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Seasonal variations in wetland bird assemblages: A case study from Dighal wetlands in Haryana, India

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Abstract The Dighal wetlands, designated an important bird area (IBA) in Haryana, India, serve as vital ecosystems, and offer suitable habitats and sustenance for a diverse array of resident and migratory wetland birds. Avian surveys were conducted by adopting direct observations and point count methods between April 2021 and March 2023, aimed to document the assembly of wetland birds within this IBA site. A total of 90 species of wetland birds distributed across 12 orders, 23 families and 62 genera were identified. The Charadriiformes order exhibited the highest species richness (24) followed by Anseriformes (19). Anatidae with 19 species emerged as the most diverse family, constituting 21% of the total species identified. The study revealed the seasonal dynamics, with 33.3% resident, 62.2% winter migrants, and 4.5% summer migrants. Notably, winter season recorded the highest species richness and population abundance. The study underscores significant differences in species richness, abundance, diversity, and evenness in both seasons of the first and second year. Moreover, the study unveiled non-significant distinctions in richness, abundance, diversity and evenness of wetland birds across these years (2021–2022 and 2022–2023). Among the recorded avifauna, three species are listed as Vulnerable and four species as Near Threatened in the IUCN Red List (2024). Additionally, two species are listed in CITES Appendix I, while six species were included in CITES Appendix II. Furthermore, ten species were listed in Schedule I of WPA (2022). Dighal wetlands played a crucial role in supporting 30 species of wetland birds experiencing a decreasing global population trend. The prevalence of a significant number of wetland bird migrants and wetland bird species of global conservation importance underlines the urgent need for robust conservation efforts to protect both the wetland birds and their habitats.

Keywords: conservation status, migrants, point count, species richness, water bird diversity

Összefoglalás Az indiai Haryanában található, fontos madárvédelmi területté (IBA) nyilvánított Dighal vizes élőhely létfontosságú ökoszisztémaként szolgál, és megfelelő élőhelyet és táplálékot kínál számos állandó és vonuló vízimadár-fajnak. Felméréseinket 2021 áprilisa és 2023 márciusa között közvetlen megfigyelési és pontszámlálási módszerek alkalmazásával végeztük azzal a céllal, hogy dokumentáljuk a területen előforduló madárfajokat. Összesen 90 vízimadár-fajt azonosítottunk, amelyek 12 rendbe, 23 családba és 62 nemzetségbe tartoznak. A Charadriiformes rend mutatta a legnagyobb fajgazdagságot (24), amelyet az Anseriformes (19) követett. Az Anatidae 19 fajjal a legváltozatosabb családnak bizonyult, amely az összes azonosított faj 21%-át tette ki. A fajok 33,3%-a állandó, 62,2%-a téli vonuló és 4,5%-a nyári vonuló volt. A fajgazdagság és a tömegesség is a téli időszakban volt a legmagasabb. Az első és második vizsgálati év mindkét szezonjában jelentős különbségek voltak a fajgazdagságban, a tömegességben, a diverzitásban és a kiegyenlítettségben. A tanulmány továbbá nem szignifikáns különbségeket tárt fel a vizes élőhelyek madarainak fajgazdagságában, tömegességében, diverzitásában és kiegyenlítettségében 2021–2022-ben és 2022–2023-ban. Az észlelt madárfajok közül három az IUCN Vörös Listáján (2024) a veszélyeztetett, négy faj pedig a közel veszélyeztetett kategóriába tartozik. Emellett két faj a CITES I. függelékében, míg hat faj a CITES II. függelékében található. Továbbá 10 faj szerepel a WPA I. jegyzékében (2022). A dighali vizes élőhelyek döntő fontosságúak 30, világszerte csökkenő tendenciát mutató faj számára. Eredményeink hangsúlyozzák a sürgős természetvédelmi erőfeszítések fontosságát mind a madarak, mind a vizes élőhelyek védelme érdekében.

Kulcsszavak: természetvédelmi státusz, vonuló madarak, pontszámlálás, fajgazdagság, vízimadár-diverzitás

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Introduction

Wetlands, serving as the crucial ecotones bridging between aquatic and terrestrial habitats, play a vital role in maintaining ecological balance and conserving biodiversity (Zedler & Kercher 2005, Byju *et al*. 2024). Encompassing about six percent of the Earth's surface, these ecosystems offer a myriad of ecological services crucial for the well-being of our planet, including aquifer recharge, flood control, carbon sequestration, erosion control, nutrient absorption, pollution abatement, and climate change mitigation (Prasad *et al*. 2002, Clarkson *et al*. 2003, Bassi *et al*. 2014). Wetlands also serve as crucial habitats for wildlife, particularly for birds (Buckton 2007). Birds, occupying various trophic levels in the nutrient cycle of wetlands, become integral components of these ecosystems (Yashmita-Ulman & Singh 2022). Wetland birds are natural allies of wetland ecosystems (Kumar & Gupta 2013, Kumar & Sharma 2019). These include a broad spectrum of avian groups such as waterfowl, waders, kingfishers, raptors, and several passerines (Kumar *et al*. 2005). Recognized as flagship species of aquatic ecosystems, wetland birds contribute positively to habitat sustenance by maintaining aquatic biodiversity, controlling insect pests, and influencing nutrient and biogeochemical cycling (Kumar *et al*. 2005, Green & Elmberg 2014). Due to their high mobility, birds remarkably sensitive to alterations in their habitat conditions, and thus, serve as valuable ecological indicators reflecting temporal changes in wetland habitats (Morrison 1986, Kumar *et al*. 2005, Mistry *et al*. 2008, Amat & Green 2010, Yashmita-Ulman & Singh 2022).

Blessed with a rich diversity of wetland habitats, crucial breeding and wintering grounds are existing in India for both resident and migratory species of water birds. (Kumar *et al*. 2005). Among 1,353 species reported from a variety of habitats throughout the geographical boundaries within India (Praveen & Jayapal 2023), there are 310 species known to be dependent on wetland habitats (Kumar *et al*. 2005). However, there are increasing human-induced pressures on India's wetlands, including those in Haryana (Kafle *et al*. 2008, Ali *et al*. 2013, Bassi *et al*. 2014, Kumar *et al*. 2016). These activities not only compromise water quality but also pose severe threats to the community parameters of wetland ecosystems, jeopardizing the survival, reproduction, and recruitment of wetland-dependent species (Renigald *et al*. 2007, Kloskowski *et al*. 2009, Ma *et al*. 2009, Butchart *et al*. 2010, Rush *et al*. 2013). To assess the integrity and functioning of the wetland ecosystem and create effective long-term conservation plans for wetland birds and their habitats, monitoring of wetland assemblages is frequently prioritised. (Lee *et al*. 2004, Sundar & Kittur 2013, Kumar & Sharma 2019).

Despite their ecological importance, only sporadic information is available for the status, diversity, migration, and population trends of wetland birds in Haryana, particularly in districts like Jhajjar (Bahuguna *et al*. 2008, Kumar & Gupta 2009, Tak *et al*. 2010). Notably, Dighal wetlands in Jhajjar district boast a rich array of wetland habitats, attracting

a significant number of water birds, especially migratory species during winters. This study aimed to address the scarcity of data on the diversity of wetland birds in Dighal wetlands, district Jhajjar, with a specific focus on documenting bird species, seasonality and conservation status.

Material and Methods

Study area

The research was performed in the Dighal wetlands (28° 22'–28° 49' N & 76° 18'–76° 59' E). Eight wetland sites were chosen for bird surveys, situated in the Beri tehsil of Jhajjar district, Haryana, North India *(Figure 1)*. Encompassing over 131.5 hectares, these wetlands comprise a network of numerous small and big ponds as well as significant areas of wet fields that have been fallowed for several years because of the elevated water table and waterlogging in the study area. Situated on the Central Asian Flyway, these wetlands are important wintering

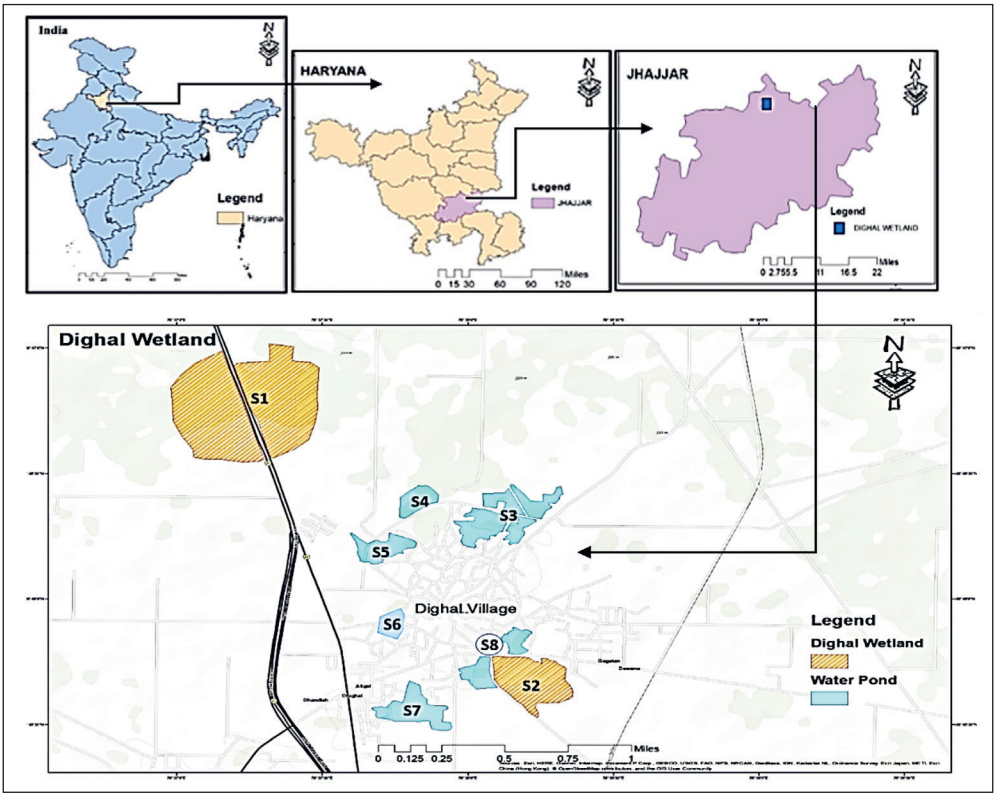

Figure 1. Study area map depicting eight selected sites (S1 to S8) within Dighal wetlands, Jhajjar district, Haryana, India

1. ábra Haryana Jhajjar körzetének Dighal vizes élőhelyén kiválasztott nyolc kutatási terület (S1–S8) térképe

habitats for numerous migratory bird species and are renowned as a popular destination for birdwatching enthusiasts. Recognized as a crucial site for avian conservation, the study area holds the designation of an Important Bird and Biodiversity Area of India, identified with the IBA code IN-HR-06 by the ENVIS Centre on Wildlife and Protected Areas (Rahmani *et al*. 2016). The Dighal wetlands in Haryana served as the focal point for the current study. The predominant crops in the region include wheat, rice, sugarcane, and mustard. Common tree species in the study area consist of Eucalyptus, Syzygium, Acacia, and Ziziphus. The research area has a subtropical climate with three discrete seasons: the cool dry season (October to February), the hot dry season (March to June), and the rainy season (July to September). Summer temperatures can rise to 45 °C, while winter lows can drop to 6 °C. On average, the district receives an annual rainfall of 444 mm.

Data collection

Avian surveys were conducted bi-weekly from April 2021 to March 2023 by means of the point count method used by Bibby *et al*. (2000). Every study site had four to six fixed points designated along its perimeter, each at least 250 meters apart. Every point was surveyed twenty-four times. A five-minute settling period was given at each point before recording bird species, and observations were made for the subsequent 10 minutes. Direct counts of wetland birds were made using field binoculars (Nikon 10×50) during peak activity hours, either from 06:00 to 10:00 hrs in the morning or between 16:00 to 18:00 hrs in the evening, depending on seasonal visibility. Photographs were taken with a DSLR Nikon D500 equipped with a 70–200 mm lens. Opportunistic bird records during other times of the day were included for an inclusive checklist of wetland birds. Birds were identified using field guide (Grimmett *et al*. 2016). The taxonomic position (family and order), common names and scientific names of the recorded bird species followed the checklist provided by Praveen and Jayapal (2023). Recorded bird species were designated with a local abundance categorized based on sighting frequency following Mackinnon and Phillipps (1993) as common (C), fairly common (F), uncommon (U), and rare (R). Residential status (winter migrant, summer migrant and resident) was determined based on presence or absence in the study area, following Kumar and Sharma (2019). Conservation status affiliated with WPA (2022), CITES (2012), and IUCN Red List (2024). A species accumulation curve was generated based on observed species richness. RDi (relative diversity index) of recorded avian families was calculated following the formula given by La Torre-Cuadros *et al*. (2007):

$$RDI = \frac{Number\ of\ bird\ species\ in\ a\ family}{Total\ number\ of\ bird\ species} \times 100$$

Species diversity was assessed using the formula given by Shannon and Wiener (1963) as

$$H = -\sum_{i=1}^{s} pi \ln pi$$

where, H species diversity index, pi is the proportion of the total sample belonging to the i^{th} species and S is the total number of species in the community.
Evenness index (E) was calculated using the formula:

$$E = \frac{H'}{\ln S}$$

where, H is Shannon–Wiener's diversity index and S is species richness.

Jaccard's similarity measures were used to perform cluster analysis with the paired group (UPGMA) method by PAST version 3.26 software. The species accumulation curve was formed based on observed species richness. Differences in species richness, evenness, abundance and diversity among two different seasons and years were compared using *t*-test.

Results

A total of 30,096 individual sightings representing 90 avian species, distributed across 12 orders, 23 families and 62 genera were recorded throughout the study period, reflecting seasonal and monthly variations in population abundance. The comprehensive checklist of wetland birds including their taxonomic position, local abundance status, residential status, and global conservation status is presented in *Table 1*. The highest species richness was recorded in the Charadriiformes order (24 species), followed by Anseriformes (19), and Pelecaniformes (12). The Anatidae with a record of 19 species emerged as the most abundant family, constituting 21.1% of the total wetland bird community. Scolopacidae was identified as the most diverse family after Anatidae comprising 13 species with a RDi value of 14.4, followed by Ardeidae (eight species, RDi = 8.8). In contrast, eight families including Phoenicopteridae, Podicipedidae, Anhingidae, Burhinidae, Accipitridae, Pandionidae and Meropidae were poorly represented, each registering only one species (RDi = 1.1) in the study area *(Table 2)*.

Of the recorded species, 62.2% (n = 56) were winter migrants, 33.3% (n = 30) were resident species, and only 4.5% (n = 4) were summer migrants. The species accumulation curve indicated a gradual increase in recorded species richness, reaching a stable value of 90 species in the last three samplings indicating the completeness of the sampling effort in that specific habitat *(Figure 2)*. Monthly variations in species richness revealed a peak in February and January in the first and second years, respectively, and July recorded the lowest richness in both years, directly correlating with the arrival and departure schedule of migratory bird species *(Figure 3)*. During the first year, the population abundance of wetland birds fluctuated across different months, with a cumulative total of 11,454 individual sightings representing 74 wetland avian species with a peak in January and a minimum in July. Meanwhile, in the second year, the cumulative number of bird sightings amounted to 18,642, representing 87 species with a peak in January and a minimum in July *(Figure 3)*.

The statistical analysis revealed significant variations ($P < 0.05$) in species richness, population abundance, diversity, and evenness between the summer and winter seasons

Table 1. Taxonomic position of wetland bird species along with residential, local abundance, conservation status, global population trend and population abundance in Dighal wetlands of Jhajjar district, Haryana, India

1. táblázat A kutatási területen megfigyelt madárfajok taxonómiai besorolása, előfordulási státusza, helyi tömegessége, természetvédelmi státusza globális állománytrendje és populációs abundanciája

S.No	Common name	Scientific name	Residential status	Local status	Conservation Status			Global trend
					IUCN 2024	WPA 2022	CITES 2012	
Order: Anseriformes Family: Anatidae								
1	Bar-headed Goose	*Anser indicus*	W	CO	LC	II	–	↓
2	Greater White-fronted Goose	*Anser albifrons*	W	RA	LC	II	–	?
3	Greylag Goose	*Anser anser*	W	FC	LC	II	–	↑
4	Lesser Whistling Duck	*Dendrocygna javanica*	S	FC	LC	II	–	↓
5	Common Shelduck	*Tadorna tadorna*	W	RA	LC	II	–	↑
6	Ruddy Shelduck	*Tadorna ferruginea*	W	FC	LC	II	–	?
7	Garganey	*Spatula querquedula*	W	UC	LC	II	–	↓
8	Red-crested Pochard	*Netta rufina*	W	UC	LC	II	–	?
9	Northern Shoveler	*Spatula clypeata*	W	CO	LC	II	–	↓
10	Common Pochard	*Aythya ferina*	W	CO	VU	I	–	↓
11	Ferruginous Duck	*Aythya nyroca*	W	UC	NT	II	–	↓
12	Tufted Duck	*Aythya fuligula*	W	FC	LC	II	–	→
13	Knob-billed Duck	*Sarkidiornis melanotos*	R	UC	LC	II	II	↓
14	Eurasian Wigeon	*Mareca penelope*	W	FC	LC	II	–	↓
15	Gadwall	*Mareca strepera*	W	FC	LC	II	–	↑
16	Northern Pintail	*Anas acuta*	W	CO	LC	II	–	↓
17	Common Teal	*Anas crecca*	W	CO	LC	II	–	?
18	Mallard	*Anas platyrhynchos*	W	RA	LC	II	–	↑
19	Indian Spot-billed Duck	*Anas poecilorhyncha*	R	CO	LC	II	–	↓
Order: Phoenicopteriformes Family: Phoenicopteridae								
20	Greater Flamingo*	*Phoenicopterus roseus*	W	RA	LC	II	–	↑
Order: Podicipediformes Family: Podicipedidae								
21	Little Grebe	*Tachybaptus ruficollis*	R	CO	LC	II	–	↓
Order: Gruiformes Family: Rallidae								
22	White-breasted Waterhen	*Amaurornis phoenicurus*	R	FC	LC	II	–	?
23	Purple Swamphen	*Porphyrio porphyrio*	R	FC	LC	II	–	?
24	Common Moorhen	*Gallinula chloropus*	R	CO	LC	II	–	→
25	Eurasian Coot	*Fulica atra*	W	CO	LC	II	–	↑
26	Baillon's Crake	*Zapornia pusilla*	W	RA	LC	II	–	?
Family: Gruidae								
27	Sarus Crane	*Antigone antigone*	R	UC	VU	I	II	↓

S.No	Common name	Scientific name	Residential status	Local status	Conservation Status			Global trend
					IUCN 2024	WPA 2022	CITES 2012	
28	Demoiselle Crane	*Grus virgo*	W	RA	LC	I	II	↑
Order: Ciconiiformes Family: Ciconiidae								
29	Asian Openbill	Anastomus oscitans	R	UC	LC	II	–	?
30	Painted Stork	*Mycteria leucocephala*	R	FC	LC	II	I	↑
31	Woolly-necked Stork	*Ciconia episcopus*	R	FC	NT	II	–	↓
Order: Pelecaniformes Family: Ardeidae								
32	Black-crowned Night Heron	*Nycticorax nycticorax*	R	UC	LC	II	–	↓
33	Indian Pond Heron	*Ardeola grayii*	R	CO	LC	II	–	?
34	Grey Heron	*Ardea cinerea*	R	UC	LC	II	–	?
35	Purple Heron	*Ardea purpurea*	R	UC	LC	II	–	↓
36	Great Egret	*Ardea alba*	R	UC	LC	II	–	?
37	Intermediate Egret	*Ardea intermedia*	R	UC	LC	II	–	↓
38	Cattle Egret	*Bubulcus ibis*	R	CO	LC	II	–	↑
39	Little Egret	*Egretta garzetta*	R	FC	LC	II	–	↑
Family: Threskiornithidae								
40	Eurasian Spoonbill*	*Platalea leucorodia*	W	UC	LC	I	–	?
41	Red-naped Ibis	*Pseudibis papillosa*	R	UC	LC	II	–	↓
42	Glossy Ibis*	*Plegadis falcinellus*	W	FC	LC	II	–	↓
43	Black-headed Ibis	*Threskiornis melanocephalus*	R	FC	LC	II	–	↑
Order: Suliformes Family: Phalacrocoracidae								
44	Great Cormorant	*Phalacrocorax carbo*	W	CO	LC	II	–	↑
45	Indian Cormorant	*Phalacrocorax fuscicollis*	R	FC	LC	II	–	?
46	Little Cormorant	*Microcarbo niger*	R	FC	LC	II	–	?
Family: Anhingidae								
47	Oriental Darter*	*Anhinga melanogaster*	W	UC	LC	II	–	↑
Order: Charadriiformes Family: Burhinidae								
48	Indian Thick-knee	*Burhinus indicus*	W	RA	LC	II	–	?
Family: Recurvivostridae								
49	Black-winged Stilt	*Himantopus himantopus*	R	CO	LC	II	–	↑
50	Pied Avocet	*Recurvirostra avosetta*	W	CO	LC	II	–	?
Family: Charadriidae								
51	Little Ringed Plover	*Charadrius dubius*	R	RA	LC	II	–	→
52	Yellow-wattled Lapwing	*Vanellus malabaricus*	R	RA	LC	II	–	→
53	Red-wattled Lapwing	*Vanellus indicus*	R	CO	LC	II	–	?
54	White- tailed Lapwing	*Vanellus leucurus*	W	UC	LC	II	–	?

S.No	Common name	Scientific name	Residential status	Local status	Conservation Status			Global trend
					IUCN 2024	WPA 2022	CITES 2012	
Family: Jacanidae								
55	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	S	RA	LC	II	–	?
56	Bronze-winged Jacana	*Metopidius indicus*	S	RA	LC	II	–	?
Family: Scolopacidae								
57	Eurasian Curlew	*Numenius arquata*	W	RA	NT	II	–	↓
58	Black-tailed Godwit	*Limosa limosa*	W	CO	NT	II	–	↓
59	Marsh Sandpiper	*Tringa stagnatilis*	W	UC	LC	II	–	↓
60	Common Redshank	*Tringa totanus*	W	CO	LC	II	–	?
61	Spotted Redshank	*Tringa erythropus*	W	UC	LC	II	–	→
62	Common Greenshank	*Tringa nebularia*	W	RA	LC	II	–	→
63	Green Sandpiper	*Tringa ochropus*	W	UC	LC	II	–	↑
64	Wood Sandpiper	*Tringa glareola*	W	CO	LC	II	–	→
65	Temminck's Stint	*Calidris temminckii*	W	UC	LC	II	–	?
66	Little Stint	*Calidris minuta*	W	UC	LC	II	–	↑
67	Ruff	*Calidris pugnax*	W	CO	LC	II	–	↓
68	Common Sandpiper	*Actitis hypoleucos*	W	CO	LC	II	–	↓
69	Common Snipe	*Gallinago gallinago*	W	RA	LC	II	–	↓
Family: Laridae								
70	River Tern	*Sterna aurantia*	W	UC	VU	I	–	↓
71	Black-headed Gull	*Chroicocephalus ridibundus*	W	UC	LC	II	–	?
Order: Accipitriformes Family: Pandionidae								
72	Osprey	*Pandion haliaetus*	W	UC	LC	I	II	↑
Family: Accipitridae								
73	Brahminy Kite	*Haliastur indus*	W	RA	LC	I	II	↓
74	Western Marsh Harrier	*Circus aeruginosus*	W	RA	LC	I	II	→
Order: Coraciiformes Family: Coracidae								
75	Blue-cheeked Bee-eater	*Merops persicus*	S	UC	LC	II	–	↑
Family: Alcedinidae								
76	Pied Kingfisher	*Ceryle rudis*	R	UC	LC	II	–	?
77	Common Kingfisher	*Alcedo atthis*	W	RA	LC	II	–	↓
78	White-throated Kingfisher	*Halcyon smyrnensis*	R	FC	LC	II	–	↑
Order: Falconiformes Family: Falconidae								
79	Peregrine Falcon	*Falco peregrinus*	W	RA	LC	I	I	↑
Order: Passeriformes Family: Motacillidae								
80	White Wagtail	*Motacilla alba*	W	CO	LC	II	–	→
81	Citrine Wagtail	*Motacilla citreola*	W	CO	LC	II	–	↑

S.No	Common name	Scientific name	Residential status	Local status	Conservation Status			Global trend
					IUCN 2024	WPA 2022	CITES 2012	
82	Western Yellow Wagtail	*Motacilla cinerea*	W	FC	LC	II	–	↓
83	White-browed Wagtail*	*Motacilla maderaspatensis*	W	CO	LC	II	–	→
84	Rosy Pipit	*Anthus roseatus*	W	UC	LC	II	–	→
85	Water Pipit	*Anthus spinoletta*	W	RA	LC	II	–	→
Family: Hirundinidae								
86	Asian Plain Martin	*Riparia paludicola*	W	RA	LC	II	–	↓
87	Pale Sand Martin	*Riparia diluta*	W	RA	LC	II	–	?
88	Streak-throated Swallow	*Petrochelidon fluvicola*	R	UC	LC	II	–	↑
89	Barn Swallow	*Hirundo rustica*	W	UC	LC	II	–	↓
90	Wire tailed Swallow	*Hirundo smithii*	R	FC	LC	II	–	↑

Residential Status: R- Resident, S- Summer Migrant, W- Winter Migrant
Local Status: CO- Common, FC- Fairly Common, UC- Uncommon, RA- Rare,
IUCN (International Union for Conservation of Nature, 2024)- LC- Least concern, NT- Near Threatened, VU-Vulnerable, EN- Endangered
WPA (The Wildlife (Protection) Amendment Act, 2022)- I & II refer to Schedule-I and Schedule- II respectively
CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2012)- I & II refer to Appendix-I and Appendix- II respectively
Global Trend- ↑- Increasing, ↓- Decreasing, →- Stable, ?- Unknown
*Species which are resident in Haryana but recorded as winter migrant in the study area

in the first year (2021–2022) *(Table 3)*. A similar trend of significant variation in both seasons was observed during the second year of the study (2022–2023) with species richness, population abundance, species diversity and evenness *(Table 4)*. The average species richness, abundance, and diversity were notably higher during the winter season compared to summer. However, the mean species evenness was found to be significantly ($P < 0.05$) greater in summer than in winter in both the years. Moreover, the study unveiled non-significant distinctions in richness, abundance, diversity and evenness of wetland birds across these years compared with the paired t-test ($P > 0.05$) *(Table 5)*.

Among the total 90 species recorded from the study area, 8 species were common to all eight selected sites whereas 19 species were unique to specific sites, and the remaining species were distributed across two or more sites. Jaccard's index measured similarity in the species composition revealed maximum similarity in between S1 and S2 sites with index of 0.647 followed by similarity index of 0.553 between sites S2 and S8. The least similarity (0.166) was recorded between the S1 and S4. In contrast, study site S4 displayed a notable divergence from other sites. Jaccard's similarity index was used for detailed cluster analysis (UPGMA) of each wetland site is depicted in *Figure 4*.

Local abundance status revealed the presence of 23 common species, 18 fairly common species, 28 uncommon species, and 21 rare species. As far as the global population trends of the recorded species concerned, 24 exhibited an increasing population trend, 29 had a decreasing trend, 12 maintained stable trend, and the population trend of 25 species was unknown. Furthermore, upon comparing the global population trend with the local abundance status *(Figure 5)*, it was revealed that nine species with a decreasing population trend globally were commonly found in the study area. This includes species such as the

Table 2. RDi (relative diversity index) of water bird families in Dighal wetlands of Jhajjar district, Haryana, India

2. táblázat A kutatási területen megfigyelt madárcsaládok relatív diverzitási indexei (RDi)

S. No.	Order	Family	Number of species	RDi value %
1.	Anseriformes	Anatidae	19	21.11
2.	Phoenicopteriformes	Phoenicopteridae	1	1.11
3.	Podicepediformes	Podicipedidae	1	1.11
4.	Gruiformes	Rallidae	5	5.55
		Gruidae	2	2.22
5.	Ciconiiformes	Ciconiidae	3	3.33
6.	Pelecaniformes	Ardeidae	8	8.88
		Threskiornithidae	4	4.44
7.	Suliformes	Phalacrocoracidae	3	3.33
		Anhingidae	1	1.11
8.	Charadriiformes	Burhindae	1	1.11
		Recurvirostridae	2	2.22
		Charadriidae	4	4.44
		Scolopacidae	13	14.44
		Laridae	2	2.22
		Jacanidae	2	2.22
		Pandionidae	1	1.11
9.	Accipitriformes	Accipitridae	2	2.22
10.	Falconiformes	Falcanidae	1	1.11
11.	Coraciiformes	Alcedinidae	3	3.33
		Meropidae	1	1.11
12.	Passeriformes	Motacillidae	6	6.66
		Hirundinidae	5	5.55

Bar-headed Goose *(Anser indicus)*, Common Pochard *(Aythya farina)*, Northern Shoveler *(Spatula clypeata)*, Indian Spot-billed Duck *(Anas poecilorhyncha)*, Northern Pintail *(Anas acuta)*, Little Grebe *(Tachybaptus ruficollis)*, Black-tailed Godwit *(Limosa limosa)*, Ruff *(Calidris pugnax)* and Common Sandpiper *(Actitis hypoleucos)*.

Among the recorded species, three species Sarus Crane *(Antigone antigone),* Common Pochard *(Aythya farina)* and River Tern *(Sterna aurantia)* are listed as Vulnerable and four species Ferruginous Pochard *(Aythya nyroca)*, Woolly-necked Stork *(Ciconia episcopus)*, Black-tailed Godwit *(Limosa limosa)* and Eurasian Curlew *(Numenius arquata)* as Near Threatened; and the remaining 83 species are Least Concern species in the IUCN Red List (2024). Two species Peregrine Falcon *(Falco peregrines)* and Painted Stork *(Mycteria leucocephala)* are recorded in Appendix I and six species Knob-billed Duck *(Sarkidiornis melanotos)*, Sarus Crane *(Antigone antigone)*, Demoiselle Crane *(Grus virgo)*, Brahminy Kite *(Haliastur indus)*, Osprey *(Pandion haliaetus)*, Western Marsh Harrier *(Circus aeruginosus)*

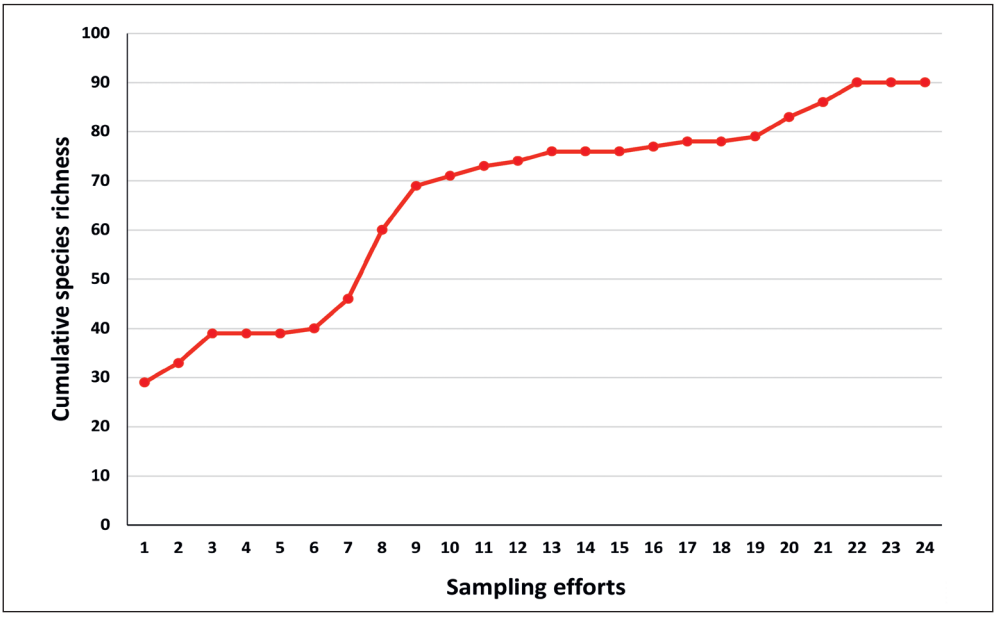

Figure 2. Species accumulation curve of wetland birds recorded in Dighal wetlands of Jhajjar district from April 2021–March 2023

2. ábra A Jhajjar körzet Dighal vizes élőhelyén 2021 áprilisától 2023 márciusáig regisztrált vizes élőhelyet használó madarak telítődési görbéje

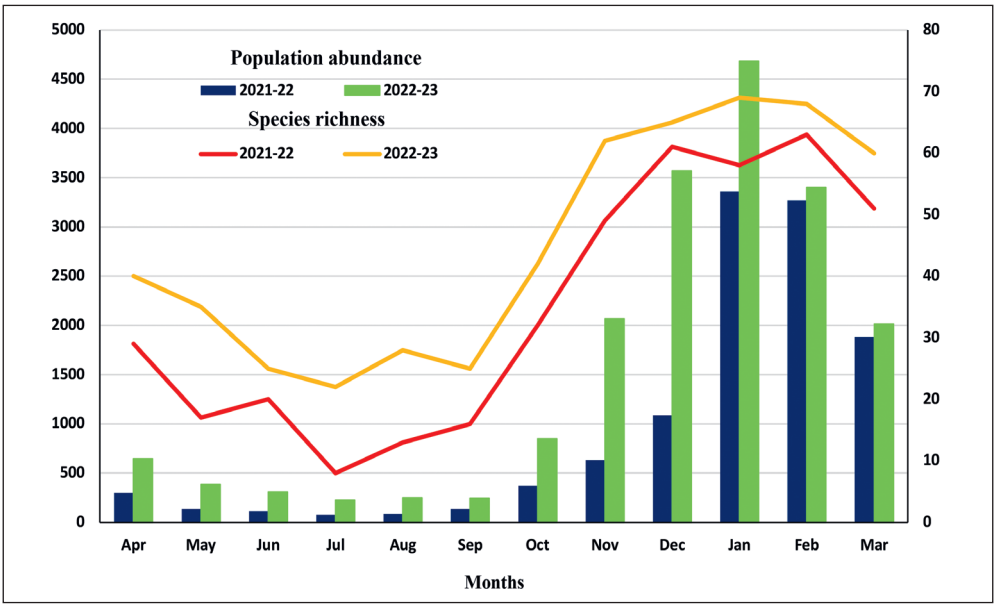

Figure 3. Monthly variations in population abundance and species richness of wetland birds in the study area from April 2021 to March 2023

3. ábra A vizes élőhelyek madárállományának és fajgazdagságának havi változásai a vizsgált területen 2021 áprilisától 2023 márciusáig

Table 3. Seasonal variations in species richness, population abundance, diversity and evenness of wetland birds recorded in Dighal wetlands in Jhajjar district, Haryana during 2021–2022.
3. táblázat A kutatási területen 2021–2022-ben megfigyelt madárfajok fajgazdagságának, abundanciájának, diverzitásának és kiegyenlítettségének szezonális változásai

Diversity indices (2021-2022)	**Summer** (mean±SE)	**Winter** (mean±SE)	**Both** (mean±SE)	**P-value**
Species richness	17.16±2.89	52.33±4.64	34.75±5.9	0.000
Population abundance	141.5±33.47	1767.5±532.32	954.5±353.19	0.012
Species diversity	2.5±0.137	3.1±0.11	2.8±0.12	0.005
Species evenness	0.78±0.03	0.49±0.07	0.63±0.05	0.005

Table 4. Seasonal variations in species richness, population abundance, diversity and evenness of wetland birds recorded in Dighal wetlands in Jhajjar district, Haryana during 2022–2023.
4. táblázat A kutatási területen 2022–2023-ban megfigyelt madárfajok fajgazdagságának, abundanciájának, diverzitásának és kiegyenlítettségének szezonális változásai

Diversity indices (2022-2023)	**Summer** (mean±SE)	**Winter** (mean±SE)	**Both** (mean±SE)	**P-value**
Species richness	29.1±2.82	61±4.04	45.08±5.34	0.000
Population abundance	342.5±65.46	2764.5±561.7	1553.5±453.88	0.002
Species diversity	2.9±0.11	3.2±0.05	3.07±0.07	0.035
Species evenness	0.65±0.02	0.43±0.04	0.54±0.04	0.002

Table 5. Temporal variation in various diversity indices of wetland bird communities recorded in Dighal wetlands of Jhajjar district, Haryana during the two-year study period
5. táblázat A kutatási területen a kétéves kutatási időszakban megfigyelt madárfajok különböző diverzitási indexeinek időbeli változása

Diversity indices	**Mean±SE**		**t-value**	**p-value**
	2021–2022	**2022–2023**		
Species richness	34.7±5.9	45±5.34	1.297	0.603
Population abundance	954.5±353.1	1553.5±453.8	1.042	0.226
Species diversity	2.8±0.12	3.07±0.07	1.578	0.053
Species evenness	0.06±0.05	0.54±0.04	1.314	0.300

are included in Appendix II of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 2012. Additionally, ten species Sarus Crane, Demoiselle Crane, Common Pochard, Osprey, Common Greenshank *(Tringa nebularia)*, River Tern, Eurasian Spoonbill *(Platalea leucorodia)*, Brahminy Kite, Peregrine Falcon, Western Marsh Harrier are nationally protected under Schedule I of The Wildlife (Protection) Amendment Act, 2022.

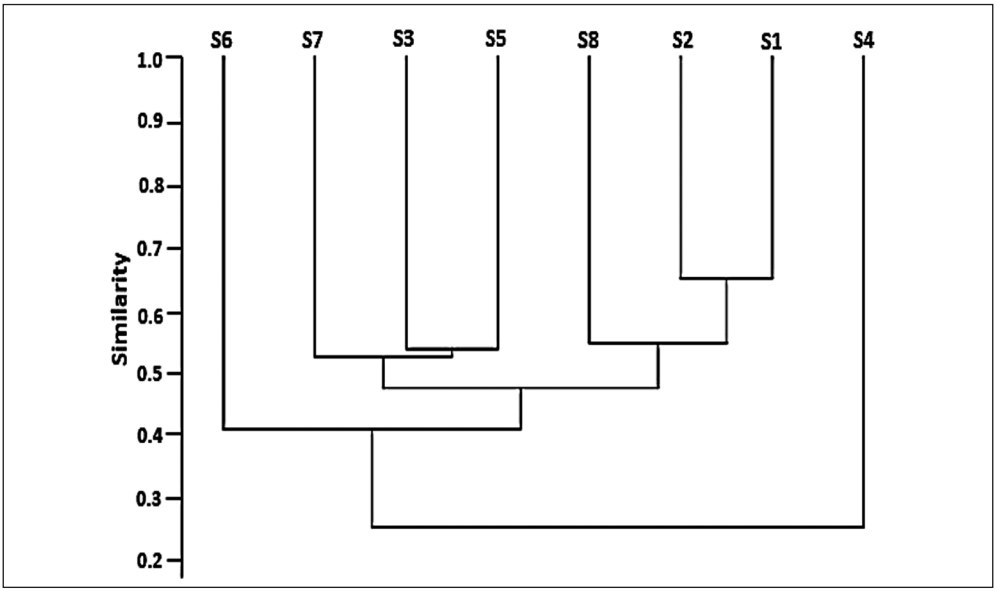

Figure 4. Cluster analysis based on Jaccard's similarity index using unweighted pair group method with arithmetic mean (UPGMA) showing similarity of wetland bird species composition across selected sites of Dighal wetlands of Jhajjar district, Haryana

4. ábra A Jaccard-féle hasonlósági indexen alapuló klaszterelemzés a súlyozatlan párcsoportos módszerrel és számtani átlaggal (UPGMA), amely a vizes élőhelyeket használó madárfajok összetételének hasonlóságát mutatja Haryana Jhajjar körzetének Dighal vizes élőhelyén

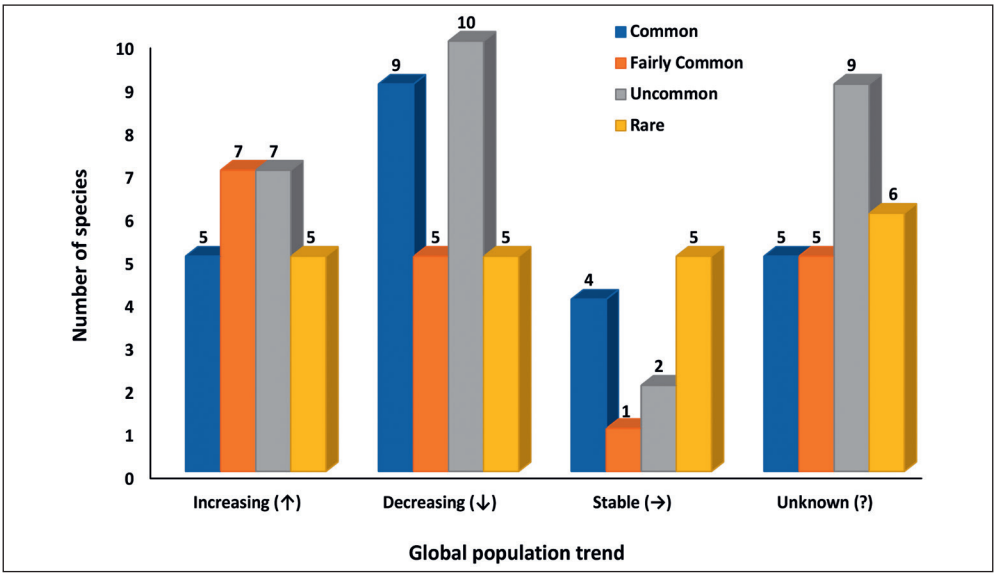

Figure 5. Comparative analysis of local abundance status and global population trends among wetland bird species documented in Dighal wetlands of Jhajjar district, Haryana

5. ábra Haryana Jhajjar körzetének Dighal vizes élőhelyén dokumentált vizes élőhelyi madárfajok helyi gyakoriságának és globális populációs trendjeinek összehasonlító elemzése

Discussion

The research area supports a notable diversity of wetland birds, representing about 16.4% of the total species documented in Haryana by Kalsi *et al*. (2020) and 6.43% avifauna of India, according to checklist of Parveen and Jayapal (2023). The results reveal that the richness of wetland bird species documented in the surveyed wetlands shows similarities with previous studies of different areas of Haryana. For instance, Kumar and Gupta (2009) identified 54 species of wetland birds in various habitats of Kurukshetra District, Gupta and Kaushik (2011) found 47 species in Hathnikund Barrage of Yamunanagar District, and Kumar and Dhankhar (2015) documented 66 species in Bhindawas wetland in Jhajjar. Moreover, Boora and Kumar (2023) reported 70 species from rural ponds in Kurukshetra district, while Alfred *et al*. (2001) extensively listed 216 species of wetland bird in the broader Indo-Gangetic Plains and Sub-Himalayan Terai of North India. The observed richness in the wetland bird community is attributed to the diverse habitats in and around the study area, featuring large wintering grounds, marshy wetlands, ponds, and agriculturally active fields. Specific tree species along the wetland edges further enhance habitat diversity, contributing to the overall richness of the avian community.

In this study, Charadriiformes emerged as the dominant avian order, comprising 23 species from six families. These findings align with previous studies, highlighting Charadriiformes as the most represented avian taxa in freshwater wetlands in India (Gupta *et al*. 2012, Mandal *et al*. 2021, Boora & Kumar 2023, Byju *et al*. 2024). Among the recorded bird families in the wetlands of Jhajjar district, Anatidae stood out as the most diverse family, consistent with broader trends observed in different wetlands across India (Manral & Khudsar 2013, Sharma & Saini 2014, Jha & McKinley 2015, Kumar & Sharma 2019, Yashmita-Ulman & Singh 2022, Makwana *et al*. 2024).

The maximum number of recorded species were winter migrants which is followed by residents and summer migrants, steady with earlier records on freshwater wetland habitats in northern India (Malik & Joshi 2013, Manral & Khudsar 2013, Sharma & Saini 2014, Kumar *et al*. 2016, Boora & Kumar 2023). January exhibited the highest species richness, consistent with earlier observations in sacred ponds, and rural ponds of Kurukshetra district (Kumar & Sharma 2019, Boora & Kumar 2023). The study indicated an upward trend in bird species from October, peaking in January due to the arrival time of migratory bird species in the wetlands during this period. Meanwhile, strategic location of Haryana on the Central Asian Flyway designates this area as critical wintering and stopover destination for these migrant species, contributing to the substantial number of winter visitors documented in this study. As migratory species gradually depart for their breeding grounds starting from March, species richness gradually decreases, reaching its minimum in July. Additionally, the study identified noteworthy differences in species richness, population abundance, and species diversity between the winter and summer seasons. The higher species richness, population abundance, and species diversity of wetland birds during the winter season align with earlier records, attributing this pattern to the influx of a relatively higher number of migrant species during the winter period (Rajashekara & Venkatesha 2017, Kumar & Sharma 2019, Yashmita-Ulman & Singh 2022, Boora & Kumar 2023).

The analysis using Jaccard's similarity index revealed distinct patterns of species distribution among the eight study sites. It highlighted that the species composition of bird community at study site S4 is fairly dissimilar from that of the remaining study sites. These findings align with previous research that underscores the role of habitat heterogeneity in influencing bird assemblages (Rathod & Padate 2008, Ganbold *et al*. 2018, Kumar & Sharma 2018, Boora & Kumar 2023).

The presence of eight common species in all the eight study sites can be attributed to their adaptability to diverse conditions including adequate food sources, stable shelter and essential resources for their survival. The study highlighted seven species considered as significance of global conservation, including three Vulnerable species and four categorized as Near Threatened. Additionally, eight species recorded in the CITES appendices occupy these wetlands, and nine species enjoy national protection under Schedule I of The Wildlife (Protection) Amendment Act, 2022. Notably, nine species having decreasing global populations were commonly identified in the study area, suggesting the persistent accessibility of favourable resources for such species within the wetlands.

Moreover, the Dighal wetlands face susceptibility to numerous challenges, stemming from the intrusion of invasive weed species such as common water hyacinth *(Eichhornia crassipes)* and anthropogenic activities. These include extensive fishing, electrocution, construction in proximity to ponds, fertilizer runoff, disposal of domestic waste, drainage of water during winter, and plastic pollution in and around the vicinity of ponds. Consequently, these factors collectively pose a significant threat to the survival of the water bird species and wetland habitat inhabiting these wetlands.

Conclusion

The Dighal wetlands located in Jhajjar district emerge as ecologically vital habitats for wetland birds, providing support to 90 species encompassing both local and migratory birds. Within this study area, seven species hold global conservation significance, and 29 species exhibit a declining global population trend. Despite its ecological importance, the Dighal wetlands face severe threats arising from invasive species and human activities such as fishing, construction, runoff, and pollution. These challenges pose a substantial risk to the habitat and the survival of various wetland bird species. Conservation efforts are imperative to address these threats and sustain the ecological balance of the wetlands. Implementing sustainable practices and mitigating human-induced pressures are crucial for preserving the diverse bird community and ensuring the long-term well-being of the Dighal wetlands.

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