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Behavioural Plasticity in Urban Avian Species: Adaptive Responses to Anthropogenic Noise and Light Pollution

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Abstract

Urbanization is rapidly transforming the Indian landscape, creating novel environmental pressures for avian communities. This paper examines Behavioural plasticity in urban birds as a mechanism for coping with anthropogenic noise and light pollution. Drawing on recent studies from across India, we document significant shifts in vocalization patterns, reproductive strategies, foraging ecology, and nesting behaviours. The Common Myna and Red-vented Bulbul exemplify successful adaptation, demonstrating frequency shifts in song, use of anthropogenic nesting materials, and dietary flexibility. However, not all species thrive. The House Sparrow shows declining breeding success in cities due to higher predation and nest abandonment rates. The Spotted Munia presents a contrasting pattern, achieving greater breeding success in urban habitats compared to forests. Our analysis reveals that species with high Behavioural plasticity are urban winners, while specialists face local extinction risks. The findings underscore the urgent need for conservation-oriented urban planning. Recommendations include reducing artificial light at night, creating vegetative buffers, protecting urban wetlands, and integrating biodiversity data into city design. This paper contributes to the growing understanding of synurbization in India and offers practical pathways for fostering human-bird coexistence in rapidly developing cities.

Keywords: Behavioural plasticity, urban avian ecology, anthropogenic noise, light pollution, synurbization, vocalization adaptation.

1. Introduction

Urbanization represents one of the most profound anthropogenic forces reshaping ecosystems across the globe. In India, this transformation is particularly pronounced. The country is experiencing rapid urban expansion, with its cities growing at an unprecedented pace. This growth brings with it a suite of environmental stressors that fundamentally alter the habitats of countless species. Among the most conspicuous and ecologically significant of these stressors are anthropogenic noise and artificial light at night. These pollutants do not merely change the physical landscape. They directly interfere with the sensory environments of animals, creating novel selection pressures. Birds, with their heavy reliance on acoustic communication and light cues for circadian rhythms, are especially vulnerable to these disruptions (Kumar, 2025). Yet, a growing body of evidence suggests that many avian species are not simply passive victims of this change. They are exhibiting a remarkable capacity for Behavioural plasticity. This capacity allows them to adjust their behaviours in ways that enable survival and even success in the challenging conditions of the city.

Behavioural plasticity, in this context, refers to the ability of an individual organism to alter its behaviour in response to environmental change. This is not a long-term evolutionary adaptation. It is a short-term, often reversible, adjustment made within the lifetime of the individual. For birds in urban environments, these adjustments can manifest in a wide variety of ways. They may alter their songs to be heard above the urban din. They may shift their breeding schedules. They might select new and unusual materials for their nests. They may even modify their foraging strategies. These shifts in behaviour are critical. They are the first line of defense against the challenges posed by urbanization. They represent the organism's immediate attempt to cope with a novel world.

The Indian context is uniquely valuable for the study of this phenomenon. India is home to a stunning diversity of avian species. It contains several major biodiversity hotspots. At the same time, it has a rapidly modernizing landscape with megacities like Mumbai, Delhi, and Kolkata. This juxtaposition of biological richness and intense urban pressure

makes it a natural laboratory for observing these adaptive responses. Moreover, there is a long and rich history of citizen science and ornithological research in India. This provides a crucial baseline of data against which to measure recent changes.

Several Indian species have become model organisms for studying synurbization, the process by which wild animals adapt to living in urban areas. The Red-vented Bulbul (*Pycnonotus cafer*), for instance, has shown remarkable adaptability in its nesting and foraging behaviours within cities (Kumar, 2025). The Common Myna (*Acridotheres tristis*) is another frequent subject of study. Even some species once thought to be sensitive to disturbance are showing surprising resilience. The Spot-billed Pelican (*Pelecanus philippensis*), a near-threatened species, has been observed using telecom towers for roosting and courtship in urban areas (Raul *et al*., 2024). This represents a significant Behavioural shift for a wetland-dependent bird, perhaps signalling a response to habitat degradation in their traditional grounds (Raul *et al*., 2024). These examples highlight the dynamic and complex nature of the avian response to the Indian urban landscape.

However, Behavioural plasticity is not a universal solution. The degree of plasticity varies greatly between species. While generalists like the Red-vented Bulbul may thrive, more specialized species may be unable to adapt, leading to local extinctions. The House Sparrow (*Passer domesticus*), once ubiquitous across India, has seen marked population declines in many urban areas (Patel *et al*., 2024). Research suggests that this decline is not caused by a single factor. Instead, it is linked to a combination of habitat changes, including the loss of nesting sites, declining green cover, and perhaps more complex interactions with the modern urban environment (Patel *et al*., 2024). Similarly, artificial light at night has been identified as a major disruptor of bird life. At places like Rabindra Sarobar in Kolkata, activists have noted that intense night illuminations disturb the sleep and natural circadian rhythms of birds, with some species even abandoning the area (ETV Bharat, 2025).

The primary objective of this paper is to synthesize the existing data and literature on the Behavioural plasticity of Indian urban birds. The focus is on their adaptive responses to the twin pressures of anthropogenic noise and light pollution. The paper will explore a range of adaptive behaviours. These include vocalization plasticity, shifts in breeding and nesting habits, and changes in foraging ecology. We will also examine how different species are impacted in distinct ways. The paper will then discuss the broader conservation implications of these findings. Ultimately, this research aims to provide a clearer picture of how India's avian communities are faring in the Anthropocene. It also seeks to offer recommendations for urban planning and conservation strategies that can foster a more harmonious coexistence between humans and birds in the rapidly developing cities of India.

2. Anthropogenic Stressors in Urban Environments: Noise and Light

Indian cities are characterized by a relentless hum of human activity. This sonic environment is dominated by noise pollution. The sources are numerous and pervasive. Road traffic is perhaps the most significant contributor. A detailed study in Delhi found that traffic congestion is the most influential predictor of environmental noise levels, with models showing a strong correlation between travel time and decibel levels (Kumar *et al*., 2024). The problem extends beyond the capital. In Pune, noise levels frequently exceed 75 decibels. This is caused by roaring traffic, industrial activity, and the persistent blaring of horns and loudspeakers (Pande, 2024). This constant acoustic barrage is not uniform in its intensity or frequency. It varies by time of day and location. Yet, the overall effect is a dramatic alteration of the natural soundscape. This alteration creates a significant challenge for birds. They must communicate, find food, and avoid predators in an environment where their primary signals are constantly masked.

In addition to the cacophony, there is the pervasive glow of artificial light at night. Light pollution is a growing problem in every Indian metropolis. Streetlights, illuminated buildings, and commercial signage create an artificial twilight that extends far into the night. This light has a disruptive effect on wildlife. Experts note that it disrupts the natural behaviour of nocturnal animals. It can also disorient fledgling birds, causing them to collide with human structures (Bangalore Mirror, 2024). For birds, the presence of artificial light is not a neutral phenomenon. It can be a potent environmental cue that interferes with their internal clocks.

The effects of artificial light at night are both direct and indirect. One of the most significant is the disruption of the circadian rhythm. This is the internal biological clock that regulates daily cycles of activity and rest. Birds rely on natural light cues to time their waking, foraging, and sleeping. Constant illumination from streetlights can trick them into sensing extended daylight (Mahapatra, 2026). This can cause them to wake earlier or sleep later. It can also lead to a premature start to the dawn chorus. Over time, this chronic disruption can lead to increased energy expenditure and elevated stress hormones. This can, in turn, affect breeding success and long-term fitness (Mahapatra, 2026). The combination of these two stressors creates a uniquely challenging environment for urban birds. They must navigate a world that is simultaneously too loud and too bright, a world that never truly rests.

3. Vocalization Plasticity: Singing in the Noisy City

Birds depend on acoustic signals for survival and reproduction. They use songs and call to defend territories, attract mates, and warn of predators. Urban environments severely interfere with this communication. The persistent, low-frequency hum of traffic and construction creates a problem. This background noise masks the sounds that birds produce. It is especially disruptive because many bird songs fall within the same frequency range as urban noise (Singh *et al*., 2023). The result is a communication breakdown. Males may fail to attract females. Territories become harder to defend. Predators become more difficult to detect (Makne, 2025).

To overcome this challenge, many species are showing a remarkable capacity for Behavioural plasticity. They are actively changing their songs. The most well-documented adjustment is a shift in frequency. Birds are singing at higher minimum and peak frequencies. This move to a higher pitch helps their songs stand out from the low-frequency hum of traffic. This phenomenon is known as the Lombard effect, where a bird raises its vocal amplitude and frequency in response to noise (Singh *et al*., 2023). A detailed study of the Common Myna (*Acridotheres tristis*) in India provides clear evidence of this. Researchers found that mynas in the metropolitan area of Ahmedabad sang at significantly higher frequencies than their counterparts in semirural areas (Gameti

& Sengupta, 2025). The study analysed 270 calls from 224 individuals. It used one-way ANOVA to confirm significant differences in all call parameters between sites (Gameti & Sengupta, 2025). Similarly, the Red-vented Bulbul (*Pycnonotus cafer*), a common urban adapter, has also shown increases in minimum and dominant frequencies and amplitude shifts in noisy city environments (Kumar, 2025).

The changes are not limited to frequency. Birds are also adjusting the temporal aspects of their songs. They are modifying syllable duration and the rate of singing. A study on the Common Myna found that syllable duration was highest in semirural areas, suggesting that birds in noisier urban settings produce shorter, faster calls (Gameti & Sengupta, 2025). The same study showed that urban environments affected both spectral and temporal traits of birdsong significantly. Weather parameters like temperature and humidity did not have a significant impact on these vocal changes (Gameti & Sengupta, 2025). This confirms that the pressure to communicate is a direct response to noise pollution and the urban canyon effect.

The ability to make these adjustments is not uniform across species. Birds that are less flexible in their vocal behaviour may be unable to adapt. They face the prospect of local extinction (Singh *et al*., 2023). In some cases, the timing of vocalizations has also shifted. Research in European forests has shown that birds like the European robin immediately advance their dawn singing in response to artificial light (de Jong *et al*., 2016). This response to light pollution is a clear example of Behavioural plasticity in the temporal domain. Combined with the changes in frequency and tempo, these vocal adjustments are a primary mechanism for survival in the city. They are a testament to the adaptive capacity of birds, but they also underscore the intensity of the pressure they face from anthropogenic noise.

4. Reproductive Adaptations: Nesting and Breeding Behaviour

Urban environments present birds with a fundamental challenge for reproduction. They must find safe places to build nests and raise their young. Natural nesting sites are scarce in cities. The trees and shrubs are often replaced by concrete and steel. The result is a severe limitation of suitable nesting locations. Birds are responding to this scarcity with remarkable Behavioural flexibility. They are finding new places to nest. They are using new materials. In some cases, they are even achieving comparable or greater breeding success than their rural counterparts.

The choice of nesting location is perhaps the most visible adaptation. In the urban setting of Jagdalpur, a detailed study found birds primarily using man-made structures like electric poles and boxes (Dahriya and Kumar Soni, 2024). This was a direct response to the limited availability of natural sites. In contrast, the nearby Machkot forest supported a wider variety of species that strongly preferred natural tree sites (Dahriya and Kumar Soni, 2024). The Indian Pied Myna and the House Sparrow are notable examples of species demonstrating this adaptability (Dahriya and Kumar Soni, 2024). They readily accept artificial nesting environments. The Red-vented Bulbul is another excellent case. This species has been observed nesting in unusual sites. These include buildings, wall holes, and even electric fixings in urban areas (Kumar, 2025). The bulbuls are not just changing locations. They are also changing materials. Their nests often contain polythene pieces, paper scraps, threads, and rags. These are materials absent from the natural world. The use of such materials represents a significant Behavioural shift.

The success of these reproductive strategies varies by species and location. A study on House Sparrows in Tamil Nadu highlights the complexities. Researchers monitored 183 nest boxes over three years. They compared parental care and breeding success between urban and rural sites (Francila *et al*., 2026). The study found a significant "urban penalty." Urban females worked harder. They invested more time and energy in nest construction, incubation, and food provisioning. This increased labour was a direct response to the challenges of the city. However, this extra effort did not translate into better outcomes. Hatching success was lower in urban habitats. Only about 55% of eggs hatched. This figure was around 62% in rural areas (Francila *et al*., 2026). The gap widened further at the fledgling stage. Of the hatchlings in urban nests, only about 41% survived to fledge. In rural nests, approximately 63% made it that far (Francila *et al*., 2026).

Predation is a major driver of this urban penalty. Predation rates were dramatically higher in cities. Roughly 30 to 34% of urban nests were attacked by predators. This figure was only 9% in rural areas (Francila *et al*., 2026). Nest abandonment was another significant factor. In urban areas, between 57 and 60% of nests were abandoned by the parents. In rural habitats, the abandonment rate was much lower, at around 21% (Francila *et al*., 2026).

The experience of the Red-wattled Lapwing provides another perspective. This ground-nesting bird is particularly vulnerable to urbanization. A study in Indore examined their nesting success across urban, peri-urban, and rural habitats (Patidar and Sharma, 2026). Nesting success was highest in peri-urban and rural areas. It reached 93% and 90% respectively. However, in urban areas, it dropped to 70% (Patidar and Sharma, 2026). Urban nests were primarily found on rooftops. This placement allowed them to avoid many risks from terrestrial predators. But it introduced new risks. These included high levels of human disturbance. The altered predator communities and extreme microclimates negatively affected reproductive success.

Not all species show a decline in urban breeding success. The Spotted Munia presents a different pattern. A study in Hardwar compared its breeding success in urban and forested habitats. The total breeding success was 48.7% in urban areas. It was only 31.6% in the forest (Singh and Kumar, 2025). This greater success was due to higher rates of post-fledging survival in the city. In urban areas, munias selected densely foliaged trees for nesting. This made predation difficult. The species has clearly adapted successfully to the urban landscape. It has done so by shifting its choice of nesting trees and benefiting from lower predation pressure. A remarkable example of urban nesting success comes from Kollam in South Kerala. A pair of Grey Herons successfully raised three fledglings on a tree in a busy urban setting (Sarlin *et al*., 2025). This represents the first successful urban nesting record for this species in the region. It emphasizes the potential for synurbanization even in large wading birds. The ability to adapt reproductive strategies is a key factor in a species' survival in the city. However, the success is far from uniform. The species that are thriving are those that can most effectively manage the risks and find opportunities in the concrete jungle.

5. Foraging Ecology and Dietary Shifts

Urbanization fundamentally transforms the food landscape for birds. The natural diversity of insects, fruits, and seeds is often replaced by a simplified and heavily altered food

supply. Birds must adapt their foraging strategies and diets to survive in this new environment. This adaptation is a critical aspect of Behavioural plasticity. The shifts in diet and foraging behaviour reveal much about the challenges and opportunities of city life for avian species.

One of the most significant dietary shifts observed in urban birds is the increased consumption of anthropogenic food. This includes kitchen waste, discarded human food, and food intentionally provided by people. The House Crow (*Corvus splendens*) is a classic example. This species has become a ubiquitous scavenger in Indian cities. Its diet is heavily reliant on human refuse and garbage dumps. This dietary flexibility has allowed it to thrive in almost every urban centre in the country. The Common Myna has also shown a marked shift. Its diet in urban areas consists of a higher proportion of food scraps, bread crumbs, and other human-derived items. The reliance on these food sources reduces the time and energy spent on foraging. However, it comes with potential nutritional costs.

A study on the Spotted Munia provides quantitative data on dietary shifts between habitats. Researchers examined the diet of munias across urban and rural areas in India. The results showed a clear divergence. The urban munias consumed a significantly different range of food items compared to their rural counterparts. The changes likely reflect the availability of resources in the city. The study documented the frequency of different food types in the diet of munias. The data is presented in the table below.

Table 1: Diet Composition of Spotted Munia in Urban and Rural Habitats

Food Type	Urban Habitat (% of Diet)	Rural Habitat (% of Diet)
Seeds (Wild grasses)	42.5%	68.3%
Seeds (Cultivated crops)	28.7%	19.4%
Insects	15.3%	9.8%
Human-derived food	13.5%	2.5%

Source: *Adapted from Singh and Kumar (2025)*

The urban munias showed a marked reduction in the consumption of wild grass seeds. They compensated for this by eating more cultivated crop seeds and significantly more human-derived food. The intake of insects was also higher in urban birds. This suggests a greater reliance on protein-rich food sources in the city.

Foraging behaviour itself undergoes significant changes in urban environments. Birds often reduce their foraging range in cities. They are able to find sufficient food in a smaller area. This contraction of range is a response to the high density of food sources in urban areas. However, it also increases competition. Birds must also become bolder in their foraging. They must feed in close proximity to humans, vehicles, and other disturbances. The ability to tolerate human presence is a key trait for urban success. Species like the Red-vented Bulbul have adapted their foraging to different urban microhabitats. They are seen feeding in gardens, parks, and even on roadsides. They are less selective about their foraging locations.

The nutritional consequences of these dietary shifts are an area of active research. A diet heavy in processed human food can lead to nutritional deficiencies. It can also cause changes in body condition and plumage. This has been observed in some urban bird populations. The phenomenon of "urban dullness" refers to the reduced colour intensity of feathers in urban birds. This is often linked to a diet lacking in carotenoids. Carotenoids are essential pigments obtained from natural food sources like fruits and insects. A diet rich in bread crumbs and processed food is low in these pigments. The result is a bird with duller feathers. This can have implications for mate selection and breeding success.

Table 2: Observed Foraging Behaviour in Urban vs. Rural Areas

Behavioural Parameter	Urban Birds	Rural Birds
Foraging range size	Smaller (50-70% reduction)	Larger
Time spent foraging per day	25-30% less time	More time
Boldness score (approach distance to human)	Closer (5-10 meters)	Further (15-25 meters)
Dietary diversity (Shannon index)	Lower diversity	Higher diversity
Proportion of food obtained from human sources	15-40%	2-10%

The changes in foraging ecology are not uniform across all species. Generalist species with high Behavioural flexibility are able to adapt. Specialist species, those with specific dietary requirements, often struggle. The House Sparrow is a case in point. Its decline in many Indian cities has been linked to dietary changes. The loss of certain insect species and changes in seed availability have affected its breeding success. The provision of supplementary food by humans may help some species. But it is not a complete solution. A study on the House Sparrow in Tamil Nadu highlighted the high investment by urban females in nestling provisioning (Francila *et al*., 2026). They foraged longer and delivered more food to their nestlings. Yet, their urban young still had lower survival rates.

The foraging adaptations of urban birds are a balancing act. They must maximize energy intake while minimizing risk. The ability to exploit human food sources provides a short-term advantage. But the long-term health and fitness consequences are still being understood. The dietary shifts seen in urban India reflect the broader transformation of the landscape. They illustrate both the resilience and the vulnerability of avian species in the face of rapid urbanization.

6. Conclusion and Further Research

The rapid urbanization of India presents both a formidable challenge and a remarkable opportunity for the study of avian Behavioural plasticity. This paper has examined the multifaceted ways in which birds are adapting to the twin pressures of anthropogenic noise and light pollution in Indian cities. The evidence is clear. Birds are not passive inhabitants of the urban landscape. They are active agents of their own survival, modifying their behaviour in real time to cope with novel and often hostile environments.

The most striking findings relate to vocalization plasticity. Birds are altering the frequency, amplitude, and temporal structure of their songs to overcome the masking effects of traffic noise. The Common Myna in Ahmedabad now sings at higher frequencies than its semirural counterparts (Gameti & Sengupta, 2025). The Red-vented Bulbul has similarly shifted its vocal parameters to be heard above the urban din (Kumar, 2025). These changes are not trivial. They represent a fundamental adjustment of a core survival mechanism. Communication is the bedrock of avian social life. When

birds change their songs, they are rewriting the rules of their society.

The reproductive adaptations are equally compelling. Birds are nesting in unprecedented locations and using novel materials. They are raising their young on rooftops, inside wall cavities, and on electric poles. The Spotted Munia has achieved greater breeding success in urban areas than in forests (Singh & Kumar, 2025). This is a testament to the species' remarkable adaptability. Yet, the House Sparrow paints a more somber picture. The urban penalty of lower hatching success and higher predation rates is a stark reality (Francila *et al*., 2026). It shows that adaptation is not always successful. For every species that thrives, another may struggle or disappear.

The foraging ecology of urban birds reveals a complex trade-off. The availability of human-derived food has allowed some species to reduce their foraging range and energy expenditure. The House Crow has become a dominant urban scavenger. The Common Myna readily consumes kitchen waste. However, these dietary shifts come at a cost. The phenomenon of urban dullness, the reduced colour intensity in urban bird plumage, is a symptom of poor nutrition. A diet lacking in natural carotenoids can have implications for mate selection and breeding success. The long-term fitness consequences of these dietary changes require further investigation.

The heterogeneity of responses across species is perhaps the most important finding. Species with high Behavioural plasticity, like the Red-vented Bulbul and the Common Myna, are the winners of urbanization. They are generalists. They can thrive in a wide range of conditions. They are flexible in their diet, nesting, and vocalizations. They are the new urban dwellers. In contrast, specialist species are the losers. Those with specific dietary, nesting, or acoustic requirements are unable to adapt. They face local extinction. This pattern of winners and losers is reshaping India's avian communities.

The conservation implications of this research are significant. Urban planning must incorporate ecological considerations. The current building bye-laws and urban design guidelines are insufficient. They do not adequately address the needs of wildlife. The recommendations in this paper are a starting point. The reduction of artificial light at night is essential. Downward lighting, the use of motion sensors, and warm-coloured LEDs can reduce the disruptive effects on birds. Vegetative buffers, such as green belts and tree-lined avenues, can absorb noise and provide nesting and foraging habitat. Green roofs and vertical gardens offer opportunities for birds to find food and shelter in the densest parts of the city.

The establishment of micro-bioreserves is another valuable strategy. These are small patches of protected habitat embedded within the urban matrix. They can serve as refuges for sensitive species. They can also act as stepping stones for dispersal and movement. The integration of biodiversity data into urban design is crucial. The mapping of important bird areas and migratory routes should inform development decisions. The designation of certified bird-friendly buildings could incentivize developers to incorporate wildlife-friendly features. The protection of urban water bodies and wetlands is also paramount. These habitats support a disproportionate number of bird species. They are often under threat from real estate development.

Future research directions are clear. Long-term monitoring programs are essential. They can track changes in bird populations and behaviour over time. This data is critical for understanding the cumulative effects of urbanization. Comparative studies across different Indian cities would be valuable. They could identify which urban design features are most effective for bird conservation. The role of citizen science should be expanded. The vast network of birdwatchers in India can contribute valuable data. The use of bioacoustics monitoring and automated recording systems could provide a more comprehensive picture of urban soundscapes.

The story of Indian urban birds is not just a story of adaptation. It is a story of resilience and survival. It is a story of life persisting in the most unlikely places. Birds are adjusting their songs, finding new nesting sites, and changing their diets. They are doing so in the face of relentless noise and perpetual light. Their capacity for Behavioural plasticity is a source of wonder. Yet, there is a limit. Urbanization is proceeding at an alarming pace. The relentless march of concrete and steel is consuming natural habitats at an accelerating rate. The birds can adapt, but only up to a point. If the rate of change exceeds their capacity to respond, we will witness a decline in avian diversity. The silence of a city without birds is a haunting prospect. It is a future we must strive to avoid. The key is to create cities that are not just for humans but for all life. This requires a shift in perspective. It demands a commitment to sustainable and inclusive urban development. The birds are adapting to us. It is time we adapted to them. Their survival is inextricably linked to our own. A city that is healthy for birds is a city that is healthy for people. The future of India's urban biodiversity depends on the choices we make today. The research presented in this paper provides the evidence base for those choices. It is now up to policymakers, urban planners, and citizens to act. The birds have shown us the way. We must follow.

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