Hacquetia 15/2 • 2016, 105–112 DOI: 10.1515/hacq-2016-0017
DE GRUYTER OPEN

Soil macrofauna (invertebrates) of Kazakhstanian *Stipa lessingiana* dry steppe

Tatyana M. Bragina[1, 2]

Key words: dark chestnut soil, *Stipa lessingiana* steppes, soil invertebrate communities (macrofauna), structure.

Ključne besede: temna kostanjeva prst, stepe z vrsto *Stipa lessingiana*, talne združbe nevretenčarjev (makrofavna), struktura.

Abstract

Stipa lessingiana steppes used to be prevalent on the dry Trans-Ural denudation plains, particularly, on the Sub-Ural and the Turgay Plateau. But, most of them have been lost because they were plowed up during the Virgin Land campaign in the second part of 20th century. This paper presents a detailed study of the faunistic composition and the structure of soil-dwelling invertebrate communities (macrofauna) of a temperate-dry bunch feather grass steppe in the Turgai Plateau (Northern-Turgai physical-geographical province of steppe Kazakhstan, Kostanay Oblast). The study site is located in the territory of the Naurzum State Nature Reserve, a part of the UNESCO World Heritage site "Saryarka - Steppe and Lakes of Northern Kazakhstan", where remnants of Virgin *S. lessingiana* steppes have been preserved to the present day. This region is the driest and most continental in climate of all the dry steppes of Kazakhstan. The total abundance and biomass of soil invertebrate communities in the investigated site were lower than in the northern and western steppe areas. Soil invertebrates are among the major components that determine the functioning of terrestrial natural ecosystems.

Izvleček

Stepe z vrsto *Stipa lessingiana* so nekoč na suhih ogolelih ravnicah Trans-Urala prevladovale, še posebej na poduralskem platoju in platoju Turgay. Številne so uničili z preoravanjem med kampanjo "Deviška zemlja" v Kazahstanu v drugi polovici 20. stoletja. Raziskava predstavlja natančno analizo sestave favne in strukturo talnih združb nevretenčarjev (makrofavna) v zmerno suhi stepi z bodalico na platoju Turgai (severno turgajska fizično geografska provinca stepe Kazahstana, oblast Kostanay). Raziskovano območje je del državnega naravnega rezervata Naurzum, ki je del zavarovanega območja svetovne naravne dediščine pri UNESCO „Saryarka – stepe in jezera severnega Kazahstana", kjer so ohranjeni ostanki step z vrsto *S. lessingiana*. Ta regija ima najbolj sušno in kontinentalno klimo izmed vseh suhih step v Kazahstanu. Za preučevanje talne favne in strukturo njihovih združb med vegetacijsko sezono smo uporabili talno-zoološke vzorce (monolite). Skupna abundanca in biomasa združb talnih nevretenčarjev v preučevani suhi stepi z vrsto *Stipa lessingiana* v Kazahstanu je bila manjša kot v severnih in zahodnih stepah, kjer sta delež humusa v tleh in količina padavin večja. Talni nevretenčarji so eni izmed najpomembnejših dejavnikov, ki so ključni za delovanje naravnih kopenskih ekosistemov.

Received: 15. 11. 2015
Revision received: 29. 5. 2016
Accepted: 31. 5. 2016

Co-ordinating Editor:
Rocco Labadessa

1 Kostanay State Pedagogical Institute, Kostanay, Taran str., 118, Kazakhstan
2 Federal State-Financed Scientific Institution "AzNIIRKH", Rostov-on-Don, Beregovaya str., 21B, Russia. E-mail: tm_bragina@mail.ru

Introduction

Steppes are important habitats for many plant and animal species. Natural steppes are highly diverse ecosystems, worthy of protection and also of great economic value. However, many steppe species have been decimated or extinct due to habitat loss or landscape fragmentation. Steppes are subject to serious conflicts between agricultural interest and nature conservation, because many types of steppe occur on soils excellent for farming (Hölzel et al. 2002, Rachkovskaya & Bragina 2012).

Soil dwelling invertebrates can be a sensitive indicator of changes in total coverage (Lavelle & Pashanasi 1989). They have a considerable impact on soil processes by regulating soil physical properties and chemical processes (Lavelle 1997, Velásquez et al. 2012). Soil invertebrates have various ecological functions and contribute to in the fertility of the soil by mineralizing organic matter, mixing of the soil, increasing macro-porosity, and enhancing humidification (Francis & Fraser 1998, Lavelle et al. 2006). A number of keystone groups of macrofauna are characterized by narrowly restricted niches with pronounced trophic preferences inside their habitats and low migratory activities. This makes them suitable as indicators of natural ecosystems (Ruiz et al. 2008). Some fundamental publications are available for steppe macrofauna (soil invertebrates) of the European part and Siberia in Russia summarized by Striganova (1996, 2005). A comparison between the soil macrofauna of floodplains and of well-drained habitats of the European steppe was done by Samoylova (2015). However, invertebrates of steppe habitats and soil invertebrates in Kazakhstan have been rather neglected in past researches (Bragina 2001, 2004, Demina & Bragina 2014, etc.). The main focus of this study is to describe the macrofaunistic biodiversity, the invertebrate community composition and its structure in the dark chestnut calcareous soil of the *Stipa lessingiana* steppe.

Methods

Study site

In total, dry steppes make up 7.1% (192,513.1 km^2) of the land area of Kazachstan. *Stipa lessingiana* steppes were very common on the plains of the Sub-Ural and the Turgai Plateau. Fescue-feather grass (*Stipa lessingiana* – *Festuca valesiaca*) steppes with xerophytic forbs (*Galatella tatarica*, *Pyrethrum achillaefolium*) on carbonate soils

Figure 1: Temperate-dry bunch feather grass steppes (with *Stipa lessingiana, Stipa capillata, Festuca valesiaca*) on the dark chestnut carbonate heavy loam soil, Turgai Plateau, Naurzum State Natural Reserve, Kazakhstan. Photo by Tatyana M. Bragina.

Slika 1: Zmerno suha stepa z bodalico (z vrstami *Stipa lessingiana, Stipa capillata, Festuca valesiaca*) na temni kostanjevi karbonatni težko ilovnati prsti, plato Turgai, državni naravni rezervat Naurzum, Kazahstan. Foto Tatyana M. Bragina.

were particularly typical. But, more than 90% of this kind of steppe vegetation has been plowed up during the Virgin Land campaign in the course of the 20th century (Rachkovskaya & Bragina 2012). Fortunately there are some conserved areas are in the Naurzum State Natural Reserve – the part of World Heritage site "Saryarka – Steppes and Lakes of Northern Kazakhstan which still harbour remnants of *Stipa lessingiana* steppe vegetation (Bragina 2009).

The study area was located in the southern part of the Turgai Plateau, in the Naurzum State National Reserve (the locality of the investigated area: 51°46'59.8"N, 63°48'41.4"E) in the feather grass steppe at 260–290 m above sea level. The climate is continental. The average annual temperature – 1.33 °C, annual precipitation – 240–260 mm (Bragina 2009).

The vegetation is characterized by xerophytic species of bunch grass like *Stipa lessingiana, S. capillata, Festuca valesiaca*, loose bunch grasses, like *Agropyron pectinatum,* and rhizome grasses, like *Leymus ramosus* (Figure 1).

Sampling

In order to accurately describe the vegetation and properties of the soil, we recorded each plant species as well as their respective cover and average height. Plant species abundances were approximated according to the scale by O. Drude (1890, see also Jaroshenko 1961):

Soc (socialis) – the dominant species, frequency of occurrence/coverage exceeds 90%;
Cop_3 (coptosal) – an abundant species, frequency of occurrence/coverage 70–90%;
Cop_2 – a species is represented by numerous individuals, frequency of occurrence/coverage 50–70%;
Cop_1 – frequency of occurrence/coverage 50–70%;
Sp_3 (sporsal) – frequency of occurrence/coverage about 30%;
Sp_2 (sporsal) – frequency of occurrence/coverage about 20%;
Sp_1 (sporsal) – frequency of occurrence/coverage about 10%;
Sol (solitarie) – scanty individuals, frequency of occurrence/coverage about to 10%;
Un (unicum) – a single individual.

Soil invertebrates were collected by means of the soil-zoological samples (monoliths) method (Ghilyarov 1965, Byzova et al. 1987, Anderson & Ingram 1993): for each plot, the soil fauna was collected from samples of 50 cm × 50 cm. Soil samples were taken at different depths from 0–10 cm, 10–20 cm, 20–30 cm and 30–50 cm using shovels/trowels and plastic cover. The top layer of the samples (litter layer) was scraped off. All samples were immediately spread out over a plastic cover and sieved with a 4-mm mesh. Living organisms were hand-sorted and preserved in 40 ml vials containing 70% ethanol for later identification in the lab. All animal organisms visible with the naked eye (measuring between 2–80 mm) qualified as macrofauna and thus counted and identified.

Species were identified according to the determinant of spiders (Tyshchenko 1971), the determinant of centipedes (Zalesskaya 1978), the determinant of the families of Coleoptera and other insect larvae (Ghilyarov 1964, 1975, Mamaev 1972, Dolin 1978, Sharova 1981 and others) and the determinant of imago of Coleoptera (Gurieva & Kryzhanovsky 1965) amongst others. All of the individuals collected from the soil and litter were further classified according to their typical ecological functions as predators (zoophagous), herbivores (phytophagous and phytosaprophagous) or detritivores (saprophagous). Trophic specialization of identified species was established according to the literary data, including published identification books and special reviews (Ghilyarov 1964, 1975, Tychshenko 1971, Kryzhanovskij et al. 1995, Dolin 1978, Zalesskaya 1978 and others). We classified/categorized pupas as non-active phase of invertebrate community.

In 2010, 12 samples were collected every 20–30 days during the growing season (from late April to early October). In total, 72 samples were collected. Soil samples at the site were selected at a distance of 10 m from each following the form of the letter Z. This increased the uniformity of coverage of the study area (Pesenko 1982). We calculated the average abundance and biomass of macrofaunal species and used the following variables: (n) = number of the samples; macrofauna species richness (S) = number of fauna groups present; macrofauna abundance, or density (N) = P/A, where P = abundance of soil specimens; A = surface area of the samples (50 × 50 cm^2). Macrofauna abundance (N) represents the total number of individuals in a sample per 0.25 m^2, and then calculated per 1 m^2.

To complement the approximation of the composition of soil invertebrates, some were caught by hand and some by pitfall traps which were additionally dug in. All macrofaunal samples were identified and classified in the research centres of Kazakhstan and Russia – A.N. Severtsov Institute of Ecology and Evolution, the Russian Academy of Sciences (Moscow); Institute of Zoology, Ministry of Education and Science of the Republic of Kazakhstan (Almaty); Zoological Institute, the Russian Academy of Sciences (Saint Petersburg). The numbers of individuals per family taxon and the number of family groups were noted. Some specimens were damaged and could not be identified, but as they only accounted for a small proportion of the whole set, they were included in the calculation of the total abundance and biomass of the collected invertebrates. Invertebrates were weighed on a torsion balance to determine the total biomass.

The species diversity was analyzed by the index of dominance (Magurran 1992) or Berger-Parker index:

$I_{BP} = N_{max}/N$,

where

N_{max} = abundance of the most numerous species,

N = total abundance of species.

This allowed to identify dominant and co-dominant groups of sampled soil invertebrate communities. The dominant species and groups made up 10% or more of the total number of collected invertebrates, the co-dominants were set to range from 5–10% of total number.

Results and Discussion

Vegetation

In the investigated area, the temperate-dry bunch feather grass steppe on dark chestnut calcareous soil includes xerophytic bunch grasses (*Stipa lessingiana, S. capillata, Festuca valesiaca*), sparse bunch grasses (*Agropyron pectinatum*) and rhizome grasses (*Leymus ramosus*) with some occurrence of forbs like *Artemisia lercheana, Galatella tatarica, Tanacetum achillaefolium, Phlomis agraria, Nepeta ukrainica, Scorzonera stricta, Serratula nitida* and others. The total coverage of vegetation amounts to 60–70%, the height of the grass stand reached 22–24 cm, and we identified an average of 25–30 species of plants per 100 square metres. The xerophytic bunch grasses *Stipa lessingiana* and *Festuca valesiaca* were dominant (cop_{3-2}); *Stipa sareptana*, *Agropyron pectiniforme*, *Koeleria cristata*, *Aneurolepidium ramosum*, *Artemisia lercheana, Galatella tatarica*, *Tanacetum achillaefolium*, *Phlomis agraria*, *Nepeta ukrainica*, *Scorzonera stricta* and *Serratula nitida* were referred to as (sp); *Linosiris villosa*, *Kochia prostrata*, *Jurinea multifida* and others were sparsely represented (sol). *Tulipa* spp. and *Gagea* spp were rarely found emphemeroids.

The vegetation is made up of 18% shrubs, 15% xerophytic bunch grasses, 7% other grasses, 4% rhizomes, 30% herbaceous perennials, 19% hemi-ephemeroids and 7% ephemeroids. Ruderal elements (weeds) are absent. The soil surface is covered by litter from dead plant material and by lichen (*Parmelia vagans*). The soil is made up of dark chestnut carbonate heavy loams. The humus content amounted to 4.1% at 0–10 cm depth, and 3.9% at 10–20 cm depth.

Invertebrates

The soil macrofauna consists of a large number of different organisms that live on the surface of soil as well as in and between soil pores. Animals were found up to a depth of 60–80 cm but the bulk of the zoomass was concentrated in the humus horizon at the depth of 0–30 cm.

The beetle group of the investigated steppe samples included 31 species of ground beetles (Carabidae), 26 species of scarab beetles (Scarabaeidae), 12 species of darkling beetles (Tenebrionidae) and there 39 beetle species of low abundances which were summarised as 'Others' (Figure 2).

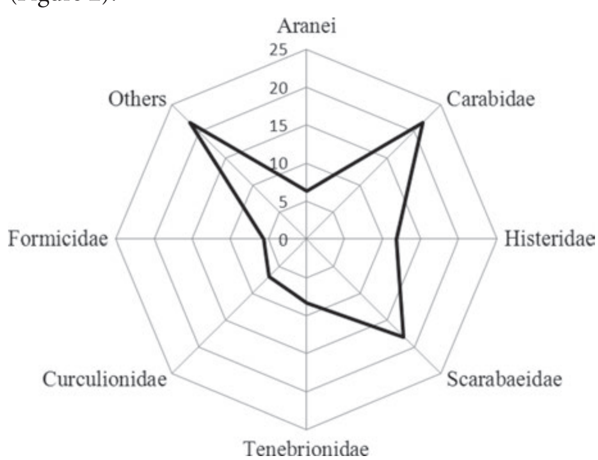

Figure 2: Total species proportion (%) in the main families of the soil invertebrates.
Slika 2: Skupen delež vrst (%) glavnih družin talnih nevretenčarjev.

Next to the ground beetle *Cicindela atrata,* some species, such as *Carabus bessarabicus*, who are common in the dry steppe, and *Cymindis cylindrica* as a typical species for Virgin Pontian and Kazakh steppes, were found. In this steppe area some desert species were also observed, such as *Poecilus nitens*, *P. crenuliger*, *Amara ambulans*, and *Cymindis picta.*

Up to 90% of scarab beetles are represented by various specimens of the genus *Aphodius* (13 species) and *Onthophagus* (7 species). Large dung beetles, like *Copris lunaris*, *Geotrupes baicalicus*, *Scarabaeus typhon* were also encountered.

In the collected soil-samples three species of click beetles (Elateridae) were recorded, of which two are among the most abundant ones. The first one, *Selatosomus latus*, is common for the steppe and forest steppe. Another species, *Agriotes sputator*, is a steppe species with a broad habitat range.

Gonocephalum pussilum, Blaps lethifera and *Tentyria nomas* are the most numerous among 11 species of darkling beetles (Tenebrionidae), but *Platyscelis hypolithos* and *Oodescelis polita* are specific to this particular habitat.

The most typical ants (Formicidae) *Leptothorax leoni*, *Tetramorium forte*, *Lasius alienus*, *Cataglyphis aenescens*, *Formica canicularia* were observed in upland habitats.

In upland *S. lessingiana* steppes, *Dorcadion politum* and multipedes like *Geophilus proximus*, *Hessebius multicalcaratus*, *Hessebius plumatus* and weevil beetle *Eusomus acuminatus* were captured.

The Berger-Parker dominance index (Magurran 1992) yielded a value of 0.07 indicating the polydominance of community (the numerical importance of the most abundant species). The total density of the soil macrofauna of upland *S. lessingiana* steppes (Table 1) during the growing season amounts to 36.9 individuals/m^2 on average (9.2±0.5 individuals/m^2 per sample, excluding imagines of ants and locusts egg capsules; the number of the latter amounted to 7.7 individuals/m^2 in early spring) with total biomass of 1.2 g/m^2. The population density of soil invertebrates reached a maximum in the early spring and autumn (50–60 individuals/m^2) with a maximum biomass of 3.3 g/m^2 dominated by insects both in abundance (80.7%) and in number (29.8 individuals/m^2). The results show that beetles are the most common group of invertebrates in the soil, making up 53.9% of the total abundance of invertebrates.

Click beetles dominate with a density of 7.2 individuals/m^2 in the collected samples, accounting for 19.5% of the total number and 12.7% of the total biomass of soil invertebrates collected. The beetles *Selatosomus latus* (3.7 individuals/m^2) and *Agriotes sputator* (3.1 individuals/m^2) constitute over 90% of the click beetles. The group of dominant invertebrates also consist of weevils (5.1–6.3 individuals/m^2), Diptera (3.2–5.6 individuals/m^2), ground beetles (4.0–1.6 individuals/m^2), spiders (3.6–4.3 individuals/m^2) and woodlice (2.0–3.1 individuals/m^2). Ground beetles, spiders, click beetles, Diptera, and in some years darkling beetles, make up the predominant part of the biomass.

The proportions of the various trophic groups of the steppe soil macrofauna are shown in Figure 3. In upland steppes, predatory forms account for about 43.0% of all collected invertebrates, of which spiders and ground beetles make up 10.0%, and Asilidae and Terevidae amount to 13.4% while centipedes make up 4.0%. Other predatory invertebrates (Staphylinidae, Histeridae, Hemiptera and others) were present in a small number. Predation plays an important role in establishing a balance between the number of consuming individuals and the quantity of available resources. Therein, predators contribute to the regulation of biological activity of the ecosystem of the soil by feeding on other organisms and taking the place at the top of the food chain.

Table 1: Density (individuals/m^2) and abundance (% of total abundance) of the soil-dwelling macrofauna of the study area.

Tabela 1: Gostota (osebki/m^2) in abundanca (% skupne abundance) talne makrofavne v preučevanem območju.

Classes	Groups of invertebrates	Density (individuals/m^2)	% of total abundance
Arachnida	Araneae	3.6	9.8
Crustacea	Isopoda	2.0	5.4
Chilopoda	Geophilomorpha, Lithobiomorpha	1.5	4.1
Insecta	Coleoptera	20.0	53.9
	Lepidoptera	1.7	4.6
	Hymenoptera	1.1	3.0
	Diptera	5.1	13.8
	Heteroptera	1.0	2.7
	Others	0.9	2.4
	Total:	36.9	100
	Abundance per sample (0.25 m^2) Mean ± s.e.	9.2±0.5	

Among phytophagous and phyto-saprophagous species, the highest number was accounted for click beetles (19.7%), and weevils (14.0%). They were mainly recorded in their larval state. Larvae of darkling beetles (1.1%) and scoops (2.0%) were not very abundant. Other groups of invertebrates amounted to 3.6%.

Only a few saprophagous species among the soil macrofauna was found. Woodlice contributed the prominent part with only 5.4%. Other groups (*Aphodius*, *Onthophagus* among Scarabaeidae, some other Coleoptera and

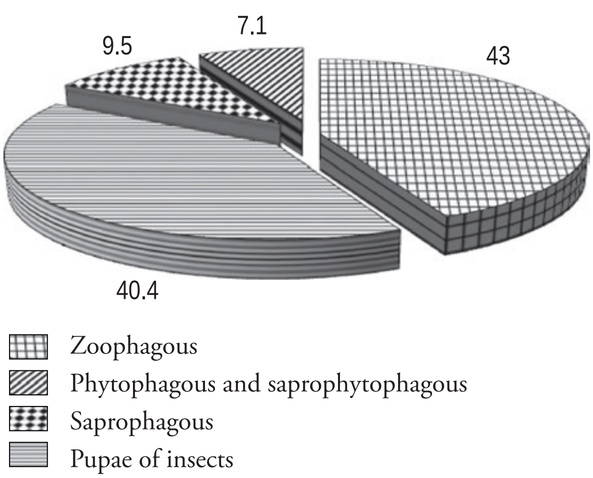

Figure 3: Trophic structure of the soil macrofauna in the study area.

Slika 3: Trofična struktura talne makrofavne v preučevanem območju.

Diptera) amounted to 4.2%, imagines of darkling beetles (1.3%) include necrophagous and coprophagous organisms (feeding on dead matter or excrements respectively) such as Diptera larvae, or larvae and adult forms of Coleoptera and Lepidoptera.

The macrofaunal community of the *Stipa lessingiana* steppe on dark chestnut calcareous soil in the Turgai Plateau (Kazakhstan) shows a high taxonomic diversity, similar to other parts of the steppe zone (Striganova, 2005). Soil macrofauna is represented by 4 distinct classes (*Arachnida*, *Crustacea*, *Myriapoda* and *Insecta*). Unlike in other regions, however, *Oligochaeta,* have not been found in the examined steppe type. Insects are the most prevalent group among investigated soil invertebrate communities (80.0–93.4% of total invertebrate abundance), especially *Coleoptera*. Earthworms were not found in our steppe samples. Animals were shown to occur in depths of up to 80 cm. The largest proportion of the zoomass, however, was concentrated in the humus horizon 0–30 cm below ground level. We discovered that animals redistributed themselves in the soil during the growing season: 89.4% of invertebrates were collected in the 0–30 cm layer in May, 91.4% in June, 98.4% in July, 100% in August, 94.9% in September. In layers deeper than 30 cm, some larvae of weevils, different larvae stages of click beetles (*Asilidae*) were found. At a depth of 20 to 40 cm, some nests of earth bees were discovered. Some imagines of ground beetles, centipedes and some other invertebrates were also found to reach even deeper layers through cracks in the soil. During the growing season the density of the soil macrofauna community of the *S. lessingiana* steppe averages 36.9 individuals/m^2 (excluding imago of ants and locusts egg capsules; in certain years the number of the locusts egg capsules amounted to 7.7 individuals /m^2 in early spring), and the total biomass amounts to 0.7–1.2 g/m^2. The density of soil invertebrates reaches its maximum in early spring and in autumn (50–60 individuals / m^2) with a maximum biomass of 3.3 g/m^2. 7.1% of collected invertebrates account for the non-active phase of metamorphosis, i.e. pupas of insects. During a long period in the dry and hot summer months lots of insect species survive as pupas or move to deeper soil layers as larvae where they stay out the time without feeding. A typical group of *Coleoptera* in the investigated area used empty burrows of marmots or susliks, for example, species of carpet beetles (genus *Dermestes*), large ground beetles *Taphoxenus gigas,* and species of dung beetle from the genus *Aphodius* (e.g, *A. arenarius*).

The total abundance and biomass of the soil invertebrate community in dry steppe of Kazakhstan are lower than in the northern and western steppe areas. For example, macrofauna of feather-grass steppe of the neighboring Chelyabinsk Region contained *Lumbricidae*, *Geophilidae*, *Enhitreidae* as the most predominant groups with very high abundances of up to 127.0 individuals/m^2 (Marakushina & Pokarzhevskii 1975). In a forest-steppe zone, Lumbricidae account for 50–70% of the total abundance of the macrofauna, and in north steppe areas they represent about 15% (Striganova 1996). In the upland steppe of the European part of Russia, the total abundance of macrofauna averages 60–70 individuals/m^2. At the same time, in the Virgin steppe of the investigated area of Turgai Plateau (Naurzum Reserve), *Lumbricidae* were not present either. In the dry steppe of Mongolia (Ulykpan 1988) and in semi-desert landscapes of Volga-Ural interfluve area (Arnoldi et al.1971) Coleoptera (Curculionidae, Carabidae, Elateridae, Tenebrionidae) dominate in macrofauna. We argue that this is a result of the dry and continental climate of the Kazakh dry steppe as well as of the lower amounts of humus in the soil. More than half of the invertebrates found were root feeding (phytophagous) and zoophagous, while the main energy flows go through grazing food chain. Levels of abundance and biomass were similar to those of the Mongolian dry steppes and semi-deserts of western Kazakhstan. We also found a number of species of invertebrates, commonly found in more southern regions of desert-steppes and deserts: for example, ground beetles as *Cicindela atrata*, *Carabus bessarabicus*, *Pterostichus serviceus*, *Pterostichus crenuliger*, *Harpalus akinini*, *Harpalus anxius*, *Taphoxenus.* L. V. Arnoldi (1969) attributed them to desert steppes at the end of the 1950–60s. Furthermore, species like *Cymindis picta* which we collected in our study area, is a typical desert species (Arnoldi 1969). Also, some desert steppe species of darkling beetles *Platyscelis hypolithos*, *Blaps lethifera* and typical species of the desert zone, like *Oodescelis polita*, *Scythis macrocephala* and others were also found to be characteristic for the *S. lessingiana* steppe of the investigated area. This shift of desert species can have been caused by the increase of temperatures inherent to global climate change over the last decades. Other factors driving desert species into steppe areas are connected to widespread plowing of Virgin steppes and overgrazing in the surrounding areas, leading to anthropgenically induced desertification of the landscape. Desertification, as a severe change in environmental conditions, inadvertently affects the structure of communities of soil invertebrates and initiates the adaptive changes of biota. Our data indicate an increasing xerophytisation of current soil-dwelling macrofauna communities of the Kazakh dry steppe.

Acknowledgments

I am very grateful to all the supporters who assisted in the field observations and laboratory analyses. I also thank everbody who contributed to this work by discussing and providing comments, especially Orsolya Valkó, Balázs Deák, Siobhan Loftus and Rocco Labadessa for editorial, linguistic edition and handling. We thank the Eurasian Dry Grassland Group (EDGG) for possibility to publish this paper.

References

Anderson, J. M. & Ingram, J. S. I. 1993: Tropical soil biology and fertility: a handbook of methods. Second edition. CAB International, The Cambrian News, Aberstwyth, United Kingdom, 221 pp.

Arnoldi, L. V. 1969: Biocomplex studies in Kazakhstan. Part 1 [in Russian]. Leningrad, Nauka, Leningrad Affiliation, pp. 32–40.

Arnoldi, K. V., Perel, T. S. & Sharova, I. H. 1971: Influence of artificial forest plantations in the clay semidesert. [in Russian]. Science, Moscow, pp. 34–54.

Bragina, T. M. 2001: Some aspects of the transformation of the soil fauna under desertification [in Russian]. Reports of the National Academy of Sciences of Kazakhstan 2: 71–75.

Bragina, T. M. 2004: Comparative analysis of the population of soil invertebrates of steppes and fallow lands in the sub zone of moderately dry steppe of Kazakhstan [in Russian]. Proceedings of the national Academy of Sciences of Kazakhstan. Biological and Medical Series 4: pp. 25–30.

Bragina, T. M. 2009: Naurzum Ecological Network (history of research, current status and long-term conservation of the biological diversity of the region representation of a natural object UNESCO World Heritage Site). – Kostanay: Kostanaypoligrafiya, 200 pp.

Byzova, Y. B., Gilyarov, M. S., Dunger, V., Zakharov, A. A., Kozlovskaya, L. S., Korganova, G. A., Mazantseva, G. P., Meletsis, V. P., Prasse, I., Puzachenko, I. G., Rybalov, L. V., Striganova, B. R. 1987: Quantitative Methods in Soil Zoology [in Russian], Science, Moscow, 288 pp.

Demina, O. & Bragina, T. 2014: Fundamental basis for the conservation of biodiversity of the Black Sea-Kazakh steppes. Hacquetia 13(1): 201–214.

Dolin, V. G. 1978: The determinant of the larvae of click beetles of the USSR, Harvest, Kiev, 126 pp.

Drude, O. 1890: Über die Prinzipien in der Unterscheidung von Vegetationsformationen, erläutert an der erlautern an der zentraleuropäischen Flora. Botanische Jahrbuch. Bd 11: 21–51.

Francis, G. S. & Fraser, P. M. 1998: The effects of three earthworm species on soil macroporosity and hydraulic conductivity. Applied Soil Ecology 10: 11–19.

Ghilyarov, M. S. (Ed.). 1964: The determinant of soil-inhabiting insect larvae [in Russian]. Science, Moscow, 919 pp.

Ghilyarov, M. S. 1965: Zoological diagnostic method of soil [in Russian]. Science, Moscow, 278 pp.

Ghilyarov, M. S. 1975: Accounting for large soil invertebrates (macrofauna) [in Russian]. In.: Methods of soil zoological research [in Russian]. Science, Moscow, pp. 12–29.

Gurieva E. L. & Kryzhanovsky O. L. (Eds.), 1965: Key to the insects of the European part of the USSR. 1965: Beetles and Strepsiptera. Volume II. Science, Moscow-Leningrad, 668 pp.

Hölzel, N., Haub, C., Ingelfinger, M. P., Otte, A. & Pilipenko, V. N. 2002: The return of the steppe – Large-scale restoration of degraded land in southern Russia during the post-Soviet era. Journal for Nature Conservation 10: 75–85.

Jaroshenko, P. D. 1961: Geobotanika [in Russian]. Science of Academy of the USSR. Moscow–Leningrad, 474 pp.

Kryzhanovskij, O. L., Belousov, I. A., Kabak, I. I., Kataev, B.M., Makarov, K. V. & Shilenkov, V. G. 1995: A Checklist of the Ground-Beetles of Russia and Adjacent Lands (*Insecta*, *Coleoptera*, *Carabidae*). Pensoft Series Faunistica 3: 271 pp.

Lavelle, P. 1997. Faunal activities and soil processes: adaptive strategies that determine ecosystem function. Advances in Ecological Research 27: 93–132.

Lavelle, P. & Pashanasi, B. 1989: Soil macrofauna and land management in Peruvian Amazonia (Yurimaguas, Loreto). Pedobiologia 33: 283–291.

Lavelle, P., Decaens, T., Aubert, M., Barota, S., Blouin, M., Bureau, F., Margerie, P., Mora, P. & Rossic, J.-P. 2006: Soil invertebrates and ecosystem services. European Journal of Soil Biology 42: 3–15.

Magurran, A. E. 1992: Ecological diversity and its measurement. Springer, 179 pp.

Mamaev, B. M. 1972: The determinant of insects on the larvae [in Russ.]. Education, Moscow, 400 pp.

Marakushina, L. P. & Pokarzhevskii A. D. 1975: Soil macrofauna under forbs vegetation of Trans Ural forest steppe [in Russian]. In: Problems of Soil Zoology. Vth All-Union Conference. Abstracts, Vilnius, pp. 222–223.

Pesenko, Y. A. 1982: Principles and methods for the quantitative analysis of faunal investigations. [In Russian]. Science, Moscow, 287 pp.

Rachkovskaya, E. I. & Bragina, T. M. 2012: Steppes of Kazakhstan: diversity and present state. in: Marinus, J. A. Werger, M. & van Staalduinen, A. (eds.) Eurasian steppes. Ecological problems and livelihoods in a changing world. Springer, Dordrecht, pp. 103–148.

Ruiz N., Lavelle P. & Jiménez J. 2008: Soil macrofauna. Field manual. Technical level. Publishing Management Service, FAO, Rome. 112 pp.

Samoylova, E. S. 2015: A comparison of the soil macrofauna of floodplain and well-drained habitats of European steppe. Euroasian Entomological Journal 14(5): 475–479.

Sharova, I. Kh. 1981: Life forms of ground beetles (*Coleoptera*, *Carabidae*) [in Russian], Science, Moscow, 359 pp.

Striganova, B. 1996: Transect Approach to the Assessment of Soil Macrofauna Diversity. Biology International 33: 16–23.

Striganova, B. R. 2005: Main Research Trends in Russian School of Soil Zoology (Based on Proceedings of the IV All-Russian Conference on Soil Zoology). Biology Bulletin 32 (6): 635–638.

Tyshchenko, V. P. 1971: The determinant of spiders of European part of the USSR. Series "Keys to the fauna of the USSR, the Zoological Institute of the Academy of Sciences of the USSR," Vol. 105 [in Russian], Science, Leningrad, 282 pp.

Ulykpan, K. 1988: Soil invertebrates. Biological resources and environmental conditions of Mongolia. Vol. XXIX. Dry steppes of Mongolia. Part 2. Stationary investigations (Somon Undzhul) [in Russian]. Science, Leningrad Affiliation, Leningrad: pp. 119–122, 213–215.

Velasquez, E., Fonte, S. J., Barot, S., Grimaldi, M., Desjardins, T. & Lavelle, P. 2012: Soil macrofauna-mediated impacts of plant species composition on soil functioning in Amazonian pastures. Applied Soil Ecology 56: 43–50.

Zalesskaya, V. N. 1978: The determinantion of centipedes of the USSR (*Chilopoda*, *Lithobiomorfa*), Science, Moscow, 212 pp.