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Avian assemblage along an urban gradient: diversity, abundance and richness

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Abstract Diversity in avian assemblages of urban (UR), peri-urban (PE) and rural (RU) areas was studied to explore variations in the avian community dynamics in rural – urban gradient. For this purpose, sampling was done from September 2013 to August 2015. A total of 35 sites, each covering an area of 300 m^2 were sampled by using point count method. At each site, randomly three points (minimally 5 m apart from each other) were selected to study the birds. According to data, species richness ($F_{2, 32}$=47.18, P<0.001) varied significantly along a rural-urban gradient. A significant difference in avian density per sampling site ($F_{2, 32}$=105.41, P<0.001) was also observed along urbanization gradient. In PE and RU areas, avian assemblages were more diverse than UR areas. Among avian guilds, omnivores were the most abundant in UR while insectivores in PE areas. Frugivores and carnivores were abundant in RU areas. Granivores were recorded in all habitats with similar diversity. A close association was recorded in bird density of RU and PE areas than UR areas. Bird species richness and diversity showed negative correlation with built area and positive correlation with vegetation cover in an area.

Keywords: avian guilds, species richness, abundance, avian diversity, habitat structure, urban (UR), peri-urban (PE), rural (RU)

Összefoglalás Három madárközösség, városi (UR), városhoz közeli (PE) és vidéki (RU) diverzitását és a dinamikáját tanulmányoztuk 2013. szeptember és 2015. augusztus között. Összesen 35, egyenként 300 m^2 területen számoltuk össze a madarakat és madárfajokat. Minden mintavételi terület további 50 m^2-es részekre lett felosztva. A fajgazdagság ($F_{2, 32}$= 47,18, P<0,001) jelentős változatosságot mutatott a vidéki-városi gradiens mentén. A mintaterületenkénti madársűrűség szignifikáns különbséget mutatott ($F_{2, 32}$= 105,41, P<0,01) a városiasodás mértéke mentén. A városhoz közeli és vidéki területek madárközössége változatosabb, mint a városi. Öt különböző madár-guildet azonosítottunk. A mindenevők voltak a leggyakoribbak a városban, míg a rovarevők nagy abundanciát mutattak a városhoz közeli területeken. A gyümölcsevők és a ragadozók a vidéki területeken voltak a leggyakoribbak. Szignifikáns összefüggés adódott a madársűrűség és az élőhely szerkezete között a vidéki és a városhoz közeli területek esetében, mind a klaszter analízis, mind a Sorensen hasonlósági koefficiens alapján. A fajgazdagság és diverzitás negatív összefüggést mutatott az épített területek arányával, de pozitívat a növényborítottsággal.

Kulcsszavak: madár guildek, fajgazdagság, faj abundancia, madár diverzitás, élőhelyszerkezet, városi, városhoz közeli, vidéki

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Introduction

Urbanization is considered as the leading force behind habitat fragmentation and degradation (Seress & Liker 2015, Leveau & Leveau 2016, Hensley 2018) but its consequences on avian biodiversity are studied only sparingly in Pakistan (Joshua & Ali 2011, Ali *et al.* 2013, Khan *et al.* 2014, Abbasi *et al.* 2015, Ali *et al.* 2016, Altaf *et al.* 2018). Urban expansion has impacted local avian species dynamics worldwide (Rottenborn 1999, Melles *et al.* 2003, White *et al.* 2005, Chace & Walsh 2006, Aronson *et al.* 2014, Peck *et al.* 2014).

Avian communities respond differently to urban development (Hostetler 2001, Lim & Sodhi 2004, Ortega-Álvarez & MacGregor-Fors 2009, Trammell & Bassett 2012). Their density increases and richness decrease as they approach the urban core. Omnivore fauna is almost similar in urban core throughout the world (McKinney 2008, Garaffa *et al.* 2009, Dallimer *et al.* 2012) and holds a few, very abundant species (Bellanthudawa *et al.* 2019). Urbanization also leads to a numerical increase in exotic species and decrease in native species (McKinney 2006, van Rensburg *et al.* 2009, Luck & Smallbone 2010, Sol *et al.* 2017). Relative contribution of introduced and native species influences the response patterns of the total avian fauna (Hansen & Urban 1992, Lim & Sodhi 2004, Villegas & Garitano-Zavala 2010).

Many studies reported that urbanization is decreasing the diversity of bird species due to loss of habitat. Fernandez-Juricic and Jokimäki (2001) reported that wooded trees in urban areas can increase landscape connectivity by increasing alternative foraging and nesting sites for birds in breeding season. Increased size of parks may enhance diversity and density of birds in urban habitats. The abundance of resident breeding birds is negatively affected by urban sprawl (van Rensburg *et al.* 2009). The work of van Rensburg *et al.* (2009) reported that the process of biotic homogenization increase in alien bird species in urban habitat. Parsons *et al.* (2006) documented that native vegetation in gardens of urban habitats positively influence the density of small birds. In Southeast Asia, heavy losses of native habitat resulted in 13-85% of decline in biodiversity in the region, including birds (Yap & Sodhi 2004, Peh 2010). However, in Pakistan a very little work has been done so far. Altaf *et al.* (2018) recorded avian diversity around river Chanab, Pakistan. They documented decrease in avian diversity from forest habitats to urban habitats. The study showed that bird diversity in urban habitat is related with anthropogenic activities and vegetation cover in the area. Joshua and Ali (2011) reported an increase in abundance of granivorous birds in densely populated areas of Lahore city that have pockets of vegetation Ali *et al.* (2013) reported that old residential areas of Islamabad city as main nesting and roosting sites of Feral Pigeons *(Columba livia domestica)*. The density of pigeons change with rooting and nesting sites and available food and water sources.

The aim of the study is to analyze the structure of residing and breeding bird community along urbanization gradient with an emphasis to explore effect of urbanization on avian assemblage. The following hypotheses were tested through this study.

1. How much species diversity and relative abundance of avifauna is similar in UR, PE and RU areas?
2. On what landscape components (viz., built area, small vegetation, bushes, woody structure and water bodies/watered soil) avian diversity depends along rural-urban gradient?

Material and methods

Study area

The present study was conducted in Gujranwala district (32.1877°N, 74.1945°E, 226 m asl) which is the 7th most populous district of Pakistan with a current human population exceeding over two million (Hussain *et al.* 2012, Minallah *et al.* 2016, Basit *et al.* 2018). Climatic conditions highly varied and temperatures above 45 °C was recorded in summer and close to or below freezing point during winter nights (Mehmood *et al.* 2017). It is located in the alluvial plains of Indus with the Chenab in north and the Ravi in the south covering an area of 3198 km^2. The study area (approximately 226 km^2) represents a mosaic of urban (49 km^2), peri-urban (30 km^2) and rural (147 km^2) areas.

Sampling strategy

Based on proportion of built area, the study area was divided into three zones i.e. urban (UR), peri-urban (PE) and rural (RU) following Marzluff and Ewing (2001), Clergeau *et al.* (2006) and McKinney (2002) using geographic information system (GIS) *(Figure 1)*. In

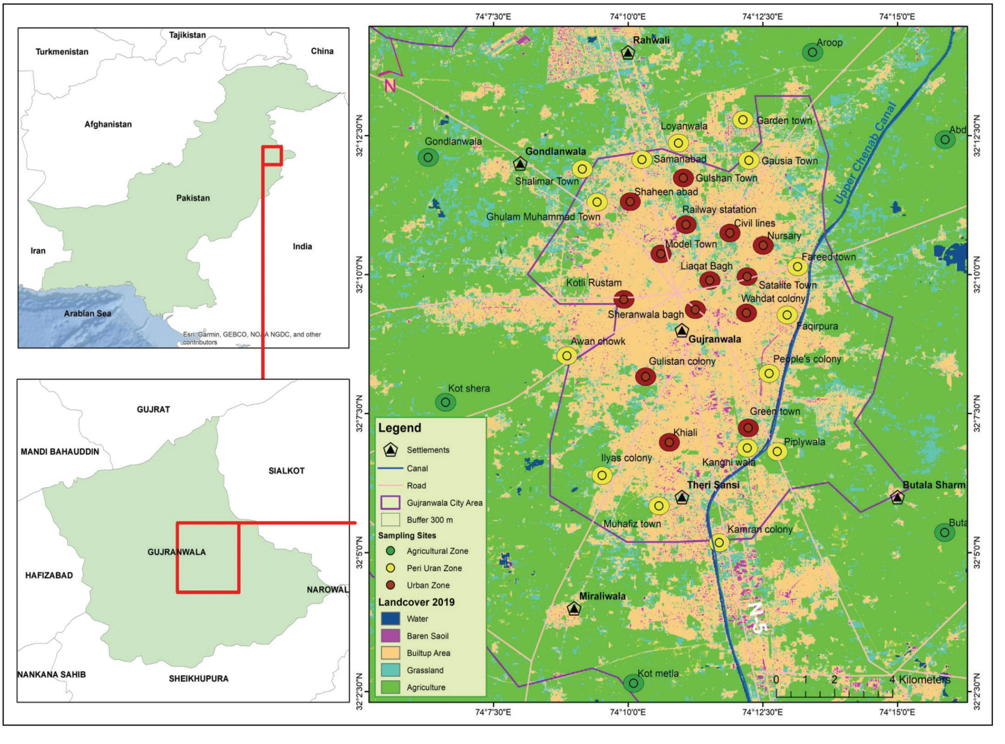

Figure 1. Location of sampling sites with land cover classes in different ecological zones along rural-urban gradient

1. ábra A mintavételi területek elhelyezkedése és felszínborítottságuk a különböző ökológiai zónákban each zone, different site each of 300 m^2, was selected to study the density and diversity of birds. At each site, the data of residential area, vegetation cover, and water bodies or watered soil was recorded using GIS (Anjum *et al.* 2016).

Avian diversity and density was recorded from all (UR, PE and RU) sites each month for a period of two years extending from September 2013 to August 2015. A total of 35 study sites were sampled once every month for 10 min. At each site, three points approximately 5 m apart from each other, were randomly selected for the survey of birds. Surveys were conducted in clear skies avoiding windy or rainy weather in evening (3–4 p.m., until sunset) to collect data of resident bird only. At each study point, birds present within 5 m radius on the grounds and on plantation were recorded. For this purpose, Olympus (10×50) binocular was also used to see birds present on the tree. High flying individuals were not recorded in the data. For identification Ali and Ripley (1983), Grimmett *et al.* (2016) and (Davidar *et al.* 1997) were used as ready reference.

Guild diversity

All avian species encountered during this study were classified into five guilds viz., granivores, frugivores, carnivores, insectivores and omnivores. Percentage share in the abundance of these guilds was calculated for each ecological zone (Jongman *et al.* 1995, Fraterrigo & Wiens 2005).

Data analysis

Relative abundance of bird species was used to determine basic ordinal scales of abundance (abundant > 7.0, common 5.1–7.0, frequent 2.1–5.0, uncommon 0.6–2.0 and rare 0.0–0.5) (Aynalem & Bekele 2008). Rarefaction curve was used to compare species diversity across habitat along the rural-urban gradient. The species richness and species abundance in three zones viz., UR, PE, and RU was plotted. The steeper curves indicated greater diversity in bird communities. The total number of species recorded for each site was considered as species richness due to equal effort of sampling at each site. For diversity, Shannon-Wiener index and for evenness, Pielou J index was calculated for each sampling site (Magurran 1988). Sorensen similarity index was applied to compare habitats on the bases of abundance data. One way ANOVA with Tukey post-hoc test was used to compare the abundance of birds in each area.

Cluster Analysis (UPGMA) was used to reveal the similarity in bird composition between different areas (Kent & Coker 1992). Canonical Correspondence analysis (CCA) revealed the association of bird species with different landscape classes along the rural urban gradient (Melles *et al.* 2003). For UPGMA and CCA, bird species that have relative abundance < 2.00 in overall abundance data per sampling site were not included in the analysis and considered as rare species.

Results

Diversity abundance and richness of the avian fauna of the three zones

To study avian diversity, 35 sites (14 UR, 15 PE and 6 RU) were sampled for two years *(Table 1, Figure 1)*. A total of 7891 birds belonging to 30 species were observed along the rural-urban gradient. Avian density was highest in RU than UR and PE areas ($F_{2, 32}$=21.41, P=0.001) *(Table 2)*. However, no difference was recorded in the bird density of UR and PE areas. Four abundant species viz., *Pycnonotus cafer*, *Corvus splendens*, *Acridotheres tristis*, and *Passer domesticus* accounted for 52.08% of total density *(Figure 2)*. The highest species richness was recorded in RU areas (30 species) followed by PE (24) and UR (14) areas. Out of thirty species, 14 were present in all three areas viz., UR, PE and RU but differ in their densities. Rarefaction accumulation cure of overall bird species showed sufficient sampling in all studied areas and significantly low richness in UR areas than PE and RU areas ($F_{2, 32}$=47.18, P=0.001) *(Figure 3)*. According to Sorensen coefficient UR and PE areas show 74%, PE and RU areas 85% and UR and RU areas 64% similarity in bird species. The avian diversity was highest in RU and lowest in UR areas ($F_{2, 32}$=32.57, P=0.001). Species evenness in UR and PE was significantly higher than RU areas ($F_{2, 32}$=10.15, P=0.001).

Avian community structure (guild)

A total of five feeding guilds of avian species were recorded in the data i.e., granivores, frugivores, insectivores, carnivores and omnivores. Among avian guilds, omnivores were the most abundant in UR while insectivores in PE areas. Frugivores and carnivores were abundant in RU areas. Granivores were recorded in all habitats with similar diversity. The highest percentage of carnivorous birds in RU areas indicated their association with the availability of a variety of insect prey items in croplands *(Figure 4)*.

Impact of landscape

The average composition of all the areas is given in *Table 3*. Results showed the highest percentage of the residential area in UR, low vegetation in RU and woody plants in PE. A slight difference in the percentage of shrub cover was observed in PE and RU. The highest percentage of water bodies was observed in RU.

A negative correlation of bird diversity and residential area (km^2) (R^2=0.38, $F_{1, 34}$=20.34, P<0.001) and positive correlation in bird diversity and small vegetation (R^2=0.44, $F_{1, 34}$=26.03, P<0.001) was recorded along rural urban gradient. However, species richness and diversity did not show any relationship with woody tree cover (km^2), bush cover and water bodies *(Figure 5)*.

Cluster analysis depicted that on the basis of species abundance, RU and PE areas showed a close relationship with each other than UR areas *(Figure 6)*. The canonical correspondence analysis (CCA) explained the association of dominant bird species with different components of landscape viz., residential area, Low vegetation cover, woody plants, shrubs

Table 1. Bird species richness (S) and abundance (N) for various study sites
1. táblázat Fajgazdagság (S) és abundancia (N) a különböző vizsgálati területeken

Site No.	Sites	Location of site	S	N
1	Civil lines	Urban Zone	14	204
2	Gulshan Town	Urban Zone	13	208
3	Model Town	Urban Zone	14	315
4	Nursary	Urban Zone	13	182
5	Railway station	Urban Zone	13	272
6	Satalite Town	Urban Zone	12	328
7	Sheranwala Bagh	Urban Zone	13	213
8	Liaqat Bagh	Urban Zone	11	140
9	Green town	Urban Zone	12	97
10	Kotli Rustam	Urban Zone	9	111
11	Khiali	Urban Zone	13	92
12	Shaheen abad	Urban Zone	14	136
13	Gulistan colony	Urban Zone	13	128
14	Wahdat colony	Urban Zone	12	262
15	Awan chowk	Peri-urban Zone	13	82
16	Loyanwala	Peri-urban Zone	16	102
17	Ghulam Muhammad Town	Peri-urban Zone	16	67
18	Gausia Town	Peri-urban Zone	10	52
19	Kangni wala	Peri-urban Zone	15	122
20	Piplywala	Peri-urban Zone	15	121
21	Ilyas colony	Peri-urban Zone	11	63
22	Kamran colony	Peri-urban Zone	12	75
23	Garden town	Peri-urban Zone	22	341
24	People's colony	Peri-urban Zone	18	352
25	Shalimar Town	Peri-urban Zone	20	251
26	Muhafiz Town	Peri-urban Zone	22	331
27	Fareed town	Peri-urban Zone	20	132
28	Faqirpura	Peri-urban Zone	15	139
29	Samanabad	Peri-urban Zone	14	129
30	Gondla wala	Agriculture Zone	24	325
31	Aroop	Agriculture Zone	26	443
32	Kot shera	Agriculture Zone	28	539
33	Butala sharm Singh	Agriculture Zone	28	669
34	Abdal	Agriculture Zone	23	382
35	Kotmetla	Agriculture Zone	26	425

Table 2. Ordinal scale of avian relative abundance per sampling site of study
2. táblázat A madarak relatív abundanciájának rangskálája az egyes mintavételi területeken UR – városi, PE – városhoz közeli, RU – vidéki

Bird species	UR/site	PE/site	RU/site	N	RA	Ordinal scale
Vanellus indicus	0	1	10	11	1.35	Uncommon
Columba livia	19	6	5	30	3.67	Frequent
Psittacula krameri	2	5	16	23	2.83	Frequent
Athene brama	0	0	2	2	0.28	Rare
Apus apus	0	2	3	5	0.64	Uncommon
Hylcyon smymensis	0	0	9	9	1.06	Uncommon
Upupa epops	0	1	0	1	0.18	Rare
Motacilla alba	6	7	28	41	5.01	Common
Coracina melaschistos	0	2	2	4	0.49	Rare
Pycnonotus cafer	12	12	43	67	8.25	Abundant
Dicrurus macrocercus	5	6	14	25	3.11	Frequent
Corvus splendens	48	17	30	95	11.66	Abundant
Acridotheres ginginianus	16	5	5	26	3.18	Frequent
Acridotheres tristis	15	20	86	121	14.83	Abundant
Passer domesticus	19	28	95	142	17.34	Abundant
Spilopelia senegalensis	6	11	15	32	3.88	Frequent
Milvus migrans	32	7	12	51	6.27	Common
Centropus sinensis	0	0	3	3	0.37	Rare
Cinnyris asiaticus	0	0	5	5	0.61	Uncommon
Bubulcus ibis	0	6	22	28	3.41	Frequent
Ardeola grayii	0	1	4	5	0.56	Uncommon
Streptopelia orientalis	0	1	4	5	0.64	Uncommon
Riparia riparia	4	7	6	17	2.07	Frequent
Cercomela fusca	0	1	10	11	1.33	Uncommon
Turdus merula	0	2	1	3	0.31	Rare
Turdoides striata	3	3	16	22	2.75	Frequent
Dinopium benghalense	0	0	2	2	0.27	Rare
Egretta garzetta	0	0	3	3	0.37	Rare
Merops orientalis	6	6	11	23	2.84	Uncommon
Gracupica contra	0	1	2	4	0.44	Rare
	192	**157**	**463**	**817**		

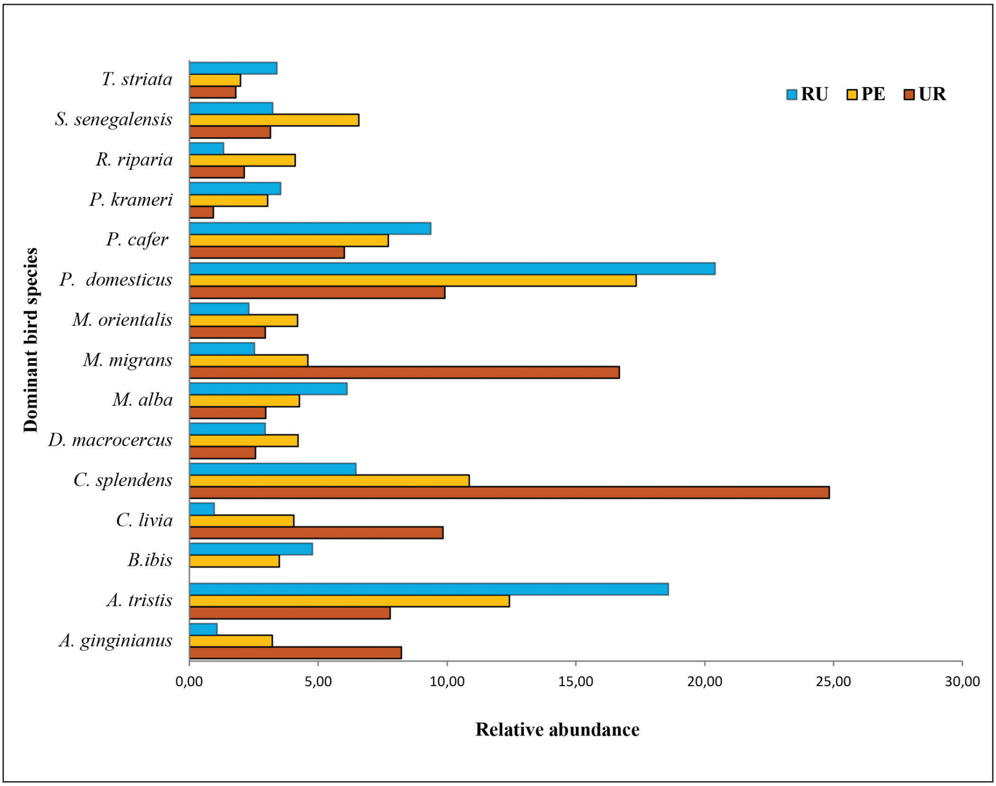

Figure 2. Variations in relative abundance per sampling site of bird species (excluding <2.00 of relative abundance) in different habitats along urban gradient

2. ábra A madárfajok relatív abundanciájának változatossága mintaterületenként a különböző élőhelyeken (a 2-nél kisebb relatív abundanciájú fajok kivételével). UR – városi, PE – városhoz közeli, RU – vidéki

Table 3. Landscape classification in 300 m^2 of circle area at each sampling site along rural-urban gradient

3. táblázat A területborítottság osztályozása a 300 m^2-es mintaterületeken. UR – városi, PE – városhoz közeli, RU – vidéki

Landscape classes	UR (n=14)			PE (n=15)			RU (n=6)		
	Av. Area (Km^2)	SD	Area %age (Km^2)	Av. Area (Km^2)	SD	Area %age (Km^2)	Av. Area Km^2)	SD	Area %age (Km^2)
Residential area	207.48	36.27	73.42	109.28	8.23	38.67	20.67	3.42	7.31
Low vegetation	45.59	24.42	16.13	85.82	14.94	30.37	217.43	6.07	76.94
Woody plants	5.94	4.79	2.10	19.03	14.63	6.73	4.45	1.20	1.57
Shrubs	22.25	17.10	7.87	59.56	20.10	21.08	34.50	4.39	12.21
Water body or Watered Soil	1.33	1.66	0.47	8.91	7.60	3.15	5.55	0.66	1.96

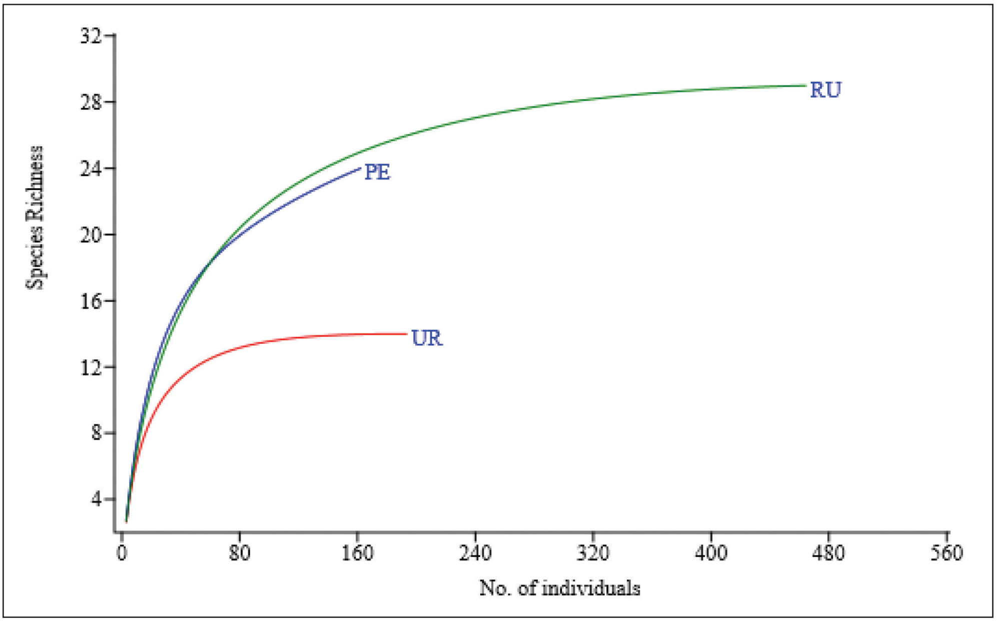

Figure 3. Rarefaction curve showing bird species richness along urban gradient on the basis of the number of individuals / sampling site

3. ábra A fajgazdagság ritkulási görbéje a mintavételi területek egyedszáma alapján. UR – városi, PE – városhoz közeli, RU – vidéki

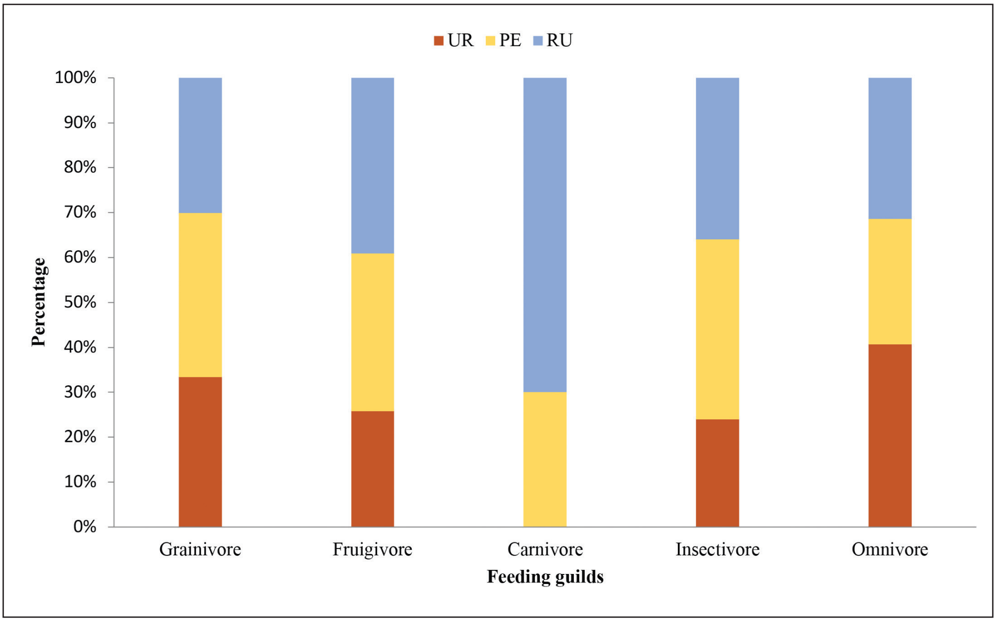

Figure 4. Percentage share of different feeding guilds of birds along urban gradient on overall data

4. ábra A különböző táplálkozási guildek százalékos megoszlása a teljes adatsor alapján. UR – városi, PE – városhoz közeli, RU – vidéki

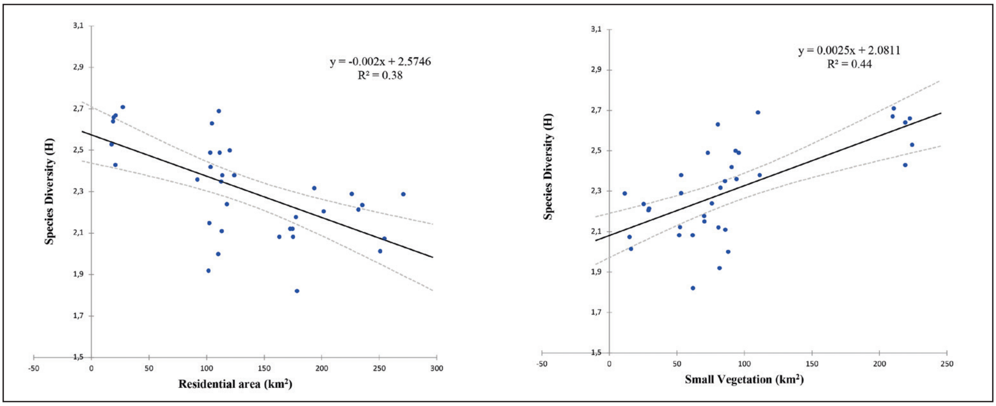

Figure 5. Regression model showing relationship between bird diversity and residential area and small vegetation

5. ábra Regressziós modellek illeszkedése a fajgazdagság és változatosság összefüggésére a különböző vegetáció borítottságú területekkel

and water bodies along a rural-urban gradient. The urban birds viz., *Columba livia domestica*, *Acridotheres ginginianus*, *Corvus splendens* and *Milvus migrans* showed association with residential areas. Three bird species viz., *Merops orientalis*, *Spilopelia senegalensis* and *Riparia riparia* showed a relationship with moderate residential area and woody plantation. Biplot depicted that *Psittacula krameri*, *Dicrurus macrocercus* and *Passer domesticus* showed relationship with shrubby and low vegetation cover. Low vegetation cover seemed to be a good habitat for bird species viz., *Pycnonotus cafer*, *Motacilla alba*, *Acridotheres tristis* and *Bubulcus ibis* with cropland habitat associated with water bodies *(Figure 7)*.

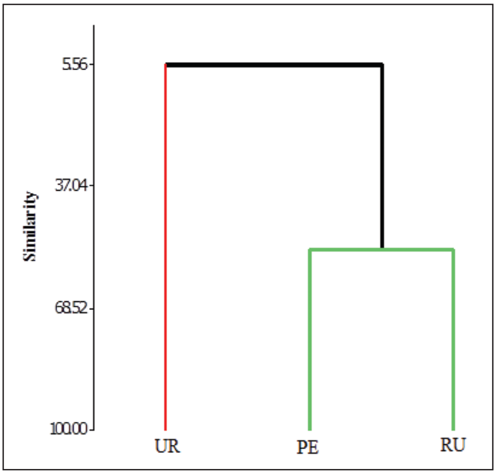

Figure 6. Dendrogram (UPGMA, average linkage between groups) based on Euclidean distances between sites showing UR, PE and RU clusters separately with respect to bird species diversity

6. ábra Euklidészi távolságon alapuló dendrogram a madarak fajgazdagsága közötti hasonlóság értékelésére. UR – városi, PE – városhoz közeli, RU – vidéki

Discussion

The present research supported our first hypothesis proposing significant variations in density along rural-urban gradient because of variable response of birds towards increasing urbanization. The density of common birds which can find food in anthropogenic resources was highest in UR than PE and RU areas (Beissinger & Osborne 1982). However, the bird diversity and richness was least in UR areas. Bird communities were evenly distributed in UR than

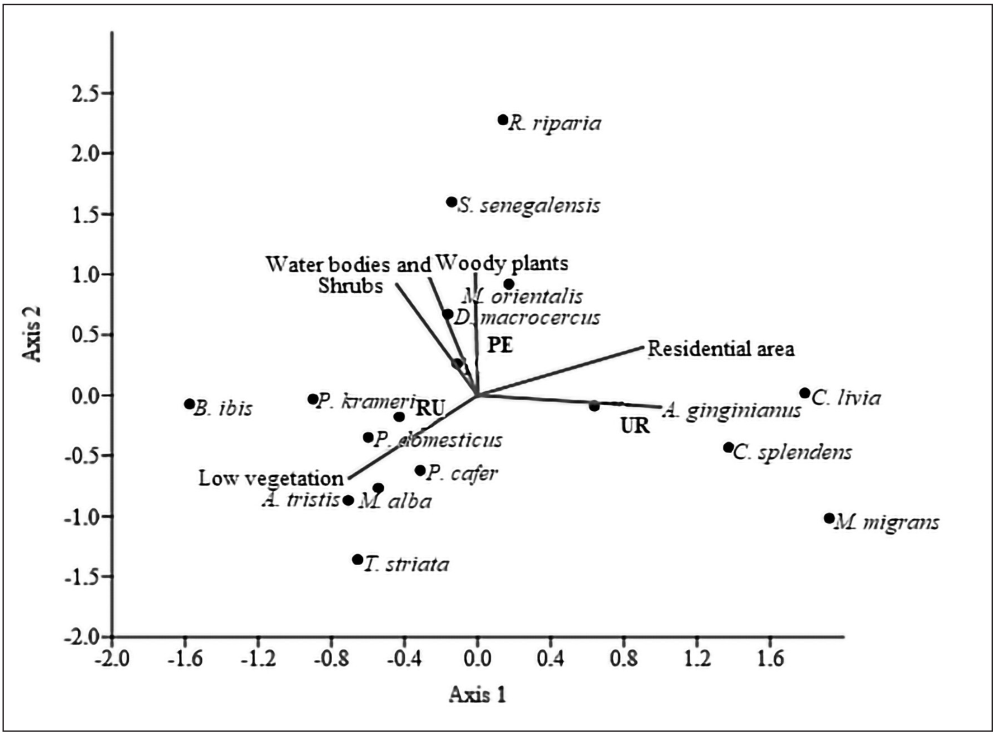

Figure 7. Triplot showing association of dominant bird species with different landscape class along rural- urban gradient

7. ábra A domináns madárfajok és a különböző vegetáció borítottságú területek összefüggése. UR – városi, PE – városhoz közeli, RU – vidéki

adjoining areas. These findings were in line with the study of Marzluff and Ewing (2001). Blair (2001) also supported the evidence that avian diversity and richness declined as developments proceeded along the rural-urban gradient. Diversity and richness of bird species also have shown a positive relationship with the diversity of trees and shrubs in all habitats.

The avian community structure showed variation along the rural-urban gradient. The analysis of the functional group illustrated resource based distribution of avian communities along a rural-urban gradient. The functional groups viz., frugivores and carnivores dominated in the rural areas which provide higher resource availability, e.g. trees and open areas as compared to urban areas. Rural communities were more evenly distributed as compared to urban areas, which had high dominance of omnivorous species like house crows and common myna. Whereas, urban areas corroborate more omnivore birds (Emlen 1974, Lancaster & Rees 1979, Beissinger & Osborne 1982, Mills *et al.* 1989, Kluza *et al.* 2000, Fraterrigo & Wiens 2005, Chace & Walsh 2006). Expectedly again, the percentages of omnivores abundances were found to be higher due to their close association with residential areas (Fraterrigo & Wiens 2005, Chiari *et al.* 2010).

The present study analyzed that avian community varied with variations in land cover classes viz., residential area, small vegetation, woody trees / bushes. Chace and Walsh

(2006) and Friesen (1998) analyzed impacts of urbanization on structure and composition of avifauna. The evidences supported that increasing structural complexity in habitat structure provided larger degrees of heterogeneity that enables birds to occupy more niches (Poulsen 2002, Machtans & Latour 2003, Loyola & Martins 2008, Shochat *et al.* 2010). The studies emphasized that *C. splendens* and *M. migrans* had shown association with UR and PE areas. These areas provided sufficient roosting and foraging sites due to natural and anthropogenic sources (Sergio *et al.* 2003). Many studies showed that these birds are attracted towards public and commercial buildings because of availability of food from anthropogenic source (Rajashekara & Venkatesha 2014, Manjula *et al.* 2015, Pattnaik *et al.* 2016, Katuwal *et al.* 2018). *A. ginginanus* primarily prefers farmland habitat that is adapted to urban habitat due to behaviorally flexible foraging habits (Kler 2009). The highest adaptability potential of *C. livia domestica* was observed among invasive urban bird species. This bird was primarily an inhabitant of cliffs while urban area cliffs of building structures provide a substitute of natural cliffs (Tiwary & Urfi 2016).

Nearly 50% of the avian population of PE was composed of just two bird species viz., *C. splendens* and *P. domesticus.* In this regard, urban adopters *(D. macrocercus, N. murina, M. orientalis)* were actually inhabitants of PE but had shown tendency to move towards UR. The present data depicted a strong association between *D. macrocercus* and *S. senegalensis* in PE. It is worth mentioning here that PE acts as a transitional zone which contains a mixed avian assemblage of both habitats of UR and RU (Dearborn & Kark 2010). Main roosting sites for *D. macrocercus* in urban area were electric wires, cables, lightning pools, and human source provide them a variety of food items (Sekercioglu 2012).

Species, such as *P. domesticus*, *A. tristis* and *P. cafer* represented 56% of avian assemblage associated with RU. Granivores get a maximum opportunity of grain food from agriculture habitat but have shown the tendency of adaptability towards UR. Peacock *et al.* (2007) reported that these birds has adaptability potential for UR because buildings can provide nesting/roosting sites and human resources provide a variety of food items. High density of *P. krameri* in maize and cereal crops in agriculture habitat has been reported (Khan *et al.* 2004). The high density and diversity of *B. ibis* was recorded near the water bodies (Changder *et al.* 2015).

This study showed response of birds to resource availability at various levels of urban development. It will help to explore the suitable conditions for wildlife in urban areas. In this connection, restoration of urban areas of vegetation will definitely help in conservation of avian fauna in urban habitat.

Conclusions

Avian assemblage has also shown pronounced variations in abundance and richness along the rural-urban gradient. It is noteworthy that the proportion of non-native species (urban exploiters) becomes more common towards the urban core. This research indicated that residential area provided roosting and nesting sites and organic waste as food from anthropogenic source to these birds. It could be inferred that human solid waste could be one of the major sources of attraction for urban birds. So, proper management of city solid waste material will be helpful in bringing back native bird species. Urban adapter birds mainly adapted to city outskirts where extensive re-vegetation facilitate the restoration of ecological succession. The present study provides public biodiversity education that could be effective in promoting an understanding of concept such as "ecological succession" and role of different landscape classification in promoting native avian diversity along a rural-urban gradient of Gujranwala city (Punjab: Pakistan).

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