BORNH Bulletin of Regional Natural History

Formerly Bollettino della Societá dei Naturalisti in Napoli

Analysis and Comparison of Breeding Bird Chorological Categories in Urban Areas through a Meta-Analysis of Ornithological Atlases of the Western Palearctic.

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DOI https://doi.org/10.6093/2724-4393/11765

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Financial Disclosure Statement: the Authors declare that no specific funding was received for this work

Competing interests: The Authors declare that they have no competing interests for this work.

Submitted: 21 November 2024
Revised: 17 February 2025
Accepted: 04 March 2025
Published: 16 April 2025

Associate Editor:
Giovanni Scillitani

Abstract

In the last decades of the 20th century and the early 21st century, significant research efforts have focused on urban bird species. As a result, a growing body of literature has emerged, including urban atlases, checklists, and comparative studies on urban and extra-urban bird communities.
This study examines the relative abundance of bird species categorized into different zoogeographical classes: Palearctic-Indomalayan, Palearctic-Paleotropical-Australasian, Holarctic, Palearctic-Paleotropical, Palearctic and Cosmopolitan breeding birds. We compared species frequency in 44 European cities, where ornithological atlases and checklists from urban areas are available, with the breeding avifauna of the surrounding Vast areas. The findings reveal an elevated frequency of species from the Palearctic-Indomalayan category in urban environments, whereas other zoogeographical groups do not exhibit this pattern. This increased presence persists over time, as confirmed by analyses of cities with repeated ornithological atlas assessments. A similar trend is also observed in North African and Middle Eastern cities where breeding bird checklists are available. This pattern is hypothesized to be linked to the extensive range characteristic of species within the Palearctic-Indomalayan category, which spans diverse biomes. This broad distribution may provide these species with a greater ability to colonize new environments, including urban landscapes.

Keywords: Urban birds**,** Palearctic-Indomalayan bird species, Urban Ornithological Atlases

Riassunto

Negli ultimi decenni del XX secolo e all'inizio del XXI secolo un notevole lavoro di ricerca è stato dedicato alle specie di uccelli urbani. Come conseguenza di ciò è stata prodotta anche una corposa letteratura in merito: atlanti urbani, check-list, ma anche studi che mettono a confronto le comunità di uccelli urbane ed extraurbane. In questo lavoro indaghiamo la frequenza delle specie di uccelli classificate in base alle categorie zoogeografiche. Abbiamo preso in considerazione gli uccelli nidificanti appartenenti alle categorie paleartico-indomalese, paleartico-paleotropicale-australasiatico, oloartica, paleartico-paleotropicale, paleartica e cosmopolita. Abbiamo confrontato la frequenza di ciascuna categoria in 44 città europee in cui sono stati pubblicati atlanti ornitologici e check-list, con la frequenza dell'avifauna nidificante delle aree vasti circostanti ciascuna città. È stata riscontrata una frequenza elevata della categoria paleartico-indomalesiano in contesti urbani, mentre le altre categorie zoogeografiche non mostrano questo fenomeno. Questa elevata frequenza persiste nel tempo, e ciò è stato convalidato attraverso le analisi ripetute degli atlanti ornitologici delle città coinvolte nello studio. Un fenomeno comparabile si è riscontrato anche nelle città nordafricane e mediorientali di cui sono disponibili check-list delle specie nidificanti. Si ipotizza che questa tendenza sia associata all'ampio areale che caratterizza le specie della categoria zoogeografica paleartico-indomalese, che è caratterizata da molti biomi di origine conferendo ad esse una maggiore capacità di colonizzare nuovi ambienti, come quelli urbani.

Parole chiave: Uccelli urbani, specie ornitiche del Paleartico-Indomalesiano, o Atlanti Ornitologici Urbani

Introduction

At the end of the 20th century and the beginning of the 21st century, there has been a notable expansion in the literature on urban avian species (Hedblom & Murgui 2017). One key area of research focuses on identifying differences and similarities between urban avifauna and that of the vast areas surrounding cities. The objective is to determine whether urban environments exert a 'filtering' effect that favors certain species or groups while disadvantaging others, and to explore the mechanisms underlying this process (Clergeau et al. 2001; Bonier et al. 2007; Croci et al. 2008; Møller 2009; Fraissinet & Fulgione 2008; Møller et al. 2012; Ferenc et al. 2013; 2018; Filloy et al. 2018).

Ecological and biogeographical analyses were made possible by conducting research on a large geographical scale and examining urban avifauna across multiple cities. Moreover, the investigated cities are situated at different latitudes and exposed to varying environmental and climatic conditions (Bonier et al. 2007; Fraissinet & Fulgione 2008; Evans et al. 2009; Luck & Smallbone 2011; Ferenc et al. 2013; Jokimäki et al. 2016; Jokimäki & Suhonen 2017; Chen & Wang 2017; Ferenc et al. 2018; Fattorini et al. 2018).

Two main aspects emerge from the literature review: the homogenization of urban avifauna (Bellocq et al. 2017; Chen & Wang 2017; Ferenc et al. 2018) and biogeographical changes, particularly the loss of both latitudinal and peninsular gradient effects on species richness (Jokimäki & Suhonen 2017; Ferenc et al. 2013; Fraissinet & Fulgione 2008).

A previous study by Fraissinet & Fulgione (2008) analyzed breeding avifauna checklists from 29 Italian urban ornithological atlases. Their research focused on differences in bird communities between urban areas and adjacent natural habitats, further contributing to the evidence of bird homogenization in urban environments. The study found a higher richness of Palearctic-Indomalayan species in the regions surrounding the analyzed urban areas.

This finding encouraged the production of new ornithological atlases and checklists on urban avifauna, particularly within Italy (Fraissinet 2023) and across Europe (Luniak 2017). Additionally, further research has highlighted how species with wide geographical distributions are more successful in colonizing urban environments (Bonier et al. 2007; Ferenc et al. 2018).

In the present study, we conduct a comprehensive investigation into the zoogeographical categories of breeding avifauna in Italian cities and selected cities within the western Palearctic region. Our aim is to determine whether certain groups of species have a greater ability to colonize urban environments. To achieve this, we performed a comparative analysis of the zoogeographical categories of breeding avifauna in urban areas and those in the surrounding vast areas. Furthermore, this study seeks to validate the observations made by Fraissinet & Fulgione (2008) by utilizing a more geographically extensive dataset.

Materials and Methods

Data Collection

A total of 44 cities with ornithological atlases and checklists were included in the present work. We analyzed the breeding avifauna lists from 25 Italian cities where ornithological atlases or comprehensive checklists of breeding species have been published. Some cities have multiple editions of ornithological atlases available, leading to a total of 37 datasets on Italian urban breeding avifauna. Additionally, we integrated the Italian dataset with records from 18 European cities, one North African city, and one Middle Eastern city where ornithological atlases or checklists have been published (see Figure 1). A complete list of works included in this study is available in Table 1.

Recognizing that multiple editions of ornithological atlases exist for certain European cities, our analysis includes a total of 23 urban bird datasets from outside Italy. All the cities included in the study are located within the Western Palearctic region. The collected data range from the publication by Adar (1982) for the city of Jerusalem to the most recent 2023 publication for the city of Caltanissetta (Nardo et al. 2023). The selection of ornithological atlases for bird lists was also driven by the need to focus on studies specifically centered on urban environments. Therefore, atlases encompassing both urban areas and regions of high naturalistic value were excluded, as the latter could influence the relative abundances of urban bird communities. Specific cases include the cities of Trento (LIPU 1998) in Italy and Bielefeld (Laske et al. 1991) in Germany. The only checklists used that were not derived from ornithological atlases were selected based on their alignment with urban fauna criteria established in ornithological atlases. Several cities – such as Udine, Cremona, Forlì, Florence, Pisa, Grosseto, Livorno, Naples, London, Brussels, Berlin, and Valencia – have had multiple editions of ornithological atlases published over time and were also included in the final dataset (Figure 1).

Urban and Extra-Urban Categorization

To categorize the data, we distinguished between urban and extra-urban areas. Urban areas (Level I) were identified according to the guidelines proposed by Dinetti et al. (1995). Briefly, urban areas are those where buildings and roads account for more than 50% of the land cover in a defined area. Extra-urban areas (Vast areas) were defined based on two levels of spatial extension: i) Level II: Areas extending up to 50,000 km² around each city; ii) Level III: Areas extending over 50,000 km² around each city.

The adoption of the ornithological atlas methodology facilitated comparisons with vast areas using consistent methodologies. For further details on the ornithological atlas method, refer to Keller et al. (2020) and Fraissinet (2023).

Zoogeographical Classification

Taxa were grouped according to a modified zoogeographical classification. The geographical distinctions regarding species origin were initially proposed by Newton (2003). Except for the Palearctic category, all other analyzed groups were derived from merging multiple regions, including Palearctic-Indomalayan, Afrotropical, Australasian, and Holarctic. The classification of individual species follows the fundamental Western Palearctic chorotypes defined by Brichetti & Gariboldi (1997) as:

Palearctic-Indomalayan: Species found in both the Palearctic and Indomalayan regions.

Palearctic-Paleotropical-Australasian: Species distributed across the Palearctic, Afrotropical, Eastern, and Australasian regions, typically restricted to southern areas of the Palearctic.

Holarctic: Species with distributions covering both the Nearctic and Palearctic regions, typically showing a Euro-Siberian distribution.

Palearctic: Species whose distribution aligns entirely with the Palearctic zoogeographical region.

Palearctic-Paleotropical: Species occurring in the Palearctic, Afrotropical, and Indomalayan regions, often restricted to southern areas of the Palearctic.

Cosmopolitan: Species found across all major zoogeographical regions, except for one (subcosmopolitan).

Detailed information regarding the global distribution of the chorotypes included in this study is presented in Figure 2.

Data Analysis

For each avifauna atlas, we calculated the

Figure 1. Location of the cities included in the study, arranged according to latitude

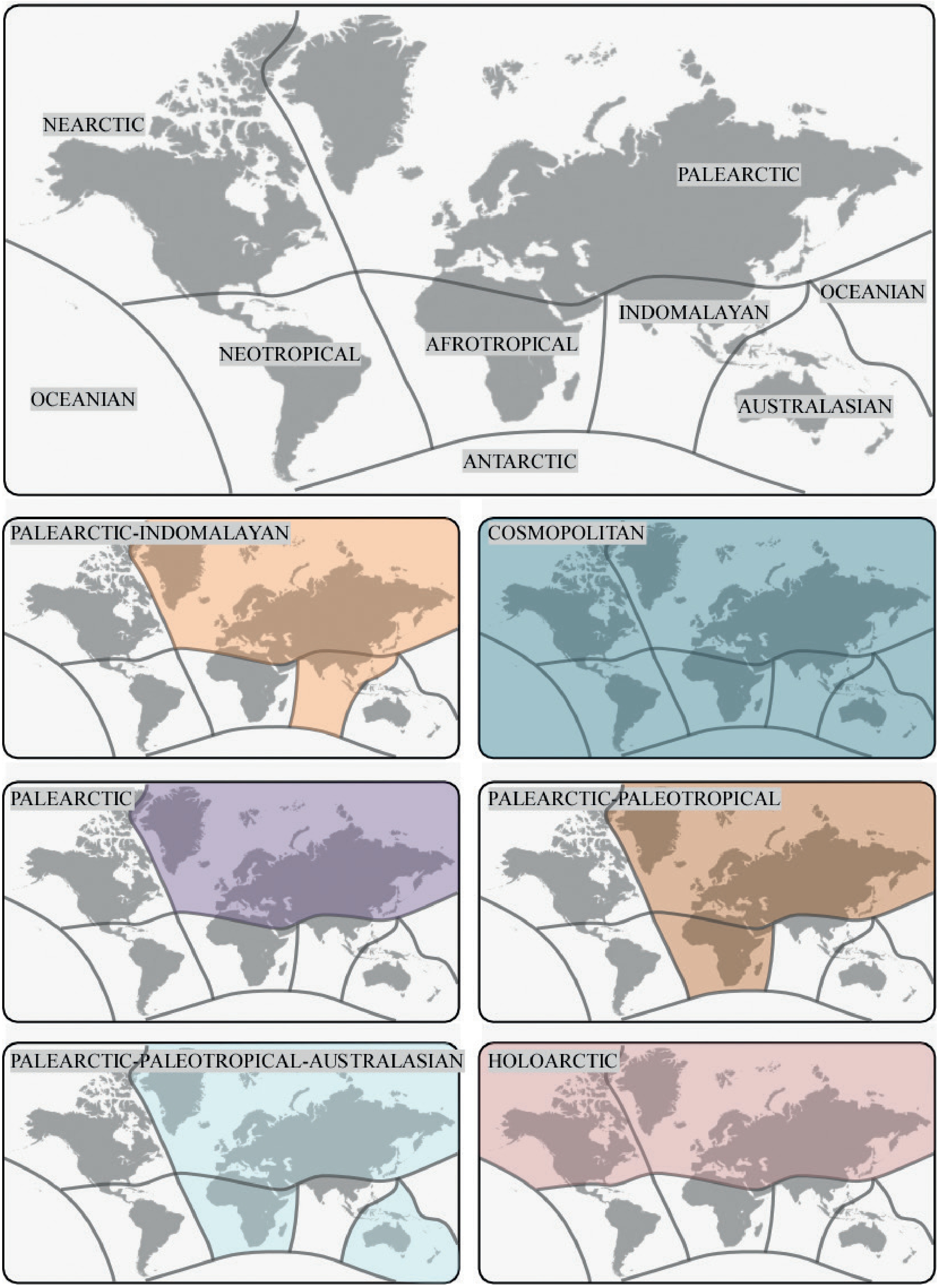

Figure 2. Maps of chorotypes included in the study according to Vigna Taglianti et al. (1992).

relative abundance of species categorized within the following chorological groups: Palearctic-Indomalayan, Palearctic-Paleotropical-Australasian, Holarctic, Palearctic-Paleotropical, Palearctic, and Cosmopolitan. To assess intrinsic variations in bird communities classified by zoogeographical origin, we conducted a Principal Component Analysis (PCA), using the relative abundance of each zoogeographical class as variables and cities and levels of extension as cases (Table 1). To confirm the exploratory analysis provided by PCA and to identify the factors most influencing changes in bird communities, we performed a PERMANOVA analysis, using zoogeographical origin as a variable and city and level of extension (Level I, II, and III) as fixed factors. Based on the results, we further analyzed the dataset at a multivariate level by conducting an additional PERMANOVA analysis with pairwise comparisons across different levels of extension. Multivariate data analysis was performed using Primer7. Percentage data were log-transformed prior to each analysis to mitigate heteroskedasticity issues.

Results

Table 1 presents the frequencies of species for each zoogeographical category in each city, compared with larger areas. Notably, only the Palearctic-Indomalayan category exhibits higher percentages in cities compared to vast areas.

The Principal Component Analysis (PCA) revealed that the relative abundance of birds from different zoogeographic categories varies according to the level of extension considered. Specifically, Palearctic (Pal), Palearctic-Indomalayan (PalIn), and Palearctic-Paleotropical (PalPal) species are more closely associated with cities that belong to Level I and Level II, which represent smaller extensions

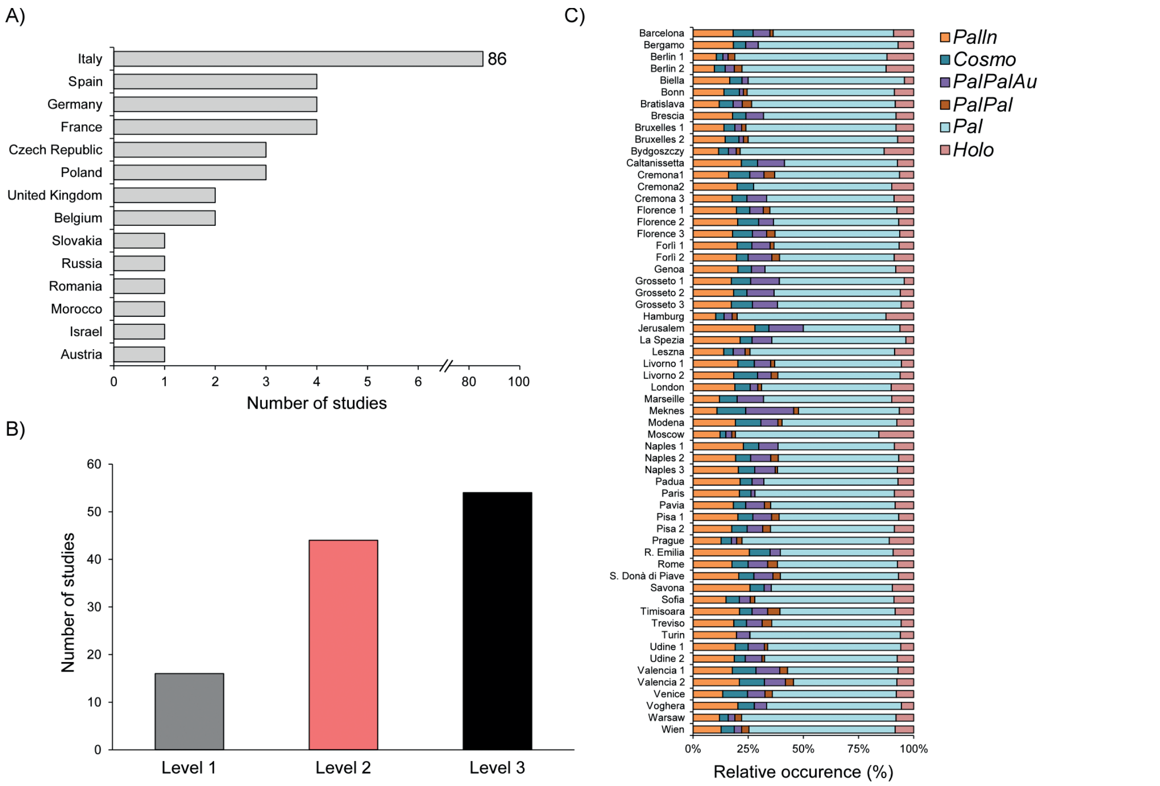

Figure 3. A) number of studies divided by country. B) number of studies divided by levels. C) Stacked bar plots on relative occurrence of PalIn, Cosmo, Pal, PalPal, PalPalAu, and Holo groups in each city included in the study.

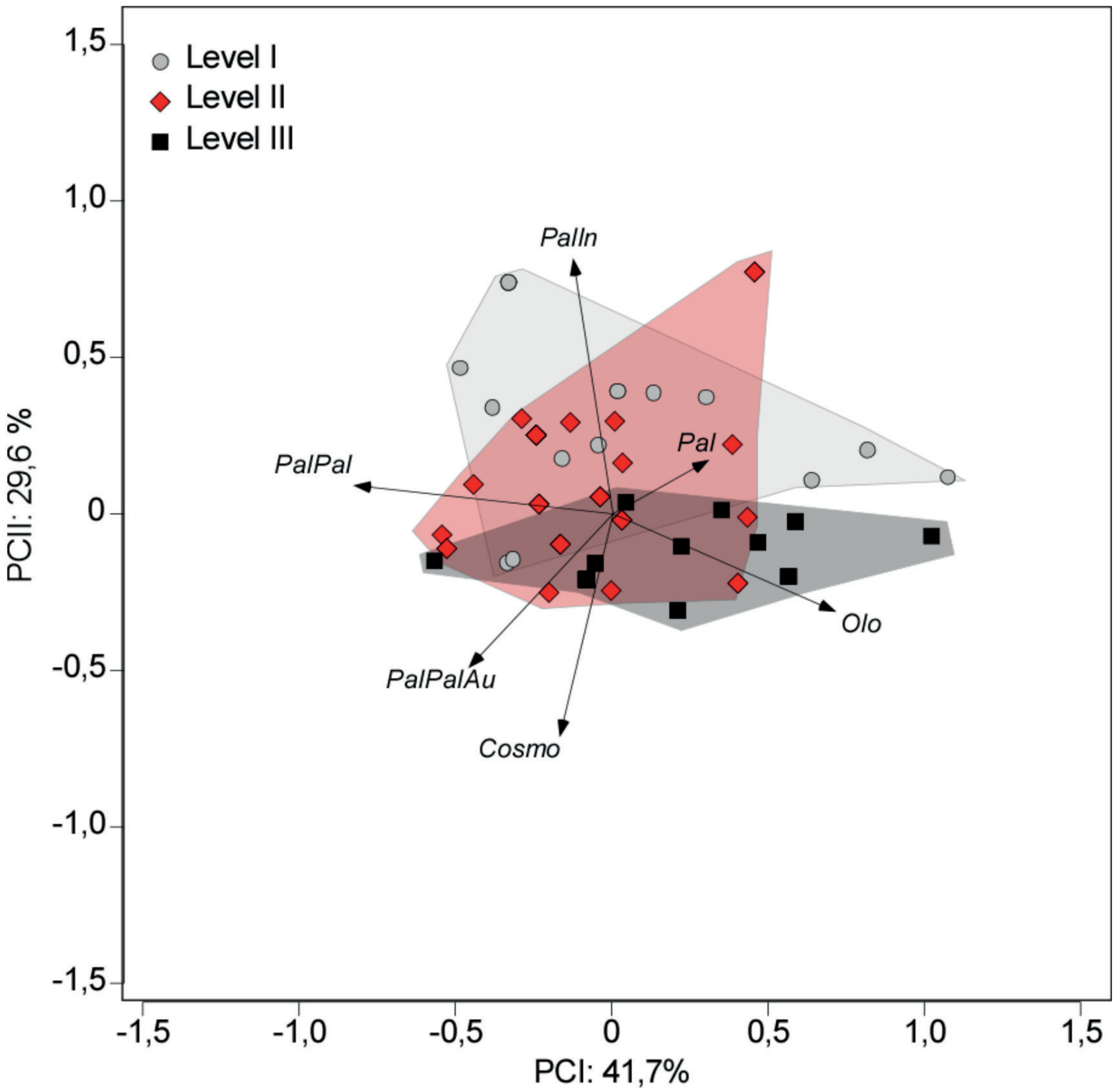

Figure 4. Principal component analysis of birds belonging to different zoogeographic categories in Europe. Different colors in legends refer to different extension of cities. Level I: urbanized areas, level II < 50,000 km^2, and level III > 50,000 km^2.

of vast areas. Conversely, the ordination in multidimensional space demonstrated that the segregation of Level III cities is primarily driven by the increased abundance of Cosmopolitan (Cosmo), Holarctic (Olo), and Palearctic-Paleotropical-Australasian (PalPalAu) species.

The findings from the PCA are further supported by the PERMANOVA analysis (Table 2 and Table 3), which confirms that the level of extension is the primary factor influencing changes in bird community composition based on zoogeographic origin (Pseudo-F: 16.6; P=0.001). However, city identity also plays a significant role in shaping bird community variations, albeit to a lesser extent (Pseudo-F: 1.82; P=0.003).

The analysis comparing different levels of extension revealed that bird communities in Level I cities show a greater differentiation from those in Level III compared to Level II.

Table 1. Frequencies of species for each zoogeographical category in individual cities and Vast areas. Bold font indicates the highest frequency value within each chorological category, level I reported as the name of the city. Refer to the text for the significance of the levels.

Cities	PalInd	Cosmo	PalPal	PalPalAu	Pal+Eur	Olo	Reference
Biella	**16.22**	5.41	2.7	0	**68.92**	4.05	Bordignon, 1999
Level II	9.52	5.29	**5.29**	3.17	59.79	**10.05**	Mingozzi et al. 1988
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Torino	**16.89**	5.19%	5.19	**5.19%**	58.44	5.19	Maffei et al. 2001
Level II	9.52	5.29	**5.29**	3.17	**59.79**	**5.29**	Mingozzi et al. 1988
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Savona	**22.86**	5.71	2.86	0	48.57	8.57	Galli e Spanò 2001
Level II	11.72	4.14	4.14	0.69	**60.69**	8.96	AA.VV. 1989
Level III	7.2	**7.5**	**5**	**3.57**	50.74	**9**	Baccetti et al. 2021
Genova	**17.24**	5.17	5.17	0	50	6.9	Borgo *et al.*, 2005
Level II	11.72	4.14	4.14	0.69	**60.69**	8.96	AA.VV. 1989
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
La Spezia	**20**	5	**8.33**	0	56.67	3.33	Dinetti 1996
Level II	11.72	4.14	4.14	0.69	**60.69**	8.96	AA.VV. 1989
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Cremona1	**19.51**	7.32	0	0	**60.98**	**9.76**	Groppali 1994
Level II	9.44	6.67	**5**	3.33	60	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	**5**	**3.57**	50.74	**9**	Baccetti et al. 2021
Cremona2	**16.67**	6.25	**8.33**	0	54.17	8.33	Groppali, 2004
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Cremona 3	**15.1**	**9**	**6**	**4.5**	52.9	6	Groppali 2015
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	7.5	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Voghera	**19.3**	**7.02**	**5.26**	0	57.89	5.26	Gatti 2011
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021

Pavia	**17.81**	5.48	**8.22**	2.74	54.79	8.22	Bernini et al. 1998
Level II	9.44	6.67	5	3.33	**60**	8.89	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Brescia	**17.31**	5.77	**7.69**	0	57.69	7.69	Ballerio & Brichetti 2003
Level II	9.44	6.67	5	3.33	**60**	**8.89**	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Bergamo	**16.88**	**5.19**	5.19	0	58.44	6.49	Cairo e Facoetti 2006
Level II	9.44	6.67	5	3.33	**60**	**8.89**	Brichetti & Fasola, 1990
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Padua	**20.69**	**5.17**	5.17	0	**58.62**	6.9	Bottazzo & Giacomini 2010
Level II	10	**8**	5	3	55.5	**10.5**	Fracasso et al, 2011
Level III	7.2	**7.5**	5	**3.57**	50.74	9	Baccetti et al. 2021
Treviso	**17.81**	5.48	**6.85**	**4.11**	**56.34**	5.48	Nardo & Mezzavilla 2017
Level II	10	**8**	5	3	55.5	**10.5**	Fracasso et al. 2011
Level III	7.2	**7.5**	5	3.57	50.74	9	Baccetti et al. 2021
S. Donà di Piave 1	**20.34**	6.78	**8.47**	3.39	52.54	6.78	Nardo 2003
Level II	10	**8**	5	3	**55.5**	**10.5**	Fracasso et al. 2011
Level III	7.2	7.5	5	**3.57**	50.74	9	Baccetti et al. 2021
S. Donà di Piave 2	**18.6**	**9.3**	2.3	2.3	**58.1**	6.9	Nardo et al. 2019
Level II	10	8	5	3	**55.5**	**10.5**	Fracasso et al. 2011
Level III	7.2	7.5	5	**3.57**	50.74	9	Baccetti et al. 2021
Venice	**12.77**	**10.64**	**7.45**	3.19	53.19	7.45	Bon & Stival 2013
Level II	10	8	5	3	**55.5**	**10.5**	Fracasso et al. 2011
Level III	7.2	7.5	5	**3.57**	50.74	9	Baccetti et al. 2021
Udine 1	**18.57**	5.71	**7.14**	1.43	**58.57**	5.71	Parodi 2008
Level II							
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021

Udine 2	**18**	4.8	**7.2**	1.2	**57.7**	7.2	Tringa FVG 2022
Level II							
Level III	7.2	**7.5**	5	**3.57**	50.74	**9**	Baccetti et al. 2021
Forlì 1	**19.35**	6.45	**8.06**	1.61	54.84	6.45	Ceccarelli et al. 2006
Level II	9.64	**8.12**	5.08	**4.06**	**55.33**	8.63	Bagni et al, 2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Forlì 2	**16.9**	4.6	**9.2**	3	44.6	7.6	Ceccarelli et al. 2020
Level II	9.64	**8.12**	5.08	**4.06**	**55.33**	8.63	Bagni et al. 2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Reggio Emilia	**24.44**	**8.89**	4.44	0	48.89	8.89	Gustin 2002
Level II	9.64	8.12	**5.08**	**4.06**	**55.33**	8.63	Bagni et al. 2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Modena	**18.87**	**11.32**	**7.55**	1.89	50.94	7.55	Fangarezzi et al. 1999
Level II	9.64	8.12	5.08	**4.06**	**55.33**	8.63	Bagni et al.2003
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Florence 1	**17.81**	5.48	5.48	2.74	52.05	6.85	Dinetti & Ascani 1990
Level II	10.43	4.91	**6.13**	**3.68**	**52.76**	7.97	Tellini et al., 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Florence 2	**18.29**	**8.54**	6.1	3.66	51.22	6.1	Dinetti &Romano 2002
Level II	10.43	4.91	**6.13**	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Florence 3	**16.28**	**8.14**	5.81	3.49	51.16	5.81	Dinetti 2009
Level II	10.43	**4.91**	**6.13**	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al., 2021
Livorno 1	**18.97**	**6.9**	6.9	1.72	**53.45**	5.17	Dinetti 1994
Level II	10.43	4.91	**6.13**	**3.68**	52.76	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021

Livorno 2	**16.44**	**9.59**	5.48	2.74	49.32	5.48	Dinetti et al… 2013
Level II	10.43	4.91	**6.13**	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Pisa 1	**19.05**	6.35	**7.94**	3.17	50.79	6.35	Dinetti 2003
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Pisa 2	**14.71%**	5.88%	5.88%	2.94%	47.06%	7.35%	Dinetti 2018
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Grosseto 1	**15.69**	**7.84**	**11.76**	0	50.98	3.92	Giovacchini 2001
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	7.5	5	3.57	50.74	**9**	Baccetti et al. 2021
Grosseto 2	**16.67**	**5.56**	**11.11**	0	51.86	5.56	Diaz 2011
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Grosseto 3	**15.2**	**8.4**	**10**	0	49	5	Giovacchini et al. 2021
Level II	10.43	4.91	6.13	**3.68**	**52.76**	7.97	Tellini et al. 1997
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Rome	**15.19**	6.33	**7.59**	**3.8**	46.84	6.33	Cignini & Zapparoli 1996
Level II	10.29	5.14	5.71	2.86	**52.57**	8	Brunelli et al, 2011
Level III	7.2	**7.5**	5	3.57	50.74	**9**	Baccetti et al. 2021
Naples 1	**20.63**	6.3	**7.9**	0	47.62	7.9	Fraissinet 1995
Level II	10.32	**7.74**	6.45	3.22	50.32	**9.03**	Fraissinet & Usai 2021
Level III	7.2	**7.5**	5	**3.57**	**50.74**	9	Baccetti et al. 2021
Naples2	**17**	6	**8**	3	48	6	Fraissinet 2006
Level II	10.32	**7.74**	6.45	3.22	50.32	**9.03**	Fraissinet & Usai, 2021
Level III	7.2	**7.5**	5	**3.57**	**50.74**	9	Baccetti et al. 2021

Naples 3	**18**	6.5	**8.1**	1	47.5	6.5	Fraissinet & Capasso 2020
Level II	10.32	**7.74**	6.45	3.22	50.32	**9.03**	Fraissinet & Usai 2021
Level III	7.2	**7.5**	5	**3.57**	**50.74**	9	Baccetti et al. 2021
Caltanissetta 1	**18.75**	6.25	**10.42**	0	43.75	6.25	Falci, pers. com.
Level II	10.38	**7.14**	8.44	3.2	44.8	8.44	AA.VV. 2008
Level III	7.2	**7.5**	5	**3.57**	**50.74**	**9**	Baccetti et al. 2021
Caltanissetta 2	**17.3**	7	7	0	48	7	Nardo et al. 2023
Level II	10.38	**7.14**	8.44	3.2	44.8	8.44	AA.VV. 2008
Level III	7.2	**7.5**	5	**3.57**	**50.74**	**9**	Baccetti et al. 2021
Warsaw	**12**	4	3	3	**70**	8	Luniak et al. 2001
Level II							
Level III	8.56	**5.86**	**3.15**	2.7	62.61	**15.32**	Tomialojc 1990
Leszna	**13.83**	4.26	**5.32**	2.13	**64.89**	8.51	Kuzniak 1996
Level II							
Level III	8.56	**5.86**	3.15	**2.7**	62.61	**15.32**	Tomialojc 1990
Bydgoszczy	**11.61**	4.46	**3.57**	1.79	**65.18**	13.39	Indykiewicz et al, 1997
Level II							
Level III	8.56	**5.86**	3.15	**2.7**	62.61	**15.32**	Tomialojc 1990
Berlin 1	**10.53**	3.01	2.26	**3.01**	**68.42**	12.03	Witt, 1985; Degen & Otto 1988
Level II							
Level III	7.05	**6.64**	**3.73**	2.49	58.51	**17.01**	Hagemeijer & Blair 1997
Berlin 2	**9.4**	4.7	**4.03**	**3.36**	**63.09**	12.08	Otto & Witt 2002
Level II							
Level III	7.05	**6.64**	3.73	2.49	58.51	**17.01**	Hagemeijer & Blair 1997
Hamburg	**10.22**	3.65	3.65	2.19	**66.42**	12.41	Mitschke & Baumung, 2001
Level II							
Level III	7.05	**6.64**	**3.73**	**2.49**	58.51	**17.01**	Hagemeijer & Blair 1997
Bonn	**13.45**	**6.72**	1.68	1.68	**63.87**	8.4	Kelcey & Rheinwald 2005
Level II							
Level III	7.05	6.64	**3.73**	**2.49**	58.51	**17.01**	Hagemeijer & Blair 1997

Moscow	**12.28**	2.63	**2.63**	1.75	**64.91**	15.79	Kalyakin & Voltzit 2006
Level II	9.6	**4.24**	2.42	**2.42**	64.85	**16.36**	Kalyakin & Voltzit 2006
Level III							
Prague	**12.7**	4.76	2.38	2.38	66.67	11.11	Fuchs et al. 2002
Level II	9.67	5.1	**3.8**	2.5	**67.05**	11.61	Ferenc, pers. com.
Level III	7.96	**6.19**	3.1	**3.1**	63.72	**12.83**	Ferenc, pers. com.
Bruxelles 1	**13.59**	4.85	2.91	1.94	**66.02**	7.77	Rabosée et al. 1995
Level II	6.81	**6.82**	**3.98**	**2.84**	59.66	**14.2**	Devillers et al. 1988
Level III							
Bruxelles 2	**13.59**	5.83	1.94	1.94	**63.11**	6.8	Weiserbs & Jacob 2007
Level II	6.81	**6.82**	**3.98**	**2.84**	59.66	**14.2**	Devillers et al.1988
Level III							
Paris	**19.67**	4.92	1.64	0	59.02	8.2	Malher 2010
Level II	16	6.7	**4.88**	**3.6**	**59.15**	10.98	Le Marechal & Lesaffre 2000
Level III	6.47	**7.19**	4.67	3.23	52.12	**13.3**	Yeatman-Berthelot, 1994
Marseille	**10**	6.67	10	0	48.33	8.33	Marchetti & Gallner 1976
Level II	7.82	8.69	**4.78**	**3.47**	**54.35**	10	Flitti et al. 2009
Level III	6.47	**7.19**	4.67	3.23	52.12	**13.3**	Yeatman-Berthelot 1994
Barcelona	**14.45**	7.22	**6.02**	1.2	43.34	7.22	Anton et al. 2017
Level II	7.48	**7.48**	5.28	**4.4**	48	8.81	Estrada et al. 2004
Level III	7.6	6.8	5.2	3.6	**48.8**	**10**	Purroy 1997
Valencia 1	**15.15**	**9.09**	**9.09**	3.03	42.42	6.06	Murgui, pers. Com.
Level II	9.04	7.97	6.91	**4.25**	41.48	6.91	Polo & Polo 2005
Level III	7.6	6.8	5.2	3.6	**48.8**	**10**	Purroy, 1997
Valencia 2	**16.9**	**9.2**	**7.6**	3	37.7	6.1	Murgui 2021
Level II	9.04	7.97	6.91	**4.25**	41.48	6.91	Polo & Polo 2005
Level III	7.6	6.8	5.2	3.6	**48.8**	**10**	Purroy 1997
Sofia	**14.15**	5.66	4.72	1.89	**59.43**	8.49	Iankov 1992
Level II							
Level III	7.6	**6.08**	**4.94**	**2.66**	57.79	**8.75**	Iankov 2007

Timisoara	**20.83**	5.56	**6.94**	**5.56**	51.39	8.33	Stanescu & Parvulescu 2008
Level II							
Level III	8.54	**7.32**	3.66	3.26	**59.34**	**10.57**	Hagemeijer & Blair 1997
London	**18.64**	**6.78**	**3.39**	**1.69**	**57.62**	10	Oliver 1997
Level II							
Level III	7.93	6.34	2.11	1.58	53.97	**20.1**	Gibbons et al.1993
Bratislava	**11.41**	**6.04**	**4.03**	**4.03**	62.42	8.05	Kelcey & Rheinwald 2005
Level II	8.22	5.48	3.2	3.2	**63.93**	**12.33**	Hagemeijer & Blair 1997
Level III							
Wien	**12.5**	5.8	3.3	**3.3**	**65**	8.3	Wichmann et al. 2009
Level II							
Level III	8.3	**6**	**3.7**	2.8	63.7	**11.6**	Craig 1994
Jerusalem	**18.75**	4.17	**10.42**	0	**29.17**	4.17	Adar 1982
Level II	8.85	**7.96**	7.08	**2.65**	22.12	**7.08**	The Israeli Birding Web Site
Level III							
Meknes	**9.09**	**10.91**	**18.18**	1.82	**38.18**	5.45	Franchimont pers.com.
Level II							
Level III	8.29	7.37	6.91	**4.15**	31.8	**6.91**	Thévenot et al. 2003

Table 2. Result of PERMANOVA (Perm. 999) analysis showing the significant difference according to zoogeographical categories of birds in Europe according to City and levels of extension. Significant differences for values of P < 0.01

	df	SS	MS	Pseudo-F	P(perm)
City	66	67.25	1.01	1.82	***0.003***
Levels	2	18.58	9.29	16.6	***0.001***
Residuals	45	25.19	0.56		
Total	113	116.37			

Table 3. Result of PERMANOVA (Perm. 999) analysis showing the significant difference for pairwise comparison between levels of extension according to changes in bird zoogeographical classification. Significant differences for values of P < 0.01

Pairwise comparison	t	P(perm)	perms
Level I vs Level II	2.26	***0.007***	999
Level I vs Level III	3.42	***0.001***	998
Level II vs Level III	5.24	***0.001***	999

Discussion:

Species belonging to the Palearctic-Indomalayan zoogeographical region show a higher frequency in urban areas compared to the vast areas they inhabit. This pattern persists despite biogeographical constraints such as latitude and longitude, encompassing species from mixed deciduous forests in temperate or cold climates as well as those from Mediterranean vegetation zones with a xeric climate. This finding aligns with existing literature highlighting the homogenizing effect of urban ecosystems on biodiversity, particularly within ornithological communities (Clergeau et al. 2006; Møller 2009; Fraissinet & Fulgione 2008; Ferenc et al. 2013; Ferenc et al. 2018).

Moreover, the frequency of Palearctic-Indomalayan species decreases as the surface area of vast areas increases (see Table 1). This suggests that the urban environment's influence weakens as the spatial scale expands, reducing its impact on bird communities in the surrounding regions. Additionally, this phenomenon appears to be temporally stable, as indicated by the consistently higher frequency of Palearctic-Indomalayan species in cities compared to vast areas, even when urban ornithological atlases have been updated over time (see Table 1).

The broad distribution of many Palearctic-Indomalayan species may be explained by their evolutionary adaptation to expansive geographic ranges, allowing them to thrive in diverse environmental conditions, withstand disturbances, and exploit new trophic niches. Urban environments often pose significant challenges for bird species, yet the plasticity of species in this zoogeographical category may have facilitated their successful colonization, unlike species with more restricted distributions or specialized ecological requirements (Møller 2009; Ferenc et al. 2013; Ferenc et al. 2018).

Interestingly, this adaptability contrasts with Cosmopolitan species, which, despite their widespread distribution, do not demonstrate the same success in urban colonization. It is well established that specialist species tend to decline along an urbanization gradient (Clergeau et al. 2006). However, some exceptions exist, such as the Peregrine falcon, a species specialized in rocky environments, which has successfully adapted to urban settings by using buildings as hunting grounds and nesting sites. This exception is largely due to the presence and high abundance of its primary prey, the Feral pigeon, a species that behaves as a generalist in trophic strategies.

The patterns observed in this study warrant further investigation, particularly by expanding the dataset to fill gaps in current observations. For example, it would be valuable to extend studies to Asian cities and regions outside the Palearctic to determine whether similar trends occur in other zoogeographical categories. Unfortunately, these regions remain underrepresented in research on this topic (Hedblom & Murgui 2017; Ferlini 2022). However, some studies from South America and China, despite not explicitly addressing zoogeographical categories, have reported similar homogenization trends (Belloq et al. 2017; Chen & Wang 2017).

Future research should also integrate geographical composition data, considering the types and number of habitats present in each city and how these factors influence different chorological species groups. Additionally, studies should assess the availability of resources and the presence of allochthonous species, both of which may significantly shape urban bird communities.

Acknowledgements

We thank Prof. Danilo Russo for the critical reading of the first manuscript, Claudio Labriola for the graphics of figure 1 and the anonymous referees for their valuable suggestions

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