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Physical-Anthropogenic Influence on House Crow (*Corvus splendens*) Abundance in Urban Areas with Varying Levels of Urbanization

(Pengaruh Fizikal-Antropogen terhadap Kelimpahan Gagak Rumah (*Corvus splendens*) di Kawasan Bandar dengan Tahap Pembandaran yang Berbeza-beza)

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ABSTRACT

House crow (*Corvus splendens*) is a well-known invasive species that has successfully been introduced outside of its native range and colonised many countries. Their population boom has caused nuisance to humans, especially those living in big cities. This study aimed to determine the influence of physical and anthropogenic factors towards the crow abundance, focusing on their night roosts. Ten selected roosting sites were grouped into highly and less urbanized sites, and several physical-anthropogenic variables were inspected. Crow census was conducted between 1730 and 1930 h, approaching roosting time. PCoA indicates a relatively strong effect of the physical-anthropogenic measures towards the crow abundance, with high urban intensity harbours greater crow abundance. GLMM analysis shows physical factors such as canopy cover and food sources positively influenced the crow abundance, whereas anthropogenic factors (disturbance index: pedestrian, traffic, trash, parked vehicle) negatively influenced the crow abundance ($p<0.05$). This suggests that crows were highly influenced by their physical surroundings, yet more adaptable to human presence. Controlling physical factors is essential for reducing suitable sites for crows to roost and breed. This study elucidates strategic plans to be undertaken by authorities and even the public to keep the crow population under control, to ensure a healthier environment for humans and other urban dwellers.

Keywords: Crow infestation; invasive species; night roosts; town-planning; urban-dwellers

ABSTRAK

Gagak rumah (*Corvus splendens*) ialah spesies invasif terkenal yang telah berjaya diperkenalkan di luar kawasan asalnya dan menjajah banyak negara. Ledakan populasi mereka telah menyebabkan gangguan kepada manusia, terutamanya mereka yang tinggal di bandar-bandar besar. Kajian ini bertujuan untuk menentukan pengaruh faktor fizikal dan antropogen terhadap kelimpahan burung gagak dengan memberi tumpuan kepada tempat mereka bermalam. Sepuluh kawasan bermalam terpilih telah dikategorikan kepada kawasan pembandaran tahap tinggi dan rendah serta beberapa pemboleh ubah fizikal-antropogen telah diperiksa. Bancian gagak telah dijalankan antara jam 1730 hingga 1930, menghampiri masa bermalam. PCoA menunjukkan kesan yang signifikan daripada faktor fizikal-antropogen terhadap kelimpahan burung gagak dengan keamatan bandar yang tinggi mempunyai kelimpahan gagak yang lebih besar. Analisis GLMM mendedahkan faktor fizikal seperti litupan kanopi dan sumber makanan mempengaruhi kelimpahan gagak secara positif, manakala faktor antropogen (indeks gangguan: pejalan kaki, lalu lintas, sampah, kenderaan yang parkir) mempengaruhi jumlah gagak secara negatif ($p<0.05$). Ini menunjukkan bahawa burung gagak sangat dipengaruhi oleh persekitaran fizikal mereka, namun lebih mudah menyesuaikan diri dengan kehadiran manusia. Pengawalan faktor fizikal adalah penting untuk mengurangkan kawasan yang sesuai untuk burung gagak bertelur dan membiak. Kajian ini menjelaskan perancangan strategik yang boleh diambil oleh pihak berkuasa dan juga orang ramai untuk mengawal populasi gagak untuk memastikan persekitaran yang lebih sihat untuk manusia dan penduduk bandar yang lain.

Kata kunci: Infestasi gagak; penghuni bandar; perancangan bandar; spesies invasif; tempat bermalam

INTRODUCTION

House crow (*Corvus splendens*) is a well-known invasive species from family Corvidae which successfully spread outside their distribution range (Ryall 2010). Native to the Indian Subcontinents, this species, however, has spread its range to Europe, the Middle East, Africa and also to

South-east Asia countries including Malaysia and Singapore (Feare & Mungroo 1990; Soh et al. 2002; Wilson, Sarim & Rahman 2015). *Corvus splendens* was introduced to these countries via ships accidentally (Ryall 2010), or for the purpose of biological control to eradicate agricultural pests and garbage elimination (Cheke 2008; Willey 1904). According to Willey (1904), *C. splendens* was introduced to Malaysia particularly in Klang and Penang to control caterpillar population in coffee plantations during the early 20th century. However, this feral species has spread inland to other parts of Peninsular Malaysia to forage on wastes from urban areas (Willey 1904; Wilson, Sarim & Rahman 2015). According to Krzemińska et al. (2016), *C. splendens* in Malaysia were most likely to have originated from Sri Lanka or nearby locations based on their genetic study. They have served as biological control agents for insects and rodents due to their opportunistic feeding behaviours, whereas their scavenging behaviours benefit the urban environment by reducing organic waste including carrions and keeping public spaces clean by consuming food scraps (Shanbhag et al. 2012). Due to the high food source and habitat availability, *C. splendens* has become well-adapted and eventually turned into pests in most parts of the country which cause adverse effects on the economy, outcompeting local bird species and pose threat to public health (Alias & Hashim 2016).

As a generalist and opportunist species, crows dwell very well in urban areas, and in fact, their population increases with increasing urbanization (Chong et al. 2012). *Corvus splendens* is highly adaptable, omnivorous and also a scavenger which consumes and scavenges a wide range of food sources such as invertebrates, small reptiles, dead sewer rats, food scraps and crops (Fraser et al. 2015; Koul & Sahi 2013) which can be easily obtained in areas with high human density, especially cities. Thus, it was considered as a commensal bird, which only lives in close association with humans in urban/semi-urban areas and lives dependently on humans (Peh & Sodhi 2002). *Corvus splendens* also prey on fledging and eggs of other bird species, hence causing their number to decline (Chongomwa 2011; Kamel 2014). Apart from the severe depletion of native species, their aggressive and gregarious behaviour reduced bird diversity by mobbing other native species, subsequently their presence caused displacement of native species (Brook et al. 2003; Kamel 2014; Ryall 1992). Their communal night roosting behaviour, which often involves large numbers (Peh & Sodhi 2002), has significant implications for native species. These species typically face competition for food and shelter and, as a result, are forced to leave and seek new roosting and nesting sites (Chong et al. 2012).

In Malaysia, *C. splendens* habitually roosts communally near urban and port areas where their basic biological needs including roosting and nesting sites were available. Besides electricity pylons, bridges and train's elevated guideways, big and shady trees which are often enclosed by buildings have become appropriate and preferable sites for them to nest and roost at night (Parker et al. 2014; Peh & Sodhi 2002). This species has also been reported to cause nuisance to humans. According to Lim and Sodhi (2009), *C. splendens* in Singapore prefers to roost in residential and commercial areas where anthropogenic food is available at all times. Availability of food scraps particularly from human consumption significantly contributed to their population rise especially in urban centres (Wilson, Sarim & Rahman 2015). Their droppings have posed problems to the hygiene and health of the environment, particularly the pedestrian walkway and vehicle park beneath the roosting trees which results in damage to private and public property apart from noise nuisance in the late evening (Brook et al. 2003; Chongomwa 2011; Peh & Sodhi 2002). *Corvus splendens* posed a risk to public health as they were reported as vectors for human pathogens such as *Chlamydiae, Campylobacter, Salmonella, Listeria,* and *Mycoplasmas* (Fadel & Ahmad 2019; Ganapathy et al. 2007; Ton & Moraes 2017).

Due to all the harmful consequences of their population boom, specific action needs to be implemented to control their population. Efforts to control the population of *C. splendens* living around urban areas have been made in many countries including Malaysia. However, most attempts were unsuccessful, as the species tend to readily abandon occupied sites when disturbed, but may return the following day. To manage *C. splendens* efficiently and effectively, a better understanding of their behavioural ecology, abundance and habitat preferences is crucial. Therefore, this study involves measuring the abundance of *C. splendens* specifically at their night roosts, apart from determining the physical and anthropogenic variables associated with their abundance in several locations in Peninsular Malaysia. The outcome of this study is anticipated to provide up-to-date information on strategic measures to keep the crow population within the threshold limit (Fraser et al. 2015). We hypothesize that physical characteristics, especially vegetation structure and the presence of anthropogenic food influenced the abundance of *C. splendens.*

MATERIALS AND METHODS

STUDY AREA

This study was conducted in ten urban sites in Peninsular Malaysia, located in the state of Selangor, Kuala Lumpur, Negeri Sembilan, Melaka and Johor between February and July 2020 (Figure 1). The study sites are Bangi (BGI) and Puchong (PCG) in Selangor, Cheras (CRS) and Kepong (KPG) in Kuala Lumpur, Seremban (SBN) and Nilai (NLI) in Negeri Sembilan, Masai (MSI) and Pasir Gudang (PG) in Johor, and Kota Laksamana (KLMN) and Bandar Hilir (BH) in Melaka. The site selection was based on the presence of a high abundance of *C. splendens* pre-roosting on nearby structures and finally roosts in roosting trees at dusk, known as roosting site or night roost. A roosting tree is defined as a tree where crows, often in large groups or at least three individuals, come together to perch and rest after sunset. Some crows also build their nests in these trees.

Population survey

Roosting trees were identified, observed, and selected prior to the population survey. A point was selected at the roosting sites (Figure 2(a), 2(b), and 2(c)) and a bird census was conducted within a 250 m radius from the point. The number of *C. splendens* in each roosting site was counted for three non-consecutive days in each location, during which the birds most actively returned to the roosting trees for night roosts. No survey was made during bad weather conditions such as strong wind and heavy rain. Only perching crows in the range of 250 m radius from the chosen point of roosting sites were observed and counted within 10 min, with 5-min intervals for two hours between 1730 and 1930 h. In cases where the flock is too big, the number of birds in a smaller and representative section of the flock was counted, then extrapolated to the total number based on the proportion of the sample to the whole flock following Sutherland (2006).

Measurements of physical and anthropogenic variables at the roosting trees

Roosting trees in the range of 50 m radius at each study location (8 to 12 trees) were selected for measurement of physical and anthropogenic variables (Figure 3). Prior to that, tree attributes such as (1) tree height (from the ground to the top end of the upper crown), (2) diameter at breast height (dbh), (3) canopy cover (measured using basal area of trees within a defined area) and (4) canopy height (measured using tape) and recorded.

Physical variables recorded in each roosting area were the distance of the central roosting tree to the (1) nearest building, (2) road, (3) food centre and (4) trash bin or any waste collection centre available which was measured using ruler function in Google Earth Pro (Google Inc. USA). Anthropogenic variables at the roosting sites were: (1) the number of pedestrians, (2) passing vehicles (including motorcycles and bicycles) and (3) parked vehicles within 50 m radius from the center point of study location at 2000 h for 10 min, when the *C. splendens* were less active and (4) the number of trash or any food items observed on the ground was also counted and recorded to represent the level of cleanliness of the roosting sites. A rating scale was designed for each component of disturbance, into five levels of disturbance following Soh et al. (2002) with adjustment (Table 1). A disturbance index was then calculated by multiplying between the scores obtained from each component (Soh et al. 2002). From this scale, together with the building density of urban sites, each study location was categorized into highly urbanized sites (BGI, CRS, NLI, MSI and BH) or less urbanized sites (PCG, KPG, SBN, PG and KLMN). The area covered by buildings was also measured using Google Earth Pro (Google Inc. USA), following Callaghan et al. (2018) and Mohd-Taib, Mohd-Saleh and Ismail (2021) with adjustment.

Data analysis

To determine if there was a difference in the abundance of *C. splendens* between the highly urbanized and less urbanized sites, an independent T-test was performed. A Welch t-test was carried out to determine if there were differences in the abundance of crows in the high urban sites and low urban sites. Inspection of the boxplot was conducted to observe any outliers in the data and Shapiro-Wilk's test was calculated to determine whether the data is normally distributed. Principal coordinates analysis (PCoA; Gower 1966) was performed to visualise spatial patterns in physical-anthropogenic conditions for each roosting area of *C. splendens* in an unconstrained ordination space. Prior to this analysis, the physical-anthropogenic data were normalised and a Euclidean distance measure was used. Differences in crow abundances and physical-anthropogenic habitat characteristics were tested for significance using a one-way PERMANOVA. When significant differences were present, Similarity Percentage analysis (SIMPER) was conducted using PAST 2.17c (Hammer, Harper & Ryan 2001) to identify which variables contributed the most in separating the highly and less urbanized sites. A Generalized Linear Mixed Model (GLMM) was carried out to identify which physical-anthropogenic microhabitat variables best explained the crow abundance at highly and less urbanized sites. Poisson with Log-link function was used in the modelling process. We used all possible combinations and chose the model with lowest AIC. Prior to GLMM analysis, a multicollinearity test was carried out to remove highly correlated variables ($|r|>0.7$) as they may cause distortions in the model (Yahya et al. 2017). Bole height and trash bins were dropped from GLMM analysis as they have high multicollinearity with DBH ($|r|=0.721$) and building respectively ($|r|=-0.899$). We also used disturbance index (DI) to replace the anthropogenic variables (traffic, pedestrian, parking and cleanliness) as it improved our model. GLMM analysis was conducted using SPSS version 27.

RESULTS

ABUNDANCE AND DISTRIBUTION OF *C. splendens* AT URBAN ROOSTING SITES

A total of 12,064 *C. splendens* were censused throughout the survey in ten-night roosts at different urban sites. BGI shows the highest abundance of crows by sunset, followed by MSI, CRS, KLMN, KPG, PCG, NLI, PG and the least at BH (Figure 4). Four locations (BGI, MSI, SBN and KLMN) show severe infestation by crows by having more than 300 individuals crow at the roosting trees and nearby buildings every day.

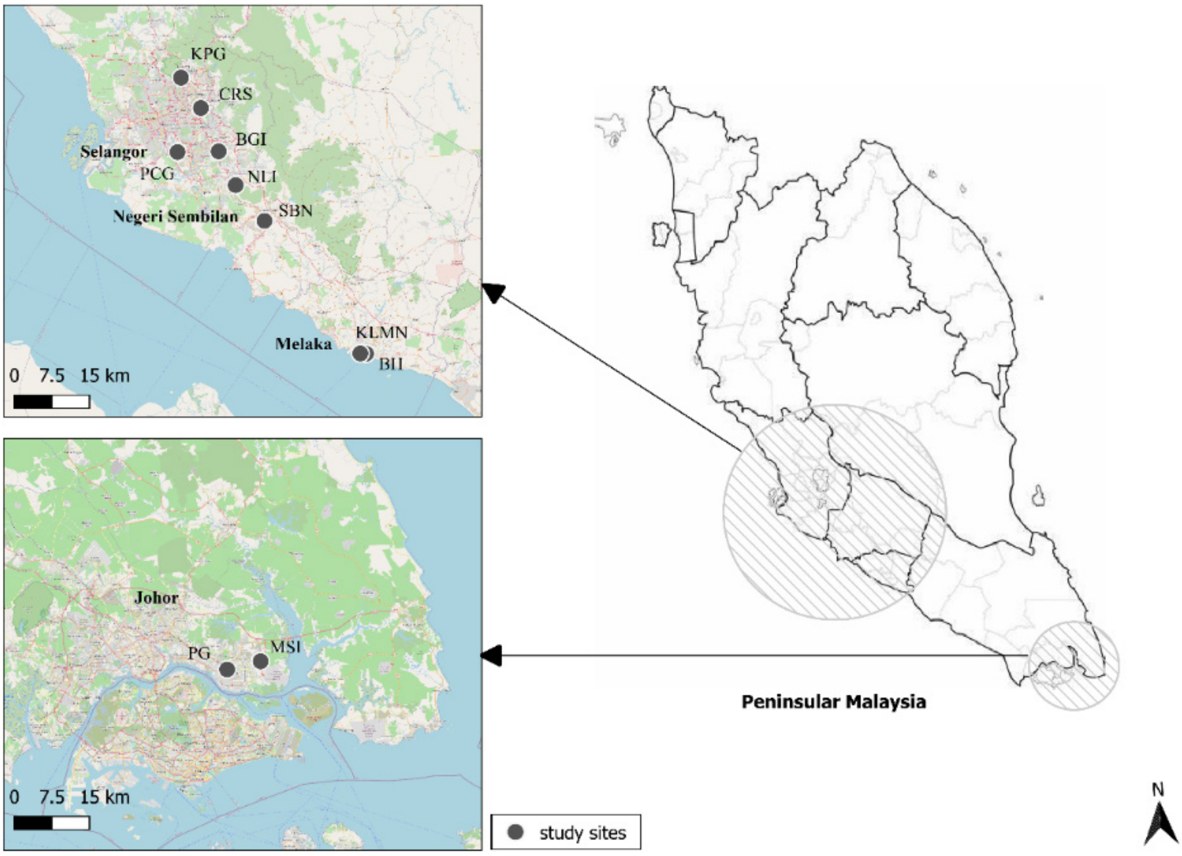

FIGURE 1. Map of study locations in the states of Selangor, Kuala Lumpur, Negeri Sembilan, Johor and Melaka of Peninsular Malaysia

FIGURE 2. Photos of (a) roosting trees of crow, (b) roosting colonies of crow and (c) perching crow at the roosting tree

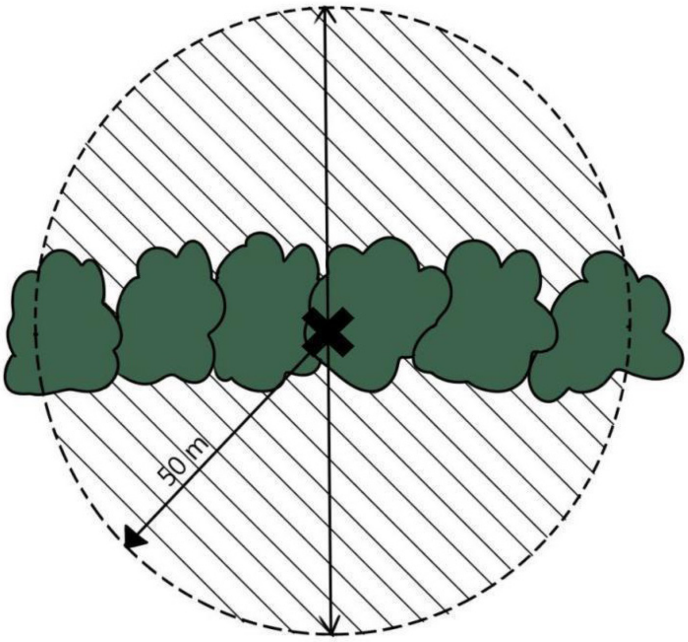

FIGURE 3. Illustration of roosting trees in a 50 m radius from the center of each sampling site

TABLE 1. Rating scale and score of disturbance at the roosting sites

Component of disturbance/ Score	1	2	3	4	5
Number of pedestrians	1-30	31-60	61-90	91-120	>120
Passing vehicles	1-90	91-180	181-270	271-360	>360
Parked vehicles	0-3	4-6	7-9	10-12	>12
Level of cleanliness	0-5	6-15	16-25	26-30	>30

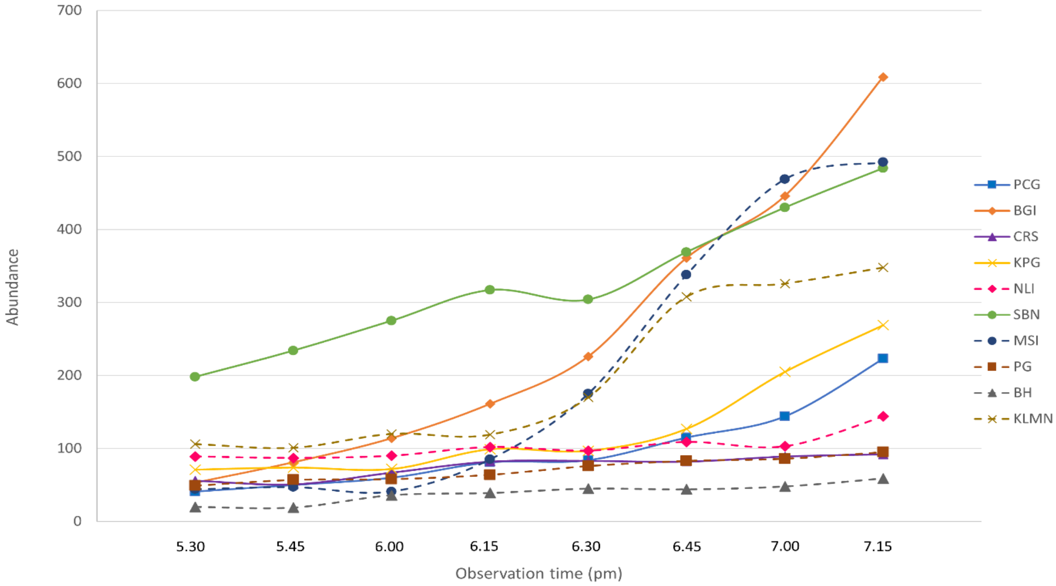

FIGURE 4. Abundance of crow in each sampling sites with time

EFFECTS OF URBAN INTENSITY TOWARDS *C. splendens* POPULATION DENSITY

The Welch t-test was carried out due to the assumption of homogeneity of variances being violated, as assessed by Levene's test for equality of variances (p=0.005). There were no outliers in the data, as assessed by inspection of a boxplot, and the abundance of crows in both highly and less-urbanized sites was normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$). The abundance of crows in high urbanized sites was slightly higher (M=279.0, SD=253.9) than in low urbanised sites (M=275.7, SD=133.6), albeit no significant difference (t (-0.048) =21.199, p = 0.962).

EFFECTS OF PHYSICAL-ANTHROPOGENIC VARIABLES ON *C. splendens* POPULATION ABUNDANCE

In the Principal coordinates analysis (PcoA) ordination plot, the first two axes explained 83.1% of the variation thus indicating a relatively strong effect of the physical-anthropogenic measures towards the crow population (Figure 6). Highly urbanized sites tended to be grouped in the ordination to separate from the less-urbanized sites. Based on the plot, distance to the nearest road and trash bin from the roosting tree, tree height, canopy cover, canopy height, level of cleanliness and pedestrians show strong association to the sites in highly urbanized sites which were explained by BGI, MSI, and CRS. These sites comprise areas with a high human population density (residential areas; high-rise, mid-rise, low-rise flats), daytime and night-time commercial buildings, and night markets which were held twice a week near the roosting sites (BGI and MSI). Because of the crow's heavy infestation documented in KLMN, this location was grouped together with the highly urbanized sites. This could be attributed to major vegetation features such as large and shady trees, as well as very poor sanitation (cleanliness). PERMANOVA showed significant differences in physical and anthropogenic variables between high and less-urbanized sites (F=3.298; p = 0.05). A post-hoc test with SIMPER analysis indicates that canopy cover of the roosting trees contributed the most (63.4%), followed by the distance of the roosting tree to the nearest food centre (7.2%), tree DBH (7.1%) and also the distance to the nearest road (7.0%). These variables contribute to separating the high and less-urbanized areas at 84.67%.

GLMM analysis indicates that *C. splendens* abundance was significantly influenced by most of the variables tested including urban level, DBH, canopy cover, distance to building and disturbance index ($p < 0.05$) (Table 2). The coefficients (B) from GLMM shows that urban level,

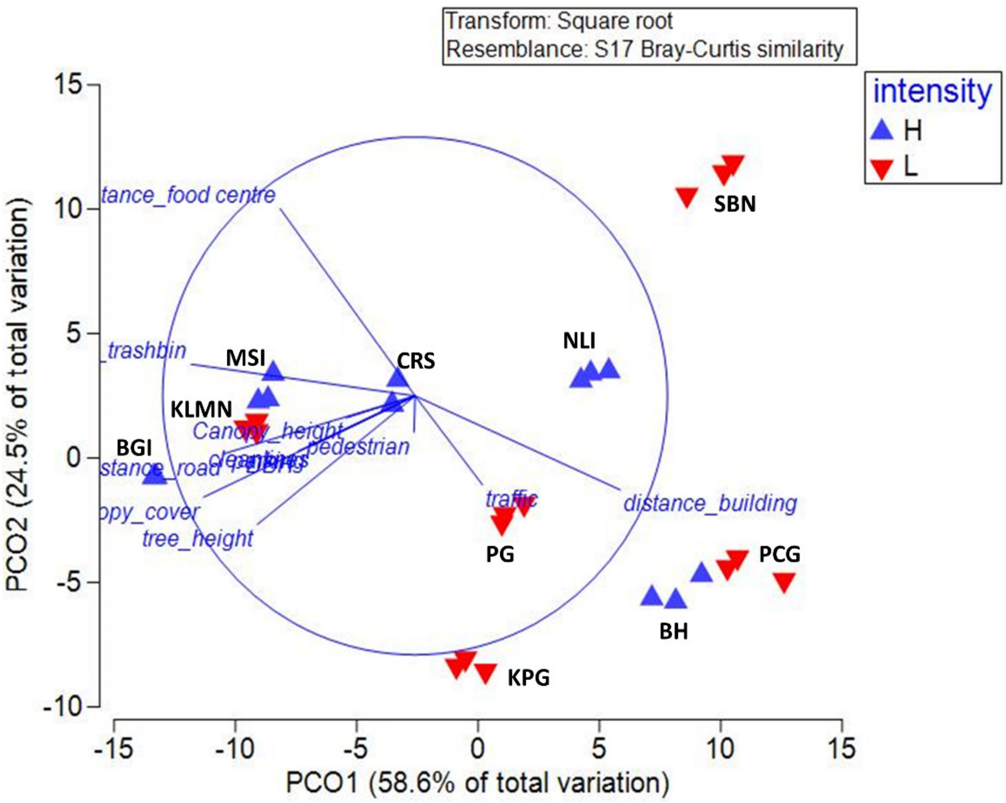

FIGURE 5. Principal coordinates analysis (PcoA) ordination plots of physical-anthropogenic data. Blue triangle represents the highly urbanized sites (BH, NLI, CRS, MSI and BGI) and red triangles represent the less urbanized sites (SBN, PCG, KPG, PG, KLMN)

TABLE 2. GLMM model for bird abundance against physical and anthropogenic factors

Variables	Coefficient	Std. error	t	Sig.
High urban	0.844	0.1777	4.750	<0.01
Low urban	-	-	-	-
DBH	-0.100	0.0119	-8.464	<0.01
Canopy height	-0.108	0.0591	-1.820	0.07
Canopy cover	0.005	0.0011	4.199	<0.01
Distance to nearest building	-0.034	0.0117	-2.900	0.01
Distance to road	0.011	0.0092	1.146	0.26
Distance to food source	0.012	0.0061	1.984	0.05
Disturbance index	-0.049	0.0078	-6.309	<0.01

canopy cover and distance to food source positively influenced the crow abundance, whereas DBH, distance to building and disturbance index negatively influenced the crow abundance. Therefore, the analysis indicates that the higher the urban level, the bigger the canopy cover, and the higher distance to food source results in increased crow abundance. On the other hand, the higher the DBH of the roosting trees, the higher the distance to building and the higher disturbance index results in decreased crow abundance. Notably, distance to road and canopy height have no influence on the crow abundance ($p > 0.05$).

DISCUSSIONS

EFFECT OF URBAN INTENSITY LEVEL ON *C. splendens* ABUNDANCE

This study shows that the abundance of *C. splendens* in high and less-urbanised sites was significantly different, indicating that the intensity of urban habitat had a high impact on the abundance of the opportunist species. From 10 urban sites, the abundance of *C. splendens* was marginally higher in the highly-urbanised sites, with four sites having severe crow infestations. This is to be expected, as invasive species and urban dwellers like the *C. splendens* favour areas that are heavily disturbed (Csurhes 2016). Heavy crow-infested areas share similar physical attributes, exhibited by tall and shady trees near human habitation (Dupak & Telizhenko 2023), close proximity to food centres (Clifton & Jones 2017; Preininger et al. 2019), 24-h operating business premises (Lim & Sodhi 2009), and a low sanitation environment (Preininger et al. 2019). Urbanization was also shown to benefit species of omnivory and granivory feeding guilds types, as well as cavity-nesting species (Chace & Walsh 2006). The omnivorous and adaptive behaviour of *C. splendens* makes this opportunist species able to survive in a wide range of habitats and conditions including the highly altered human environment (Marvuer, Kareiva & Neubert 2004). Thus, urban development and the hustle of the capital are among the factors encouraging them to become successful urban exploiters, rather than declining in numbers with increasing urbanization. The high abundance of *C. splendens* in urban centres subsequently prevents other species from thriving, and worse, resulting in biodiversity loss (Romain et al. 2006). Furthermore, the positive associations with urban settings, imply that their reproductive success in the city is much better than in rural or natural environments (Soh et al. 2002).

Our study shows a distinct feature of roosting areas between the high and less urbanized sites, in which highly urbanized sites were associated with distance to the nearest road and trash bin from the roosting tree, tree height, canopy cover, canopy height, level of cleanliness, and pedestrians. These sites generally comprise areas of high-density residential areas, along with daytime and night-time commercial buildings, and night markets. Canopy cover was especially the most important factor in distinguishing the higher and less-urbanized sites. Dupak and Telizhenko (2023) and Kövér et al. (2015) indicate that crows nest lower in trees and prefer habitats with dense tree cover, and typically have more uniform canopy cover and height, with crows avoiding areas with sparse tree cover. The presence of trash bins and food scraps significantly attracts crows, as they rely heavily on anthropogenic food sources (Lim & Sodhi 2009; Preininger et al. 2019; Wilson, Sarim & Rahman 2015). Human food waste as well as other food resources such as carcasses, and small animals predominantly contributed the most to the success of *C. splendens* to thrive in human-dominated landscapes (Wilson, Sarim & Rahman 2015). On the other hand, crows in less urbanized areas rely more on natural food sources, which may be less abundant compared to urban settings (Heiss, Clark & McGowan 2009).

More importantly, the study indicates that physical variables have a greater influence on *C. splendens* abundance, compared to anthropogenic variables like pedestrians, passing vehicles, parked vehicles and the level of cleanliness. This is supported by the preference of house crows for specific urban habitats that provide ample food resources and suitable nesting sites (Lim & Sodhi 2009; Lim et al. 2003). While the number of pedestrians, passing vehicles, and parked vehicles are not explicitly the major factors, the availability of anthropogenic food sources is a significant driver of house crow populations. For instance, house crows in Singapore were found to prefer areas with higher amounts of anthropogenic food, such as commercial and public housing areas (Lim & Sodhi 2009). House crows exhibit significant behavioral plasticity and adaptability, allowing them to exploit urban resources effectively. This includes their ability to use anthropogenic materials for nesting and their tolerance of human presence, thus, their success in urban environments is more related to their adaptability and resourcefulness rather than the direct influence of pedestrian or vehicle traffic (Benmazouz et al. 2021).

EFFECTS OF PHYSICAL-ANTHROPOGENIC VARIABLES ON *C. splendens* POPULATION AT NIGHT ROOSTS

Several physical-anthropogenic variables were evaluated to determine which attributes influence *C. splendens'* preference of night roosts between high and less-urbanized sites. The selection of the crow night roost in the highly urbanized sites is significantly influenced by diameter at breast height (DBH) and canopy cover. Our GLMM model shows a significant positive correlation of canopy cover and crow abundance, indicating larger canopy cover harbours greater number of *C. splendens*. Large roosting trees harbour a greater area, which allows for a greater number of birds in the flock and improves their chance of survival (Peh & Sodhi 2002). Crows benefit from environments with significant canopy cover, which provides nesting sites and protection. Interestingly, DBH shows a significantly negative correlation with crow abundance. This result contrasts with previous studies on crows in urban areas (Peh & Sodhi 2002; Soh et al. 2002), where they found roosting trees to have higher DBH than random trees in Singapore. However, Soh et al. (2002) has highlighted that suitable branching also contributes to the tree selection for roosting. Although DBH and canopy height were negatively correlated, large canopy cover is an essential tree characteristic for *C. splendens* when choosing a night roost since it provides safety from nearby traffic and passing pedestrians below the roost trees.

Roosting trees in highly intense cities show a significant positive correlation with distance to the nearest food source, indicating lower bird abundance near the food centre. This result contrasts with the findings of Soh et al. (2002) but aligns with Wilson, Sarim and Rahman (2015). Soh et al. (2002) found that roosting trees are often near food centres while Wilson, Sarim and Rahman (2015) found the highest abundance of *C. splendens* in business areas but the roosting trees were in the neighbouring residential area. This suggests that there is a shift in roosting-site selection in recent years, where the crows prefer roosting in areas in the vicinity of the food source but not exactly near it. This may be attributed to human activities that are not favourable to crows. Based on our observation, disturbances such as human activities and loud passing vehicles could trigger the crows to make noises, likely indicating their distress. Natural food sources, such as insects and fruits, are crucial for crows. In urban settings, crows often rely on a mix of natural and anthropogenic food sources, with a preference for natural foods in the morning and human-derived foods later in the day (Clifton & Jones 2017). As proven in this study, the presence of waste sites and other food-rich environments significantly increases crow populations (Preininger et al. 2019).

Approaching evening, *C. splendens* being social animals, often cause nuisance to the local residents by making noise as they return to their night roosts (Soh et al. 2002). From our observation, the noise subsided by 2000 to 2015 h when the sky darkens. However, disturbances such as human activities and loud passing vehicles could trigger them to make some noise even during night-time. Our analysis on disturbance index supports this notion as it showed a significant negative correlation with crow abundance, which indicates that the crow prefers to roost in locations with less human activity in the vicinity of urban features such as buildings and food centres. As mentioned earlier, this is likely to reduce disturbance particularly by humans during the night, when the birds are inactive. Various forms of human disturbance, such as pedestrian traffic, vehicular movement, and trash, negatively impact crow abundance. In line with other studies, crows tend to avoid areas with high human activity and noise, which can disrupt their natural behaviors and reduce their numbers (Khadraoui & Toews 2015; Walker & Marzluff 2015). Additionally, repeated shooting operations conducted by the local municipality may have also contributed to the crow's change in roost preference.

In addition, the distance of buildings from the night roost was negatively correlated with the abundance of *C. splendens,* indicating higher bird abundance near buildings. Sites with heavy *C. splendens* infestation (BGI, MSI, CRS, and KLMN) were located in close proximity to buildings, particularly BGI and KLMN sites located near the mid-rise flats, while MSI and CRS sites were near the business premises with several food stalls, hawkers, and restaurant nearby. This is because the presence of food stalls, hawkers and restaurants near buildings provides a constant supply of food to the bird. Similarly, Soh et al. (2002) also found high crow abundance in built areas particularly near buildings as the area is often associated with food sources. While crows are known to scavenge, excessive trash and parked vehicles can create environments that are less suitable for nesting and foraging, leading to a decrease in crow populations in those areas (Anjum et al. 2022; Marzluff & Neatherlin 2006). Despite this being the case, urban greenery remains the most important factor for crow abundance as they are used for roosting, breeding, shelter, and forage (MacGregor-Fors & Schondube 2011).

CONCLUSIONS

This study elucidates the physical-anthropogenic factors contributing to *C. splendens* abundance in both high and less-urbanized urban sites. Several physical factors of the roosting trees such as the distance to nearest buildings, food centre and trash bin and other associated factors like hygiene significantly contribute to *C. splendens'* infestation. Crows are significantly influenced by their physical surroundings, such as canopy cover and natural food sources, which positively affect their abundance. However, anthropogenic factors like pedestrian traffic, vehicular movement, and trash can negatively impact their populations. Despite these challenges, crows demonstrate a high level of adaptability to human presence, often thriving in urban environments where they can exploit human-derived food sources. This dual influence highlights the complex relationship between crows and their environments, underscoring their resilience and adaptability. These findings are crucial to constructing strategic planning in controlling the crow population to a more acceptable size. City planning and management should focus on the vegetation-physical characteristics first in order to manage the high crow population. Regular pruning might be one of the best ways to prevent this species from residing on the big trees and continuing to breed. Proper waste management and self-awareness also can assist in addressing the problem of low-sanitary compounds caused by animal pests. Implementing physical barriers such as installing protective nets or using covered trash bins, may be the most effective approach to prevent crow infestations that can be implemented by the municipal council. Besides, public awareness is also important for local residents to properly manage their household wastes thereby limiting access by pest species. Proper physical-anthropogenic management is critical in reducing and limiting the number of invasive and opportunist species, as well as maintaining a clean and healthy environment.

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