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Flight initiation distance of Eurasian tree sparrow (*Passer montanus*) across residential vegetation gradients in Bogor, West Java, Indonesia

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Abstract. *Rohman SN, Mardiastuti A, Mulyani YA. 2025. Flight initiation distance of Eurasian tree sparrow (*Passer montanus*) across residential vegetation gradients in Bogor, West Java, Indonesia. Biodiversitas 26: 6188-6196.* Birds inhabiting urban areas must adapt to coexist with humans in order to survive. Exposure to human activities may threaten their presence, as anthropogenic stimuli often trigger behavioral reactions similar to those induced by predators, such as moving away when approached. This anti-predator behavior represents an adaptive response indicating vigilance and can be quantitatively measured using Flight Initiation Distance (FID) to assess bird tolerance to human disturbance. This study aimed to examine the tolerance of Eurasian tree sparrows (*Passer montanus*) in three residential areas of Bogor, West Java, Indonesia, with differing vegetation density and canopy cover. In total, 120 individuals were recorded across vegetation density categories: high (n = 46), medium (n = 36), and low (n = 38). The data were analyzed using non-parametric methods because the distribution was not normal, applying the Kruskal-Wallis test followed by Dunn's post hoc analysis. The results revealed significant differences in FID across sites ($p<0.05$). FID values increased with vegetation density: 2.82±0.77 m (low), 4.22±1.57 m (medium), and 6.24±2.09 m (high). These results indicate that Eurasian tree sparrows exhibit greater tolerance in urban environments with lower vegetation density and canopy cover, highlighting their resilience and adaptability to human-dominated habitat changes. By situating these findings in a tropical urban context, this study contributes baseline data to a region where behavioral ecology remains underrepresented.

Keywords: Bogor, canopy cover, flight initiation distance, human disturbances, vegetation density

INTRODUCTION

Urbanization reduces biodiversity by transforming green spaces into human-dominated landscapes (Aouissi et al. 2021; Karjee et al. 2022; Mulyani et al. 2023). This landscape transformation presents birds with two key options: reduce vigilance to enhance foraging activities or increase vigilance to avoid potential hazards earlier. Birds frequently regard humans as threats, even when interactions are not harmful (Ye et al. 2025). Anthropogenic stimuli can cause behavioral and physiological responses comparable to those triggered by natural predators, prompting birds to initiate escape when approached. To understand these behavioral shifts, it is essential to consider theoretical frameworks on tolerance and habituation. The theoretical foundation of this study refers to Blumstein (2003) and Møller (2008), who demonstrated that continuous and repeated human encounters in natural habitats may reduce birds' fear responses. This notion is further supported by recent studies from Morelli et al. (2022) and Ye et al. (2025), which emphasize that urban birds have developed selective tolerance through habituation, adapting to human presence while maintaining sensitivity to non-human predators. As an additional form of adaptation, urban birds may serve to reduce perceived risk and enhance safety in human-dominated environment (Mikula et al. 2025).

These behavioral adaptations are not only theorized but also quantified through standardized metrics. Anti-predator behavior, particularly Flight Initiation Distance (FID), is an adaptive response commonly used to quantify avian tolerance to human disturbance. It serves as a key indicator of birds' vigilance and tolerance levels in human-dominated habitats (Jiang et al. 2020). In addition to FID, there are three supporting metrics: Start Distance (SD), Detection Distance (DD), and Alert Distance (AD). Bird species that have lived in urban contexts for a long time exhibit lower alertness toward humans (Davey et al. 2019), indicating adaptation to human-dominated environments with complex disturbances such as human frequency, traffic, and noise (Yin et al. 2023). Birds can become accustomed to constant stimuli or disturbances based on their experiences (Jiang et al. 2020).

Granivorous birds, such as the Eurasian tree sparrows (*Passer montanus*), are widespread in urban areas due to resource flexibility (Novarino et al. 2008; Rohman et al. 2023; Nugroho et al. 2024). There have been few experimental investigations that quantify and characterize the Eurasian tree sparrow's tolerance distances. There is, however, tolerance study on its close related, the House sparrow (*Passer domesticus*), being undertaken in Pune, India. The study in India found that House sparrows' tolerance distances were shorter in densely populated urban

(1.65-2.69 m) compared to rural areas (3.69-4.62 m) (Desai and Bharucha 2022).

Studies on avian tolerance to human presence have primarily focused on temperate regions, with scant research in tropical ecosystems. Several ecological factors, such as higher predation risk from natural predators, increased hunting pressure (Ripple et al. 2016), and smaller nest sizes in tropical bird species relative to their temperate counterparts, may influence tolerance levels. To fill this research vacuum, we undertook a study in Bogor, West Java, Indonesia, to investigate how these local characteristics influence the response of Eurasian tree sparrows to human presence.

Bogor has a highly humid tropical climate with an average annual rainfall of 4,000-4,500 mm and a mean annual temperature of around 26°C (Hidayat and Farihah 2020), making it an ideal location for investigating bird tolerance in tropical urban areas. The study was conducted in three different residential areas: Institut Pertanian Bogor Residence, Pakuan Residence, and Dramaga Cantik Residence. Sites were selected for their boundaries and reduced hunting pressure, ensuring tolerance reflects everyday human activity (Guay et al. 2013).

Despite growing research on urban bird behavior, studies from tropical regions remain limited. This study addresses that gap by examining escape responses of Eurasian tree sparrows in Bogor, Indonesia. We define behavioral tolerance as reduced FID, acknowledging that it may arise from mechanisms such as habituation or selective filtering. Specifically, we test variation in FID across residential areas with differing vegetation density and canopy cover. We hypothesize that FID will be longer in sites with higher vegetation density, reflecting lower tolerance to human presence, and shorter in low-vegetation areas due to habituation. Because FID is influenced by Start Distance (SD) (Jiang et al. 2020), SD was recorded to control for this effect.

MATERIALS AND METHODS

Study area

Data collection was conducted from May to September 2024. Three residential areas in Dramaga (Bogor, West Java, Indonesia) were selected as study sites: Institut Pertanian Bogor Residence, Pakuan Residence, and Dramaga Cantik Residence. These sites share similar infrastructure, including buildings, canopy cover, and green open spaces, and were chosen within an adjacent grid to minimize geographical bias while capturing differences in vegetation density and canopy cover classes. The distances between sites were 2.65 km from Institut Pertanian Bogor Residence to Dramaga Cantik Residence, 2.60 km from Institut Pertanian Bogor Residence to Pakuan Residence, and 1.1 km between Pakuan Residence and Dramaga Cantik Residence.

Prior to bird data collection, vegetation density was classified using the Normalized Difference Vegetation Index (NDVI). Landsat 9 Level-2 Surface Reflectance imagery (scene ID: LC09_L2SP_122065_20231101) was processed in ArcMap 10.8, with NDVI calculated from Band 4 (Red) and Band 5 (Near Infrared) at 30 m spatial resolution using the Raster Calculator tool. Cloud masking was applied based on metadata and visual inspection. NDVI values were categorized following (Khairawan et al. 2020): high (0.250-0.350), medium (0.150-0.249), and low (0.031-0.149). The NDVI results classified Institut Pertanian Bogor Residence as high-density vegetation, Pakuan Residence as medium-density, and Dramaga Cantik Residence as low-density. These classifications effectively characterized vegetation differences across the study locations, representing high, medium, and low vegetation density levels (Figure 1).

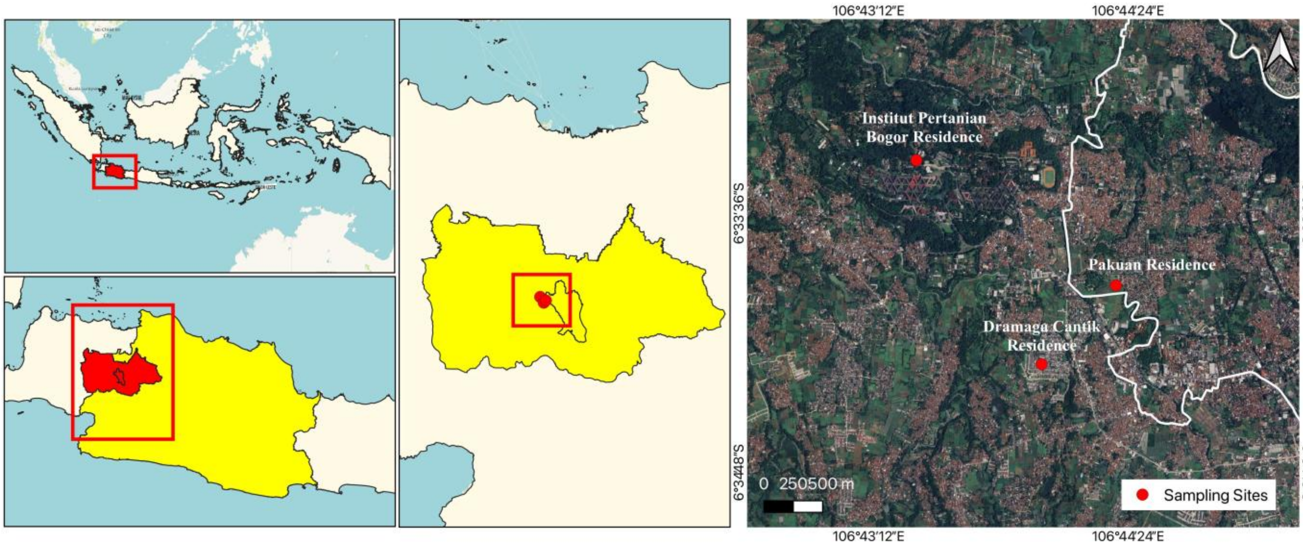

Figure 1. Distribution of residential areas as data collection sites

In addition to the NDVI analysis, the Leaf Area Index (LAI) was used to quantify canopy density and validate NDVI classifications. Although LAI is not identical to percent canopy cover, it is widely used as a proxy for canopy density. Data were obtained by photographing tree canopies across all habitats using a Canon EOS 60D DSLR equipped with a Sigma EX 15mm f/2.8 DG fisheye lens. The camera was positioned at 1.25 m above ground, and photographs were taken under diffuse light conditions (early morning or overcast sky) to minimize glare. Fifteen hemispherical photographs were collected at randomly selected points within each residential area. Images were analyzed using HemiView 2.1 (Delta-T Devices), which estimates LAI through gap fraction analysis. The average LAI indicated that Institut Pertanian Bogor Residence had the highest canopy density (1.078), followed by Pakuan Residence (0.499), and Dramaga Cantik Residence (0.324). These results confirmed that LAI measurements were consistent with NDVI-based vegetation density classifications.

Methods

Eurasian tree sparrows (*P. montanus*) were abundantly present in all three study sites. To reduce pedestrian volume and other anthropogenic disturbances, surveys were conducted on weekdays from 08:00 to 10:00 on clear days (Prestes et al. 2018). Although birds are generally most active between 06:00 and 10:00 a.m., residential areas in the study region experienced peak human mobilization between 06:00 and 08:00 a.m. (commuting to work and school). Therefore, the observation period was restricted to 08:00-10:00 a.m. to limit the impact of human activity and ensure that behavioral responses could be more clearly attributed to the observer's approach. Prior to data collection, the observer was trained to maintain a consistent step length and constant speed (0.5 m/s). Only birds that appeared relaxed and engaged in behaviors such as feeding, resting, or preening on streets or low tree branches (<1.5 m) were approached. To control for potential confounding effects of appearance, the observer wore similar clothing during each survey (Zhou and Liang 2020). To avoid inter-observer variation, all data were collected by a single person (Charuvi et al. 2020). After spotting an individual bird, the observer conducted approach experiments by walking toward it in a straight line, maintaining direct line of sight and consistent approach geometry.

Tolerance metrics were recorded in real time using a laser distance meter, which allowed the observer to capture behavioral transitions (detection, alert, flight) without missing the moment. Each observer position was marked in the field as the bird's behavior changed, ensuring that all distances were documented sequentially during the approach. The device was aimed at the nearest object aligned with the bird's position (e.g., leaf, branch, patch of ground) to avoid interfering with natural behavior. After the bird departed, the marked points were connected and verified using a 50-m measuring tape reel. Measurement consistency was defined with a tolerance threshold of ≤5% between laser and tape values; only measurements within this tolerance were retained as valid data. With this procedure, consistent laser values were used as the final values in the analysis, while measurements exceeding the tolerance were not recorded and therefore did not enter the dataset.

To reduce the risk of pseudo-replication, individual birds were not observed more than once within a single session. Observations followed a moving (patrolling) pattern, so that after one individual was observed, the observer shifted to another point. If the same bird was believed to remain visible at the observation site (e.g., an individual previously perched on the ground flew to a roof and then returned), data were not recorded because it was considered the same individual rather than a new one. Eurasian tree sparrows in the study areas were typically found in small flocks of 3-5 individuals. Because individual behavior within a flock was not independent, the response of one bird (e.g., flying) was often followed by others, flocks were treated as single observation units. The data recorded represented the first response observed within the flock, which was considered to reflect the group's response to the observer's approach. Observations were conducted alternately across locations and days to minimize the likelihood of observing the same flock repeatedly. With this procedure, the analysis consistently focused on bird tolerance responses in urban environments, without bias from interdependent individuals within a group, and the methodological approach can be considered robust and defensible. An illustration of the distance metrics used during this procedure is presented in Figure 2.

As illustrated in Figure 2, the distances marked during the approach were then used to define tolerance metrics that describe the stages of bird responses to the observer. The first metric was Start Distance (SD), defined as the distance between the observer and the bird at the moment the bird was first visually detected by the observer, prior to any approach. The observer then walked toward the bird in a straight line at a constant speed until the bird exhibited scanning behavior. This distance was recorded as Detection Distance (DD), ensuring that the primary disturbance was caused by the observer rather than external factors. Detection behavior was characterized by visual and auditory orientation toward the approaching threat (Prestes et al. 2018).

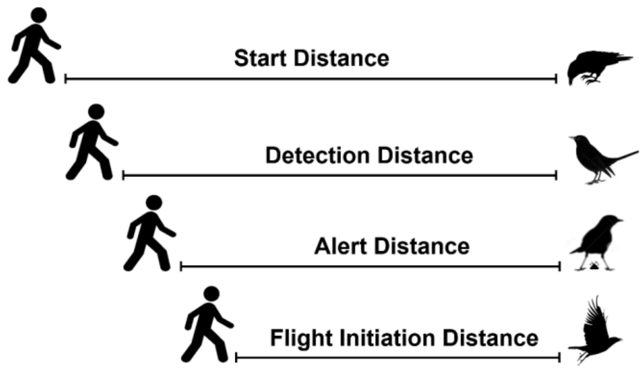

Figure 2. Illustration of distance metric used in the study: Start Distance (initial encounter), Detection Distance (bird showed scanning behavior), Alert Distance (bird showed alert behavior), and Flight Initiation Distance (bird initiated to flight)

The observer continued to approach until the bird displayed alert behavior. Alert Distance (AD) was indicated by behaviors such as raising the head, continuously scanning the surroundings, pausing activities, or defecating as a sign of increased stress. The approach was continued until the bird-initiated escape, defined as the Flight Initiation Distance (FID). FID was measured as the horizontal distance between the observer and the bird when it flew, ran, or hopped in reaction to being approached (Jiang et al. 2020).

Data analysis

Tolerance distance data were analyzed using descriptive statistics (mean and standard deviation) as well as inferential statistics. Normality tests indicated that the data did not follow a normal distribution, so non-parametric tests were applied. To identify differences in tolerance values across research locations, the Kruskal-Wallis test was conducted using Flight Initiation Distance (FID) as the dependent variable and vegetation density (high, medium, low) as the grouping factor. If the results were significant, Dunn's post hoc test was conducted to determine specific pairwise differences.

In addition, effect sizes (r) were calculated for pairwise comparisons to assess the magnitude of differences between groups. As an additional analysis, Spearman correlation tests were conducted among tolerance metrics (SD, DD, AD, FID) to explore behavioral relationships across response stages. These correlation analyses were included to enrich interpretation and provide deeper insights into the structure of bird responses. The significance level for group comparisons was set at α: 0.05, while α: 0.01 was applied for Spearman correlation analyses as a conservative approach to determining behavioral relationships. This stricter threshold was chosen to minimize the risk of Type I error and to ensure that only robust associations were reported. No multiple-comparison corrections were applied, as the number of correlation tests was limited and the analyses were exploratory in nature. All statistical analyses were conducted using IBM SPSS Statistics version 24.

RESULTS AND DISCUSSION

Results

We collected 46 samples in high-density areas, 36 in medium-density areas, and 38 in low-density areas. The variation in sample size reflects the availability of Eurasian tree sparrows at each location, which was influenced by environmental conditions and the species' mobility behavior. In the high-density area, SD demonstrated the highest mean value of 15.10±3.02 m, reflecting a consistent initial reaction to disturbances. Similarly, DD, AD, and FID followed this pattern with mean values of 11.26±2.75 m, 8.51±2.62 m, and 6.24±2.09 m, respectively. The standard deviations indicated relatively consistent behavioral responses within this area. In the medium-density area, mean distances were slightly lower, with SD recorded at 14.78±4.47 m, DD at 11.11±3.49 m, AD at 7.25±2.35 m, and FID at 4.22±1.57 m. The larger standard deviations suggested increased variability in bird responses to disturbances in this area. In contrast, the low-density area exhibited the shortest distances across all variables, reflecting a higher tolerance to human presence, as birds delayed their flight responses until closer proximity. SD averaged 13.46±3.93 m, DD 9.54±3.10 m, AD 5.85±1.43 m, and FID 2.82±0.77 m (Figure 3). The narrower standard deviations, particularly for FID, reflected more uniform behavioral adaptations in this area. Notably, the reduced mean distances in low-density environments indicated greater tolerance to disturbances, as birds allowed closer human approach before initiating flight. The line graph (Figure 3) further highlights these trends and variability, providing an overview of central tendencies and the spread of the data.

Additionally, Spearman rank correlation analyses revealed varying relationships among the variables. In the high-density area, strong positive correlations were observed among all pairs of variables, such as between SD and DD (r_s: 0.861, p<0.001) and between AD and FID (r_s: 0.964, p<0.001). The medium-density area also exhibited a very strong correlation between SD and DD (r_s: 0.965, p<0.001), while SD and FID showed a moderate correlation (r_s: 0.635, p<0.001). In contrast, the low-density area presented varied results, including a very strong correlation between SD and DD (r_s: 0.866, p<0.001), moderate correlations between AD and FID (r_s: 0.456, p: 0.005) and SD and AD (r_s: 0.485, p: 0.002), but no significant relationships between SD and FID (r_s: -0.065, p: 0.692) or between DD and FID (r_s: 0.091, p: 0.585). Spearman correlation coefficients, providing a more detailed view of relationships among tolerance metrics across vegetation classes, are presented in Table 1.

Further statistical analyses were conducted using the Kruskal-Wallis test to evaluate differences among the three location categories. For the variable SD, no significant difference was detected ($\chi^2_{(df:2)}$: 4.913, p: 0.086), with mean ranks of 66.72, 63.21, and 50.41 for high, medium, and low-density areas, respectively. The median values and interquartile ranges (IQR) for SD were 15.50 and 5.00, 16.00 and 6.75, and 12.75 and 6.50 for high, medium, and low-density areas, respectively. In contrast, significant differences were identified for DD, AD, and FID. For DD, the test statistic was $\chi^2_{(df:2)}$: 8.730, p: 0.013, with mean ranks of 68.51 (high-density), 64.57 (medium-density), and 46.95 (low-density). The median values and IQR for DD were 11.50 and 4.00, 10.75 and 7.13, and 9.00 and 3.13 for high, medium, and low-density areas, respectively. AD showed highly significant differences ($\chi^2_{(df:2)}$: 24.227, p<0.001), with mean ranks of 77.08, 61.25, 39.72 for high, medium, and low-density areas, respectively. The median values and IQR for AD were 8.75 and 4.13, 7.00 and 2.00, and 5.50 and 1.50 for high, medium, and low-density areas, respectively. FID also showed highly significant differences ($\chi^2_{(df:2)}$: 61.084, p<0.001), with mean ranks of 88.13, 58.56, 28.89 for high, medium, and low-density areas, respectively. The median values and IQR for FID were 6.00 and 3.27, 4.00 and 2.00, and 3.00 and 1.50 for high, medium, and low-density areas, respectively (Figure 4).

Post hoc Dunn's tests clarified these differences, indicating specific significant pairwise comparisons. For DD, only the low-density area and high-density area pair showed significance (p: 0.014; r: 0.259, moderate effect). For AD, the largest effect size occurred between low-density area and high-density area (r: 0.449, large effect), while for FID, significant differences were observed across all pairs, with effect sizes ranging from r: 0.336 (large effect) to r: 0.712 (very large effect) between low- and high-density areas. The box plot (Figure 4) visualized these results, emphasizing the distribution patterns and significant differences among groups.

These findings demonstrated that the distributions of DD, AD, and FID varied significantly among the location categories, while the relationships among variables also differed across the areas. The line graph (Figure 3) provided a descriptive overview of the trends and variability in the data, helping to contextualize overall patterns. Meanwhile, the box plot (Figure 4) highlighted the statistical differences among groups, offering a detailed analysis of significant relationships and distributions. The largest differences, particularly for FID between the low- and high-density areas, reflected potential behavioral adaptations to differing environmental pressures.

Table 1. Spearman correlation coefficients among tolerance metrics

Vegetation density	SD-DD	SD-AD	SD-FID	DD-AD	DD-FID	AD-FID
High	0.861**	0.880**	0.844**	0.953**	0.930**	0.964**
Medium	0.965**	0.775**	0.635**	0.794**	0.610**	0.764**
Low	0.866**	0.485**	-0.065	0.606**	0.091	0.456**

Note: **: Indicates significance at α: 0.01 (2-tailed)

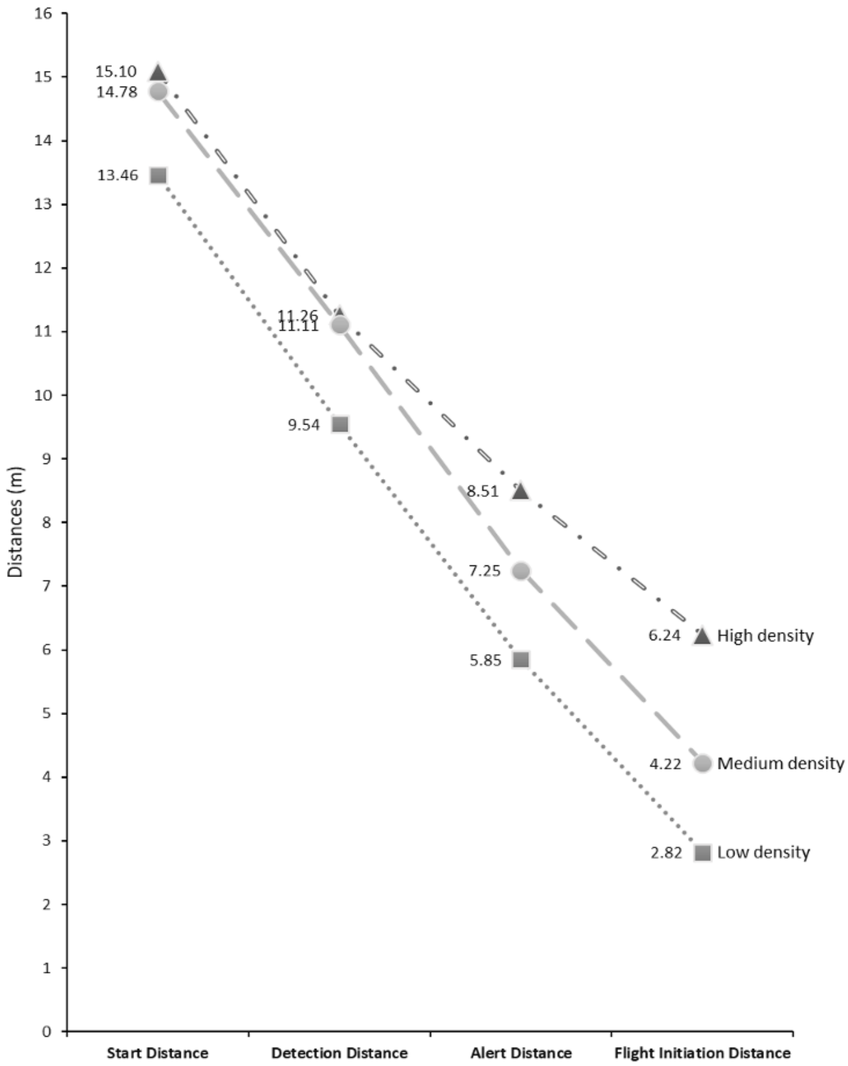

Figure 3. Line graph showing the mean of tolerance metrics in each study sites

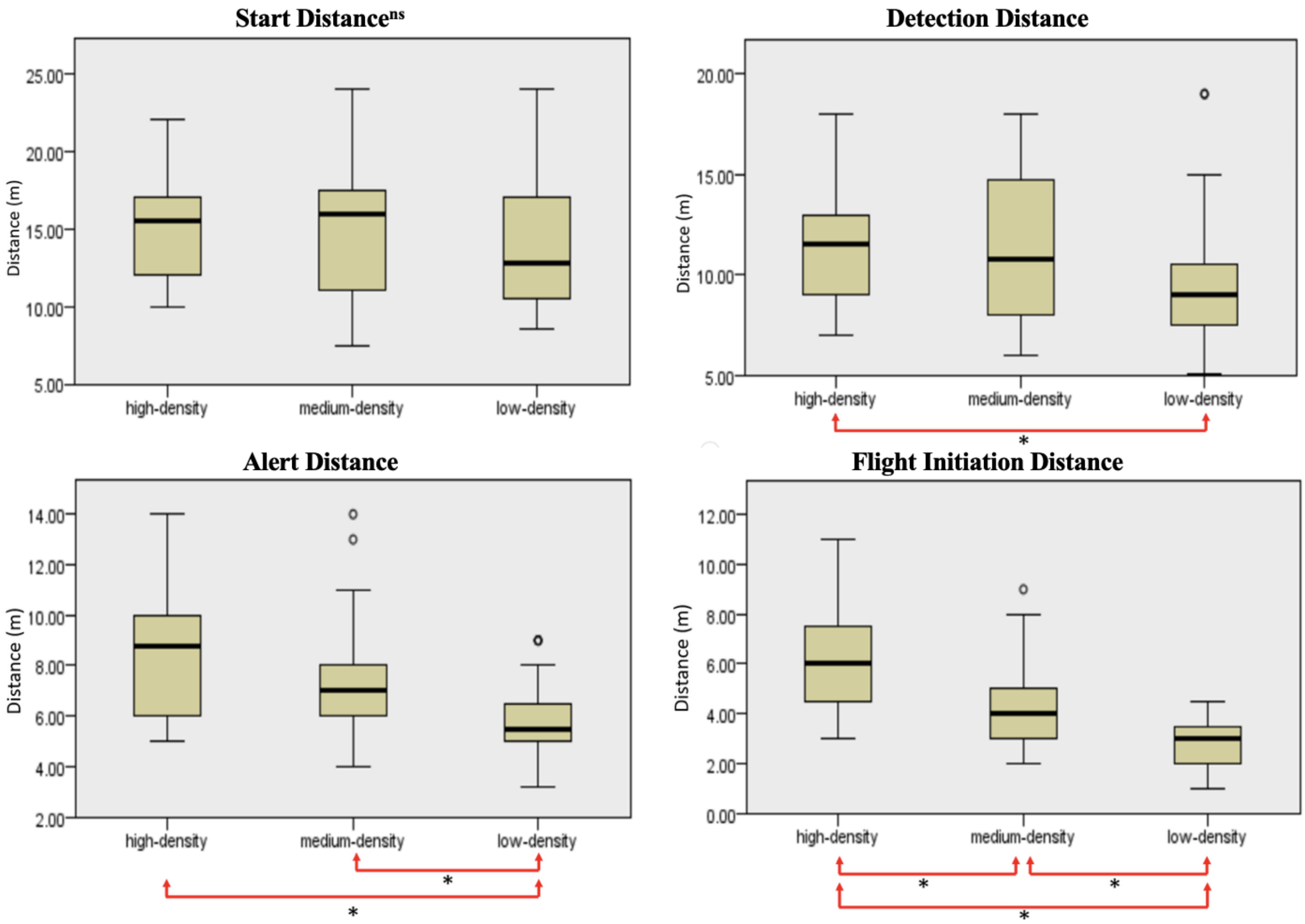

Figure 4. Box plot showing the distribution of values for each tolerance metric. Red horizontal lines indicate pairwise comparisons conducted using Dunn's post hoc test. Asterisks (*) denote statistically significant differences ($p<0.05$), while "ns" indicates non-significant results

Discussion

Birds play a vital role in sustaining ecological balance and ensuring ecosystem stability (Senior et al. 2024) across various land cover types, ranging from forests to urban areas. Although urban habitats can support a diverse range of bird species, including those in residential areas (Mardiastuti 2021), rapid and extensive urbanization has transformed natural landscapes into urban environments, may exerting significant pressure on bird populations and necessitating adaptation to ensure continued access to essential resources (Desai and Bharucha 2022). In response to these changes, green open spaces and suburban areas may play an important role in sustaining bird populations, especially in environments with high human pressures (Karjee et al. 2022). Even private gardens have been recognized for their contribution to urban bird diversity (Pollock et al. 2024).

Vegetation density and canopy cover have been shown to positively influence urban bird species richness (Leveau et al. 2019). Birds prefer settings with high vegetation and canopy cover that supply all required biological components while reducing exposure to human disturbance (Mardiastuti and Mulyani 2024). More densely vegetated areas, particularly those with trees planted in clusters or rows, not only create suitable habitat patches but also function as ecological corridors that enhance biodiversity and maintain population levels. As a result, habitat density plays a fundamental role in shaping bird adaptation strategies in urban settings.

This study demonstrates that plant density and canopy cover have a major impact on birds' behavioral responses to human presence. Species diversity is greater in areas with higher plant density; nevertheless, individual birds within each species are more scattered due to the availability of large green spaces. Consequently, the number of individuals seen at a particular place is generally low, and birds in these environments had larger reaction distances across all measured variables. This suggests heightened sensitivity to human presence, with perceived threats recognized from greater distances (Charutha et al. 2021).

In contrast, in habitats with lower vegetation density, species diversity diminishes while the number of individuals from the surviving species increases due to restricted accessible space, leading to a more concentrated population distribution (Charutha et al. 2021). These birds have fewer opportunities to relocate to habitats with denser vegetation, requiring them to adjust to open environments. As an adaptive response, they have lower response distances to human presence, notably in-Flight Initiation Distance (FID), indicating a higher tolerance to anthropogenic disturbances.

This phenomenon represents a form of natural selection, in which thickly vegetated habitats provide optimal conditions for more species to express their natural behaviors. However, open habitats remain feasible for a few species that can survive ecological constraints. Birds inhabiting such environments must optimize available resources for survival, which leads to enhanced tolerance to human presence. A notable example is the Eurasian tree sparrow, which has demonstrated remarkable adaptability to urban landscapes with sparse vegetation.

The descriptive statistical analysis also revealed that the mean and standard deviation values of each variable changed among habitat groups, indicating the differing degrees of Eurasian tree sparrow reactions to environmental conditions. This variability suggested that high-density habitats had more consistent response patterns, whereas low-density habitats had more diversity in bird responses due to higher environmental pressures. Birds in more stable habitats, such as high-density areas, tended to adopt more selective escape strategies, while birds in open environments demonstrated greater tolerance due to spatial limitations and increased interactions with humans.

The results of the Kruskal-Wallis test revealed significant differences in the variables DD, AD, and FID among the three locations, demonstrating that habitat density influenced birds' tolerance patterns toward humans. Post hoc Dunn's test confirmed that the most substantial differences occurred between low-density and high-density areas, particularly for the variables AD and FID, which exhibited large to very large effects. Birds in open areas were more acclimated to human presence, resulting in lower FID, whereas birds in densely vegetated habitats tended to exhibit longer FID as a more cautious escape strategy. These findings aligned with previous studies, which demonstrated that birds in environments with higher human pressures tended to habituate more rapidly and exhibited higher tolerance to human disturbances (Carrete et al. 2016; Vincze et al. 2016; Bernard et al. 2018; Mayer et al. 2019; Desai and Bharucha 2022; Yin et al. 2023).

In high-density areas, the environment was more stable and supportive for birds. These areas comprised residential housing within the Institut Pertanian Bogor, inhabited by lecturers and academic staff. The residents' socioeconomic standing and level of education most likely increased environmental consciousness, contributing to habitat quality (Philippsen et al. 2017). Furthermore, these areas were formerly rubber plantations (Mardiastuti and Mulyani 2024), which experienced natural succession, resulting in denser vegetation and better canopy cover than other locations. These conditions provided more abundant resources, allowing birds not to rely on a single food source. With the availability of plentiful food, birds could choose to flee immediately when faced with disturbances, as they could easily find alternative resources at different times.

On the other hand, in low-density areas, high levels of human disturbance and minimal vegetation cover caused birds to become more accustomed to human presence, exhibiting more tolerant responses. Resource limitations in these habitats may have influenced birds to maximize foraging efforts and potentially delay escape behaviors to ensure adequate energy intake, although this mechanism was not directly measured in our study. Birds that interacted more frequently with humans exhibited lower AD and FID, indicating increased tolerance due to the habituation process. Interestingly, a study in Beijing (Yin et al. 2023) also demonstrated that bird species inhabiting areas with abundant food and dense vegetation exhibited shorter flight initiation distances, suggesting that both repeated human exposure and favorable habitat conditions may contribute to increased tolerance.

The existence of canopy cover offered more safety, but it also increased birds' dependency on shelter, prompting them to stay further away from humans and hide when movement occurred. Another influential element was the limited amount of free space. Increased human presence reduced open areas for birds, restricting escape routes and causing them to initiate flight at shorter distances (Prestes et al. 2018). Frequent interactions with humans further elevated birds' tolerance levels. This suggests that shorter FIDs imply a higher level of avian adaptation to urban environmental pressures (Desai and Bharucha 2022).

Food sources from vegetation density are crucial factors in reducing FID and increasing tolerance levels in urban bird species (Fleming and Bateman 2017; Feng and Liang 2020). Birds often choose to delay escaping to maximize their resource intake and reduce their fear of human presence. Besides vegetation density and canopy cover, several other factors outside this study can influence bird tolerance, including body size, brain size, eye size, sex, habitat structure, body size, migratory status or residential characteristics of species in certain areas, group size, age, flocking behavior, habituation to human presence (Blumstein 2016), variation in altitude when encountering humans (Yin et al. 2023), females rearing young (Dowling and Bonier 2018), stimuli such as types of vehicles (Bernard et al. 2018), speed and direction (Battle et al. 2016), clothing color (Zhou and Liang 2020), and noise (Petrelli et al. 2017) also played a role in shaping birds' responses to humans. Differences in bird tolerance toward humans could also be the product of natural selection, where urban-dwelling species tend to be smaller in size. Smaller birds possess faster escape capabilities, making them better adapted to tolerate human presence. In contrast, larger birds are more conspicuous, have smaller escape spaces, and face limitations in finding shelter, making them more vulnerable to predators and humans.

This study has several limitations that should be acknowledged. Although flocks were treated as the unit of analysis to minimize pseudo-replication, individuals were unmarked and independence among flocks cannot be fully guaranteed, especially given the proximity of sites. Observations were restricted to morning hours in a single dry season, limiting temporal generalization. Human disturbance was not directly quantified (e.g., pedestrian density, traffic, or noise), so conclusions about tolerance remain inferential. While Kruskal-Wallis and Dunn's tests were chosen because the data were non-parametric, non-normal, and unbalanced across sites, these tests assume independence, no correction for multiple comparisons was applied, and effect size reporting was limited. Finally, although FID serves as an operational measure of tolerance, it does not provide evidence of natural selection or broader behavioral syndromes, and confounding ecological factors such as food availability or predator density were not tested. These limitations underscore the descriptive nature of our findings and highlight the need for cautious interpretation and further research in tropical urban contexts.

Despite certain limitations, this study provides baseline evidence of behavioral flexibility in Eurasian tree sparrows inhabiting tropical urban environments. The observed reduction in FID in low-density residential areas indicates adaptive tolerance to human presence, likely shaped by repeated exposure and resource constraints. These findings may contribute to tropical urban ecology by clarifying how disturbance and habitat structure jointly influence escape behavior. They also provide a comparative framework for future studies on urban bird adaptation across different ecological contexts.

In conclusion, the reduced FID of Eurasian tree sparrows observed in low-canopy areas reflects a survival strategy to optimize foraging opportunities under urban pressure, rather than a genuine habitat preference. This adaptive tolerance highlights the species' resilience, yet it also underscores the ecological importance of densely vegetated habitats in maintaining broader avian diversity and natural behaviors. By linking behavioral responses to habitat conditions, the study points to the importance of preserving and managing urban green spaces as critical refuges. Such efforts are important for biodiversity conservation and for fostering sustainable bird-human coexistence in residential landscapes.

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REFERENCES

Aouissi HA, Petrişor AI, Ababsa M, Boştenaru-Dan M, Tourki M, Bouslama Z. 2021. Influence of land use on avian diversity in north African urban environments. Land 10 (4): 434. DOI: 10.3390/land10040434.

Battle KE, Foltz LS, Moore IT. 2016. Predictors of flight behavior in rural and urban songbirds. Wilson J Ornithol 128 (3): 510-519. DOI: 10.1676/1559-4491-128.3.510.

Bernard GE, van Dongen WFD, Guay PJ, Symonds MRE, Robinson RW, Weston MA. 2018. Bicycles evoke longer flight-initiation distances and higher intensity escape behavior of some birds in parks compared with pedestrians. Landsc Urban Plan 178: 276-280. DOI: 10.1016/j.landurbplan.2018.06.006.

Blumstein DT. 2003. Flight-Initiation distance in birds is dependent on intruder starting distance. J Wildl Manag 67 (4): 852. DOI: 10.2307/3802692.

Blumstein DT. 2016. Habituation and sensitization: New thoughts about old ideas. Anim Behav 120: 255-262. DOI: 10.1016/j.anbehav.2016.05.012.

Carrete M, Martínez-Padilla J, Rodríguez-Martínez S, Rebolo-Ifrán N, Palma A, Tella JL. 2016. Heritability of fear of humans in urban and rural populations of a bird species. Sci Rep 6 (8): 31060. DOI: 10.1038/srep31060.

Charutha K, Roshnath R, Sinu PA. 2021. Urban heronry birds tolerate human presence more than its conspecific rural birds. J Nat His 55 (9-10): 561-570. DOI: 10.1080/00222933.2021.1912844.

Charuvi A, Lees D, Glover HK, Rendall AR, Dann P, Weston MA. 2020. A physiological cost to behavioural tolerance. Behav Process 181: 104250. DOI: 10.1016/j.beproc.2020.104250.

Davey S, Massaro M, Freire R. 2019. Differences in Flight Initiation Distance (FID) between rural and urban populations of two species of Australian birds. Behaviour 156 (11): 1151-1164. DOI: 10.1163/1568539X-00003559.

Desai M, Bharucha E. 2022. An assessment of avian tolerance towards human presence in urban, semi-urban, and rural settings of Pune. Indian Birds 18 (2): 45-48.

Dowling L, Bonier F. 2018. Should I stay, or should I go: Modeling optimal flight initiation distance in nesting birds. Plos One 13 (11): 0208210. DOI: 10.1371/journal.pone.0208210.

Feng C, Liang W. 2020. Behavioral responses of black-headed gulls (*Chroicocephalus ridibundus*) to artificial provisioning in China. Glob Ecol Conserv 21 (3): e00873. DOI: 10.1016/j.gecco.2019.e00873.

Fleming PA, Bateman PW. 2017. Scavenging opportunities modulate escape responses over a small geographic scale. Ethology 123 (3): 205-212. DOI: 10.1111/eth.12587.

Guay PJ, McLeod EM, Cross R, Formby AJ, Maldonado SP, Stafford-Bell RE, St-James-Turner ZN, Robinson RW, Mulder RA, Weston MA. 2013. Observer effects occur when estimating alert but not flight-initiation distances. Wildl Res 40 (4): 289-293. DOI: 10.1071/WR13013.

Hidayat R, Farihah AW. 2020. Identification of the changing air temperature and rainfall in Bogor. Jurnal Pengelolaan Sumberdaya Alam Lingkungan 10 (4): 616-626. DOI: 10.29244/jpsl.10.4.616-626.

Jiang X, Liu J, Zhang C, Liang W. 2020. Face masks matter: Eurasian tree sparrows show reduced fear responses to people wearing face masks during the COVID-19 pandemic. Glob Ecol Conserv 24: e01277. DOI: 10.1016/j.gecco.2020.e01277.

Karjee R, Palei HS, Konwar A, Gogoi A, Mishra RK. 2022. Bird assemblages in a peri-urban landscape in Eastern India. Birds 3 (4): 383-401. DOI: 10.3390/birds3040026.

Khairawan A, Falih N, Handoko TD. 2020. Analisis perubahan indeks kerapatan vegetasi memanfaatkan citra landsat (Studi kasus: Provinsi DKI Jakarta). Senamika 1 (2): 62-72. [Indonesian]

Leveau LM, Ruggiero A, Matthews TJ, Isabel-Bellocq M. 2019. A global consistent positive effect of urban green area size on bird richness. Avian Res 10 (1): 30. DOI: 10.1186/s40657-019-0168-3.

Mardiastuti A. 2021. Urban trees to attract wild birds in a tropical urban residential complex in Sentul, West Java, Indonesia. IOP Conf Ser Earth Environ Sci 918 (1): 012003. DOI: 10.1088/1755-1315/918/1/012003.

Mardiastuti A, Mulyani YA. 2024. Integrating arborists and birds: Habitat management options for birds in the tropical urban green space. IOP Conf Ser Earth Environ Sci 1433 (1): 012021. DOI: 10.1088/1755-1315/1433/1/012021.

Mayer M, Natusch D, Frank S. 2019. Water body type and group size affect the flight initiation distance of European waterbirds. Plos One 14 (7): 0219845. DOI: 10.1371/journal.pone.0219845.

Mikula P, Grünwald J, Reif J. 2025. Species' urbanization time but not present urban tolerance predicts avian fear responses towards human. BMC Biol 23 (1): 295. DOI: 10.1186/s12915-025-02427-0.

Møller AP. 2008. Flight distance of urban birds, predation, and selection for urban life. Behav Ecol Sociobiol 63 (1): 63-75. DOI: 10.1007/s00265-008-0636-y.

Morelli F, Mikula P, Blumstein DT, Díaz M, Markó G, Jokimäki J, Kaisanlahti-Jokimäki M-L, Floigl K, Zeid FA, Siretckaia A. 2022. Flight initiation distance and refuge in urban birds. Sci Total Environ 842: 156939. DOI: 10.1016/j.scitotenv.2022.156939.

Mulyani YA, Hermawan R, Rushayati SB, Suryani R, Zulhidayat H, Marcellia, Mahesa R. 2023. Bird diversity and guild composition in five urban parks of DKI Jakarta. IOP Conf Ser Earth Environ Sci 1271 (1): 012013. DOI: 10.1088/1755-1315/1271/1/012013.
Novarino W, Mardiastuti A, Prasetyo LB, Widjakusuma R, Mulyani YA, Kobayashi H, Salsabila A, Nazri Janra M. 2008. Komposisi guild dan lebar relung burung strata bawah di Sipisang. Biota 13 (3): 155-162. [Indonesian]
Nugroho SPA, Mardiastuti A, Mulyani YA, Rahman DA. 2024. Bird communities in the tropical peri-urban landscape of Bogor, Indonesia. Biodiversitas 24 (12): 6986-6998. DOI: 10.13057/biodiv/d241260.
Petrelli AR, Levenhagen MJ, Wardle R, Barber JR, Francis CD. 2017. First to flush: The effects of ambient noise on songbird flight initiation distances and implications for human experiences with nature. Front Ecol Evol 5 (6): 67. DOI: 10.3389/fevo.2017.00067.
Philippsen SJ, Soares AFH, Santana RG. 2017. Education level and income are important for good environmental awareness: A case study from south Brazil. Ecol Austral 27 (1): 39-44.
Pollock HS, van Riper CJ, Goodson DJ, Lerman SB, Hauber ME. 2024. The public-private divide and seasonal variation shape bird diversity in greenspaces of two neighboring midwestern USA cities. Landsc Urban Plan 247 (7): 105060. DOI: 10.1016/j.landurbplan.2024.105060.
Prestes TV, Manica LT, Guaraldo AC. 2018. Behavioral responses of urban birds to human disturbance in urban parks at Curitiba, Paraná (Brazil). Rev Bras Ornitol 26 (2): 77-81. DOI: 10.1007/bf03544418.
Ripple WJ, Abernethy K, Betts MG, Chapron G, Dirzo R, Galetti M, Levi T, Lindsey PA, Macdonald DW, Machovina B. 2016. Bushmeat hunting and extinction risk to the world's mammals. R Soc Open Sci 3 (10): 160498. DOI: 10.1098/rsos.160498.
Rohman SN, Mardiastuti A, Mulyani YA. 2023. Bird diversity in several land use types in Boyolali, Central Java. IOP Conf Ser Earth Environ Sci 1220 (1): 012009. DOI: 10.1088/1755-1315/1220/1/012009.
Senior RA, Bagwyn R, Leng D, Killion AK, Jetz W, Wilcove DS. 2024. Global shortfalls in documented actions to conserve biodiversity. Nature 630 (8016): 387-391. DOI: 10.1038/s41586-024-07498-7.
Vincze E, Papp S, Preiszner B, Seress G, Bókony V, Liker A. 2016. Habituation to human disturbance is faster in urban than rural house sparrows. Behav Ecol 27 (5): 1304-1313. DOI: 10.1093/beheco/arw047.
Ye HY, Yu J, Hong K, Li YL, Zhao JM. 2025. Similar tolerance of urban birds towards both benign human and lethal cat predators. J Ornithol 166 (1): 157-164. DOI: 10.1007/s10336-024-02194-9.
Yin L, Wang C, Han W, Zhang C. 2023. Birds' flight initiation distance in residential areas of beijing are lower than in pristine environments: Implications for the conservation of urban bird diversity. Sustainability 15 (6): 4994. DOI: 10.3390/su15064994.
Zhou B, Liang W. 2020. Avian escape responses to observers wearing clothing of different colors: A comparison of urban and rural populations. Glob Ecol Conserv 22 (3): e00921. DOI: 10.1016/j.gecco.2020.e00921.