# Bird species assemblages in railway stations: variations along an urban-rural gradient

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**Abstract** The transportation infrastructures like railway tracks and roads bear negative impacts on natural environment. However, the opposite effects are also true in some instances where the man-made constructions have positive effect on faunal assemblages. This proposition was justified through the assessment of bird species using railway stations as model man-made structures in an urban-rural gradient, in the suburbs of Kolkata, India. During the entire study period along nine different railway stations, a total of 43 bird species belonging to 12 orders and 26 families were observed. Among these, the order Passeriformes was predominant in its species composition having 18 different species from 11 different families. In urban railway stations, a total of 23 bird species under 22 genera and 14 families were observed. In suburban railway stations, a total of 35 bird species under 32 genera and 22 families were documented. The railway stations from rural region showed the maximum number of species and abundance of bird families, where a total of 36 bird species under 32 genera and 23 families were observed. The railway stations from the suburban and rural regions were more similar in species composition. Irrespective of the locations, during the entire study period, the House Crow *(Corvus splendens)* was the dominant species followed by the Common Myna *(Acridotheres tristis)*. About 18 bird species exhibited a decreasing population trend observed through the global population trend analysis. In all the railway stations, the abundance of omnivores were dominant while, the number of granivores were higher in the rural regions and the nectarivores were absent in the urban regions. It was apparent that the railway stations bear a positive effect on the bird species assemblages, which can be sustained through proper environmental management planning inclusive of urban greening.

Keywords: bird species, positive effects, railway network, habitat heterogeneity

**Összefoglalás** A közlekedési infrastruktúra – például a vasút- és úthálózat – legtöbbször negatív hatással van a természetes környezetre. Ezeknek az ember alkotta létesítményeknek a faunákra nézve azonban pozitív hozadéka is lehet, melyet e vizsgálat is igazol. A kutatás során azt tanulmányozták, hogy az egyes madárfajok hogyan használják a vasútállomásokat – mint az ember által létrehozott struktúrákat – egy városi-vidéki gradiens mentén, az indiai Kolkata külvárosában. A teljes vizsgálati időszak alatt kilenc különböző vasútállomás mentén összesen 12 rendbe tartozó 43 madárfajt és 26 családot figyeltek meg. A fajösszetételben az énekesmadár-alakúak rendje (Passeriformes) dominált 18 különböző fajjal, 11 különböző családból. A városi vasútállomásokon összesen 23 madárfajt (22 nemzetség és 14 család), az elővárosi vasútállomásokon összesen 35 madárfajt (32 nemzetség és 22 család) dokumentáltak. A vidéki régió vasútállomásai mutatták a legmagasabb fajszámot, a családokat tekintve pedig a legnagyobb abundancia értéket: ebben a térségben összesen 36 madárfajt észleltek 32 nemzetségből és 23 családból. Az elővárosi és a vidéki vasútállomások fajösszetételükben hasonlóbbak voltak. A helyszínektől függetlenül a teljes vizsgálati időszak alatt az indiai varjú *(Corvus splendens)* volt az uralkodó faj, amelyet a pásztormejnó *(Acridotheres tristis)* követett. Körülbelül 18 faj mutatott csökkenő populációs tendenciát a globális populáció trendelemzés alapján. Valamennyi vasútállomáson a mindenevők domináltak. A vidéki régiókban nagyobb számban voltak jelen magevők, a városi régiókból hiányoztak a nektárevők. Nyilvánvalóvá vált, hogy a vasútállomások pozitív hatást gyakorolnak a madárfajok együtteseire, és a kedvező állapot megfelelő környezetvédelmi tervezéssel és környezetgazdálkodással – beleértve a városok zöldítését is – hosszú távon is fenntartható lehet.

Kulcsszavak: madárfajok, pozitív hatás, vasúthálózat, élőhely-heterogenitás

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## Introduction

Birds are one of the most suitable species to monitor the short and the long-term environmental changes (Koskimies 1989, Bibby 1999, Khan & Naher 2009). Use of birds as indicators for habitat conditions (Canterbury *et al.* 2000, Browder *et al.* 2002, Vallecilo *et al.* 2016), including forests (Pain *et al.* 2004, Venier & Pearce 2004, Aich & Mukhopadhyay 2008, Chatterjee *et al.* 2014), agro-ecosystems (Dhindsa & Saini 1994, Borad *et al.* 2001, Basavarajappa 2006, Sundar & Kittur 2013, Hossain & Aditya 2016) and aquatic bodies (Kumar *et al.* 2006, Kumar & Gupta 2013), biological diversity (Gregory *et al.* 2003, Fraixedas *et al.* 2020) and urbanization (Pollack *et al.* 2017) are well-recognized, apart from the application of birds as flagship species in conserving diversity (Williams *et al.* 2000) and enhancing tourism (Veríssimo *et al.* 2009). Due to an increasing appreciation of the ecosystem services provided by the birds (Whelan *et al.* 2008, Şekercioğlu 2012a, 2012b), the focus for the monitoring, conservation and ecological studies on birds are continued at different biogeographical context (Bradford *et al.* 1998, Browder *et al.* 2002, Lee *et al.* 2004, Sundar & Kittur 2013, Hossain & Aditya 2016). Initiation for the conservation strategies for the birds requires idea about the assemblage pattern at varied spatio-temporal scales. This applies particularly for the conservation initiative in the urban landscapes, which offer habitats for the birds in the form of gardens, parks and green lanes (Chamberlain *et al.* 2009). In comparison to the limited attention given to human-dominated urban biodiversity earlier (Melles *et al.* 2003), in the last few decades, there is an increasing awareness about the faunal biodiversity including birds of urban landscapes and their importance in bio-monitoring and conservation perspectives.

Urban landscapes differ substantially and extensively from natural and semi-natural habitats (Marzluff 2001, Chace & Walsh 2006), in terms of food resources, predator communities (Haskell *et al.* 2001, Sorace 2002), weather conditions (Haggard 1990), and pollution disturbance (Eeva *et al.* 2000). As a consequence, the bird assemblages vary considerably revealed through studiesfrom urban areas of India (Sengupta *et al.* 2014, Kale *et al.* 2018a, 2018b, Pal *et al.* 2019) and elsewhere (Chace & Walsh 2006, Chamberlain *et al.* 2009). In many instances, the rapid urbanization in association with infrastructural revolution leads to extensive modification of natural landscapes that eventually results in a profound restructuring of the preferred habitats of birds (Blair 1996, Chamberlain *et al.* 2009, Morelli *et al.* 2014). As a result, an alteration in the bird species assemblages may be observed along the urbanization gradient with varying levels of the habitat conditions and the degree of disturbances (Gering & Blair 1999, Kale *et al.* 2018a, 2018b, Rodrigues *et al.* 2018, Filloy *et al.* 2019, Pal *et al.* 2019). Although the effects of urbanization on the environmental processes are usually complex and poorly understood, the birds can be considered as bio-monitoring tool to retrieve the consequences on human and wildlife biota (Chace & Walsh 2006, Pollack *et al.* 2017).

An inherent aspect of the urbanization is the increased transportation network in the form of metallic roads and railroads that pose a complete different extent of challenges on the biota (Gilbert 2012), including birds (Beissinger & Osborne 1982, Benítez-López *et al.* 2010, Morelli *et al.* 2014). In addition to the continuous increase of global human population, the improvement in transportation network is now getting more compulsory, therefore, the enlargement of urban regions and associated railway networks is indisputable. Thus, proper knowledge and understanding of the relationships between avian species and railway networks and associated human structures should be beneficial for conservation-focused landscape management (Morelli *et al.* 2014, Wiącek *et al.* 2015). Railways play an essential role in the global transportation service and currently being promoted by various governments because of their superior economic and environmental advantages relative to other transportation means. Apart from economic benefits, railways also present several environmental advantages in contrast to roads, such as lower pollution and reduced land occupancy (Profillidis 2006, Pereira *et al.* 2012), resulting in the growth of the railway network, globally and emergence of the research on railway ecology (Borda-de-Água *et al.* 2017). As a consequence of an increased railway network, the wildlife faces severe challenges in the form of habitat loss, habitat fragmentation, anthropogenic interference, and audio-visual disorder, mortality by collisions, barrier effect, and chemical pollution (Morelli *et al.* 2014, Borda-de-Água *et al.* 2017). Thus, the railway network emerges as a prospective and perceived threat to the wildlife biota, including birds. However, the potential positive consequences of the railway network as well as the rail-associated construction structures on birds are increasingly appreciated (Li *et al.* 2010, van der Ree *et al.* 2011, Morelli *et al.* 2014, Wiącek *et al.* 2015, 2019, 2020, Kaiser-Bonk *et al.* 2019). Some of the plausible positive effects of rail-associated structures includes the marginal vegetation along railways (bridges, shrubs etc.) may provide nesting sites for several species of birds (Wiącek *et al.* 2015, 2019, 2020, Kaiser-Bonk *et al.* 2019), high structures like electricity posts and cables are extensively utilized by many passerine species for perching (DeGregorio *et al.* 2014, Morelli *et al.* 2014), singing and relaxing. The railway platform can also act as a good foraging ground for several species of birds and lastly, some birds utilize railway tracks as a resting site as it becomes heated rapidly during the day and thereby providing protection from cold and windy situations during winter (Morelli *et al.* 2014, Wiącek *et al.* 2015). All these factors render a positive effect on birds and possibly the reason why they are found in higher aggregations near rail-associated structures than in the deeper forest (Wiącek *et al.* 2015, 2019, 2020).

In view of the positive effects of the railway network on the bird species assemblages (Li *et al.* 2010, Morelli *et al.* 2014, Wiącek *et al.* 2015, 2019, 2020, Kaiser-Bonk *et al.* 2019), it would be worthy to evaluate for any variations in the effect against the urban-rural gradient. As a mode of transport, the railway network extends beyond the urban landscapes and more commonly dissects the rural areas including forests. A gradient of urbanization results in a differntial level of bird species richness, including variations in the foraging guilds and similarity in species composition (Kale *et al.* 2018a, 2018b, Pal *et al.* 2019), which may also apply for the railway network connecting urban and rural destinations. In order to justify this proposition, a pioneer attempt was made to explore the bird species diversity in

railway stations of urban, semi-urban, and rural landscapes of West Bengal, India. The primary objectives of the study were (1) to make a checklist of the birds observed in railway stations, (2) to evaluate the species diversity and the functional diversity of the birds in the railway stations along an urban rural gradient and (3) to evaluate species specific differences in abundance in the railway stations along an urban rural gradient. Elucidation of the species specific benefits derived from the railway network will enhance the sustenance of diversity (Grimmett *et al.* 2016) and the ecosystem services (Whelan *et al.* 2008, Şekercioğlu 2012a, 2012b) of birds, especially in an Indian context. Apart from substantiating the urbanization effect, the results will validate the role of railway stations in supporting bird assemblages and thus, prospects in conservation management.

## Materials and methods

### Study area

Our present study on avian biodiversity was carried out between March and May in 2019 in railway stations in West Bengal, India. To carry out the study, nine railway stations were selected randomly in between Howrah railway junction and Barddhaman railway junction *(Figure 1)* of the Eastern Railways section of Indian Railways. Three railway stations [Talandu (23°0'38.43"N; 88°20'44.15"E), Khanyan (23°2'48.03"N; 88°18'55.92"E) and Simlagarh (23°5'46.95"N; 88°13'53.38"E)] were located in rural areas (R), three stations [Baidyabati (22°47'43.28"N; 88°19'55.26"E), Bhadreswar (22°49'42.24"N; 88°20'29.99"E) and Mankundu (22°50'48.99"N; 88°20'48.90"E)] were selected from suburban areas (SU), and the remaining three railway stations [Liluah (22°37'14.88"N; 88°20'21.84"E), Belur (22°38'8.88"N; 88°20'23.27"E) and Uttarpara (22°40'2.99"N; 88°20'28.33"E)] were chosen from urban areas (U). The categorization of urban, suburban, and rural areas was designated based on population size and density. The surroundings of U areas were enriched mainly with large buildings and small factories while the SU areas were surrounded by relatively smaller houses, discrete vegetation as well as small water bodies at the vicinity. The R areas were encircled mainly by agricultural lands and jungles. All of these nine stations covered three districts (Howrah, Hooghly, and Purba Bardhaman) of West Bengal, India. The average temperature in the studied areas varied from 35–45 ºC in summer (March to May), relative humidity lied between 50 and 75%, depending on weather conditions with an average annual rainfall of 150 mm for the concerned area.

### Methodology

The birds were observed and counted in sampling sites for three consecutive months from March to May in 2019. Each site was intensely surveyed twice every month at an interval of two weeks. Adopting line transect method and maintaining constant transect length the surveys were carried out in each selected railway station in the morning time (between 6:00 AM to 9:00 AM) and in the afternoon (from 3:00 PM to 6:00 PM) depending on the
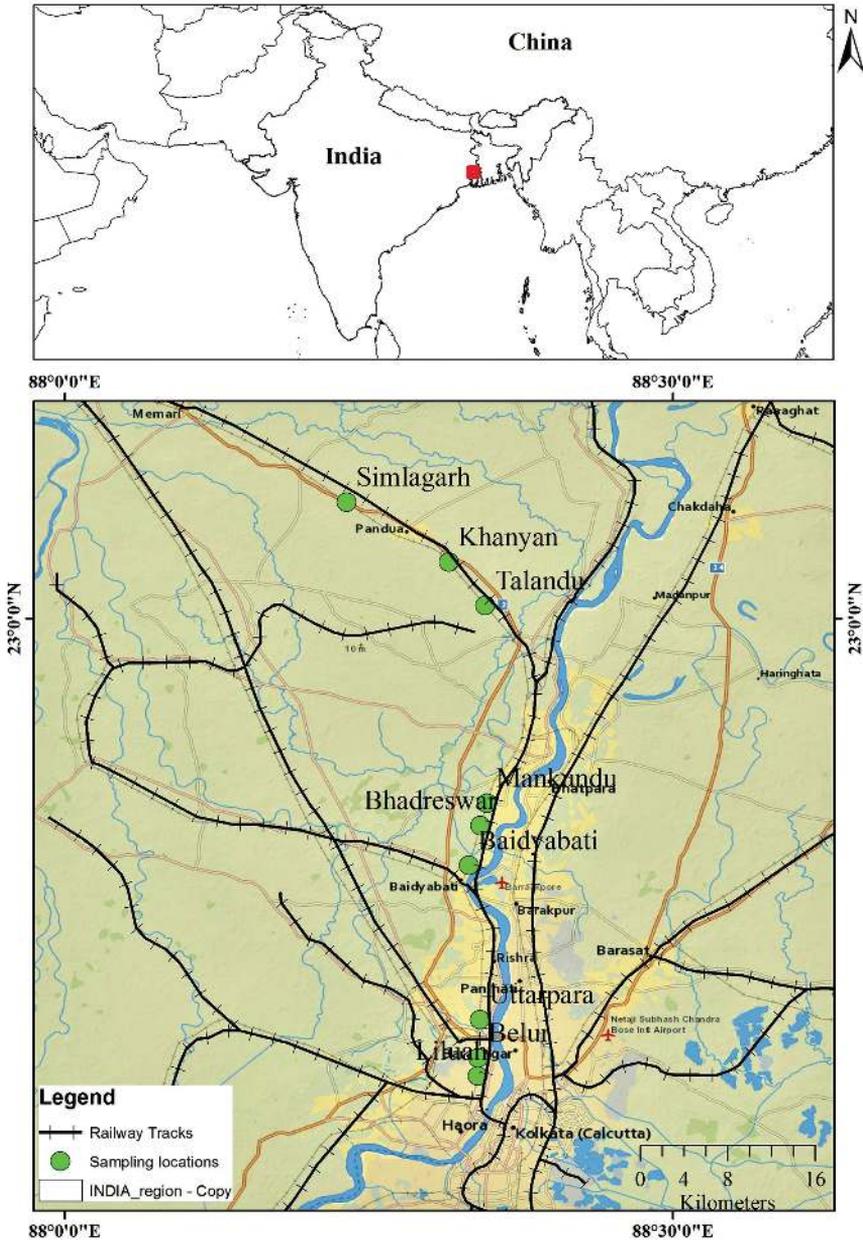
*Figure 1.* Map of India with the study areas including nine railway stations in West Bengalbeing highlighted. Three stations (Talandu, Khanyan and Simlagarh) were chosen from rural areas (R), three stations (Baidyabati, Bhadreswar and Mankundu) were from suburban areas (SU) and other three railway stations (Liluah, Belur and Uttarpara) were taken from urban areas (U)

*1. ábra* A vizsgálati terület térképe, 9 nyugat-bengáliai vasútállomás megjelölésével. Három állomás (Talandu, Khanyan és Simlagarh) vidéki (R), három állomás (Baidyabati, Bhadreswar és Mankundu) előVárosi (SU) és három állomás (Liluah, Belur és Uttarpara) Városi (U) területről lett választva

day length when the birds were found to be more active (Buckland *et al*. 1993, Bibby *et al*. 2000). The starting point and the direction of transects were often arbitrary. Each survey site was visited six times throughout the study period, three times in the morning time and three times in the afternoon. Cloudy and overcast days were strictly avoided for a field visit. The birds were observed either by unaided eyes or by binocular (Olympus 7x21 PS III) depending upon distance and photographs were captured by Nikon P900 for documentation of the avifauna. Based on observations and captured photographs, birds were identified (Ali 1996, Grimmett *et al*. 2016) and recorded for tabulation and statistical analysis. In some cases, birds' calls were used as an identifying key. The taxonomic categorization of bird species was made by following Praveen *et al*. 2016. During the survey period, the foraging behaviours, nesting and resting positions, areas of displaying and singing as well as their overall activities were observed.

**Data analysis**

The information about the status of global population trends for each observed bird species was collected from the IUCN Red List (del Hoyo *et al*. 1996). Foraging guilds were determined by examining their feeding habitat and categorized into six feeding guilds i.e. carnivore (Car), omnivore (Omn), nectarivore (Nect), granivore (Gran), insectivore (Ins) and frugivore (Frug) (Ali & Ripley 1980, Hutto 1986). To obtain the diversity indices of bird abundance, the data taken from each study site from three areas (U, SU and R) were analyzed separately by using Biodiversity Pro software (McAleece *et al*. 1997, Biodiversity Professional; Scottish Association for Marine Science and the Natural History Museum, London, UK). Species richness (S) was calculated by summing the number of different species present in that area (Mukherjee *et al*. 2015, Issa 2019). Diversity of species was represented by calculating Shannon diversity index [$H'=-\sum (P_i \ln P_i)$], Simpson's Index of diversity [$(1-D)=1-\frac{\sum n(n-1)}{N(N-1)}$], where $P_i$ is the proportion of total samples belonging to the $i$th species, n is the total number of birds belongs to a particular species and N includes the total number of birds of all species (Magurran 1988). To compare the similarity of population size of each bird species in an area, the evenness [$J=H'/H_{max}$] was calculated. Fisher's alpha (α) is a parametric diversity index was estimated to analyse diversity within the population. The Margalef's richness was estimated as [$D_{Mg}=(S-1)/\ln N$], (Margalef 1958), where S is the total number of avian species and N is the total number of individuals. The relationship among species richness (S), information (H), and evenness (J) in the samples was made by SHE analysis (Buzas & Hayek 1998). The proximity and similarity of avifaunal community structures of three different habitats (U, SU and R), in terms of species composition was estimated by the Jaccard coefficient ($Jc=\frac{M}{M+N}$) and Sorensen coefficient ($Sc=\frac{2\times C}{A+B}$), where M denotes the number of common species between communities, N is the total number of unique species present in both communities, C is the common species between two habitats, whereas the components A and B are the number of bird species at two different habitats proposed to be compared for similarity (Ludwig & Reynolds 1988, Krebs 1999). Agglomerative hierarchical clustering (AHC) was carried out based on the Pearson's similarity coefficient of habitat types and avian species richness associated to these habitats. To comment

on the variation in abundance of different species along the urban gradients, a mixed model ANOVA was performed with the species as the repeated factors and the urban, suburban and rural regions as the fixed factors. In order to specify if there were any difference in their abundance related to time of the day variation, ANOVA was performed (Zar 1999). All abundance data were presented as mean±SE and significance were tested at p<0.05. Diversity index, species richness, evenness and associated analysis were performed by using Biodiversity Pro (2.0) software. The statistical analyses were performed following Zar (1999) using the XLSTAT software (Addinsoft 2010).

# Result

**Bird species records and their relative abundance**

During the entire study along the nine different railway stations irrespective of urban to rural gradient, a total of 43 bird species belong to 12 orders and 26 families were observed *(Table 1)*. Among the recorded birds, the order Passeriformes was predominant on its species composition having 18 different species from 11 different families. In urban railway stations (U), a total of 23 bird species belongs to 22 genera and 14 families were observed. The maximum number of bird species recorded in U sites were under family Columbidae with 4 species (17.40%) followed by Sturnidae with 3 species (13.04%), Apodidae, Cuculidae, Corvidae, and Ardeidae, each containing 2 species (8.70% each) and Accipitridae, Cisticolidae, Dicruridae, Passeridae, Pycnonotidae, Phalacrocoracidae, Picidae, Psittaculidae, each with 1 species (4.35% each). In suburban railway stations (SU), a total of 35 bird species belongs to 32 genera and 22 families were documented. The maximum number of species recorded in SU were under the families Columbidae, Corvidae, Sturnidae, and Ardeidae, each having 3 species (8.60% each), followed by Apodidae, Cuculidae, Cisticolidae, Nectariniidae, and Pycnonotidae, with 2 species (5.71% each) and Accipitridae, Jacanidae, Alcedinidae, Rallidae, Dicruridae, Hirundinidae, Leiothrichidae, Muscicapidae, Oriolidae, Passeridae, Phalacrocoracidae, Megalaimidae and Picidae, each having 1 species (2.85% each). Nevertheless, railway stations from rural regions (R) showed the highest number of species and abundance of bird families, where a total of 36 bird species were recorded throughout the study period which belongs to 32 genera and 23 families. In rural regions (R) the maximum number of species listed under families Columbidae, Corvidae, and Sturnidae each of which has 3 species (8.3% each), followed by Apodidae, Alcedinidae, Cuculidae, Nectariniidae, Pycnonotidae, Ardeidae, and Megalaimidae, each with 2 species (5.6% each), and Anatidae, Rallidae, Cisticolidae, Dicruridae, Leiothrichidae, Muscicapidae, Oriolidae, Passeridae, Ciconiidae, Phalacrocoracidae, Threskiornithidae, Picidae, and Psittaculidae, each having 1 species (2.8% each). The possible variations in the relative abundance of different observed families in three different sites (U, SU and R) might be due to the alterations in habitat conditions. The relative abundance of bird species *(Figure 2)* and the abundance of families *(Figure 3)* were highest in the rural railway stations followed by suburban and urban areas.

*Table 1.* List of bird species with their relative abundance (mean ± SE) in urban railway station (U), suburban railway station (SU) and rural railway station (R) sites of West Bengal, India, recorded during study period, together with their feeding guilds (Car = carnivore, Omn = omnivore, Nect = nectarivore, Gran = granivore, Ins = insectivore and Frug = frugivore) and global population trend (ST= stable, IN= increasing, DE= decreasing and UN= unknown)

*1. táblázat* A madárfajok relatív abundancia értékei (átlag ±standard hiba) városi (U), elővárosi (SU) és vidéki (R) vasútállomásokon, Nyugat-Bengália, India területén, a táplálkozási guildek (Car = ragadozó, Omn = mindenevő, Nest = nektárfogyasztó, Gran = magevő, Ins = rovarevő, Frug = gyümölcsevő) és a globális populációs trendek (ST = stabil, IN = növekvő, DE = csökkenő, UN = ismeretlen) feltüntetésével

| Family | Common and Scientific Name | Feeding Guild | Global Trend | U | SU | R |
|---|---|---|---|---|---|---|
| Order: Accipitriformes | | | | | | |
| Accipitridae | Black Kite *Milvus migrans* (Boddaert, 1783) | Omn | UN | 4.33±0.65 | 0.44±0.18 | 0 |
| Order: Anseriformes | | | | | | |
| Anatidae | Lesser Whistling-duck *Dendrocygna javanica* (Horsfield, 1821) | Omn | DE | 0 | 0 | 0.17±0.17 |
| Order: Caprimulgiformes | | | | | | |
| Apodidae | Asian Palm Swift *Cypsiurus balasiensis* (Gray, 1829) | Ins | ST | 1.61±0.51 | 1.11±0.32 | 1.28±0.35 |
| | Indian House Swift *Apus affinis* (Gray, 1830) | Ins | IN | 1.28±0.46 | 0.94±0.29 | 0.39±0.16 |
| Order: Charadriiformes | | | | | | |
| Jacanidae | Bronze-winged Jacana *Metopidius indicus* (Latham, 1790) | Omn | UN | 0 | 0.22±0.12 | 0 |
| Order: Columbiformes | | | | | | |
| Columbidae | Rock Dove *Columba livia* (Gmelin, 1789) | Gran | DE | 7.22±2.21 | 2.56±0.73 | 8±0.95 |
| | Eurasian Collared Dove *Streptopelia decaocto* (Frivaldszky, 1838) | Gran | IN | 0.11±0.07 | 1.17±0.47 | 3.17±0.58 |
| | Spotted Dove *Spilopelia chinensis* (Scopoli, 1786) | Gran | IN | 1.72±0.45 | 1.17±0.34 | 1.94±0.39 |
| | Yellow-footed Green Pigeon *Treron phoenicopterus* (Latham, 1790) | Gran | IN | 0.44±0.35 | 0 | 0 |

| Family | Common and Scientific Name | Feeding Guild | Global Trend | U | SU | R |
|---|---|---|---|---|---|---|
| **Order: Coraciiformes** | | | | | | |
| Alcedinidae | Stork-billed Kingfisher *Pelargopsis capensis* (Linnaeus, 1766) | Car | DE | 0 | 0 | 0.06±0.05 |
| | White-breasted Kingfisher *Halcyon smyrnensis* (Linnaeus, 1758) | Car | IN | 0 | 0.22±0.22 | 0.28±0.1 |
| **Order: Cuculiformes** | | | | | | |
| Cuculidae | Greater Coucal *Centropus sinensis* (Stephens, 1815) | Omn | ST | 0.17±0.09 | 0.06±0.05 | 0 |
| | Asian Koel *Eudynamys scolopaceus* (Linnaeus, 1758) | Omn | ST | 1.78±0.41 | 0.61±0.14 | 1±0.16 |
| | Common Hawk-cuckoo *Hierococcyx varius* (Vahl, 1797) | Ins | ST | 0 | 0 | 0.11±0.07 |
| **Order: Gruiformes** | | | | | | |
| Rallidae | White-breasted Waterhen *Amaurornis phoenicurus* (Pennant, 1769) | Omn | UN | 0 | 0.11±0.11 | 0.11±0.07 |
| **Order: Passeriformes** | | | | | | |
| Cisticolidae | Plain Prinia *Prinia inornata* (Sykes, 1832) | Ins | ST | 0 | 0.11±0.07 | 0 |
| | Common Tailorbird *Orthotomus sutorius* (Pennant, 1769) | Ins | ST | 1.11±0.40 | 1.06±0.28 | 1±0.16 |
| Corvidae | Rufous Treepie *Dendrocitta vagabunda* (Latham, 1790) | Ins | DE | 0.33±0.19 | 0.78±0.24 | 0.06±0.05 |
| | House Crow *Corvus splendens* (Vieillot, 1817) | Omn | ST | 16.5±2.02 | 17.44±2.55 | 16.17±1.91 |
| | Large-billed Crow *Corvus macrorhynchos* (Wagler, 1827) | Omn | ST | 0 | 0.06±0.05 | 0.67±0.21 |

| Family | Common and Scientific Name | Feeding guild | Global Trend | U | SU | R |
|---|---|---|---|---|---|---|
| Order: Passeriformes | | | | | | |
| Dicruridae | Black Drongo *Dicrurus macrocercus* (Vieillot, 1817) | Ins | UN | 0.33±0.11 | 0.50±0.21 | 1.17±0.27 |
| Hirundinidae | Barn Swallow *Hirundo rustica* (Linnaeus, 1758) | Ins | DE | 0 | 0.44±0.44 | 0 |
| Leiothrichidae | Jungle Babbler *Turdoides striata* (Dumont, 1823) | Omn | ST | 0 | 0.83±0.35 | 0.22±0.22 |
| Muscicapidae | Oriental Magpie-robin *Copsychus saularis* (Linnaeus, 1758) | Ins | ST | 0 | 0.33±0.18 | 0.28±0.11 |
| Nectariniidae | Purple-rumped Sunbird *Leptocoma zeylonica* (Linnaeus, 1766) | Nect | ST | 0 | 0.44±0.27 | 0.56±0.44 |
| | Purple Sunbird *Cinnyris asiaticus* (Latham, 1790) | Nect | ST | 0 | 0.17±0.09 | 0.11±0.11 |
| Oriolidae | Black-hooded Oriole *Oriolus xanthornus* (Linnaeus, 1758) | Omn | ST | 0 | 0.22±0.10 | 0.06±0.05 |
| Passeridae | House Sparrow *Passer domesticus* (Linnaeus, 1758) | Omn | DE | 0.33±0.14 | 1.50±0.42 | 1.56±0.47 |
| Pycnonotidae | Red-whiskered Bulbul *Pycnonotus jocosus* (Linnaeus, 1758) | Omn | DE | 0 | 1.00±0.49 | 0.11±0.11 |
| | Red-vented Bulbul *Pycnonotus cafer* (Linnaeus, 1766) | Omn | IN | 1.44±0.44 | 2.72±0.55 | 6.00±1.11 |
| Sturnidae | Asian Pied Starling *Gracupica contra* (Linnaeus, 1758) | Omn | IN | 0.56±0.22 | 3.44±0.84 | 13.33±1.30 |
| | Common Myna *Acridotheres tristis* (Linnaeus, 1766) | Omn | IN | 10.39±0.98 | 11.00±1.48 | 12.94±1.00 |
| | Jungle Myna *Acridotheres fuscus* (Wagler, 1827) | Omn | DE | 0.17±0.16 | 0.22±0.13 | 1.00±0.32 |

| Family | Common and Scientific Name | Feeding guild | Global Trend | U | SU | R |
|---|---|---|---|---|---|---|
| **Order: Pelecaniformes** | | | | | | |
| Ardeidae | Indian Pond-heron *Ardeola grayii* (Sykes, 1832) | Car | UN | 0.06±0.05 | 2.22±0.56 | 0.06±0.05 |
| | Cattle Egret *Bubulcus ibis* (Linnaeus, 1758) | Car | IN | 2.06±0.90 | 10.56±7.40 | 6.39±1.72 |
| | Little Egret *Egretta garzetta* (Linnaeus, 1766) | Car | IN | 0 | 0.11±0.08 | 0 |
| Ciconiidae | Asian Openbill *Anastomus oscitans* (Boddaert, 1783) | Car | UN | 0 | 0 | 0.56±0.33 |
| Phalacrocoracidae | Little Cormorant *Microcarbo niger* (Vieillot, 1817) | Car | UN | 2.94±1.67 | 1.56±0.49 | 2.00±0.32 |
| Threskiornithidae | Glossy Ibis *Plegadis falcinellus* (Linnaeus, 1766) | Car | DE | 0 | 0 | 0.50±0.25 |
| **Order: Piciformes** | | | | | | |
| Megalaimidae | Coppersmith Barbet *Psilopogon haemacephalus* (Statius Müller, 1776) | Frug | IN | 0 | 0.44±0.29 | 0.11±0.11 |
| | Lineated Barbet *Psilopogonl ineatus* (Vieillot, 1816) | Frug | ST | 0 | 0 | 0.06±0.05 |
| Picidae | Lesser Golden-backed Woodpecker *Dinopium benghalense* (Linnaeus, 1758) | Ins | ST | 0.06±0.05 | 0.11±0.11 | 0.28±0.12 |
| **Order: Psittaciformes** | | | | | | |
| Psittaculidae | Rose-ringed Parakeet *Psittacula krameri* (Scopoli, 1769) | Frug | IN | 1.44±0.62 | 0 | 0.56±0.35 |
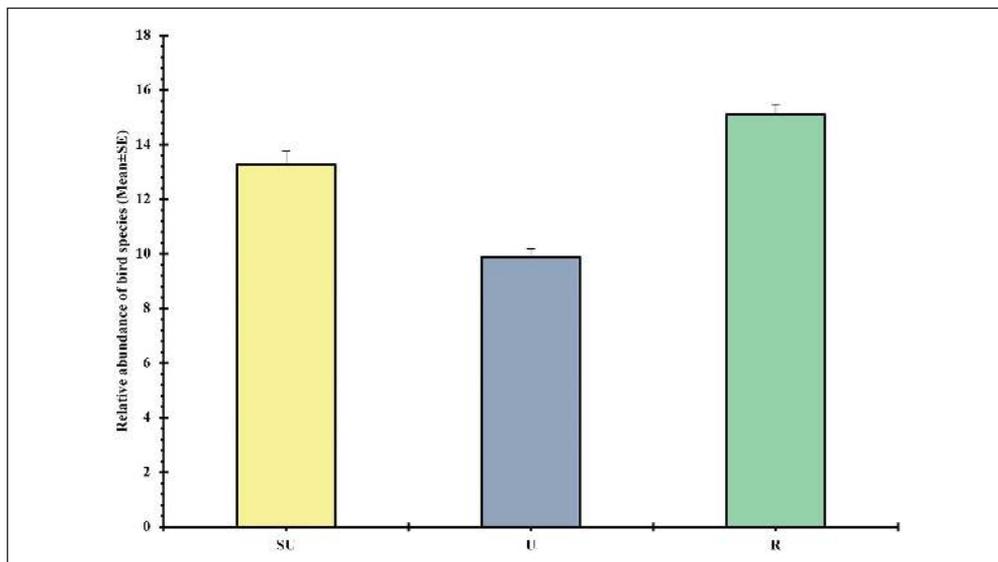
*Figure 2.* Relative abundance of bird species recorded from three different sites (SU, U and R)
*2. ábra* A madárfajok relatív abundanciája három különböző területtípusban (elővárosi (SU), városi (U) és a vidéki (R))
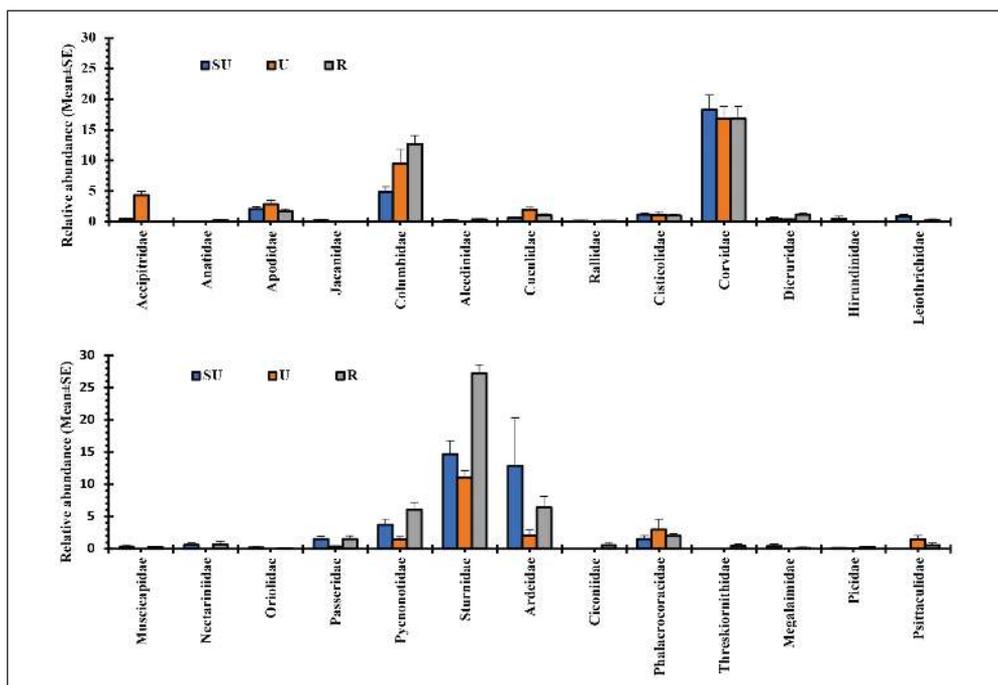


*Figure 3.* The relative abundance of the different bird family in the suburban (SU), urban (U) and rural (R) station areas sampled during the study period
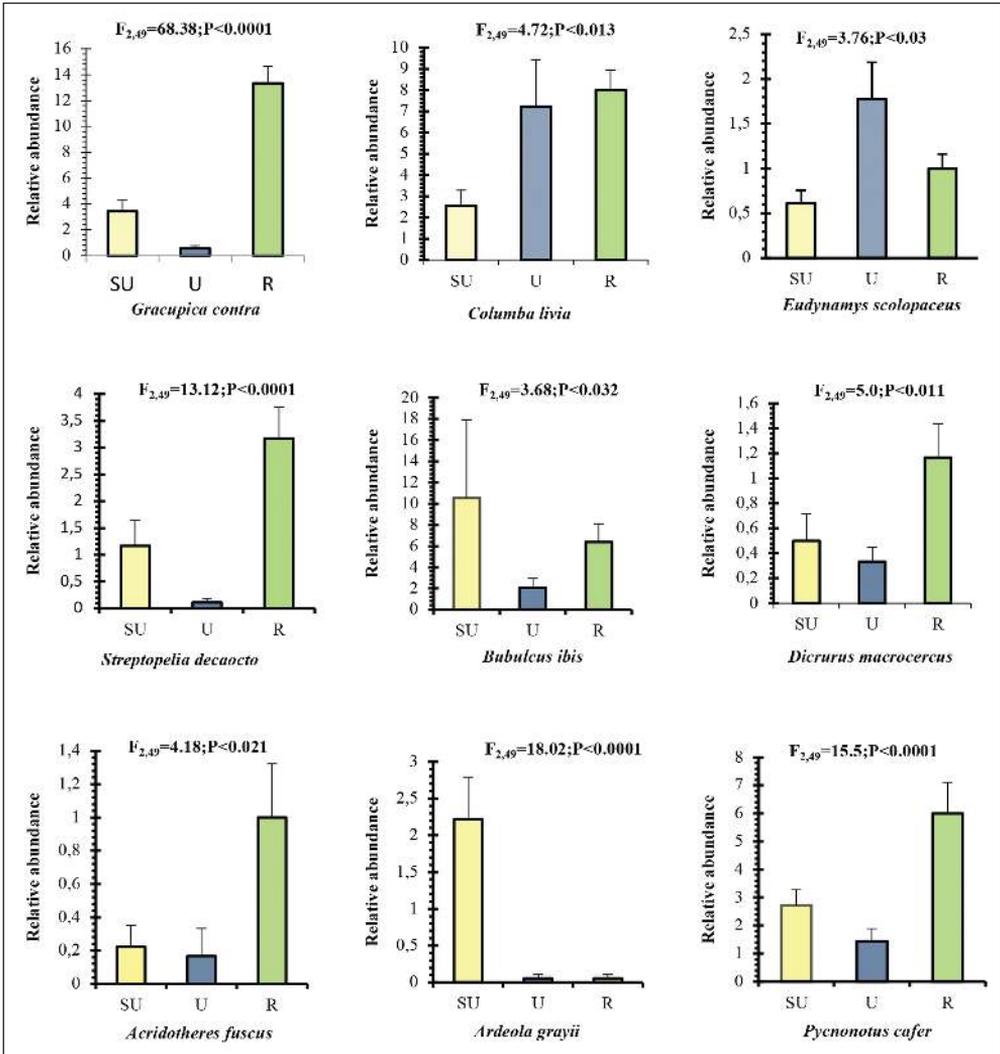*3. ábra* A különböző madárcsaládok relatív abundanciája az elővárosi (SU), városi (U) és a vidéki (R) állomásokon

*Figure 4.* Selected bird species, which were available in each habitat (SU = suburban, U = urban and R = rural) and are known to differ significantly (P < 0.05) in their relative abundance

*4. ábra* A relatív abundanciájukban jelentősen különböző madárfajok összehasonlítása terület típusonként (elővárosi (SU), városi (U) és a vidéki (R))

During the entire study period, House Crow *(Corvus splendens)* was the most predominant species in all railway stations irrespective of three different landscapes with a relative abundance (mean±SE) of 16.5±2.0 for U, 17.4±2.5 for SU and 16.2±1.9 for R areas. Compared to House Crows, in U the abundance of the total number of species was higher for Common Myna *(Acridotheres tristis)* (10.4±0.9) and lowest for *Ardeola grayii* and *Dinopium benghalense* (0.06±0.1 for each). In addition to that, *Acridotheres tristis* was also found in higher abundance (11.0±1.5) in SU followed by *Bubulcus ibis* (10.6±7.4) whereas, minimum relative abundance recorded from species *Centropus sinensis* and *Corvus*

*macrorhynchos* with 0.1±0.1, for each. In addition to *Corvus splendens,* the relative abundance of *Gracupica contra* and *Acridotheres tristis* were also higher in R with an abundance of 13.3±1.3 and 12.9±1.0, respectively, although, least relative abundance recorded from species *Pelargopsis capensis, Dendrocitta vagabunda, Oriolus xanthornus, Ardeola grayii, Psilopogon lineatus* each which mean abundance value of 0.06±0.05.

Species based relative abundance in three different areas *(Figure 4)* were analyzed. Significant difference ($F_{2,49}$=68.38, P<0.0001) was found on the distribution of Asian Pied Starling *(Gracupica contra)* in higher number in rural railway areas and in lowest number in urban railway stations. Rock Dove *(Columba livia)* was found to be more abundant in Rural railway stations and relatively moderate number in urban railway stations and lowest number in suburban railway stations ($F_{2,49}$=4.72, P=0.013). Abundance of Red-vented Bulbul *(Pycnonotus cafer)* was found in higher number in rural railway stations and lowest in urban railway station ($F_{2,49}$=15.5, P<0.0001), as well as Jungle Myna *(Acridotheres fuscus)* was also found in higher number in rural railway stations and lowest in urban railway stations ($F_{2,49}$=4.18, P=0.021). Eurasian Collared Dove *(Streptopelia decaocto)* ($F_{2,49}$=13.12, P<0.0001) and Black Drongo *(Dicrurus macrocercus)* ($F_{2,49}$=5.0, P=0.011) were found in higher number in the rural area and relative moderate number in semi urban area and were found lowest in urban area. Significant difference in the abundance ($F_{2,49}$=3.76, P=0.03) of Asian Koel *(Eudynamys scolopaceus)* was found in higher number in urban area and lowest in the semi-urban area. Significant difference in the abundance of Cattle Egret *(Bubulcus ibis)* ($F_{2,49}$=3.68, P=0.032), Indian Pond-Heron *(Ardeola grayii)* ($F_{2,49}$=18.02, P<0.0001), Rufous Treepie *(Dendrocitta vagabunda)* ($F_{2,49}$=4.34, P=0.018) were also noticed along the urban gradient with their higher availability in suburban railway station areas.Considering the time of surveys that were carried out in the morning (6:00 AM to 9:00 AM) and in the afternoon (3:00 PM to 6:00 PM), depending on the day length when birds were found to be most active, it was reported that expect of two species *(Cypsiurus balasiensis, Halcyon smyrnensis)*, other species did not show significant differences (P>0.05) in both morning and afternoon time irrespective of urban-rural gradient *(Figure 5)*.The number of Asian Palm Swift ($F_{1,52}$=4.7, P<0.05) and White Throated Kingfisher ($F_{1,52}$=5.49, P<0.05) are significantly differ in their abundance in
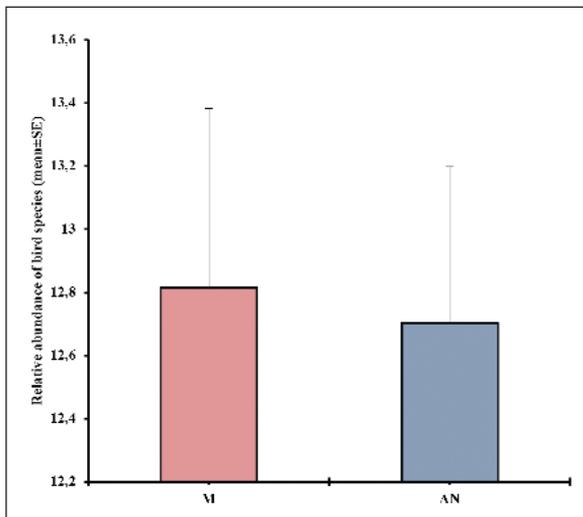


Figure 5. Relative abundance of bird species observed during different sampling time (M=Morning, AN = Afternoon) from all stations irrespective of rural-urban gradient

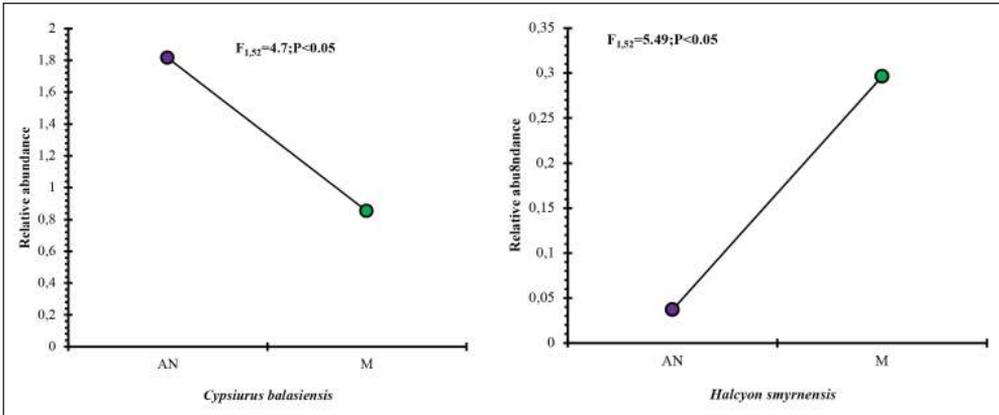5. ábra A reggeli (M) és délutáni (AN) mintavételi órákban megfigyelt relatív abundancia értékek

*Figure 6.* Relative abundance of selected bird species differ significantly (P<0.05) in different sampling time (M = Morning, AN = Afternoon)

*6. ábra* A mintavételi időszakokban (M = reggel, AN = délután) jelentősen eltérő relatív abundanciájú madárfajok összehasonlítása

between the two times *(Figure 6)*. Asian Palm Swift *(Cypsiurus balasiensis)* is more fre-quent in number at afternoon than in morning whereas the White Throated Kingfisher *(Halcyon smyrnensis)* is more frequent in morning times (P=0.023).

## Global population trends of the recorded species

By analysing the global population trend it was noted that the railway stations belong to ur-ban regions includes 6 such species of birds known to follow the stable population trend (ST), 9 increasing (IN), 4 with unknown (UN) and notably other 4 species marked to follow the decreasing (DE) population trend, whereas railway stations from suburban regions with 13 such species that are following the ST population trend, 10 with IN, 6 with UN and oth-er 6 species known follow the DE population trend. On the contrary, railway stations from rural regions include 13 bird species that are known to follow the ST population trend, 10 IN, 5 with UN, and remaining 8 species are following the DE population trend (del Hoyo *et al.* 1996).

## Analysis of diversity indices

Along the railway stations of urban-rural gradient, the values of diversity indices re-corded *(Table 2)* for bird species as Species richness (S), Shannon diversity index (H'), Simpson's Index of diversity (1-D), evenness (J), Fisher's alpha (α), Margalef's Rich-ness index ($D_{Mg}$). The highest Shannon diversity index (H') of birds recorded in railway stations belongs to rural regions (2.24±0.03), followed by suburban regions (2.07±0.08) and urban regions (1.81±0.05). Species richness (S) was higher in the rural (15±0.38) and suburban (13.28±0.49) rail stations than in the urban rail stations (9.89±0.30), which showed the lowest species richness amongst three sampling regions. The Simpson's

*Table 2.*      Diversity indices of the bird communities recorded from three different habitats
*2. táblázat*  A három különböző élőhelyet jellemző diverzitási indexek összehasonlítása

| Diversity Indices | SU | U | R |
|---|---|---|---|
| Species richness_(S) | 13.28±0.49 | 9.89±0.30 | 15.00±0.38 |
| Simpson's index of diversity_(1-D) | 0.82±0.02 | 0.79±0.01 | 0.86±0.01 |
| Shannon diversity index _ (H') | 2.07±0.08 | 1.81±0.05 | 2.24±0.03 |
| Evenness_(J) | 0.80±0.02 | 0.79±0.01 | 0.83±0.01 |
| Fisher_ α | 5.64±0.47 | 3.59±0.16 | 5.54±0.18 |
| Margalef_ ($D_{Mg}$) | 1.73±0.07 | 1.28±0.04 | 1.93±0.05 |

Index, which measures community diversity found to be highest in the railway stations in rural (0.86±0.01) regions, followed by the suburban (0.82±0.02) regions and the urban (0.79±0.01) regions. Shannon evenness (J) is the ratio of H' to $H_{max}$, a measure of species evenness found higher in the railway stations that come under rural (0.83±0.01) and suburban (0.8±0.02) regions as compared to urban (0.79±0.01) regions. The results revealed that railway stations from rural and suburban regions were highly species-rich as compared to urban regions and further demonstrate that from rural to urban matrices, species diversity and richness decreases, showing influences of urbanization on the avian community. Fisher's alpha (α) is a parametric diversity index to estimate the diversity within the population found to be highest in the suburban (5.64±0.47) railway stations, followed by the rural (5.54±0.18) and urban (3.59±0.16) railway stations. The Margalef's Richness index ($D_{Mg}$), which was used as another measure of species richness also is the highest in rural (1.93±0.05) sampling sites than that of the suburban (1.73±0.07) and urban (1.28±0.04) sites. As revealed through the results of SHE analysis *(Figure 7)*, the relationship among S (species richness), H (information), and E (evenness) in the samples can interpret well and represents higher species richness in the railway stations from the rural and suburban regions than in the urban regions. In addition to the species abundance in samples as a variable for comparison, the rank abundance curves also generated for rail stations belonging to urban-rural gradient *(Figure 8)*, where the species count plotted in descending order for all the species and found to be highest in rural railways, followed by suburban and urban railway station areas. The railway stations from the suburban and rural landscapes were the regions with the most similar species composition. The Jaccard and Sorensen similarity coefficients for these two sampling sites were 0.69 and 0.817, respectively, and were the highest. In contrast, the rural and urban rail stations had Jaccard and Sorensen similarity coefficients of 0.512 and 0.678 respectively, and were the least similar in terms of species composition *(Figure 9a)*. Dendrogram based on the species richness along different railway stations areas of urban, semi-urban and rural landscapes formed two distinct clusters where rural stations and suburban stations clustered together, whereas urban habitat was in a separate cluster *(Figure 9b)*.
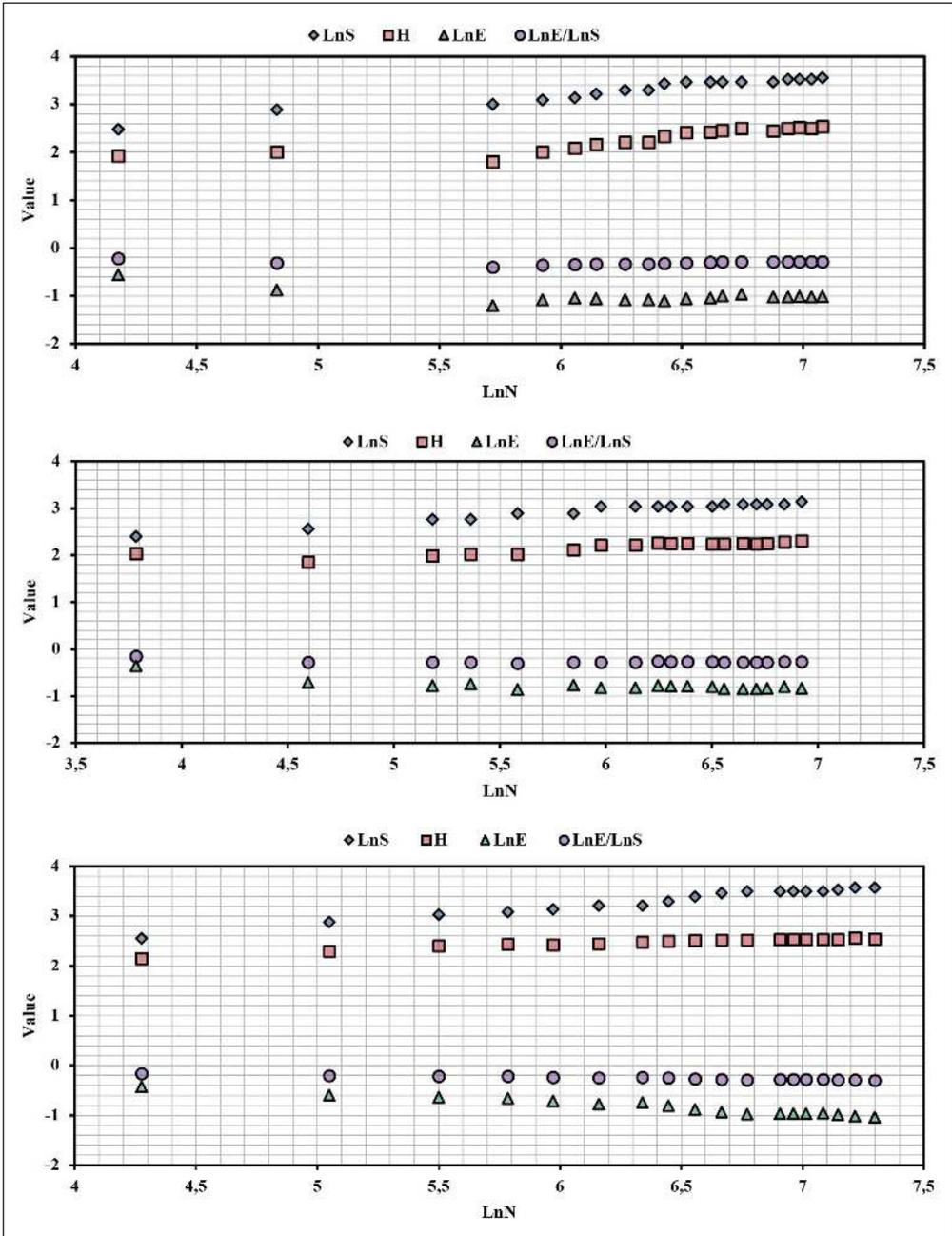
*Figure 7.* Plot of SHE analysis [S (species richness), H (information) and E (evenness) in the samples] calculated on relative abundance of 43 bird species of three different sites of (A) suburban; (B) urban; (C) rural railway station areas. These represent the turnover of species between sites

*7. ábra* Az SHE elemzés eredményei (S – fajgazdagság, H – információtartalom, E – egyenletesség) 43 madárfaj relatív abundancia adatainak felhasználásával. A – elővárosi, B – városi, C – vidéki területek
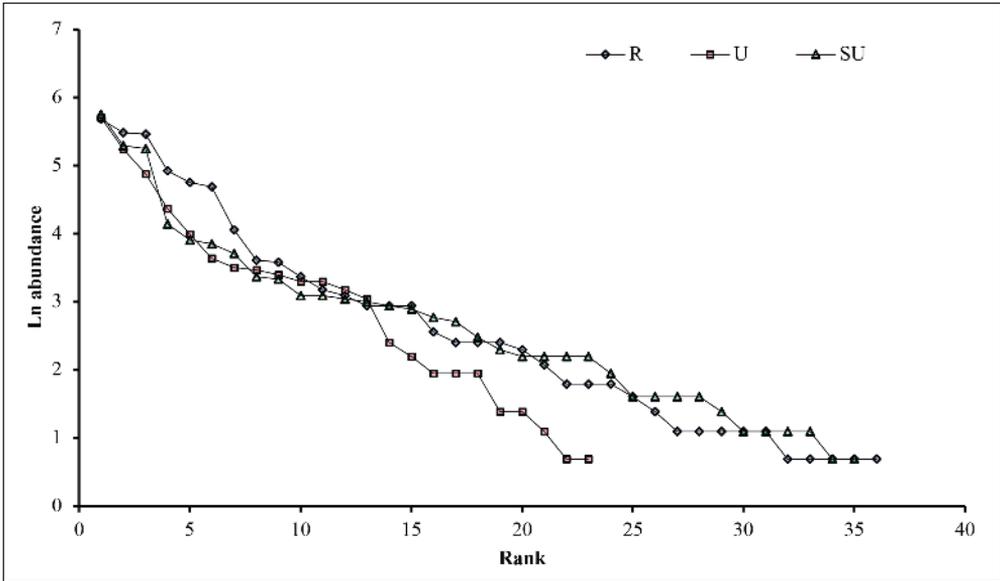
*Figure 8.* Rank-abundance curve of log (n+1) transformed data of bird species abundance were used to show the rank of bird in suburban, urban and rural sites

*8. ábra* Rank-abundancia görbe az elővárosi (SU), vidéki (R) és városi (U) madárfajok összehasonlítására



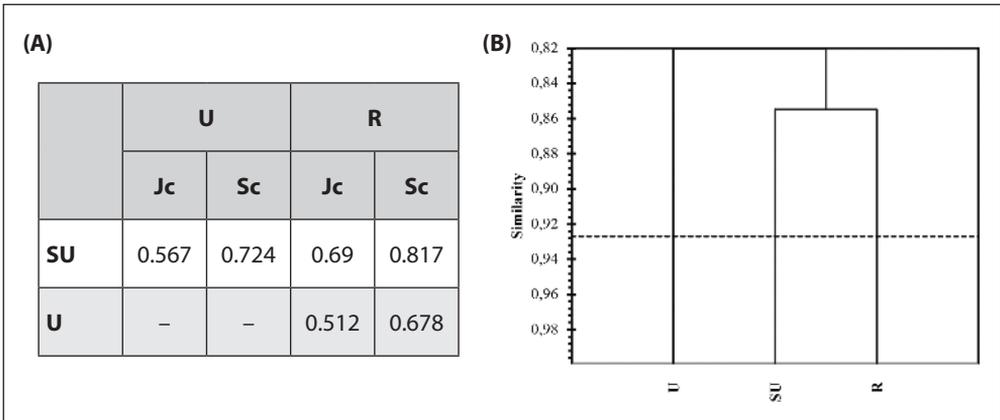| (A) | | | | |
|---|---|---|---|---|
| | **U** | | **R** | |
| | **Jc** | **Sc** | **Jc** | **Sc** |
| **SU** | 0.567 | 0.724 | 0.69 | 0.817 |
| **U** | – | – | 0.512 | 0.678 |

*Figure 9.* (A) Sorenson's (Sc) and Jaccard's (Jc) similarity coefficients calculated for different habitats in the study area (U = Urban station areas, SU = Suburban station areas and R = Rural station areas); (B) Hierarchical cluster analysis of similarity in species composition among the three study areas (SU, U and R)

*9. ábra* (A) Sorenson és Jaccard hasonlósági koefficiensek a három területtípusban. (B) A hierarchikus klaszterelemzés eredménye. U – városi terület, SU – elővárosi terület, R – vidéki terület

**Feeding guilds of birds**

Analysis of feeding guilds revealed that among the 43 species observed during the entire study period in selected railway stations irrespective of the urban-rural gradient, 16 species (37.2%) were omnivorous, 10 (23.25%) were insectivorous, 8 (18.6%) were carnivorous, 4 (9.3%) were granivorous, 3 (6.98%) were frugivorous, and the remaining 2 bird species (4.65%) were nectarivorous. Omnivores were the most dominant species in suburban (42.86%), urban (39.13%), and rural (36.11%) rail stations, followed by insectivores, with 26.08%, 25.71% and 22.22%, for U, SU and R stations, respectively. Nonetheless, the carnivore bird species recorded in the rural, suburban and urban station areas were 19.44%, 14.28% and 13.04%, respectively, while the granivorous species were highest in rural (17.4%) regions as compared to urban (8.57%) and suburban (8.33%) regions. Nectarivorous species were recorded only from the suburban (5.71%) and rural (5.5%) railways *(Figure 10)*.
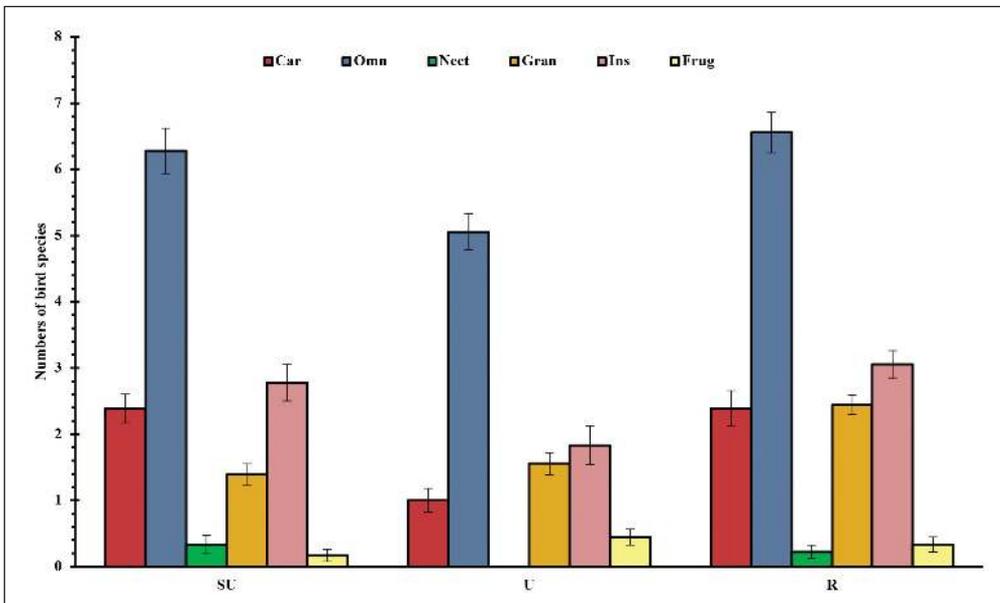


*Figure 10.* Numbers of bird species belong to six foraging guilds (i.e. Car=carnivore, Omn=omnivore, Nect=nectarivore, Gran=granivore, Ins=insectivore and Frug=Frugivore) recorded from the railway stations of suburban, urban and rural areas

*10. ábra* A hat különböző táplálkozási guildbe (Car = ragadozó, Omn = mindenevő, Nest = nektárfogyasztó, Gran = magevő, Ins = rovarevő, Frug = gyümölcsevő) tartozó madárfajok száma a három különböző területen vizsgált vasútállomásokon (SU – elővárosi, U – városi, R – vidéki)

## Discussion

The assessment of the bird diversity in the railway stations provided imperative information about the species assemblage patterns, variations in species composition, and species-specific abundance and richness in the station areas, much in support of the positive effects of railways on bird assemblages (Li *et al*. 2010, Morelli *et al*. 2014, Wiącek *et al*. 2015, 2019, 2020, Kaiser-Bonk *et al*. 2019). Variations in the bird species composition along the rural-urban gradient context remained similar to the observations made from Kolkata (Sengupta *et al*. 2014, Pal *et al*. 2019) and Amravati (Kale *et al*. 2018a, 2018b), India. During the entire study period, a total of 43 bird species belonging to 12 orders and 26 families were recorded in the railway stations irrespective of the urban-rural gradient, with the dominance of representatives from Passeriformes. The dominance of birds from Sturnidae, Corvidae, Columbidae, and Ardeidae families was observed in each area. While, the relative abundance of Sturnidae and Columbidae were higher in rural railway stations, the abundance of Corvidae was higher in suburban railway station areas. The House Crow *(Corvus splendens)* and the Common Myna *(Acridotheres tristis)* were the predominant species in all railway stations. Considering global population trend of birds, 4 species of urban areas, 6 species in suburban areas and 8 species from rural areas exhibited a decreasing trend in abundance. However, further monitoring is required to confirm the reasons for the decline in the abundance of these bird species. The species richness and the diversity indices of the bird assemblages were highest for the rural railway stations followed by the railway stations of suburban and urban areas. The Jaccard and Sorensen similarity coefficients revealed that the railway stations from the suburban and rural landscapes were the regions with the most similar species composition. In contrast, the rural and urban rail stations were the least similar in terms of species composition. Such patterns appear to be similar to the observations made from Kolkata (Sengupta *et al*. 2014, Pal *et al*. 2019) and Amravati (Kale *et al*. 2018a, 2018b), where the bird species richness were higher in rural areas contrast to the urban areas. In all these studies, a nestedness (Sengupta *et al*. 2014, Kale *et al*. 2018a, Pal *et al*. 2019) pattern were observed where the majority of the species of the urban areas were part of bigger species-rich assemblages of rural areas. Likewise, in the present instance, the species commonness between the rural and urban areas was observed, reflected through the indices of community similarity. Changes in the relative abundance of feeding guild of one bird may influence the abundance of others and thus, affects the community composition of the ecosystem (Barik *et al*. 2019). In this study, we found relatively higher abundance of omnivores in each selected railway stations irrespective of the urban-rural gradient followed by insectivores, while the abundance of other four guilds were the least. In the railway tracks near the forest areas, the insectivores dominate owing to the abundance of the macroinvertebrates like insects, more likely due to the edge effect (Wiącek *et al*. 2020). The granivorous bird species were the most abundant in rural railway stations as compared to urban and suburban station regions. A possible reason might be the presence of the agricultural landscapes along the railway tracks in the rural regions (Hossian & Aditya 2016). The nectarivorous species were recorded only from the suburban and rural railway station areas and were completely missing in the urban railway stations. Positive effects of manmade infrastructures in course of urbanization on the reproductive success of some wildlife population were

reported previously (Cardilini *et al*. 2013). The animals usually preferred to use the roadside constructions and associated structures have the physical and cognitive abilities to endure the possible risk (Fahrig & Rytwinski 2009). Utilization of small territory size, ability to avoid conflict with human activities, high productiveness could provide those animals the adaptability to survive with the anthropogenic interferences. Reduction of predation pressure, occurrence of roadside agriculture practices (Sundar & Kittur 2013, Hossain & Aditya 2016) as well as abundance of vegetation (Morelli *et al*. 2014, Wiącek *et al*. 2015, 2019, 2020, Kaiser-Bonk *et al*. 2019) provide foraging and nesting habitats to make a unique ecological corridor. The power lines, over bridge pillars, station railing borders, lamp posts possibly provide the suitable sites for chasing the prey by carnivores and insectivores (Morelli *et al*. 2014). The anthropogenic constructions somehow attract a large number of opportunist bird species by offering environmental heterogeneity (Morelli *et al*. 2014, Kaiser-Bonk *et al*. 2019, Wiącek *et al*. 2019, 2020). In this study, it was evident that the anthropogenic structures can be utilized to attract species too effectively to increase diversity irrespective to urban-rural gradient. The vegetation near railway station areas acting as ecological corridors for many insects, made these areas suitable for foraging habitat for many insectivorous bird species. It was reported that the passerine species used artificial light along the railway station areas, which increase their activity period. The passerines also used warm surface of station grounds, which could conserve their metabolic energy. Besides, the shrubs, lamp posts, bridges in station areas provide better place to construct nests for these species (Morelli *et al*. 2014). Construction along the railway tract, mainly the electric wires and poles provide suitable place for displaying and singing for the passerines. For granivorous bird species the availability of small stones near railway track could be a source for gastroliths and surface sand on station ground could help the passerine species to accomplish their sand-bathing, helpful for cleaning their feathers (Morelli *et al*. 2014). It was observed that the railway station areas are most suitable territory for rodents as they found it better ground for availability of food and safest hiding place. The availability of rodents and their traffic mortality turns the railway station area as a better foraging ground for carnivorous birds. During the study, it was reported that near the railway tracks, the relative abundance of omnivorous bird species were maximum irrespective of urban-rural gradient. It may be due to the fondness of bird species always to share ecotone environment. In addition to the open agricultural landscape along the railway track, which could provide excellent foraging ground due to the better insulation, higher temperature in station areas reinforce the growth and availability of rodents and invertebrates (Delgado *et al*. 2007). The abundance of various kinds of food along the railway station areas due to the existence of special microclimatic conditions might be qualified as an anthropogenic construction suitable for various bird species occupying different feeding guilds along with the dominance of omnivores due to their inclination towards the marginal habitats, which could provide them an ecotone environment (Delgado *et al*. 2007, Barbaro *et al*. 2014). Diverse and more affluent vegetation near the railway tracks provide most favourable habitat for a large number of invertebrate populations (Vermeulen 1994), which attracted various insectivorous birds species towards that ecotone environment. Though the noise from busy roadside traffic provides negative impact on many bird species (Rheindt 2003, Summers *et al*. 2011), in our study, we did not observe any negative interactions with the train movements to their surroundings. Such bird species frequently

observed in station areas did not react much in response to the noise made by the movement of trains through the station (Wiącek *et al*. 2015, 2019, 2020).

In the present observations, the railway stations across urban-rural gradient appear to bear a positive impact on the bird species assemblages. Considerable extent of taxonomic and functional diversity of birds was observed across the urban-rural gradient with prominent differences in the rural against the urban areas. Such observations tally with the characteristic bird species assemblages in urban areas (Pollack *et al.* 2017, Rodriguez *et al.* 2018, Filloy *et al.* 2019) and the differences in the urban and rural context (Sengupta *et al.* 2014, Kale *et al.* 2018a, 2018b, Pal *et al.* 2019). In the present study, higher diversity and species richness were observed in thesuburban and rural station areas than that of urban areas. Higher species richness and diversity index in periurban and suburban landscape as well as railway construction suggests human constructions are attractive to numerous bird species (Sandilyan & Sudha 2013). On the basis of the habitat requirements, species can be divided into two groups. Some species that are highly accustomed to human activities and those with special habitat requirements (Fernández-Juricic 2000). Birds accustomed to stay with the human activities are not usually afraid of human activities rather they usually preferred such constructions like railway stations, bridges, light posts, which potentially have positive effects on their population to provide nesting sites, alternative feeding habitat increase habitat heterogeneity to support more species. Perhaps, these factors contributed to the abundance of the birds in the railway stations observed in the present instance, where, densely populated areas or agricultural landscapes in the adjacent regions were a redundant feature. As an extension to the present observation, the biotic homogenization (Pal *et al.* 2019) and the nestedness pattern (Sengupta *et al.* 2014) of the bird species assemblages in the railway associated landscapes can be explored to promote sustenance of the birds in the concerned spaces. Nonetheless, the present study substantiates the observations made on the railways associated bird species assemblages in different geographical locations (Morelli *et al.* 2014, Kaiser-Bonk *et al.* 2019, Wiącek *et al.* 2015, 2019, 2020), justifying that railway transportation infrastructures may play more positive role in organizing the bird species assemblages than their negative impacts. However, a gradient of the urban-rural context was also prominent in the assemblage structure and the guild features of the birds occurring in different railway stations considered in the study. Observations of the present study provide a foundation to consider the railway infrastructure of West Bengal and similar regions of India to be a prospective organizer of the bird species assemblages and thus, suitable for conservation initiatives.

## Acknowledgement

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