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Comparative analysis of the diversity of bees in agroecosystem habitats

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Biodiversity has a great importance on agroecosystems, since it determines their actual and potential productivity. Bees provide crucial ecological service in the agricultural landscape in most geographical regions because they are considered to be predominant and most economically important group of pollinators. The objective of the study was the assessment of bees (domestic, wild, bumblebees) diversity in different types of habitats in agroecosystems of Central Forest-Steppe zone of Ukraine. Bee communities were investigated in agrocenosis, semi-natural habitats and ecotones between on territories of 6 farms. In total were sampled 1131 individuals of bees that were presented by 60 species. Species composition, density and richness of bees were investigated. Indexes of Shannon, Simpson and Sorensen were used for biodiversity analysis. The results indicated that the species richness of bees grows by gradient: agrocenosis – semi-natural habitat – ecotone. The most common and spread species were *Apis mellifera* L., *Bombus lapidarius* L., *B. terrestris* L., *Halictus simplex* Blüthgen, *Systropha curvicornis* Scopoli, *Lasioglossum leucozonium* Schrank. Density of *Apidae* increases in agrocenosis and falls in semi-natural habitats. Forming of bees' fauna in agrocenosis depends on beesfauna of semi-natural habitats. Availability of ecotones promotes increasing of bee diversity in agroecosystems because it performs preservation function for biota and improves the spreading of bees and other species. The presented results could be used to predict changes in the formation of bee entomocomplexes in order to preserve their biodiversity.

Key words: agroecosystems, habitats, bees diversity, species richness, species density.

Introduction. The development of agriculture takes on a variety of forms, among which extensive land use tends to land transformation through the destruction and fragmentation of habitats. Such an approach can lead to a reduction of the biodiversity in agroecosystems. Over the past 50 years, intensification of agriculture has led to the disappearance of many wild plant and animal species both at the regional and national levels and has led to profound changes in the functioning of agroecosystems [8, 12].

Reducing the species diversity due to the intensification of agriculture can affect the sensitivity of agroecosystems to exogenous changes in the environment. The consequences of these processes are currently poorly investigated, but biodiversity is known to be of great importance for agroecosystems, since it determines their actual and potential productivity [6]. Unfortunately, the definition of an optimal level of biodiversity is very complicated, because the removal of pests, competitor species and pathogens can positively affect the productivity of agriculture, but at the same time reduce the resistance of agroecosystem to the impact of external environmental factors.

Preservation of biodiversity is one of the priorities of the state ecological policy in many countries, among which the relevance of implementation of continuous monitoring of quantitative and qualitative indicators of natural resources, as well as the creation of a system of scientifically based assessment of biodiversity objects using the ecosystem approach are indicated.

Considering the importance of invertebrate for continental ecosystems in the schemes of biomonitoring special attention is paid to insects. According to various scientific estimates, the percentage of insects in biota is from 53 to 75 %, and their total biomass exceeds the biomass of all other animals. Therefore, insects provide a significant portion of the biotic cycle of matter, energy and information in the biosphere, which determines the maintenance of environmental equilibrium. It is insects, such as cicadas [24], ants [17], butterflies [10], earthen bugs [16], locust [1], spiders [5], etc, are the most commonly used bioindicators of a satisfactory state of biota in general and of its zonal peculiarities in particular.

Bees (*Apidae, Sphecidae, Eumenidae, Pompilidae*) occupy a special place among entomoindicators. They are characterized by complex life histories and have specific requirements for foraging and nesting recourses [15]. They need habitats rich in flowering plants [3], as a large proportion of the species only collect pollen from certain plants. In addition, bees have specific nesting sites, such as dead wood, bare soil, plant stems or small rock cavities which should be close to feeding sites.

Bees provide crucial ecological service in the agricultural landscape in most geographical regions because they are considered to be predominant and most economically important group of pollinators [14]. A decline in bee diversity will affect the pollination of many insect-pollinated crops and wild plant species. Although the honeybee (*Apis mellifera L.*) is generally regarded as the most important bee pollinator [25], wild bees are also relevant [22]. There has been growing concern about suspected declines in wild bee populations and the implications for agricultural and natural ecosystems [11]. The role of the landscape context and of the land-use change on pollination has been comprehensively synthesized by Kremen et al. [13]. There is also a greater likely hood of toxicological effects of insecticides in agriculturally dominated landscapes [21].

With respect to farming systems, Holzschuh et al. (2010) demonstrated that organic farming increases bee diversity by enhancing flower availability. In addition, bee diversity was influenced by the landscape context and the interaction of both, organic farming being more effective in homogeneous landscapes [9].

Since 1962, the bee has increasingly been employed to monitor environmental pollution by heavy metals in territorial and urban surveys, pesticides in rural areas and radionuclide presence in the environment [4].

As a result of a number of studies, several features associated with agriculture management make farm poor habitat for bees and other pollinators. Intensification of agriculture has led to a more homogenous landscape, characterized by large crop fields and fewer non cultivated habitats. Loss of complex landscape elements between farmland and adjacent ecosystems, as well as the increased use of agrochemicals, has been linked to the reducing in richness of bee speciesin agroecosystems.

Locally, species richness and abundance depend on plant species richness and cover as well as on the habitat composition and diversity in the surrounding landscape [9, 22]. Furthermore, Schweiger et al. [19] showed in an extensive sampling across Europe that wild bee communities are first influenced by the land use intensity in a region, then by the landscape structure, i.e., the proportion of semi-natural elements in the landscape. Other investigations demonstrated a response of bees to field margins and boundaries, which suggests that they may be good indicators of agri-environmental schemes [6, 23]. By observed the decline in species richness and crop visitation rate for pollination in response to the distance to natural habitats for several crops worldwide, Ricketts et al. [18] emphasized the importance of conserving and managing sufficient resources for wild pollinators within the agricultural landscape to maintain the pollination services.

The bee thus enables us to throw light on a situation of environmental change and risk that otherwise would have remained hidden in shadow.

The aim of the study was the assessment of bees (domestic, wild, bumblebees) diversity in different types of habitats in agroecosystems of Central Forest-Steppe zone of Ukraine.

Materials and methods of recearch. Our study sites were located in Dniester-Dnipro province of Central Forest-Step of Podilska and Pridneprovska hills. The study sites were situated in Kiev region (villages Yablunivka, Bloschintsi, Terezine, Matyushi, Bugayivka, Karapishi) (Figure 1).

The habitat mapping method is based on generic system of habitat definitions “General Habitat Categories” [7]. We applied QGIS tool (GNU General Public License, http://qgis.org) for creating digital maps of surveyed habitats. Data validation was carried out in a field conditions.

At each farm, studied habitats were divided into 3 groups: agrocenoses – fields of winter wheat, soybeans, corn, barley, buckwheat; ecotones–ecotone between agrocenosis and single-row wind-protection trees, ecotone between agrocenosis and forest band, a grass band on a field road between agrocenoses; semi-natural territories – grasslands (Figures 2, 3).

Fig. 1. **Location of the case study area** (scale: 1:288980 m): 1 – Karapishi, 2 – Matyushi, 3 – Terezine, 4 – Bloschintsi,5 – Yablunivka, 6 – Bugayivka.

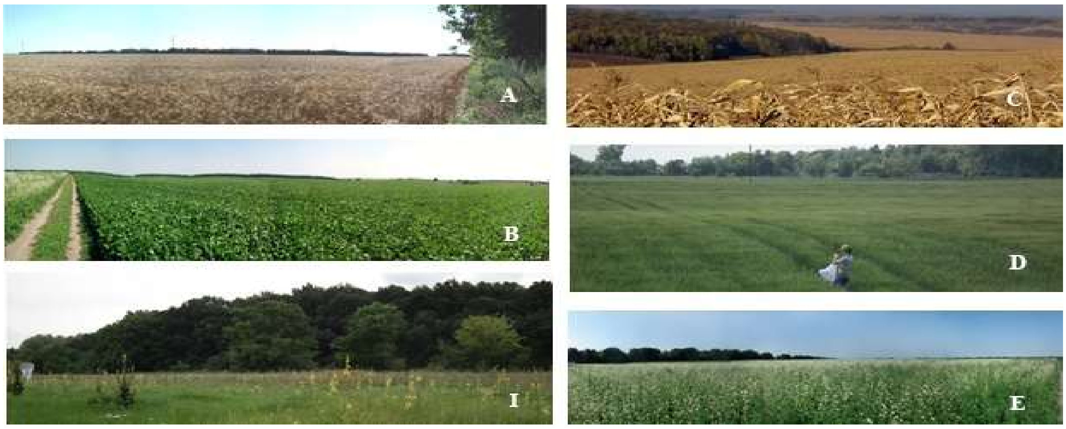

Fig. 2. **Agrocenosis and semi-natural habitats:** A – winter wheat, B – soybean, C – corn, D – barley, E – buckwheat, I – grassland (pasture).

Fig. 3. **Ecotones: F – between agrocenosis and single-row wind-protection trees, G –between agrocenosis and forest band, H – grassband on a field road between agrocenoses.**

The management was rather similar at all farms. Agro-chemicals are not applied on the grasslands, stocking rates are very low (0.15–1.75 LU/ha grassland). Zero or low inputs of fertilizers (15–50 t/4 year solid cattle manure or 20–30 kg N/ha/year inorganic fertilizer) and one or two pesticide applications are usual on the arable fields.

Bees were captured with an insect net. The aerial net method along transect ("belt") walks has been used for years in ecological studies [2]. Slow walks along 100 meters long surveyed each habitat/field plot and 2-meter-wide transect crossing the middle of the location of the vegetation. In case of shorter plots than 100 m, 2 x 50 m transects were surveyed. The transect walk lasted 15 minutes (the speed of walking was of about 6-7 m per minute). While walking, the collector caught all individual bees seen within the 2 m wide "belt" with a standard entomological aerial net.

Captured specimens were transferred into a vial with ether. Then samples of bees were pierced with an entomologic needle, brought to the laboratory and then accumulated before dispatch to a taxonomist for identification. Each sample was labeled with date, habitat name, conditions and place of sampling. When bees could be identified in the field (for example, domestic bees), they were registered and released. Particular attention was put on bee species of Anthophoridae and to a less extent Megachilidae because they are wasp-like in appearance.

Sampling was carried out only between 10.00 and 19.00 hours on days that are sunny, not too windy and a temperature higher than 15° C.

During the agriculture season, each plot of the farms was surveyed three times – in May, July and September. Transect walks were carried out in habitats when vegetation was present. One habitat was surveyed at different times of the day for each of three sampling dates (the start point of the route was changed for each survey). In agrocenosis transect walks were made during the growing season of the cultivated plant, in natural and semi-natural habitats – when vegetation height was >15 cm.

Species composition, density and richness of bees were investigated. Indexes of Shannon, Simpson and Sorensen were used for biodiversity analysis [20].

Results and discussion. Bee communities were investigated in agrocenosis, semi-natural habitats and ecotones between. In total were sampled 1131 individuals of bees that were presented by 60 species (Table 1).

The species richness of bees grows by gradient: agrocenosis – semi-natural habitat – ecotone. Increasing of species' richness was established in grass stripes on an agrocenosis edge close to forest bands, one-row wind-protection trees and meadows. In total 40 species were sampled in ecotones. The lowest number of bee species was found in agrocenosis (18 species), and medium species number – in semi-natural habitats (28).

The dominant speciesin agrocenosis, semi-natural habitats and ecotones was *Apis mellifera* L. with the highest density in agrocenosis (7.9 samples per 100 m^2) during blooming period. Other species were rare in fields. Some of them could be observed on specific plant species only. *Andrena pilipes*, *Megachile centuncularis* were found in soya cenosis only, likewise *Evylaeus leucopus*, *Lasioglossum sexnotatum*, *L. xanthopus* – could be seen in barley, and *Osmia cerinthidis*, *Sphecodes sp*. – in cenosis of buckwheat and alfalfa. At the same time *Osmia cerinthidis* is typical for South regions, it is not often found in north regions of Ukraine.

Ecotones on the edge of agrocenosis close to forest bands and meadows were presented by 40 species of bees. The most spread and common species were *Apis mellifera* (4.5 samples/100 m^2), *Bombus lapidarius* (0.8 samples/100 m^2), *B. terrestris* (0.8 samples/100 m^2), *Halictus simplex* (0.7 samples/100 m^2). We have found *Bombus argillaceus* (0.03 samples/100 m^2) from the Red List of Ukraine in grass stripes between agrocenosis and wind-protection trees.

Ecotones between agrocenosis were not rich for bee species and were presented by 5 species only. The most spread were *Systropha curvicornis* (0.5 samples/100 m^2), *Lasioglossum leucozonium* (0.3 samples/100 m^2). The same species were common for other types of ecotones.

Density of *Apidae* increases in agrocenosis and decreases in semi-natural habitats. The average density of *Apidae* was 1.0±0.21 samples/100 m^2in agrosenosis, 0.9±0.20 – in ecotones and 2.4±0.38 – in semi-natural habitats.

The comparative analysis showed the strong correlation between abundance of bees species and habitat affiliation to semi-naturalterritories (biotopes) (r=0.59). We have found the highest average numbers of bee species diversity in meadows and pastures (0.8 species per 100 m^2) that could be explained by the diversity of flowering plants (Fig. 4).

The lower level of average bee species diversity (0.2 species/100 m^2) and density (1.0 individual/100 m^2) were noticed in agrocenosis that linked to monoculture and agromanagement treats (mineral fertilizing, pesticides applying etc). At the same time, we have found the strong correlation between numbers of bee species and sizes of agrocenosis plots.

Table 1 – **Species composition of bees and bumblebees**

№	Species	Samples
1	*Ammobatoides abdominalis* (Eversmann, 1852)	2
2	*Andrena dorsata* (Kirby, 1802)	3
3	*Andrena flavipes* Panzer, 1799	19
4	*Andrena gelriae* van der Vecht, 1927	1
5	*Andrena haemorrhoa* (Fabricius, 1781)	1
6	*Andrena nanaeformis* Noskiewicz, 1925	1
7	*Andrena ovatula* (Kirby, 1802)	2
8	*Andrena pilipes* Fabricius 1781	2
9	*Andrena polita* Smith, 1847	5
10	*Andrena subopaca* Nylander, 1848	1
11	*Apis mellifera* L.	766
12	*Bombus muscorum* (Linnaeus, 1758)	1
13	*Bombus (Psithyrus) rupestris* (Fabricius, 1793)	1
14	*Bombus argillaceus* (Scopoli, 1763)	1
15	*Bombus lapidarius* (Linnaeus, 1758)	28
16	*Bombus pascuorum* (Scopoli, 1763)	9
17	*Bombus sylvarum* (Linnaeus, 1761)	5
18	*Bombus terrestris* (Linnaeus, 1758)	56
19	*Dasypoda altercator* (Harris, 1780)	1
20	*Eucera chrysopyga* Pérez, 1879	1
21	*Evylaeus calceatus* (Scopoli, 1763)	5
22	*Evylaeus laticeps* (Schenck, 1869)	8
23	*Evylaeus leucopus* (Kirby, 1802)	1
24	*Evylaeus malachurus* (Kirby, 1802)	1
25	*Evylaeus politus* (Schenck, 1853)	4
26	*Evylaeus sexstrigatus* (Schenck, 1870[", 1869"])	2
27	*Halictus maculatus* Smith, 1848	3
28	*Halictus quadricinctus* (Fabricius, 1776)	15
29	*Halictus sajoi* Blüthgen, 1923	10
30	*Halictus sexcinctus* (Fabricius, 1775)	3
31	*Halictus simplex* Blüthgen, 1923	43
32	*Halictus tetrazonius* (Klug, 1817)	1
33	*Hoplosmia spinulosa* (Kirby, 1802)	1
34	*Lasioglossum discum* (Smith, 1853)	14
35	*Lasioglossum laterale* (Brullé, 1832)	1
36	*Lasioglossum leucozonium* (Schrank, 1781)	8
37	*Lasioglossum majus* (Nylander, 1852)	2
38	*Lasioglossum sexnotatum* (Kirby, 1802)	1
39	*Lasioglossum sp.*	1
40	*Lasioglossum xanthopus* (Kirby, 1802)	1
41	*Lasioglossum zonulum* (Smith, 1848)	5
42	*Lithurgus cornutus* (Fabricius, 1787)	2
43	*Megachile centuncularis* (Linnaeus, 1758)	1
44	*Megachile melanopyga* Costa, 1863	1
45	*Melitta tricincta* Kirby, 1802	6
46	*Osmia cerinthidis* F.Morawitz, 1876	4
47	*Panurgus calcaratus* (Scopoli, 1763)	2
48	*Pseudoanthidium nanum* (Mocsáry, 1879)	2
49	*Rophites algirus* Pérez, 1895	5
50	*Rophites hartmanni* Friese, 1902	11
51	*Seladonia confusa* (Smith, 1853)	2
52	*Seladonia kessleri* (Bramson, 1879)	1
53	*Seladonia semitecta* (Morawitz, 1874)	2
54	*Seladonia subaurata* (Rossi, 1792)	3
55	*Seladonia tumulorum* (Linnaeus, 1758)	3
56	*Sphecodes albilabris* (Fabricius, 1793)	1
57	*Sphecodes sp.*	2
58	*Systropha curvicornis* (Scopoli, 1770)	33
59	*Systropha planidens* Giraud, 1861	13
60	*Tetralonia malvae* (Rossi, 1790)	1
	Total	1131

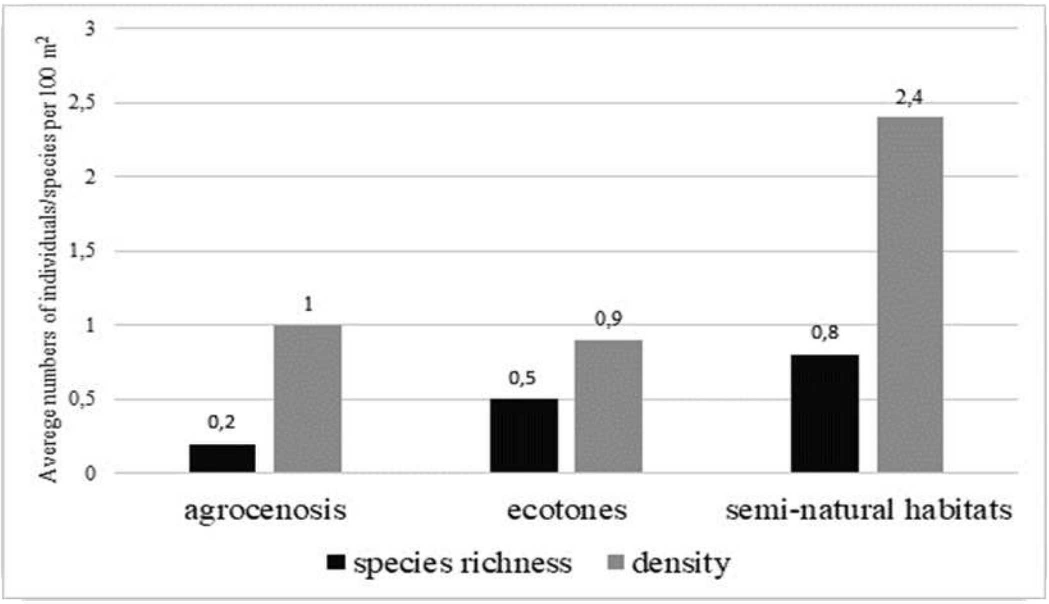

Fig. 4. **Species diversity and density of bees in different types of habitats.**

The average numbers of bee species diversity and density were about 0.5 species/100 m^2 and 0.9 individuals/100 m^2 in ecotones. Giving this, availabilityof ecotones promote increasing of bee diversity in agroecosystems because it performs preservation function for biota and improves the spreading of bees and other species.

In total 28 species of *Apidae* were found in semi-natural biotopes (habitats). The dominant species were *Apis mellifera* L. (12.1 individuals/100 m^2), *Bombus terrestris* Linnaeus (2.1 individuals/100 m^2), *Systropha curvicornis* Scopoli (1.3 individuals/100 m^2), *Halictus quadricinctus* Fabricius (0.9 individuals/100 m^2), *H. simplex* Blüthgen (0.8 individuals/100 m^2). Most of them we have also found in ecotones on the edge of fields close to forest bands, meadows and in gross stripes between fields.

The highest numbers of Shannon index for bees diversity were established in grass stripes between agrocenosis and forest bands, meadows (H=2.12). The species evenness in ecotones was J=0.76. Lower level of species diversity and higher level of evenness were found in agrocenosis (H=1.73, J=0.97). The lowest numbers of species diversity and evenness were noticed in semi-natural habitats (H=1.45, J=0.75).

The highest similarity of bees species were found in both agrocenosis and semi-natural habitats (Sorensen similarity index – 0.50).That points toward dependents of bees fauna forming in agrocenosis from fauna of semi-natural habitats. The decreasing of Sorensen index was established for semi-natural habitats and ecotones between them and agrocenosis (down to 0.3). The lowest similarities were observed in ecotones and agrocenosis.

The results obtained make it possible to assume that bees respond to changes in their environment and in particular to increased intensiveness of agriculture management. That makes them a reliable indicator and allows their use in biomonitoring of the environment.

Conclusion. The species richness of bees grows by gradient: agrocenosis – semi-natural habitat – ecotone and presented by 60 species in the observed farm territory of Kiev region (Dniester-Dnipro province of Central Forest-Step of Podilska and Pridneprovska hills). The most common and spread species are *Apis mellifera* L., *Bombus lapidarius* L., *B. terrestris* L., *Halictus simplex* Blüthgen, *Systropha curvicornis* Scopoli, *Lasioglossum leucozonium* Schrank.

Density of *Apidae* increases in agrocenosis and falls in semi-natural habitats. Forming of bees fauna in agrocenosis depends from fauna of semi-natural habitats. Availability of ecotones promotes increasing of bee diversity in agroecosystems because it performs preservation function for biota and improves the spreading of bees and other species.

The presented results could be usedto predict changes in the formation of bee entomocomplexes in order to preserve their biodiversity.

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Порівняльний аналіз різноманіття бджіл в **оселищах антропогенного типу**

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Відомо, що біорізноманіття має велике значення для агроекосистем, оскільки визначає їх реальну та потенційну продуктивність. Важливий екологічний сервіс у сільськогосподарських ландшафтах більшості географічних регіонів забезпечують бджоли, оскільки їх вважають переважною та найбільш економічно значущою групою запилювачів. Метою дослідження було оцінювання різноманіття бджіл (домашньої, диких, джмелів) у різних оселищах антропогенного типу Центрального Лісостепу України. Бджолині угруповання досліджували в агроценозах, напівприродних біотопах та екотонах між ними на територіях 6 господарств. Всього було відібрано 1131 особин бджіл, які було представлено 60 видами. Досліджено видовий склад, щільність і видове багатство бджіл. Для аналізу біорізноманіття використовували індекси Шеннона, Сімпсона та Соренсена. Результати показали, що видове багатство бджіл зростає за градієнтом: агроценоз – напівприродне оселище – екотон. Найбільш поширеними видами були *Apis mellifera L., Bombus lapidarius L., B. terrestris L., Halictus simplex Blüthgen, Systropha curvicornis Scopoli, Lasioglossum leucozonium Schrank*. Щільність *Apidae* зростає в агроценозах і зменшується в напівприродних оселищах. Формування фауни бджіл в агроценозах залежить від їх різноманіття в напівприродних оселищах. Наявність екотонів сприяє збільшенню різноманіття бджіл в агроекосистемах, оскільки виконує функцію збереження біоти та покращує розповсюдження бджіл та інших видів. Представлені результати можуть бути використані для прогнозування змін у формуванні ентомокомплексів бджіл з метою збереження їх біорізноманіття.

Ключові слова: агроекосистеми, оселища, різноманіття бджіл, видове багатство, щільність особин.