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Cover: Emperor Tamarin *Saguinus imperator*: a look into a better world through the mustache lens – mixed media illustration. © Maya Santhanakrishnan.



Factors influencing the occurrence of the House Sparrow *Passer domesticus* (Linnaeus, 1758) (Aves: Passeriformes: Passeridae) in Bhavnagar, Gujarat, India

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Abstract: The present study aims to understand key factors influencing the House Sparrow population across different habitat scales in Bhavnagar, Gujarat, India. Correspondingly, different variables such as changes in habitat composition, sound levels, and density of mobile phone base stations were considered with reference to the occurrence of the House Sparrows across the study area. During the study period (December 2016 to November 2018), the number of House Sparrows was recorded through point count without distance estimate method. Non-parametric tests were employed to assess variations in different variables and their correlation with the presence of House Sparrows, revealing that changes in local habitat composition significantly influence their occurrence. Shrubby vegetation, cowsheds, and old/traditional structures emerged as crucial predictors positively impacting House Sparrow's presence, particularly in urban areas where suitable habitat patches are scarce due to urbanization and modern lifestyles. The decline in these habitats has significantly impacted House Sparrow populations. To counter this decline, implementing strategies like providing artificial nest sites is being considered. However, it's crucial to ensure that there are adequate shelter and food resources available to effectively conserve the species.

Keywords: Bushy vegetation, cowsheds, electromagnetic radiation, green cover, habitat change, house sparrow density, mobile phone base station, nesting habitats, sound level, urbanization.

Gujarati: પ્રસ્તુત અભ્યાસનો ઉદ્દેશ ભારતના ગુજરાત રાજ્યમાં આવેલ ભાવનગર શહેર ના વિવિધ પ્રકાર ના વસવાટો માં ઘર ચકલી ની વસ્તીને પ્રભાવિત કરતા મુખ્ય પરિબલોને સમજવાનો છે. જેને અનુરૂપ, સમગ્ર અભ્યાસ વિસ્તારમાં જોવા મળતી ઘર ચકલી ના સંદર્ભમાં વિવિધ ચલ જેમ કે વસવાટની રચનામાં ફેરફાર, ધ્વનિ સ્તર અને મોબાઇલ ફોન બેઝ સ્ટેશનની ઘનતા ને અભ્યાસ દરમિયાન ધ્યાનમાં લેવામાં આવી હતી. અભ્યાસ સમયગાળા દરમિયાન (ડિસેમ્બર ૨૦૧૬ થી નવેમ્બર ૨૦૧૮), ઘર ચકલી ની સંખ્યા અંતર અંદાજ પદ્ધતિ વિના પોઇન્ટ કાઉન્ટ દ્વારા નોંધવામાં આવી હતી. વિવિધ ચલોમાં ભિન્નતા અને ઘર ચકલી ની હાજરી સાથેના તેમના સહસંબંધનું મૂલ્યાંકન કરવા માટે બિન-પેરામેટ્રિક પરીક્ષણોનો ઉપયોગ કરવામાં આવ્યો હતો, જે દર્શાવે છે કે સ્થાનિક વસવાટની રચનામાં ફેરફાર તેમની ઘટનાને નોંધપાત્ર રીતે પ્રભાવિત કરે છે. ખાસ કરીને શહેરી વિસ્તારોમાં જ્યાં શહેરીકરણ અને આધુનિક જીવનશૈલીને કારણે યોગ્ય વસવાટની જગ્યાઓ ટુકડાં છે, ત્યાં ઝાડી-ઝાંખરા વાળી વનસ્પતિ, ગૌશાળા/પશુપાલન અને જૂની/પરંપરાગત બાંધકામ ની રચનાઓ ઘર ચકલી ની હાજરીને સકારાત્મક અસર કરતા પરિબલો તરીકે નોંધાયા છે. આ વસવાટોમાં થયેલા ઘટાડાઓ ઘર ચકલી ની વસ્તીને નોંધપાત્ર રીતે અસર કરી છે. આ ઘટાડાઓ સામનો કરવા માટે, કૃત્રિમ માળાઓ પ્રદાન કરવા જેવી વ્યૂહરચનાઓ ધ્યાનમાં લેવામાં આવી રહી છે. જો કે, પ્રજાતિઓને અસરકારક રીતે બચાવવા માટે પર્યાપ્ત આશ્રય અને ખાદ્ય સંસાધનો ઉપલબ્ધ છે તેની ખાતરી કરવી પણ મહત્વપૂર્ણ છે.

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INTRODUCTION

The House Sparrow *Passer domesticus* (Linnaeus, 1758) is an excellent urban exploiter species. Due to its sensitivity to changing urban environments, it can be considered as a model species for investigating the effects of urbanization (Manger 2008; Meillère et al. 2015a; Hanson et al. 2020; Mohring et al. 2021). Although the species has widespread distribution, alarming decline in the House Sparrow populations have been reported from different parts of the world (Crick et al. 2002; Summer-Smith 2003; Raven et al. 2005; Murgui & Maclas 2010; Summers-Smith et al. 2015). Studies in India have also shown a decline in the population of House Sparrows (Ghosh et al. 2010, Khera et al. 2010; Modak 2017). Besides, recent analyses suggest that changes in House Sparrow population show marked regional variation and are especially severe in urbanized habitats (Siriwardena et al. 2002; Chamberlain et al. 2005; Mohring et al. 2021). Many studies have noticed a pattern, where socioeconomically deprived areas harbour a large number of House Sparrows with a lower rate of population decline (Dröscher 1992; Bland 1998; Paston 2000; Robinson et al. 2005). Despite being an intriguing urban dweller, it appears that the heavily human modified urban environment has adverse effects on this urban sentinel species (Siriwardena et al. 1998; Balaji et al. 2014; Modak 2017; Meeran et al. 2021; Mohring et al. 2021).

Various hypotheses that negatively affect the House Sparrow population are proposed, including habitat change, specifically the loss of feeding, sheltering, or nesting sites (Vincent 2005; Anderson 2006; Shaw et al. 2008; Mouldrá et al. 2018). Additionally, the population decline may be attributed to the intensification of pollution sources such as traffic pollution (Summers-Smith 2003; Peach et al. 2008; Herrera-Dueñas et al. 2017), noise pollution (Bhattacharya et al. 2011; Meillère et al. 2015b), light pollution (Ghosh et al. 2010; Dominoni et al. 2013), air pollution (Summers-Smith 2003; Eeva et al. 2009), and electromagnetic radiation (Balmori & Hallberg 2007; Everaert et al. 2009). Additionally, these several stressors may interact and contribute cumulatively to the decline of House Sparrows (De Coster et al. 2015). However, conclusive evidence for any of these causes is still lacking.

There has been a great deal of research conducted in European countries concerning the decline of the House Sparrow population (Summers-Smith 2005; Wilkinson 2006; Chamberlain et al. 2007; Murgai & Maclas 2010; Peach et al. 2015; Ponce et al. 2018; Mohring et al. 2021).

In India, the decline in the House Sparrow population has engendered deep public concern, particularly across Delhi, Haryana, Uttar Pradesh, and in West Bengal (Dandapat et al. 2010; Ghosh et al. 2010; Khera et al. 2010; Kumar et al. 2015; Patel & Dodia 2017); however, the proximate causes of this decline remain poorly understood. A relatively limited amount of information is currently available regarding the species' habitat associations within urbanized environments in India (Hussain et al. 2014). Besides, most of studies related to factors affecting House Sparrows' population has been conducted in southern India (Kurhade et al. 2013; Balaji et al. 2014; Pandian & Natarajan 2018; Maxmellion et al. 2020; Meeran et al. 2021; Pandian 2023; Veerá & Lanka 2023), in northern India (Hussain et al. 2014; Wani & Sahi 2018; Waldia & Bhatt 2022) and few from West Bengal (Ghosh et al. 2010; Modak 2017). However, a systematic account on factors influencing House Sparrow occurrence in Gujarat are lacking.

The present study pertains to examine the impact of different variables including habitat composition, sound levels, and density of mobile phone base stations on the occurrence of the House Sparrows across different habitat scale in Bhavnagar, Gujarat, India. The data set would be useful for identifying underlying environmental or anthropogenic factors negatively affecting the House Sparrow population. Moreover, understanding the factors contributing to the decline of the House Sparrow population will assist in developing effective conservation strategies.

MATERIALS AND METHODS

Study area

The present study was conducted in and around the coastal city of Bhavnagar in the Saurashtra region of Gujarat, India (Image 1). The area encompassed by the city of Bhavnagar is approximately 119 km², as reported by the Bhavnagar Municipal Corporation (2023). The Gulf of Khambhat lies on the west side of Bhavnagar. The outer region of the city is drained by Kansara, a small river that flows intermittently and is nonperennial in nature.

Throughout the year, Bhavnagar's climate remains fairly humid due to its proximity to the Gulf of Khambhat. There is a hot semi-arid climate with a hot dry summer, a wet monsoon, and a mild winter. Bhavnagar is a Class I Urban Agglomeration with a population density of 4,700 persons per km² (Bhavnagar Urban Region Population 2011 – 2024 (2022); Bhavnagar Municipal Corporation

(2023)). Due to the presence of the Bhavnagar Port, industrial growth has been catalysed in the city. As a result, Bhavnagar has become a hub for various industries, including diamond cutting and polishing units, salt and marine chemicals, plastics, shipbuilding, textiles, chemicals, and wood products. Major crops are Cotton, Groundnut, Bajra, Sesame, Jowar, Onion, while major horticultural crops include Mango, Citrus, Sapota (Chiku), and Banana (Jagdish 2022). Vegetation mostly dominated by deciduous plant species such as Gando Baval *Prosopis juliflora*, Desi Baval *Acacia nilotica*, Gorad Baval *Acacia senegal*, Khijado *Prosopis cineraria*, and Khati Amli *Tamarindus indica*.

Study design

In order to identify differential responses of the House Sparrow to distinct habitat scales, the study area has been divided into three gradients, namely: urban (URB) – dense residential area in the city; suburban (SUB) – area adjacent to the city or surrounding the main city (located at an approximate 2 km distance adjacent to the core city area); and rural (RUR) – open countryside outside the densely populated urban towns or city (approximate distance of 9–10 km from the core

city area). Based on the primary survey, three potential sites (harbouring more than 100 House Sparrows) were selected from each gradient; hence, a total of nine sites were monitored throughout the study period. To avoid biases in the data collection due to the population mixture of different sample sites, it was ensured that each sample site was at least 2-km apart from each other. Hence, 2×2 km grids were created and superimposed over the study area with the help of Google Earth Pro v. 7.3.6.9345 (2022). From the urban gradient – Barsomahadev (URB1) (21.774N, 72.139E), Bharatnagar (URB2) (21.744N, 72.160E), and Anandnagar (URB3) (21.788N, 72.157E) study sites were selected for data collection; while from the suburban gradient – VP Society (SUB1) (21.759N, 72.170E), Forest Colony (SUB2) (21.737N, 72.150E), and Fulsar (SUB3) (21.746N, 72.094E) study sites were selected for data collection; and from the rural area – Akwada (RUR1) (21.739N, 72.180E), Nari (RUR2) (21.783N, 72.077E), and Sidsar (RUR3) (21.721N, 72.110E) study sites were selected for the study.

Methods

The study period has been divided into four seasons,

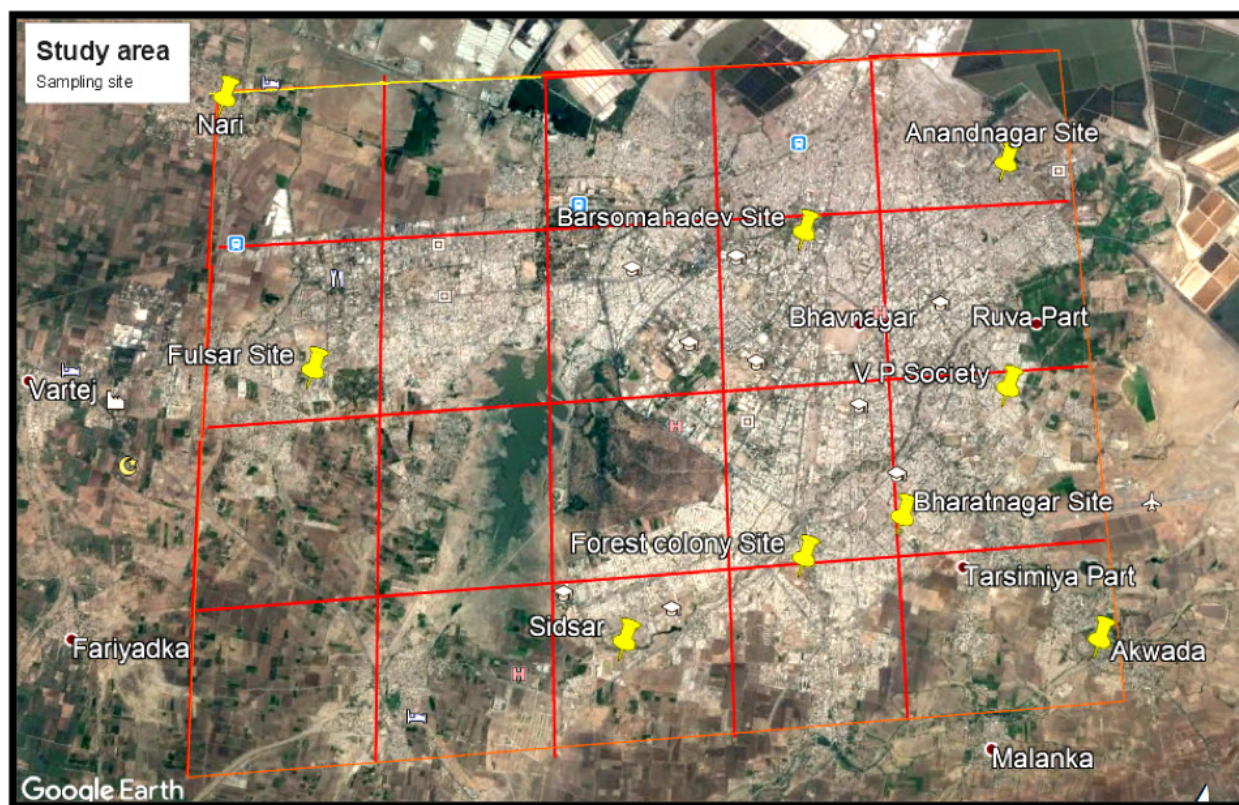


Image 1. Google Earth satellite image showing nine different sampling sites within the study area (approx. grid line of 2×2 km).

i.e., winter (December–February), summer (March–May), monsoon (June–August), and post monsoon (September–November). Each site has been visited at least once a month. House Sparrows were counted by point count without distance estimate method from December 2016 to November 2018. The density of the House Sparrow was estimated by dividing the number of House Sparrows by monitoring sites. The survey area across each site was measured using Google Earth Pro program. Individuals of House Sparrows were observed by Nikon Aculon A211 8 x 42 binoculars. Besides, green cover was identified as an important component of habitat-influencing species occurrence at a local scale. Correspondingly, changes in green cover were monitored through Google Earth Pro program across different sampling sites. Besides, plant species used by the House sparrow for pre-roosting or roosting were also recorded by direct observation. In 2018, sound levels were measured at different study sites using an LT Biss digital Sound meter (range: 30–130 dB) with an accuracy of ± 1.5 dB. The minimum and maximum sound levels were recorded at 10-minute intervals during each field visit. In order to identify possible associations between mobile phone base stations and the presence of House Sparrow, the number of mobile phone base stations within 1-km radius of sample sites was considered using Tarang Sanchar Portal. Besides, basic information about electromagnetic fields (EMF), including potential effects, emission modes from towers, and radiation power thresholds from various telecom towers, was acquired through reference materials from the Tarang Sanchar Portal. During the study, numbers for each type of nest located within a 0.5 km radius of the roosting sites were also counted as indicative of nesting opportunities for House Sparrows at each site.

Statistical analysis

The data were analysed using IBM SPSS Statistics software (IBM SPSS Statistics for Windows, Version 22.0, Armonk, New York: IBM Corp. Software) after being exported from Microsoft Excel. We applied Kolmogorov-Smirnov and Shapiro-Wilk tests to assess the normality of the data. Given the non-normal distribution of the data, non-parametric tests were employed to determine variances (Hartvigsen 2021). We assessed variations in the percent density of House Sparrows, percent green cover, and sound levels across urban, suburban, and rural gradients using the non-parametric Kruskal-Wallis H test. Results are reported with asymptotic significances from two-sided tests, and significance levels were adjusted for multiple comparisons using the

Bonferroni correction method. Due to insufficient point counts at the Akwada site (RUR1) in 2017, data from this location were excluded from the analysis for that year.

We explored the relationships between percent of green cover, sound levels, and the number of mobile phone base stations with the occurrences of House Sparrows using the Spearman's rank-order correlation coefficient test. A significance threshold was set at $P < 0.05$ for all statistical analyses. For each analysis, we report the degrees of freedom (df) and significance levels. Results are presented as means \pm standard error (SE), and findings from post hoc analyses are reported using the compact letter display format.

RESULTS

The mean density of the House Sparrow was estimated based on a total of 204-point counts conducted at nine study sites across three gradients: urban, suburban, and rural during the study period. In 2017, the highest density of the House Sparrow was recorded at a rural gradient ($0.0719 \pm 0.0119/\text{m}^2$), followed by suburban ($0.0351 \pm 0.0063/\text{m}^2$) and urban ($0.0275 \pm 0.0042/\text{m}^2$) respectively ($H(2) = 9.66$, $p < 0.05$) (Table 1, Figure 2). In 2018, the density of the House Sparrow decreased to $0.0366 \pm 0.0089/\text{m}^2$ in rural gradient followed by suburban ($0.0247 \pm 0.0066/\text{m}^2$) and urban ($0.0113 \pm 0.0017/\text{m}^2$) respectively ($H(2) = 3.35$, $P > 0.05$) (Table 1, Figure 2).

Vegetation cover plays a critical role in maintaining a healthy ecosystem on a local scale. In the current study, besides direct observations, changes in habitat composition were examined by analysing vegetation cover through Google Earth Pro. There was an average green cover of 29.08% of the total surveillance area across the urban gradient in 2017. Within the urban gradient, it was observed that green cover was primarily restricted to public gardens, private courtyards, roadside plantations, and green fields in certain locations. In 2018, green cover decreased to 24.52% across the urban gradient mainly due to the removal of vegetation from green fields (e.g., Bharatnagar (URB2), Image 2) or local regeneration efforts (e.g., Anandnagar (URB3)) (Figure 1).

In 2017, the suburban gradient boasted a green cover averaging 29.39% of the surveillance area, predominantly comprising green fields, private courtyards, and roadside plantations. However, by 2018, this green coverage diminished to 19.04% due to the deliberate removal of shrubby vegetation from

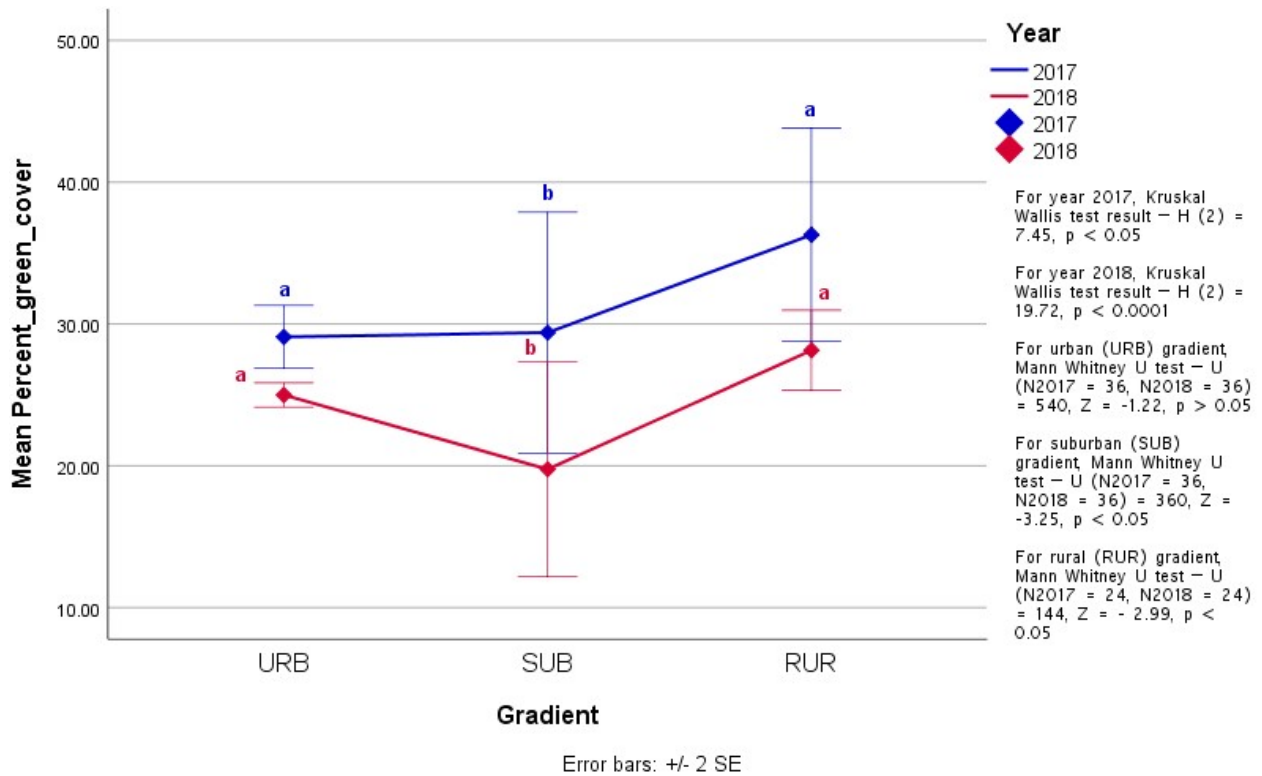


Figure 1. The mean percent green cover across urban (URB), suburban (SUB), and rural (RUR) gradients of Bhavnagar during the years 2017 and 2018.

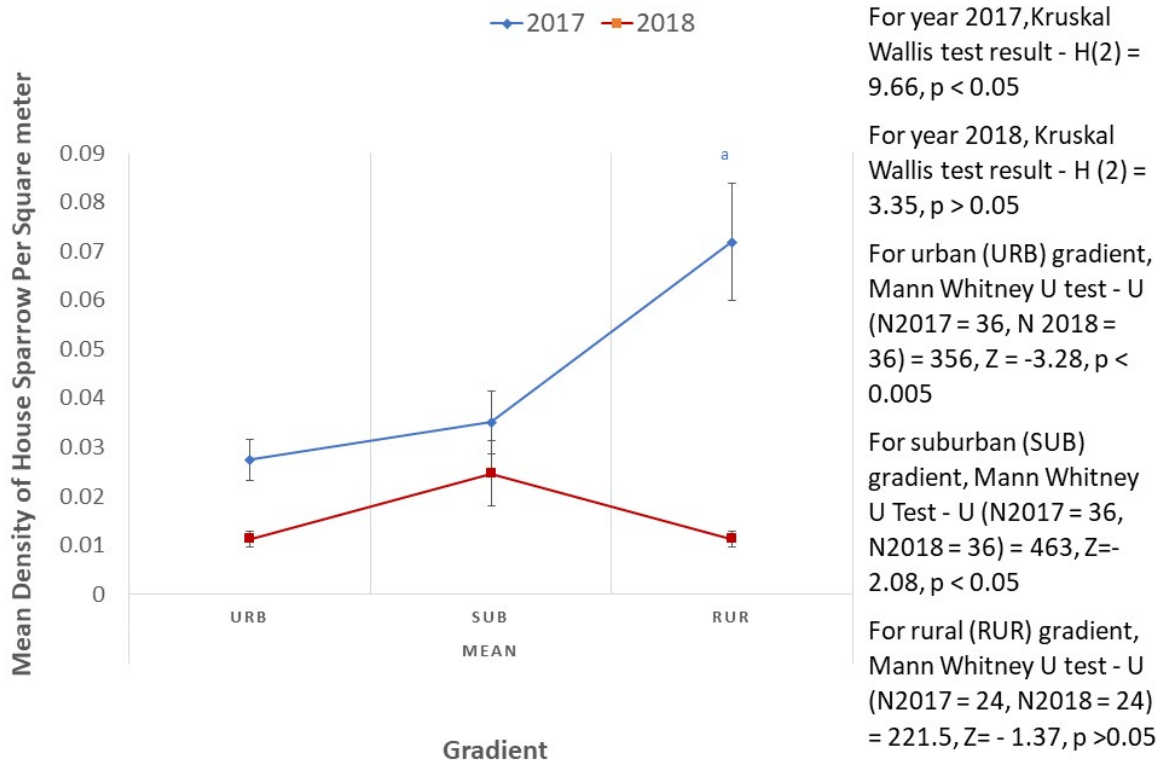


Figure 2. Mean density of House Sparrow across urban (URB), suburban (SUB), and rural (RUR) gradients of Bhavnagar during the years 2017 & 2018.

Table 1. The mean number of birds counted during point counts across the urban (URB), suburban (SUB), and rural (RUR) gradient during the study period from December 2016 to November 2018.

Year	Gradient	Mean Birds counted during point count
2016–17	Urban (URB)	1143.67 ± 197.456
	Suburban (SUB)	463.69 ± 72.797
	Rural (RUR)	309.29 ± 52.176
2017–18	Urban (URB)	447.06 ± 79.233
	Suburban (SUB)	204.75 ± 31.089
	Rural (RUR)	242.64 ± 37.861

Table 2. Spearman's rho correlations between the percent density of the House Sparrow and percent green cover across urban, suburban, and rural areas of Bhavnagar.

Percent density of the House Sparrow	Percent green cover			
		Urban (URB)	Suburban (SUB)	Rural (RUR)
	Correlation coefficient	0.547**	-0.517**	-0.577**
	Sig. (2-tailed)	0.000	0.000	0.000
	N	72	72	60

**Correlation is significant at the 0.01 (2 – tailed).

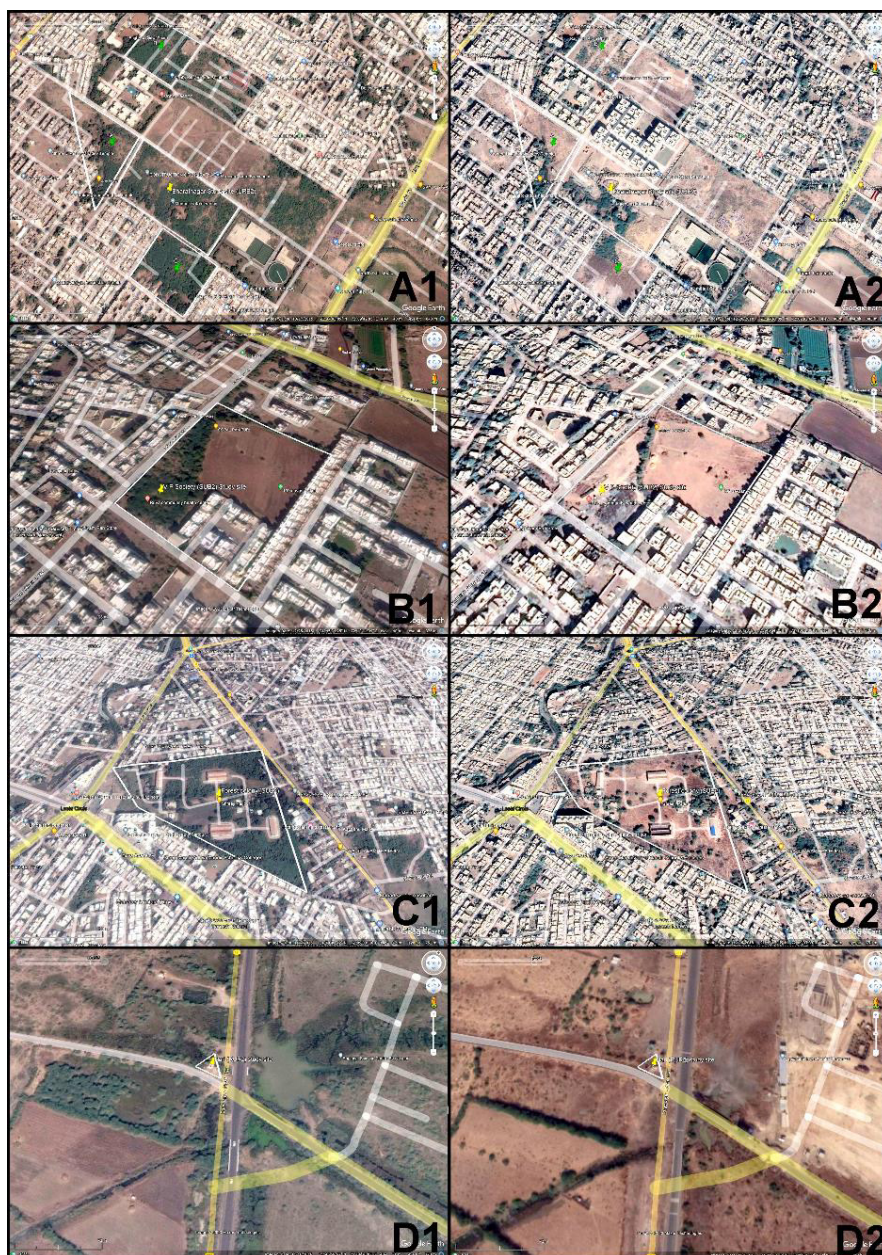


Image 2. Changes in habitat composition evidenced through Google Earth at Bharatnagar (A1, A2), VP Society (B1, B2), Forest colony (C1, C2), and Nari (D1, D2).

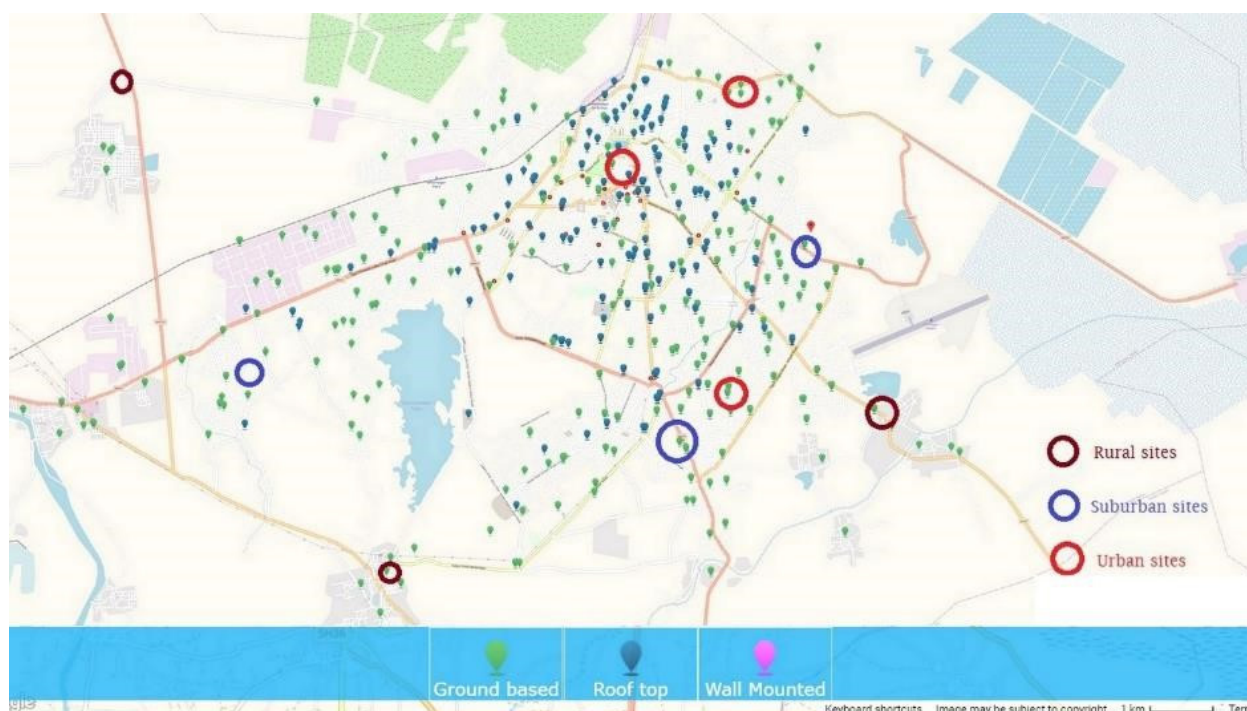


Image 3. Screenshot of Tarang Sanchar portal showing the density of mobile towers across urban, suburban, and rural gradients of Bhavnagar.

Table 3. Spearman's rho correlations between the percent density of the House Sparrow and different sound levels across the study area.

Percent density of the House Sparrow	Sound level			
		Sound level min	Sound level max	Sound level mean
	Correlation coefficient	0.085	-0.097	0.047
	Sig. (2-tailed)	0.382	0.320	0.632
	N	108	108	108

green fields for construction purposes, particularly evident at VP Society (SUB1). Concurrently, at Forest Colony (SUB2), a similar clearance of shrubby vegetation occurred for undisclosed reasons, presenting ambiguity regarding the rationale behind this action during field observations. Thus, while construction activities accounted for the decline in green cover in some areas, the precise motivation for vegetation removal at Forest Colony remained elusive throughout the study. (Figure 1, Image 2).

There was an average green cover of 34.47% of the total surveillance area across the rural gradient in 2017. Within the rural gradient, vegetation cover was mainly found in the form of farmland, green fields, private courtyards, and roadside plantations. In 2018, green cover decreased to 28.14% across the rural gradient mainly due to the removal of vegetation from green fields (e.g., Nari (RUR2)) for constructing a regional

science centre) (Figure 1, Image 2).

During the study, there was a strong positive correlation found between the percent green cover and the mean density of the House Sparrow at urban gradient ($r_s(70) = 0.547$, $p < 0.0001$) (Table 2). While strong negative correlation was found between the percent green cover and mean density of the House Sparrow at suburban ($r_s(70) = -0.517$, $p < 0.0001$) and rural gradient ($r_s(58) = -0.577$, $p < 0.0001$) (Table 2).

During the study, House Sparrows were mostly found to prefer shrubby vegetation for shelter, primarily composed of shrubby plant species such as *Prosopis juliflora*, *Ziziphus jujuba*, *Ziziphus xylopyrus* and *Acacia senegal* (Image 5B). In addition, often in the absence of aforementioned plant species, House Sparrow also used *Bambusa vulgaris*, *Punica granatum*, *Morus alba*, *Syzygium cumini*, *Ficus religiosa*, and *F. benghalensis* for roosting & pre-roosting purposes. In addition, it was also

noted with the presence of livestock/cowsheds near the monitoring sites of two urban sites (Barsomahadev (URB1); Anandnagar (URB3)), all three suburban sites (V P Society (SUB1), Forest colony (SUB2), Fulsar (SUB3)) and two rural sites (Akwada (RUR1), Sidsar (RUR3)). The Bharatnagar (URB2) site was characterized by dense residential areas with scattered wasteland patches. In contrast, the Nari (RUR2) site was surrounded by open farmland.

During the study, the highest sound level was recorded at urban gradient (Min.: 59.60 ± 1.14 dB; Max.: 77.26 ± 1.28 dB; Avg.: 68.43 ± 0.92 dB) followed by suburban (Min.: 59.30 ± 1.17 dB; Max.: 74.26 ± 0.71 dB; Avg.: 66.78 ± 0.76 dB) and rural (Min.: 55.55 ± 1.13 dB; Max.: 74.74 ± 1.63 dB; Avg.: 65.15 ± 1.11 dB), respectively (Figure 3). High sound levels across urban sites were due to the presence of large factories nearby and heavy vehicles passing from the roadside. In the present study, however, no such statistically significant relationship was established between the percent density of House Sparrow and different sound levels, i.e., minimum sound level ($r_s(106) = 0.085$, $p > 0.05$), maximum sound level ($r_s(106) = -0.097$, $p > 0.05$) and mean sound level ($r_s(106) = 0.047$, $p > 0.05$) (Table 3).

In the present study, compared to suburban and rural sites, urban sites typically had more mobile phone base stations (Image 3, Table 5). There was no significant correlation found between a number of mobile phone base stations and the occurrence of House Sparrows across the study area $r_s(7) = 0.271$, $p > 0.05$ (Table 4). Similarly, no significant relation was found between several active nests of House Sparrows and the density of mobile towers, $r_s(7) = 0.513$, $p > 0.05$ (Table 4). Hence, no mechanistic relationship was established between the densities of mobile phone base stations and occurrences of House Sparrows.

DISCUSSION

Green cover was found to be a critical habitat factor that influences House Sparrow occurrences directly or indirectly, notably serving as their preferred shelter for pre-roosting and roosting. The observed decline in density of the House sparrow could be partly linked to the removal of bushy vegetation, particularly in urban areas such as Bharatnagar (URB2) (Table 2). Wastelands or green fields with ruderal bushy vegetation were identified as vital shelters that support large communal gatherings of House Sparrows. For instance, in 2017, Bharatnagar (URB2) had dense bushy areas covering

16,934 m², hosting between 1,730 and 3,882 roosting House Sparrows (Foram Patel pers. obs. 26.iii.2017, 21.ix.2017) (Image 2A1, 4A). This bushy vegetation, along with nearby dunghills, provides essential foraging opportunities, corroborating findings from earlier studies that House Sparrows exhibit a preference for living near bushy vegetation (Summers-Smith 1963; Heij & Moeliker 1986; Wilkinson 2006; Weir 2015). In addition to offering shelter, these bushy areas are crucial for maintenance activities (Patel & Dodia 2021) and serve as a significant source of invertebrate prey, a vital component of the House Sparrow's diet during the nestling phase (Vincent 2005).

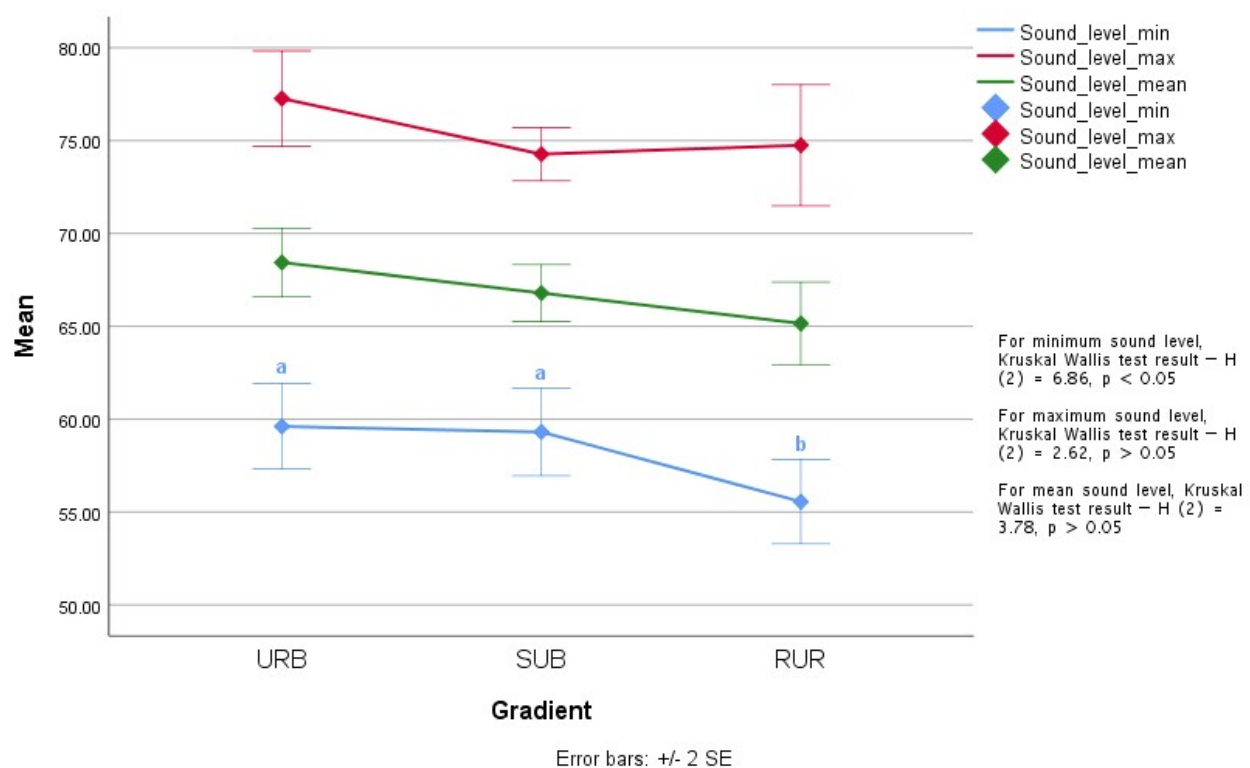
Furthermore, it was observed that traditional constructions provided better nesting opportunities compared to newer buildings, which lack suitable nooks for nesting (Shaw et al. 2008). Nonetheless, nesting opportunities for the House Sparrow were compensated by the artificial nest sites located throughout the study area. There were an average 90.43% of artificial nests in urban sites, 75.17% in suburban sites, and 79.67% in rural sites during the study. House Sparrows used a variety of artificial nests for nesting purposes, including wooden boxes, earthen pots, cardboard nests, and even empty detergent boxes and shoeboxes placed across the residential areas.

Except for Bharatnagar (URB2) and Nari (RUR2), cowsheds were commonly found within or nearby all other study sites (Image 5A). According to Cordero (1993), House Sparrows are more likely to be found around livestock or cowsheds, which are more frequent in rural locales than in suburbs with modern infrastructure. The litter and dunghills found in these cowsheds were significant sources of insects. Delgado et al. (2012) suggested that poultry manure has a positive effect on the abundance of invertebrates, which are essential components of the House Sparrow's diet, particularly during the breeding season (Vincent 2005; Peach et al. 2015). Many studies have reported similar observations where House sparrows rely heavily on seeds and invertebrates obtained from backyard poultry or dunghill at farmsteads (Balaji et al. 2014; Salek et al. 2015). Additionally, it was observed that House sparrows feed on household scraps or other supplementary foods or seeds in the courtyard. According to Hussain et al. (2014), the traditional lifestyle of seminomadic pastoralists (Van Gujjar) facilitates the availability of shelter and food for the House sparrows.

In the study, a notable absence of House Sparrows was observed in areas with a higher socioeconomic status, which were characterised by modern

Table 4. Correlation between number of mobile base stations and number of active nests of House Sparrow with abundance of the House Sparrow across the study area.

			Number of mobile towers	Abundance of House Sparrow	Active nests of House Sparrow
1	Number of mobile towers	Correlation Coefficient	1.000	0.271	0.513
		Sig. (2-tailed)	.	0.480	0.158
		N	9	9	9
2	Abundance of House Sparrow	Correlation Coefficient	0.271	1.000	0.504
		Sig. (2-tailed)	0.480	.	0.166
		N	9	9	9
3	Active nest of House Sparrow	Correlation Coefficient	0.513	0.504	1.000
		Sig. (2-tailed)	0.158	0.166	.
		N	9	9	9

**Figure 3.** Variances in minimum, maximum, and mean sound levels across urban (URB), suburban (SUB), and rural (RUR) gradients of Bhavnagar in the year 2018.

infrastructure, paved surfaces, enhanced cleanliness, and ornamental landscaping. Conversely, House Sparrows were more commonly found in areas with older building structures, bushy vegetation, and the presence of cowsheds. This distribution pattern aligns with findings from various studies in urban settings, indicating that lower socioeconomic areas tend to have higher House Sparrow populations compared to affluent areas (Witt 2000, 2005; Pauleit et al. 2005; Shaw et al. 2008). Moreover, modern construction with improved

hygiene, paved area and ornamental plantation has significantly reduced ideal foraging, nesting and roosting opportunities for the House Sparrow (Summers-smith 2003; Vincent 2005). Modak (2017) further supports this notion, highlighting the negative impact of urbanization on House Sparrow populations, particularly in planned urban regions like greater Kolkata.

During the study highest density of the House Sparrow was recorded at the Rural gradient. This finding aligns with numerous studies that have reported similarly high

densities of House Sparrows in rural areas (Robinson et al. 2005; Balaji et al. 2014). In rural gradient, bushy vegetation, cowsheds, and old/traditional constructions were common, harbouring a large number of House Sparrows (Figure 2). The extensive bushy vegetation found in suburban and rural areas offered ample opportunities for species dispersal. In contrast, the limited availability of suitable habitat patches resulted in a patchy distribution of House Sparrows in urban areas. The reduction in bushy vegetation due to commercial or residential development in urban and suburban sites could have a negative impact on the species, as indicated by observations from Vincent (2005) and Weir (2015).

Based on literature survey, high sound level was found to be another factor influencing House Sparrow populations (E.g., Bhattacharya et al. 2011). However, in our present study, we did not find any significant associations between various sound levels and the presence of House Sparrows. Furthermore, we observed active nests in study areas where high sound levels were recorded. Specifically, we noted high sound levels at three locations: Anandnagar (URB3) (maximum sound level: 80.58 ± 2.44 dB), VP Society (SUB1) (maximum sound level: 73.58 ± 1.26 dB), and Nari (RUR2) (maximum sound level: 85.97 ± 1.53 dB). During our study, we recorded 26 active nests in Anandnagar (URB3), 15 active nests in VP Society (SUB1), and 15 active nests in Nari (RUR2). In contrast to our findings, Bhattacharya et al. (2011) reported that nest boxes located in high-noise zones were inactive. However, in the present study House Sparrow found to be adaptive towards usual sound levels of civilised area. This aligns with the observations of Ghosh et al. (2010), who suggested that House Sparrows are accustomed to loud noises, and thus sound pollution is unlikely to significantly impact their population.

Our findings did not reveal any significant association between House Sparrow occurrence and the number of mobile phone base stations across the study area. Besides, we recorded active nests in locations with mobile phone base stations (Table 5). A similar study conducted by Meeran et al. (2021) found no correlation between mobile phone towers and the population of House Sparrows in Tamil Nadu, India. Furthermore, Pandian & Natarajan (2018) reported that House Sparrows breed in villages with mobile towers. Additionally, Nath et al. (2022) suggested that the low levels of electromagnetic radiation typical in urban environments do not induce thermal effects and thus have no discernible impact on sparrows and other urban avifauna.

As per information available on Tarang Sanchar Portal

Table 5. Number of mobile phone towers and active nests within a 0.5 km radius of the mobile phone tower in the year 2018.

Study sites	No. of mobile phone tower at the study site (within 1 km perimeter of the study site)	No. of active nests within a 0.5 km radius of the mobile phone tower
Barsomahadev (URB1)	4	30
Bharatnagar (URB2)	3	40
Anandnagar (URB3)	4	26
VP Society (SUB1)	1	15
Forest colony (SUB2)	2	16
Fulsar (SUB3)	0	17
Akwada (RUR1)	1	35
Nari (RUR2)	0	15
Sidsar (RUR3)	3	30



Image 4. A—Presence of a large patch of bushy vegetation in the form of a green field at the Bharatnagar (URB2) Site in 2017 | B—Commercial and residential development at Bharatnagar (URB2) Site in 2018. © A-B – K. R. Tadha.



Image 5. A—Presence of livestock/ cowsheds at the study site | B—Female House Sparrow sitting on bushy plant | C—Foraging House Sparrow. © A,C-F.P. Patel | B-K.R. Tadha.

- mobile phone base stations are located near mobile phone users and produce the lowest possible power, with the optimal network design. Due to the narrow vertical transmit pattern of the antennas and their wide horizontal spread, the radio signal intensity directly beneath them is very low (). Moreover, the transmitted power levels vary depending on the geographical area covered by the cell (Base stations and Health, 2022).

In contrast, according to Balmori (2021), the recent decline in the sparrow population is believed to be linked to the proliferation of mobile towers. Furthermore, studies conducted in India have reported a rapid decline in House Sparrow population as a result of contamination resulting from increased use of cell phones (Dandapat et al. 2010; Shende & Patil 2015). Moreover, Wotton et al. (2002) demonstrated that House Sparrows are particularly vulnerable to electromagnetic radiation due to their nesting behaviours, often selecting elevated locations like roof spaces where radiation from base stations may be more concentrated. Moller et al. (2011) reported instances of birds abandoning nests near mobile base stations within a week of construction, although such incidents were not observed in our study. Nonetheless, a basic correlation study between mobile phone towers and the presence of house sparrows does not establish a causal link.

Notably, our study did not assess the strength of electromagnetic radiation. While there's a lack of standardized baseline data on the direct impact of electromagnetic radiation emitted by base stations on birds, it remains uncertain whether radiation significantly contributes to the decline of House Sparrows. Therefore, a comprehensive analysis of the long-term effects of electromagnetic fields (EMF) on House Sparrows using standardized tools and protocols is essential to draw accurate conclusions.

CONCLUSION

Changes in habitat composition at a local scale had a significant impact on the presence of House Sparrows. Key factors positively influencing their occurrence included the presence of bushy vegetation, cowsheds, and old/traditional structures. Bushy vegetation served as an important shelter for the House Sparrows. Residential and commercial developments have reduced bushy vegetation patches in urban and suburban sites, resulting in fewer suitable foraging and roosting areas for the House Sparrow. Such small-scale changes in habitat composition could have significant negative effects on

the abundance of the House Sparrow especially in urban areas, where suitable habitat patches are scarce.

In order to develop effective conservation strategies, it is essential to consider other aspects of the species' habitat requirements in addition to providing nesting opportunities through artificial nest sites. Effective green urban architectural planning and management are necessary to ensure heterogeneous green areas with suitable vegetative cover in order to provide a high availability of natural resources to the species. Besides, studies conducted at finer scale are important for defining management options that can be applied at a large scale.

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