Urban Forestry & Urban Greening 38 (2019) 84–96

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Diversity and structure of bird assemblages along urban-rural gradient in Kolkata, India

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ARTICLE INFO

Keywords:
Biotic homogenization
Bird assemblage
Guild
Kolkata
Species composition
Urban-rural gradient

ABSTRACT

This study examined the bird assemblages by comparing the bird species diversity, composition, guild structure, and habitat and height utilization along the urban-rural gradient. Birds were surveyed from January 2008 to December 2009 using fixed-radius point counts in 20 sampling points randomly selected within four different habitat. A total of 134 species were recorded from 160 point count sampling plots. Of all the species recorded, 37 (28%) were found in all habitats and 35 (26%) found exclusively in some of the habitats. Out of 35 exclusive species, 30 (22%) were found in rural and semi-rural habitat, 5 (4%) were found in urban parks, and no exclusive species were found in high-density residential habitat. The species and guild composition in rural natural sites showed dissimilar assemblages in comparison to other habitat types, for example, the decline of insectivorous birds in response to increasing urbanization. The observed differences in bird assemblages reflect the differential availability of resources along the urbanization gradient. The results of this study support to the hypothesis that avian species richness or diversity failing to respond to urbanization linearly, but instead peaks at a level of intermediate disturbance or development.

1. Introduction

Humanity is experiencing a dramatic shift to urban living (Grimm et al., 2008; Kowarik, 2011). The fraction of the world population that lived in urban areas was only 10% by 1990, which increased to 54% by 2014 (United Nations, 2007) and by 2050, 66% population of the world is projected to be urban (United Nations, 2014). Cities play a central role in changes in biodiversity, due to habitat fragmentation and exotic species, and changes in land use and cover on a global scale (Grimm et al., 2008; Kowarik, 2011).

Urbanization can increase the rates of extinction and loss of native species, leading to synurbization of local bird assemblages (François et al., 2008; Møller, 2009; Shochat et al., 2011; Jadczyk and Drzeniecka-Osiadacz, 2013; Ciach and Fröhlich, 2016) which can mean that the number of specialists reduce whereas more generalists are accommodated by the changes. This phenomenon has been observed in several studies throughout the world: Oceania (Sewell and Catterall, 1998; Hodgson et al., 2007), Asia (Kark et al., 2007), South America (Silva et al., 2016), North America (Emlen, 1974; Beissinger and Osborne, 1982; Ortega-Álvarez and MacGregor-Fors, 2009; Carbó-Ramírez and Zuria, 2011) and Europe (Sandström et al., 2006; François et al., 2008). In these studies, it was found that there is a marked increase in abundance of omnivores (and granivores and nectarivores in certain case in decreasing frequency in literature) as one proceeds from rural/peripheral landscape to a suburban/urban landscape, whereas the reverse trend has been observed for insectivores and carnivores. These feeding guilds therefore acts as proxies/indicators for classification into generalists or specialists, due to their plasticity and adaptability in feeding habit and their utilization of urban resources (McKinney, 2006). The term "generalists" are functionally quite interchangeable with "synanthropes" or "urbanophiles" or "urban adapters/exploiters" and "specialists" with "urbanophobes" or "urban avoiders/intolerant". But in one particular study, the urbanization gradient did not select against the insectivores (Evans et al., 2011) and in another, omnivores showed no higher preference for urban areas, but granivores and insectivores showed the expected pattern (Lim and Sodhi, 2004).

Urbanization is regarded as a threat to biodiversity and a cause of biotic homogenization (Kark et al., 2007; Kowarik, 2011; Seto et al., 2012) and because of the land-use change, alteration in ecosystem patterns and processes are expected (Ellis et al., 2012; Seto et al., 2012). Earlier studies on the effects of urbanization on bird assemblages indicated significant effects on species abundance, diversity, evenness,

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https://doi.org/10.1016/j.ufug.2018.11.005
Received 23 February 2018; Received in revised form 18 October 2018; Accepted 11 November 2018
Available online 30 November 2018
1618-8667/

richness, distribution, and community composition (McDonnell and Hahs, 2008; Suarez-Rubio and Thomlinson, 2009; Møller, 2009; Pautasso et al., 2011; McGill et al., 2015; Koparde and Raote, 2016). Many studies that have compared bird assemblages across urban-rural gradients suggest that species richness and diversity peak at intermediate levels of urbanization (Blair, 2001; Leveau and Leveau, 2005; Marzluff, 2005; McDonnell and Hahs, 2008; Lepczyk et al., 2008; Malavasi et al., 2009; Graham and Duda, 2011). However, there are many studies which shows other trends, most commonly - monotonic negative relationship between species richness/diversity and urbanization gradient (and rarely positive relationship), or no discernible change or pattern at all (Hohtola, 1978; Cam et al., 2000; Melles et al., 2003; Palomino and Carrascal, 2006; Sandström et al., 2006; van Heezik et al., 2008; Suarez-Rubio and Thomlinson, 2009; Ortega-Álvarez and MacGregor-Fors, 2009; Sanz and Caula, 2014; Koparde and Raote, 2016; Leveau et al., 2017). In an old review by Marzluff (2001) of bird studies along an urbanization gradient, it was found that it 61% of the studies, there was a monotonic decrease in species richness, whereas only one study (out of 51) clearly exhibited a peak at moderately disturbed sites. Chace and Walsh (2006) shows examples of mid-disturbance as well as other patterns in different habitat types. In a very recent meta-analysis, the pattern of decreasing species richness along the gradient stands out (Batáry et al., 2018).

Because urban areas often appear as a dense highly developed core surrounded by suburban and exurban developments, the gradient analysis is a powerful organizing tool for ecological research on urban influences on ecosystems (McDonnell and Pickett, 1990; Blair, 1999; Williams et al., 2005; Malkinson et al., 2018). Also, urbanization presents ecologists with a diverse spatial array to use in explaining or predicting environmental and ecological effects and provides an opportunity to examine the role of humans in shaping urban-rural gradients. However, few long-term studies have focused on bird assemblages across a gradient of landscapes, from undisturbed forest to urban landscapes.

In this study, the effects of urbanization on the bird assemblages along a gradient of increasing urbanization was examined in Kolkata by comparing the bird species composition, guild structure with the habitat and height utilization along the urban-rural gradient. Kolkata is a relevant case to study the effects of urbanization on tropical birds because it is highly populated, has a high degree of urban sprawl, and significant historical changes in land use and land cover. Urban development in Kolkata results in the conversion of rural habitats, such as forests, shrublands, grasslands, cultivated areas, and fishponds, into a built environment. Although the original bird assemblages have significantly been affected by these dramatic changes, no longterm study has monitored the effects of urban development on bird communities in Kolkata. The ideal situation to study the effects of urbanization on birds is comparing the bird communities before and after development (eg: Graber and Graber, 1963; Batten, 1972; Walcott, 1974; Xiao et al., 2016). However, most developed areas of Kolkata lack avian historical records. An alternative way to estimate the effects of urban development on birds is studying the changes of bird communities along the urbanization gradient. This approach has been followed in North America (e.g., Guthrie, 1974; Jones, 1981; Blair, 1996, 2001; Melles et al., 2003; Marzluff, 2005; Lepczyk et al., 2008; Ortega-Álvarez and MacGregor-Fors, 2009), South America (Leveau and Leveau, 2005; Sanz and Caula, 2014), Europe (e.g., Hohtola, 1978; Jokimäki and Suhonen, 1993; Palomino and Carrascal, 2006; Sandström et al., 2006) and Asia (Sengupta et al., 2013; Koparde and Raote, 2016).

The objectives of this work is to assess and draw broader conclusions about the following assumptions:

1) The relationship between species diversity and urbanization is non-linear and peaks around mid-region of the urban-rural gradient.
2) A decline in the number of specialist species will be observed as one moves from rural to urban sites, with a simultaneous increase in generalist species.

2. Material and methods

2.1. Study site

Kolkata is the capital of the Indian state of West Bengal and is the largest city in eastern India. This geographic region covers an area of 185 km^2 lying within 22.5726 °N and 88.3639 °E coordinates with a city population of 4.5 million and sub-urban population of 14.1 million (Kolkata Municipal Corporation Demographics, Census of India, 2011). The city lies linearly along banks of River Hooghly and subject to a tropical wet and dry climate. The annual mean temperature is 26.8 °C with May as hottest month (temperature ranging from 27 to 37 °C), January as coldest month (12–23 °C) and April-June experiences heavy rains and thunderstorm (Canty and Associates LLC, 2011).

Birds were studied along urbanization gradient in eight localities belonging to four different habitat types: (1) Rural-natural vegetation, consisting of secondary forest and shrubland, characterized by no buildings and low human disturbances, (2) Semi-rural vegetation, areas between the rural and urbanized area, (3) Urban parks characterized by cultivated vegetation and various recreational facilities, (4) High-density residential areas characterized by multistory buildings, more than 80% cover of artificial surfaces, few trees with little or no understory, heavy traffic and high human disturbances (Table 1).

2.2. Field sampling

Birds were surveyed using (25 m) fixed-radius point count method (Hutto et al., 1986) in 20 sampling points randomly selected within each sampling location that belongs to each habitat, resulting in a total of 160 sample points for two years. To prevent overlapping of observations, the distance between survey points (sites) was set to at least 200 m. All individuals of bird species seen or heard were recorded within 10 min at every point. Although it is possible that differences in detectability of birds among habitats might contribute to some of the patterns documented in this study, it is unlikely that detectability differences had a significant effect. Most birds were detected in point counts by their vocalizations. It is unlikely that substantial observer error occurred for identification of vocalizations occurred among habitats.

Every point was visited twelve times each year during clear days with little or no wind. All birds seen were identified and, their flock sizes, height above ground, food consumption and activity were recorded. Double counting was prevented by noting the direction of movement of birds and flock size.

Sampling effort was estimated for each of the 8 locations belonging to 4 habitat types using a sample-based rarefaction curve. The expected species accumulation curve for each location was calculated using the Sobs (Mao Tau) estimator in the software Estimate S 7.5 (Colwell, 2005). It was found that seven of the eight sites reached saturation with a minimal slope lower or equal to 0.04. To avoid bias for survey efforts, the sampled richness was standardized for all the sites to the richness estimated at the minimal slope.

2.3. Data analysis

Due to the difficulty in detection of species assemblages in the study area, and the corresponding unreliable nature of species numbers as descriptors of diversity (Gotelli and Colwell, 2001), Fisher's alpha of the log series was used as a measure of total diversity, calculated using EstimateS 7.5 (Colwell, 2005). One way ANOVA was used to compare the diversity indices of birds among habitats. Equitability was determined by the equation, $J = H/\ln S$ (where H = Shannon's Diversity Index and S = total number of species in the community). These indices were used to test the interemediate-disturbance hypothesis. Higher the

Table 1
A brief description of eight study locations belongs to four habitat types.

Habitat	Localities	Brief description
High-density residential Characterized by multi-story buildings, more than 80% cover of artificial surfaces, few trees with little or no understory, heavy traffic and high human disturbances.	Salt Lake residential	Redeveloped from a resettlement area. Recently landscaped residential streetscapes were lacking mature trees occurring in new housing estates characterized by limited planting and structural diversity. Native and exotic vegetation observed.
	Ballygunge residential	Located in densely populated residential part of central Kolkata. Established residential streetscapes with indigenous and exotic trees. In between the roads, open stretches have grasses which are kept short by constant grazing of cattle.
Urban parks: Characterized by cultivated vegetation and various recreational facilities.	Banobitan Central Park	This sprawling park has lots of trees, some open spaces, wetlands, and manicured garden. There are many ornamental, and fruiting trees present and some of them are quite old. Water bodies are mostly covered with water hyacinth. The nursery present here is well tended and location wise remains undisturbed.
	Rabindra Sarovar (Lake gardens)	This artificial wetland area is surrounded by groves of trees. There are some treecovered islands. The water surface is free of any emergent vegetation; however, some parts covered with lotus, *Nelumbo nucifera*.
Semi-rural: Areas between the rural and urbanized area.	Panchasayar (Garia)	The area has wetlands and fairly dense planted areas with good ground cover, but a lot of buildings are coming up, decreasing the area of vegetation. Some wetlands are leased for an intensive fishery. Still, Typha bed remains persisted to grow naturally.
	Nature Park (Brace-Bridge)	Comprises mixture of natural and planted vegetation developed around networks of natural and planted vegetation which is under intensive fish culture; so most of the water body is devoid of any vegetation, either floating submerged or emergent. There are embankments crisscrossing the whole area, which have dense plantation of trees
Rural natural: Characterised by secondary forest and shrubland, characterized by no buildings and low human disturbances.	Chintamoni Kar Bird Sanctuary (Narendrapur)	Seventeen acres of the area comprising mainly of mango trees (*Mangifera indica*) with dense vegetation undergrowth. Other fruiting trees include *Artocarpus heterophyllus*, *Syzygium cumini*, etc.
	Birla Park (Budge Budge)	The area consists of villages with dense orchards, a mixture of natural and planted vegetation, open croplands, and ponds of different sizes. There are several bamboo undergrowths present with highly dense shrubs and herbs.

value for these indices for a specific habitat, higher the diversity or equitability.

Diversity was understood by comparing representation of different species and different guilds (functional diversity) along the gradient (as illustrated in Magurran, 1988). Guilds are groups based on the specialization or non-specialization of different behaviours/activities to exploit different resources; regardless of their taxonomic relationship; over spatial and temporal scales; notably to reduce competition (Hawkins and MacMahon (1989); Ranawana and Bambaradeniya, 1998; Wilson, 1999). Guild-wise classification was similar to the one followed by Prajapati and Prajapati (2013), but condensed to reflect only the feeding habits. Species were divided into “generalists” and “specialist” species based on their ecological niche/niche breadth (Ducatez et al., 2015). This means that species exploiting a larger amount of resources in multiple habitats were classified as generalists whereas those restricted to the certain habitats and feeding habits were classified as specialists. Species were also divided as per their residency/migratory status into “resident”, “winter visitor”, “local migrant”, “passage migrant”, “rare vagrant”, and “summer visitor” (Ali and Ripley, 1983; Grimett et al. (2014).

The similarity across sites was depicted as Bray-Curtis similarities (Krebs, 1989), using both species and guild composition. Multidimensional scaling (MDS) plots were constructed based upon similarity values of species composition across habitat types in program PRIMER (Clarke and Gorley, 2001). Analysis of similarities (ANOSIM – Clarke, 1993) was performed between each pair of habitat types to detect any significant differences between the bird assemblages in the four main habitat types. The data were fourth-root transformed before analysis to reduce the weight of common species (Clarke and Warwick, 1994). ANOSIM was interpreted to figure out the guild-wise composition of assemblages so as to discern the generalists and the specialists.

The ANOSIM procedure of PRIMER is a nonparametric permutation procedure applied to rank similarity matrices underlying sample ordinations (Clarke, 1993). This method generates a global *R*-statistic, which is a measure of the distance between groups. An *R*-value that approaches one indicates strongly distinct assemblages, whereas, towards zero, the assemblages are barely separable (Clarke, 1993). Where ANOSIM revealed significant differences between groups, Similarity percentages (SIMPER) analyses (in PRIMER) were used to identify those species that contributed most to the observed assemblage differences (Clarke and Gorley, 2001). SIMPER allowed identification of species and guild important in discriminating between groups that differed significantly from each other. Cumulative contributions were cut arbitrarily at 50%. The species with the highest dissimilarity to standard deviation ratios were identified as good discriminators for each comparison (Clarke, 1993).

3. Results

3.1. Local diversity and guild

A total of 58,784 individuals of 134 species were recorded in this study (Appendix A). The pooled species accumulation curve for this study reached an asymptote for both Chao1 and Jacknife2, indicating that sampling was almost complete at the regional level. Therefore, the current study paints a comprehensive picture of the species diversity and composition along the urban-rural gradient.

Most of the bird species were residents (46%), followed by winter visitor (28%), local migrant (15%), passage migrant (4%), rare vagrant (4%), and summer visitors (3%). Resident species (86% of all individuals) dominated the bird assemblage in semi-rural and rural natural habitat (72%) compared to urban parks and high-density residential habitat (52%). Although winter visitors constituted 28% of all species, they accounted for less than 8% of the individuals (Figs. 1 and 2). There was an increase in abundance in winter months (November to February) in three habitats, except high-density residential habitat

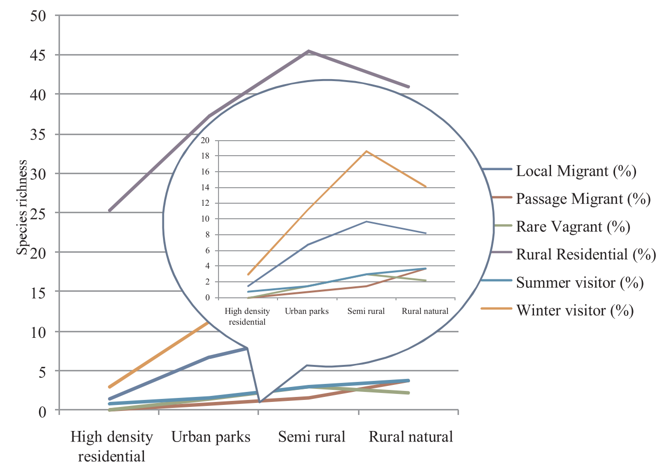

Fig. 1. Status of species richness along the urbanization gradient in four habitat types.

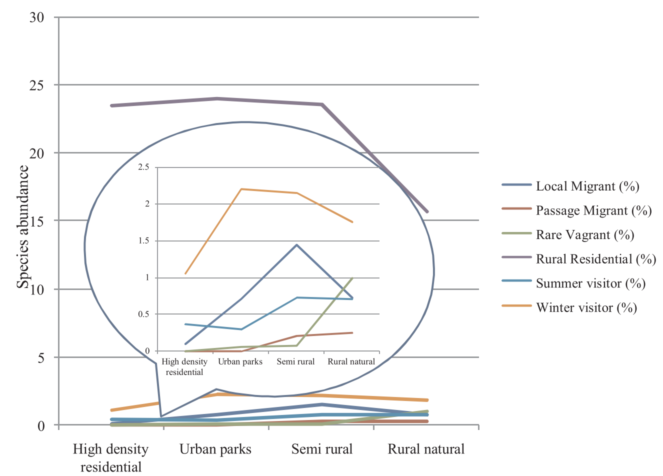

Fig. 2. Status of species abundance along the urbanization gradient in four habitat types.

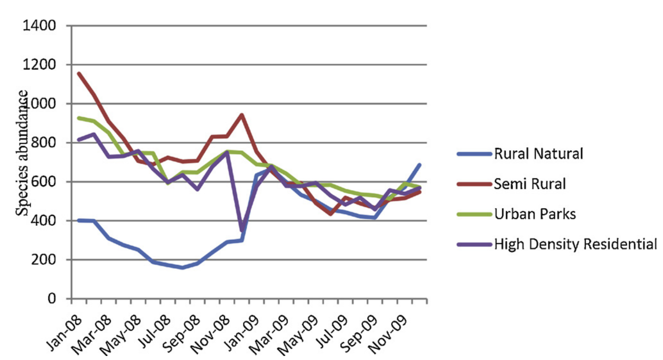

Fig. 3. The seasonal abundance of bird assemblages in four habitats of Kolkata from January 2008 to December 2009.

(Fig. 3).

Mean diversity per point count differed significantly among habitats ($F(3,156) = 31.10$, $P < 0.001$). The highest diversity occurred in semi-rural habitat (68.15 ± 3.16 SE) and the lowest in high density residential habitat (43.02 ± 3.28 SE) (Fig. 4). Mean equitability also differed among habitats ($F(3,156) = 7.60$, $P < 0.001$).

Of all species recorded, 37 (28%) species were found in all habitats (generalists) and 35 (26%) species found exclusively in one of the habitats (specialists). Out of 35 exclusive species, 30 (22%) were found in rural and semi-rural habitat, five (4%) were found in urban parks, and no exclusive species were found in high-density residential habitat (Fig. 5).

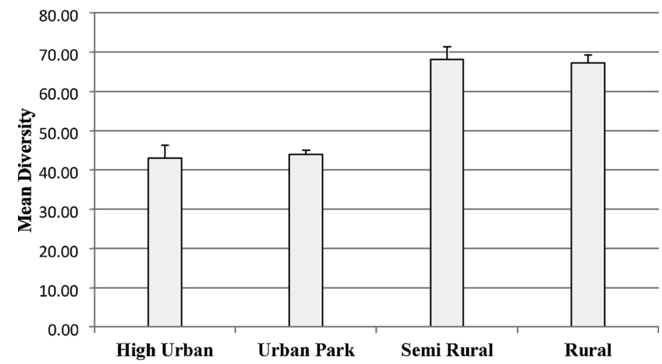

Fig. 4. Mean bird diversity (fisher's alpha) in four habitat types.

To understand the distinct local pattern of bird assemblages and their interaction with urban structure, most of the rare visitors were not included in this study. Species like White Eyed Buzzard (*Butaster teesa*), Curlew Sandpiper (*Calidris ferruginea*), Indian Pitta (*Pitta brachyura*), Plaintive Cuckoo (*Cocomantis merulinus*), Lesser Racket Tailed Drongo (*Dicrurus remifer*), Eastern and Western Crowned Warbler (*Phylloscopus coronatus* and *P. occipitalis*), Pied Harrier (*Circus melanoleucos*), Crested Serpent Eagle (*Spilornis cheela*) etc. which were recorded once or twice for the entire sampling period, were not included for analysis.

In each habitat, two to five species made up more than 2% of the total bird abundance and could be possibly defined as dominant species following Huhtalo and Jarvinen (1977). House Crow (*Corvus splendens*) is the most dominant species in all habitats sampled. House Crow (*Corvus splendens)*, Common Myna (*Acridotheres tristis*), House Sparrow (*Passer domesticus*), Red Vented Bulbul (*Pycnonotus cafer*), Jungle Babbler (*Turdoides striata*) were dominant species at urban habitats (combining urban parks and high- density residential habitat sites) and House Crow, Common Myna, House Sparrow, Asian Pied Starling (*Gracupica contra*), and Black Drongo (*Dicrurus macrocercus*) were dominant species at rural habitats (combining semi-rural and rural natural vegetation habitat sites) (Appendix B). Most of the individual birds in the rural habitats were mainly recorded in trees and aquatic vegetation whereas birds in the urban habitats were mainly recorded in open areas and grasses. Most of the individual birds were recorded below 6 m. Birds in the high-density residential area and parks foraged primarily on the ground; where as those in rural habitat sites rarely use ground (Fig. 6).

3.2. Species composition and site similarity

Comparison among different sites revealed that on average, species composition was much more similar within the same habitat type than among different habitat types. MDS plot generated from relative abundances of different bird species in each habitat type showed that sampling sites from each habitat type clustered together (Fig. 7). Sampling sites of rural natural habitat were well separated from other habitats, which clustered together. Sampling sites of urban parks and high-density residential habitat grouped together, and showed little overlap with semi-rural habitat type (Fig. 8). Based on Bray–Curtis similarity indices, there was a significant difference in avifaunal composition between habitats (ANOSIM). All pairwise comparisons differed significantly between treatment types ($P < 0.05$), indicating that each urban habitat type had a distinct avifaunal assemblage. Pairwise ANOSIM test showed most of the differences in species composition occurred between the urban park and rural natural habitat sites ($R = 0.56$, $P = 0.01$), while the least difference was seen between the urban park and high-density residential habitat ($R = 0.16$, $P = 0.01$) (Appendix C).

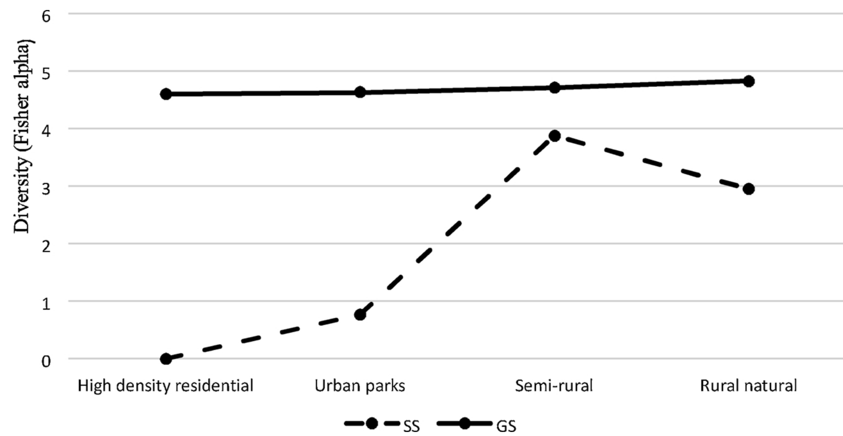

Fig. 5. Diversity pattern of bird assemblage for specialist and generalist species in four habitat types.

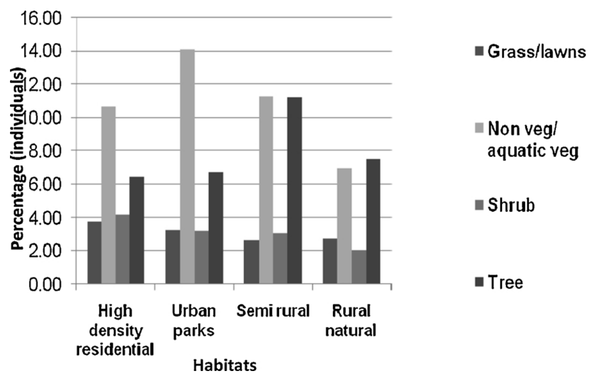

Fig. 6. Percentage of individuals recorded for using different strata of vegetation in four habitat types.

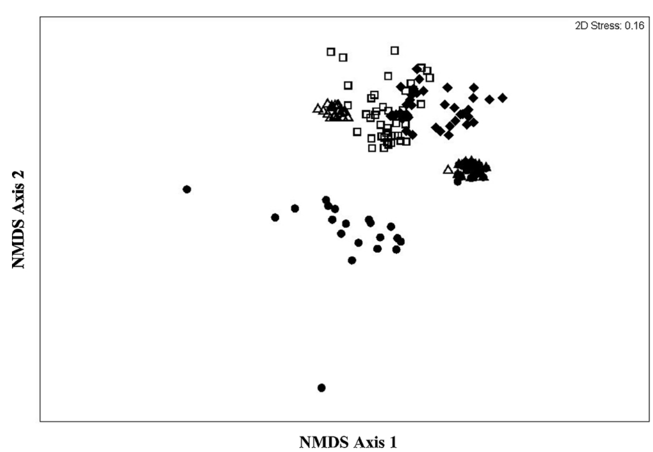

Fig. 7. MDS ordination plots of sampling sites in the Kolkata, generated by species composition sorted according to habitat types (open triangle: High-density residential sites, closed diamond: Semi-rural sites, open square: Urban park sites, closed circle: Rural natural sites).

Thirty-two species contributed around 50% to the difference between groups of sites. These species differed in mean abundance, which was reflected in the degree of group association. Six bird species were almost absent from urban park sites and present in high abundance in rural natural vegetation sites, whereas Alexandrine Parakeet (*Psittacula eupatria*), Blacknaped Oriole (*Oriolus chinensis*), Blue Rock Pigeon (*Columba livia*) were absent from rural natural vegetation sites and found in greater abundance at urban park sites (Appendix C).

3.3. Guild composition and site similarity

Feeding guilds of 134 species are listed in Appendix A. Most species were insectivores (37%), or carnivores (25%) and the species richness of these two guilds peaked in rural and semirural habitats (Fig. 7). Omnivores (13%) and granivores (11%) were the most abundant group in residential areas and urban parks, whereas insectivores (24%), carnivores (15%), and frugivores (2%) were the most abundant group in rural habitats (Fig. 8).

The MDS plot generated from relative abundances of bird guild was similar to that generated from bird species concerning habitat associations (Fig. 9). Rural natural habitat sites were well separated from other three habitat sites which showed overlapping. Pairwise ANOSIM test showed most of the differences in guild composition occurred between rural natural and urban parks sites (R = 0.41, P = 0.01), while the least difference was seen between urban parks and high-density residential habitat (R = 0.14, P = 0.10). Results of SIMPER analysis (Table 2) revealed that frugivore-granivore guild is contributing mostly to group difference between rural natural and urban parks sites. Birds belonging to frugivore-granivore, and omnivore were predominant at urban park sites, whereas frugivore guilds and insectivore-granivore guilds are dominant at rural natural vegetation sites.

4. Discussions

This study shows that urbanization affects the distribution, species composition and structure of bird assemblages in Kolkata. A similar short-term study with urban-rural gradient and fewer guilds was conducted (Sengupta et al., 2013) in Kolkata shared similar hypothesis as this study. The number of species identified in their study was 48, whereas, in this study, 134 species were identified. The hypothesis of decreasing diversity along the urban-rural gradient was confirmed. But, no pattern of this variation was noted. Our study indicates that high levels of urbanization resulted in decreased species richness of bird assemblages (biotic homogenization) (McKinney, 2006), but the variation shows a pattern – that of unimodal distribution, which peaked at one level of development and decreased either with greater or lesser urbanization (Blair, 1996). The result confirms similarity with the mid-disturbance hypothesis and distinction of functional diversity /community structure were corroborated in both the studies.

The distribution of individual species varied along the urban gradient, and their abundances displayed unimodal distributions (Malavasi et al., 2009). As predicted, the abundance and richness of native birds decreased with urbanization, which suggests that urban habitats are inappropriate for these species. The proportions of migratory species were found at much higher in rural habitats in comparison to core urban habitats. But, in cases where sites for roosting, nesting and foraging are plenty, even heavily polluted areas (wetlands) in urban

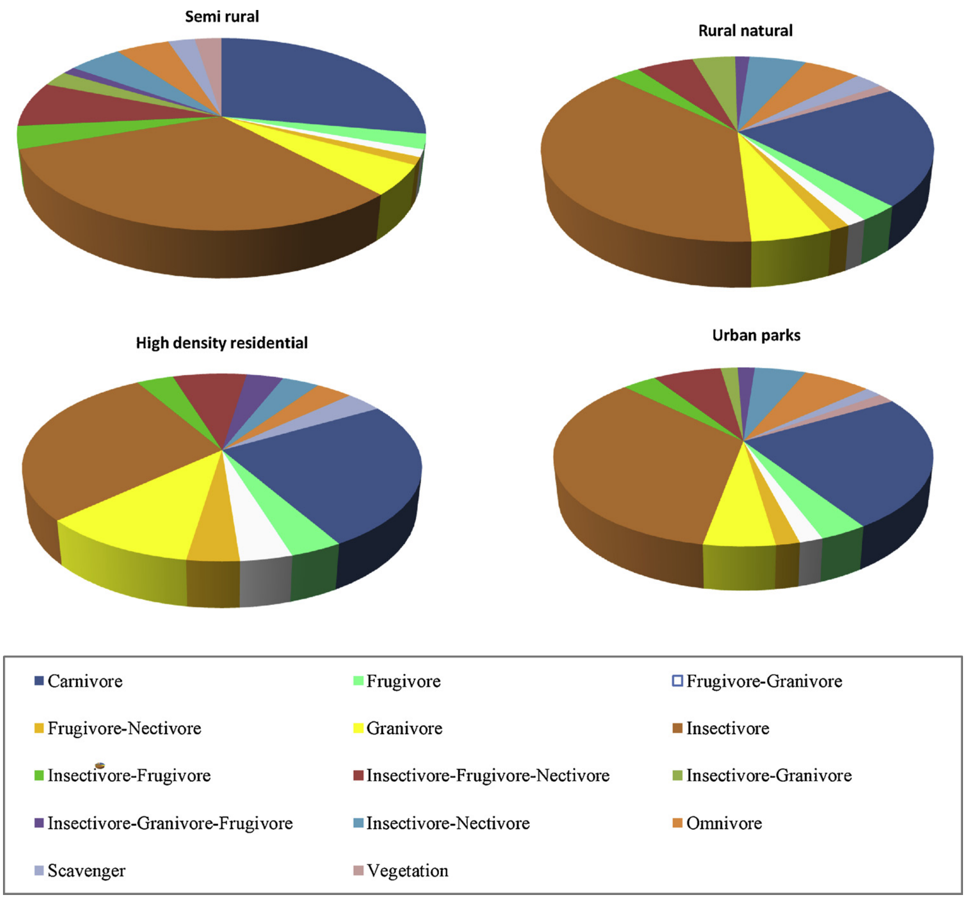

Fig. 8. Guild-wise composition of birds along the urban-rural gradient.

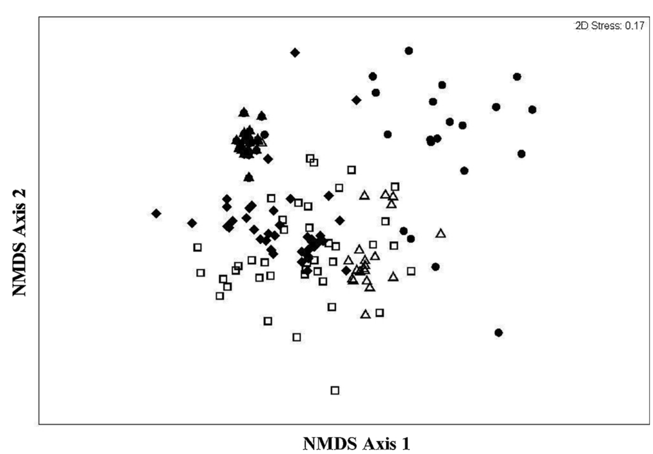

Fig. 9. MDS ordination plots of sampling sites in the Kolkata, generated by guild composition sorted according to habitat types (open triangle: High-density residential sites, closed diamond.
Semi-rural sites, open square: Urban park sites, closed circle: Rural natural sites).

areas may be preferred (Koparde and Raote, 2016). In this study, the transition from rural to urban landscape documented the progressive loss of native birds reflecting the reliance of these species on structurally diverse and/or native vegetation for foraging, nesting or roosting sites, and their sensitivity to anthropogenic disturbance.

In this study, high levels of urbanization resulted in decreased species richness of bird assemblages and created a pattern of biotic homogenization in which only a few urban specialist species dominated in urban habitats. However, moderate levels of urbanization increased species richness, and this increase may be related to habitat heterogeneity. Our study found that generalist species were more in number and abundance in urban areas when compared to rural and semi-rural areas. The opposite trend was observed in the case of specialists. It is concordant with other studies which found evidence that specialists had lower urban densities and more generalist species for reasons such as higher food type innovation rate (Evans et al., 2011; Ducatez et al., 2015). The pattern of generalist and specialist species observed in the present study shows the opposite trend as found in the study of Battisti and Fanelli (2016), who evidenced that species inhabiting highly disturbed areas showed high specialization, which is possibly due to less habitat heterogeneity in urban areas and high habitat heterogeneity in rural areas.

At the higher levels of urbanization, most of the land area is dominated by buildings or paved areas, and any vegetation is primarily ornamental (Beissinger and Osborne, 1982; Blair, 1996; Germaine et al., 1998). Semi-rural sites, however, represent an intermediate level of development in which most of the land area is still vegetated, some

Table 2
SIMPER analysis of differences in guilds of bird assemblage contributing to the dissimilarity between most dissimilar habitat types found.

Groups: Urban parks and Rural natural (Average dissimilarity = 16.93%)			
Guilds	Mean Abundance	Mean Abundance	Cumulative contribution%
Frugivore-Granivore	1.51	0.21	16.21
Omnivore	2.88	1.97	27.55
InsectivoreGranivore	0.28	0.98	49.46
Frugivore	1.33	1.15	59.13

areas of native vegetation may remain, and trees and ponds are common. Landscape diversity may actually increase under such a scenario, as structural diversity is added through changes in vegetation as well as the introduction of buildings and other structures that may serve as nest sites or perch sites, openings are created for edge species, and artificial wetlands are capable of supporting high numbers of ground-foraging birds (Silva et al., 2015; Ciach and Fröhlich, 2016; Silva et al., 2016; Leveau et al., 2017). This potential increase in landscape diversity at low-to-moderate levels of development is particularly noticeable in the urban landscape. There is a strong positive correlation between bird species diversity and habitat diversity (MacArthur and MacArthur, 1961), such that any increase in habitat diversity, particularly in a relatively simple landscape such as a city, is likely to result in increased species richness (Emlen, 1974).

This study shows that different avian feeding guilds have different responses to urbanization. The number of species of insect-eating birds declined with increasing urbanization. Frugivores numerically dominated in rural areas, while granivores dominated in urban areas (Kark et al., 2007; Silva et al., 2016). In general, other studies have also found that insectivores are more abundant or accounted for a higher proportion in rural habitats (Kark et al., 2007; Conole and Kirkpatrick, 2011) and the proportion decreased with urbanization (Lim and Sodhi, 2004). Insectivores are sensitive to environmental quality (Clergeau et al., 1998) and insufficient vegetation (Beissinger and Osborne, 1982), or planted rather than natural vegetation might not be able to support them in urban areas as well as rural areas (DeGraff and Wentworth, 1981).

Consistent with previous studies (Emlen, 1974; Beissinger and Osborne, 1982; Kark et al., 2007), most omnivorous and scavenger birds seem to benefit from urbanization with some species reaching their highest abundances in urban habitats. In general, the omnivore and scavenger guilds showed a strong association with urban variables (e.g., percent developed land and house density), and some omnivores were superabundant in urban habitat accounting for about 13% of the total guild abundance, although species richness of omnivores did not increase with urbanization. Numerically, the omnivore guild was dominated by resident species of which *C. splendens* and *A. tristis* were most abundant. The increase in abundance of these species with habitat disturbance was expected given the species' ability to colonize new habitats, utilize a diversity of foods, and occupy empty niches.

The species and guild composition in rural natural sites showed different assemblages in comparison to other habitat types. Possible reasons may be the presence of large tree patches, old trees with cavities, and high richness of woody plant species affecting the number of different microhabitats available to birds. However, broad habitat types investigated in this urban landscape supported different bird assemblages based on richness, abundance, and species composition. These observed differences in bird assemblages may in part reflect the availability of different resources. For example, semi-rural and rural natural habitat displayed the highest degree of habitat complexity, having a well-established ground, shrub and canopy layer. This diversity of vegetation strata would be expected to increase the foraging, nesting and shelter opportunities for a range of species (Conole and Kirkpatrick, 2011).

5. Conclusion

In this study, clear patterns emerged in the responses of individual bird species to urbanization, and this variation in sensitivity resulted in assemblages specific to the degree of disturbance along a gradient of urbanization. Though the pattern may vary by considering the version of the neutral metacommunity model of Convertino et al. (2009, 2011) and Muneepeerakul et al. (2008), it has been shown that real dynamics is mostly reflected by a combination of niche and neutral dynamics. At one extreme, in rural natural habitat, this study recorded a relatively high richness of birds that occurred at relatively low abundances. At the opposite extreme of the urban-rural gradient, the urban matrix, many of these species were rare or absent. Results suggest that avian assemblages in this urbanizing landscape are shaped by the differential responses of individual species to a gradient of development. Identification of species-specific traits associated with sensitivity to urbanization is essential to understand the processes involved in community assembly. Selective extirpation of "losers" and selective success of "winners" will act to enhance large-scale biotic homogenization and to accelerate biodiversity loss (McKinney and Lockwood, 1999). Considering that most decisions regarding management in urban greenspaces are made at a local scale, and commonly without the benefit of scientific knowledge about their ecological effects (Miller and Hobbs, 2000), this study may help in management recommendations for increasing the diversity of bird species in the urbanizing Kolkata.

Acknowledgments

We are grateful to the Faculty of Zoology, Kalyani University for their encouragement and support. We acknowledge Mr. Kushal Mookherjee, Mr. Dilip Kr. Pal, and Mr. Utpal Kr. Hore for their help during the field work. Dr. Shantanu Basu and Dr. Sutirtha Dutta had also helped in data analysis and made valuable comments on the manuscript. We are very thankful to all the anonymous reviewers for the constructive criticism which has bettered the quality of the paper and the Editor for the opportunity to publish in this journal.

Appendix A. Status, guilds, nest sites and abundance of bird species recorded in four habitat 406 types across a gradient from rural to high urban development in Kolkata

Common name	Scientific Name	Status	Guild	Nest site	High density residential	Urban parks	Semirural	Rural natura l
Alexandrine Parakeet	*Psittacula eupatria eupatria*	R	I/F	H	0	100	473	0
Ashy Drongo	*Dicrurus leucophaeus*	SV	I	T	0	0	55	18
Asian Brown Flycatcher	*Muscicapa latirostris*	WV	I	H	0	0	4	1
Asian Koel	*Eudynamys scolopaceus*	R	I/F	A	194	122	289	266
Asian Openbill	*Anastomus oscitans*	R	C	T	0	0	688	0
Asian Palm-Swift	*Cypsiurus balasiensis*	R	I	A	0	129	84	243
Asian Paradise flycatcher	*Terpsiphone paradisi*	SV	I	T	0	10	0	43
Asian Pied Starling	*Gracupica contra*	R	I/G/F	T	649	389	699	504
Bank Myna	*Acridotheres ginginianus*	R	O	G	0	0	0	145
Barn Owl	*Tyto alba*	R	C	H	3	0	2	40
Barn Swallow	*Hirundo rustica*	WV	I	A	264	86	360	310
Baya Weaver	*Ploceus philippinus*	R	I/G	T	0	0	18	98
Bengal Bushlark	*Mirafra assamica*	R	I/G	G	0	28	0	1
Black Drongo	*Dicrurus macrocercus*	R	I	T	436	276	549	452
Black Kite	*Milvus migrans*	R	S	T	182	106	189	149

Black-crowned Night Heron	*Nycticorax nycticorax*	R	C	T	0	66	262	133
Black-headed Munia	*Lonchura atricapilla*	R	I/G	B	0	0	28	1
Black-hooded Oriole	*Oriolus xanthornus*	R	I/F/N	T	287	179	270	242
Black-Naped Monarch	*Hypothymis azurea*	R	I	T	0	4	0	0
Black-naped Oriole	*Oriolus chinensis*	WV	I/F/N	T	0	57	40	0
Black-rumped Flameback	*Dinopium benghalense*	R	I	H	222	138	176	172
Blue-tailed Bee-eater	*Merops philippinus*	SV	I	G	0	0	40	4
Bluethroat	*Luscinia svecica*	WV	I	B	0	4	0	0
Blue-throated Barbet	*Megalaima asiatica*	LM	F/N	H	55	30	121	90
Blunt-winged Warbler	*Acrocephalus concinens*	PM	I	B	0	0	0	2
Blyth's Reed-Warbler	*Acrocephalus dumetorum*	WV	I	B	0	0	0	6
Brahminy Kite	*Haliastur indus*	R	S/C	T	0	0	7	11
Brahminy Starling	*Haliastur indus*	R	F/N	H	0	0	101	74
Bronzed Drongo	*Dicrurus aeneus*	LM	I	T	0	0	0	15
Brown Hawk Owl	*Ninox scutulata*	LM	C	H	0	1	2	0
Brown Shrike	*Lanius cristatus*	WV	C	T	71	45	113	74
Brown-breasted Flycatcher	*Muscicapa muttui*	WV	I	B	0	10	2	0
Cattle Egret	*Bubulcus ibis*	R	I	T	92	449	176	310
Chestnut-headed Beeeater	*Merops leschenaulti*	R	I	G	0	0	7	0
Chestnut-tailed Starling	*Sturnia malabarica*	SV	I/F/N	H	217	166	307	262
Citrine Wagtail	*Motacilla citreola*	WV	I	B	0	0	31	0
Common Hawk- Cuckoo	*Hierococcyx varius*	SV	I	A	0	0	26	91
Common Coot	*Fulica atra*	WV	V	G	0	91	22	33
Common Hoopoe	*Upupa epops*	LM	C	A	0	20	11	57
Common Iora	*Aegithina tiphia*	R	I/N	T	0	27	23	119
Common Kingfisher	*Alcedo atthis*	R	C	G	0	44	210	110
Common Moorhen	*Gallinula chloropus*	R	O	G	0	35	78	0
Common Myna	*Acridotheres tristis*	R	S	H	1388	1143	695	673
Common Sandpiper	*Actitis hypoleucos*	WV	I	G	0	40	31	34
Common Shelduck	*Tadorna tadorna*	WV	O	G	0	0	0	1
Common Starling	*Sturnus vulgaris*	WV	I	H	0	21	23	0
Common Tailorbird	*Orthotomus sutorius*	R	I	T	443	545	325	348
Common Teal	*Anas crecca*	WV	O	G	0	0	0	1
Common Tern	*Sterna hirundo*	WV		G	0	42	3	0
Coppersmith Barbet	*Megalaima haemacephala*	R	F/N	H	283	207	192	200
Darter	*Anhinga*	R	C	T	0	47	48	0
Emerald Dove	*Chalcophaps indica*	PM	G	T	0	0	0	1
Eurasian Collared-Dove	*Streptopelia decaocto*	R	G	A	77	36	121	40
Eurasian Cuckoo		WV	C	T	0	0	69	0
Eurasian Golden-Oriole	*Oriolus oriolus*	LM	I/F/N	T	0	62	29	99
Eurasian Marsh Harrier	Circus aeruginosus	WV	C	G	0	0	0	1
Forest Wagtail	*Dendronanthus indicus*	PM	I	T	0	0	41	6
Fulvous-breasted Woodpecker	*Dendrocopos macei*	R	I	H	0	0	14	36
Garganey	*Anas querquedula*	PM	O	G	0	2	0	0
Great Cormorant	*Phalacrocorax carbo*	WV	C	T	0	503	0	0
Great Egret	*Ardea alba*	R	C	T	0	0	2	0
Great Tit	*Parus major*	WV	I/F	H	0	0	4	25
Greater Coucal	*Centropus sinensis*	R	C	T	428	246	217	209
Greater Flameback	*Chrysocolaptes lucidus*	R	I	H	80	0	58	136
Greater Racket-tailed Drongo	*Dicrurus paradiseus*	LM	I	T	0	0	0	26
Green Sandpiper		WV	I	G	0	4	0	0
Greenish Warbler	*Phylloscopus trochiloides*	WV	I	B	16	9	4	32
Grey-headed Lapwing	*Vanellus cinereus*	WV	I	G	0	0	0	81
Hodgson's HawkCuckoo	*Cuculus fugax*	WV	I	T	0	34	360	0
House Crow	*Corvus splendens*	R	O	A	2187	2406	1022	484
House Sparrow	*Passer domesticus*	R	G	A	1126	928	892	425
House Swift	*Apus affinis*	R	I	A	193	452	481	433
Indian Cormorant	*Phalacrocorax fuscicollis*	LM	C	T	0	76	59	0
Indian Pond-Heron	*Ardeola grayii*	R	C	T	111	279	306	16
Indian Roller	*Coracias benghalensis*	LM	C	H	0	17	70	7
Intermediate Egret	*Mesophoyx intermedia*	R	C	T	0	10	14	6
Jungle Babbler	*Turdoides striata*	R	I	B	880	560	669	196
Jungle Myna	*Acridotheres fuscus*	R	I/G/F	H	314	0	262	57
Large-billed crow	*Corvus macrorhynchos*	R	O	T	0	0	3	38
Large Hawk-Cuckoo	*Hierococcyx sparverioides*	WV	I	T	0	2	53	31
Large-billed Leaf Warbler	*Phylloscopus magnirostris*	PM	I	B	0	0	0	15
Large-tailed Nightjar	*Caprimulgus macrurus*	R	I	G	0	2	0	4
Lesser Whistling-duck	*Centropus bengalensis*	R	V	T	0	394	58	0
Lineated Barbet	Megalaima lineata	LM	F	H	2	176	112	26
Little Cormorant	*Microcarbo niger*	R	C	T	130	508	183	2
Little Egret	*Egretta garzetta*	LM	C	T	0	0	0	2
Little Grebe	*Tachybaptus ruficollis*	R	C	G	0	0	2	0
Little Green Bee-eater	*Merops orientalis*	R	I	G	12	125	142	33
Little Stint	*Calidris minuta*	WV	C	G	0	0	2	0
Long-tailed Shrike	*Lanius schach*	WV	C	B	0	0	27	0
Loten's Sunbird	*Cinnyris lotenius*	LM	I/N	T	0	0	42	27
Northern Pintail	*Anas acuta*	WV	O	G	0	81	35	0

Orange-headed Thrush	*Zoothera citrina*	WV	I	B	0	0	0	35
Oriental Honey Buzzard	*Pernis ptilorhynchus*	R	I	T	0	5	12	0
Oriental Magpie-Robin	*Copsychus saularis*	R	I/F	A	324	276	191	64
Oriental Pratincole	*Glareola maldivarum*	LM	I	G	0	0	2	0
Oriental White-eye	*Zosterops palpebrosus*	R	I/F/N	T	0	0	18	22
Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	R	V	G	0	0	46	101
Plain Prinia	*Prinia inornata*	R	I	B	0	82	0	101
Purple Heron	*Ardea purpurea*	LM	C	T	0	0	8	0
Purple Sunbird	*Cinnyris asiaticus*	R	I/N	T	432	519	286	266
Purple Swamphen	*Porphyrio porphyrio*	R	O	G	0	0	10	0
Purple-rumped Sunbird	*Leptocoma zeylonica*	R	I/N	T	98	178	152	199
Red-rumped Swallow	*Cecropis daurica*	WV	I	G	0	0	42	86
Red-vented Bulbul	*Pycnonotus cafer*	R	I/F/N	B	971	538	467	409
Red-wattled Lapwing	*Vanellus indicus*	LM		G	0	0	37	41
Red-whiskered Bulbul	*Pycnonotus jocosus*	R	I/F/N	B	0	57	30	105
Rock Pigeon	*Columba livia*	R	G	A	561	118	290	0
Rose-ringed Parakeet	*Psittacula krameri*	R	F/G	H	326	373	345	47
Ruddy-breasted Crake	*Porzana fusca*	RV	C	G	0	2	4	2
Rufous Treepie	*Dendrocitta vagabunda*	R	C	T	409	341	292	297
Rufous Woodpecker	*Micropternus brachyurus*	R	I	H	0	10	0	20
Scaly-breasted Munia	*Lonchura punctulata*	PM	G	T	0	0	80	122
Scarlet-backed Flowerpecker	*Dicaeum cruentatum*	WV	I/F/N	T	0	0	25	0
Shikra	*Accipter badius*	R	C	T	0	26	23	57
Spangled Drongo	*Dicrurus bracteatus*	R	I/N	T	0	1	0	7
Spotted Dove	*Spilopelia chinensis*	R	G	A	450	374	384	247
Spotted Owlet	*Athene brama*	R	C	H	6	19	20	49
Spotted Redshank	*Tringa erythropus*	WV	C	G	0	0	2	0
Stork-billed Kingfisher	*Pelargopsis capensis*	R	C	G	185	289	256	225
Streak-throated Woodpecker	*Picus xanthopygaeus*	RV	I	H	0	32	0	11
Striated Grassbird	*Megalurus palustris*	RV	C	B	0	0	2	0
Verditer Flycatcher	*Eumyias thalassina*	WV	I	H	0	0	21	0
White Wagtail	*Motacilla alba*	WV	I	B	274	307	304	144
White-bellied Drongo	*Dicrurus caerulescens*	RV	I/N	A	0	0	4	0
White-breasted Waterhen	*Amaurornis phoenicurus*	R	O	G	99	324	286	205
White-browed Wagtail	*Motacilla maderaspatensis*	RV	I	B	0	0	36	47
White-rumped Munia	*Lonchura striata*	WV	I/G	T	0	0	47	113
White-throated Fantail	*Rhipidura albicollis*	LM	I	T	0	2	2	37
White-throated Kingfisher	*Halcyon smyrnensis*	R	C	G	289	435	368	402
Yellow Wagtail	*Motacilla tschutschensis*	WV	I	B	0	0	2	16
Yellow-bellied Prinia	*Prinia flaviventris*	R	I	B	0	0	52	0
Yellow-browed Warbler	*Phylloscopus inornatus*	WV	C	B	0	0	2	8

Appendix B. Changes in species composition (presence and absence matrix) across the urban 420 gradient (asterisks represents the presence of species)

Species	Habitat			
	High density residential	Urban parks	Semi rural	Rural natural
Alexandrine Parakeet		*	*	
Ashy Drongo			*	*
Asian Brown Flycatcher			*	*
Asian Koel	*	*	*	*
Asian Openbill			*	
Asian Palm-Swift		*	*	*
Asian Paradise-flycatcher		*		*
Asian Pied Starling	*	*	*	*
Bank Myna				*
Barn Owl	*		*	*
Barn Swallow	*	*	*	*
Baya Weaver			*	*
Bengal Bushlark		*		*
Black Drongo	*	*	*	*
Black Kite	*	*	*	*
Black-crowned Night Heron		*	*	*
Black-headed Munia			*	*
Black-hooded Oriole	*	*	*	*
Black-Naped Monarch		*		
Black-naped Oriole		*	*	
Black-rumped Flameback	*	*	*	*
Blue-tailed Bee-eater			*	*
Bluethroat		*		
Blue-throated Barbet	*	*	*	*
Blunt-winged Warbler				*
Blyth's Reed-Warbler				*
Brahminy Kite			*	*
Brahminy Starling			*	*

Bronzed Drongo				*
Brown Hawk Owl		*	*	
Brown Shrike	*	*	*	*
Brown-breasted Flycatcher		*	*	
Cattle Egret	*	*	*	*
Chestnut-headed Beeeater			*	
Chestnut-tailed Starling	*	*	*	*
Citrine Wagtail			*	
Common Hawk- Cuckoo			*	*
Common Coot		*	*	*
Common Hoopoe		*	*	*
Common Iora		*	*	*
Common Kingfisher		*	*	*
Common Moorhen		*	*	
Common Myna	*	*	*	*
Common Sandpiper		*	*	*
Common Shelduck				*
Common Starling		*	*	
Common Tailorbird	*	*	*	*
Common Teal				*
Common Tern		*	*	
Coppersmith Barbet	*	*	*	*
Darter		*	*	
Emerald Dove				*
Eurasian Collared-Dove	*	*	*	*
Eurasian Cuckoo			*	
Eurasian Golden-Oriole		*	*	*
Eurasian Marsh Harrier				*
Forest Wagtail			*	*
Fulvous-breasted Woodpecker			*	*
Garganey		*		
Great Cormorant		*		
Great Egret			*	
Great Tit			*	*
Greater Coucal	*	*	*	*
Greater Flameback	*		*	*
Greater Racket-tailed Drongo				*
Green Sandpiper		*		
Greenish Warbler	*	*	*	*
Grey-headed Lapwing				*
Hodgson's Hawk-Cuckoo		*	*	
House Crow	*	*	*	*
House Sparrow	*	*	*	*
House Swift	*	*	*	*
Indian Cormorant		*	*	
Indian Pond-Heron	*	*	*	*
Indian Roller		*	*	*
Intermediate Egret		*	*	*
Jungle Babbler	*	*	*	*
Jungle Myna	*		*	*
Large Hawk-Cuckoo		*	*	*
Large-billed crow			*	*
Large-billed Leaf Warbler				*
Large-tailed Nightjar		*		*
Lesser Whistling-duck		*	*	
Lineated Barbet	*	*	*	*
Little Cormorant	*	*	*	*
Little Egret				*
Little Grebe			*	
Little Green Bee-eater	*	*	*	*
Little Stint			*	
Long-tailed Shrike			*	
Loten's Sunbird			*	*
Northern Pintail		*	*	
Orange-headed Thrush				*
Oriental Honey Buzzard		*	*	
Oriental Magpie-Robin	*	*	*	*
Oriental Pratincole			*	
Oriental White-eye			*	*
Pheasant-tailed Jacana			*	*
Plain Prinia		*		*
Purple Heron			*	
Purple Sunbird	*	*	*	*
Purple Swamphen			*	
Purple-rumped Sunbird	*	*	*	*
Red-rumped Swallow			*	*
Red-vented Bulbul	*	*	*	*
Red-wattled Lapwing			*	*
Red-whiskered Bulbul		*	*	*
Rock Pigeon	*	*	*	

Rose-ringed Parakeet	*	*	*	*
Ruddy-breasted Crake		*	*	*
Rufous Treepie	*	*	*	*
Rufous Woodpecker		*		*
Scaly-breasted Munia			*	*
Scarlet-backed Flowerpecker			*	
Shikra		*	*	*
Spangled Drongo		*		*
Spotted Dove	*	*	*	*
Spotted Owlet	*	*	*	*
Spotted Redshank			*	
Stork-billed Kingfisher	*	*	*	*
Streak-throated Woodpecker		*		*
Striated Grassbird			*	
Verditer Flycatcher			*	
White Wagtail	*	*	*	*
White-bellied Drongo			*	
White-breasted Waterhen	*	*	*	*
White-browed Wagtail			*	*
White-rumped Munia			*	*
White-throated Fantail		*	*	*
White-throated Kingfisher	*	*	*	*
Yellow Wagtail			*	*
Yellow-bellied Prinia			*	
Yellow-browed Warbler			*	*
Yellow-footed GreenPigeon		*	*	*

Appendix C. SIMPER analysis of differences in the species of bird assemblage contributing to the dissimilarity between most dissimilar habitat types found

Groups: Urban parks and Rural natural (Average dissimilarity = 43.67%)

Species	Mean Abundance	Mean Abundance	Cumulative contribution%
Rose-ringed Parakeet	1.51	0.21	2.47
House Crow	2.76	1.56	4.75
Jungle Babbler	1.47	0.79	6.8
Greater Flameback	0	1.1	8.67
Scaly-breasted Munia	0	1.09	10.54
White Wagtail	1.59	0.79	12.39
Indian Pond-Heron	1.11	0.26	14.21
White-breasted Waterhen	1.21	0.98	15.94
Lineated Barbet	1.13	0.33	17.66
Barn Swallow	0.66	0.99	19.38
Oriental Magpie-Robin	1.56	0.64	21.05
Common Hawk- Cuckoo	0	0.93	22.71
Little Green Bee-eater	1.2	0.39	24.32
Common Iora	0.36	1.03	25.85
Chestnut-tailed Starling	1.02	1.22	27.36
Common Kingfisher	0.47	1.07	28.86
Alexandrine Parakeet	0.83	0	30.33
Cattle Egret	1.56	1.33	31.78
Rock Pigeon	0.78	0	33.22
Red-whiskered Bulbul	0.54	1.06	34.66
Blue-throated Barbet	0.37	0.94	36.06
Brahminy Starling	0	0.82	37.44
Black-crowned Night Heron	0.47	0.78	38.82
Plain Prinia	0.58	0.74	40.19
Black-naped Oriole	0.72	0	41.51
Baya Weaver	0	0.79	42.8
Bank Myna	0	0.81	44.1
Asian Palm-Swift	0.99	1.42	45.37
Black Kite	0.92	1.13	46.63
Eurasian Golden-Oriole	0.74	0.94	47.87
Brown Shrike	0.58	0.94	49.12
House Sparrow	2.16	1.6	50.34

Appendix D. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ufug.2018.11.005.

References

Ali, S., Ripley, S.D., 1983. Compact Handbook of the Birds of India and Pakistan Together with Those of Bangladesh. Oxford University Press, Nepal, Bhutan and Sri Lanka. New Delhi.

Battisti, C., Fanelli, G., 2016. Applying indicators of disturbance from plant ecology to vertebrates: the hemeroby of bird species. Ecol. Indic. 61, 799–805. https://doi.org/

10.1016/j.ecolind.2015.10.032.
Batáry, P., Kurucz, K., Suarez-Rubio, M., Chamberlain, D.E., 2018. Non-linearities in bird responses across urbanization gradients: a meta-analysis. Glob. Change Biol. 24 (3), 1046–1054. https://doi.org/10.1111/gcb.13964.
Batten, L.A., 1972. Breeding bird species diversity in relation to increasing urbanisation. Bird Study 19 (3), 157–166. https://doi.org/10.1080/00063657209476337.
Beissinger, S.R., Osborne, D.R., 1982. Effects of urbanization on avian community organization. Condor 84, 75–83. https://doi.org/10.2307/1367825.
Blair, R.B., 1996. Land use and avian species diversity along an urban gradient. Ecol. Appl. 6 (2), 506–519. https://doi.org/10.2307/2269387.
Blair, R.B., 1999. Birds and butterflies along an urban gradient: surrogate taxa for assessing biodiversity? Ecol. Appl. 9 (1), 164–170. https://doi.org/10.2307/2641176.
Blair, R.B., 2001. Birds and butterflies along urban gradients in two ecoregions of the United States: is urbanization creating a homogeneous fauna? Biotic Homogenization. Springer, Boston, MA, pp. 33–56. https://doi.org/10.1007/978-1-4615-1261-5_3.
Cam, E., Nichols, J.D., Sauer, J.R., Hines, J.E., Flather, C.H., 2000. Relative species richness and community completeness: birds and urbanization in the Mid-Atlantic States. Ecol. Appl. 10 (4), 1196–1210. https://doi.org/10.1890/1051-0761(2000)010[1196:RSRACC]2.0.CO;2.
Canty and Associates LLC, 2011. Weatherbase Entry for Kolkata. Archived From the Original on 7. September 2011. .
Carbó-Ramírez, P., Zuria, I., 2011. The value of small urban greenspaces for birds in a Mexican city. Landsc. Urban Plan. 100 (3), 213–222. https://doi.org/10.1016/j.landurbplan.2010.12.008.
Chace, J.F., Walsh, J.J., 2006. Urban effects on native avifauna: a review. Landsc. Urban Plan. 74 (1), 46–69. https://doi.org/10.1016/j.landurbplan.2004.08.007.
Ciach, M., Fröhlich, A., 2016. Habitat type, food resources, noise and light pollution explain the species composition, abundance and stability of a winter bird assemblage in an urban environment. Urban Ecosyst. 20 (3), 547–559. https://doi.org/10.1007/s11252-016-0613-6.
Clarke, K.R., 1993. Nonparametric multivariate analyses of changes in community structure. Aust. J. Ecol. 18 (1), 117–143. https://doi.org/10.1111/j.1442-9993.1993.tb00438.x.
Clarke, K.R., Warwick, R.M., 1994. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Plymouth Marine Laboratory, Plymouth, UK.
Clarke, K.R., Gorley, R.N., 2001. Primer v5 Users Manual/Tutorial. PRIMER-E Ltd., Plymouth.
Clergeau, P., Savard, J.P., Mennechez, G., Falerdau, G., 1998. Bird abundance and diversity along an urban-rural gradient: a comparative study between two cities on different continents. Condor 100, 413–425. https://www.jstor.org/stable/1369707.
Colwell, R.K., 2005. EstimateS: Statistical Estimation of Species Richness and Shared Species From Samples. Version 7.5 User's Guide and Application Published. URL. http://purl.oclc.org/estimates.
Conole, L.E., Kirkpatrick, J.B., 2011. Functional and spatial differentiation of urban bird assemblages at the landscape scale. Landsc. Urban Plan. 100 (1–2), 11–23. https://doi.org/10.1016%2Fj.landurbplan.2010.11.007.
Convertino, M., Muneepeerakul, R., Azaele, S., Bertuzzo, E., Rinaldo, A., Rodriguez-Iturbe, I., 2009. On neutral metacommunity patterns of river basins at different scales of aggregation. Water Resour. Res. 45 (8). https://doi.org/10.1029/2009WR007799.
Convertino, M., 2011. Neutral metacommunity clustering and SAR: River basin vs. 2-D landscape biodiversity patterns. Ecol. Modell. 222 (11), 1863–1879. https://doi.org/10.1016/j.ecolmodel.2011.03.015.
DeGraff, R.M., Wentworth, J.M., 1981. Urban bird communities and habitats in New England. Trans. North Am. Wildl. Nat. Resour. Conf. 46, 396–413.
Ducatez, S., Clavel, J., Lefebvre, L., 2015. Ecological generalism and behavioural innovation in birds: technical intelligence or the simple incorporation of new foods? J. Anim. Ecol. 84 (1), 79–89. https://doi.org/10.1111/1365-2656.12255.
Ellis, E.C., Kaplan, J.O., Fuller, D.Q., Vavrus, S., Goldewijk, K.K., Verburg, P.H., 2012. Used planet: a global history. Proc. Natl. Acad. Sci. 110 (20), 7978–7985. https://doi.org/10.1073/pnas.1217241110.
Emlen, J.T., 1974. An urban bird community in Tucson, Arizona: derivation, structure, regulation. Condor 76, 184–197. https://www.jstor.org/stable/1366729.
Evans, K.L., Chamberlain, D.E., Hatchwell, B.J., Gregory, R.D., Gaston, K.J., 2011. What makes an urban bird? Glob. Chang. Biol. 17 (1), 32–44. https://doi.org/10.1111/j.1365-2486.2010.02247.x.
François, C., Alexandre, L., Julliard, R., 2008. Effects of landscape urbanization on magpie occupancy dynamics in France. Landsc. Ecol. 23 (5), 527–538. https://doi.org/10.1007/s10980-008-9211-1.
Germaine, S.S., Rosenstock, S.S., Schweinsburg, R.E., Richardson, W.S., 1998. Relationships among breeding birds, habitat, and residential development in Greater Tucson, Arizona. Ecol. Appl. 8 (3), 680–691. https://doi.org/10.1890/1051-0761(1998)008[0680:RABBHA]2.0.CO;2.
Gotelli, N.J., Colwell, R.K., 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4 (4), 379–391. https://doi.org/10.1046/j.1461-0248.2001.00230.x.
Graber, R.R., Graber, J.W., 1963. A Comparative Study of Bird Populations in Illinois, 1906–1909 and 1956–1958. Illinois Nat. Hist. Survey Bull. 28 (3), 377–527 http://hdl.handle.net/2142/44083.
Graham, J.H., Duda, J.J., 2011. The humpbacked species richness-curve: a contingent rule for community ecology. Int. J. Ecol. https://doi.org/10.1155/2011/868426.
Grimett, R., Inskipp, C., Inskipp, T., 2014. Birds of the Indian Subcontinent. Oxford University Press, London.
Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global change and the ecology of cities. Science 319 (5864), 756–760. https://doi.org/10.1126/science.1150195.
Guthrie, D.A., 1974. Suburban bird populations in southern California. Am. Midl. Nat. 461–466. https://doi.org/10.2307/2424310.
Hawkins, C.P., MacMahon, J.A., 1989. Guilds: the multiple meanings of a concept. Annu. Rev. Entomol. 34 (1), 423–451. https://doi.org/10.1146/annurev.en.34.010189.002231.
Hodgson, P., French, K., Major, R.E., 2007. Avian movement across abrupt ecological edges: differential responses to housing density in an urban matrix. Landsc. Urban Plan. 79 (3-4), 266–272. https://doi.org/10.1016/j.landurbplan.2006.02.012.
Hohtola, E., 1978. Differential changes in bird community structure with urbanisation: a study in central Finland. Ornis Scand. 94–100. https://doi.org/10.2307/3676143.
Huhtalo, H., Järvinen, O., 1977. Quantitative composition of the urban bird community in Tornio, Northern Finland. Bird Study 24 (3), 179–185. https://doi.org/10.1080/00063657709476554.
Hutto, R.L., Pletschet, S.M., Hendricks, P., 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103, 593–602. https://www.jstor.org/stable/4087132.
Jadczyk, P., Drzeniecka-Osiadacz, A., 2013. Feeding strategy of wintering rooks *Corvus frugilegus* L. in urban habitats. Pol. J. Ecol. 61 (3), 587–596.
Jokimäki, J., Suhonen, J., 1993. Effects of urbanization on the breeding bird species richness in Finland: a biogeographical comparison. Ornis Fennica 70 71-71.
Jones, D.N., 1981. Temporal changes in the suburban avifauna of an inland city. Wildl. Res. 8 (1), 109–119. https://doi.org/10.1071/WR9810109.
Kark, S., Iwaniuk, A., Schalimtzek, A., Banker, E., 2007. Living in the city: can anyone become an 'urban exploiter'? J. Biogeogr. 34 (4), 638–651. https://doi.org/10.1111/j.1365-2699.2006.01638.x.
Kolkata Municipal Corporation Demographics. Census of India, 2011. Retrieved 16 June 2018.
Koparde, P., Raote, N., 2016. Areas of avian richness across an urban-rural setting: a case study of selected water-bodies from Pune, Maharashtra, India. Indian BIRDS 12 (2& 3), 50–55.
Kowarik, I., 2011. Novel urban ecosystems, biodiversity, and conservation. Environ. Pollut. 159 (8–9), 1974–1983. https://doi.org/10.1016/j.envpol.2011.02.022.
Krebs, C.J., 1989. Ecological Methodology. Harper and Row Publishers, New York.
Lepczyk, C.A., Flather, C.H., Radeloff, V.C., Pidgeon, A.M., Hammer, R.B., Liu, J., 2008. Human impacts on regional avian diversity and abundance. Conserv. Biol. 22 (2), 405–416. https://doi.org/10.1111/j.1523-1739.2008.00881.x.
Leveau, C.M., Leveau, L.M., 2005. Avian community response to urbanization in the Pampean region, Argentina. Ornitol. Neotrop. 16, 503–510.
Leveau, L.M., Leveau, C.M., Villegas, M., Cursach, J.A., Suazo, C.G., 2017. Bird communities along urbanization gradients: a comparative analysis among three Neotropical cities. Ornitol. Neotrop. 28, 77–87.
Lim, H.C., Sodhi, N.S., 2004. Responses of avian guilds to urbanisation in a tropical city. Landsc. Urban Plan. 66 (4), 199–215. https://doi.org/10.1016/S0169-2046. (03) 00111-7.
MacArthur, R.H., MacArthur, J.W., 1961. On bird species diversity. Ecology 42, 594–598. https://doi.org/10.2307/1932254.
Magurran, A.E., 1988. Ecological Diversity and Its Measurement. Croom Helm, London.
Malkinson, D., Kopel, D., Wittenberg, L., 2018. From rural-urban gradients to patch-matrix frameworks: plant diversity patterns in urban landscapes. Landsc. Urban Plan. 169, 260–268. https://doi.org/10.1016/j.landurbplan.2017.09.021.
Malavasi, R., Battisti, C., Carpaneto, G.M., 2009. Seasonal bird assemblages in a Mediterranean patchy wetland: corroborating the intermediate disturbance hypothesis. Pol. J. Ecol. 57 (1), 171–179.
Marzluff, J.M., 2001. Worldwide urbanization and its effects on birds. Avian Ecology and Conservation in an Urbanizing World. Springer, Boston, MA, pp. 19–47. https://doi.org/10.1007/978-1-4615-1531-9_2.
Marzluff, J.M., 2005. Island biogeography for an urbanizing world: how extinction and colonization may determine biological diversity in human-dominated landscapes. Urban Ecosyst. 8 (2), 157–177. https://doi.org/10.1007/s11252-005-4378-6.
McDonnell, M.J., Hahs, A.K., 2008. The use of gradient analysis studies in advancing our understanding of the ecology of urbanizing landscapes: current status and future directions. Landsc. Ecol. 23 (10), 1143–1155. https://doi.org/10.1007/s10980-008-9253-4.
McDonnell, M.J., Pickett, S.T., 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 1232–1237. https://doi.org/10.2307/1938259.
McGill, B.J., Dornelas, M., Gotelli, N.J., Magurran, A.E., 2015. Fifteen forms of biodiversity trend in the Anthropocene. Trends Ecol. Evol. 30 (2), 104–113. https://doi.org/10.1016/j.tree.2014.11.006.
McKinney, M.L., 2006. Urbanization as a major cause of biotic homogenization. Biol. Conserv. 127, 247–260. https://doi.org/10.1016/j.biocon.2005.09.005.
McKinney, M.L., Lockwood, J.L., 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. Trend Ecol. Evol. 14, 450–453. https://doi.org/10.1016/S0169-5347(99)01679-1.
Melles, S., Glenn, S., Martin, K., 2003. Urban bird diversity and landscape complexity: species–environment associations along a multiscale habitat gradient. Conserv. Ecol. 7 (1). https://www.jstor.org/stable/26271915.
Miller, J.R., Hobbs, N.T., 2000. Recreational trails, human activity, and nest predation in lowland riparian areas. Landsc. Urban Plan. 50, 227–236. https://doi.org/10.1016/S0169-2046(00)00091-8.
Møller, A.P., 2009. Successful city dwellers: a comparative study of the ecological characteristics of urban birds in the Western Palearctic. Oecologia 159, 849–858. https://doi.org/10.1007/s00442-008-1259-8.
Muneepeerakul, R., Bertuzzo, E., Lynch, H.J., Fagan, W.F., Rinaldo, A., Rodriguez-Iturbe, I., 2008. Neutral metacommunity models predict fish diversity patterns in

Mississippi–Missouri basin. Nature 453 (7192), 220. https://doi.org/10.1038/nature06813.
Ortega-Álvarez, R., MacGregor-Fors, I., 2009. Living in the big city: effects of urban land-use on bird community structure, diversity, and composition. Landsc. Urban Plan. 90 (3–4), 189–195. https://doi.org/10.1016/j.landurbplan.2008.11.003.
Palomino, D., Carrascal, L.M., 2006. Urban influence on birds at a regional scale: a case study with the avifauna of northern Madrid province. Landsc. Urban Plan. 77 (3), 276–290. https://doi.org/10.1016/j.landurbplan.2005.04.003.
Pautasso, M., Böhning-Gaese, K., Clergeau, P., Cueto, V.R., Dinetti, M., Fernández-Juricic, E., Kaisanlahti-Jokimäki, M.L., Jokimäki, J., McKinney, M.L., Sodhi, N.S., Storch, D., Tomialojc, L., Weisberg, P.J., Woinarski, J., Fuller, R.A., Cantarello, E., 2011. Global macroecology of bird assemblages in urbanized and semi-natural ecosystems. Glob. Ecol. Biogeogr. 20 (3), 426–436. https://doi.org/10.1111/j.1466-8238.2010.00616.x.
Prajapati, S.H., Prajapati, R.P., 2013. Classified guilds in avian community with respect to food and feeding behaviour. Indian J. Sci. Res. Technol. 1, 1–7.
Ranawana, K.B., Bambaradeniya, C.N.B., 1998. Species composition, status and feeding ecology of avifauna in high altitude forests of Sri Lanka. J. Bombay Nat. Hist. Soc. 93 (3), 292–307. http://www.biodiversitylibrary.org/part/155958.
Sandström, U.G., Angelstam, P., Mikusiński, G., 2006. Ecological diversity of birds in relation to the structure of urban green space. Landsc. Urban Plan. 77 (1–2), 39–53. https://doi.org/10.1016/j.landurbplan.2005.01.004.
Sanz, V., Caula, S., 2014. Assessing bird assemblages along an urban gradient in a Caribbean island (Margarita, Venezuela). Urban Ecosyst. 18 (3), 729–746. https://doi.org/10.1007/s11252-014-0426-4.
Sengupta, S., Mondal, M., Basu, P., 2013. Bird species assemblages across a rural urban gradient around Kolkata, India. Urban Ecosyst. 17 (2), 585–596. https://doi.org/10.1007/s11252-013-0335-y.
Seto, K.C., Güneralp, B., Hutyra, L.R., 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proc. Natl. Acad. Sci. 109 (40), 16083–16088. https://doi.org/10.1073/pnas.1211658109.
Sewell, S.R., Catterall, C.P., 1998. Bushland modification and styles of urban development: their effects on birds in south-east Queensland. Wildl. Res. 25 (1), 41–63. https://doi.org/10.1071/WR96078.
Shochat, E., Lerman, S., Fernández-Juricic, E., 2011. Birds in urban ecosystems: population dynamics, community structure, biodiversity, and conservation. Urban Ecosyst. Ecol. Urban Ecosyst. 75–86. https://doi.org/10.2134/agronmonogr55.c4.
Silva, C.P., García, C.E., Estay, S.A., Barbosa, O., 2015. Bird richness and abundance in response to urban form in a Latin American city: Valdivia, Chile as a case study. PLoS One 10, e0138120. https://doi.org/10.1371/journal.pone.0138120.
Silva, C.P., Sepúlveda, R.D., Barbosa, O., 2016. Nonrandom filtering effect on birds: species and guilds response to urbanization. Ecol. Evol. 6 (11), 3711–3720. https://dx.doi.org/10.1002%2Fece3.2144.
Suarez-Rubio, M., Thomlinson, J.R., 2009. Landscape and patch-level factors influence bird communities in an urbanized tropical island. Biol. Conserv. 142 (7), 1311–1321. https://doi.org/10.1016/j.biocon.2008.12.035.
United Nations, 2007. World Urbanization Prospects: The 2007 Revision.
United Nations, 2014. World urbanization prospects: the 2014 revision, highlights. Department of Economic and Social Affairs. Population Division. United Nations.
Van Heezik, Y., Smyth, A., Mathieu, R., 2008. Diversity of native and exotic birds across an urban gradient in a New Zealand city. Landsc. Urban Plan. 87 (3), 223–232. https://doi.org/10.1016/j.landurbplan.2008.06.004.
Walcott, C.F., 1974. Changes in Bird Life in Cambridge, Massachusetts From 1860 to 1964. The Auk. pp. 151–160. https://www.jstor.org/stable/4084670.
Williams, N.S.G., Morgan, J.W., McDonnell, M.J., McCarthy, M.A., 2005. Plant traits and local extinctions in natural grasslands along an urban-rural gradient. J. Ecol. 93, 1203–1213. https://doi.org/10.1111/j.1365-2745.2005.01039.x.
Wilson, J.B., 1999. Guilds, functional types and ecological groups. Oikos 86 (3), 507–522. https://www.jstor.org/stable/3546655.
Xiao, L., Wang, W., He, X., Lv, H., Wei, C., Zhou, W., Zhang, B., 2016. Urban-rural and temporal differences of woody plants and bird species in Harbin city, northeastern China. Urban For. Urban Green. 20, 20–31. https://doi.org/10.1016/j.ufug.2016.07.013.