



Original Article



Seasonal Variation in Foraging Behaviour and Microhabitat Use of Urban–Rural Birds in District Swat, Pakistan

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ABSTRACT

Urban birds face ecological challenges including fluctuating temperatures, variable microhabitats, and persistent human disturbance, demanding continuous behavioral adjustment for survival. **Objectives:** To examine seasonal foraging behaviors in five sympatric urban bird species, *Pycnonotus cafer*, *Acridotheres tristis*, *Columba livia*, *Corvus splendens*, and *Passer domesticus*, in District Swat under urban–rural conditions. **Methods:** A total of 500 focal observations (100 per species) were recorded between 07:00 AM and 06:00 PM from 15 July, 2024 to 22 December 2025, spanning the summer-to-winter transition. Variables included species identity, ambient temperature, habitat type, flock size, anthropogenic disturbance, and foraging duration. Analyses included Kruskal–Wallis, Dunn post hoc, Spearman correlation, and a generalized linear model. **Results:** Significant interspecific differences were found in foraging duration ($\chi^2 = 225.33$, $p < 0.001$) and flock size ($\chi^2 = 336.17$, $p < 0.001$). Ambient temperature positively correlated with foraging duration (Spearman $\rho = 0.523$, $p < 0.001$). Habitat type significantly influenced feeding behaviors ($\chi^2 = 157.23$, $p < 0.001$), with residential courtyards and rooftops supporting the longest foraging periods. The generalized linear model confirmed that temperature, species identity, habitat type, and anthropogenic disturbance all significantly affected foraging duration, with moderate disturbance linked to reduced feeding time. **Conclusions:** Urban bird species exhibit considerable behavioral flexibility, adjusting foraging strategies in response to seasonal shifts, habitat structure, and human activity. Microhabitat availability and environmental conditions are central to urban foraging patterns, offering insight into how synanthropic communities persist in human–modified landscapes.

INTRODUCTION

Global environmental changes are associated with human activities, most notably urbanization, which increases the vulnerability of ecosystems, especially arid and semi-arid ecosystems, to temperature changes and resource exploitation [1–4]. Rapid urban growth results in a changing landscape, different species communities and new environmental pressures for organisms, while providing stability in predation and resources, and increasing disturbance like noise and artificial light [5–8]. Urban habitats tend to have high densities of birds with low species diversity, with species that have more wide-ranging habitat tolerances or dietary flexibility being best

suited to take advantage of urban environments [9, 10]. Food availability is one of the key drivers of bird dynamics in urban areas, with the provision of food decreasing foraging costs but potentially increasing the risk of disease transmission and predation [6, 11]. Animals forage optimally by focusing on resource-rich patches, based on availability, predation risk, and energetic needs; the role of climate in foraging boundaries is poorly understood [12, 13]. Highly dependent on habitat configuration on spatial scales, movement between complementary habitats is controlled by these scales [14–16], and connectivity between resource patches is a fundamental factor that



influences foraging behaviors. Food availability is known to be a key determinant of foraging success [17], and knowledge of microhabitat selection is fundamental to urban bird conservation [18].

Despite the ecological importance of urban–rural mosaics, limited information exists on how sympatric bird species adjust their foraging behavior and microhabitat use across seasonal environmental gradients in South Asian landscapes. In particular, comparative field studies examining behavioral flexibility among multiple coexisting species under natural conditions remain scarce. The present study aimed to investigate seasonal adjustments in foraging duration, microhabitat use and flock size among five common urban–rural bird species in District Swat, Pakistan.

METHODS

The observational study was conducted across an urban–rural gradient in District Swat, encompassing urban, peri-urban and semi-rural environments classified by human population density, built infrastructure and land-use patterns. Habitats included residential courtyards, rooftops, gardens, orchards, village lanes, roadsides and market areas, where natural and anthropogenic food sources coexist. Five synanthropic species were selected: *Pycnonotus cafer*, *Acridotheres tristis*, *Columba livia*, *Corvus splendens* and *Passer domesticus*, all widespread and behaviorally adaptable across urban and rural landscapes of northern Pakistan. Field observations were conducted from 15 July, 2024 to 22 December 2025, daily between 07:00 AM and 06:00 PM, yielding 500 independent foraging observations with 100 per species. Focal animal sampling was used to record species identity, ambient temperature, habitat type, foraging substrate, foraging technique, foraging bout duration, flock size, and anthropogenic disturbance level, classified as low, moderate, or high. The study was strictly non-invasive with no capturing, marking, or manipulation.

Data were recorded in field notebooks, transferred into Microsoft Excel, and analyzed in R version 4.5.1 within RStudio. Foraging duration was evaluated using the Shapiro–Wilk test, which showed that it was not normally distributed, and therefore Kruskal–Wallis tests with Dunn's post-hoc comparisons and Bonferroni adjustment were used. Ambient temperature and foraging duration were correlated using Spearman's rank correlation. A GLM with Gaussian error distribution evaluated the simultaneous influence of multiple predictors on foraging duration. Seasonal variation was assessed by grouping observations into summer (July–August), autumn (September–October) and early winter (November–December). Visualizations were generated using ggplot2, and $p < 0.005$ was applied throughout.

RESULTS

Overall descriptive statistics of environmental and behavioral variables recorded during the study period (Table 1).

Table 1: Descriptive Statistics of Environmental and Behavioral Variables

Variables	Mean \pm SD
Ambient Temperature ($^{\circ}$ C)	22.07 \pm 7.79
Foraging Duration (min)	7.02 \pm 3.22
Flock Size	4.89 \pm 4.76

A total of 500 independent foraging observations were recorded for the five focal bird species during the study period, which ran from 15 July to 22 December across 2024 and 2025. Each species accounted for exactly 100 observations. This ensured a balanced comparison of behavioral patterns across all five species. Observations were carried out under natural environmental conditions across a range of urban and semi-urban habitats. Ambient temperature varied quite substantially during the study period. This was expected given the natural seasonal transition from summer to winter. Considerable variation was also observed in foraging duration and flock size. This points to a degree of behavioral flexibility among the species as environmental and habitat conditions changed throughout the study (Table 2).

Table 2: Species-Wise Descriptive Statistics of Ambient Temperature, Foraging Duration, and Flock Size Recorded During the Study Period

Species	Observations	Temperature ($^{\circ}$ C), (Mean \pm SD)	Foraging Duration (min), (Mean \pm SD)	Flock Size, (Mean \pm SD)
<i>Acridotheres tristis</i>	100	22.91 \pm 7.64	5.68 \pm 2.18	2.68 \pm 1.01
<i>Columba livia</i>	100	22.21 \pm 7.57	10.20 \pm 3.12	13.75 \pm 3.06
<i>Corvus splendens</i>	100	21.72 \pm 7.92	8.94 \pm 2.84	2.32 \pm 0.68
<i>Passer domesticus</i>	100	21.79 \pm 7.99	4.60 \pm 1.36	3.79 \pm 1.39
<i>Pycnonotus cafer</i>	100	21.72 \pm 7.92	5.68 \pm 2.10	1.92 \pm 0.49

Foraging duration was assessed for normality using the Shapiro–Wilk test. The results showed that the data deviated significantly from normality ($W = 0.9347$, $p < 0.001$). Since the assumption of normality was clearly violated, non-parametric statistical tests were used for all subsequent analyses of behavioral differences among species and habitats.

Variation in foraging duration among the five species was examined using the Kruskal–Wallis rank sum test. The analysis revealed a highly significant difference in foraging duration across species ($\chi^2 = 225.33$, $df = 4$, $p < 0.001$). Post-hoc Dunn's tests with Bonferroni correction revealed significant differences in foraging duration among several species' pairs. Large effect sizes were observed between *Acridotheres tristis* and *Columba livia* ($r = 0.419$), *Columba*

livia and *Passer domesticus* ($r = 0.554$), and *Corvus splendens* and *Passer domesticus* ($r = 0.465$). Moderate effect sizes were detected between *Acridotheres tristis* and *Corvus splendens* ($r = 0.330$) and between *Corvus splendens* and *Pycnonotus cafer* ($r = 0.322$). In contrast, no significant difference was observed between *Columba livia* and *Corvus splendens* or between *Acridotheres tristis* and *Pycnonotus cafer* (Table 3).

Table 3: Pairwise Comparisons of Foraging Duration among Bird Species Using Dunn's Test with Bonferroni Correction and Effect Size Estimates

Species Comparison	Z-value	Adjusted p-value	Effect size (r)	Magnitude	Interpretation
<i>Acridotheres tristis</i> vs <i>Columba livia</i>	-9.38	<0.001	0.419	Large	Significant
<i>Acridotheres tristis</i> vs <i>Corvus splendens</i>	-7.38	<0.001	0.330	Medium	Significant
<i>Columba livia</i> vs <i>Corvus splendens</i>	1.99	0.461	0.089	Small	Not significant
<i>Acridotheres tristis</i> vs <i>Passer domesticus</i>	3.01	0.026	0.134	Small	Significant
<i>Columba livia</i> vs <i>Passer domesticus</i>	12.38	<0.001	0.554	Large	Significant
<i>Corvus splendens</i> vs <i>Passer domesticus</i>	10.39	<0.001	0.465	Large	Significant
<i>Acridotheres tristis</i> vs <i>Pycnonotus cafer</i>	-0.18	1.000	0.008	Negligible	Not significant
<i>Columba livia</i> vs <i>Pycnonotus cafer</i>	9.19	<0.001	0.411	Large	Significant
<i>Corvus splendens</i> vs <i>Pycnonotus cafer</i>	7.20	<0.001	0.322	Medium	Significant
<i>Passer domesticus</i> vs <i>Pycnonotus cafer</i>	-3.19	0.014	0.143	Small	Significant

The distribution of foraging duration among species reflects considerable variability in feeding time across all five species (Figure 1).

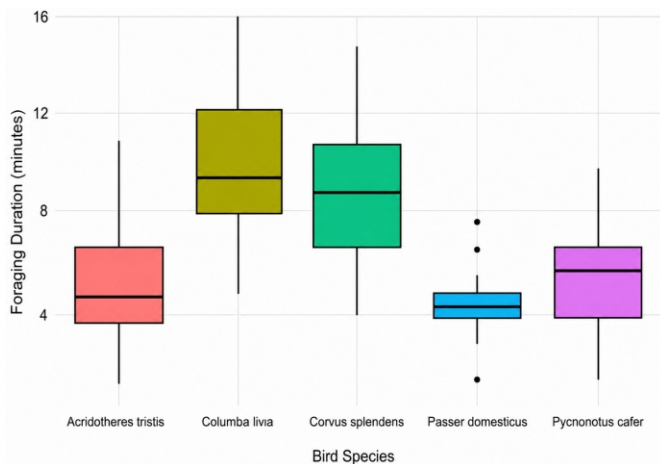


Figure 1: Species Comparison of Foraging Duration

The Spearman's rank correlation analysis was used to assess the relationship between ambient temperature and foraging duration. The results showed a significant positive correlation between the two variables ($\rho = 0.523$, $p < 0.001$). Birds tended to spend longer periods foraging as ambient temperature increased during the observation period. The relationship between temperature and foraging duration clearly reflects an increasing trend in foraging duration as temperatures rose (Figure 2).

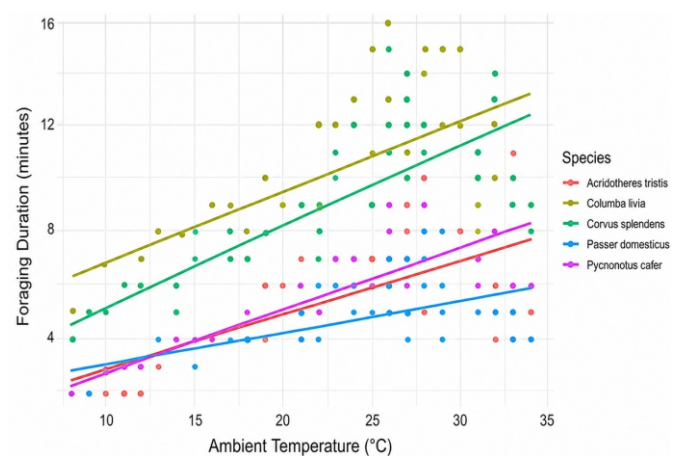


Figure 2: Relationship Between Ambient Temperature and Foraging Duration

Ambient temperature varied quite noticeably across the months covered by the study. Seasonal patterns in temperature are illustrated. The findings clearly capture the gradual transition from warmer summer conditions to cooler winter conditions that took place during the observation period. Species differences in flock size were also examined using the Kruskal-Wallis's test. The analysis revealed a highly significant difference among species ($\chi^2 = 336.17$, $df = 4$, $p < 0.001$) (Figure 3).

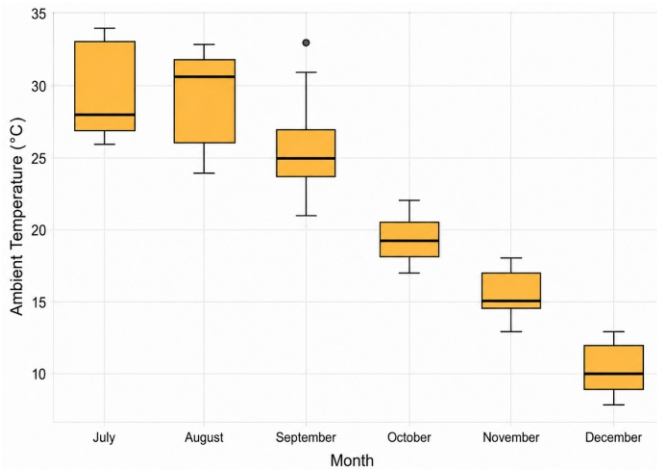


Figure 3: Seasonal Variation in Ambient Temperature During the Observation Period (July–December)

Dunn post hoc comparisons showed that flock sizes differed significantly for most species' pairs. There were, however, two exceptions. No significant difference was detected between *Acridotheres tristis* and *Corvus splendens*, nor between *Corvus splendens* and *Pycnonotus cafer*. These findings suggest that there is notable interspecific variation in social foraging behaviors within this bird community (Figure 4).

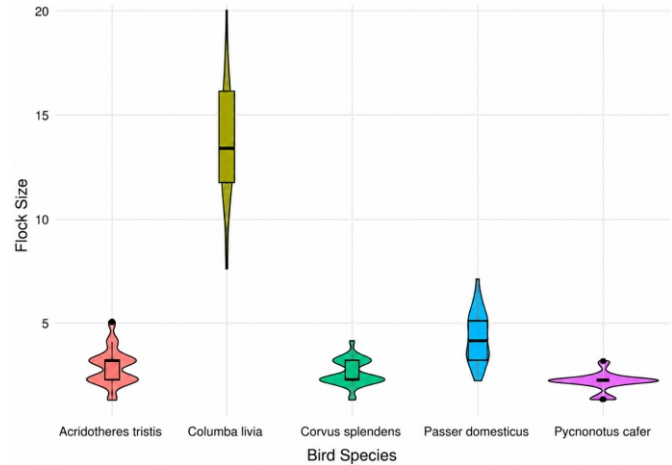


Figure 4: Variation in Flock Size among Bird Species (Violin Plot)

The influence of habitat type on foraging behaviors was evaluated using the Kruskal-Wallis's test. The analysis revealed a significant difference in foraging duration among habitat types ($\chi^2 = 157.23$, $df = 11$, $p < 0.001$). These results show quite clearly that birds adjusted their feeding behaviors depending on the habitat they were foraging in. To evaluate the combined influence of environmental and biological factors on foraging behaviors, a generalized linear model (GLM) was fitted with foraging duration as the

response variable. The generalized linear model demonstrated that ambient temperature significantly increased foraging duration (Estimate = 0.213, 95% CI = 0.194–0.232, $p < 0.001$). Compared with the reference species *Acridotheres tristis*, both *Columba livia* and *Corvus splendens* exhibited significantly longer foraging durations, whereas *Passer domesticus* showed slightly shorter durations. There was no significant difference for *Pycnonotus cafer*. Foraging duration was significantly longer in residential courtyard habitat and residential rooftop habitat than in any other habitat variables. Moderate anthropogenic disturbance significantly reduced foraging duration relative to high disturbance conditions (Table 4).

Table 4: Generalized Linear Model Examining Factors Affecting Foraging Duration

Predictors	Estimate	95% CI	p-value	Interpretation
Ambient Temperature	0.213	0.194 to 0.232	<0.001	Foraging Duration Increased with Temperature
<i>Columba livia</i>	3.91	2.89 to 4.94	<0.001	Significantly Longer Foraging Duration
<i>Corvus splendens</i>	3.77	3.21 to 4.32	<0.001	Significantly Longer Foraging Duration
<i>Passer domesticus</i>	-0.68	-1.22 to -0.13	0.016	Slightly Shorter Foraging Duration
<i>Pycnonotus cafer</i>	-0.13	-0.66 to 0.41	0.642	No Significant Difference
Residential Courtyard Habitat	2.29	0.68 to 3.90	0.005	Increased Foraging Duration
Residential Rooftop Habitat	2.47	1.08 to 3.86	<0.001	Increased Foraging Duration
Moderate Disturbance	-1.43	-2.49 to -0.36	0.009	Reduced Foraging Duration

Diagnostic evaluation of the generalized linear model indicated acceptable residual distribution patterns and no evidence of strongly influential observations, supporting the validity of model inferences. The predicted relationship between ambient temperature and foraging duration derived from the GLM is illustrated in figure 5, which clearly shows the positive trend between temperature and foraging duration. There was a strong effect of season on foraging time for the bird communities observed (Kruskal-Wallis $\chi^2 = 166.03$, $df = 2$, $p < 0.001$). Foraging behavior was significantly different during summer, autumn, and early winter, reflecting seasonal shifts in feeding activity in response to environmental change (Figure 5).

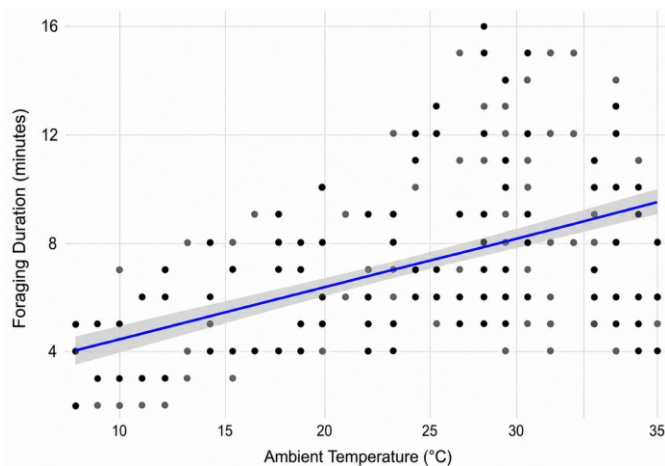


Figure 5: Relationship Between Ambient Temperature and Foraging Duration Predicted by the Generalized Linear Model

DISCUSSION

This study demonstrated the importance of ambient temperature, species identity, habitat structure, and anthropogenic disturbance on foraging duration and social feeding activities among the sympatric bird species of an urban–rural setting. Foraging durations were most strongly correlated with ambient temperature, which is known to influence foraging duration in urban bird communities, and foraging duration was greater in warmer conditions because food availability was greater and metabolic rate was more efficient [6, 11], a pattern well documented in urban bird communities [16, 17]. Interspecific differences in foraging behaviors were observed between species: Foraging time was longer in *Columba livia* and *Corvus splendens*, which foraged more on anthropogenic food sources [11], and shorter but more frequent in *Passer domesticus* for foraging on seeds and small invertebrates. The most stable food availability of residential courtyards and rooftops resulted in the longest foraging periods, whereas a moderate anthropogenic disturbance markedly reduced foraging duration, which may impact energy balance when resources are limiting. *Corvus splendens* and *Columba livia* most frequently foraged in larger groups near concentrated food resources, while other species foraged singly or in small groups, reflecting interspecific variation in social behaviors and habitat use [7]. These findings highlight the considerable behavioral flexibility of urban birds in dynamic landscapes [19–23].

Although this study provides insights into behavioral adjustments among sympatric bird species, several limitations should be acknowledged. Observations were only conducted during daylight hours and in one geographic area, so the results cannot be generalized beyond that. Further studies of urban–rural birds using longer temporal scales, more environmental variables, and experimental designs could be used to further understand how these birds respond to seasonal environmental changes.

CONCLUSIONS

This study reveals that there are measurable differences in foraging time, flock size, and habitat use of urban bird species depending upon the environmental conditions of District Swat. Foraging behaviors was significantly predicted by temperature and habitat type, and anthropogenic disturbance. These findings contribute to understanding how synanthropic birds interact with heterogeneous urban landscapes in South Asia.

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Authors' Contribution

Conceptualization: AA

Methodology: AA

Formal analysis: AA

Writing and Drafting: AA

Review and Editing: AA

Author approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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