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Density variation in "rare" breeding birds in native forests and urban parks

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Density variation in "rare" breeding birds in native forests and urban parks. — O. Dubovyk, H. Kuzyo, A. Bokotey. — Biodiversity protection and conservation of rare species are typically the main goals of protected areas. Protected areas are commonly created within native ecosystems where anthropogenic pressure is low. Meanwhile, a growing body of literature has focused on the effectiveness of protected areas to provide important habitats for rare taxa. To highlight this issue, we examined avian species, the most diverse vertebrate class in Ukraine. Forest ecosystems vary relative to conservation status and native integrity. With this in mind, we considered Lviv, Ukraine and outskirts. To determine conservation status, we used regulatory instruments such as the National Red Book of Ukraine, Resolution 6 of the Bern Convention on the Conservation of European Wildlife and Natural Habitats and appendices, the Bonn Convention on the Conservation of Migratory Species of Wild Animals and appendices, and Species of European Conservation Concern (SPEC) status to define rare species. The weighted density of SPEC species and those listed in the Bern Convention and Bonn Convention vary considerably and are higher in forests where native integrity has been lost to various degrees. The density of rare taxa within forests exhibiting high biodiversity loss (e.g. urban parks) was starkly evident. Degree of urbanization, as a function of distance from Lviv, was an insignificant predictor of a species listed in Resolution 6 of the Bern Convention or Red Book of Ukraine. We found that weighted density of species with mean species statuses weight were lower in more native forests than parks. Given that weighted densities were highly correlated with general density, we attribute this finding to the luxury effect. That is, density of birds is higher in more urbanized areas of a particular habitat type (e.g. forests and parks). Our conclusion supports previous findings that an increase in overall bird density is common among European cities. To a lesser extent, these findings suggest ineffective nature conservation management of forests in the Lviv region of Ukraine and imply the lack of interest in urban parks as habitat for rare taxa.

Key words: rare species, forest birds, nature conservation, conservation areas, conservation status, Ukraine, urban parks.

Introduction

Regulations on the consumption of natural resources have a long history. A restriction on natural resource use began more than 2000 years ago in ancient Asia and more recently in Medieval Europe for hunting by monarchs and feudals. Since the 19th century, this protection of resources has progressed to what we now know as nature conservation areas, including such modern examples as Yosemite or Yellowstone National Parks in the United States (Phillips 2004).

The impetus to establish conservation areas are varied. On the one hand, protected areas (PAs), any areas protected by a national law such as national parks or nature reserves, are established to preserve rare species. At times, the protection of species may be through umbrella species where, for example, protection of a predator may result in the protection of its prey (Simberloff 1998). On the other hand, PAs are an important instrument for biodiversity conservation, which is needed against

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the backdrop of species extinctions and potential lack of biological resources (Lopoukhine 2008). Ukrainian nature conservation law gives wide and opaque latitude when defining the rationale for the creation of PAs: to save the natural diversity of landscapes and gene pool of animals and plants, to support ecological balance, and to conduct environmental monitoring. Oddly, neither biodiversity nor rare species protection are mentioned, although they can be alluded to when attempting to save gene pools.

The effectiveness of PAs and their functioning and management is questionable (Arcese & Sinclair 1997). For instance, there is poor overlap between potentially suitable habitat of globally threatened birds of mainland Africa and PAs (Beresford *et al.* 2011). Likewise, there is a mismatch between suitable habitat for plants and the occurrence of PAs (Burgess *et al.* 2005). Even more striking are the numerous examples where rare animal taxa do not even use PAs (Rodrigues *et al.* 2004). Ironically, there are also areas without any formal status as a nature conservation site that serve a similar function of PAs (Bhagwat *et al.* 2005). Despite these telling facts, the evidence does not suggest an ineffectiveness of modern PAs, but rather, a message that the management of PAs are in need of improvement (Rodrigues *et al.* 2004; Burgess *et al.* 2002).

Therefore, a question arises: do PAs perform their functions effectively in protection of rare species and especially in providing for future long-term survival? To answer this question, we focus on birds, the most diverse group of vertebrates in Ukraine and a taxonomic group that serves as an indicator and which are relatively convenient to study (Gorban & Tsaryk 2012). The comparative study of the density of rare bird species can help to elucidate general patterns of habitat preference.

The majority of studies use a more traditional approach to define both rare species and PAs. There is, however, a lack of research on the distribution of rare taxa within urban gradients of native integrity. This alternative approach appropriately captures this relationship between native integrity and the effectiveness of PAs. As PAs are commonly created in ecosystems of a high degree of native integrity, the use of native integrity gradient or the degree of urbanization gradient is more convenient than "protected areas' regime acerbity" gradient.

Therefore, we examined forest communities of breeding birds that exhibit the highest biodiversity in western Ukraine. The comparative element lays in the way of studying forest ecosystems in "urbanization — native integrity" gradient (or urban gradient *sensu* Blair (Blair 1996), but despite the fact that urban gradient implies "from more native to more urbanized", we used "from more urbanized to more native" approach). The aim of this work was to reveal the preferences of rare taxa within this gradient by a comparison of density of rare species in forested park ecosystems within city limits relative to native forests in nature reserves outside the city.

Material and methods

Study area

The study area included Lviv city within its ecological (i.e. at the edge of the urban matrix where it meets the non-urban interface) and administrative boundaries, including suburbs and adjacent territories (Fig. 1).

Material for this work was collected during the breeding period (Apr — Jun) in 2018 and 2019. Twelve parks and cemeteries were chosen in geographically representative areas of Lviv. We also included two forests in the suburbs and two PAs distant from the city. Linear transects of 500 m in length and 100 m in width were established within each plot. Number of transects per plot depended on the area of the plot: 1 to 10 transects per plot (3.7 transects per plot in average), N = 59 transects.

We conducted bird counts during the breeding season (15 Apr — 20 Jun) every ~30 days three times on each transect. A typical survey was conducted within 5 hrs after sunrise. Species were identified by sight and sound and all individuals within 50 m of the transect were recorded. Transects were traversed at a mean rate of ~1 kph.

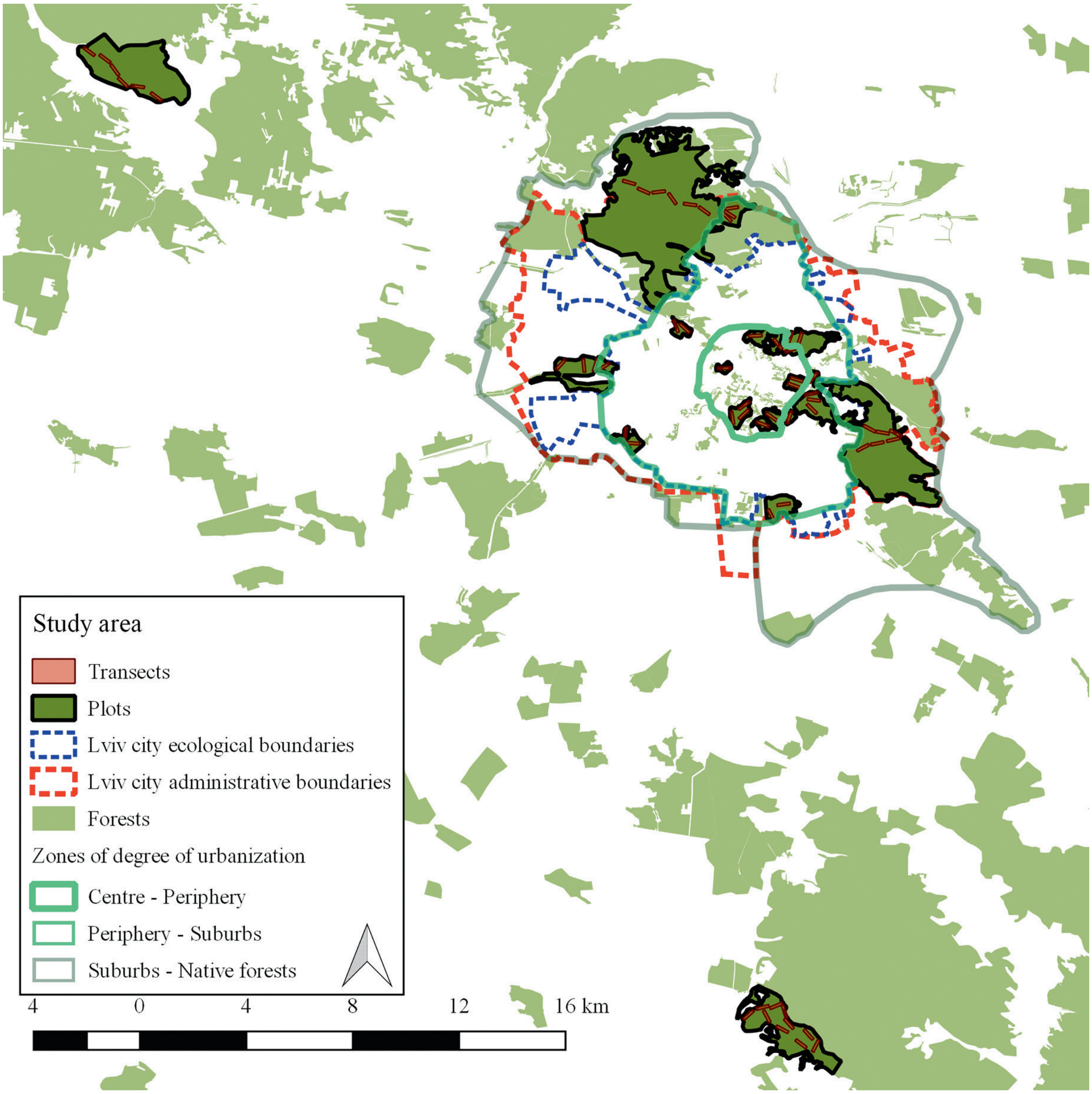

Fig. 1. Study area, linear transects, and forest ecosystem zones of degree of urbanization.
Рис. 1. Територія досліджень, трансекти та зони ступеню урбанізованости лісових насаджень.

We assigned a degree of urbanization value to every transect (Fig. 1, Table 1), irrespective of whether the transect was within a PA, because PA statuses are irrelevant in some cases. For example, there are two regional landscape parks among model plots: Znesinya is located near the centre and is a popular place for recreation with developed infrastructure. The other is Stilske Gorbogirya, which is located 10–30 km south of the city and consists of mature broadleaf forests used for forestry.

Plots were grouped as follows:

- Parks in the centre of the city (11 transects in Ivan Franko Park, Vysokyi Zamok Park and Znesinnia Regional Landscape Park partly, Zalizna Voda Park, Lychakiv Cemetery, Stryisky Park);
- Parks in the periphery of the city (17 transects in Znesinnia Regional Landscape Park partly, John Paul II Park, Pogulianka Park, Snopkivsky Park, Holoskivske Cemetery, Sknyliv Park, Yaniv old Cemetery, Lychakiv park, Bilogorshya Forest partly);
- Forests in suburbs (15 transects in Bilogorshya Forest partly, Briukhovychi forest, Vynnyky forest);

• Forests distant from the city (16 transects in Stilske Gorbogirya Regional Landscape Park and Roztochya Nature Reserve).

Although this classification is approximate, it facilitated data analysis because the number of transects was relatively equal among groups. We call the classes listed above the zones of degree of urbanization here and later. It is notable that some plots are listed in different zones related to habitat heterogeneity along linear transects within the plot (Table 1).

Table 1. **Sample transects, their location, distance from the city centre, activity of pedestrians, and zones of degree of urbanization**

Таблиця 1. **Модельні трансекти, їх розташування, дистанція від центру міста, відвідуваність людьми, приналежність до зон ступеню урбанізованости**

Plot	Number of transects	Distance between the city centre and the transect, km ±SD	Activity of pedestrians, persons/ transect ± SD	Zone of degree of urbanization
Ivan Franko Park	1	0.6	176.2 ± 77.0	1 — Centre
Vysokyi Zamok Park and Znesinnia Regional Landscape Park	3	1.3 ± 0.3	24.1 ± 13.3	1 — Centre
Zalizna Voda Park	2	2.1 ± 0.1	30.0 ± 14.8	1 — Centre
Lychakiv Cemetery	2	1.7 ± 0.1	28.9 ± 29.6	1 — Centre
Stryisky Park	3	1.6 ± 0.2	45.2 ± 41.1	1 — Centre
Znesinnia Regional Landscape Park	2	1.9 ± 0.3	8.1 ± 5.5	2 — Periphery
John Paul II Park	2	5.4 ± 0.1	16.3 ± 14.6	2 — Periphery
Pogulianka Park	3	2.6 ± 0.2	25.1 ± 22.1	2 — Periphery
Snopkivsky Park	1	2.4	14.2 ± 7.6	2 — Periphery
Holoskivske Cemetery	3	5.6 ± 0.2	20.9 ± 18.8	2 — Periphery
Sknyliv Park	2	4.9 ± 0.1	10.8 ± 4.7	2 — Periphery
Yaniv Cemetery	2	2.5 ± 0.2	13.8 ± 14.3	2 — Periphery
Lychakiv park	1	2.4	41.3 ± 20.9	2 — Periphery
Bilogorshya Forest	1	5.1	13.4 ± 7.1	2 — Periphery
Bilogorshya Forest	3	6.1 ± 0.6	2.6 ± 2.1	3 — Suburbs
Briukhovychi forest	6	6.8 ± 0.8	0.5 ± 1.6	3 — Suburbs
Vynnyky forest	6	5.6 ± 0.4	2.6 ± 3.6	3 — Suburbs
Stilske Gorbogirya Regional Landscape Park	10	24.7 ± 0.5	0.2 ± 1.0	4 — Native forests
Roztochya Nature Reserve	6	25.6 ± 1.1	0.2 ± 0.5	4 — Native forests

Classification of rare species

Legal and regulatory instruments were analysed to assign rarity designations among species. We did not assume that the formal status of a species implied its ecological rarity (Gaston 1994).We did not take into account IUCN status when calculating the mean weight of each status because all taxa had the same status (Least Concern) except the European turtle dove *Streptopelia turtur* (L.).

We used Species of European Conservation Concern (SPEC) categories to assess the rarity of species in Europe (BirdLife International 2017): Non-SPEC (species whose global population is not concentrated in Europe, and whose European population status is currently considered to be Secure); SPEC 3 (species whose global population is not concentrated in Europe, but which is classified as Regionally Extinct, Critically Endangered, Endangered, Vulnerable, Near Threatened, Declining, Depleted or Rare at European level); SPEC 2 (species whose global population is concentrated in Europe, and which is classified as Regionally Extinct, Critically Endangered, Endangered, Vulnerable, Near Threatened, Declining, Depleted or Rare at European level); and SPEC 1 (European species of global conservation concern, i.e. classified as Critically Endangered, Endangered, Vulnerable or Near Threatened at global level).

We used the Bern Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, BC) and Bonn Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention, CMS) among international documents that are implemented in Ukraine. We took into account the presence of species in Appendix II (Strictly protected fauna species),

Appendix III (Protected fauna species) and Resolution 6 (listing the species requiring specific habitat conservation measures) of BC and presence of species in Appendix I (Threatened migratory species) and Appendix II (Migratory species requiring international cooperation) of CMS.

The statuses of the third edition of the National Red Book of Ukraine (RB) were used to determine status relative to national laws.

We used an approach similar to that used by Zagorodniuk (Zagorodniuk 2008): the categories of each conservation status ranged from 0 to 1. Thus, RB status was as follows: 1.00 = Vulnerable, 0.75 = Rare, 0.50 = Undefined, and 0.25 = Not Evaluated. Categories of SPEC were as follows: 1.00 = SPEC 1, 0.67 = SPEC 2, 0.33 = SPEC 3, and 0.00 = Non-SPEC; presence in Appendix II of BC = 1.0, Appendix III = 0.5. Presence on the list of Resolution 6 of BC (R6) was considered separately and given a weight of 1.0. The presence in one of two appendices of CMS was given a weight of 0.5, but if present in both a weight of 1.0 was used.

Additionally, we used the mean of weights (MW) as a measure of conservation importance of species, despite the fact that this system of evaluation was used more as a matter of convenience. Species status, distribution among plots and mean weights are listed in Table 2.

Table 2. **Breeding bird species, their distribution among plots and conservation statuses**
Таблиця 2. **Види гніздових птахів, їх поширення на модельних ділянках та природоохоронні статуси**

Species	Model plots																Conservation status						
	LC	SP	ZP	FP	VP	OP	HC	YC	PP	LP	AP	BP	BF	VF	KF	RF	RB	IUCN	BC	R6	CMS	SPEC	MW
Accipiter gentilis							+					+	+	+	+	+		LC	2		2		0.3
Accipiter nisus			+		+	+					+	+	+	+	+	+		LC	2		2		0.3
Acrocephalus palustris					+						+							LC	2				0.2
Aegithalos caudatus	+	+	+		+		+	+			+	+	+	+	+	+		LC	3		2		0.2
Anas platyrhynchos		+	+		+				+		+	+	+	+	+			LC	3		2		0.2
Anthus trivialis			+									+	+	+	+	+		LC	2			3	0.27
Asio otus											+	+	+	+	+			LC	2				0.2
Buteo buteo			+				+		+			+	+	+	+	+		LC	2		2		0.3
Coccothraustes coccothraustes	+	+	+		+			+	+		+	+	+	+	+			LC	2				0.2
Carduelis carduelis	+	+			+		+		+		+	+	+	+	+			LC	2				0.2
Certhia brachydactyla	+	+	+	+	+	+						+	+			+		LC	2				0.2
Certhia familiaris	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		LC	2				0.2
Chloris chloris	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+		LC	2				0.2
Clanga pomarina															+		RA	LC	2	1	2		0.65
Columba oenas	+	+	+	+	+				+			+	+	+	+	+	VU	LC	3				0.3
Columba palumbus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC					0
Corvus corax					+		+	+	+			+	+	+	+	+		-					0
Corvus cornix			+						+		+							LC	3				0.1
Corvus frugilegus				+														LC					0
Cuculus canorus	+				+	+	+				+	+	+	+	+			LC	3				0.1
Cyanistes caeruleus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	2				0.2
Dendrocopos leucotos									+			+	+	+	+	+	RA	LC	2	1			0.55
Dendrocopos major	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	2				0.2
Dendrocopos syriacus					+							+						LC	2	1			0.4
Dryobates minor	+				+				+			+	+	+	+	+		LC	2				0.2
Dryocopus martius									+			+	+	+	+	+		LC	2	1			0.4
Emberiza citrinella					+		+											LC	2			2	0.33
Erithacus rubecula	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	2		2		0.3
Ficedula albicollis	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		LC	2	1	2		0.5
Ficedula parva												+	+	+	+	+		LC	2	1	2		0.5
Fringilla coelebs	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	3				0.1
Gallinula chloropus													+	+				LC					0
Garrulus glandarius	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC					0
Hippolais icterina	+	+	+		+		+		+		+	+	+	+	+			LC	2		2		0.3
Jynx torquilla	+		+		+		+	+	+		+	+	+	+	+			LC	2			3	0.27
Lanius collurio							+											LC	3			2	0.23
Leiopicus medius		+	+		+				+			+	+	+	+	+		LC	2	1			0.4
Linaria cannabina	+											+	+	+	+			LC	2			2	0.33
Lophophanes cristatus																+		LC	2				0.2

Species	Model plots																Conservation status						
	LC	SP	ZP	FP	VP	OP	HC	YC	PP	LP	AP	BP	BF	VF	KF	RF	RB	IUCN	BC	R6	CMS	SPEC	MW
Loxia curvirostra															+	+		LC	2				0.2
Luscinia luscinia			+		+	+						+	+	+	+	+		LC	2		2		0.3
Motacilla alba							+				+							LC	2		2		0.3
Muscicapa striata	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+		LC	2		2	2	0.43
Oriolus oriolus	+				+		+	+	+		+	+	+	+	+	+		LC	2		2		0.3
Parus major	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	2				0.2
Passer domesticus										+	+							LC				3	0.07
Passer montanus					+							+						LC	3			3	0.17
Periparus ater	+						+	+				+	+	+	+			LC	2				0.2
Phoenicurus ochruros	+	+	+		+		+	+	+	+	+	+						LC	2		2		0.3
Phoenicurus phoenicurus		+			+			+	+		+							LC	2		2		0.3
Phylloscopus collybita	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+		LC	2		2		0.3
Phylloscopus sibilatrix	+	+	+	+	+	+			+	+	+	+	+	+	+	+		LC	2		2		0.3
Phylloscopus trochilus	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+		LC	2		2	3	0.37
Pica pica	+	+	+	+	+		+	+	+	+	+	+						LC					0
Picus canus		+	+	+	+	+			+		+	+	+	+	+	+		LC	2	1			0.4
Picus viridis					+									+		+	VU	LC	2				0.4
Poecile montanus		+	+		+	+		+	+			+	+	+	+	+		LC	2			3	0.27
Poecile palustris	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	2				0.2
Prunella modularis															+	+		LC	2				0.2
Regulus ignicapilla													+		+	+	NE	LC	2		2		0.35
Regulus regulus												+	+	+		+		LC	2			2	0.33
Serinus serinus	+				+		+	+	+		+							LC	2			2	0.33
Sitta europaea	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	2				0.2
Spinus spinus								+						+	+	+		LC	2				0.2
Streptopelia decaocto	+	+	+	+	+			+	+	+	+							LC	3				0.1
Streptopelia turtur												+	+	+	+			VU	3		2	1	0.4
Strix aluco				+	+				+			+	+	+	+			LC	2				0.2
Strix uralensis													+	+	+	+	UN	LC	2	1			0.5
Sturnus vulgaris	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC				3	0.07
Sylvia atricapilla	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	2		2		0.3
Sylvia borin					+		+					+	+	+				LC	2		2		0.3
Sylvia communis					+						+	+				+		LC	2		2		0.3
Sylvia curruca	+	+	+		+		+	+	+	+	+	+	+	+	+			LC	2		2		0.3
Tachybaptus ruficollis					+									+				LC	2		1,2		0.4
Troglodytes troglodytes	+	+	+		+		+	+	+		+	+	+	+	+	+		LC	2				0.2
Turdus merula	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	3		2		0.2
Turdus philomelos	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		LC	3		2		0.2
Turdus pilaris	+	+	+	+	+	+	+	+	+	+	+							LC	3		2		0.2
Upupa epops												+	+		+			LC	2				0.2

Notes. Model plots are signed as LC — Lychakiv cemetery, SP — Stryisky Park, ZP — Zalizna Voda Park and Snopkivsky Park, FP — Ivan Franko Park, VP — Vysokyi Zamok Park and Regional Landscape Park "Znesinnia", OP — John Paul II Park, HC — Holoskivske Cemetery, YC — Yaniv Cemetery, PP — Pogulianka Park, LP — Lychakiv park, AP — Sknyliv Park, BP — Bilogorshya Forest, BF — Briukhovychi forest, VF — Vynnyky forest, KF — Regional Landscape Park "Stilske Gorbogirya", RF — "Roztochya" Nature Reserve. Conservation statuses are signed as RB — National Red Book of Ukraine (RA — Rare, VU — Vulnerable, NE — Not Evaluated, UN — Undefined), IUCN — IUCN 3.1. Red List global status, BC — Bern Convention appendices, R6 — Resolution 6 of Bern Convention, CMS — Bonn Convention appendices, SPEC — SPEC status, MW — mean conservation weight value.

Примітки. Модельні ділянки відмічено як LC — Личаківське кладовище, SP — Стрийський парк, ZP — парк «Залізна вода» і Снопківський парк, FP — Парк імені Івана Франка, VP — Парк «Високий замок» та РЛП «Знесіння», OP — Парк імені Івана Павла II, HC — Голосківське кладовище, YC — Янівське кладовище, PP — лісопарк «Погулянка», LP — Личаківський парк, AP — Скнилівський парк, BP — лісопарк Білогорща, BF — Брюховицький лісовий масив, VF — Винниківський лісовий масив, KF — РЛП «Стільське Горбогір'я», RF — Природний заповідник «Розточчя». Охоронні статуси видів відмічено як RB — Червона книга України (RA — Рідкісний, VU — Вразливий, NE — Неоцінений, UN — Недостатньо відомий), IUCN — глобальний статус Червоного списку МСОП, BC — додатки Бернської конвенції, R6 — Резолюція №6 Бернської конвенції, CMS — додатки Боннської конвенції, SPEC — статус SPEC, MW — середня вага охоронних статусів виду.

Statistical analysis

Statistics were calculated in R 4.0.1. (R Core Team 2020) using the RStudio integrated development environment (1.3.959) and libraries xtable, usedist, rcompanion, ggpubr, gvlma, mblm. The map was designed in QGIS (Open Source Geospatial Foundation Project) using satellite imagery of Bing and Google Maps with postprocessing in FastStone Image Viewer (FastStone Soft).

Data were transformed for analyses to reduce dimensionality into eigenvectors. The status weights were used to reduce the transect densities for each species to weighted sums of densities.

The raw data were presented as a matrix of density values (pairs per transect, equivalent to a belt transect area of 500 m × 100 m = 5 ha) of species by transect. The density of a species on a transect was presumed to be equal to the maximum number of pairs observed during three consecutive counts. Before the data were transformed, they were presented as a matrix of density values d (pairs/5 ha) of the species s on the transect t, or $d_{s,\ t}$. In addition, each species had the defined status weight (one of six conservation statuses CS) w_{CS}. To calculate the weighted densities of species we transformed the initial matrix into six matrices with values of $d_{s,\ t}{\cdot}w_{CS}$. This action allowed us to summarise weighted densities for each transect taken as $\Sigma d_{s,\ t}{\cdot}w_{CS} = d_{1,\ t}{\cdot}w_{CS} + d_{2,\ t}{\cdot}w_{CS} + \ldots + d_{S,\ t}{\cdot}w_{CS}$ for S species registered on the transect. Thus, we received six values per transect that corresponded to each conservation status and were used in further statistical analysis.

The census data collected in previous studies (from 2012 to present) was also used to assess the species diversity on plots. These data were not used in statistical analysis, but instead were used in Table 2. This information can be essential because transect method implies ignoring all birds outside the transect, therefore we get relatively precise density data, but species list could be incomplete.

We used Shapiro-Wilk test to check the normality of raw data — vectors of weighted values. Also, to check a suitability of parametrical methods, we used this test to check the normality of residuals of ANOVA and linear model. Zone of degree of urbanization was used in ANOVA as a predictor. Although, a simple linear model needs a continuous predictor, and we used the natural logarithm of distance between the transect and city centre (49°50'22.8"N, 24°1'46.6"E) in this role. Linear models were also checked with global validation of linear model assumptions (Peña & Slate 2006) using gvlma in R. All of the above signified that parametrical methods could be used in limited cases in our data (Table 3 & 4).

Thereby, we used non-parametric analogous methods: Kruskal-Wallis test was used instead of ANOVA and Kendal-Theil Sen Siegel nonparametric linear regression instead of linear model.

Table 3. **Shapiro-Wilk tests of raw data vectors of weighted densities and residuals of ANOVA and linear models**
Таблиця 3. **Результати тесту Шапіро-Уілка для векторів вихідних значень зважених щільностей та залишків ANOVA й лінійних моделей**

Status weight	Raw vector		ANOVA residuals		Linear model residuals	
	W	p	W	p	W	p
RB	0.727	<0.001	0.917	<0.001	0.797	<0.001
BC	0.987	0.793	0.976	0.281	0.984	0.648
R6	0.940	0.006	0.954	0.025	0.957	0.037
R6-FA	0.779	<0.001	0.933	0.003	0.918	<0.001
CMS	0.971	0.173	0.979	0.424	0.983	0.589
SPEC	0.821	<0.001	0.902	<0.001	0.888	<0.001
MW	0.987	0.761	0.983	0.578	0.987	0.763
OD	0.955	0.028	0.961	0.058	0.974	0.237

Table 4. **Global validation of linear models' assumptions with a logarithm of distance from the city centre as a predictor**
Таблиця 4. **Глобальна валідація припущень лінійних моделей із логарифмованою дистанцією від центру міста в якості предиктора**

Validation	Dependent variable status weight							
	RB	BC	R6	R6-FA	CMS	SPEC	MW	OD
Global	−	+	+	+	+	−	+	+
Skewness	−	+	+	−	+	−	+	+
Kurtosis	−	+	+	+	+	−	+	+
Link function	+	+	+	+	+	+	+	+
Heteroscedasticity	−	+	+	+	+	−	+	+

Results

Primarily, the appropriateness of comparison of the logarithm of the distance from the centre with a zone of degree of urbanization has to be verified. Those logarithms are not distributed normally (W = 0.906, p < 0.001), so we checked this with Kruskal-Wallis test: KW $\chi^2 = 51.964$, $p < 0.001$. Therefore, we could use the logarithm of the distance from the city to assess the trend of weighted densities' changes throughout the urban gradient.

As it was mentioned above, not all raw vectors of weighted densities had a normal distribution neither residuals of parametrical models did. Thus, parametrical models are not acceptable for analysis of variations of weighted densities with weights of RB, R6, SPEC statuses used (Table 3).

Zone of degree of urbanization was not a good predictor of Red Book weighted density status in Kruskal-Wallis test (Table 5). Given that most "red-book" species in our data lacked any estimates of density (only 5 species' densities are known precisely: the stock dove *Columba oenas* L. and the Eurasian green woodpecker *Picus viridis* L. are Vulnerable, the white-backed woodpecker *Dendrocopos leucotos* (Bechstein) is Rare, the Ural owl *Strix uralensis* Pallas is Undefined, the common firecrest *Regulus ignicapilla* (Temminck) is Not Evaluated), we assumed that analysis of densities of those species would be inappropriate.

Table 5. **Results of Kruskal-Wallis test with a zone of degree of urbanization as a predictor and results of Kendal-Theil Sen Siegel nonparametric linear regression with a logarithm of distance from the centre as a predictor; weighted densities were used as a dependent variable in both models**

Таблиця 5. **Результати тесту Крускала-Валліса із зонами ступеню урбанізованості в якості предиктора та результати непараметричної лінійної регресії із логарифмованою дистанцією від центру міста в якості предиктора; зважені щільності були використані в якості залежної змінної в обох моделях**

Status weight	Kruskal-Wallis test		Nonparametric linear regression			
	KW χ^2	p-value	Intercept	Intercept p-value	Coefficient	Coefficient p-value
RB	9.333	0.025	0.000	0.609	0.000	0.003
BC	23.885	<0.001	38.865	<0.001	−4.133	<0.001
R6	16.852	<0.001	2.181	<0.001	0.000	0.098
R6-FA	4.108	0.250	0.000	<0.001	0.000	0.147
CMS	40.185	<0.001	14.981	<0.001	−2.855	<0.001
SPEC	16.017	0.001	1.206	<0.001	−0.299	<0.001
MW	26.515	<0.001	11.698	<0.001	−1.374	<0.001
OD	36.559	<0.001	58.035	<0.001	−9.402	<0.001

The sums of weighted densities of species listed in appendices of the Bern Convention were related significantly to zones of degree of urbanization. Nonparametric linear regression supported the trend of this relation (see Fig. 2, *b*): the closer to the city centre transect is, the higher weighted density is observed.

Some species listed in Resolution 6 of Bern Convention preferred distant plots from the city (such as the white-backed woodpecker, the red-breasted flycatcher *Ficedula parva* (Bechstein), and the Ural owl) and others were distributed evenly throughout all plots (the collared flycatcher *Ficedula albicollis* (Temminck), the middle spotted woodpecker *Leiopicus medius* (L.), and the gray-faced woodpecker *Picus canus* Gmelin). In the latter case, the even distribution can compensate for the variance in weighted densities, which makes this analysis uninformative: it concerns the collared flycatcher especially, as this species is frequent in forests of western Ukraine (Hnatyna 2017) (row "R6-FA" in Table 5 means weighted densities with the collared flycatcher density ignored). In both cases, the significance of variation of weighted densities of R6 species throughout the urban gradient is unclear. When the collared flycatcher densities are not ignored (row "R6"), variation of weighted densities in different zones of degree of urbanization can be seen without any visible trend (Fig. 2, *c*). Pairwise comparisons using Wilcoxon rank test (with Benjamini & Hochberg p-value adjustment method) showed that weighted densities are significantly different in zones of degree of urbanization of 2 and 3 (p = 0.001), 2 and 4 (p = 0.034), 1 and 2 (p = 0.034).

The negative coefficient of a nonparametric linear model with CMS statuses weights implied that the abundance of species protected by CMS was lower on transects in more native forests (Fig. 2, *d*).

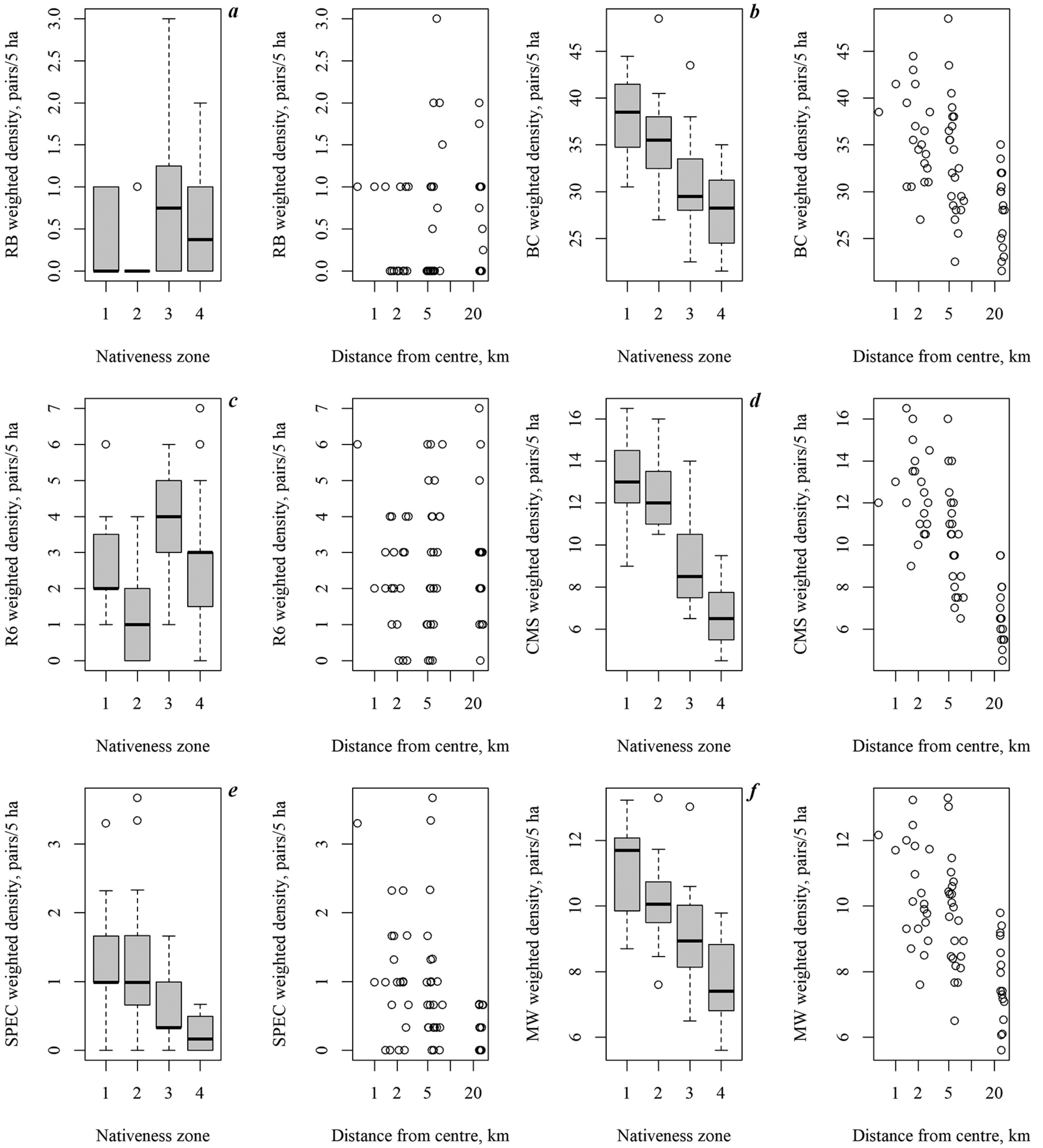

Fig. 2. Weighted densities of breeding birds relatively to the zone of degree of urbanization and distance from the centre of Lviv. Weights correspond to the following statuses: *a* — National Red Book of Ukraine, *b* — Bern Convention, *c* — Resolution 6 of the Bern Convention (*Ficedula albicollis* is not ignored), *d* — Bonn Convention, *e* — SPEC, *f* — mean weight of conservation statuses.

Рис. 2. Зважені щільності населення гніздових птахів відносно зони нативності лісової екосистеми і дистанції від центру міста. Ваги відповідають наступним статусам: *a* — Червона книга України, *b* — Бернська конвенція, *c* — Резолюція № 6 Бернської конвенції (із мухоловкою білошиєю), *d* — Боннська конвенція, *e* — SPEC, *f* — усереднена вага природоохоронних статусів.

Weighted density of SPEC species was significantly predicted by zones of degree of urbanization with a significant decline in more native forests (Fig. 2, *e*). Zone of degree of urbanization was a significant predictor of SPEC weighted densities between zones 1 and 4 ($p = 0.004$) and 2 and 4 ($p = 0.004$) (pairwise comparisons using Wilcoxon rank test).

The mean weight of conservation status can be described as an integral conservation value of a species. However, it gives the same value to all the conservation statuses we used, so it makes our formal approach to assess the rarity of species even more formal. As it was in previous cases, weighted densities significantly vary on different zones of degree of urbanization and the trend of this variance is to decrease in more native forests.

When the overall density of breeding birds is analysed (rows "OD" in Tables 3–5), it can be seen that all of the significant results above are the same as the trend of birds' overall density in urban gradient: the overall population of birds, irrespective of their taxa and their conservation status, is more dense in parks of the city than in native forests.

Correlation of weighted densities of those statuses that returned significant results with an overall density vector is also significant. Thus, Pearson correlation between BC weighted densities and overall densities is $R = 0.919$ ($p < 0.001$), between CMS weighted densities and overall densities is $R = 0.885$ ($p < 0.001$), between SPEC weighted densities and overall densities is $R = 0.927$ ($p < 0.001$).

Discussion

Our conclusion, in general, is that the density of rare species is lower outside the city, in native forests that belong to PAs. However, the density of breeding birds of all species was higher in urban parks than in native forest.

Such findings might be attributed to a difference in track lengths if we had used routes of different lengths. However, the study was designed to avoid such problems, so all of the study units used linear transects with equivalent areas and lengths. We assume that densities of breeding forest birds certainly depend on transect position, so that a higher density may be expected in urban parks more so than in native forest outside the city.

It is notable that the significant results returned by statistical models concerned those statuses that are commonly assigned to species. Weighted densities with weights of BC, CMS and SPEC statuses, whose negative regression coefficients were significant, correlated significantly with density of all species, which is obvious because they were derived from the last one. When we analysed weighted densities by the mean weight of status, there were not so many species that did not have any conservation status (see Table 2), so it is obvious that a big part of variance remains after data transformation and models return significant results.

It is assumed that species diversity and quantitative density can be higher in cities in the works of different authors. The species diversity cannot be discussed from the positions of our work to compare our results with others, additionally, more habitat types except forest ecosystems should be analyzed to make objective conclusions (Blair 1996). With regard to density, in general, it is thought that moderately built-up areas contain bird communities with higher densities (Tratalos *et al.* 2007). This fact can be explained by the additional food resources, local microclimate associated with urban habitats and invasion patterns of urbanized species (Møller *et al.* 2012). Higher densities of breeding birds have been previously documented in more urbanized areas. For example, bird abundance may increase across an urban gradient with a bimodal distribution and the highest abundance of invasive species in the most urbanized areas and the highest abundance of indigenous species in residential areas with high vegetation (Clergeau *et al.* 1998). An increase in overall bird density is a common phenomenon in central and north-western European cities (Tomiałojć 1998). Avifauna of eastern European cities, such as Lviv, shares this feature as evidenced by our findings, although the timing (when exactly this fact became true) is under question because of the lack of studies in this field.

The above mentioned touches the topic of the "luxury effect", but researches concerning this ecological effect are usually applied to the whole urban and non-urban habitat with a diversity of habitat types (Chamberlain *et al.* 2019). In contrast, we have studied only forest-like habitats, which explains the linearity of density changes in urban gradient.

Conclusions

Within the region of Lviv and its outskirts, the densities of forest breeding birds listed in the appendices of the Bern Convention on the Conservation of European Wildlife and Natural Habitats and the Bonn Convention on the Conservation of Migratory Species of Wild Animals, as well as of species with Species of European Conservation Concern status, exhibit a strong, positive relationship with a degree of urbanization of a forest. We were unable to assess species with statuses in the National Red Book of Ukraine and Resolution 6 of Bern Convention because of insufficient sample sizes for quantitative assessments.

Our approach, taking into account several conservation statuses of species, shows that species who are formally designated as rare species (i.e. species with many conservation statuses) are at higher densities in urban parks than in native forests.

We are not implying that protected areas serve no value, but our findings suggest that conservation management of forests within the Lviv region is ineffective for the conservation of rare forest breeding birds. More confidently, we assume that our results point at the general density patterns of breeding birds within urban gradients, at least for single forest-like habitat types. In terms of nature conservation, urban parks may play an essential role as valuable nature conservation sites, especially for the conservation of rare species. From the perspective of urban ecology, bird community density patterns are being affected by anthropogenic pressure, leading to a corresponding change in the density of rare species.

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References

Arcese, P., A. R. E. Sinclair. 1997. The role of protected areas as ecological baselines. *Journal of Wildlife Management*, **61** (3): 587–602. https://doi.org/10.2307/3802167

Beresford, A.E., G. M. Buchanan, P. F. Donald, S. H. M. Butchart, L. D. C. Fishpool, C. Rondinini. 2011. Poor overlap between the distribution of Protected Areas and globally threatened birds in Africa. *Animal Conservation*, **14** (2): 99–107. https://doi.org/10.1111/j.1469-1795.2010.00398.x

Bhagwat, S. A., C. G. Kushalappa, P. H. Williams, N. D. Brown. 2005. The role of informal protected areas in maintaining biodiversity in the Western Ghats of India. *Ecology and Society*, **10** (1): 1–40. https://doi.org/10.5751/ES-01285-100108

BirdLife International. 2017. European birds of conservation concern: populations, trends and national responsibilities. *BirdLife International*, Cambridge, 1–170.

Blair, R. B. 1996. Land use and avian species diversity along an urban gradient. *Ecological Applications*, **6** (2): 506–519. https://doi.org/10.2307/2269387

Burgess, N., W. Küper, J. Mutke, J. Brown, S. Westaway, S. Turpie, C. Meshack, J. Taplin, C. McClean, J. C. Lovett. 2005. Major gaps in the distribution of protected areas for threatened and narrow range Afrotropical plants. *Biodiversity and Conservation*, **14** (8): 1877–1894. https://doi.org/10.1007/s10531-004-1299-2

Burgess, N. D., C. Rahbek, F. W. Larsen, P. Williams, A. Balmford. 2002. How much of the vertebrate diversity of sub-Saharan Africa is catered for by recent conservation proposals? *Biological Conservation*, **107** (3): 327–339. https://doi.org/10.1016/S0006-3207(02)00071-X

Chamberlain, D. E., D. A. W. Henry, C. Reynolds, E. Caprio, A. Amar. 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. https://doi.org/10.1111/gcb.14682

Clergeau, P., J.-P. L. Savard, G. Mennechez, G. Falardeau. 1998. Bird abundance and diversity along an urban-rural gradient: a comparative study between two cities on different continents. *Condor*, **100** (3): 413–425. https://doi.org/10.2307/1369707

Gaston, K. J. 1994. *Rarity*. Chapman & Hall, London, 1–205.

Gorban, I., J. Tsaryk. 2012. Heterotrophic indicators of natural ecosystems state. *Visnyk of the Lviv University. Series Biology*, **58**: 209–220. [In Ukrainian]

Hnatyna, O. S. 2017. Report of the curator of the Data base of nests and clutches of the birds for 2016-2017. *Troglodytes. Proceedings of the West-Ukrainian Ornithological Society*, **8**: 113–118. [In Ukrainian]

Lopoukhine, N. 2008. Protected areas — for life's sake. In: L. Janishevski, K. Noonan-Mooney, S. B. Gidda, K. J. Mulongoy, comps. *Protected Areas of Today's World: Their Values and Benefits for the Welfare of the Planet*. Secretariat of the Convention on Biological Diversity, Montreal, 1–3.

Møller, A. P., M. Diaz, E. Flensted-Jensen, T. Grim, J. D. Ibáñez-Álamo, J. Jokimäki, R. Mänd, G. Markó, P. Tryjanowski. 2012. High urban population density of birds reflects their timing of urbanization. *Oecologia*, **170**: 867–875. https://doi.org/10.1007/s00442-012-2355-3

Peña, E. A., E. H. Slate. 2006. Global validation of linear model assumptions. *Journal of the American Statistical Association*, **101** (473): 341–354. https://dx.doi.org/10.1198%2F016214505000000637

Phillips, A. 2004. The history of the international system of protected area management categories. *International Journal for Protected Area Managers*, **14** (3): 4–14.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for statistical computing Vienna, Austria (https://www.R-project.org).

Rodrigues, A. S. L., S. J. Andelman, M. I. Bakarr, L. Boitani, T. M. Brooks, R. M. Cowling, L. D. C. Fishpool, G. A. B. da Fonseca, K. J. Gaston, M. Hoffman, J. S. Long, P. A. Marquet, J. D. Pilgrim, R. L. Pressey, J. Schipper, W. Sechrest, S. N. Stuart, L. G. Underhill, R. W. Waller, M. E. J. Watts, X. Yan. 2004. Effectiveness of the global protected area network in representing species diversity. *Nature*, **428**: 640–643. https://doi.org/10.1038/nature02422

Simberloff, D. 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biological Conservation **83** (3):247–257. https://doi.org/10.1016/S0006-3207(97)00081-5

Tomiałojć, L. 1998. Breeding densities in some urban versus non-urban habitats: the Dijon case. *Acta Ornithologica*, **33**: 159–171.

Tratalos, J., R. A. Fuller, K. L. Evans, R. G. Davies, S. Newson, J. J. D. Greenwood, K. J. Gaston. 2007. Bird densities are associated with household densities. *Global Change Biology*, **13** (8): 1685–1695. https://doi.org/10.1111/j.1365-2486.2007.01390.x

Zagorodniuk, I. 2008. Rare and valuable fauna and criteria of species rarity. *Proceedings of the Theriological School*, **9**: 7–20. [In Ukrainian]