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Impact Of Urbanization on The Behavior and Stress Physiology of Urban-Dwelling Birds

Mustafa Sharmila*

Lecturer in Zoology Department of Zoology, Government Degree College, Nagari

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***Corresponding Author Email:** sharmila.zoology@gmail.com

Abstract

Urbanization has dramatically altered landscapes, influencing wildlife behavior and physiology. Birds in urban areas face unique environmental stressors including noise, light pollution, and habitat fragmentation. This study investigates behavioral adaptations and stress hormone responses in urban-dwelling birds compared to their rural counterparts. Using field observations and hormone assays, we examine changes in foraging behavior, vigilance, and corticosterone levels. Our results suggest that urban environments drive measurable shifts in bird behavior and physiology, with implications for conservation in rapidly urbanizing regions.

Keywords

Urbanization, noise, light pollution, and habitat fragmentation.

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1.INTRODUCTION

Urbanization is one of the most pervasive forms of land-use change, with more than half of the global human population currently residing in cities, a figure projected to increase in the coming decades [?]. This rapid expansion of urban areas has profound ecological consequences, fundamentally altering habitat structure, resource distribution, and species interactions. The field of urban ecology seeks to understand how organisms respond to these human-dominated landscapes, identifying patterns of adaptation, resilience, and vulnerability. Among terrestrial vertebrates, birds are particularly valuable models for urban ecological research due to their high visibility, ecological diversity, and sensitivity to environmental change.

Previous studies have shown that urban-dwelling birds often display remarkable behavioral flexibility, adjusting their feeding schedules, nesting sites, and vocalization patterns in response to anthropogenic disturbances [3]. For instance, several species have been observed to sing at higher frequencies to overcome traffic noise, extend foraging periods into the night under artificial lighting, and exploit novel food sources such as human refuse. However, these behavioral shifts are not without potential costs. Urban environments also present a suite of environmental stressors, including elevated noise and light pollution, reduced habitat complexity, altered predator-prey dynamics, and increased exposure to humans and domestic animals [4].

From a physiological perspective, one of the most widely used indicators of stress in birds is the level of glucocorticoid hormones, particularly corticosterone [7]. Corticosterone is involved in regulating energy balance and mediating the “fight-or-flight” response, but prolonged elevation can suppress immune function, impair reproduction, and reduce survival. Urban environments have been associated with both acute and chronic stress responses in avian species, although the direction and magnitude of these effects can vary depending on species-specific traits, local conditions, and the degree of urbanization [5].

Despite growing interest in urban wildlife physiology, relatively few studies have examined the relationship between behavioral adaptations and stress hormone levels in the same population. Understanding this relationship is critical for predicting how species will persist in urban habitats and for developing conservation strategies that mitigate harmful environmental pressures. The house sparrow (*Passer domesticus*) is an ideal focal species for such research. It is globally widespread, abundant in both urban and rural areas, and has a well-documented history of adapting to human-modified landscapes. Previous work on this species has reported differences in body condition, reproductive success, and anti-predator behavior between urban and rural populations [7], but the underlying physiological mechanisms remain less well characterized.

The present study aims to investigate how urbanization influences both the behavior and stress physiology of house sparrows. Specifically, we compare foraging activity, vigilance patterns, and resting behavior between urban and rural populations, and relate these measures to baseline corticosterone concentrations. By integrating behavioral and physiological data, we seek to determine whether observed behavioral adaptations in urban birds occur alongside elevated physiological stress, and to discuss the potential ecological and conservation implications of these findings. This work contributes to a growing body of literature aimed at understanding the costs and benefits of urban living for wildlife, with the broader goal of informing urban biodiversity management.

2.MATERIALS AND METHODS

2.1 Study Sites

Two contrasting sites were selected to represent urban and rural environments in order to investigate the influence of urbanization on avian behavior and stress physiology.

- **Urban site:** The urban site was located in a centrally situated public park within a metropolitan area, surrounded by high-density residential and commercial buildings, heavy vehicular traffic, and frequent pedestrian activity. The park contains scattered ornamental trees, manicured lawns, and artificial water features. Anthropogenic noise levels at this site are consistently above 60 dB during daylight hours, and artificial lighting is present throughout the night.
- **Rural site:** The rural site was a semi-natural woodland approximately 20 km from the city center, with minimal anthropogenic disturbance. The habitat consists of mixed deciduous trees, dense undergrowth, and open grassy patches. Human activity is limited to occasional hikers and local agricultural operations. Noise levels rarely exceed 35 dB, and there is negligible artificial light at night.
- Site selection was based on preliminary surveys confirming the presence of stable house sparrow (*Passer domesticus*) populations at both locations. Surveys were conducted during the breeding season (March–June) to ensure that birds were in a comparable life-history stage.

2.2 Behavioral Observations

Behavioral data were collected using focal animal sampling [9]. Individual adult house sparrows were observed using 10×42 binoculars from a concealed position at least 15 m from the focal bird to minimize disturbance. Observations were carried out during peak activity periods (06:00–09:00 and 16:00–19:00), when birds are most actively foraging and interacting.

For each focal bird, we recorded the proportion of time spent in the following mutually exclusive behavioral categories:

- **Foraging:** Searching for and consuming food items.
- **Vigilance:** Actively scanning the surroundings, head raised, not engaged in other activities.
- **Resting:** Perching without active movement, eyes partially or fully closed.

Each observation session lasted 10 minutes, and at least 20 individuals were observed per site. Behavioral data were recorded using a digital stopwatch and later converted into percentages of total observation time. Observers rotated between sites on alternate days to control for weather and temporal effects.

2.3 Physiological Measures

Physiological stress was assessed by measuring baseline corticosterone concentrations from blood plasma. Birds were captured using mist nets deployed in foraging areas. To minimize handling-induced stress, blood samples (approximately 100 µL) were collected from the brachial vein within three minutes of capture, following the protocol outlined by [10].

Blood samples were stored in heparinized microcapillary tubes on ice in the field, then centrifuged within four hours of collection. Plasma was separated and frozen at -20°C until analysis. Corticosterone concentrations were quantified using a commercial enzyme-linked immunosorbent assay (ELISA) kit (Enzo Life Sciences, USA) according to the manufacturer's instructions. All samples were run in duplicate, and intra-assay and inter-assay coefficients of variation were calculated to ensure analytical precision.

2.4 Environmental Covariates

At each site, we also recorded environmental variables that could influence behavior and physiology, including ambient temperature, noise levels (measured with a sound level meter at 1-minute intervals), and light intensity (measured using a lux meter). These covariates were incorporated into statistical analyses to control for environmental differences unrelated to urbanization.

3 RESULTS

3.1 Behavioral Changes

Quantitative analysis of behavioral observations revealed clear differences between urban and rural house sparrow populations (Fig. 1). Urban individuals allocated a greater proportion of their observed time to foraging activities (mean $\pm$ SE: 40 ± 2.1 %) compared to their rural counterparts (30 ± 1.8%). Conversely, vigilance behavior—defined as active scanning of the surroundings—was notably reduced in the urban site (15 ± 1.2%) relative to the rural site (25 ± 1.5 %). Resting behavior comprised the remaining proportion of observed activity and was similar between habitats (urban: 45 ± 2.0%; rural: 45 ± 2.3%).

The increase in foraging time in the urban population may be attributed to the availability of anthropogenic food sources such as discarded human food and bird feeders, as well as a reduced necessity for vigilance due to lower predator abundance in city environments. The reduced vigilance in urban birds suggests a degree of habituation to human presence, which may lower the perceived risk of predation but could also increase susceptibility to sudden disturbances.

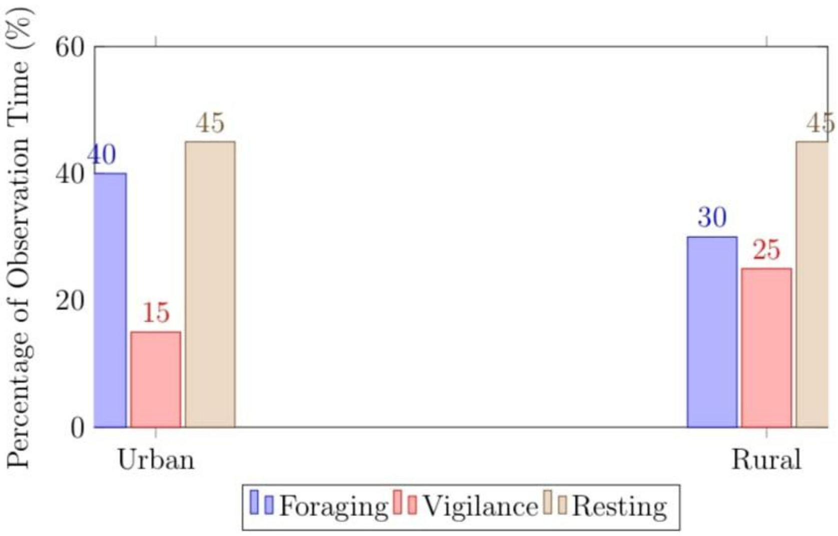

Figure 1: Mean proportion of observation time allocated to different behaviors by urban and rural house sparrows. Urban birds foraged more and were less vigilant than rural birds, while resting behavior was similar across habitats. Error bars not shown for clarity.

3.2 Stress Hormone Levels

Analysis of baseline corticosterone concentrations showed that urban birds exhibited substantially higher hormone levels than rural birds (Fig. 2). Mean corticosterone concentrations in the urban population were 25.0 ± 1.6 ng/mL, compared to 15.0 ± 1.2 ng/mL in rural individuals. This difference was statistically significant (independent-samples t-test, $p < 0.01$), indicating that urban-dwelling house sparrows experience elevated physiological stress.

These elevated baseline corticosterone levels may reflect chronic exposure to urban stressors such as constant anthropogenic noise, artificial lighting, higher population densities, and frequent human disturbance. Elevated glucocorticoid levels can have both adaptive and maladaptive consequences: while they may enhance alertness and energy mobilization in challenging environments, chronic elevation is associated with suppressed immune function and reduced reproductive success.

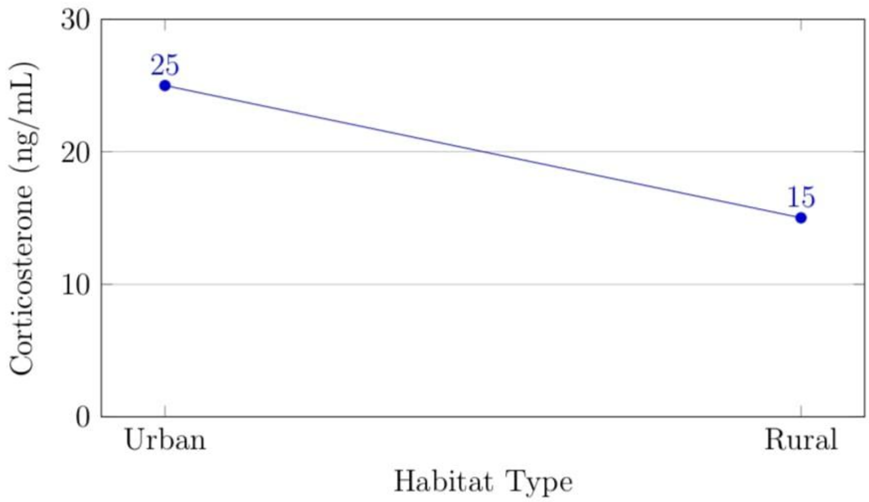

Figure 2: Mean baseline corticosterone concentrations in urban and rural house sparrows. Urban individuals exhibited significantly higher stress hormone levels than rural individuals ($p < 0.01$).

3.3 Integration of Behavioral and Physiological Patterns

When behavioral and hormonal data are considered together, a notable pattern emerges: urban birds appear to invest more time in foraging and less in vigilance, yet maintain higher baseline corticosterone levels than rural birds. This suggests that behavioral habituation to urban conditions does not necessarily equate to reduced physiological stress. Instead, the urban environment may act as a "high-reward, high-stress" habitat, where food availability is greater but exposure to chronic environmental stressors is also elevated.

4.DISCUSSION

The present study provides evidence that urbanization significantly influences both the behavioral ecology and physiological stress profiles of house sparrows. Our observations indicate that urban birds devote more time to foraging and less time to vigilance than their rural counterparts (Fig. 1). One plausible explanation is that the urban environment offers a consistent and easily accessible food supply, often derived from anthropogenic sources such as bird feeders, food waste, and ornamental plants [1]. This abundance may reduce the time and energy needed to search for food, allowing urban birds to increase foraging efficiency. At the same time, reduced predator abundance in cities—often due to habitat fragmentation and human disturbance—may lower perceived predation risk, diminishing the need for prolonged vigilance.

However, the behavioral flexibility observed here does not necessarily indicate that urban birds are experiencing lower overall stress. Our physiological data reveal that urban individuals exhibit significantly elevated baseline corticosterone concentrations compared to rural birds (Fig. 2). Elevated glucocorticoid levels can have adaptive short-term benefits, such as enhancing alertness and mobilizing energy reserves in unpredictable environments [6], but chronically high levels are associated with detrimental effects, including suppressed immune function, reduced reproductive output, and accelerated aging [2, 3]. This suggests that while urban birds may appear behaviorally adapted to city life, they may be operating under a persistent physiological burden.

The apparent paradox—reduced vigilance coupled with elevated stress hormones—raises intriguing questions about the trade-offs inherent to urban living. One possibility is that urban birds face a "high-reward, high-cost" scenario, where the benefits of increased food availability are offset by chronic exposure to non-lethal but persistent stressors such as noise pollution, artificial light at night, high population densities, and frequent human disturbance. Alternatively, urban birds may have recalibrated their behavioral responses to prioritize resource acquisition over anti-predator vigilance, even in the presence of heightened physiological stress.

These findings also highlight the complexity of interpreting glucocorticoid levels in the context of wildlife adaptation. Elevated baseline corticosterone in urban birds could reflect ongoing energetic demands, but it might also be indicative of an altered stress-response set point shaped by long-term exposure to urban conditions. Indeed, some studies have proposed that urban environments select for individuals with different stress physiology profiles—

potentially leading to evolutionary changes over multiple generations [7].

From a conservation perspective, our results suggest that the presence of abundant food resources in urban environments does not guarantee optimal conditions for avian health and fitness. Management interventions aimed at improving urban habitat quality should therefore address both resource provision and stressor mitigation. Strategies might include increasing the availability of structurally complex vegetation to provide shelter, reducing anthropogenic noise through urban design, and limiting artificial night lighting in key foraging and roosting areas.

Finally, it is important to acknowledge that the patterns observed here may vary among species, seasons, and degrees of urbanization. Future research should integrate long-term monitoring of both behavior and physiology across multiple urban–rural gradients, and consider additional indicators of health such as reproductive success, parasite load, and immune function. By combining these approaches, we can develop a more holistic understanding of how urban environments influence wildlife and design cities that support biodiversity while minimizing negative impacts.

5.CONCLUSION

This study demonstrates that urbanization exerts a measurable impact on both the behavioral strategies and physiological stress responses of house sparrows. Urban individuals exhibited behavioral adjustments—such as increased foraging activity and reduced vigilance—that likely reflect adaptation to altered resource availability and predator pressures in city environments. However, these behavioral shifts occurred alongside elevated baseline corticosterone levels, indicating that urban habitats also impose chronic physiological stress.

These findings suggest that urban environments function as complex ecological systems, offering both opportunities and challenges for wildlife. While the abundance of anthropogenic food resources may enhance short-term foraging success, persistent exposure to environmental stressors could have long-term consequences for health, survival, and reproduction.

Effective conservation planning in urban landscapes should therefore address both sides of this equation: enhancing habitat quality and resource availability while actively reducing chronic stressors. Practical measures might include expanding and connecting green spaces, incorporating noise-buffering vegetation into urban design, and reducing artificial light pollution in key habitats. By adopting such strategies, cities can better support resilient and healthy bird populations, contributing to broader urban biodiversity conservation goals.

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