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Influence of habitat features of urban streetscapes on richness and abundance of avian species

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Abstract In human-dominated landscapes, roads are known to negatively influence birds causing decline in species richness, as well as reduction in the number of avian species. However, linear stretches of green spaces formed by roadside plantations in urban streetscapes can support diverse avian communities. In spite of being an integral habitat feature of urban areas, there is a clear paucity of studies on avian diversity in urban streetscapes. The present study was carried out in Kolkata, where data on avian species richness and abundance was collected from 16 randomly placed belt transects (replicates), each of 500 m length and 20 m width, on different major roads throughout the study area keeping a minimum gap of 200 m between adjacent transects to avoid data overlapping. Each of these transects were traversed on foot twice in a month from January to March 2017 during days with calm weather conditions. We recorded 31 species of birds belonging to 8 orders and 19 families, of which maximum species belonged to the order Passeriformes (13 species). We found that both abundance and species richness of birds in transects with higher number of trees (78±4.1 individuals and 19.55±1.703 species of birds) were significantly higher than transects with fewer trees (53.74±2.5 individuals and 9.5±0.789 species of birds). Amongst various habitat features along these streetscapes, the total number of trees positively influenced both species richness (GLMM: $F_{1, 90}$=14.485, P<0.05) and abundance of birds (GLMM: $F_{1, 90}$=8.081, P<0.05). However, the other land use variables (i.e. number of bushes, waterbodies, markets and buildings) neither influenced the abundance of birds nor the species richness. Our findings can be useful for urban development to perceive the importance of various habitat features in urban streetscapes in sustaining avian diversity.

Keywords: avifauna, species richness, streetscape, roadside vegetation, habitat, urbanization

Összefoglalás Az emberi tevékenység révén átalakított környezetben az utak negatív hatással vannak a madarakra, csökkentik a fajok számát és a populációk egyedszámát. Ezzel együtt az utak mentén kialakított zöld növényzeti sávok diverz madárközösségnek adhatnak otthont. Habár az útmenti növényzet a városi élőhely integráns része, ritkán vizsgálják az itt előforduló madarakat. E vizsgálatban Kalkutta főútjai mentén 16, egyenként 500 m hosszú és 20 m széles transzektben vizsgáltuk az előforduló madárfajok számát és denzitását. A madárszámolásokat gyalog végeztük 2017. január és március között, transzektenként 6 alkalommal. Összesen 31 fajt (8 rendből, 19 családból) figyeltünk meg, melyek nagy része énekesmadár volt (Passeriformes). Azokban a transzektekben, amik mentén sok fa található, a madarak denzitása és fajszáma is nagyobb volt (78±4,1 egyed 19,55±1,703 faj), mint azokban a transzektekben, amelyek mentén kevés fa volt (53,74±2,5 egyed és 9,5±0,789 faj). A vizsgált élőhelyi tulajdonságok közül kizárólag a fák száma volt hatással a madarak denzitására (GLMM: $F_{1, 90}$=8,081, P<0,05) és a fajszámra (GLMM: $F_{1, 90}$=14,485, P<0,05). A többi változó, mint a bokrok száma, víztestek, piacok és épületek száma sem a fajszámra, sem a madarak denzitására nem volt hatással. Eredményeink hasznosak lehetnek a városfejlesztési tervek kidolgozásában, a városi élőhelyek kialakításában és így a madarak diverzitásának megőrzésében.

Kulcsszavak: madárfauna, fajgazdagság, utcakép, útmenti növényzet, élőhely, urbanizáció

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Introduction

Cities and towns across the globe are ever-expanding with explosion in human population (Fuller *et al.* 2009). As compared to the year 2000, a three-fold increase in urban areas have been predicted by 2030 (Seto *et al*. 2012) leading to large scale loss, degradation and fragmentation of habitats coupled with environmental changes (McKinney 2006, Bar-Massada *et al.* 2014), destruction of forests (Fischer *et al.* 2007), reduction of wilderness areas (Olagunju 2015) and increase in impervious surfaces (Barnes *et al*. 2001), which often threatens the survival of many species worldwide in these areas (Marzluff *et al*. 2001, Sol *et al.* 2017). Animals in urban areas also face greater amount of anthropogenic pressures (such as increased vehicular traffic, air, noise and light pollution, loss of vegetation cover and increased impervious surfaces). In such scenario, various native greenspaces serve as important and remnant patches of habitats for wildlife thriving in human-dominated landscapes (Miller 1997, Milton 2002). Green spaces in urban areas are often rich in biodiversity (Shwartz *et al.* 2014a, 2014b) and have long been identified to increase the functional connectivity for the local fauna (Ikin *et al.* 2015). Studies on the richness and diversity of birds have been carried out in urban greenspaces, like parks, forest remnants, cemeteries (Lussenhop 1977, Kocian *et al.* 2003, Croci *et al.* 2008, Nielsen *et al.* 2014).

Roads are often known to negatively influence birds by increasing impervious surfaces, leading to fragmentation and destruction of habitats; as well as increase traffic and consequent mortality being hit by speeding vehicles; elevated levels of air, noise and light pollutions etc., which often decline the abundance of various avian species (Lim & Sodhi 2004, Cooke *et al.* 2020). Increasing area of roads have been reported to lead to a decline in species richness (Villasenor *et al.* 2017). Nevertheless, the linear stretches of green spaces formed by roadside plantations are an integral habitat feature of urban areas (Gonzalez Sosa *et al.* 2017), which increase the functional connectivity to the local fauna (Ikin *et al.* 2015). Urban streetscapes are also known to support diverse avian communities (White *et al.* 2005). However, there is a clear paucity of studies on avian diversity in urban streetscapes from highly populated countries with intense population explosion and rapid urbanization, like India. Therefore, we carried out this study in an urban area to (i) make an assessment of the community composition, species richness and abundance of avifauna in different streetscapes and (ii) to assess which habitat features influenced the abundance and species richness of birds. Our findings can be useful in the management of urban streetscapes sustaining the avian diversity thriving there.

Methods

Study design

We carried out this study in Kolkata (22.330°N, 88.300°E; 6.4 m a.s.l.) *(Figure 1)*, which spreads linearly along the banks of the Hooghly River and inhabited by around 4.5 million residents. This study area is located in the lower Ganges basin and one of the largest urban agglomeration in India and also of the world. Data on avian species richness and abundance was collected following the belt-transect method (Bibby *et al.* 2000, Sutherland 2006). 16 belt transects (replicates), each of 500 m length and 20 m width were randomly placed on different major roads throughout the study area keeping a minimum gap of 200 m between adjacent transects to avoid data overlapping. All transects were well dispersed from each other (Hurlbert 1984) and representative of the entire study area *(Figure 1)*. Each of these transect was traversed on foot twice in a month from January to March 2017, which resulted in a total of six surveys per transect. Surveys were carried out during days with calm weather

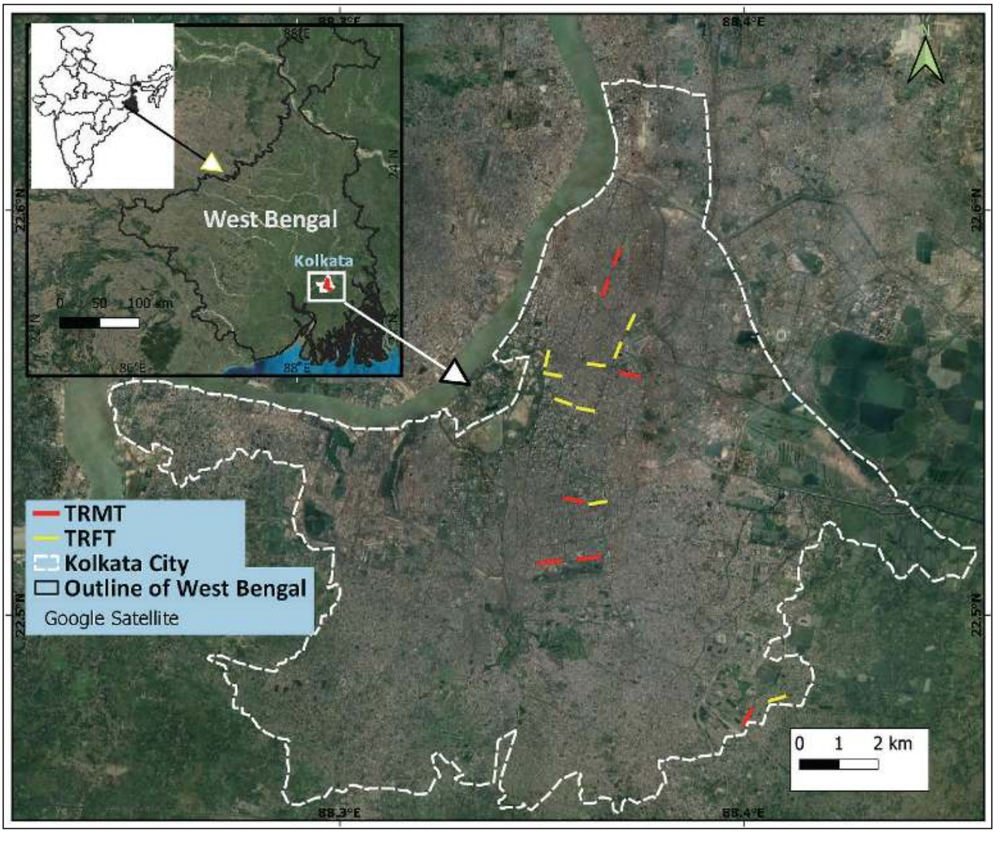

Figure 1. Map of study area in West Bengal, India showing the locations of transects with many trees (TRMT) and with few trees (TRFT)

1. ábra A vizsgálati terület térképe (Kalkutta, Nyugat-Bengál, India). A transzektek helyét piros (transzekt sok fával) és sárga (transzekt kevés fával) vonalak jelölik conditions (without rain and strong wind) and during morning hours (between 06:00 and 09:30), when birds are usually most active. While traversing the transect, we collected data on the abundance and species richness of the avifauna. Any bird noticed horizontally 10 m on either side of transects were recorded, as well as, the individuals within 10 m height were recorded. Flying birds were recorded only to get a 'snap-shot' of all the birds recordable from the transect (Bibby *et al.* 2000). However, the 'fly through' and 'fly over' individuals were excluded from subsequent analyses as they would produce overestimates (Bibby *et al.* 2000). Birds were observed either with unaided eyes or with the help of a pair of binoculars (Nikon 8 × 40) and photographs were taken with a digital camera (Nikon D500 Digital SLR Camera) for documentation. Birds were identified and their migratory status (resident/migratory) were determined using field guides (Grimmett *et al.* 2016). We also calculated the percentage occurrence score of each species to assess their local abundance, where very common (Vc) bird species were recorded on 80–100% of field visits, common (Co) species on 50–79% of field visits, fairly common (Fc) on 20–49% of field visits and rare (Ra) on less than 20% of the field visits (Khan & Naher 2009). The conservation status of birds and their global population trend were taken from the IUCN Red List (del Hoyo *et al.* 2014). Feeding guild is defined as a group of species with similar foraging habits (Hutto 1985). Our observed avian species were divided into seven guilds, i.e. carnivore (Car), omnivore (Omn), frugivore (Frug), herbivore (Herb), nectarivore (Nect), granivore (Gran) and insectivore (Ins), following Ali and Ripley (1987).

In urban areas, trees (White *et al.* 2005), canopy cover (Alberti & Marzluff 2004, MacGregor-Fors & Schondube 2011), bushes/greenspaces (Ortega-Álvarez & MacGregor-Fors 2009), presence of waterbodies (Johnson *et al.* 2012) and building density (Germaine *et al.* 1998) and other urban structures (Ortega-Álvarez & MacGregor-Fors 2009) are known to potentially influence the diversity and abundance of avian communities present there. Hence, the habitat features like numbers of trees, bushes, waterbodies (any permanent water sources like inland waterbodies, pond, artificial, natural lake, canal which potentially influence bird abundance), buildings and markets (permanent commercial places demarcated by municipal corporation) present within each of the belt transects were assessed from the cloud free high-resolution satellite image of Kolkata (Image acquisition: 24.11.16) obtained from Google Earth Pro software (ver. 7.3.3.7699), which was confirmed through rigorous ground-truthing on field. These were used as habitat features of each transect.

Data analysis

Non-parametric tests were performed for data analysis as Shapiro-Wilk's tests revealed that the abundance ($W=0.972$, $df=96$, $P=0.036$) and species richness ($W=0.782$, $df=96$, $P<0.05$) were non-normally distributed. The mean value of trees in all 16 transects were 9.69 ± 1.34. Therefore, we used presence of 10 trees per 500 m as threshold for classifying the transects into two broad categories like (i) *transects with few trees* (i.e.<10 trees/500 m; henceforth TRFT) and (ii) *transects with many trees* (i.e.>10 trees/500 m; henceforth TRMT). Then Mann-Whitney U test was applied to find out if the species richness and abundance of birds showed any significant variation between TRFT and TRMT.

Table 1. The bird species observed in the streetscapes of Kolkata, West Bengal, India together with their respective taxonomic positions (order, family), feeding guild (Car – carnivore, Omn – omnivore, Herb – herbivore, Nect – nectarivore, Gran – granivore, Ins – insectivore, Frug – frugivore), migratory status (R – resident, M – Migratory), local status (Vc – very common, Co – common, Fc – fairly common, Ra – rare), IUCN status (LC – Least Concern, NT – Near-Threatened), global population trend (Dec. – declining, Inc. – increasing. Stable – stable, and Unknown)

1. táblázat A vizsgálatban megfigyelt madárfajok neve, a faj taxonómiai besorolása (család és rend), táplálkozási típusa (Car: ragadozó, Omn: mindenevő, Herb: növényevő, Nect: nektárfogyasztó, Gran: magevő, Ins: rovarevő, Frug: gyümölcsevő), vonulási kategóriája (R: állandó, M: vonuló), lokális gyakorisági kategóriája (Vc: nagyon gyakori, Co: gyakori, Fc: viszonylag gyakori, Ra: ritka), IUCN státusza, valamint globális populáció trendje (Dec: csökken, Inc: növekszik, Satble: stabil, Unknown: nem ismert)

Common Name	Scientific name	Family	Order	Feeding guild	Local Status	IUCN Status	Global trend
House Crow	*Corvus splendens*	Corvidae	Passeriformes	Omn	Vc	LC	Stable
Jungle Babbler	*Turdoides striata*	Leiothrichidae		Omn	Co	LC	Stable
House Sparrow	*Passer domesticus*	Passeridae		Omn	Vc	LC	Dec.
Common Myna	*Acridotheres tristis*	Sturnidae		Omn	Vc	LC	Inc.
Jungle Myna	*Acridotheres fuscus*	Sturnidae		Omn	Fc	LC	Dec.
Rufous Treepie	*Dendrocitta vagabunda*	Corvidae		Ins	Co	LC	Stable
Red-vented Bulbul	*Pycnonotus cafer*	Pycnonotidae		Omn	Co	LC	Inc.
Asian Pied-starling	*Gracupica contra*	Sturnidae		Omn	Co	LC	Inc.
Black-hooded Oriole	*Oriolus xanthornus*	Oriolidae		Omn	Co	LC	Unknown
Oriental Magpie-robin	*Copsychus saularis*	Muscicapidae		Ins	Co	LC	Stable
Common Tailorbird	*Orthotomus sutorius*	Cisticolidae		Ins	Fc	LC	Stable
Black Drongo	*Dicrurus macrocercus*	Dicruridae		Ins	Vc	LC	Unknown
Purple Sunbird	*Cinnyris asiaticus*	Nectariniidae		Nect	Co	LC	Stable
Alexandrine Parakeet	*Psittacula eupatria*	Psittacuidae	Psittaciformes	Frug	Ra	NT	Dec.
Rose-ringed Parakeet	*Psittacula krameri*	Psittacuidae		Frug	Co	LC	Dec.

Common Name	Scientific name	Family	Order	Feeding guild	Local Status	IUCN Status	Global trend
Coppersmith Barbet	*Psilopogon haemacephala*	Megalaimidae	Piciformes	Frug	Co	LC	Inc.
Blue-throated Barbet	*Psilopogon asiaticus*	Megalaimidae		Frug	Ra	LC	Inc.
Lineated Barbet	*Psilopogon lineatus*	Megalaimidae		Frug	Fc	LC	Stable
Lesser Golden-backed Woodpecker	*Dinopium benghalense*	Picidae		Ins	Co	LC	Stable
Rufous Woodpecker	*Micropternus brachyurus*	Picidae		Ins	Fc	LC	Dec.
Fulvous-breasted Woodpecker	*Dendrocopos macei*	Picidae		Ins	Co	LC	Stable
White-throated King-fisher	*Halcyon smyrnensis*	Alcedinidae	Coraciiformes	Car	Fc	LC	Inc.
Stork-billed Kingfisher	*Pelargopsis capensis*	Alcedinidae		Car	Ra	LC	Dec.
Common Kingfisher	*Alcedo atthis*	Alcedinidae		Car	Fc	LC	Unknown
Asian Green Bee-eater	*Merops orientalis*	Meropidae		Ins	Co	LC	Inc.
Indian Cormorant	*Phalacrocorax fuscicollis*	Phalacrocoracidae	Suliformes	Car	Ra	LC	Unknown
Little Cormorant	*Microcarbo niger*	Phalacrocoracidae		Car	Ra	LC	Unknown
Spotted Dove	*Spilopelia chinensis*	Columbidae	Columbiformes	Gran	Co	LC	Inc.
Rock Dove	*Columba livia*	Columbidae		Gran	Vc	LC	Dec.
Common Cuckoo	*Cuculus canorus*	Cuculidae	Cuculiformes	Ins	Co	LC	Dec.
Indian Spotted Eagle	*Clanga hastata*	Accipitridae	Accipitriformes	Car	Ra	VU	Dec.

We found that the distribution of species richness and abundance were over-dispersed and negatively skewed (variance > mean). Hence, two Generalized Linear Mixed Models (GLMMs) with negative binomial distribution and log-link were carried out separately considering species richness and abundance of birds as response variables against the habitat features (i.e. total number of trees, bushes, waterbodies, buildings and market) as predictor variables (fixed factors) and transect ID (as a random factor) in both the models. Prior to running the GLMMs, we tested multicollinearity between variables using variance inflation factor (VIF) method (Zuur *et al.* 2013) and only included the predictor variables with a VIF value < 5 (Montgomery & Peck 1992) to ensure that no variables were strongly correlated. Statistical tests were performed using SPSS software (ver. 20). Significance was tested at $p < 0.05$ and data were presented as mean±standard error.

Results

A total of 31 species of birds belonging to eight orders and 19 families were recorded during the study *(Table 1)*, of which most species belonged to the order Passeriformes (13 species) followed by the order Piciformes (6 species). Most of the recorded species were resident (96.55%). Among all avian species observed during the study, only the Indian Spotted Eagle *Clanga hastata* fall under the IUCN vulnerable (VU) category, while the remaining species are categorized as least concern (LC) species (del Hoyo *et al.* 2014). Assessment of local abundance revealed that out of 31 species recorded, five species (16.1%) were very common, 14 species (45.2%) were common, six species (19.4%) were fairly common and six species (19.4%) were rare. When this local abundance was compared with the global population trend for the species (del Hoyo *et al.* 2014), we found that two species having a globally declining trend were still very common in the study area *(Table 1)*.

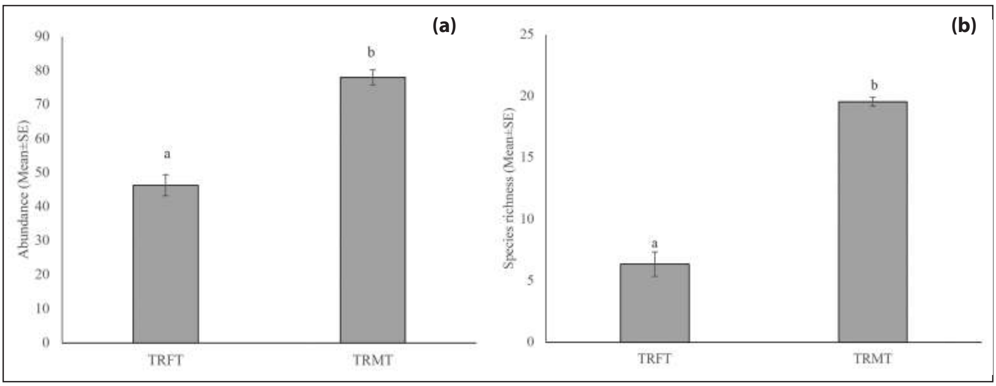

Figure 2. (a) Abundance and (b) species richness of birds in TRFT and TRMT [Columns with different letters indicate significant difference (Bonferroni post hoc tests P<0.05). Error bars indicate standard errors (SE) of means]

2. ábra A madarak (a) denzitása és (b) fajszáma a kevés (TRFT) és sok (TRMT) sok fát tartalmazó transzektek mentén. Az oszlopok magassága és a vonalak az átlagot±SE mutatják, az oszlopok fölötti eltérő betűk a szignifikáns különböző átlagot jelzik (P< 0,05, Bonferroni post hoc teszt)

Table 2. Variables in the GLMMs describing the species richness and abundance of birds in streetscapes of Kolkata, West Bengal, India

2. táblázat Az élőhelyi változók kapcsolata a transzektek mentén mért fajgazdasággal és denzitással. A táblázat az elemzéshez használt lineáris kevert modell (GMML) eredményét mutatja

Variables	Species richness				Abundance			
	F	df1	df2	P	F	df1	df2	P
Number of trees	**14.485**	**1**	**90**	**0.000**	**8.081**	**1**	**90**	**0.006**
Number of bushes	1.238	1	90	0.269	2.81	1	90	0.097
Number of waterbodies	1.415	1	90	0.237	1.796	1	90	0.184
Number of markets	0.152	1	90	0.697	1.45	1	90	0.232
Number of buildings	1.312	1	90	0.255	0.051	1	90	0.822

Out of all species of birds recorded during this study, only two species (Stork-billed Kingfisher *Pelargopsis capensis* and Lineated Barbet *Psilopogon lineatus*) were found exclusively in the TRMT and 29 species (93.55%) were found in both TRFT and TRMT. We also found that the abundance of birds in TRMT (78±4.1 individuals) were significantly higher (Mann Whitney test: U=189, P=0.000) than the abundance of birds recorded from TRFT (53.74±2.5 individuals) as shown in *Figure 2a*. Similarly, *Figure 2b* shows that the species richness of TRMT (19.55±1.7 species) was also significantly higher (Mann Whitney test: U=200.5, P=0.000) than TRFT (9.5±0.8 species). GLMM further revealed that the species richness ($F_{1, 90}$=14.485, P<0.05) and the abundance of birds ($F_{1, 90}$=8.081, P<0.05) were positively influenced by the number of trees *(Table 2)*. However, the other land use variables (i.e. number of bushes, waterbodies, markets and buildings) neither influenced the abundance of birds nor the species richness *(Table 2)*.

Discussion

Urban areas across the globe are inhabited by many species of flora and fauna (Shwartz *et al.* 2014a, 2014b), including birds (Gatesire *et al.* 2014). Birds are often abundant in areas with suitable survival conditions (Veech *et al.* 2010) and the structural features of any habitat give important cues for birds to decide upon whether to use that particular habitat or not (Cody 1981). Greenspaces with suitable structure and floral composition favour bird communities in urban areas (Jokimäki 1999, Daniels & Kirkpatrick 2006, MacGregor-Forz *et al.* 2009) and areas with rich vegetation in the greenspaces usually sustain greater bird abundance as compared to areas with impoverished vegetation (Chace & Walsh 2006). We also found that species richness and the abundance of birds were higher in TRMT than in TRFT. Moreover, amongst various land use features, the increasing number of trees also increased the species richness and abundance of birds during the present study. Several authors found that trees in urban areas usually attract the moderately abundant species (Jokimäki 1999, Ortega-Álvarez & MacGregor-Fors 2009, MacGregor-Fors *et al.* 2010). Few others mentioned that sufficient number of greenspaces in urban areas may even support forest birds (Mortberg & Wallentias 2000, Park & Lee 2000). Again, Sandstrom *et* *al.* (2006) emphasized the importance of large trees and multi-layered vegetation for urban avian richness. Increasing tree cover provides crucial resources for the arboreal and forest birds (Ciach & Frohlich 2017).

Urban bird communities highly depend on the structure and type of vegetation (White *et al.* 2005). Abundance of bird species are positively influenced by the richness of native tree species (Chace & Walsh 2006, Paker *et al.* 2014). Particularly the native species that existed prior to urbanization are largely benefitted by the plantation of various native tree species (Bhullar & Majer 2000). As compared to exotic trees, the diversity and abundance of insects as well as other resources for birds (such as fruits, nectar etc) are often higher in native trees (White *et al.* 2005, Ikin *et al.* 2013). The indigenous species also support greater number of arthropods (Bhullar & Majer 2000) and therefore, are frequented by large number of insectivorous birds (Majer *et al.* 1994, Recher *et al.* 1996). During the present study, we also noticed several old and native trees (such as Banyan, Peepal etc.) which supported great number of birds. However, due to paucity of scientific studies, exotic tree species are arbitrarily planted along the roadside in many urban areas. Thus, implementation of effective strategies and incentives that encourage the planting of native vegetation in streetscapes and garden should be paramount (White *et al.* 2005). Protection of large indigenous trees along the roads, plantation of a greater number of native trees and retaining the existing bushes will undoubtedly be beneficial to sustain the bird communities in the urban landscape (White *et al.* 2005).

Water birds (like ducks, waders and piscivores) and other wetland associated birds (like kingfishers) are mainly benefitted by increasing water area (Yuan *et al.* 2014) as they often aggregate around such water bodies. Chamberlain *et al.* (2007) reported that the presence of waterbodies in urban areas increased avian species richness. However, only three species of kingfishers (White-throated Kingfisher *Halcyon smyrnensis*, Stork-billed Kingfisher *Pelargopsis capensis* and Common Kingfisher *Alcedo atthis*) and two species of cormorants (Indian Cormorant *Phalacrocorax fuscicollis* and Little Cormorant *Microcarbo niger*) were rarely noticed during the present study. Possibly, due to such rare presence of water birds in our study area, we did not find any influence of water bodies on the abundance and species richness of birds.

Bushes are important mainly for forest-dwelling birds and urban avoiders to thrive in the human dominated habitats (Brandt *et al.* 2013, Gopal *et al.* 2018) and increasing number of buildings have been reported to decrease species richness (Evans *et al.* 2009). Few species of urban exploiters and scavengers congregate around the markets and its adjacent garbage dumping sites (Mazumdar *et al.* 2016, 2018, 2019) and forage on the refuse as these foods are plenty and predictable. However, we did not notice any significant influence of bushes, markets and buildings on the species richness and abundance of birds.

Our findings indicate that plantation of indigenous trees along the roads might be beneficial in sustaining greater avian diversity in urban streetscapes. Particularly in urban areas of developing countries, which are rapidly losing the greenspaces due to infrastructure development, the roadside plantations might serve as important habitat for birds. Street trees in urban areas are also associated with higher property values, reduced crime rates, economic benefits (Abd Kadir & Othman 2012), as well as are known to perform various important ecological roles (Bhullar & Majer 2000). They provide manifold benefits such as absorption of GHGs, reduction of air pollution due to vehicular exhausts (Johnson 2009), watershed protection, providing shade on asphalt and concrete structures thereby, reducing the ambient air temperature (Abd Kadir & Othman 2012). However, sometimes falling of street trees lead to casualties and damage of properties, particularly after storms. Falling of large trees in urban areas often happen due to unplanned developmental activities around the root area of the trees (such as random and unplanned cutting the roots for various infrastructural modifications, higher abundance of rodents or termites around the tree roots making the root loosening the soil around the root system etc.). Plantation of appropriate roadside trees will be useful to sustain and also elevate the avian diversity in urban areas, as well as increase the aesthetic value of citizens. Empirical evidences of this research can be useful for urban planners to perceive the importance of various habitat features in urban streetscapes in sustaining the avian diversity. The managers and wildlife planners need to realize the importance of the streetscapes in conservation of urban avian diversity.

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