Avifaunal diversity in urban parks of Delhi is shaped by both anthropogenic and natural factors

Author: Nirjesh Gautam
Correspondence: theenquiringlayman@gmail.com
ORCID: 0009-0002-4859-2546

Affiliation:
Centre for Urban Ecology and Sustainability
Dr. B. R. Ambedkar University Delhi

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Abstract

Urbanization leads to fragmentation and reduction of natural habitats which become islands of remnant biodiversity. As predicted by the Theory of Island Biogeography (TIB), fragment area and fragment isolation are major predictors of bird species richness in urban and rural habitats. This study is to understand patterns in avifaunal composition in select urban parks specifically in terms of area and size effect. To assess this, alpha and beta diversity indices were calculated and compared. Species–area curves were generated to test the relevance of TIB, and correlations were examined between species abundance, park area, and proximity to forested patches. Overall, the findings suggest that TIB alone is insufficient to explain avifaunal diversity in urban context. Instead, factors such as vegetation complexity, habitat age, human disturbance, and park management appear more significant, highlighting the multifaceted nature of urban ecological dynamics. This study demonstrates that small urban parks can support surprisingly rich avifaunal diversity, even in densely populated cities. The urban ecological future depends on recognizing and nurturing these green fragments as critical spaces for biodiversity.

Introduction

It is estimated that by the mid-twenty first century 2/3rd of the entire world's population is expected to be living in cities (Schilthuizen, 2018) which was only 10% during 1990s (United Nations, 2007). Perpetual and ever increasing internal and outward expansion of cities has resulted in the formation of fragmented landscapes within it. "Urbanization produces fragments of remnant habitat that represent a challenge for species because of decreased connectivity between fragments and reduced habitat" (MacArthur & Wilson, 1967).

Although, fragmentation caused by the continued growth of roads and buildings has led to a decline in the ability of cities to maintain biodiversity (Ferenc et al., 2014; Norton et al., 2016), but this consequential fragmentation creates "islands" of natural habitat (Oliver et al., 2011) which become important refuges for urban biodiversity (Sandström et al., 2006). The urban green spaces like parks and gardens, campuses and greenways (ibid) provide habitats and multitude of niches supporting a rich, but heavily fragmented biodiversity (Schilthuizen, 2018).

Typically, large connected fragments with diverse habitats sustain larger populations of migratory and resident birds with lower extinction rates (Gottfried, 1979; Husté & Boulinier, 2007). This may not necessarily be the case, as, bird species richness can also peak at intermediate levels of urbanization because of the increase in habitat diversity (Tratalos et al., 2007). As predicted by TIB, some empirical work suggests that fragment area, habitat structure, and fragment isolation are major predictors of bird species richness in urban and rural habitats (Bohning-Gaese, 1997; Fernández-Juricic, 2004; Godefroid & Koedam, 2003; Murgui, 2007).

The dramatic shift to urban living (Grimm et al., 2008; Kowarik, 2011) has increased the distance between island and mainland, thereby causing drastic habitat changes and negatively affecting urban biodiversity (Mckinney, 2008; Sol et al., 2017; Karn and Harada, 2001). With the rapid and often unplanned growth of urban centers across India (UNPFA, 2011), parks, gardens, tree lined avenues and residential yards are the only remnant habitats left for birds (Belaire et al., 2015).

Delhi is one such case and can easily be identified by the declining hues of ecological diversity. The gazetter of Delhi in 1887 divided it into four natural zones- kohi or hilly tracts, bangar or level main land, khadar or sandy riverine of the Yamuna and dabar or the flood plains (Krishen, 2006). However, an unprecedented urban growth, which has led to an irreversible change in land-use, has created discrete patches of woodlands within the city (Taubenböck et al., 2009). The central parts of Delhi have tree-lined avenues with 22 species of trees (Krishen, 2006) and residential yards are planted with trees, have parks and flower gardens, while the remainder of the city is homogeneously urbanized with visibly fewer green spaces (Tiwari & Urfi, 2016).

Irrespective of Delhi's inward and outward expansion there are still semi-wilderness areas left in Delhi. The total recorded forest area in Delhi is 85 sq. km. i.e. 5.73% of the geographic area of which the Reserved and Protected Forests constitute 91.76% and 8.24% of the total forest area respectively (Forest Department, n.d.). There are more than 18000 parks and gardens in NCT spread in about 8000 ha in various locations throughout Delhi which makes up for 20% of the green cover (Govt. of NCT, n.d.).

Despite rapid urbanisation and habitat loss in the Delhi-NCR region, a surprisingly high number of bird species continue to be recorded here. Based on the report generated using the MYNA feature of State of India's Birds, the region exhibits rich avifaunal diversity, with a total of 436 bird species reported. Among these, 191 are migratory species, and 66 are listed under Schedule I of the Wildlife Protection Act. Black-bellied Tern, Indian Skimmer, Great White Pelican, Isabelline Shrike are four species of highest Conservation Priority which are found here SoIB (2023).

Nevertheless, urban biodiversity has received very little attention from conservation biologists as compared to natural and protected ecosystems (Jules, 1997) and the current literature at the local scale mostly revolves around avifaunal composition and diversity (Rathod & Bhaduri, 2022;) and distribution studies like absence presence (Jain, N. K., Patel, S. N., & Patel, M. V. (2005). Furthermore, most of the preferred sampling sites were either educational institutes (Sagar & U, 2014) or important biodiverse sites (Urfi, 2003) or some reputable garden (Singh et al., 2018; Khan et al, 2021) in and around the city.

Given the importance of urban green space for maintaining urban biodiversity, the study of avifauna in select urban parks of Delhi would be of great importance for biodiversity conservation.

Whether parks and garden provide marginal habitat for species and what are the ecological processes which determine how many species can be accumulated in parks and gardens are broader and significant questions to be asked. Moreover, Evans, Newson, and Gaston (2009), in a review of bird studies that address effects of urbanization, found that local scale factors (i.e., park level) are better predictors than regional factors for species richness.

Keeping all this in mind the study proposes to understand patterns in avifaunal composition in selected parks specifically in terms of area effect and size effect.

Materials and methods:

Study sites

The National Capital Territory Region of Delhi is situated in Gangetic Plain covering about 34,144 sq km across 4 states. The geographical terrain ranges from wetlands, scrub forests and open grasslands to fallow fields. Delhi has extreme climatic conditions characterized by heat waves, dust storms, cold and foggy winters with an average annual rainfall of 800mm (Nazneen, 2019).

Three urban parks in New Delhi were selected from a list of parks and gardens maintained by DDA. The selection was based on three considerations: that, at least two parks must be comparable in size; that they should have different distance from nearest woodland from them; and the least significant was that they should be reachable during early hours of the day. Following three parks were selected based on differences in size, structure, and location:

1. Lodhi Gardens (LG): The Garden is located between Lodhi Road, Amrita Shergill Marg and Max Muller Marg. There are four monuments of archaeological importance in the park, built between 1433 to 1533 AD on the land of village Khairpur (Important Gardens of NDMC, n.d.). The park was named Lodhi Gardens recently in 1968 and was initially known as Lady Willingdon Park inaugurated in 1936 during British period. It is now maintained by Archaeological Survey of India (Srinivas, 2023). The historical and archaeological importance of the park led to further development which includes a 300 metre long and 1.3-metre-deep lake, a glass house for indoor plants and a Bonsai Park (Important Gardens of NDMC, n.d.). Along with these, there is a Rose Garden in the park as well. Lodhi gardens sustain a tree population of 4380 individuals of 120 different species (Bhalla & Bhattacharya, 2015). The park also has a mango tree classified as one among the Heritage Trees listed by Delhi government in September 2016 (Isrg, 2019; C, 2017). Ebird field checklist of Lodhi Gardens for June throughout all years suggests presence of 66 different avifaunal species (see appendix for species list).

2. Buddha Jayanti Park (BJP): Buddha Jayanti Park (BJP) which is planted mostly with ornamental plants is one of the two parks which have been carved out of Central Ridge Forest and contain swathes of natural landscape (Krishen, 2006). It lies on the eastern side of Vandemataram Marg which is also known as Upper Ridge Road. It was inaugurated by ex-PM late Lal Bahadur Shastri on 25th October 1964. It sustains almost 100 different tree species and 40 shrubs species (Landscape Works and Horticulture Activities, n.d.). BJP is managed by CPWD (Forest Department, n.d.) and is considered to be a precious environmental heritage of the NCT and acts as a heat sink in both summer and winter seasons (Das & Padmanabhamurty, 2021). This park is also used for religious ceremonies for example Buddha Purnima. It also contains two man-made water bodies one of which is not inundated with water. Ebird field checklist of Buddha Jayanti Park for June throughout all years suggests presence of 36 different bird species in the park (see appendix for species list).

3. Bandarwala Park (BWP): Bandarwala Park is located in Shastri Nagar along Swami Narayan Marg. A drain runs along its western boundary and eventually flows into the Sahibi River. The park remains open to visitors at all times. However, it is in relatively poor condition compared to nearby parks like LG and BJP Park. It is managed by the Delhi Development Authority (DDA).

   Within the park premises, there are three makeshift houses inhabited by daily wage labourers. Security presence is minimal, with very few guards stationed, contributing to a general lack of surveillance. The park experiences considerable disturbance, especially in the mornings and evenings, when it is frequently used as an informal cricket ground.

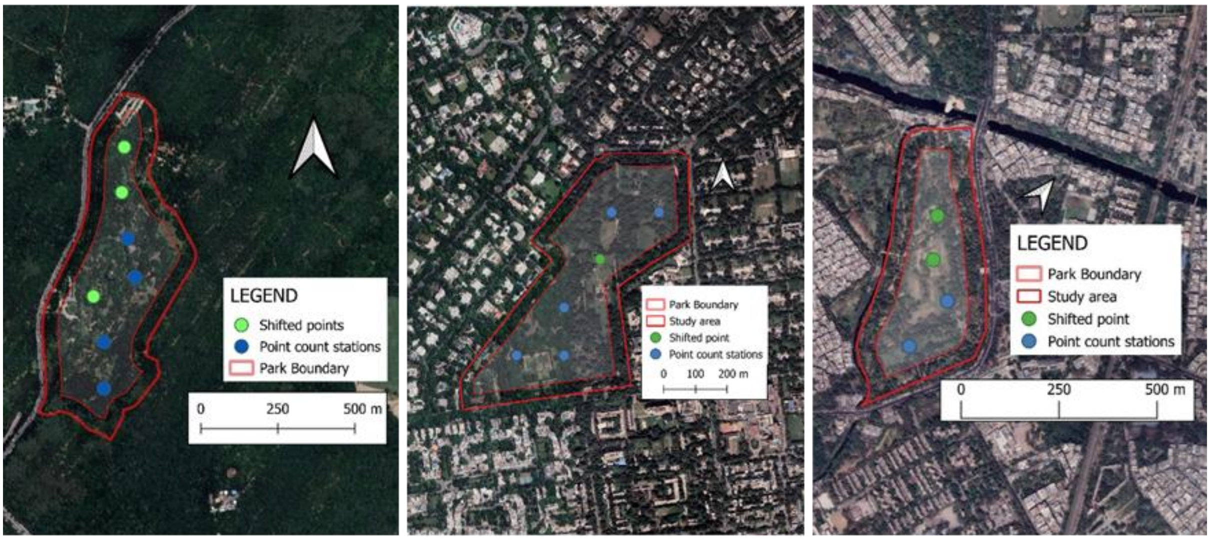
   Bandarwala Park also supports a significant population of stray dogs and monkeys, many of which are fed by regular visitors.

S.No	Name of the park	Perimeter (km)	Area (km^2)	PA Ratio	Distance from nearest woodland (km) | Name
1.	Bandarwala Park	1.78	0.16	11.1250	2.70 | Kamla Nehru Ridge
2.	Buddha Jayanti Park	2.60	0.33	7.7878	0 | Central ridge forest
3.	Lodhi Garden	2.53	0.30	8.4333	3.43 | Central ridge forest

Table 1: Selected urban parks and study variables in Delhi.

Methodology

The approximate area and perimeter of each park and its proximity to forest/woodland was estimated using Google Earth Pro. For the selected parks, an outline was projected on their maps by QGIS 3.32.0 'Lima' software. The consistent flow of energy, nutrients and species across the mutual boundary of two adjacent ecosystems results in "direct biological effects" (Forman & Godron ,1986) which may affect the abundance and distribution of species (Murica, 1995). Therefore, in order to reduce such variability caused by edge effect, a buffer of 50 m within the interior of the boundary was superimposed.



The urban parks which were selected for this study are complex or heterogeneous sites usually containing planted species which do not follow any natural pattern. Therefore, it is desirable to employ a fair number of stations (Morrison et al. 1981). The sampling strategy being followed is systematic sampling so that: firstly, the counts from each station are truly representative of the area within the survey boundaries; and secondly, to increase the effort/unit area.

Infrastructure such as roads, lawns and wires cause a non-random bird distribution complicating line transect methods (Emlen, 1974). And moreover, considering the complexities within each park and variable influences of neighbourhood in each park and within each park, the line transect method is not used. After preliminary surveys of the parks, Single count Plots (Bibby & Burgess, 1993) with a measuring distance of 50m were made. 5-minute bird count method (Dawson and Bull, 1975) was used, as keeping count duration as short as possible (e.g., </= 5 min per point) will reduce potential influence of evasive movements (Scott and Ramsey 1981). Also, in order to obtain an outline of diversity and richness “nothing can be gained by using longer counts” (Fuller & Langslow, 1984). Prior to every effort, a 2-minute settling time is observed to allow birds to settle down from any disturbance caused by observer.

For each park four efforts conducted in clear sky and non-rainy and non-windy days between June-July, 2023. The data is collected in the standardised sheet as recommended in Dawson and Bull (1975). Sampling was conducted each morning between 06:00-08:00 a.m. (Marsden, 1999; Wunderle, 1994; Rathore & Bhaduri, 2022). this being the period where bird detectability is highest and mobility is low, reducing the chance of recording contacts multiple times Birds flying above the canopy level were not recorded in the data collection sheet (Tiwary & Urfi, 2016). Distances to all observations are recorded (Bibby,1993). Observations taken using a Nikon Aculon binocular (12 x 50; 5.2 degree). Point count stations are located using Garmin 62s GPS device. Distances are measured using Bushnell Elite 1500 RangeFinder (7 x 26). Birds are identified using Grimmett et al. (1999) and ebird and merlyn mobile application. Photography done using Nikon D7000 and Nikon Coolpix P900.

Statistical analysis

To assess variations in bird diversity within and between parks, several diversity indices were used. At first Whittaker plots which display varying patterns of species richness amongst assemblages (Smith & Wilson, 1996) for each park were plotted in sequence from the most to least abundant against abundance (log10 format). Shannon index, a heterogeneity measure calculated considering the degree of evenness in species abundances. Shannon index is used to describe the disorder and uncertainty of individual species. Further, Simpson evenness index which captures the variance of the species abundance distribution (Magurran,1955) was calculated. Pileou's index, an index of community structure was calculated using the values of Shannon index for each park. Species accumulation curves were made for each park, they illustrate the rate at which new species are added and whether the effort was sufficient enough to make the raw data representative of the sites. In order to compare the variations between the selected parks Sorenson index was calculated. Based on Shannon index ENS (effective number of species) was calculated (Hill, 1973). Effective number of species indicates the true diversity of a site by taking exponential of Shannon values. Species area curves were made to check for the theory of island biogeography. Abundance and distance to nearest forest and Abundance and Area of park were also plotted against each other.

Results:

In total, 24 avifaunal species were found in Lodhi Gardens (LG) followed by Buddha Jayanti Park (BJP) and Bandarwala Park (BWP) with 22 and 14 species, respectively. Abundance of avifaunal species in each park and in comparison, to other variables are shown in the following graph.

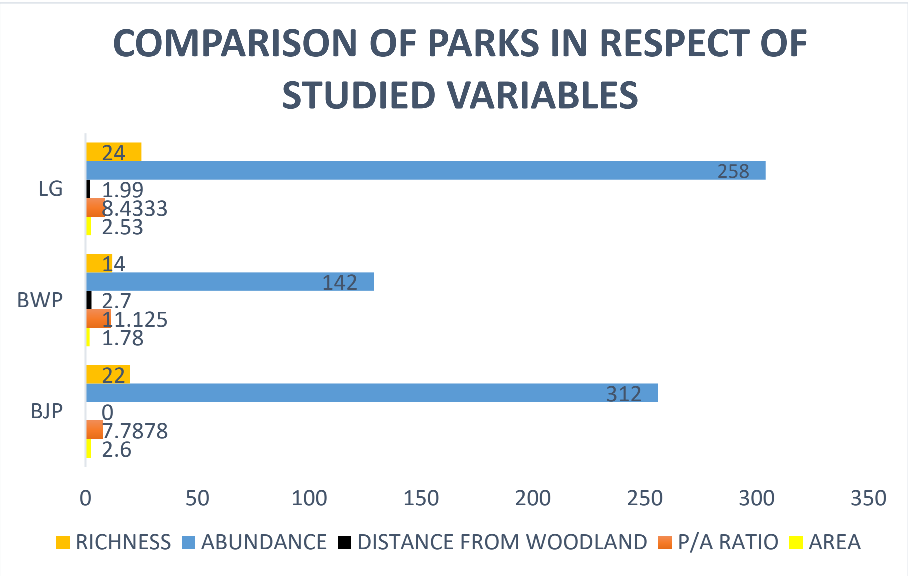


Figure 1: Comparison of parks in respect to studied variables

While LG had the highest species count, diversity indices revealed interesting contrasts. The Simpson Index, which emphasizes dominant species and downplays rare ones, was highest for BJP (figure 2), indicating greater evenness and dominance diversity compared to LG and BWP. On the other hand, LG has more rare species and less common ones but still has less diversity in accordance of this index. The Shannon Index, which accounts for both richness and evenness, also indicated BJP as the most diverse.

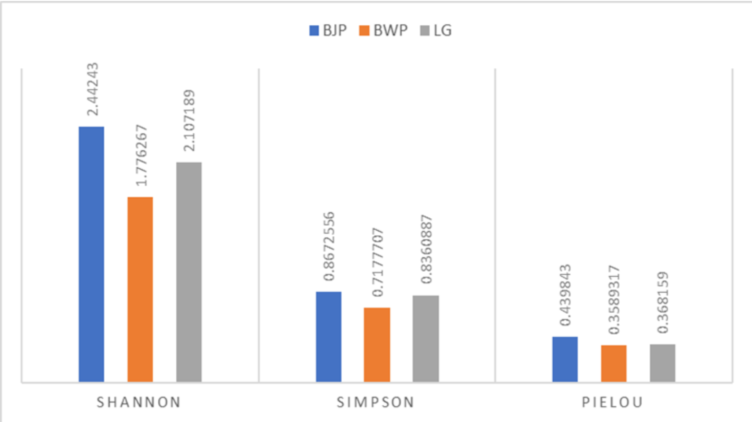


Figure 2: Comparison of bird diversity indices—Shannon, Simpson, and Pielou's Evenness—across three urban parks (BJP, BWP, LG).

However, Whittaker plots (figure 3) indicate that species are more equitably distributed in Lodhi Gardens (LG). The following plot clearly indicates that LG has more richness and moreover, even the lower ranking species or rare species have a greater number of individuals as compared to BJP or BWP.

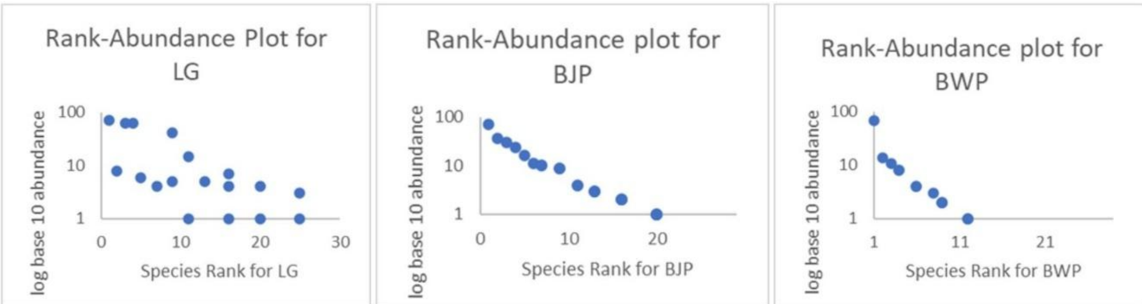


Figure 3: Rank-abundance (Whittaker) plots for each park.

Plots for BWP and BJP indicate less diversity as rare species have a very smaller number of individuals. Whittaker plots indicate that LG is most diverse followed by BJP and BWP. The lower ranking species in the latter parks are not equitably distributed. This discrepancy underscores how different indices capture different aspects of diversity.

This low evenness of the remaining parks is also suggested by Pileou's index. The higher value of BJP, i.e., 0.43 (figure 1) indicates more evenness in comparison to BWP and LG. Also, Bandarwala Park has least effective number of species whereas Buddha. Jayanti Park has 12 effective number of species (ENS). ENS indicates the true diversity of a site by taking exponential of Shannon values. This means that BJP can sustain at least 12 equally common species. On the other hand, LG can include 8 effective number of species followed by BWP which has scope for at least 6 species. This makes BJP more diverse in the sense of "true" diversity as at least 12 effective number of species can be included in it.

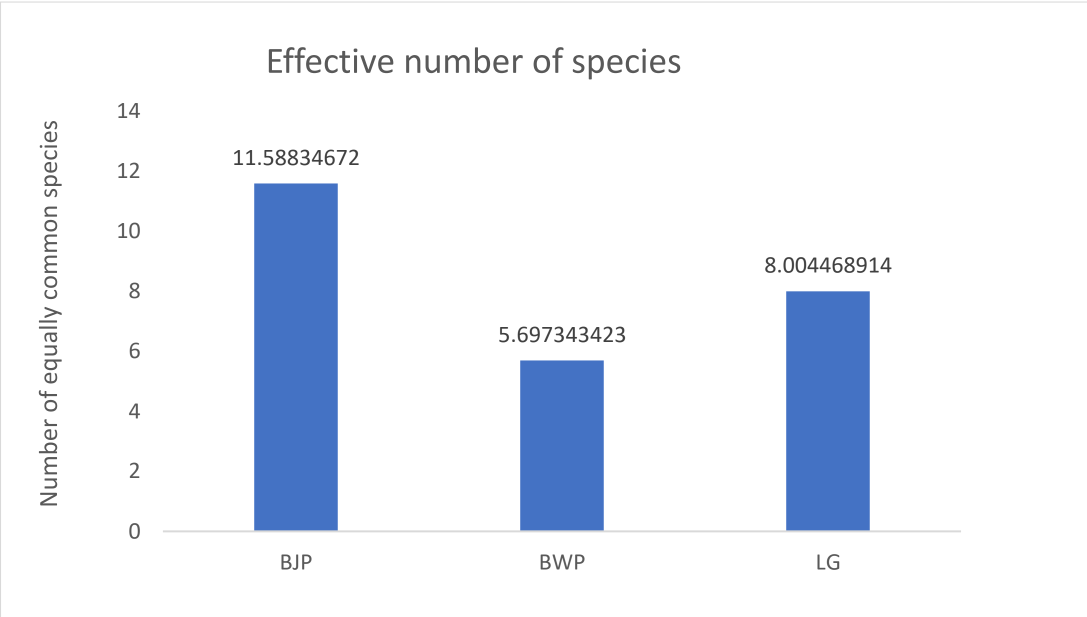


Figure 4: Effective number of species in each park.

However, Whittaker plots showed that LG had a more equitable distribution of individuals across species, especially among rare ones, suggesting higher true richness. Pielou's Evenness Index supported these findings, with BJP scoring higher than LG and BWP.

Species–area relationships showed inconsistent patterns. The following species area curve indicates that S (species richness) increases with area in case of BJP and LG which are comparable in terms of area. Conventionally, BJP for the given area should have more diversity in avifaunal species.

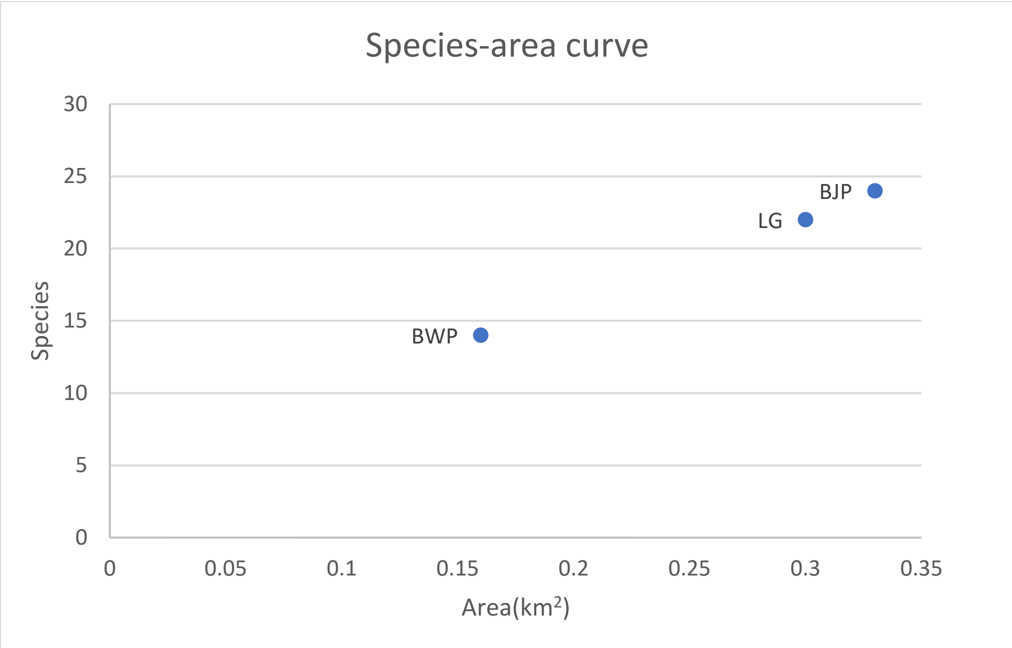


Figure 5: Number of species in each park plotted against their corresponding area.

The perimeter-to-area (P/A) ratios also varied. In the following figure, BJP had the lowest (7.79), suggesting reduced edge disturbance, while BWP had the highest (11.12), which may explain its lower diversity. For LG, species richness increases with P/A ratio. The larger the P/A Ratio greater is the spillover effect indicating greater disturbance leading to less diversity.

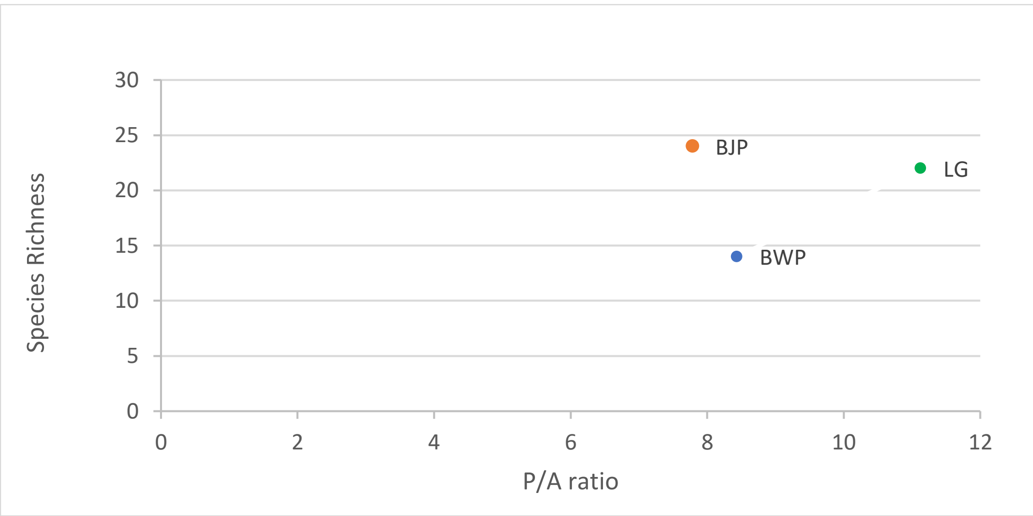


Figure 6: Species richness of each park plotted against their corresponding P/A ratio.

Pearson's correlation analysis supported a positive, though statistically non-significant, relationship between park area and species richness (r = 0.85, p = 0.35), and a weak negative correlation between distance from woodland and richness (r = -0.38, p = 0.75).

An interesting finding was the apparent link between avifaunal diversity and vegetation age. Coppersmith Barbets, for example, were seen only on older trees with sparse canopy, suggesting that tree age and structure influence species presence. Though not quantified, the degree of “parkification”—how landscaped or managed a park is—also seemed to matter. Older parks supported a higher number of bird species, while newer parks exhibited reduced diversity. In the case of BWP, the presence and activity of dogs and monkeys may also be contributing to the lower species richness. Furthermore, BJP, which is located within the Ridge area and was expected to host greater species richness, may have shown reduced diversity due to disturbances caused by the Kanwar Yatra during the data collection period.

Human activity played a role too. While common urban birds like Mynas and Crows were expected around food waste, sightings of Rufous Treepies and Black Kites feeding on leftovers suggest expanding synurbization. This raises questions about how human-provided food shapes urban bird communities.

Figure 7: A Black Kite shares scattered "namkeen" with a group of House Crows and a Jungle Crow. (Picture: Nirjesh)

Figure 8: A Rose-ringed Parakeet pecks at scattered grains, a common sight in many urban parks and gardens. (Picture: Nirjesh)

Overall, the findings suggest that factors such as vegetation complexity, habitat age, human disturbance, and park management play a significant role in shaping avifaunal diversity in urban settings. This underscores the multifaceted nature of ecological dynamics in cities.

Discussion:

Urbanization fragments habitats but does not entirely erase biodiversity. Parks, gardens, and tree-lined avenues remain critical refuges for birds, offering shelter, nesting sites, and food in the midst of built environments (Belaire et al., 2015). This study demonstrates that small urban parks can support surprisingly rich avifaunal diversity, even in densely populated cities.

While the Theory of Island Biogeography offers a useful starting point, its classic predictors—area and isolation—are inadequate for explaining biodiversity in cities without considering additional variables. Habitat quality, vegetation age and structure, and human activity often exert greater influence on urban biodiversity patterns.

As cities like Delhi continue to expand, integrating biodiversity into urban design is no longer optional—it is essential. Urban green spaces should not be viewed as decorative extras, but as functioning ecosystems. Enhancing habitat quality, increasing native vegetation cover, and ensuring connectivity through corridors or stepping-stone habitats can foster more resilient urban biodiversity.

Moreover, conservation in urban landscapes must move beyond a "preserve-only" mindset. Parks, wastelands, and even roadside vegetation should be recognized as legitimate ecological spaces. Public engagement, local stewardship, and inclusive planning are all vital for creating more bird-friendly cities.

Limitations:

This study offers valuable insights but is subject to several limitations. Observations were restricted to a single season, potentially missing migratory or seasonal variations in bird populations. The study's limited scope—just three parks—also restricts broader generalization. Rarefaction curves suggest that sampling effort, especially in Bandarwala Park, was insufficient to capture full avifaunal diversity. Temporary disturbances like flooding may also have influenced species presence.

Recommendations for future research:

Future research should adopt a multi-seasonal approach and include a broader range of parks with varied ecological characteristics. Seasonal shifts can reveal temporal variations in species composition, habitat use, and behaviour that may otherwise be missed in single-season surveys.

Increasing sampling intensity in terms of both frequency and duration will improve the reliability of species detection, especially for elusive or transient species. A broader inclusion of parks that differ in size, management regimes and historical land use also provide a more comprehensive understanding of the factors shaping urban avifauna. Similarly, analysing vegetation structure in terms of age, diversity, canopy complexity vertical stratification and the proportion of native versus exotic flora would illuminate habitat preferences.

An important and often underexplored dimension is the quantification of human disturbance. Metrics such as ambient noise levels, foot traffic, recreational activity, and food provisioning practices (both intentional and incidental) could be systematically recorded to evaluate their direct and indirect impacts on bird communities. These data could help disentangle the nuanced ways in which human presence alters bird behaviour, habitat use, and community structure.

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