



UDC: [598.2:591.54](477.83)

WINTER AVIFAUNA HABITAT TYPES OF URBAN AGGLOMERATIONS: COMPARISON BY QUALITATIVE AND QUANTITATIVE INDICATORS

Vadym Zhulenko , Roksolana Drekaló 

Ivan Franko National University of Lviv, 4 Hrushevsky St., Lviv 79005, Ukraine

Zhulenko, V., & Drekaló, R. (2023). Winter avifauna habitat types of urban agglomerations: comparison by qualitative and quantitative indicators. *Studia Biologica*, 17(4), 143–156. doi:[10.30970/sbi.1704.750](https://doi.org/10.30970/sbi.1704.750)

Background. The winter avifauna of urban agglomerations is a rather dynamic object of research, whose indicators differ across cities and years of observation. Depending on the species characteristics and the level of anthropogenization, birds in the territory of cities choose different types of habitats, which also requires analysis.

Materials and Methods. Research on the species composition of wintering birds on the territories of Zhydachiv and Lviv urban agglomerations was carried out in winter periods of 2020–2023 by means of field trips using the method of point records (Bibby *et al.*, 2000).

In order to count small species of Passeriformes accurately, a slightly modified version of this method was used. In this case, observations were carried out in a double radius. Birds were recorded separately in R1 – up to 25 m and R2 – from 25 to 50 m. The optimal time for counting at one point is 8–10 minutes. The counting area corresponds to a circle with a known radius. Research was carried out mainly in morning hours – from 8:00 to 11:00 in the case of absence of heavy precipitation, fog or strong wind.

Results and Discussion. After comparing the winter avifauna of urban agglomerations of the regional (Lviv) and district (Zhydachiv) levels, which differ in the level of environmental transformation, we established certain differences. A total of 48 species of wintering birds have been recorded, of which the Common Goldeneye (*Bucephala clangula*) and the Ural Owl (*Strix uralensis*) are protected by the Red Data Book of Ukraine.



Conclusion. For each of the agglomerations, dominant species of birds have been determined. Admittedly, birds in the territory of cities seek to occupy a territory with conditions most similar to the natural environment. Additionally, we attempted to understand the patterns of distribution of wintering species in the study area and the reasons for such placement.

Keywords: winter avifauna, urban ecosystems, synanthropic species, Lviv, Zhydachiv

INTRODUCTION

Birds as a component of ecosystems play an important role in the structure of natural communities. A decrease in the number of certain species or even entire bird complexes in anthropogenically transformed biotopes is observed quite often. Some species «thrive» in new artificial ecosystems, while others are negatively affected. Some representatives of urban avifauna may benefit from such a residence, for example a warmer climate, especially during winter period, as well as additional food source of anthropogenic origin. However, birds also face many new and potentially stressful anthropogenic factors, such as constant presence of humans, high density of predators (e.g. cats and dogs), noise and light pollution. These factors create a sort of selective environment that gives preference to the individuals which are able to adapt to such “urban conditions” (Partecke *et al.*, 2006).

The radical transformation of landscape combined with the excessive needs of cities for resources beyond their borders has profound and negative consequences for ecosystems. Urbanization processes lead to habitat loss, degradation, and fragmentation. These factors have a negative impact on biodiversity (Piano *et al.*, 2020).

On the territory of cities, the species richness of birds decreases sharply in comparison with natural habitats. It is also characterized by a significant increase in quantitative indicators and the dominance of a limited number of species (Peneaux *et al.*, 2021; Wood & Esaian, 2020). In urban areas, wildlife often encounters new, potentially stressful situations, such as changes in food resources, interactions with new species, increased human pressure and exposure to pollutants (Iglesias-Carrasco, 2020).

Despite the adverse effects of urbanization on local species, many of them have successfully adapted to the biotic and abiotic conditions of urban habitats. Although urbanization reduces the overall diversity of birds, many species thrive in the anthropogenically transformed environment (Bhatta, 2023). This can be explained by the fact that urban ecosystems provide enough food resources for birds and have a more moderate and relatively stable microclimate and fewer natural predators than in the natural environment (Méndez *et al.*, 2020).

Many cities often have fragments of vegetation under protection, which help to support biodiversity (Bhakti *et al.*, 2020). Green urban infrastructure has a positive impact on human health and provides habitat for animals (Felappi *et al.*, 2020; Machar *et al.*, 2022). The diversity of birds in city parks is more related to natural factors than to anthropogenic; however, these areas are significantly affected by recreational activities. The factors that affect the diversity of birds in urban green areas require further comprehensive research.

Due to constant anthropogenic transformation of the natural environment, the study of the organization of natural ecosystems on the biotope level is necessary for

understanding of their stable functioning, which is important for the current issues of biodiversity conservation. The evaluation of changes in the number of wintering bird species is an important element of ornithological monitoring of species richness and the condition of their natural populations.

MATERIALS AND METHODS

Research on the species composition of wintering birds on the territories of Zhydachiv and Lviv urban agglomerations (**Fig. 1**) was carried out in winter periods of 2020–2023 by means of field trips using the method of point records. This method is suitable for counting birds at some points, beyond which the observer does not record any species at all when moving between the points with a fixed detection band (Bibby *et al.*, 2020).

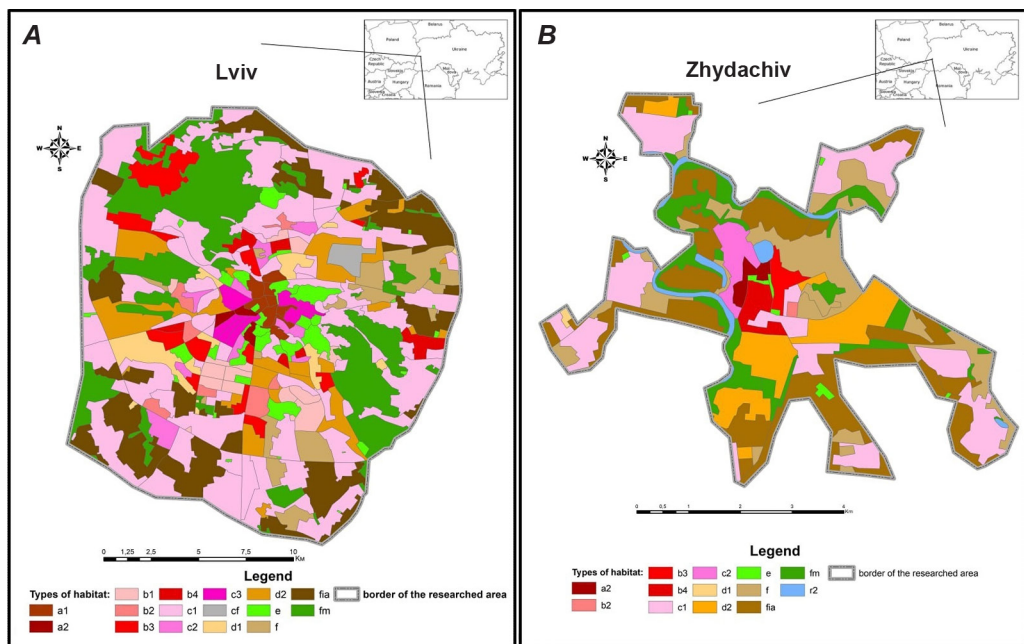


Fig. 1. Boundaries of urban agglomerations (a - Lviv, b - Zhydachiv) and types of dwellings.

The following habitat types within the territories of Zhydachiv and Lviv urban agglomerations were distinguished: a1, a2, c1, c2, c3, d2, e, f, r2, fm, fia habitat types are characteristic for **Zhydachiv agglomeration**, while a1, a2, b1, b2, b3, c1, d2, e, fm, fia for **Lviv** one, accordingly (Bokotei, 2019)

Note: a1 – old densely built-up downtown districts with small greenery areas; a2 – old densely built-up downtown districts with large greenery areas and modern multi storey building district inclusions; b1 – modern multi storey buildings with small greenery areas; b2 – modern multi storey buildings with medium greenery areas; b3 – modern multi storey buildings with medium greenery areas and private building district inclusions; b4 – modern multi storey buildings with large greenery areas and private building district inclusions; c1 – private buildings with large greenery areas; c2 – private buildings with large greenery areas and multi storey building district inclusions; c3 – private buildings with large greenery areas and old dense building district inclusions; d1 – industrial buildings with small greenery areas; d2 – industrial buildings with medium greenery areas; e – parks and cemeteries; f – ruderal areas; r1 – riparian areas without greenery; r2 – riparian areas with greenery; fm – forests; fia – agricultural fields; fig – dumping grounds; cf – sewage plants (Bokotei, 2019) (Notations are relevant to the rest of the figures)

In order to count small species of Passeriformes accurately, a slightly modified version of this method was used. In this case, observations were carried out in a double radius. Birds were recorded separately in R1 – up to 25 m and R2 – from 25 to 50 m. The optimal time for counting at one point is 8–10 minutes. The counting area corresponds to a circle with a known radius. Research was carried out mainly in morning hours – from 8:00 to 11:00 in the case of absence of heavy precipitation, fog or strong wind. In total, we established 1.514 points for accounting (Lviv – 1.406, Zhydachiv – 108). On average, observations were repeated in duplicate per point in Lviv, and in triplicate per point in Zhydachiv.

During the surveys, bird species were recorded by the following optical devices: Sigeta Farland binoculars (8x40); Canon EOS 250D (Focal distance: 28–88) and Nikon P1000 digital cameras (Focal distance: 24–3000). The species of birds were determined by the following keys: “Ptakhy fauny Ukrayiny (Birds of the fauna of Ukraine)” (Fesenko & Bokotei, 2002) and “Collins bird guide” (Svenson *et al.*, 2009). Scientific names of birds are used in accordance with the “The Annotated List of the Ukrainian Scientific Names of the Bird Species Belonging to the Fauna of Ukraine (with Characteristics of Status of the Species)” (Fesenko & Bokotei, 2007).

The collected data are stored as electronic accounting lists in the program – eBird (Cornell University) and All-In-One Offline Maps. Google maps and QGIS were used for mapping. MS Excel 2016 software package (©Microsoft) was used for the evaluation of the biodiversity level.

The comparative characteristics of bird species composition in different areas were calculated using the Jacquard similarity index (K_j):

$$K_j = c / (a + b - c)$$

where: c is the number of species occurring simultaneously in area “1” and “2”; a – number of species in area “1”; b – the number of species in area “2”.

To analyze the dominance structure of bird species, we used the following classification: dominants (the species part is >10 %), subdominants (1–10 %) and recedents (<1 %).

In the territories of both agglomerations, slightly different types of habitats can be distinguished, which is explained by the absence of modern multi storey buildings on the territory of Zhydachiv agglomeration and the presence of the Stryi River that flows through the territory of the town. In contrast, in Lviv, such a type of habitat as riparian area with or without greenery cannot be found as there are no open rivers here. Also, in the territory of Lviv agglomeration three types of multi storey buildings with different parts of greenery area were identified, whereas in Zhydachiv agglomeration, different types of buildings can be distinguished including multi storey ones as well as old densely built-up districts.

We start the field season according to meteorological indicators, such as: the formation of a constant snow cover, as well as the presence of a constant negative temperature (usually at the end of November). We finish the field season when these constant indicators decrease (usually in the middle or at the end of March).

RESULTS AND DISCUSSION

Zhydachiv agglomeration. During the survey on the territory of Zhydachiv agglomeration, 45 species of wintering birds were recorded and identified, two of which, namely,

the Common Goldeneye (*Bucephala clangula*) and the Ural Owl (*Strix uralensis*) are included to the Red Data Book of Ukraine (Akimov, 2009; Shydlovskyy *et al.*, 2023).

After calculating the percentage ratio of each species, it was established that the dominant species in winter period of 2020–2021 were the Great Tit (*Parus major*) – 21.7 % and the Rook (*Corvus frugilegus*) – 12.3 %; in 2021–2022 – the Mallard (*Anas platyrhynchos*) – 23.6 %, which is most likely caused by the mild winter favorable for the mass wintering of this species. In the winter period of 2022–2023, the dominant species on the territory of Zhydachiv agglomeration were the Rook – 13.5 % and the Great Tit – 11.5 %. A high share of the presence of mallards in the winter season of 2021–2022 can be explained by a mild winter, due to which water bodies did not freeze.

Our observations show that birds in urban areas tend to occupy territories with a significant amount of trees and shrubs, as well as forage of plant origin, such as weed seeds, which are the main food source for many species of birds. In the course of research on the distribution of different species of birds in urban agglomerations, P. R. Martin and F. Bonier (2018) put forward several hypotheses that can explain the spatial distribution of wintering birds. One of the hypotheses is related to the competition of urban species among themselves, which we also followed in the course of our own research. For example, the gray pigeon actively competes with small sparrow-like birds, such as the house sparrow. Thus in those types of dwellings where we recorded a large number of gray pigeons, we did not record or recorded the minimum number of house sparrows, although such a correlation with the number of gray pigeons, according to our observations, does not in any way affect the population of another dominant species of urban areas – the great tit. We believe that this is primarily due to the differences in nutrition of these two species.

The bird species whose numbers were the highest during winter periods of 2020–2023 were the representatives of Passeriformes, with the shares of 75.8 % (2020–2021), 63 % (2021–2022) and 73 % (2022–2023), respectively.

The species recorded on the territory of Zhydachiv agglomeration refer to 21 families. The most numerous ones are the Corvidae, the Paridae and the Anatidae.

Types of wintering habitat “f” and “c1” were the most similar in terms of species composition in 2020–2021 (**Fig. 2**). In the next winter period (2021–2022), the most similar habitats were “d2” and “r2” (**Fig. 3**). In 2022–2023, the most similar ones were: “r2” and “fia” (**Fig. 4**).

We can see in Figure 2 that “f” habitat type has the most similar bird species composition to “c1” type (Jaccard coefficient 0.7). Probably it creates the best conditions for protection and feeding of wintering birds. This is less typical for “c3”, as well as for “e” for which the Jaccard similarity coefficient is 0.5.

Figure 3 shows that “r2” has the most similar bird species composition to “d2” (the Jaccard similarity coefficient is 0.7). On the contrary, due to its specificity and lack of sufficient green space and forage base, “d2” has almost nothing similar to the other five habitat types (“a2”, “c3”, “f”, “fm”, “fia”), where the similarity coefficient is only 0.1.

According to Figure 4, “r2” is most similar to “fia”, which is associated with a significant open water surface area and the field itself (the level of similarity is 0.7). Also, a high level of similarity is observed with “c1” and “fm”, which is probably related to the presence of a sufficient number of shrubs that serve as hedges and food collection sites, and create good protective conditions (similarity level is 0.5–0.6).

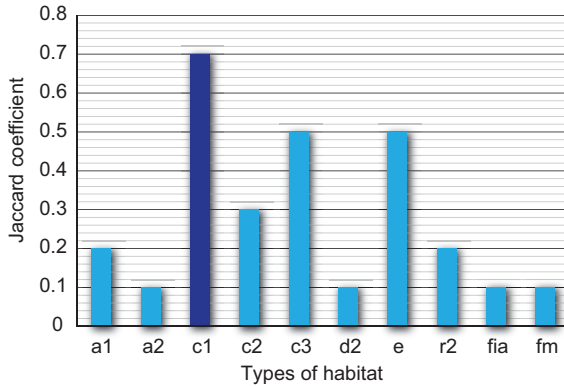


Fig. 2. Comparison of the species composition of the avifauna of “f” habitat type with others according to the Jaccard similarity index (2020–2021)

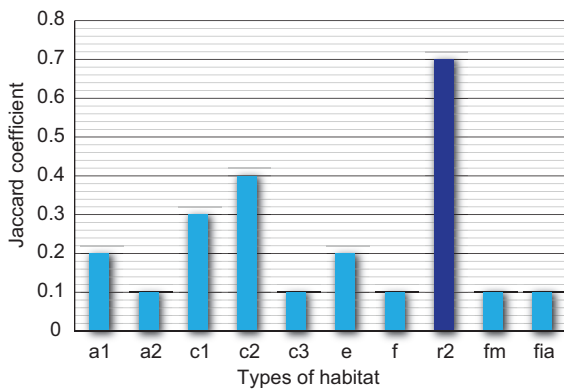


Fig. 3. Comparison of the species composition of the avifauna of “d2” habitat type with others according to the Jaccard similarity index (2021–2022)

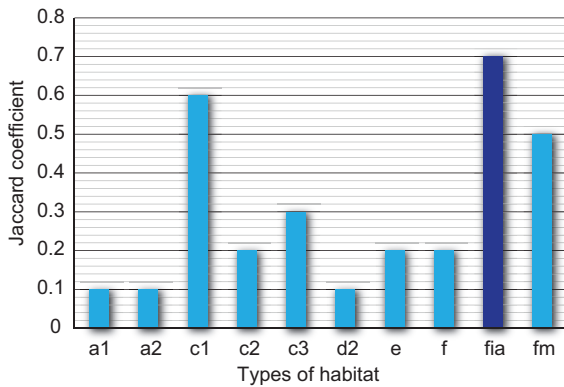


Fig. 4. Comparison of the species composition of the avifauna of “r2” habitat type with others according to the Jaccard similarity index (2022–2023)

Lviv agglomeration. During the research period in Lviv agglomeration, 32 species of wintering birds were recorded, of which the Eurasian goshawk (*Accipiter gentilis*) is included in Appendix II of the CITES Convention.

Based on the data of the percentage ratio of species, it was established that the dominant species in winter period of 2020–2021 were the Great Tit (18 %) and the Rook (15 %). The Rock Pigeon (*Columba livia*) – 41.8 %, whose percentage has increased significantly compared to the previous year, the Great Tit – 21 %, the Rook and the

Hooded Crow (*Corvus cornix*) – 19.4 % and 14 %, respectively, were the dominant species of the 2021–2022 winter period. Similar data were obtained for 2022–2023 winter season: the Rock Pigeon – 47.84 %, the Great Tit – 21.1 % and the Rook remained on the same level – 15 %.

The bird species with the highest numbers in the winter period of 2020–2021 belonged to Passeriformes, whose share was 85.1 %. In 2021–2022 and 2022–2023, the share of this taxonomic group of birds was 56 % and 55 %, respectively. It is important to note that the percentage of the Columbidae has grown significantly and currently accounts for 44 %. This is due to the fast growth of the population of the Rock Pigeon, which is an absolute urbanist and has adapted well to living in the urban environment. The main reasons for this are a significant number of warm places, the availability of food resources in winter, the possibility of constant reproduction and a small number of predatory birds.

According to the obtained data, we found that the largest number of species recorded during 2022–2023 winter period on the territory of Lviv agglomeration belong to the following three families: Columbidae, Corvidae and Paridae.

The results indicate that in 2020–2021 winter period “a1” and “a2” habitat types were the most similar (Fig. 5). In the winter period of 2021–2022, the highest similarity between species composition of avifauna was noticed between types “b3” and “d2” (Fig. 6). In 2022–2023, the most similar were “b1” and “e” habitat types (Fig. 7).

Fig. 5. Comparison of “a2” – old densely built-up downtown districts with a small greenery area – with the other habitat types according to the Jaccard similarity index (2020–2021)

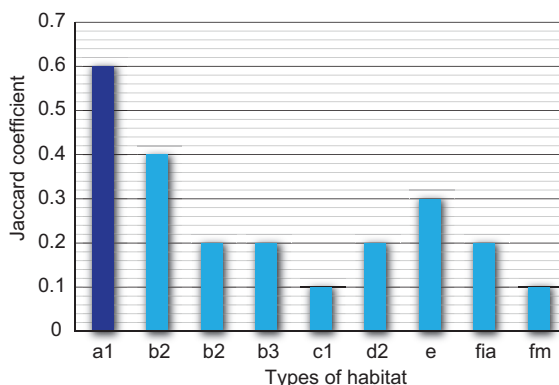
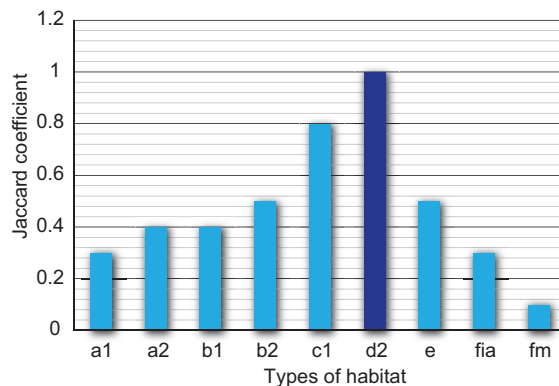


Fig. 6. Comparison of the species composition of “b3” – modern multi storey buildings with medium greenery area and private building district inclusions – with the other habitats according to the Jaccard similarity index (2021–2022)



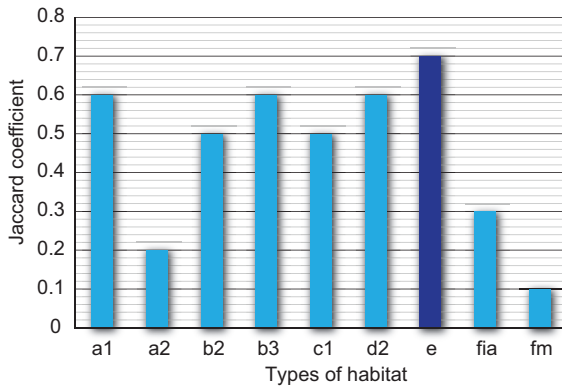


Fig. 7. Comparison of “b1” – modern multi storey buildings with a small greenery area – with the other habitats according to the Jaccard similarity index (2022–2023)

Data presented in Figure 4 indicate the variability of similarity level of “a2” compared to the other habitat types. In such type of habitat, appear well synanthropized species of birds that can feed from feeders or garbage cans. An almost complete dissimilarity of “a2” and “c1” types is noticeable, which is due to the absence of shrubs in the central part of the city that serve as a perch and a place for feeding for small sparrow-like birds (the similarity index is 0.1). One of the reasons for the disappearing of sparrows from the central part of Lviv was the cutting down of shrubs (Save the House Sparrows, 2021).

“B3” is a universal type of habitat for almost all bird species which have a sufficient level of synanthropization (**Fig. 6**). The only complete dissimilarity is observed when compared to “fm”, which is explained by the lack of species with a low level of synatropization that usually do not visit transformed areas.

According to Figure 6, “b1” habitat type shows a lot of similarity with certain habitat types, while being quite different from others. The similarity is caused by the presence of synanthropic bird species, a high diversity of the forage base and a moderate amount of trees and shrubs. Differences with other habitats are caused by similar reasons mentioned in the analysis of Figures 5 and 6.

Comparison of Lviv and Zhydachiv agglomerations by winter avifauna habitat types. The Jaccard similarity index (K_j) was also used to reveal the similarity between the species composition of the avifauna in the territories of Zhydachiv and Lviv agglomerations for the winter period of 2020–2023. However, since different types of habitats are distinguished on the territories of these agglomerations, we conducted a comparative analysis of only those types that were present in both agglomerations during the years of observation.

According to the obtained results, “a1” and “c1” habitat types were most similar in terms of the species composition of winter bird fauna (for the period of 2020–2021). The results are presented in **Figure 8**.

According to **Fig. 8**, a high level of variability of the similarity is observed in the territories of urban agglomerations at the district and regional level. The reason for this, in our opinion, is a combination of factors: the level of urbanization and the level of synanthropy of wintering birds, meteorological features of each field season and the availability of the forage base. However, the above is not always true for other cities (Thompson *et al.*, 2022; Dementieieva, 2021).

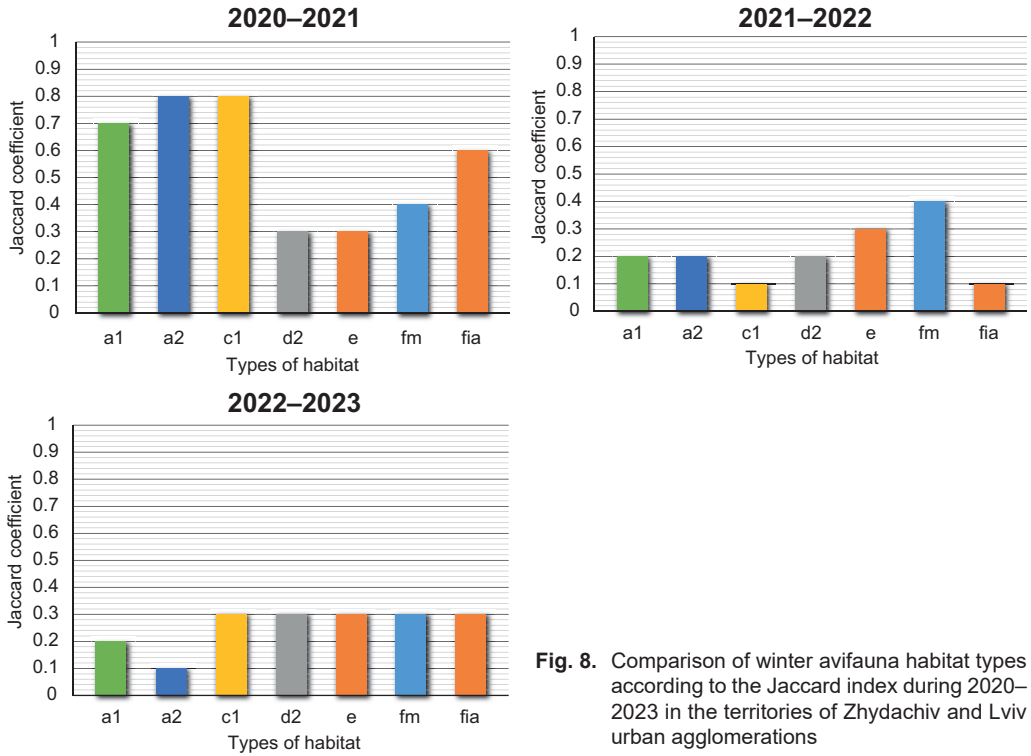


Fig. 8. Comparison of winter avifauna habitat types according to the Jaccard index during 2020–2023 in the territories of Zhydachiv and Lviv urban agglomerations

The average value of bird number in each of the habitat types was calculated and is presented below (Fig. 9).

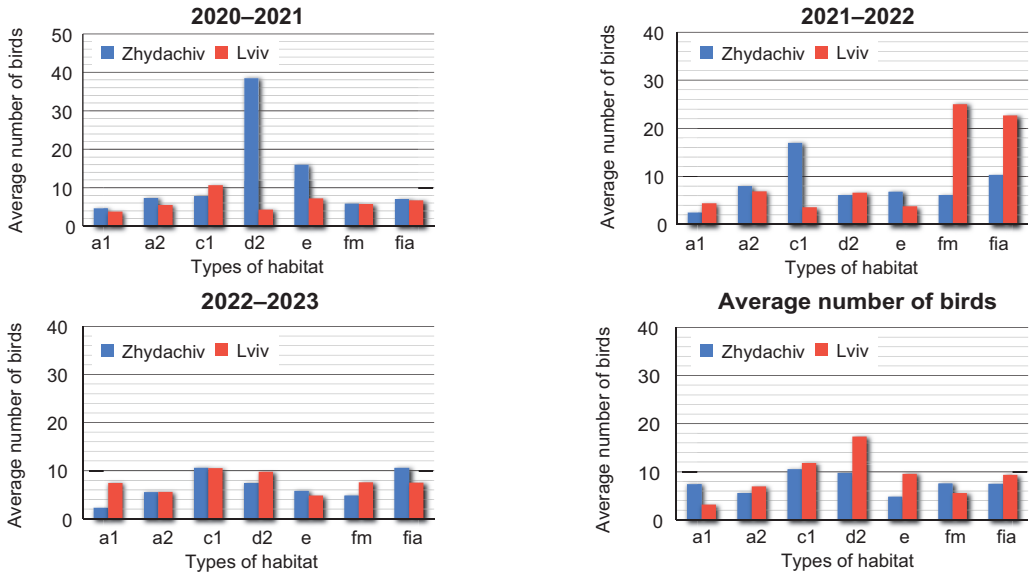


Fig. 9. Comparison of the quantitative indicators of avifauna in the research areas of each year and their average value

Differences in the quantitative indicators of bird fauna of different types of habitats on the territory of two urban agglomerations are explained by different levels of urbanization, as well as meteorological indicators of winter conditions. The winter of 2020–2021 was relatively mild, with moderate precipitation and not constant negative temperature indicators. Thus, the quantitative distribution of birds was generally similar between the studied agglomerations. However, abnormally high density of avifauna was observed on the territory of Zhydachiv agglomeration in “d2” habitat type, mainly comprising the Great Tit and the Rook. This was due to the presence of a large number of people in “d2” area during the research season that winter, which attracted these two well-anthropogenic bird species.

The winter of 2021–2022 was rather cold with frequent persistent snow cover and significant negative temperatures, which encouraged birds to visit “fm” and “fia” territories more often within more anthropogenic Lviv agglomeration than in Zhydachiv one.

The winter of 2022–2023 was mostly warm, without significant snow cover and without significant negative temperature values. Therefore, the distribution of representatives of winter avifauna was mostly homogeneous, without significant differences.

In general, the qualitative distribution of birds indicates a strong tendency to visiting the areas with a higher level of anthropogenization during the seasons with unfavorable meteorological conditions in order to find sources of food and comfort and to reduce the level of energy expenditure. If the meteorological indicators remain acceptable for the survival of birds in the territories with a lower level of anthropogenization, the birds prefer habitats in the territories of smaller agglomerations. This distribution, to a greater extent, is provoked by the attraction of birds to the territories more familiar to them, since highly anthropogenized areas often cause increased anxiety levels in birds (Martin & Bonier, 2018; Dixon, 2022). R. Thompson, M. Tamayo, S. Sigurdsson (2022) also recorded the highest qualitative and quantitative indicators of bird fauna in similar territories. Apparently, the reason for such distribution of avifauna is the relatively rich forage base and the affinity of these territories with the locations that are common for birds.

CONCLUSIONS

The study on the species composition of birds on the territory of Zhydachiv and Lviv urban agglomerations during the winter periods of 2020–2023 was conducted. A total of 48 species of wintering birds were recorded, of which the Common Goldeneye and the Ural Owl are protected by the Red Data Book of Ukraine. Dominant species of birds have been determined for each of the agglomerations: the Rock Pigeon (31 %), the Great Tit (19 %), the Rook (17%) for Lviv and the Rook (18 %), the Mallard (16 %), and the Great Tit (15 %) for Zhydachiv.

According to our observations, Lviv agglomeration has shown a significant increase in the percentage of the number of pigeons, in particular gray ones over the past two years. Presumably, this tendency will persist, as this species is found in all types of habitats, but mostly in urbanized areas, both in the vicinity of new and old high-rise buildings. In our opinion, the number of house sparrows during the winter, in our opinion, depends on the intensity of the anthropogenic transformation of urban agglomerations. In the central part of Zhydachiv, we recorded a small number of birds of this species every year, and in the central part of Lviv, during the three years of research, the house sparrow was never detected.

A comparative analysis of the types of biotopes on the territory of Lviv and Zhydachiv city agglomerations was carried out. To reveal the similarity between the same types of biotopes in the territories of both agglomerations, the Jacquard similarity index was calculated. It is 0.1 for such types of biotopes as “a2” and “c1”, which indicates a low similarity between these agglomerations.

Based on the obtained results, it can be stated that the highest diversity of bird species is observed in such types of habitats as “e”, “fm” and “fia”. This result indicates that birds in the territory of urban agglomerations give preference to the territories, which are as similar as possible to the natural environment in terms of their conditions. Heavily transformed types of habitats, such as “d1” serve as a wintering place only for synanthropic bird species, which is due to the significant differences of these areas from natural habitats.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflict of interest.

Animal studies: The experiment was conducted in compliance with bioethics, in accordance with the provisions of the Convention on the Protection of Vertebrate Animals Used for Experimental and Other European Scientific Purposes (Strasbourg, 1986), and does not violate the conventions on wildlife protection in Europe (Berne Convention), the Law of Ukraine “On Fauna” (March 3, 1993), the Law of Ukraine “On Environmental Protection” (June 26, 1991).

AUTHOR CONTRIBUTIONS

Conceptualization, [V.Zh.] methodology, [V.Zh.] validation, [V.Zh.; R.D.]; formal analysis [V.Zh.; R.D.]; investigation, [V.Zh.; R.D.] resources, [V.Zh.; R.D.]; data curation, [V.Zh.; R.D.]; writing – original draft preparation, [V.Zh.; R.D.]; writing – review and editing, [V.Zh.; R.D.]; visualization, [V.Zh.; R.D.].

All authors have read and agreed to the published version of the manuscript.

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ТИПИ ОСЕЛИЩ ЗИМОВОЇ ОРНІТОФАУНИ МІСЬКИХ АГЛОМЕРАЦІЙ: ПОРІВНЯННЯ ЗА ЯКІСНИМИ ТА КІЛЬКІСНИМИ ПОКАЗНИКАМИ

Вадим Жуленко, Роксолана Дрекало

*Львівський національний університет імені Івана Франка
вул. Грушевського, 4, Львів 79005, Україна*

Обґрунтування. Зимова орнітофауна міських агломерацій є досить динамічним об'єктом досліджень, показники якого відмінні в різних містах і в різні роки спостережень. Залежно від видових особливостей і рівня антропогенізації птахи на території міст обирають різні типи оселищ, що також потребує аналізу.

Матеріали та методи. Дослідження щодо встановлення видового складу зимуючих птахів на територіях Жидачівської та Львівської міських агломерацій проводили в зимовий період 2020–2023 рр. польовими виїздами, застосовуючи метод точкових обліків із фіксованою смугою виявлення.

Для точного підрахунку дрібних видів горобцеподібних використовували трохи модифікований варіант цього методу. Відповідно, обліки проводили у подвійному радіусі. Окремо фіксували птахів у R1 (до 25 м) і окремо у R2 (від 25 м до 50 м). Оптимальний час перебування на одній точці 8–10 хв. У цьому разі площа обліку відповідає колу з відомим радіусом. Дослідження проводили переважно в ранковій годині – з 8:00 до 11:00 у дні без рясних опадів, туману чи сильного вітру.

Результати. Порівнявши зимову орнітофауну міських агломерацій обласного (Львів) та районного (Жидачів) рівнів, які різняться за ступенем трансформації середовища, ми встановили певні відмінності, однією з причин яких є різна міра антропогенізації цих територій. Сумарно зафіксовано 48 видів зимуючих птахів, із яких гоголь (*Bucephala clangula*) та сова довгохвоста (*Strix uralensis*) занесені до Червоної книги України. Для кожної з агломерацій визначено домінантні види птахів.

Висновки. На основі одержаних результатів можна стверджувати, що найбільше видове різноманіття птахів є в типах оселищ “парки та сквери”, “ліс” і “сільськогосподарські поля”. Це вказує на те, що птахам у містах властиво займати територію, яка би за своїми умовами була максимально наближеною до природного середовища.

Ключові слова: зимова орнітофауна, міські екосистеми, синантропні види, Львів, Жидачів