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Research Article

Population density dynamics and habitat vegetation composition of the Great Coucal (*Centropus sinensis*) in the vicinity of the Cholistan Desert

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Abstract

Growing habitat fragmentation, agricultural development, urbanization, and other environmental factors are posing major threats to the habitat and population density. This study examined the population dynamics of the Great Coucal (*Centropus sinensis*) in southern Punjab, Pakistan, from 2022 to 2024, across nine sites, assessing spatial, temporal, and seasonal variations. Results showed significant fluctuations, with peak densities in natural vegetation and farmlands during warmer months (April–June), reaching 45.67 ± 1.53 individuals/km² in June at Site 4. Conversely, the lowest densities occurred in semi-arid and urban areas during winter, dropping to 9.33 ± 7.02 individuals/km². A consistent population decline was observed from 2022 to 2024, particularly in semi-arid irrigated croplands (15.00 ± 7.89 individuals/km² in 2024). A temporary increase in 2022 was linked to reduced human activity during COVID-19 lockdowns, underscoring the species' sensitivity to anthropogenic pressures. Vegetation analysis highlighted *Zizyphus nummularia*, *Mangifera indica*, and *Saccharum officinarum* as dominant flora, providing essential resources. The study identifies habitat degradation, seasonal resource variability, and human activities as key drivers of population decline. Conservation strategies, including habitat restoration, sustainable land-use practices, and reduced anthropogenic disturbances, are urgently needed. Further research on environmental drivers and reproductive ecology is recommended to inform effective conservation planning for the Great Coucal in southern Punjab.

Keywords: Biodiversity, Conservation, Habitat preference, Temporal variation

Introduction

The Greater Coucal (*Centropus sinensis*), a large avian species within the Cuculidae family, plays a vital ecological role as both a seed disperser and insect predator (Alby et al., 2023; Qu et al., 2017). Distributed widely across Asia, including regions such as Southern Punjab, Pakistan, this species contributes significantly to maintaining ecosystem balance through its feeding and foraging behaviors. Many South Asian tribes view Great Coucal as a symbol of great fortune (Surender et al., 2013) and recognized by various indigenous names across different languages, such as Mhoka (Hindi), Kmadi Kukar (Punjabi), Kubo (Bengali), Hokku (Gujarati), Bhardwaj (Marathi), and Kalli Kaka (Tamil) (Fayyaz & Hussain, 2023). Taxonomically, Great Coucal is divided into several subspecies, some of which are considered distinct species (Bushra et al., 2020). These birds have been observed in a variety of environments, including gardens, grassy scrublands, big woods, and areas near towns and cities (Singh, 2024).

The Great Coucal exhibits sexual dimorphism, with males displaying glossy black plumage, white streaks, and prominent chestnut wing patches, likely for mate attraction, while females have duller, camouflaged colors, possibly for nesting protection. Both sexes feature rich russet eyes, dark grey legs and feet, and long, straight hind claws, adaptations potentially linked to perching, climbing, or prey capture. These traits reflect evolutionary adaptations to their ecological and reproductive roles (Qu et al., 2017).

Like many developing nations, Pakistan must deal with the dual issues of biodiversity protection and sustainable agriculture (Fayyaz & Hussain, 2023). The increased intensity of agriculture brought about by population growth and growing food demands has led to a widespread use of agrochemicals like pesticides. While increased productivity and crop protection have resulted from these inputs, questions have been raised over their ecological impacts, particularly with regard to wildlife species that are not the intended objectives (Surender et al., 2013). This occurs when agricultural practices intrude upon natural habitats, resulting in fewer breeding sites, foraging areas, and overall habitat quality for avian species (Qu et al., 2017). Numerous non-target animals, including as birds like the Greater Coucal, might be exposed to possible toxicity and sub-lethal effects due to the extensive use of pesticides in agricultural areas. The Greater Coucal is listed as Least Concern by the IUCN, but the decline in their numbers indicates the larger problem.

Conservation efforts to protect Greater Coucal populations necessitate a multidisciplinary approach, integrating ecological, behavioral, and demographic studies. By elucidating the complex interplay between ecological factors and contemporary population dynamics, this research aims to contribute critical insights for biodiversity conservation. The present study was designed to investigate the habitat preferences and population dynamics of the Greater Coucal in South Punjab, Pakistan, over three years.

Material and Methods

Ethics approval and consent to participate

This study was approved from the Institute of Forest Sciences, Faculty of Agriculture and Environment, the Islamia University of Bahawalpur, and was conducted in complete compliance with the established guidelines stated in Pakistan's Prevention of Cruelty to Animals Act (1890), Punjab Wildlife Protection, Preservation, Conservation and Management Act (1974), Pakistan.

Study Area (Topography and Climate)

The study was conducted in southern Punjab, Pakistan, encompassing the districts of Lodhran and Bahawalpur. Lodhran is predominantly agricultural (60–70% of land area), with crops such as cotton, wheat, sugarcane, rice, and vegetables, supported by 60–70% irrigated land and 5–10% orchards. In contrast, Bahawalpur has less agricultural land due to urbanization and 20–30% desert encroachment, with 1–5% of the area comprising water bodies and transportation infrastructure. Topographically, Lodhran features flat, fertile plains influenced by the Indus River basin, ideal for agriculture, while Bahawalpur exhibits varied terrain, including riverine plains, the arid Cholistan Desert with sand dunes, and mildly undulating areas near its eastern and northern borders. The study area lies between 100–200 meters above sea level.

The climate is typical of southern Punjab, characterized by hot summers with daytime temperatures reaching ~40°C (104°F) and mild winters with daytime highs of 15–25°C (59–77°F) but colder nights at 5–10°C (41–50°F). The region experiences low annual rainfall (100–200 mm; 4–8 inches), primarily during the monsoon season (July–September), which delivers short, intense showers critical for agriculture. The area's semi-arid climate and pronounced seasonal temperature variations influence both ecological and agricultural dynamics (Fig. 1).

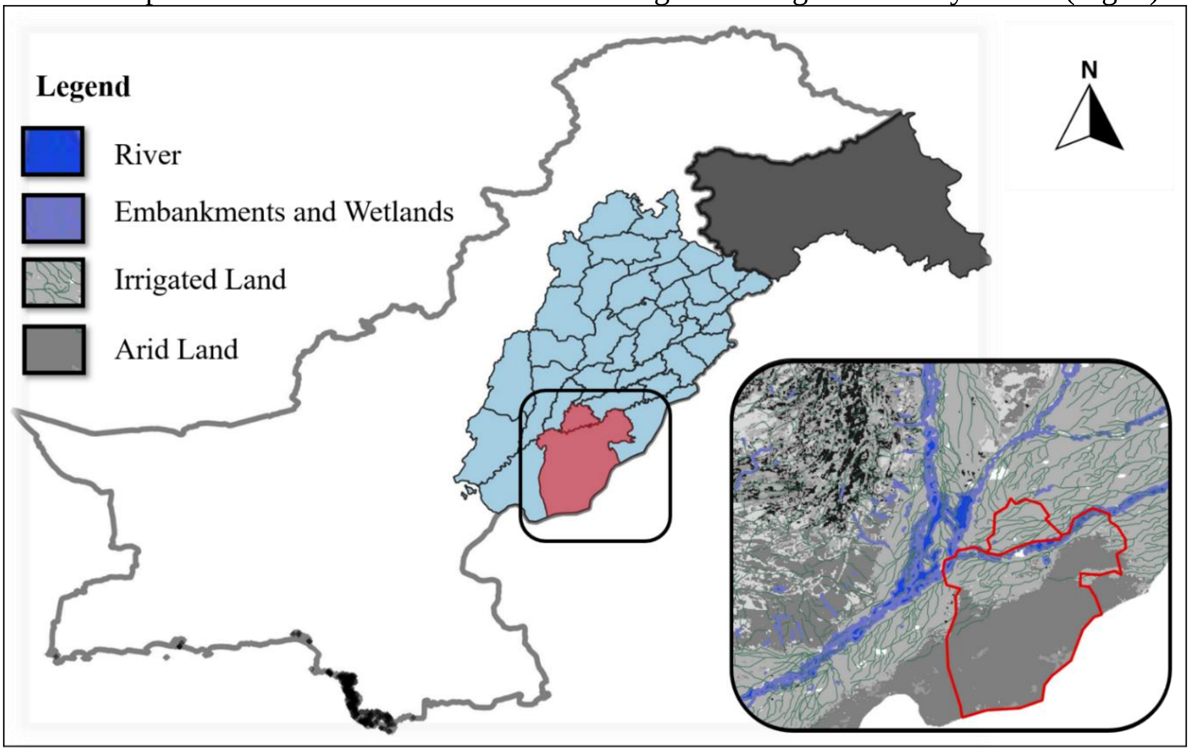

Figure 1. Location and Topography of Study Area

Field design

The research was conducted in the Bahawalpur and Lodhran districts of southern Punjab, Pakistan. Six potential sites were selected in Bahawalpur District, and three sites were chosen in Lodhran District for the study. The sampling sites were selected based on habitat diversity, geographical coverage, accessibility, species presence, and standardized survey methodology. Sites encompassed varied habitats, including urban and rural settlements, agricultural lands, natural vegetation, irrigation canals, national parks, and lakeside areas to ensure ecological representation. Locations were chosen across Bahawalpur and Lodhran districts to cover a broad range of environmental conditions while ensuring feasibility for monthly surveys. Preliminary field visits and expert consultations confirmed the presence of Greater Coucal, and a standardized one-kilometer-square grid system was used for structured and unbiased sampling. Each sampling site was divided into four 1 km² grids, yielding 24 sample stations in Bahawalpur and 12 in Lodhran. By employing distance sampling and the Line Transect Method, the Greater Coucal population was calculated (Buckland et al., 2001). Every month from January 2022 to December

2024, one of the four 1-kilometer transects at each location was randomly surveyed during daylight hours. Details of sampling sites and stations have been tabulated in Table 1 with their respective GPS coordinates. The sampling sites encompass a diverse range of habitat types, including urban settlements, rural settlements, agricultural crop lands, natural vegetation, irrigation canal embankments, national parks, semi-arid irrigated crop lands, and lakeside areas with natural vegetation.

Table 1. Sampling sites in Lodhran and Bahawalpur districts

Sr. No.	District	Sampling Site	GPS Coordinates	Land Use Type
1	Lodhran	Gharibabad colony, Near Railway Station	29.488313 N, 71.517158 E	Urban Settlement
2	Lodhran	Cheley Wahin, Near Darbar Aban Peer	29.643371 N, 72.083792 E	Rural Settlement
3	Lodhran	Chak 357 WB, Near Dunyapur	2945512 N, 71.39036 E	Agricultural Crop Land
4	Bahawalpur	Bahawalpur Khalwan, Near Uch Shareef	29.276986 N, 71.121465 E	Natural Vegetation
5	Bahawalpur	Chak No. 11/BC and 12/BC, Near Cholistan University of Veterinary and Animal Sciences	29.291128 N, 71.627507 E	Irrigation Canal Embankments
6	Bahawalpur	Guddan, Lal Suhanra National Park	29.456716 N, 72.009622 E	National Park
7	Bahawalpur	Chak No. 88/DB, Yazman Mandi	29.112879 N, 71.781970 E	Rural Settlement
8	Bahawalpur	Shahpur, Near Hasilpur	29.765541 N, 72.423878 E	Semi-Arid Irrigated Crop Land
9	Bahawalpur	Fort Derawar	28.767507 N, 71.339243 E	Lake side, Natural Vegetation

We used top-notch binoculars (Aculon A211, 12x50, NikonTM) to observe and identify birds from a distance. For the purpose of identifying Greater Coucal based on their behavior, plumage, and preferred habitat, field guides proved to be quite beneficial. The location of bird observations could be accurately recorded using an Android smartphone with GPS, and the Prostaff 7i, 1200m, NikonTM laser range-finder assisted in determining the distance between the observer and the birds. Records of bird sightings, species, observer distance, and environmental factors (rain, sandstorm etc) were kept on data collecting forms (Buckland et al., 2001).

Population Density

A cumulative number of birds identified by direct sightings and call identifications were collectively tabulated for each site during all 12 months of three respective years i.e., 2022, 2023 and 2024.

Mean Population Densities at all 9 sites were calculated based on the following formulae.

$$\text{Mean Population Density} = \frac{\text{Mean Number of Birds Sighted or Called in an Area}}{\text{The total Area Surveyed at each Location}}$$

The study evaluated monthly population density variations of Greater Coucals across nine sampling sites in Bahawalpur and Lodhran districts. Mean population densities were calculated annually by averaging monthly observations, and trends in population fluctuations over subsequent years were analyzed. The year was divided into three seasons based on climatic patterns: winter (November–February), summer (March–July), and monsoon (August–October), with summers being particularly prolonged and intense due to the proximity to the Cholistan Desert. Monthly data were averaged to determine seasonal population density ranges, enabling an assessment of how seasonal variations influenced Greater Coucal population dynamics. This approach provided insights into the species' ecological responses to seasonal changes in the study region.

Habitat Preference and Demographic Distribution

The habitat preferences and demographic distribution of Great Coucal populations were evaluated across multiple sampling sites, including Urban Settlement, Rural Settlement, Agricultural Crop Land, Natural Vegetation, Irrigation Canal Embankments, National Park, Semi-Arid Irrigated Crop Land, and Lakeside Natural Vegetation, using presence-only modelling method (Brotons et al., 2004). The study was conducted on a seasonal basis, with the year divided into three distinct seasons: winter (November–February), summer (March–July), and monsoon (August–October). Summers were characterized by prolonged and harsher conditions due to the region's proximity to the Cholistan Desert. Monthly population density observations were averaged to assess seasonal habitat preferences. Individuals were categorized by sex (male, female) and age (juveniles) based on morphological characteristics such as plumage, behavior, and body size. Male-to-female ratios were calculated annually for the period 2022–2024.

Vegetation Composition of Habitats

Vegetation composition of Greater Coucal habitats were documented through vegetation sampling near nesting sites. A comprehensive floristic inventory was compiled, detailing plant families, genera, and vernacular names. Triplicate samples of flowering, fruiting, or seeding species were collected, preserved as herbarium sheets, and identified using the Flora of Pakistan (Harriman, 2004) and relevant literature (Wariss et al., 2014). Plant species were classified by life form (tree, shrub, grass) following Raunkiaer (1934). Monthly sampling at each site allowed for the assessment of relative species abundance, providing insights into habitat composition and its potential influence on Greater Coucal ecology.

Statistical analysis

The collected data were analyzed using one-way ANOVA and the nonparametric Kruskal-Wallis test in GraphPad Prism (Version 8.4.3), with a significance threshold set at $P < 0.05$.

Results

Population Density

Monthly population density data for the Great Coucal across nine sampling sites are presented in Table 2. The results revealed significant spatial and temporal variations in population density throughout the study period. The highest density was recorded in June at Site 4 (Natural Vegetation), with a mean of 45.67 ± 1.53 individuals/km², followed by April at Site 6 (National Park) (41.67 ± 7.57 individuals/km²) and June at Site 5 (Irrigation Canal Embankments) (41.33 ± 5.51 individuals/km²). In contrast, the lowest densities were observed in February at Site 8 (Semi-Arid Irrigated Crop Land) (9.33 ± 7.02 individuals/km²) and March at Site 1 (Urban Settlement) (9.33 ± 1.53 individuals/km²). These findings suggest that population density peaks during the warmer months (April–June), potentially coinciding with breeding seasons or increased resource availability in habitats such as natural vegetation and national parks. Conversely, the lower densities observed in February and March at semi-arid and rural sites may reflect seasonal resource limitations or suboptimal habitat conditions.

Table 2. Great Coucal average population/Km^2 density at different sampling sites on monthly basis.

Month	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
January	17±6.9^b	13.67±4.16^b	18.67±7.23^b	10.33±7.09^c	19.3±6.6^b	17.33±6.43^b	14±6.5^b	11.33±4.73^c	18.67±7.51^b
February	14.67±6.03^b	18.00±3.46^b	11.33±10.5^c	13.67±4.73^b	16.67±7.02^b	16.33±5.51^b	15.67±8.33^b	9.33±7.02^c	19±7^b

March	9.33±1.53[c]	13.67±2.08[b]	11.67±9.29[c]	15±9.17[b]	16.67±3.06[b]	13±1[b]	14.67±5.69[b]	13±2.65[b]	16±2.65[b]
April	32.67±10.69[a]	39±6.08[a]	36.33±19.86[a]	34±10.44[a]	32.67±5.86[a]	41.67±7.57[a]	37.33±13.01[a]	26±6.08[a]	35±9.54[a]
May	36.33±14.74[a]	37±3.61[a]	29.33±3.79[a]	33.33±7.02[a]	33.67±7.51[a]	38.67±8.14[a]	34.67±21.08[a]	27.67±13.43[a]	39±9[a]
June	36±5.29[a]	34.33±15.95[a]	31.33±4.93[a]	45.67±1.53[a]	41.33±5.51[a]	31±4.36[a]	30±12.49[a]	29.33±14.29[a]	40.67±2.31[a]
July	31±9.54[a]	28.33±7.02[a]	23.33±10.07[a]	29.33±12.10[a]	24.33±2.89[a]	28.67±11.02[a]	25±5.57[a]	22.67±8.08[a]	31.67±6.03[a]
August	36.67±1.53[a]	21±11.27[a]	26±12[a]	27±1.73[a]	21.33±5.51[a]	23.67±10.02[a]	19.67±3.06[b]	18.33±3.51[b]	30±2.65[a]
September	18.33±8.50[b]	27.67±13.65[a]	26.67±5.77[a]	23.33±9.71[a]	27.33±8.50[a]	27.33±5.03[a]	30±11.79[a]	19±17.35[b]	32.33±7.02[a]
October	31.67±7.77[a]	23±9.54[a]	26.67±6.81[a]	33±4.00[a]	20.33±4.16[b]	25±2.65[a]	20.33±3.06[b]	20.67±14.64[b]	26.67±6.11[a]
November	17.67±2.08[b]	16±2[b]	16.67±11.24[b]	18±8.00[b]	18.33±5.86[b]	16±8.54[b]	15.67±4.04[b]	17±5.57[b]	18.67±4.73[b]
December	16±8[b]	18.67±8.33[b]	18.67±8.14[b]	17.33±9.07[b]	17.33±1.53[b]	16.33±0.58[b]	17.33±4.93[b]	16±2.65[b]	21.33±5.51[a]

Means ± SD with different superscript (a, b, c) in a row are statistically significant at $P<0.05$.

Across all sampling sites during the study period (2022–2024), a consistent pattern in Great Coucal sightings was observed. Bird sightings were consistently low during the first three months of the year (January–March). However, a notable increase in sightings occurred from April through July, with peak densities typically recorded during this period. A gradual decline in population density was observed beginning in July. A modest recovery in sightings was noted during August, September, and October, coinciding with the monsoon season. However, as November approached, population densities sharply declined, returning to the lower levels characteristic of the early months of the year.

The annual population density of the Great Coucal was assessed across nine sampling sites over three consecutive years (2022–2024). Statistical analysis revealed significant differences in population densities among the sampling sites (see Table 3 for detailed results). In 2022, the highest mean population density was recorded at sampling site 3 (Agricultural Crop Land) and site 9 (Lake side, Natural Vegetation), both with an average density of 31.25 individuals per Km^2 (site 3: 31.25 ± 10.26; site 9: 31.25 ± 8.73). In contrast, the lowest population density was observed at sampling site 8 (Semi-Arid Irrigated Crop Land), with a mean density of 22.83 ± 7.42. During 2023 and 2024, sampling site 9 (Lake side, Natural Vegetation) consistently supported the highest population densities, with mean values of 26.25 ± 11.31 and 24.75 ± 8.76, respectively. Conversely, sampling site 8 (Semi-Arid Irrigated Crop Land) exhibited the lowest densities in both years, with means of 19.75 ± 13.29 in 2023 and 15.00 ± 7.89 in 2024. These findings suggest a potential preference of the Great Coucal for habitats with natural vegetation and proximity to water bodies, while semi-arid, irrigated agricultural landscapes appear less favorable. These variations suggest that habitat type and environmental conditions may play a critical role in influencing the distribution and abundance of the species.

Table 3. Great Coucal average population/Km^2 density at different sampling sites on annual basis.

Locations	Year 2022	Year 2023	Year 2024
Site 1	29.08±12.34[a]	22.75±8.96[a]	22.50±13.31[a]
Site 2	28.00±9.43[a]	25.75±13.45[a]	18.83±8.88[a]
Site 3	31.25±10.26[a]	21.17±9.16[b]	16.75±9.48[b]
Site 4	31.08±9.29[a]	23.42±11.16[a]	20.50±13.71[b]
Site 5	27.67±8.89[a]	22.75±7.99[a]	21.92±9.98[a]
Site 6	28.33±9.40[a]	24.33±9.62[a]	21.08±12.20[a]

Site 7	30.58±13.37[a]	20.00±8.80[b]	18.00±7.54[b]
Site 8	22.83±7.42[a]	19.75±13.29[a]	15.00±7.89[a]
Site 9	31.25±8.73[a]	26.25±11.31[a]	24.75±8.76[a]

Means ± SD with different superscript (a, b, c) in a row are statistically significant at $P<0.05$.

The population density of the Great Coucal was assessed across nine sampling sites during three distinct seasons: winter, summer, and monsoon. The data revealed significant seasonal and spatial variations in population density, as summarized in Table 4. Population densities were consistently lower across all sites during winter, ranging from 13.42 ± 3.68 individuals/km² at Site 8 (Semi-Arid Irrigated Crop Land) to 19.42 ± 1.29 individuals/km² at Site 9 (Lake side, Natural Vegetation). The lower densities during winter may be attributed to reduced resource availability, colder temperatures, and limited foraging opportunities, which are common in temperate and subtropical regions during this season. Population densities peaked during summer, with the highest density recorded at Site 9 (36.58 ± 4.05 individuals/km²), followed by Site 4 (35.58 ± 7.03 individuals/km²) and Site 6 (35.00 ± 6.16 individuals/km²). The increase in density during summer likely reflects favorable conditions such as higher temperatures, increased food availability (e.g., insects, small vertebrates), and the onset of the breeding season, which is typical for many avian species. During the monsoon, population densities remained relatively high but showed a slight decline compared to summer.

Table 4. Average bird population/km² at different sampling sites during winter, summer, and monsoon seasons.

Sampling Sites	**Winter**	**Summer**	**Monsoon**
Site 1	16.33±1.31[b]	34±2.60 [a]	30.17±8.15[a]
Site 2	16.58±2.25[c]	34.67±4.63[a]	26.58±6.07[b]
Site 3	16.33±3.46[b]	30.08±5.38[a]	27.35±1.85[a]
Site 4	14.83±3.55[b]	35.58±7.03[a]	29.73±5.58[a]
Site 5	17.92±1.17[b]	33±6.95[a]	25.50±5.88[a]
Site 6	16.50±0.58[b]	35±6.16[a]	27.75±5.07[a]
Site 7	15.67±1.36[b]	31.75±5.43[a]	25.44±6.33[a]
Site 8	13.42±3.68[b]	26.42±2.85[a]	21.10±3.68[a]
Site 9	19.42±1.29[b]	36.58±4.05[a]	31.40±4.17[a]

Means ± SD with different superscript (a, b, c) in a row are statistically significant at $P<0.05$.

Site 9 recorded the highest monsoon density (31.40 ± 4.17 individuals/km²), while Site 8 had the lowest (21.10 ± 3.68 individuals/km²). The monsoon season may provide abundant food resources due to increased insect activity and vegetation growth, but heavy rainfall and flooding could also create suboptimal conditions in certain habitats, leading to moderate declines in density. Site 8 (Semi-Arid Irrigated Crop Land) consistently exhibited the lowest population densities across all seasons (winter: 13.42 ± 3.68; summer: 26.42 ± 2.85; monsoon: 21.10 ± 3.68 individuals/km²). This suggests that semi-arid, agriculturally dominated landscapes may provide less suitable habitat for the Great Coucal, possibly due to limited vegetation cover, water availability, or nesting sites. Site 9 (Lake side, Natural Vegetation) supported the highest densities in all seasons (winter: 19.42 ± 1.29; summer: 36.58 ± 4.05; monsoon: 31.40 ± 4.17 individuals/km²), highlighting the importance of natural vegetation and proximity to water bodies for the species' habitat preference.

The population density of the Great Coucal was analyzed across three years (2022–2024) and three seasons (winter, summer, and monsoon), with data stratified by sex (male, female) and age class (juvenile), revealing significant seasonal, annual, and demographic variations as mentioned in table 5. In 2022, males exhibited the lowest density in winter (7.33 ± 1.13 individuals/km²) and the highest in summer (12.58 ± 2.85 individuals/km²), while females showed similar trends, with winter densities at 7.39 ± 0.70 individuals/km² and summer peaks at 13.53 ± 2.23 individuals/km². Juveniles in 2022 also followed this pattern, with winter densities at 7.03 ± 1.20 individuals/km² and summer peaks at 11.89 ± 2.52 individuals/km², while the male-to-female ratio remained stable at 1:1 across all seasons. In 2023, males had lower winter densities (5.64 ± 1.28 individuals/km²) compared to summer (10.53 ± 2.36 individuals/km²) and monsoon (8.52 ± 2.91 individuals/km²), with females showing similar trends, and juveniles peaking in summer (10.94 ± 2.08 individuals/km²) but declining during the monsoon (7.19 ± 1.08 individuals/km²), while the male-to-female ratio showed slight variations, with 1.12 males per female in winter and 1.16 males per female during the monsoon.

Table 5. Demographic distribution of great Coucal during winter, summer and monsoon seasons.

Year	Sex	Winter	Summer	Moonson
2022	Male	7.33±1.13[b]	12.58±2.85[a]	9.44±1.98[a]
	Female	7.39±0.70[b]	13.53±2.23[a]	8.85±2.51[b]
	Juvenile	7.03±1.20[b]	11.89±2.52[a]	11.74±2.10[a]
	Male: Female	1/1	1/1	1/1
2023	Male	5.64±1.28[b]	10.53±2.36[a]	8.52±2.91[a]
	Female	5.00±0.61[b]	11.31±2.27[a]	7.33±3.03[b]
	Juvenile	4.86±1.43[b]	10.94±2.08[a]	7.19±1.08[b]
	Male: Female	1.12/1	1/1	1.16/1
2024	Male	5.11±2.71[b]	10.94±2.71[a]	8.00±2.17[a]
	Female	5.11±2.34[b]	11.06±3.67[a]	7.85±3.68[a]
	Juvenile	5.44±2.29[b]	11.50±3.46[a]	9.04±3.13[a]
	Male: Female	1/1	1/1	1/1

Means ± SD with different superscript [(a, b, c)] in a row are statistically significant at $P<0.05$.

In 2024, males and females both exhibited the lowest densities in winter (5.11 ± 2.71 and 5.11 ± 2.34 individuals/km², respectively), peaking in summer (10.94 ± 2.71 and 11.06 ± 3.67 individuals/km², respectively), and declining during the monsoon (8.00 ± 2.17 and 7.85 ± 3.68 individuals/km², respectively), while juveniles followed a similar pattern, with winter densities at 5.44 ± 2.29 individuals/km² and summer peaks at 11.50 ± 3.46 individuals/km², and the male-to-female ratio remained stable at 1:1 across all seasons. Consistently lower densities in winter across all years and demographic groups likely reflect reduced resource availability and colder temperatures, while summer peaks coincide with the breeding season and increased food availability, and monsoon declines may result from heavy rainfall and flooding disrupting foraging and nesting activities. Juveniles showed high densities during summer and monsoon, indicating successful breeding and fledging, while the stable male-to-female ratio suggests balanced sex distribution with no significant sex-based disparities in habitat use or survival. These findings highlight the influence of environmental factors such as temperature, precipitation, and resource availability on population dynamics, with future research recommended to investigate specific environmental drivers, long-term impacts of climate change, and the species' reproductive ecology to better understand its population dynamics.

The Kruskal-Wallis test was employed to evaluate differences in bird population densities across nine sampling sites during the winter, summer, and monsoon seasons, with results summarized in Table 6. The mean ranks of the sampling sites ranged from 8.00 (Site 8) to 18.67 (Site 9), indicating varying levels of bird population density across the study area. Site 9 (Lake side, Natural Vegetation) achieved the highest mean rank (18.67), reflecting its consistently high bird population density across all seasons, likely due to the availability of natural vegetation, proximity to water, and abundant resources that support avian diversity. In contrast, Site 8 (Semi-Arid Irrigated Crop Land) had the lowest mean rank (8.00), suggesting that its semi-arid, agriculturally dominated landscape provides less favorable conditions for bird populations, potentially due to limited vegetation cover, water availability, and nesting sites.

Table 6. Ranks of sampling sites based upon average bird population/km^2 during winter, summer, and monsoon seasons.

Locations	Mean rank	Kruskal-Wallis's statistic	P Value
Site 1	15.5	3.453	0.9028
Site 2	15		

Site 3	12.5		
Site 4	15		
Site 5	14		
Site 6	15.67		
Site 7	11.67		
Site 8	8		
Site 9	18.67		

Intermediate mean ranks were observed for Sites 1 (15.5), 2 (15), 4 (15), 5 (14), 6 (15.67), and 7 (11.67), indicating moderate bird population densities. These sites likely represent a mix of habitat types with varying degrees of suitability for avian species. The Kruskal-Wallis statistic (3.453) and associated p-value (0.9028) indicate no statistically significant differences in bird population densities across the sampling sites at the 0.05 significance level. This suggests that, while there are observable variations in mean ranks, these differences are not strong enough to conclude that habitat type or seasonal changes significantly influence bird population densities in this study. However, the relatively high mean rank of Site 9 and the low mean rank of Site 8 highlight the potential importance of habitat quality and environmental factors in shaping avian population distributions.

Vegetation Composition of Habitats

The relative abundance of plant species in the Great Coucal habitat was assessed across 58 species from 18 families during the study period (2022–2024), with results analyzed using the Kruskal-Wallis test as shown in table 7. The highest mean ranks were observed for *Zizyphus nummularia* (547.6, Rhamnaceae), *Mangifera indica* (525.3, Anacardiaceae), and *Saccharum officinarum* (489.4, Poaceae), indicating their dominance and high relative abundance in the study area. These species are likely key components of the habitat, providing critical resources such as food, shelter, and nesting sites for the Great Coucal and other associated fauna. For instance, *Zizyphus nummularia* and *Mangifera indica* are known for their dense foliage and fruit production, which may support avian populations, while *Saccharum officinarum* (sugarcane) and other Poaceae species contribute to the structural complexity of the habitat.

Table 7. Relative abundance of different plant species sampled across the Great Coucal habitats during the study period (2022-24).

Sr. No.	Family	Botanical Name	Mean rank	Kruskal-Wallis's statistic	P value
1	*Arecaceae*	*Phoenix dactylifera*	365.4	120	<0.0001
2	*Chenopodiaceae*	*Haloxylon recurvum*	455.9		
3	*Chenopodiaceae*	*Haloxylon salicornicum*	360.2		
4	*Chenopodiaceae*	*Salsola baryosma*	256.3		
5	*Chenopodiaceae*	*Suaeda fruticose*	346.8		
6	*Myrtaceae*	*Eucalyptus camaldulensis*	474.5		
7	*Meliaceae*	*Azadirachta indica*	342.8		
8	*Rhamnaceae*	*Zizyphus mauritiana*	333.5		
9	*Rhamnaceae*	*Zizyphus nummularia*	547.6		
10	*Salvadoraceae*	*Salvadora oleoides*	215.1		
11	*Tamaricaceae*	*Tamarix dioica*	378.8		
12	*Papilionacea*	*Crotalaria burhia*	260.4		

	e				
13	*Papilionaceae*	*Tephrosia uniflora*	260.4		
14	*Capparaceae*	*Capparis decidua*	283		
15	*Capparaceae*	*Capparis spinosa*	260.4		
16	*Asclepiadaceae*	*Calotropis procera*	260.4		
17	*Asclepiadaceae*	*Leptadenia pyrotecnica*	328.3		
18	*Mimosaceae*	*Acacia jacquemontii*	305.6		
19	*Mimosaceae*	*Acacia nilotica*	215.1		
20	*Mimosaceae*	*Prosopis cineraria*	283		
21	*Mimosaceae*	*Prosopis juliflora*	305.6		
22	*Amaranthaceae*	*Aerva javanica*	260.4		
23	*Amaranthaceae*	*Aerva pseudotomentosa*	373.5		
24	*Compositae*	*Pulicaria rajputanae*	373.5		
25	*Malvaceae*	*Abutilon muticum*	328.3		
26	*Rhamnaceae*	*Ziziphus nummularia*	305.6		
27	*Polygonaceae*	*Calligonum polygonoides*	283		
28	*Poaceae*	*Aeluropus lagopoides*	352.8		
29	*Poaceae*	*Aristida adscensionis*	392		
30	*Poaceae*	*Aristida funiculata*	275.8		
31	*Poaceae*	*Aristida hystricula*	237.8		
32	*Poaceae*	*Aristida mutabilis*	289		
33	*Poaceae*	*Cenchrus biflorus*	392.6		
34	*Poaceae*	*Cenchrus ciliaris*	398.1		
35	*Poaceae*	*Cenchrus prieurii*	345.3		
36	*Poaceae*	*Cenchrus setigerous*	398.7		
37	*Poaceae*	*Cymbopogon jwarancusa*	341.3		
38	*Poaceae*	*Cynodon dactylon*	419.6		
39	*Poaceae*	*Enneapogon desvauxii*	285.1		
40	*Poaceae*	*Eragrostis barrelieri*	309.4		
41	*Poaceae*	*Eragrostis ciliaris*	372.3		
42	*Poaceae*	*Eragrostis japonica*	317		
43	*Poaceae*	*Eragrostis minor*	394.8		
45	*Poaceae*	*Lasiurus scindicus*	260.4		
46	*Poaceae*	*Leptothrium senegalense*	253.2		
47	*Poaceae*	*Ochthochloa compressa*	253.2		
48	*Poaceae*	*Panicum turgidum*	333.5		
49	*Poaceae*	*Panicum antidotale*	350.9		
50	*Poaceae*	*Pennisetum divisum*	336.5		
51	*Poaceae*	*Oryza sativa*	402.3		

52	*Poaceae*	*Triticum aestivum*	420.5		
53	*Poaceae*	*Saccharum officinarum*	489.4		
54	*Malvaceae*	*Gossypium spp.*	403.8		
55	*Poaceae*	*Zea mays*	455.1		
56	*Poaceae*	*Sorghum bicolor*	388		
57	*Poaceae*	*Pennisetum glaucum*	365.7		
58	*Anacardiaceae*	*Mangifera indica*	525.3		

Intermediate mean ranks were recorded for species such as *Eucalyptus camaldulensis* (474.5, Myrtaceae), *Zea mays* (455.1, Poaceae), and *Haloxylon recurvum* (455.9, Chenopodiaceae), suggesting moderate abundance and ecological significance. These species may play a role in shaping the microhabitat conditions, such as providing shade, reducing soil erosion, or serving as foraging substrates for the Great Coucal. For example, *Eucalyptus camaldulensis* is often planted for its fast growth and timber value, while *Zea mays* (maize) and other agricultural species reflect the influence of human-modified landscapes on the habitat.

Lower mean ranks were observed for species such as *Salvadora oleoides* (215.1, Salvadoraceae), *Acacia nilotica* (215.1, Mimosaceae), and *Aristida hystricula* (237.8, Poaceae), indicating their relatively low abundance in the study area. These species may be less dominant due to factors such as poor soil conditions, limited water availability, or competition with more abundant species. Despite their lower abundance, they may still contribute to the overall biodiversity and ecological functioning of the habitat. This variability may influence the availability of resources such as food, nesting sites, and shelter, which are critical for the survival and reproduction of the Great Coucal. For example, the high abundance of fruit-bearing species like *Zizyphus nummularia* and *Mangifera indica* may provide a reliable food source, while grasses and shrubs like *Cenchrus setigerous* (398.7, Poaceae) and *Tamarix dioica* (378.8, Tamaricaceae) may offer nesting and foraging opportunities. Additionally, long-term monitoring of plant populations and their interactions with the Great Coucal could provide valuable insights into the conservation and management of this species and its habitat.

Discussion

In current study, mean population density of Greater Coucal sighted across different locations in Bahawalpur and Lodhran district varied between 31.25 Birds/Km^2 at Lake side, natural vegetation in 2022 to 15.00 Birds/Km^2 at semi-arid irrigated crop land in 2024. These findings suggest a potential preference of the Great Coucal for habitats with natural vegetation and proximity to water bodies, while semi-arid, irrigated agricultural landscapes and urban settlement appear less favorable. These variations suggest that habitat type and environmental conditions may play a critical role in influencing the distribution and abundance of the species. The observed decline in Greater Coucal population densities from 2022 to 2024 was a concerning trend that aligned with findings from several studies highlighting the vulnerability of avian populations due to anthropogenic pressures (Rajpar & Zakaria, 2013). Studies by Smith et al. (2020) and Surender et al. (2013) have demonstrated similar declines in bird populations, attributing them to factors such as habitat loss, climate variability, and pesticide exposure. Furthermore, study conducted by Nan et al. (2004), who observed that Great Coucal were most commonly found in highly disturbed habitats, characterized by a significant presence of secondary vegetation and proximity to farmland.

Steady decline in population density was observed from 2022 to 2024. The increased sightings of Great Coucals in 2022 are likely associated with the environmental shifts resulting from COVID-19 pandemic-related lockdowns. These measures significantly reduced anthropogenic activities, lowered pollution levels, and facilitated temporary habitat restoration, thereby enhancing conditions conducive to the species' proliferation. This finding is consistent with global evidence of short-term ecological benefits during the pandemic, underscoring the vulnerability of wildlife populations to human-induced environmental changes (Basile et al., 2021; Gordo et al., 2021).

Researchers have hypothesized that variations in habitat characteristics such as topography and food availability, greatly influenced the frequency of bird sightings (Vázquez-Carrero, 2022). The inherent quality of available freshwater and soil has been linked to determining the most desirable habitat characteristics (Piczak et al., 2023). Observable shifts in waterbird populations have been noted along gradients of habitat complexity and food availability (Schneiberg et al., 2020). Consequently, the authors specifically chose locations in a district that were geographically distant from each other but in close proximity to a water reservoir or body. Therefore, most of the selected locations were peri-rural. It has also been suggested that sites with monotonous and natural vegetation, often times provided less attractive foraging and resting habitats for certain species of birds (Schneiberg et al., 2020). Similarly, Great Coucal preferred natural vegetation near lake and canal embankment as a more suitable alternative compared to semi-arid agriculture lands.

The seasonal and monthly trends in Greater Coucal population densities reflected the species' adaptability to changing environmental conditions. Consistent with previous research by Fayyaz and Hussain (2023), our study found higher population densities during summer months. This could be attributed to favorable breeding and foraging conditions during this period. Conversely, lower densities during winter months could be linked to reduced resource availability, as documented in studies on migratory bird populations by Finch et al. (2017) and Lee and Hammer (2022). Understanding these seasonal variations is crucial for effective conservation planning and management strategies (Smith et al., 2022).

The vegetation composition revealed a diverse range of plant species in Greater Coucal habitats, with cultivated crops and fruiting trees dominating the landscape. This finding was consistent with studies emphasizing the importance of agricultural landscapes as habitat for various bird species. Research by Tworek (2002) and Radford and Bennett (2007) has highlighted the role of agricultural areas in providing food and shelter for avian populations. However, the impact of specific plant species on Greater Coucal population dynamics requires further investigation. Recent studies by Schneiberg et al. (2020) and Lerman et al. (2021) have explored the interactions between plant diversity and bird communities, shedding light on the complex relationships that influence population trends. Additional floral diversity (*Zizyphus nummularia*, *Haloxylon recurvum*, *Eucalyptus camaldulensis*, *Pulicaria rajputanae*, *Cenchrus ciliaris*, *Cenchrus setigerous*, *Cynodon dactylon*, and *Eragrostis*) was observed during present study as compared to previous findings (Fayyaz & Hussain, 2023). This variation could be rationalized by the fact that sampling sites in current investigation were predominantly located near farmlands as well as Great Coucal is being adapt to disturbance in environment. Moreover, cultivated crops namely *Saccharum officinarum*, *Zea mays* and orchards of *Mangifera indica* were abundantly observed near our selected sampling site.

The declining population trends observed in our study underscored the urgent need for targeted conservation efforts to safeguard Greater Coucal populations. Habitat conservation, sustainable land management practices, and pesticide regulation are critical aspects that require immediate attention. Lessons from successful conservation initiatives for avian species, as demonstrated in studies by Lewis et al. (2021) and Dayer et al. (2020), can inform conservation strategies for Greater Coucals. Collaborative efforts involving researchers, policymakers, and local communities are essential for implementing effective conservation measures and preserving biodiversity. While our study provided valuable insights into Greater Coucal population dynamics, it is essential to acknowledge certain limitations. The study's scope focused primarily on population densities and habitat characteristics, and future research should delve deeper into the specific environmental factors driving population declines. Genetic studies to assess the diversity within Greater Coucal populations and long-term monitoring programs are also recommended. Additionally, assessing the impact of climate change and land-use changes on avian populations will be crucial for predicting future trends and implementing adaptive management strategies.

Conclusion

The persistent decline in the Greater Coucal population raises significant conservation concerns. The species exhibited an unpredictable habitat preference pattern, with higher abundance observed in natural vegetation and farmlands compared to urban areas. Notably, the study period (2022–2024) overlapped with COVID-19 lockdowns, which temporarily reduced anthropogenic pressures. However, the findings suggest that anthropogenic factors have directly contributed to the observed population decline. Further research is essential to elucidate the drivers of this decline, particularly in the natural habitats of southern Punjab, Pakistan, to inform targeted conservation strategies and mitigate ongoing threats to the species.

Availability of data and materials

The authors declare that the experimental data supporting the present study findings have been made available to the corresponding author MAY.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Experimental design was conceived by AA and JN. Data were collected by AA and MAY Statistical analysis was conducted by AA, JN, TH, AS, and SH. Original draft was written by AA and MAY. All authors have contributed to the revision and final proof-reading of the manuscript.

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