арнольди, Арнольди, 1938; Медведев, 1964). E. M. Lavrenko (Лавренко, 1938) pointed out clear relationships between the Donetsk forest-steppe refugium and the Crimea, the Caucasus and the Carpathian-Balkan floristic centre. Therefore, presence of traces of ancient contact with the Mediterranean region in soil microfauna is quite explicable.

Conclusion

1. The fauna of Collembola of South-East Ukraine includes not less than 115 species belonging to 52 genera and 16 families. Six species of Collembola have been noted for the first time for the territory of Ukraine. The families Entomobryidae, Onychiuridae, Isotomidae form the taxonomic core of the natural forest fauna of the region. Such genera as *Entomobrya* (9 species), *Sminthurinus* (8), *Protaphorura* (7),

Mesaphorura (6), *Pseudosinella* (6) are the richest in species. The richest fauna of Collembola was recorded in gully forests (97 species) and the poorest fauna was that of highland pine forests (45 species).

2. The forest fauna of Collembola of the studied territory is geterogenous and includes different chorologic elements. Eight zoogeographical complexes are represented, with European, Holarctic and cosmopolitan species being predominant.

3. Prevailing of forest species in most of the examined coenoses with the exeption of highland pine forests demonstrate a sylvatization process under forest canopy in steppe zone conditions. Nevertheless, considerable share of eurybiont, meadow and steppe species in forests of Donetsk highland shows possibility of their migrations from adjoining artificial landscapes and preserved steppe plots.

4. The predominance of upper-litter biomorphs in all cases is apparently not accidental and can be explained by peculiar regional climatic conditions.

5. The variety of the spectrum of springtails' hygromorphs shows instability of hydrothermic conditions in natural forests of steppe zone.

Above described ecological and faunistic features of springtails assemblages reflect peculiarities of forest microclimate in steppe and can be used for zoodiagnostics in natural and artificial forests.

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