



A hemeroby gradient reveals the structure of bird communities in urban parks

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The spatial structure and composition of urban parks play a crucial role in shaping bird communities by determining the availability and quality of suitable sites for nesting, feeding, and shelter. In this study, we investigated bird communities inhabiting urban parks and squares in Dnipro, Ukraine, during the breeding seasons of 2022–2024. Using transect counts, information-logical data analysis, and ecological data classification methods, we analyzed bird species composition and their substrate preferences to identify ecological clusters. Based on substrate preferences and ecological adaptations, we identified 12 distinct clusters, some of which reflect different levels of hemeroby – the degree of anthropogenic impact on ecosystems. Species such as the lesser whitethroat (*Sylvia curruca*), tree pipit (*Anthus trivialis*), icterine warbler (*Hippolais icterina*), and common cuckoo (*Cuculus canorus*) were rarely found in urban parks due to specific habitat requirements, indicating areas of low hemeroby. Conversely, species like the woodpigeon (*Columba palumbus*), common starling (*Sturnus vulgaris*), collared flycatcher (*Ficedula albicollis*), and fieldfare (*Turdus pilaris*) were more prevalent, suggesting areas with moderate to high levels of hemeroby. Moreover, we identified bird species that exhibit remarkable adaptability, thriving both in urban park areas and natural habitats. These include the great tit (*Parus major*), hooded crow (*Corvus cornix*), and chaffinch (*Fringilla coelebs*). Their widespread presence across diverse environments underscores their ecological versatility and importance in both urban and natural ecosystems. The widespread presence of species such as the tree sparrow (*Passer montanus*) indicates significant ecological transformation within these urban parks. These findings emphasize the importance of specific habitat features in supporting diverse bird communities and reveal varying degrees of species sensitivity to urbanization. The presence of these species in park bird communities allows one to assess the level of anthropogenic landscape transformation and can be used for monitoring the ecological state of urban areas. The results underscore the critical importance of conserving and restoring diverse habitats in urban parks and squares, which will support a wide range of bird species, including those adapted to urban environments and those more sensitive to changes.

Keywords: bird distribution; avian communities; species diversity; anthropogenic impact; urban ecosystems; indicator species.

Introduction

In urban areas, parks provide a favorable habitat for various species, including birds, to live and reproduce. Research on bird communities in parks is crucial for biodiversity conservation, understanding ecological interactions between species, and maintaining natural environments within urban landscapes (Fernández-Juricic & Jokimäki, 2001). The spatial structure and composition of parks significantly influence bird communities. Studies have shown that areas with diverse landscapes, such as tree stands, ponds, and lawns, attract more bird species (Zymarioeva et al., 2022). Moreover, a park's size and geographical location determine birds' spatial distribution within urban environments and play an important role in bird migration. Parks in different cities have been studied for bird species diversity. Urban parks have been found to serve as corridors for both migratory and resident bird communities (Shochat et al., 2006). Studies on the diversity and abundance of birds in urban parks have shown that many species are well-adapted to the urban environment (Dubovyk et al., 2020). Complex ecological and nesting patterns that ensure birds' adaptation to the urban environment have also been revealed in studies of the interactions between different bird species in parks (Chamberlain et al., 2019; Robinson et al., 2021).

Species can be divided into two groups based on the nature of their adaptation. Generalists have diverse food and shelter needs and can adapt to various conditions. Specialists have narrow ecological requirements, which limits their adaptability. Specialist species often respond differently to anthropogenic impacts than generalists. Generalists tend to better tolerate environmental changes caused by human activities. Due to their flexi-

bility, generalists can quickly adapt to new, altered environments, making them more resilient to human impacts. In contrast, specialized species are more vulnerable to such changes (Julliard et al., 2008; Reif et al., 2013). Specialized species are heavily dependent on specific resources, particular plant species, or specific environmental conditions (Zymarioeva et al., 2022). These resources may be destroyed or significantly altered by anthropogenic activities such as urbanization, pollution, or climate change. The loss of such key habitat elements often leads to the decline or even extinction of specialized species (Katayama et al., 2014).

Hemeroby focuses on measuring the degree of anthropogenic impact on ecosystems. It reflects the degree of disturbance and change in the landscape resulting from human activity (Kunakh et al., 2024). It is an approach that helps us to understand the extent to which ecosystems have been altered by urbanization, industrialization, and other types of anthropogenic impacts (Winter, 2012; Walz & Stein, 2014). It also differentiates altered ecosystems from natural landscapes, which are characterized by high levels of naturalness and biodiversity. Indicators of anthropogenic impacts include changes in species composition, such as the emergence of invasive species and the decline or extinction of native species (Kunakh et al., 2024). Thus, hemeroby serves as a tool for quantifying changes in ecosystems. Hemeroby helps to identify key species and ecological processes that are most affected by human activities (Fanelli et al., 2006).

An analysis of the impact of the urban environment on bird communities shows that landscape change and transformation, air pollution, and noise have an impact on their ability to survive and breed. The activity of bird communities is also affected by anthropogenic factors, such as noise, air pollution, and human presence (Koshelev et al., 2021). Some species

can adapt to urban environments and coexist effectively. Other birds avoid these areas, opting for more natural habitats away from human settlements (McKinney, 2006).

Material and methods

The study area encompasses the largest parks and squares in Dnipro. The foundation of this work is based on data collected during field research conducted in the breeding seasons of 2022–2024. Bird surveys were carried out in the early morning hours, from 6:00 to 11:00, during the months of April to July each year. To achieve maximum effectiveness, the surveys were conducted in clear, calm weather conditions, when bird activity peaked. The presence and activity of birds in the surveyed areas were recorded both visually and acoustically.

The transect survey method was chosen to study the ornithofauna of parks and squares in the city of Dnipro (Bibby et al., 1998). The primary reason for selecting this method was its ability to cover the maximum area of the territories and account for all bird species inhabiting the surveyed plots within a relatively short period. This was crucial, as the research aimed to create a comprehensive species list and examine the structure of the ornithofauna in the surveyed areas. The transect survey method is ide-

ally suited for recording more mobile and conspicuous bird species, as well as those that can be easily startled by the observer. The method involves the continuous movement of the observer along a selected route, recording all bird species encountered along the way. The observer moves at a consistent speed, registering birds on both sides of the route. The usual pace of movement is 0.75–1.00 km/hour. To reduce the likelihood of double-counting the same bird, surveys were conducted with an interval of 40–50 meters. This distance was chosen considering that most birds during the breeding season tend to stay within their nesting territories, which provide protection for offspring and facilitate effective feeding. For small birds, which dominate the studied ornithofauna, the nesting territory typically ranges from 30 to 70 meters in diameter, depending on the species, habitat, population density, and other ecological factors.

During observations, the following parameters were recorded: bird species, type of tree or shrub where the bird was observed, height and age condition of the stand, substrate where bird activity was noted, height of bird location, presence of shrubs, their species composition and height, presence of herbaceous cover and its height, as well as the geographical coordinates of the registration point. In total, data were collected on 4621 bird records, covering 25 parks, squares, and forest areas within the city of Dnipro (Fig. 1).

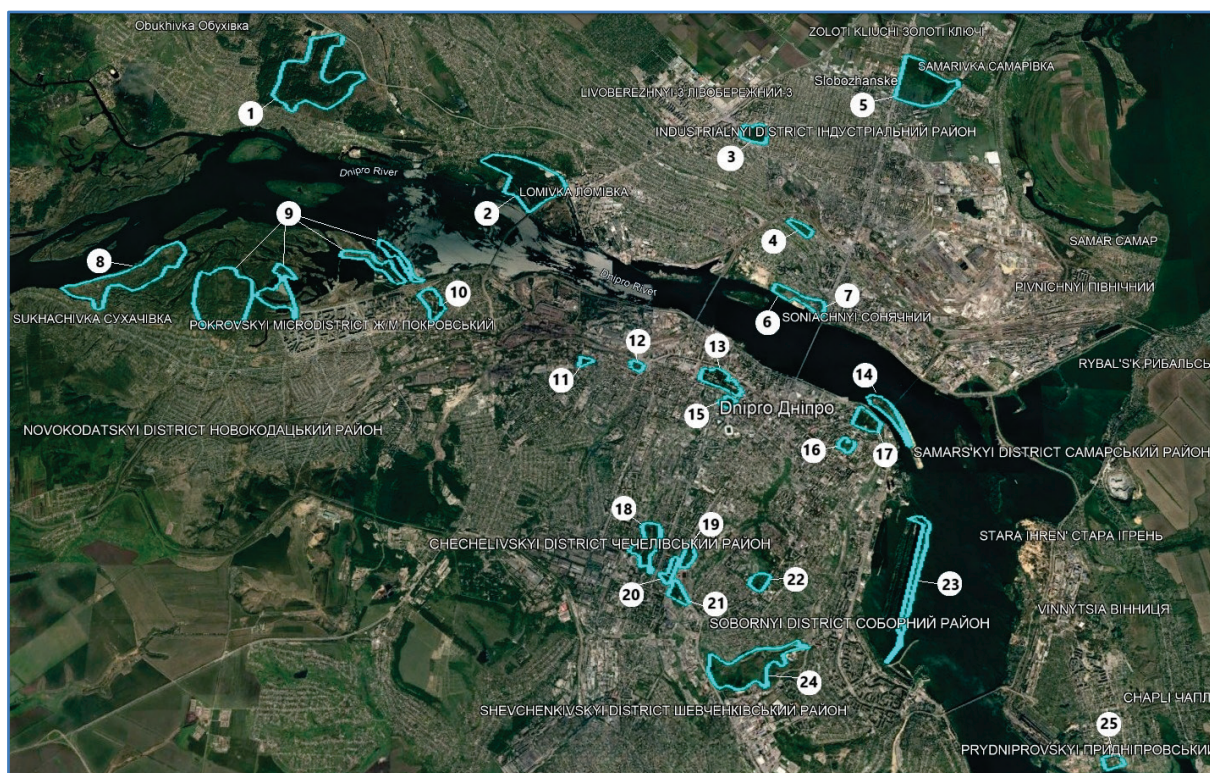


Fig. 1. Map of the surveyed areas in the city of Dnipro (2022–2024): 1 – Obukhiv Forest Park, 2 – Frunzenskyi Forest Park, 3 – Civil Cemetery, 4 – Kyrylivka Park, 5 – Forest Park of Friendship of Peoples, 6 – Park Sahaydak, 7 – Manuylyv's'kyi Park, 8 – Sukhachivskyi Forest Park, 9 – Diiivski Plavni, 10 – Urban Youth Park recreation and leisure "Novokodatskyi," 11 – The Square of Metalurhiv, 12 – Park Pamiati ta Prymyrennia, 13 – Lazar Globa Park, 14 – Monastyrskyi Island, 15 – Heroiv Garden Square, 16 – Soborna Square, 17 – Taras Shevchenko Central Park of Culture and Rest, 18 – Green Grove Park, 19 – Bohdan Khmelnytsky Park, 20 – Park Pysarzhevskoho, 21 – Park 40-Richchya Vyzvolennya Dnipra, 22 – Yuriy Gagarin Park, 23 – Mandrykivska Spit, 24 – Tonel'na Balka Tract, 25 – Park of Culture and Rest "Prydniprovskyi"

The total length of the survey routes was 124.76 km (Table 1). The area surveyed during the breeding seasons of 2022–2024 covered 1203.45 hectares. Table 1 presents the data on the actual surveyed areas for each site. The territories of small parks and squares, such as Kyrylivka Park, Lazar Globa Park, The Square of Metalurhiv, and others, were surveyed in their entirety. In contrast, the investigation of larger parks, which occupy extensive areas and gradually transition into transformed natural forests along the Dnipro River valley – such as Diiivski Plavni, Obukhiv Forest Park, and Frunzenskyi Forest Park – was limited to areas located closer to the city.

To process the material in this study, methods of information-logical data analysis were used, along with the TWINSpan (two-way indicator

species analysis) classification method for ecological data (Vermeersch et al., 2003). This method was applied to identify natural species groupings based on their distribution across habitats (Vermeersch et al., 2003). During the analysis, the entire data matrix was divided according to two main parameters, considering species similarity in their ecological preferences, made possible through the use of cluster analysis. TWINSpan was chosen to investigate the substrate preferences of various bird species for several reasons. Firstly, this method allows for the objective grouping of species based on their substrate preferences, significantly enhancing the accuracy of the analysis (Esmailzadeh et al., 2016). Secondly, TWINSpan aids in identifying natural species groupings, which is crucial for understanding ecological interactions and the specific environmental re-

quirements of birds (Roleček et al., 2009). Two-way indicator species analysis is a technique for hierarchical divisive classification of communities. It is based on the progressive refinement of a single ordination axis obtained by correspondence analysis (CA) or detrended correspondence analysis (DCA) of a community composition (site species) data matrix (Hill, 1979). The algorithm, which is relatively intricate, is elucidated in detail by Kent & Coker (1992). One particularly appealing aspect of the computer

output is a two-way table in which the sites are arranged following the divisions of the hierarchical classification. The species (rows) are also sorted in a manner that forms blocks corresponding to the groups of sites within the classification. The body of the table contains the highest pseudospecies scores observed at the sites. An additional feature of TWINSPLAN is that it computes an indicator values index for each species at every split of the hierarchical classification of the sites (Legendre, 2013).

Table 1
Characteristics of the surveyed parks and squares in the city of Dnipro (2022–2024)

No.	Parks and squares	Dates of research	Area of surveyed territory, ha	Route length, km	Number of records	Number of bird species
1	Obukhiv Forest Park	02.06.2024 – 09.06.2024	183.00	9.60	77	20
2	Frunzenskyi Forest Park	18.05.2024 – 19.05.2024	126.00	5.90	181	35
3	Civil Cemetery	30.05.2024	22.30	3.00	177	19
4	Kyrylivka Park	06.05.2024	9.49	2.15	148	24
5	Forest Park of Friendship of Peoples	04.05.2024 – 01.06.2024	104.00	10.20	139	20
6	Park Sahaydak	24.04.2024 – 28.04.2024	16.78	1.39	175	21
7	Manuylivs'kyi Park	24.04.2024 – 28.04.2024	8.72	0.61	139	15
8	Sukhachivskyi Forest Park	23.05.2024 – 26.05.2024	196.00	7.50	207	36
9	Diiivski Plavni	29.05.2024 – 25.06.2024	226.50	19.40	344	39
10	Urban Youth Park Recreation and Leisure "Novokodatskyi"	11.05.2024	22.40	3.20	190	17
11	The Square of Metalurhiv	13.05.2023	4.00	1.14	84	14
12	Park Pamiati ta Prymyrennia	18.06.2023	4.72	1.73	112	15
13	Lazar Globa Park	21.05.2023	26.20	4.81	412	22
14	Monastyrskyi Island	14.05.2023 – 25.06.2023	22.90	4.22	176	30
15	Heroiv Garden Square	21.05.2023	5.81	1.35	42	8
16	Soboma Square	20.05.2024	7.37	1.80	194	12
17	Taras Shevchenko Central Park of Culture and Rest	02.05.2022 – 16.07.2022	19.40	5.98	322	21
18	Green Grove Park	30.04.2022 – 30.05.2022	31.40	7.39	247	26
19	Bohdan Khmelnytskyi Park	04.06.2023	9.54	3.57	129	13
20	Park Pysarzhevskoho	04.06.2023	8.13	2.10	174	14
21	Park 40-Richchya Vyzvolennya Dnipra	07.05.2023	10.70	2.44	106	14
22	Yuriy Gagarin Park	26.05.2022 – 28.05.2022, 06.05.2023	10.50	3.10	227	25
23	Mandrykivska Spit	12.05.2024	36.10	6.80	203	22
24	Tonel'na Balka Tract	20.05.2023 – 11.06.2023	82.70	13.50	288	30
25	Park of Culture and Rest "Prydniprovskyi"	10.06.2023	8.79	1.88	128	24
Total			1203.45	124.76	4621	–

The data matrix used in this research is based on bird species recorded during the breeding seasons of 2022–2024 and the number of occurrences on each of the substrates where they were observed. The substrates include trees, shrubs, soil, water, coastal areas, anthropogenic structures, and airspace. Tree and shrub species were grouped at the genus level during the analysis. A five-point scale, based on cut levels, was used in the study to assess the significance of substrates for the species. Level 1 (0 records) indicates that the substrate is either not used by the species or is used so rarely that it was not detected during the study. This level reflects a minimal or non-existent significance of the substrate for the species. Level 2 (1–2 records) denotes low frequency or significance, being less common for the species. Level 3 (3–5 records) corresponds to medium frequency or importance, where the substrate is quite common but not dominant for the species. Level 4 (6–10 records) indicates high frequency or importance, being one of the main substrates for the species. Level 5 (>11 records) means the substrate is dominant, most frequently encountered, and is key for characterizing the species.

Results

In the parks and squares of Dnipro, 66 bird species belonging to 33 families and 17 orders were recorded (Table 2). The largest group was Passeriformes, with 38 species, representing 57.7% of the total number of bird species. This order includes families such as Muscicapidae (11 species), Corvidae (6 species), Fringillidae (4 species), Sylviidae (4 species), along with other families with fewer species. Passeriformes species were present in all the surveyed parks and squares, demonstrating broad ecological plasticity and a variety of habitats. The second most numerous order was Piciformes, comprising 6 species (9.1%). These species belong to the family Picidae and are associated with the forest complex. Charadriiformes accounted for 6.1% of the total number of species and were represented

by four species. Species of this order belong to the wetland ecological complex. Columbiformes were represented by three species, making up 4.5% of the total number of species. The most numerous among them was *Columba livia* (740 records), a representative of the synanthropic ecological complex. Gruiformes were represented by two species, accounting for 3.0% of the total number of species. The order Pelecaniformes was represented by two species, accounting for 3.0% of the total number of species. One species, *Anas platyrhynchos*, represented Anseriformes, accounting for 1.5% of the total. Gruiformes, Pelecaniformes, and Anseriformes were classified as part of the wetland ecological complex. Accipitriformes, Apodiformes, Bucerotiformes, Coraciiformes, Cuculiformes, Falconiformes, Galliformes, Podicipediformes, Strigiformes, and Suliformes were also each represented by one species, accounting for 1.5% of the total number of species for each order. Species from these orders were associated with various ecological complexes, such as woodland edges, forested areas, or wetlands.

The forest bird complex is the most numerous, comprising 24 species (Table 3), accounting for 36.4% of the total species. Their habitats were areas with forest vegetation in parks and forest parks, such as Tonel'na Balka Tract, Diiivski Plavni, Frunzenskyi Forest Park, Yuriy Gagarin Park, Green Grove Park, and Taras Shevchenko Central Park of Culture and Rest. The woodland edge complex, which included 19 species (28.8%), was represented by orders such as Columbiformes, Cuculiformes, Falconiformes, Galliformes, and some representatives of the order Passeriformes. The wetland complex, comprising 14 species from the orders Anseriformes, Gruiformes, Pelecaniformes, and Charadriiformes, accounted for 21.2%. The synanthropic complex was mainly represented by Passeriformes and Apodiformes and included 7 species, making up 10.6% of the total number of species. The meadow and steppe complexes were the least numerous, with each containing only one species, accounting for 1.5% of the total for each complex (Table 3).

Table 2

Species composition of birds in the parks and squares of Dnipro during the breeding seasons of 2022–2024 along a 124.76 km route (1203.45 ha study area)

Order	Family	Species	English name of birds	Ecological complex	Number of bird records
Accipitriformes	Accipitridae	<i>Circus cyaneus</i> (Linnaeus, 1766)	hen harrier	steppe complex	1
Anseriformes	Anatidae	<i>Anas platyrhynchos</i> Linnaeus, 1758	mallard	wetland complex	90
Apodiformes	Apodidae	<i>Apus apus</i> Linnaeus, 1758	swift	synanthropic complex	28
Bucerotiformes	Upupidae	<i>Upupa epops</i> (Linnaeus, 1758)	hoopoe	forest edge complex	21
Charadriiformes	Charadriidae	<i>Charadrius dubius</i> Scopoli, 1786	little ringed plover	wetland complex	4
Charadriiformes	Laridae	<i>Larus ridibundus</i> (Linnaeus, 1766)	black-headed gull	wetland complex	12
Charadriiformes	Laridae	<i>L. cachinnans</i> Pallas, 1811	yellow-legged gull	wetland complex	19
Charadriiformes	Laridae	<i>Sterna hirundo</i> Linnaeus, 1758	common tern	wetland complex	9
Columbiformes	Columbidae	<i>Streptopelia decaocto</i> (Frivaldszky, 1838)	collared dove	forest edge complex	38
Columbiformes	Columbidae	<i>Columba livia</i> Gmelin, 1789	rock dove	synanthropic complex	740
Columbiformes	Columbidae	<i>C. palumbus</i> Linnaeus, 1758	woodpigeon	forest edge complex	54
Coraciiformes	Alcedinidae	<i>Alcedo atthis</i> (Linnaeus, 1758)	common kingfisher	wetland complex	5
Cuculiformes	Cuculidae	<i>Cuculus canorus</i> Linnaeus, 1758	cuckoo	forest edge complex	11
Falconiformes	Falconidae	<i>Falco tinnunculus</i> Linnaeus, 1758	common kestrel	forest edge complex	7
Galliformes	Phasianidae	<i>Phasianus colchicus</i> Linnaeus, 1758	pheasant	forest edge complex	11
Gruiformes	Rallidae	<i>Gallinula chloropus</i> (Linnaeus, 1758)	common moorhen	wetland complex	1
Gruiformes	Rallidae	<i>Fulica atra</i> Linnaeus, 1758	coot	wetland complex	39
Passeriformes	Acrocephalidae	<i>Acrocephalus arundinaceus</i> (Linnaeus, 1758)	great reed warbler	wetland complex	9
Passeriformes	Acrocephalidae	<i>Hippolais icterina</i> (Vieillot, 1817)	icterine warbler	forest complex	1
Passeriformes	Corvidae	<i>Corvus corax</i> Linnaeus, 1758	raven	forest edge complex	13
Passeriformes	Corvidae	<i>C. cornix</i> Linnaeus, 1758	hooded crow	forest edge complex	156
Passeriformes	Corvidae	<i>C. monedula</i> Linnaeus, 1758	jackdaw	forest edge complex	1
Passeriformes	Corvidae	<i>Garrulus glandarius</i> (Linnaeus, 1758)	Eurasian jay	forest complex	61
Passeriformes	Corvidae	<i>Pica pica</i> Linnaeus, 1758	magpie	forest edge complex	109
Passeriformes	Emberizidae	<i>Emberiza citrinella</i> Linnaeus, 1758	yellowhammer	forest edge complex	12
Passeriformes	Fringillidae	<i>Carduelis carduelis</i> (Linnaeus, 1758)	European goldfinch	forest edge complex	19
Passeriformes	Fringillidae	<i>Chloris chloris</i> Linnaeus, 1758	greenfinch	forest complex	105
Passeriformes	Fringillidae	<i>Fringilla coelebs</i> (Linnaeus, 1758)	chaffinch	forest complex	147
Passeriformes	Hirundinidae	<i>Delichon urbica</i> (Linnaeus, 1758)	house martin	synanthropic complex	65
Passeriformes	Hirundinidae	<i>Hirundo rustica</i> (Linnaeus, 1758)	swallow	synanthropic complex	29
Passeriformes	Laniidae	<i>Lanius collurio</i> Linnaeus, 1758	red-backed shrike	forest edge complex	29
Passeriformes	Motacillidae	<i>Anthus trivialis</i> (Linnaeus, 1758)	tree pipit	forest edge complex	6
Passeriformes	Motacillidae	<i>Motacilla alba</i> (Linnaeus, 1758)	pieb wagtail	meadow complex	57
Passeriformes	Muscicapidae	<i>Erithacus rubecula</i> (Linnaeus, 1758)	european robin	forest complex	11
Passeriformes	Muscicapidae	<i>Ficedula albicollis</i> (Temminck, 1815)	collared flycatcher	forest complex	185
Passeriformes	Muscicapidae	<i>Luscinia luscinia</i> (Linnaeus, 1758)	thrush nightingale	forest complex	28
Passeriformes	Muscicapidae	<i>Muscicapa striata</i> (Pallas, 1764)	spotted flycatcher	forest edge complex	46
Passeriformes	Muscicapidae	<i>Phoenicurus ochruros</i> (S. G. Gmelin, 1774)	black redstart	synanthropic complex	54
Passeriformes	Muscicapidae	<i>P. phoenicurus</i> (Linnaeus, 1758)	common redstart	synanthropic complex	2
Passeriformes	Oriolidae	<i>Oriolus oriolus</i> Linnaeus, 1758	Eurasian golden oriole	forest complex	36
Passeriformes	Paridae	<i>Cyanistes caeruleus</i> (Linnaeus, 1758)	blue tit	forest complex	10
Passeriformes	Paridae	<i>Parus major</i> Linnaeus, 1758	great tit	forest complex	471
Passeriformes	Passeridae	<i>Passer domesticus</i> (Linnaeus, 1758)	house sparrow	synanthropic complex	44
Passeriformes	Passeridae	<i>P. montanus</i> (Linnaeus, 1758)	tree sparrow	synanthropic complex	546
Passeriformes	Phylloscopidae	<i>Phylloscopus collybita</i> (Vieillot, 1817)	chiffchaff	forest complex	44
Passeriformes	Phylloscopidae	<i>P. sibilatrix</i> (Bechstein, 1793)	wood warbler	forest complex	6
Passeriformes	Remizidae	<i>Remiz pendulinus</i> (Linnaeus, 1758)	penduline tit	wetland complex	15
Passeriformes	Stumidae	<i>Sturnus vulgaris</i> Linnaeus, 1758	starling	forest complex	634
Passeriformes	Sylviidae	<i>Sylvia atricapilla</i> (Linnaeus, 1758)	Eurasian blackcap	forest edge complex	27
Passeriformes	Sylviidae	<i>S. borin</i> (Lichtenstein, 1823)	garden warbler	forest edge complex	2
Passeriformes	Sylviidae	<i>S. communis</i> Latham, 1787	whitethroat	forest edge complex	8
Passeriformes	Sylviidae	<i>S. curruca</i> (Linnaeus, 1758)	lesser whitethroat	forest edge complex	2
Passeriformes	Turdidae	<i>Turdus merula</i> Linnaeus, 1758	common blackbird	forest complex	1
Passeriformes	Turdidae	<i>T. philomelos</i> C. L. Brehm, 1831	song thrush	forest complex	16
Passeriformes	Turdidae	<i>T. pilaris</i> Linnaeus, 1758	fieldfare	forest complex	294
Pelecaniformes	Ardeidae	<i>Ardea cinerea</i> Linnaeus, 1758	grey heron	wetland complex	9
Pelecaniformes	Ardeidae	<i>Nycticorax nycticorax</i> (Linnaeus, 1758)	night heron	wetland complex	4
Piciformes	Picidae	<i>Picus canus</i> (Gmelin, 1788)	grey-headed woodpecker	forest complex	21
Piciformes	Picidae	<i>Dendrocopos major</i> (Linnaeus, 1758)	great spotted woodpecker	forest complex	53
Piciformes	Picidae	<i>D. minor</i> (Linnaeus, 1758)	lesser spotted woodpecker	forest complex	1
Piciformes	Picidae	<i>D. medius</i> (Linnaeus, 1758)	middle spotted woodpecker	forest complex	4
Piciformes	Picidae	<i>D. syriacus</i> (Hemprich & Ehrenberg, 1833)	syrian woodpecker	forest complex	50
Piciformes	Picidae	<i>Jynx torquilla</i> (Linnaeus, 1758)	wryneck	forest complex	4
Podicipediformes	Podicipedidae	<i>Podiceps cristatus</i> (Linnaeus, 1758)	great crested grebe	wetland complex	41
Strigiformes	Strigidae	<i>Asio otus</i> (Linnaeus, 1758)	long-eared owl	forest complex	5
Suliformes	Phalacrocoracidae	<i>Phalacrocorax carbo</i> (Linnaeus, 1758)	great cormorant	wetland complex	38
Total					4621

Note: the bird species names are provided according to the guide "Birds of the Fauna of Ukraine" (Fesenko & Bokotey, 2002).

Based on the analysis of the data obtained during field research and their subsequent analysis, the recorded bird species were grouped into 12 clusters according to their substrate preferences (Table 4).

The obtained results revealed significant diversity in the species composition of the avifauna in urban parks and squares during the breeding season. The identified bird clusters reflected species preferences for vari-

ous substrate types, allowing for a clear identification of specific habitats for each cluster. Bird species were grouped based on the frequency of substrate usage, such as *Ulmus*, *Pinus*, *Populus*, *Quercus*, various artificial structures, water bodies, and shoreline zones. This grouping made it possible to establish birds' preferences for different substrate types depending on the ecological conditions of the specific environment. For example, so-

Shafaeipour et al., 2024). It is thus a rare inhabitant of urban areas (Müller et al., 2009). The middle spotted woodpecker, like the lesser spotted woodpecker, has a rather narrow ecological niche. This limits its distribution in anthropogenic landscapes. The presence of the species of this cluster may indicate a relatively low level of community transformation and hence a low level of hemeroby in these communities, as in the first cluster. The species in the second cluster can also be considered indicators of hemeroby within the city.

The third cluster includes species that were more abundant in the field surveys and utilized a wider range of substrates for nesting and feeding. This suggests that they are more flexible in their habitat selection in urban environments. The common blackbird (*Turdus merula* L.) prefers dense stands with well-developed undergrowth and dense canopy (Ibáñez-Álamo & Soler, 2010). This species prefers shady forest habitats, where it finds ideal conditions for nesting and feeding. The thrush nightingale (*Luscinia luscinia* L.) has similar ecological preferences to the common blackbird. This species nests in the lower layer of vegetation in the undergrowth. The thrush nightingale has been observed on trees close to shrubs and on young generative trees that form dense undergrowth. The robin (*Erithacus rubecula* L.) is usually found in shrubs near water bodies. It is most common in deciduous forests and mixed forests, especially where there is a dense undergrowth (Johnstone, 1998). The robin prefers areas with adequate vegetation at ground level, which provides cover and nesting sites (Karpíńska et al., 2021). Its presence has also been observed on trees of the genera *Fraxinus*, *Acer*, and *Salix*. These trees scored 4–5 (Table 4). The chiffchaff (*Phylloscopus collybita* Vieill.) is also a forest species. It nests in the lower vegetation layer, on the ground near stumps, ruts, or fallen trees. The chiffchaff needs forests with tall trees and thick undergrowth to thrive. It also needs uneven ground, stumps, and debris. In urban parks, such habitats are rare. The blackcap (*Sylvia atricapilla* L.) prefers areas with open, non-isolated tree cover, characterized by initial fragmentation of the upper layer and the presence of developed undergrowth. The yellowhammer (*Emberiza citrinella* L.) is a species that prefers sunlit forest edges and sparse forests with low grass and shrubs. It prefers open areas with diverse vegetation and low grass (Chaplygina, 2015). The great spotted woodpecker (*Dendrocopos major* L.) was recorded more frequently during the surveys on the outskirts of the city or in habitats that are close to natural conditions. This species likely faces competition from the Syrian woodpecker (*Dendrocopos syriacus* Hempr. & Ehrenb.). This may limit the realization of the great spotted woodpecker's ecological niche in urban areas (Gapanovich et al., 2019; Piacentini & Chiatante, 2022). The great spotted woodpecker can be considered an indicator of a moderate degree of hemeroby. In general, the species of this cluster are more active in urban environments, but each of them is affected by specific limiting factors. Almost all species in this cluster, except the great spotted woodpecker, require dense undergrowth. This bird community mainly includes typical forest dwellers. The yellowhammer is a typical forest edge species.

The fourth group of birds shows a greater diversity of substrates used for nesting and feeding. This indicates their adaptability and ability to exploit different ecological niches. The blue tit (*Cyanistes caeruleus* L.) generally avoids human settlements and is rarely seen in cities. The blue tit has a preference for natural forests and parks, where it finds suitable nesting sites in tree holes (Schlicht & Kempnaers, 2020; Garrido-Bautista et al., 2023). The blue tit is most common in deciduous and mixed forests. These forests are rich in insects, which are the blue tit's main food source. The magpie (*Pica pica* L.) prefers to nest in individual trees in open landscapes, making it less common in urban parks (Šálek et al., 2020). Magpies are most commonly seen in open fields, meadows, pastures, and roadsides. They use both individual trees and groups of trees as nesting sites and vantage points. Magpies often nest in tall trees or on human-made structures such as electricity pylons in urban areas (Xu et al., 2020; Dupak & Telizhenko, 2023). During the surveys, magpies were most commonly recorded on *Ulmus*, *Populus*, *Quercus*, and *Fraxinus* (Table 4). This indicates their ability to effectively use wood of different species for nesting and foraging. This is confirmed by the high scores (4–5 levels) assigned to these substrates (Table 4). The white wagtail (*Motacilla alba* L.) prefers meadows and open areas in the vicinity of water bodies with a sparse shrub cover (Shydlovskyy et al., 2021). It is often found near water bodies

such as rivers, lakes, ponds, and ditches. The white wagtail feeds on a wide variety of insects (Dickinson et al., 2022). In urban areas, it seeks out sparse woodland and forest edges due to the lack of extensive meadows. The house sparrow (*Passer domesticus* L.) is a typical synanthrope, found near human settlements. It is rarely recorded in parks, where it is replaced by the tree sparrow (*Passer montanus* L.). The spotted flycatcher (*Muscicapa striata* Pall.) is slightly less adaptable, preferring high forest edges. The spotted flycatcher is most commonly found in deciduous and mixed woodlands with many old trees and open areas where it can catch flying insects. The activity of the spotted flycatcher has been recorded on trees of the genera *Fraxinus* and *Salix*, which scored 3–5 levels. The species included in this cluster demonstrate greater plasticity in their use of urban areas.

The fifth cluster of birds includes medium-sized species that have larger territorial needs than small passerines. The golden oriole (*Oriolus oriolus* L.) is most common in deciduous or mixed forests, dominated by tall trees with dense crowns. It selects sites with well-developed undergrowth and old trees that provide shelter and nesting sites, exhibiting secretive behavior. The song thrush (*Turdus philomelos* L.) is often found in deciduous and mixed forests with dense undergrowth and old trees (Chaplygina, 2015). It prefers humid forests with well-developed herbaceous cover and dense vegetation, which provide shelter and a rich food base. Similar to the golden oriole, the song thrush is cautious in its behavior and leads a hidden lifestyle, foraging on the forest floor. The greenfinch (*Chloris chloris* L.) is usually found in sparse deciduous or mixed forests, where there is sufficient dense undergrowth and open spaces. It prefers forest edges and clearings with a wide variety of plants to feed on (Hanmer et al., 2022). The greenfinch has adapted well to urban environments, utilizing a variety of habitats. It is often found in parks, squares, and gardens where trees, shrubs, and other plants provide food and nesting sites. Observations showed that these species are dependent on tree species such as *Ulmus*, *Populus*, and *Fraxinus* (Table 4), which received high scores (4–5 levels). This suggests a preference for areas with rich woody vegetation, which offers suitable conditions for nesting and feeding. In both urban and rural environments, Syrian woodpeckers (*Dendrocopos syriacus* Hempr. & Ehrenb.) have adapted well to living in parks (Shupova, 2021), gardens, and even suburban areas. It is often found where there are plenty of trees, especially fruit trees, which serve as a food source (Shafaeipour et al., 2024). It was more frequently observed in central city parks, suggesting competition with the great spotted woodpecker for habitat resources (Stański, 2020). The wryneck (*Jynx torquilla* L.) uses old trees with holes and cracks for nesting and feeding (Yarys, 2021), which are rare in city parks. The presence of such trees is crucial for its survival, as they rely on hollows for nesting. The hoopoe (*Upupa epops* L.) also prefers old hollow trees, posing a challenge for nesting in the city due to the scarcity of these trees (Mouawad et al., 2023). The hoopoe is often found at forest edges, in sparse woodlands where open spaces for foraging and trees for nesting are combined (Listopadsky, 2014). The pheasant (*Phasianus colchicus* L.) prefers the edges of forests (Listopadsky, 2014), where open fields are adjacent to reed beds or habitats with dense bushes and shrubs. The black redstart (*Phoenicurus ochruros* L.) is naturally found in rocky areas and mountains, where it nests in rock crevices or between stones (Martínez & Spek, 2022). However, it has adapted well to living in cities (Shupova, 2021) and villages, often nesting on buildings, old houses, ruins, industrial areas, and other man-made structures that resemble natural rocks. It chooses to nest in abandoned buildings or stone structures that offer hiding places and protection from predators. In the cluster analysis, the black redstart scored highly on anthropogenic substrates and soil (Table 4), highlighting its adaptability to urban environments. The Eurasian jay (*Garrulus glandarius* L.) prefers large areas of broadleaf or mixed woodland. In urban areas, it is often found in parks, squares, and large gardens with an old stock of trees. When vegetation is abundant, it easily adapts to living near human settlements. The birds in this cluster show both a high degree of specialization and flexibility in substrate selection, allowing them to survive and breed in various environments, including urban ones.

The sixth cluster consists of bird species that utilize different types of substrates and actively invade urban environments. In the region, the woodpigeon (*Columba palumbus* L.) is most often found in forest belts (Shupova, 2021) and in light forests, where it builds its nests (Floigl et al.,

2022; Luna et al., 2024). In the urban environment, the woodpigeon is often found in parks, squares, and large gardens, where there are a sufficient number of trees for nesting. In recent years, the species has actively begun exploring park areas, which it previously avoided. This shift is due to the intensive use of chemicals on farmland, which has destroyed almost all biota except for crops. The rock dove (*Columba livia* Gmel.) is most common in urban areas, frequently seen on streets, squares, roofs, windowsills, and entrances. It has adapted very well to the urban environment and often takes up residence in buildings, under bridges, on top of monuments, and other man-made structures. Although not a typical park inhabitant, this species is often found near feeders or in areas with access to food, such as crumbs and leftovers. The common starling (*Sturnus vulgaris* L.) inhabits forest edges and belts (Chaplygina, 2015; Vīgants et al., 2023) where hollow trees or other protected nesting places are available. It shows a high degree of adaptability and uses a wide variety of substrates, including *Juglans*, *Quercus*, *Salix*, and *Acer* (Table 4), which received a high score (4–5 levels). It shows the ability to successfully use a variety of nesting habitats, including urban areas, by nesting in building crevices and specially prepared birdhouses. The collared dove (*Streptopelia decaocto* Friv.) can be found at the edge of woodland and in wooded belts, especially where there are open spaces and protected nesting sites. It often nests in trees, bushes, or artificial structures like lamp posts. It easily adapts to anthropogenic environments (Shupova, 2021). This is especially true if there is access to water and food. HEREThe collared flycatcher (*Ficedula albicollis* Temm.) is naturally found in deciduous and mixed forests, especially those containing old trees. It prefers forests with many hollows for nesting and often lives on forest edges and in forest belts where open spaces and dense forests are combined. The collared flycatcher has successfully adapted to the urban environment, which explains why it is found in parks. This species shows a high adaptive capacity, making it a potential indicator of a moderate level of hemeroby in the urbanized ecosystems of Dnipro. The fieldfare (*Turdus pilaris* L.) exhibits a high degree of ecological plasticity, utilizing both traditional forest substrates and anthropogenically modified environments, highlighting its adaptability to urban landscapes. It often inhabits deciduous and mixed forests (Pisotska, 2020), especially in areas with an abundance of berry bushes, and often forages on the ground for invertebrates and berries. The fieldfare has a preference for a variety of light woodlands and forest edges where it is easy to find food and nest sites (McKinlay et al., 2024). The common occurrence of collared flycatchers and fieldfares in large numbers is an indication that these species can be used to monitor the state of natural communities in urban areas. In general, the birds in this cluster show a high degree of adaptability to anthropogenic environments, using different types of substrate to meet their ecological needs. These species are among the most widespread in the parks and were consistently recorded in each study area during the walkover surveys. Overall, the birds in this cluster exhibit significant adaptability to anthropogenic environments, utilizing various substrates to fulfill their ecological needs. Their dominance in avifaunal communities should be regarded as an indicator of a significant degree of hemeroby in these ecosystems.

Two species, the whitethroat (*Sylvia communis* L.) and the goldfinch (*Carduelis carduelis* L.) comprise the seventh group of birds. The whitethroat prefers dense scrub in wooded belts and on the edges of wooded areas. It is often found in fields and meadows with dense thickets of shrubs, especially blackthorn, rose hip, amorphia, and other thorny plants. In urban areas, the whitethroat can be found in parks and gardens, where there are sufficiently dense shrubs to create favorable nesting and sheltering conditions. The goldfinch is a rare forest species (Listopadsky, 2014) that prefers open areas with free-standing trees and shrubs, characteristic of the clump mosaic (Sheil & Ducey, 2002; Zhao et al., 2012; Geng et al., 2016). Ideal habitats for the goldfinch are forest edges with rich vegetation, especially those with thorny shrubs. In urban areas, the goldfinch can be found in gardens, parks, and forest edges. It has a preference for sites with sparse tree cover, where seeds are abundant for food. These species occupy distinct micro-habitats in parks and gardens. Their similar habitat preferences explain their presence on nearly identical substrates. Both species show a clear specialization in their choice of substrate. They prefer trees of the genera *Ulmus*, *Robinia*, *Salix*, the shrub *Cotinus*, and soil (Table 4). They are most commonly found in sparse forests with dense

shrubs, which provide optimal conditions for their survival and reproduction. It is important to note that these species have limited ecological plasticity, which may contribute to their lower numbers in urban parks. The conditions in these parks usually lack the diversity of tree species and grasses necessary for these birds to thrive.

The eighth group of birds includes species that are typical inhabitants of urban parks and are well-adapted to urban conditions. The hooded crow (*Corvus cornix* L.) is highly adaptable and is frequently encountered in cities and towns. It easily adapts to living among humans and can thrive in various urban environments, from densely populated centers to parks and suburbs. In urban environments, hooded crows often inhabit parks, squares, and large gardens, where there are sufficient trees for nesting and ample space for foraging (Novčić & Parača, 2021; Dupak & Telizhenko, 2023). In terms of feeding behavior, the hooded crow is an observer. It prefers open areas with low grass where it can easily find food. It also uses trees, electricity poles, and other elevated places for observation. It often inhabits wooded belts and the edges of forests, where open spaces combine with tree plantations. The chaffinch (*Fringilla coelebs* L.) is most common in deciduous and mixed forests, especially in places with well-developed undergrowth. It prefers sites with a sufficient number of trees and dense vegetation, which provides it with shelter and nest sites. Wooded belts are also ideal for the chaffinch as they provide a combination of dense vegetation and open areas for foraging. The chaffinch is well adapted to various habitats; in natural forests, it is second only to the great tit (*Parus major* L.) in numbers, a trend that continues in most parks in Dnipro. The red-backed shrike (*Lanius collurio* L.) prefers sparse forests with dense shrubs, such as blackthorn, rosebay, hawthorn, and other thorny plants. These provide safe hiding places, nesting, and hunting grounds. It also has a preference for habitats with young trees at the 'scrub' stage. In urban areas, the red-backed shrike did not show strong substrate preferences. It was found on a variety of substrate types, receiving level 3 (Table 4). The tree sparrow (*Passer montanus* L.) is most commonly found in fields, pastures, and in the vicinity of agricultural land (Yuzyk, 2015). In natural forests with well-formed stands, it is rarely found. In urban areas, the tree sparrow is often found in parks, gardens, and on the outskirts of human settlements (Lee et al., 2024). It is more commonly found in green areas with dense vegetation, though it may also use buildings for nesting. The tree sparrow is more likely to live in places with natural nesting substrates and is less dependent on people than the house sparrow. The tree sparrow is widespread in urban green spaces and can serve as an indicator of significant levels of hemeroby in the urban environment. The great tit is one of the most versatile adaptors, inhabiting a wide range of habitats (Zimaroeva et al., 2016). It shows great adaptability and the ability to use different types of substrates. The great tit can be found in both deciduous and mixed forests with a wide variety of stand structures. It is often found on the edges of forests and in forest belts where trees are adjacent to open areas (Seress et al., 2020; Song et al., 2020; Wawrzyniak et al., 2020). This species is often seen nesting in birdhouses or the hollows of old trees in parks. Despite its abundance and wide distribution in different habitats, the great tit is not an indicator of hemeroby. It thrives equally well in both natural and urban environments. Its ability to adapt to different environments makes it a versatile species that is not dependent on the level of anthropogenic impact on the environment. Hooded crows and chaffinches show a strong preference for tree substrates such as *Ulmus*, *Pinus*, *Robinia*, *Quercus*, and *Fraxinus* (scoring 4–5). This demonstrates their ability to adapt successfully to a variety of forest environments and to make efficient use of available resources for nesting and feeding. The red-backed shrike is more associated with *Salix* and *Juglans* trees, which may indicate that it requires specific conditions for hunting and nesting. The tree sparrow, in contrast, demonstrates a high degree of adaptability. It uses both natural and anthropogenic substrates, allowing it to thrive in urban environments. The great tit is one of the most plastic species in this cluster, using a variety of tree species for nesting, including *Tilia*, *Acer*, *Sorbus*, and *Pyrus*. This demonstrates its ability to adapt to different landscapes and environmental conditions. In general, the species in this cluster demonstrate considerable ecological plasticity, allowing them to thrive in various environments. This enables them to coexist successfully in urban areas. The species in this cluster are typical of hemerobic communities and are characteristic of the conditions in Dnipro's parks. These parks have

sparsely wooded habitats, which provide shelter for chaffinches and great tits, but are also open enough to support tree sparrows, red-backed shrikes, and hooded crows.

The ninth cluster consists of bird species that primarily or exclusively hunt in the air and demonstrate high adaptability to anthropogenic environments. The common raven (*Corvus corax* L.) is a highly adaptable species (Listopadsky, 2014), capable of living in a wide range of environments, from wild mountains to human settlements. Ravens are frequently observed on the outskirts of towns and cities, as well as in nearby areas. As a result, when observed in parks, they are typically recorded in flight. The kestrel (*Falco tinnunculus* L.) hunts by hovering over open, low-grazed areas (Rzypała et al., 2023), scanning the ground for prey. Both species, scoring 5 in the data matrix (Table 4), showed a preference for using *Populus* and *Salix* trees as perches. The hen harrier (*Circus cyaneus* L.) prefers large open areas with dense grass or shrubs, where it pursues prey by flying at low altitudes. Its appearance at the site is likely accidental. This species was recorded only once as an accidental visitor to the Tonelna Balka tract. The swift (*Apus apus* L.) and the house martin (*Delichon urbica* L.) spend most of their day in the air, hunting for insects. These species are highly adapted to the urban environment and extensively use anthropogenic substrates, which highlights their ability to make effective use of buildings and other man-made structures as nesting sites. This behavior is typical of these species in urban environments. The swallow (*Hirundo rustica* L.) tends to be more dependent on open and rural landscapes that provide the necessary natural or semi-natural conditions for survival. In general, this group of birds shows a high degree of specialization and adaptability to a variety of environmental conditions, including urbanized landscapes. The species in this cluster are united by a common feature: hunting in the air.

The tenth group consists of species that specialize in wetland environments and are dependent on aquatic substrates. The cormorant (*Phalacrocorax carbo* L.), The yellow-legged (Caspian) gull (*Larus cachimans* Pall.), common tern (*Sterna hirundo* L.), and black-headed gull (*Larus ridibundus* L.) all rank highly on substrates associated with water bodies and riparian zones, receiving scores of 4–5 levels (Table 4). This highlights their strong dependence on aquatic ecosystems that provide optimal conditions for nesting, feeding, and resting. These species may also use vegetation substrates, such as phragmites, within riparian zones, further emphasizing their reliance on balanced wetlands. Yellow-legged gulls and black-headed gulls are often found in artificial reservoirs and other man-made water bodies (Atamas & Loparov, 2008; Ponomarenko et al., 2021), indicating their ability to adapt to anthropogenic environmental changes. These species also show a dependence on certain landscape features, such as having open water and sufficient fish and other aquatic organisms, which are their main food source. A common feature of the species in this cluster is their role as aerial observers of wet areas, rarely straying far from water bodies.

The eleventh cluster of birds also includes species that inhabit wetland environments. This cluster comprises the grey heron (*Ardea cinerea* L.), mallard (*Anas platyrhynchos* L.), little ringed plover (*Charadrius dubius* Scop.), black-crowned night heron (*Nycticorax nycticorax* L.), common coot (*Fulica atra* L.), common moorhen (*Gallinula chloropus* L.), and great crested grebe (*Podiceps cristatus* L.). These species all score very highly on aquatic substrates, such as riparian zones and open water, with 3–5 levels on the data matrix (Table 4), indicating their strong dependence on aquatic ecosystems. The grey heron typically hunts by standing in shallow water and may use trees near water bodies as perches. The black-crowned night heron tends to perch on riverside trees while hunting, watching for prey from these elevated positions. The mallard, common coot, and common moorhen show a strong attachment to riparian zones and water bodies rich in reed beds, using these substrates as primary sites for nesting and feeding. The great crested grebe requires open water areas for nesting and gathers food by diving through various water layers. The little ringed plover is an example of a species that depends on wet areas, such as shallow waters and riverbanks. During migration, it may travel quite far from water bodies while exploring its surroundings. All these species are also observers of aquatic territories, but unlike the birds of the tenth cluster, they forage close to the water, focusing on surface substrates and nearby objects.

The twelfth cluster of birds is represented by two species that are highly specialized in wetland environments: the great reed warbler (*Acrocephalus arundinaceus* L.) and the common kingfisher (*Alcedo atthis* L.). Both species exhibit a strong attachment to aquatic ecosystems (Listopadsky et al., 2014; MÉRÓ et al., 2022), particularly to substrates associated with reeds and riparian vegetation, scoring 4 on Table 4. This indicates their reliance on dense riparian vegetation, which provides perches, shelter, and nesting sites. The great reed warbler typically builds its nests in dense reed beds, where it is protected from predators and has access to water, which is essential for its feeding. The common kingfisher is a typical representative of species that depend on clean water bodies and reed beds. Both species have narrow ecological niches, making them sensitive to changes in wetland ecosystems. It is noteworthy that the species in this cluster exhibit consistent behavior in both natural and urbanized landscapes.

Conclusion

The avifauna of the parks and squares of Dnipro is represented by a wide range of species belonging to 17 different orders. Among the recorded species, passerines dominate, accounting for 57.7% of the total. Based on the collected data, 12 clusters were identified, each characterizing the ecological preferences and adaptive capacities of species in urban environments. Each cluster groups together bird species that exhibit certain similar behavioral and ecological traits, depending on their choice of substrates for nesting, feeding, and habitat. Birds in the first and second clusters use various substrates but are rarely found in urban parks due to specific habitat requirements. Their low abundance in urban conditions may be due to a lack of suitable substrates and changes in the overall landscape. The presence of these species may indicate a relatively low transformation of communities and thus a low level of hemeroby. The species in the second cluster can also be considered indicators of low hemeroby levels in urban bird communities. The third cluster includes typically forest species that are rarely encountered in Dnipro parks due to the absence of biotopes with dense canopies and thick undergrowth. Among the third cluster, the great spotted woodpecker can be considered an indicator of a moderate degree of hemeroby in the urban environment. Birds in the fourth cluster include species that more actively adapt to the urban environment. These bird communities have specific substrate preferences, which prevent them from fully realizing their ecological niches in urban parks. Birds in the fifth cluster prefer old forests with tall trees and well-developed undergrowth. In urban conditions, these species are less common due to the limited availability of suitable nesting sites. The sixth and eighth clusters contain species that actively penetrate the urban environment and use a variety of substrates. These species demonstrate a high degree of adaptability and can serve as indicators of significant levels of anthropogenic impact. The collared flycatcher, common starling, and fieldfare demonstrate a high capacity for adaptation. The dominance of these species allows them to be considered potential indicators of moderate levels of hemeroby in bird communities. The dominant presence of species in the eighth cluster should be seen as an indication of a significant degree of hemeroby in these communities. The most prominent indicator of a high degree of hemeroby is the presence of the tree sparrow in bird communities. Among the listed clusters, the sixth and eighth clusters most accurately reflect the conditions of the parks and squares of Dnipro. These parks feature biotopes with tree stands that provide shelter for some forest species, but at the same time, these stands are quite sparse and not densely populated, allowing edge and shrub species to find a place to exist. Overall, it can be concluded that the parks of Dnipro, in most cases, do not form stable, high-quality tree stands suitable for typically forest bird species, as noted for the third cluster.

The identified bird clusters offer deeper insights into the species most sensitive to varying degrees of hemeroby in urban environments, which can serve as indicators of ecosystem changes. This knowledge is critically important for ecological planning and the management of urban green spaces. Identifying areas where species with low adaptation levels to urbanized environments are present allows the prioritization of zones for ecological restoration, where conditions favorable for the conservation of forest and other ecological complexes need to be created or maintained.

Furthermore, focusing on maintaining ecological niches for these species not only contributes to the preservation of their biodiversity but also improves the overall ecological condition of urban parks. This, in turn, enhances their value as recreational areas, which are important for the health and well-being of city residents, and contributes to the resilience of urban ecosystems to climate change and other external factors.

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References

- Adams, T. A., Ivande, S. T., & Wilson, M. (2022). Aspects of the nonbreeding ecology of the tree pipit *Anthus trivialis* in and around Amurum Forest Reserve, Jos Plateau, Nigeria. *Ostrich*, 93(3), 187–191.
- Atamas, N. S., & Loparov, S. O. (2008). Kommodobuvni stratehii ta biotychni vziaemodii zhovtonohogo martyna *Larus cachinnans* Pall. – adventyvnogo vydu na Seredn'omu Dnipro [Foraging strategy and biotic interactions of the yellow-legged gull *Larus cachinnans* Pall., an invading species in the Middle Dnipro]. *Naukovyi Visnyk Uzhhorodskoho Universytetu*, 23, 5–11 (in Ukrainian).
- Bibby, C., Jones, M., & Marsden, S. (1998). Expedition field techniques: Bird surveys. Royal Geographical Society, London.
- Briggs, K. B., & Deeming, D. C. (2021). Localized habitat affects size and materials used in the construction of common redstart *Phoenicurus phoenicurus* nests. *Bird Study*, 68(1), 9–20.
- Chamberlain, D. E., Henry, D. A. W., Reynolds, C., Caprio, E., & Amar, A. (2019). The relationship between wealth and biodiversity: A test of the luxury effect on bird species richness in the developing world. *Global Change Biology*, 25(9), 3045–3055.
- Chaplygina, A. B. (2015). Ekolohe-faunistychnyi analiz i uspishnist rozmnozhenia dendrofilnykh ptakhiv na transformovanykh terytoriyakh Pivnichno-Skhidnoyi Ukrainy [Ecofaunistic analysis and breeding success of dendrophilous birds on transformed territories of North-Eastern Ukraine]. *Biologichni Studii*, 9(2), 133–146 (in Ukrainian).
- Dickinson, A. M., Locke, E., Gray, L. A., Bennett, S. L., Biddle, L. E., Goodman, A. M., & Deeming, D. C. (2022). Composition of nests constructed by species in the Motacillidae, Sylviidae and Prunellidae. *Avian Biology Research*, 15(1), 21–33.
- Dubovyk, O., Kuzyo, N., & Bokotey, A. (2020). Density variation in “rare” breeding birds in native forests and urban parks. *Geo&Bio*, 19, 20–31.
- Dupak, V. S., & Telizhenko, V. S. (2023). Interactions between hooded crows (*Corvus cornix*) and Eurasian magpies (*Pica pica*) and their nesting site preferences in anthropogenic landscapes. *Ecoscience*, 30(3–4), 210–222.
- Esmalzaadeh, O., Soleymani, S. S., Hosseini, S. M., & Asadi, H. (2016). New stopping rules for dendrogram classification in TWINSpan. *Taxonomy and Biosystematics*, 7(25), 53–68.
- Fanelli, G., Tescarollo, P., & Testi, A. (2006). Ecological indicators applied to urban and suburban floras. *Ecological Indicators*, 6(2), 444–457.
- Fernández-Juricic, E., & Jokimäki, J. (2001). A habitat island approach to conserving birds in urban landscapes: Case studies from Southern and Northern Europe. *Biodiversity and Conservation*, 10(12), 2023–2043.
- Fesenko, H. V., & Bokotey, A. A. (2022). Ptakhy fauny Ukrainy [Birds of the fauna of Ukraine]. Ukrainian Society for the Protection of Birds, Kyiv (in Ukrainian).
- Floigl, K., Benedetti, Y., Reif, J., & Morelli, F. (2022). Spatial distribution and habitat overlap of five Columbidae species in the Czech Republic. *Animals*, 12(6), 743.
- Gapanovich, V., Lagutenko, O., & Nesteka, T. (2019). Vydove riznomanitтя ptakhiv riadu Horobtsopodobni (Passeriformes) na terytorii Holosiivskoho parku mista Kyieva [Species diversity of Passeriformes on the territory of Kyiv Golosevsky park]. *Young Scientist*, 65, 302–305 (in Ukrainian).
- Garrido-Bautista, J., Hernández-Ruiz, C., Ros-Santaella, J. L., Pintus, E., Bernardo, N., Comas, M., & Moreno-Rueda, G. (2023). Habitat-dependent breeding biology of the blue tit (*Cyanistes caeruleus*) across a continuous and heterogeneous Mediterranean woodland. *Avian Research*, 14, 100109.
- Geng, J., Chen, J.-M., Tu, L.-L., Tian, Q.-J., Wang, L., Yang, R.-R., Yang, Y.-J., Huang, Y., Fan, W.-L., Lv, C.-G., & Zheng, G. (2016). Influence of the exclusion distance among trees on gap fraction and foliage clumping index of forest plantations. *Trees*, 30, 1683–1693.
- Hanner, H. J., Cunningham, A. A., John, S. K., Magregor, S. K., Robinson, R. A., Seilem-Moy, K., Siriwardena, G. M., & Lawson, B. (2022). Habitat-use influences severe disease-mediated population declines in two of the most common garden bird species in Great Britain. *Scientific Reports*, 12, 18880.
- Hill, M. O. (1979). Twinspan: A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, New York.
- Ibáñez-Álamo, J. D., & Soler, M. (2010). Does urbanization affect selective pressures and life-history strategies in the common blackbird (*Turdus merula* L.)? *Biological Journal of the Linnean Society*, 101(4), 759–766.
- Johnstone, I. (1998). Territory structure of the robin (*Eriothacus rubecula*) outside the breeding season. *Ibis*, 140(2), 241–251.
- Julliard, R., Clavel, J., Devictor, V., Jiguet, F., & Couvet, D. (2006). Spatial segregation of specialists and generalists in bird communities. *Ecology Letters*, 9(11), 1237–1244.
- Karpińska, O., Kamionka-Kanclerska, K., Neubauer, G., & Rowiński, P. (2022). Characteristics and selection of nest sites of the flexible cavity-nester, the European robin (*Eriothacus rubecula*), in the temperate primeval forest (Białowieża National Park, Poland). *The European Zoological Journal*, 89(1), 492–505.
- Katayama, N., Amano, T., Naoe, S., Yamakita, T., Komatsu, I., Takagawa, S.-I., Sato, N., Ueta, M., & Miyashita, T. (2014). Landscape heterogeneity – biodiversity relationship: Effect of range size. *PLoS One*, 9(3), e93359.
- Kent, M., & Coker, P. (1992). Vegetation description and analysis: A practical approach. John Wiley & Sons, New York.
- Koshelev, O., Koshelev, V., Fedushko, M., & Zhukov, O. (2021). Annual course of temperature and precipitation as proximal predictors of birds’ responses to climatic changes on the species and community level. *Folia Oecologica*, 48(2), 118–135.
- Kunakh, O., Lisovets, O., & Zhukov, O. (2024). Hemeroby and naturalness differ in spatial patterns: The case of aquatic macrophytes. *International Journal of Environmental Studies*, 2024, 2379117.
- Kunakh, O., Lisovets, O., Podpriatova, N., & Zhukov, O. (2024). Plant community hemeroby is a reliable indicator of the dynamics of reclamation of lands disturbed by mining. *Ekológia (Bratislava)*, 43(1), 43–53.
- Lee, J.-H., Kim, S.-Y., & Sung, H.-C. (2024). Nest site selection, nest characteristics, and breeding ecology of the Eurasian tree sparrow, *Passer montanus*, living in an urban area. *Animal Taxonomy and Ecology*, 70(1), 46–60.
- Legendre, P. (2013). Indicator species: Computation. In: Levin, S. A. (Ed.). *Encyclopedia of biodiversity*. 2nd ed. Elsevier, Amsterdam. Pp. 264–268.
- Listopadsky, M. A. (2014). Zvolozhennia, yak faktor strukturoy orhanizatsiyi naselelnia ptakhiv drevnykh nasadzen’ biosferneho zapovidnyka Askaniia-Nova [Humidification as a factor of structural organization of bird populations in the wood stands of the Biosphere Reserve Askaniia-Nova]. *Biological Bulletin of Melitopol State Pedagogical University named after Bohdan Khmelnytskyi*, 4(1), 73–100 (in Ukrainian).
- Luna, A., Pomedá-Gutiérrez, F., & Galán Díaz, J. (2024). Feeding ecology of the common wood pigeon (*Columba palumbus*) in a major European city. *Royal Society Open Science*, 11(7), 231721.
- Lystopadskyi, M. A., Havrylenko, V. S., Mezinov, O. S., & Chehorka, P. P. (2014). Rol’ podovykh ekosystem u formuvanni vodno-bolotnykh omitokompleksiv Dniprovsko-Molochnianskoho mezhyrichchia [The role of floodplain ecosystems in the formation of wetland bird communities in the Dnipro-Molochnyi interfluv]. *Bulletin of the Biosphere Reserve "Askaniia-Nova"*, 16, 30–45 (in Ukrainian).
- Martinez, N., & Spek, V. (2022). Geographical variation in black redstart *Phoenicurus ochuuros* (S. G. Gmelin, 1774) calls. *Bulletin of the British Ornithologists’ Club*, 142(4), 466–477.
- McKinlay, S. E., Morganti, M., Mazzoleni, A., Labate, A., Sorrenti, M., & Rubolini, D. (2024). Non-breeding ranging behaviour, habitat use, and pre-breeding migratory movements of fieldfares (*Turdus pilaris*) wintering in Southern Europe. *Journal of Ornithology*, 165, 337–346.
- McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation*, 127(3), 247–260.
- Méró, T. O., Žuljević, A., Kolykhanova, O., & Lengyel, S. (2022). Reuse of nests in the great reed warbler (*Acrocephalus arundinaceus*): A behavior to save time and energy and to deter nest parasites? *Ecology and Evolution*, 12(10), e9452.
- Mouawad, L. R., Kattar, S., Rizkallah, J., El Obeid, D., El Haddad, S. P., & Bou Azza, K. (2023). Mapping the distribution of the Eurasian hoopoe *Upupa epops* and the pine processionary moth in Lebanon based on a citizen science approach. *Avocetta*, 47(1), 1–7.
- Müller, J., Pöllath, J., Moshhammer, R., & Schröder, B. (2009). Predicting the occurrence of middle spotted woodpecker *Dendrocopos medius* on a regional scale, using forest inventory data. *Forest Ecology and Management*, 257(2), 502–509.
- Novčić, I., & Parača, V. (2021). Seasonal differences in escape behaviour in the urban hooded crow, *Corvus cornix*. *Journal of Vertebrate Biology*, 71, 1–10.
- Piacentini, E., & Chiatante, G. (2022). Habitat selection, density and breeding of great spotted woodpecker *Dendrocopos major* in a protected natural area in Northern Italy. *Avocetta*, 46, 97–114.
- Pisotska, V. (2020). Osoblyvosti rozmishchennia hnidz drozda spivochoho (*Turdus philomelos* Brehm) ta drozda chomoho (*Turdus merula* L.) v polezasyvnykh lisosmuhakh Kharkivskoi oblasti [Features of location of nests of song thrush (*Turdus philomelos*) and blackbird (*Turdus merula*) in forest protection strips of Kharkiv region]. *Ecological Sciences*, 29, 86–90 (in Ukrainian).

- Ponomarenko, O., Banik, M., & Zhukov, O. (2021). Assessing habitat suitability for the common pochard, *Aythya ferina* (Anseriformes, Anatidae) at different spatial scales in Orel' river valley, Ukraine. *Ekológia (Bratislava)*, 40(2), 154–162.
- Reif, J., Marhoul, P., & Koptík, J. (2013). Bird communities in habitats along a successional gradient: Divergent patterns of species richness, specialization and threat. *Basic and Applied Ecology*, 14(5), 423–431.
- Robinson, W. D., Hallman, T. A., & Hutchinson, R. A. (2021). Benchmark bird surveys help quantify counting accuracy in a citizen-science database. *Frontiers in Ecology and Evolution*, 9, 568278.
- Roleček, J., Tichý, L., Zelený, D., & Chytrý, M. (2009). Modified TWINSpan classification in which the hierarchy respects cluster heterogeneity. *Journal of Vegetation Science*, 20(4), 596–602.
- Rzepala, M., Kasprzykowski, Z., Obloza, P., Mitrus, C., & Golański, A. (2023). The influence of habitat and the location of nest-boxes on the occupation of boxes and breeding success of the kestrel *Falco tinnunculus*. *The European Zoological Journal*, 90(1), 1–9.
- Šálek, M., Grill, S., & Riegert, J. (2020). Nest-site selection of an avian exploiter, the Eurasian magpie *Pica pica*, across the urban-rural gradient. *Journal of Vertebrate Biology*, 70(1), 20086.
- Schlicht, L., & Kempenaers, B. (2020). The effects of season, sex, age and weather on population-level variation in the timing of activity in Eurasian blue tits *Cyanistes caeruleus*. *Ibis*, 162(4), 1146–1162.
- Seress, G., Sándor, K., Evans, K. L., & Liker, A. (2020). Food availability limits avian reproduction in the city: An experimental study on great tits *Parus major*. *Journal of Animal Ecology*, 89(7), 1570–1580.
- Shafaipour, A., Michalczuk, J., & Fathinia, B. (2024). Habitat preferences and nest site selection by sympatric populations of middle spotted woodpecker (*Dendrocopos medius*) and Syrian woodpecker (*Dendrocopos syriacus*) in natural mountain forests of Southwest Iran. *Avian Research*, 15(1), 100167.
- Sheil, D., & Ducey, M. (2002). An extreme-value approach to detect clumping and an application to tropical forest gap-mosaic dynamics. *Journal of Tropical Ecology*, 18(5), 671–686.
- Shochat, E., Warren, P. S., Faeth, S. H., McIntyre, N. E., & Hope, D. (2006). From patterns to emerging processes in mechanistic urban ecology. *Trends in Ecology and Evolution*, 21(4), 186–191.
- Shupova, T. V. (2021). Zv'язky chuzhoridnykh vydiv ptakhiv z adventyvnymy roslynamy nasadzen' parkiv i botanichnykh sadiv [Connections of alien bird species with alien plants of parks and botanical gardens]. *Biologichni Studii*, 15(1), 79–92 (in Ukrainian).
- Shydlovskyy, I., Dubovyk, O., Hrynyuk, P., Zahorodnyi, I., & Matejchuk, V. (2021). Omifotuna luchnykh ekosystem u prykordonnykh raionakh Lvivshchyny ta Volyni [Avifauna of meadow ecosystems in borderland areas of Lviv and Volyn oblasts]. *Geo&Bio*, 20, 117–134 (in Ukrainian).
- Song, G., Zhang, R., Machado-Stredel, F., Alström, P., Johansson, U. S., Irestedt, M., Mays, H. L. Jr., McKay, B. D., Nishiumi, I., Cheng, Y., Qu, Y., Ericson, P. G. P., Fjeldså, J., Peterson, A. T., & Lei, F. (2020). Great journey of great tits (*Parus major* group): Origin, diversification and historical demographics of a broadly distributed bird lineage. *Journal of Biogeography*, 47(7), 1585–1598.
- Stański, T., Czeszczewik, D., Stańska, M., & Walankiewicz, W. (2020). Foraging behaviour of the great spotted woodpecker (*Dendrocopos major*) in relation to sex in primeval stands of the Białowieża National Park. *Acta Ornithologica*, 55(1), 120–128.
- Timo, P., Juha, T., Heikki, P., Markus, P., & Jari, K. (2022). Dynamics of the cavities of grey-headed woodpeckers (*Picus canus*) reveal their long- and short-term ecological roles in boreal forests. *Acta Ornithologica*, 56(2), 199–208.
- Turner, K. (2020). The structure and function of drumming in the middle spotted woodpecker (*Dendrocopos medius*). *Acta Ornithologica*, 55(1), 129–138.
- Vermeersch, S., Van den Genst, W., Vermoesen, F., & Triest, L. (2003). The influence of transformations of an ordinal scale of a floristic gradient, applied on a TWINSpan classification. *Flora – Morphology, Distribution, Functional Ecology of Plants*, 198(5), 389–403.
- Vīgants, V., Keišs, O., Dinsbergs, I., Jaunzemis, V., Zacmane, E. M., Priedniece, A., & Briedis, M. (2023). Migration strategies, performance and annual activity budget in a short-distance migrant, the common starling (*Sturnus vulgaris*). *Journal of Avian Biology*, 2023(5–6), e03080.
- Walz, U., & Stein, C. (2014). Indicators of hemeroby for the monitoring of landscapes in Germany. *Journal for Nature Conservation*, 22(3), 279–289.
- Wawrzyniak, J., Gładalski, M., Kaliński, A., Bańbura, M., Markowski, M., Skwarska, J., Zieliński, P., & Bańbura, J. (2020). Differences in the breeding performance of great tits (*Parus major*) between a forest and an urban area: A long-term study on first clutches. *The European Zoological Journal*, 87(1), 294–309.
- Winter, S. (2012). Forest naturalness assessment as a component of biodiversity monitoring and conservation management. *Forestry*, 85(2), 293–304.
- Xu, Y., Cao, Z., & Wang, B. (2020). Effect of urbanization intensity on nest-site selection by Eurasian magpies (*Pica pica*). *Urban Ecosystems*, 23, 1099–1105.
- Yarys, O. O. (2021). Do biolohii rozmnozhennia krutyholovky (*Jynx torquilla* Linnaeus, 1758) u shtuchnykh hnizdivliakh v umovakh pivnichnoho skhodu Ukrainy [The reproduction biology of the wryneck (*Jynx torquilla* Linnaeus, 1758) in artificial nests in northeastern Ukraine]. *Ecology and Noospherology*, 32(1), 61–67 (in Ukrainian).
- Yuzyk, D. I. (2015). Do ekolohii horobtsia pol'ovoho *Passer montanus* (Linnaeus, 1758) na pivnichnomu skhodi Ukrainy [Ecology of the Eurasian tree sparrow *Passer montanus* (Linnaeus, 1758) on the north-east of Ukraine]. *Scientific Foundations of Biodiversity Conservation*, 6(13), 263–274 (in Ukrainian).
- Zhao, F., Strahler, A. H., Schaaf, C. L., Yao, T., Yang, X., Wang, Z., Schull, M. A., Román, M. O., Woodcock, C. E., Olofsson, P., Ni-Meister, W., Jupp, D. L. B., Lovell, J. L., Culvenor, D. S., & Newnham, G. J. (2012). Measuring gap fraction, element clumping index and LAI in Sierra forest stands using a full-waveform ground-based lidar. *Remote Sensing of Environment*, 125, 73–79.
- Zimarioeva, A. A., Zhukov, O. V., & Ponomarenko, O. L. (2016). Determining spatial parameters of the ecological niche of *Parus major* (Passeriformes, Paridae) on the base of remote sensing data. *Vestnik Zoologii*, 50(3), 251–258.
- Zymarioeva, A., Zhukov, O., Fedoniuk, T., & Svenning, J.-C. (2022). Strong decline in breeding-bird community abundance throughout habitats in the Azov region (Southeastern Ukraine) linked to land-use intensification and climate. *Diversity*, 14(12), 1028.