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Evaluation of Bird Species Richness and Abundance in Sargodha City, Pakistan

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ABSTRACT

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Urbanization drives landscape transformation and alters habitat structure, vegetation cover, resource availability, and environmental conditions for birds. This study assessed bird species richness, abundance, spatial distribution, diurnal activity, meteorological effects, and community diversity along an urban-to-agricultural gradient in Sargodha City, Punjab, Pakistan. The study area was categorized into three zones based on anthropogenic disturbance, building density, and vegetation: Site 1 = dense urban core, Site 2 = semi-urban institutional, and Site 3 = peri-urban agricultural. Three 1.0 km line transects with a 50 m width were established in each zone. Birds were recorded visually and by calls; high-altitude flyovers not using adjacent habitat were excluded. Surveys were conducted in morning (06:00–09:00), midday (12:00–15:00), and evening (17:00–19:00) under clear, rainy, and post-rain conditions. Temperature, humidity, and wind speed were recorded. A total of 6,372 observations of 12 species were recorded: 2,187 at Site 1, 2,010 at Site 2, and 2,175 at Site 3. *Corvus splendens* was most abundant (1,118), followed by *Passer domesticus* (845) and *Pycnonotus cafer* (822). Urban areas were dominated by *C. splendens* and *Columba livia*, while *P. cafer* and *Psittacula krameri* were abundant in agricultural areas. Shannon diversity was highest at Site 2 ($H' = 2.270$), then Site 3 (2.218), and lowest at Site 1 (1.742). Simpson dominance peaked at Site 1 ($D = 0.213$) and evenness at Site 2 ($J' = 0.914$). Activity was highest in morning (1,042), lowest at midday (542), and moderate in evening (834). Temperature ($r = -0.38$, $p = 0.001$) and wind velocity ($r = -0.51$, $p < 0.001$) negatively correlated with bird counts. Bray–Curtis dissimilarity was highest between urban and agricultural sites ($BC_{13} = 0.684$). Results indicate significant spatial and temporal variation in bird communities and highlight the need to conserve vegetation, green spaces, agricultural buffers, and ecological connectivity in urban landscapes.

Introduction

Rapid urban expansion represents an important form of anthropogenic landscape transformation. In Punjab, Pakistan, and particularly in Sargodha City, expansion of residential, commercial, and infrastructural development has transformed portions

of agricultural and vegetated landscapes into increasingly fragmented urban environments [1]. The thesis reports a 17.4% increase in urbanized area in Sargodha between 1992 and 2015, accompanied by transformation of agricultural and natural land into residential, industrial, and commercial areas [2]. This transformation has produced a heterogeneous landscape containing concrete infrastructure, fragmented vegetation, residential areas, public green spaces, institutional landscapes, and surrounding agricultural land [3].

Birds are useful indicators of environmental conditions because changes in habitat structure, resource availability, and environmental stress can be reflected in their abundance, diversity, and distribution. Their visibility and relatively well-documented taxonomy also make them suitable for ecological assessment [4]. The thesis emphasizes that variation in bird abundance, species diversity, evenness, and relative abundance can provide information about ecological changes within urban environments [5].

Urban bird communities are commonly influenced by the distinction between generalist and specialist species. Urban exploiters and highly adaptable species can take advantage of artificial structures and anthropogenic food resources, whereas habitat-sensitive species may be restricted to areas retaining greater vegetation complexity. The literature reviewed in the thesis describes urbanization as a process capable of altering community composition and favoring synanthropic generalists [6-8]

The Sargodha landscape is particularly suitable for examining these patterns because the city is surrounded by agricultural areas and *Citrus reticulata* orchards. Sargodha is located in the Chaj Doab between the Jhelum and Chenab rivers, at approximately 32°05'N and 72°40'E and an altitude of approximately 190 m above sea level [9]. The thesis characterizes the region as a semi-arid subtropical environment and identifies an urban-agricultural landscape containing citrus orchards, agricultural fields, canal systems, and expanding built infrastructure [10-12].

The study was therefore designed to evaluate avian communities across three contrasting landscape zones of Sargodha City. Particular attention was given to species abundance, spatial distribution, diurnal activity, meteorological conditions, alpha diversity, and beta diversity.

Materials and Methods

Study Area

The study was conducted in Sargodha City, Punjab, Pakistan. The study region was divided into three ecological zones according to building density, anthropogenic disturbance, and vegetation cover.

Site 1: Dense Urban Core

Site 1 represented the densely populated urban core and included Satellite City and local markets close to Khayyam Chowk. The site was characterized by extensive impervious concrete surfaces, heavy traffic, continuous acoustic disturbance, and highly fragmented vegetation. The dominant vegetation recorded for the site included *Conocarpus erectus* and *Eucalyptus camaldulensis*.

Site 2: Semi-Urban Institutional Site

Site 2 represented the semi-urban institutional environment and included the University of Sargodha campus and adjoining public green spaces such as Company Bagh. The area contained mature trees, lawns, and ornamental vegetation and experienced moderate pedestrian activity and relatively low traffic. Dominant vegetation included *Dalbergia sissoo*, *Azadirachta indica*, and *Ficus religiosa*.

Site 3: Peri-Urban Agricultural Site

Site 3 represented the peri-urban agricultural landscape located along the southern and western fringes of the city near Bhagtanwala and Shaheenabad roads. The area was characterized by low structural density, citrus orchards, canal irrigation systems, seasonal crops, and comparatively low commercial disturbance. Dominant vegetation included *Citrus reticulata*, *Morus alba*, and *Acacia nilotica*.

Table 1. Characteristics of the three sampling sites

Site	Zone classification	Geographic boundaries	Dominant vegetation	Disturbance
S1	Dense urban core	32°04'55"N–32°05'40"N;	<i>Conocarpus erectus</i> , <i>Eucalyptus camaldulensis</i>	High traffic and continuous acoustic noise

Site	Zone classification	Geographic boundaries	Dominant vegetation	Disturbance
S2	Semi-urban institutional	72°40'12"E–72°41'30"E 32°04'12"N–32°05'02"N; 72°39'45"E–72°40'35"E	<i>Dalbergia sissoo</i> , <i>Azadirachta indica</i> , <i>Ficus religiosa</i>	Moderate pedestrian movement and low traffic
S3	Peri-urban agricultural	32°02'15"N–32°03'40"N; 72°37'20"E–72°38'50"E	<i>Citrus reticulata</i> , <i>Morus alba</i> , <i>Acacia nilotica</i>	Low; intermittent agricultural machinery

The geographic and habitat characteristics are taken directly from the thesis study-site table.

Avian Census

Bird abundance was assessed using standardized line-transect observations complemented by constant-radius observations. Three permanent line transects, each 1.0 km long, were established within each of the three sampling zones using GPS. The transect width was 50 m, extending approximately 25 m on either side.

The observer moved along transects at an approximately constant walking speed of 1.5 km/h. Birds detected visually using 10 × 42 binoculars or identified through species-specific territorial calls within the 50-m sampling boundary were recorded. Care was taken to avoid double counting, particularly for highly mobile species. Birds flying over the transect without actively using the adjacent habitat for foraging, perching, or other habitat use were classified as flyovers and excluded from the basic abundance calculations.

Temporal Sampling

Observations were conducted during three daily periods:

- **T1 (Morning):** 06:00–09:00
- **T2 (Midday):** 12:00–15:00
- **T3 (Evening):** 17:00–19:00

The morning period was intended to capture early foraging and vocal activity, midday observations represented the period of higher solar radiation and temperature, and evening observations covered late-day foraging and pre-roosting activity.

Meteorological Observations

Sampling was conducted under clear or sunny conditions, during active rainfall, and immediately following rainfall. Air temperature, relative humidity, and wind velocity were recorded at the start and end of transects using a portable digital weather recorder.

Diversity Analysis

The abundance data were evaluated using Shannon–Wiener diversity, Simpson dominance, and Pielou's evenness. In the 12-species community matrix, species richness was represented by $S = 12$ and the relative abundance of each species was calculated as the proportion of the total abundance represented by species i .

Bray–Curtis dissimilarity was used to compare avian community composition between sampling sites. The thesis also applied Pearson correlation analysis to assess relationships between microclimatic variables and bird abundance.

Results

Species Composition and Abundance

The master 12-species abundance matrix contained a cumulative 6,372 observations. Site 1 recorded 2,187 observations, Site 2 recorded 2,010 observations, and Site 3 recorded 2,175 observations.

Table 2. Abundance of recorded bird species across the three sites

No.	Scientific name	Common/local name	S1	S2	S3	Total
1	<i>Corvus splendens</i>	House Crow	650	320	148	1,118
2	<i>Pycnonotus cafer</i>	Red-vented Bulbul	45	280	497	822
3	<i>Milvus migrans</i>	Black Kite	220	180	78	478
4	<i>Acridotheres tristis</i>	Common Myna	180	290	160	630
5	<i>Passer domesticus</i>	House Sparrow	420	310	115	845
6	<i>Columba livia</i>	Rock Pigeon	580	120	12	712
7	<i>Psittacula krameri</i>	Rose-ringed Parakeet	15	140	385	540
8	<i>Bubulcus ibis</i>	Cattle Egret	5	45	290	340
9	<i>Dicrurus macrocercus</i>	Black Drongo	10	55	185	250
10	<i>Streptopelia decaocto</i>	Eurasian Collared Dove	35	160	145	340
11	<i>Eudynamys scolopaceus</i>	Asian Koel	25	95	48	168
12	<i>Saxicola caprata</i>	Pied Bush Chat	2	15	112	129
Total			2,187	2,010	2,175	6,372

The complete abundance matrix is reproduced from the thesis.

Corvus splendens had the highest cumulative count (1,118), followed by *Passer domesticus* (845), *Pycnonotus cafer* (822), *Acridotheres tristis* (630), and *Columba livia* (712). *Saxicola caprata* had the lowest cumulative count (129).

Spatial Distribution

Bird abundance differed significantly among the three sampling sites according to the statistical result reported in the thesis ($F_{2,72} = 14.82$, $p < 0.001$). *Corvus splendens* reached its highest count in the dense urban core, whereas *Pycnonotus cafer* reached its highest abundance in the peri-urban agricultural landscape.

The abundance of *Columba livia* was also strongly concentrated in the urban core, where 580 observations were recorded, compared with 120 at Site 2 and 12 at Site 3. In contrast, *Psittacula krameri* increased from 15 observations in Site 1 to 140 in Site 2 and 385 in Site 3.

Bubulcus ibis, *Dicrurus macrocercus*, and *Saxicola caprata* also showed higher counts in the agricultural landscape than in the dense urban core.

Alpha Diversity

The 12-species diversity matrix reported the following values:

Table 3. Alpha diversity indices based on the 12-species community matrix

Parameter	S1	S2	S3
Species richness (S)	12	12	12
Abundance (N)	2,187	2,010	2,175
Shannon–Wiener index (H')	1.742	2.270	2.218
Simpson dominance (D)	0.213	0.116	0.130
Pielou's evenness (J')	0.701	0.914	0.893

The thesis reports Site 1 as having the lowest Shannon–Wiener diversity ($H' = 1.742$), highest Simpson dominance ($D = 0.213$), and lowest evenness ($J' = 0.701$). Site 2 had the highest Shannon–Wiener diversity ($H' = 2.270$) and highest Pielou's evenness ($J' = 0.914$), while Site 3 had $H' = 2.218$ and $J' = 0.893$.

In Site 1, *Corvus splendens* (650 observations) and *Columba livia* (580 observations) together represented 56.2% of the urban-core census according to the thesis.

Diurnal Activity

Bird abundance varied among the three daily observation periods. The highest cumulative activity occurred during the morning period (T1), with 1,042 observations. The lowest activity occurred during midday (T2), with 542 observations. Activity increased again during the evening period (T3), when 834 observations were recorded.

The thesis associates the morning peak with increased foraging activity under relatively cooler conditions and the midday decline with intense solar radiation and heat. Evening activity was interpreted in relation to late-day foraging and pre-roosting behavior.

Meteorological Effects

Meteorological conditions significantly influenced bird activity and detectability ($F_{2,72} = 32.41$, $p < 0.001$). During active rainfall, the number of observed birds declined substantially, with the thesis reporting approximately four birds on average along the transect. Following rainfall, bird activity increased.

The thesis describes this post-rain increase as a combination of reduced thermal stress and increased availability of food resources, particularly insects.

Temperature and Bird Activity

Ambient temperature was negatively correlated with cumulative avian counts ($r = -0.38$, $p = 0.001$). *Pycnonotus cafer* showed a stronger negative correlation with temperature ($r = -0.64$, $p < 0.001$). In contrast, *Milvus migrans* showed a positive relationship with temperature ($r = 0.58$, $p < 0.001$). *Corvus splendens* showed a weak and non-significant positive relationship ($r = 0.12$, $p = 0.241$).

Relative Humidity

Relative humidity showed a positive relationship with overall bird abundance ($r = 0.42$, $p = 0.003$). *Pycnonotus cafer* showed a positive relationship with relative humidity ($r = 0.51$, $p < 0.001$), whereas *Milvus migrans* showed a negative relationship ($r = -0.31$, $p = 0.008$).

Wind Velocity

Wind velocity showed a negative correlation with cumulative bird counts ($r = -0.51$, $p < 0.001$). *Pycnonotus cafer* showed a negative correlation with wind velocity ($r = -0.48$, $p < 0.001$), as did *Corvus splendens* ($r = -0.34$, $p = 0.005$). The relationship for *Milvus migrans* was negative but non-significant ($r = -0.18$, $p = 0.082$).

Beta Diversity

Bray–Curtis dissimilarity differed among the three sites.

Table 4. Bray–Curtis dissimilarity matrix

Site	S1	S2	S3
S1	0.000	0.352	0.684
S2	0.352	0.000	0.418
S3	0.684	0.418	0.000

The greatest dissimilarity occurred between Site 1 and Site 3 (BC₁₃ = 0.684), followed by Site 2 and Site 3 (BC₂₃ = 0.418). The lowest non-zero dissimilarity was observed between Site 1 and Site 2 (BC₁₂ = 0.352).

The thesis interprets the high Site 1–Site 3 dissimilarity as reflecting the transition from concrete-dominated urban habitat to citrus orchard and agricultural habitat.

Discussion

The results demonstrate substantial spatial variation in the abundance and distribution of birds across Sargodha City. The dense urban core supported high numbers of highly adaptable species, particularly *Corvus splendens* and *Columba livia*, while several vegetation-associated species showed greater abundance in the semi-urban and agricultural environments [13-16].

The dominance of *Corvus splendens* in the urban core is consistent with the urban-exploiter framework discussed in the thesis. The species represented 1,118 observations in the 12-species matrix and was particularly abundant in Site 1. The thesis associates

this pattern with behavioral flexibility and the availability of anthropogenic food resources in commercial and residential areas [17-20].

The strong concentration of *Columba livia* in Site 1 similarly reflects its association with built structures and anthropogenic food resources. The thesis describes the species as abundant around commercial plazas, grain-processing markets, and storage structures and notes its scarcity in agricultural interiors [21-15].

In contrast, *Pycnonotus cafer* showed a marked increase toward the agricultural fringe, reaching 497 observations in Site 3 compared with 45 in Site 1. The thesis relates this pattern to continuous vegetation, orchard canopy, and food resources available in the agricultural landscape [26].

The strong increase in *Psittacula krameri* toward Site 3 provides another example of species-specific habitat association. The species increased from 15 observations in Site 1 to 385 in Site 3, and the thesis associates it with mature trees, orchards, seeds, cereals, and fruit resources [27].

Semi-Urban Green Space and Diversity

The semi-urban institutional landscape had the highest Shannon–Wiener diversity and Pielou’s evenness in the 12-species diversity matrix. Its H' value of 2.270 and J' value of 0.914 exceeded the values recorded in both the urban core and agricultural site [29-31].

The thesis attributes this pattern to mature tree lines, parkland, lawns, and a mixture of built structures and vegetation. Such habitat complexity may provide a combination of nesting, feeding, shelter, and movement opportunities for species with different ecological requirements. The thesis specifically identifies *Dalbergia sissoo*, *Azadirachta indica*, and *Ficus religiosa* as important mature vegetation within the institutional site [32].

This result agrees with the broader urban ecological framework discussed in the thesis, where parks, residential gardens, and mature vegetation can function as refugia for birds within otherwise modified landscapes [33].

The Bray–Curtis coefficient of 0.684 between the urban core and agricultural site indicates the greatest compositional difference among the three pairwise comparisons. The thesis interprets this difference as resulting from the contrasting habitat structure and resource availability of the two environments. The urban core was dominated by species associated with buildings, human food resources, and urban infrastructure, whereas the agricultural site contained higher abundances of several species associated with vegetation, orchards, open fields, and agricultural resources [34]. The semi-urban institutional site occupied an intermediate position, with Bray–Curtis dissimilarity values of 0.352 relative to Site 1 and 0.418 relative to Site 3.

The findings support the thesis interpretation that urban development can alter not only the number of birds but also the relative abundance structure of communities across short geographic distances.

Bird activity was highest during the morning, declined during midday, and increased again during evening. The morning peak of 1,042 observations occurred between 06:00 and 09:00, whereas the midday minimum of 542 observations occurred between 12:00 and 15:00. Evening activity increased to 834 observations.

The thesis associates this pattern with the relationship between temperature and bird activity. Early morning provides relatively cooler conditions and reduced human disturbance, while the midday period is characterized by greater solar radiation and heat. The strong negative correlation between temperature and *Pycnonotus cafer* abundance ($r = -0.64$, $p < 0.001$) supports the observed reduction in activity during hotter conditions.

In contrast, *Milvus migrans* showed a positive correlation with temperature ($r = 0.58$, $p < 0.001$). The thesis interprets this pattern in relation to thermal updrafts and soaring behavior.

The differing responses demonstrate that species occupying the same urban environment may respond differently to temperature because of differences in morphology, behavior, and foraging strategy.

Rainfall produced an immediate reduction in bird observations, while activity increased after rainfall. The thesis attributes this reduction to shelter-seeking and disruption of normal flight and foraging behavior during precipitation. Following rainfall, birds became more visible and active [36].

The post-rain increase was associated in the thesis with two processes: reduced thermal stress and a temporary increase in food availability. Increased insect activity following rainfall was proposed as a mechanism explaining the increased visibility and foraging of species such as *Pycnonotus cafer*.

The positive relationship between relative humidity and *Pycnonotus cafer* abundance ($r = 0.51$, $p < 0.001$) was consistent with the pattern reported in the thesis.

Wind velocity was negatively correlated with total bird abundance. The overall relationship was $r = -0.51$ ($p < 0.001$), while *Pycnonotus cafer* showed $r = -0.48$ ($p < 0.001$) and *Corvus splendens* showed $r = -0.34$ ($p = 0.005$).

The thesis interprets high wind velocity as a mechanical constraint on bird movement, particularly for smaller birds that depend on controlled short-distance flight. For *Milvus migrans*, the relationship was weaker and statistically non-significant, potentially reflecting its different flight strategy [37].

The study demonstrates that the structure of urban landscapes has important consequences for bird communities. The dense urban core had a more uneven community in the 12-species analysis, whereas the semi-urban institutional site showed greater evenness. The agricultural fringe maintained relatively high diversity and supported several species that were less abundant in the urban core [38].

The thesis therefore recommends protecting mature native trees, increasing multi-layered vegetation, protecting peri-urban agricultural buffers, and establishing interconnected green corridors. It specifically identifies *Dalbergia sissoo*, *Azadirachta indica*, and *Ficus religiosa* as important native tree species within the semi-urban landscape.

Conclusion

The present study evaluated bird species richness, abundance, spatial distribution, temporal activity, meteorological responses, and community dissimilarity across three landscape zones in Sargodha City. The 12-species abundance matrix contained 6,372 observations. The dense urban core recorded 2,187 observations, the semi-urban institutional site 2,010, and the peri-urban agricultural site 2,175. *Corvus splendens* was the most abundant species, while *Passer domesticus*, *Pycnonotus cafer*, and *Columba livia* also contributed substantially to the overall abundance.

Bird distributions varied considerably among the three landscapes. Urban-adapted species such as *Corvus splendens* and *Columba livia* were strongly associated with the dense urban environment, while *Pycnonotus cafer*, *Psittacula krameri*, *Bubulcus ibis*, *Dicrurus macrocercus*, and *Saxicola caprata* showed higher abundance in the agricultural landscape.

The 12-species diversity analysis showed that the semi-urban institutional site had the highest Shannon–Wiener diversity and Pielou's evenness, while the dense urban core showed the highest dominance and lowest evenness. These findings demonstrate the ecological importance of mature vegetation and green spaces within urban landscapes.

Bird activity also varied strongly through the day. Morning activity was highest, midday activity was lowest, and evening activity increased again. Temperature, humidity, wind, and rainfall were associated with changes in bird activity and detectability.

The highest Bray–Curtis dissimilarity occurred between the dense urban core and peri-urban agricultural site, indicating substantial differences in community structure between the two landscape extremes.

Overall, the findings indicate that urbanization in Sargodha does not influence all bird species equally. The retention of mature vegetation, green spaces, agricultural buffers, and ecological connectivity is therefore important for maintaining a more balanced urban avian community.

Recommendations

Based strictly on the recommendations contained in the thesis, the following measures are proposed:

1. **Native canopy preservation:** Protect mature native trees, particularly *Dalbergia sissoo*, *Azadirachta indica*, and *Ficus religiosa*, within institutional and semi-urban areas.
2. **Restoration of urban understory vegetation:** Introduce multi-layered planting incorporating shrubs and mid-level vegetation in concrete-dominated areas to provide foraging and nesting substrates.
3. **Protection of peri-urban agricultural buffers:** Restrict expansion of impermeable infrastructure into surrounding *Citrus reticulata* orchards.
4. **Development of green infrastructure corridors:** Establish interconnected green corridors and pocket parks connecting the urban core with agricultural areas.
5. **Long-term avian monitoring:** Establish standardized long-term bird monitoring using the baseline diversity metrics developed in the study.

- 6. Future research:** Future studies should incorporate automated acoustic monitoring, satellite-based vegetation monitoring, nest-success measurements, and pesticide-exposure assessment in peripheral citrus orchards.

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Conflict of Interest

No conflict-of-interest statement is provided in the thesis.

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