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Behavioral Flexibility in Urban Birds: Nesting Adaptations in Cities

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Abstract: Urban environments test the behavioral flexibility of birds, forcing them to adapt to anthropogenic stressors. This study examines nesting choices made by five common urban bird species in Shanghai in relation to urban pressures—specifically noise disturbance, pedestrian movement, vehicle flow, and water accessibility—using data from 85 nests surveyed across five green spaces from January to March 2025. The results show that Spotted Dove, Little Egret, and Night Heron often nest at higher elevations in noisier or busier settings, suggesting species-specific adaptive responses. These results highlight the importance of avian behavioral plasticity in urban ecology and support long-term, species-level monitoring to strengthen biodiversity conservation strategies.

1. Introduction

1.1 Adaptation in Urban Environments

Scientists have long studied the interaction between organisms and their environments, but adaptation to urban contexts has only recently gained popularity in ecological research. Beginning in the mid-20th century, rapid urbanization and suburban expansion following World War II increased both public awareness and scientific interest in human impact on nature. The presence of organisms thriving in human-dominated landscapes has inspired ecologists to reconsider cities not as ecological voids but as complex, novel ecosystems where organisms are constantly adapting. A classic example is the peppered moth (*Biston betularia*), which evolved a dark coloration during the Industrial Revolution—an early and visible case of adaptive evolution driven by urban pollution. As cities continue to expand and transform, so do the environmental pressures faced by urban wildlife, driving continued adaptation for survival in city landscapes (Lambert et al., 2022)[9]. In the case of avian populations, increases in impervious surfaces, vegetation loss, and habitat fragmentation have caused urban ecosystems to differ significantly from natural ones in terms of food availability, nesting sites, and predator presence (Cooper et al., 2022)[3]. These shifts have led to the emergence of nesting behaviors that are unique to birds in urban environments.

1.2 Interaction of Birds with the Urban Environment

It is often assumed that urbanization harms bird populations. While this holds true in cases such as window collisions (Klem, 1990)[7], pollution (Marteinson & Verreault, 2020)[10], invasive plant species (Ortega et al., 2006)[13], and reduced vegetation (Kurucz et al., 2012)[8], other factors must be considered—such as greater availability and diversity of food sources (Crates et al., 2016)[4], which may make feeding and breeding more energy-efficient in cities than in natural habitats. Meanwhile, recent empirical evidence confirms that behavioral plasticity are enhancing urban survival prospects among birds (Ducatez et al., 2020)[5]. Studies also show that some synanthropic species prefer urban areas to rural ones and that shrub nest survival strongly correlates with the degree of urbanization (Kurucz et al., 2021). In other words, the relationship between birds and urban development is dynamic and complex; much remains to be explored.

1.3 Why Study Nesting Behavior of Birds?

To preserve biodiversity in urban environments, conservationists need more analysis on species richness, distribution, and related behaviors. Nesting biology is a central focus in ornithology, as nesting directly affects reproductive success (Ryder et al., 2010)[12]. Nesting behavior also reflects a population's adaptability to local environmental pressures (Chamberlain et al., 2009)[2]. Therefore, this study aims to evaluate the current condition of urban bird communities by documenting their nesting behavior in city habitats.

1.4 Selected Habitat

1.4.1 Introduction to City

This study was conducted in Shanghai, China's most economically developed city, divided into Pudong and Puxi districts by the Huangpu River (31°13′43″N, 121°28′29″E). The study focuses primarily on the Puxi district, south of the river. By 2024, Shanghai's population had reached 24,802,600, making it one of the most densely populated cities in East Asia. The city features a humid subtropical monsoon climate, with hot, humid summers and relatively dry, cool winters. The annual mean temperature is 17.1 ℃, and annual precipitation averages 1,200 mm. Fig. 1 is the map of Shanghai, with the studied regions marked. The center of the circle indicates the targeted location of interest.

Fig.1 Map of Shanghai with studied regions marked.

1.4.2 Specific Sites

Fig.2 Map of Shanghai Botanical Garden

To compare nesting behaviors in different habitat fragments, specimens were collected and categorized based on the locations they were taken from. Main sites of interest include the Shanghai Botanical Garden, the Shanghai Zoo, the Minhang Sports Park, and Huangjincheng Road.

(1) Shanghai Botanical Garden

Shanghai Botanical Garden, located in the Xuhui District in the southwestern part of Shanghai (31°09′43″N, 121°25′26″E), spans approximately 81 hectares and is known for its rich plant diversity and tranquil environment. In 2024, the garden was recorded attracting between 12,000 to 15,000 visitors daily. Fig. 2 is the map of the Shanghai Botanical Garden. The route of investigation is traced, with major nesting sites marked out.

(2) Shanghai Zoo

Shanghai Zoo, located in the Changning District within the Yangzte River Delta (31°11′38″N, 121°21′55″E), covers about 74 hectares of land and is characterized by its low-lying, deltaic landscape. The zoo is widely recognized for its extensive collection of captive animals, along with abundant feed and food available for them. The average daily visitor count in 2024 ranged from 9,000 to 10,000. Fig. 3 is the map of the Shanghai Zoo. The route of investigation is traced, with major nesting sites marked out.

Fig.3 Map of Shanghai Zoo

(3) Minhang Sports Park

Minhang Sports Park, located in the Minhang District in southern Shanghai (31°06′39″N, 121°23′16″E), lies in proximity to the Shanghai Zoo and encompasses over 25 hectares of land. The park is characterized by its semi-natural landscape embedded within a dense urban-residential context, featuring a mosaic of open grassy areas, scattered woodland patches, and recreational infrastructure. It serves as a multifunctional green space for both active and passive recreation, frequented by local residents throughout the week. In 2024, the average daily number of recreational visits ranged from 5,000 to 7,000, with peaks at weekends and public holidays. Fig. 4 is the map of the Minhang Sports Park.The route of investigation is traced, with major nesting sites marked out.

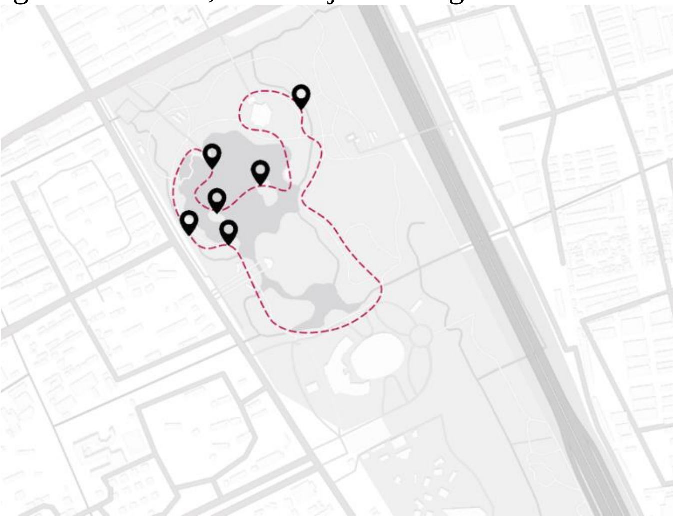

Fig.4 Map of Minhang Sports Park

(4) Huangjincheng Road Greenway

Huangjincheng Road Greenway, located in the Changning District of Shanghai (31°12′40″N, 121°24′10″E), is a 1.5-kilometer-long pedestrian corridor characterized by its linear design, lush vegetation, and integration with the surrounding residential neighborhoods, which house a total population of approximately 33,000. The greenway functions as both a transit route and a recreational space, offering shaded walking paths, seating areas, as well as stores and restaurants. In 2024, the average daily number of recreational visits ranged from 4,000 to 6,000, with heightened foot traffic observed during mornings, evenings and weekends. Fig. 5 is the map of the Huangjincheng Road. The route of investigation is traced, with major nesting sites marked out.

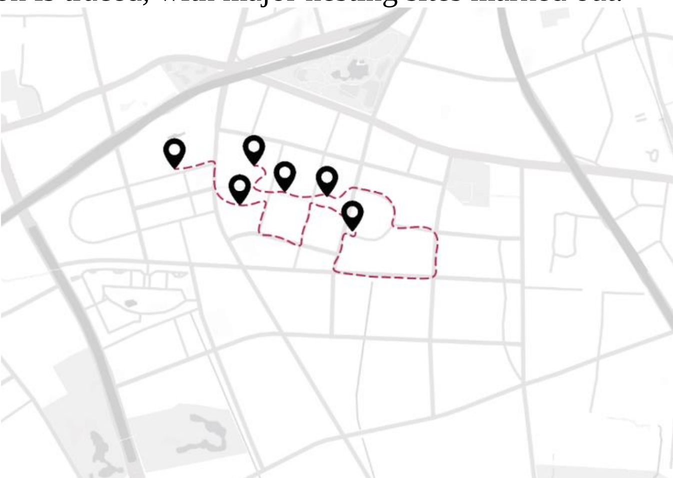

Fig.5 Map of Huangjincheng Road

(5) Binjiang

Binjiang, located in the Xuhui District along the western bank of the Huangpu River in central Shanghai (31°10′45″N, 121°27′35″E), spans approximately 4.3 kilometers of revitalized waterfront space. It is characterized by flat, open terrain typical of the Yangtze River Delta and features a mix of landscaped green areas, industrial heritage architecture, and modern public amenities. The area is renowned for its riverside promenades, art galleries, and leisure spaces that attract both locals and tourists. In 2024, the average daily number of recreation visits ranged from 6,000 to 8,000, particularly peaking at weekends and public holidays. Fig. 6 is the map of Binjiang. The route of investigation is traced, with major nesting sites marked out.

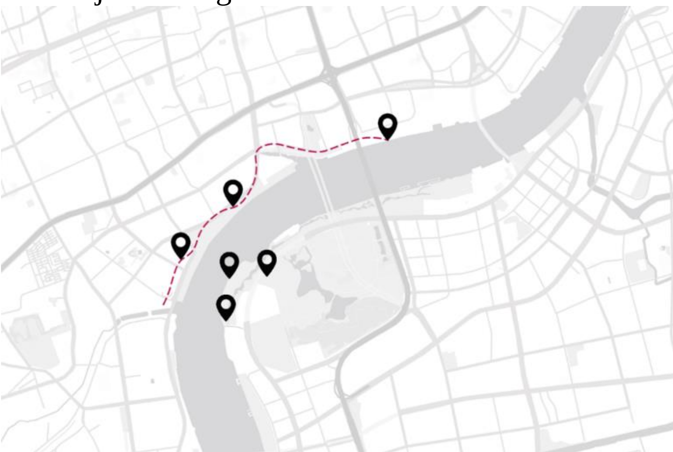

Fig.6 Map of Binjiang

(6) Others

Samples are also taken along roadsides to observe the impact of traffic on nesting behavior.

2. Method

2.1 Procedure

From January to March, 2025, I recorded a total of 85 bird nests, built either inthe previous year or the present. Data were collected within the time range of 7 A.M. to 10 A.M.. Each site was investigated for an average of three hours. Table 1 gives a summary to the procedure of the study.

Table 1 Procedure of monitoring study

Selecting location
Determine region to monitor Limit boundaries
Identifying nests
Locate nest on map
Use camera to capture image of nest
Record characteristics of nest: -Height- -Level of noise disturbance- -Nearby pedestrian flow- -Nearby vehicle flow -Distance to water source

2.2 Measures

2.2.1 Height and Distance

Height of a nest was determined by the perpendicular distance from the nest to the ground. If the nest is directly above the water surface, then the height is the perpendicular distance from nest to water. Measurements were calculated by Measure in meters.

Distance of a nest from the nearest sustainable water source (which excludes puddles, drains, and other temporary water sources) is determined by calculating the horizontal linear distance from nest to the body of the water in meters. Same measurement method is applied to determining the nest distance from the road.

2.2.2 Species and Nest Composition

The species of vegetation (or type of architectural building) each nest inhabits is recorded and identified. The composition of bird nest was analyzed manually by observation of close up pictures of bird nests. Bird species targeted in this study are Chinese Blackbird (*Turdus mandarinus*), Spotted Dove (*Spilopelia chinensis*), Light-vented Bulbul (*Pycnonotus sinensis*), little egret (*Egretta garzetta*), and black-crowned night-heron (*Nycticorax nycticorax*), which are common urban birds in the region with relatively observable nests.

2.2.3 Data Analysis

Fig.7 Close-up view of monitored nests of different species showing nest composition and structure.

The gathered data were organized and analyzed on Excel. Factors are graphed on python. Table 2 presents the independent variables linked to nest height, while Figure 7 illustrates the relationship between the height of bird nests above the ground and noise disturbance in the surrounding environment, with noise measured at ground level. A positive slope in Fig. 7 indicates that the species tends to nest at greater heights in areas characterized by higher noise levels.

Table 2 Independent variables associated with nest height

			Nest Height		
Independent Variable	Chinese Blackbird	Spotted-Dove	Light-vented Bulbul	Little Egret	Night Heron
Noise Disturbance	b = 1.53, p < .124	b = 5.22, p < .043	b = 0.08, p < .955	b = 1.97, p < .024	b = 1.94, p < .00004
Pedestrian	b = 0.10 p < .444	b = -0.08 p < .683	b = -0.04, p < .863	b = 0.26, p = .005	b = 0.30, p = 0001
Vehicle	b = 0.01, p = .977	b = -0.01, p = .977	b = -0.67, p < 0.01	b = 0.81, p < .032	b = 0.17, p < .154

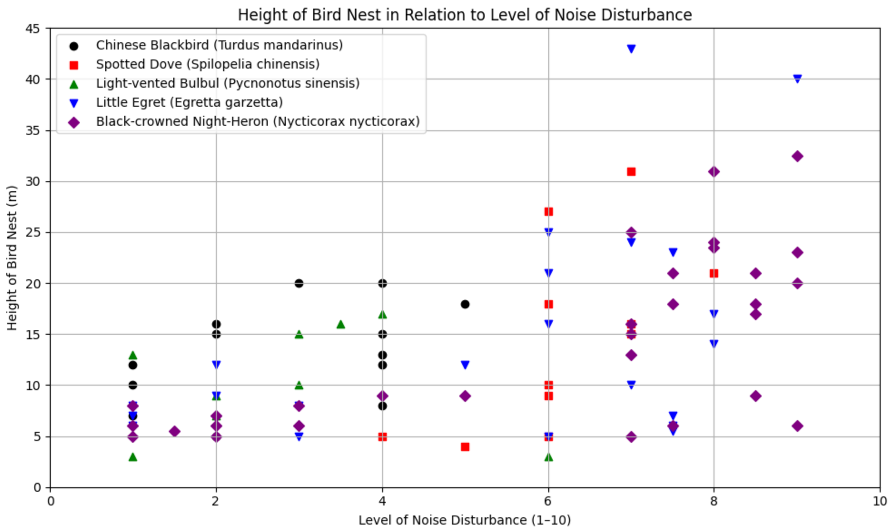

Fig.8 Height of bird nests from ground in relation to the surrounding environment's noise disturbance,

3. Results

Based on Fig. 8, all species exhibit a general trend of increasing nesting height along the gradient of growing noise disturbances. Yet, there is no statistically significant correlation between the nest height of the overall bird population and the level of noise disturbance. However, there are significant positive correlations between the level of noise disturbance and the nest height of the Spotted Dove, with a p-value of 0.043 and a correlation coefficient of 5.22; the Little Egret, with a p-value of 0.024 and a correlation coefficient of 0.480; and the Black-crowned Night-Heron, with a p-value of 0.0004 and a correlation coefficient of 0.681. Although Spotted Doves exhibit higher sensitivity to noise when nesting, they occupy regions with significantly higher noise disturbances than the Chinese Blackbird and the Light-vented Bulbul.

Notably, while both the Chinese Blackbird and Light-vented Bulbul appear to be clustered within low to moderate noise levels (ranging from 1 to 6), their nest height variation does not show a consistent pattern with respect to noise intensity. This suggests a degree of behavioral or ecological constraint in their nest site selection. In contrast, Black-crowned Night-Herons show a pronounced elevation in nest height as noise increases, indicating strong noise avoidance behavior likely tied to their sensitivity during nesting. Additionally, the steep vertical distribution of Little Egret nests under high noise conditions further highlights the species' adaptive response, possibly leveraging elevation for improved acoustic insulation or reduced human interference.

Fig. 9 presents a visualized association between nest height and pedestrian traffic, measured at ground level within a 50-meter radius of each nest, expressed in persons per minute. The nesting patterns suggest that Chinese Blackbirds, Little Egrets, and Black-crowned Night-Herons exhibit an upward shift in nesting height with increasing pedestrian flow, indicating possible avoidance behavior. In contrast, Light-vented Bulbuls and Spotted Doves show a slight decline in nest height under elevated foot traffic, potentially reflecting species-specific nesting constraints or differing tolerance thresholds. Among all species, only the Little Egret demonstrates a statistically significant response to pedestrian density, with a p-value of 0.005 and a correlation coefficient of 0.577, suggesting a strong and consistent trend of vertical nesting adjustment in response to human presence. This behavior may reflect sensitivity to visual disturbances or noise levels typically associated with high pedestrian activity.

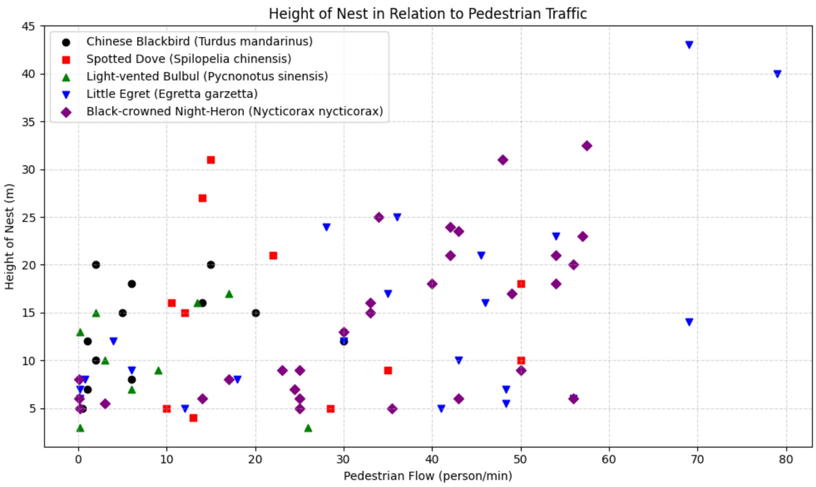

Fig.9 Height of bird nests in relation to pedestrian flow

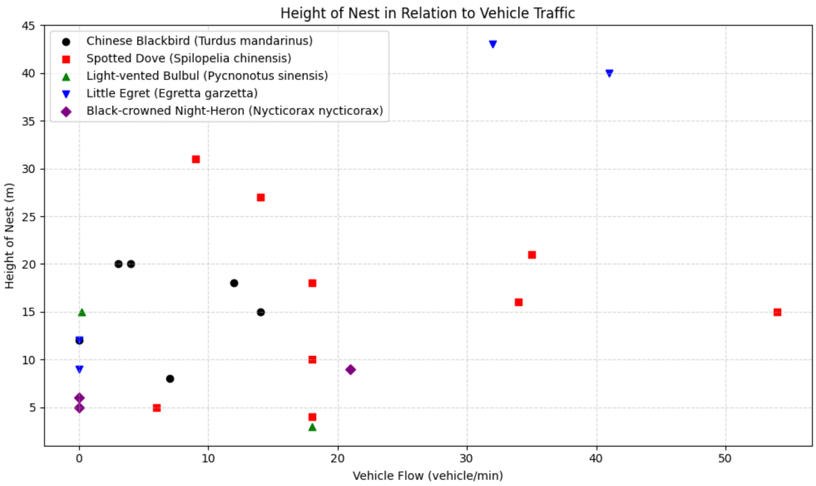

Fig.10 Height of bird nests in relation to vehicle flow measured at ground level within a 50-meter radius of each nest, expressed in vehicles per minute

Fig. 10 illustrates the relationship between nest height and vehicle traffic based on a limited dataset of 23 recorded nest points. The data are insufficient to determine a clear overall trend for all species, but certain patterns emerge. Spotted Doves and Little Egrets are observed nesting in areas with notably high vehicle flow, implying a relatively high tolerance to vehicular disturbances. Present data further suggest weak positive correlations between nest height and vehicle traffic for Chinese Blackbirds, Little Egrets, and Black-crowned Night-Herons, while Spotted Doves and Light-vented Bulbuls appear to respond negatively. Given the limited number of data points and uneven species representation across the traffic gradient, however, any inferred trends should be interpreted with caution. Additional sampling would be required to substantiate these preliminary observations.

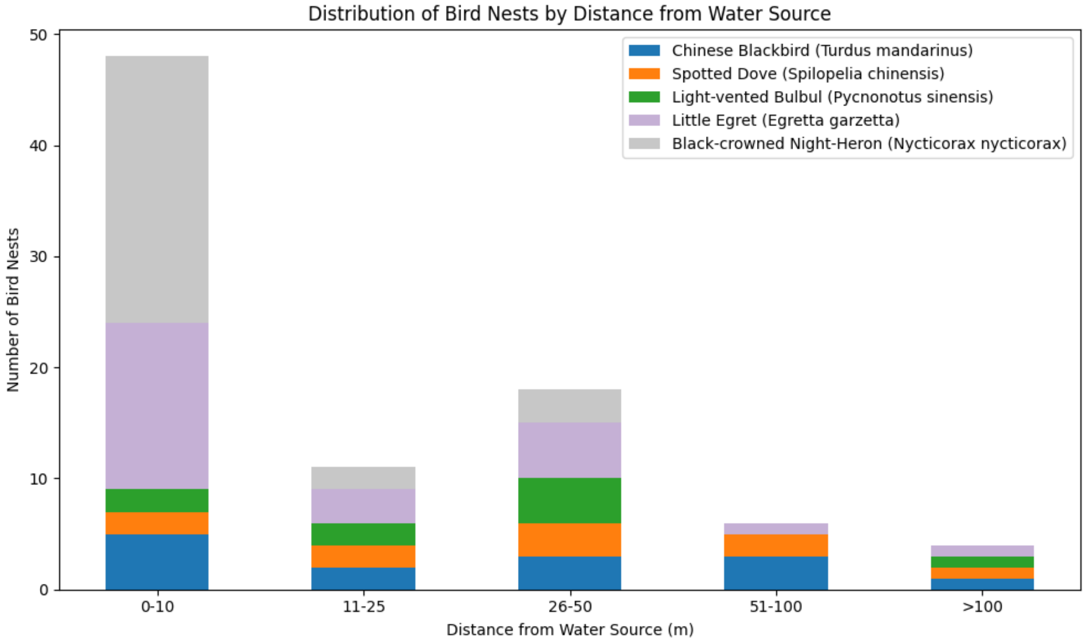

Fig.11 Distribution of bird nests from nearest water source, expressed in number of nests

Based on Fig.11, all five species demonstrate a general trend of declining nest abundance as the distance from the water source increases. However, the strength and consistency of this pattern vary by species. Notably, Black-crowned Night-Herons exhibit the steepest decline, with nests almost exclusively clustered within the 0–10 m range, underscoring a strong spatial dependence on close proximity to water. Similarly, Little Egrets show a marked reduction in nesting beyond 50 meters, suggesting moderate to high site fidelity to water-adjacent habitats.

In contrast, Chinese Blackbirds and Spotted Doves are more broadly distributed across all distance intervals, with only a mild decrease in abundance, indicating lower spatial sensitivity and greater nesting flexibility. Light-vented Bulbuls, while present across all distances, appear to peak at intermediate zones (26–50 m), suggesting either a preference for transitional habitats or tolerance for varied hydrological proximity.

4. Discussion

The study monitored the influence of noise and human activity on the nesting behavior of urban birds. These two factors—anthropogenic noise and human presence—are often closely intertwined in urban environments. The results indicate that most species tend to avoid high levels of noise and dense pedestrian or vehicle traffic by selecting higher nesting sites. This vertical adjustment in nest placement suggests an adaptive response aimed at reducing disturbance and possibly improving breeding success.

In addition to noise and human activity, the presence of nearby water sources was assessed as well. Results suggest that Little Egrets and Night Herons, waterbird species, show a strong preference for nesting in close proximity to sustainable water bodies, likely due to the direct relationship between water access and foraging efficiency. In contrast, forest-dwelling species such as Chinese Blackbirds and Light-vented Bulbuls show lesser affinity for water sources, indicating that breeding factors such as foraging, thermal regulations or predation avoidance in these species are influenced more by vegetation structure or noise than by aquatic access.

This fieldwork was conducted over a three-month period, across two consecutive years, to account for temporal variation. However, given the dynamic nature of urban landscapes—marked by construction, changing vegetation, and fluctuating human activity—long-term monitoring is necessary to gain a comprehensive understanding of how bird populations adapt to ongoing urban development (Aronson et al., 2014)[1].

Among the studied species, Chinese Blackbirds showed a moderately high tolerance to noise pollution, which is consistent with earlier findings and highlighting their flexible acoustic strategies, such as raising song pitch or volume to compete with background noise (Nordt & Klenke, 2013)[11]. Interestingly, Black-crowned Night-Herons exhibited an unexpectedly high tolerance to both noise and pedestrian traffic. This pattern is likely attributable to feeding conditions at the Shanghai Zoo, where an abundance of animal feed appears to attract wild herons to nest near enclosures despite the unfavorable acoustic environment. These findings suggest that, for certain species, access to reliable food sources may outweigh the disadvantages of human disturbance when selecting breeding sites.

However, this behavioral adaptation of night herons may come at a cost. Previous research has demonstrated that nestlings of species such as herons are particularly vulnerable to frequent human presence, which can result in increased stress and reduced fledging success (Fernández-Juricic et al., 2007)[6]. Consequently, while the zoo provides foraging opportunities, it may simultaneously pose developmental risks for chicks, making it a potentially unsuitable environment for successful rearing.

Moreover, the contrasting nesting responses observed in Spotted Doves—exhibiting high nest placement in relation to noise but lower placement under heavy pedestrian flow—suggest that different types of urban disturbance may induce distinct adaptive strategies even within the same species. This complexity highlights the need to distinguish the nuanced effects of various urban stressors and encourages future research that considers multi-factorial urban pressures in tandem.

5. Reflection

The period of observation was relatively short to ensure the robustness of the association between ecological situations and the behavior of birds. For many species, including Chinese Blackbirds (*Turdus mandarinus*) and Spotted Doves (*Spilopelia chinensis*), nesting typically begins in the early to mid-spring, often starting in early March. The period of monitoring covered late January and early March, but was majorly focused on February. Due to this, most of the data collected was constrained to sampling the previous year's breeding cycle, rather than real-time nesting.

This time limitation not only restricted the number of active nests that could be monitored, but also reduced the opportunity to track and predict long-term patterns in nesting behavior. Rapid changes and development in the urban landscape make habitat conditions vary each year. If future opportunities allow, I plan to extend the period of monitoring from March to July—ideally covering the entire nesting season, from the onset of nesting to the first signs of fledging—for two or three consecutive years. Doing so, I hope to gather a more authentic dataset of nesting behavior in a complete nesting cycle, and compare them to data from different years to observe the variation of behavior in association with environmental changes, and to achieve higher precision in assessing the factors.

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