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Effect of Soil Moisture on the Epigeic Arthropods Diversity in Steppe Landscape

Marina Kirichenko-Babko[1*], Yaroslav Danko[2], Małgorzata Franus[3], Witold Stępniewski[4]

[1] Schmalhausen Institute of Zoology NAS of Ukraine, B. Khmelnitsky Str. 15, 01030 Kyiv, Ukraine
[2] Sumy Makarenko State Pedagogical University, Romenska Str. 87, 40002 Sumy, Ukraine
[3] Lublin University of Technology, Faculty of Civil Engineering and Architecture, Nadbystrzycka 40, 20-618 Lublin, Poland
[4] Lublin University of Technology, Faculty of Environmental Engineering, Nadbystrzycka 40B, 20-618 Lublin, Poland
* Corresponding author's e-mail: kirichenko@izan.kiev.ua

ABSTRACT
The consequences of global climate change are a decrease in precipitation as well as an increase in the length of the period with high temperatures from spring to autumn. The climate change intensified the negative consequences of land reclamation and regulation of rivers by dams in Ukraine in the 20th century. The modern landscape of the Circum-Pontic and Circum-Azov regions in Ukraine has undergone desertification, and a multiple reduction in the freshwater runoff has manifested itself in a violation of the water balance of soils and their salinization. In addition to the climate change and anthropic landscape transformations, most upland areas in southern Ukraine have been converted into farmland, systematically fertilized and treated with pesticides and herbicides. Total plowing of the territory also led to soil erosion and degradation. The global climate change and the impact of human activity have affected the diversity of the steppe fauna as well. The questions of the influence of soil humidity on the diversity of epigeic arthropods were considered on the example of ground beetles (Coleoptera, Carabidae). Soil moisture is one of the key factors that determines their diversity.

Keywords: steppe, humidity, ground-dwelling beetle, distribution, south-western Ukraine

INTRODUCTION

The current issues of conservation of biological diversity have gone far beyond the conservation of species populations [Myers et al. 2000]. Today, it is obvious that the problem of species conservation is the problem of preserving their habitats on the one hand and preserving the component composition of ecosystems on the other [Van Drop 1987; Berg et al. 1994]. Often, the disappearance of one species entails the disappearance of a number of other species that most often did not have any visible interconnections (trophic, topical, edaphic, etc.) and were not in competitive relations. On the one hand, this proves that our ideas about the structure and interactions of individual ecosystem components are quite incomplete, and on the other hand it shows that the extinction of species indicates the violation of important environmental parameters common to many species. In this context, two aspects are particularly important today. First of all, these are negative anthropic factors operating on the local scale, the effects of which are often unpredictable. Apart from that it is a phenomenon of global warming, the causes of which are also associated with the human activities. Global warming is accompanied by large-scale climate changes in entire regions and even continents. Distinct ecosystems described in detail in the 20th century, e.g. on the Eurasian continent – steppe, forest-steppe, woodland, etc. were the result of prolonged co-evolution of animals and plants under fairly stable conditions, in which the amplitude of deviations of individual factors remained, as a rule, within the ranges of ecological tolerance of most species. This predetermined the pronounced physiognomy of the composition of these ecosystems, their recognizability. However, the processes triggered by the climatic changes in combination with such forms of human activity as, for example, land reclamation, caused a significant change in the conditions, which led to a reduction in the abundance of species populations and it has already become obvious that we are witnessing a mass extinction of the flora and fauna representatives [Wilson, MacLean 2011; Ceballos et al. 2015; Kirichenko-Babko et al. 2017]. A manifestation of these processes is a universally observed reduction in the diversity of natural ecosystems [Butchart et al. 2019].

Especially noticeable reduction in diversity is observed among plants and invertebrates, both aquatic and terrestrial [Dirzo et al. 2014]. For most insects, one of the significant factors that determined their evolution and their spatial distribution is humidity. Humidity was the key factor in the high diversity of floodplain ecosystems [Hammond 1998]. Humidity, combined with temperature and seasonal fluctuations of these factors, as well as their gradients in individual landscape elements, determined a significant variety of ecological niches. At present, the dry periods have been significantly extended, whereas the areas of wet landscape elements have decreased, or they even have disappeared completely. This is one of the reasons for the creation of Wetland International program and close attention to the waterlogged ecosystems. In fact, against the background of global warming, the xerophytic species are in an extremely favorable position and, as a result, they are expanding to the previously wet landscape elements.

The fact that family of Carabidae (Coleoptera) is one group epigeic arthropods, the representatives which show the changes in the environmental conditions. This study is devoted to the analysis of the ground beetles distribution from various ecological groups, according to the elements of the steppe landscape with different humidity.

MATERIAL AND METHODS

Study area

The valley of the Tsarega River and the system of ravines (Velyka Zlodijka, Mala Zlodijka, Sazhneva and along left riverside of Tsarega) adjacent to it are included in the territory of the Tiligul Regional Park (nature reserve) (Ukraine, Mykolaiv Oblast). The study area is located at an altitude of 117 to 290 m above sea level. The climate of this region is continental with an average temperature of -18°C in January and +30°C in July. The potential evaporation rate is 600–900 mm.

Most of the flat interfluve areas are plowed and used as farmland. The steppe vegetation on the plateau has been preserved only along the edges and the slopes of ravines. Previously, the Tsarega River was full-flowing and a number of tributaries flowed into it. Today, the valleys of the tributaries are turned into ravines, and the Tsarega itself in the upper reaches is blocked by dams. As a result, on the territory of the park in the estuarine part of the river, the channel is shallow, swampy, and the current is practically absent. At the confluence with the Tiligulsky estuary, the mouth of Tsarega is blocked by a dam. In the Tsarega valley and along the bottom of the ravines adjacent to it, the meadow vegetation is preserved. The steppe vegetation is affected by salinization, present in the area with alkali clay soils.

Traps were placed at three levels: flat interfluves, slopes and the bottom of ravines. At each level, transects of 10 traps were set. The traps (plastic cups of 8 cm diameter and 12 cm depth, partly filled with 40% ethylene glycol) were placed 5 m from each other. The samples were taken once a week for three months (from June to August in 2009–2011). In the places of sampling, the soil moisture level was recorded. The values of humidity ranging from 1 to 3 were considered as dry, from 4 to 7 as moist and from 8 to 10 as wet. According to the humidity requirements, the carabid species were classified as xerophilic, mesophilic or hydrophilic, after Turin [2000].

In total, 30 locations were studied. In the analysis, the points with an identical relief, belonging to the same habitat and having the same soil moisture level were interpreted as one location. Therefore, he data on the locations identical in the indicated parameters were averaged; the result was 14 units for analysis.

Statistical analysis

The data were processed using R version 3.6.1 [R Core Team 2019]. The employed R – software environment for statistical data curation and graphics visualization is currently widely applied in ecology and environmental engineering

[Majerek et al. 2017; Pliashechnyk et al. 2018; Babko et al. 2019; Łagod et al. 2019]. Hierarchical clustering was performed with hclust (function ward.D2) from core R package stats. Two types of p-values (AU and BP) for the nodes of hierarchical clustering dendrograms were calculated with R package pvclust. According to the package documentation, "AU p-value, which is computed by multiscale bootstrap resampling, is a better approximation to unbiased p-value than BP value computed by normal bootstrap resampling. Clusters with AU larger than 95% are highlighted by rectangles, which are strongly supported by data" [Suzuki 2015]. Fuzzy clustering was performed with function fanny from package cluster [Maechler 2019] and plotted on the plain of principal components with fviz_cluster from factoextra [Kassambara, Mundt 2017]. Canonical Correspondence Analysis was performed with cca from vegan package [Oksanen et al. 2017]. The plots were produced using the ggplot2 [Wickham 2009], factoextra [Kassambara, Mundt 2017], ggrepel [Slowikowski 2018], and directlabels [Hocking 2018] packages.

RESULTS

The species composition of the ground beetles assemblage studied in the steppe landscape in four ravines (Mykolaiv oblast, Ukraine) includes 57 species of ground beetles (Table 1). In most stations of the studied ravines, 22 species were found.

In the dry periods, a noticeable moisture gradient persisted in the study area mainly in ravines. The structure of the ground beetles assemblage in the soil moisture gradient was analyzed. The results of hierarchical clustering showed that the sampling sites was divided into two clusters, the reliability of which is confirmed by the approximately unbiased (AU) p-values obtained by means of the bootstrap method (Fig. 1A). Most of the sites where steppe vegetation is preserved fell into one cluster, while the sites at the bottom of the ravines where meadow vegetation dominates – in another. Smaller clusters, although reliable according to the same criterion, do not have a clear biological interpretation.

The fact that the ground beetle assemblage can be meaningfully divided into only two groups indicates that the climate change, together with the negative impact of humans on the water accessibility in the steppe landscape, is significant. In the studied territory, the species composition of ground beetles is represented mainly by common species, many of which are tolerant to a wide amplitude of humidity fluctuations. At the same time, the hygrophilous species: *Carabus clatratus, Elaphrus cupreus, Chlaenius nigricornis, Ch. vestitus, Demetrias imperialis* did not disappear from the ground beetle species assemblage in the steppe.

The results of fuzzy clustering essentially coincide with the results of hierarchical clustering. These two groups of habitats superimposed on the plane of the first two principal components of PCA (Fig. 1B) overlap minimally, which additionally confirms the presence of the areas with different humidity conditions – dry and wet – in the steppe.

As already mentioned, the conditions in the studied areas differed in such a factor as soil moisture. It is customary to classify the conditions with moisture values from 1 to 3 as dry, and from 4 to 7 – as wet. The CCA ordination plot (Fig. 2A) shows the relative location of the studied habitats that differ in the type of vegetation and the substrate moisture level, based on the data on the abundance of ground beetles. Thus, the steppe locations were concentrated mainly on the left side of the plot, and on the right side – the stations located mainly on the bottom of the ravines.

On the CCA ordination plot (Fig. 2B), the species were distributed from left to right, according to their moisture requirements from xerophilous to mesophilous and hygrophilous. Among the species found, 31 species (Table 1) showed an affinity to the habitats where substrate moisture values varied from 4.5 to 7.0; 26 species demonstrated an affinity to the xerophilic conditions with moisture values below 4.

The preferences of species with respect to the humidity conditions are usually established by their occurrence under various conditions and rarely based on the laboratory results, which makes the existing characteristics of species not always objective. In addition, some species have a significantly greater amplitude of tolerance to the humidity conditions. This fact could remain undetected, since the extreme values of the humidity spectrum could simply be absent under those specific conditions, based on the study of which the ground beetles were classified by humidity preferences. Therefore, such designations as xero- meso- or hygrophilous assigned to the

Table 1. Carabid species collected in steppe ravines, their occurrence in relief elements and soil humidity conditions. Abbreviation: X – xerophilous, M – mesophilous, H – hygrophilous, X(G) – halophiles, O – open habitat, F – forest, G – generalists, R – riparian

Species	Code of species	Moisture require-ment	Habitat preference	Frequency of occurrence in elements of ravines		Soil humidity *	
				slopes	bottoms	dry	moist
Acupalpus elegans	A_elegan	X	O	-	1	x	-
Agonum dorsalis	A_dorsal	X	O	-	1	-	x
Amara aenea	A_aenea	X	O	2	2	x	-
Amara similata	A_simila	X	O	-	3	-	x
Anisodactylus binotatus	A_binota	H	O	1	2	-	x
Anisodactylus poeciloides	A_poecil	X	O	-	1	-	x
Anisodactylus signatus	A_signat	M	O	2	1	x	-
Badister bullatus	B_bullat	M	G	-	1	-	x
Bembidion properans	B_proper	M	O	-	1	-	x
Broscus cephalotes	B_cephal	X	O	-	1	-	x
Calathus ambiguus	C_ambigu	X	O	2	1	x	-
Calathus erratus	C_erratus	X	O	-	1	-	x
Calathus fuscipes	C_fuscip	X	O	2	-	x	-
Calathus melanocephalus	C_melano	X	O	1	-	x	-
Calosoma auropunctatum	C_auropu	X	O	1	-	x	-
Carabus besseri	C_besser	X	O	1	1	x	-
Carabus clatratus	C_clathr	H	R	-	1	-	x
Chlaenius nigricornis	C_nigric	H	R	1	-	-	x
Chlaenius vestitus	C_vestit	H	R	1	-	-	x
Demetrias imperialis	D_imperi	H	R	-	1	-	x
Dromius meridionalis	D_meridi	M	R	-	1	-	x
Dyschirius rufipes	D_rufipe	M	O	2	-	x	-
Elaphrus cupreus	E_cupre	H	R	-	1		x
Harpalus anxius	H_anxius	X	O	2	1	x	
Harpalus calathoides	H_calath	X	O	3	2	x	
Harpalus distinguendus	H_distin	X	O	-	4	-	x
Harpalus flavicollis	H_flavic	X	O	3	2	x	-
Harpalus fuscipes	H_fuscip	X	O	1	-	x	-
Harpalus honestus	H_honest	X	O	2	-	x	-
Harpalus modestus	H_modest	X	O	-	1	x	-
Harpalus pumilis	H_pumili	X	O	3	-	x	-
Harpalus rubripes	H_rubrip	X	O	-	1	-	x
Harpalus serripes	H_serrip	X	O	-	1	x	-
Harpalus smaragdinus	H_smarag	X	O	2	1	x	-
Harpalus tardus	H_tardus	X	O	2	-	x	-
Microlestes maurus	M_maurus	M	O	5	1	x	-
Microlestes minutulus	M_minutu	M	O	4	3	x	-
Ophonus azureus	O_azureu	X	O	1	3	-	x
Ophonus rupicola	O_rupico	X	O	-	1	-	x
Ophonus seladon	O_selado	X	O	-	1	-	x
Poecilus cupreus	P_cupreu	M	O	-	1	-	x
Poecilus sericeus	P_serice	X	G	1	1	x	-
Porotachys bisulcatus	P_bisulc	M	G	1	-	x	-
Pseudoophonus calceatus	Ps_calce	X	O	-	1	-	x
Pseudoophonus rufipes	P_rufipe	X	O	1	6	-	x
Pterostichus anthracinus	P_anthra	H	F	-	4	-	x
Pterostichus cursor	P_cursor	X(G)	O	3	1	-	x
Pterostichus diligens	P_dilige	M	F	-	1	-	x
Pterostichus elongatus	P_elonga	X(G)	O	-	1	-	x

Table 1. cont.

Species	Code of species	Moisture require-ment	Habitat preference	Frequency of occurrence in elements of ravines		Soil humidity *	
				slopes	bottoms	dry	moist
Pterostichus incommodus	P_incomm	M	O	-	1	-	x
Pterostichus macer	P_macer	X(G)	O	-	2	-	x
Pterostichus melas	P_melas	M	F	3	4	-	x
Syntomus obscuroguttatus	S_obscur	X	O	2	1	x	-
Syntomus pallipes	S_pallip	X	O	-	2	-	x
Trechus quadristriatus	T_quadri	M	G	-	3	-	x
Zabrus spinipes	Z_spinip	X	O	8	1	x	-
Zabrus tenebrioides	Z_tenebr	X	O	3	-	x	-
Number of species				30	45	26	31

* **Note:** description of the soil humidity given in the Material and methods. x – presence of species.

species can be considered as somewhat vague and should be refined as information accumulates.

As can be seen from the CCA ordination plot (Fig. 3A), most species were distributed in a moisture gradient according to their known preferences. However, it should be noted that some xerophilous species were found in the habitats with high soil moisture, which indicates their high tolerance to the moisture content in the soil, and can be considered as a basis for clarifying their characteristics. In any case, these species of *Anisodactylus poeciloides*, *Harpalus rubripes*, *Ophonus seladon*, *O. rupicola*, *Pseudoophonus calceatus*, *P. rufipes*, *Syntomus pallipes*, *Agonum dorsalis* and *Calathus erratus*, which, according to the existing classification, are xerophiles, were observed under the conditions of humidity value 5 and higher.

Moreover, the study habitats with dry soil moisture were distinguished by the steppe beetle species such as *Calathus ambiquus, C. fuscipes, Harpalus sericeps*, *H. tardus* and *Pterostichus sericeus. P. sericeus* is the most dominant species of the steppe and is a common species in most of Europe [Alignan et al. 2018].

The halophiles species – *Pterostichus cursor*, *P. elongatus*, *P. mace*r were also founded in the ravine of the Tsarega river valley and steppe landscape testifies to the process of soil salinization, the cause of which is the filling of the Tiligul estuary with sea water.

The steppe ecosystem in river deltas prior to its active development by humans was characterized by a developed system of wet ravines with temporary and constant flows. The presence of bayrack forests and shrubs in ravines and depressions was characteristic of the steppe.

The ground beetles were analyzed according to their preferences for open and closed habitats. It can be seen in the plot (Fig. 3B) that the species characteristic of open habitats prevails in the steppe ravines, most of them belong to the xerophilous species. In turn, the species that prefer closed habitats are hygrophilous (Fig. 3A, B). The analysis of the current situation in the distribution of ground beetle species showed that under the conditions of high humidity, the forest and riparian species were encountered (Fig. 3B). To date, three forest species have been found in the ravines on the territory of the Tiligulsky RLP: *Pterostichus anthracinus*. *P. diligens* and *P. melas*. The riparian species found in ravines are not considered by us as preferring closed habitats, but their presence at the bottom of ravines overgrown with near-water vegetation indicates the presence of surface water outcrops.

DISCUSSION

Dry or steppe grasslands are considered regional biodiversity hotspots [Cremene et al. 2005]. In Central and Eastern Europe, they have been drastically affected by agricultural intensification [Dutoit, Jaunatre, Buisson 2013; Alignan et al. 2018]. Since the second half of the 20th century, most of the territories in the south of Ukraine, which are open landscapes with a flat relief, have been overexploited and become one of the most degraded ecosystems. As a result, the steppe ecosystem has almost disappeared [Huston 2005]. The remains of the steppe sites account for 1% of the area of the steppe zone of Ukraine, which in turn is 40% of the total area of the country. Such a large-scale impact on the natural landscapes certainly affected the animals. The negative effect of agriculture

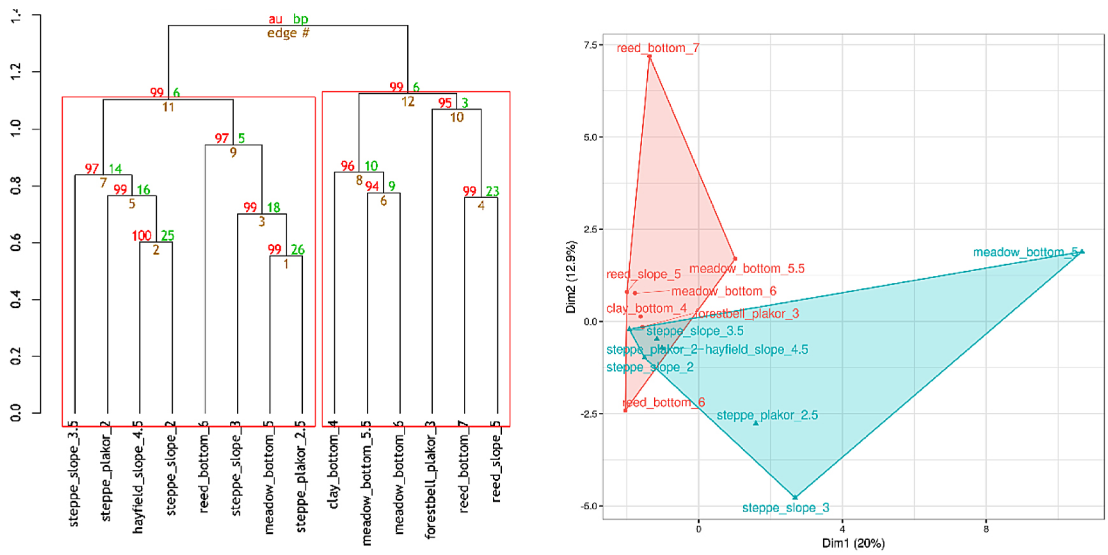

Figure 1. Clustering of sampling sites in the studied ravines, named accordingly to habitats, relief and humidity values (numbers at the end): A – hierarchical Ward's clustering and B – fuzzy clustering. The data were Hellinger-transformed

on invertebrates is also obvious, but an assessment of the human impact on the diversity of invertebrates requires further research [Holland, Reynolds 2003; Perner, Malt 2003].

It is known that arthropods are able to adapt to the conditions of cultivated soils and, in some cases, achieve significant abundances [Hummel 2002; Amador, Görres 2007; Saska 2007]. Arthropods in such soil condition have been quite actively studied since the 1960s [Cinītis, Vilks 1962; Vickerman 1978; Siemann 1998; Fournier, Loreau 1999; Belovsky, Slade 2000]. The structure of the carabid assemblage in the fields has been sufficiently studied and is interpreted as an assemblage of "field" species [Sobeleva-Dokuchayeva 1996; Romankina,

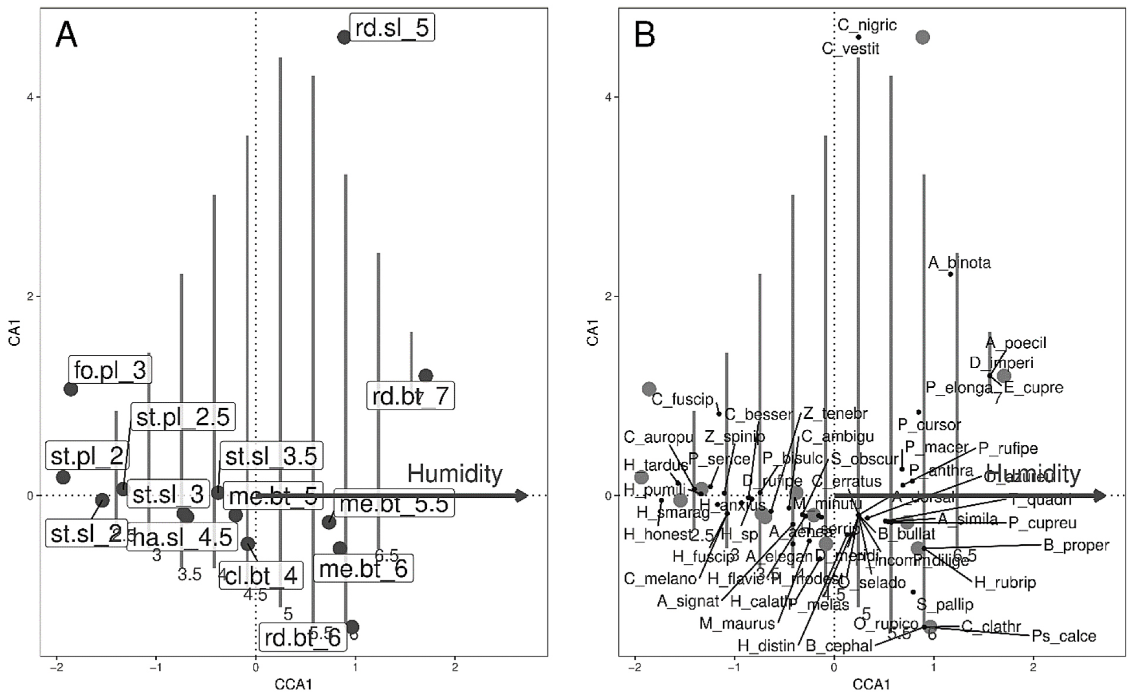

Figure 2. CCA ordination: A – studied habitats in the gradient of soil moisture; B – distribution of ground beetle species in a moisture gradient. Habitats: st – steppe, me – meadow, rd – reeds, fo – forestbelt. Relief of the study ravines: pl – plakor, sl – slope, bt – bottom

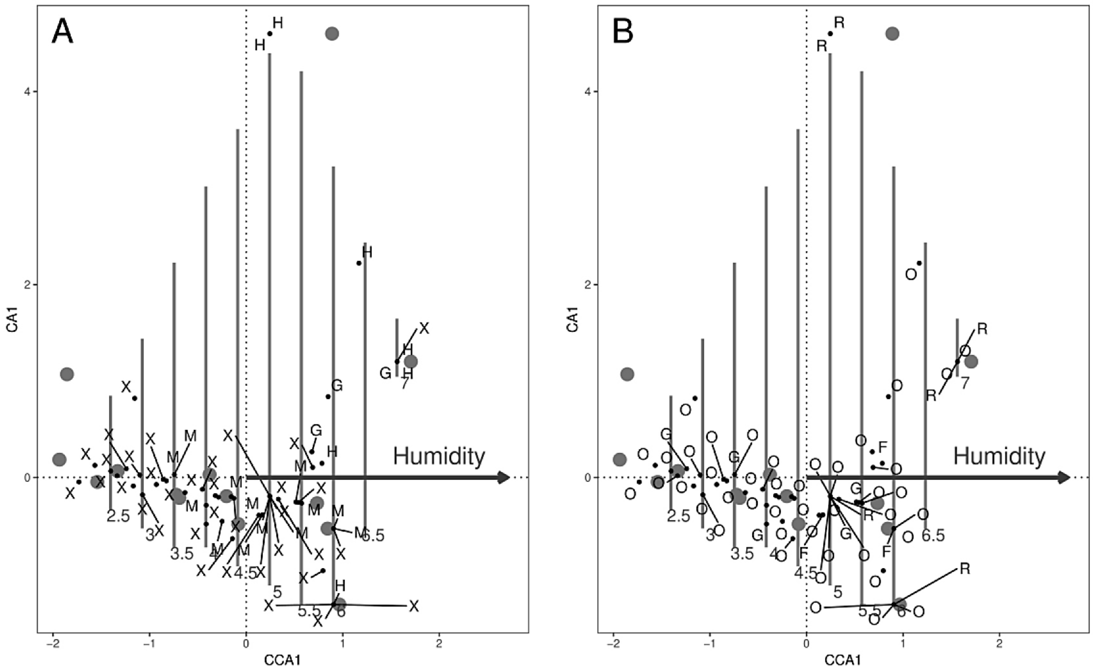

Figure 3. CCA ordination plot of study sites and distribution of 57 ground beetles species, classified: A – according to their preferred soil moisture conditions (X – xerophilous, M –mesophilous, H – hygrophilous, G – halophilous) and B – preferred habitats (O – open habitat, F – forest, G – generalists, R – riparian)

Sharova 2011]. Obviously, the species present in the fields are agriculturally tolerant fraction of the species that existed previously in the steppe landscape [Andersen 2000]. According to Ouchtati et al. [2012] who conducted studies in Algeria, the soil humidity values in the natural steppe area are more favorable for the hygrophilous ground beetles than in agricultural landscapes. The changes in the structure of arthropod communities, a decrease in their diversity, obviously occur as a result of human activity and, of course, climate change [Kimberling et al. 2001; Andrew 2013; Andrew et al. 2013].

In addition to the total chemicalization of agricultural territories, in the last decade, an additional negative factor in the south of Ukraine is a decrease in precipitation and an increase in temperature as a result of a global climate change. It is known that the water content in the upper layers of the soil decreases relatively quickly compared with the deeper layers, and the amount of moisture is an important factor for invertebrates at all stages of their development [Nepstad et al. 2002]. Such basic climate parameters as temperature and humidity directly and indirectly affect insects [Parmazan 2007; Jaworski, Hilszczanski 2013]. According to Andrew et al. [2013], humidity is one of the main factors to be measured when studying the effect of climate change on insects.

The representatives of the carabids species are epigeic arthropods and can tolerate significant fluctuations in temperature and humidity [Baranovská et al. 2019]. However, moisture is an important factor for them and affects their distribution [Lott 1996, 2002; Hammond 1998; Brose 2003]. Terrestrial invertebrates cope with the periods of drought due to the changes at the cellular level leading to hypoxia or even anoxia. Such changes at the physiological level affect the activity and behavior of invertebrates, provoking their spatial movements largely determined by humidity [Hoback, Stanley 2001; Harrison et al. 2006].

In the steppe ecosystem, where abiotic conditions and litter quality determine the slow cycle of nutrients, carabids, along with other epigeic arthropods, play a significant role in detrital food chains [Coleman et al. 2004; Moore et al. 2004; Culliney 2013]. The spatial distribution of ground beetles is determined by many factors, which allows us to consider their spatial structure as an indicator of the local quality of the environment. Although ground beetles are attracted to the areas with high vegetation cover, they move freely through open spaces in search of food or suitable living conditions [Fournier, Loreau 1999; Halaj et al. 2000; Woodcock, Pywell 2010].

Many species of ground beetles are sensitive to environmental disturbances, especially soil conditions, and therefore are good indicators reflecting the changes in the abiotic conditions, in particular, as a result of the processes of drainage and desertification. For example, in the region where the considered research was conducted as a result of hydraulic engineering, the tributaries of the river Tsarega – steppe ravines – are now blocked by dams.

The heterogeneity of the vegetation cover – from steppe dry vegetation to reeds and marshy vegetation at the bottom of ravines – associated with the differences in the abiotic conditions forms an assemblage of ground beetles since it is the vegetation that largely determines the number and variety of victims of carnivorous arthropods. As the results of our studies have shown, the heterogeneity of conditions in the steppe ravines determines the small-scale distribution of ground beetles in them.

As for the presence of hygrophilous ground beetle species in the structure of the assemblage, our findings of *Carabus clathratus* in the steppe ravines are also confirmed by the data of Nagumanova [2007]. According to her research, this mesophilous species occurred in the steppe ravines and depressions in the Transural Steppe region. Nagumanova [2007] notes that the such hygrophilous as *Pterostichus diligens*, *Badister bipustulatus*, and *Synuchus nivalis*, more often occur in the places where the underground waters lie close to the soil surface.

As laboratory studies have shown [Baranovská et al. 2019], the species from the wet habitats had higher water loss rate compared to the species from the dry habitats; as a result the species from the wet habitats were more sensitive to desiccation. Size also mattered and the species of larger body size were more resistant compared to smaller species. *Pseudoophonus rufipes* was the most resistant out of the carabid species. This species was not superior to other species with respect to water loss rate but it had the highest relative water content. According to our studies, *P. rufipes* was found in humid habitats of steppe ravines, as well as on agricultural lands on flat interfluvia [Kirichenko & Nazarenko 2011].

The results of a study on soil invertebrates in the Ural steppe [Nagumanova 2007] showed that the total abundance of hygrophilous soil invertebrates is strongly decreased by the permanent deficiency of water during the summer and autumn seasons. She also claims that the diversity and abundance of soil mesofauna decreased from the forbgrass steppes to saline sites, as humidity decreases and the pH value increases.

The structure of the ground beetles assemblage on the steppe ravines of the south-west of Ukraine is dominated by steppe xerophilous species, as well as in the Transural steppes, where the fraction of steppe species increases in the dry steppes [Nagumanova 2007]. According to her data, 48 species of ground beetles were found in the steppes of the Orenburg province. In our study, the core of the structure of the assemblage of ground beetles is formed by xerophilous species (65% of the total number of species found). The share of meso- and hygrophilous species (23% and 12%) combined is half as much; these species are confined to relief depression and ravines.

In the studied territory, the species of open habitats make up the majority (75% of the total number of species). The proportion of species gravitating to other habitats was lesser: riparian species – 10.5%, generalist species – 8%, forest species – 5% (Table 1).

CONCLUSION

The remains of the steppe vegetation are preserved in natural reserves. Today, small fragments of the steppe along the edges of ravines and ravines with steppe vegetation on the slopes remain the last refuge for many arthropods and small vertebrates. The climate change and a decrease in water content led to the changes in the structure of the steppe vegetation; bayrack forests and shrubbery disappeared along the ravines. The remains of shrubby vegetation are localized mainly on small areas in the places where groundwater reaches the surface. Due to the lowering of the groundwater level, the number of springs in the ravines has decreased manyfold, and the meadow vegetation is found along the bottom of the ravines. The above-mentioned processes determine the structure of the ground beetles assemblage in this territory. In addition to the ubiquitous reduction in the diversity of arthropod species, the xerophilous forms prevail.

The core of the structure of the assemblage of ground beetles is formed by xerophilous species (65%). Despite the considerable distance from the Black Sea coast (45 km) in the structure of the assemblage of ground beetles in the studied territory, 5% of species are represented by typical halophiles, which is evidence of a stable, directed process of salinization [Kirichenko, Babko 2009]. The meso- and hygrophilous species constituting 35% of the total number of species found and are observed mainly in limited local areas at the bottom of ravines in the places where groundwater escapes.

In the structure of the ground beetles assemblage in the steppe ravines, the species of open habitats prevail (75% of the total number of species).

Given the current trends in the climate change and a further decrease in the groundwater levels due to the river flow regulation in this region, it is safe to predict a decrease in the number of mesophilic and hygrophilic constituents of the assemblages of epigeic arthropods.

Isolated areas with steppe vegetation surrounded by vast areas occupied by agricultural lands remain the last refugia for the steppe fauna. Most of the nature reserves in the south of Ukraine are represented by fragments remote from each other and occupying negligible areas. This situation with the fragmentation of natural reserves, the lack of spatial contacts between them, can also trigger the extinction mechanisms of species and lead to a further reduction in the species diversity in this region.

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