Research Article

Assessment of Avian Assemblage from different Microhabitats in Bajwat Wetland, Punjab, Pakistan

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Abstract | The loss and degradation of wetland habitats have posed a serious threat to bird biodiversity, especially in regions where ecological data is scarce. Bajwat Wetland (32°41'04.0"N, 74°32'43.1"E), covering 14,319 acres in northern Sialkot District, Punjab, Pakistan, is a biologically rich but understudied area. This wetland features a network of complex microhabitats supported by the River Chenab and its tributaries, providing essential resources that attract and sustain diverse bird populations. From August 2021 to October 2023, surveys were conducted using total count and block count methods, supported by standard field guides for species identification. This study aimed to document migratory and resident bird species by analyzing their habitat preferences, feeding behaviors, migration patterns, and conservation status. A total of 130 bird species were recorded, representing 18 orders and 47 families. Of these, eight species were near threatened, four vulnerable, four endangered, and two critically endangered. The high diversity, including threatened and migratory species, highlights the ecological significance of Bajwat Wetland as a critical refuge for avian biodiversity. This study provides a foundational dataset that can inform future conservation strategies in the region.

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Introduction

Over 790 bird species have been recorded in Pakistan, and their dispersal across three zoogeographical zones (Ethiopian, Palearctic, and Oriental) is unique worldwide. Every year, thousands of migratory birds arrive from different parts of the world. There are seven flyways globally, including one in Pa-

kistan known as the Indus flyway a species rich route hosting millions of migratory and resident birds (Pakistan M.T.F, 2016). Bajwat, located in the Sialkot district of Punjab, Pakistan, covers 48,068 acres, of which 14,319 acres were declared a Wildlife Reserve and wetland in January 2022 under Section 12 of the Punjab Protected Areas Act 2020. The area is 800 feet above sea level and is categorized as sub-mountainous, with non-calcareous, loamy soil and a sub-tropical to tropical climate with an average rainfall of 965 mm (Qazi *et al.*, 2000). Bajwat is of global wetland importance due to its complex riverine network and freshwater habitats formed by the Chenab River and its tributaries, extending to the Indian border. These features provide vital breeding, staging, and wintering grounds for a wide range of migratory and resident birds.

Birds are among the most widespread and ecologically important organisms on the planet. They inhabit diverse environments and play crucial ecological roles as pollinators, scavengers, predators, and seed dispersers (Whelan *et al.*, 2008; Tandan *et al.*, 2015). The Indian subcontinent hosts about 1,340 bird species more than 13% of global avian diversity (Singh *et al.*, 2020). Due to their high sensitivity to environmental changes, birds are considered excellent bioindicators for assessing habitat quality and ecosystem health (Egwumah *et al.*, 2017; Huang *et al.*, 2023). Pakistan is home to 225 nationally important wetlands, with 19 recognized as Ramsar sites. These wetlands cover about 780,000 hectares (Chaudhry, 2010) and provide critical habitats for migratory birds, especially along the Central Asian flyway. Migrants such as Mallards, Cranes, and Pelicans rely on Pakistan's wetlands for wintering and staging (Ali, 2015;Dawn, 2016; Express Tribune, 2016). However, the number of visiting bird species is steadily declining, primarily due to human activities and habitat degradation (Hu *et al.*, 2011; Aarif *et al.*, 2014).

Despite the global and national significance of these migratory routes and wetland ecosystems, very few studies have focused on the avian diversity of northern Punjab, especially in the Bajwat Wetland. While some national bird checklists exist, there is a notable lack of localized, habitat specific, and conservation-focused data from this region (William *et al.*, 2024). This study fills that gap by providing the first comprehensive checklist of bird species from the Bajwat Wetland, along with insights into their preferred habitats, feeding and migratory patterns, and conservation status. The Bajwat Wetland, due to its variety of microhabitats and abundant food supply, presents an ideal site for such ecological assessments. This research not only contributes baseline ecological data but also offers practical guidance for future conservation planning in one of Pakistan's lesser-studied but ecologically valuable wetland ecosystems.

Material and methods

Study area

Bajwat wetland (32°41'04.0N" 74°32'43.1"E) is an important wetland which encompasses complex small freshwater streams along with River Chenab and its two tributaries (Jammu Tavi River and Manawarwala Tavi River) expending up to the border of India (Figure 1). The wetland covers an area of 14319 acres and is located in Sialkot district, Punjab, Pakistan. The research area is also a part of the well-known water regulating structure known as Marala Barrage and Headworks situated on the River Chenab. Being a significant wetland, it provides a unique refuge for many migratory and residential avian species and also provides socio-economic services such as tourism and fishing. This unique area features a wide variety of habitats such as freshwater swamps, wetland, Rivers, freshwater stream systems, forests, and grassl and (Bhatti *et al.*, 2019).

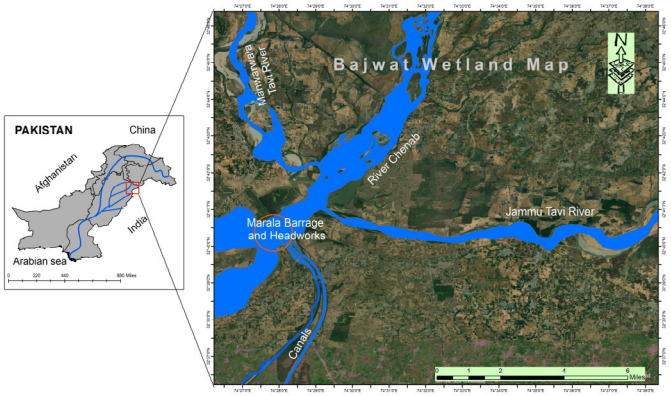

Figure 1: *Map of the study area Bajwat wetland.*

Bird survey

To develop the scientific background of the avian assemblages, surveys were conducted in the study area from August 2021 to October 2023 covering the wide regional periods of winter, summer, and monsoon season. Bimonthly surveys were conducted in the entire wetland area for the assessment of avian assemblage

structure using boats, 10×42 mm Olympus binoculars, and a Nikon spotting scope (20×50 mm). Bird species were identified in the field using a field guide (Kumar *et al.*, 2005; Grimmett *et al.*, 2016). MS Excel 2016 was used to perform the data analysis. Counts of birds were made during the early morning (5:00 to 10:00 hrs) as this is the most suitable time when birds are more active (William *et al.*, 2014). The survey began near the areas of the River and the whole wetland was covered along the water edges using a boat with minimum disruption. During the survey, appropriate measures were taken to count the bird species only once. For the estimation of the bird population, the block and total count method was applied (Howes and Bakewell, 1989). A suitable vantage point from a fixed area in the total count method was selected in the study region to count all the birds. Furthermore, the block count method was also applied to estimate the single species flock.

Data analysis

Based on the seasonality of movement and occurrence in the study region the bird species were classified into Resident (R) species observed during the whole year, Winter Visitor (WV) species observed in the winter season, Summer Visitor (SV) species observed in the summer season, and Monsoon Visitor (MV). Similarly based on the possibility of spotting in different habitats of the research region at any certain time, the bird species were counted as Abundant (AB) spotted on nine to ten out of ten surveys, Common (C) spotted on six to eight out of ten surveys, Occasional (O) spotted on three to five out of ten surveys, and Rare (R) spotted on less than two out of ten surveys.

For the evaluation of different influencing aspects on the species priority, threatened bird species were identified in the current study according to the IUCN Red List category. It comprises Least concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), and Critically Endangered (CR).

Different bird species prefer and occupy various microhabitats for breeding and feeding purposes in the study area. These microhabitats in the study region include Forest (F), Marshes (M), Aerial (A), Grassland (GL), Shallow waters (SW), Open waters (OW), and Water edges (WE).

Relative diversity (RDi) is used to calculate the percentage of the total species within a family to the total number of species by using the following formula (Koli 2014).

$$RDi = \frac{\text{Number of species in family}}{\text{Total number of species}} \times 100$$

Species richness (S) refers to the number of species in a specific area. Total number of species = Richness (S).

Furthermore to understand the temporal and seasonal patterns in bird abundance, a Two-Way Repeated Measures ANOVA was conducted. This analysis revealed statistically significant differences in bird populations across different seasons and survey periods, highlighting clear trends in their distribution over time.

Results

Avian assemblage and relative abundance

A total of 130 bird species belonging to 18 orders and 47 families were reported during the present research from the Bajwat wetland. Family Anatidae was the dominant family in the study area encompassing the highest number of bird species (16), followed by Scolopacidae (8), and Accipitridae (6). In Bajwat wetland, Passeriformes (42 species, 18 families) was the leading order followed by Charadriiformes (18 species, 7 families), Anseriformes (16 species in a single family), Pelecaniformes (8 species, 2 families), Coraciiformes (7 species, 4 families), Accipitriformes (6 species in a single family), Columbiformes and Cuculiformes (each order in a single family and 5 species), Suliformes (3 species and 2 families), Ciconiiformes, Gruiformes, and Strigiformes (each order having 3 species and 1 family), Galliformes, Psittaciformes, and Piciformes (each order having 2 species in a single family), Caprimulgiformes, Upupiformes, and Podicipediformes (each order having 1 species and 1 family). A comprehensive checklist of avian species recorded from the Bajwat wetland and their common names, scientific names, migratory status, and IUCN status are shown in Table 1.

Figure 2 illustrates the relative abundance of bird species in the research area. During the current survey, 23 species of birds (17.7%) were abundant, 54 species (41.5%) were common, 34 species (26.2%) were occasional and 19 species (14.6%) *Aythya nyroca, Oxyura leucocephala, Aythya ferina, Haliaeetus leucoryphus, Gyps indiucs, Ciconia nigra, Vanellus gregarious,*

Table 1: *Checklist of Birds recorded from Bajwat wetland.*

	Order	Common name	Scientific name	Migratory Status	Microhabitat usage	IUCN status	Relative abundance
	Anseriformes	Anatidae					
1		Marbled Teal	*Marmaronetta angustirostris*	R	OW,SW	VU	O
2		Ferruginous Pochard	*Aythya nyroca*	WV	OW,SW	NT	R
3		White-headed duck	*Oxyura leucocephala*	WV	SW	EN	R
4		Gadwall	*Anas strepera*	WV	SW	LC	C
5		Mallard	*Anas platyrhynchos*	WV	OW,SW	LC	AB
6		Common Teal	*Anas crecca*	WV	OW	LC	C
7		Ruddy shelduck	*Tadornaferruginea*	WV	OW	LC	AB
8		Shoveler	*Anas clypeata*	WV	SW	LC	O
9		Common pochard	*Aythya ferina*	WV	OW,SW	VU	R
10		Northern pintail	*Anas acuta*	WV	OW,SW	LC	O
11		Bar-headed goose	*Anser indicus*	WV	OW	LC	C
12		Common shelduck	*Tadorna tadorna*	WV	OW,SW	LC	O
13		Spot-billed duck	*Anas poecilorhyncha*	SV	SW	LC	O
14		Eurasian wigeon	*Anas penelope*	WV	SW	LC	C
15		Gargany	*Anas querquedula*	WV	SW	LC	AB
16		Tufted duck	*Aythya fuligula*	WV	SW	LC	C
	Accipitriformes	Accipitridae					
17		Blacked winged kite	*Elanus caeruleus*	R	A	LC	O
18		Shikra	*Accipiter badius*	R	A	LC	O
19		Pallas's fish eagle	*Haliaeetus leucoryphus*	R	A	EN	R
20		Long billed vulture	*Gyps indiucs*	R	A	CR	R
21		Pariha kite	*Milvus migrans*	R	A	LC	C
22		Tawny eagle		R	A	LC	O
	Caprimulgiformes	Apodidae					
23		Little swift	*Apus affinis*	R	A	LC	O
	Coraciiformes	Alcedinidae					
24		Pied kingfisher	*Ceryle rudis*	R	A	LC	AB
25		White breasted king-fisher	*Halcyon smyrnensis*	R	A	LC	AB
26		Common kingfisher	*Alcedo atthis*	R	A	LC	O
		Meropidae					
27		Little green bee-eater	*Merops orientalis*	SV	F	LC	C
28		Blue cheeked bee-eater	*Merops superciliosus*	SV	F	LC	C
		Coraciidae					
29		Indian roller	*Coracias benghalensis*	R	F	LC	C
	Upupiformes	Upupidae					
30		Hoopoe	*Upupa epops*	R	F	LC	O
	Ciconiiformes	Ciconiidae					
31		Painted stork	*Mycteria leucocephala*	WV	WE,SW,M	LC	C
32		Black necked stork	*Ephippiorhynchus asiaticus*	R	WE,SW,M	NT	O
33		Black stork	*Ciconia nigra*	WV	SW,WE	LC	R
	Charadriiformes	Charadriidae					
34		Social lapwing	*Vanellus gregarius*	WV	WE,GL	CR	R
35		Northern lapwing	*Vanellus vanellus*	WV	WE,GL	NT	R

36		Red wattled lapwing	*Vanellus indicus*	R	WE,GL	LC	AB
		Jacanidae					
37		Pheasant tailed jacana	*Hydrophasianus chirurgus*	SV	SW,WE	LC	O
		Scolopacidae					
38		Little stint	*Calidris minuta*	WV	SW,WE	LC	O
39		Common redshank	*Tringa totanus*	WV	SW,WE	LC	C
40		Eurasian curlew	*Numenius arquata*	WV	SW,WE	NT	C
41		Common snipe	*Gallinago gallinago*	WV	SW,WE	LC	C
42		Common greenshank	*Tringa nebularia*	WV	SW,WE	LC	C
43		Black-tailed Godwit	*Limosa limosa*	WV	SW,WE	NT	R
44		Great knot	*Calidris tenuirostris*	WV	SW,WE	EN	R
45		Dunlin	*Calidris alpina*	WV	SW,WE	LC	O
		Recurvirostridae					
46		Black winged stilt	*Himantopus himantopus*	SV	SW,WE	LC	C
47		Pied Avocet	*Recurvirostra avosetta*	WV	SW,WE	LC	O
		Glareolidae					
48		Little pratincole	*Glareola lacteal*	SV	GL	LC	O
		Laridae					
49		Black headed gull	*Larus ridibundus*	WV	OW	LC	C
		Sternidae					
50		Black-bellied tern	*Sterna acuticauda*	R	A	EN	R
51		Indian river tern	*Sterna aurantia*	R	A	VU	R
	Columbiformes	Columbidae					
52		Spotted dove	*Streptopelia chinensis*	WV	F	LC	O
53		Eurasian collared dove	*Streptopelia decaocto*	R	F	LC	AB
54		Common pigeon	*Columba livia*	R	F	LC	C
55		Little brown dove	*Streptopelia senegalensis*	R	F	LC	AB
56		Red turtle dove	*Streptopelia tranquebarica*	SV	F	LC	C
	Cuculiformes	Cuculidae					
57		Greater coucal	*Centropus sinensis*	R	F	LC	AB
58		Koel	*Eudynamys colopacea*	SV	F	LC	C
59		Indian cuckoo	*Cuculus micropterus*	SV	F	LC	AB
60		Common Hawk-cuckoo	*Hierococcyx varius*	SV	F	LC	O
61		Jacobin cuckoo	*Clamator jacobinus*	MM	F	LC	R
	Galliformes	Phasianidae					
62		Grey partridge	*Francolinus pondicerianus*	R	F,GL	LC	AB
63		Black partridge	*Francolinus francolinus*	R	F	LC	R
	Gruiformes	Rallidae					
64		Common coot	*Fulic aatra*	WV	WE,SW,M	LC	O
65		Common moorhen	*Gallinulachloropus*	R	WE,SW,M	LC	C
66		White breasted water hen	*Amaurornisphoenicurus*	R	SW,M,F	LC	C
		Gruidae					
67		Sarus crane	*Grus antigone*	R	SW,M	VU	R
68		Common crane	*Grus grus*	WV	SW,M	LC	O
	Psittaciformes	Psittacidae					
69		Alexdrine parakeet	*Psittacula eupatria*	R	F	NT	R
70		Rose ringed parakeet	*Psittacula krameri*	R	F	LC	AB

	Piciformes	Picidae					
71		Mahratta woodpecker	*Dendrocopos mahrattensis*	R	F	LC	O
72		Black-rumped flame-back	*Dinopium benghalense*	R	F	LC	O
		Megalaimidae					
73		Coppersmith barbet	*Psilopogon haemacephalus*	R	F	LC	O
	Podicipediformes	Podicipedidae					
74		Little grebe	*Tachybaptus ruficollis*	R	OW	LC	O
	Pelecaniformes	Pelecanidae					
75		Dalmatian pelican	*Pelicanus crispus*	WV	OW	NT	R
		Ardeidae					
76		Great egret	*Ardea alba*	WV	WE,SW,M	LC	AB
77		Little egret	*Egretta garzetta*	R	SW,WE	LC	AB
78		Intermediate egret	*Egretta intermedia*	R	SW,M	LC	O
79		Cattle egret	*Bubulcus ibis*	R	WE,M	LC	C
80		Grey heron	*Ardea cinerea*	WV	WE,M	LC	O
81		Night heron	*Nycticorax nycticorax*	SV	WE,M	LC	C
82		Yellow bittern	*Ixobrychus sinensis*	R	WE,M	LC	C
	Passeriformes	Motacillidae					
83		White wagtail	*Motacilla alba*	R	WE,GL	LC	C
84		Yellow wagtail	*Motacilla flava*	WV	WE,GL	LC	C
85		Grey wagtail	*Motacilla cinerea*	WV	GL	LC	C
86		paddyfield pipit	*Anthus rufulus*	R	GL	LC	C
87		Large pied wagtail	*Motacilla maderaspatensis*	R	GL	LC	O
		Alaudidae					
88		Crested lark	*Galerida cristata*	R	F,GL	LC	C
89		Oriental skylark	*Alauda gulgula*	R	F,GL	LC	C
90		Eurasian skylark	*Alauda arvensis*	R	F,GL	LC	O
		Hirundinidae					
91		Wire tailed swallow	*Hirundo smithii*	SV	A	LC	C
92		House martin	*Delichon urbica*	SV	A	LC	C
93		Indian cliff swallow	*Hirundo fluvicola*	R	A	LC	AB
94		Sand martin	*Riparia paludicola*	R	A	LC	C
		Pycononotidae					
95		White cheeked bulbul	*Pycnonotus leucotis*	R	F	LC	C
96		Red vented bulbul	*Pycnonotus cafer*	R	F	LC	C
		Laniidae					
97		Bay backed shrike	*Lanius vittatus*	R	F	LC	C
98		Rufous backed shrike	*Lanius schach*	R	F	LC	C
		Turdidae					
99		Magpie robin	*Copsychus saularis*	R	F	LC	C
100		Pied bus chat	*Saxicola caprata*	R	F	LC	C
		Timaliidae					
101		Jungle babbler	*Turdoides striatus*	R	F	LC	C
102		Common babbler	*Turdoides caudatus*	R	F	LC	C
103		Large grey babbler	*Turdoides malcolmi*	R	F	LC	C
		Nectariniidae					
104		Purple sunbird	*Nectarinia asiatica*	SV	F	LC	O

		Estrildidae					
105		Scaly-breasted munia	*Lonchura punctulata*	R	F,GL	LC	O
		Ploceidae					
106		Streaked weaver	*Ploceus manyar*	R	F	LC	C
107		Baya weaver	*Ploceus philippinus*	R	F	LC	C
108		Black throated weaver	*Ploceus benghalensis*	R	F	LC	C
		Passeridae					
109		House sparrow	*Passer domesticus*	R	F	LC	AB
110		Yellow throated sparrow	*Petronia xanthocollis*	SV	F	LC	C
		Sturnidae					
111		Pied myna	*Sturnus contra*	SV	WE,F	LC	C
112		Bank myna	*Acridotheres ginginianus*	R	WE,F	LC	C
113		Common myna	*Acridotheres tristis*	R	WE,F	LC	AB
114		Barhamny myna	*Sturnus pagodarum*	SV	F	LC	R
		Oriolidae					
115		Golden oriole	*Oriolus oriolus*	SV	F	LC	O
		Corviidae					
116		Jungle crow	*Corvus macrorhynchos*	WV	F	LC	C
117		House crow	*Corvus splendens*	R	F	LC	AB
118		Rook	*Corvus frugilegus*	WV	F	LC	C
119		Rufous treepie	*Dendrocitta vagabunda*	R	F	LC	C
120		Black-headed jay	*Garrulus lanceolatus*	R	F	LC	C
		Dicruridae					
121		Black drongo	*Dicrurus macrocercus*	R	A	LC	AB
		Cisticolidae					
122		Ashy prinia	*Prinia socialis*	R	F,GL	LC	AB
		Muscicapidae					
123		Brown rock chat	*Oenanthe fusca*	R	F,GL	LC	AB
		Paridae					
124		Great tit	*Parus major*	WV	F,GL	LC	O
	Strigiformes	Strigidae					
125		Little owl	*Athene noctua*	R	F	LC	O
126		Tawny owl	*Strix aluco*	R	F	LC	C
127		Barn owl	*Tyto alba*	R	F	LC	C
	Suliformes	Anhingidae					
128		Oriental darter	*Anhinga melanogaster*	R	WE,SW,M	NT	R
		Phalacrocoridae					
129		Little cormorant	*Phalacrocorax niger*	R	OW	LC	AB
130		Great cormorant	*Phalacrocorax carbo*	WV	OW	LC	AB

R = Resident, WV = Winter visitor, SV = Summer visitor, LC = Least concern, NT = Near threatened, VU=Vulnerable, EN=Endangered, CR=Critically endangered, O=Occasional, AB=Abundant, R=Rare, C=Common, WE=Water edge, F=Forest, SW=Shallow water, OW=Open water, M=Marshes, GL=Grassland, A=Aerial,

Vanellus vanellus, Limosa limosa, Calidris tenuirostris, Sterna acuticauda, Sterna aurantia, Clamator jacobinus, Francolinus francolinus, Grus antigone, Psittacula eupatria, Pelicanus crispus, Sturnus pagodarum, Anhinga melanogaster were recorded as rare.

Relative diversity

In the Bajwat wetland, the family Anatidae of order Anseriformes with RDi of 12.30% was the leading and diverse family, followed by Scolopacidae with 6.15%, Ardeidae, 5.38%, and Accipitridae with 4.61%.

Families Columbidae, Cuculidae, Motacillidae, and Corviidae showed 3.84% while Hirundinidae, and Sturnidae families represented 3.07% whereas families Alcedinidae, Ciconiidae, Charadriidae, Alaudidae, Timaliidae, Ploceidae, and Strigidae were recorded with 2.30% RDi. Meropidae, Recurvirostridae, Sternidae, Phasianidae, Rallidae, Gruidae, Psittacidae, Picidae, Pycononotidae, Laniidae, Turdidae, Passeridae, and Phalacrocoridae reported with 1.53%. Apodidae, Upupidae, Coraciidae, Jacanidae, Glareolidae, Laridae, Megalaimidae, Podicipedidae, Pelecanidae, Nectariniidae, Estrildidae, Oriolidae, Dicruridae, Cisticolidae, Muscicapidae, Paridae, and Anhingidae were the least recorded families with 0.7%. (Table 2).

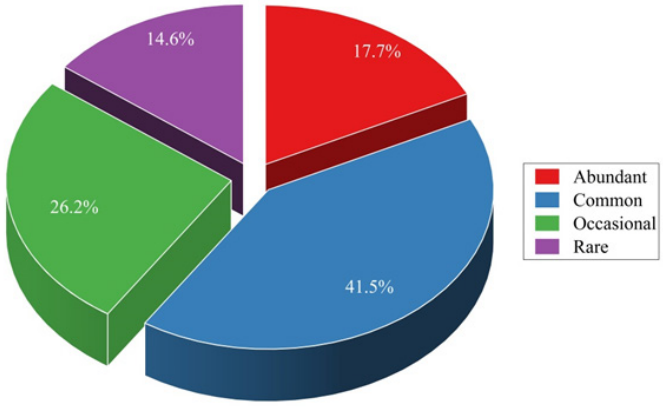

Figure 2: *Proportional representation of species based on abundance categories. 'Common' species constituted the largest group (41.5%), followed by 'Occasional' (26.2%), 'Abundant' (17.7%), and 'Rare' species (14.6%), reflecting a moderately diverse assemblage with a notable presence of less frequently observed taxa.*

Table 2: *Relative diversity (RDi) of different Avifaunal families from different microhabitats in Bajwat wetland.*

Sr #	Families	Relative diversity (RDi)
1	Anatidae	12.30
2	Accipitridae	4.61
3	Apodidae	0.7
4	Alcedinidae	2.30
5	Meropidae	1.53
6	Upupidae	1.53
7	Coraciidae	1.53
8	Ciconiidae	2.30
9	Charadriidae	2.30
10	Jacanidae	0.7
11	Scolopacidae	6.15
12	Recurvirostridae	1.53
13	Glareolidae	0.7
14	Laridae	0.7
15	Sternidae	1.53
16	Columbidae	3.84
17	Cuculidae	3.84
18	Phasianidae	1.53
19	Rallidae	1.53
20	Gruidae	1.53
21	Psittacidae	1.53
22	Picidae	1.53
23	Megalaimidae	0.7
24	Podicipedidae	0.7
25	Pelecanidae	0.7
26	Ardeidae	5.38
27	Motacillidae	3.84
28	Alaudidae	2.30
29	Hirundinidae	3.07
30	Pycononotidae	1.53
31	Laniidae	1.53
32	Turdidae	1.53
33	Timaliidae	2.30
34	Nectariniidae	0.7
35	Estrildidae	0.7
36	Ploceidae	2.30
37	Passeridae	1.53
38	Sturnidae	3.07
39	Oriolidae	0.7
40	Corviidae	3.84
41	Dicruridae	0.7
42	Cisticolidae	0.7
43	Muscicapidae	0.7
44	Paridae	0.7
45	Strigidae	2.30
46	Anhingidae	0.7
47	Phalacrocoridae	1.53

Species richness assessment

According to a recent assessment it was found that the habitat type, food availability, year, and season significantly affect the sustainability of the avian assemblages in the Bajwat wetland. The seasons were classified into three categories in the study area viz pre-migratory season (April to August), migratory (September to December), and post-migratory (January to March). It was found that the post-migratory season had the maximum species richness (assessment I = 130, assessment II = 126) and migratory season (assessment I = 114, assessment II 122) in both years (Figure 3).

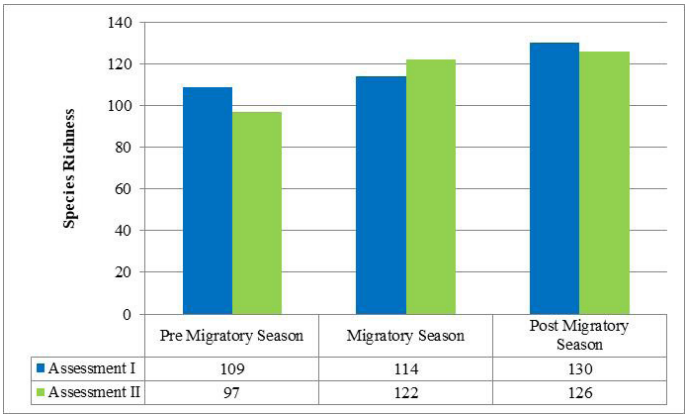

Figure 3: *Seasonal variation of bird species recorded during 2021 to 2023 in the study area (Assessment I = 2021–2022, Assessment II = 2022–2023). Species richness increased from the pre-migratory to the post-migratory season in both assessments, with the highest richness observed during the post-migratory phase (130 in Assessment I and 126 in Assessment II), indicating notable seasonal turnover and enhanced habitat suitability during this period.*

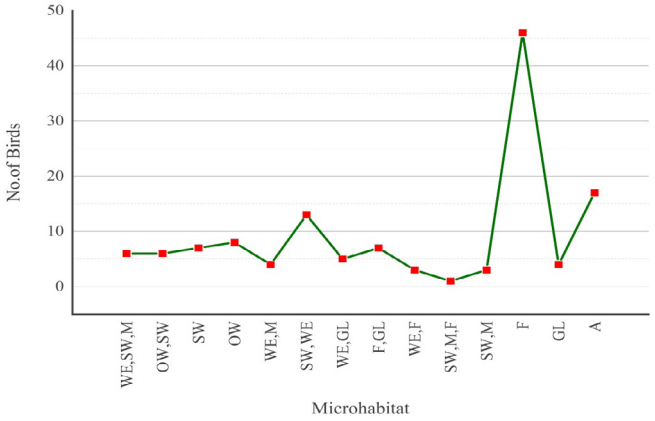

Figure 4: *Bird abundance across different microhabitats recorded during the study period. A sharp peak in the number of individuals was observed in forested habitats (F), indicating their high ecological value and structural complexity in supporting avian diversity. Comparatively lower bird counts in mixed and transitional habitats suggest limited suitability or lower habitat specialization for many species. (WE, Water edge; SW, Shallow water; OW, Open water; M, Marshes; GL, Grassland; A, Aerial; F, Forest).*

Microhabitats and migratory status

The study area is associated with three major rivers (Chenab River, Jammu Tavi, and Manawarwala) and is characterized by spatially isolated heterogeneous microhabitats. The study region is mainly comprised of seven different microhabitats such as Open waters, Shallow waters, Water edge, Forest, Marshes, Aerial, and Grassland. Results of the current study showed that out of 130 species, 46 bird species solely utilize the forest habitat for breeding and feeding. Whereas 17 species use aerial habitat, and 13 species use shallow waters and water edges. Many avian species require a wide range of habitats. Shorebirds utilize most of the microhabitats in study region such as shallow waters, water edges, and marshes. Many species utilize forests while some species are favored by grasslands owing to the availability and abundance of food sources (Figure 4).

The present study showed that out of 130 species, 54.61% (n = 71) species were residents recorded in the Bajwat wetland while the remaining 45% (n = 59) were seasonal migrant species; in which 30.76% (n = 40) were winter migrants which were spotted from November to March whereas 14.61% (n =19) were summer visitor and were observed during May and June. Only one species *Clamator jacobinus* with 0.76% (n = 1) was monsoon migrant (Figure 5).

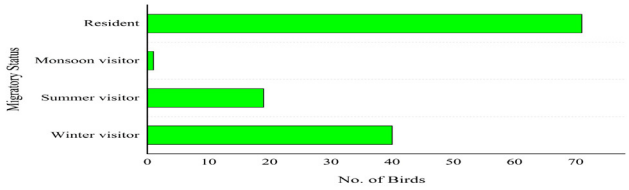

Figure 5: Migratory status of bird species recorded in the study area. *Resident species were most abundant, followed by winter visitors, summer visitors, and a very small number of monsoon visitors, highlighting the area's importance for both permanent and seasonal bird populations.*

Conservation profile of avian species based on IUCN categories

Results of the current study showed that 112 bird species are least concern in the study area. Eighteen species were identified as near threatened, vulnerable, endangered, and critically endangered; most of these species have restricted distribution and limited numbers. Eight species *Aythya nyroca, Ephippiorhynchus asiaticus, Vanellus vanellus, Numenius arquata, Limosa limosa, Psittacula eupatria, Pelicanus crispus,* and *Anhinga melanogaster* were categorized as near threatened, four species *Marmaronetta angustirostris, Aythya ferina, Sterna aurantia,* and *Grus antigone* were listed as vulnerable, four species *Oxyura leucocephala, Hali-*

aeetus leucoryphus, Calidris tenuirostris, and *Sterna acuticauda* were endangered while two species *Gyps indiucs,* and *Vanellus gregarious* were reported as critically endangered species. Three species *Vanellus gregarious*, *Oxyura leucocephala,* and *Gyps indiucs* were very low and needed immediate conservation measures and attention. According to the IUCN Red List 2023 one species painted stork *Mycteria leucocephala* is listed as the least concern species in July 2023 (IUCN 2023) as this species was previously listed as near threatened.

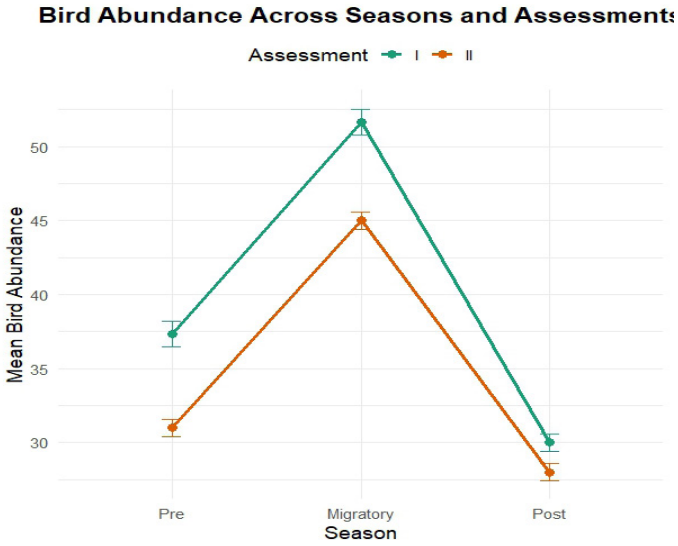

Figure 6: *Mean bird abundance (± SE) across three seasonal phases (Pre Migratory, Migratory, and Post Migratory) for two assessment periods (I and II). A Two-Way Repeated Measures ANOVA revealed significant effects of both Season and Assessment on bird abundance. Abundance was highest during the migratory season and consistently greater in Assessment I compared to Assessment II, indicating temporal shifts in bird activity likely linked to migration dynamics.*

Seasonal dynamics and temporal variation in bird abundance

The Figure 6 presents a clear and ecologically meaningful pattern of bird abundance across three seasonal phases Pre-migratory, Migratory, and Post-migratory over two separate assessment periods. The data reveal a marked increase in bird abundance during the migratory season in both assessments, indicating that the study area functions as an important migratory habitat, likely offering key ecological resources such as foraging opportunities, resting sites, and favorable microclimates. This peak highlights the critical role of the landscape in supporting seasonal bird movements and maintaining regional avian diversity. A Two-Way Repeated Measures ANOVA confirmed that both season and assessment period had statistically significant effects on bird abundance. The seasonal effect reinforces the biological expectation that bird populations fluctuate in response to migration cycles, while the consistent difference between assessments where Assessment I showed higher abundance than Assessment II suggests potential temporal shifts in habitat suitability or broader ecological conditions over time. These differences could be attributed to climate variability, anthropogenic disturbances, land use change, or other environmental stressors that may have reduced the area's capacity to support large bird populations in the latter assessment period. Despite inter-assessment differences, the consistent seasonal trend across both datasets highlights the robustness of the observed patterns. This alignment not only strengthens confidence in the data but also emphasizes the need for sustained, long-term ecological monitoring to track shifts in bird populations. The integration of rigorous statistical analysis with ecologically relevant patterns provides a strong foundation for understanding the dynamics of avian communities in the context of migration ecology and environmental change.

Discussion

The Bajwat wetland is a hub of complex and diverse bird communities that drive benefit with a variety of food sources in numerous microhabitats. The current assessment of avian assemblage structure highlights that the study area has healthy diversity of birds with 130 species belonging to 18 orders and 47 families. The order Passeriformes has the maximum number of species (42 species) followed by the order Charadriiformes (18 species). These results indicate that the Bajwat wetland sustains a substantial number of terrestrial birds from the orders Columbiformes, Passeriformes, Psittaciformes, Cuculiformes, Galliformes, Strigiformes, Accipitriformes, and Upupiformes. In Anseriformes, the family Anatidae has the highest number of species (16), followed by Scolopacidae (8), and Accipitridae (6). A large number of aquatic bird communities were found in the study area due to the occurrence of significant feeding regions such as marshes and ponds. The primary focus of the current research was on the residential, migratory, and conservational status of the avian community in various types of microhabitats which shows the research area provides important breeding, feeding, and wintering grounds to several bird species.

Photographs of birds in their natural habitats within the study area, highlighting habitat specific associations

Water physicochemical properties and prey availability extremely influenced the distribution of aquatic bird species (Manikannan *et al*., 2012). Water depth and level affect the diversity and distribution of many shorebird species. With the parallel study (Veeramani and Usha, 2018), the abundance, diversity, and distribution, of bird species are all affected by water and also disturb the food resources and composition of aquatic flora in wetland biomes. Suitable habitats preferred by avian species for their breeding and nonbreeding seasons ought to provide sufficient food resources and abiotic conditions that help them during their migration trip (González-gajardo *et al*., 2009). Our study area supports 40 winter visitors, 19 summer visitors, 1 monsoon visitor, and 71 resident bird species. The major factors that determine where species prefer to live, especially migrant species during the non-breeding season, are the availability of food, disturbance level, and safe nesting sites. Some species that use various habitats for rest and feeding, food distribution, and the distance they cover from nourishing regions to the resting sites all have very important roles in determining the distribution and feeding areas of aquatic birds (Ntiamoa-baidu *et al*., 2008). Results of the current study showed that some species such as *Aythya nyroca, Oxyura leucocephala, Aythya ferina, Haliaeetus leucoryphus, Gyps indiucs, Ciconia nigra, Vanellus gregarious, Vanellus vanellus, Limosa limosa, Calidris tenuirostris, Sterna acuticauda, Sterna aurantia, Clamator jacobinus, Francolinus francolinus, Grus antigone, Psittacula eupatria, Pelicanus crispus, Sturnus pagodarum, Anhinga melanogaster* were identified as rare species in the study region. Out of these 19 rare species *Psittacula eupatria* was observed first time in the study area in April 2023. Thus it is evident that the study region is home to rare and unique species.

The wetland areas are the crucial for aquatic bird species whether it is shallow or open waters and it is associated with food accessibility. Thus, it fluctuates the abundance and composition of bird species (Paracelsus, 2006). Species of the order Accipitriformes and Passeriformes mainly use aerial and forest habitats. Shorebirds and many aquatic birds prefer shallow water and water edges over other microhabitats as food resources are abundantly found in these microhabitats during low water availability. This indicates that a fluctuation in water level in wetlands is an important factor in the avian assemblage (Pandiyan and Asokan, 2015). The study area provides a wide range of microhabitats that support many aquatic and terrestrial birds for their various activities such as roosting, nesting, loafing, and foraging. Availability of food resources, habitat size, and abiotic factors are major factors that greatly control the avian assemblage within a microhabitat. Avian species coexist due to the availability of resources in the specific area which minimizes competition and increases resource partitioning. According to Kularatne *et al*. (2021), various aquatic and terrestrial birds are not specific to a particular habitat as they are provided with available

material for foraging and nesting. Many birds, particularly aquatic birds, utilize a wide range of microhabitats within a given area for resting, breeding, and feeding during various seasons of the year (Clausen and Clausen, 2014).

According to IUCN red list criteria (IUCN 2023), of the total recorded bird species, eight were identified as near threatened, four were vulnerable, four were endangered, and two species were critically endangered whereas 112 species were listed as least concern. Classification of avian fauna based on their visit and occurrence in the study area given in Roberts (1991) indicates that of the 18 threatened recorded species, nine species *Aythya nyroca, Oxyura leucocephala, Aythya ferina, Vanellus gregarious, Vanellus vanellus, Numenius arquata, Limosa limosa, Calidris tenuirostris,* and *Pelicanus crispus* were winter visitor and rest of the nine *Ephippiorhynchus asiaticus, Psittacula eupatria, Anhinga melanogaster*, *Marmaronetta angustirostris, Sterna aurantia, Grus antigone, Haliaeetus leucoryphus, Sterna acuticauda,* and *Gyps indiucs,* were recorded as a resident. Our findings are almost consistent with Chaudhry *et al.* (2012) who identified nine near threatened, one endangered, one critically endangered, and five vulnerable species in the various important wetlands of Punjab, Pakistan including Bajwat wetland. Brohi and Asim (2017) also identified one endangered species namely *Oxyura leucocephala* (White-headed duck), and three near threatened species *Aythya nyroca* (White-eyed pochard), *Vanellus vanellus* (Northern lapwing), and *Limosa limosa* (Black-tailed Godwit) on the following important wetlands of upper Punjab, Pakistan: Nammal lakes, Uchali lake, Kalar kahar, Jinnah barrage, Khabbeki lake, and Jhallar lake. In Pakistan threatened avian species associated with wetlands that need immediate conservation measures are, *Oxyura leucocephala* (White-headed duck), *Vanellus gregarious* (sociable plover), *Aythya nyroca* (Ferruginous duck), *Grus Antigone* (Sarus crane), *Marmaronetta angustirostris* (Marbled teal), *Pelicanus crispus* (Dalmatian pelicane), *Haliaeetus leucoryphus* (Pallas fish eagle), *Grus Leucogeranus* (Siberian crane), and *Anser erythropus* (White-fronted goose) (Khurshid, 2000). We recorded the maximum number of threatened species belonging to four categories (Near Threatened, Vulnerable, Endangered, and Critically Endangered) in the study area than the studies conducted ever before in this area. This indicates that the study area has great potential for migratory and residential avian fauna conservation in Punjab, Pakistan.

The most significant factors that determine and affect the population of migratory species are the season and year which directly impact the selection of habitat to the degree of available habitat having minimum predation (Pandiyan *et al.*, 2021). Species richness and diversity in the Bajwat wetland increased mostly during the winter season and monsoon season, when considerable rainfall occurs, which might increase the density of prey. The findings of Jagadheesan and Pandiyan (2021) showed the significance of time-based dynamics that highlight the impact on the diversity, abundance, and species richness of the aquatic birds as these aspects were extremely correlated with the migration of aquatic birds in any favorable environment. Seasons and months are also important time factors that determine the accessibility of food and other ecological aspects for the migrant species.

Maximum species richness during the winter season is due to the arrival of aquatic birds as compared to the summer visitors species with minimum migratory species (Sharma and Minakshi 2014). The degradation of non-breeding habitats of aquatic birds, particularly wetland habitats, has a negative effect on the fitness of species as a result species migrate to another sustainable wetland habitat. Hence, restoring wetland habitats will considerably increase the variety and breeding efficiency of aquatic birds (Mander *et al.*, 2021). The current study reveals that the Bajwat wetland has been under anthropogenic stress such as rapid urban expansion, poaching, agricultural land, firewood collection, and grazing pressure. The study region is surrounded by urban areas which are exerting more pressure and disrupting the natural balance of the wetland by converting its most part to polluted areas. Our study reveals that terrestrial bird populations were also very diverse along with aquatic bird populations in the study area. Many factors such as food partition, predation risk, trophic structure, and prey preference influence the shorebird's habitat utilization. Human activities affect in many ways such as the destruction of habitat causing competition among the species for resources and also impacting the diversity and abundance of bird species patterns (Pandiyan and Asokan 2015). Furthermore, the findings of our study provided the latest assessment of the dynamics of the avian fauna in the Bajwat wetland, Punjab, Pakistan (Ali *et al.*, 2021; 2022).

The observed pattern of bird abundance across seasonal phases reveals a biologically coherent trend, with a pronounced peak during the migratory season in both assessment periods. This seasonal surge aligns with established migration ecology, where birds rely heavily on stopover sites for rest and refueling during long-distance movements (Faaborg *et al*., 2010). The elevated abundance during migration suggests that the study area serves as an important migratory corridor or staging habitat, offering essential ecological resources that support transient avian populations (Stanley *et al*., 2021). The application of a Two-Way Repeated Measures ANOVA confirmed that both season and assessment period significantly influenced bird abundance, highlighting not only the natural cyclical variation associated with migration but also a notable decline in overall abundance from Assessment I to Assessment II. This temporal reduction may indicate shifts in habitat quality, climatic variability, or increasing anthropogenic pressures such as land-use change, noise disturbance, or resource depletion all of which can reduce site attractiveness or ecological capacity for supporting large bird populations (Studds *et al*., 2017; Wang *et al*., 2022).

Importantly, the consistent seasonal trend across both assessments reinforces the ecological validity and robustness of the findings. The difference in abundance between assessments suggests potential long-term degradation of habitat suitability or broader environmental stressors influencing avian community dynamics. Similar trends have been observed in other migratory systems, where cumulative pressures led to measurable reductions in species abundance and altered stopover use patterns (Rodewald and Brittingham, 2007; Stanley *et al*., 2021).

Conclusion

Bajawt wetland is an ecologically favorable region for numerous aquatic birds in terms of migrant and native species. The results show that there are 130 different bird species in this region, 18 of which are threatened species. Throughout the study period, the distributions of birds varied throughout the investigated habitat types. As the Bajwat wetland is an attractive landscape for recreation, and ecotourism, human activities like fishing, boating, surfing, sewage, pollution, and solid waste material from the nearby regions are the few near future concerns that could jeopardize its ecological integrity and potentially disrupt the diversity of birds and their preferred habitats. The spotting of four endangered, and two critically endangered species and a variety of microhabitats emphasizes the significance of the Bajwat wetland as an important bird habitat in Sialkot district. According to the study, the diversity of the habitat is crucial for bird biodiversity. The importance of wetland habitat for birds needs to be sustained or maintained at the proper times of year and location by sustaining adequate provisions of water. Thus, the study region requires certain conservation priorities to maintain the highest level of species diversity and abundance and also aid in enhanced management by assisting these threatened species that arrive during the migratory period. Since this region is important for the avian species using the Central Asian Flyway as a wintering or stopping place, effective habitat management is needed to conserve birds in this area.

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Novelty Statement

This study presents the first detailed, habitat-specific assessment of avian assemblages across the microhabitats of the Bajwat Wetland, part of the ecologically vital Marala Barrage region in Punjab, Pakistan. Reporting the highest number of bird species recorded to date from this area (130 species), including several globally threatened and migratory species, the research offers a comprehensive avian checklist and critical insights into species-habitat associations. These findings not only fill a major knowledge gap in regional ornithology but also provide an essential scientific basis for future biodiversity conservation and wetland management in South Asia.

Author's Contribution

Gulzaman William: Conceptualization, Methodology, Software, Field Investigation, Visualization, Writing Original Draft.
Muhammad Azhar Ali: Field Investigation, Resources, Validation, Project Administration, Proofreading, Visualization.
Malik Shahzaib Khalid: Data Collection, Data Entry,

Project Administration, Editing, References Management.
Burhan Hafeez: Field Support, Data Entry, Project Administration, Proofreading, Validation, References Management.
Mohsan Raza: Data Collection, Data Entry, Project Administration, Editing, Proofreading, Validation, References Management.
Aqsa Naeem: Data Collection, Data Entry, Project Administration, Editing, Validation, Visualization.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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