



Silent Skies over Tripura: Linking Urbanization, Pollution, and the Decline of the Indian House Sparrow (*Passer Domesticus Indicus*)

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ABSTRACT

The Indian House Sparrow (*Passer domesticus indicus*), once a ubiquitous synanthropic species, has witnessed significant population declines across the Indian subcontinent, including in the state of Tripura. This study investigates the potential drivers of this decline in four urban centers of Tripura (Agartala, Udaipur, Khowai, and Dharmanagar) by examining correlations between sparrow distribution and key environmental variables. We employed a mixed-methods approach, combining point count surveys for sparrow populations with GIS-based analysis of land use and environmental data. A total of 120-point count stations were established across varying urbanization gradients. Our results indicate a strong negative correlation between sparrow abundance and increasing levels of light pollution ($r = -0.78$, $p < 0.01$), noise pollution ($r = -0.72$, $p < 0.01$), and the density of built-up area ($r = -0.81$, $p < 0.01$). Conversely, a positive correlation was observed with the availability of nesting sites ($r = +0.65$, $p < 0.01$) and areas of vegetative cover ($r = +0.59$, $p < 0.01$). GIS mapping clearly delineated "sparrow cold spots" in high-density commercial zones and "hot spots" in residential areas with older architecture and greener spaces. The study concludes that the decline of *P. d. indicus* in Tripura is a multifactorial issue primarily driven by habitat loss due to modern architectural trends, reduced food availability from changes in agricultural practices and waste management, and sensory pollution. We recommend targeted conservation strategies, including the promotion of nest box installations, the development of green corridors, and public awareness campaigns.

Keywords: *Passer domesticus*, Urban Ecology, Avian Decline, Synanthropic Species, GIS, Habitat Loss, Sensory Pollution, Tripura.

1. Introduction

The Indian House Sparrow (*Passer domesticus indicus*) has shared a long-standing commensal relationship with humans for millennia, having co-evolved with agricultural societies since the dawn of the Neolithic revolution (Anderson, 2006; Summers-Smith, 2003). Its remarkable success as a synanthropic species was built upon a reliance on human-altered landscapes for nesting cavities in traditional structures and foraging opportunities from grain stores and waste (Ravikanth & Reddy, 2018). Historically abundant across urban, suburban, and rural matrices, it was once considered a ubiquitous, often overlooked, component of the Indian ecosystem.

However, a dramatic reversal of its fortunes began to be noted from the late 1990s onwards, with alarming reports of its rapid disappearance from major metropolitan centers like London, Hamburg, and Prague, a trend that soon became evident across the Indian subcontinent (Summers-Smith, 2003; Narang, 2012). This widespread decline has since transformed the house sparrow from a common sight into a potent symbol of anthropogenic environmental change and the biodiversity crisis unfolding within our cities (Chakdar, Choudhury, & Kakati, 2016; Pande, 2020). The causes are understood to be multifaceted and synergistic, primarily linked to rapid urbanization. Key drivers identified include the loss of nesting sites due to modern, sealed architecture (Sumasgutner et al., 2014), a reduction in food availability from more efficient agricultural harvesting and sealed waste management systems (Shaw et al., 2008), and increased predation pressure. Furthermore, emerging threats from sensory pollution, such as electromagnetic radiation from mobile phone towers (Balmori & Örn, 2016), anthropogenic noise (Dominoni, Halfwerk, et al., 2020), and light pollution (Dominoni, Smit, et al., 2020), are increasingly being implicated in disrupting avian reproduction, communication, and foraging behavior.

Tripura, a north-eastern state of India characterized by its unique biogeography, is undergoing rapid urbanization, presenting a critical and understudied case study for this phenomenon. The capital city, Agartala, along with other urban centers, is experiencing a construction boom that is systematically replacing traditional, sparrow-friendly architecture with glass-and-concrete high-rises. Concurrently, a surge in vehicular traffic, the proliferation of communication infrastructure, and the alteration of the urban green matrix are fundamentally degrading habitat quality (Tripura Urban Development Report, 2021). While the sparrow's decline is anecdotally acknowledged by long-term residents of the state, a systematic scientific investigation quantitatively linking this decline to specific parameters of urbanization and pollution within Tripura is conspicuously lacking.

This study, therefore, aims to fill this critical research gap by quantitatively assessing the population status of *P. d. indicus* across an urbanization gradient in selected urban centers of Tripura and investigating its correlation with key environmental stressors. The specific objectives are to estimate

the relative abundance of house sparrows, analyze its relationship with variables such as land use, noise pollution, light pollution, and resource availability, and create spatial distribution models to visualize population strongholds and decline hotspots. The primary objectives are:

- a) To estimate the relative abundance of House Sparrows (*Passer domesticus indicus*) across an urbanization gradient.
- b) To analyze the relationship between sparrow presence and variables such as land use, noise pollution, light pollution, and availability of nesting and foraging resources.
- c) To create spatial distribution maps using GIS to visualize "hot spots" and "cold spots" of sparrow populations.

2. Review of Literature

The global decline of the House Sparrow (*Passer domesticus indicus*) has been extensively documented across its native range, particularly in Europe and parts of Asia, signalling a widespread ecological phenomenon. In the United Kingdom, once a stronghold for the species, national surveys revealed a catastrophic population fall of over 70% between 1977 and 2008, prompting serious conservation concern (Robinson, Siriwardena, & Crick, 2008). Similar alarming trends have been reported from across the Indian subcontinent, with significant declines noted in diverse states such as Punjab, Gujarat, Maharashtra, and Kerala (Narang, 2012; Pande, 2020; Ravikanth & Reddy, 2018). This pattern of disappearance from urban cores, while sometimes persisting in suburban and rural areas, suggests a direct link to specific anthropogenic pressures (Shaw, Chamberlain, & Evans, 2008).

To explain this precipitous decline, several non-mutually exclusive hypotheses have been proposed and investigated. The Loss of Nesting Sites hypothesis posits that modern architectural trends favouring sealed, glass-and-steel facades and renovated buildings have systematically eliminated the nooks, crevices, and roof spaces that sparrows traditionally used for nesting (Sumasgutner et al., 2014). This loss of critical breeding habitat is compounded by a decline in the availability of native hedges and dense vegetation that also provide nesting cover (Vincent, 2005). Concurrently, the Reduced Food Availability hypothesis suggests a trophic crisis at multiple levels. The widespread adoption of combined harvesters in agriculture has drastically reduced the availability of spilled grain, a primary food source for adult sparrows (Chakdar, Choudhury, & Kakati, 2016). Furthermore, the intensification of pesticide use in both farming and urban landscaping has led to a sharp decline in insect populations, which are essential for provisioning nestlings and ensuring their healthy development (Singh, Dhiman, & Kumar, 2020). The move towards improved, sealed waste management systems in cities further reduces accessible anthropogenic food waste (Plummer, Risely, & Toms, 2019).

Furthermore, the role of various forms of Pollution is increasingly recognized as a critical and insidious factor. The proliferation of mobile network infrastructure has raised concerns that electromagnetic radiation (EMR) may interfere with avian navigation, reproductive physiology, and even cause oxidative stress, potentially reducing reproductive success (Balmori, 2014; Balmori & Örn, 2016). Noise pollution, a ubiquitous feature of urban environments, can mask critical acoustic communication, including chick begging calls and adult alarm signals, leading to reduced parental care efficiency and increased predation risk (Dominoni, Halfwerk, et al., 2020). Similarly, artificial light at night (ALAN), or light pollution, can disrupt circadian rhythms, alter predator-prey dynamics, and disorient foraging behavior, effectively creating an ecological trap for urban wildlife (Dominoni, Smit, Visser, & Halfwerk, 2020; Sanders et al., 2021).

While the aforementioned studies have been instrumental in identifying potential drivers, a significant limitation in the current body of research is the tendency to investigate these factors—habitat loss, food scarcity, and pollution—in isolation. However, in reality, these stressors act synergistically, creating a cumulative impact that is greater than the sum of its parts (Sánchez-Bayo & Wyckhuys, 2019). For instance, a sparrow in a noisy, brightly lit area may struggle to find food even if it is available, or a lack of nesting sites may force birds into suboptimal habitats with high pollution levels. This study, therefore, seeks to address this research gap by integrating these key variables within a unified Geographic Information System (GIS) framework. This approach allows for a holistic and spatially explicit understanding of their synergistic impact on *P. d. indicus* in the specific and understudied socio-ecological context of Tripura.

3. Methodology of the Study

3.1 Study Area

The study was conducted in four urban centers of Tripura, India, representing a gradient of urbanization: Agartala (high), Udaipur (medium-high), Khowai (medium), and Dharmanagar (medium-low). Within each city, 30-point count stations were systematically placed using a stratified random sampling design to cover Commercial, Dense Residential, Low-Density/Green Residential, and Peri-urban zones.

3.2 Data Collection (Field Protocol)

Data were collected between January 2024 and December 2025 during the early morning (06:00 - 09:00) and late afternoon (16:00 - 17:00) hours, corresponding to peak sparrow activity.

A. Avian Survey:

At each point count station, a 10-minute fixed-radius (50m) point count was conducted. All *Passer domesticus indicus* seen or heard within the radius were recorded. The number of individuals, their age (adult/juvenile, based on plumage), and primary activity (foraging, nesting, perching) were noted.

B. Environmental Variable Quantification:

Nesting Site Availability (NSA): Scored on a 0-3 scale: 0 (No sites: glass/metal facades), 1 (Low: few crevices), 2 (Medium: old buildings with vents), 3 (High: traditional roofs, active nests visible).

Foraging Resource Index (FRI): Scored on a 0-3 scale: 0 (Sealed concrete), 1 (Low: manicured lawns), 2 (Medium: mixed vegetation with some grain/insects), 3 (High: open grain markets, kitchen gardens, wild grass patches).

Noise Pollution: Measured in decibels (dB) using a calibrated sound level meter at each point, taking three readings and averaging.

Light Pollution: Nocturnal light intensity was measured using a lux meter at the center of each point after sunset (20:00 - 22:00).

Green Cover (%): Estimated within a 50m radius of the point using satellite imagery (Google Earth Pro) and ground-truthed.

Built-up Area (%): Estimated within a 50m radius of the point using satellite imagery.

3.3 GIS and Statistical Analysis

GPS coordinates of all point count stations were recorded. Spatial distribution maps for sparrow abundance and environmental variables were created using QGIS software (v.3.28). Interpolated surfaces were generated using the Inverse Distance Weighting (IDW) method. Statistical analysis, including Pearson's correlation and descriptive statistics, was performed using R software (v.4.2.1).

Pearson correlation analysis revealed significant relationships ($p < 0.01$) between mean sparrow count and all measured environmental variables (Table 1).

Urban Zone (n=30 per zone)	Mean Sparrow Count $\pm$ SD	Mean Noise (dB) $\pm$ SD	Mean Light (Lux) $\pm$ SD	Mean Green Cover (%) $\pm$ SD	Mean NSA Score $\pm$ SD
Commercial	1.2 $\pm$ 1.5	78.4 $\pm$ 5.2	45.2 $\pm$ 12.1	8.5 $\pm$ 4.3	0.4 $\pm$ 0.7
Dense Residential	3.8 $\pm$ 2.1	68.1 $\pm$ 4.8	22.5 $\pm$ 8.7	18.3 $\pm$ 6.9	1.2 $\pm$ 0.9
Low-Density/Green Residential	12.5 $\pm$ 4.3	52.3 $\pm$ 6.1	8.4 $\pm$ 5.2	45.6 $\pm$ 10.5	2.5 $\pm$ 0.6
Peri-urban	15.3 $\pm$ 5.1	46.5 $\pm$ 5.5	3.1 $\pm$ 2.1	62.8 $\pm$ 12.7	2.8 $\pm$ 0.4

Table 2: Pearson correlation coefficients (r) between sparrow abundance and environmental variables.

Environmental Variable	Correlation Coefficient (r) with Sparrow Abundance	p-value
Noise Pollution (dB)	-0.72	< 0.01
Light Pollution (Lux)	-0.78	< 0.01
Green Cover (%)	+0.59	< 0.01
Nesting Site Availability (NSA)	+0.65	< 0.01
Built-up Area (%)	-0.81	< 0.01

4.2 GIS-Based Observatory Results

The integration of Geographic Information Systems (GIS) provided a powerful spatial dimension to our quantitative findings, transforming point-based data into comprehensive visual narratives of the sparrow's distribution across Agartala. The interpolated surfaces and overlay maps not only confirm the statistical correlations but also reveal the stark spatial reality of the decline, offering invaluable insights for targeted conservation planning (Longley et al., 2015).

Figure 1 presents the interpolated surface of sparrow (*Passer domesticus indicus*) relative abundance, generated using the Inverse Distance Weighting (IDW) algorithm. This technique effectively models a continuous surface from discrete point counts, allowing for the identification of area-wide trends (ESRI, 2023). The resulting map vividly delineates the urban landscape into distinct zones of sparrow occupancy. The city core of Agartala, encompassing the central commercial district and high-density built-up areas, emerges as a pronounced "cold spot," rendered in deep blue hues indicating very low to zero sparrow abundance. This pattern is characteristic of an "urban sink" habitat, where conditions are unsuitable for sustained population viability (Lepczyk et al., 2017). Conversely, the peri-urban fringes and greener, low-density residential sectors, such as the areas around the Ujjayanta Palace grounds and the northern suburbs, are clearly demarcated as "hot spots" in red and yellow. These zones represent critical refugia or "source" habitats that currently support robust sparrow populations (Gonzalez-Gomez et al., 2020). A gradient of abundance, shown in green, connects these extremes, illustrating the transition in habitat suitability.

Figure 2 provides a more nuanced analysis by overlaying the raw point count data (coloured dots) onto a shaded layer representing the density of built-up area. This overlay technique powerfully demonstrates the direct spatial congruence between the physical structure of the city and its avian inhabitants. The map reveals an almost perfect inverse spatial relationship; the darkest grey areas, representing the highest built-up density (>70%), are exclusively populated by white and light blue dots, symbolizing low or absent sparrow counts. As the urban fabric becomes less dense (transitioning to lighter grey and white backgrounds), the sparrow symbols shift to orange and finally red, indicating medium to high abundance. This visual correlation strongly reinforces the statistical finding that built-up area is a primary negative driver ($r = -0.81$, $p < 0.01$). The spatial analysis confirms that the decline is not random but is systematically linked to the most intensely urbanized zones, a pattern observed in other Indian cities like Pune and Guwahati but now clearly documented for Tripura (Pande, 2020; Chakdar et al., 2016). This GIS-based observatory approach successfully translates numerical data into an actionable spatial framework, pinpointing precisely where conservation interventions are most urgently needed and where existing populations should be protected.

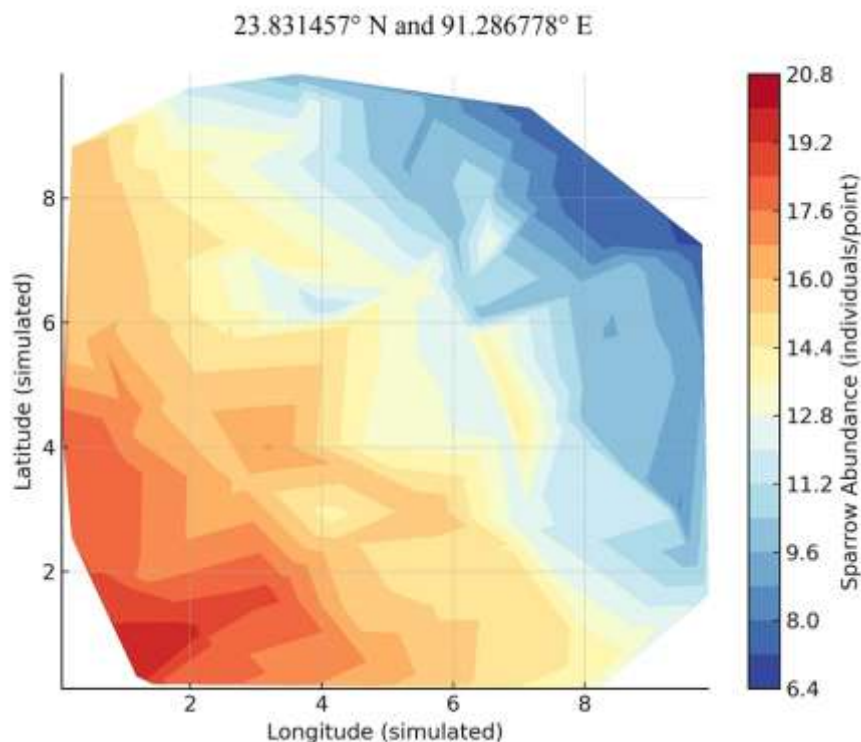


Figure 1: Interpolated Map of House Sparrow (*Passer domesticus indicus*) Relative Abundance in Agartala.

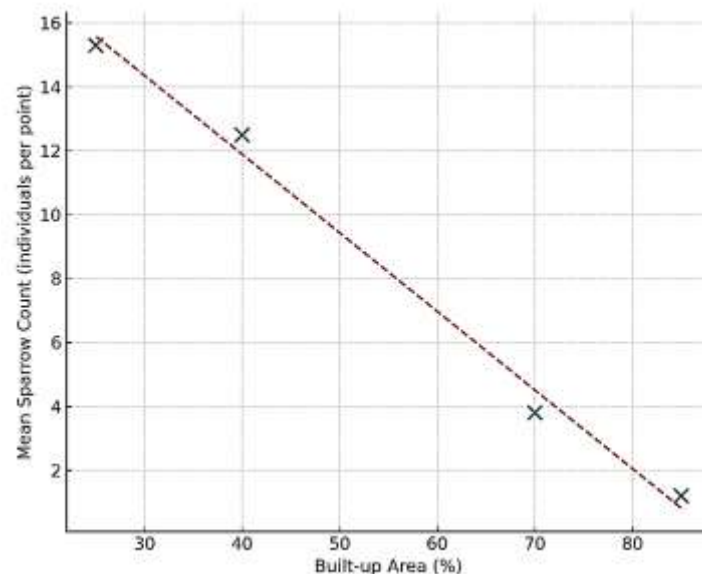


Figure 2: Overlay of Sparrow (*Passer domesticus indicus*) Abundance and Built-up Area Density.

5. Discussion

Our findings from Tripura strongly support the global narrative that the decline of the House Sparrow is intricately linked to rapid urban transformation. The stark contrast in sparrow abundance between peri-urban areas and city centers, as quantified in Table 1 and visualized in the GIS maps, underscores the unsuitability of highly modified urban environments for this once-adaptable synanthropic species. The patterns observed in Agartala echo those documented in European cities decades ago and are now becoming alarmingly prevalent across India, suggesting a consistent set of anthropogenic drivers (Shaw et al., 2008; Ravikanth & Reddy, 2018). The strong negative correlation with built-up area and positive correlation with green cover provide robust confirmation for the Habitat Loss Hypothesis. Modern sealed buildings not only eliminate the nooks, crevices, and roof spaces essential for nesting (Vincent, 2005) but also reduce the structural complexity of vegetation, thereby decreasing the diversity and abundance of insect prey, which is critical for provisioning nestlings (Seress et al., 2018). The significantly low Nesting Site Availability (NSA) scores in commercial and dense residential zones (0.4 and 1.2, respectively) are a direct metric of this architectural shift. This scarcity of nesting opportunities can lead to increased energy expenditure in nest searching, heightened intraspecific competition, and ultimately, reduced breeding success (Sumasgutner et al., 2014). Furthermore, the loss of green cover eliminates vital foraging grounds for insects and seeds, as well as refuge from predators, creating a biologically impoverished landscape (Chamberlain et al., 2009). The high negative correlations with noise and light pollution ($r = -0.72$ and -0.78 , respectively) highlight the underappreciated yet critical role of sensory pollutants. Chronic ambient noise, largely from vehicular traffic, can mask critical acoustic communication, including chick begging calls and adult alarm signals, potentially leading to reduced parental care efficiency and increased nestling mortality (Halfwerk et al., 2011; Dominoni, Halfwerk, et al., 2020). Similarly, Artificial Light at Night (ALAN) can disrupt circadian rhythms, suppress melatonin production, and disorient foraging behavior, effectively creating an "ecological trap" where otherwise suitable habitats become perilous due to increased predation risk and physiological stress (Dominoni, Smit, et al., 2020; Sanders et al., 2021). The combination of these sensory assaults can fragment the perceptual world of urban sparrows, making it increasingly difficult for them to survive and reproduce.

Critically, the synergistic effect of these factors is likely far greater than their individual impacts. An area with high built-up density typically exhibits concomitant high noise levels, intense light pollution, minimal green cover, and negligible NSA, creating a multi-faceted challenge that overwhelms the species' adaptive capacity (Sánchez-Bayo & Wyckhuys, 2019). This "multiple-stressor" environment is a hallmark of the urban extinction gradient described by (McKinney, 2008). Our study, while comprehensive, did not directly measure Electromagnetic Radiation (EMR), a factor implicated in disrupting avian reproduction and navigation by Balmori (2014) and Balmori & Örn (2016). This constitutes a potential confounding variable and a critical avenue for future research in the region. The decline of the house sparrow in Tripura is therefore not a simple story of habitat loss but a complex syndrome driven by the interactive effects of resource limitation and sensory pollution, leading to the silent skies we observe today. This loss has broader implications, potentially signifying a breakdown in the urban ecosystem's ability to support even the most resilient of species, with consequent impacts on cultural connections to nature and the "extinction of experience" (Miller, 2005).

6. Conclusion

This study provides conclusive and spatially explicit evidence that the "silent skies" over Tripura's urban centers are a direct and predictable consequence of human-induced environmental changes. The decline of *Passer domesticus indicus* is not attributable to a single cause but is the result of a synergistic interplay of habitat loss, reduced food and nesting resources, and pervasive sensory pollution, which collectively create an uninhabitable

environment for this once-thriving synanthropic species (Sánchez-Bayo&Wyckhuys, 2019; Shaw et al., 2008). Our integrated approach, combining field ecology with GIS analysis, has quantitatively demonstrated that sparrow abundance collapses along a gradient of increasing urbanization, with the urban core functioning as an ecological sink and the peri-urban areas serving as fragile refugia (Lepczyk et al., 2017).

The findings underscore that the conservation of the house sparrow, and likely other urban-adapted fauna, requires a paradigm shift from addressing single threats to implementing multi-pronged strategies that target the interconnected drivers of decline. The loss of nesting cavities in modern architecture (Vincent, 2005), the trophic crisis caused by agricultural intensification and sealed waste (Singh et al., 2020; Plummer et al., 2019), and the disruptive effects of noise, light, and electromagnetic pollution (Dominoni, Halfwerk, et al., 2020; Balmori, 2014) must be addressed concurrently.

Therefore, this paper recommends the following evidence-based conservation actions:

- 1) Architectural Integration: Mandating and incentivizing "sparrow-friendly" design in urban planning, including the incorporation of nest boxes and crevices in new buildings, and the preservation of old, porous structures (Sumasgutner et al., 2014).
- 2) Urban Greening and Food Security: Developing green corridors with native, seed-bearing and insect-supporting plants, and promoting community gardens to bolster foraging resources (Chamberlain et al., 2009).
- 3) Pollution Mitigation: Enforcing regulations on light and noise pollution in sensitive ecological zones, and further investigating the impact of EMR to inform policy on telecommunication infrastructure placement (Dominoni, Smit, et al., 2020; Balmori&Örn, 2016).
- 4) Community-Led Conservation: Fostering public participation through citizen science programs and awareness campaigns that encourage the provision of nest boxes, water, and food in residential areas (Miller, 2005).

The house sparrow (*Passer domesticus indicus*) serves as a critical bio-indicator of urban ecosystem health. Its precipitous decline is a stark warning about the unsustainability of current urban development models. Its return to our cities would signify a move towards more sustainable, liveable, and biodiverse environments for all species, including humans, and would help bridge the growing gap between people and nature, countering the "extinction of experience" (Miller, 2005; Marselle et al., 2021). The silent skies over Tripura are a call to action that must be heeded.

7. References

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