

A Quantitative Study of Avifaunal Diversity and Anthropogenic Threats at Rasul Barrage Wetland Ecosystem

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ABSTRACT

Rasul Barrage is a vital wetland that supports a diverse range of birds, including residents, waterfowl, and migratory species. A study was conducted from November 2023 to May 2024 to assess bird diversity and abundance. Data were collected using direct observations, flock counts, and point counts across four transect points, supplemented by interviews with local residents and hunters. Field visits were conducted during early morning (6:30–9:30 am) and late afternoon (3:30–6:30 pm) to capture peak activity. During the study period, 105 bird species were recorded, comprising 48 residents and 40 migratory species, including 2 summer visitors, 11 winter visitors, and 4 year-round species. In total, 19,869 individual birds were counted. Species richness and diversity were higher in winter than in summer. The Shannon-Weiner diversity index showed that Transect Point 1 had the highest diversity ($H' = 3.35$), followed by Points 2 (3.10), 3 (2.95), and 4 (2.75). The Simpson index (1-D) indicated maximum diversity at Points 2 and 3 (0.76 and 0.72), with Points 1 and 4 recording 0.80 and 0.068. Species evenness varied among transects: 0.84 (TP1), 0.81 (TP2), 0.78 (TP3), and 0.74 (TP4). Despite this rich avifauna, the diversity of birds at Rasul Barrage is declining due to habitat degradation, plastic pollution, illegal hunting, and limited public awareness. Conservation efforts involving local communities, government agencies, and wildlife organizations like WWF and IUCN are essential to preserve this wetland and its bird populations.

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Key words

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INTRODUCTION

Wetlands are among the most productive ecosystems in the world, sustaining a wide array of species and providing vital ecological services. They act as natural water reservoirs, filter pollutants, recharge groundwater, regulate floods, and provide habitat to thousands of organisms, especially waterbirds (Ali and Ripley, 1987). Avifauna, in particular, is highly dependent on wetlands for breeding, nesting, foraging, and as stopover sites during long migratory journeys. Birds are also considered effective bioindicators of environmental health due to their sensitivity to ecological changes (Ali *et al.*, 2011).

Globally, wetlands cover nearly 6% of the Earth's surface but host more than 20% of known biodiversity, including a significant proportion of migratory bird populations (Abbas *et al.*, 2018). It has recognized wetlands as ecosystems of international importance and has emphasized their role in biodiversity conservation (Abid *et al.*, 2024). Despite their importance, wetlands worldwide are under pressure from urbanization, agricultural expansion, pollution, and climate change, leading to rapid biodiversity declines (Akbar *et al.*, 2006).

Pakistan occupies a strategically significant position along the Central Asian Flyway (CAF), one of the world's eight major migratory routes. Each year, millions of birds travel from Siberia, Central Asia, and northern Russia to South Asia, passing through Pakistan and using its rivers, lakes, and reservoirs as staging, feeding, and wintering sites (Bilal *et al.*, 2021). More than 225 migratory species have been reported from Pakistan, and wetlands like Chashma Barrage, Taunsa Barrage, and Mangla Dam are already recognized as Ramsar sites due to their international importance (APHA, 2012).

The River Jhelum, an important tributary of the Indus River, hosts several barrages and reservoirs that provide

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rich wetland habitats for waterfowl and passerines. Among these, Rasul Barrage is located in District Mandi Bahauddin and plays a dual role in irrigation management and biodiversity support. The wetland mosaic includes shallow waters, mudflats, sandbanks, reed beds, and adjoining agricultural fields, all of which provide shelter and feeding grounds for diverse avifauna. However, unlike other well-studied wetlands of Pakistan, Rasul Barrage has received limited scientific attention (Shah *et al.*, 2022).

Previous studies have documented avifaunal richness at Chashma Barrage (Haider *et al.*, 2022), Mangla Dam (Islam and Rahmani, 2008), and Taunsa Barrage (Grimmett *et al.*, 2008), highlighting their ecological roles in sustaining migratory and resident birds. These sites revealed seasonal fluctuations, with greater species richness during winter due to the influx of migratory ducks, geese, and waders. Despite these insights, Rasul Barrage remains underexplored, and there is little published information on its bird community composition, seasonal variation, and conservation threats (Gaston, 2010). The present study was conducted to: (i) document the diversity and abundance of avifauna at Rasul Barrage, (ii) compare seasonal variation in species richness and diversity indices, and (iii) identify major anthropogenic threats and suggest appropriate conservation measures.

By addressing these objectives, this study aims to provide baseline data that will contribute to future monitoring and conservation of avifaunal diversity in Pakistan's wetlands.

MATERIALS AND METHODS

Study area

The study was conducted at Rasul Barrage, located on the River Jhelum in District Mandi Bahauddin, Punjab, Pakistan (32°40'–32°42' N, 73°30'–73°33' E). The barrage serves as a major irrigation structure, but its reservoir and adjoining habitats function as an important wetland ecosystem. The area encompasses a mosaic of open water, mudflats, reed beds, riparian scrub, sandbanks, and adjacent agricultural fields, providing diverse ecological niches for avifauna.

The climate of the region is subtropical, characterized by hot summers (with maximum temperatures above 40 °C) and cool winters (minimum ~5 °C). The wetland experiences seasonal fluctuation in water levels due to irrigation demands and rainfall, influencing bird abundance and distribution. Four representative transects were selected for systematic surveys: TP.1 (Rasul Hydel Power Station Wild life Office Old Rasul Barrage), TP.2 (New Rasul Barrage), TP.3 (New Rasul Barrage Bridge End Police choki area), and TP.4 (Heaven view area).

Sampling design and field surveys

Bird surveys were carried out weekly from November 2023 to May 2024, covering both winter (November–February) and spring/summer (March–May) seasons. Observations were conducted during early morning (06:30–09:30) and late afternoon (15:30–18:00), coinciding with peak bird activity. Following ornithological census techniques were applied: (i) point counts: Birds were recorded within a fixed radius of 100 m at predetermined stations (Roberts, 1991). (ii) transect walks: Observers walked along each transect (1–1.5 km in length) recording all species seen or heard. (iii) flock counts: Applied to large waterbird aggregations (e.g., ducks, geese, coots) to obtain reliable abundance estimates. Birds were identified with the aid of binoculars (10×50), a spotting scope (15–60×), and a DSLR camera for photographic verification. Identification followed field guides.

Data recording and diversity indices

All birds encountered were recorded with date, time, habitat type, and number of individuals. Species richness (S) and abundance (N) were calculated for each site and month. To evaluate community structure, standard ecological indices were applied: Shannon–Wiener Index (H'): $H' = -\sum (p_i \ln p_i)$ where p_i is the proportion of individuals of species i . Simpson's Diversity Index (1–D): $D = \sum (p_i^2)$, $1-D = \text{diversity measure}$.

Pielou's Evenness (E): $E = H' / \ln(S)$. These indices were calculated using PAST software v4.1.

Water quality analysis

To assess habitat quality, water samples were collected in January 2024 from all four transects. Samples were taken at a depth of ~35 cm in sterilized 1-L polypropylene bottles, stored in ice boxes, and transported to the laboratory for analysis. Parameters measured included pH, dissolved oxygen (DO), turbidity, and electrical conductivity (EC) following standard protocols of the American Public Health Association (APHA, 2012).

Data analysis

Monthly and seasonal comparisons of diversity indices were performed. Differences between winter and summer assemblages were interpreted qualitatively, and abundance of dominant species was visualized using bar graphs and relative abundance charts.

RESULTS

Species richness and composition

A total of 105 bird species, belonging to 14 orders and

30 families, were recorded from Rasul Barrage during the study period (November 2023–May 2024). The surveyed assemblage comprised both migratory (58 species; 55.2%) and resident (47 species; 44.8%) birds. Water birds such as ducks, geese, herons, and shorebirds dominated the wetland habitats, while passerines and raptors were more abundant in adjacent scrublands and agricultural fields. The overall abundance accounted for 19,869 individuals across all months.

Passeriformes contributed the highest species richness (35 species), followed by Anseriformes (17 species) and Charadriiformes (12 species). In terms of families, Anatidae was the most speciose group (17 species), followed by Ardeidae (8 species) and Accipitridae (7 species). Bird species observed in seven months. The characteristics, common names with scientific names, family names, and their occurrence are mentioned (Table I).

Table I. Birds observed on all sites.

S.N.	Family/ Name of birds	Occurrence
Family: Columbidae		
1	Blue-rock pigeon (<i>Columba livia</i>)	Resident
2	Domestic pigeon (<i>Columba livia domestica</i>)	Resident
3	Indian-ring dove (<i>Streptopelia decaocto</i>)	Resident
4	Wood pigeon (<i>Columba palumbus</i>)	Winter visitor
5	Red turtle dove (<i>Streptopelia tranquebarica</i>)	Resident
6	Yellow-footed green pigeon (<i>Treron phoenicoptera</i>)	Resident
7	Eastern stock pigeon (<i>Columba eversmanni</i>)	Winter Visitor
Family: Cuculidae		
8	Pied crested cuckoo (<i>Clamator jacobinus</i>)	Resident
9	Short-winged cuckoo (<i>Cuculus iconiaqua</i>)	Resident
Family: Strigidae		
10	Short-rared owl (<i>Asio flammeus</i>)	Resident
Family: Alaudidae		
11	Crested lark (<i>Galerida cristata</i>)	Resident
12	Red-winged bush lark (<i>Mirafra erythroptera</i>)	Resident
13	Indus sand lark (<i>Clandrella raytal</i>)	Resident
14	Small skylark (<i>Alauda gulgula</i>)	Resident
15	Eurasian skylark (<i>Alauda arvensis</i>)	Resident
16	Singing bush lark (<i>Mirafra cantillans</i>)	Resident
Family: Sturnidae		
17	Common myna (<i>Acridotheres tristis</i>)	Resident

Table continues on next column.....

S.N.	Family/ Name of birds	Occurrence
Family: Passeridae		
18	House sparrow (<i>Passer domesticus</i>)	Resident
Family: Corvidae		
19	House crow (<i>Corvus splendens</i>)	Resident
Family: Ardeidae		
20	Crested honey (<i>Pernis ptilorhynchus</i>)	Resident
21	Large egret (<i>Egretta alba</i>)	Resident
22	Bar headed goose (<i>Anser indicus</i>)	Winter visitor
23	Cattle egret (<i>Bubulcus ibis</i>)	Resident
24	Little green heron (<i>Butorides Striatus</i>)	Resident
25	Indian pond heron (<i>Ardeola grayii</i>)	Resident
26	Crested honey	Resident
27	Little egret (<i>Egretta garzetta</i>)	Year-round visitor
28	Intermediate egret (<i>Egretta intermedia</i>)	Year-round visitor
29	Purple heron (<i>Ardea purpurea</i>)	Winter birds
Family: Accipitridae		
30	Buzzard (<i>Pernis ptilorhynchus</i>)	
31	Indian kite (<i>Milvus migrans</i>)	Winter visitor
32	Shikra (<i>Accipiter badius</i>)	Resident
33	Common buzzard (<i>Buteo buteo</i>)	Resident
34	Black-shouldered kite (<i>Elanus Caeruleus</i>)	Resident
35	Indian kite (<i>Milvus migrans</i>)	Winter visitor
36	Ring tailed fish eagle (<i>Haliaeetus leucorhynchus</i>)	Winter visitor
37	Short-toed eagle (<i>Circus gallicus</i>)	Resident
38	Hen harrier (<i>Circus cyaneus</i>)	Summer visitor
39	Long-legged buzzard (<i>Buteo rufinus</i>)	Winter visitor
40	Black eagle (<i>Lctinaetus malayensis</i>)	Resident
Family: Phasianidae		
41	Common quail (<i>Coturnix coturnix</i>)	Winter visitor
42	See-see partridge (<i>Ammoperdix grisegularis</i>)	Resident
43	Grey partridge (<i>Francolinus pondicerianus</i>)	Resident
44	Chukar partridge (<i>Alectoris chukar</i>)	Winter visitor
45	Black partridge (<i>Francolinus francolinus</i>)	Resident
Family: Rallidae		
46	Eurasian coot (<i>Fulica atra</i>)	Winter visitor
47	Eurasian coot (<i>Fulica atra</i>)	Resident
48	Water rail (<i>iconiaquaticus</i>)	Winter birds
49	White-breasted water hen (<i>Amaurornis phoenicurus</i>)	Winter birds

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S.N.	Family/ Name of birds	Occurrence
50	Siberian crane (<i>Leucogeranus leucogeranus</i>)	Winter visitor
51	Purple swamphen (<i>porpyrio porpyrio</i>)	Winter birds
	Family: Muscicapidae	
52	Pied bushchat (<i>Saxicola caprata</i>)	Resident
53	Oriental magpie robin (<i>Copsychus saularis</i>)	Resident
	Family: Acrocephalidae	
54	Reed warbler (<i>Acrocephalus scirpaceus</i>)	Winter visitor
	Family: Anatidae	
55	Common teal (<i>Anas crecca</i>)	Winter visitor
56	Common shelduck (<i>Tadorna tadorna</i>)	Winter visitor
57	Common pochard (<i>Aythya ferina</i>)	Winter visitor
58	Gadwall (<i>Mareca strepera</i>)	Winter visitor
59	Eurasian wigeon (<i>Mareca iconia</i>)	Winter visitor
60	Mallard (<i>Anas platyrhynchos</i>)	Winter visitor
61	Northern pintail (<i>Anas acuta</i>)	Winter visitor
62	Ruddy shelduck (<i>Tadorna ferruginea</i>)	Winter visitor
63	Shoveler (<i>Anas clypeata</i>)	Winter visitor
64	Garganey (<i>Spatula querquedula</i>)	Winter visitor
65	Indian spot billed duck (<i>Anas poecilorhyncha</i>)	Winter visitor
66	Lesser whistling teal (<i>Dendrocygna javanica</i>)	Winter visitor
67	Graylag goose (<i>Anser anser</i>)	Winter visitor
68	Red crested pochard (<i>Netta rufina</i>)	Winter visitor
69	Ferruginous pochard (<i>Aythya nyroca</i>)	Winter visitor
70	Tufted duck (<i>Aythya fuligula</i>)	Winter visitor
71	Cotton pygmy goose (<i>Nettapus coromandelianus</i>)	Winter visitor
72	Chestnut-bellied sandgrouse (<i>Anas castanea</i>)	Winter visitor
73	Northern Pintail (<i>Anas acuta</i>)	Winter visitor
	Family: Phalacrocoracidae	
74	Great cormorant (<i>Phalacrocorax carbo</i>)	Winter visitor
	Family: Scolopacidae	
75	Common sandpiper (<i>Actitis hypoleucos</i>)	Winter visitor
76	Green shank (<i>Tringa Nebularia</i>)	Winter visitor
77	Wood sandpiper (<i>Tringa glareola</i>)	Winter visitor
78	Green sandpiper (<i>Tringa ochropus</i>)	Winter visitor
79	Marsh sandpiper (<i>Tringa stagnatilis</i>)	Winter visitor
	Family: Phalacrocoracidae	
80	Indian cormorant (<i>Phalacrocorax fuscicollis</i>)	Resident

Table continues on next column.....

S.N.	Family/ Name of birds	Occurrence
	Family: Falconidae	
81	Lesser kestrel (<i>Falco naumanni</i>)	Summer visitor
82	Common kestrel (<i>Falco tinnunculus</i>)	Resident
	Family: Motacillidae	
83	Grey wagtail (<i>Motacilla cinerea</i>)	Winter visitor
84	Pied wagtail (<i>Motacilla alba</i>)	Resident
	Family: Pycnonotidae	
85	Red vented bulbul (<i>Pycnonotus cafer</i>)	Resident
	Family: Alcedinidae	
86	White throated kingfisher (<i>Halcyon smyrnensis</i>)	Resident
87	Pied kingfisher (<i>Ceryle rudis</i>)	Resident
	Family: Charadriidae	
88	Red wattled lapwing (<i>Vanellus indicus</i>)	Resident
89	White-tailed plover (<i>Vanellus leucurus</i>)	Winter bird
90	Yellow bittern (<i>Ixobry chusseinensis</i>)	Winter bird
91	Yellow wattled lapwing (<i>Vanellus malabaricus</i>)	Winter bird
	Family: Gruidae	
92	Sarus crane (<i>Antigone antigone</i>)	Resident
	Family: Dicruridae	
93	Black drongo (<i>Dicruridae macrocercus</i>)	Resident
	Family: Hirundinidae	
94	Wired tailed swallow (<i>Hirundo smithii</i>)	Resident
	Family: Ciconiidae	
95	White stork (<i>C. ciconia</i>)	Winter bird
	Family: Recurvirostridae	
96	Black winged stilt (<i>Himantopus iconiaqu</i>)	Resident
	Family: Ploceidae	
97	Baya weaver (<i>Ploceus philippinus</i>)	Resident
	Family: Cuculidae	
98	Plaintive cuckoo (<i>Cacomantis passerines</i>)	Resident
	Family: Sylviidae	
99	Desert warbler (<i>Sylvia nana</i>)	Resident
	Family: Meropidae	
100	Blue-cheeked bee-eater (<i>Merops superciliosus</i>)	Resident
101	European bee-eater (<i>Merops apiaster</i>)	Resident
	Family: Coraciidae	
102	Kashmir roller (<i>Coracias garruls</i>)	Resident
103	Indian roller (<i>Coracias benghalensis</i>)	Resident

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S.N.	Family/ Name of birds	Occurrence
Family: Upupidae		
104	Eurasian hoopoe (<i>Upupa epops</i>)	Resident
Family: Threskiornithidae		
105	White spoonbill (<i>Platalea aleucorodia</i>)	Winter bird

Monthly variation in diversity

Monthly fluctuations in biodiversity from November 2023 to May 2024 are summarized in the Table II. The number of individuals (N) and species richness (S) grew starting in November and reached a peak in January 2024 (74 species; 3562 individuals), suggesting the highest level of community complexity in the middle of winter. As a result of increased species diversity and decreased dominance, diversity indices like Shannon (H') and Simpson (1-D) also peaked in December-January (Fig. 1A). The species richness, abundance, and diversity indices gradually decreased after January, peaking in May 2024. Despite seasonal variations in richness and abundance, evenness (E) stayed reasonably high during the study period (0.78–0.88), indicating a highly uniform distribution of individuals among species.

Table II. Monthly variation in species richness, abundance, and diversity indices at Rasul Barrage.

Month	Species richness (S)	Individuals (N)	Shannon (H')	Simpson (1-D)	Evenness (E)
Nov 2023	64	2850	3.41	0.44	0.82
Dec 2023	72	3210	3.56	0.47	0.83
Jan 2024	74	3562	3.58	0.46	0.83
Feb 2024	69	2941	3.42	0.45	0.81
Mar 2024	58	2142	3.16	0.39	0.78
Apr 2024	53	1590	3.02	0.36	0.76
May 2024	49	1574	2.98	0.34	0.77

Table III shows combined values of Shannon's diversity index (H'), Simpson's diversity index (1-D), and Evenness (E) recorded at four study sites of Rasul Barrage from November 2023 to May 2024. The results indicate that Site 1 (Old Rasul Barrage) consistently exhibited comparatively higher Shannon's diversity values during the initial months, whereas the lowest values were observed at Site 4 (Heaven View Lake) throughout the study period. Simpson's diversity index similarly reflected greater avifaunal diversity Sites 2 and 3, while reduced values were noted at Site 4, suggesting limited species

heterogeneity. Evenness values varied among months, with relatively higher values at Sites 2 and 3, representing a more equitable distribution of species, in contrast to the lower values at Sites 1 and 4, where dominance of certain species was evident. Overall, the combined indices highlight that avian diversity was greater during the winter months and declined gradually toward late spring and early summer, demonstrating both seasonal variation and site-specific differences in the avifaunal community structure of Rasul Barrage.

Table III. Diversity Indices (Nov 2023 – May 2024).

	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Mar 2024	Apr 2024	May 2024
Shannon Index (H')							
Site 1	3.35	3.45	3.50	3.30	3.05	2.90	2.85
Site 2	3.10	3.20	3.25	3.05	2.80	2.65	2.60
Site 3	2.95	3.05	3.10	2.90	2.65	2.50	2.45
Site 4	2.75	2.85	2.90	2.70	2.45	2.30	2.20
Simpson index (1-D)							
Site 1	0.80	0.82	0.83	0.79	0.74	0.72	0.70
Site 2	0.76	0.78	0.79	0.75	0.70	0.68	0.66
Site 3	0.72	0.74	0.75	0.71	0.66	0.64	0.62
Site 4	0.68	0.70	0.71	0.67	0.62	0.60	0.58
Evenness index (E)							
Site 1	0.84	0.86	0.87	0.83	0.79	0.76	0.75
Site 2	0.81	0.83	0.84	0.80	0.76	0.73	0.72
Site 3	0.78	0.80	0.81	0.77	0.73	0.70	0.69
Site 4	0.74	0.76	0.77	0.73	0.69	0.66	0.64

Site-wise species distribution

Examination of the transect data shows that people are not evenly distributed over the surveyed area, but were instead unevenly spread with varying degrees of density. Transect TP2 had the highest abundance with 6,421 individuals being 32.3% of the total population observed. In addition, transect TP3 also showed high densities with 6,028 individuals (30.4% of the total). By contrast, Transect TP1 (4,315 individuals; 21.7%) and particularly Transect TP4 (3,105 individuals; 15.6%) had much lower counts. This clumped nature of spatial heterogeneity in the transition zone, is due to potential modifier factors such as environmental gradients or differences in resources available among different locations across the transect (Table IV, Fig. 1B).

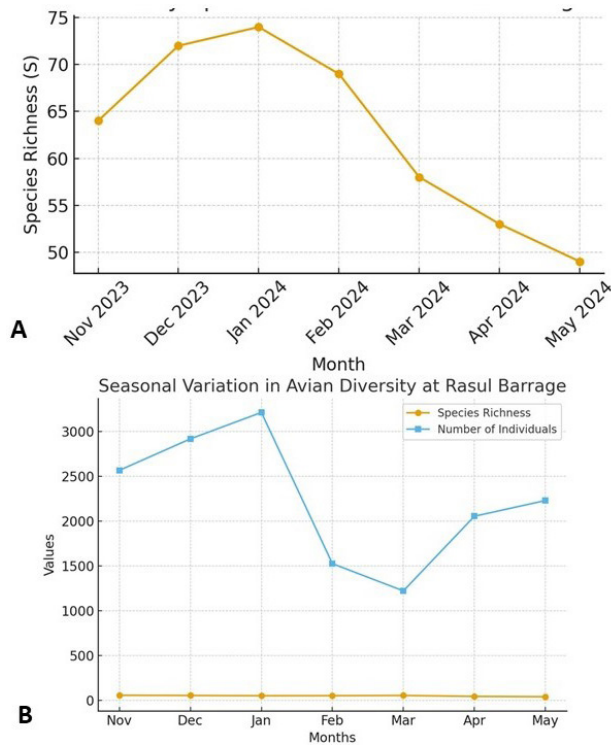


Fig. 1. A: Monthly species richness, recorded individual by transects. B: Seasonal variation in avian diversity at Rasul Barrage.

A total of 2,865 Northern Shovelers were counted, making them the single most common species in this sample of 20,000 birds. At 14.4%, they made up nearly 2/5 of all birds identified during the 2019 study. The second most common bird species identified was the common teal (*Anas crecca*) at 12.2% (2,421 birds), followed closely by the Eurasian coot (*Fulica atra*) with 11.6% (2,310 birds). Northern pintails and Gadwalls had significant populations with 9.5% (1,790 birds) and 6.6% (1,323 birds), respectively, while mallards comprised 6.1% (1,209 birds). In addition to these high density species, there were a number of lower density species, such as the little cormorant (*Phalacrocorax niger*), the black-headed gull (*Chroicocephalus ridibundus*), the Indian pond heron (*Ardeola grayii*), and the purple swamphen (*Porphyrio porphyrio*), which each represent between 3.8% and 4.7% of the total population. The composition of the population suggests a habitat that favors foraging in shallow waters as well as supports many generalist wetland species (Table IV).

Seasonal comparison

Seasonal analysis indicated that winter (Nov–Feb) supported higher diversity and abundance than summer

(Mar–May). Winter contributed 71% of total individuals, dominated by migratory waterfowl, while summer was dominated by resident species such as herons, egrets, and passerines. Graphical representation (Fig. 1B) shows a sharp decline in bird abundance after February, reflecting the migration of Palearctic species back to their breeding grounds.

Table IV. Site-wise and species-wise bird abundance at Rasul Barrage.

Transect	Individuals recorded	% of total
Site-wise abundance		
TP1	4315	21.7%
TP2	6421	32.3%
TP3	6028	30.3%
TP4	3105	15.6%
Total	19,869	100%
Species recorded		
Northern shoveler	2865	14.4
Common teal	2421	12.2
Eurasian coot	2310	11.6
Northern pintail	1884	9.5
Gadwall	1322	6.6
Mallard	1208	6.1
Little cormorant	940	4.7
Black-headed gull	815	4.1
Indian pond heron	795	4.0
Purple swamphen	761	3.8

TP, transect

DISCUSSION

Pakistan serves as an important wintering and breeding ground for many migratory birds, with its trees, orchards, and grasslands providing essential resources. However, over-hunting of species like Dalmatian pelicans, black-headed ibises, painted storks, geese, coots, and ducks, along with deforestation, overgrazing, and habitat degradation, has caused population declines (Khan *et al.*, 2014, Khan and Ali, 2015).

Landscape and wetland feature strongly influence bird diversity and distribution. While large-scale forest conservation is important, small wetlands and green spaces also play a vital role, particularly in retaining water during summer and supporting resident species like woodpeckers and ducks (Khan *et al.*, 2020; Roberts, 1991). Human activities such as grazing, urbanization,

agricultural expansion, and habitat disturbance further threaten avifauna.

The study recorded 105 species across 14 orders and 30 families at Rasul Barrage. Shannon-Weiner diversity (H') ranged from 2.98 to 3.58, comparable to Taunsa Barrage ($H' = 3.18\text{--}3.98$) and higher than Uchalli Wetland ($H' = 2.99$) (Ali *et al.*, 2022). Simpson index (D) ranged 0.34–0.47, lower than Uchalli and Jahlar ($D = 0.93$), likely due to habitat degradation, while evenness (0.78–0.88) indicated a relatively balanced species distribution (Alam *et al.*, 2023).

The abundance of resident species such as house crow (*Corvus splendens*), common myna (*Acridotheres tristis*), house sparrow (*Passer domesticus*), and blue rock pigeon (*Columba livia*) reflects a globally recognized pattern of the success of synanthropic bird communities in urbanized habitats. Research conducted by Ali *et al.* (2023) confirmed that these generalist species thrive in habitats that are being increasingly modified and created. These species take advantage of a homogenized environment, as well as resources supplied through an urban ecosystem, which negatively impacts the populations of specialist birds (Bibi and Ali, 2013). Additionally, the large number of resident raptors that inhabit the site (black-shouldered kite, common kestrel, shikra) indicates that the local ecosystems are operating with the functional food webs that can support apex predators, which is consistent with previous research that identified the ecological importance of heterogeneous agricultural and wetland mosaics (Altaf *et al.*, 2018).

However, the most influential ecological factor is the large number of waterbirds, particularly members of the family Anatidae (ducks and geese), that visit the area in the winter months. The presence of many different species of dabbling ducks (e.g., Northern pintail, common teal, gadwall, Eurasian wigeon), diving ducks (e.g., common pochard, tufted duck), and geese (bar-headed goose, greylag goose) indicates the importance of the site as a wintering area. This is supported by satellite telemetry studies that demonstrate the role of the South Asian wetland network within the Central Asian Flyway (Bauer, 2018). *Anser indicus* is an intended avian species, while *Aythya ferina* is a threatened aquatic species, and their distributions in this region highlight the conservation value of this habitat (Ambrosini *et al.*, 2023). The diversity of bird species found within the location, both waders (i.e. sandpipers, greenshanks, stilts) and other waterbirds (i.e. coots, swamphen, herons), indicates that the wetland habitat provides multiple foraging options (i.e. shallow water, mudflats, reedbeds), a key factor supporting a high level of avian diversity (Ashraf *et al.*, 2019; Ayejoto *et al.*, 2023).

In addition, the presence of both Palaearctic (e.g.

European bee-eater, short-eared owl) and oriental resident species forms a unique ecotonal community; an area that is quickly becoming recognized as a biodiversity hotspot, as well as a potential for range shifts due to climate change (Braulik *et al.*, 2014). Continued study of the residency status of certain migratory species on this list may provide insight into the potential for partial migrations and the possibility of changes in phenology as a result of climate warming, which has become increasingly documented in the literature (Bilal *et al.*, 2021; Fatima *et al.*, 2024).

The avifauna of the area has two different characters a resident community that has adapted to living in areas developed by humans and a diverse population of seasonal migratory birds that represents this site as being internationally significant within the Central Asia flyway. To effectively conserve the migratory species and their habitats, wetland habitats must be maintained by preserving their hydrological integrity and maintaining multiple types of wetlands; wetland conservation will also require consideration of the surrounding landscape to meet the needs of both synanthropic birds and more sensitive resident birds. Dominant species included American coot, black partridge, and grey partridge ($RA = 5.84$), followed by ring dove (3.31) and shoveler (1.94), reflecting favorable habitat conditions. Seasonal patterns showed higher diversity and abundance in winter, highlighting the importance of Rasul Barrage as a habitat along migratory flyways (Chakroborty *et al.*, 2023).

While spatially heterogeneous (areas with a high concentration of waterbirds), the majority of the waterbirds were located in transect points TP2 (32.3%) and TP3 (30.4%), while the densest concentration of birds was found at the lowest density in transect point TP4 (15.6%). The lower number of birds in TP4 may indicate that this area does not support conditions optimal for the location of waterbirds; possibly due to factors such as the depth of the water, structure of the vegetation, and the level of disturbance (factors that have been observed in many wetland mosaic studies). The species composition within the area shows that the majority of the birds were dabbling ducks, close to 49% of the total number of birds observed in the area were dabbling ducks, with the two most notable species being the northern shoveler (14.4%) and common teal (12.2%). This abundance of dabbling ducks is indicative of highly productive shallow water wetlands that are abundant in submerged aquatic vegetation and invertebrate species, consistent with previously established foraging ecological literature. Also noteworthy was the abundance of Eurasian coots (11.6%) within the system; the co-dominance of this herbivorous generalist species suggests the system likely has an abundant resource (Chowdhury *et al.*, 2020).

There were fewer piscivorous (e.g. little cormorant)

and opportunistic (e.g., black-headed gull) species present, suggesting that the trophic structure of the community may be one where primary consumer (e.g. dabbling ducks) are disproportionately supported. The synthesis of the transects and species data imply that while TP2 and TP3 represent core habitats for these dabbling duck species, as indicated by the distribution of birds along the transects, the clumped distribution of those birds is indicative of the availability of habitat types within a larger area; thereby indicating the importance of habitat heterogeneity in determining abundance and composition of wetland birds (Cooke *et al.*, 2024).

Comparisons with Taunsa Barrage ($H' = 3.18$ – 3.98) and Head Khanki ($H' = 2.64$) confirm its regional significance (Cote *et al.*, 2017). Despite threats from pollution, deforestation, climate change, and invasive species, ongoing conservation efforts show progress. Continued research and management are essential to preserve this wetland's rich avifaunal diversity.

CONCLUSION

The data on bird diversity from the study area revealed a total of 105 species belonging to 30 families and 14 orders. Evaluation of bird populations in District Mandi Bahauddin indicates that the site holds high conservation value. Bird abundance varied across different land-use categories, with increased land-use intensity negatively affecting diversity. Vegetation was found to play a key role in shaping bird community composition and density. Birds contribute significantly to ecological balance, yet their diversity is threatened by habitat degradation, climate change, population pressures, and invasive species. Therefore, conserving avian species requires protecting and restoring habitats, reducing human-induced threats, managing invasive species, monitoring populations, and raising awareness among local communities. Such measures are essential to maintain bird diversity and ensure their survival for future generations.

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Data availability

All data generated or analyzed during this study are included in this published article.

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The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

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