

Are Heteroptera communities able to be bioindicators of urban environments?

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The Heteroptera is a group of animals associated with the vegetation cover. The conducted analysis indicates that groups of heteropterans in the urban environment have a pattern of reaction to the environmental factors, determined using the phytoindication method. In the study, we considered the following hypotheses: 1) phytoindicational assessments of ecological factors may explain the patterns of variation of the groups of heteropterans; 2) among Heteroptera species, comparatively homogenous ecological groups could be distinguished which are characterized by similar character of response to the effect of certain environmental factors; 3) these groups could be used for bioindication of the conditions of environment in urban ecosystems. Stationary collection of heteropterans was performed during three years from May to October of 2017–2019 on six plots in Kharkiv. The article describes factors which affect the structure of groups of Heteroptera within the ecosystem of the large city and assess the bioindication possibilities. The data presented in the article, as well as the conclusions drawn, are to a large extent associated with stenotopic species, most of which could be used as bioindicators of the condition of one or another biocenosis. According to the results of a taxonomical survey in the territory of Kharkiv, 180 species of Heteroptera were found, belonging to 120 genera and 17 families. The highest species diversity was seen for the family Miridae, accounting for 50 species (27.0% of the total number of counted species). Fewer species were identified as the representatives of families Lygaeidae – 46 species (24.9%) and Pentatomidae – 23 (12.4%). Family Rhopalidae was represented by 11 species (5.9%). Nabidae and Tingidae – 10 species each (5.4%). Families Coreidae – 8 (4.3%), Cydnidae and Scutelleridae – 4 species each (2.2%), Anthorcoridae – 3 (1.6%). The families Berytidae, Piesmatidae, Pyrrhocoridae and Reduviidae were represented by only 2 species each (1.1%). Families Acanthosomatidae, Alydidae and Aradidae were represented by 1 species each, in total accounting for 1.5%. The reasonably high level of species and ecological diversities of Heteroptera in the territory of the city allows them to be used in bioindication studies. We determined comparatively homogenous ecological groups of heteropterans which have a similar pattern of response to the impact of certain environmental factors. The study demonstrates that phytoindicatory assessments of the ecological factors can explain the patterns of variation in groups of heteropterans. We determined the factors which have effects on the structure of the group of heteropterans within the metropolitan ecosystem. The level of their effect on groups of heteropterans within the city is different. The most influential were light and humidity. Comparison of potential and realized projections of ecological space allows us, to a certain extent, to generate hypotheses about the orientations of transformation of the group heteropterans.

Keywords: Homoptera; biodiversity; ecological groups; metropolis; phytoindicatory assessment; bioindicators.

Introduction

There is a paradox of the double way of looking at communities (Matějka, 1992; Zhirkov, 2017). The nature of the community is discussed from the opposite points of view: holistic or meristic. According to the holistic paradigm (organisms or structuralism), the biotic component of an ecosystem is a kind of superorganism. The meristic paradigm (or continualism) assumes that various species have a relatively high degree of freedom (Panikov, 2010). Within the framework of continualism, the organism's response to environmental factors is considered as a specific property, which is generally explained by a bell-shaped curve (Mölder et al., 2008; Chytrý et al., 2018). The conclusion about living organisms as indicators of environmental properties is logical and became the basis for creating a set of indicator scales. One of the first such scales was created by L. Ramensky, the founder of continuum paradigm (Ramenskiy et al., 1956). The principles of phytoindication are a practical consequence of the theory of biotope (Dahl, 1908; Townsend & Hildrew, 1994; Newson & Newson, 2000) according to which biocenosis (Möbius, 2000) is based on the observable physical properties of the environment (Jowett, 1993; Padmore, 1998; Clifford et al., 2006). An ecosystem, in turn, is a combination of biotope and biocenosis.

Within the framework of structuralism, environmental factors are relegated to the background and intra-systemic interactions are brought to

the forefront, which results in the observed boundaries of biotic communities being explained as those of endogenous nature. Recently, the conflict between continualism and structuralism has taken the form of competition between the theory of ecological niche (Hutchinson, 1965) and the theory of neutral diversity (Hubbell, 2005; Ricklefs, 2006; Zhou & Zhang, 2008). The constructive consequence of this confrontation is mitigation of the problem, namely, which of the alternative concepts is the only true one and which is false. The solution moves on to the clarification of the question under which circumstances one of the viewpoints explains a greater range of observed facts than the other, and under which circumstances the priority moves to a competing viewpoint (Zhukov et al., 2017; Zhukov, 2018).

Biogeocenosis is a combination of biocenosis and ecotope (Sukachov, 1964). The term ecotope was suggested by Vysotsky (1925), but in English-language literature, Sørensen is considered the author (Sørensen, 1936) or Tansley (1939). An ecotope is the smallest integral unit of the Earth's surface which is characterized by homogeneity of at least one of the properties of the geosphere: atmosphere, vegetation, soil cover, rocks, water, etc. with non-extreme variation of other properties (Naveh & Lieberman, 1994). In the tradition of biogeocenology, the ecotope includes a climatope and an edaphotope. In turn, the climatope consists of a heliotope and a thermotope, while the edaphotope consists of a hygrototope and a trophotope (Belgard, 1950; Sukachov, 1964). Sukachov (1964) considers the biotope to be the zoological equivalent of the botanical term ecotope.

Nevertheless, the history and practice of using these terms allows them to be interpreted as the equivalent of abiotic properties of the environment within the framework of continualism (the biotope is a component of the dimensionless concept of ecosystem) and abiotic properties of the environment transformed by biota (the ecotope is a component of biogeocenosis as an ecosystem within the boundaries of phytocenosis) within the framework of structuralism.

In the late 1940s Belgard (1950) created a typology of forests in the steppe zone of Ukraine, which is a striking example of the effectiveness of the principles of biogeocenology, and in this sense this concept should certainly be recognized as structuralist. The typology was supplemented by a system of plant ecomorphs. According to Belgard's ideas, the ecomorphs reveal the relationship between organisms and environment and reflect the degree of their adaptation to the most important elements of biogeocenosis. The term ecomorph is preferred for the reason that the life form is usually understood as adaptation, which is expressed in the appearance of the plant, while adaptation not to all structural elements of the biogeocenosis has a physiognomic manifestation. The ecomorph system was extended to other biogeocenosis components (Zhukov et al., 2017), which allows the ecomorph to be interpreted as an adaptation of the biotic and biocenosis component of a biogeocenosis to the biogeocenosis as a whole. In its turn, adaptivity is defined as the reaction of different objects to environmental factors, which manifests itself in changes in the structure and functions of reacting objects and their groups in response to various changing conditions, resulting in their existence.

Before our study, the groups of heteropterans in the urban and transformed system had been surveyed fragmentally (Brygadyrenko, 2015, 2016; Zhuravel et al., 2016; Fedyay et al., 2020).

In the study we shall consider the following hypotheses.

1. Phytoindication assessments of ecological factors may explain the variation patterns of groups of Heteroptera.

2. Among the species of Heteroptera, comparatively homogenous ecological groups could be distinguished, which characterize the responses to the effect of separate environmental factors by similar pattern.

3. These groups could be used for bioindication of the conditions of the environment in urban ecosystems.

The objective of the study was to determine the factors which affect the structure of the group of Heteroptera within the ecosystems of a large city and assess their bioindicational possibilities. The data presented in the article, as well as the conclusions drawn are to a large degree related to the stenotopic species, most of which could be used as bioindicators of the condition of one or another biocenosis.

Material and methods

Stationary collection of heteropterans was performed during three years from May to October of 2017–2019 on six plots in Kharkiv: Pere-moha Park, territory of the Botanical Garden of the H. S. Skovoroda Kharkiv National Pedagogical University (SKNPU), Kharkiv Forest-Park, Zhuravlivsky Hydropark, territory of the multi-storey residential area in the Sarzhyn Yar Ravine. A detailed description of the plots is given in the previous surveys (Putchkov et al., 2017).

For the account of the heteropterans, we used the standard method of butterfly net sweeping and also Barber pit-fall traps (plastic cups of 0.2 L capacity filled with 10% solution of acetic acid) and manual collecting of insects in the detritus (soil litter). In each plot, we performed no less than 150 sweeps with the butterfly net and set 10–20 traps. Furthermore, heteropterans were collected while following itineraries in the city by examining separate plants and trees.

Phytoindication scales are given according to Didukh (2011). The edaphic phytoindication scales are the indicators of hydromorphs (Hd), variability in humidity (fH), aeration (Ae), acidity regime (Re), saline regime (SI), content of carbonate salts (Ca), content of absorbed forms of nitrogen (Nt). The climatic scales include the thermoregime (Tm), ombroregime (Om) [ombroregime is an indicator of aridity-humidity of climate characterizing air humidity and is associated with the amount of precipitations, runoff, evaporation and transpiration, soil humidity and the groundwater level], cryoregime (Cr) and the continental climate (Kn). Thermal properties of soils were identified according to the thermoregime scale, and

hydrothermal – ombroregime scale. Among the various methods available, we used correspondence analysis (CA; Hill 1974), also known as reciprocal averaging (RA; Hill 1973), which is a method of ordination for studying division of niches between the species or ecological amplitude of species (Chessel et al., 1982; Thioulouse & Chessel, 1992). Based on this analysis, to study the differentiation of ecological niches between the species alongside the gradients of the environment, ter Braak (1986) has developed a multi-dimensional technique focusing on application of the canonical correspondence analysis (CCA). Canonical analysis of correspondences to a greater extent is applicable to all cases when the reaction of species to the environmental factors has a pattern of unimodal curve (Palmer, 1993).

The normal probability plot was used as a graphical technique for assessing whether or not the canonical axes scores were approximately normally distributed (Chambers et al., 1983). The data are plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line. Departures from this straight line indicate departures from normality. The mixture of the normal distributions may be the cause of departures from normality.

All statistical analyses were performed in R (v. 3.5.0., R Foundation for Statistical Computing, Vienna, AT), using the following software packs: *vegan* (v. 2.5-2, <https://CRAN.R-project.org>).

Results

As a result of the conducted studies, in the territory of Kharkiv, 180 species of Heteroptera were found, belonging to 120 genera and 17 families. The Miridae family showed highest species diversity – 50 species (27.0% of the total number of species counted). A lower number of species was seen for the family Lygaeidae – 46 species (24.9%) and Pentatomidae – 23 (12.4%). The family Rhopalidae was represented by 11 species (5.9%). Nabidae and Tingidae – 10 species each (5.4%). Families Coreidae – 8 (4.3%), Cydnidae and Scutelleridae – 4 species each (2.2%), Anthocoridae – 3 (1.6%). The families Berytidae, Piesmatidae, Pyrrhocoridae and Reduviidae were represented by only 2 species each (1.1%). The Acanthosomatidae, Alydidae and Aradidae families were represented by 1 species each, in total accounting for 1.5%.

Humidity regime among the studied biotopes, according to phytoindication assessment, ranged 6.8–11.5 (Table 1). These conditions are favourable for plants ranging from subxerophytes to mesophytes. Among heteropterans, we can presume representativeness by chiefly mesophiles, to a lesser extent mesoxerophiles and mesohydrophiles. The humidity regime variability ranged 7.1–9.8, which corresponds to favourable conditions for plants in the spectrum from hemihydrocontrastophiles to hydrocontrastophiles. Presence of the corresponding ecological groups could be presumed also among the groups of heteropterans. Acidity of edaphotope according to the phytoindication assessments was determined to be within 7.6–9.2. Such conditions are favourable for plants in the range from subacidophiles to neutrophiles. Among heteropterans, we can presume the presence in the group of separate acidophiles, subacidophiles and neutrophiles. Phytoindication assessments of the saline regime were within 9.4–13.6, corresponding to the conditions favourable for eutrophs to glycotrophs. Among heteropterans, we can presume the representativeness in the group of eutrophs, subglycotrophs and glycotrophs. Content of carbonates in the soils of the surveyed biotopes contributed to the development of plants, ranging 7.6–8.9, which corresponds to favourable conditions for acarbonatophiles to hemicarbonatophiles. Phytoindication assessments of the applied forms of nitrogen were within 7.1–9.8, indicating the conditions favourable for plants and heteropterans ranging from nitrophiles to eunitrophiles. The conditions of aerations were favourable for subaerophiles and hemiaerophobes, ranging 6.5–7.6 (Table 1).

Phytoindication according to the thermoregime scale assessed the radiation balance of the territory ranging 1,716–2,533 $\text{mJ/m}^2 \cdot \text{year}$. According to this parameter, the climate of the area could be evaluated as nemoral / submediterranean. Ombroregime was within the range from subaridophyte (difference between the precipitations and evaporations equaled –359 mm) to subomniphyle (difference was +209 mm). The assessment of the continentality of the climate ranged hemioceanic to hemicontinental. Cryoclimate corresponds to the range from mild winters (ave-

rage temperature of the coldest place was -2.9°C) to warm winters (average temperature of the coldest place was $+5.8^{\circ}\text{C}$).

Table 1
Phytoindicatory assessment of ecological factors according to Didukh

Ecological factors	Residential area	Zhuravlivka	Forest-Park	Pere-moha	Sarzhyn Yar	SKNPU
Hd	10.0	11.1	6.8	9.2	11.5	8.6
fH	7.1	8.1	7.9	7.3	9.8	9.2
Rc	8.3	8.2	7.6	8.7	9.2	8.3
Sl	9.4	9.6	10.0	13.6	9.7	9.6
Ca	8.9	7.6	8.8	8.9	8.0	8.6
Nt	9.8	9.7	8.4	9.2	7.1	8.1
Ae	7.5	6.5	7.3	7.6	7.4	6.7
Tm	8.2	11.5	9.9	10.8	12.1	10.3
Om	14.0	13.0	11.2	11.1	12.5	12.5
Kn	7.6	8.6	8.6	8.2	9.0	7.7
Cr	11.5	10.5	10.8	10.1	10.5	9.2
Lc	7.8	6.7	8.8	8.6	9.0	4.9

Phytoindicatory assessment of the light regime ranged 4.9–9.0, corresponding to the conditions from light forests to open spaces. Therefore, light conditions are favourable for sciophytes to heliophytes. Similarly, the animals living in the corresponding conditions, by preference of the light regime, could be identified to sciophiles (shade-loving), hemisciophile (shade-tolerant), subheliophiles (light-tolerant) and heliophiles (light-loving).

Canonical correspondence analysis allowed us to conduct the ordination of groups of heteropterans. As a result of the analysis, the extracted axes could be explained using ecological factors which were assessed using the phytoindicatory approach (Table 2). The most informatively valuable are the phytoindicatory assessments of edaphic and microclimatic factors. Climatic factors have no significant role for the differentiation of groups of heteropterans at the surveyed spatial level.

Table 2
Adjustment of ecological factors for axes, extracted using the results of canonical correspondence analysis

Ecological factors	Canonical axes						R^2	Pr(>r)
	CA1	CA2	CA3	CA4	CA5	CA6		
Hd	-0.06	0.99	-0.01	0.02	-0.09	0.08	0.95	<0.001
fH	0.16	0.20	0.19	-0.93	-0.09	0.16	0.93	<0.001
Rc	-0.02	0.21	-0.96	-0.09	-0.17	-0.05	0.86	<0.001
Sl	-0.17	-0.11	0.04	0.07	-0.07	-0.97	0.89	<0.001
Ca	-0.05	-0.28	0.26	-0.20	0.90	0.04	0.88	<0.001
Nt	0.17	0.07	-0.01	0.98	-0.10	-0.04	0.92	<0.001
Ae	-0.38	-0.12	-0.86	0.26	0.14	-0.13	0.94	<0.001
Tm	-0.16	0.49	-0.15	-0.69	-0.42	-0.25	0.51	0.15
Om	0.49	0.72	-0.03	0.27	0.04	0.40	0.41	0.34
Kn	-0.73	0.18	-0.05	-0.46	-0.47	0.06	0.60	0.04
Cr	-0.74	0.07	0.07	0.52	-0.01	0.41	0.56	0.09
Lc	-0.97	0.15	-0.04	0.10	-0.09	-0.11	0.98	<0.001

Notes: Hd – humidity regime, fH – regime of variation of humidity, Ae – regime of aeration, Rc – regime of acidity, Sl – saline regime, Ca – content of carbonate salts, Nt – content of the absorbed forms of nitrogen, Tm – thermoregime parameter, Om – ombroregime, Cr – cryoregime, Kn – continental climate, Lc – scale of light.

Each ordination axis could be interpreted using one or several ecological factors. Axis 1 reflects the variation of groups of heteropterans, synchronized with the regime of light of ecosystem. Axis 2 is a result of structuralization of groups in the gradients of conditions of humidity. Axis 3 correlates with acidity and regime of aeration of edaphotope. Axis 4 was synchronized with the regime of variability of humidity and the content of the absorbed forms of nitrogen. Axis 5 correlates with the content of carbonates in the soil, and axis 6 – with mineralization of interstitial water.

Thus, each canonical axis is the result of coordinated variability of the abundance of species in groups, which was the result of similarity of reaction to the effect of the external factors. This allowed us to perform ecological classification of species of groups in relation to the reaction of species to one or the other factor. Ultimately, the final behaviour of species in a group is determined by the total of actions of various external factors and inter-species relationships. Ecological ordination allows us to determine the aspects of variation in a group which correspond to certain ecological

factors most. Thus, weightings of species according to the corresponding canonical axes could be considered as quantitative characteristic of position of species within the corresponding gradient: on axis 1 – in the gradient of light regime, on axis 2 – in the gradient of humidity regime, etc.

Light regime of the surveyed ecosystems encompassed a broad range, therefore we can presume existence of four heteropteran heliomorphs among the surveyed species – sciophile, hemisciophiles, subheliophiles and heliophiles. The turning points at the normal probability graph confirm the presumption and indicate that the value -0.5 according to the canonical axis 1 divides heliophiles and subheliophiles, the value 0.5 is the border between subheliophiles and hemisciophiles, and value 1.5 was the border between hemisciophiles and sciophiles (Fig. 2).

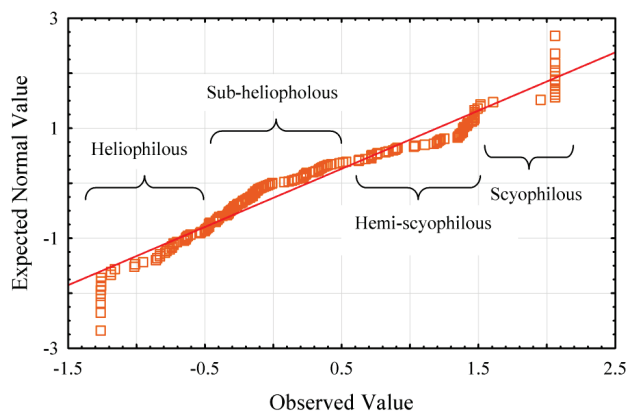


Fig. 2. Normal probability graph of the canonical axis 1 and identification of ecological groups of heteropterans according to the preference of the light regime: abscissa axis – the observed values of the canonical axis 1; ordinate axis – z-transformational value of this axis (hypothetic normal value); points – diagram of scattering, red line – the observed dependence for the ideally normal distribution

As a result of classification, we determined that 64 species belonged to sciophiles (35.6% of the total number of species), 25 species to hemisciophiles (13.9%), 56 species to subheliophiles (31.1%) and 35 species to heliophiles (19.4%). As we see, different heliomorphs are quite fully saturated with species. The most numerous representatives of sciophiles were *Adelphocoris lineolatum* (Goeze, 1778) and *Polymerus vulneratus* (Panzer, 1806). The most numerous hemisciophiles were *Nysius thymi* (Wolff, 1804) and *Lygus rugulipennis* Poppius, 1911, subheliophiles – *Myrmus miriformis* (Fallén, 1807) and *Stenodema laevigata* (Linnaeus, 1758) and heliophiles – *Megaloceroea recticornis* (Geoffroy, 1785) and *Leptopterna dolabrata* (Linnaeus, 1758).

The basis of the structure of the groups of heteropterans of the surveyed ecosystems was formed by subheliophiles (25.7–50.6% of the number of species, Table 3). Slightly inferior to them were sciophiles (11.1–51.4%). Much less represented in the groups were hemisciophiles (14.7–19.3%) and heliophiles (3.8–29.6%). Quantitatively, also the subheliophiles dominated, but the range of variation of this ecological group as a part of the total quantity of the group significantly increases (14.4–71.9%). The share of sciophiles was much more strongly represented in the group according to the quantity rather than the species diversity (13.8–68.6%). The level of representativeness of hemisciophiles in the group practically did not change numerically compared to the assessment according to species diversity (7.5–23.1%), whereas according to the quantity, the share of heliophytes significantly decreased (0.2–17.9%).

Table 3
Structure of groups of heteropterans in relation to the light regime

Ecological groups	Residential area		Zhuravlivka		Forest-Park		Pere-moha		Sarzhyn Yar		SKNPU	
	S	A	S	A	S	A	S	A	S	A	S	A
Sc	21.6	20.6	41.8	53.6	11.1	13.8	18.8	15.2	13.2	17.8	51.4	68.6
GSc	19.3	23.1	17.7	11.1	17.3	10.4	16.5	11.5	14.7	7.5	18.3	16.4
SHe	50.0	54.4	36.7	35.1	42.0	57.9	50.6	71.9	42.6	68.8	25.7	14.4
He	9.1	1.9	3.8	0.2	29.6	17.9	14.1	1.5	29.4	5.8	4.6	0.6

Notes: S – in % of the number of species; A – in % of the quantity of group; Sc – sciophiles; GSc – hemisciophiles; SHe – subheliophiles; He – heliophytes.

The range of the conditions determined using phytoindication, within the surveyed ecosystem, allows us to presume the presence of the representatives of three ecological groups among the heteropterans, classified according to the preference of humidity conditions (hygromorphs): xeromesophiles, mesophiles and mesohygrophiles. Canonical axis 2 indicates re-structuring in the structure of the group in the gradient of the humidity conditions. Values of this axis -0.5 divide xeromesophiles and mesophiles, and the values of 0.5 – mesophiles and mesohygrophiles (Fig. 3). A total of 44 species of heteropterans (24.4% of the total number of species) was identified to the representatives of mesoxerophiles. A total of 104 species was identified as mesophiles (57.8%), and 32 species (17.8%) as mesohygrophiles. The most numerous mesophiles in the group were *Adelphocoris lineolatum* and *Myrmus miriformis*, *Lygaeus equestris* (Linnaeus, 1758) and *Lygus pratensis* (Linnaeus, 1758), mesoxerophiles – *Orthops basalis* (A. Costa, 1853) and *Nabis punctatus* Costa, 1847, and certain mesohygrophiles – *Stenotus binotatus* (Fabricius, 1794) and *Nabis rugosus* (Linnaeus, 1758).

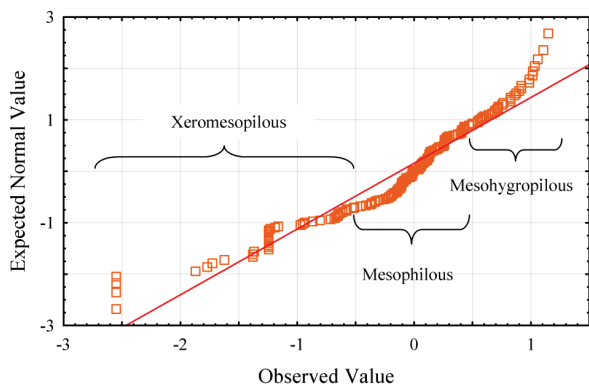


Fig. 3. The normal probability graph of axis 2 and determination of the ecological groups of heteropterans according to the humidity regime preference: abscissa axis – the observed values of the canonical axis 2; ordinate axis – z-transformed value of this axis (hypothetically normal value); point – diagram of scattering, red line – the observed dependence on the ideally normal distribution

Thus, the group of heteropterans was chiefly mesophilic. Therefore, among species of the surveyed groups of heteropterans, mesophiles accounted for 51.9–70.5% (Table 4). Slightly lower representativeness in groups belonged to hygromesophiles (11.1–24.1%) and the lowest share in the group comprised xeromesophiles (8.9–22.0%). The exception was the Forest-Park, where the share of this hygromorph sometimes accounted for over 30.0% by the number of species). According to the quantity, the group was dominated by mesophiles (68.1–93.9% of the total number of the group). By number, the shares of both xeromesophiles and mesohygrophiles decreased compared with the assessment of their roles in the group regarding species diversity (1.6–26.5% and 3.7–10.0% respectively).

Table 4

Structure of the groups of heteropterans according to hygropreferendum (preferred humidity)

Ecological groups	Residential area		Zhuravlivka		Forest-Park		Pere-moha		Sarzhyn Yar		SKNPU	
	S	A	S	A	S	A	S	A	S	A	S	A
KsMs	17.0	3.4	8.9	1.6	37.0	26.5	17.6	1.9	10.3	2.6	22.0	7.7
Ms	70.5	88.5	67.1	88.4	51.9	68.1	69.4	93.9	67.6	89.6	64.2	88.5
MsHg	12.5	8.1	24.1	10.0	11.1	5.5	12.9	4.3	22.1	7.8	13.8	3.7

Notes: S – in % of the number of species; A – in % of the number of the group; KsMs – xeromesophiles; Ms – mesophiles; MsHg – mesohygrophiles.

The range of the conditions of soil acidity within the surveyed ecosystem assessed using the phytoindication approach allows us to assume that heteropterans belong to three acidomorphs: neutrophiles, subacidophiles and acidophiles. Acidophiles prefer acidic soils (pH of 4.5–5.5). Subacidophile plants grow in low-acidic (pH 5.5–6.5) soddy podzolic soils, grey forest soils of acidophile oak forests and also in meadow-swamp biotopes. Neutrophiles grow in acidic and neutral (pH 6.5–7.1) soils of oak forests

of basiphile type, grey forest soils, leached chomozems, soils of meadow steppes and stepped meadows, in common and typical chomozems.

Analysis of the normal probability graph of the canonical axis 3 indicates the validity of this presumption (Fig. 4). The value of the canonical axis 3 equaling -0.75 allows us to differentiate the neutrophiles and subacidophiles, and the value of $+1.0$ differentiates subacidophiles and acidophiles. A total of 22 species of heteropterans were identified to possible acidophiles (or 12.2% of the total number of species), 132 species were identified to subacidophiles (or 73.7%), and 26 species to neutrophiles (14.4%). The most numerous acidophiles were *Pionosomus opacellus* Horváth, 1895 and *Oxycarenus pallens* (Herrich-Schäffer, 1850), neutrophiles – *Stenotus binotatus* and *Stenodema calcarata* (Fallén, 1807), subacidophiles – *Adelphocoris lineolatum* and *Myrmus miriformis*. However, such division is highly conditional and requires special studies on ecological preferences of most species of heteropterans according to this characteristic.

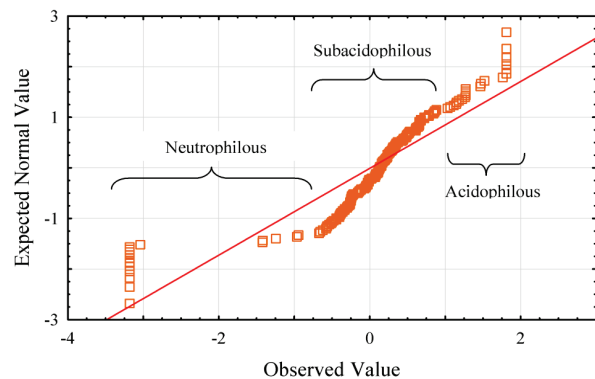


Fig. 4. Normal probability graph of the canonical axis 3 and the determination of the ecological groups of heteropterans according to the acidity regime preference: abscissa axis – observed values of the canonical axis 3; ordinate axis – z-transformed value of this axis (hypothetically normal value); points – diagram of scattering, red line – the observed dependence for the ideally normal distribution

According to the number of species, the share of subacidophiles was significantly higher in particular groups than in the metagroup in general (86.1–92.2%) except the biotopes of SKNPU, where this indicator equaled only 60.6% (Table 5). According to the share in the total quantity of the group, the role of this acidomorph increases for each ecosystem (75.6–97.8%). The role of acidophiles in the group was not significant, except SKNPU, where this acidomorph comprised a significant share of the group (20.2% by the number of species). By the share of the total number of the group, the role of acidophiles was lower than this parameter represented according to the number of species (0.1–14.3%). Neutrophiles formed a stable component of the group.

According to the regime of contrast of the humidity conditions, among the heteropterans, one can determine the presence of two contrastomorphs: hemihydrocontrastophiles and hydrocontrastophiles. Hemihydrocontrastophiles are characteristic of dry forest-meadow and meadow-steppe ecotopes with uneven humidity of the root-bearing soil layer during moderate or insignificant soaking of it by precipitations and meltwater. Hydrocontrastophiles are characteristic of dry steppe or humid ecotopes which form in the conditions with extremely uneven humidity of the root-bearing soil horizon during insignificant soaking of it in the precipitations and meltwater (Didukh, 2011).

Table 5

Structure of groups of heteropterans according to the soil acidity preference

Ecological groups	Residential area		Zhuravlivka		Forest-Park		Pere-moha		Sarzhyn Yar		SKNPU	
	S	A	S	A	S	A	S	A	S	A	S	A
Ac	3.4	0.3	6.3	1.7	1.2	0.1	3.5	0.1	2.9	0.3	20.2	14.3
SAC	88.6	94.1	86.1	92.2	91.4	95.4	88.2	96.5	91.2	97.8	60.6	75.6
Neutr	8.0	5.5	7.6	6.1	7.4	4.5	8.2	3.4	5.9	1.8	19.3	10.2

Notes: S – in % of the number of species; A – in % of the number of the group; Ac – acidophiles; SAC – subacidophiles; Neutr – neutrophiles.

Canonical axis 4 is the most sensitive to the variation of the group of heteropterans associated with the changeability of the regime of humidity of ecotope. The value of this axis equaling 0 divides the group into hydrocontrastophiles and hemihydrocontrastophiles (Fig. 5).

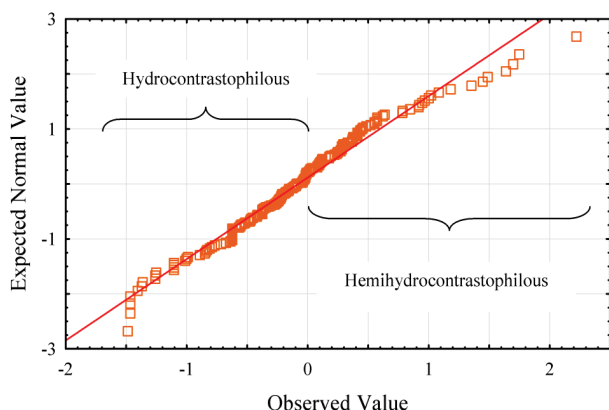


Fig. 5. Normal probable graph of the axis 4 and determination of the ecological groups of heteropterans by preference for contrast regime: abscissa axis – the observed values of the canonical axis 4; ordinate axis – z-transformed value of this axis (hypothetically normal value); points – diagram of scattering, red line – the observed dependence for the ideally normal distribution

Of the total number of species of heteropterans, 75 (41.7%) were identified to hydrocontrastophiles, and the rest – to hemihydrocontrastophiles. Among the groups, the share of hydrocontrastophiles, by the number of species, ranged between 28.4 to 53.4%. Hemihydrocontrastophiles are characteristic of dry forest-meadow and meadow-steppe ecotopes with uneven humidity of root-bearing soil horizon subject to moderate and insignificant soaking by precipitations and meltwater. In turn, hydrocontrastophiles are characteristic of dry steppe or humid ecotopes which form in the conditions with extremely uneven humidity of the root-bearing horizon subject to insignificant soaking precipitations and meltwater. According to the total number, the share of hydrocontrastophiles was higher than according to this parameter expressed in species diversity. Therefore, probability of increase in the number of species is higher when it belongs to the contrastomorph of hydrocontrastophiles (Table 6).

Table 6
Structure of the groups of heteropterans during changeability of the humidity regime

Ecological groups	Residential area		Zhuravlivka		Forest-Park		Pere-moha		Sarzhyn Yar		SKNPU	
	S	A	S	A	S	A	S	A	S	A	S	A
Contr	53.4	78.6	45.6	67.7	53.1	73.2	52.9	83.2	41.2	75.6	28.4	46.8
GCont	46.6	21.4	54.4	32.3	46.9	26.8	47.1	16.8	58.8	24.4	71.6	53.2

Notes: Contr – hemihydrocontrastophiles; GCont – hydrocontrastophiles.

According to the of the content of carbonates in the soil preference, the heteropterans were divided into two different-sized ecological groups: acarbonatophiles and hemicarbonatophiles (Fig. 6).

Acarbonatophile plants grow in neutral ecotopes and tolerate insignificant content of carbonates in the soil, which due to the rinsing regime do not elevate to the upper layers. These are, on the one hand, grey forest soils, which are characterized by the processes of podzolisation despite being formed on the loess base. On the other hand, these are solonchaks, where the carbonate base is replaced by sulfates and chlorides. Hemicarbonatophiles grow in chernozems, sufficiently enriched with carbonates which do not wash out and can occur as small inclusions, concretions. Among the studied species of heteropterans, 22 species were identified to acarbonatophiles (12.2% of the total number of species) and 158 – to hemicarbonatophiles (87.8%). The share of hemicarbonatophiles in the group was high both according to the species diversity and population size. Acarbonatophiles played the most important role in the group in the biotopes of Zhuravlivka and SKNPU (Table 7).

According to the mineralization of soil interstitial water, species of heteropterans were divided into subglycophiles, eutrophiles and semieutro-

philes (Fig. 7). Subglycophiles grow in the soils with excessive content of hydrocarbonates, which leads to carbonate salinization. These soils are typical chernozems, outcrops of cretaceous deposits, limestones, products of their erosion, which are insufficiently rinsed by water due to the low amount of precipitations (<500 mm) and their excessive evaporation (evaporation coefficient of <1). Eutrophs grow in rich chernozems best provided with salts, and developed soddy podzolic soils with no signs of salinization. These soils form on loess rocks, as well as deposits of dolomites, lime and chalk, rich in carbonates. Semieutrophs grow in salt-rich soils, including dark grey forest soils, podzolic chernozems.

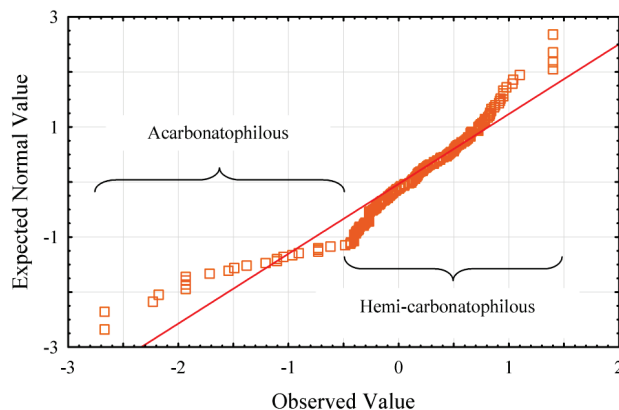


Fig. 6. Normal probability graph of axis +5 and identification of the ecological groups according to the carbonate content in soil preference: abscissa axis – the observed values of the canonical axis 5; ordinate axis – z-transformed value of this axis (hypothetically normal value); points – diagram of scattering, red line – the observed dependence for the ideally normal distribution

Table 7
Structure of the group of heteropterans according to the preference of content of carbonates and mineralization of soil interstitial water

Ecological groups	Residential area		Zhuravlivka		Forest-Park		Pere-moha		Sarzhyn Yar		SKNPU	
	S	A	S	A	S	A	S	A	S	A	S	A
ACar	5.7	1.1	15.2	18.6	11.1	7.2	9.4	0.8	10.3	1.8	7.3	15.2
HCar	94.3	98.9	84.8	81.4	88.9	92.8	90.6	99.2	89.7	98.2	92.7	84.8

Notes: S – in % of the number of species; A – in % of the number of the group; ACar – acarbonatophiles; HCar – hemicarbonatophiles.

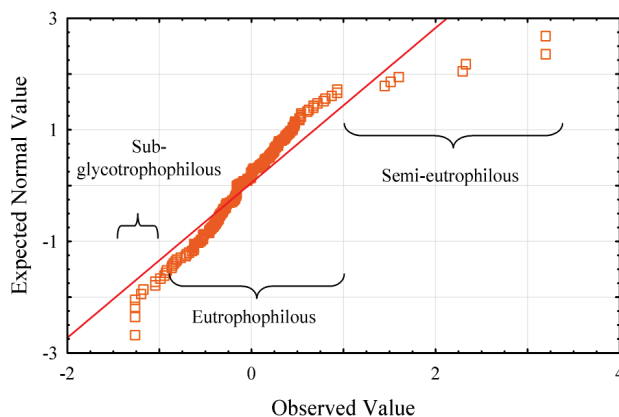


Fig. 7. Normal probability graph of the axis 6 and identification of groups of heteropterans according to salinity regime preference: abscissa axis – the observed values of the canonical axis 6; ordinate axis – z-transformed value of this axis (hypothetically normal value); points – diagram of scattering, the red line – the observed dependence for the ideally normal distribution

The vast majority of the species of heteropterans were eutrophiles (165 species or 91.7% of the total number of species). There were far fewer subglycophiles and semieutrophiles (8 and 7 species respectively, Table 8).

Discussion

Traditional units of the ecological classification of species are ecological groups, or ecomorphs (Belgard, 1950). Ecological group as a unit of classification is a less discussable category because in fact it implies no certain conceptual limitations on the units of ecological classification. These units could be considered as such that exist within the framework of structuralism, or could be considered as such as have artificial origin for the purpose of practicability when the classification units are dealt with within the scope of continualism. Ecomorphs are ecological groups of living organisms with a structuralistic, or organismic, approach. According to this, a biogeocenosis as a spatial level of ecosystem really exists in the sense that its borders are due to also intra-systematic relationships, and it forms not only as a result of influence of gradients of the external factors (Kunah, 2016). Accordingly, the elements of morphology of such structures are ecomorphs. Such approach deals with ecomorphs as universal elements of the structure of ecosystems of particular level of organization, which are general both for plant and animal components of the ecosystem. This allowed us to apply the ecological classification of plants for ecological classification of species of heteropterans according to their coordinated dynamics in the group.

Table 8

Structure of groups of heteropterans according to the mineralization of soil interstitial water

Ecological groups	Residential area		Zhuravlivka		Forest-Park		Pere-moha		Sarzhyn Yar		SKNPU	
	S	A	S	A	S	A	S	A	S	A	S	A
SGL	1.1	–	–	–	1.2	0.1	8.2	0.6	–	–	–	–
Eu	96.6	99.9	100.0	100.0	90.1	95.4	91.8	99.4	100.0	100.0	99.1	99.9
Seu	2.3	0.1	–	–	8.6	4.5	–	–	–	–	–	0.9

Notes: S – in % of the number of species; A – in % of the number of the group; SGL – subglycotrophiles; Eu – eutrophiles; Seu – semieutrophiles.

Designating ecomorphs is based on the presumption about qualitative homogeneity of the representatives of one ecological group (ecomorphs). The extent of relation of a species to a certain gradient of environment identifies the role of this species on the canonical axis which is the most correlated with the corresponding factor of the environment (ter Braak, 1985; ter Braak & Looman, 1986; Jongman et al., 1987; Borcard & Legendre, 1994). The values of the corresponding significances of species could be distributed according to the normal law in the case of homogeneity or could be a combination of normal distributions in the case of combination of two or more ecological groups (ecomorphs) of species according to the corresponding gradient. The indication of the magnitude as normal probability graph, where the observed value is presented as abscissa axis, and the expected normal value of z-variable as the ordinate axis, is a common tool of visualization of the assessment of correspondence distribution of the normal law (Zhukov et al., 2016). When such graph has the form of a fine line, then the observed value could be described with the normal law of distribution. The turning points on such line indicate the combinations of the normal distributions. The turning point could indicate the most probable position of the border between the normal distributions, and in our case – threshold value of indicator for division of the list of species according to the criterion of belonging to the ecological groups (ecomorphs). The idea of correspondence of plants and animals is the basis for generating primary hypotheses for determining the number of probable ecological groups of animals and their qualitative interpretation.

Heteroptera are a group of animals closely associated to the vegetation. According to the criterion of the relationship with different layers of the vegetative cover, there are distinguished stratobionts, herpetobionts, hortobionts [living in grass], tamnobionts [linked with trees and bushes], dendrobionts and transitional forms. Moreover, most species of Heteroptera are phytophages of different specialization, far fewer species are predators. In turn, the vegetation is a sensitive indicator of the properties of the environment (Didukh, 2011). Phytoindicatory methods allow, based on geobotanical information, performance of quantitative assessments of ecological factors which have a complex character and have no unequivocal equivalents measured using the instrumental methods. Therefore, the category of trophicity of edatophote depends on many factors of soil

fertility and is not determined by any of them alone. That is why phyto-indication is practically the only tool for the quantitative assessment of integral properties of the environment.

Phytoindicatory scales developed for the natural ecosystems and their informative value for anthropogenically transformed ecosystems require further study. The accuracy of phytoindication is significantly affected by decrease of phytodiversity under the influence of the anthropogenic factor, as well as increase in the value of alien species in the groups. Therefore, the development of bioindicatory tools using other taxonomic groups of living organisms is of certain interest. As shown in our studies (Markina et al., 2018), fauna of heteropterans of urbanized ecosystems is characterized by significant species and ecological diversities, allowing them to be considered as a promising object for biondication of urbanized environments. The conducted analysis suggests that the groups of heteropterans in the urban environment naturally react to the impact of the environmental factors. The corresponding trends reflect in multi-dimensional axes which could be qualitatively interpreted as a result of the influence of factors of different origin in the groups. The axes are ranked according to the importance level, therefore may indicate the hierarchy of importance of environmental factors in the structure of groups of heteropterans. The most important factor is the light regime. Such result completely corresponds to the ideas about the close relationship between heteropterans and vegetation, because the light regime is the most important for phytocenoses as well. The light intensity was found to be an important direct or indirect factor structuring Heteroptera communities (Gossner, 2009). Both insect composition and spatial preference of insect families was strongly dependent on light regime (De Cauwer et al., 2006).

It should be noted that the light factor is not the only one and manifests in close coordinated effect with other climatic factors – cryoclimate and continentality indicator. We distinguished the ecological groups of heteropterans according to the criterion of sensitivity to the light regime, the range of which completely corresponds to the range of heliomorphs of plants. Thus, the group heteropterans could be used as an alternative tool for indication of light regime of ecosystems.

The next influential factor for groups of heteropterans is the humidity of edatophote. Sensitive reaction to the humidity regime is important for determining the informational significance of groups of heteropterans in the system of bioindication. Content of humidity affects the conditions of life of plants and their performance of protective functions in city environment. Also, humidity underlies the conditions and regimes of migration and transformation of toxic substances. The surveyed biotopes include mostly mesophilous regimes and regimes of humidity tangent to them. Practically all types of biotopes were observed to have the hygromorphological spectrum narrowing according to the populations of species compared with the assessments according to species diversity. This allows us to presume that in the conditions of urban environment, the regimes of humidity of ecosystem unify – both dry and humid conditions demonstrate a tendency towards mesophilous conditions. Such unification or decrease in ecological diversity could have harmful effects such as reduction of resistance and functional activity of ecosystems within urban agglomerations.

Regimes of acidity and aeration determine the canonical axis 3. They have practically parity values for the identification of the variation of this axis. We presumed that among two factors, particularly the acidity effect of soil could be more significant than the regime of aeration. The effect of aeration is the result of coordinated dynamics together with the acidity regime in the range of the surveyed types of ecosystems. We should note that the acidity regime significantly affects the mobility of toxicants. Therefore, the assessment of this factor is of great importance for characteristic of the ecological environment of cities.

The next significant trend of variation is due to combined effect of the variability of the humidity regime and content of available forms of nitrogen. We presumed that the effect of the content of nitrogen undergoes indirectly, through the vegetation which in turn determines certain peculiarities of the structure of heteropterans. Also, a possible mechanism would be such when the variation of the humidity conditions determines the regimes favourable for the accumulation of available forms of nitrogen for plants. It has to be noted that the variability of the humidity conditions could directly affect the species of heteropterans. Therefore, we identified this axis as the one marking the relation of species of heteropterans to

variability of particularly the conditions of humidity. The obtained results indicate that the species composition in the groups of heteropterans is characterized by potential adaptation to the conditions ranging non-uniform to extremely non-uniform regime of humidity. At the same time, the realized ecological conditions in urban environments contribute to increase in the populations of species which are able to tolerate extremely uneven conditions of humidity. We can presume that the transformation of life conditions in the urban environment is orientated towards the increase in the contrastiveness of conditions of humidity. Interpretation of the canonical axes also indicates that a significant role in the structurizing of groups of heteropterans belongs to the content of carbonates and the general level of trophicity of the edaphotope.

Thus, according to the level of the effect on groups of heteropterans, the ecological factors could be ranked in the following order: light > humidity > acidity > variability of humidity > content of carbonates > trophicity. Particularly this order can have diagnostic importance for characteristic of ecological conditions, therefore determines the hierarchy of limiting factors for the dynamics of group. The dominating value of the light regime, as a factor which structurizes the groups of heteropterans, obviously reflects the stripy structure of biogeocenotic cover of urban ecosystems. The entire canopy of trees is more likely an exception in the conditions of urban environments. The high level of patchiness of dense vegetation areas creates a broad range of light conditions, which in the natural conditions could be seen in ecotone [transitional communities] complexes. Thus, the leading role in the light regime could be explained by the totally ecotonic character of urban ecosystems. In such context, the bioindicational assessment of light regime is especially valuable. In the conditions of urban ecosystems, it could be considered a marker of stripiness of ecological systems.

The results of the study could be used during assessments of the projects for optimization of urban environment and development of measures for protection of biological diversity in ecological ecosystems of urbanized territories. A promising direction of this research would be the enlargement of the range of the surveyed conditions for detailing the composition of ecomorphs of heteropterans in marginal positions of ecological gradients.

Conclusions

The high level of taxonomic and ecological diversities in the groups of heteropterans in the urban environment makes this group promising for purposes of bioindication. The close relationship between heteropterans and vegetation allows use of phytoindicators assessments of environmental factors for interpretation of the main patterns of variation of groups of heteropterans. According to the level of effect on the groups of heteropterans, the ecological factors form the following sequence: light, humidity, acidity, variability of humidity, content of carbonates, trophicity. Among the species of heteropterans, there could be determined the ecological groups which are analogues to the plant ecomorphs. The ranges of ecomorphs of heteropterans could be determined for the purposes of bioindication of the conditions in urban ecosystems. The ranges of ecomorphs developed on the basis of the number of species indicates the super position of the total of potential niches of heteropterans, and the ranges of ecomorphs developed based on abundance indicate the peculiarities of the realized ecological niches. Comparison of potential and realized projections of ecological space allows one, to a certain extent, to generate hypotheses about the directions of transformation of the group of heteropterans, which requires further study, especially autecological peculiarities of most stenotopic species.

References

Belgard, A. L. (1950). *Lesnaja rastitel'nost' jugo-vostoka USSR* [Forest vegetation of South-East part of the Ukraine]. Kiev University Press, Kiev (in Russian).

Borcard, D., & Legendre, P. (1994). Environmental control and spatial structure in ecological communities: An example using oribatid mites (*Acari, Oribatei*). *Environmental and Ecological Statistics*, 1(1), 37–61.

Brygadyrenko, V. V. (2015). Influence of tree crown density and density of the herbaceous layer on the structure of litter macrofauna of deciduous forests of Ukraine's steppe zone. *Visnyk of Dnipropetrovsk University, Biology, Ecology*, 23(2), 134–148.

Brygadyrenko, V. V. (2016). Influence of litter thickness on the structure of litter macrofauna of deciduous forests of Ukraine's steppe zone. *Visnyk of Dnipropetrovsk University, Biology, Ecology*, 24(1), 240–248.

Chambers, J. M., William, C. S., Beat, K., & Tukey, P. A. (1983). *Graphical methods for data analysis (Statistics)*. Wadsworth International Group, Duxbury Press, Belmont, Boston. Vol. 14. P. 395.

Chessel, D., Lebreton, J. D., & Prodon, R. (1982). Mesures symétriques d'amplitude d'habitat et de diversité intracchantillon dans un tableau espèces-reliefs: Cas d'un gradient simple. *Compte Rendu de l'Académie des Sciences de Paris D*, 295, 83–88.

Chytrý, M., Tichý, L., Dřevojan, P., Sádlo, J., & Zelený, D. (2018). Ellenbergovské indikační hodnoty pro českou flóru [Ellenberg-type indicator values for the Czech flora]. *Preslia*, 90(2), 83–103 (in Czech).

Clifford, N. J., Harmar, O. P., Harvey, G., & Petts, G. E. (2006). Physical habitat, eco-hydraulics and river design: A review and re-evaluation of some popular concepts and methods. *Aquatic conservation: Marine and freshwater ecosystems*, 16(4), 389–408.

Dahl, F. (1908). Grundsätze und Grundbegriffe der biozönotischen Forschung. *Zoologischer Anzeiger*, 33, 349–353.

De Cauwer, B., Reheul, D., De Laethauwer, S., Nijs, I., & Milbau, A. (2006). Effect of light and botanical species richness on insect diversity. *Agronomy for Sustainable Development*, 26(1), 35–43.

Didukh, Y. P. (2011). The ecological scales for the species of Ukrainian flora and their use in synphytoindication. *Phytosociocentre*, Kyiv.

Fedyay, I. A., & Markina, T. Y. (2020). Ecological and faunistic review of the true bugs of infraorder Cimicomorpha (Heteroptera) of urbocenoses of Kharkiv city (Ukraine). *Zoodiversity*, 54(2), 133–146.

Gossner, M. M. (2009). Light intensity affects spatial distribution of Heteroptera in deciduous forests. *European Journal of Entomology*, 106(2), 241–252.

Hill, M. O. (1973). Reciprocal averaging: An eigenvector method of ordination. *Journal of Ecology*, 61, 237–249.

Hill, M. O. (1974). Correspondence analysis: A neglected multivariate method. *Journal of the Royal Statistical Society (London)*, 23, 340–354.

Hubbell, S. P. (2005). Neutral theory in community ecology and the hypothesis of functional equivalence. *Functional Ecology*, 19(1), 166–172.

Hutchinson, G. E. (1965). *The niche: An abstractly inhabited hypervolume. The ecological theatre and the evolutionary play*. Yale University Press, New Haven.

Jongman, R. H. G., Ter Braak, C. J. F., & Van Tongeren, O. F. R. (1995). *Data analysis in community and landscape ecology*. Cambridge University Press, Cambridge.

Jowett, I. G. (1993). A method for objectively identifying pool, run, and riffle habitats from physical measurements. *New Zealand Journal of Marine and Freshwater Research*, 27(2), 241–248.

Kunah, O. N. (2016). Functional and spatial structure of the urbotechnozem mesopedobiont community. *Visnyk of Dnipropetrovsk University, Biology, Ecology*, 24(2), 473–483.

Markina, T. Y., Putschkov, A. V., & Fedyay, I. A. (2018). Novi ta malovidomi vydy klopiiv (Insecta: Hemiptera, Heteroptera) dlia fauny Ukrainy [New and little known species Hemiptera for the fauna of Ukraine]. *Biology and Valeology*, 20, 43–48 (in Ukrainian).

Matějka, K. (1992). Some aspects of the theory of the ecosystem spatial structure. *Ústav Krajinej Ekológie SAV, Ekológia (CSFR)*, 11(4), 369–377.

Möbius, K. (2000). The Oyster bank is a biocenose, or a social community. In: Keller, D. R., & Golley, F. B. (Eds.). *The philosophy of ecology (From science to synthesis)*. University of Georgia Press, Athens. Pp. 111–114.

Mölder, A., Bernhardt-Römermann, M., & Schmidt, W. (2008). Herb-layer diversity in deciduous forests: Raised by tree richness or beaten by beech? *Forest Ecology and Management*, 256(3), 272–281.

Naveh, Z., & Lieberman, A. S. (1994). *Landscape ecology: Theory and application* (2nd ed.). Springer-Verlag, New York.

Newson, M. D., & Newson, C. L. (2000). Geomorphology, ecology and river channel habitat: Mesoscale approaches to basin-scale challenges. *Progress in Physical Geography: Earth and Environment*, 24(2), 195–217.

Padmore, C. (1998). The role of physical biotopes in determining the conservation status and flow requirements of British rivers. *Aquatic Ecosystem Health and Management*, 1(1), 25–35.

Palmer, M. (1993). Putting things in even better order: The advantages of canonical correspondence analysis. *Ecology*, 74, 2215–2230.

Panikov, N. S. (2010). *Microbial ecology*. In: *Environmental biotechnology. Humana Press, Totowa*. Pp. 121–191.

Ramenskiy, L. G., Tsatsenkin, I. A., Chizhikov, O. N., & Antipin, N. A. (1956). Ecological evaluation of the fodder lands by vegetation cover. *Sel'khozgiz, Moscow*.

Ricklefs, R. E. (2006). The unified neutral theory of biodiversity: Do the numbers add up? *Ecology*, 87(6), 1424–1431.

Sørensen, T. (1936). Some ecosystemal characteristics determined by Raunkiaer's circling method. In: *To designate the fundamental unit of ecological plant sociology I propose the term ecotope, viz. the field delimited as an ob-*

- ject of investigation within a given ecosystem (Tansley). *Nordiska (19. Skandinaviska) Naturforskarmöteti, Helsingfors*. Pp. 474–475.
- Sukachov, V. N. (1964). *Osnovnye poniatija lesnoj bigeocenologii* [The main concepts of the forest biogeocenology]. Nauka, Moscow (in Russian).
- Tansley, A. G. (1939). *The British Isles and their vegetation*. Cambridge University Press, Cambridge.
- ter Braak, C. J. F. (1985). Correspondence analysis of incidence and abundance data: Properties in terms of a unimodal response model. *Biometrics*, 41(4), 859.
- ter Braak, C. J. F., & Looman, C. W. N. (1986). Weighted averaging, logistic regression and the Gaussian response model. *Vegetatio*, 65(1), 3–11.
- Thioulouse, J., & Chessel, D. (1992). A method for reciprocal scaling of species tolerance and sample diversity. *Ecology*, 73, 670–680.
- Townsend, C. R., & Hildrew, A. G. (1994). Species traits in relation to a habitat template for river systems. *Freshwater Biology*, 31(3), 265–275.
- Vysotsky, G. N. (1925). *Pokrovovedenie* [Cover science]. Main Botanical Garden, Minsk, Leningrad (in Russian).
- Zhirkov, I. A. (2017). *Bio-geography, general and specialty*. KMK Pres, Moscow.
- Zhou, S., & Zhang, D. (2008). Neutral theory in community ecology. *Frontiers of Biology in China*, 3(1), 1–8.
- Zhukov, A. V., Kunah, O. N., Novikova, V. A., & Ganzha, D. S. (2016). Phytoindication estimation of soil mesopedobionts communities catena and their ecomorphic organization. *Biological Bulletin of Bogdan Chmelnytsky Melitopol State Pedagogical University*, 6(3), 91–117.
- Zhukov, O. V. (2018). Interpretation of the plants ceonomorphes from the South-East of Ukraine in terms of phyto-indicative scales. *Acta Biologica Sibirica*, 2, 57–69.
- Zhukov, O., Kunah, O., Dubinina, Y., Ganga, D., & Zadorozhnaya, G. (2017). Phylogenetic diversity of plant metacommunity of the Dnieper River arena terrace within the 'Dnieper-Orilskiy' Nature Reserve. *Ekologija Bratislava*, 36(4), 352–365.
- Zhuravel, N., Polchaninova, N., Lezhenina, I., Drogvalenko, O., Putschkov, A. (2016). Preliminary survey of the ground-dwelling arthropods of the floodplain meadows in the southeast of Poltava region (Ukraine). *Biological Bulletin of Bogdan Chmelnytsky Melitopol State Pedagogical University*, 6(3), 5–17.