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Impact of urbanization on seasonal population status and occupancy of house sparrows in Delhi, India

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Urbanization has a direct impact on avian communities as it modifies the landscape, consequently changing bird distribution, abundance and the resources on which avian populations depend. With increasing anthropocentric activities, there has been a marked decline in the urban population of house sparrows in Delhi, India. This study was undertaken to determine the impact of varying levels of urbanization (high-, medium- and low-density urban areas, suburban areas and agricultural areas) on the population and occupancy of sparrows. The encounter rate and occupancy probability were high in sub-urban and high-density urban areas, while they were low in low-density urban and agricultural areas. With active public participation, the sparrows can be conserved and their population can be re-established in areas where they have become extinct.

Keywords: Encounter rate, house sparrow, occupancy, population status, urbanization.

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AS a landscape becomes more urbanized and anthropocentric, ecological conditions change rapidly and ultimately influence the distribution and population status of urban birds. Avian population density often increases, but species diversity tends to decrease[1,2]. Urbanization has direct and indirect effects on the native bird population, as town planning can change habitat, food availability, nest site availability, predator diversity, competitors and disease. These factors significantly affect the population structure and composition of urban birds[3]. As a result the most common and abundant bird species have become rare. The house sparrow (*Passer domesticus*) is one such urban bird that has suffered extensively due to urbanization[4,5].

The house sparrow is a member of family Passeridae which naturally occurs in Europe, parts of Asia and the Indian subcontinent. From these regions it has been introduced by humans, intentionally or accidentally, to the rest of the world[6]. The bird had a robust association with human civilization since the Bronze Age[7], and has always been a crucial part of our culture and traditions. Across the world, the house sparrow is the most familiar bird and because of this familiarity, it is portrayed as the main character in many of our folklore, fables, ceremonial songs, stories, poems, idioms and phrases[4,8]. House sparrows serve as an important bioindicator species in urban landscapes[9], and also have ecological services as they feed on insects from their surroundings and play a role in eliminating harmful insects like mosquito larvae.

A species once considered as a pest to crops and having a negative influence on native avifauna and human[10], is now on the verge of extinction in urban landscapes across the globe. It is presently a 'Least concern' species in the IUCN Red List[11]. However, in recent decades a marked decline in the sparrow population has been reported in many cities around the world[4–6,9,12]. Since the mid-1970s, sparrow populations in rural areas have declined by 47%, while a 60% reduction in urban sparrow populations has been reported[12]. Most population surveys conducted in different urban centres across India show a declining trend[9,13–18]. According to a survey report of Indian Council of Agricultural Research, house sparrow population had declined by 80% in Andhra Pradesh, 20% in Kerala, Gujarat and Rajasthan and around 70–80% in the coastal areas[4]. According to the state of India Bird report[19], six largest metro cities (including Delhi) in the country witnessed a gradual decline in sparrow abundance.

A lack of interest among bird-watchers and labelling of house sparrow as a pest have overshadowed the importance of this species and also developed a negative perception. For years, sparrows have remained as the most neglected species. However, with reports of their disappearance in the late 19th century, they have now been able to catch the attention of many ecologist and conversationalists[20]. Celebration of 20 March as 'World Sparrow Day' in India is an effort of the scientific community, bird-watchers, and conservationists, towards proactive conservation measures and research on house sparrows[15]. As a conservation effort, India has also taken an initiative by naming the sparrow as the State Bird of its national capital, New Delhi. The sparrow is a significant member of the urban ecosystem[21], and its decline is a grim reminder of the degradation of urban environments and of the dangers to human welfare in the long run[22].

It is of grave concern that a species which was common just a few decades ago, has now become rare. In this study, we determine the impact of urbanization on house sparrow populations and occupancy patterns.

East Delhi (28°38′24″N, 77°17′24″E), also known as trans-Yamuna, covers an area of 64 km^2. According to the 2011 census, its population is more than 16 million with a density of more than 26,500 inhabitants/km^2. River Yamuna marks its western boundary. It has a mosaic of planned and unplanned areas, modern and old built-up areas, rehabilitated colonies, and villages and slum clusters. Delhi has five seasons, namely winter (December–January), spring (February–March), summer (April–June), monsoon (July–mid September) and autumn (September end–November)[23]. In the present study, it was not possible to strictly follow this seasonal categorization, so a few modifications were made. Based on annual temperature and humidity of Delhi, we divided the year into five seasons: winter (November–January), pre-summer (February–March), summer (April–June), monsoon (July–August) and post-monsoon (September–October).

The study area was categorized into five urbanization types, i.e. high-density urban area (HDUA), medium-density urban area (MDUA), low-density urban area (LDUA), suburban area (SUA) and agricultural area (AR) based on the density of built-up structures (Figure 1). Grids of 1 km × 1 km were laid. Urbanization type was quantified using Google Earth imageries and subsequent ground verifications. A grid with >75% area under buildings or houses was classified as high-density urban area or suburban area (Figure 2 *a*). Suburban areas were differentiated from high-density urban areas on the basis of ground verification. Suburban areas included urban villages with extremely unhygienic surroundings like open drainages and open household dumps, old and clustered houses and traditional grocery shops. Similarly, high-density urban areas had densely constructed houses, both old and new, open drainage with no proper disposal of household garbage and a large number of grocery shops. In both of these habitat types, green cover was sparse. Medium-density urban areas were those where the density of building was between 50% and 75% (Figure 2 *b*). These areas were well organized with green cover (parks) and new buildings, absence of grocery shops, closed drainage and proper household waste disposal system. Low-density urban areas had building density between 25% and 50% (Figure 2 *c*). These areas had modern buildings, no grocery shops, clean surroundings and lot of open areas. Agricultural areas were present all along River Yamuna, with a built-up density of <25% (Figure 2 *d*). The area had scattered, small mud houses, fully covered with thick black tarps, the main crop included seasonal vegetables and a few families reared cattle.

A total of 58 transects (500 m long and 10 m wide) were walked across different urbanization types (HDUA – 18 transects; MDUA – 11 transects; LDUA – 7 transects; SUA – 10 transects and AR – 12 transects). The number of transects was set in proportion to the area occupied by different urbanization types. The total effort was 936 h.

The study area was actively surveyed from August 2017 to July 2018 covering all the five seasons. Population trends of house sparrows based on the encounter rate were obtained from systematic searches based on direct observations. Monthly surveys were conducted between 0600 and 0900 h, as house sparrows are active during this period. Encounter rate (ER)/km was estimated separately for all five seasons and all five urbanization types.

$$\text{Encounter rate} = \frac{\text{Total number of sightings}}{\text{Total walking effort}}.$$

$$\text{Total waking effort} = \text{Length of the transect (km)} * \text{Number of times surveyed.}$$

For occupancy modelling, the study area was divided into grids to 1 km × 1 km. Grids of this dimension were laid because sparrows do not disperse more than 1 or 2 km from the natal colony[24]. A total of 58 transects were laid, with one transect in each grid (Figure 3). The monthly presence or absence of house sparrows for each grid was recorded. Data were arranged according to the five seasons and a single-season occupancy model in Presence ver. 5.8 (ref. 25) was used for the estimation of occupancy probability[26].

Of the 5143 sightings of house sparrows during the study period, 1290 were sighted in HDUA, 422 in MDUA, 143 in LDUA, 3052 in SUA and 246 in AR. The highest average annual encounter rate of house sparrows was from suburban areas (ER = 50.80 individuals/km) followed by high-density urban areas (ER = 15.55 individuals/km), while the lowest average annual encounter rate was recorded in low-density urban areas (Figure 4).

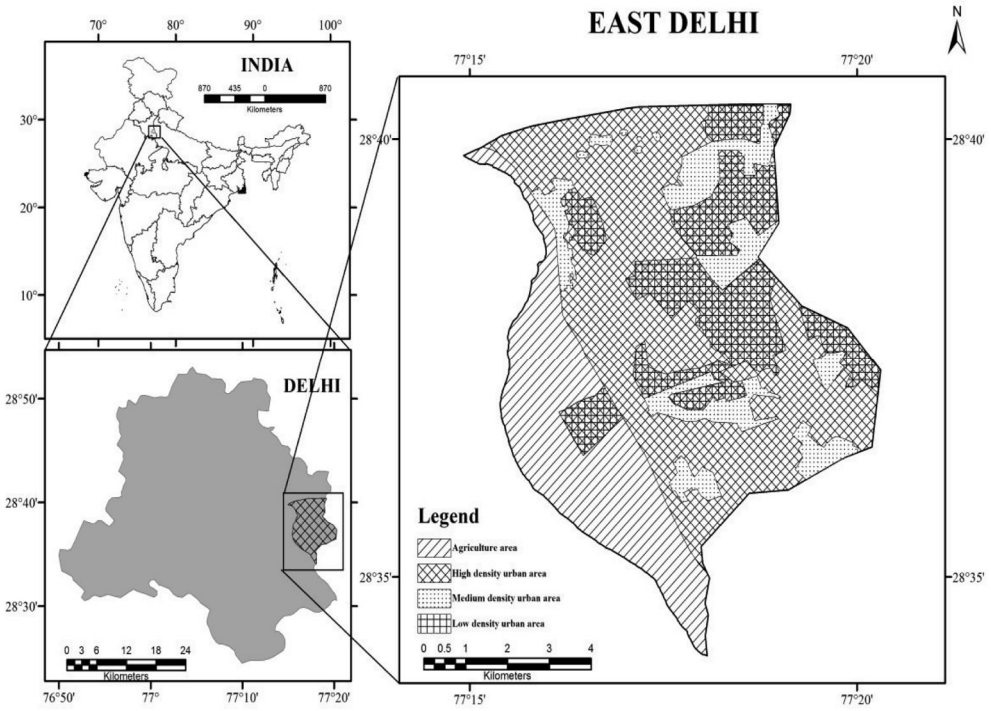

Figure 1. Location map of the study area and classification into urbanization types.

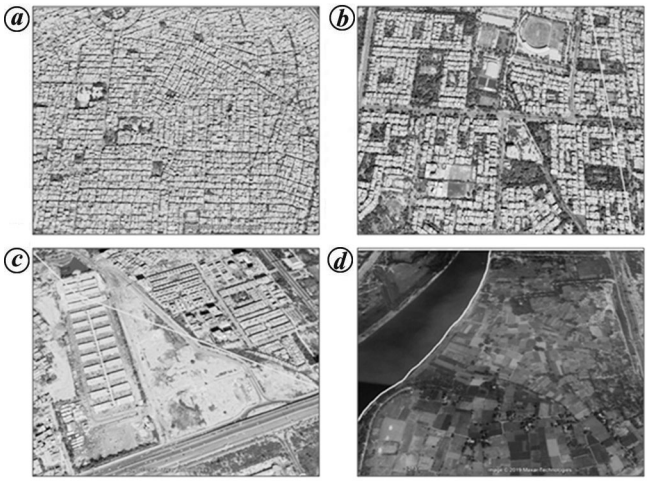

Figure 2. Google Earth images showing different habitat types. ***a***, High-density urban area; ***b***, medium density urban area; ***c***, low-density urban area; ***d***, agricultural area.

There was a significant difference ($\chi^2 = 105.64$, d$f = 4$, $P < 0.05$) in the average encounter rate of house sparrows across different urbanization types.

In high-density urban areas, the highest occupancy probability (AIC = 42.12, –2 log likelihood = 38.12, $\psi = 0.98$, SE = 0.06) was recorded in pre-summer, while the highest encounter rate (15.55 individuals/km) was recorded during the post-monsoon season (Figure 5 *a*). A negative relation between encounter rate and occupancy probability was observed.

The highest encounter rate (8.66 individuals/km) and highest occupancy probability (AIC = 33.53, –2 log likelihood = 29.53, $\psi = 0.75$, SE = 0.21) were observed in breeding seasons (pre-summer and summer) in medium-density urban areas (Figure 5 b). The lowest occupancy probability (AIC = 26.74, –2 log likelihood = 22.74, $\psi = 0.40$, SE = 0.17) and least encounter rate (3 individuals/km) were recorded during the monsoon season.

In low-density urban areas, both encounter rate and occupancy probability remained low throughout the year, except during the post-monsoon season (Figure 5 *c*). During this season, the encounter rate was 8.7 individuals/km while the occupancy probability was 0.57 (AIC = 20.15, –2 log likelihood = 16.15, $\psi = 0.57$, SE = 0.34).

In suburban areas, the highest occupancy probability was reported during the pre-summer season (AIC = 12.50, –2 log likelihood = 5.50, $\psi = 0.93$, SE = 0.0.09), followed by summer and the monsoon. The highest encounter rate was recorded during winter, though the encounter rate and occupancy probability remained high throughout the year compared to other urbanization types (Figure 5 *d*). A negative relation between encounter rate and occupancy probability was also observed in suburban areas.

In agricultural area, the encounter rate (4.33 individuals/km) and occupancy probability (AIC = 30.85, –2 log likelihood = 26.85, $\psi = 0.75$, SE = 0.515) were highest during the pre-summer season. The lowest encounter rate (2.83 individuals/km) was recorded in the winter season, while the lowest occupancy probability (AIC = 14.81, –2 log likelihood = 10.81, $\psi = 0.16$, SE =0.107) was reported in the monsoon season (Figure 5 *e*).

The availability of food and suitable nesting sites might be the most critical factor for the high encounter

rate in suburban areas[27,28]. A region with a mosaic of old and new buildings, a large number of traditional grocery shops, open drainage systems and garbage dumps favoured a good sparrow population in high-density urban areas[27,28]. Similar findings were reported by Modak[22], and Sudhira and Gururaj[29]. They recorded higher sparrow density in high-density urban areas (with a low socio-economic level among residents) and in suburban areas (urban villages), than in medium- and low-density urban areas. Balkhande and Kulkarni[18] reported that residential areas supported higher sparrow populations compared to agricultural areas, grasslands and river areas. The reasons cited were the availability of food, presence of vegetation and old buildings that provided nesting sites. Siriwardena *et al.*[30] observed a high population density of sparrows in suburban and rural areas compared to agricultural areas. Chopra *et al.*[17] also observed higher house sparrow populations in open rural and residential areas than in agricultural areas due to the presence of food and nesting sites in the former. Lack of nesting sites[28] and food for adults and nestlings, closed drainage systems and clean surroundings[27,28,31] in medium- and low-density urban areas might be the causes of low seasonal encounter rates of house sparrows[27]. However, Khera *et al.*[16] reported higher sparrow density in medium- and low-density urban areas than in high-density urban areas. Modern houses without holes and crevices and a lower number of mud houses in urban areas were the main reason for declining sparrow population[32].

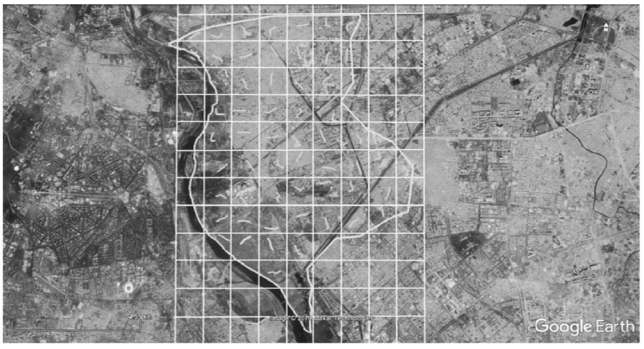

Figure 3. Google Earth image map showing grids (yellow squares) of 1 km × 1 km and transects (green lines) in each grid.

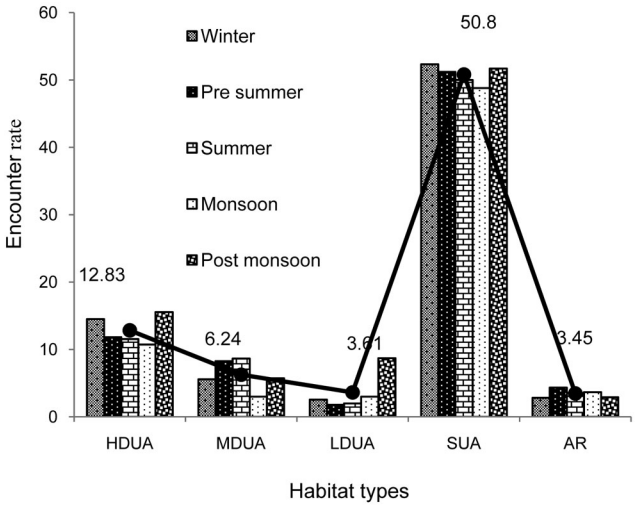

Figure 4. Encounter rate of house sparrows in different seasons across all urbanization types.

Agricultural areas had meagre encounter rates, as these areas do not provide enough food for adults or suitable nesting sites[27,28]. Widespread use of pesticides and herbicides in agricultural fields, adoption of monoculture and modern harvesting techniques have also resulted in the absence of insects needed by nestlings[33]. However, Goyal[34] recorded more sparrows in agricultural areas than in residential areas due to abundant food supply and relatively peaceful and pollution-free surroundings in agricultural areas. Khera *et al.*[16] also reported a higher density of sparrows in agricultural areas compared to urban areas, due to the availability of food in the former.

In suburban and high-density urban areas, high encounter rates were reported during the non-breeding season, post-monsoon and winter, though the occupancy probability was low. The high encounter rate could be due to the congregation of sparrows to their natal flock after the breeding season. Sparrows were found in large numbers at certain locations only and were not reported uniformly across all the areas. Lower encounter rates and high occupancy probability during the breeding season could be due to the dispersal of sparrows in loose groups, leading to the recording of lower numbers in more transects.

High encounter rate and occupancy probability in pre-summer and summer from medium-density urban areas might be due to the fact that these areas were used or occupied by house sparrows only during the active breeding season. Once the breeding season was over, the sparrows left these areas as there was a scarcity of food due to non-availability of grocery shops[27,28]. In low-density urban areas, the encounter rate and occupancy probability were high only during the post-monsoon season, as these areas were devoid of suitable nesting sites and were thus not used during the breeding season. Lack of food also meant this area was not used extensively during the non-breeding season.

High encounter rate and occupancy probability in agricultural areas during the pre summer season could be due to the onset of the breeding season in late February. House sparrows were found to become active and vocal during this season, leading to their easy detection. Also during this period, sparrows disperse in search of suitable nesting sites, leading to their presence/occupancy in many areas. However, Chopra *et al.*[17] recorded the highest sparrow population during the post-monsoon season and the lowest during winter. Agricultural areas did not provide suitable nesting grounds for the sparrows[28], leading to encounter rate and occupancy probability being

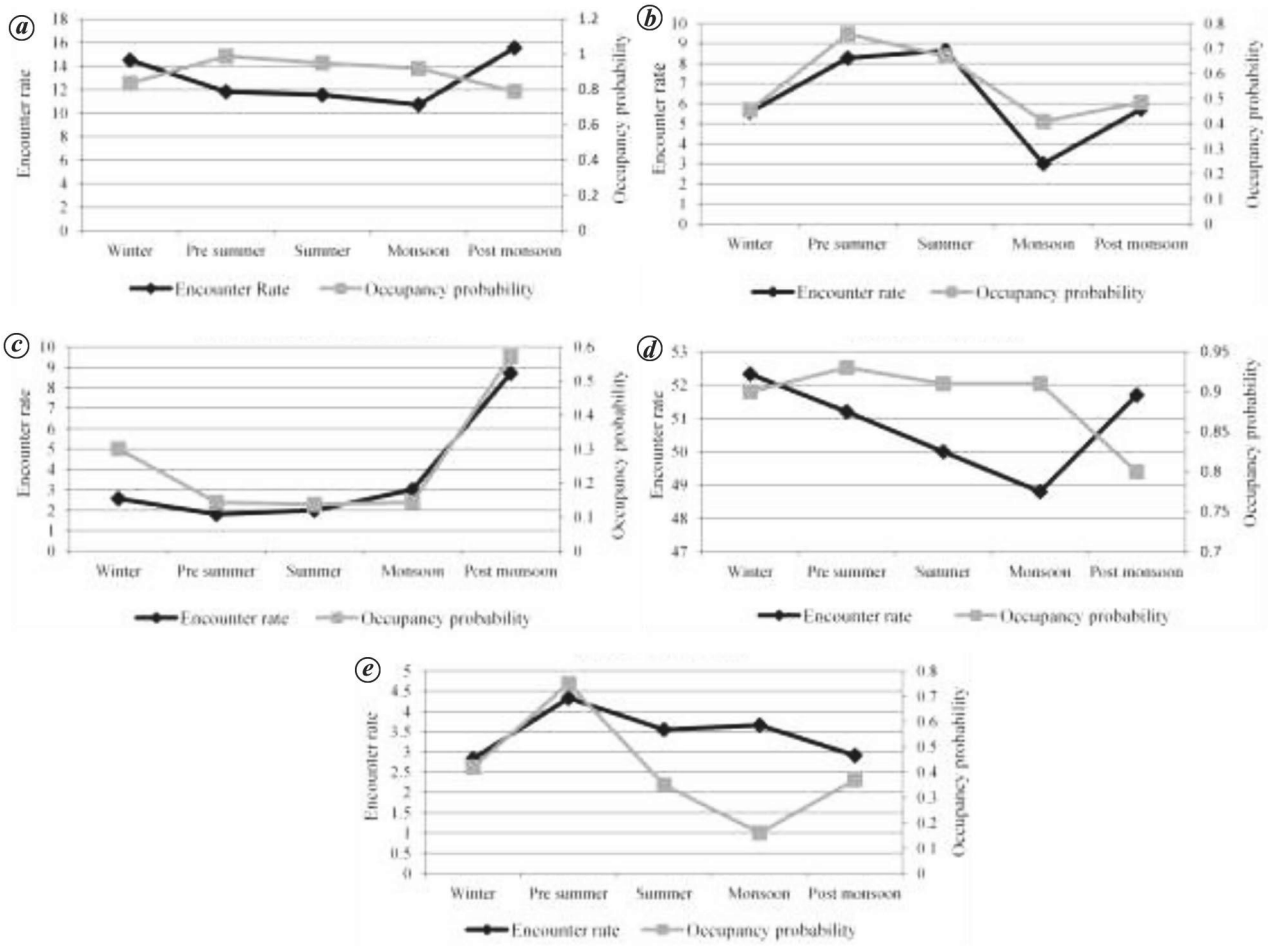

Figure 5. Encounter rate and occupancy probability of house sparrows across urbanization types in different seasons. ***a***, High-density urban area. ***b***, Medium-density urban area. ***c***, Low-density urban area. ***d***, Suburban area. ***e***, Agriculture area.

reduced in the forthcoming summer and monsoon season. Once the breeding season culminated in the post monsoon and winter season, occupancy probability started to recover marginally. This might be due to the recruitment of new members from the last breeding season. Low encounter rate during the non-breeding season might be due to lack of food available for adults, as farmers practised only floriculture (flower farming) and olericulture (vegetable farming), and did not grow grains and cereals. The only source of grains for sparrows in agricultural areas was from food provisioning sites (pearl millet, rice and corn kept in a particular place for birds) and from the open food-cooking sites in mud houses.

Urbanization has a direct impact on the sparrow population and distribution. In Delhi, they are found mainly in suburban and high-density urban areas, where food is in abundance and nesting sites are easily available. Low-density urban areas and agricultural areas are almost devoid of sparrow presence. A seasonal variation was recorded in the population and occupancy of house sparrows across urbanization types. Natural habitats in suburban areas need protection, while it is important to create suitable foraging and nesting sites for sparrows in medium- and low-density urban areas so that their population can recover. By creating awareness among the public and with active public participation we can help save the sparrow from local extinction.

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