

Avian Richness, Assemblages and Migration Connectivity of Geese Species with Habitat Suitability in Wetlands of the Punjab, Pakistan

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ABSTRACT

Understanding the species assemblages and migration connectivity of geese species is crucial for their conservation and management. It helps identify important stopover sites, breeding grounds, and wintering areas, allowing for targeted conservation efforts and the preservation of key habitats along their migratory routes. This study was designed to investigate the avian richness and habitat suitability of geese species at wetlands of Punjab, Pakistan. The surveys were conducted from October 2020 to March 2021 and October 2021 to March 2022 on monthly basis using point count method. Five species of geese were recorded at the wetlands including bar-headed goose *Anser indicus*, with the highest number of individuals (2,701 at eleven sites) followed by greylag goose *Anser anser* (1,224 at nine sites), cotton pygmy-goose *Nettapus coromandelianus* (74 at eleven sites), greater white-fronted goose *Anser albifrons* (46 at five sites) and lesser white-fronted goose *Anser erythropus* (seven at three sites). Overall, 175 species were recorded at the study sites belonging to 13 orders and 39 families. According to the IUCN red list, 148 species were least concern, 16 were near threatened and 11 were threatened (vulnerable (06), endangered (04) and critically endangered (01)). Habitat suitability index was used to rank the suitability of geese species at various sites from highly suitable to least suitable. Marala Headworks was found to be at the top as per habitat suitability score for all geese species, followed by Chashma, Taunsa and Bajwat. Even if these sites are suitable, they fall short of being highly suitable. Thus, maintenance of these locations must be given top priority in order to conserve the goose species that rely on them.

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Authors' Contribution

GR and ZA conceptualized the study. GR, ZA and RA conducted the field visits. GR, AA and ZA assembled and analyzed the dataset. GR and RA drafted the manuscript. AA and ZA reviewed and improved the manuscript.

Key words

Avian richness, Species assemblages, Migration, Geese, Habitat suitability, Conservation

INTRODUCTION

Wetlands play a vital role in ecosystems, offering numerous ecological and economic advantages. As an individual ecosystem, they vary in species diversity, geology, landscape exposure, and climate. They are influenced and regulated by their surroundings, including water sources and atmospheric conditions (Bhowmik, 2022). Wetlands are vital for biodiversity, hosting numerous bird species, but human-driven habitat changes harm wetland avifauna (Htay et al., 2023). The Province Punjab, Pakistan, is a region that is rich in wetland ecosystems, which provide vital habitats for a diverse range of avian

species, including geese (Haider et al., 2022). Wetlands in Punjab, such as the Indus River Floodplain, offer abundant food resources and nesting sites for geese, making them important areas for the conservation of these species. There are several species of geese that can be found in Punjab's wetlands, including the bar-headed goose, greylag goose, and bean goose. These species are known to migrate from Siberia to Punjab during the winter months, where they can be found in large flocks (Liu et al., 2017). However, the geese populations that migrate to Punjab's wetlands during the winter months are likely breeding in the Arctic regions of Russia, Mongolia, and China. These geese rely on the wetlands in Punjab as a key stopover site during their long-distance migrations, where they feed and rest before continuing their journey (Köppen et al., 2010).

Avian richness, species assemblages and migration connectivity play significant roles in the behavior and ecology of geese species. Geese are known for their impressive long-distance migrations and their tendency to form large flocks and exhibit spatial aggregation (Aikens et al., 2022). This behavior serves several purposes, including protection from predators, improved foraging efficiency, and social interactions (Varpe and Bauer, 2022). Geese often form large flocks during migration, breeding,

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and wintering periods. The degree of interaction and connectivity between different populations or geographic locations during migration, geese species exhibit varying levels of migration connectivity, depending on their migratory strategies and ecological requirements (Clausen *et al.*, 2018; Wilson *et al.*, 2022). These species may travel thousands of kilometers and encounter various stopover sites along their migration routes, where they interact with other populations (Gesicki and Bingman, 2022). The variety of Pakistan's wetlands represents the Indus River's course from the high mountains to the sea, as well as the whole range of wetland habitats (Balwan and Kour, 2021). Moreover, the Indus Flyway is an important migration path for water birds such as ducks, cranes, shorebirds and geese (Chapman *et al.*, 2014).

Several factors can influence the migration connectivity of geese species. For instance, the availability of suitable breeding, wintering, and stopover habitats can affect the connectivity between different populations (Fattorini *et al.*, 2023). Geese's movement patterns can be influenced by the quality and accessibility of habitats that meet their needs for feeding, resting, and breeding (Faaborg *et al.*, 2010). Sometimes, physical barriers, such as mountain ranges, large bodies of water, or unsuitable habitats, can limit migration connectivity. Favorable conditions may promote the congregation of different populations at specific stopover sites or wintering areas (Lei *et al.*, 2019). Furthermore, seasonal bird monitoring is critical for detecting dynamic bird migration in specific habitats (Sethy *et al.*, 2015). Wetland avifauna species are virtuous ecological markers that indicate the status of wetlands, and they serve as a source of uniting forces across nations all over the world through migration (Stephenson *et al.*, 2020).

Enormous number of the world's bar-headed geese (*Anser indicus*) and the greylag goose (*Anser anser*) yearly migrate from Siberia to their wintering areas in Pakistan and India (Köppen *et al.*, 2010), while greater white-fronted goose (*Anser albifrons*) and lesser white-fronted goose (*Anser erythrotopus*) are infrequent winter visitors in Pakistan. The habitat suitability of these species is largely determined by the availability of suitable wetland habitats that provide sufficient food resources, shelter, and nesting sites (Mishra *et al.*, 2020). The conservation of wetland habitats in Punjab is crucial for maintaining the migratory connectivity and habitat suitability of geese population. Efforts to conserve wetland habitats in Punjab, including habitat restoration, pollution control, and the establishment of protected areas, can help to support the abundance and diversity of geese and other avian species in the region (Altat *et al.*, 2018).

The information about the habitat suitability and

their latest population status in Punjab's wetlands lacks in published literature. The research was planned to study the avian richness of thirty wetlands, species assemblages and habitat suitability of geese species at wetlands of Punjab. This study adds latest information about the recent status of geese along with other avian species in the selected wetlands.

MATERIALS AND METHODS

Punjab (31.1704° N, 72.7097° E) is the north-eastern province of Pakistan (Sidra *et al.*, 2022). Thirty wetlands of Punjab were selected for the current study as highlighted in Figure 1. The field surveys were conducted from October 2020 to March 2021 and October 2021 to March 2022 on monthly basis. The point count method was used during field surveys (Verner, 1985). Fifteen minutes were spent at each point to observe the species. Garmin GPS map 76CSx, Harrier 65mm ED Spotting Scope, camera (Nikon p-900) and binoculars (Bushnell power view, 60 X 90 m) were used during the surveys. A field guide by Grimmett *et al.* (2008) was used for the bird identification.

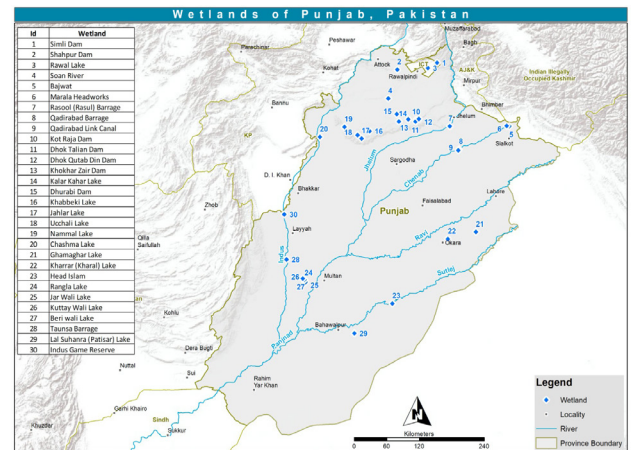


Fig. 1. Map showing selected wetlands in Punjab, Pakistan.

Data analysis

To analyze the data, different indices were employed including Shannon wiener, Simpson index and species evenness using the following formulas.

Shannon wiener index (H') = $\sum [p_i \ln p_i]$ (Shannon, 1948)

where p_i is proportion of the species relative to the total number of the species $\ln$, and p_i is natural logarithm of p_i .

Simpson index (D) = $1 - \sum n(n-1) / N(N-1)$ (Simpson, 1949).

where n is total number of individuals of a particular species, N is total number of individuals of all species.

Species evenness (E) = $H'/\ln(S)$ (Peet, 1974)
where S is species richness.

Habitat suitability index (HSI)

During the field surveys, many physical and ecological variables were recorded including geographical location (based on their occurrence), food availability, hunting pressure, predation pressure, waste/pollution, climatic changes (temperature and precipitation), habitat destruction, water quality, breeding and roosting sites and fishing activities. HSI of each site was calculated using the following formula:

$HSI = (SI1 \times SI2 \times SI3 \times SI4 \times SI5 \times SI6 \times SI7 \times SI8 \times SI9 \times SI10)^{1/10}$ (Hess and Bay, 2000).
where SI is suitability indicator.

The overall HSI score ranges from 0 (least suitable) to 1 (highly suitable). The score categorization is given in Table I (Ahmad *et al.*, 2022).

Table I. HSI score categorization.

Category	HSI score	Suitability
Poor	< 0.50	Least suitable
Below average	0.50 - 0.59	
Average	0.60 - 0.69	Less suitable
Good	0.70 - 0.79	Moderately suitable
Excellent	> 0.8	Highly suitable

RESULTS

Habitat suitability of geese species

Five geese species were recorded from the wetlands including bar-headed goose (*Anser indicus*), greylag goose (*Anser anser*), greater white-fronted goose (*Anser albifrons*), cotton pygmy-goose (*Nettapus coromandelianus*) and lesser white-fronted goose (*Anser erythropus*). Bar-headed goose has the highest number of individuals (2,701 at eleven sites) followed by greylag goose (1,224 at nine sites), cotton pygmy-goose (74 at eleven sites), greater white-fronted goose (46 at five sites) and lesser white-fronted goose (seven at four sites).

The habitat suitability index was based on the factors given in section 2.2. Bar-headed geese were found at eleven sites and out of these, Marala Headworks and Taunsa were moderately suitable with 0.71 and 0.65 HSI score respectively followed by Chashma (0.60) which is less suitable for the species. The other sites including Bajwat, Qadirabad Barrage, Indus game reserve, Rawal lake, Shahpur dam, Soan River, Simli Dam, Qadirabad Link Canal were least suitable with values 0.49, 0.46, 0.46,

0.45, 0.44, 0.44, 0.43 and 0.28, respectively (Fig. 2A).

Greylag goose was found at nine sites and none of the sites qualified for highly suitable or moderately suitable. Among nine sites, Marala Headworks and Chashma had the highest scores (0.69) followed by Taunsa and Bajwat (0.68) (Fig. 2). As shown in Figure 2B, six sites including Chashma, Taunsa, Bajwat, Indus game reserve and Qadirabad Barrage fell under the category of less suitable as per cumulative score of selected suitability parameters. Rest of the sites had worse situation and were found to be least suitable for the species.

Greater white-fronted goose were observed at five sites and among these five sites, Marala Headworks had the highest scores (0.68) followed by Chashma, Bajwat (0.67) and Taunsa (0.65) (Fig. 2C), which fell under the category of less suitable (Fig. 2). The remaining sites had worse state and were deemed to be least suitable for the species.

Lesser white-fronted goose were recorded at four sites and none of the sites meet the requirements of being highly suitable or moderately suitable. Among these four sites, Marala Headworks had the highest scores (0.67) followed by Chashma (0.63) and Bajwat (0.61) (Fig. 2). These sites were classified as less suitable while Qadirabad link canal was categorized as least suitable with score of 0.32 (Fig. 2D).

Cotton pygmy-goose were found at eleven sites and out of these, Marala Headworks was highly suitable (0.80) followed by Chashma (0.77), Qadirabad Barrage (0.77), Bajwat (0.74), Taunsa (0.73) and Indus game reserve (0.71), which qualified for moderately suitable category. Rasul barrage and Simli Dam were less suitable with 0.68 and 0.64 scores while Head Islam, Ghamaghar lake, Qadirabad Link Canal and Jar Wali Lake were least suitable with 0.52, 0.39, 0.32 and 0.28 score, respectively (Fig. 2E).

Bird species composition

A total of 175 species of 13 orders and 39 families were recorded from thirty wetlands in Punjab, Pakistan during field surveys (Supplementary Table S1). Order Charadriiformes has the highest diversity (48 species) followed by Passeriformes (33 species), Anseriformes (25 species), Pelecaniformes (18 species), Gruiformes (13 species), Accipitriformes (12 species), Ciconiiformes (7 species), Coraciiformes (5 species), Falconiformes (4 species), Podicipediformes (4 species), Suliformes (4 species), Phoenicopteriformes (2 species), and Bucerotiformes (1 species). Anatidae, Scolopacidae, Ardeidae, Laridae and Rallidae were the leading families with 26, 18, 14, 12 and 11 species, respectively.

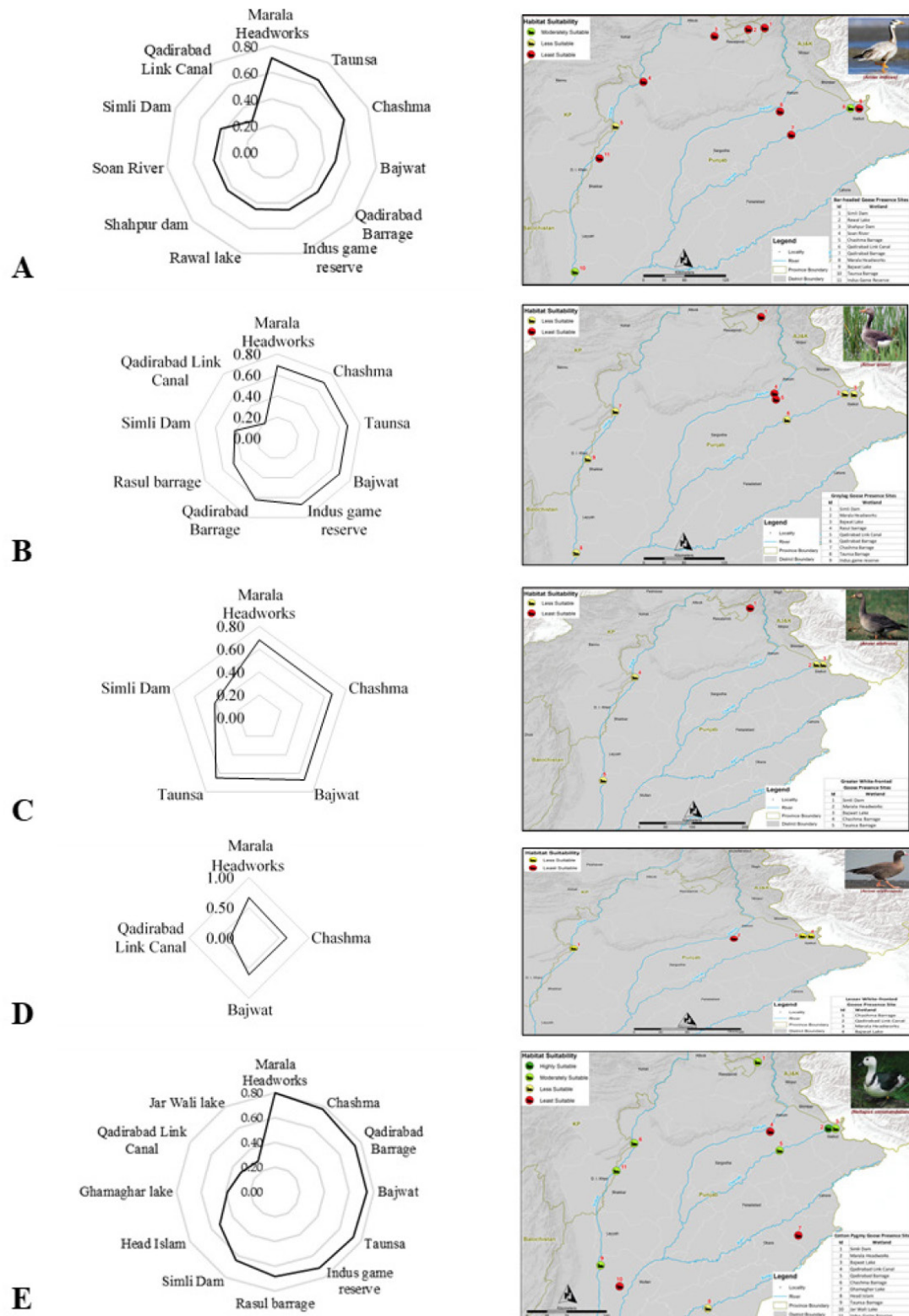


Fig. 2. Habitat suitability score (left) and map showing site suitability (right) of bar headed goose (A), greylag goose (B), greater white-fronted goose (C), lesser white-fronted goose (D) and cotton pygmy goose (E).

Table II. Species occurrence categorization in the study area.

Occurrence	Number of species
Winter migrant	84
Year-round residents	62
Passage migrants	14
Vagrant	8
Summer breeder	7

Out of total bird species, 48% were winter migrants, 35% were year-round residents, 8% were passage migrants, 5% were vagrant and 4% were summer breeder

(Table II). According to the IUCN red list, 148 species were least concern while 16 were near threatened, eleven were threatened (Table III). The population of 30 species is growing while the trend for 76 species is declining. Moreover, population trend of 37 species is stable while for 32 species it is still unknown as per IUCN. At the species level, common coot (*Fulica atra*), little cormorant (*Phalacrocorax niger*), house crow (*Corvus splendens*), common pochard (*Aythya ferina*) and mallard (*Anas platyrhynchos*) were most abundant at these sites cumulatively with 72,171, 20,829, 11,105, 10,971 and 10,811 number of individuals respectively having relative abundance of 22.75, 6.56, 3.50, 3.45 and 3.40, respectively (Table III).

Table III. Avian richness, diversity and abundance at different wetlands in Punjab, Pakistan.

S. No	Sites	Species richness	Number of individuals	Simpson index	Shannon wiener	Species evenness
1	Chashma	138	30,360	0.90	3.16	0.64
2	Jahlar	82	3,484	0.92	3.15	0.71
3	Khabakki	99	4,255	0.88	3.15	0.68
4	Taunsa	160	6,283	0.94	3.95	0.77
5	Uchalli	100	23,536	0.77	2.39	0.51
6	Bajwat	161	20,399	0.94	3.66	0.71
7	Baeri wali lake	83	868	0.98	4.10	0.92
8	Dhok Kutab Din dam	74	928	0.89	3.28	0.76
9	Dhok Talian Dam	80	924	0.97	3.85	0.88
10	Dhurabi Dam	92	1,505	0.94	3.65	0.80
11	Ghamaghar lake	122	1,088	0.98	4.27	0.88
12	Head Islam	141	1,176	0.94	3.71	0.74
13	Indus game reserve	168	18,400	0.95	3.77	0.73
14	Jar Wali lake	113	1,781	0.97	4.13	0.87
15	Kalar Kahar lake	119	12,988	0.94	3.59	0.75
16	Kharral lake	97	324	0.98	4.22	0.92
17	Khokhar Zair dam	81	6,981	0.96	3.61	0.82
18	Kot Raja dam	94	6,295	0.96	3.55	0.77
19	Kutty Wali lake	92	1,039	0.97	4.04	0.89
20	Lal Suhanra lake	97	1,273	0.96	3.97	0.86
21	Marala headworks	167	35,552	0.94	3.74	0.72
22	Nammal lake	109	21,310	0.89	3.29	0.69
23	Qadirabad barrage	146	22,364	0.91	3.39	0.68
24	Qadirabad link canal	147	11,450	0.96	3.90	0.77
25	Rangla lake	108	9,085	0.95	3.66	0.78
26	Rasul barrage	127	15,827	0.92	3.37	0.69
27	Rawal lake	119	15,575	0.91	3.33	0.69
28	Shahpur dam	102	14,529	0.90	3.08	0.66
29	Simli dam	166	14,607	0.97	3.44	0.67
30	Soan river	111	12,908	0.92	3.25	0.69

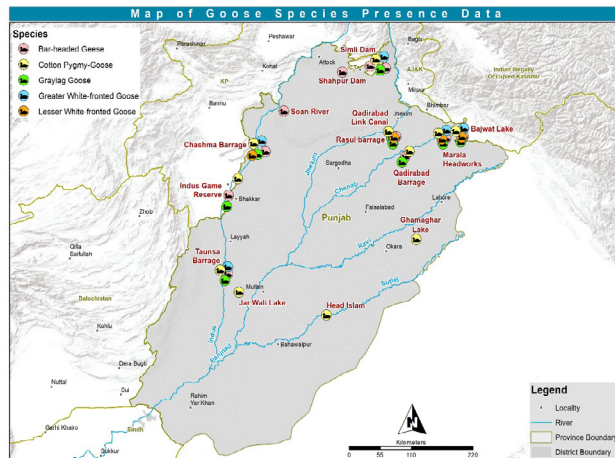


Fig. 3. Occurrence of geese in the wetlands of Punjab, Pakistan.

Birds diversity, richness and abundance

The maximum number of species were observed at Indus game reserve (168) followed by Marala headworks (167), Simli dam (166), Bajwat (161) and Taunsa (160). Moreover, the maximum number of individuals were recorded at Marala headworks (35,552) followed by Chashma, Uchalli, Qadirabad Barrage and Nammal lake with 30,360, 23,536, 22,364 and 21,310 number of individuals, respectively. The abundance details for each site and species are given in [Supplementary Table SII](#). The species diversity fluctuated among sites with maximum Shannon wiener value of 4.28 (Ghamaghar lake) to minimum 2.39 (Uchalli lake). The Shannon wiener diversity of Ghamaghar lake (4.27) was followed by Kharral lake, Jar wali lake and Baeri wali lake with 4.22, 4.13 and 4.10 H' values respectively. The species evenness was found to be 0.92 for Baeri wali Lake and Kharral Lake while 0.89 for Kutty Wali Lake and 0.88 for Ghamaghar lake ([Table III](#)).

The value of Simpson's index was 0.98 for three sites namely Kharral Lake, Baeri wali Lake and Ghamaghar lake, while the value was 0.97 for six sites including Kutty Wali Lake, Dhok Talian Dam, Taunsa, and Jar wali lake. The minimum value of this index was 0.77 for Uchalli lake ([Table I](#)).

DISCUSSION

Geese migration and habitat suitability

Three flyways including West Asian-Eastern African Flyway, the Central Asian Flyway and the East Asian-Australasian Flyway encompass the geese migration across Asia ([Boere and Stroud, 2006](#)). Pakistan is one of the

countries covered by Central Asian Flyway. This flyway is defined by the a wide (200-400 km) barrier of Himalayas. Moreover, the waterbird migration from northern breeding sites to the Indian subcontinent for the winter is impeded by the Himalayas. The bar-headed goose and greylag goose are the only two populations of geese that routinely winter on the Indian subcontinent and number in the thousands ([Takekawa *et al.*, 2017](#)). Little is known about the migration of these species but there are evidences that greylag goose is frequently found in relatively small flocks of tens to low thousands, typically in the same wintering habitats as the bar-headed goose. Various migration routes are described for Bar-headed goose and one of them includes Ravi and Chenab River ([Köppen *et al.*, 2010](#)). The current study provides the evidence ([Fig. 3](#)) as these species were found in the wetlands nearby Chenab and Ravi River.

In the current study, these two species shared eight sites including Chashma, Taunsa, Bajwat, Indus game reserve, Marala Headworks, Qadirabad Barrage, Qadirabad link canal and Simli dam. Although these species coexisted at these sites but the habitat suitability score were different for these species at the study sites because of their response to each studied factor; such as, predation and hunting pressure etc. For example, it is reported in literature that bar-headed geese are killed ruthlessly in this region ([Khan and Ali, 2014](#)) and similar observations were made during current research. One of the main reasons behind their ruthless killings is the large number of individuals that visit the sites. Marala headworks is the main site where these species stop during their migration and unfortunately get killed by the hunters. While there are no such reports and observations for other geese species.

Bar-headed goose was the most abundant among geese species in the selected wetlands, inhabiting eleven sites with maximum (1,148) individuals at Marala headworks. [Bhatti *et al.* \(2019\)](#) recorded 1,710 individuals of this species between year 2000 and 2001 in same area. The presence of this species was reported at Taunsa barrage by [Haider *et al.* \(2022\)](#) and [Köppen *et al.* \(2010\)](#) and in the current study 19 individuals of bar-headed goose were recorded at the same site. A total of 44 individuals of greylag goose were recorded at Chashma in this study while [Ali and Akhtar \(2005\)](#) observed 37 individuals.

Little information is available about the migration pattern of greater white-fronted goose, lesser white-fronted goose and cotton pygmy-goose and there are only a few published records of their presence in Pakistan. Lesser white-fronted goose is vulnerable according to IUCN and it was reported at Banjosa lake of Poonch district Azad Jammu and Kashmir in 2009 ([Nazir *et al.*, 2018](#)).

Avian richness and assemblages

A total of 175 species of 13 orders and 39 families were recorded from thirty wetlands in Punjab, Pakistan during field surveys. The maximum number of species were observed at Indus game reserve followed by Marala headworks, Simli dam, Bajwat and Taunsa. Moreover, the maximum number of individuals were recorded at Marala headworks followed by Chashma, Uchalli, Qadirabad Barrage and Nammal lake.

In the current study, 100 species with 23,536 number of individuals were recorded at Uchalli wetland while 133 species with 18,331 individuals were recorded by [Kazam et al. \(2022\)](#) between 2020 to 2021. Moreover, 47 species with 25,361 individuals were recorded from 2011 to 2013 at the same site ([Dauda et al., 2017](#)). From October 2015 to September 2016, [Ashraf et al. \(2019\)](#) observed 36 bird species and 13,342 individuals at the same location. [Arshad \(2014\)](#) recorded 1,139 individuals belonging to eleven bird species in 2010 and 18,606 individuals belonging to 34 bird species in 2011. In 2007, [Arshad \(2011\)](#) documented 40 avian species while in 2003, [Ali and Akhtar \(2005\)](#) recorded 103 avian species with 1,591 individuals at Uchalli Lake.

As part of this study, 99 species with 4,255 individuals were observed at Khabbaki lake while 92 bird species having 3,053 individuals were recorded by [Kazam et al. \(2022\)](#). [Arshad \(2011\)](#) documented 39 species while [Ali \(2011\)](#) observed 37 birds' species of 428 individuals in 2006. [Ali and Akhtar \(2005\)](#), recorded 91 bird species of 1,246 individuals in 2003 at this lake.

At Jahlar lake 82 species with 3,484 individuals were recorded in this study while in another study, 88 bird species and 2,394 individuals were recorded at the same site ([Kazam et al., 2022](#)). [Arshad \(2011\)](#) reported 41 avian species in 2007, [Ali and Akhtar \(2005\)](#) recorded 53 species with 370 individuals in 2003. [Ali et al. \(2011\)](#) observed 47 species with 2,275 individuals in 2006 at this lake.

At Taunsa, 160 species with 6,283 individuals were recorded in this study while 50 species having 10,845 individuals were observed in 2019 to 2020 ([Haider et al., 2022](#)), 171 species with 58,598 individuals were recorded between 2009 to 2011 ([Bibi et al., 2013](#)). The annual bird population trends at Taunsa were observed from 2008 to 2014 and a decreasing trend of 14 bird species and an increasing trend of 157 bird species was reported ([Bibi et al., 2016](#)).

At Kallar Kahar lake 119 species were recorded in this study while [Rais et al. \(2011\)](#) observed 86 species from 2008 to 2009 and 91 species with 1,246 individuals were recorded by [Ali and Akhtar \(2005\)](#). Moreover, at Chashma, 138 species with 30,360 individuals, at Nammal lake, 109 species with 21,310 individuals were recorded

in this study while 126 species of 71,008 individuals and 115 species with 1,726 individuals were recorded at these respective sites ([Ali and Akhtar, 2005](#)). At Bajwat lake, 161 species were recorded in this study while 110 species were sighted ([Bhinder et al., 2015](#)).

Threats

Illegal hunting can be considered as the main threat to these species. In addition, attack by the stray dogs on these species was also witnessed during the study. Moreover, predation, trapping, over hunting, shooting, use of pesticides, habitat loss, pollution, infrastructure developments and anthropogenic activities are major threats to avifauna and the observations are in accordance with different previous studies ([Umar et al., 2018](#); [Robinson et al., 1995](#); [Grimmett et al., 2008](#); [Ghalib et al., 2008](#)).

CONCLUSIONS

Five geese species were recorded from the wetlands including bar-headed goose, greylag goose, greater white-fronted goose, cotton pygmy-goose and lesser white-fronted goose. Among five geese species found at the wetlands of Punjab, Marala Headworks was found to be the most suitable site (specific category varies with the species) for all the species, followed by Chashma, Taunsa and Bajwat. Moreover, the avian diversity of wetlands in Punjab varies from rich (Ghamaghar lake) to moderate (Uchalli lake) according to Shannon wiener diversity index. The maximum number of species were observed at Indus game reserve followed by Marala headworks and Simli dam. Moreover, the maximum number of individuals were recorded at Marala headworks followed by Uchalli and Chashma.

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Ethical statement

No species was harmed during the current study.

Supplementary material

There is supplementary material associated with this article. Access the material online at: <https://dx.doi.org/10.17582/journal.pjz/20230724085011>

Statement of conflict of interest

The authors have declared no conflict of interest.

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