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## BIODIVERSITY AND THE STRUCTURAL AND FUNCTIONAL CHARACTERISTICS OF RIVER BIRD COMMUNITIES OF MONTANE AND LOWLAND ZAKARPATTIA IN THE BREEDING SEASON

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**Background.** The species and taxonomic diversity of biotic communities are directly related to changes in the environment. The more diverse an ecosystem is in terms of its biotic and abiotic components, the more complex are its functional structure and the relationships between species and habitats. The restoration of species and taxonomic diversity in ecosystems affected by anthropogenic impacts of varying intensity takes place under different scenarios. This is illustrated by the analysis of the structural and functional characteristics of bird communities in montane and lowland river ecosystems in Zakarpattia. The key component of these bird communities is the ecological group of wetland species, which was analysed by the number and abundance of species, and changes of species composition in the past 100 years.

**Materials and Methods.** The bird communities of the middle course of the montane Uzh River and of the lowland Botar River were analysed in 1994–2002 and 2016–2020, and in 2014–2015, respectively, in the breeding season (April–June). Birds were counted during route surveys. The width of the survey stripes was 100 m (50 m on both sides of the route). A 13 km-long section of the middle course of the Uzh River was examined in two different habitats: 7 km in natural and 6 km in urbanised areas. Additionally, a 17 km-long lowland section of the Botar River was studied, which included channelised parts and riverbed ponds as well as 6 km of the preserved natural riverbed and floodplain. In total, a 308 km-long route was surveyed. For statistical analysis of data obtained during the study of birds on the Uzh and Botar Rivers, Pearson's chi-squared test was used. Calculations were performed using Microsoft Excel.

**Results and Discussion.** During the breeding season, 81 bird species (of 65 genera, 35 families, and 14 orders) were recorded in the valley of the middle Uzh River, and



81 species (of 58 genera, 33 families, and 15 orders) in the lowland course of the Botar River. The structural and functional characteristics of the bird communities of both rivers are reflected in the proportion, population density, and presence status (resident or migratory) of each species, in the combination of ecological groups, and in the trophic and spatial structure of the community. All of these parameters depend on the diversity of habitats in these river ecosystems and characterise the carrying capacity of the environment.

In terms of ecological groups, the bird community of the middle Uzh is dominated by forest species, both in species richness (45.7 %) and density of individuals per km<sup>2</sup> (52.6 %). Wetland (17.3 %) and forest-steppe species (18.5 %) are also well represented. Species of anthropogenic landscapes, in addition to forest species, also have a relatively high population density (21.7 %). Within the lowland part of the Botar River, the bird community is dominated by forest and wetland species (32 % and 29.6 %, respectively), but the highest population density is characteristic of forest-steppe species (32.6 %), followed by forest and wetland species (27 % and 18.6 %, respectively). Birds of anthropogenic landscapes are the least represented by both species richness (6.2 %) and population density (7.6 %). Despite the dramatic transformation of the Botar River in the twentieth century due to the creation of an irrigation system, wetland bird species, compared to the Uzh River, have a significant proportion by both their number and density. This is due to the specific structural features of habitats and ecological niches of the montane and lowland river ecosystems. The difference in living conditions between the mountain river and the lowland river is significant for wetland bird species ( $\chi^2 = 5,2$ ;  $p < 0.05$ ).

With regard to spatial distribution, the dominant group in the bird community of the middle Uzh is the hollow-nesting species (26.5%), followed by tree-nesting and ground-nesting species (23.5 % each). Hollow-nesting species also predominate by population density (32.1 %), whereas urban-nesting birds are sub-dominants (21.8 %). In contrast, the bird community of the lowland Botar River is dominated by ground-nesting species (35.3 %), although the proportion of tree- (23.5%) and shrub-nesting (19.1 %) species is also relatively high. In terms of population density, the dominant species are hollow-nesting (34.1 %), whereas the sub-dominants are ground-nesting (31.4 %).

In terms of trophic specialisation, the bird community of the Uzh River is dominated by carnivores both by species richness (65.4 %) and population density (48.4 %). In the bird community of the Botar River, however, carnivores notably dominate by species composition (70.3 %), but omnivores dominate by population density (50.6 %). Ground-nesting carnivores and omnivores make up a significant proportion of wetland bird species, the functional role of which is clearly noticeable in this community. The bird community in the middle Uzh River is dominated by forest-dwelling hollow-nesting carnivores, which inhabit the strip of riverine willow and poplar forests.

**Conclusion.** The analysis of the structural and functional characteristics of bird communities in the montane and lowland river ecosystems of Zakarpattia, which in the twentieth century underwent anthropogenic transformation to varying degrees, illustrates the main differences between these ecosystems. Anthropogenic impacts associated with the drainage and loss of much of the natural floodplain of both rivers led to a decline in the species diversity of wetland birds. However, the compensation for the loss of bird diversity of the two rivers occurred under different scenarios. These differences lie in habitat conditions, carrying capacity, and the previous history of species diversity.

**Keywords:** biodiversity, lowland and montane rivers, structural and functional characteristics, bird community

## INTRODUCTION

Biodiversity is the basis of ecosystem functioning providing humanity with services necessary for its survival. Understanding the importance of biodiversity conservation at both local and global scales has led to the development and adoption of the European Green Deal policy, in which the EU Biodiversity Strategy for 2030 plays a key role.

Degraded ecosystems are characterised by a complete or temporary loss of biodiversity, and the succession process of biodiversity stabilisation is dynamic and unpredictable. In ecology, the concept of biodiversity is largely associated with the diversity of communities and the diversity of species (Protasov, 2002; Beck & Schwanghart, 2010). The species diversity of ecological communities is closely related to habitat structure and diversity. The nature of habitat changes and the intensity of the impact that lead to ecosystem degradation will determine the direction of changes in the species composition of the community: some species will become rare or entirely disappear, some will adapt and increase their representation in the community (in biomass or abundance), and some will appear in the community as introduced species. These changes will be reflected not only in the species composition, but also in the spatial structure of the community and will depend on a seasonal aspect (Curzel & Leveau, 2021; Nava-Díaz *et al.*, 2022; Zhang *et al.*, 2024).

Such changes have been found in the species structure of bird communities in the middle rivers of the Bohemian Massif (the Czech Republic), and the Carpathian Mountains (Poland, Slovakia), wetlands of the nature conservation area (Lampertheimer Altrein, near Mannheim) in southwestern Germany (Pšeničková & Horák, 2022; Kajtoch *et al.*, 2024), seven rivers around Lake Chaohu (China), natural and artificial wetlands in the Sindh province of Pakistan (Rajpar *et al.*, 2022; Xu *et al.*, 2022). This was the result of the impact of landscape modification in riparian ecosystems, urbanization, loss of food resources and habitats. Species diversity indices (Shannon's diversity index, species richness, and species evenness) are used to assess biodiversity (Schrauth & Wink, 2018; Iswandaru *et al.*, 2025). Various statistical analysis methods are used to compare data on bird biodiversity of different water bodies. Quantitative indicators can be compared using the one-way Kruskal–Wallis analysis of variance. For qualitative indicators, the chi-squared test is used (Chicco *et al.*, 2025).

Biodiversity conservation strategies must be based on a thorough understanding of the relationships between changes in habitats of communities as a result of anthropogenic impacts and changes that may occur in the species composition and functional structure of the affected communities. This objective can be achieved by studying the structural and functional characteristics of communities (Odum, 1968; Emelyanov, 1999; Sarmiento-Garavito *et al.*, 2022).

## MATERIALS AND METHODS

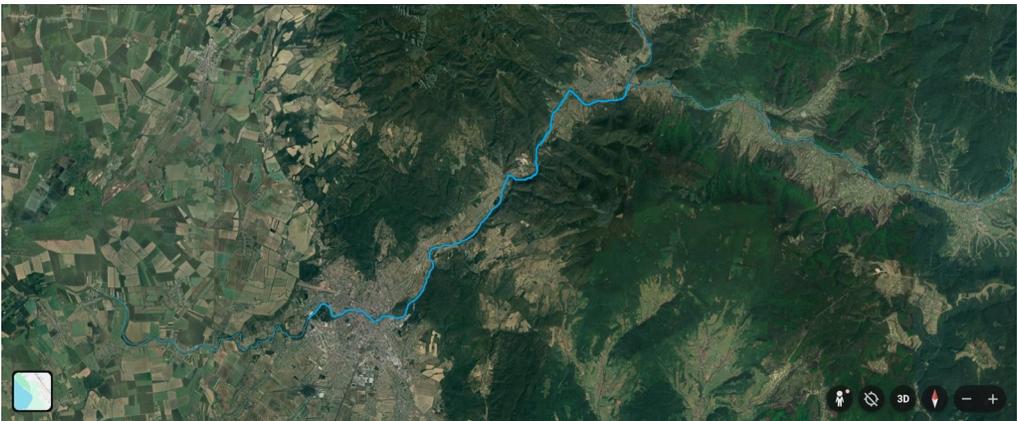
The structural and functional characteristics of bird communities of the middle course of the Uzh River were studied in 1994–2002 and 2016–2020, whereas bird communities of the section of the Botar River within the Transcarpathian Lowland were analysed in 2014–2015.

The headwaters of the Uzh River are located in the north-west of Zakarpattia, in the Ukrainian Carpathians, on the southern slopes of the Verkhovyna Divide 970 m a.s.l. Its total length is 133 km, of which 107 is located within Ukraine and 26 km in Slovakia. The upper course of the Uzh flows across a wide valley bypassing the western slopes of the Polonyňa Massif. Its middle course runs through the Vyhorlat-Gutin volcanic range, and the river enters the Transcarpathian Lowland downstream of Uzhhorod. The upper and middle courses of the Uzh have montane, while its lower course has lowland features.

The river meanders in its middle course and has a width of 15–30 m, and up to 100 m near the city of Uzhhorod. The riverbed is rocky, but silted in sections with slow current, such as within Uzhhorod. Riffles and rapids alternate with backwaters, and the deposits in the riverbed create numerous islands overgrown with willow and other vegetation. The floodplain is discontinuous, often asymmetric, has a width of 50–500 m, and is bounded by a dyke along its right bank. The banks are steep with a height of 1–2 m or higher. Along the right bank grows a stripe of floodplain forest with a large amount of dead wood. The left bank is characterised by either a similar stripe of floodplain forest, or slopes with hornbeam–oak and beech forests of the Vyhorlat-Gutin Ridge. Within the city of Uzhhorod, both banks with a total length of 2.5 km are covered by fragments of floodplain forest, whereas the 3.5 km-long banks in the city centre are represented by urban waterfronts with protective embankments. Along the embankments are wide avenues for walking and recreation, and the area between them is regularly mowed.

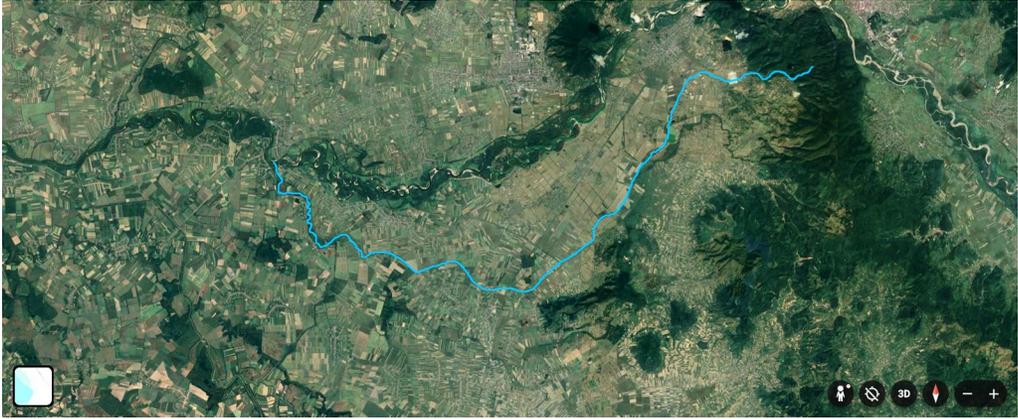
The current is fast and the water is well aerated, and therefore much of the riverbed lacks aquatic vegetation. However, aquatic vascular plants appear during baseflow periods, which indicates that rheophilic conditions have been retained, except for the section in the village of Kamianytsia where a dam is located. Water from the upper pond is channelled to a derivative canal with two mini hydroelectric power plants. Upstream from the dam, the hydrological conditions of the river are similar to those of a slow-flowing watercourse. In the centre of Uzhhorod, on sections with slow current, mats of watermilfoil appear in periods of baseflow, which indicates that there are sources of biogenic elements in the river. However, when the water level rises during rainfall, backwater areas are washed well.

The narrow valley of the middle Uzh in the mountains is quite urbanised – the cities of Uzhhorod and Perechyn and four villages are located along the river (**Fig. 1**).



**Fig. 1.** The narrow valley of the middle Uzh

The headwaters of the Botar River are located on the slopes of Mt Frasn in the south-eastern part of the Vyhorlat-Gutin Ridge that stretches 125 km through Transcarpathia, from Slovakia to Romania (**Fig. 2**). The length of the river is 53 km. Upon entering the Transcarpathian Lowland, it acquires characteristics of a lowland river.



**Fig. 2.** The Botar River: from source to mouth

However, except for its lower course, it was completely transformed into a canal as part of the Botar transboundary irrigation system. The width of the riverbed is up to 3–8 m, the bottom is silty, and the current is extremely slow. Some sections of the banks are overgrown with willows, poplars, and shrubs, while others are covered with thickets of bulrush and sweetgrass. Aquatic vascular plants, common for slow-flowing lowland rivers, and algae are abundant. In the lower course, near the state border, the natural state of the Botar River has been preserved, with meanders and a small, dyked floodplain. Wetlands, meadows, small oxbow lakes, and artificial ditches have been preserved in the floodplain. The river flows into the Tysa near Vylok (**Fig. 3**).



**Fig. 3.** The natural state of the Botar River near its mouth

In the early twentieth century, the Botar was a typical lowland river with a natural, meandering bed. Its floodplain meadows were regularly flooded and waterlogged. Various wetland birds nested in the thickets and the locals used the meadows as pastures.

Floodplain forests stretched along the river. Now the river is straightened and dyked on both banks, the width between which varies between 1 and 15 m, occasionally to 500 m. The ploughed floodplain is covered with a system of irrigation canals, parts of which have been abandoned – they are dry and overgrown with shrubs. Fields and some pastures are located nearby, with small plots of oak forests.

In summer, during periods of baseflow, the lowland section of the river dries out and turns into a cascade of disconnected small puddles, which in some years can also dry out completely. This is due to the malfunction of locks of the hydrotechnical structures in various parts of the river. There is a hydrotechnical complex near the village of Dyula, from which the Novyi Botar canal was laid to the Tysa. Another complex is located in Hudya, the locks of which regulate the waterflow from the Botar River to the Hudya Reservoir. A third complex and a fish pond are located upstream, near the village of Cherna, on the Mlynovytsia River, the Botar's tributary.

The lower course of the Botar near and along the state border is probably the sole and last area in the entire Transcarpathian Lowland where the natural riverbed and the floodplain complex of a small river have been preserved.

The bird fauna was studied during the breeding season, from April to June. Route surveys were conducted. The width of the survey stripe was 100 m (50 m on both sides of the route). The surveys were carried out in the morning in good weather. All birds that could be identified either visually or vocally within the survey stripe were counted. Birds of prey were also identified mid-flight.

A 13 km-long section of the middle course of the Uzh River was surveyed in two different habitats: a 7 km-long natural section between the villages of Kamianytsia and Onokivtsi, and a 6 km-long urbanised section within the city of Uzhhorod. Of the Botar River, a 17 km-long section of its lowland course was studied, including the Hudya Reservoir and the fish pond in Cherna. Of this length, 6 km were represented by the preserved natural floodplain. The total length of the survey routes was 308 km.

The categories of bird abundance correspond to the previously adopted classification (Stankiewicz-Volosianchuk, 2023): abundant – 10–100 ind./km<sup>2</sup>; common – 1–10 ind./km<sup>2</sup>; occasional – 0.1–1.0 ind./km<sup>2</sup>; and rare – 0.01–0.1 ind./km<sup>2</sup>.

The scientific names of birds follow the currently adopted system after Avibase (<https://avibase.bsc-eoc.org/checklist.jsp?region=UA>).

For statistical analysis of data obtained as a result of studies of birds on the Uzh River and the Botar River, Pearson's chi-squared test was used. This test was used to compare the frequency of occurrence of different ecological groups of birds within the Uzh and Botar Rivers separately. The frequency of occurrence of one ecological group of birds in the conditions of both rivers was also compared. The chi-squared test allows testing the hypothesis about the dependence of the distribution of different ecological groups of birds in the community on environmental conditions. To determine the critical value of chi-squared, a probability level of 5 % ( $p = 0.05$ ) was taken.

The calculations were performed using Microsoft Excel.

## RESULTS AND DISCUSSION

In the breeding season, 81 bird species were recorded in both the middle Uzh and the lowland Botar valleys. The 81 species of the middle Uzh represent 65 genera, 35 families, and 14 orders, whereas those of the Botar River belong to 58 genera, 33 families, and 15 orders (**Table 1**).

**Table 1. Taxonomic diversity of bird communities of the middle Uzh and lowland Botar rivers in Zakarpattia**

| Order            |       | Family |       | Genus |       | Species |       |
|------------------|-------|--------|-------|-------|-------|---------|-------|
| Uzh              | Botar | Uzh    | Botar | Uzh   | Botar | Uzh     | Botar |
| Anseriformes     |       | 1      | 1     | 3     | 2     | 3       | 2     |
| Galliformes      |       | 1      | 1     | 1     | 2     | 1       | 2     |
| Podicipediformes |       | 0      | 1     | 0     | 2     | 0       | 2     |
| Columbiformes    |       | 1      | 1     | 2     | 2     | 4       | 4     |
| Cuculiformes     |       | 1      | 1     | 1     | 1     | 1       | 1     |
| Caprimulgiformes |       | 1      | 0     | 1     | 0     | 1       | 0     |
| Gruiformes       |       | 0      | 1     | 0     | 2     | 0       | 2     |
| Charadriiformes  |       | 2      | 2     | 5     | 2     | 5       | 2     |
| Ciconiiformes    |       | 1      | 1     | 1     | 1     | 2       | 2     |
| Pelecaniformes   |       | 1      | 1     | 2     | 3     | 3       | 4     |
| Accipitriformes  |       | 1      | 1     | 2     | 4     | 2       | 6     |
| Bucerotiformes   |       | 1      | 1     | 1     | 1     | 1       | 1     |
| Coraciiformes    |       | 1      | 1     | 1     | 1     | 1       | 1     |
| Piciformes       |       | 1      | 1     | 6     | 2     | 8       | 2     |
| Falconiformes    |       | 1      | 1     | 1     | 1     | 1       | 1     |
| Passeriformes    |       | 21     | 18    | 38    | 32    | 48      | 49    |
| 14               | 15    | 35     | 33    | 65    | 58    | 81      | 81    |

The species composition of the bird communities of each river has its own features. The distribution of species by their abundances, particularly by their evenness, is balanced and similar to that in natural ecosystems (Whittaker, 1970). The abundance of birds in the middle Uzh is 723.94 ind./km<sup>2</sup>. There are 20 abundant species in the community, and their share is 80.3 %. The number of common species is 38 (18.4 %). Of the remaining species 17 are occasional (1.24 %) and 6 species are rare (0.06 %). However, the number of species recorded increases with the number of surveys conducted.

The abundance of birds in the Botar River valley is 641.14 ind./km<sup>2</sup>. Of the 81 species revealed, 16 are abundant (76.4%), including the European starling (*Sturnus vulgaris*) and the Eurasian tree sparrow (*Passer montanus*), which are the most frequently observed. Of the rest of the species, 39 are common (21.32 %), 24 are occasional (2.2 %), and 2 are rare (0.08 %).

Among the birds of the middle Uzh River, 32 are resident breeding species, 38 are migratory breeding species, and 2 are resident non-breeding species (the black-headed gull *Chroicocephalus ridibundus* and the mute swan *Cygnus olor*). There are also 6 summering and 3 accidental species in the community, which are all wetland birds: the grey heron *Ardea cinerea*, the great egret *Ardea alba*, the little egret *Egretta garzetta*, the Caspian gull *Larus cachinnans*, the black stork *Ciconia nigra*, the common snipe *Gallinago gallinago*, the little ringed plover *Charadrius dubius*, the common merganser *Mergus merganser*, and the western marsh harrier *Circus aeruginosus* (**Table 2**).

Table 2. Species structure of bird communities of the middle Uzh and lowland Botar rivers in Zakarpattia

| No. | Species                           | Middle course of the Uzh |        |    |    | Lowland course of the Botar |        |    |    |
|-----|-----------------------------------|--------------------------|--------|----|----|-----------------------------|--------|----|----|
|     |                                   | A                        | B      | C  | D  | A                           | B      | C  | D  |
| 1   | 2                                 | 3                        | 4      | 5  | 6  | 7                           | 8      | 9  | 10 |
| 1.  | <i>Sturnus vulgaris</i>           | 64.3                     | Br     | Ho | Om | 98.8                        | Br     | Ho | Om |
| 2.  | <i>Parus major</i>                | 59.2                     | Re, Br | Ho | Ca | 11.3                        | Re, Br | Ho | Ca |
| 3.  | <i>Fringilla coelebs</i>          | 55.4                     | Re, Br | Tr | Om | 1.8                         | Re, Br | Tr | Om |
| 4.  | <i>Delichon urbica</i>            | 50.4                     | Br     | Ur | Ca | 0.4                         | Br     | Ur | Ca |
| 5.  | <i>Anas platyrhynchos</i>         | 44.3                     | Re, Br | Gr | Om | 20.8                        | Re, Br | Gr | Om |
| 6.  | <i>Apus apus</i>                  | 42.2                     | Br     | Ur | Ca | –                           |        |    |    |
| 7.  | <i>Turdus merula</i>              | 38.8                     | Re, Br | Sh | Om | 25.6                        | Re, Br | Sh | Om |
| 8.  | <i>Cyanistes caeruleus</i>        | 27.2                     | Re, Br | Ho | Ca | 0.6                         | Re, Br | Ho | Ca |
| 9.  | <i>Hirundo rustica</i>            | 25.2                     | Br     | Ur | Ca | 42.7                        | Br     | Ur | Ca |
| 10. | <i>Chroicocephalus ridibundus</i> | 24.4                     | Re     |    | Om | –                           |        |    |    |
| 11. | <i>Carduelis carduelis</i>        | 22.4                     | Re, Br | Tr | He | 18.2                        | Re, Br | Tr | He |
| 12. | <i>Turdus philomelos</i>          | 20.5                     | Br     | Sh | Om | 2.5                         | Br     | Sh | Om |
| 13. | <i>Poecile palustris</i>          | 19.3                     | Re, Br | Ho | Ca | 0.6                         | Re, Br | Ho | Ca |
| 14. | <i>Passer montanus</i>            | 19.0                     | Re, Br | Ho | Om | 94.5                        | Re, Br | Ho | Om |
| 15. | <i>Columba livia f. domestica</i> | 12.8                     | Re, Br | Ur | He | 3.3                         | Re, Br | Ur | He |
| 16. | <i>Alauda arvensis</i>            | 12.0                     | Br     | Gr | Ca | 41.7                        | Br     | Gr | Ca |
| 17. | <i>Erithacus rubecula</i>         | 11.8                     | Re, Br | Gr | Ca | 1.1                         | Re, Br | Gr | Ca |
| 18. | <i>Sitta europaea</i>             | 11.2                     | Re, Br | Ho | Om | –                           |        |    |    |
| 19. | <i>Motacilla alba</i>             | 10.7                     | Br     | Gr | Ca | 22.7                        | Br     | Gr | Ca |
| 20. | <i>Passer domesticus</i>          | 10.2                     | Re, Br | Ur | Om | –                           |        |    |    |
| 21. | <i>Serinus serinus</i>            | 8.6                      | Br     | Tr | He | –                           |        |    |    |

| 1   | 2                                    | 3   | 4      | 5  | 6  | 7    | 8      | 9  | 10 |
|-----|--------------------------------------|-----|--------|----|----|------|--------|----|----|
| 22. | <i>Certhia familiaris</i>            | 8.4 | Re, Br | Ho | Ca | –    |        |    |    |
| 23. | <i>Corvus corone</i>                 | 7.4 | Re, Br | Tr | Om | 3.1  | Re, Br | Tr | Om |
| 24. | <i>Phasianus colchicus</i>           | 7.2 | Re, Br | Gr | Om | 16.7 | Re, Br | Gr | Om |
| 25. | <i>Motacilla cinerea</i>             | 5.5 | Br     | Gr | Ca | –    |        |    |    |
| 26. | <i>Oriolus oriolus</i>               | 5.3 | Br     | Tr | Ca | 5.4  | Br     | Tr | Ca |
| 27. | <i>Coccothraustes coccothraustes</i> | 5.2 | Re, Br | Tr | He | 0.4  | Re, Br | Tr | He |
| 28. | <i>Phylloscopus collybita</i>        | 5.2 | Br     | Gr | Ca | 2.1  | Br     | Gr | Ca |
| 29. | <i>Phylloscopus sibilatrix</i>       | 5.0 | Br     | Gr | Ca | 2.1  | Br     | Gr | Ca |
| 30. | <i>Picus canus</i>                   | 4.8 | Re, Br | Ho | Ca | –    |        |    |    |
| 31. | <i>Aegithalos caudatus</i>           | 4.6 | Re, Br | Tr | Ca | 5.2  | Re, Br | Tr | Ca |
| 32. | <i>Chloris chloris</i>               | 4.4 | Re, Br | Tr | He | 0.5  | Re, Br | Tr | He |
| 33. | <i>Dendrocopos major</i>             | 4.2 | Re, Br | Ho | Ca | 0.3  | Re, Br | Ho | Ca |
| 34. | <i>Columba palumbus</i>              | 4.0 | Br     | Tr | Om | 7.5  | Br     | Tr | Om |
| 35. | <i>Silva atricapilla</i>             | 3.8 | Br     | Sh | Ca | 1.9  | Br     | Sh | Ca |
| 36. | <i>Lanius collurio</i>               | 3.6 | Br     | Tr | Ca | 10.4 | Br     | Tr | Ca |
| 37. | <i>Streptopelia decaocto</i>         | 3.6 | Re, Br | Ur | He | 1.1  | Re, Br | Ur | He |
| 38. | <i>Phylloscopus trochilus</i>        | 3.4 | Br     | Gr | Ca | 1.8  | Br     | Gr | Ca |
| 39. | <i>Turdus pilaris</i>                | 3.4 | Re, Br | Sh | Om | 0.8  | Re, Br | Sh | Om |
| 40. | <i>Cuculus canorus</i>               | 2.8 | Br     |    | Ca | 5.1  | Br     |    | Ca |
| 41. | <i>Ardea cinerea</i>                 | 2.7 | Su     |    | Ca | 6.1  | Su     |    | Ca |
| 42. | <i>Phoenicurus ochruros</i>          | 2.6 | Br     | Ur | Ca | –    |        |    |    |
| 43. | <i>Garrulus glandarius</i>           | 2.5 | Re, Br | Tr | Om | 0.7  | Re, Br | Tr | Om |
| 44. | <i>Curruca curruca</i>               | 2.4 | Br     | Sh | Ca | 18.7 | Br     | Sh | Ca |

| 1   | 2                              | 3   | 4      | 5  | 6  | 7    | 8      | 9  | 10 |
|-----|--------------------------------|-----|--------|----|----|------|--------|----|----|
| 45. | <i>Luscinia megarhynchos</i>   | 2.2 | Br     | Sh | Ca | 5.0  | Br     | Sh | Ca |
| 46. | <i>Troglodytes troglodytes</i> | 2.0 | Re, Br | Gr | Ca | –    |        |    |    |
| 47. | <i>Periparus ater</i>          | 2.0 | Re, Br | Ho | Ca | 0.6  | Re, Br | Ho | Ca |
| 48. | <i>Dendrocoptes medius</i>     | 2.0 | Br     | Ho | Ca | –    |        |    |    |
| 49. | <i>Curruca communis</i>        | 1.9 | Br     | Sh | Ca | 3.2  | Br     | Sh | Ca |
| 50. | <i>Ardea alba</i>              | 1.9 | Su     |    | Ca | 0.5  | Su     |    | Ca |
| 51. | <i>Falco tinnunculus</i>       | 1.7 | Br     | Ur | Ca | 1.7  | Br     | Ur | Ca |
| 52. | <i>Actitis hypoleucos</i>      | 1.6 | Br     | Gr | Ca | –    |        |    |    |
| 53. | <i>Buteo buteo</i>             | 1.5 | Br     | Tr | Ca | 0.9  | Br     | Tr | Ca |
| 54. | <i>Ciconia ciconia</i>         | 1.4 | Br     | Ur | Ca | 1.1  | Su     |    | Ca |
| 55. | <i>Egretta garzetta</i>        | 1.3 | Su     |    | Ca | –    |        |    |    |
| 56. | <i>Emberiza calandra</i>       | 1.1 | Br     | Gr | Om | 8.0  | Br     | Gr | Om |
| 57. | <i>Alcedo atthis</i>           | 1.0 | Re, Br | Bu | Ca | 1.9  | Re, Br | Bu | Ca |
| 58. | <i>Larus cachinnans</i>        | 1.0 | Su     |    | Ca | –    |        |    |    |
| 59. | <i>Corvus corax</i>            | 0.9 | Re, Br | Tr | Om | 0.4  | Re     | Tr | Om |
| 60. | <i>Streptopelia turtur</i>     | 0.7 | Br     | Tr | Om | 0.8  | Br     | Tr | Om |
| 61. | <i>Prunella modularis</i>      | 0.7 | Br     | Tr | Ca | –    |        |    |    |
| 62. | <i>Anthus trivialis</i>        | 0.7 | Br     | Gr | Ca | –    |        |    |    |
| 63. | <i>Emberiza citrinella</i>     | 0.7 | Br     | Sh | Om | 3.3  | Br     | Sh | Om |
| 64. | <i>Ciconia nigra</i>           | 0.7 | Su     |    | Ca | 0.4  | Su     |    | Ca |
| 65. | <i>Dryobates minor</i>         | 0.7 | Re, Br | Ho | Ca | 0.4  | Re, Br | Ho | Ca |
| 66. | <i>Saxicola rubetra</i>        | 0.6 | Br     | Gr | Ca | 9.6  | Br     | Gr | Ca |
| 67. | <i>Saxicola torquata</i>       | 0.5 | Br     | Gr | Ca | 12.5 | Br     | Gr | Ca |

| 1   | 2                                | 3    | 4      | 5  | 6  | 7    | 8      | 9  | 10 |
|-----|----------------------------------|------|--------|----|----|------|--------|----|----|
| 68. | <i>Lullula arborea</i>           | 0.5  | Br     | Gr | Ca | –    |        |    |    |
| 69. | <i>Pica pica</i>                 | 0.4  | Re, Br | Tr | Om | 20.3 | Re, Br | Tr | Om |
| 70. | <i>Muscicapa striata</i>         | 0.4  | Br     | Ho | Ca | –    |        |    |    |
| 71. | <i>Dryocopus martius</i>         | 0.4  | Re, Br | Ho | Ca | –    |        |    |    |
| 72. | <i>Mergus merganser</i>          | 0.4  | Ac     |    | Om | –    |        |    |    |
| 73. | <i>Cygnus olor</i>               | 0.3  | Re     |    | Om | –    |        |    |    |
| 74. | <i>Circus aeruginosus</i>        | 0.2  | Ac     |    | Ca | 1.2  | Br     | Gr | Ca |
| 75. | <i>Charadrius dubius</i>         | 0.2  | Ac     |    | Ca | –    |        |    |    |
| 76. | <i>Upupa epops</i>               | 0.08 | Br     | Ho | Ca | 0.5  | Su     |    | Ca |
| 77. | <i>Dendrocopos leucotos</i>      | 0.08 | Re, Br | Ho | Ca | –    |        |    |    |
| 78. | <i>Picus viridis</i>             | 0.08 | Re, Br | Ho | Ca | –    |        |    |    |
| 79. | <i>Jynx torquilla</i>            | 0.08 | Br     | Ho | Ca | –    |        |    |    |
| 80. | <i>Regulus regulus</i>           | 0.08 | Br     | Tr | Om | –    |        |    |    |
| 81. | <i>Gallinago gallinago</i>       | 0.04 | Su     |    | Ca | –    |        |    |    |
| 82. | <i>Vanellus vanellus</i>         | –    |        |    |    | 22.6 | Br     | Gr | Ca |
| 83. | <i>Corvus frugilegus</i>         | –    |        |    |    | 12.6 | Re     |    | Om |
| 84. | <i>Acrocephalus arundinaceus</i> | –    |        |    |    | 8.8  | Br     | Sh | Ca |
| 85. | <i>Motacilla flava</i>           | –    |        |    |    | 7.8  | Br     | Gr | Ca |
| 86. | <i>Gallinula chloropus</i>       | –    |        |    |    | 6.7  | Br     | Gr | Ca |
| 87. | <i>Luscinia luscinia</i>         | –    |        |    |    | 5.8  | Br     | Sh | Ca |
| 88. | <i>Spatula querquedula</i>       | –    |        |    |    | 4.9  | Br     | Gr | Om |
| 89. | <i>Tringa ochropus</i>           | –    |        |    |    | 2.7  | Su     |    | Ca |
| 90. | <i>Sylvia borin</i>              | –    |        |    |    | 2.4  | Br     | Sh | Ca |

| 1     | 2                                 | 3      | 4 | 5 | 6 | 7      | 8      | 9  | 10 |
|-------|-----------------------------------|--------|---|---|---|--------|--------|----|----|
| 91.   | <i>Acrocephalus schoenobaenus</i> | –      |   |   |   | 2.2    | Br     | Sh | Ca |
| 92.   | <i>Lanius minor</i>               | –      |   |   |   | 2.1    | Br     | Tr | Ca |
| 93.   | <i>Nycticorax nycticorax</i>      | –      |   |   |   | 1.8    | Su     |    | Ca |
| 94.   | <i>Lanius excubitor</i>           | –      |   |   |   | 1.6    | Re, Br | Tr | Ca |
| 95.   | <i>Motacilla feldegg</i>          | –      |   |   |   | 1.6    | Br     | Gr | Ca |
| 96.   | <i>Remiz pendulinus</i>           | –      |   |   |   | 1.3    | Br     | Sh | Ca |
| 97.   | <i>Riparia riparia</i>            | –      |   |   |   | 1.1    | Su     |    | Ca |
| 98.   | <i>Tachybaptus ruficollis</i>     | –      |   |   |   | 1.1    | Br     | Gr | Ca |
| 99.   | <i>Perdix perdix</i>              | –      |   |   |   | 0.9    | Re, Br | Gr | Om |
| 100.  | <i>Fulica atra</i>                | –      |   |   |   | 0.9    | Br     | Gr | Ca |
| 101.  | <i>Podiceps cristatus</i>         | –      |   |   |   | 0.8    | Br     | Gr | Ca |
| 102.  | <i>Emberiza schoeniclus</i>       | –      |   |   |   | 0.8    | Br     | Gr | Om |
| 103.  | <i>Clanga pomarina</i>            | –      |   |   |   | 0.7    | Su     |    | Ca |
| 104.  | <i>Accipiter gentilis</i>         | –      |   |   |   | 0.6    | Re     |    | Ca |
| 105.  | <i>Circus pigargus</i>            | –      |   |   |   | 0.3    | Br     | Gr | Ca |
| 106.  | <i>Ficedula albicollis</i>        | –      |   |   |   | 0.1    | Br     | Ho | Ca |
| 107.  | <i>Botaurus stellaris</i>         | –      |   |   |   | 0.07   | Br     | Gr | Ca |
| 108.  | <i>Accipiter nisus</i>            | –      |   |   |   | 0.07   | Re, Br | Tr | Ca |
| Total |                                   | 723.94 |   |   |   | 641.14 |        |    |    |

**Notes:** **A** – density (individuals per 1 km<sup>2</sup>); **B** – species status: Re – resident, Br – breeding, Su – summering, Ac – accidental; **C** – nesting type: Tr – tree-nesting, Sh – shrub-nesting, Ho – hollow-nesting, Gr – ground-nesting, Bu – burrow-nesting, Ur – urban-nesting; **D** – trophic group: Ca – carnivorous, Om – omnivorous, He – herbivorous

In the valley of the Botar River, 26 resident breeding species, 43 migratory breeding species, 3 resident non-breeding species, and 9 summering species were recorded. The summering species include the lesser potted eagle *Clanga pomarine* and the Eurasian hoopoe *Upupa epops*, as well as wetland birds such as the grey heron *Ardea cinerea*, the great egret *Ardea alba*, the black-crowned night heron *Nycticorax nycticorax*, the black stork *Ciconia nigra*, white stork *Ciconia ciconia*, the green sandpiper *Tringa ochropus*, and the bank swallow *Riparia riparia*.

The analysis and comparison of the species composition and diversity of bird communities of the studied sections of the Uzh and Botar rivers allows assessing the quality of the complex of these river and riverine ecosystems in the context of their carrying capacity. The surveyed portions of both rivers have been affected by anthropogenic transformations. The structural and functional characteristics of the bird communities reflected in the number, population density, and presence status (resident or accidental) of each species, along with the trophic and spatial structure of the community, characterise the carrying capacity, i.e., the energy reserve of the ecosystem converted into resources (Emelyanov *et al.*, 1999; Zagorodniuk *et al.*, 1995).

When considering ecological groups, the bird community of the middle Uzh is dominated by forest species both by number (45.7 %) and density per 1 km<sup>2</sup> (52.6 %). Wetland and forest-steppe species are also relatively well represented (17.3 % and 18.5 %, respectively). In terms of population density, forest species are followed by birds of anthropogenic landscapes (21.7 %). The least represented by both number and density is the group of steppe species (7.4 % and 3.2 %, respectively).

A comparison of the frequency of occurrence of different ecological groups of birds within the Uzh and Botar rivers using the chi-squared test (**Table 3**) indicates a clear dependence of the distribution of ecological groups in the bird community on environmental conditions.

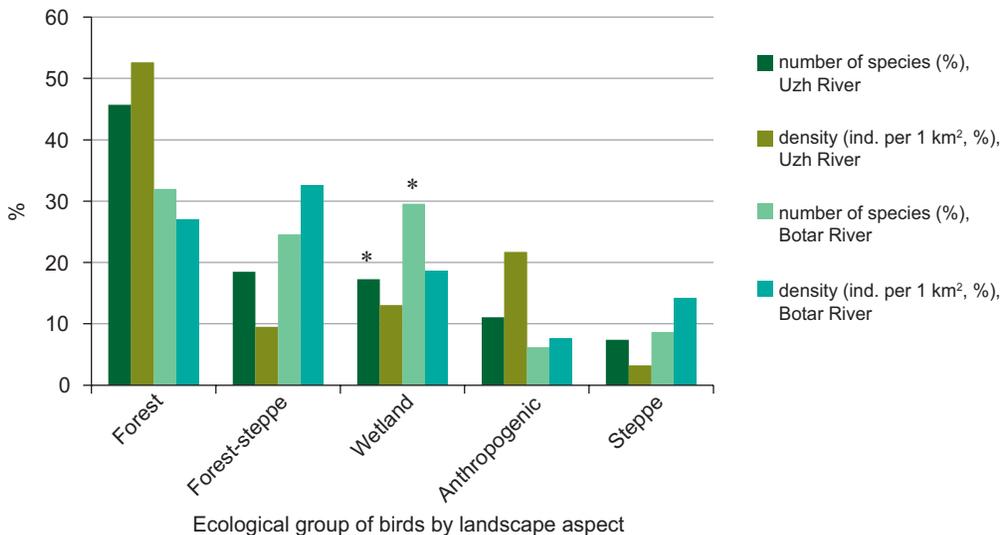
**Table 3. Comparison of the frequency of occurrence of different ecological groups of birds in the conditions of one river (Chi-square test)**

| The Uzh River                          |                         |  |                       |
|--|-------------------------|--|-----------------------|
| Ecological group of birds in community | df (degrees of freedom) | critical value for probability level of 5 % (p = 0.05) | the chi-squared value |
| By landscape                           | 4                       | 9.488  | 36.67                 |
| By nesting                             | 5                       | 11.07  | 18.07                 |
| By trophicity                          | 2                       | 5.99   | 42.23                 |
| The Botar River                        |                         |  |                       |
| Ecological group of birds in community | df (degrees of freedom) | critical value for probability level of 5 % (p = 0.05) | the chi-squared value |
| By landscape                           | 4                       | 9.488  | 23.45                 |
| By nesting                             | 5                       | 11.07  | 28.59                 |
| By trophicity                          | 2                       | 5.99   | 51.3                  |

In all cases, the chi-square value is greater than the critical value. This means that the frequency of occurrence of different ecological groups of birds by landscape feature, type of feeding and nesting method, both on the Uzh River and on the Botar River,

is not accidental. This distribution of these groups in the bird community is determined by the influence of factors within the river ecosystem. This will be further demonstrated by an analysis of the structural and functional characteristics of the bird communities of the Uzh and Botar rivers, including landscape, trophic and spatial aspects.

Little information can be found about the species diversity of bird communities of the middle Uzh River before the transformation of its riverbed and floodplain (Hrabár, 1938; Lugovoy, 1994). However, existing studies indicate that over the past 100 years, as a result of partial regulation of the natural floodplain hydrological regime and urbanisation of the Uzh River valley in its middle course, certain changes have occurred in the species composition and abundance of bird communities, which also exhibit a seasonal aspect (Lugovoy *et al.*, 2001; Stankiewicz-Volosianchuk, 2023). Due to the reduction of the floodplain area and the replacement of its shrubby vegetation and wet meadows with agricultural and urbanised lands, several forest-steppe and wetland species have declined or disappeared completely from this territory. Such birds include the red-backed shrike *Lanius collurio*, the little ringed plover, the green sandpiper, the Eurasian woodcock *Scolopax rusticola*, and the Eurasian hoopoe, whose abundance substantially decreased in the Uzh valley. The great grey shrike *Lanius excubitor*, the lesser grey shrike *L. minor*, the western yellow wagtail *Motacilla flava*, the gadwall *Mareca strepera*, and the osprey *Pandion haliaetus* completely vanished from the area. Later, the lost species diversity of birds of the middle Uzh, except for the wetland species, has been compensated by forest and urban species, as well as wetland species prone to synanthropy, such as the mallard *Anas platyrhynchos*, the mute swan, the black-headed gull, and the Caspian gull (Fig. 4).



**Fig. 4.** The proportion of different ecological groups in the bird communities of the Uzh and Botar rivers by number of species and population density, % (note: differences between ecological groups of birds, marked with asterisks, on the mountain and plain rivers are significant at  $p < 0.05$ )

The bird community of the lowland section of the Botar River is dominated by forest and wetland species (32 % and 29.6 %, respectively). However, in terms of population density, forest-steppe species predominate (32.6 %) the groups of forest and wetland birds (27 % and 18.6 %, respectively). The least represented are birds of anthropogenic

landscapes by both the number of species (6.2 %) and population density (7.6 %). Unlike the Uzh, which is a montane river with a narrow valley flowing through human settlements, the Botar flows through lowland agricultural lands relatively far from villages.

The proportion of wetland species in the bird community of both rivers attracts attention. Irrigation and the construction of various hydrotechnical structures on rivers have been known to have a severely negative impact on the diversity of wetland birds (Kingsford & Thomas, 2004; Kajtoch & Figarski, 2013; Figarski & Kajtoch, 2015). Despite the substantial transformation of the Botar River in the twentieth century due to the construction of the irrigation system, wetland birds are represented here in relatively high numbers and densities compared to the Uzh River. In our opinion, this is natural because montane and lowland river ecosystems have considerably different wetland habitats, carrying capacities, and previous histories of formation of the diversity of this group in the community (Vaccaro *et al.*, 2022; Zagorodniuk *et al.*, 2023).

We also tested this hypothesis using the Chi-square test. We compared the frequency of occurrence of birds of each ecological group according to landscape principle and nesting type in two different locations: the montane Uzh River and the lowland Botar River (**Table 4**). We did not compare ecological groups of birds by feeding type due to the insignificant difference in their proportions in the Uzh and Botar river communities.

**Table 4. Comparison of the frequency of occurrence of each ecological group of birds in the conditions of both rivers (results of Chi-square calculation)**

| By landscape                           |                         |  |                       |
|--|-------------------------|--|-----------------------|
| Ecological group of birds in community | df (degrees of freedom) | critical value for probability level of 5 % (p = 0.05) | the chi-squared value |
| Wetland                                | 1                       | 3.48   | <b>5.2</b>            |
| Forest                                 | 1                       | 3.48   | 2.4                   |
| Forest-steppe                          | 1                       | 3.48   | 0.71                  |
| Steppe                                 | 1                       | 3.48   | 0.08                  |
| Anthropogenic                          | 1                       | 3.48   | 1.4                   |
| By nesting                             |                         |  |                       |
| Tree-nesting                           | 1                       | 3.48   | 0.04                  |
| Shrub-nesting                          | 1                       | 3.48   | 1.2                   |
| Hollow-nesting                         | 1                       | 3.48   | <b>3.8</b>            |
| Ground-nesting                         | 1                       | 3.48   | 1.9                   |
| Urban-nesting                          | 1                       | 3.48   | 1.2                   |
| Burrow-nesting                         | 1                       | 3.48   | 0                     |

The results of the chi-square test confirm our assumption that the difference in living conditions between the mountain river and the lowland river is significant for wetland bird species: the chi-square test value exceeds the critical value for a probability level of 0.05.

The fast current makes the Uzh River poor in nutrients and in both aquatic and riparian vegetation. Even the deposit islands in the riverbed, which could be suitable for the nesting of some wetland species, are unreliable habitats. During floods, which occur frequently in the breeding season, the fast current washes away everything on its path. The floodplain of the montane Uzh River is narrow and often bordered by forest,

which is unfavourable for the accumulation of wetland birds. Under such conditions, the typical species of montane rivers are the common sandpiper *Actitis hypoleucos*, the white-throated dipper *Cinclus cinclus*, the grey wagtail *Motacilla cinerea*, the little ringed plover, the green sandpiper, the Eurasian woodcock, and the common kingfisher *Alcedo atthis*, as well as single individuals of the black stork and the grey heron. Among waterfowl, the typical species are the mallard and several other ducks that mainly visit the river in winter and form large congregations.

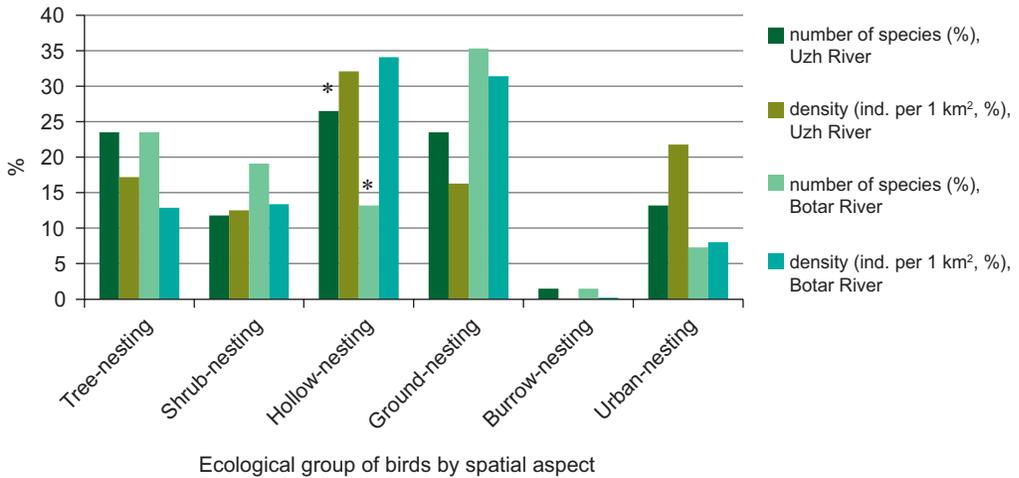
Lowland rivers, however, are characterised by completely different conditions. During floods, the water, rich in biogenic elements, gradually fills up the floodplain of the Botar River. The current is slow, the banks have dense thickets of reed, bulrush, sweetgrass, and shrubs; and there is also rich aquatic vegetation. The river, its banks, and floodplain meadows are places where many wetland species aggregate to nest and forage. The presence of species that disappeared from the bird community of the Uzh 50 years ago (the lesser grey shrike, the great grey shrike, and the western yellow wagtail) indicates that the floodplain complexes of this lowland river are better saturated in spite of their large-scale melioration.

Nonetheless, the current diversity of wetland birds represents only a small part of the species richness that had existed here before the melioration (Hrabár, 1938; Lugovoy, 2003; Lugovoy, 2005). The marshy floodplains of lowland rivers of Zakarpattia provided habitat for species that have now disappeared from the region's fauna, such as the gadwall, the pygmy cormorant *Microcarbo pygmaeus*, the common crane *Grus grus*, the black-tailed godwit *Limosa limosa*, and the little tern *Sternula albifrons*. At the same time, the ferruginous duck *Aythya nyroca*, the purple heron *Ardea purpurea*, the squacco heron *Ardeola ralloides*, the graylag goose *Anser anser*, and the white-tailed eagle *Haliaeetus albicilla* have become rare. In recent years, the Eurasian spoonbill *Platalea leucorodia*, the glossy ibis *Plegadis falcinellus*, the black-winged stilt *Himantopus himantopus*, and the pied avocet *Recurvirostra avosetta*, which have not been seen for decades, have been observed on stopover during migration on water bodies of lowland Zakarpattia.

The analysis of the trophic and spatial aspects of the species composition of bird communities provides an insight into their functional characteristics. For instance, species that nest in hollows predominate (26.5 %) in the bird community of the middle Uzh, followed by tree-nesting and ground-nesting species (23.5 % each). The hollow-nesting species also predominate by their population densities (32.1 %), but the sub-dominants are those that nest on anthropogenic substrates (21.8 %). This structure clearly demonstrates the spatial aspect of ecological niches of the habitats of the middle Uzh River, which are in close contact with forested and urbanised environments (**Fig. 5**).

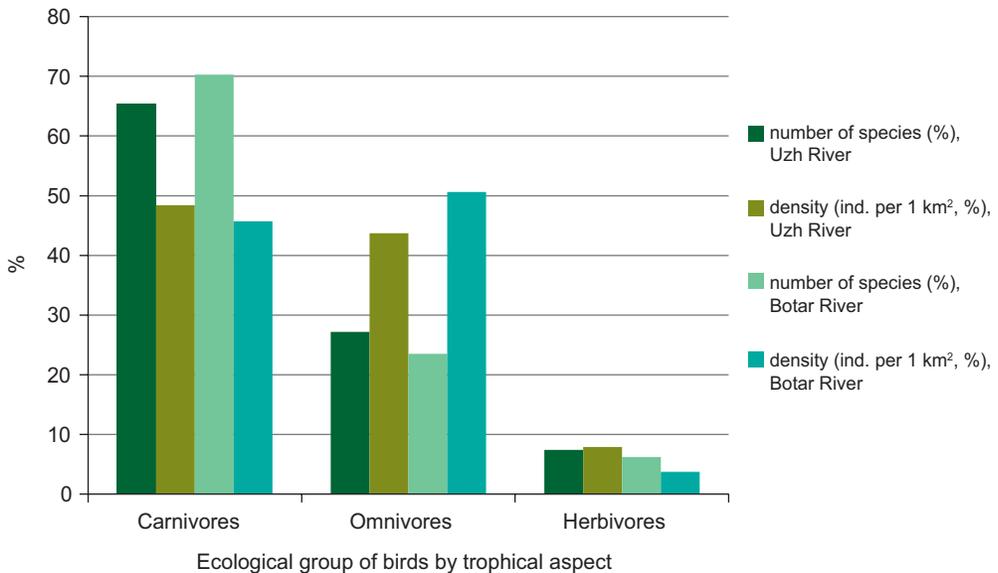
In contrast, the bird community of the Botar River is dominated by ground-nesting species (35.3 %), but the share of tree-nesting (23.5 %) and shrub-nesting birds (19.1 %) is also relatively high. In terms of population density, the group of hollow-nesting species predominates (34.1 %) owing to the common starling *Sturnus vulgaris* and the Eurasian tree sparrow *Passer montanus*, which nest in high numbers on old black poplars along the dykes and forage on adjacent fields. The sub-dominants are the ground-nesting species (31.4 %). These two groups are the most represented in the bird community of the Botar River (65.5 %).

In terms of trophic specialisation, the bird community of the Uzh River is dominated by carnivores in both the number (65.4 %) and density of species (48.4 %). Omnivores come second by both parameters (27.2 % and 43.7 %, respectively), whereas the group of herbivores is the least represented in the community (7.4 % and 7.9 %, respectively).



**Fig. 5.** The proportion of various nesting groups in the bird communities of the Uzh and Botar rivers by the numbers and relative densities of species, % (note: differences between ecological groups of birds, marked with asterisks, on the mountain and plain rivers are significant at  $p < 0.05$ )

A somewhat different distribution characterises the bird community of the Botar River (**Fig. 6**): carnivores notably predominate by the number of species (70.3 %), although omnivores predominate by densities (50.6 %). Herbivores are even less represented than in the bird community of the Uzh (6.2 % and 3.7 %, respectively).



**Fig. 6.** The proportion of different trophic groups in the bird communities of the Uzh and Botar rivers by numbers and relative densities of species, %

Comparison of the quantitative and qualitative characteristics of the species composition of the bird communities of both rivers by landscape, nesting and trophic aspects, has revealed that in the Uzh River, forest-dwelling carnivores that nest in hollows and

tree crowns play an important functional role in energy distribution. The chi-square test confirmed the obvious association between habitat conditions within the studied river ecosystems and the species representation of cavity-nesting birds. This can be explained by the large amount of dead wood in the floodplain forest along the Uzh River. Dead wood is a determining factor in the diversity of cavity-nesting species in the bird community of the Uzh River. The difference in the distribution of species of other ecological groups in the bird communities of both rivers is insignificant. However, the slightly higher proportion of herbivores, compared to the bird community of the Botar River, can be explained by the high population densities of urban species that nest on anthropogenic substrates. These birds also compensate the diversity losses of wetland and forest-steppe species, which have gradually disappeared from the Uzh valley due to environmental changes leading to more arid conditions. These changes have resulted from the construction of hydrotechnical structures on the river for the regulation of the waterflow, and the damming of the floodplain to protect the growing human settlements from floods.

The ground-nesting carnivores and omnivores of the Botar River are mainly represented by wetland bird species that play an important functional role in the community and the ecosystem by distributing the flow of energy across the food webs. The species diversity of this ecological group that has been lost or has declined in this area as a result of the drainage of wet floodplain meadows and forests by the irrigation system has been compensated by forest-steppe species. The newly created agricultural landscapes with their rich feeding sources and mosaic structure – arable lands, pastures, shrubberies, and sparse orchards – have become optimal habitats for the forest-steppe species.

## CONCLUSION

The analysis of the structural and functional characteristics of bird communities of a montane and lowland river ecosystem of Zakarpattia, which underwent different degrees of anthropogenic transformation, illustrates the main differences between these ecosystems. Anthropogenic impacts related to the drainage and loss of much of the natural floodplains of both rivers led to losses in species diversity of wetland birds, which were compensated differently. In the middle course of the Uzh River, the lost diversity of wetland species was compensated by forest-dwelling, hollow-nesting carnivores and synanthropic urban species, whereas in the lowland section of the Botar River, these were mainly forest-steppe, tree- and shrub-nesting carnivores.

The difference in the environmental conditions of mountain and lowland rivers is significant for wetland bird groups. For the Uzh and Botar rivers, we also found an association between habitat and cavity-nesting bird species. For other ecological groups, this difference is insignificant.

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## COMPLIANCE WITH ETHICAL STANDARDS

**Conflict of Interests:** the author declares that the research was carried out without having any commercial or financial relationships from which potential conflicts of interest could arise.

**Animal Rights:** no manipulations have been performed on living animals in the course of the study.

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## БІОРИЗНОМАНІТТЯ Й ОСОБЛИВОСТІ СТРУКТУРНО-ФУНКЦІОНАЛЬНИХ ХАРАКТЕРИСТИК УГРУПОВАНЬ ПТАХІВ РІЧОК ПЕРЕДГІР'Я ТА РІВНИННОГО ЗАКАРПАТТЯ У ГНІЗДОВИЙ ПЕРІОД

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**Вступ.** Видове і таксономічне різноманіття біотичних угруповань перебувають у прямій залежності від змін середовища існування. Чим різноманітніша екосистема за біотичними й абіотичними компонентами, тим складнішою є її функціональна структура та взаємозв'язки між видами і середовищем існування. Відновлення видового й таксономічного різноманіття екосистем, які зазнали антропогенного впливу різної інтенсивності, відбувається за різними сценаріями. Це проілюстровано на прикладі дослідження структурно-функціональних характеристик угруповань птахів гірської та рівнинної річкових екосистем у Закарпатті. Ключовими у цих угрупованнях птахів є водно-болотна екологічна група, яку проаналізовано за кількістю видів, подано чисельне представлення кожного виду та зміни у видовому складі, які відбулись упродовж останніх 100 років.

**Матеріали і методи.** Досліджено структурно-функціональні характеристики угруповань птахів середньої течії гірської р. Уж упродовж 1994–2002 та 2016–2020 років і рівнинної р. Ботар упродовж 2014–2015 років у гніздовий період (10 квітня – 30 червня). Обліки птахів вели маршрутним методом. Ширина облікової смуги становила 100 м (по 50 м з обох боків маршруту). Обстежено 13 км середньої течії р. Уж на 2-х різних за структурою середовища ділянках: 7 км природної ділянки річки та 6 км урбанізованої ділянки річки. Також обстежено 17 км рівнинної частини р. Ботар включно з каналізованою частиною русла і русловими ставками та 6 км збереженого природного русла і заплави. Всього пройдено маршрутами 308 км. Для статистичного аналізу даних, отриманих у результаті досліджень птахів на річках Уж і Ботар, застосовано критерій узгодженості Пірсона. Обчислення проводили за допомогою програми Microsoft Excel.

**Результати.** У результаті досліджень у гніздовий період нами виявлено 81 вид птахів (65 родів, 35 родин та 14 рядів) у долині середньої течії р. Уж та 81 вид птахів (58 родів, 33 родини та 15 рядів) на території рівнинної частини р. Ботар. Структурно-функціональні характеристики угруповань птахів обох річок відображено щільністю населення, представленістю в угрупованні кожного виду (численністю), характером включеності кожного виду в угруповання (осілий вид чи залітний), комбінацією екологічних груп, трофічною та просторовою структурою. Усі ці параметри залежать від різноманіття оселищ річкових екосистем і характеризують

емність середовища. За екологічними групами в угрупованні птахів середньої течії р. Уж домінують лісові види як за кількістю видів (45,7 %), так і за щільністю особин на 1 км<sup>2</sup> (52,6 %). За видовим складом тут також добре представлені водно-болотні (17,3 %) та лісостепові види птахів (18,5 %). За щільністю населення разом з лісовими видами найкраще представлені види антропогенних ландшафтів (21,7 %). В угрупованні птахів рівнинної частини р. Ботар за кількістю видів домінують лісові та водно-болотні види (32 % та 29,6 % відповідно). За щільністю населення тут домінантами є лісостепові види (32,6 %), частка лісових і водно-болотних видів менша (27 % і 18,6 %). Найменш представленими за обома параметрами є птахи антропогенних ландшафтів (6,2 % і 7,6 %). Незважаючи на кардинальну трансформацію р. Ботар у ХХ ст., пов'язану зі створенням системи іригації, водно-болотні види птахів, порівняно з р. Уж, тут займають вагому частку і за кількістю видів, і за щільністю населення. Це пов'язано з особливостями структури річкових оселищ і екологічних ніш гірської та рівнинної річкових екосистем. Різниця умов існування на гірській річці Уж та на рівнинній річці Ботар для водно-болотних видів птахів є значущою ( $\chi^2 = 5,2$ ;  $p < 0,05$ ).

За просторовим аспектом домінуючою групою птахів в угрупованні середньої течії р. Уж за видовим складом є дуплогнізні види (26,5 %), субдомінують кронагнізні та наземногнізні види (по 23,5 % відповідно). За щільністю населення домінують ті ж дуплогнізні види (32,1 %), субдомінують види, які гніздяться на антропогенному субстраті (21,8 %). В угрупованні птахів рівнинної частини р. Ботар за видовим складом домінують наземногнізні види (35,3 %). Значну частку займають також кронагнізні (23,5 %) та чагарникові (19,1 %). За щільністю населення домінантами є дуплогнізні (34,1 %), а субдомінантами – наземногнізні види (31,4 %).

За трофічною спеціалізацією в угрупованні птахів р. Уж домінують зоофаги і за видовим складом (65,4 %), і за щільністю населення (48,4 %). В угрупованні птахів р. Ботар зоофаги суттєво домінують за видовим складом (70,3 %), однак за щільністю населення домінують поліфаги (50,6 %). Наземногнізні зоофаги та поліфаги становлять значну частку водно-болотних видів птахів, функціональна роль яких у цьому угрупованні є помітною. В угрупованні птахів середньої течії р. Уж домінують дуплогнізні зоофаги, які є лісовими видами. Ці види населяють смугу прирічкових вербово-тополевих лісів.

**Висновки.** Аналіз структурно-функціональних характеристик угруповань птахів гірської та рівнинної річкових екосистем Закарпаття, які у ХХ ст. зазнали антропогенної трансформації різного ступеня, ілюструє основні відмінності між цими екосистемами. Антропогенні впливи, пов'язані з осушенням і втратою більшої частини природної заплави обох річок, призвели до втрат видового різноманіття водно-болотної групи видів птахів в угрупованнях. Однак компенсація втраченого різноманіття видів птахів обох річок відбулася за різними сценаріями. Відмінності сценаріїв полягають в умовах існування видів птахів, емності середовища та попередній історії формування видового різноманіття.

**Ключові слова:** біорізноманіття, рівнинна і гірська річка, структурно-функціональні характеристики, угруповання птахів