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Seasonal variations and migration phenology of the avifauna of Mandothi wetlands, India

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Abstract The Mandothi wetlands, a lesser-known but ecologically significant ecosystem in Haryana, India, serve as an excellent habitat for diverse flora and fauna. This wetland plays a vital role in groundwater recharge, flood control, and climate regulation while supporting livelihood for local communities. Using scan sampling and point-cum-line transect techniques, the region was surveyed fortnightly from April 2022 to March 2024. A total of 79 migratory bird species were identified, classified into 12 orders, 25 families, and 48 genera. Out of these, 20 species were summer migrants and 59 were winter migrants. The order Charadriiformes exhibits the highest diversity of avian fauna with 24 migratory species. Among all guilds, insectivores were the most prevalent, according to the classification into feeding guilds. As per the IUCN Red List criteria, 71 species were classified as Least Concern (LC) whereas five species were classified as Near Threatened (NT) [Ferruginous Duck *(Aythya nyroca)*, Black-tailed Godwit *(Limosa limosa),* Eurasian Curlew *(Numenius arquata),* Curlew Sandpiper *(Calidris ferruginea)*, Black-necked Stork *(Ephippiorhynchus asiaticus)* and three species were classified as Vulnerable (VU) such as Eastern Imperial Eagle *(Aquila heliaca)*, Greater Spotted Eagle *(Clanga clanga)* and Common Pochard *(Aythya ferina)*]. The study area plays a significant role in sustaining the diversity of birds and facing various stress factors, thus, it needs to be conserved effectively.

Keywords: ecological interactions, habitat preferences, population dynamics, summer migrant, winter migrant

Összefoglalás A Mandothi vizesélőhely-rendszer, mely India Haryana tartományának kevéssé ismert, de ökológiai értelemben jelentős ökoszisztémája, változatos növény- és állatvilág számára ad otthont. Ez a vizesélőhely-rendszer kulcsfontosságú szerepet játszik a talajvíz megőrzésében, az áradások szabályzásában és a klímaregulációban, valamint hozzájárul helyi közösségek létfenntartásához. Szkenneléses és pont-transzekt számlálásos felmérési módszerek alkalmazásával a térség madárvilágát mintáztuk 2022 áprilisa és 2024 márciusa között. Ebben az időszakban 79 madárfaj jelenlétét rögzítettük, melyek 12 rendbe, 25 családba és 48 nembe tartoztak. Ezek közül 20 faj nyári vonuló, 59 faj téli vonuló. A Charadriiformes rend volt a legnagyobb fajszámmal jelen, 24 vonuló fajjal. Az összes táplálkozási guild közül a rovarevők alkották a legnagyobb halmazt. Az IUCN Vörös Listájának kritériumrendszere szerint 71 faj volt Nem Fenyegetett (LC), míg öt faj bizonyult Közel Veszélyeztetettnek (NT), mint a cigányréce *(Aythya nyroca)*, nagy goda *(Limosa limosa)*, nagy póling *(Numenius arquata)*, sarlós partfutó *(Calidris ferruginea)*, feketenyakú gólya *(Ephippiorhynchus asiaticus)*; emellett három faj tartozott a Sérülékeny (VU) kategóriába: parlagi sas *(Aquila heliaca)*, fekete sas *(Clanga clanga)* és barátréce *(Aythya ferina)*.

Kulcsszavak: élőhelypreferencia, nyári vonuló, ökológiai interakciók, populációdinamika, téli vonuló

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Introduction

India's biodiversity is vast and multifaceted, largely due to the heterogeneity of its physical features, distinctive ecological history, and extreme eco-climatic variations (Chakraborty *et al*. 2023). It is one of the world's 17 mega-bio-diverse countries, with abundant biodiversity and distinctive environments. Preserving avian diversity requires resources like wetlands, which are home to a variety of bird species as well as a wide variety of animals, plants and invertebrates (Weller 1999). Wetlands are complex ecosystems that integrate aquatic and terrestrial environments (Torell *et al*. 2001, Zedler & Kercher 2005, Kumar *et al*. 2006). Birds also use wetlands as a source of drinking water and habitats for feeding, resting, shelter and social interactions (Stewart 2001). Wetlands are defined as "an area of fen, marsh, peat land or water, either natural or artificial, temporary or permanent, static or flowing fresh, marine, brackish or saltwater along with a depth of six meters at low tide", according to the Ramsar Convention Secretariat (2013). According to Ministry of Environment, Forest and Climate Change (MoEFCC 2024), India harbours 1,309 wetlands in total; 91 Ramsar sites, 110 significant wetlands and 1,108 other wetlands.

Birds classified as migratory are those that make regular, seasonal, large-scale, long-distance movement of a population between a designated breeding area and a fixed non-breeding area (Lack 1954, 1968, Sutherland 1998, Alerstam *et al*. 2003, Greenberg & Marra 2005, Somveille 2016, Tapia Harris 2022). Since migratory birds occupy multiple trophic levels in the wetland food web, they constitute an important biotic component of the ecosystem (Rai *et al*. 2017). A number of bird species migrate seasonally and regularly throughout the globe. Approximately 200 migratory species are currently considered globally threatened, and more than 40% of them are on the verge of decline (Rai *et al*. 2017). The sites of key conservation concern which are important for migratory avifauna needs to be managed adequately. Ornithological surveys are frequently utilized as archives of fundamental data, and they also function as a biodiversity catalogue for species presence, distribution, ecological condition, conservation status and adaptations to climate change (Gardner *et al*. 2011, Rai & Vanita 2022, Rai & Yadav 2023).

However, due to paucity of research data, the present study aims to address the diversity assessment, seasonal variations and migration phenology of the avifauna of Mandothi wetlands, India. Furthermore, the research highlights the need for integrating role of local communities and various stakeholders in conservation initiatives to ensure the long-term protection of such wetlands.

Material and Methods

Study area

The study was carried out in the Mandothi wetlands in District Jhajjar, Haryana, India, located between the latitudes of 28°22'49" N and the longitudes of 76°18'59" E *(Figure 1)*. A section of the Indo-Gangetic Plain is represented by the district Jhajjar. Village Mandothi,

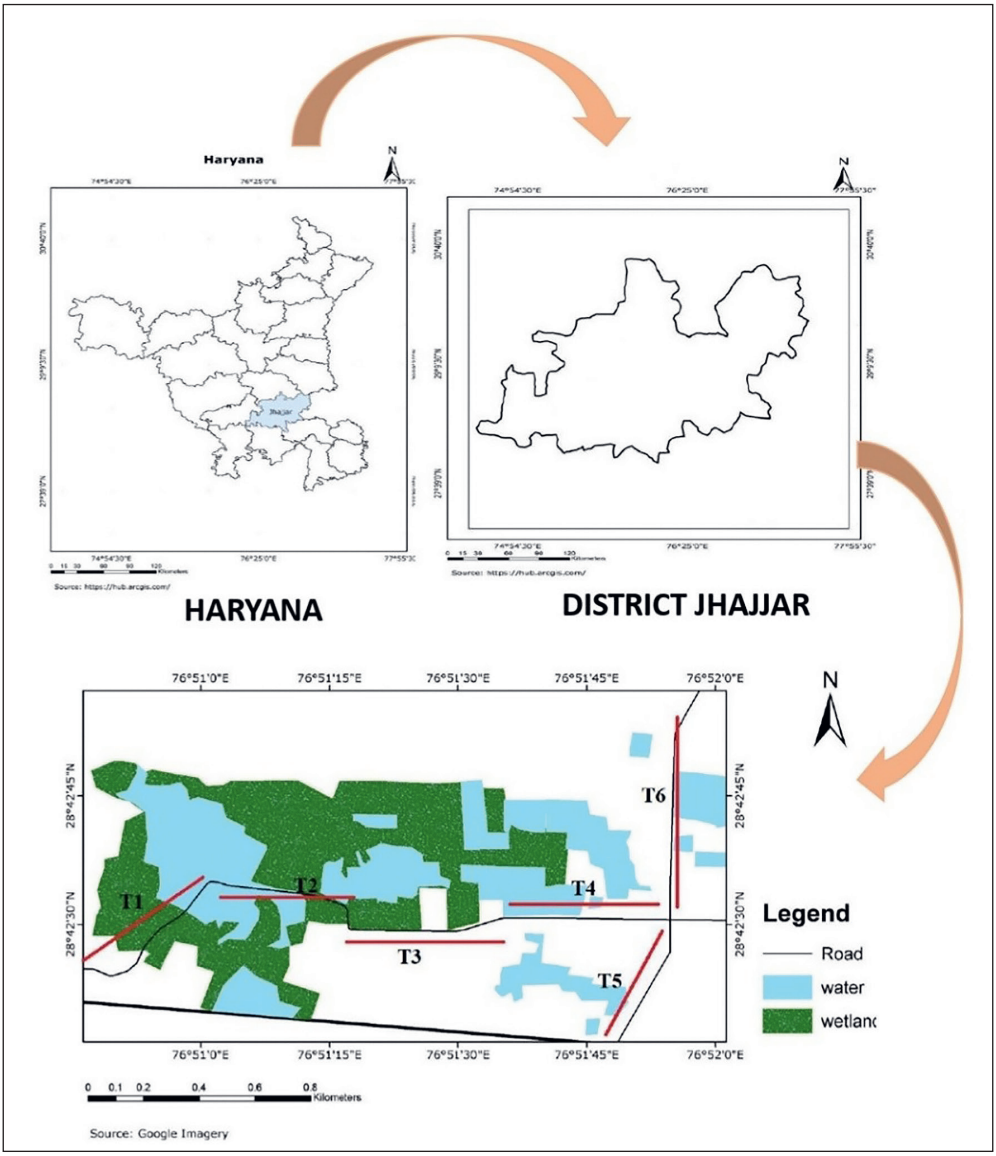


Figure 1. Map showing the location of Mandothi wetlands, Haryana
1. ábra A Hariyana-beli Mandothi wetlands földrajzi elhelyezkedése

located at 28°70'585" N and 76°81'225" E, is situated on the NH-9 in the Bahadurgarh assembly and Rohtak parliamentary constituencies. The region experiences extreme climatic conditions, typical of northwestern India, with hot summers (temperature often exceeding 40 °C) and cool winters (temperature dropping to around 5 °C) (Yadav & Rai 2024). A total of 6 transects with different habitats were selected in the study area *(Table 1)*. This area acts as a catchment for rainwater and supports local groundwater recharge.

Table 1. Selected transects with different lengths and habitats of Mandothi wetlands, India
1. táblázat Az indiai Mandothi wetlands területén kiválasztott transzektek, illetve ezek hossza és élőhelytípusa

S. N.	Transects	Transects length (km)	Coordinates	Habitats observed nearby at transect
1.	Transect T1	2.3	28.7262° N, 76.8470° E	Aquatic, Littoral Zone, Roadside railing, Fallow land
2.	Transect T2	1.2	28.7141° N, 76.8485° E	Aquatic, Littoral zone, Agricultural fields
3.	Transect T3	1.3	28.7096° N, 76.8513° E	Aquatic, Littoral zone, Roadside Plantation, Agricultural fields
4.	Transect T4	1.0	28.7080° N, 76.8502° E	Littoral zone, Roadside Plantation, Industrial area, Fallow land
5.	Transect T5	1.1	28.7016° N, 76.8501° E	Agricultural fields, Industrial area, Fallow land
	Transect T6	2.0	28.7105° N, 76.8643° E	Industrial area, Roadside Plantation, Fallow land

Field methods

From April 2022 to March 2024, fortnightly periodic visits were made at the study site using various techniques such as scan sampling and point-cum-line transect (Altmann 1974, Gaston 1975, Sutherland *et al*. 2005). Migratory status of the reported avian species was assigned as per Rai and Yadav (2023) *(Table 2)*. Equipment such as binoculars and Nikon COOLPIX P1000 were used to observe the diversity of avian fauna. Merlin Bird ID and field guides such as Grimmett *et al*. (2015), Arlott (2015), Grimmett and Inskipp (2019), Kalsi *et al*. (2019) were used to identify the birds. Using Praveen *et al*. (2019), Praveen and Jayapal (2022), and IUCN (2024), a checklist of reported bird species was made and categorized based on common name, scientific name, order, family and genus. Evaluation of the species, conservation status and population trends (increasing ↑, decreasing ↓, stable →, and unknown?) were done with the help of IWPA (1972), CITES (2012) and IUCN (2024). Based on in-depth research and literature (Ali & Ripley 1987, Grimmett *et al*. 1999), avian feeding guilds were divided into seven groups: carnivores, insectivores, omnivores, herbivores, frugivores, granivores and piscivores. The Percent occurrence of reported avian orders and Relative Diversity index (RDi) of bird families was assessed using the following formulas:

$$Percent\ occurence = \frac{Number\ of\ bird\ species\ in\ an\ order}{Total\ number\ of\ bird\ species} \times 100$$

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

Table 2. Criteria for status of migratory avian species (Rai & Yadav 2023)
2. táblázat A vonuló madárfajok státuszának kritériumai (Rai & Yadav 2023)

Residential status	Consideration criteria
Summer Migratory (SM)	Reports of species over the summer only (April–September)
Winter Migratory (WM)	Species seen in the winter months only (October–March)
Along with the migratory status, the tentative schedule including arrival and departure of the migratory avian species will also be recorded in selected area.	

Results and Discussion

The Mandothi wetlands located in the state of Haryana, India, are well-known for their remarkable bird diversity (Rai & Yadav 2023). The present two-year study documented 79 migratory bird species including 59 winter and 20 summer migratory species classified into 48 genera, 25 families and 12 orders (from April 2022 to March 2024) in selected transects of Mandothi wetlands, Haryana. A checklist of recorded avian species with their taxonomy and IUCN status is presented in *Table 3*. Findings of the study also revealed that during the first year (April 2022 – March 2023), a total of 65 migratory species were reported in which 49 species were winter migrants and 16 species were summer migrants, and during the second year (April 2023 – March 2024), out of total reported 66 migratory species, 51 species were winter migrants and 15 species were summer migrants, respectively. Along with these, 8 winter and 5 summer migrant species were different in the first year of the study period whereas 10 winter and 4 summer migrant species were different during the second year of the study *(Table 4)*.

Results of the study revealed that order Charadriiformes dominate the current study area consisting of 24 species and 7 families with 15 genera, followed by Passeriformes (17 species, 7 families and 12 genera), Anseriformes (15 species, 1 family and 8 genera), Accipitriformes and Pelecaniformes (5 species each; 2 and 1 families respectively and 5 genera each), Coraciiformes and Cuculiformes (3 species, 1 family and 1 genera each), Podicipediformes and Suliformes (consist of 2 species each and both with single family and genera), whereas Ciconiiformes, Gruiformes and Piciformes with one species, single family and genera (*Table 5*). Among the 25 families, the maximum number of species were recorded in the Scolopacidae with 16 species followed by Anatidae with 15 species, Motacillidae (7 species), Ardeidae (5 species), Accipitridae (4 species), Meropidae, Cuculidae, Alaudidae and Muscicapidae (3 species each), Charadriidae, Laridae, Podicipedidae and Phalacrocoracidae consist of 2 species each, while families like Pandionidae, Recurvirostridae, Jacanidae, Rostratulidae, Glareolidae, Ciconiidae, Rallidae, Laniidae, Oriolidae, Phylloscopidae, Sylviidae, Picidae observed with one species each.

During the study, it was observed that insectivores were the dominant feeding guilds with 41% of the species, whereas carnivores were the second dominant with 25%, followed by omnivores (22%) and herbivores (13%). To maximise food sources and extend their lifespan, birds employ a range of feeding techniques (Nudds & Bowlby 1984). Since the wetlands offer a wet climate and a wide variety of plants, the existence of a significant percentage of

Table 3. List and status of migratory avifauna recorded in Mandothi wetlands, India
3. táblázat Az indiai Mandothi wetlands területén megfigyelt madárfajok listája és státusza

S. No.	Order/ Family/ Common name	Scientific name with Authority	Feeding guild	IUCN Global population trends	Conservation status			Migratory Status	Local Abundance Status
					IUCN (2022)	CITES (2012)	IWPA (1972)		
1. ORDER ANSERIFORMES (No. of species = 15, No. of family = 1, Percent occurrence = 18.99)									
1.1. Family Anatidae (No. of species = 15, RDi value = 18.99)									
1.	Bar-headed Goose	*Anser indicus* (Latham, 1790)	H	↓	LC	-	IV	WM	A
2.	Greylag Goose	*Anser anser* (Linnaeus, 1758)	H	↑	LC	-	IV	WM	A
3.	Greater White-fronted Goose	*Anser albifrons* (Scopoli, 1769)	O	?	LC	-	IV	WM	RA
4.	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	O	↓	VU	-	IV	WM	C
5.	Tufted Duck	*Aythya fuligula* (Linnaeus, 1758)	H	→	LC	-	IV	WM	RA
6.	Ferruginous Duck	*Aythya nyroca* (Güldenstädt, 1770)	O	↓	NT	-	IV	WM	FC
7.	Eurasian Wigeon	*Mareca penelope* (Linnaeus, 1758)	H	↓	LC	-	IV	WM	C
8.	Gadwall	*Mareca strepera* (Linnaeus, 1758)	H	↑	LC	-	IV	WM	C
9.	Garganey	*Spatula querquedula* (Linnaeus, 1758)	H	↓	LC	-	IV	WM	A
10.	Northern Shoveler	*Spatula clypeata* (Linnaeus, 1758)	O	↓	LC	-	IV	WM	A
11.	Common Teal	*Anas crecca* Linnaeus, 1758	O	?	LC	-	IV	WM	C
12.	Northern Pintail	*Anas acuta* Linnaeus, 1758	Cv	↓	LC	-	IV	WM	A
13.	Lesser Whistling-Duck	*Dendrocygna javanica* (Horsfield, 1821)	O	↓	LC	-	IV	SM	FC
14.	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	O	?	LC	-	IV	WM	C
15.	Cotton Pygmy-goose	*Nettapus coromandelianus* (Gmelin, JF, 1789)	O	→	LC	-	IV	WM	RA

S. No.	Order/ Family/ Common name	Scientific name with Authority	Feeding guild	IUCN Global population trends	Conservation status			Migratory Status	Local Abundance Status
					IUCN (2022)	CITES (2012)	IWPA (1972)		
2. ORDER CUCULIFORMES (No. of species = 3, No. of family=1, Percent occurrence = 3.80)									
2.1. Family Cuculidae (No. of species = 3, RDi value = 3.80)									
16.	Western Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	O	→	LC	-	IV	SM	C
17.	Common Hawk Cuckoo	*Hierococcyx varius* (Vahl, 1797)	In	→	LC	-	IV	SM	FC
18.	Jacobin Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	In	→	LC	-	IV	SM	C
3. ORDER GRUIFORMES (No. of species = 1, No. of family = 1, Percent occurrence = 1.27)									
3.1. Family Rallidae (No. of species = 1), RDi value = 1.27									
19.	Eurasian Coot	*Fulica atra* Linnaeus, 1758	H	↑	LC	-	IV	WM	A
4. ORDER PODICIPEDIFORMES (No. of species = 2, No. of family = 1, Percent occurrence = 2.53)									
4.1. Family Podicipedidae (No. of species = 2, RDi value = 2.53)									
20.	Great Crested Grebe	*Podiceps cristatus* (Linnaeus, 1758)	Cv	?	LC	-	IV	WM	RA
21.	Black-necked Grebe	*Podiceps nigricollis* Brehm, CL, 1831	Cv	?	LC	-	IV	WM	RA
5. ORDER CHARADRIIFORMES (No. of species = 24, No. of families = 7, Percent occurrence = 30.38)									
5.1 Family Scolopacidae (No. of species = 16, RDi value = 20.25)									
22.	Black-tailed Godwit	*Limosa limosa* (Linnaeus, 1758)	In	↓	NT	-	IV	WM	FC
23.	Common Greenshank	*Tringa nebularia* (Gunnerus, 1767)	Cv	→	LC	-	IV	WM	FC
24.	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	In	?	LC	-	IV	WM	FC
25.	Spotted Redshank	*Tringa erythropus* (Pallas, 1764)	In	→	LC	-	IV	WM	FC
26.	Green Sandpiper	*Tringa ochropus* Linnaeus, 1758	In	↑	LC	-	IV	WM	C
27.	Wood Sandpiper	*Tringa glareola* Linnaeus, 1758	In	→	LC	-	IV	WM	C
28.	Marsh Sandpiper	*Tringa stagnatilis* (Bechstein, 1803)	In	↓	LC	-	IV	WM	C
29.	Ruff	*Calidris pugnax* (Linnaeus, 1758)	In	↓	LC	-	IV	WM	FC

S. No.	Order/ Family/ Common name	Scientific name with Authority	Feeding guild	IUCN Global population trends	Conservation status			Migratory Status	Local Abundance Status
					IUCN (2022)	CITES (2012)	IWPA (1972)		
30.	Temminck's Stint	*Calidris temminckii* (Leisler, 1812)	In	?	LC	-	IV	WM	FC
31.	Little Stint	*Calidris minuta* (Leisler, 1812)	In	↑	LC	-	IV	WM	FC
32.	Curlew Sandpiper	*Calidris ferruginea* (Pontoppidan, 1763)	In	↓	NT	-	IV	WM	RA
33.	Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	In	↓	LC	-	IV	WM	C
34.	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	Cv	↓	LC	-	IV	WM	RA
35.	Eurasian Curlew	*Numenius arquata* (Linnaeus, 1758)	In	↓	NT	-	IV	WM	RA
36.	Jack Snipe	*Lymnocryptes minimus* (Brünnich, 1764)	Cv	→	LC	-	IV	WM	RA
37.	Ruddy Turnstone	*Arenaria interpres* (Linnaeus, 1758)	In	↓	LC	-	IV	SM	RA
5.2. Family Recurvirostridae (No. of species = 1, RDi value = 1.27)									
38.	Pied Avocet	*Recurvirostra avosetta* Linnaeus, 1758	Cv	?	LC	-	IV	WM	C
5.3. Family Jacanidae (No. of species = 1, RDi value = 1.27)									
39.	Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786)	O	↓	LC	-	IV	SM	C
5.4. Family Rostratulidae (No. of species = 1, RDi value = 1.27)									
40.	Greater Painted-snipe	*Rostratula benghalensis* (Linnaeus, 1758)	O	↓	LC	-	IV	SM	FC
5.5. Family Glareolidae (No. of species = 1, RDi value =1.27)									
41.	Oriental Pratincole	*Glareola maldivarum* J.R. Forster, 1795	In	↓	LC	-	IV	SM	FC
5.6. Family Charadriidae (No. of species = 2, RDi value = 2.53)									
42.	Pacific Golden Plover	*Pluvialis fulva* (Gmelin, JF, 1789)	Cv	↓	LC	-	IV	SM	FC
43.	White-tailed Lapwing	*Vanellus leucurus* (M.H.C. Lichtenstein, 1823)	Cv	?	LC	-	IV	WM	C

S. No.	Order/ Family/ Common name	Scientific name with Authority	Feeding guild	IUCN Global population trends	Conservation status			Migratory Status	Local Abundance Status
					IUCN (2022)	CITES (2012)	IWPA (1972)		
5.7 Family Laridae (No. of species = 2, RDi value = 2.53)									
44.	Brown-headed Gull	*Chroicocephalus brunnicephalus* (Jerdon, 1840)	Cv	→	LC	-	IV	WM	RA
45.	Black-headed Gull	*Chroicocephalus ridibundus* (Linnaeus, 1766)	Cv	?	LC	-	IV	WM	RA
6. ORDER CICONIIFORMES (No. of species = 1, No. of family = 1, Percent occurrence = 1.27)									
6.1. Family Ciconiidae (No. of species = 1, RDi value = 1.27)									
46.	Black-necked Stork	*Ephippiorhynchus asiaticus* (Latham, 1790)	Cv	↓	NT	-	IV	WM	C
7. ORDER SULIFORMES (No. of species = 2, No. of family = 1, Percent occurrence = 2.53)									
7.1. Family Phalacrocoracidae (No. of species = 2, RDi value = 2.53)									
47.	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	Cv	↑	LC	-	IV	WM	C
48.	Indian Cormorant	*Phalacrocorax fuscicollis* Stephens, 1826	Cv	?	LC	-	IV	WM	C
8. ORDER PELECANIFORMES (No. of species = 5, No. of families = 1, Percent occurrence = 6.33)									
8.1. Family Ardeidae (No. of species = 5, RDi value = 6.33)									
49.	Western Reef Egret	*Egretta gularis* (Bosc, 1792)	Cv	→	LC	-	IV	WM	RA
50.	Black Bittern	*Ixobrychus flavicollis* (Latham, 1790)	Cv	↓	LC	-	IV	SM	RA
51.	Cinnamon Bittern	*Ixobrychus cinnamomeus* (Gmelin, JF, 1789)	Cv	→	LC	-	IV	SM	RA
52.	Yellow Bittern	*Ixobrychus sinensis* (Gmelin, JF, 1789)	Cv	?	LC	-	IV	SM	RA
53.	Common Little Bittern	*Ixobrychus minutus* (Linnaeus, 1766)	Cv	↓	LC	-	IV	SM	FC
9. ORDER ACCIPITRIFORMES (No. of species = 5, No. of family = 2, Percent occurrence = 6.33)									
9.1. Family Accipitridae (No. of species = 4, RDi value = 5.06)									
54.	Brahminy Kite	*Haliastur indus* (Boddaert, 1783)	Cv	↓	LC	II	I	WM	RA

S. No.	Order/ Family/ Common name	Scientific name with Authority	Feeding guild	IUCN Global population trends	Conservation status			Migratory Status	Local Abundance Status
					IUCN (2022)	CITES (2012)	IWPA (1972)		
55.	Eastern Imperial Eagle	*Aquila heliaca* Savigny, 1809	Cv	↓	VU	I	I	WM	RA
56.	Western Marsh Harrier	*Circus aeruginosus* (Linnaeus, 1758)	Cv	→	LC	II	I	WM	FC
57.	Greater Spotted Eagle	*Clanga clanga* (Pallas, 1811)	Cv	↓	VU	II	I	WM	RA
9.2. Family Pandionidae (No. of species = 1, RDi value = 1.27)									
58.	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	Cv	↑	LC	II	I	WM	FC
10. ORDER CORACIIFORMES (No. of species = 3, No. of families = 1, Percent occurrence = 3.80)									
10.1. Family Meropidae (No. of species = 3, RDi value = 3.80)									
59.	Asian Green Bee-eater	*Merops orientalis* Latham, 1801	In	↑	LC	-	IV	SM	A
60.	Blue-cheeked Bee-eater	*Merops persicus* Pallas, 1773	In	→	LC	-	IV	SM	FC
61.	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus, 1767	In	→	LC	-	IV	SM	FC
11. ORDER PICIFORMES (No. of species = 1, No. of families = 1, Percent occurrence = 1.27)									
11.1. Family Picidae (No. of species = 1, RDi value = 1.27)									
62.	Eurasian Wryneck	*Jynx torquilla* Linnaeus, 1758	In	↓	LC	-	IV	WM	RA
12. ORDER PASSERIFORMES (No. of species =17, No. of families = 7, Percent occurrence = 21.52)									
12.1. Family Alaudidae (No. of species = 3, RDi value = 3.80)									
63.	Ashy-crowned Sparrow-lark	*Eremopterix griseus* (Scopoli, 1786)	O	→	LC	-	IV	SM	FC
64.	Bengal Bushlark	*Mirafra assamica* Horsfield, 1840	O	→	LC	-	IV	SM	FC
65.	Sand Lark	*Alaudala raytal* (Blyth, 1845)	O	→	LC	-	IV	SM	FC
12.2. Family Laniidae (No. of species = 1, RDi value = 1.27)									
66.	Isabelline Shrike	*Lanius isabellinus* Hemprich & Ehrenberg, 1833	In	→	LC	-	IV	WM	RA

S. No.	Order/ Family/ Common name	Scientific name with Authority	Feeding guild	IUCN Global population trends	Conservation status			Migratory Status	Local Abundance Status
					IUCN (2022)	CITES (2012)	IWPA (1972)		
12.3. Family Motacillidae (No. of species = 7, RDi value = 8.86)									
67.	Western Yellow Wagtail	*Motacilla flava* Linnaeus, 1758	In	↓	LC	-	IV	WM	C
68.	White Wagtail	*Motacilla alba* Linnaeus, 1758	In	→	LC	-	IV	WM	A
69.	Grey Wagtail	*Motacilla cinerea* Tunstall, 1771	In	→	LC	-	IV	WM	C
70.	Citrine Wagtail	*Motacilla citreola* Pallas, 1776	In	↑	LC	-	IV	WM	C
71.	Eastern Yellow Wagtail	*Motacilla tschutschensis* Gmelin, JF, 1789	In	↓	LC	-	IV	WM	FC
72.	Tawny Pipit	*Anthus campestris* (Linnaeus, 1758)	In	→	LC	-	IV	WM	FC
73.	Tree Pipit	*Anthus trivialis* (Linnaeus, 1758)	In	↓	LC	-	IV	WM	C
12.4. Family Oriolidae (No. of species = 1, RDi value = 1.27)									
74.	Indian Golden Oriole	*Oriolus kundoo* Sykes, 1832	O	?	LC	-	IV	SM	RA
12.5. Family Phylloscopidae (No. of species = 1, RDi value = 1.27)									
75.	Common Chiffchaff	*Phylloscopus collybita* (Vieillot, 1817)	In	↑	LC	-	IV	WM	FC
12.6. Family Sylviidae (No. of species = 1, RDi value = 1.27)									
76.	Lesser Whitethroat	*Curruca curruca* (Linnaeus, 1758)	O	→	LC	-	IV	WM	FC
12.7. Family Muscicapidae (No. of species = 3, RDi value = 3.80)									
77.	Bluethroat	*Luscinia svecica* (Linnaeus, 1758)	In	→	LC	III	IV	WM	C
78	Red-breasted Flycatcher	*Ficedula parva* (Bechstein, 1792)	In	↑	LC	III	IV	WM	RA
79.	Siberian Stonechat	*Saxicola maurus* (Pallas, 1773)	In	→	LC	-	IV	WM	FC

Abbreviations: **Feeding guilds:** H- Herbivore/ O-Omnivore/ In-Insectivor/ Cv-Carnivore/ G-Grainivore/ F-Frugivore/ P-Piscivore/ In/N-Insectivore/Nectarivore;
Conservation status: LC- Least Concern/ NT- Near threatened/ VU-Vulnerable;
Population trends: ↑ – Increasing/ ↓ – Decreasing/ → Stable/ ?- Unknown;
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora;
IWPA – Indian Wildlife Protection Act/ I- Schedule I of IWPA (highly preferred species)/ IV- Schedule IV of IWPA (moderately preferred species);
M status: Migratory status: WM-Winter Migrant/ **SM**-Summer Migrant;
LA status–Local Abundance status: **A**-Abundant/ **C**-Common/ **FC**-Fairly Common/ **RA**-Rare.

Table 4. Variations in the number of seasonal migrant species at Mandothi wetlands, India from April, 2022 to March, 2024

4. táblázat Az indiai Mandothi wetlands területén megfigyelt szezonálisan vonuló madárfajok száma

Mandothi wetlands			
Migratory Status	April 2022–March 2023	April 2023–March 2024	Total Richness
Winter Migrants	49 (8)	51 (10)	59
Summer Migrants	16 (5)	15 (4)	20
Overall reported migratory avian species from April 2022-March 2024			79

Table 5. Number of Species, families, genera per reported avian order of Mandothi wetlands, India from April, 2022 to March, 2024

5. táblázat Az indiai Mandothi wetlands területén 2022 áprilisa és 2024 márciusa között megfigyelt madárrendek faj-, család- és nemszáma

S. No.	Order Name	Number of Species/ Order	Number of Families/ Order	Number of Genera/ Order
1.	Charadriiformes	24	7	15
2.	Passeriformes	17	7	12
3.	Anseriformes	15	1	8
4.	Accipitriformes	5	2	5
5.	Pelecaniformes	5	1	5
6.	Coraciiformes	3	1	1
7.	Cuculiformes	3	1	1
8.	Podicipediformes	2	1	1
9.	Suliformes	2	1	1
10.	Ciconiiformes	1	1	1
11.	Gruiformes	1	1	1
12.	Piciformes	1	1	1

insectivorous birds in the area suggests that the insect assemblage is diverse (Gregory *et al.* 2001, Sohil & Sharma 2020, Rai & Vanita 2023). Insectivores were shown to be prevalent across all guilds based on the feeding guild study similarly to the results of Rai and Vanita (2023). As per the IUCN Red List criteria (IUCN 2024) 71 species were classified as Least Concern (LC), whereas 5 species were classified as Near Threatened (NT) i.e. Ferruginous Duck *(Aythya nyroca)*, Black-tailed Godwit *(Limosa limosa),* Eurasian Curlew *(Numenius arquata)*, Curlew Sandpiper *(Calidris ferruginea)*, Black-necked Stork *(Ephippiorhynchus asiaticus),* and 3 species were classified as Vulnerable (VU) such as Eastern Imperial Eagle *(Aquila heliaca)*, Greater Spotted Eagle *(Clanga clanga)*, Common Pochard *(Aythya ferina)* in the study area. The IUCN Red List (IUCN 2024) of recorded avian species indicates that 11 species have an increasing trend, 30 species have decreasing trend, 25 species have stable trend, and the trend of 13 species is unknown.

The relationship between the documented bird species' local abundance and their migratory status at the study site shows the ecological significance of this habitat, as it supports migrants

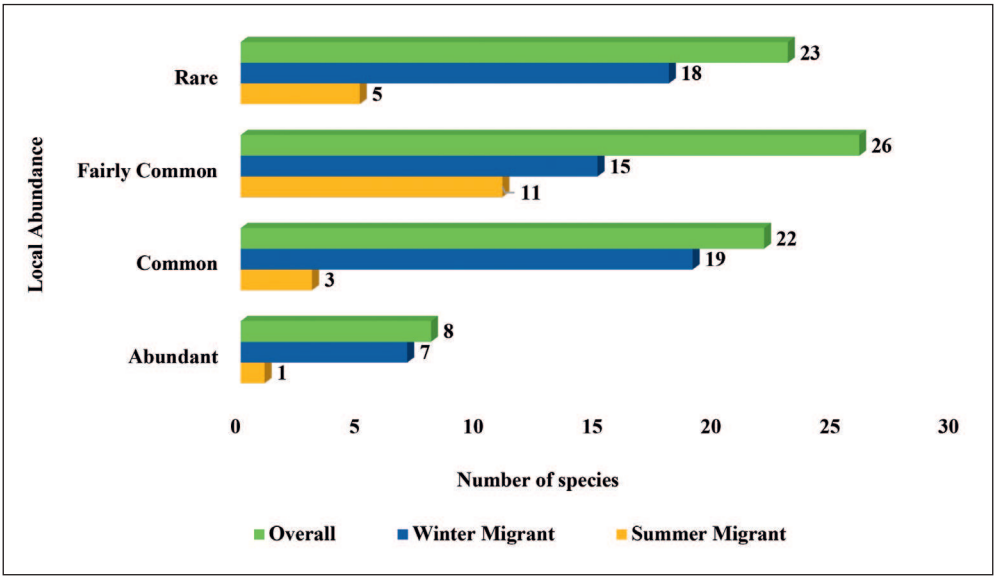


Figure 2. Relationship between documented bird species' local abundance and migratory status at Mandothi wetlands, India from April 2022 to March 2024

2. ábra Az indiai Mandothi Wetlands területén 2022 áprilisa és 2024 márciusa között megfigyelt madárfajok lokális abundanciája és vonulási stratégiája közötti kapcsolat

from both seasons. Out of the total summer migrants, 25% species were rare, 55% species were fairly common, 15% species were common and 5% species was abundant. Similarly, for winter migrants, 30.5% species were rare, 25.4% species were fairly common, 32.2% species were common and 11.9% species were abundant *(Figure 2)*.

The IUCN global population trends of avian species provide valuable insights into their conservation status and vulnerability, which can be linked to their local abundance at the study site. Out of the total avifauna with increasing population trend, 27.3% species were abundant, 36.4% were common, 27.3% were fairly common and 9.1% were rare. Out of species with decreasing population trend, 13.3% species were abundant, 26.7% were common, 30.0% were fairly common and 30.0% were rare. Out of species with stable population trends, 4.0% species were abundant, 20.0% were common, 48.0% were fairly common and 28.0% were rare. Similarly, out of species with unknown population trends, 38.5% were common, 15.4% were fairly common and 46.2% were rare *(Figure 3)*.

Unlike resident or wintering birds, passage migrants do not remain in one location for extended periods, instead, they use such stopover sites as resting and refuelling stations to recover energy for the next part of their journey (Beauchamp 2024). The Mandothi wetlands serve as an important stopover site for passage migrant birds, which use the area during their seasonal migrations. These birds pause at the study site to rest and refuel before continuing their long journeys between breeding and wintering grounds. Some species are passage migrants often include shorebirds, waders and waterfowl, whose presence highlights the wetlands' role in supporting migratory routes and maintaining avian biodiversity. Species like Cotton Pygmy-goose *(Nettapus coromandelianus)* (Anseriformes), Jacobin Cuckoo *(Clamator*

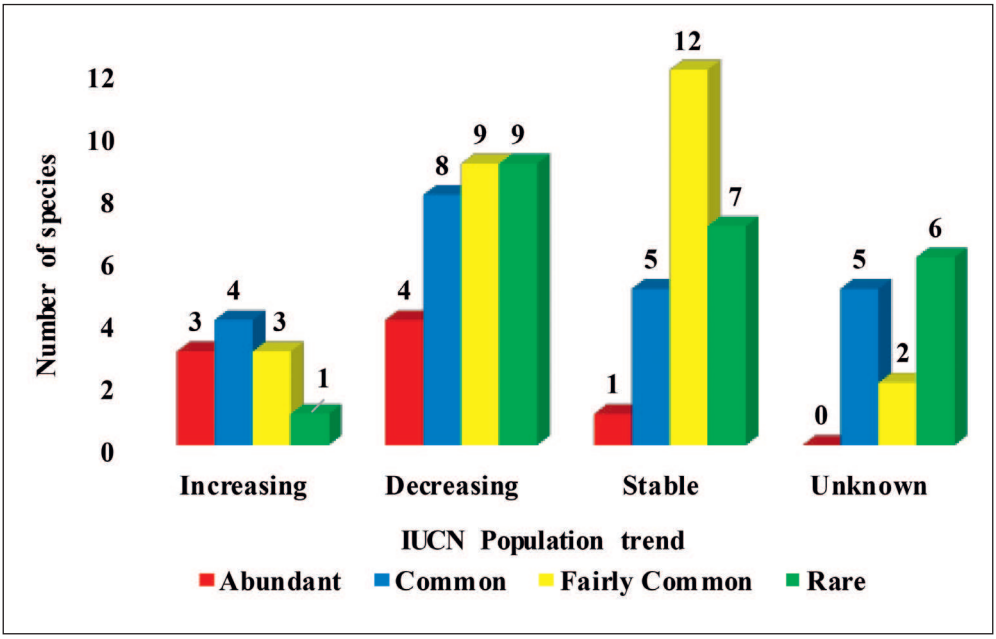


Figure 3. IUCN population trend and its relationship with local abundance status of reported avian species at Mandothi wetlands, India from April 2022 to March 2024

3. ábra Az indiai Mandothi wetlands területén 2022 áprilisa és 2024 márciusa között megfigyelt madárfajok lokális abundanciája és IUCN-alapú populációs trendjei közötti kapcsolat

jacobinus), Common Hawk Cuckoo *(Hierococcyx varius)* (Cuculiformes), Black-necked Grebe *(Podiceps nigricollis)* (Podicipediformes), Curlew Sandpiper *(Calidris ferruginea)*, Eurasian Curlew *(Numenius arquata)*, Jack Snipe *(Lymnocryptes minimus)*, Brown-headed Gull *(Chroicocephalus brunnicephalus)*, Black-headed Gull *(Chroicocephalus ridibundus)* (Charadriiformes), Western Reef Egret *(Egretta gularis)*, Cinnamon Bittern *(Ixobrychus cinnamomeus)* (Pelecaniformes), Osprey *(Pandion haliaetus)*, (Accipitriformes), Eurasian Wryneck *(Jynx torquilla)* (Piciformes), Bengal Bushlark *(Mirafra assamica)*, Sand Lark *(Alaudala raytal)*, Indian Golden Oriole *(Oriolus kundoo)*, Lesser Whitethroat *(Curruca curruca)* (Passeriformes) are significant passage migrants in the study area *(Table 6)*.

Monitoring these species provides insights into migration patterns and ecosystem health, emphasizing the need for conservation measures to protect this vital habitat. Further monitoring is also recommended for migratory patterns and to assess the area's ability to sustain its avifauna in the long-term conservation initiatives. Other researchers also reported variable number of migratory avian species from other studied locations of the state of Haryana *(Table 7)*.

Table 6. Monthly migration phenology of avian species reported at Mandothi wetlands, India from April, 2022 to March, 2024

6. táblázat Az indiai Mandothi wetlands területén 2022 áprilisa és 2024 márciusa között megfigyelt madárfajok havi vonulási fenológiája

S. No.	Common Name	Y/M	A	M	J	J	A	S	O	N	D	J	F	M
1.	Bar-headed Goose	1st												
		2nd												
2.	Greylag Goose	1st												
		2nd												
3.	Greater White-fronted Goose	1st												
		2nd												
4.	Common Pochard	1st												
		2nd												
5.	Tufted Duck	1st												
		2nd												
6.	Ferruginous Duck	1st												
		2nd												
7.	Eurasian Wigeon	1st												
		2nd												
8.	Gadwall	1st												
		2nd												
9.	Garganey	1st												
		2nd												
10.	Northern Shoveler	1st												
		2nd												
11.	Common Teal	1st												
		2nd												
12.	Northern Pintail	1st												
		2nd												
13.	Lesser Whistling-Duck	1st												
		2nd												
14.	Ruddy Shelduck	1st												
		2nd												
15.	Cotton Pygmy-goose	2nd												
		1st												
16.	Western Koel	2nd												
		1st												
17.	Common Hawk Cuckoo	1st												
		2nd												
18.	Jacobin Cuckoo	1st												
		2nd												

S. No.	Common Name	Y/M	A	M	J	J	A	S	O	N	D	J	F	M
19.	Eurasian Coot	1st												
		2nd												
20.	Great Crested Grebe	1st												
		2nd												
21.	Black-necked Grebe	1st												
		2nd												
22.	Black-tailed Godwit	1st												
		2nd												
23.	Common Greenshank	1st												
		2nd												
24.	Common Redshank	1st												
		2nd												
25.	Spotted Redshank	1st												
		2nd												
26.	Green Sandpiper	1st												
		2nd												
27.	Wood Sandpiper	1st												
		2nd												
28.	Marsh Sandpiper	1st												
		2nd												
29.	Ruff	1st												
		2nd												
30.	Temminck's Stint	1st												
		2nd												
31.	Little Stint	1st												
		2nd												
32.	Curlew Sandpiper	1st												
		2nd												
33.	Common Sandpiper	1st												
		2nd												
34.	Common Snipe	1st												
		2nd												
35.	Eurasian Curlew	1st												
		2nd												
36.	Jack Snipe	1st												
		2nd												
37.	Ruddy Turnstone	1st												
		2nd												

S. No.	Common Name	Y/M	A	M	J	J	A	S	O	N	D	J	F	M
38.	Pied Avocet	1st												
		2nd												
39.	Pheasant-tailed Jacana	1st												
		2nd												
40.	Greater Painted-snipe	1st												
		2nd												
41.	Oriental Pratincole	1st												
		2nd												
42.	Pacific Golden Plover	1st												
		2nd												
43.	White-tailed Lapwing	1st												
		2nd												
44.	Brown-headed Gull	1st												
		2nd												
45.	Black-headed Gull	1st												
		2nd												
46.	Black-necked Stork	1st												
		2nd												
47.	Great Cormorant	1st												
		2nd												
48.	Indian Cormorant	1st												
		2nd												
49.	Western Reef-Egret	1st												
		2nd												
50.	Black Bittern	1st												
		2nd												
51.	Cinnamon Bittern	1st												
		2nd												
52.	Yellow Bittern	1st												
		2nd												
53.	Common Little Bittern	1st												
		2nd												
54.	Brahminy Kite	1st												
		2nd												
55.	Eastern Imperial Eagle	1st												
		2nd												
56.	Western Marsh Harrier	1st												
		2nd												

S. No.	Common Name	Y/M	A	M	J	J	A	S	O	N	D	J	F	M
57.	Greater Spotted Eagle	1st												
		2nd												
58.	Osprey	1st												
		2nd												
59.	Asian Green Bee-eater	1st												
		2nd												
60.	Blue-cheeked Bee-eater	1st												
		2nd												
61.	Blue-tailed Bee-eater	1st												
		2nd												
62.	Eurasian Wryneck	1st												
		2nd												
63.	Ashy-crowned Sparrow-lark	1st												
		2nd												
64.	Bengal Bushlark	1st												
		2nd												
65.	Sand Lark	1st												
		2nd												
66.	Isabelline Shrike	1st												
		2nd												
67.	Western Yellow Wagtail	1st												
		2nd												
68.	White Wagtail	1st												
		2nd												
69.	Grey Wagtail	1st												
		2nd												
70.	Citrine Wagtail	1st												
		2nd												
71.	Eastern Yellow Wagtail	1st												
		2nd												
72.	Tawny Pipit	1st												
		2nd												
73.	Tree Pipit	1st												
		2nd												
74.	Indian Golden Oriole	1st												
		2nd												
75.	Common Chiffchaff	1st												
		2nd												

S. No.	Common Name	Y/M	A	M	J	J	A	S	O	N	D	J	F	M
76.	Lesser Whitethroat	1st												
		2nd												
77.	Bluethroat	1st												
		2nd												
78.	Red-breasted Flycatcher	1st												
		2nd												
79.	Siberian Stonechat	1st												
		2nd												

Table 7. Number of migratory bird species reported at various locations of Haryana, India by various researchers in different studies

7. táblázat India Haryana tartományában megfigyelt vonuló madárfajok száma és ezek irodalmi hivatkozása

Author	Study location	Number of migratory bird species reported
Gupta *et al.* 2012	Khaparwas Wildlife Sanctuary, Haryana	50
Chopra *et al.* 2017	Bhindwas Wildlife Sanctuary, Haryana	37
Rai *et al.* 2017	Basai Wetlands, Haryana	49
Rai *et al.* 2019	Basai Wetlands, Haryana	62
Parul & Kumar 2023	Dighal Wetlands, Haryana	70
Rai & Vanita 2023	Ottu Lake, Sirsa, Haryana	46
Rai & Yadav 2023	Mandothi Wetlands, Haryana	51
Yadav & Rai 2024	Mandothi Wetlands, Haryana	54
Vanita & Kumar 2024	District Rewari, Haryana	56

Conclusion

The study site provides an ideal environment for migratory as well as passage migrant avian species due to abundant food resources, freshwater availability, and safe roosting areas. This information can be used as an important point for evaluating suitable management strategies for preserving wetlands and their sustainable use. So, long-term monitoring is required, to assess the consequences of anthropogenic pressures and other stress factors and execute conservation plans for the area's avifaunal diversity.

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Temporal dynamics of shorebird assemblages in Valinokkam Lagoon, Southeast India: A new wintering site along the Central Asian Flyway

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Abstract Anthropogenic activities are global threats to natural coastal wetlands that are crucial for shorebirds. Man-made wetlands such as salt extraction ponds provide alternate sites for feeding and roosting. Valinokkam Lagoon, a salt extraction site on the southeast coast of India, has emerged as a critical wintering and over-summering site along the Central Asian Flyway. A five-year study (2019 to 2024) documented 32 shorebird species, which include eight Near Threatened, two Vulnerable, two Endangered, and a single regional endemic Hanuman Plover, unassessed (IUCN). 87.5% of the species were winter visitors and four were breeding residents. Eleven species of over-summering shorebirds were documented, highlighting consistent resources in the lagoon throughout the year. Temporal abundance patterns peaked in 2023–2024, with the highest total monthly abundance in January 2023. Little Stint, Siberian Sand Plover, Curlew Sandpiper, and Kentish Plover were the dominant species. The highest species richness and diversity were in 2021–2022, and lowest in 2023–2024. This is the first pivotal study from this unprotected lagoon, which acts as a substitute for natural wetlands. This study further contributes to the estimation of global population trends, and hence this site requires further conservation action plans both regionally and internationally, as 72% of the species recorded here show a declining global trend.

Keywords: artificial lagoon, over-summering, saltpans, unprotected wetland, wetland

Összefoglalás Az emberi tevékenységek globális mértékben veszélyeztetik a természetes tengerparti vizes élőhelyeket, melyek a partimadarak számára kulcsfontosságúak. A mesterséges vizes élőhelyek viszont, mint például a sólepárló tavak, alternatív élőhelyeket kínálnak ezen fajok számára mind táplálkozásra, mind pihenésre. A Valinokkam-lagúna, amely egy sólepárló terület India délkeleti partvidékén, a Közép-Ázsiai Madárvonulási Útvonal egyik kritikusan fontos telelő- és átnyaraló élőhelyeként ismert. A jelen, öt évet átölelő (2019–2024) tanulmány 32 partimadár-faj jelenlétét dokumentálta, melyek közül az IUCN besorolása szerint nyolc faj Mérsékelten Fenyegetett, kettő Sebezhető, kettő Veszélyeztetett, valamint egy besorolatlan faj – a korábban a széki lile egy alfajaként ismert, de újra faji rangra emelt *Charadrius seebohmi* – regionális endemizmusként ismert a területen. A vizsgált fajok 87,5% téli vendég, négy faj állandó és fészkelő volt. A vizsgálat során 11 átnyaraló partimadár-fajt azonosítottak, ami jelzi, hogy a lagúna táplálékforrásai folyamatosan rendelkezésre állnak. Az abundanciák időbeli csúcsa 2023–2024-ben volt megfigyelhető, amin belül a legmagasabb abundancia-értéket 2023 januárjában rögzítették. A vizsgálat domináns fajai az apró partfutó, a tibeti lile, a sarlós partfutó és a széki lile voltak. A legmagasabb fajgazdagsági és fajdiverzitási értékeket 2021–2022-ben, míg a legalacsonyabbakat 2023–2024-ben detektálták. Ez az első jelentős tanulmány ebből a nem védett lagúnából, amely természetes élőhelyeket helyettesít. Emellett ez a vizsgálati terület hozzájárul globális szinten a partimadár-állományok fenntartásához, így a lagúna további, regionális és nemzetközi szintű természetvédelmi beavatkozást igényel, mivel az itt megfigyelt fajok 72%-a csökkenő állomány-adatokat mutat világszerte.

Kulcsszavak: mesterséges lagúna, átnyaralás, sólepárlók, nem védett terület, vizes élőhely

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Introduction

Waterbird populations experience a global decline (Hansen *et al*. 2015, Wang *et al*. 2017, Rashiba *et al*. 2022), and 50% of waterbird populations in Asia have declined (Haq *et al*. 2018, Mundkur *et al*. 2023). Birdlife International (2022) estimated that 8% of migratory bird species in the Central Asian Flyway (CAF) are globally threatened and 6% are Near Threatened in the IUCN Red List. Coastal wetlands, among the most threatened ecosystems worldwide (Newton *et al*. 2018, Rodrigues-Filho *et al*. 2023), act as critical habitats for both migratory and resident waterbird species, especially shorebirds (Masero *et al*. 2000, Colwell 2010). The species diversity and population abundance of birds are considered as bio-indicators of environmental change in wetlands (Zhang *et al*. 2020) due to their long lifespan and migratory behaviors (Piatt *et al*. 2007, Parson *et al*. 2008).

Shorebird populations are sensitive to habitat changes (Rogers *et al*. 2006, Méndez *et al*. 2018), and their survival and population fluctuations are intricately linked to land use changes (Rogers *et al*. 2006) and human disturbance (Koleček *et al*. 2021), both in their breeding grounds and wintering habitats (Jourdan *et al*. 2021, Comber *et al*. 2023). Hence, artificial wetlands such as aquaculture ponds and coastal saltpans (Warnock & Takekawa 1995, Li *et al*. 2013, Rogers *et al*. 2015), are increasingly recognized for their role in providing alternative feeding and roosting areas for waterbirds (Perez-Hurtado & Hortas 1991, Green *et al*. 2015, Byju *et al*. 2023a), although they cannot replace natural wetlands completely (Choi *et al.* 2014, Sebastián-González & Green 2016). The ecological value of these artificial or restored wetland habitats are widely recognized (Elphick 2000, Czech & Parsons 2002, Pandiyan *et al*. 2021), as the loss of the stopover sites or wintering sites is one of the major reasons for migratory birds' population decline globally (Wen *et al*. 2016, Liao *et al*. 2017).

Saline habitats such as coastal saltpans provide critical support to migratory shorebirds due to their high productivity and suitable water depths (Aarif *et al*. 2024), which create ideal feeding and roosting conditions (Britton & Johnson 1987). Saltpans are utilized by shorebirds across diverse geographic regions, including Africa, North America, Europe, the Mediterranean, Asia and Australia (Lei *et al*. 2018). In India, the country's diverse coastlines support rich shorebird diversity and abundance, which are associated with important habitats like sandy beaches, mangroves, intertidal zones, saltpans, lagoons and mudflats (Joshi *et al*. 2020, Sangha 2021, Rashiba *et al*. 2022).

The present study investigates the potential of Valinokkam Lagoon as a critical wintering site for shorebirds and its significance as an internationally important wetland within CAF. India, the third largest salt producer globally, has substantial saltpan areas, with Tamil Nadu ranking as the second largest salt-producing state in the country, after Gujarat. Approximately 12,000 hectares (ha) of land in Tamil Nadu are under salt extraction (Pandiyan *et al*. 2014, Tamil Nadu Salt Corporation 2018). Traditional saltpans in the state play a pivotal role

in sustaining overwintering shorebird populations (Sandilyan 2017). However, despite existing studies, the identification of critical shorebird habitats, stopover sites, key seasons and ecosystems along India's coast remains incomplete (Rao *et al*. 2022).

Shorebird populations in natural coastal lagoons are in decline; while saltpans in the Gulf of Mannar (GoM), continue to support over-summering winter migrants (Byju *et al*. 2024). Studies in the region have provided insights into shorebird populations on the Valinokkam avifauna (Byju *et al*. 2023a), 21 islands of GoM (Byju *et al*. 2023b) and Karangadu mangroves (Byju *et al*. 2023c). However, significant knowledge gaps persist regarding the ecological role of anthropogenic wetlands in supporting shorebird populations in this region. This study aims to address these gaps by assessing the abundance and diversity of shorebirds in Valinokkam Lagoon, with a particular focus on temporal variations. We evaluated shorebird population trends and seasonal dynamics to determine the potential of Valinokkam Lagoon as a vital wintering site within the CAF. Our objectives include: 1) to assess the abundance and species diversity of shorebirds during the winters in five migratory seasons; 2) to analyze temporal trends in shorebird populations and identify peak periods of shorebird activity; 3) to evaluate the ecological significance of the site as a critical wintering habitat within the CAF, and 4) to provide baseline data for formulating effective conservative measures to protect shorebird population and their habitats.

Material and Methods

Study area

Valinokkam Lagoon (9.1661° N, 78.6141° E) is a man-made coastal lagoon situated in the Kadaladi Taluk, Ramanathapuram District, Tamil Nadu, on the southeast coast of India *(Figure1)*. This lagoon extends over 10.12 km, encompassing an area of 1,145.84 ha. The lagoon, on one side, is surrounded by saltpans, which constitute around 1,197.34 ha, operated by the State-owned Salt Corporation. Seawater is pumped into these reservoirs for salt production. Over time, the evaporation process has led to the formation of expansive mudflats within the reservoir pond, which now serve as vital habitats for waterbirds, especially shorebirds that prefer these mudflats rather than the actual salt evaporation ponds. Although fishing activities and prawn culture occur intermittently, these activities are limited to periods when water levels are sufficient, supporting the local communities with livelihood opportunities.

Data collection

Shorebird surveys were conducted monthly once over five migratory seasons, spanning from June 2019 to May 2024 between 06.00 to 10.00 and 15.00 to 18.00 hours. Bird abundance was estimated using the block count and direct visual count methods (Howes & Bakewell 1989*,* Bibby *et al*. 2000). Block counts were used for large flocks of birds, either by distance or by how dense they are. This method involves estimating 'blocks' of birds within a flock

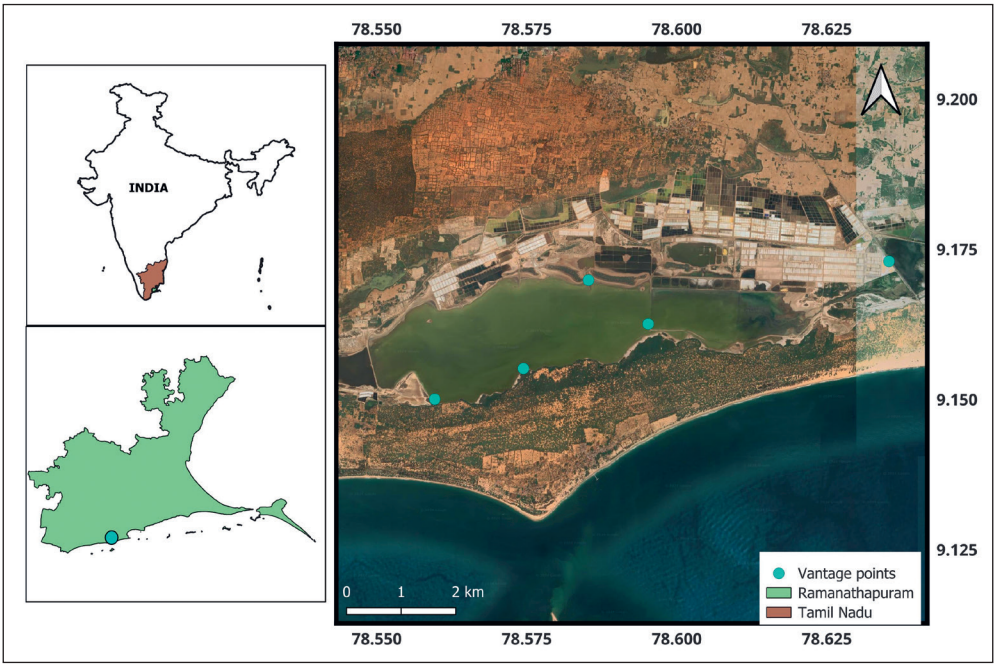


Figure 1. Map of the study area showing the vantage points and adjacent saltpans in Valinokkam Lagoon

1. ábra A vizsgálati terület térképe a megfigyelési pontokkal és szomszédos sólepárlókkal a Valinokkam-lagúnában

depending on the overall flock size. The 'block' is used to measure the remainder of the flock from our previous experiences in the field monitoring for more than a decade. Five scanning points, ranging from 600–1,500 meters apart, were selected based on year-round water availability and shorebird congregation dynamics *(Figure 1)*. Observations were carried out using Nikon binoculars (10×50) and Vanguard spotting scope (14×70) and birds were photographed for identification with a Canon 100–400 mm lens. Field guides (Grimmett *et al*. 2011, Hayman *et al*. 2011) were employed to aid species identification. To minimize disturbance to birds, a five-minute acclimatization period was observed upon arrival at each scanning point before commencing counts. As Valinokkam is a man-made lagoon, no tidal variations were observed during the study. Smaller groups of shorebirds were counted directly, while larger congregations were estimated with assistance from two or three teams for accuracy.

Shorebird status classification

The residential status of shorebirds was determined as either Resident (R) or Winter Visitor (WV), based on their temporal and distribution patterns (Grimmett *et al*. 2011). Resident species are the ones that are present throughout the year in the study area and may breed locally. Winter Visitors are those observed during winter months (September to April).

These species undertake long-distance migrations from their breeding grounds in temperate or arctic regions to wintering grounds in the Indian subcontinent, including the study area. The global conservation status was categorized following the International Union for Conservation of Nature (IUCN) Red List classifications, including Least Concern (LC), Near Threatened (NT), Vulnerable (VU) and Endangered (EN) (IUCN 2024). Population sizes and global trends for each species were referenced from Birdlife International (2024). Shorebird species listed under the Convention on the Conservation of Migratory Species of Wild Animals (CMS) were referred from CMS (2024) data. The study also considered the Conservation of Migratory Waterbirds and their Habitats-CAF, which promotes international cooperation for the conservation of migratory birds and their habitats under CMS Appendix II. Additionally, we integrated priorities outlined by the Arctic Migratory Birds Initiative (AMBI), which emphasizes the conservation of migratory shorebird species that traverse flyways from the Arctic to other regions (Arctic Council 2024). This multi-layered approach gives a comprehensive assessment of the conservation status of shorebirds observed at Valinokkam Lagoon.

Data analysis

Shorebird species diversity was quantified using the Shannon–Wiener index (Shannon & Wiener 1949), and the Menhinick index, which gives a relative estimation of species richness, accounting for varying sample sizes (Menhinick 1964). Higher values indicate high diversity and richness for both indices, respectively. Pielou's index was employed to evaluate species evenness across different years (Pielou 1975), which ranges from 0 (highly uneven) to 1 (even). The Berger–Parker index, ranging from 0 (no dominance) to 1 (complete dominance), was assessed whether one or few shorebird species dominated the lagoon during the study period (Berger & Parker 1970). Given the non-normal distribution of the species abundance data (as confirmed by the Shapiro–Wilk test, $p < 0.05$) the Kruskal–Wallis test, a non-parametric method, was performed to examine whether there is a statistically significant difference in the shorebird species abundances among five years (Kruskal & Wallis 1952).

To further investigate species composition, similarity percentage analysis (SIMPER) was performed, quantifying the percentage contribution of each bird species to temporal variations. Individual rarefaction curves were generated for each dataset to accurately compare species richness across years. This method enables standardized comparisons of species richness across samples of varying sizes, ensuring that observed differences in species richness reflect ecological patterns rather than sampling discrepancies (Gotelli & Colwell 2001). Seasonal trend decomposition using LOESS (STL) (LOESS – Locally Estimated Scatterplot Smoothing), a non-parametric regression method, was performed to visualize the non-linear patterns and variabilities in the time series of five study years. STL method filters the temporal data into components like the actual data, overall long-term trend, seasonal patterns, and remainders (Cleveland *et al*. 1990). The trend component represents the long-term direction of the data. It does not reflect the short-term fluctuations. The seasonal component shows the recurring, regular temporal patterns in the data, capturing

the monthly fluctuations. The remainder component represents the amount of noise or outliers in the data, after the calculations of the trend and seasonal components. It represents the random variations or the data points, which deviate from the expected trend, and are not explained by the trend or seasonal components.

All statistical analyses and graphical representations were done using PAST version 4.17 (Hammer *et al*. 2001) and R 4.4.1 (R Core Team 2023).

Results

Shorebird species composition

A comprehensive five-year survey conducted in Valinokkam Lagoon recorded a total of 32 shorebird species from the order Charadriiformes, represented by four families: Scolopacidae (n = 21), Charadriidae (n = 8), Burhinidae (n = 2) and Recurvirostridae (n=1). As per the IUCN Red List (2024), 25% (n=8) of the shorebird species observed in the lagoon are categorized as Near Threatened. These include Bar-tailed Godwit *(Limosa lapponica)*, Black-tailed Godwit *(L. limosa)*, Eurasian Curlew *(Numenius arquata)*, Dunlin *(Calidris alpina)*, Ruddy Turnstone *(Arenaria interpres)*, Red-necked Stint *(C. ruficollis)* from the family Scolopacidae, Beach Stone-curlew *(Esacus magnirostris)* and Great Stone-curlew *(E. recurvirostris)* from Burhinidae. Two species, the Curlew Sandpiper *(C. ferruginea)* and Grey Plover *(Pluvialis squatarola)* were categorized as Vulnerable, while Great Knot *(C. tenuirostris)* and Siberian Sand Plover *(Anarhynchus mongolus)* were classified as Endangered. Notably, Hanuman Plover *(A. seebohmi)* is Not Assessed. The remaining 59.3% (n=19) of the species were classified as Least Concern. Notably, 87.5% (n=28) of the species recorded at Valinokkam Lagoon are listed under Appendix II of CMS (2024) *(Table 1)*.

Winter visitors constituted 87.5% (n=28) of the total shorebird species documented. Resident species accounted for 12.5% (n=4), of which three species – Great Stone-curlew, Black-winged Stilt *(Himantopus himantopus)* and Hanuman Plover – were confirmed breeding within the lagoon. Global population trends indicated that 72% of the shorebird species recorded have declined (Birdlife International 2024), while global population size remained unknown for 62.5% *(Table 1)*.

Community dynamics and diversity indices

Alpha diversity indices were analyzed to better understand the community dynamics of shorebirds in the study site over five years. Pielou's evenness index revealed a relatively uneven distribution of shorebird species across the years. The highest evenness was observed during the 2021–2022 migratory season (0.26), while the lowest was recorded in 2023–2024 (0.19). These findings were supported by the Berger–Parker dominance index, which indicated a slight dominance of a few species in 2023–2024 (0.38) compared to 2021–2022, which exhibited the lowest dominance (0.28). Despite the unevenness, there was no complete dominance by any single species in any of the five years. Menhinick's index highlighted

Table 1. Checklist of shorebirds in Valinokkam Lagoon with IUCN, migration and global population statuses

1. táblázat A Valinokkam-lagúna partimadár-fajainak listája, IUCN-besorolásokkal és globális állomány-státuszokkal

Common name	Scientific name	Migration status	IUCN status	Global population (BirdLife International)	Global population trend (BirdLife International)	CMS (Appendix II) species
Scolopacidae						
Whimbrel	*Numenius phaeopus*	*WV*	*LC*	1,800,000–2,650,000	Decreasing	✓
Eurasian Curlew	*Numenius arquata*	*WV*	*NT*	Unknown	Decreasing	✓
Bar-tailed Godwit	*Limosa lapponica*	*WV*	*NT*	Unknown	Decreasing	✓
Black-tailed Godwit	*Limosa limosa*	*WV*	*NT*	Unknown	Decreasing	✓
Terek Sandpiper	*Xenus cinereus*	*WV*	*LC*	Unknown	Decreasing	✓
Common Sandpiper	*Actitis hypoleucos*	*WV*	*LC*	Unknown	Decreasing	✓
Marsh Sandpiper	*Tringa stagnatilis*	*WV*	*LC*	Unknown	Decreasing	✓
Green Sandpiper	*Tringa ochropus*	*WV*	*LC*	Unknown	Increasing	✓
Wood Sandpiper	*Tringa glareola*	*WV*	*LC*	Unknown	Stable	✓
Common Greenshank	*Tringa nebularia*	*WV*	*LC*	Unknown	Stable	✓
Common Redshank	*Tringa totanus*	*WV*	*LC*	Unknown	Unknown	✓
Curlew Sandpiper	*Calidris ferruginea*	*WV*	*VU*	420,000–960,000	Decreasing	✓
Red-necked Stint	*Calidris ruficollis*	*WV*	*NT*	Unknown	Decreasing	✓
Dunlin	*Calidris alpina*	*WV*	*NT*	3,000,000–7,000,000	Decreasing	✓
Temminck's Stint	*Calidris temminckii*	*WV*	*LC*	110,000–850,000	Decreasing	✓
Little Stint	*Calidris minuta*	*WV*	*LC*	1,000,000–1,100,000	Increasing	✓
Great Knot	*Calidris tenuirostris*	*WV*	*EN*	Unknown	Decreasing	✓
Sanderling	*Calidris alba*	*WV*	*LC*	900,000–1,200,000	Unknown	✓
Ruff	*Calidris pugnax*	*WV*	*LC*	Unknown	Decreasing	✓
Ruddy Turnstone	*Arenaria interpres*	*WV*	*NT*	750,000–1,750,000	Decreasing	✓
Red-necked Phalarope	*Phalaropus lobatus*	*WV*	*LC*	Unknown	Decreasing	✓
Charadriidae						
Grey Plover	*Pluvialis squatarola*	*WV*	*VU*	1,000,000–2,500,000	Decreasing	✓

Common name	Scientific name	Migration status	IUCN status	Global population (BirdLife International)	Global population trend (BirdLife International)	CMS (Appendix II) species
Pacific Golden Plover	*Pluvialis fulva*	*WV*	*LC*	Unknown	Decreasing	—
Common Ringed Plover	*Charadrius hiaticula*	*WV*	*LC*	Unknown	Decreasing	✓
Greater Sand Plover	*Anarhynchus leschenaultii*	*WV*	*LC*	100,000-225,000	Decreasing	✓
Little Ringed Plover	*Thinornis dubius*	*WV*	*LC*	Unknown	Stable	✓
Siberian Sand Plover	*Anarhynchus mongolus*	*WV*	*EN*	18,000–50,000	Decreasing	✓
Hanuman Plover	*Anarhynchus seebohmi*	*R*	*NE*	Unknown	Not assessed	—
Kentish Plover	*Anarhynchus alexandrinus*	*WV*	*LC*	100,000–499,999	Decreasing	✓
Burhinidae						
Great Stone-curlew	*Esasus recurvirostris*	*R*	*NT*	Unknown	Decreasing	—
Beach Stone-curlew	*Esacus magnirostris*	*R*	*NT*	4000	Decreasing	—
Recurvirostridae						
Black-winged Stilt	*Himantopus himantopus*	*R*	*LC*	Unknown	Increasing	✓

IUCN status: LC- Least Concern, NT- Near Threatened, VU- Vulnerable, EN- Endangered, NE- Not Evaluated| Migration status: R-Resident, WV- Winter Visitor| CMS status- ✓ listed in CMS appendix II, — not listed in CMS appendix II.

Table 2. Abundance of shorebirds and biodiversity indices across five years
2. táblázat A partimadarak abundanciája és diverzitási indexei a vizsgált öt évben

	2019–2020	2020–2021	2021–2022	2022–2023	2023–2024
Pielou's Evenness index	0.2300	0.2443	0.2645	0.1913	0.2029
Shannon–Wiener index	1.8260	1.8490	2.0370	1.7470	1.8390
Menhinick index	0.5425	0.5542	0.7003	0.5030	0.4393
Berger–Parker index	0.3295	0.3671	0.2893	0.3404	0.3852

variations in species richness, with the highest value recorded in 2021–2022 (0.7) and the lowest in 2023–2024 (0.4). Intermediate richness values were observed during 2019–2020, 2020–2021 and 2022–2023, with minimal fluctuations (0.5). The Shannon–Wiener index exhibited significant inter-annual variability in shorebird diversity. The highest diversity was recorded in 2021–2022 (2.0), while the lowest was observed in 2022–2023 (1.7). Other years demonstrated relatively stable diversity, with values clustering around the rest of the years (1.8) *(Table 2)*.

Temporal patterns and trends

Across the five study years, total shorebird abundance was highest in 2023–2024 (n=59,750), followed by 2022–2023 (n=42,687), while the lowest abundance was recorded in 2021–2022 (n=20,572) *(Figure 2)*. Familywise, Scolopacidae species including Little Stint *(C. minuta)*, Curlew Sandpiper and Common Redshank *(Tringa totanus)* were most abundant across all years. In the Charadriidae family, Kentish Plover *(A. alexandrinus)*, Siberian Sand Plover and Greater Sand Plover *(A. leschenaultii)* were predominant *(Figure 3)*. 26 species were recorded consistently in all the years. Of the remaining six species, Dunlin was recorded only in 2021–2022, Red-necked Stint, Red-necked Phalarope *(Phalaropus lobatus)* and Black-tailed Godwit in 2022–2023 and 2023–2024. Wood Sandpiper *(T. glareola)* was recorded only in 2021–2022 and 2023–2024, and Sanderling *(C. alba)* was absent in 2020–2021 but recorded in other years.

Monthly abundance data showed that January 2023 had the highest total abundance (n=14,038), followed by January 2024 (n=11,220) *(Figure 4)*. The five most abundant and threatened species one-time peak monthly counts from the lagoon include Little Stint (n=6,520), Kentish Plover (n=2,400) and Greater Sand Plover (n=1,930) were observed in January 2023. The highest annual abundance of the Endangered Siberian Sand Plover was recorded in 2022–2023, with a peak monthly count in September 2022 (n=3,300), abundant from January to March in all study years. Number of Curlew Sandpiper was highest in 2023–2024, with a peak count in September 2023 (n=2,800) *(Figure 5)*.

Among the threatened species, the Endangered Great Knot was recorded at its highest abundance (n=10) in February 2022, followed by March 2023 (n=8), and was absent in 2019–2020 and 2020–2021. The Vulnerable Grey Plover was most abundant in 2022–2023,

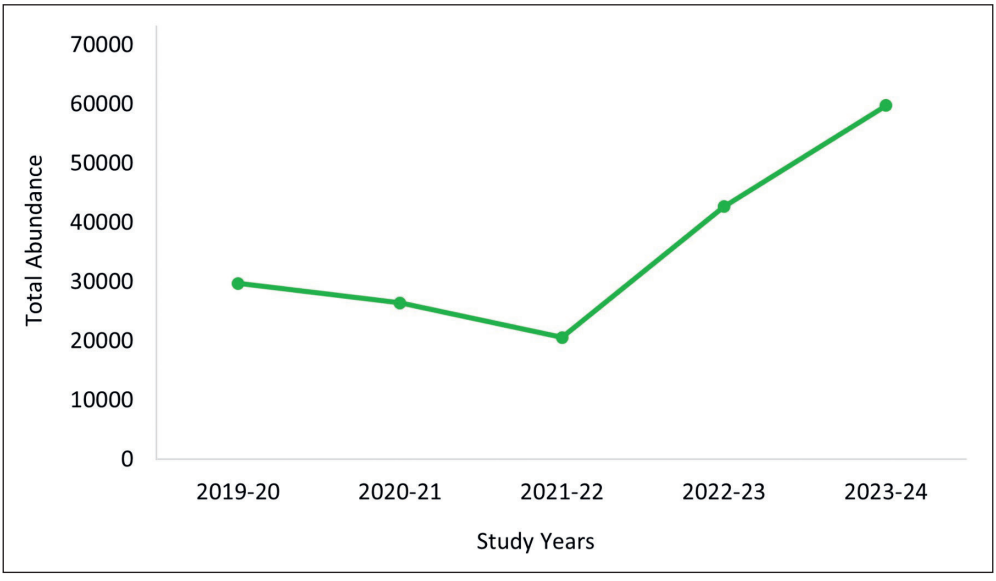


Figure 2. Total abundance of shorebirds in each year
2. ábra A partimadarak teljes évenkénti abundanciája

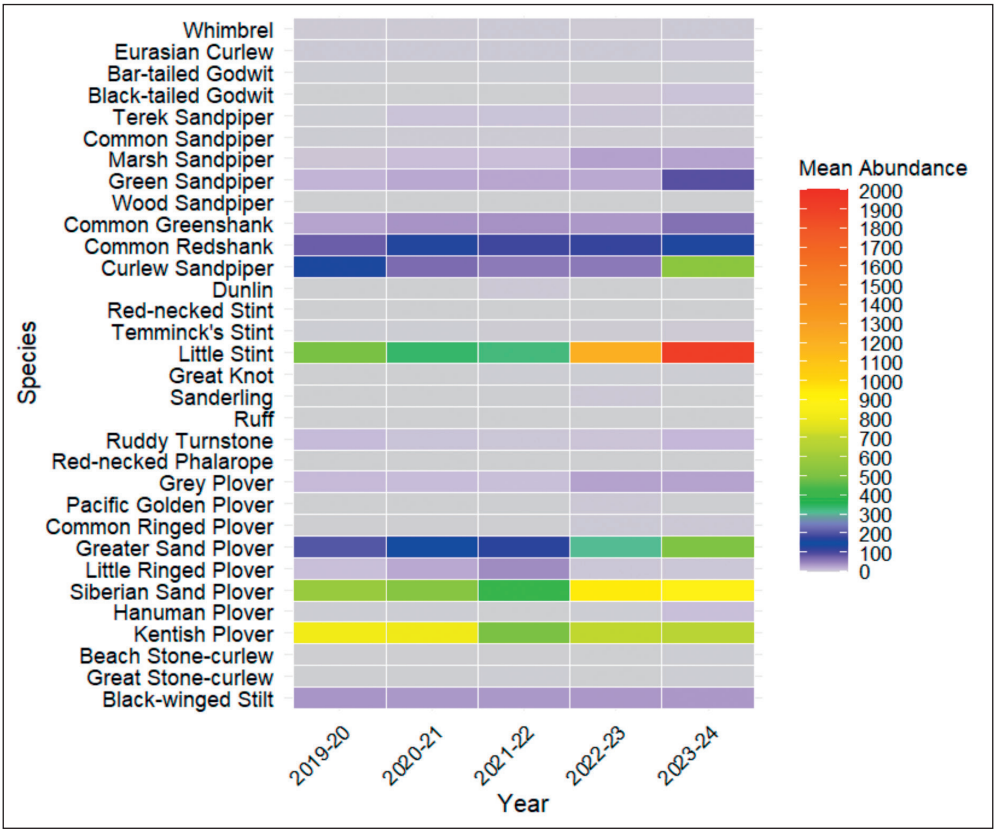


Figure 3. Mean abundance of shorebird species across five years
3. ábra A partimadár-fajok átlagos abundanciája, az ötéves adatsort feldolgozva

followed by 2023–2024, with a peak count in January 2023 (n=62). The Near Threatened Dunlin was observed only in April 2022 (n=60). One or two individuals of Beach Stone-curlew were recorded annually. Great Stone-curlew highest record was in April 2022 (n=8), and one or two individuals were recorded consistently across all years. Bar-tailed Godwit was present each year, peaking in January 2023 (n=10). Black-tailed Godwit was recorded from September to March in 2022–2023 and 2023–2024, with the highest count in November 2022 (n=40). Red-necked Stint was recorded only in December 2022 (n=4) and September 2023 (n=2). Ruddy Turnstone was recorded in all the years, with its peak count in August 2023 (n=60). Eurasian Curlew abundance increased in September across all years, with the highest count in September 2022 and November 2020 (n=12) *(Figure 6)*.

SIMPER analysis identified four species as primary contributors (80.9%) to the temporal dissimilarity in shorebird communities, based on the Bray–Curtis similarity index across the study period. Little Stint accounted for 41.9% of the dissimilarity, followed by Siberian Sand Plover (17.08%), Curlew Sandpiper (11.76%) and Kentish Plover (10.17%), indicating their dominant influence on community dynamics at Valinokkam Lagoon. The remaining 28 species contributed only 19.1% to the temporal variation *(Table 3)*. STL decomposition

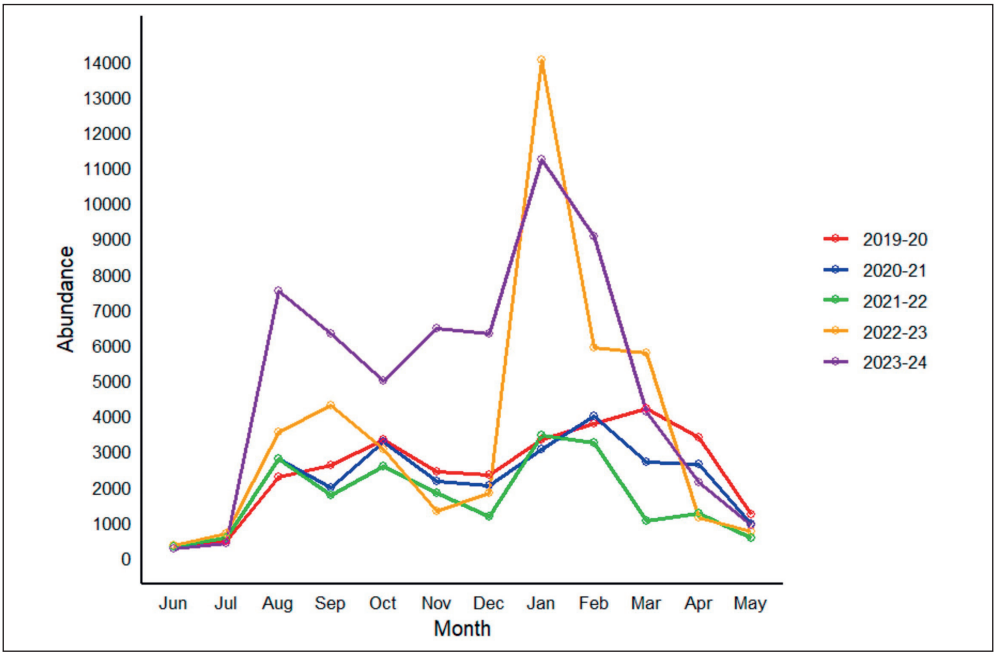


Figure 4. Total monthly abundance of shorebirds across five study years
4. ábra A partimadarak teljes havi abundanciája az öt vizsgálati év alatt

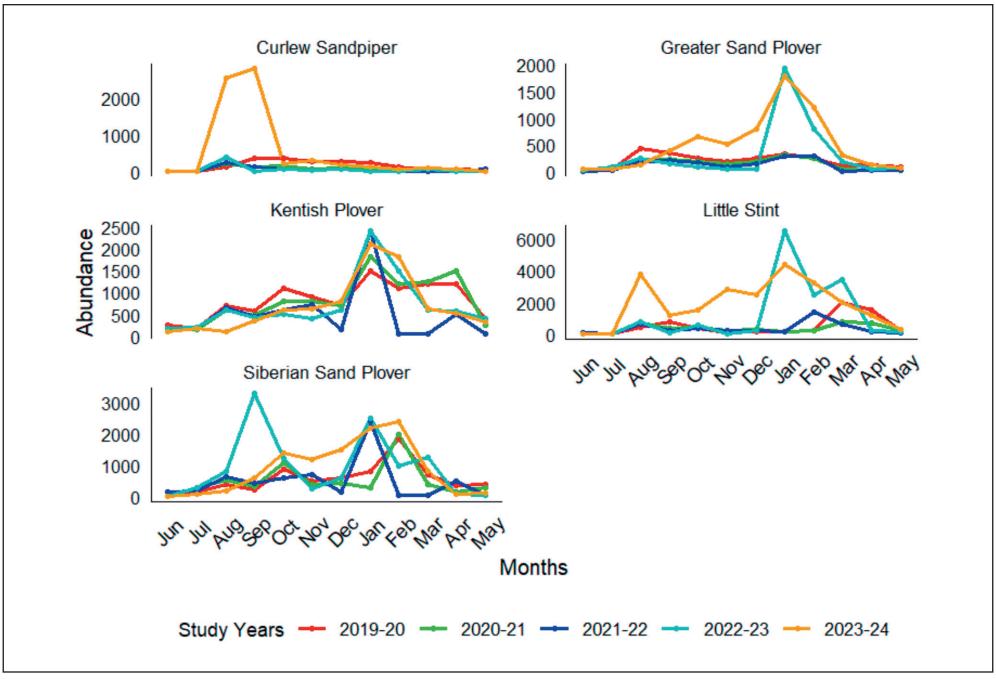


Figure 5. Monthly abundance of the five most abundant shorebird species
5. ábra Az öt leggyakoribb partimadár-faj havi abundancia-értékei

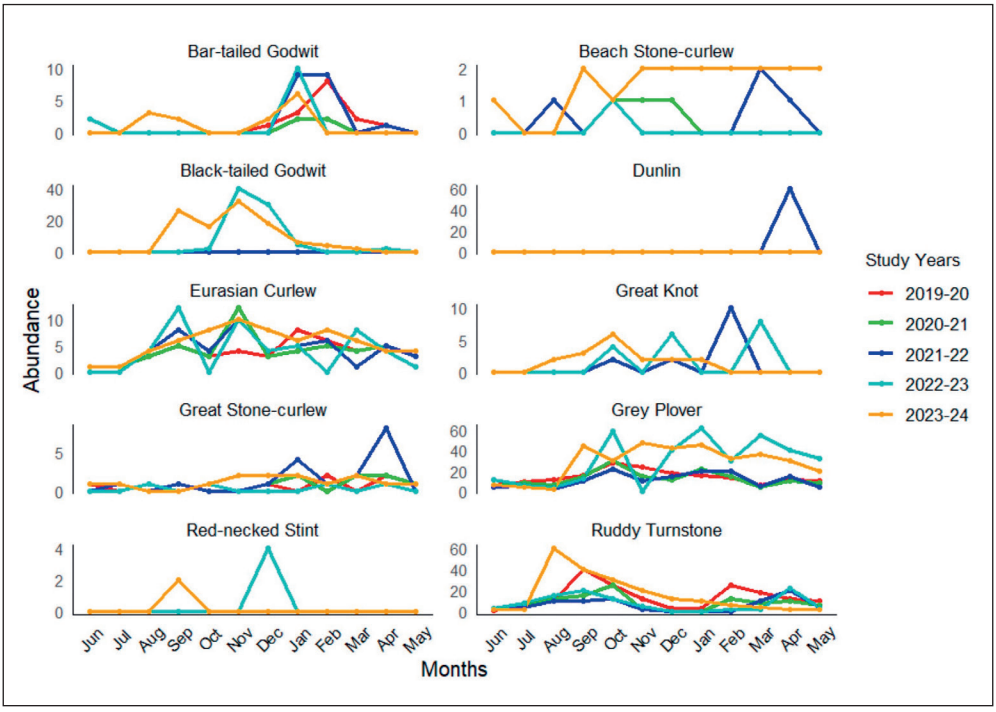


Figure 6. Monthly abundance of the 10 threatened shorebird species
6. ábra A 10 legveszélyeztetettebb partimadár-faj havi abundancia-értékei

confirmed the temporal trends in shorebird abundance. The data plot illustrated patterns in the actual data with abundance fluctuating between 2,000 and 14,000 individuals, with a notable peak reaching approximately 14,038 individuals in 2022–2023. The trend component revealed a substantial increase during 2022–2024, rising from approximately 3,500 to 5,000 individuals, representing a positive trend of approximately 1,500 individuals over this period with a typical monthly rise of around 622 individuals. Outliers and fluctuations were also high in these two years, as indicated in the remainder plot, with deviations ranging from -2,000 to +6,000 individuals, including a pronounced positive anomaly of approximately 6,000 individuals in 2022–2023. The standard deviation of the remainder component was 1,492.0, indicating outliers. The seasonal component displayed a regular repeating pattern with a consistent amplitude of approximately 6,476.6 individuals, with peaks occurring in August annually *(Figure 7)*.

11 shorebird species were found to be over-summering in Valinokkam Lagoon from June 15 to July 31 (Byju *et al*. 2024). These included Grey Plover, Greater Sand Plover, Siberian Sand Plover, Whimbrel *(N. phaeopus)*, Eurasian Curlew, Common Greenshank *(T. nebularia),* Common Redshank, Curlew Sandpiper, Little Stint, Ruddy Turnstone and Kentish Plover, with Siberian Sand Plover being the most abundant over-summering species.

Species accumulation patterns analyzed using individual rarefaction curves indicated a continuous rise without reaching a plateau, indicating the possibility of documenting more species, particularly in 2019–2020 and 2021–2022. The highest species richness was

recorded in 2022–2023 and 2023–2024, and the lowest in 2020–2021 *(Figure 8)*. Despite these temporal trends, the Kruskal–Wallis test results revealed no statistically significant difference in shorebird abundances across the five study years ($p = 0.66$, $Chi^2 = 2.392$).

Table 3. SIMPER analysis of shorebird species
3. táblázat A partimadár-fajok SIMPER-elemzése

Taxon	Contribution %
Little Stint	41.900
Siberian Sand Plover	17.080
Curlew Sandpiper	11.760
Kentish Plover	10.170
Greater Sand Plover	9.727
Common Redshank	1.544
Green Sandpiper	1.435
Wood Sandpiper	1.258
Little Ringed Plover	1.195
Common Greenshank	0.819
Marsh Sandpiper	0.673
Grey Plover	0.584
Ruddy Turnstone	0.288
Terek Sandpiper	0.251
Black-tailed Godwit	0.250
Hanuman Plover	0.212
Dunlin	0.141
Common Ringed Plover	0.129
Pacific Golden Plover	0.117
Sanderling	0.115
Black-winged Stilt	0.073
Temminck's Stint	0.047
Great Knot	0.042
Eurasian Curlew	0.038
Bar-tailed Godwit	0.035
Great Stone-curlew	0.034
Beach Stone-curlew	0.031
Common Sandpiper	0.028
Red-necked Stint	0.009
Red-necked Phalarope	0.006
Ruff	0.006

Discussion

This five-year study provides critical insights into the temporal patterns and community dynamics of shorebirds in Valinokkam Lagoon, underscoring its ecological importance as a wintering and breeding site for species, including those classified as threatened by the IUCN Red List (2024). We documented fluctuations in species richness, abundance, and community composition, highlighting both consistent seasonal trends and inter-annual variations. Monthly monitoring and counts aimed to identify the important periods during which the site is used by shorebirds, like the months with the maximum count or species diversity and to record the regular changes in the site usage as this is a first attempt on this important wintering site. Below, we discuss the significance of these findings in the context of shorebird conservation and potential drivers of observed patterns.

Shorebird composition and community dynamics

Valinokkam Lagoon supported 32 shorebird species, including eight Near Threatened and four globally threatened species, reaffirming the critical role of the habitat. As 72% of the recorded species show declining global population trends (Birdlife International 2024), sustained monitoring and protection of this habitat is vital for their survival. The high proportion (87.5%) of migratory species among the documented shorebirds aligns with earlier findings (Razak & Rahman 2020, Byju *et al*. 2023e, Shree & Malathi 2024),

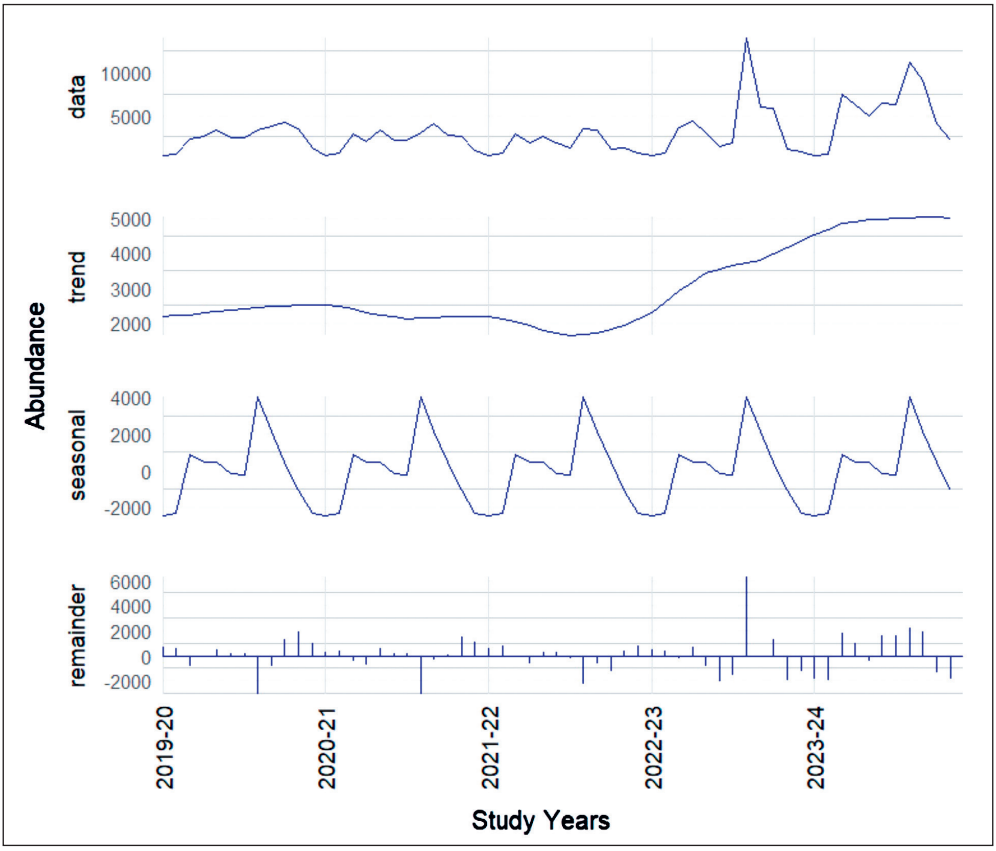


Figure 7. Seasonal Trend decomposition plot using LOESS (STL) across five years
7. ábra Az öt évet felölelő partimadár-adatok Szezonális Trend-dekompozíciós ábrája LOESS (STL) alkalmazásával

emphasizing the importance of this coastal lagoon as a stopover and wintering site along CAF. The over-summering of 11 species in the lagoon highlights the year-round ecological value with the availability of prey and suitable environmental conditions for the shorebirds in Valinokkam Lagoon.

SIMPER analysis further elucidated the dominant influence of four species (Little Stint, Siberian Sand Plover, Curlew Sandpiper and Kentish Plover) on community dynamics, contributing over 80% to temporal dissimilarity. Their predominance suggests that the ecological health of Valinokkam Lagoon is closely tied to the habitat preferences of these key and common species in coastal wetlands of the CAF and are known to be highly responsive to changes in habitat conditions (Ma *et al*. 2013). This makes them useful bioindicators for monitoring ecosystem changes (Barter 2002, MacKinnon *et al*. 2012).

The relatively uneven species distribution and the dominance index also substantiated the SIMPER results. The year 2023–2024 marked the highest total abundance contributed mainly by the four most abundant species, yet the lowest values of species evenness, richness and diversity, whereas the year 2021–2022 had the lowest abundance yet slightly

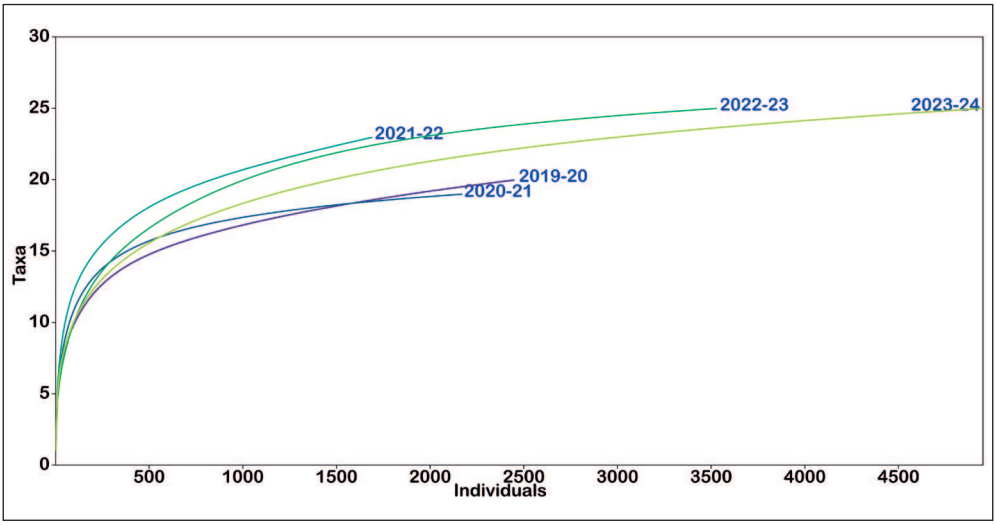


Figure 8. Individual rarefaction curves across five years
8. ábra Évenkénti ritkítási görbék az öt éves vizsgálati adatsorokra

more even community with less dominance, high species diversity and richness. The factors that influence such species distribution dynamics could be the availability of macroinvertebrates, particularly chironomid larvae that are key food items of shorebirds (Sánchez *et al*. 2006, Yasué & Dearden 2009) as their high production depends mainly on salinity and water level in the saltpans (Velasquez 1992, Rehfisch 1994). Some studies noted a positive correlation between the benthic organisms like bivalves, gastropods, salinity and water level in the saltpans to the abundance and diversity of shorebirds (Warnock *et al*. 2002, Rocha 2013, Pandiyan *et al*. 2021), which is especially true in winter where shorebirds density purely depends on prey density (Pandiyan *et al*. 2006, Sultana *et al*. 2024). These factors could be the potential reasons behind Valinokkam presenting higher abundances of smaller shorebirds (plovers and Little Stint) in all the seasons, which needs further investigation on the benthic fauna and micro-environmental variables in the lagoon.

Inter-annual variability and species-specific trends

Our results revealed notable inter-annual variability in shorebird abundance and species richness. The highest total abundance was in 2023–2024 and the lowest in 2021–2022, suggesting potential links to environmental conditions, prey availability and habitat quality. The increase in shorebird abundance in 2023–2024 warrants further investigation into annual climatic variability and its effects on shorebird assemblages. The rarefaction curves suggested that the lagoon may still host additional undocumented species. This pattern aligns with studies showing that wetlands with fluctuating hydrological regimes often support dynamic shorebird communities, where species richness depends on annual climatic conditions (Galbraith *et al*. 2014).

Species-specific trends highlighted the influence of habitat preferences and migratory patterns on species assemblages. For example, the Siberian Sand Plover population peaked in September 2022, with consistent abundance during the January–March period, aligning with its migration schedule and reliance on intertidal habitats (Rogers *et al*. 2020). Black-tailed Godwit was present from October to March 2022–2023 and 2023–2024, peaking in November 2022. These findings align with studies on the east coast of India by Balachandran (2006), that small and medium-sized shorebirds peak in January and long-legged shorebirds like Black-tailed Godwits from November to March. Similarly, the absence of Dunlin in most years except 2021–2022 and the restricted presence of Red-necked Stint during 2022–2023 and 2023–2024 suggest either habitat-specific requirements or stochastic events influencing their occurrence. The lack of significant differences in species abundances between years, as revealed by the Kruskal–Wallis test, further suggests the lagoon's consistent provision of key habitat types, including mudflats, saltpans and grassy areas, which support a diverse range of shorebirds throughout the year, apart from micro-environmental factors.

Seasonal patterns

We observed a clear seasonal peak in shorebird abundance in August, substantiated by monthly abundance analysis. Despite minor variations over time, shorebird abundance generally started increasing in August, peaked in January and February, and reached its lowest in June and July. This is consistent with earlier studies on a few wintering sites on the southeast coast of India (Balachandran 2006, Pandiyan & Asokan 2016, Rao *et al*. 2022). The observed decline in abundance during May–July likely corresponds to the northward migration of shorebirds to breeding grounds, as well as seasonal shifts in habitat conditions, such as reduced prey availability or water levels. The seasonal pattern might be due to the rainfall from the northeast monsoon in the region (October–December). Temporal fluctuations in shorebird abundance could also occur due to localized movements of birds other than the local environmental factors (Townshend 1981, Pienkowski & Evans 1984).

Conservation challenges and recommendations

From our results, it is evident that Valinokkam is a crucial habitat for both winter visitors and the resident shorebirds. Apart from the IUCN assessed threatened species mentioned earlier, five species recorded in Valinokkam such as Whimbrel, Bar-tailed Godwit, Curlew Sandpiper, Dunlin and Great Knot are listed as Central Asian Flyway Priority Species in AMBI (Arctic Council 2024), whereas 28 of the total shorebirds are recorded in Appendix II of CMS, implying the need of an international cooperative framework for the conservation of these birds and their breeding and wintering grounds. The lagoon is also a breeding ground for two near-threatened species (Beach Stone-curlew and Great Stone-curlew) along with the regional endemic shorebird Hanuman Plover (Byju *et al*. 2023d).

The absence of statistically significant differences in shorebird abundances across years does not diminish the ecological significance of the temporal trends observed. Rather, it

highlights the inherent variability in shorebird populations, driven by a complex interplay of local and global factors. The careful management of manmade wetlands, such as industrial saltpans, might boost their utility as a foraging site for waterbirds, particularly migrant shorebirds, during their times of high energy demand (Ntiamoa-Baidu *et al*. 2000). Since Valinokkam lagoon is an unprotected area, the threats of encroachment for developmental activities or establishments of extensive prawn culture persist. We have observed children picking up the eggs of Hanuman Plover and stray dogs disturbing the birds. These observations emphasize the need to warrant a protection status for this lagoon.

To ensure the long-term sustainability of Valinokkam Lagoon as a shorebird habitat, we recommend the following:

1. **Strengthening habitat protection**: Designate Valinokkam Lagoon as a protected wetland under the Ramsar Convention and implement site-specific management strategies to mitigate habitat degradation.
2. **Monitoring and research**: Establish a long-term monitoring program to track population trends and habitat changes. Future studies should focus on understanding prey availability, hydrological dynamics, and the impact of climate change on migratory patterns.
3. **Community engagement**: Involve local communities in conservation efforts through awareness programs and sustainable livelihood initiatives, such as eco-tourism and birdwatching activities.
4. **Collaborative networks**: Strengthen collaborations with international flyway initiatives, such as the CAF Partnership, to align conservation actions with global efforts. Shorebird population data of Valinokkam Lagoon can be a significant contribution to the global database upgrade, since the global population size of more than 62% of the shorebird species that are recorded in this site is unknown.

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Seasonal variation in wetlands influence the dynamics of waterbird communities in Dungarpur district, Rajasthan, India

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Abstract Human activities have rendered freshwater ecosystems among the most endangered in the globe, yet these ecosystems provide critical habitats for a variety of waterbird species. Semi-arid landscapes, characterized by variable climatic conditions and water availability, present unique challenges to these ecosystems. In our study, we investigated how wetland size and seasonal variations in a semi-arid climate influence waterbird populations, distribution, and habitat preferences. Using an *a-priori* field design, we surveyed areas with varying wetland extents across different seasons in the Dungarpur district, Rajasthan, western India. Between March 2021 and January 2022, we recorded 69 waterbird species belonging to 9 orders, including 10 species of global conservation concern. We found that both bird species diversity and richness were significantly higher in areas with high wetland extent. Interestingly, seasonal changes did not significantly affect waterbird diversity and richness. However, encounter rates were higher in winter than summer and monsoon seasons. The encounter rates of different feeding guilds varied across wetland classes, except for omnivores, which showed significant seasonal variation. Overall, our findings indicate that wetland extent is a major driver of waterbird population and distribution. Therefore, we strongly recommend the protection of extensive wetland areas to enhance waterbird conservation in the study area.

Keywords: bird conservation, wetlands, bird diversity, Mewar region, Aravalli region

Összefoglalás Az emberi tevékenységek következtében az édesvízi ökoszisztémák a világ legveszélyeztetettebb ökológiai rendszerei közé sorolódnak annak ellenére, hogy ezek a rendszerek a vízimadarak széles taxonómiai skálájának nyújtanak kritikusan fontos élőhelyeket. A félsivatagos tájak, amelyeket változatos klimatikus feltételek és vízellátottság jellemez, ezen ökoszisztémák számára különleges kihívásokat jelentenek. Jelen vizsgálatunkban azt elemeztük, hogy a vizes élőhelyek kiterjedése és a félsivatagos klíma szezonális változása hogyan befolyásolja a vízimadár-populációkat, ezek elterjedését és élőhelyválasztását. Előre meghatározott (a priori) terepi kísérleti elrendezést alkalmazva, változatos kiterjedésű vizesélőhely-rendszereket mértünk fel különböző évszakokban a nyugat-indiai Rajasthan Dungapur tartományban. 2021 márciusa és 2022 januárja között 9 madárrend 69 vízimadár-fajáról gyűjtöttünk adatokat, melyek közül 10 faj globális szinten veszélyeztetett. Eredményeink alapján a madarak fajdiverzitása és -gazdagsága szignifikánsan magasabb volt a nagy vizesélőhely-arányt mutató területeken. Érdekes módon a szezonális változások nem befolyásolták jelentősen a vízimadarak diverzitását és fajgazdagságát. Ezzel szemben viszont a megfigyelési arányok magasabbak voltak télen, mint nyáron vagy a monszun ideje alatt. Az eltérő táplálkozási guildek megfigyelési arányai változtak a vizesélőhely típusa szerint, a mindenevők kivételével, melyek szignifikáns szezonális változást mutattak. Összességében eredményeink rámutatnak, hogy a vizesélőhelyek a vízimadarak állománynagyságainak és elterjedésének fő meghatározó tényezői. Így nyomatékosan ajánljuk a kiterjedt vizesélőhely-rendszerek védelmét, ami a vizsgált területen erősítheti a vízimadarak védelmét.

Kulcsszavak: madárvédelem, vizes élőhelyek, madár diverzitás, Mewar régió, Aravalli régió

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Introduction

Freshwater ecosystems are vital for maintaining ecological balance and supporting biodiversity by providing essential habitats for numerous species. However, these ecosystems are among the most endangered ones globally due to a range of human activities and environmental changes, including overexploitation, habitat degradation, agricultural conversion, wetland drainage, urban development, the spread of invasive species, and industrial and agricultural runoff (Craig *et al*. 2017, Reid *et al*. 2019). Over the past century, more than half of the world's wetlands have either disappeared or been severely degraded, with approximately 35% being destroyed since 1970 (Ramsar Convention on Wetlands 2018). This widespread loss exerted devastating effects on wetland-dependent species, particularly waterbirds, which rely heavily on these ecosystems for their survival. Currently, 38% of the world's waterbird populations are in decline, largely due to the degradation and loss of wetlands (Kirby *et al*. 2008).

Wetlands in tropical and subtropical Asia are deeply intertwined with the socio-cultural relations and are often actively managed, as seen in paddy fields and aquaculture ponds (Gopal 2013). Precipitation variability and seasonal changes are key factors influencing these ecosystems, affecting hydrological patterns, wetland extent, and the provision of ecological services (Bassi *et al*. 2014). A significant ratio of the human population living near wetlands depends heavily on them for agriculture and livelihoods (Blake *et al*. 2004). In recent decades, these wetlands have attracted global attention due to their critical role in supporting diverse wildlife (Kumar & Sharma 2019, Chatterjee & Bhattacharyya 2021, Rawal *et al*. 2021). Many wetland ecosystems, such as Keoladeo National Park, a Ramsar site, are renowned for their high avian biodiversity. Chatterjee and Bhattacharyya (2021) highlighted that 11 mammal species dependent on Indian wetlands are under significant threat. Rawal *et al*. (2021) recently emphasized the importance of ponds as vital remnant ecosystems for bird diversity in Delhi, India's capital, one of the world's most densely populated megacities. They found that bird abundance in city ponds increases with pond size and greater shoreline heterogeneity.

Semi-arid tropics and sub-tropics are characterized by distinct climatic conditions and often experience high human population densities (Huang *et al*. 2016, Marcotullio *et al*. 2021). Over the past 60 years, semi-arid regions have seen the most significant expansion of dry areas globally (Huang *et al*. 2016). These areas are marked by pronounced seasonal changes and variability in precipitation, creating unique habitats. Nonetheless, recent changes in their land cover pose survival challenges for both wildlife and human populations. The availability of water fluctuates over time, impacting ecological services and wildlife habitats

in these regions. Most wetlands in semi-arid areas are agricultural wetlands, which are used for a variety of purposes, including agriculture, domestic water supply, cattle grazing, and the harvesting of wetland products such as fish, reed and silt (Gopal 2005, Sundar & Kittur 2013). Despite these diverse uses, recent studies have increasingly recognized these wetlands as critical habitats for biodiversity conservation (Verhoeven & Setter 2010). However, much of the wetland research to date has focused on individual and large wetland sites, with a limited application of landscape-level approaches, particularly in India (Foote *et al*. 1996, Ladhar 2002, Sundar *et al*. 2015, Ramachandran *et al*. 2017, Kumar & Sharma 2019, Rawal *et al*. 2021).

Effective wetland management requires a fundamental understanding of ecosystem processes, species interactions, and life history strategies (Gray *et al*. 2013). Williamson *et al*. (2013) observed that many threatened inland-breeding waterbirds are concentrated in Asia, yet studies on these species remain limited. To address this gap, we conducted our study with an *a-priori* study design, stratifying the landscape based on wetland extent in the semi-arid region of Dungarpur, the southernmost district of Rajasthan, western India. Our goal was to examine the effects of two key drivers – seasonal changes and wetland extent – on waterbird populations. This area, interspersed with the Aravalli Mountain range, provides a unique habitat for study. Our broad objectives were: (1) to document waterbird diversity in the Dungarpur district, (2) to assess the impact of seasonal changes and wetland extent on waterbird diversity, richness and abundance as well as (3) to evaluate waterbird habitat use within the study area. Given that waterbirds primarily depend on wetlands, we hypothesized that waterbird biodiversity, richness, and density would be higher in areas with greater wetland extent, with waterbirds predominantly utilizing wetland habitats. Additionally, considering the study area's significance as a habitat for winter migratory bird species (Sharma & Tehsin 1994), we anticipated higher waterbird diversity and richness during the winter season. In Dungarpur, natural wetlands typically fill during the monsoon season and are subsequently used for agriculture throughout the rest of the year. Most wetlands dry out between the end of winter and the onset of summer, and larger wetlands that retain water during these dry periods (with temperatures reaching ~45 °C) attract waterbirds (Sundar 2006, Asawra *et al*. 2022). Therefore, we expected that areas with larger wetlands would support a greater density or encounter rate of waterbirds during the summer. Finally, we predicted that waterbirds would be encountered more frequently in wetland habitats compared to other habitat types.

Material and Methods

Study area

Our study was conducted in the Dungarpur district (23°00'–24°01' N, 73°22'–74°24' E, covering 3,770 km^2), located in the southernmost region of Rajasthan state, western India *(Figure 1)*. The district has a human population of 1,388,552, with approximately 70% belonging to tribal communities who primarily rely on agriculture and animal husbandry

for their livelihoods (Census of India 2011, Asawra *et al*. 2022). A network of streams traverses the district, eventually discharging into the two major rivers, the Som and the Mahi. The Som Kamla reservoir on the Som River and the Kadana Dam on the Mahi River play crucial roles in mitigating the area's arid climate. Most natural wetlands in the district fill up during the monsoon season and are utilized for various purposes, including irrigation. These wetlands typically dry up by the end of winter, leaving only the larger wetlands with some water throughout the hot summer months (Asawra *et al*. 2022). The region experiences three distinct seasons based on temperature and precipitation: summer (March-June), monsoon (July–October), and winter (November–February). Temperatures range from a minimum of ~5 °C in winter to a maximum of ~45 °C in summer. The area received 877.6 mm of rainfall in 2020 (Monsoon Report Rajasthan 2020). Dungarpur is located in the humid southern plains agro-climatic zone. Agriculture in the district includes both rain-fed and irrigated crops (Rao & Singh 2018). Most farmers practice mixed farming, which includes crops, fruit orchards, vegetables, dairy, and poultry (Asawra *et al*. 2022). Common crops during the Kharif season include maize *(Zea mays)*, paddy *(Oryza sativa)*, and sorghum (*Sorghum* sp.), while wheat (*Triticum* spp.) and small millets are grown in the Rabi season. Cotton (*Gossypium* spp.) and sugarcane *(Saccharum officinarum)* are also commercially cultivated across the district. Previous studies in this region have shown that it supports a healthy population of several threatened waterbird species (Sharma & Tehsin 1994, Koli *et al*. 2013, Asawra *et al*. 2022).

Study design

The study area was initially divided into 5×5 km grids, resulting in 128 squares *(Figure 1)*. We then estimated the Normalized Difference Water Index (NDWI) (McFeeters 1996) for the entire Dungarpur district using the green (Band 3) and near-infrared (Band 8) bands from Sentinel-2 satellite imagery (spatial resolution 10 m) downloaded from https://scihub.copernicus.eu. NDWI was calculated for the first two months of each season – summer, monsoon, and winter – to capture seasonal variation. To represent each season, we averaged the NDWI values for March–April 2021 for summer, July–August 2021 for monsoon, and November–December 2021 for winter. Subsequently, we manually classified the NDWI scores to identify surface water presence. Using the "Tabulate Area" feature in ArcMap (Version 10.8), we calculated the proportion of each 5×5 km grid square covered by water during each season. The wetland area within each grid square ranged from 0.002 to 7.73 km^2, with over 73% of the squares containing less than 1 km^2 of wetlands. We categorized the squares into three classes based on the availability of wetland extent: low (<0.1 km^2), medium (0.1–0.3 km^2), and high (>0.3 km^2). Due to limited manpower and funding, we randomly selected five squares from each category for sampling during the first season (summer) and repeated the sampling in the subsequent seasons, resulting in a total of 15 grid squares *(Figure 1)*. Before sampling, we ensured that the selected grids consistently represented the same wetland extent classes across all seasons.

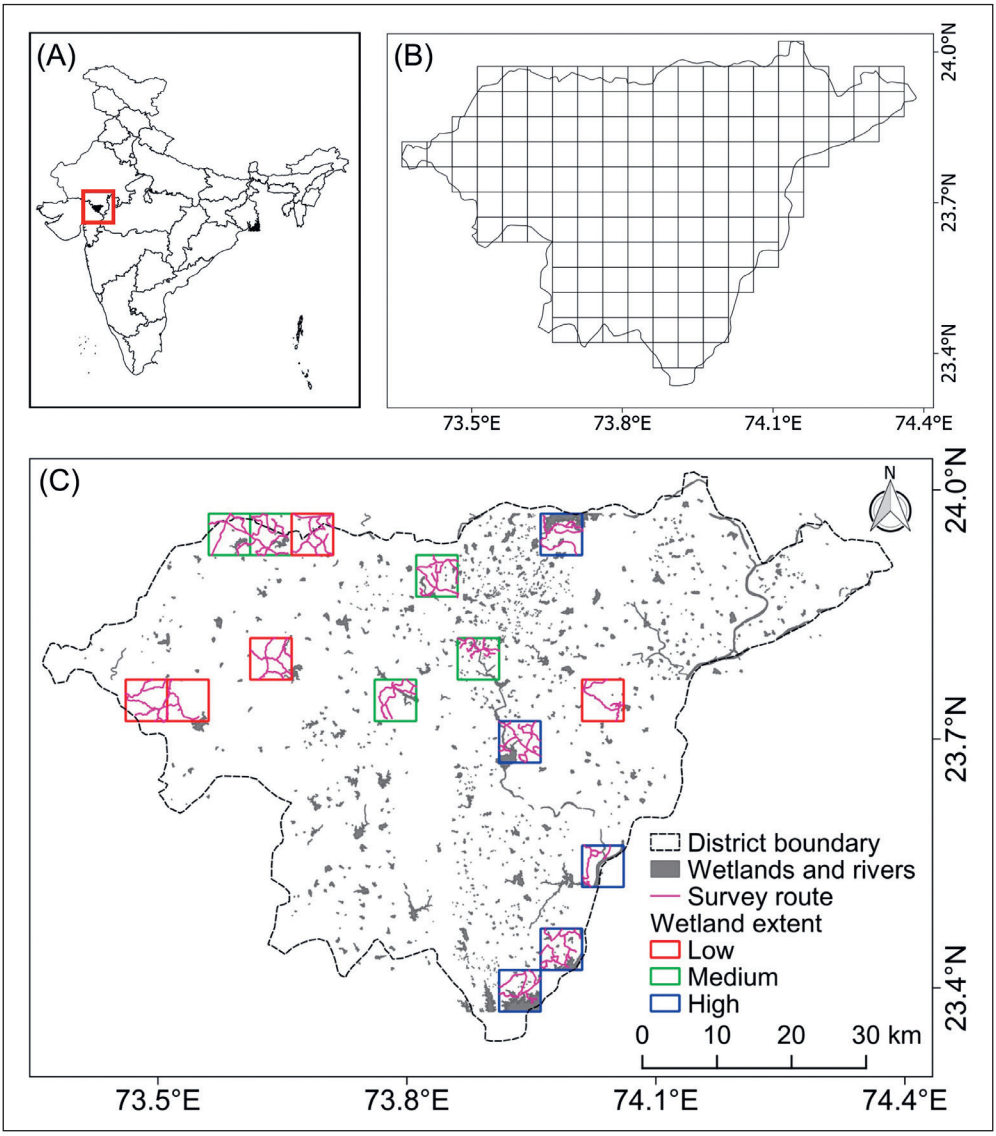


Figure 1. Study area i.e. Dungarpur district, located southern Rajasthan, India (A). The district was divided into 5 × 5 km squares (B), and 15 squares with varied wetland extents (low, medium, and high) were chosen randomly to count waterbirds (C). The sampling effort (roads travelled) in each square is also shown

1. ábra A nyugat-indiai Rajasthan Dungarpur tartományában elhelyezkedő vizsgálati terület (A). A területet 5 × 5 km kvadrátra osztottuk (B), melyek közül 15, változatos vizesélőhely-kiterjedéssel jellemzett (alacsony, közepes, magas) kvadrátot véletlenszerűen választottunk ki a vízimadarak felméréséhez (C). A felmérés ráfordítását (megtett útvonal) is feltüntettük az ábrán

Field method

Field surveys were conducted across 15 selected grid squares in random order between March 2021 and January 2022 to cover all three seasons, using motorbikes driven at a speed of ~20 km/hr. Wetland areas outside the district boundaries were not included in the survey. The survey routes and the distance covered were recorded using the smartphone application LOCUS map (Ver. 4.25.1). For large wetlands near road networks that could not be fully observed from a vantage point, we conducted on-foot surveys to count all waterbirds present, and the walking distance was also included in the survey track. Each grid square was surveyed once per season, and waterbirds observed within approximately 200 meters on either side of transects were recorded. Given our primary objective of assessing the impact of wetland extent and seasonal changes on waterbird diversity, richness, and abundance, the sampling methodology was kept consistent across these factors. For instance, the field surveys were carried out by the same two observers (KS and AM) following nearly identical routes throughout all seasons to minimize potential biases, such as observer bias and variations in visibility.

Waterbird sightings were categorized according to habitat types: agriculture (land with standing or growing crops), wetlands (both in water and on wet soil adjacent to wetlands), open areas (uncultivated land), and other categories (including garbage sites, drainage lines, grasslands, and roadsides). Bird species were identified and classified by their feeding guilds (carnivore, herbivore, insectivore, piscivore, omnivore, molluscivore) and migratory status (resident vs. migratory) based on Rasmussen and Anderton (2005), Ali and Ripley (2007), and Grimmett *et al*. (2011). Bird nomenclature followed Clements *et al*. (2023), and the global conservation status of species was obtained from BirdLife International (2024).

Statistical analysis

Given the slightly unequal distribution of road transects across the grids, waterbird abundance was estimated per grid based on the encounter rate (waterbirds counted/ transect length in km). To understand the habitat utilization by waterbirds, we used the raw number of birds (abundance), as estimating encounter rates at the habitat level was difficult. Waterbird diversity was assessed using various metrics, including Shannon–Wiener index (for species diversity) and species richness. The Shannon–Wiener index and Simpson's index was calculated using PAST software (Version 3.15) (Hammer *et al*. 2001). To evaluate the adequacy of our seasonal sampling and compare species richness across seasons, we employed sample-size-based rarefaction curves using the 'ggiNEXT' function in the R package 'iNEXT' (Chao *et al*. 2014). We used species richness (Hill number q = 0) to thoroughly assess our sampling coverage across different subnetworks. This approach allowed us to determine whether observed differences between subnetworks were more likely due to sampling effectiveness rather than biological processes. Hill numbers are valuable statistic for measuring species diversity, assessing sampling coverage, and comparing datasets (Chao *et al*. 2014, Roswell *et al*. 2021). We used the

Chao 1 index of species richness and the 'ChaoRichness' function from the same package to estimate the number of undiscovered species throughout our investigation (Colwell &Coddington 1994).

We employed Permutational Multivariate Analysis of Variance (PERMANOVA; a non-parametric test) to compare species diversity (Shannon–Wiener index and Simpson's index), species richness, and encounter rates across different wetland classes and seasons. In this analysis, we tested two-way interactions between wetland extent and seasons to determine whether variations in species diversity, species richness, and encounter rates were attributable solely to wetland extent, seasons, or their interaction. This analysis was conducted in R using the 'lmPerm' package (Ver. 2.1.0) and the 'aovp' function (Wheeler & Torchiano 2016). Additionally, due to small sample size, Fisher's Exact Test was utilized in R to evaluate whether the distribution and abundance of waterbirds varied across different habitat categories, wetland extent classes, and seasons.

Results

Waterbird diversity, richness and composition

A total of 1,436.1 km was surveyed in search of waterbirds (565.7 km covered in summer, 437.4 km in the monsoon, and 433 km in winter). During the study period, we recorded 69 waterbird species across 9 orders and 19 families *(Table 1)*. According to Chao 1 index, we observed the highest proportion 84.50% (n = 60) of the potential total species richness in winter (mean Chao = 63.99±5.29 SE), followed by summer with 70.42% (n = 50; mean Chao = 61.12±1.76 SE), and monsoon with 60.53% (n = 43; mean Chao = 63.99±5.29 SE) *(Figure 2)*. Of the total species recorded, 39 were resident and 30 were migratory. In terms of feeding guilds, 28 species were carnivores, 14 were omnivores, 10 were herbivores, 10 were piscivores, 6 were insectivores, and a single species was a molluscivore. According to BirdLife International, most species (n = 59) were classified as Least Concern, with 6 species being Near Threatened and 4 being Vulnerable *(Table 1)*.

Species diversity (Shannon–Wiener index and Simpson's index) varied significantly across different wetland classes ($P < 0.0001$) but did not differ significantly between seasons ($P = 0.55$) *(Figure 3)*. Grids with a high extent of wetlands exhibited significantly greater species richness ($P < 0.0001$). There was no significant interactive effect of seasons and wetland extent on either species diversity ($P = 1.0$) or species richness ($P = 0.91$) *(Figure 3)*.

Encounter rate

The overall encounter rate of waterbirds per grid was 7.95 (±7.03 SD; range: 0.05–29.62). Winter had the highest encounter rate (10.48±9.08 SD; range: 0.66–28.17), followed by summer (7.23±7.64 SD; range: 0.15–29.62) and monsoon (6.14±3.96 SD; range: 0.05–14.04). Encounter rates were significantly higher during winter ($P = 0.03$) and in grids with a high extent of wetlands ($P < 0.0001$). The interaction between wetland extent and seasonal

Table 1. A checklist of waterbirds and their number of individuals recorded in different seasons in Dungarpur district, Rajasthan, India from March 2021 and January 2022 along with their taxonomic order, IUCN and local status, and feeding guild

1. táblázat A 2021 március és 2022 január között a nyugat-indiai Rajasthan Dungarpur tartományában különböző évszakokban megfigyelt madárfajok egyedszáma, taxonómiai helyzete, IUCN-besorolása, helyi státusza és táplálkozási guildje

Order	Family	Common name	Scientific name	Number of individuals			IUCN status	Local status	Feeding guild
				Summer	Monsoon	Winter			
Anseriformes	Anatidae	Bar-headed Goose	*Anser indicus*	0	0	18	LC	M	Herbivore
		Common Pochard	*Aythya ferina*	0	0	21	VU	M	Herbivore
		Tufted Duck	*Aythya fuligula*	0	0	10	LC	M	Omnivore
		Eurasian Wigeon	*Mareca penelope*	0	0	238	LC	M	Herbivore
		Gadwall	*Mareca strepera*	0	0	140	LC	M	Herbivore
		Garganey	*Spatula querquedula*	132	0	19	LC	M	Carnivore
		Graylag Goose	*Anser anser*	0	0	27	LC	M	Herbivore
		Eurasian Teal	*Anas crecca*	0	0	69	LC	M	Herbivore
		Indian Spot-billed Duck	*Anas poecilorhyncha*	234	14	78	LC	R	Herbivore
		Northern Pintail	*Anas acuta*	0	12	92	LC	M	Omnivore
		Knob-billed Duck	*Sarkidiornis melanotos*	10	0	17	LC	R	Herbivore
		Lesser Whistling-duck	*Dendrocygna javanica*	241	84	188	LC	R	Herbivore
		Northern Shoveler	*Spatula clypeata*	0	0	47	LC	M	Omnivore
		Ruddy Shelduck	*Tadorna ferruginea*	65	0	18	LC	M	Omnivore
Gruiformes	Rallidae	Eurasian Coot	*Fulica atra*	2	18	1109	LC	R	Omnivore
		Eurasian Moorhen	*Gallinula chloropus*	20	4	0	LC	R	Omnivore
		Gray-headed Swamphen	*Porphyrio poliocephalus*	6	0	0	LC	R	Herbivore
		White-breasted Waterhen	*Amaurornis phoenicurus*	20	16	16	LC	R	Omnivore
	Gruidae	Common Crane	*Grus grus*	0	0	1	LC	M	Omnivore
		Sarus Crane	*Antigone antigone*	4	0	0	VU	R	Omnivore
Charadriiformes	Burhinidae	Great Thick-knee	*Esacus recurvirostris*	13	5	0	LC	R	Carnivore

Order	Family	Common name	Scientific name	Number of individuals			IUCN status	Local status	Feeding guild
				Summer	Monsoon	Winter			
	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	102	196	186	LC	R	Insectivore
	Charadriidae	Little Ringed Plover	*Charadrius dubius*	11	18	1	LC	M	Carnivore
		Red-wattled Lapwing	*Vanellus indicus*	571	615	212	LC	R	Insectivore
		Yellow-wattled Lapwing	*Vanellus malabaricus*	1	14	3	LC	R	Carnivore
	Rostratulidae	Greater Painted-snipe	*Rostratula benghalensis*	10	0	0	LC	R	Omnivore
	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	20	4	16	LC	R	Omnivore
		Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	0	1	4	LC	R	Carnivore
	Scolopacidae	Black-tailed Godwit	*Limosa limosa*	132	3	20	NT	M	Carnivore
		Common Redshank	*Tringa totanus*	8	3	0	LC	M	Carnivore
		Green Sandpiper	*Tringa ochropus*	1	16	29	LC	M	Carnivore
		Wood Sandpiper	*Tringa glareola*	95	41	74	LC	M	Omnivore
		Common Snipe	*Gallinago gallinago*	0	0	2	LC	M	Omnivore
		Wood Snipe	*Gallinago nemoricola*	0	0	3	VU	M	Carnivore
		Little Stint	*Calidris minuta*	0	0	3	LC	M	Carnivore
		Ruff	*Calidris pugnax*	0	0	39	LC	M	Omnivore
	Glareolidae	Small Pratincole	*Glareola lactea*	0	0	62	LC	R	Insectivore
	Laridae	Common Sandpiper	*Actitis hypoleucos*	42	8	0	LC	M	Carnivore
		Gull-billed Tern	*Gelochelidon nilotica*	2	0	0	LC	M	Carnivore
		Pallas's Gull	*Ichthyaetus ichthyaetus*	3	0	7	LC	M	Carnivore
		River Tern	*Sterna aurantia*	200	31	55	VU	R	Piscivore
		Whiskered Tern	*Chlidonias hybrida*	0	0	9	LC	M	Carnivore
Podicipediformes	Podicipedidae	Great Crested Grebe	*Podiceps cristatus*	0	0	3	LC	M	Carnivore
		Little Grebe	*Tachybaptus ruficollis*	111	28	56	LC	R	Carnivore
Ciconiiformes	Ciconiidae	Asian Openbill	*Anastomus oscitans*	123	29	127	LC	R	Molluscivore

Order	Family	Common name	Scientific name	Number of individuals			IUCN status	Local status	Feeding guild
				Summer	Monsoon	Winter			
		Black-necked Stork	*Ephippiorhynchus asiaticus*	3	2	3	NT	R	Piscivore
		Painted Stork	*Mycteria leucocephala*	52	31	22	NT	R	Piscivore
		Woolly-necked Stork	*Ciconia episcopus*	10	10	7	NT	R	Carnivore
Suliformes	Anhingidae	Oriental Darter	*Anhinga melanogaster*	0	1	1	NT	M	Piscivore
	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	24	5	0	LC	M	Piscivore
		Indian Cormorant	*Phalacrocorax fuscicollis*	97	37	16	LC	R	Piscivore
		Little Cormorant	*Microcarbo niger*	178	173	264	LC	R	Piscivore
Pelecaniformes	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*	105	76	102	NT	R	Carnivore
		Eurasian Spoonbill	*Platalea leucorodia*	57	7	0	LC	R	Piscivore
		Glossy Ibis	*Plegadis falcinellus*	72	48	366	LC	R	Carnivore
		Red-naped Ibis	*Pseudibis papillosa*	171	202	53	LC	R	Carnivore
	Ardeidae	Cattle Egret	*Bubulcus ibis*	671	613	641	LC	R	Insectivore
		Great Egret	*Ardea alba*	47	52	37	LC	R	Carnivore
		Grey Heron	*Ardea cinerea*	9	9	6	LC	R	Piscivore
		Intermediate Egret	*Ardea intermedia*	29	22	5	LC	R	Carnivore
		Purple Heron	*Ardea purpurea*	11	2	4	LC	R	Carnivore
		Indian Pond Heron	*Ardeola grayii*	68	27	26	LC	R	Carnivore
		Little Egret	*Egretta garzetta*	159	284	130	LC	R	Carnivore
Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*	2	0	4	LC	R	Carnivore
		Pied Kingfisher	*Ceryle rudis*	2	5	3	LC	R	Piscivore
		White-throated Kingfisher	*Halcyon smyrnensis*	10	1	13	LC	R	Carnivore
Passeriformes	Motacillidae	White-browed Wagtail	*Motacilla maderaspatensis*	5	0	2	LC	R	Insectivore
		Western Yellow Wagtail	*Motacilla flava*	15	9	1	LC	M	Insectivore
		White Wagtail	*Motacilla alba*	1	7	0	LC	M	Carnivore

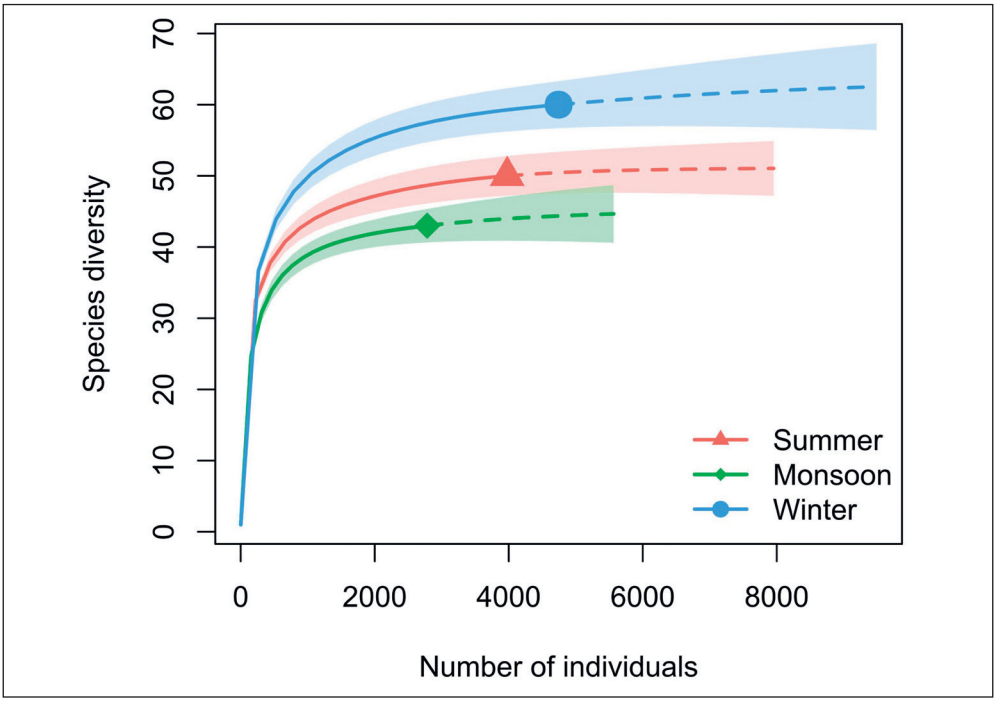


Figure 2. Waterbird species' diversity (estimated by Hill numbers, q = 0 species richness) varies by seasons (summer, monsoon and winter). The shaded area depicted 95% confidence interval, whereas dotted line depicted extrapolation

2. ábra A vízimadarak fajgazdagsága (Hill-számokkal becsülve, q = 0), mely az évszakok szerint változott (nyár, monszun és tél). Az árnyékolt terület a 95%-os konfidenciaintervallumokat, míg a szaggatott vonal az extrapolált értékeket mutatja

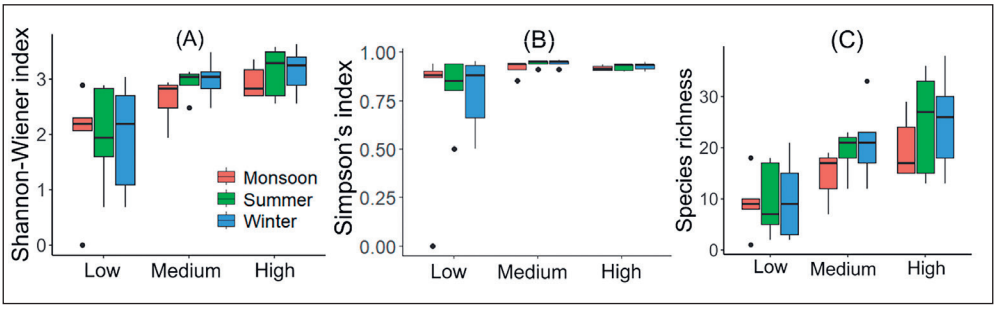


Figure 3. Shannon–Wiener index (A), Simpson's index (B) and species richness (C) per grid recorded across different wetland extent classes in Dungarpur district, southern Rajasthan, India from March 2021 to January 2022.

3. ábra A 2021 márciusa és 2022 januárja között különböző vizesélőhely-típusokban, a nyugat-indiai Rajasthan Dungarpur tartományában megfigyelt madárfajok gridenként mért Shannon–Wiener-indexe (A), Simpson-indexe (B) és fajgazdagsága (C)

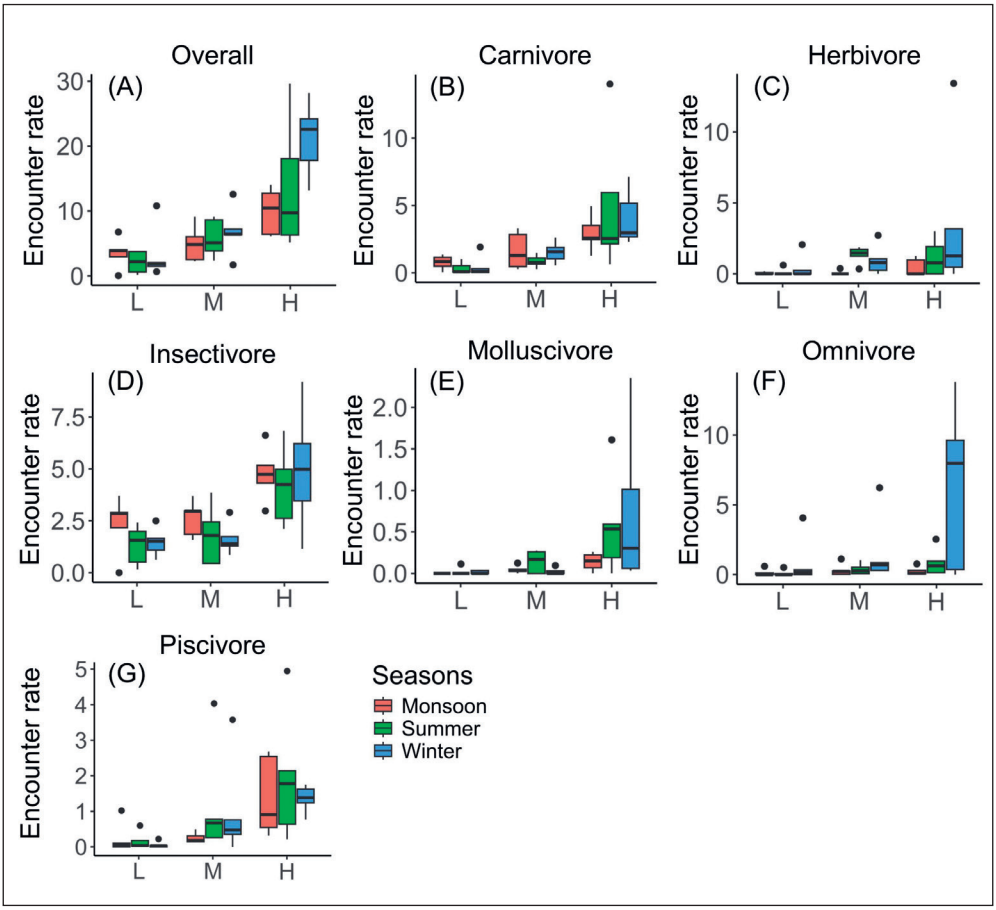


Figure 4. Seasonal encounter rates (waterbird seen per km in individual grids) of waterbird recorded across different wetland extent classes (L-low, M-Medium, H-high) in Dungarpur district, Rajasthan, India recorded from March 2021 and January 2022.

4. ábra A 2021 márciusa és 2022 januárja között különböző vizesélőhely-típusokban, a nyugat-indiai Rajasthan Dungarpur tartományában felvett, évszakonkénti megfigyelési ráták (az egyes gridekben megfigyelt vízimadár-egyedek száma) vizesélőhely-típusok szerint (L-alacsony, M-közepes, H-magas)

changes did not have a significant effect ($P = 0.31$). Significant differences in encounter rates between wetland extent classes were observed for carnivore ($P < 0.0001$), insectivore ($P < 0.0001$), piscivore ($P < 0.0001$), and molluscivore ($P < 0.001$) feeding guilds, whereas only omnivores showed a significant seasonal difference ($P < 0.01$) *(Figure 4)*.

Habitat selection

Most waterbird sightings (total n = 395) occurred in wetlands (n = 185; 46.84%), followed by agriculture (n = 175; 44.30%), other habitats (n = 21; 5.32%), and open areas (n = 14; 3.54%). Overall, waterbird sightings across various habitat categories differed significantly

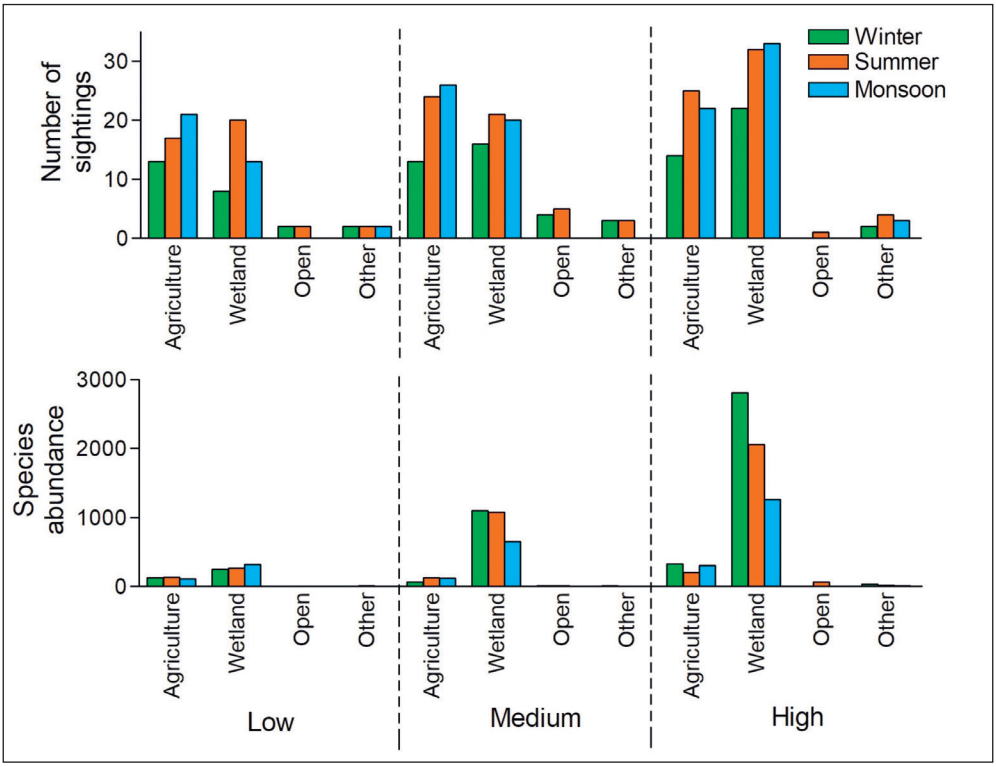


Figure 5. Sightings and species abundances of waterbirds were recorded in different habitats seasons in three wetland extent classes in Dungarpur district, Rajasthan, India, between March 2021 and January 2022.

5. ábra A 2021 március és 2022 január között különböző vizesélőhely-típusokban, a nyugat-indiai Rajasthan Dungarpur tartományában megfigyelt vízimadár-fajok abundanciája

between seasons (P = 0.04), but no significant variation was observed across different wetland extent classes (low: P = 0.472; medium: P = 0.063; high: P = 0.992). Wetland habitats consistently supported higher bird abundance compared to other habitats throughout all seasons (monsoon: P = 0.002; winter: P = 0.0004; summer: P = 0.0004) *(Figure 5)*.

Discussion

Waterbird diversity, richness and composition

Our study represents one of the first systematic investigations in western India employing an *a-priori* study design to assess waterbird diversity, composition, and density. We documented 69 waterbird species, with populations varying across seasons and wetland classes. The study area supports several species of global conservation significance, including six Near Threatened species: Black-tailed Godwit *(Limosa limosa)*, Black-necked Stork *(Ephippiorhynchus asiaticus)*, Painted Stork *(Mycteria leucocephala)*, Woolly-necked Stork

(Ciconia episcopus), Black-headed Ibis *(Threskiornis melanocephalus)*, and Oriental Darter *(Anhinga melanogaster)*, as well as four Vulnerable species: Common Pochard *(Aythya ferina)*, River Tern *(Sterna aurantia)*, Wood Snipe *(Gallinago nemoricola)*, and Sarus Crane *(Antigone antigone)*. Of these, six species were resident in our study area, highlighting its importance for future conservation efforts. The presence of Black-tailed Godwits throughout all three seasons suggests their resident nature in the area, while Common Pochards and Wood Snipes were only observed during winter. Previous studies have reported a healthy population of Painted Storks, Black-headed Ibises, and Sarus Cranes (Vyas 2002, Koli *et al*. 2013, Chaudhury & Koli 2018, Koli *et al*. 2019). Additionally, nesting of Painted Storks, Black-headed Ibises, Oriental Darters, and Black-necked Storks has been documented in Dungarpur district (Koli *et al*. 2019).

Our findings indicate that species diversity and richness were higher in grids with a high extent of wetlands, with no significant interaction between wetland extent and seasonal changes. This underscores the importance of wetlands for waterbirds. We observed nearly equal numbers of resident (n = 39) and migratory species (n = 30), with no seasonal variation in species diversity or richness, suggesting that waterbird species have landscape preferences that remain consistent throughout the year.

Encounter rate

Contrary to our expectations, the highest encounter rate of waterbirds was observed during winter rather than summer, particularly in grids with extensive wetland coverage. This is likely due to the influx of winter migratory birds into the larger wetland areas of our study region. The encounter rate was lowest during the monsoon, likely because the widespread availability of water throughout the district may have encouraged local movements of waterbirds away from our sampled grids or from areas with high wetland coverage to nearby locations. The summer season, which is the breeding period for many waterbirds in our study area, likely promotes the aggregation of waterbirds at nesting sites (Chaudhury & Koli 2018, Mehta *et al*. 2024), which may explain the reduced encounter rates during this time.

In our study, birds in the carnivore, insectivore, piscivore, and molluscivore feeding guilds showed a preference for areas with extensive wetlands, likely due to the high availability of water and their specific feeding requirements. The molluscivore category, represented by a single species – the Asian Openbill *(Anastomus oscitans)* – similarly relies heavily on wetlands for food. Previous studies have shown that certain waterbird species select roosting and nesting sites near wetlands to facilitate breeding and chick rearing (Chaudhury & Koli 2018, Koli *et al*. 2019), which could be another reason for their preference for these high-wetland areas. In contrary, omnivorous species, which can exploit a variety of food resources and habitats such as agricultural fields, fallow lands, urban drainage lines, and garbage sites (Chaudhury & Koli 2018, Ameta *et al*. 2022, 2024, Asawra *et al*. 2022,), do not rely solely on wetlands. This could explain why encounter rates of omnivores did not vary significantly across different wetland extent classes. However, seasonal differences in omnivore encounter rates may be related to local movements or the influx of migratory

omnivorous species such as the Northern Pintail *(Anas acuta)*, Northern Shoveler *(Spatula clypeata)*, Ruddy Shelduck *(Tadorna ferruginea)*, Tufted Duck *(Aythya fuligula)*, and Wood Sandpiper *(Tringa glareola) (Table 1)*.

Habitat selection

Our study identified wetlands as the primary habitat for waterbirds in the Dungarpur district; however, agricultural areas also play a significant role, accounting for 44.3% of sightings. Habitat use by waterbirds varied significantly with the seasons but did not differ across wetland classes. Water availability in the region is primarily determined by seasonal rainfall, mainly during the monsoon, with most wetlands drying out between the end of winter and the onset of summer *(pers. obs.)*. Dungarpur is among the least developed districts, with 93% of the human population residing in rural areas and relying on domestic livestock and agriculture, which covers about 34% of the district's geographical area (Rao & Singh 2018). This extensive agricultural landscape is likely to provide important habitat for waterbirds. In recent decades, agricultural lands in various parts of India have been recognized as vital natural habitats for several waterbird species (Czech & Parsons 2002, Sundar 2006, 2011, Sundar *et al*. 2015, Ameta *et al*. 2022), and our findings align with these observations. Seasonal shifts in agricultural practices are likely the primary drivers of changes in habitat use by waterbirds in our study area. Agriculture is practiced at several of our study sites, including the beds of wetlands once they dry out. Wetland water is often used for crop irrigation, accelerating the drying process. In such mixed conditions, waterbirds frequently venture into agricultural areas to feed on planting seeds, rodents, and insects *(pers. obs.)*. Sundar and Kittur (2013) noted that the conservation of waterbirds in the agricultural landscapes of northern India cannot rely solely on a few large wetlands. Habitat use by waterbirds varies also by species (Sundar 2006); for example, the abundance of Woolly-necked Storks, Asian Openbills, and Sarus Cranes increases in areas with more wetlands, while Cattle Egrets *(Bubulcus ibis)* decline (Sundar 2011, Sundar & Kittur 2012, Kittur & Sundar 2021). Ameta *et al*. (2022) and Asawra *et al*. (2022) identified fallow agricultural fields (fields with no standing crops) as key foraging habitats for Red-naped Ibis in southern Rajasthan. Conversely, Sundar and Kittur (2013) identified the highest known bird species richness in South Asia within the agricultural landscape of northern India, despite the intense human pressure on wetlands. Waterbird habitat selection is also influenced by the availability of that habitat (Kittur & Sundar 2021, Ameta *et al*. 2022), which was not accounted for in our study. Consequently, habitat utilization by waterbirds appears to be more complex than our basic structured study in the semi-arid region of southern Rajasthan could fully explain due to the small sample size. Further research is needed to explore the intricate dynamics of waterbird-agriculture interactions in our study area, which is both intriguing and complex. Studies on landscapes with different crop types are lacking, and additional research will help determine which crops in agricultural areas attract or deter specific waterbird species.

A few limitations of this work bear addressing. Previous research highlights that the presence and abundance of waterbird species are influenced by various habitat characteristics, including water quality, soil texture, water depth, aquatic vegetation,

shoreline heterogeneity, food availability, and the presence of islands (Kumar *et al*. 2007, Rawal *et al*. 2021, Mukherjee *et al*. 2022). However, our study focused exclusively on two environmental variables: wetland extent and seasonal changes. Besides to that, our study design stratified areas solely based on wetland extent, without accounting for other available habitat types that waterbirds use, such as agriculture and open land. Additionally, the selected few sampling grids were geographically adjacent, which may have introduced spatial bias. Lastly, few variations in survey route lengths due to landscape changes occasionally occurred, potentially influencing the accuracy of our observations.

Conclusions

Our study provides the first preliminary assessment of waterbird diversity, richness, and abundance in the semi-arid landscape of Dungarpur district, western India. Our findings indicate that wetlands are the primary habitat for waterbirds in the area, with agricultural lands serving as the second most important feeding habitat. Notably, we did not observe substantial seasonal effects on habitat use. Habitat preferences among waterbirds varied according to their feeding guilds. The presence of globally significant species underscores the conservation relevance of our study area. We recommend prioritizing the protection of areas with extensive wetlands to safeguard waterbird populations. We also recommend further research to better understand the impact of additional variables on the presence and distribution of waterbirds in Dungarpur district and similar environments in Rajasthan state, India.

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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

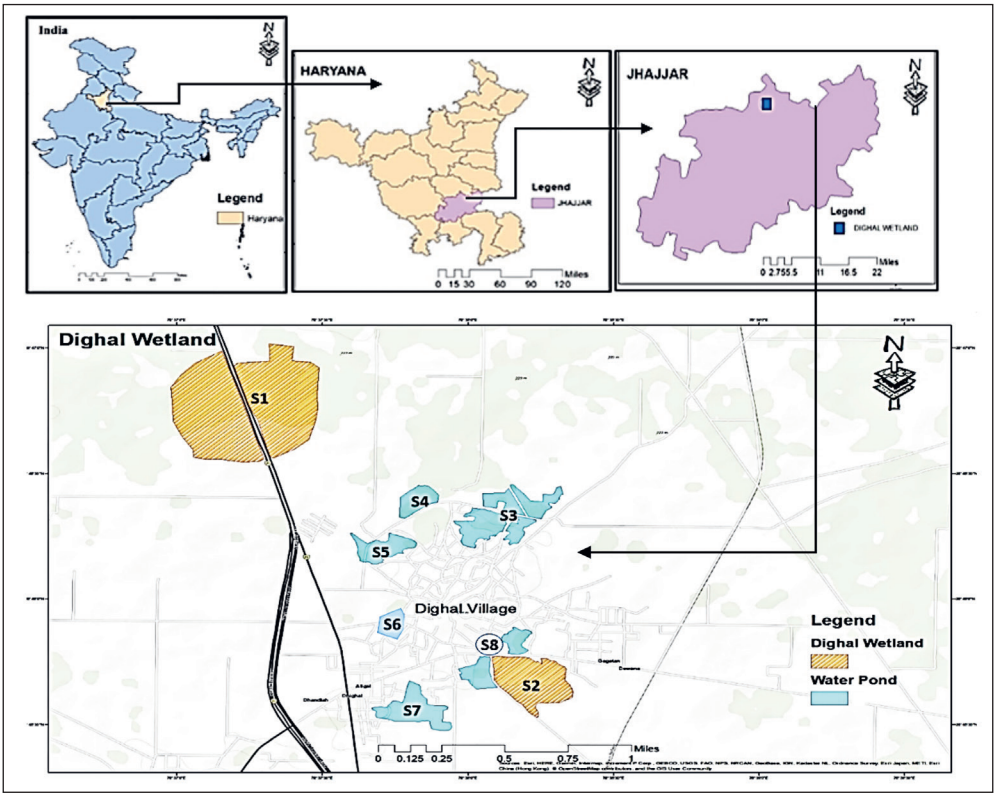


Figure 1. Study area map depicting eight selected sites (S1 to S8) within Dighal wetlands, Jhajjar district, Haryana, India

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)*

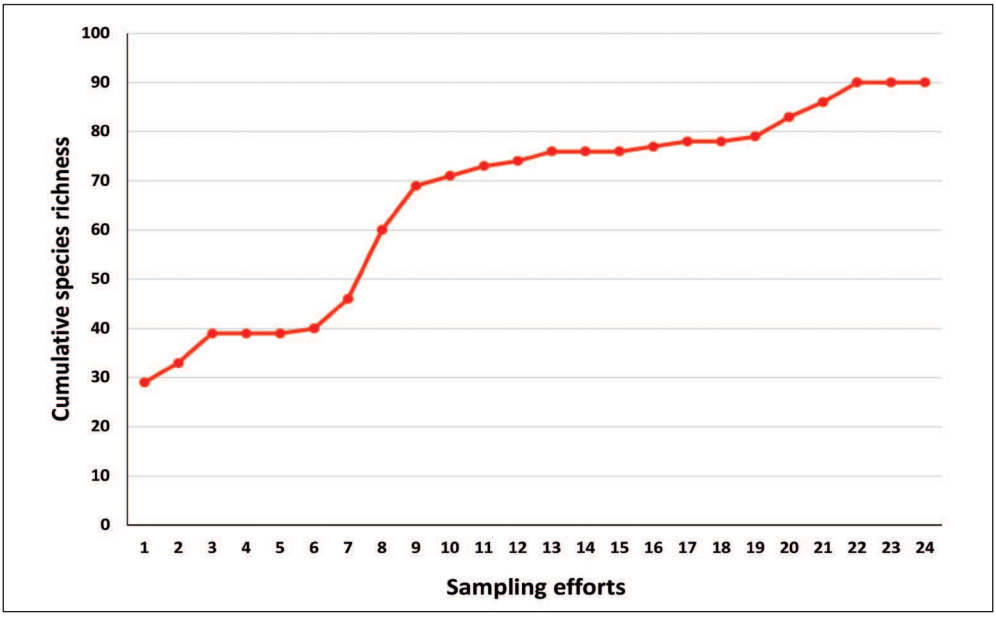


Figure 2. Species accumulation curve of wetland birds recorded in Dighal wetlands of Jhajjar district from April 2021–March 2023

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

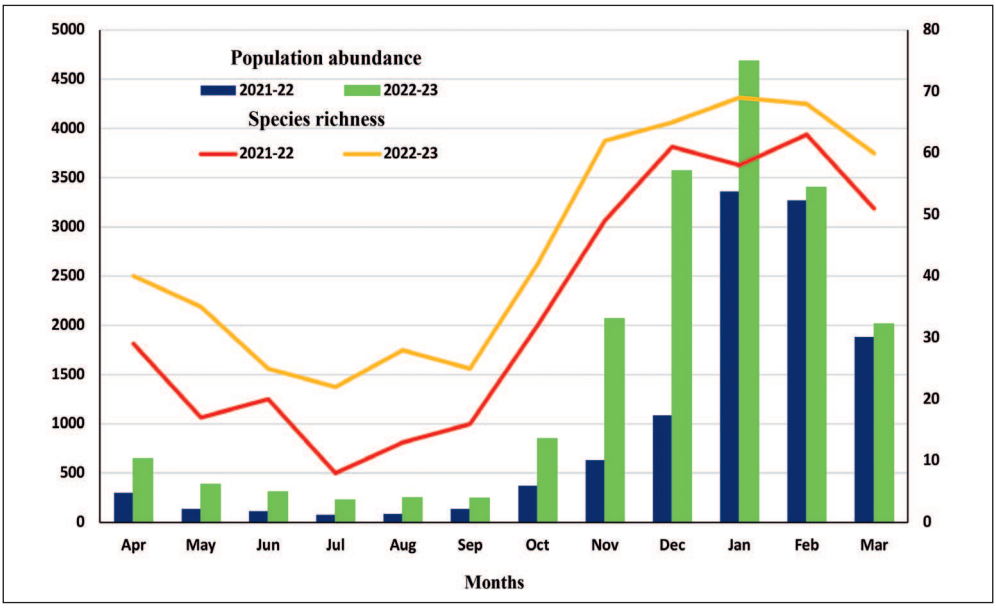


Figure 3. Monthly variations in population abundance and species richness of wetland birds in the study area from April 2021 to March 2023

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.

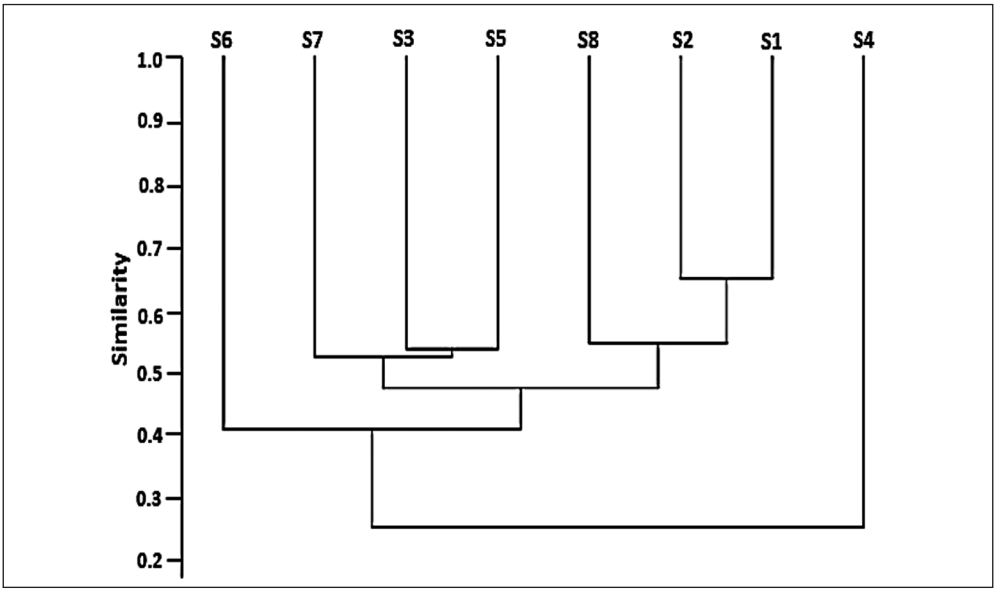


Figure 4. Cluster analysis based on Jaccard's similarity index using unweighted pair group method with arithmetic mean (UPGMA) showing similarity of wetland bird species composition across selected sites of Dighal wetlands of Jhajjar district, Haryana

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

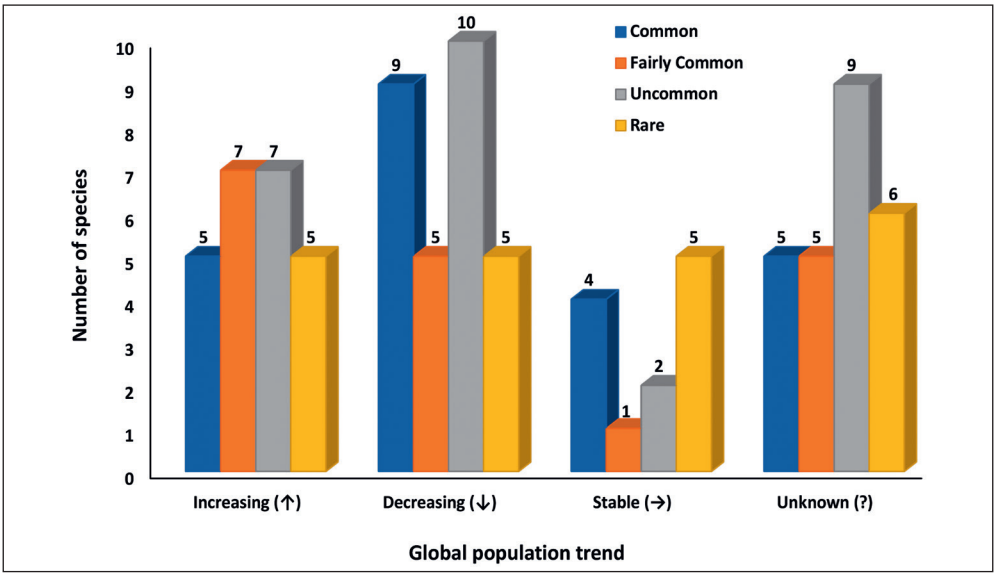


Figure 5. Comparative analysis of local abundance status and global population trends among wetland bird species documented in Dighal wetlands of Jhajjar district, Haryana

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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Assessment of winter migratory waterbirds diversity and distribution in Asan Conservation Reserve, Uttarakhand (Western Himalayas), India

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Abstract The current study presented information on waterbird diversity in the Asan Conservation Reserve (Western Himalayas), India. The waterbirds survey was conducted from October 2023 to April 2024 in and around the ACR, Dehradun, India. The findings revealed that 47 wetland bird species from 13 families and 8 orders have been observed during the study. Out of a total of 14 winter migrants (WM), 14 residents (R), 11 residents with local migrant (R/LM), 3 residents with influx and passage movement (R/WM/SM), 2 residents with altitudinal winter movement (R/AM/WM), one species is winter migrant with passive migration (WM/PM) and one species is resident with summer and winter movement (R/SM/WM) observed during the study. The Anatidae family has the most species (15) and the maximum relative diversity value (31.91). The result of Bird Species Diversity (BSD) showed that the value of BSD was highest (2.49) in December compared to other months. Similarly, the analysis of Bird Species Richness (BSR) showed that the maximum BSR was found in December (5.96) when compared to other months. The results showed that the Eurasian Coot was the most dominating species, accounting for 23.11% of overall abundance when compared to other species. A total of 23 omnivorous, 17 carnivorous, and 7 insectivorous species were recorded based on their feeding guilds. During the study period four threatened species were observed as per IUCN. Out of total three species such as River Lapwing, Painted Stork, and Ferruginous Duck were listed as Near Threatened (NT), one, Pallas's Fish-Eagle as Endangered (EN), and the remaining 43 as Least Concern (LC) in the IUCN Red data book.

Keywords: diversity, migration, threatened species, waterbirds, Western Himalayas

Összefoglalás A jelenlegi vizsgálat az indiai Asan Természetvédelmi Terület (Nyugat-Himalája – rövidítve ACR) vízimadarainak diverzitási mintázatait elemzi. A vízimadár-felmérések 2023 októberétől 2024 áprilisáig zajlottak a vizsgált területen. Eredményeink alapján nyolc madárrend 13 családjába tartozó 47 madárfajt regisztráltunk. Ezek közül 14 áttelelő (WM), 14 állandó illetve áttelelő faj (R/WM), 11 állandó vagy rövidtávon vonuló (R/LM); 3 állandó beáramlási és átvonulási mintázatokkal (R/WM/SM), 2 állandó faj, magassági vonulási és telelési mozgalmakkal (R/AM/WM), 1 téli vonuló és passzív vonuló (R/WM/SM), 1 állandó nyári és téli vonulási mozgalmakkal (R/SM/WM), valamint 1 állandó faj. A legnagyobb fajszámot (15) és legmagasabb relatív diverzitás indexet (31,91) az Anatidae család fajai alapján becsültük. A madarak fajdiverzitási indexe (BSD) decemberben volt a legmagasabb (BSD = 2,49). Hasonlóképpen, a madarak fajgazdagsági indexe (BSR) is decemberben volt a legmagasabb (BSD = 5,96). A felmérések alapján a szárcsa volt a legmagasabb dominanciájú faj, amely a teljes abundancia 23,11%-át képviselte az összes faj közül. A táplálkozási guildeket tekintve, a regisztrált fajok közül 23 mindenevő, 17 ragadozó és 7 rovarevő volt. A vizsgálat időtartama alatt négy fajt figyeltünk meg, amely az IUCN besorolása alapján veszélyeztetettnek minősül. Három faj esett a Mérsékelten Fenyegetett (NT: folyami bíbic, hindu gólya, cigányréce), egy a Veszélyeztetett (EN: szalagos sas), 43 a Nem Fenyegetett (LC) kategóriába.

Kulcsszavak: diverzitás, vonulás, veszélyeztetett faj, vízimadár, Nyugat-Himalája

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Introduction

Wetlands, both natural and artificial, host a variety of resident and migrant water-dependent birds (Cowardin *et al.* 1979, Amezaga *et al.* 2002). The wetland zone occurs between the aquatic and terrestrial systems (Cowardin *et al.* 1979, Joshi *et al.* 2021), and wetland areas are among the most biologically diverse ecosystems on the globe (Bachheti *et al.* 2023). In India, wetlands account for around 5.16% of total geographical area (SAC 2011, Arya *et al.* 2020). Currently, these aquatic ecosystems have declined due to numerous human activity-related causes, so regular survey of wetland species of birds is essential to determine the health of the natural ecosystem. Water-dependent birds are an essential indication of the health of wetland ecosystems because they play critical roles in the global food web and nutrient cycles. According to reports, there has been a major drop in the population of wetland birds (Saikia & Bhattacharjee 1993, Wetlands (Conservation and Management) Rules 2017). The decline in migrating bird populations may be due to environmental changes and wetlands degradation, while the specific cause is unknown. Long-term research on the status of wetlands and migratory birds in Uttarakhand is quite low. According to reports, over-exploitation of resources, population growth, and fast industrialization have all contributed to the degradation of India's wetlands (Islam & Rahmani 2004). Several duck species in India are experiencing population declines (Islam & Rahmani 2004, Wetlands International 2006). Due to significant bird endemism, the western part of the Indian Himalayas has been designated an Endemic Bird Area (EBA 128), which includes 27 Important Bird Areas (IBAs) (Islam & Rahmani 2004). Out of 310 wetland-dependent avian species, 175 (56%) were found in Uttarakhand. The lower elevations of the northwestern Indian Himalayan Range (Dehradun, Haridwar, and Corbett Landscape) provide appropriate environments for both long and short-distance migratory bird species (Bhatt *et al.* 2015, Saini *et al.* 2017, Arya *et al.* 2019, Arya *et al.* 2021). Monitoring a bird species' abundance, habitat preference, and association with habitat quality can help identify factors causing population swings. Monitoring the distribution of a species population at the regional level is crucial for understanding the status of that species globally. This study focuses on the diversity and distribution of selected winter migratory bird species at the Asan Conservation Reserve (ACR), a critical habitat in northern India. By analyzing these patterns, we aim to understand the factors influencing bird migration and the conservation needs of these species.

Material and Methods

Study area

Asan Conservation Reserve (ACR) is in the Dehradun district of Uttarakhand, India (30°25′60'' N, 77°42′00''E, 389.4 m asl. *(Figure 1)*. It is located between the Asan and Yamuna rivers, creating a unique wetland ecosystem that supports a broad diversity of different species of animals and plants. The reserve covers an area of approximately 4.44 km^2 and it has been designated to be an Important Bird Area (IBA) and Ramsar Site due to its significance for

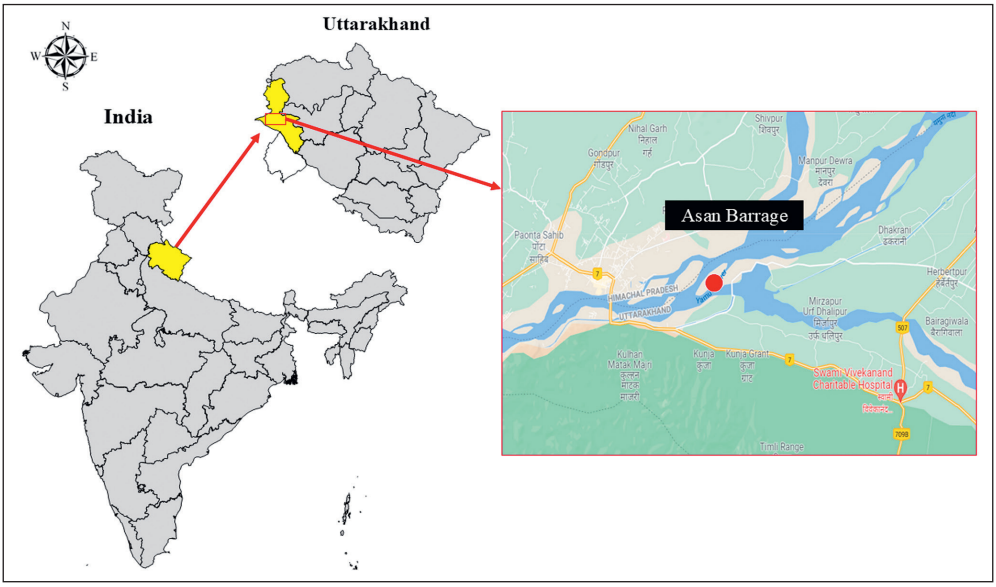


Figure 1. Map of study area (Source: Google Maps)
1. ábra A vizsgálati terület földrajzi elhelyezkedése

migratory birds. The ACR provides a variety of habitats, including open water, marshes, and mudflats, which are essential for different bird species. The wetland is particularly important during the winter months when it serves either stopover or wintering location for numerous avian migrant species. The reserve's strategic location along the Central Asian Flyway makes it a crucial site for monitoring migratory bird populations. The climatic conditions of the region are characterized by very low temperatures found in winter and pleasant time of summer, with the wetland receiving significant rainfall during the monsoon season.

Methodology

The waterbirds survey was conducted from October 2023 to April 2024 in and around the ACR, Dehradun, India. The number and abundance of avian species were recorded. Field survey was averted during the non-favorable climatic conditions such as rainy or foggy weather. Field trips were done during the morning session (10:00–13:00). The field equipment kit included Nikon 1050 prismatic field binoculars, a Nikon field scope ED 82 with 72 zooms, a tally counter and a Nikon P1000 camera for observation counts and pictures. Avian species identification was made through the field guides such as The Book of Indian Birds (Ali 1996), Birds of the Indian Subcontinent (Grimmett *et al.* 1998), A Field Guide to the Birds of India (Kazmierczak & Perlo, 2006), and Handbook on Indian Wetland Birds (Kumar *et al.* 2005). The point count method was adopted in the bird survey (Bibby *et al.* 2000). Data from the citizen science database (e-Bird) was also used for analysis. The checklist contains the Family, Common Name, Scientific Name (Praveen *et al.* 2021), and IUCN Status (IUCN 2022). The evaluation of the feeding guilds was made through the direct observation Ali (1996) and Grimmett *et al.* (1998).

Data analysis

Shannon's diversity index
The species diversity was calculated through the Shannon's diversity index H′
H′ = H′=S*∑*Pi* ∗ *Ln Pi*
where: S = total no. of species in the sample
Pi = proportion of individuals belonging to a species
Ln = natural logarithm

Relative abundance
The Relative abundance was calculated by the given formula
RA = n/N * 100
where:
n = the number of particular species
N = the total individuals detected for all species.

Species richness
Margalef's richness index (Mg) was used as a simple measure of species richness (Margalef 1963).
Mg = (S – 1) / In N
where:
S = total number of species
N = total number of individuals in the sample
In = natural logarithm

Relative diversity (RDi)
The relative diversity value (RDi) was calculated by the formula of Torre-Cuadros *et al.* (2007). The formula is following:
RDi = Number of species in a family ÷ Total number of species * 100

The Microsoft Excel 2011 was used for the Data Analysis.

Results

During the study period, a total of 47 wetland bird species belonging to 13 families and 8 orders were observed. The species belonging to family Anatidae was dominantly found in the study area with the total number of 15 species followed by Scolopacidae (7), Laridae (5), Charadriidae, Motacillidae, Rallidae with three species, Ardeidae, Alcedinidae, Phalacrocoracidae, Podicipedidae with two species each and Accipitridae, Ciconiidae, Recurvirostridae with one species *(Table 1)*. The RDi value indicated that Anatidae was the most dominated family with highest relative diversity value (31.91%) *(Table 2)*.

The value of Bird Species Diversity (BSD) indicated that the maximum diversity was found in December (2.49) compared to other months. Similarly, the value of (BSR) was maximum in December (5.96) as compared to different months of the study *(Table 3)*.

Table 1. A checklist of water-dependent birds observed during the study period
1. táblázat A vizsgált periódusban megfigyelt madárfajok listája

Common name	Scientific name	IUCN status	Status	Feeding habit
Anseriformes: Anatidae				
Lesser Whistling-duck	*Dendrocygna javanica*	LC	R/LM	Omnivorous
Bar-headed Goose	*Anser indicus*	LC	R/WM	Omnivorous
Ruddy Shelduck	*Tadorna ferruginea*	LC	R/WM/PM	Omnivorous
Green-winged Teal	*Anas crecca*	LC	R/LM	Omnivorous
Gadwall	*Mareca strepera*	LC	WM	Omnivorous
Eurasian Wigeon	*Mareca strepera*	LC	WM	Omnivorous
Mallard	*Anas platyrhynchos*	LC	R/WM	Omnivorous
Northern Shoveler	*Spatula clypeata*	LC	WM	Omnivorous
Garganey	*Spatula querquedula*	LC	WM	Omnivorous
Red-crested Pochard	*Netta rufina*	LC	WM	Omnivorous
Common Pochard	*Aythya ferina*	LC	WM	Carnivorous
Ferruginous Duck	*Aythya nyroca*	NT	R/WM	Omnivorous
Tufted Duck	*Aythya fuligula*	LC	WM	Omnivorous
Knob-billed Duck	*Sarkidiornis melanotos*	LC	WM	Omnivorous
Northern Pintail	*Anas acuta*	LC	WM	Omnivorous
Phoenicopteriformes: Podicipedidae				
Little Grebe	*Tachybaptus ruficollis*	LC	R/LM	Carnivorous
Great Crested Grebe	*Podiceps cristatus*	LC	R/WM	Carnivorous
Pelecaniformes: Ciconiidae				
Painted Stork	*Mycteria leucocephala*	NT	R/LM	Carnivorous
Pelecaniformes: Ardeidae				
Black-crowned Night Heron	*Nycticorax nycticorax*	LC	R/LM	Omnivorous
Purple Heron	*Ardea purpurea*	LC	R/LM	Carnivorous
Pelecaniformes: Phalacrocoracidae				
Little Cormorant	*Microcarbo niger*	LC	R/LM	Carnivorous
Great Cormorant	*Phalacrocorax carbo*	LC	R/WM	Carnivorous
Gruiformes: Rallidae				
Eurasian Coot	*Fulica atra*	LC	R/WM	Omnivorous
Eurasian Moorhen	*Gallinula chloropus*	LC	R/WM	Omnivorous
Gray-headed Swamphen	*Porphyrio poliocephalus*	LC	R/LM	Carnivorous
Charadriiformes: Scolopacidae				
Common Redshank	*Tringa totanus*	LC	R/WM	Carnivorous
Common Greenshank	*Tringa nebularia*	LC	WM	Carnivorous
Wood Sandpiper	*Tringa glareola*	LC	WM	Carnivorous
Green Sandpiper	*Tringa ochropus*	LC	R/WM	Carnivorous

Common name	Scientific name	IUCN status	Status	Feeding habit
Common Sandpiper	*Actitis hypoleucos*	LC	R/WM	Insectivorous
Spotted Redshank	*Tringa erythropus*	LC	WM	Carnivorous
Temminck's Stint	*Calidris temminckii*	LC	WM	Insectivorous
Charadriiformes: Laridae				
Pallas's Gull	*Ichthyaetus ichthyaetus*	LC	WM	Omnivorous
Brown-headed Gull	*Chroicocephalus brunnicephalus*	LC	R/WM	Omnivorous
Black-headed Gull	*Chroicocephalus ridibundus*	LC	WM/PM	Omnivorous
Whiskered Tern	*Chlidonias hybridus*	LC	R/WM/PM	Omnivorous
River Tern	*Sterna aurantia*	LC	R	Omnivorous
Charadriiformes: Recurvirostridae				
Black-winged Stilt	*Himantopus himantopus*	LC	R/LM	Carnivorous
Charadriiformes: Charadriidae				
River Lapwing	*Vanellus duvaucelii*	NT	R/LM	Omnivorous
Little Ringed Plover	*Charadrius dubius*	LC	R/WM	Insectivorous
Kentish Plover	*Charadrius alexandrinus*	LC	R/WM	Insectivorous
Accipitriformes: Accipitridae				
Pallas's Fish-Eagle	*Haliaeetus leucoryphus*	EN	R/WM	Carnivorous
Coraciiformes: Alcedinidae				
Common Kingfisher	*Alcedo atthis*	LC	R/WM/SM	Carnivorous
White-throated Kingfisher	*Halcyon smyrnensis*	LC	R/LM	Carnivorous
Passeriformes: Motacillidae				
White Wagtail	*Motacilla alba*	LC	R/WM/PM	Insectivorous
Gray Wagtail	*Motacilla cinerea*	LC	R/AM/WM	Insectivorous
Citrine Wagtail	*Motacilla citreola Pallas*	LC	R/AM/WM	Insectivorous

R – Resident; **WM –** Winter migrant; **R/LM –** Resident with local migrant; **R/WM –** Resident and winter migrant; **R/AM –** Resident and altitudinal movement; **R/SM –** Resident with Summer migrant; **WM/PM –** Winter migrant as well as passive migrant; **R/WM/PM –** Resident with influx as well as passage movement; **R/AM/WM –** Resident with altitudinal and winter movement; **R/WM/SM –** Resident with summer and winter movement; **R/LM/SM –** Resident local as well as summer movement: **LC –** Least concern; **NT –** Near Threatened; **EN –** Endangered

Table 2. Family-wise distribution and relative diversity (RDi**)** of the birds
2. táblázat A megfigyelt madárfajok családok szerinti eloszlása és relatív diverzitása (RDi)

S.No.	Family	Number of species	RDi value (%)
1.	Anatidae	15	31.91
2.	Podicipedidae	2	4.26
3.	Ciconiidae	1	2.13
4.	Ardeidae	2	4.26
5.	Phalacrocoracidae	2	4.26
6.	Rallidae	3	6.38
7.	Scolopacidae	7	14.89
8.	Laridae	5	10.64
9.	Recurvirostridae	1	2.13
10.	Charadriidae	3	6.38
11.	Accipitridae	1	2.13
12.	Alcedinidae	2	4.26
13.	Motacillidae	3	6.38

Table 3. Monthly indices of water-dependent birds' species
3. táblázat A megfigyelt vízimadárfajok időbeli eloszlási adatai

Parameters	Oct	Nov	Dec	Jan	Feb	Mar	Apr
No. of species observed	28	29	47	39	36	29	8
No. of individuals	180	887	2250	3552	1723	590	78
Bird species diversity	1.52	2.21	2.49	2.44	2.33	2.36	1.18
Bird species richness	5.20	4.13	5.96	4.65	4.70	4.39	1.61

The result revealed that the Eurasian Coot *(Fulica atra)* was the most dominant species with 23.11% of the total abundance of the species followed by Red-crested Pochard *(Netta rufina)* (14.45), Common Pochard *(Aythya ferina)* (12.96), Tufted Duck *(A. fuligula)* (11.94), Gadwall *(Mareca strepera)* (6.38). The relative abundance of the top 10 dominant species is shown in *(Table 4)*.

Three species *viz*., River Lapwing *(Vanellus duvaucelii)*, Painted Stork *(Mycteria leucocephala)*, Ferruginous Duck *(A. nyroca)* were Near Threatened (NT), one species Pallas's Fish Eagle *(Haliaeetus leucoryphus)* was Endangered (EN) and the remaining species were categorized under the Least Concern (LC) category as per IUCN. A total of 23 omnivorous, 17 carnivorous, and 7 insectivorous species were recorded according to their feeding habitat.

Out of a total of 14 winter migrants (WM), 14 residents (R), 11 residents with local migrant (R/LM), 3 residents with influx and passage movement (R/WM/SM), 2 residents with altitudinal winter movement (R/AM/WM), and one species are winter migrant with passive migration (WM/PM) and one species is resident with summer and winter movement (R/SM/WM) observed during the study *(Figure 2)*.

Table 4. Relative abundance (RA) of the top 10 dominant species during the study period
4. táblázat A 10 legmagasabb dominanciájú madárfaj relatív dominanciája (RA) a vizsgálat időtartama alatt

S.No.	Common name	Scientific name	RA (%)
1	Eurasian Coot	*Fulica atra*	23.11
2	Red-crested Pochard	*Netta rufina*	14.45
3	Common Pochard	*Aythya ferina*	12.96
4	Tufted Duck	*Aythya fuligula*	11.94
5	Gadwall	*Mareca strepera*	6.38
6	Ruddy Shelduck	*Tadorna ferruginea*	6.32
7	Little Cormorant	*Microcarbo niger*	5.31
8	Great Cormorant	*Phalacrocorax carbo*	2.84
9	Eurasian Wigeon	*Mareca strepera*	2.20
10	Northern Pintail	*Anas acuta*	2.18

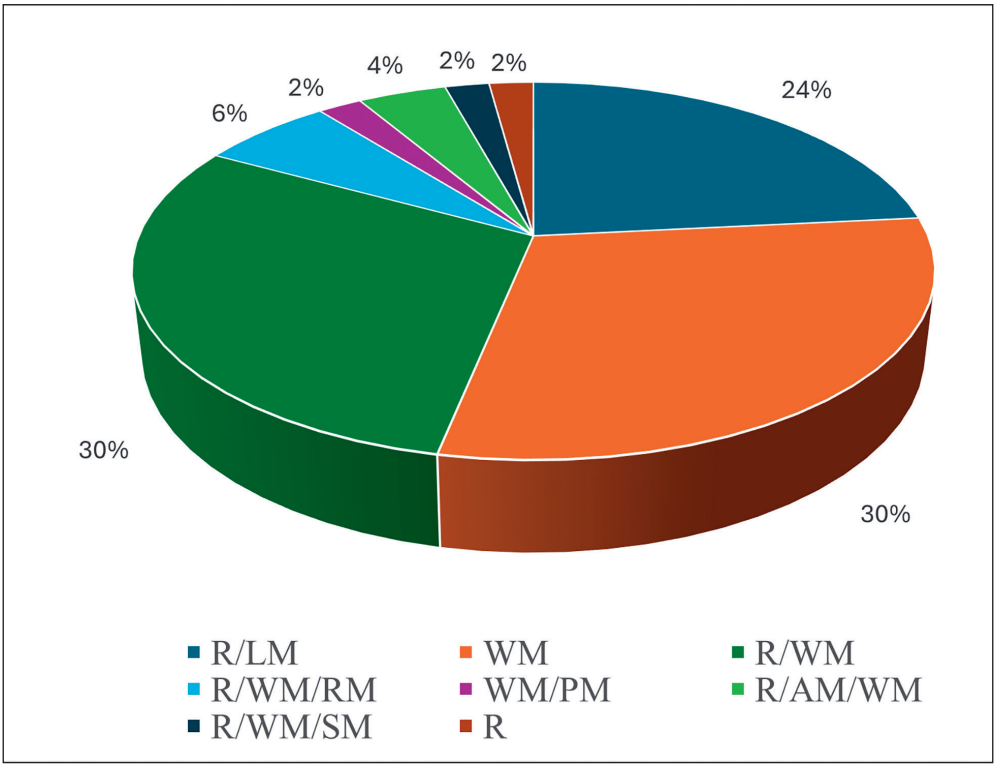


Figure 2. Status of migratory species recorded during the study period
2. ábra A vonuló fajok vonulási stratégia szerinti eloszlása a vizsgálat időtartama alatt

Discussion

This study has provided baseline information on winter migrant avian species in Asan Conservation Reserves. A total of 47 water dependent species were reported throughout the study period. During the winter, many high-altitude bird species migrate to lower-altitude areas such as ACR (Chopra & Sharma 2012). The highest number of species indicates that the ACR provides suitable habitat for many winter migrants, as well as this area is an essential wintering and stopover location (Kaushik & Gupta 2013). The results showed that the Anatidae family was the most abundant during this study. The significant domination of Anatidae indicates that this area significantly contributes to providing adequate habitat and substantial food for different waterbirds such as geese and ducks (Bachheti *et al.* 2023).

The feeding pattern of observed species revealed that 17 of the bird species were carnivorous, 7 were insectivorous, and 23 species were omnivorous. The Alcedinidae and Accipitridae are strong indicators of the health of ecosystems since they exist at the highest level of the native food chain. As top predators, the Alcedinidae are important biological indicators for understanding the structure and function of regional ecosystems. Their prevalence in ACR most possibly represents the abundance of modest animals such as avian species, reptiles, fish, and insects (Jamwal *et al.* 2017).

The total number of individuals of various species fluctuated, and there were minor seasonal fluctuations in bird species diversity (BSD) and richness (BSR) in the study sites. These monthly fluctuations may be attributable to the species' regional movement from one wetland to elsewhere (Arya *et al.* 2019). The different ecological factors such as the total cover and composition of vegetation are essential elements that influence habitat structure as well as the distribution, diversity, and abundance of wetland dependent avian species. Rajpar and Zakaria (2011) found that vegetation type effects the availability of food supplies, which increases the abundance of waterbird species in the area.

Furthermore, we have identified four threatened species (8% of the total). It has been observed that the population of water-dependent birds, both resident and migrant, has decreased substantially (Saini *et al.* 2017). The threatened species highlight the importance of additional management and conservation initiatives in ACR and its surrounding areas. As a result, the ACR wetland is not only a great location for the protection of rare and internationally vulnerable species, but also its known for a significant diversity of plants and animal species which they help to attract such a wide range of avifaunal diversity.

Conclusions

The winter migratory avian species was commonly found in the study area and the summer migratory species was very infrequent highlighting the region's value for serving as wintering site for high-altitude native birds. The continued existence of internationally threatened species considers the conservation of this wetland significantly more important. This study provides basic information to helpful with subsequent observations in this particular area, as well as an example to begin implementing conservation programs in other distant IBAs.

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Avian faunal diversity in adjoining forest habitats along the Sharda River system near the Indo-Nepal border, India

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Abstract An extensive survey was conducted along the Sharda River system at the Indo-Nepal border using the line-transect and direct observation methods from August 2017 to July 2019. A total of 203 bird species belonging to 63 families and 16 orders were observed throughout the study period. The highest number of individuals recorded from Sharda Sagar Dam (17,799, 32%), followed by Surai Reserved Forest (13,208, 24%), Pancheshwar (9,363, 17%), Jauljibi (8,977, 16%), and Tawaghat (6,062, 11%), whereas the number of species was higher in Surai Reserved Forest (109) followed by Sharda Sagar Dam (82), Pancheshwar (80), Jauljibi (76) and Tawaghat (66). Different diversity indices were used to analyze the avian diversity and show variation across different study sites. One-way ANOVA and *post hoc* tests were performed to understand the significant difference of avian species diversity in different study areas. The results showed a strong indication of avian diversity.

Keywords: avifauna, diversity, river, forest, agricultural area, wetland

Összefoglalás 2017 augusztusától 2019 júliusáig kiterjedt madártani felmérést végeztek az indiai-nepáli határon lévő Sharda folyórendszer mentén, vonal transzekt és közvetlen megfigyelési módszerekkel. A vizsgálati időszak alatt összesen 203 madárfajt figyeltek meg, amelyek 63 családba és 16 rendbe tartoztak. A legtöbb egyedet a Sharda Sagar Dam területén (17 799, 32%), majd a Surai erdőrezervátumban (13 208, 24%), Pancheshwarban (9363, 17%), Jauljibiban (8977, 16%) és Tawaghatban (6062, 11%) regisztrálták, míg a fajok száma a Surai erdőrezervátumban (109), majd a Sharda Sagar Dam területén (82) volt a legmagasabb. Ezt követte Pancheshwar (80), Jauljibi (76) és Tawaghat (66). Különböző diverzitási indexeket használtak a madarak diverzitásának elemzésére és a különböző vizsgálati helyszínek közötti eltérések kimutatására. Egyszempontú varianciaelemzést (ANOVA) és *post hoc* tesztet alkalmaztak a különböző területek diverzitásában tapasztalható jelentős különbségek megértéséhez. Az eredmények jól mutatták a madárfajok sokféleségét.

Kulcsszavak: madárfauna, diverzitás, folyó, erdő, mezőgazdasági terület, vizes élőhely

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Introduction

Birds are excellent indicators of all ecosystems and contribute significantly to various biodiversity monitoring programs based on changes in their community structure, especially in understanding habitat alteration and management (Vielliard 2000, Fraixedas *et al.* 2020).

The distribution of birds in a particular area depends on various factors, including the availability of suitable food, roosting and nesting sites (Aggarwal *et al.* 2008, Singh *et al.* 2019, Ding *et al.* 2023).

Various studies on bird communities have been made to estimate the effects of habitat fragmentation as the response to different environmental gradients through changes in species composition, decreased overall regional diversity, increased population densities and changes in community structure (Huste & Boulinier 2011, Santos *et al.* 2024). Furthermore, as birds are highly mobile, they respond quickly to changes in their habitat, which makes them well suited as response organisms to study the ecological effects of interventions in natural systems through urbanization, industrialization, etc. (Peng *et al.* 2024).

Riparian zones have essential roles in supporting biodiversity, balancing the temperature of the aquatic habitat and providing woody debris. Riparian zones act as ecological corridors offsetting the effects of landscape fragmentation connecting other isolated habitats. Riparian areas provide food and cover for bird species and serve as colonization and dispersal corridors, whereby birds can spread from riparian corridors to adjacent green spaces (Keten *et al.* 2020). Riparian corridors are considered among the most diverse and complex habitats on earth because they occur at land-water junctions, and act as a buffer between uplands and streams and are often considered ecological hotspots (DeFries *et al.* 2023).

High species richness and abundance are considered the standard features in riparian zones (Guo *et al. 2*019). The notion that riparian habitats support a rich and abundant fauna compared to surrounding non-riparian habitats has significant consequences for species conservation since river networks dissect landscapes and provide a natural framework for conservation planning and connectivity strategies (Xu *et al.* 2023). The habitat function of riparian corridors could be important to re-establish connectivity since some rivers may be a source of spillover effects at the landscape level (Brudvig *et al.* 2009, Didham 2010, Montes-Rojas *et al.* 2024). Riparian corridors also play a role in biodiversity conservation in intense agricultural landscapes because they represent remnants of both wetlands and forest habitats once available for wildlife (Catteral *et al.* 2007, He *et al.* 2023).

The Indian Himalayan region is well recognized for its broad altitudinal range and ecological values, offering a powerful test system for understanding biodiversity. However, it is realized that research on avian community composition and diversity in and around the Sharda River system in the Western Himalayas of Uttarakhand has not received enough attention. The present investigation aimed to explore the avian species diversity and their conservation status along the different altitudinal gradient of Sharda River system.

Material and Method

Study area

The Sharda River or Mahakali River is also called Kaliganga in the Uttarakhand state of India. The Kali River originates from the Greater Himalayas at Kalapani, at an altitude of 3,600 m asl in the Pithoragarh district of Uttarakhand. This river forms India's continuous eastern boundary with Nepal on its upper course. The river changes its name several times throughout its run, generally below significant tributary rivers. The area around Pancheshwar is called Kali Kumaun. Once the Kali River descends from the Himalayan foothills and the Gangetic plain, including the large barrage across the river at Banbassa near Tanakpur, its name changes to the Sharda River. The present study was conducted in forest habitats along the Sharda River system at different study sites i.e. Tawaghat, Jauljibi, Pancheshwar, Surai Reserved Forest and Sharda Sagar Dam at different altitudes from 185 to 1,300 m asl *(Figure 1)*.

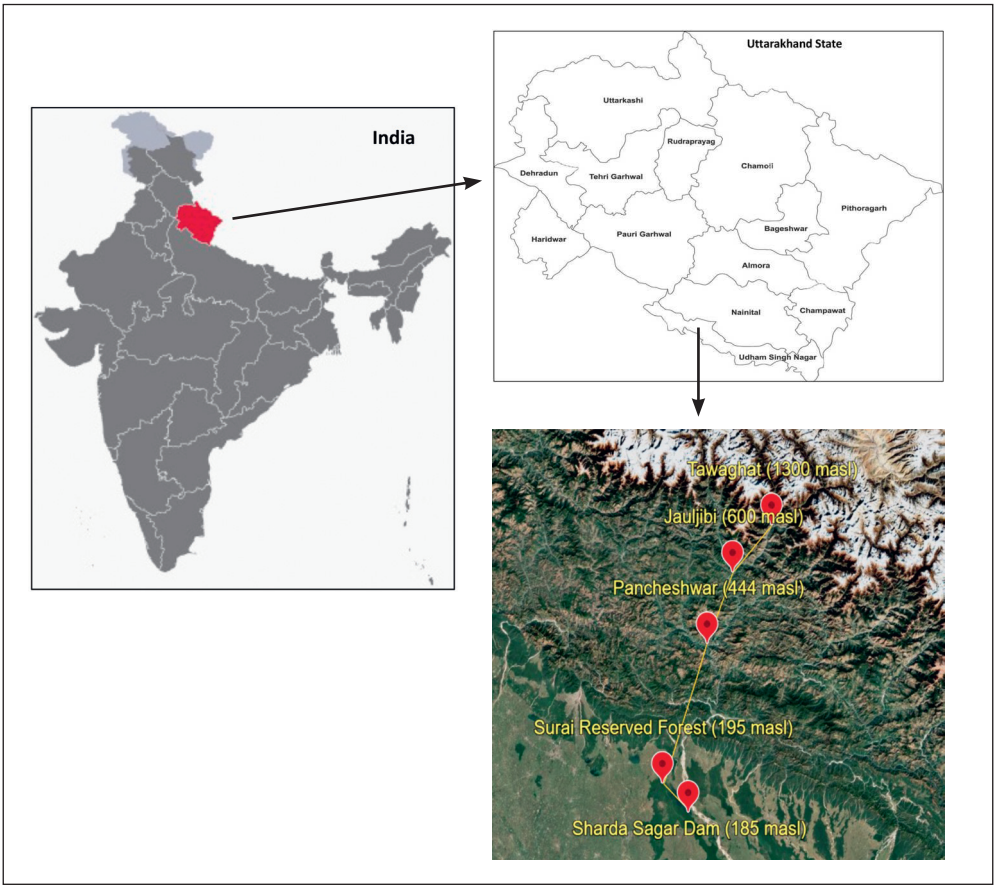


Figure 1. Map showing the different study sites along the altitudinal gradients of Sharda River system
1. ábra A Sharda folyórendszer mentén található kutatási helyek térképe

Field survey

The field survey was conducted along the altitudinal zones around the Sharda River system, in different study sites from August 2017 to July 2019, using field binoculars and Nikon point-shoot cameras. As per Grimmett *et al.* (2011), identification was made, and GPS was used to mark the location. For bird counting, two standard methods, i.e. the line-transect method and the point count method were used. The transect length was 1 km, and the width was 50 m on both sides. A total of 216 transects and 4,320 points were laid during the first year of study. The same transects and points were revised in the second year. 432 transects and 8,640 points were laid in all three study sites during the study period. Surveys and observations were made twice daily when avifauna is usually most active (05:00 am to 10:00 am and 03:00 pm to 06:00 pm).

Table 1. An overview of the study areas, including their geographical location and dominant vegetation structures along the Sharda River system

1. táblázat A kutatási területek földrajzi elhelyezkedésének és a domináns vegetáció bemutatása

S.No.	Study area	Altitude (m asl)	Latitude	Longitude	Vegetation
1	Tawaghat	1300	29°57′29.42″	80°36′02.20″	banj oack *(Quercus leucotricopora)*, chir pine *(Pinus roxburghii)*
2	Jauljibi	600	29°45′09.78″	80°22′45.49″	sal *(Shorea robusta)*, chebulic myrobalan *(Terminalia chebula)*, beleric myrobalan *(Terminalia bellirica)*
3	Pancheshwar	444	29°26′41.84″	80°14′33.70″	pure sal, mix sal
4	Surai Reserved Forest	195	28°43′20.47″	79°54′35.49″	pure and mix sal, open grasslands, ravine, swamps and plantations of teak *(Tectona grandis)* and Tasmanian blue gum *(Eucalyptus globulus)*
5	Sharda Sagar Dam	185	29°49′48.28″	80°03′18.14″	grasslands, swamps, agricultural land and plantations of teak and Tasmanian blue gum

Statistical analysis

Shannon–Wiener's diversity index was used to calculate the avian diversity of the study area by the following formula:

$$H' = \sum Pi(lnPi)$$

where, Pi proportion of each species in the sample, ln natural log of the number.
Margalef's formula was used to calculate species richness as follows:

$$SR = (S-1)/logN$$

where S = total number of species and N = total number of individuals present in the sample. Equitability or evenness was calculated by:

$$Equitability = H'/H_{max}$$

where H' = Shannon–Wiener's index, H_{max} = ln (total number of species)
The relative diversity index (RDi) of various avian families recorded in the selected study sites was calculated using the following formula:

$$RDi = Numberofspecies \in afamily/Totalnumberofspecies \times 100$$

Pearson's correlation coefficient and ANOVA test were used to determine bird's relationship with altitudinal gradients. Post Hoc tests were performed using LSD (least significant difference) for the multiple comparisons between different habitats and avian species diversity. All the findings were analyzed using PAST version 3.20 (Hammer *et al.* 2001).

Results

A total of 203 species of birds belonging to 63 families and 16 orders were recorded from all study sites during the entire study period. Out of the 16 orders, the most dominant was Passeriformes, which comprises 32 families (50.79%), whereas out of the 63 families, the most dominant one was Muscicapidae, which comprises 17 species. The relative abundance of birds varied from 0.01 to 5.93% *(Appendix I)*. The most dominant species was Rock Pigeon

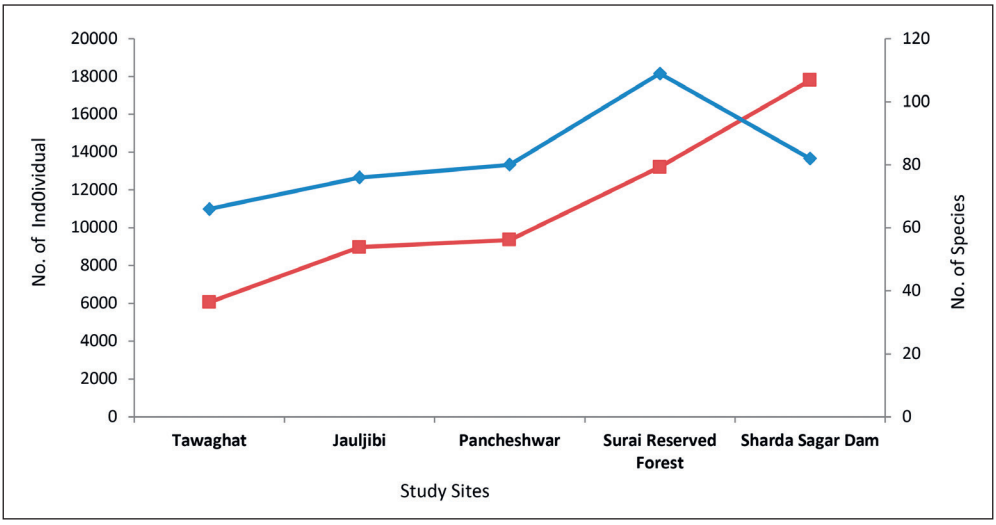


Figure 2. Avian diversity in terms of number of individuals (red) and species (blue) in different study sites (August 2017 – July 2019)

2. ábra A madarak diverzitása azok egyedszáma (piros) és fajszáma (kék) alapján a különböző kutatási területeken 2017 augusztusa és 2019 júliusa között

(Columba livia), which comprises 3,286 individuals (5.93%). The number of bird species and individuals varied across different study sites. The highest number of individuals were recorded from Sharda Sagar Dam (17,799, 32%) followed by Surai Reserved Forest (13,208, 24%), Pancheshwar (9,363, 17%), Jauljibi (8,977, 16%) and Tawaghat (6,062, 11%), whereas the number of species was highest in Surai Reserved Forest (109) followed by Sharda Sagar Dam (82), Pancheshwar (80), Jauljibi (76) and Tawaghat (66), respectively *(Figure 2)*.

The diversity indices varied across different study sites and seasons. Shannon–Wiener's diversity was highest in Surai Reserved Forest (4.25) followed by Sharda Sagar Dam (4.06), Pancheshwar (3.99), Jauljibi (3.98) and Tawaght (3.77). Margalef's species richness was highest in Surai Reserved Forest (11.38) followed by Pancheshwar (8.64), Sharda Sagar Dam (8.28), Jauljibi (8.24) and Tawaghat (7.46). Equitability was highest in Sharda Sagar Dam and Juljibi (0.92) followed by Surai Reserved Forest and Pancheshwar (0.91) and lowest in Tawaghat (0.90) *(Table 2)*. The one-way ANOVA showed that the different altitudinal gradients along the Sharda River system indicated avian diversity ($F = 34.716$; $P < 0.001$).

Post hoc tests were performed using LSD for the multiple comparisons between different habitats and avian species diversity. A significant difference was observed between the forest system of Surai Reserved Forest and all the other study sites ($P < 0.001$). Similarly, Tawaghat showed a significant difference among Jauljibi ($P < 0.05$), Pancheshwar ($P < 0.01$), and Sharda Sagar Dam ($P < 0.01$). The results indicate that the highest avian species

Table 2. Diversity Indices of avian species in different study sites along Sharda River system during the study period (August 2017 – July 2019)

2. táblázat A különböző diverzitási indexek a Sharda folyórendszer mentén található kutatási területeken 2017 augusztusa és 2019 júliusa között

Diversity Indices	Tawaghat	Jauljibi	Pancheshwar	Surai Reserved Forest	Sharda Sagar Dam
Shannon–Wiener's diversity (H)	3.77	3.98	3.99	4.25	4.06
Species richness (Margalef)	7.46	8.24	8.64	11.38	8.28
Equitability (J)	0.90	0.92	0.91	0.91	0.92
No. of species	66	76	80	109	82
Individuals	6062	8977	9363	13208	17799

Table 3. Effect of habitats at different altitudes on species diversity of avian fauna along the Sharda River System. Statistical analysis based on *post hoc* test performed using LSD.

3. táblázat A különböző tengerszint feletti magasságokon található élőhelyek hatása a Sharda folyórendszer mentén élő madárfajok diverzitására. A statisztikai elemzések az LSD segítségével elvégzett *post hoc* teszteken alapulnak

Study Sites	Jauljibi	Pancheshwar	Surai Reserved Forest	Sharda Sagar Dam
Tawaghat	0.017	0.002	0.000	0.003
Jauljibi		0.197	0.000	0.282
Pancheshwar			0.000	0.812
Surai Reserved Forest				0.000

diversity in Surai Reserved Forest must be due to rich vegetation and nesting grounds *(Table 3)*. Based on the conservation priorities, all avian species were categorized according to the IUCN Red List, as follows: 1 species was found under endangered category (EN), 2 species under critically endangered category (CR), 4 species under near threatened category (NT), 6 species were categorized under vulnerable category (VU) and the remaining 190 species were ranked as least concern category (LC) *(Appendix I)*.

Discussion

The results of the present study indicate that the area is home to many avian species. During the study period, 203 bird species were recorded from the study area. The highest number of bird species were observed in Surai Reserved Forest followed by Sharda Sagar Dam, Pancheshwar, Jauljibi and Tawaghat, respectively. In contrast, the highest number of individuals were recorded from Sharda Sagar Dam followed by Surai Reserved Forest, Pancheshwar, Jauljibi and Tawaghat. According to the findings of this study, the existence of forest has a substantial impact on bird variety, and the dam region attracts a large number of migratory and aquatic birds. The findings are consistent with previous research in West Africa and Sri Lanka (Dawson *et al.* 2011, Subasinghe *et al*. 2014). There is evidence that heterogeneous habitats allow more species to coexist because they either match the habitat requirements or can be ascribed to lower competition due to geographical isolation (May 1986).

The forest, which is of mixed type and covers the largest area of the study sites along the river, is primarily made up of *Quercus leucotricopora*, *Pinus roxburghii, Shorea robusta*, *Terminalia chebula, Terminalia bellirica, Tectona grandis* and *Eucalyptus globulus,* while the Sharda Sagar Dam is covered in shrubs, ferns, and other plant species. These plants offer diverse water bird guilds, a form of edge habitat in addition to food, nesting and breeding habitats, as well as protection from predators. Generalist and opportunistic species that feed on insects, fruits and seeds choose mixed woods as their preferred habitats (Basile 2021).

Based on these findings, it is possible to conclude that bird communities are highly related to plant species richness, supporting the findings of Block and Brennan (1993), Augenfeld *et al*. (2008), Earnst and Holmes (2012) as well as Tanalgo *et al*. (2015). According to our findings, forest and shrub-land environments supported more bird diversity and abundance than other habitat types, owing to vegetation cover for sheltering and nesting, food availability and a lack of predation accessibility. In other words, forest and shrub-land ecosystems serve as micro-refuges for birds, resulting in greater richness and diversity of bird species in these environments. Low species richness at mountain range summits can be linked to smaller area, harsher climatic conditions, lower productivity and resource constraints (Acharya *et al*. 2011).

The study's findings indicate that the present study is the first report on avian fauna of the Sharda River system along the altitudinal gradient after independence (1947). Surai Reserved Forest showed the highest number of avian species, whereas Sharda Sagar Dam

found the highest number of individuals. It supports that the dam area is an ideal habitat for all birds, including the migratory species. Our results showed that different habitats, i.e. forests, an agricultural area and wetlands along the Sharda Rives system, are highly productive, and attract a wide range of local and migratory bird species. Thus, the present study is an ideal attempt to understand the present status of knowledge regarding the local and migratory birds. Furthermore, conservation awareness programs among the local people are required to sensitize the people about the sustainable use of the forest, which is home to many plants and animals, including fascinating creatures like birds.

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Appendix 1. Checklist of avian fauna, their relative abundance and their IUCN status in different study sites along Sharda River system during the study period (August 2017 to July 2019)

1. melléklet A Sharda folyórendszer mentén található kutatási területeken 2017 augusztusa és 2019 júliusa között megfigyelt madárfajok listája, azok relatív abundanciája és IUCN státusza

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
Anseriformes	**Anatidae**	Fulvous Whistling Duck	*Dendrocygna bicolor* (Vieillot, 1816)	0.67	LC
		Lesser Whistling Duck	*Dendrocygna javanica* (Horsfield, 1821)	1.24	LC
		Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	0.23	LC
		Bar-headed Goose	*Anser indicus* (Latham, 1790)	0.08	LC
		Red-crested Pochard	*Netta rufina* (Pallas, 1773)	0.83	LC
		Common Pochard	*Aythya ferina* (Linnaeus, 1758)	0.54	VU
		Ferruginous Duck	*Aythya nyroca* (Guldenstadt, 1770)	0.54	NT
		Tufted Duck	*Aythya fuligula* (Linnaeus, 1758)	0.53	LC
		Gadwall	*Mareca strepera* (Linnaeus, 1758)	0.41	LC
		Mallard	*Anas platyrhynchos* (Linnaeus, 1758)	0.08	LC
		Cotton Pygmy Goose	*Nettapus coromandelianus* (J.F. Gmelin, 1789)	0.44	LC
		Common Merganser	*Mergus merganser* (Linnaeus, 1758)	0.03	LC
Galliformes	**Phasianidae**	Indian Peafowl	*Pavo cristatus* (Linnaeus, 1758)	0.11	LC
		Red Junglefowl	*Gallus gallus* (Linnaeus, 1758)	0.03	LC
Columbiformes	**Columbidae**	Rock Pigeon	*Columba livia* (J.F. Gmelin, 1789)	5.93	LC
		Oriental Turtle Dove	*Streptopelia orientalis* (Latham, 1790)	2.30	LC
		Eurasian Collard Dove	*Streptopelia decaocto* (Frivaldszky, 1838)	0.86	LC
		Spotted Dove	*Streptopelia chinensis* (Scopoli, 1786)	2.74	LC
		Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	0.02	LC
		Wedge-tailed Green Pigeon	*Treron sphenurus* (Vigors, 1832)	0.02	LC
Caprimulgiformes	**Caprimulgidae**	Large-tailed Nightjar	*Caprimulgus macrurus* (Horsfield, 1821)	0.11	LC
	Apodidae	Little Swift	*Apus affinis* (J.E. Gray, 1830)	3.27	LC

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
Cuculiformes	**Cuculidae**	Common Hawk Cuckoo	*Hierococcyx varius* (Vahl, 1797)	0.01	LC
		Indian Cuckoo	*Cuculus micropterus* (Gould, 1838)	0.04	LC
		Greater Coucal	*Centropus sinensis* (Stephens, 1815)	0.18	LC
		Asian Koel	*Eudynamys scolopaceus* (Linnaeus,1758)	0.06	LC
Gruiformes	**Rallidae**	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	0.15	LC
		Purple Swamphen	*Porphyrio porphyrio* (Linnaeus, 1758)	1.04	LC
		Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	1.22	LC
		Eurasian Coot	*Fulica atra* (Linnaeus, 1758)	2.07	LC
	Gruidae	Sarus Crane	*Antigone antigone* (Linnaeus, 1758)	0.05	VU
		Demoiselle Crane	*Grus virgo* (Linnaeus, 1758)	0.03	LC
Pelecaniformes	**Ciconiidae**	Lesser Adjutant	*Leptoptilos javanicus* (Horsfield, 1821)	0.06	VU
		Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	0.63	LC
		Woolly-necked Stork	*Ciconia episcopus* (Boddaert, 1783)	0.09	VU
	Ardeidae	Cinnamon Bittern	*Ixobrychus cinnamomeus* (J.F. Gmelin, 1789)	0.07	LC
		Yellow Bittern	*Ixobrychus sinensis* (J.F. Gmelin, 1789)	0.09	LC
		Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	0.43	LC
		Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	0.69	LC
		Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	0.10	LC
		Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	0.14	LC
		Intermediate Egret	*Ardea intermedia* (Wagler, 1829)	0.41	LC
		Little Egret	*Egretta garzetta* (Linnaeus, 1766)	0.89	LC
	Threskiornithidae	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	0.27	LC
	Phalacrocoracidae	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	0.78	LC
		Indian Cormorant	*Phalacrocorax fuscicollis* (Stephens, 1826)	0.29	LC
Charadriiformes	**Burhinidae**	Great Thick-knee	*Esacus recurvirostris* (Cuvier, 1829)	0.13	NT

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	0.48	LC
	Charadriidae	Common Ringed Plover	*Charadrius hiaticula* (Linnaeus, 1758)	0.12	LC
		River Lapwing	*Vanellus duvaucelii* (Lesson, 1826)	0.32	NT
		Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	1.25	LC
	Rostratulidae	Greater Painted-snipe	*Rostratula benghalensis* (Linnaeus, 1758)	0.19	LC
	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786)	0.61	LC
		Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	0.78	LC
	Scolopacidae	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	0.15	LC
		Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	0.08	LC
		Green Sandpiper	*Tringa ochropus* (Linnaeus, 1758)	0.03	LC
		Wood Sandpiper	*Tringa glareola* (Linnaeus, 1758)	0.08	LC
		Temminck's Stint	*Calidris temminckii* (Leisler, 1812)	0.21	LC
	Laridae	Brown-headed Gull	*Chroicocephalus brunnicephalus* (Jerdon, 1840)	0.47	LC
		Black-headed Gull	*Chroicocephalus ridibundus* (Linnaeus, 1766)	0.41	LC
		Pallas's Gull	*Larus ichthyaetus* (Pallas, 1773)	0.05	LC
Accipitriformes	**Accipitridae**	Red-headed Vulture	*Sarcogyps calvus* (Scopoli, 1786)	0.04	CR
		Indian Vulture	*Gyps indicus* (Scopoli, 1786)	0.04	CR
		Himalayan Vulture	*Gyps himalayensis* (Hume, 1869)	0.15	NT
		Griffon Vulture	*Gyps fulvus* (Hablizl, 1783)	0.17	LC
		Crested Serpent Eagle	*Spilornis cheela* (Latham, 1790)	0.12	LC
		Mountain Hawk-Eagle	*Nisaetus nipalensis* (Hodgson, 1836)	0.17	LC
		Black Eagle	*Ictinaetus malaiensis* (Temminck, 1822)	0.08	LC
		Steppe Eagle	*Aquila nipalensis* (Hodgson, 1833)	0.49	EN
		Golden Eagle	*Aquila chrysaetos* (Linnaeus, 1958)	0.06	LC

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
		Indian Spotted Eagle	*Clanga hastata* (Lesson, 1831)	0.04	VU
		Eurasian Sparrowhawk	*Accipiter nisus* (Linnaeus, 1758)	0.25	LC
		Oriental Honey Buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	0.09	LC
		Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	0.12	LC
		Black Kite	*Milvus migrans* (Boddaert, 1783)	1.07	LC
		Shikra	*Accipiter badius* (J.F. Gmelin, 1788)	0.13	LC
Strigiformes	**Tytonidae**	Common Barn Owl	*Tyto alba* (Scopoli, 1769)	0.01	LC
	Strigidae	Asian Barred Owlet	*Glaucidium cuculoides* (Vigors, 1831)	0.32	LC
		Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	0.07	LC
		Spotted Owlet	*Athene brama* (Temminck, 1821)	0.13	LC
		Spot-bellied Eagle Owl	*Bubo nipalensis* (Hodson, 1836)	0.01	LC
Bucerotiformes	**Bucerotidae**	Oriental Pied Hornbill	*Anthracoceros albirostris* (Shaw & Nodder, 1807)	0.11	LC
		Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	0.21	LC
	Upupidae	Common Hoopoe	*Upupa epops* (Linnaeus, 1758)	0.23	LC
Piciformes	**Picidae**	Common Golden-backed	*Dinopium javanense* (Ljungh, 1797)	0.18	LC
		Lesser Golden-backed Woodpecker	*Dinopium benghalense* (Linnaeus, 1758)	0.13	LC
		Rufous Woodpecker	*Micropternus brachyurus* (Vieillot, 1818	0.03	LC
		Greater Golden-backed Woodpecker	*Chrysocolaptes lucidus* (Scopoli, 1786)	0.14	LC
		Grey-headed Woodpecker	*Picus canus* (J.F. Gmelin, 1788)	0.43	LC
		Brown-capped Pygmy Woodpecker	*Dendrocopos moluccensis* (J.F. Gmelin, 1788)	0.03	LC
		Speckled Piculet	*Picumnus innominatus* (E. Burton, 1836)	0.03	LC
		Lesser Yellow-naped Woodpecker	*Picus chlorolophus* (Vieillot, 1818)	0.21	LC

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
		Yellow-crowned Woodpecker	*Dendrocopos mahrattensis* (Latham, 1801)	0.05	LC
		Brown-fronted Woodpecker	*Dendrocopos auriceps* (Vigors, 1831)	0.06	LC
		Grey-capped Pygmy Woodpecker	*Dendrocopos canicapillus* (Blyth, 1845)	0.01	LC
	Ramphastidae	Great Barbet	*Psilopogon virens* (Boddaert, 1783)	0.42	LC
		Brown-headed Barbet	*Psilopogon zeylanicus* (J.F. Gmelin, 1788)	0.26	LC
		Blue-throated Barbet	*Psilopogon asiaticus* (Latham, 1790)	0.11	LC
		Coppersmith Barbet	*Psilopogon haemacephalus* (Statius Muller, 1776)	0.03	LC
Coraciiformes	**Meropidae**	Green Bee-eater	*Merops orientalis* (Latham, 1801)	0.59	LC
		Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus, 1767)	0.15	LC
	Coraciidae	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	0.20	LC
	Alcedinidae	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	0.12	LC
		Crested Kingfisher	*Megaceryle lugubris* (Temminck, 1834)	0.26	LC
		White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	0.36	LC
Falconiformes	**Falconidae**	Common Kestrel	(*Falco tinnunculus* (Linnaeus, 1758)	0.03	LC
Psittaciformes	**Psittaculidae**	Slaty-headed Parakeet	*Psittacula himalayana* (Lesson, 1832)	0.28	LC
		Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	0.89	LC
		Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	3.06	LC
Passeriformes	**Pittidae**	Indian Pitta	*Pitta brachyura* (Linnaeus, 1766)	0.07	LC
	Eurylaimidae	Long-tailed Broadbill	*Psarisomus dalhousiae* (Jameson, 1835)	0.05	LC
	Campephagidae	Long-tailed Minivet	*Pericrocotus ethologus* (Bangs & J.C. Phillips, 1914)	0.31	LC
		Scarlet Minivet	*Pericrocotus flameus* (J.R. Forster, 1781)	0.48	LC
	Oriolidae	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	0.10	LC
		Indian Golden Oriole	*Oriolus kundoo* (Sykes, 1832)	0.07	LC

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
	Aegithinidae	Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	0.02	LC
	Dicruridae	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	2.20	LC
		Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)	0.40	LC
		Crow-billed Drongo	*Dicrurus annectens* (Hodgson, 1836)	0.10	LC
		Lesser Racket-tailed Drongo	*Dicrurus remifer* (Temminck, 1823)	0.09	LC
		Greater Racket-tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	0.06	LC
	Rhipiduridae	White-throated Fantail	*Rhipidura albicollis* (Vieillot, 1818)	0.27	LC
		Yellow-bellied Fantail	*Chelidorhynx hypoxanthus* (Blyth, 1843)	0.23	LC
	Laniidae	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	0.72	LC
	Corvidae	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	0.18	LC
		Grey Treepie	*Dendrocitta formosae* (Swinhoe, 1863)	0.43	LC
		Yellow-billed Blue Magpie	*Urocissa flavirostris* (Blyth, 1846)	0.22	LC
		Red-billed Blue Magpie	*Urocissa erythroryncha* (Boddaert, 1783)	0.36	LC
		Common Green Magpie	*Cissa chinensis* (Boddaert, 1783)	0.01	LC
		House Crow	*Corvus splendens* (Vieillot, 1817)	1.03	LC
		Indian Jungle Crow	*Corvus macrorhynchos* (Wagler, 1827)	1.69	LC
	Monarchidae	Indian Paradise-flycatcher	*Terpsiphone paradise* (Linnaeus, 1758)	0.04	LC
	Dicaeidae	Fire-breasted Flowerpecker	*Dicaeum ignipectus* (Blyth, 1843)	0.34	LC
	Nectariniidae	Crimson-backed Sunbird	*Leptocoma minima* (Sykes,1832)	0.18	LC
		Black-throated Sunbird	*Aethopyga saturata* (Hodgson, 1836)	0.02	LC
		Green-tailed Sunbird	*Aethopyga nipalensis* (Hodgson, 1836)	0.02	LC
		Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	0.12	LC
	Ploceidae	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	0.22	LC
	Estrildidae	White-rumped Munia	*Lonchura striata* (Linnaeus, 1766)	0.49	LC

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
		Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	0.75	LC
	Passeridae	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	2.28	LC
		Russet Sparrow	*Passer cinnamomeus* (Gould, 1836)	0.74	LC
	Motacillidae	Tree Pipit	*Anthus trivialis* (Linnaeus, 1758)	0.26	LC
		Paddyfield Pipit	*Anthus rufulus* (Vieillot, 1818)	0.19	LC
		Yellow Wagtail	*Motacilla flava* (Linnaeus, 1758)	1.93	LC
		White Wagtail	*Motacilla alba* (Linnaeus, 1758)	1.95	LC
		White-browed Wagtail	*Motacilla maderaspatensis* (J.F. Gmelin, 1789)	0.80	LC
		Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	0.31	LC
	Fringillidae	Common Rosefinch	*Erythrina erythrina* (Pallas, 1770)	0.09	LC
		Yellow-breasted Greenfinch	*Chloris spinoides* (Vigors, 1831)	0.93	LC
	Stenostiridae	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	0.81	LC
	Paridae	Great Tit	*Parus major* (Vieillot, 1818)	0.71	LC
		Green-backed Tit	*Parus monticolus* (Vigors, 1831)	0.15	LC
		White-naped Tit	*Machlolophus nuchalis* (Jerdon, 1845)	0.36	VU
		Black-lored Tit	*Machlolophus xanthogenys* (Vigors, 1831)	0.59	LC
		Black-throated Tit	*Aegithalos concinnus* (Gould, 1855)	0.13	LC
	Alaudidae	Crested Lark	*Galerida cristata* (Linnaeus, 1758)	0.08	LC
	Cisticolidae	Ashy Prinia	*Prinia socialis* (Sykes, 1832)	0.16	LC
		Rufescent Prinia	*Prinia rufescens* (Blyth, 1847)	0.45	LC
		Plain Prinia	*Prinia inornata* (Sykes, 1832)	1.03	LC
		Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	0.86	LC
	Hirundinidae	Barn Swallow	*Hirundo rustica* (Linnaeus,1758)	2.18	LC

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
		Plain Martin	*Riparia paludicola* (Vieillot, 1817)	0.31	LC
	Pycnonotidae	Black Bulbul	*Hypsipetes leucocephalus* (J.F. Gmelin, 1789)	0.70	LC
		Himalayan Bulbul	*Pycnonotus leucogenis* (J.E. Grey, 1835)	2.51	LC
		Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	2.08	LC
		Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	1.19	LC
		Ashy Bulbul	*Hemixos flavala* (Blyth, 1845)	0.05	LC
	Phylloscopidae	Grey-cheeked Warbler	*Seicercus poliogenys* (Blyth, 1847)	0.14	LC
		Green Warbler	*Phylloscopus nitidus* (Blyth, 1843)	0.10	LC
	Zosteropidae	Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)	1.39	LC
	Timaliidae	Black-chinned Babbler	*Cyanoderma pyrrhops* (Blyth, 1844)	0.12	LC
	Leiothrichidae	Jungle Babbler	*Turdoides striata* (Dumont, 1823)	1.09	LC
		White-crested Laughingthrush	*Garrulax leucolophus* (Hardwicke, 1816)	0.45	LC
		White-throated Laughingthrush	*Garrulax albogularis* (Gould, 1836)	0.18	LC
		Streaked Laughingthrush	*Trochalopteron lineatum* (Vigors, 1831)	0.84	LC
	Sittidae	Chestnut-bellied Nuthatch	*Sitta castanea* (Lesson, 1830)	0.22	LC
		Velvet-fronted Nuthatch	*Sitta frontalis* (Swainson, 1820)	0.14	LC
		Wallcreeper	*Tichodroma muraria* (Linnaeus, 1766)	0.19	LC
	Sturnidae	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	4.08	LC
		Common Starling	*Sturnus vulgaris* (Linnaeus, 1758)	0.29	LC
		Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	1.34	LC
		Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	0.92	LC
	Cinclidae	Brown Dipper	*Cinclus pallasii* (Temminck, 1820)	0.35	LC
	Muscicapidae	Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)	0.53	LC
		Verditer Flycatcher	*Eumyias thalassinus* (Swainson, 1838)	0.11	LC
		Rusty-tailed Flycatcher	*Muscicapa ruficauda* (Swainson, 1838)	0.27	LC

Order	Family	Species common name	Scientific name	Relative abundance (%)	IUCN status
		Ferruginous Flycatcher	*Muscicapa ferruginea* (Hodgson, 1845)	0.09	LC
		Rufous-bellied Niltava	*Niltava sundara* (Hodgson, 1837)	0.06	LC
		Little Forktail	*Enicurus scouleri* (Vigors, 1832)	0.69	LC
		Spotted Forktail	*Enicurus maculatus* (Vigors, 1831)	0.47	LC
		Blue Whistling Thrush	*Myophonus caeruleus* (Scopoli, 1786)	0.92	LC
		Plumbeous Water Redstart	*Rhyacornis fuliginosa* (Vigors, 1831)	0.14	LC
		White-capped Redstart	*Chaimarrornis leucocephalus* (Vigors, 1831)	0.11	LC
		Black Redstart	*Phoenicurus ochruros* (S.G. Gmelin, 1774)	0.05	LC
		Blue Rock Thrush	*Monticola solitarius* (Linnaeus, 1758)	0.10	LC
		Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	0.31	LC
		Brown Rock Chat	*Oenanthe fusca* (Blyth, 1851)	0.23	LC
		Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)	0.40	LC
		Grey Bushchat	*Saxicola ferreus* (J.E. & G.R. Gray, 1847)	0.11	LC
		Greenish Leaf Warbler	*Seicercus trochiloides* (Sundevall, 1837)	0.11	LC
	Turdidae	Grey-winged Blackbird	*Turdus boulboul* (Latham, 1790)	0.10	LC

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Avifaunal diversity and status of Chhilchhila Wildlife Sanctuary, India

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Abstract Chhilchhila Wildlife Sanctuary, located in Haryana, India, represents a vital habitat for diverse avifaunal species. This study systematically documents the avifaunal diversity of the sanctuary, emphasizing its ecological significance and conservation status. Field surveys, conducted fortnightly using line transect and point count methods from October 2022 to September 2024, recorded a total of 162 species belonging to 18 orders, 56 families and 118 genera. The order Passeriformes exhibited the highest species richness (66 species), followed by Charadriiformes (18 species) and Anseriformes (13 species). Anatidae was the most diverse family with 13 species (RDi = 8.02), followed by Muscicapidae with 11 species (RDi = 6.80) and Scolopacidae with 10 species (RDi = 6.17). Of the recorded species, 88 species (54.32%) were resident, 12 (7.4%) were summer migrant and 62 (38.28%) were winter migrant, highlighting the sanctuary's importance as a critical migratory stopover. Local abundance assessments classified 27.16% of the species as abundant, 19.75% as common, 16.67% as fairly common and 36.42% as rare. Conservation status analysis revealed that Common Pochard *(Aythya ferina)* and River Tern *(Sterna aurantia)* classified under Vulnerable and Asian Woolly-necked Stork *(Ciconia episcopus)* and Alexandrine Parakeet *(Psittacula eupatria)* under Near Threatened categories by the IUCN Red List, with 46 species (28.40%) showing declining population trends globally. These findings underscore the sanctuary's role as a biodiversity hotspot, necessitating continued monitoring and conservation efforts.

Keywords: avian biodiversity, conservation biology, ecological indicator, migratory birds, seasonal variations

Összefoglalás Az indiai Haryanában található Chhilchhila Wildlife Sanctuary létfontosságú élőhelyet jelent a különböző madárfajok számára. Ez a tanulmány dokumentálja a terület madárvilágának sokféleségét, kiemelve annak ökológiai jelentőségét és természetvédelmi helyzetét. A 2022 októbere és 2024 szeptembere között kéthetente végzett terepi felmérések során transzekt mentén és pontszámlálást alkalmazva összesen 162 fajt figyeltünk meg, amelyek 18 rendhez, 56 családhoz és 118 nemzetséghez tartoztak. A legnagyobb fajgazdagságot a Passeriformes rend mutatta (66 faj), amelyet a Charadriiformes (18 faj) és az Anseriformes (13 faj) követett. Az Anatidae volt a legváltozatosabb család 13 fajjal (RDi = 8,02), amelyet a Muscicapidae 11 fajjal (RDi = 6,80) és a Scolopacidae 10 fajjal (RDi = 6,17) követett. A megfigyelt fajok közül 88 (54,32%) rezidens, 12 (7,4%) nyári vonuló és 62 (38,28%) téli vonuló volt, ami rávilágít a terület fontosságára, mint kritikus vonulási megállóhelyre. A lokális abundancia értékelése szerint a fajok 27,16%-a tömeges, 19,75%-a gyakori, 16,67%-a meglehetősen gyakori és 36,42%-a ritka volt. A természetvédelmi helyzetelemzés kimutatta, hogy a barátréce *(Aythya ferina)* és a folyómenti csér *(Sterna aurantia)* a veszélyeztetett, az ázsiai gyapjasnyakúgólya *(Ciconia episcopus)* és a Nagy Sándor-papagáj *(Psittacula eupatria)* pedig a közel veszélyeztetett kategóriába tartozik az IUCN vörös listája szerint. 46 faj (28,40%) populációja csökkenő tendenciát mutat világszerte. Ezek az eredmények kiemelik, hogy a védett terület a biológiai sokféleség egyik forró pontjaként működik, ami folyamatos megfigyelést és védelmi erőfeszítéseket igényel.

Kulcsszavak: madarak diverzitása, természetvédelmi biológia, ökológiai indikátor, vonuló madarak, szezonális variációk

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Introduction

Biodiversity plays a pivotal role in maintaining the balance and health of ecosystems, providing ecological services, and supporting human well-being. Among the various components of biodiversity, avifaunal diversity plays a crucial role in maintaining ecological balance and serves as an important bioindicator of environmental health (Bibby *et al*. 2000, Gregory *et al*. 2009). Birds occupy diverse trophic levels, exhibit wide-ranging habitat preferences, and are highly sensitive to environmental changes, making them ideal subjects for biodiversity and conservation studies (Sekercioglu 2006). Studying avifaunal diversity not only enhances our understanding of ecosystem functioning but also provides insights into the impacts of anthropogenic pressures, such as habitat loss, climate change and pollution (Chace & Walsh 2006, Jetz *et al*. 2007). Documenting and analyzing avifaunal diversity is therefore crucial for understanding ecosystem dynamics and formulating effective conservation strategies. Globally, more than 11,000 bird species have been recorded, with their distribution influenced by geographical, climatic, and ecological factors (BirdLife International 2024). Regions with higher habitat heterogeneity often exhibit greater bird diversity due to the availability of resources and niche opportunities (MacArthur & MacArthur 1961). In tropical and subtropical regions, where biodiversity is at its peak, bird species play essential roles in seed dispersal, pollination and pest control (Sekercioglu *et al*. 2004). Despite their ecological significance, many bird populations are declining at alarming rates. Studies report that approximately 1 in 8 bird species is threatened with extinction due to deforestation, agricultural expansion and urbanization (IPBES 2019, BirdLife International 2024). Documenting and monitoring avifaunal diversity are, therefore, crucial to inform conservation efforts and assess the effectiveness of policies aimed at safeguarding biodiversity (Ceballos *et al*. 2017).

India, renowned for its rich biodiversity, is home to an incredible variety of avian species, owing to its diverse landscapes and climates. Stretching from the towering Himalayas in the north to the tropical rainforests in the south, the country features a wide range of habitats, including wetlands, grasslands, forests, deserts and mangroves. India is considered as one of the 17 mega-biodiverse countries and also acts as a hotspot for avian diversity by hosting 1,364 bird species that covers 26 orders, 115 families and 497 genera including several endemic and migratory bird species (Praveen & Jayapal 2024). Haryana, a north Indian state, complements this national diversity with its unique blend of landscapes. Despite its relatively small geographical size and only 3.65% (1,613.74 km^2) of its area under forest and tree cover (ISFR 2023), Haryana's landscapes dominated by plains, also includes Shivalik foothills in the north and semi-arid regions in the south. Haryana's wetlands, particularly Ramsar sites such as Sultanpur National Park and Bhindawas Bird Sanctuary, serve as crucial stopover sites for migratory birds, attracting species from Central Asia and Europe. The state's agricultural fields, forests and river systems further enhance its importance for both resident and migratory bird species, contributing significantly to India's overall avian diversity.

Chhilchhila Wildlife Sanctuary, located in Haryana, encompasses a variety of habitats, including wetlands and forested areas, making it a significant refuge for numerous bird species. Previous research has documented the presence of 57 species of wetland birds in Chhilchhila Wildlife Sanctuary, spanning 37 genera and 16 families, with notable species

including the Oriental Darter *(Anhinga melanogaster)* and the Painted Stork *(Mycteria leucocephala)*, both were classified as Near Threatened (Kumar & Gupta 2013). However, there is a paucity of recent data on the current status of avifaunal diversity in the sanctuary.

The present study aims to address this gap by providing an updated assessment of the avifaunal diversity in Chhilchhila Wildlife Sanctuary, focusing on species composition, abundance and conservation status. The findings from this study are anticipated to have broader implications for biodiversity conservation, particularly in the context of increasing habitat degradation and climate change. Furthermore, the research highlights the need for integrating local communities and stakeholders in conservation initiatives to ensure the long-term protection of such ecologically valuable areas.

Material and Methods

Study area

The study was conducted in Chhilchhila Wildlife Sanctuary, located between 29°52'–30°00' N latitudes and 76°36'–76°46' E longitudes, in Kurukshetra district of Haryana, India *(Figure 1)*. It was designated as a bird sanctuary in November 1986. The sanctuary covers an area of approximately 28.92 hectares and features diverse habitats, including

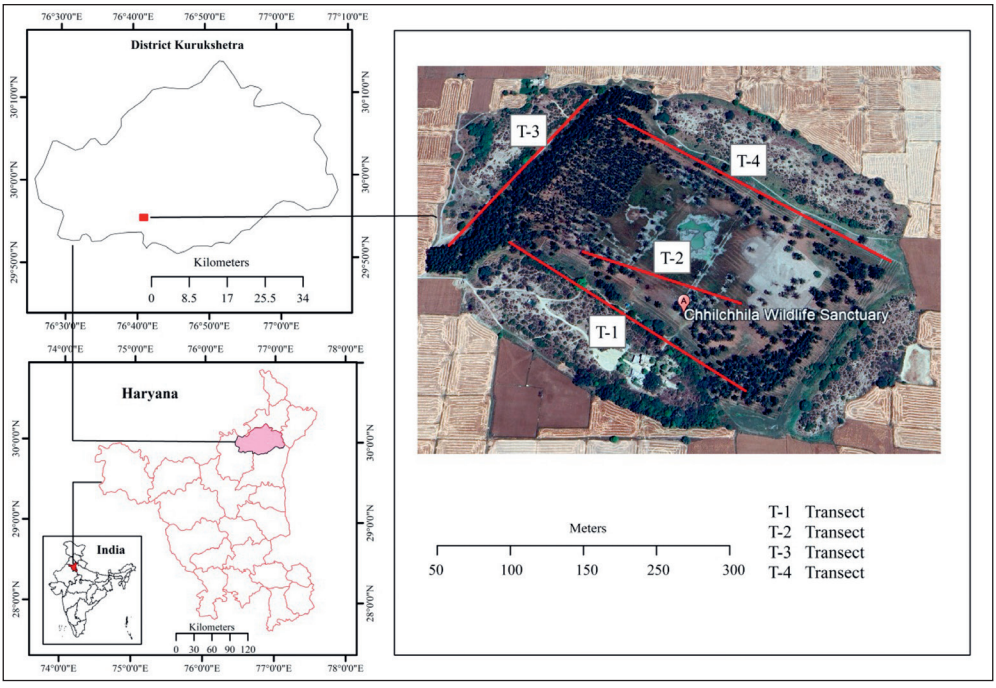


Figure 1. Map of study area showing four transects (T1 to T4) of Chhilchhila Wildlife Sanctuary, India
1. ábra Az indiai Chhilchhila Wildlife Sanctuary területén található kutatási terület térképe a négy transzekttel (T1-től T4-ig)

wetlands, grasslands, and scattered woodland patches. The sanctuary features a shallow, rain-fed lake whose water levels fluctuate seasonally, ranging from about 4.5 meters during the monsoon to 1.8–2.7 meters in the summer (Kumar & Gupta 2013). The climate of the region is subtropical, characterized by hot summers, monsoon rains and cool winters.

The sanctuary's vegetation structure is dominated by dry deciduous communities, supporting a variety of plant species. The vegetation plays a critical role in sustaining diverse wildlife, especially birds. Major tree species includes babool *(Acacia arabica)*, neem *(Azadirachta indica)*, khejri *(Prosopis cineraria)*, shisham *(Dalbergia sissoo)*, banyan *(Ficus benghalensis)*, peepal *(Ficus religiosa)*, safeda *(Eucalyptus hybrida)* and vilayati kikar *(Prosopis juliflora)*, shrubs and herbs include karir *(Capparis decidua)*, aak *(Calotropis procera)* and vasaka *(Adhatoda vasica)*, while aquatic and wetland plants include *Hydrilla* sp., *Typha* sp., *Cyperus* sp., *Azolla* sp. and various native grass species that support herbivorous wildlife and prevent soil erosion.

Methodology

Avifaunal surveys were carried out fortnightly from October 2022 to September 2024, using line transect and point count methods (Gaston 1975, Sutherland *et al*. 2005), which are recognised as standard techniques for bird population studies. Observations were conducted during the early morning hours (6:00 AM to 10:00 AM) and late afternoon hours (4:00 PM to 6:00 PM) when bird activity is highest. Four line transects, each varying in length and traversing distinct habitats, were established in different directions to ensure thorough coverage of the sanctuary *(Table 1)*. Birds were observed while walking slowly along a fixed path, recording all birds seen or heard over the transect line. Binoculars (Nikon 10×50) were used for observing and identifying birds from a distance, while a digital camera (Nikon Coolpix P1000) was used to capture photographs of the birds for documentation. Identification was confirmed using standard field guides (Grimmett *et al*. 2016, Kalsi *et al*. 2019), and re-verified by smartphone applications like eBird and Merlin Bird ID. Records of species presence were cross-checked with historical bird records for the sanctuary, and species not previously documented were confirmed with regional ornithological experts.

Table 1. Depiction of transects with varying lengths and habitats in Chhilchhila Wildlife Sanctuary, India

1. táblázat A különböző hosszúságú és élőhelyeken áthaladó transzektek leírása az indiai Chhilchhila Wildlife Sanctuary területén

Sr. No.	Transects number	Transects length	Habitats
1.	T1	0.52 km	Agricultural fields, Fallow land, Forest Patches
2.	T2	0.38 km	Aquatic, Littoral zone, Forest Patches
3.	T3	0.64 km	Littoral Zone, Fallow land, Tree Plantations
4.	T4	0.55 km	Aquatic, Littoral zone, Agricultural fields, Forest Patches, Fallow land

A checklist of observed avian species was compiled, including their scientific name, common name, family, order and genus as per IOC World Bird List (v14.2) and other relevant sources (Praveen & Jayapal 2022, Gill *et al.* 2024, IUCN 2024). Residential/migratory status was assessed based on available literature, observations and seasonal variations in species presence. Birds were categorized strictly with reference to the study area as resident (species present year-round), winter migrant (species that visit the sanctuary during October–March months), or summer migrant (species that visit the sanctuary during April–September months). The local abundance status of each bird species was calculated based on the number of surveys during which each species was observed. Different categories assigned were abundant, common, fairly common, or rare according to the frequency of their sightings. The conservation status (Least Concern, Near Threatened, Vulnerable) and global population trends (increasing ↑, decreasing ↓, stable → and unknown ?) of reported bird species were assessed as per IUCN Red List (IUCN 2024). The Relative Diversity index (RDi) of bird families was assessed using the formula provided by Torre-Cuadros *et al*. (2007):

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

Results

A total of 162 bird species were recorded in the study area during the study period, representing 118 genera, 56 families and 18 orders *(Table 2)*. The highest species richness was observed in the order Passeriformes (songbirds), with 66 species, accounting for 40.74% of the total bird species recorded. This was followed by Charadriiformes (shorebirds and seabirds) with 18 species (11.11%), Anseriformes (waterfowls) with 13 species (8.02%), Pelecaniformes (pelicans and relatives) with 12 species (7.4%), Accipitriformes (hawks, eagles and allies) with eight species (4.94%), Columbiformes (pigeons and doves) with seven species (4.32%) and others (Caprimulgiformes and Podicipediformes, each represented by only a single species). The diverse order-wise composition reflects the sanctuary's varied habitats, which support a broad spectrum of avian species. The assessment of Relative Diversity index of the 56 families showed that Anatidae was the most diverse (13 species, RDi = 8.02), followed by Muscicapidae (11 species, RDi = 6.80), Scolopacidae (10 species, RDi = 6.17), Ardeidae (eight species, RDi = 4.94), Accipitridae, Columbidae and Motacillidae (seven species each, RDi = 4.32) and others. However, many families (25 in total) such as Pandionidae, Upupidae, Bucerotidae, Glareolidae, Jacanidae, Recurvirostridae, Burhinidae, Laridae, Coraciidae, Apodidae, Acrocephalidae, Fringillidae, Nectariniidae, Pycnonotidae, Ploceidae, Leiothrichidae, Monarchidae, Oriolidae, Paridae, Stenostiridae, Zosteropidae, Podicipedidae, Strigidae, Tytonidae and Anhingidae had the lowest representation metrics (one species each, RDi = 0.62). The analysis of RDi values revealed that the study area supports a diverse avian community, with a major representation of waterfowls, songbirds, and shorebirds *(Table 2, Figure 2)*. While some families dominated due to habitat suitability, many are under-represented, indicating potential areas for conservation focus and underscore the sanctuary's ecological importance.

Table 2. List of avian species recorded from October 2022 to September 2024 in Chhilchhila Wildlife Sanctuary, India

2. táblázat Az indiai Chhilchhila Wildlife Sanctuary területén 2022 októbere és 2024 szeptembere között megfigyelt madárfajok listája

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
ORDER GALLIFORMES (No. of Species = 3 and No. of Families = 1)						
Family Phasianidae (3), RDi = 1.85						
1	Indian Peafowl	*Pavo cristatus* Linnaeus, 1758	R	A	LC	→
2	Grey Francolin	*Ortygornis pondicerianus* (Gmelin, JF, 1789)	R	A	LC	→
3	Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)	R	RA	LC	→
ORDER ANSERIFORMES (No. of Species = 13 and No. of Families = 1)						
Family Anatidae (13), RDi = 8.02						
4	Knob-billed Duck	*Sarkidiornis melanotos* (Pennant, 1769)	R	C	LC	↓
5	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	WM	RA	VU	↓
6	Eurasian Wigeon	*Mareca penelope* (Linnaeus, 1758)	WM	C	LC	↓
7	Gadwall	*Mareca strepera* (Linnaeus, 1758)	WM	C	LC	↑
8	Eurasian Teal	*Anas crecca* Linnaeus, 1758	WM	A	LC	?
9	Indian Spot-billed Duck	*Anas poecilorhyncha* Forster, JR, 1781	R	A	LC	↓
10	Northern Pintail	*Anas acuta* Linnaeus, 1758	WM	A	LC	↓
11	Lesser Whistling Duck	*Dendrocygna javanica* (Horsfield, 1821)	SM	A	LC	↓
12	Northern Shoveler	*Spatula clypeata* (Linnaeus, 1758)	WM	A	LC	↓
13	Garganey	*Spatula querquedula* (Linnaeus, 1758)	WM	RA	LC	↓
14	Greylag Goose	*Anser anser* (Linnaeus, 1758)	WM	FC	LC	↑
15	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	WM	RA	LC	?
16	Cotton Pygmy Goose	*Nettapus coromandelianus* (Gmelin, JF, 1789)	WM	RA	LC	?
ORDER CAPRIMULGIFORMES (No. of Species = 1 and No. of Families = 1)						
Family Apodidae (1), RDi = 0.62						
17	Little Swift	*Apus affinis* (Gray, JE, 1830)	R	RA	LC	↑
ORDER CUCULIFORMES (No. of Species = 5 and No. of Families = 1)						
Family Cuculidae (5), RDi = 3.08						
18	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	R	A	LC	→
19	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	SM	A	LC	→
20	Jacobin Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	SM	C	LC	→
21	Common Hawk-Cuckoo	*Hierococcyx varius* (Vahl, 1797)	SM	C	LC	↓
22	Grey-bellied Cuckoo	*Cacomantis passerinus* (Vahl, 1797)	SM	RA	LC	→

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
ORDER COLUMBIFORMES (No. of Species = 7 and No. of Families = 1)						
Family Columbidae (7), RDi = 4.32						
23	Rock Dove	*Columba livia* Gmelin, JF, 1789	R	A	LC	↓
24	Yellow-footed Green Pigeon	*Treron phoenicopterus* (Latham, 1790)	R	A	LC	↑
25	Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky, 1838)	R	A	LC	↑
26	Oriental Turtle Dove	*Streptopelia orientalis* (Latham, 1790)	WM	RA	LC	↓
27	Red Collared Dove	*Streptopelia tranquebarica* (Hermann, 1804)	R	RA	LC	↓
28	Laughing Dove	*Spilopelia senegalensis* (Linnaeus, 1766)	R	A	LC	→
29	Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)	R	A	LC	↑
ORDER GRUIFORMES (No. of Species = 4 and No. of Families = 1)						
Family Rallidae (4), RDi = 2.47						
30	Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	R	A	LC	→
31	Eurasian Coot	*Fulica atra* Linnaeus, 1758	WM	C	LC	↑
32	Purple Swamphen	*Porphyrio porphyrio* (Linnaeus, 1758)	R	C	LC	?
33	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	R	A	LC	?
ORDER PODICIPEDIFORMES (No. of Species = 1 and No. of Families = 1)						
Family Podicipedidae (1), RDi = 0.62						
34	Little Grebe	*Tachybaptus ruficollis* (Pallas, 1764)	R	C	LC	↓
ORDER CHARADRIIFORMES (No. of Species = 18 and No. of Families = 7)						
Family Charadriidae (3), RDi = 1.85						
35	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	R	A	LC	?
36	White-tailed Lapwing	*Vanellus leucurus* (Lichtenstein, MHC, 1823)	WM	RA	LC	?
37	Little Ringed Plover	*Charadrius dubius* Scopoli, 1786	WM	RA	LC	→
Family Glareolidae (1), RDi = 0.62						
38	Oriental Pratincole	*Glareola maldivarum* Forster, JR, 1795	SM	RA	LC	→
Family Jacanidae (1), RDi = 0.62						
39	Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786)	SM	FC	LC	?
Family Recurvirostridae (1), RDi = 0.62						
40	Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	R	A	LC	↑
Family Burhinidae (1), RDi = 0.62						
41	Indian Thick-Knee or Indian Stone-curlew	*Burhinus indicus* (Salvadori, 1866)	R	RA	LC	?

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
Family Scolopacidae (10), RDi = 6.17						
42	Temminck's Stint	*Calidris temminckii* (Leisler, 1812)	WM	RA	LC	?
43	Ruff	*Calidris pugnax* (Linnaeus, 1758)	WM	FC	LC	↓
44	Little Stint	*Calidris minuta* (Leisler, 1812)	WM	RA	LC	↑
45	Spotted Redshank	*Tringa erythropus* (Pallas, 1764)	WM	FC	LC	→
46	Common Greenshank	*Tringa nebularia* (Gunnerus, 1767)	WM	FC	LC	→
47	Green Sandpiper	*Tringa ochropus* Linnaeus, 1758	WM	A	LC	↑
48	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	WM	FC	LC	?
49	Wood Sandpiper	*Tringa glareola* Linnaeus, 1758	WM	C	LC	→
50	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	WM	RA	LC	↓
51	Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	WM	C	LC	↓
Family Laridae (1), RDi = 0.62						
52	River Tern	*Sterna aurantia* Gray, JE, 1831	R	RA	VU	↓
ORDER CICONIIFORMES (No. of Species = 3 and No. of Families = 1)						
Family Ciconiidae (3), RDi = 1.85						
53	Asian Woolly-necked Stork	*Ciconia episcopus* (Boddaert, 1783)	R	C	NT	↓
54	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	R	C	LC	↑
55	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	R	RA	LC	?
ORDER SULIFORMES (No. of Species = 4 and No. of Families = 2)						
Family Anhingidae (1), RDi = 0.62						
56	Oriental Darter	*Anhinga melanogaster* Pennant, 1769	WM	FC	LC	↑
Family Phalacrocoracidae (3), RDi = 1.85						
57	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	R	A	LC	?
58	Great Comorant	*Phalacrocorax carbo* (Linnaeus, 1758)	WM	A	LC	↑
59	Indian Cormorant	*Phalacrocorax fuscicollis* Stephens, 1826	R	FC	LC	?
ORDER PELECANIFORMES (No. of Species = 12 and No. of Families = 2)						
Family Ardeidae (8), RDi = 4.94						
60	Purple Heron	*Ardea purpurea* Linnaeus, 1766	R	A	LC	↓
61	Grey Heron	*Ardea cinerea* Linnaeus, 1758	R	A	LC	?
62	Great White Egret	*Ardea alba* Linnaeus, 1758	R	C	LC	?
63	Intermediate Egret	*Ardea intermedia* Wagler, 1829	R	A	LC	↓
64	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	R	A	LC	?
65	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	R	A	LC	↑
66	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	R	C	LC	↑
67	Black-crowned Night Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	R	FC	LC	↓

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
Family Threskiornithidae (4), RDi = 2.47						
68	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	R	FC	LC	↑
69	Eurasian Spoonbill	*Platalea leucorodia* Linnaeus, 1758	WM	RA	LC	?
70	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	R	FC	LC	↓
71	Glossy Ibis	*Plegadis falcinellus* (Linnaeus, 1766)	R	RA	LC	↓
ORDER ACCIPITRIFORMES (No. of Species = 8 and No. of Families = 2)						
Family Accipitridae (7), RDi = 4.32						
72	Black Kite	*Milvus migrans* (Boddaert, 1783)	R	C	LC	→
73	Brahminy Kite	*Haliastur indus* (Boddaert, 1783)	WM	C	LC	↓
74	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	R	FC	LC	→
75	Crested Serpent Eagle	*Spilornis cheela* (Latham, 1790)	R	RA	LC	→
76	Oriental Honey-Buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	R	RA	LC	↓
77	Shikra	*Accipiter badius* (Gmelin, JF, 1788)	R	A	LC	→
78	Western Marsh Harrier	*Circus aeruginosus* (Linnaeus, 1758)	WM	RA	LC	→
Family Pandionidae (1), RDi = 0.62						
79	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	WM	RA	LC	↑
ORDER STRIGIFORMES (No. of Species = 2 and No. of Families = 2)						
Family Strigidae (1), RDi = 0.62						
80	Spotted Owlet	*Athene brama* (Temminck, 1821)	R	A	LC	→
Family Tytonidae (1), RDi = 0.62						
81	Common Barn Owl	*Tyto alba* (Scopoli, 1769)	R	RA	LC	→
ORDER BUCEROTIFORMES (No. of Species = 2 and No. of Families = 2)						
Family Upupidae (1), RDi = 0.62						
82	Common Hoopoe	*Upupa epops* Linnaeus, 1758	R	C	LC	↓
Family Bucerotidae (1), RDi = 0.62						
83	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	R	C	LC	→
ORDER CORACIIFORMES (No. of Species = 5 and No. of Families = 3)						
Family Alcedinidae (2), RDi = 1.23						
84	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	R	A	LC	↑
85	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	R	RA	LC	?
Family Meropidae (2), RDi = 1.23						
86	Green Bee-eater	*Merops orientalis* Latham, 1801	SM	A	LC	↑
87	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus, 1767	SM	C	LC	→
Family Coraciidae (1), RDi = 0.62						
88	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	R	RA	LC	↑

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
ORDER PICIFORMES (No. of Species = 5 and No. of Families = 2)						
Family Megalaimidae (2), RDi = 1.23						
89	Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin, JF, 1788)	R	C	LC	↓
90	Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, PLS, 1776)	R	RA	LC	↑
Family Picidae (3), RDi = 1.85						
91	Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	R	C	LC	↓
92	Eurasian Wryneck	*Jynx torquilla* Linnaeus, 1758	WM	RA	LC	↓
93	Yellow-crowned Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)	R	RA	LC	→
ORDER PSITTACIFORMES (No. of Species = 3 and No. of Families = 1)						
Family Psittaculidae (3), RDi = 1.85						
94	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	R	C	NT	↓
95	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	R	A	LC	↑
96	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	WM	RA	LC	↓
ORDER PASSERIFORMES (No. of Species = 66 and No. of Families = 25)						
Family Acrocephalidae (1), RDi = 0.62						
97	Blyth's Reed Warbler	*Acrocephalus dumetorum* Blyth, 1849	WM	RA	LC	↑
Family Campephagidae (2), RDi = 1.23						
98	Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	R	RA	LC	↓
99	Scarlet Minivet	*Pericrocotus flammeus* (Forster, JR, 1781)	WM	RA	LC	↓
Family Cisticolidae (4), RDi = 2.47						
100	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	R	FC	LC	?
101	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	R	FC	LC	→
102	Plain Prinia	*Prinia inornata* Sykes, 1832	R	C	LC	→
103	Ashy Prinia	*Prinia socialis* Sykes, 1832	R	A	LC	→
Family Corvidae (2), RDi = 1.23						
104	House Crow	*Corvus splendens* Vieillot, 1817	R	C	LC	→
105	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	R	A	LC	↓
Family Dicruridae (3), RDi = 1.85						
106	Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	R	A	LC	?
107	Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817	WM	RA	LC	?
108	Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)	WM	RA	LC	↓

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
Family Estrildidae (3), RDi = 1.85						
109	Indian Silverbill	*Euodice malabarica* (Linnaeus, 1758)	R	A	LC	→
110	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	R	FC	LC	→
111	Red Avadavat	*Amandava amandava* (Linnaeus, 1758)	R	RA	LC	→
Family Emberizidae (2), RDi = 1.23						
112	White-capped Bunting	*Emberiza stewarti* (Blyth, 1854)	WM	RA	LC	→
113	Rock Bunting	*Emberiza cia* Linnaeus, 1766	WM	RA	LC	→
Family Fringillidae (1), RDi = 0.62						
114	Common Rosefinch	*Carpodacus erythrinus* (Pallas, 1770)	WM	RA	LC	↓
Family Hirundinidae (5), RDi = 3.08						
115	Asian Plain Martin/ Grey-throated Martin	*Riparia chinensis* (Gray, JE, 1830)	R	FC	LC	↓
116	Streak-throated Swallow	*Petrochelidon fluvicola* (Blyth, 1855)	R	FC	LC	↑
117	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	R	FC	LC	↑
118	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	WM	RA	LC	↓
119	Red-rumped Swallow	*Cecropis daurica* (Laxmann, 1769)	R	RA	LC	↑
Family Laniidae (2), RDi = 1.23						
120	Long-tailed Shrike	*Lanius schach* Linnaeus, 1758	R	A	LC	?
121	Bay-backed Shrike	*Lanius vittatus* Valenciennes, 1826	WM	RA	LC	→
Family Leiothrichidae (1), RDi = 0.62						
122	Jungle Babbler	*Argya striata* (Dumont, 1823)	R	A	LC	→
Family Monarchidae (1), RDi = 0.62						
123	Indian Paradise-Flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)	SM	FC	LC	→
Family Motacillidae (7), RDi = 4.32						
124	Western Yellow Wagtail	*Motacilla flava* Linnaeus, 1758	WM	C	LC	↓
125	White Wagtail	*Motacilla alba* Linnaeus, 1758	WM	C	LC	→
126	Grey Wagtail	*Motacilla cinerea* Tunstall, 1771	WM	FC	LC	→
127	Citrine Wagtail	*Motacilla citreola* Pallas, 1776	WM	FC	LC	↑
128	White-browed Wagtail	*Motacilla maderaspatensis* Gmelin, JF, 1789	R	RA	LC	→
129	Tree Pipit	*Anthus trivialis* (Linnaeus, 1758)	WM	FC	LC	↓
130	Paddyfield Pipit	*Anthus rufulus* Vieillot, 1818	R	FC	LC	→
Family Nectariniidae (1), RDi = 0.62						
131	Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	R	A	LC	→
Family Oriolidae (1), RDi = 0.62						
132	Indian Golden Oriole	*Oriolus kundoo* Sykes, 1832	SM	A	LC	?

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
Family Passeridae (3), RDi = 1.85						
133	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	R	FC	LC	↓
134	Sind Sparrow	*Passer pyrrhonotus* Blyth, 1845	R	RA	LC	→
135	Chestnut-shouldered Bush-Sparrow	*Gymnoris xanthocollis* (Burton, E, 1838)	WM	RA	LC	→
Family Paridae (1), RDi = 0.62						
136	Fire-capped Tit	*Cephalopyrus flammiceps* (Burton, E, 1838)	WM	RA	LC	↓
Family Muscicapidae (11), RDi = 6.80						
137	Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)	R	A	LC	→
138	Siberian Stonechat	*Saxicola maurus* (Pallas, 1773)	WM	C	LC	→
139	Grey Bush Chat	*Saxicola ferreus* Gray, JE & Gray, GR, 1847	WM	RA	LC	→
140	Bluethroat	*Luscinia svecica* (Linnaeus, 1758)	WM	FC	LC	→
141	Indian Robin	*Copsychus fulicatus* (Linnaeus, 1766)	R	A	LC	→
142	Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)	R	C	LC	→
143	Brown Rock Chat	*Oenanthe fusca* (Blyth, 1851)	R	C	LC	→
144	Black Redstart	*Phoenicurus ochruros* (Gmelin, SG, 1774)	WM	RA	LC	↑
145	Red-breasted Flycatcher	*Ficedula parva* (Bechstein, 1792)	WM	FC	LC	↑
146	Ultramarine Flycatcher	*Ficedula superciliaris* (Jerdon, 1840)	WM	RA	LC	→
147	Verditer Flycatcher	*Eumyias thalassinus* (Swainson, 1838)	WM	RA	LC	↓
Family Phylloscopidae (5), RDi = 3.08						
148	Common Chiffchaff	*Phylloscopus collybita* (Vieillot, 1817)	WM	A	LC	→
149	Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	WM	C	LC	↑
150	Grey-hooded Warbler	*Phylloscopus xanthoschistos* Gray, JE & Gray, GR, 1847	WM	RA	LC	↓
151	Sulphur-bellied Warbler	*Phylloscopus griseolus* Blyth, 1847	WM	RA	LC	→
152	Hume's Leaf Warbler	*Phylloscopus humei* (Brooks, WE, 1878)	WM	RA	LC	→
Family Ploceidae (1), RDi = 0.62						
153	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	SM	C	LC	→
Family Pycnonotidae (1), RDi = 0.62						
154	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	R	A	LC	↑
Family Sturnidae (4), RDi = 2.47						
155	Brahminy Starling	*Sturnia pagodarum* (Gmelin, JF, 1789)	R	RA	LC	?

Sr. No.	Common name	Scientific name with Authority	Residential Status	Local Abundance Status	IUCN Status	Population Trend
156	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	R	A	LC	↑
157	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	R	RA	LC	↑
158	Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	R	C	LC	↑
Family Sylviidae (2), RDi = 1.23						
159	Lesser Whitethroat	*Curruca curruca* (Linnaeus, 1758)	WM	FC	LC	→
160	Yellow-eyed Babbler	*Chrysomma sinense* (Gmelin, JF, 1789)	R	RA	LC	→
Family Stenostiridae (1), RDi = 0.62						
161	Grey-headed Canary-Flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	WM	RA	LC	↓
Family Zosteropidae (1), RDi = 0.62						
162	Indian White-Eye	*Zosterops palpebrosus* (Temminck, 1824)	R	RA	LC	↓

Abbreviations:
Residential Status: R – Resident, **SM** – Summer Migrant, **WM** – Winter Migrant
Local Abundance Status: **A** – Abundant, **C** – Common, **FC** – Fairly Common, **RA** – Rare
IUCN Status: **LC** – Least Concern, **NT** – Near Threatened, **VU** – Vulnerable
Population Trend: ↑ – Increasing, ↓ – Decreasing, → – Stable, **?** – Unknown
RDi – Relative Diversity index values of families
IUCN – International Union for Conservation of Nature and Natural Resources

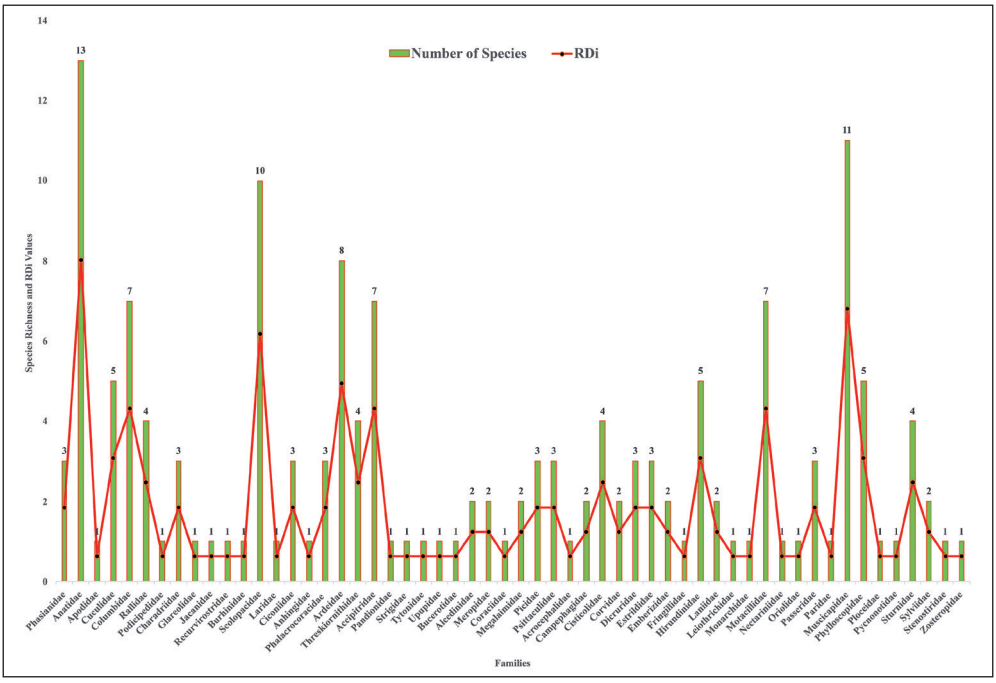


Figure 2. Species richness and RDi values of families recorded in Chhilchhila Wildlife Sanctuary, India
2. ábra Az indiai Chhilchhila Wildlife Sanctuary területén megfigyelt fajgazdagság és a madárcsaládok RDi értékei

Of the 162 species recorded, 88 species (54.32%) were classified as resident birds, while 74 species (45.68%) were migratory. Among the migratory species, 62 species (83.78%) were winter migrants, while 12 species (16.22%) were summer migrants *(Table 2)*. Notable migratory species included the Ruddy Shelduck *(Tadorna ferruginea)*, Garganey *(Spatula querquedula)*, Common Snipe *(Gallinago gallinago)*, Oriental Turtle Dove *(Streptopelia orientalis)*, Ashy Drongo *(Dicrurus leucophaeus)*, Eurasian Wryneck *(Jynx torquilla)*, Oriental Pratincole *(Glareola maldivarum)*, Indian Paradise Flycatcher *(Terpsiphone paradisi)* and Grey-bellied Cuckoo *(Cacomantis passerinus)*, which use the sanctuary as an important stopover during their migration. The local abundance status of bird species was assessed based on encounter rates and visual sightings. A total of 44 species (27.16%) were categorized as abundant, 32 species (19.75%) were considered common, 27 species (16.67%) were classified as fairly common and only 59 species (36.42%) were considered rare *(Table 2)*. Species such as the Indian Peafowl *(Pavo cristatus)* (Galliformes), Greater Coucal *(Centropus sinensis)* (Cuculiformes), White-breasted Waterhen *(Amaurornis phoenicurus)* (Gruiformes), Red-wattled Lapwing *(Vanellus indicus)*, Black-winged Stilt *(Himantopus himantopus)* (Charadriiformes), Little Cormorant *(Microcarbo niger)* (Suliformes), Cattle Egret *(Bubulcus ibis)* (Pelecaniformes), White-throated Kingfisher *(Halcyon smyrnensis)* (Coraciiformes), Common Myna *(Acridotheres tristis),* Jungle Babbler *(Turdoides striata)*, Red-vented Bulbul *(Pycnonotus cafer)* (Passeriformes) were abundant, reflecting their adaptability to a wide range of habitats and anthropogenic landscapes (BirdLife International 2024). Conversely, species like the Glossy Ibis *(Plegadis falcinellus)* (Pelecaniformes), Small Minivet *(Pericrocotus cinnamomeus)*, Indian White-eye *(Zosterops palpebrosus)* (Passeriformes) were rare, possibly due to specific habitat requirements and declining populations, echoing trends noted in other studies (Rahmani 2012). Asian Openbill *(Anastomus oscitans)*, Yellow Crowned Woodpecker *(Leiopicus mahrattensis)*, Hair-crested Drongo *(Dicrurus hottentottus)*, Fire-capped Tit *(Cephalopyrus flammiceps)*, White-capped Bunting *(Emberiza stewarti)* and Rock Bunting *(Emberiza cia)* were sighted only once during the whole study period.

A relationship between the residential status and local abundance of observed species revealed that among the 88 resident species, 38.63% were abundant, 20.45% were common, 14.77% were fairly common and 26.13% were rare. Of the 62 winter migrants, 9.67% were abundant, 16.13% were common, 19.35% were fairly common and 54.84% were rare. Among the 12 summer migrants, 33.33% species were abundant, 33.33% were common, 16.67% were fairly common and 16.67% were rare *(Figure 3)*.

In terms of conservation status, two species (1.23%) were listed as Vulnerable (VU), two species (1.23%) as Near Threatened (NT) and other 158 species (97.54%) as Least Concern (LC) according to the International Union for Conservation of Nature & Natural Resources (IUCN 2024) Red List. The Vulnerable species were the Common Pochard *(Aythya ferina)* and the River Tern *(Sterna aurantia)*, whereas Near Threatened species were the Asian Woolly-necked Stork *(Ciconia episcopus)* and Alexandrine Parakeet *(Psittacula eupatria)*. No species categorized as Endangered (EN) or Critically Endangered (CR) were recorded during the study period. Population trends of bird species within the sanctuary were analyzed based on long-term global monitoring by IUCN and data

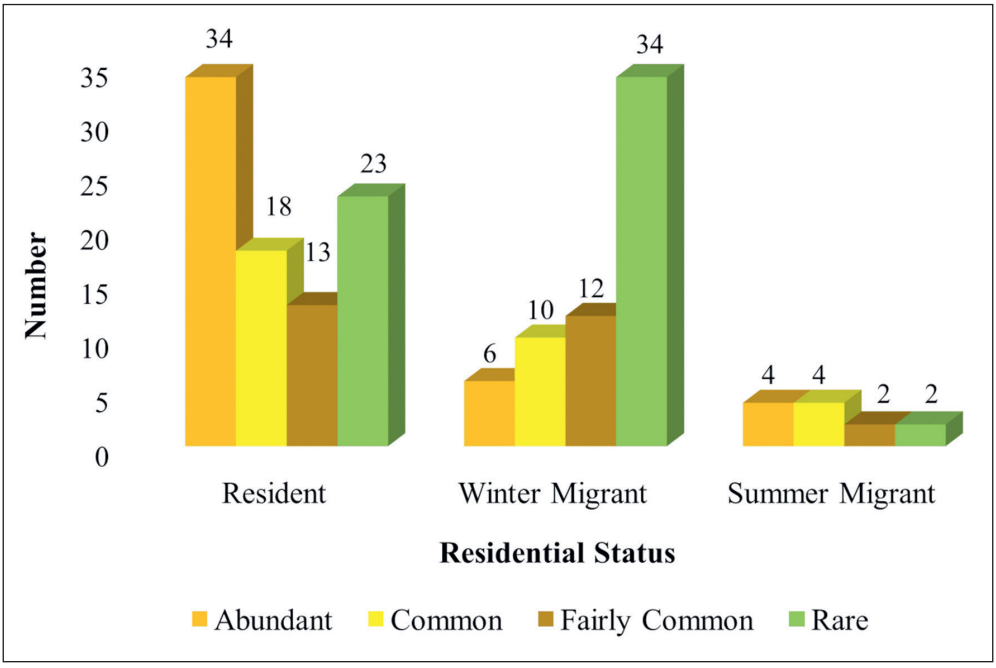


Figure 3. Relationship between residential status and local abundance status of recorded avian species

3. ábra A megfigyelt madárfajok helyi abundanciája és előfordulási státusza közti összefüggés

collected during the study period. Out of the 162 species, 34 species (20.98%) showed increasing population trends, 46 species (28.40%) displayed declining population trends, 57 species (35.18%) showed stable population trends and population trends of 25 species (15.44%) were unknown.

An analysis of global IUCN population trends based on the local abundance status of birds revealed that, among 44 abundant species, 27.27% exhibited an increasing trend (↑), 18.18% decreasing trends (↓), 34.10% remained stable (→), and 20.45% had an unknown trend (?). For 32 common species, 18.75% showed an increasing trend (↑), 37.50% decreasing trends (↓), 37.50% were stable (→) and 6.25% had an unknown trend (?). Similarly, among 27 fairly common species, 25.92% displayed an increasing trend (↑), 22.22% decreasing trends (↓), 37.03% were stable (→) and 14.81% had an unknown trend (?), while among 59 rare species, 15.25% displayed an increasing trend (↑), 33.90% decreasing trend (↓), 33.90% were stable (→), and 16.95% had an unknown trend (?) *(Figure 4)*. A comparison of local abundance and population trends revealed that eight species – Indian Spot-billed Duck *(Anas poecilorhyncha)*, Lesser Whistling-duck *(Dendrocygna javanica)*, Northern Pintail *(Anas acuta)*, Northern Shoveler *(Spatula clypeata)* (Anseriformes), Rock Dove *(Columba livia)* (Columbiformes), Intermediate Egret *(Ardea intermedia)*, Purple Heron *(Ardea purpurea)* (Pelecaniformes), Rufous Treepie *(Dendrocitta vagabunda)* (Passeriformes) – were abundant in the sanctuary, despite their globally declining population trends as reported by the IUCN.

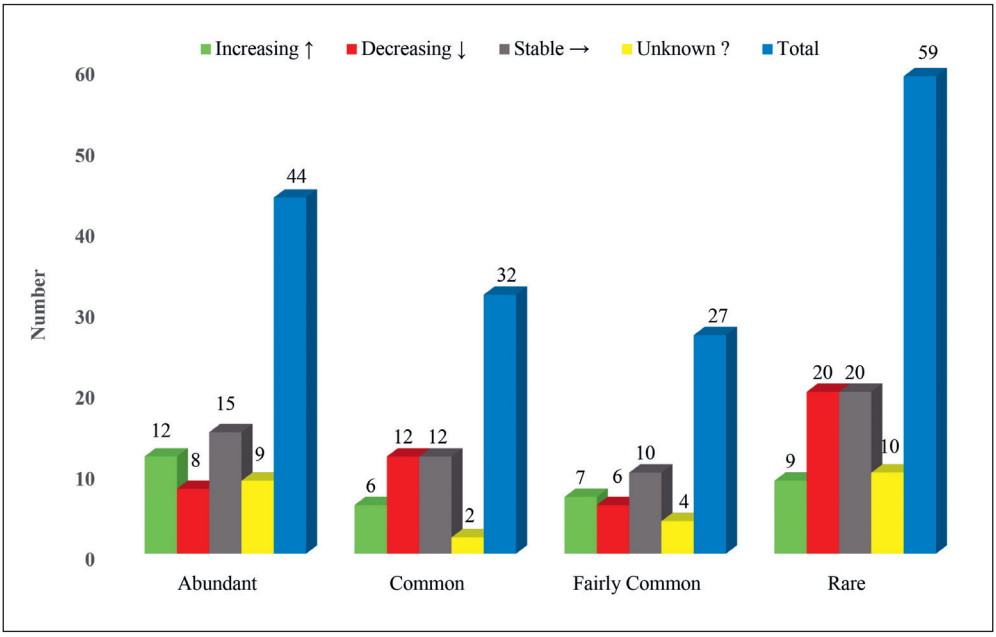


Figure 4. Local abundance status and its relationship with IUCN global population trends of recorded avian species

4. ábra A megfigyelt fajok helyi abundanciája és az IUCN által meghatározott világállomány-trend közötti összefüggés

Discussion

The avifaunal diversity of Chhilchhila Wildlife Sanctuary reflects a mosaic of ecological niches supporting a wide array of bird species. This study shows that the Chhilchhila Wildlife Sanctuary, a protected area, harbours 11.87% of the total avian species found across India (Praveen & Jayapal 2024) and 30.56% of the bird species recorded in Haryana (Kalsi *et al*. 2019). The findings indicate that the bird species diversity observed in this protected area aligns with previous studies conducted in other protected areas of Haryana, where species richness ranges from 104 to 164 species, i.e. Khaparwas Bird Sanctuary, district Jhajjar (Gupta *et al*. 2012), Sultanpur National Park, district Gurugram (Kaushik & Gupta 2016), Bhindawas Bird Sanctuary, district Jhajjar (Chopra *et al*. 2017), Kalesar National Park, district Yamunanagar (Rai *et al*. 2017), Bhindawas Bird Sanctuary, district Jhajjar (Singh & Malik 2019), Sultanpur National Park, district Gurugram (Rani *et al*. 2023). Among the recorded 18 orders, Passeriformes was the most species-rich, followed by Charadriiformes and Anseriformes. This finding is consistent with the general trend observed in other protected and non-protected areas of Haryana (Chopra *et al*. 2012, Rai *et al*. 2017, 2019, Rai & Vanita 2021, Parul & Kumar 2023, Rani *et al*. 2023), where passerines dominate the avian diversity due to their adaptability to a wide range of habitats and feeding behaviours (Beresford *et al*. 2005, Rai & Vanita 2023, Rai & Yadav 2023). The high number of species in Passeriformes also reflects the availability of diverse microhabitats and ecological niches

within the sanctuary, such as grasslands, wetlands, and forests, which support different foraging strategies and nesting requirements.

An analysis of the residential and migratory status revealed that the sanctuary serves as a year-round haven for resident species while also being a pivotal stopover and wintering site for migratory species. The presence of long-distance migrants, such as Anseriformes and Charadriiformes, highlights the sanctuary's role in sustaining migratory bird populations, consistent with observations in other Indian wetland habitats (Kumar *et al*. 2005, Sundar & Kittur 2013). Such dual functionality underscores the importance of conserving habitats that cater to both resident and migratory birds, particularly in the face of habitat loss and climate change. The migratory species from orders Anseriformes and Charadriiformes, significantly contribute to the seasonal variation in bird community composition, with some species such as the Northern Pintail *(Anas acuta)*, Garganey *(Spatula querquedula)*, Greylag Goose *(Anser anser)*, White-tailed Lapwing *(Vanellus leucurus)*, Common Snipe *(Gallinago gallinago)* and Common Redshank *(Tringa totanus)* using the sanctuary as a crucial stopover or wintering site. These migratory species highlight the importance of the sanctuary as a part of regional migratory flyways, and underscore the need for continuous monitoring to understand the long-term impacts of climate change on migratory patterns.

The conservation status of species, as assessed by the IUCN Red List, revealed a spectrum from Least Concern to Vulnerable. Notably, the presence of Vulnerable species such as the Common Pochard and River Tern highlights the sanctuary's role as a refuge for threatened taxa. The population trends of these species, marked by gradual declines due to habitat destruction and human disturbance, align with global trends reported by Wetlands International (2020) and BirdLife International (2024). It is also worth mentioning that the conservation status of three Near Threatened bird species recorded in the sanctuary were upgraded to the Least Concern as per the IUCN (2024), i.e. Painted Stork, Black-headed Ibis *(Threskiornis melanocephalus)* and Oriental Darter.

However, the study also identified challenges that threaten the sanctuary's ecological integrity, including habitat fragmentation, anthropogenic pressures and potential impacts of climate change. While the sanctuary is protected under the Indian Wildlife Protection Act, 1972 (IWPA 1972), illegal fishing, grazing and deforestation in certain parts of the sanctuary continue to affect bird populations. The construction of nearby infrastructure and agricultural activities are contributing to habitat fragmentation, which could negatively impact migratory and resident species in the long term. Addressing these challenges requires effective conservation strategies, including stricter enforcement of protection laws, community engagement, and sustainable resource management practices. Further monitoring is recommended to track the impact of climate change on migratory patterns and to assess the sanctuary's ability to sustain its avifauna in the long term.

Conclusion

The Chhilchhila Wildlife Sanctuary, located in Haryana, India, represents a crucial habitat for avifaunal diversity, harbouring a wide array of bird species, including both resident and

migratory populations. This study provides a comprehensive assessment of the avifaunal diversity within the sanctuary, documenting 162 bird species spanning 118 genera, 56 families and 18 orders. The findings highlight the sanctuary's role as a critical refuge for species of ecological, conservation, and aesthetic importance. Seasonal variations in species composition underscore the sanctuary's significance for migratory birds, further emphasizing its role as part of the larger regional and global flyways. The ecological significance of this protected area is heightened by the presence of two bird species classified as Vulnerable and two as Near Threatened on the IUCN Red List, along with 46 species exhibiting declining global population trends. In conclusion, the Chhilchhila Wildlife Sanctuary serves as an indispensable avian habitat and a vital component of regional biodiversity. Continued research, coupled with effective management strategies, is essential to monitor and preserve the sanctuary's avifaunal diversity, ensuring its contribution to ecological balance and biodiversity conservation remains intact.

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Diversity of avifauna in relation to habitat types in selected areas of Guinea savanna zone of Nigeria

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Abstract Human disturbances have degraded Nigeria's dense vegetation and this is leading to a continuous habitat destruction of avian species in the Guinea Savanna zone of Nigeria. This study investigated the diversity of avifauna in relation to habitat types in selected areas of Guinea Savanna zone of Nigeria. The point count method was used to record bird species richness and abundance in four stratified habitats – forest, woodland, grassland, and riverside. A total of 2,545 individuals from 50 families of 136 species were recorded across 64 sampling points in the four habitats, in 2023 and 2024. The forest habitat had the highest species richness (86), followed by woodland (85) and grassland (54). The difference was only significant through pairwise comparisons that is between forest and grassland as well as between woodland and grassland. Riverside habitat had the highest abundance (54.5.0±38.7) while grassland had the least (28.1±8.93). The difference in abundance significantly varied across habitat types. Meanwhile, the woodland habitat recorded the highest bird species diversity (2.59). Common Bulbul *(Pycnonotus barbatus)* – a generalist – had the highest relative abundance while White-faced Whistling Duck *(Dendrocygna viduata)* had the highest abundance in a single habitat, the riverside habitat, recognized as a specialist. In conclusion, the diversity index of bird species was high in all the habitats with no significant difference, and therefore, the results highlighted the importance of habitat diversity in the Guinea Savanna zone. Conservation efforts should focus on protecting and restoring habitats, particularly forests and woodlands, to maintain the rich avifaunal diversity of the region.

Keywords: avifauna, abundance, habitat type, species richness, diversity, Guinea savanna

Összefoglalás Nigéria sűrű vegetációját az emberi zavarás jelentősen degradálta, ami folyamatos élőhelypusztulást eredményez a madárfajok számára Nigéria guineai szavanna-övezetében. A jelen tanulmány a madárfauna sokféleségét vizsgálta az élőhelytípusokkal összefüggésben, a guineai szavanna-övezet néhány kiválasztott területén. A pontszámlálásos módszert alkalmazva négy rétegzett élőhelytípusban – erdő, nyílt erdő (woodland), gyep és vízpart – rögzítettük a madárfajok gazdagságát és egyedszámát. 2023 és 2024 során összesen 2545 egyedet regisztráltunk, 136 fajból, 50 család képviseletében, 64 mintavételi ponton. Az erdei élőhelyen volt a legnagyobb fajgazdagság (86 faj), ezt követte a nyílt erdő (85 faj), majd a gyep (54 faj). A különbség csak páronkénti összehasonlításban bizonyult statisztikailag szignifikánsnak: az erdő és a gyep, valamint a nyílt erdő és a gyep között. A legnagyobb egyedszámot a vízparti élőhelyen figyeltük meg (átlagosan 54,5±38,7), míg a legalacsonyabbat a gyepen (átlagosan 28,1±8,93). Az egyedszám jelentősen eltért az egyes élőhelytípusok között. Ezzel szemben a madárfajok diverzitása a nyílt erdőben volt a legmagasabb (Shannon-index: 2,59). A legnagyobb relatív abundanciával a közönséges bülbül *(Pycnonotus barbatus)* – egy generalista faj – rendelkezett, míg az apáca-fütyülőlúd *(Dendrocygna viduata)* egyetlen élőhelyen, a vízparton mutatott kiemelkedően magas egyedszámot, így specialistának tekinthető. Összességében a madárfauna diverzitási indexe minden élőhelyen magas volt, szignifikáns különbség nélkül, ami kiemeli az élőhelyi sokféleség fontosságát a guineai szavanna övezetben. A természetvédelmi erőfeszítéseknek az élőhelyek – különösen az erdők és nyílt erdők – megóvására és helyreállítására kell összpontosítaniuk, hogy fenntartható maradjon a térség gazdag madárvilága.

Kulcsszavak: madárfauna, abundancia, élőhelytípus, fajgazdagság, diverzitás, guineai szavanna

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Introduction

The Guinea Savanna zone of Nigeria is a vital component of the West African savanna ecosystem, covering approximately 30% of the country's land area (Adebayo *et al*. 2015). This region is characterized by diverse habitats, including woodlands, grasslands, and farmlands, which support a wide range of plant and animal species (Ibrahim *et al*. 2024). Among these, birds are an important component of the ecosystem, playing crucial roles in pollination, seed dispersal, and pest control (Whelan *et al*. 2008). They are also bio-indicators of healthy ecosystems, birds of prey (raptors) eat up carcasses, thereby cleaning the environment (Egwumah *et al*. 2017).

About 2,300 species of birds are identified in Africa of which 975 species occurred in Nigeria (Avibase 2023, Clements *et al*. 2023). Avian species constitute the most common fauna of all habitat types and they are responsive to changes in Nigerian environment (Birdlife International 2018).

Avifaunal diversity is closely linked to habitat diversity, and changes in habitat structure and composition can have significant impacts on bird populations (Fahrig 2003). The Guinea Savanna zone is facing numerous environmental challenges, including habitat fragmentation, deforestation, and climate change, which threaten the long-term survival of many bird species (IPPC 2013).

Despite the importance of the Guinea Savanna zone for avifaunal diversity, there is a paucity of information on the relationship between habitat types and bird species diversity in this region (Afolayan *et al*. 2015). The aim of this study was to investigate the diversity of avifauna in relation to habitat types in selected areas of the Guinea Savanna zone of Nigeria, to provide insights into the conservation of bird species and their habitats in this critical ecosystem.

Materials and Methods

Description of the study area

The study area covered selected parts of the Guinea Savanna zone of Nigeria on latitude 7°42′55.29″N – 11°5′55.62″N and longitude 4°0′44.05″E – 8°43′53.40″E. Almost half of the territory of Nigeria is occupied by Guinea Savanna. The annual precipitation is 1000–1400 mm on the average. The plots of these savannas border the banks of the rivers with gallery forests. The grass reaches above 2 m height. Among the savanna vegetation in Nigeria,

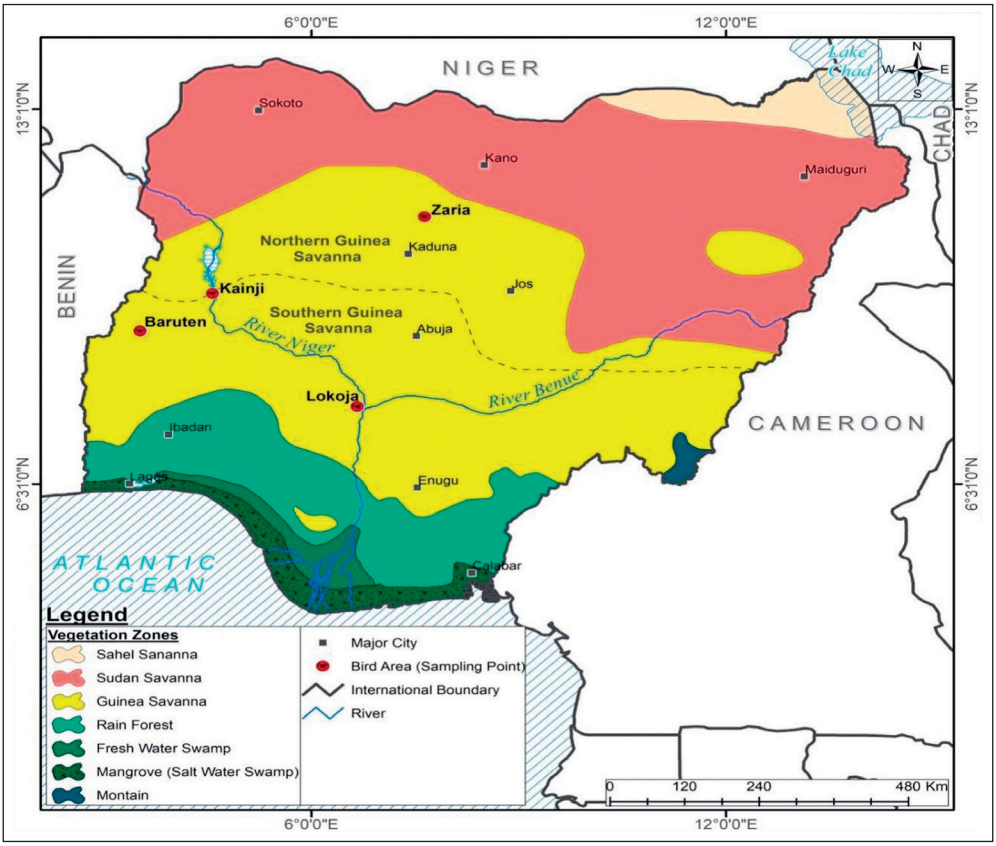


Figure 1a Vegetation map of Nigeria showing sampling locations (Source: Modified from Moberg & Esu 1991)
1a ábra Nigéria növényzeti térképe a vizsgálati pontokkal (Moberg és Esu 1991 módosítva)

various types of so-called elephant grass predominate. The ecological zone is known with two seasons; dry season (November–February) and wet season (March–October). The Guinea Savanna is composed of the northern Guinea Savanna and southern Guinea Savanna *(Figure 1a)*. The northern part is covered with grasses, with scattered trees and shrubs dominate the vegetation. Trees are shorter and thorny and are fewer in numbers than in the southern Guinea Savanna (Kupika *et al*. 2017, Makinwa 2017).

Study design

The study was conducted in purposively selected areas of the Guinea Savanna vegetation, considering especially forests, woodlands, and rivers/lakes around Important Bird Areas (IBAs), including protected reserves within the region as shown in *Figure 1*. The specific areas selected by authoritative sampling are: ABU Phase II forests, ABU dam (Zaria, Kaduna State); Federal University, Lokoja forests, River Lokoja (Lokoja, Kogi State); Western Borgu forests, River Moshi (Baruten, Kwara State), Kainji Lake National Park and Kainji dam (Kainji, Niger State). These sampling sites are listed in *Table 1*.

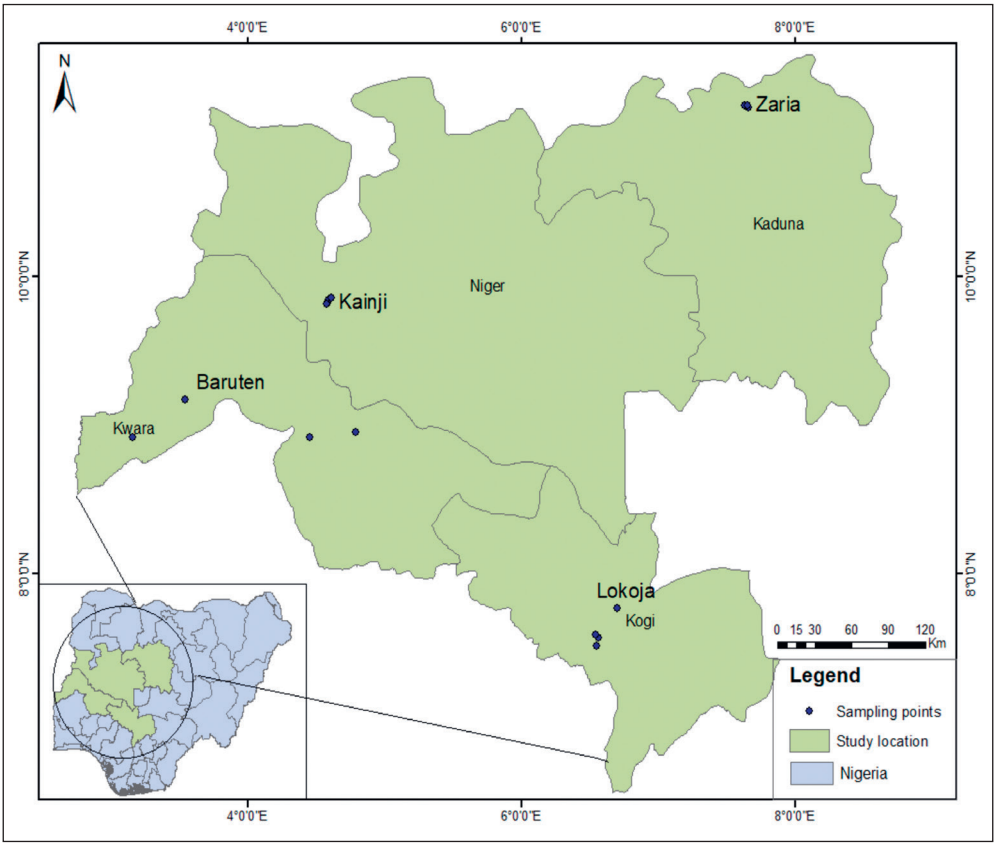


Figure 1b Sampling sites and points in Guinea Savanna zone of Nigeria (Source: ArcGIS 10.8 Version)
1b ábra Mintavételi helyek és pontok Nigéria guinea szavanna zónájában (ArcGIS 10.8 verzió)

The area was stratified into natural habitats (Forest, Woodland, Grassland and Riverside). Then, the position of each habitat was Geo-referenced by coordinates taken using a hand-held GPS, Model N9 GARMIN eTrexLegend personal navigator.

Random sampling method was employed to select four permanent counting points of 30 m radius with a distance of at least 100 m apart (Jankowski *et al*. 2009) using Geographical Information System (GIS). Each of the four habitat types had four points in four sites of the study area, making a total of 64 sampling points. The Point Count Method was adopted, and the most suitable for the uneven terrain and dense undergrowth in which detection of birds using other techniques may be difficult (Fiala *et al*. 2006).

Determination of bird species composition and abundance

Birds were counted in each sampling point. Here, upon reaching a point, birds were immediately counted on sight or hearing of their sounds/calls (Bryan *et al*. 1984). Ten minutes was used to count and record all birds observed or heard within 30 m radius (Terborgh *et al*. 1990, Robinson *et al*. 2000)

Table 1. Sampling locations within Guinea Savanna Zone with their coordinates in the study area
1. táblázat A mintavételi helyek a Guinea Szavanna Zónán belül a területek koordinátáival

S/N	Sampling locations	Central coordinates	Habitat type
1	Ahmadu Bello University Phase II	11°11′60″N – 7°41′59.9″E	Forest
2	Ahmadu Bello University Dam	11°7′60″N – 7°39′59.8″E	Riverine
3	Area BZ, ABU- Zaria	11°09′28″N – 07°37′56″E	Woodland/Grassland
4	Kainji Lake National Park	10°21′59″N – 4°32′59.9″E	Forest/Woodland/ Grassland
5	Kainji Dam	9°8′25″N – 4°59′33″E	Riverine
6	Borgu Game Reserve, Baruten	10°02′27″N – 4°03′36″E	Forest/Woodland/Grassland
7	River Moshi, Baruten	9°9′22″N – 4°25′36″E	Riverine
8	Federal University, Lokoja	6°31′0″N – 3°23′10″E	Forest/Woodland/Grassland
9	River Niger, Lokoja	7°45′51″N – 6°41′45″E	Riverine

The recording of birds was conducted from 6:30–10:30 in the morning and from 16:00–18:00 in the evening of the same day, as this is the period when most birds are active (Bryan *et al*. 1984). Observation of birds were done with naked eyes, sound/calls and binoculars 12 × 32 m (Model: 1080P), where they were far away or similar with one another. The date, bird species, number, habitat type, were recorded and coordinates were taken using a hand-held GPS (Model N9 GARMIN eTrexLegend) personal navigator. Based on field guides of Borrow and Demey (2013), birds were identified to the species level. The abundance of each species of bird was recorded and the mean abundance was determined for each.

$$\text{Relative abundance} = (ni / N) \times 100$$

where ni = number of individuals of bird species in an area, and N = total number of individuals in that community.

Data analyses

Bird species diversities and richness were determined using Shannon–Wiener Diversity Index using R Core Team (2022). One-way ANOVA was used to compare mean abundance of birds, as well as diversities across habitats and locations of study. Tukey HSD test was used as a *post-hoc* for pairwise comparisons where a significance difference was shown. Generalized Linear Model (GLM) with family Poisson was used to compare bird richness across habitats.

'Vegan and Biodiversity R' were used to plot rank abundance and species accumulation curves while Bray–Curtis distance was used to compare similarity of bird species across habitats.

A P-value threshold of ≤ 0.05 was considered statistically significant using R-Statistics package for Windows version 4.1.2 (R Core Team 2022).

Result

Bird species composition and abundance in habitat types of the study area

A total of 2,545 birds were recorded across the 64 sampling points in four habitats, four sites and in two years of study. The recorded species were from 50 families of 136 species, and the distribution of the first 20 species across habitat types and relative abundance in the study area is presented in *Table 2*.

Table 2. Bird species composition based on their relative abundance in the study area
2. táblázat A fajösszetétel a relatív abundanciáik alapján

S/N	Habitat	Common name	Scientific name	Family	Abundance	Rel. Abundance
1	Riverside	White-faced Whistling Duck	*Dendrocygna viduata*	Anatidae	172	19.725
2	Riverside	Spur-wing Lapwing	*Vanellus spinosus*	Charadriidae	62	7.110
3	Forest	Common Bulbul	*Pycnonotus barbatus*	Pycnonotidae	51	7.634
4	Riverside	Ethiopean Swallow	*Hirundo aethiopica*	Hirudinidae	49	5.619
5	Riverside	Common Bulbul	*Pycnonotus barbatus*	Pycnonotidae	48	5.505
6	Grassland	Bronze Mannikin	*Spermestes cucullatus*	Estrildidae	46	10.222
7	Forest	Piapiac	*Ptilostomus afer*	Corvidae	43	6.437
8	Forest	Bronze Mannikin	*Spermestes cucullatus*	Estrildidae	42	6.287
9	Forest	Long-tailed Starling	*Lamprotormis caudatus*	Sturnidae	39	5.838
10	Grassland	Common Bulbul	*Pycnonotus barbatus*	Pycnonotidae	38	8.444
11	Woodland	Common Bulbul	*Pycnonotus barbatus*	Pycnonotidae	37	6.666
12	Riverside	Cattle Egret	*Bubulcus ibis*	Ardeidae	31	3.555
13	Riverside	Brown Barbler	*Turdoides plebejus*	Timaliidae	29	3.325
14	Woodland	Piapiac	*Ptilostomus afer*	Corvidae	29	5.225
15	Woodland	Long-tailed Glossy Starling	*Lamprotormis caudatus*	Sturnidae	28	5.045
16	Forest	Village Weaver	*Ploceus cucullatus*	Ploceidae	27	4.041
17	Riverside	Long-tailed Glossy Starling	*Lamprotormis caudatus*	Sturnidae	26	2.981
18	Woodland	Vinacious Dove	*Turtur abyssinicus*	Columbidae	26	4.684
19	Forest	Brown Barbler	*Turdoides plebejus*	Timaliidae	25	3.742
20	Riverside	Yellow-crowned Gonolek	*Laniarius barbarous*	Malaconotidae	25	2.866

ANOVA results indicated that mean bird species abundance varied significantly across habitat types ($F(3) = 5.2651$, $P = 0.006$), ranging from 28.1 ± 8.93 in grassland to 54.5 ± 38.7 at riverside *(Figure 2)*. Post-hoc Tukey HSD tests revealed no significant pairwise differences among most habitats, except between riverside and woodland, and riverside and grassland, where significant differences were detected ($P < 0.05$) *(Table 3)* .

Species richness ranged from 54 on grassland to 86 in forest. The difference between any two habitats was statistically significant (GLM: $Chi^2 = 10.182$, $df = 3$, $P = 0.017$). However, the difference was only through a pairwise comparison, between forest and grassland ($P = 0.03$); and grassland and woodland ($P = 0.04$) *(Figure 3)*. Bird species diversity (SWI) did not differ significantly across habitat types ($P = 0.148$). It ranged from 2.32 on grassland to 2.59 on woodland *(Figure 4)*. The similarity indices showed the distance apart between one habitat and the other. Since it is a distance matrix, the higher the values the father apart are the habitats *(Table 4)*.

The closest value to zero (0) under forest is 0.456311 in woodland which clearly showed the most similar bird species recorded while 0.622727 in riverside was the farthest to forest which revealed that there was little or no similarity of bird species recorded among those habitats *(Table 4)*.

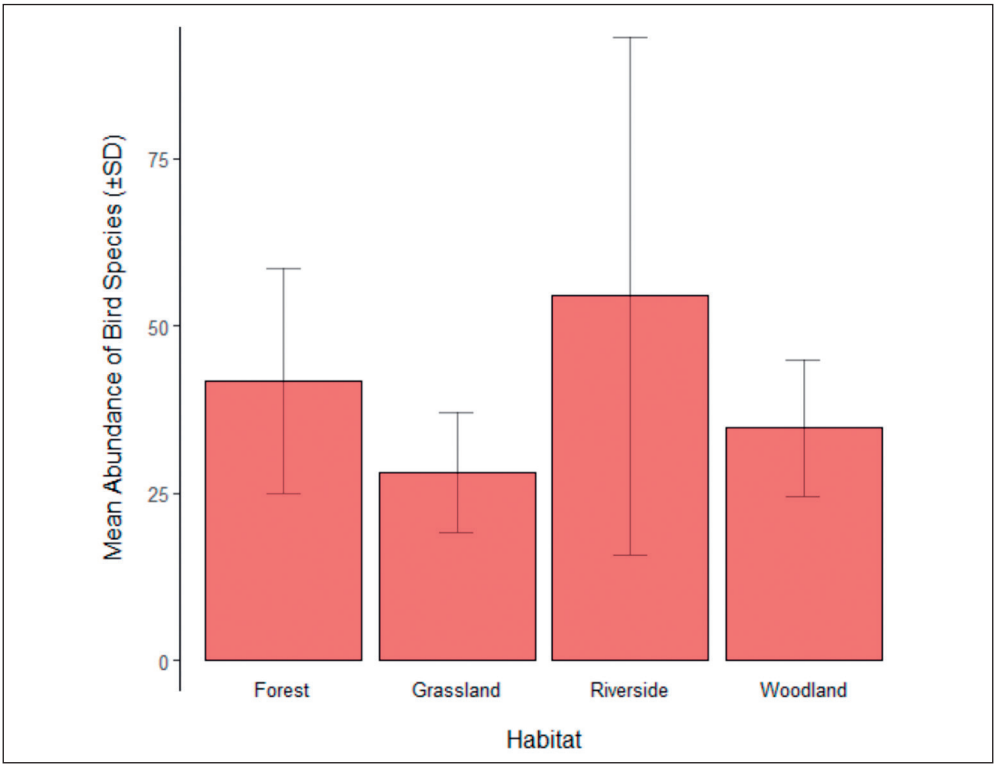


Figure 2. Mean abundance of bird species across habitat types in the study area (ANOVA: $F(3) = 5.2651$, $P = 0.006$)

2. ábra A madárfajok átlagos abundanciája a különböző élőhelyek között (ANOVA: $F(3) = 5.2651$, $P = 0.006$)

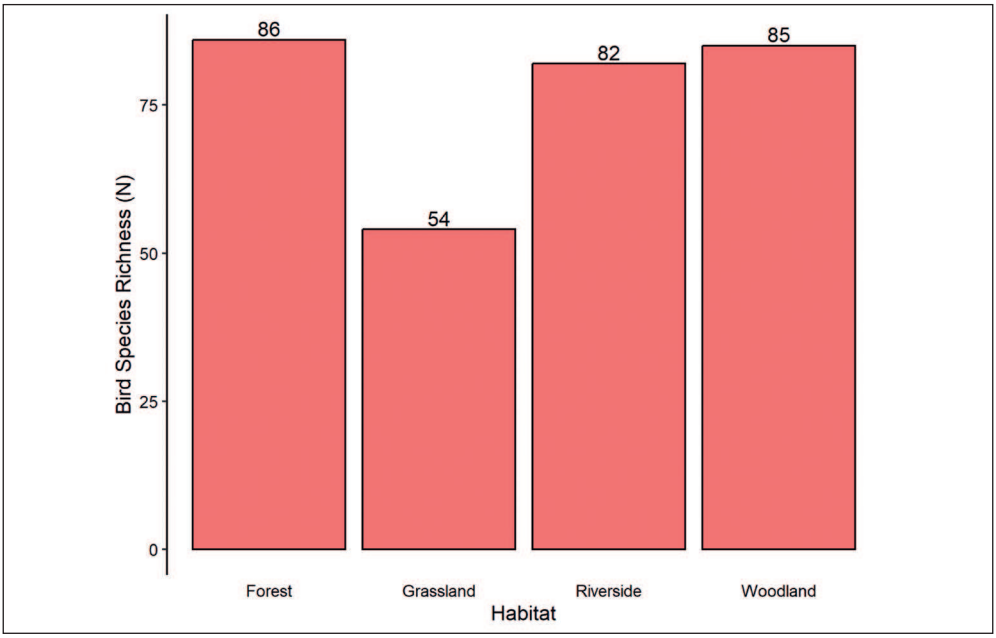


Figure 3. Species richness of birds across habitats in the study area (GLM: $Chi^2 = 10.182$, df = 3, P = 0.017)

3. ábra Fajgazdagság a különböző élőhelyek között (GLM: $Chi^2 = 10.182$, df = 3, P = 0.017)

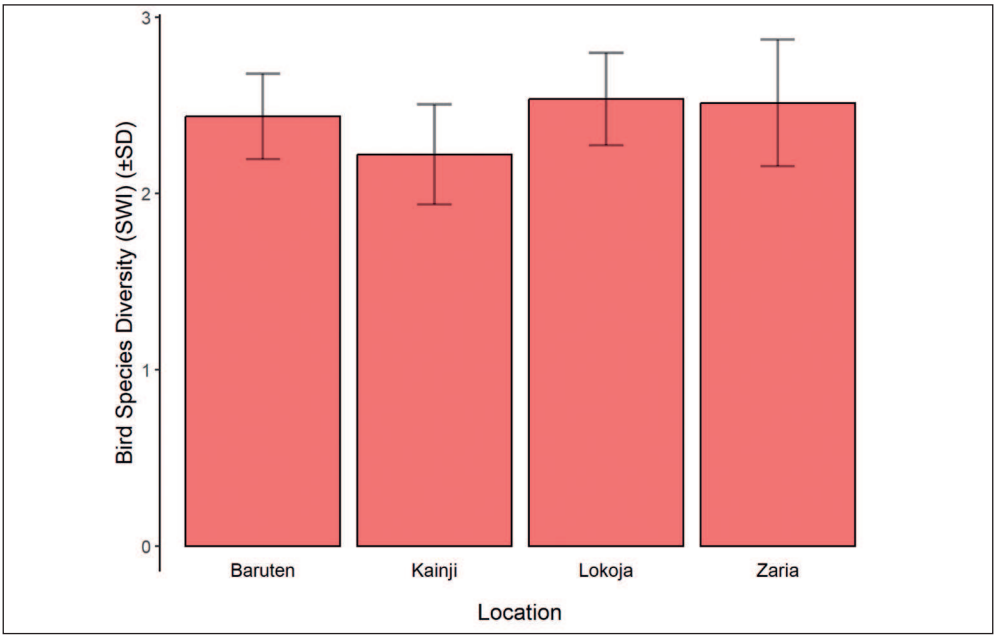


Figure 4. Bird species diversity across all habitats in the study area (ANOVA: F3 = 2.1461, df = 3, P = 0.148)

4. ábra A madárfajok diverzitása az élőhelyek között (ANOVA: F3 = 2.1461, df = 3, P = 0.148)

Table 3. *Post-hoc* test of mean abundance of bird species across habitats in the study area
3. táblázat A fajok élőhelyek közötti átlagos abundanciájának *post-hoc* tesztje

Habitat	Difference	Lower bound	Upper bound	P-value
Grassland-Forest	-13.625	-32.0464	4.796391	0.179542
Riverside-Forest	12.750	-5.6714	31.17139	0.222397
Woodland-Forest	-7.062	-25.4839	11.35889	0.674234
Riverside-Grassland	26.375	7.9536	44.79639	0.005357
Woodland-Grassland	6.562	-11.8589	24.98389	0.720293
Woodland-Riverside	-19.812	-38.2339	-1.39111	0.033875

s = significant; ns = not significant at P = 0.05

Table 4. Similarity Distance (Bray–Curtis Distance) across habitats in respect to bird species in the study area
4. táblázat Az élőhelyek közötti Similarity Distance (Bray–Curtis távolság) a vizsgálati területen található madárfajok tekintetében

	Forest	Grassland	Riverside	Woodland
Forest	0	0.568238	0.589286	0.456311
Grassland	0.568238	0.000000	0.611675	0.572539
Riverside	0.589286	0.611675	0.000000	0.622727
Woodland	0.456311	0.572539	0.622727	0.000000

Note: Bray–Curtis's distance estimates the dissimilarity of habitats based on presence/absence and number of bird species in each habitat. The value ranges from 0 (which means perfect similarity and no difference in bird species composition) to 1 (which means any two habitats do not share any bird species in common). Therefore, the higher the values the farther apart the habitats.

The overall ranking among all bird species recorded across the habitat types was the Common Bulbul *(Pycnonotus barbatus)* as the first *(Figure 5)*. The cumulative number of bird species across the 64 sampling points showed that newer species were recorded as we counted from the first sampling point to the last. The curve reveals that more newer species will be recorded if the study period was extended *(Figure 6)*.

Discussion

There are factors which influence the high number of bird species in the Guinea Savanna zone of Nigeria, in the habitats studied. The highest bird species abundance observed in the riverside habitat was largely a result of the water bodies around the habitat where many species in high numbers converge for feeding and breeding since such habitats have water, food and nesting materials. This record of high abundance could also be attributed to the fact that most bird species use river channels as corridors of migration to other landscapes for their wellbeing. This agrees with the report of Sinha *et al*. (2019) that birds use riverine environments and wetlands for breeding, nesting and habituating young, as a source of drinking water, feeding, resting, shelter and for social interaction. The habitat is also unique because of the large number of White-faced Whisling Duck *(Dendrocygna viduata)* which

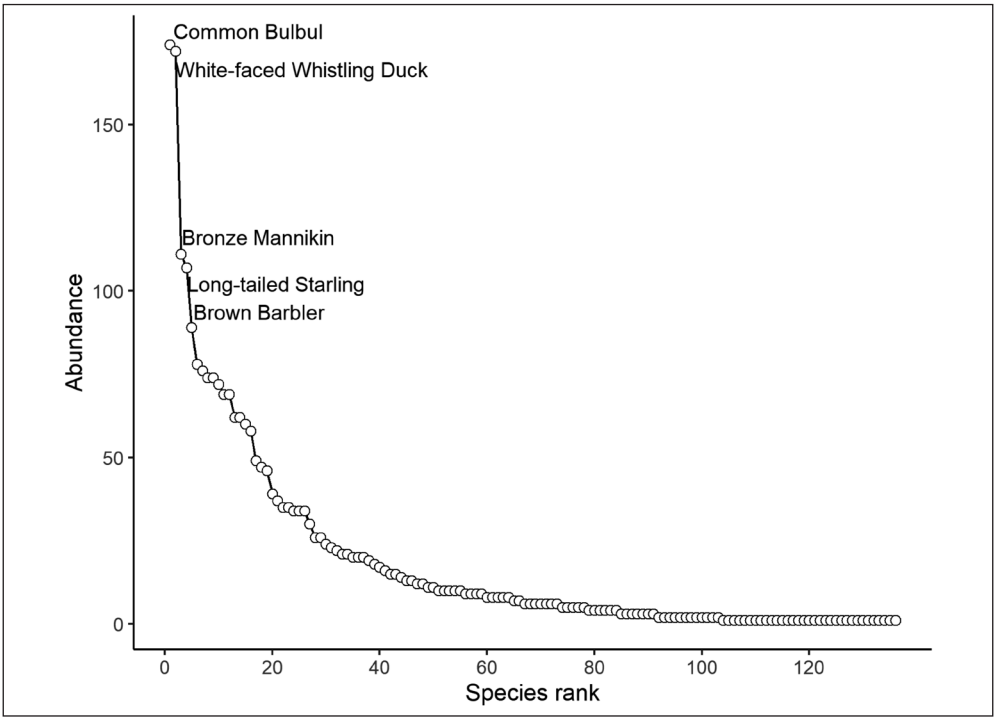


Figure 5. Overall bird species ranking by abundance across all habitats and sites in the study area
5. ábra A madárfajok összesített rangsora a vizsgált terület összes élőhelyén és helyszínén a madárfajok gyakorisága alapján

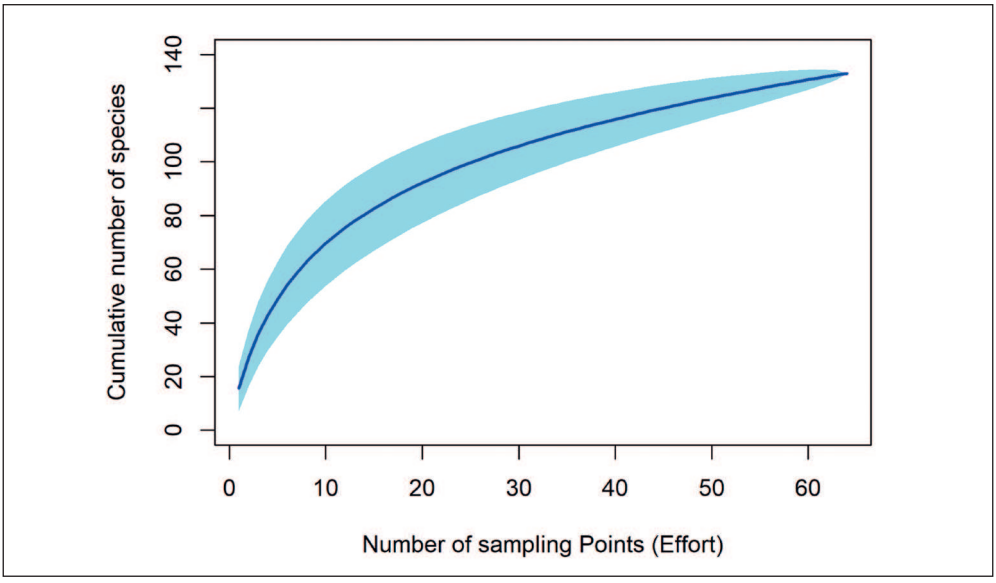


Figure 6. Cumulative number of bird species by sampling points in the study area
6. ábra A madárfajok összesített száma a vizsgált terület mintavételi pontjai szerint

are gregarious in nature. Ringim *et al.* (2019) also recorded this species with the highest abundance across some IBAs in Nigeria and attributed it to the protection of the areas.

Meanwhile, the forest habitat recorded the highest species richness, and it is next to riverside in terms of abundance due to its complexity of more trees with close canopy. The presence of trees with understory vegetation in this area provided food resources, breeding habitat and cover for the birds. Again, this habitat has a suitable nesting environment for several bird species. Okosodo and Okosodo (2020) reported a high number of bird species in a study in Okomu National Park, Nigeria. Meanwhile, Askins *et al*. (2012) reported that the more complex the structure or composition of the vegetation, the more likely that habitat will contain more bird species.

The high species richness and abundance in the woodland habitat is not unrelated to the habitat's proximity with the forest, since there were similar species recorded in both habitats. The open vegetation of the habitat is also an added advantage for several species that enjoy flight between trees at short distances like the Northern Red-billed Hornbill *(Tockus erythrorhynchus),* Green Wood Hoopoe *(Phoeniculus purpureus)* and the starlings. The high number of species and their abundance here could be attributed to the fact that woodland serves as the boundary between forest and grassland habitats, and birds that are both specialists and generalists were recorded. This is in compliance with many other studies like Clergeau *et al*. (1998), Chace and Walsh (2006) and Sandstrom *et al*. (2005) that high vegetation of woodland support higher diversity of birds.

Furthermore, the grassland habitat recorded the least species richness and abundance possibly due to the lowest number of tree population and probably it is too open for some species of birds to hide from predators. It may also largely be related with non-availability of certain food items but mainly grasses and seeds. This was evidenced by the sights of granivores like Laughing Dove *(Spilopelia senegalensis)*, Red-eyed Dove *(Streptopelia semitorquata)* and the finches. The findings of this research agree with the report of Chace and Walsh (2006) who concluded that human-disturbed grassland areas provide heterogeneous habitats which attract human tolerant bird species. Higher abundance per species counts and density near settlements could have contributed by few species that can coexist with humans such as Bronze Mannikin *(Spermestes cucullatus)* and Common Bulbul.

The highest similarity of bird species that was found between forest and woodland habitats is attributed to the fact that the habitats are closely related in terms of tree population, with woodland having open canopy while forest has closed canopy. This is similar to the study of Johnsingh and Joshua (1994) who found 52% similarity in bird species between secondary vegetation and dry deciduous forest. Bideberi (2013) also had high similarity between forest and woodland habitats in a study on bird species diversity in relation to habitat types. Both generalists and specialists' bird species were found in these habitats. This is explained by the availability of ecological requirements for the species offered by a mixture of an environment with garden patches (Shochat *et al*. 2010). This highlights the fact that, while species may be similar between habitats, there is still a difference in requirement hence it is important to conserve a mosaic of natural habitats.

The overall abundance showed a distribution pattern of bird species according to the spatial structure of the environment and habitat requirement. This explains habitat specificity

and generalization that was observed. For example, Common Bulbuls ranked first in all habitat types except in riverside, but it ranked the overall highest abundance because they are generalists. Meanwhile, the cumulative species curve revealed high diversity of bird species since newer species were encountered from one sampling point to the other. This corresponds with Tanko *et al*. (2022) who reported a similar curve of recording new species within sampling points in different habitats.

Climate change is also likely to impact avifaunal diversity in the Guinea Savanna zone of Nigeria. Changes in temperature and rainfall patterns may alter the distribution and abundance of bird species, as well as the availability of food resources (IPCC 2013). Therefore, conservation efforts should focus on protecting and restoring habitats, as well as promoting sustainable land-use practices that can help to mitigate the impacts of climate change.

In conclusion**,** this study revealed that forest, woodland and riverside habitats are most suitable for bird species diversity. The findings also underscore the importance of habitat heterogeneity in maintaining avifaunal diversity. It is recommended that sustainable land-use practices such as agroforestry and permaculture should be promoted to reduce habitat fragmentation and degradation.

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First data on bird species composition of Djebel Aïssa National Park, Southwestern Algeria

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Abstract Algeria has a diverse bird fauna, yet data from arid and semi-arid regions are scarce. To fill this knowledge gap, we conducted a study on the composition and conservation status of bird species of Djebel Aïssa National Park in the Naama province of Southwestern Algeria between September 2021 and September 2023. We collected data by using progressive frequency sampling (PFS) and line transects, which allowed us to systematically assess bird species across different habitats within the park. We recorded 94 species of birds belonging to 11 orders and 27 families. Passeriformes was the most abundant order, comprising 16 families and 67 species. The bird species detected were predominantly sedentary (50%) or wintering (39%), and some were visiting (8%) or migratory (3%). Most species were insectivores (45%), followed by granivores/insectivores (24%), carnivores (13%), omnivores (7%), granivores (6%), and carnivores/insectivores (5%). Most bird species were classified as "Least Concern" by the IUCN Red List, two species were "Near Threatened", and one was "Vulnerable". In addition, 29 species are protected under Executive Fiat 12–235 of 24 May 2012. Our study provides a baseline for future monitoring efforts and a basis for the development and implementation of conservation strategies in Djebel Aïssa National Park and the surrounding regions.

Keywords: birds, monitoring, species composition, conservation, Djebel Aïssa National Park

Összefoglalás Algéria változatos madárfaunával rendelkezik, azonban a száraz és félszáraz területekről kevés adat áll rendelkezésre. Ennek a tudáshiánynak a pótlására felmértük a délnyugat-algériai Naama tartományban, a Djebel Aïssa Nemzeti Parkban élő madárvilág összetételét és természetvédelmi helyzetét egy kétéves időszakban, 2021 szeptembere és 2023 szeptembere között. Az adatokat progresszív gyakoriságú mintavétel (PFS) és vonalas transzektek mentén gyűjtöttük, mely lehetővé tette a madárfajok szisztematikus felmérését a park különböző élőhelyein. A vizsgálat során 94 madárfajt rögzítettünk, amelyek 11 rendbe és 27 családba tartoztak. A verébalakúak (Passeriformes) volt a legnagyobb számban képviselt rend, mely 16 családot és 64 fajt foglalt magába. Az észlelt madárfajok túlnyomó része állandó (50%) vagy telelő (39%) faj volt, néhány kóborló (8%) vagy vonuló (3%) fajjal. A legtöbb faj rovarevő volt (45%), ezt követték a magevők/rovarevők (24%), ragadozók (13%), mindenevők (7%), kizárólag magevők (6%) és ragadozók/rovarevők (5%). A madárfajok többsége az IUCN Vörös Lista szerint nem fenyegetett státuszú, két faj mérsékelten fenyegetett, egy faj pedig közel veszélyeztetett helyzetű volt. A 2012. május 24-i 12-235. számú végrehajtási utasítás értelmében 29 faj részesül védelemben. Tanulmányunk viszonyítási alapot szolgáltat a jövőbeli monitorozási erőfeszítésekhez, valamint a természetvédelmi stratégiák kidolgozásához és végrehajtásához a Djebel Aïssa Nemzeti Parkban és a környező régiókban.

Kulcsszavak: madarak, monitorozás, fajösszetétel, természetvédelem, Djebel Aïssa Nemzeti Park

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Introduction

Protected areas play a vital role in the conservation of biodiversity (Oldekop *et al.* 2016, Feng *et al.* 2021, Pulido-Chadid *et al.* 2023). National Parks and biosphere reserves have long been regarded as key sites for research on the environment, biodiversity, conservation and sustainable development (Yoccoz *et al*. 2001). Therefore, biodiversity monitoring is an essential component of protected area management (Mandeville *et al.* 2023). This process involves a continuous and systematic study of various elements of biodiversity to assess their current status, identify potential threats, and detect patterns of change (Hochkirch *et al.* 2021). Effective biodiversity monitoring is crucial for evaluating the success of conservation efforts and guiding management decisions in protected areas (Rodrigues & Cazalis 2020).

Studies on animal community diversity offer a direct approach to assessing species richness and composition, as well as the relative abundance of individual species (Robinson 1999, Magurran 2004, Sigel *et al*. 2006, Laurance *et al.* 2008). Such data are particularly relevant in protected areas, where they inform the development of effective conservation and management programs. In these contexts, human activities should focus on the sustainable use of natural resources while ensuring the protection of biodiversity (Sigel *et al.* 2006, Negrões *et al.* 2011).

Avifaunal diversity is an important component of biodiversity and serves as a vital environmental indicator due to birds' essential ecological roles, such as pollination, pest control, predation and seed and propagule dispersal (Sekercioglu 2006). Avifaunal biodiversity has faced severe declines, mainly due to habitat fragmentation, human activities and the proliferation of non-native species (Stanton *et al.* 2018). Unfortunately, the current availability of accurate and publicly accessible information regarding bird diversity in numerous regions is limited, potentially leading to a significant underestimation of losses occurring in various areas (Politi *et al.* 2021).

Algeria is renowned for its remarkable climatic diversity, spanning from humid to Saharan climates (Stevenson *et al.* 1988). Arid and semi-arid landscapes are pivotal ecosystems that provide breeding and foraging grounds for many avian species, including those facing endangerment (Ogendi & Ondieki 2020). Studies on bird diversity and composition in Southwestern Algeria are scarce, with few historical investigations primarily focused on this region. Research on bird diversity and ecology in this region includes significant studies such as those by Blondel (1962), Heim de Balsac (1979), Ledant *et al.* (1981), Isenmann and Moali (2000), Mostefai and Grenot (2006), as well as recent work on the trophic ecology of the Royal Eagle by Djilali *et al.* (2023). The most recent update on bird diversity in Naama province (Southwestern Algeria) is provided by the checklist compiled by Youcefi and Marouf (2022).

The aim of this study was to gain knowledge on the composition and diversity of bird species in Djebel Aïssa National Park, a newly established park located in the Naama province of Southwestern Algeria. To date, no information has been available on the faunal diversity of the park, particularly concerning avian species, which should be the foundation for effective conservation efforts.

Material and Methods

Study area

Djebel Aïssa National Park is located in the Ksour Mountains, in the commune of Ain Sefra in the province of Naama of Southwestern Algeria *(Figure 1)*. Djebel Aïssa was classified as a national park under Executive Decree No. 03-148 of the General Forest Direction (DGF) on 29 March 2003. The park spans 24,500 hectares, and it features the highest peak in the region at 2,236 meters and supports a rich biodiversity of flora and fauna *(Figure 1)*.

The climate of the region can be moderate when it's cold during the day and hot at night. The average temperature is between 2 °C and 36 °C throughout the year, and the annual precipitation is between 189 mm and 483 mm. The vegetation in Djebel Aïssa is diverse and comprises pre-forest formations, psammophyte vegetation and sub-desertic flora, harboring a variety of plant types adapted to the unique climatic and geological conditions (Bouallala 2006, Gordo 2014, Benaradj 2017, Boucherit 2018, Benaradj *et al.* 2021, Boucherit *et al*. 2024). Djebel Aïssa National Park is subdivided into 11 zones *(Figure 1)*. We surveyed 12 sites in the national park *(Table 1)*.

Methodology

To gain an in-depth knowledge of the bird species in Djebel Aïssa National Park, we carried out extensive bird surveys from September 2021 to August 2023. These surveys covered the park during the four seasons of each year. Observations took place from 6:00 am to 12:00 pm and from 4:00 pm to sunset, capturing the times of day when bird activity is highest (Robbins 1981).

We used Progressive Frequency Sampling (PFS) for our surveys, which can be conducted at any time of day and throughout the year, including outside the reproduction season. Briefly, it consists of recording, on a presence/absence scale, all the species, both seen or heard, from a point, during a 20-minute session. This method is cost-effective and straightforward to implement, though it does not estimate population density but rather provides a bird inventory (Blondel 1975). We established 54 georeferenced listening points *(Figure 1)*, distributed across various habitats and plant formations along the northern and southern slope of Djebel Aissa National Park. To ensure the reliability of our survey, each point was visited twice a month, with a listening duration of 10 to 20 minutes per point (Prodon 1987).

In addition to the PFS methodology, we used the "random transect method" to ensure the reliability of the species observations, particularly for the raptors. This approach involved

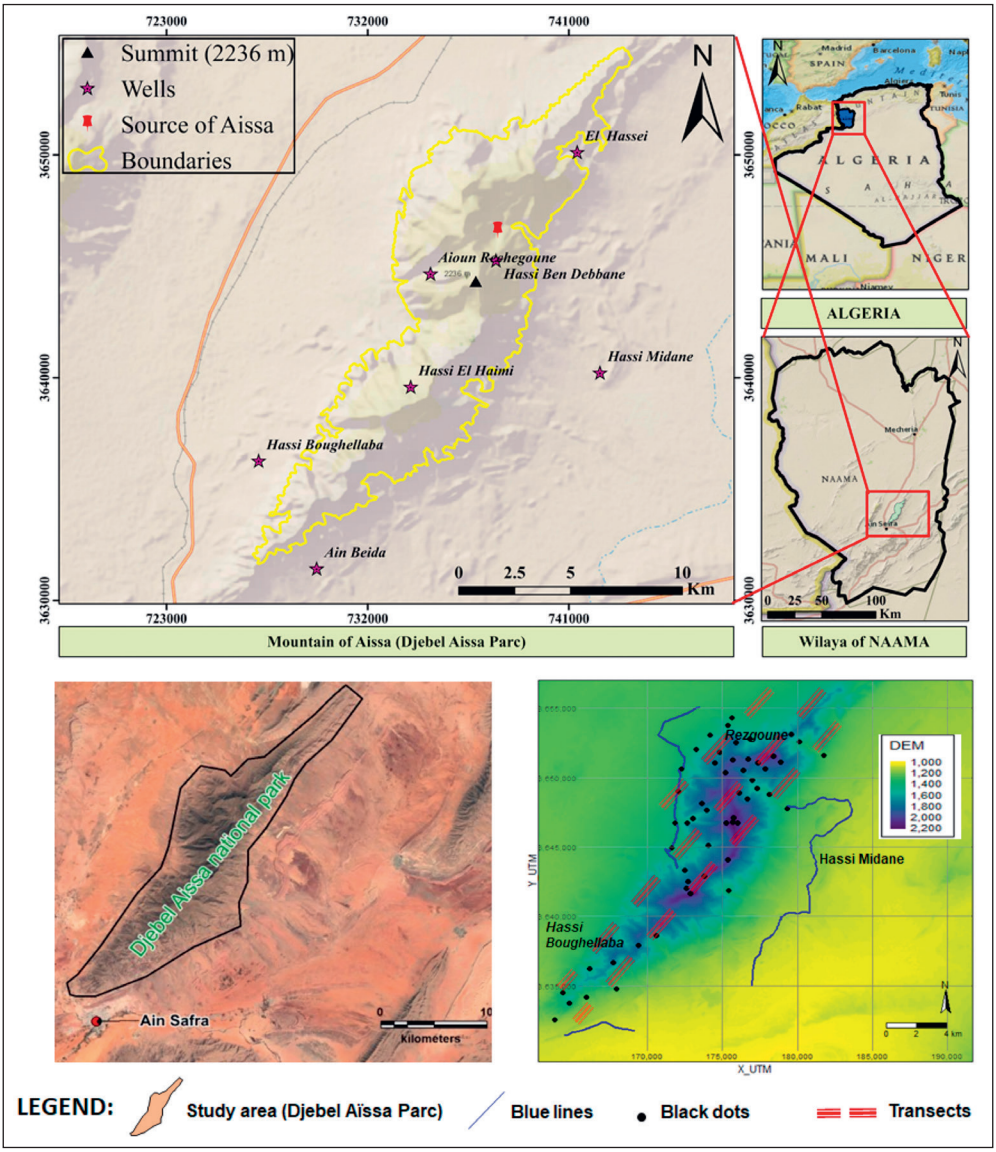


Figure 1. Map of the study area and location of transects (blue lines) and listening points (black dots).
1. ábra A vizsgálati terület és a felmérési pontok térképe

establishing three transects: the first one was located in the northern slope of Djebel Aïssa Mountain (16 km), while the second and third transect in its southern side, with 22 and 5 km, respectively *(Figure 1)*. We surveyed each transect from a vehicle moving at moderate speed (30 km/h) four times during the autumn season (September to December 2022) and spring-summer season (March to July 2023). These surveys enhanced the probability of detecting raptors across various habitats and ensured that no significant observations were missed (Fuller & Mosher 1981, Benmammar-Hasnaoui & Bounaceur 2019).

Table 1. Main characteristics of the 12 sites surveyed for birds in Djebel Aïssa National Park
1. táblázat A Djebel Aïssa Nemzeti Parkban kijelölt 12 madárfelmérési pont fő jellemzői

Sites	Coordinates	Characteristics
Hassi Rechegoun	0°29′45.37″O 32°54′47.08″N	Semi-open habitat dominated by *Stipa tenacissima* and *Artemisia herba alba*, with some trees of *Pinus halepensis, Ziziphus lotus, Quercus ilex, Juniperus phoenicea,* near the well (Hassi Rechegoun)
Hassi Ben Himmi	0°29′55.50″O 32°52′2.93″N	Semi-open habitat corresponding the well of Ben-Himmi, covered by a mix between *Q. ilex*, *J. phoenicea* and *J. oxycedrus* with some trees of *P. halepensis*
Hassi Boudjenib	0°47′35.76″O 32°97′41.88″N	An open gravel habitat with a relatively sparse vegetation cover, dominated by *S. tenacissima* and *A. herba alba*, with some trees of *P. halepensis, Z. lotus, Q. ilex, J. phoenicea,* near the well (Hassi Boudjenib)
Ain Aghlal	0°27′2.90″O 32°56′1.70″N	Semi-open habitat near the water point of Ain Aghlal, covered with a mix of *P. halepensis, Z. lotus, Q. ilex, J. phoenicea J. oxycedrus, Pistacia atlantica* and some trees of *Ceratonia silique*
Ain Aissa	0°27′17.56″O 32°56′21.16″N	Dense habitat with diverse vegetation cover (*P. halepensis Q. ilex, J. phoenicea*, *P. atlantica, Ceratonia siliqua*) especially near the water point of Ain Aissa
Pinus halepensis Forest	0°27′64.36″O 32°56′23.16″N	Dense habitat of *P. halepensis* associated with some trees of *Juniperus* spp. and *Q. ilex* with the presence of herbaceous plants such as *Ferula communis*
Tifkert Mont	0°26′24.79″O 32°57′18.78″N	Open barren habitat featuring cliffs and massive rock
Maita Mont	0°28′19.66″O 32°54′38.07″N	Semi-open habitat with cliffs including some trees of *P. halepensis* and *Q. ilex*
Mekalis	0°28′42.05″O 32°57′22.37″N	Urban area, open habitat with a water point and presence of *S. tenacissima, A. herba alba, Z. lotus*
Hassi Ouled-Ziad	0°25′19.80″O 32°57′52.52″N	Semi-open habitat dominated by *Atractylis, Hammada scoparia* especially in the border of well (Hassi Ouled-ziad)
Ain El-Baydha	0°32′56.23″O 32°49′3.53″N	Open habitat, *H. scoparia*, *A. herba alba* and some trees of *P. altantica*, *Q. ilex* and *Juniperus* spp.
Steppe	0°34′1.92″O 32°47′41.41″N	Open habitat dominated by herbaceous plants such as *Atractylis cancellata, H. scoparia, Ferula communis*

Regular monitoring was carried out through monthly surveys, supplemented by additional surveys in various biotopes, especially during the primary postnuptial and prenuptial bird migration seasons (Chedad *et al.* 2021, Benaradj 2023).

Listening points were determined based on the distribution of habitats and vegetation cover, as well as water sources in the study area (Arendt *et al.*1999, Bibby *et al.* 2000), especially during the nesting, breeding and migration seasons (Gregory 2000, Laiolo 2005, Ehnes *et al.* 2018, Morelli *et al.* 2022). The sampling process was conducted monthly over the large size of the massif (24,400 hectares) with very rugged terrain (Rahmani *et al.* 2017, Habibi *et al.* 2024). Birds were counted at each of the points at least twice per month. As for transects along the paths, surveys were carried out four times per month. All observed

species, either seen, heard, or detected indirectly through signs such as footprints, droppings, nests, or feathers, were recorded.

To record the presence of species by visual observations, we used binoculars Tasko 10×32 Black Roof, while Nikon P900, Canon 7D Mark II and 5D Mark III cameras, equipped with a 150–600 mm lens, were employed for photographing. To identify birds, we used ornithology guidebook (Svensson 2012). We also recorded the presence of bird species by recording songs and voices, bird droppings and footprints.

The phenological and feeding habits (granivorous, insectivorous, Carnivorous, Omnivorous) of the bird species detected were determined based on data from Heim de Balsac (1928), Ledant *et al*. (1981), Blondel (1982), Isenmann and Moali (2000). To determine foraging behaviour, we conducted direct observations of the birds and used the website oiseaux.net (https://www.oiseaux.net/). The final list of birds is organized according to the classification system established by Heinzel *et al*. (1988).

To assess the conservation status of the bird species observed during our study, we used Executive Decree 12-235 of May 24, 2012, which lists protected non-domestic animal species in Algeria. We also consulted Ordinance 06–05 of July 15, 2006, which focuses on the protection and conservation of endangered species. Additionally, we used the IUCN Red List 2022 to evaluate the global conservation status of the species.

Results

Species composition

We found that the checklist of bird species for Djebel Aïssa National Park currently holds 94 species *(Table 2)*, which could be classified into 11 orders and 27 families. The order Passeriformes was the most abundant, comprising 71% of the species, with 16 families and 67 species. Within this order, the Muscicapidae family was the most prevalent, with 18 species. Additionally, 15 species of raptors belonging to three orders were documented: Accipitriformes (7 species), Strigiformes (4 species), and Falconiformes (4 species).

Phenological patterns

The bird species of Djebel Aïssa National Park show high variability in seasonal phenology. The park's bird fauna includes seven visiting species (8%), 50 breeding species, of which 47 are sedentary (50%), three migratory (3%), and 37 wintering species (39%). This variability highlights the complex interactions of seasonal movements and ecological niches within the park.

Trophic status and feeding habits

The insectivorous category dominated, which made up 45% of the total bird species richness. This was followed by granivorous species at 6% and by carnivorous species at

Table 2. The checklist of bird species in Djebel Aïssa National Park (September 2021 – August 2023)
2. táblázat A Djebel Aïssa Nemzeti Park madár fajlistája (2021. szeptember – 2023. augusztus)

Order	Family	Common name	Scientific name	Phenological status	Feeding habits	Protection status	
						Nationally (Algeria)	UICN
Galliformes	Phasianidae	Barbary Partridge	*Alectoris barbara*	S	O		LC
Caprimulgiformes	Caprimulgidae	Eurasian Nightjar	*Caprimulgus europaeus*	V	I	P	LC
Cuculiformes	Cuculidae	Common Cuckoo	*Cuculus canorus*	V	I	P	LC
Columbiformes	Columbidae	Common Wood-Pigeon	*Columba palumbus*	S	O		LC
		Rock Pigeon	*Columba livia*	S	G		LC
		European Turtle-Dove	*Streptopelia turtur*	M	G		VU
		Eurasian Collared-Dove	*Streptopelia decaocto*	S	G.I		LC
		Laughing Dove	*Spilopelia senegalensis*	S	G.I		LC
Accipitriformes	Accipitridae	Booted Eagle	*Aquila pennatus*	W	C	P	LC
		Eurasian Sparrowhawk	*Accipiter nisus*	W	C	P	LC
		Long-legged Buzzard	*Buteo rufinus*	S	C	P	LC
		Short-toed Snake-Eagle	*Circaetus gallicus*	S	C		LC
		Golden Eagle	*Aquila chrysaetos*	S	C	P	LC
		Bonelli's Eagle	*Aquila fasciata*	S	C	P	LC
		Black Kite	*Milvus migrans*	V	C	P	LC
Strigiformes	Strigidae	Little Owl	*Athene noctua*	S	C.I	P	LC
		Eurasian Scops-Owl	*Otus scops*	V	C.I	P	NE
		Pharaoh Eagle-Owl	*Bubo ascalaphus*	S	C	P	LC
		Long-eared Owl	*Asio otus*	S	C	P	LC
Bucerotiformes	Upupidae	Eurasian Hoopoe	*Upupa epops*	S	I	P	LC
Coraciiformes	Coraciidae	European Roller	*Coracias garrulus*	V	I	P	LC
	Méropidae	European Bee-eater	*Merops apiaster*	V	I	P	LC
Piciformes	Picidae	Eurasian Wryneck	*Jynx torquilla*	W	I	P	LC

Order	Family	Common name	Scientific name	Phenological status	Feeding habits	Protection status	
						Nationally (Algeria)	UICN
Falconiformes	Falconidae	Lesser Kestrel	*Falco naumanni*	S	C.I	P	LC
		Peregrine Falcon	*Falco peregrinus*	S	C		LC
		Lanner Falcon	*Falco biarmicus*	S	C	P	LC
		Peregrine Falcon	*Falco peregrinus pelegrinoides*	S	C	P	LC
Passeriformes	Alaudidae	Desert Lark	*Ammomanes deserti*	S	G		LC
		Crested or Maghreb Lark	*Galerida cristata*	S	G		LC
		Thekla Lark	*Galerida theklae*	S	G.I		LC
		Thick-billed Lark	*Ramphocoris clotbey*	S	G.I		LC
	Emberizidae	House Bunting	*Emberiza sahari*	S	G.I		LC
		Corn Bunting	*Emberiza calandra*	S	G.I		LC
		Rock Bunting	*Emberiza cia*	S	G.I		LC
	Muscicapidae	Moussier's Redstart	*Phoenicurus moussieri*	S	I	P	LC
		Common Redstart	*Phoenicurus phoenicurus*	W	I	P	LC
		Black Redstart	*Phoenicurus ochruros*	W	I	P	LC
		Spotted Flycatcher	*Muscicapa striata*	W	I		LC
		Collared Flycatcher	*Ficedula albicollis*	W	I		LC
		Atlas Flycatcher	*Ficedula speculigera*	W	I		NE
		Blue Rock-Thrush	*Monticola solitarius*	S	O		LC
		Rufous-tailed Rock-Thrush	*Monticola saxatilis*	W	I	P	LC
		Western Black-eared Wheatear	*Oenanthe hispania*	W	I		LC
		Black Wheatear	*Oenanthe leucura*	S	I		LC
		Desert Wheatear	*Oenanthe deserti*	M	I		LC
		Red-rumped Wheatear	*Oenanthe moesta*	S	I		LC
		White-tailed Wheatear	*Oenanthe leucopyga*	S	I		LC

Order	Family	Common name	Scientific name	Phenological status	Feeding habits	Protection status	
						Nationally (Algeria)	UICN
Passeriformes	Muscicapidae	Northern Wheatear	*Oenanthe oenanthe*	W	I		LC
		European Robin	*Erithacus rubecula*	W	G.I		LC
		Whinchat	*Saxicola rubetra*	W	I		LC
		European Stonechat	*Saxicola rubicola*	W	I		NE
		Rufous-tailed Scrub-Robin	*Cercotrichas galactotes*	M	I		LC
	Turdidae	Common Blackbird	*Turdus merula*	S	I		LC
		Ring Ouzel	*Turdus torquatus*	W	G.I		LC
		Mistle Thrush	*Turdus viscivorus*	W	G.I		LC
		Song Thrush	*Turdus philomelos*	W	G.I		LC
		Redwing	*Turdus iliacus*	W	G.I		NT
		Fieldfare	*Turdus pilaris*	W	G.I		LC
	Paridae	Tenerife Blue Tit	*Cyanistes teneriffae*	S	G.I		LC
	Fringillidae	Common Chaffinch	*Fringilla coelebs*	S	O		LC
		Brambling	*Fringilla montifringilla*	W	G.I		LC
		Trumpeter Finch	*Bucanetes githagineus*	S	G		LC
		European Greenfinch	*Chloris chloris*	S	G.I		LC
		Eurasian Linnet	*Linaria cannabina*	S	G.I		LC
		Eurasian Siskin	*Spinus spinus*	W	G.I		LC
		Red Crossbill	*Loxia curvirostra*	S	G	P	LC
		European Serin	*Serinus serinus*	S	G	P	LC
	Laniidae	Great Grey Shrike	*Lanius excubitor*	S	C.I		LC
		Woodchat Shrike	*Lanius senator*	W	I		LC
	Sylviidae	Tristram's Warbler	*Curruca deserticola*	S	I		LC
		Dartford Warbler	*Curruca undata*	W	I		NT
		Eurasian Blackcap	*Sylvia atricapilla*	W	I		LC

Order	Family	Common name	Scientific name	Phenological status	Feeding habits	Protection status	
						Nationally (Algeria)	UICN
Passeriformes	Sylviidae	Common Whitethroat	*Curruca communis*	W	I		LC
		Western Orphean Warbler	*Curruca hortensis*	S	I		LC
		Western Subalpine Warbler	*Curruca iberiae*	W	I		LC
	Corvidae	Eurasian Jay	*Garrulus glandarius*	S	O	P	LC
		Brown-necked Raven	*Corvus ruficollis*	S	O		LC
		Red-billed Chough	*Pyrrhocorax pyrrhocorax*	W	G.I	P	LC
	Oriolidae	Eurasian Golden Oriole	*Oriolus oriolus*	V	I	P	LC
	Hirundinidae	Barn Swallow	*Hirundo rustica*	S	I		LC
		Eurasian Crag Martin	*Ptyonoprogne rupestris*	S	I		LC
		Northern House-Martin	*Delichon urbicum*	W	I		LC
		Sand Martin	*Riparia riparia*	W	I		LC
	Passeridae	Rock Sparrow	*Petronia petronia*	S	G.I		LC
		Spanish Sparrow	*Passer hispaniolensis*	S	G.I		LC
		House Sparrow	*Passer domesticus*	S	O		LC
	Motacillidae	White Wagtail	*Motacilla alba*	W	I		LC
		Tree Pipit	*Anthus trivialis*	W	I		LC
		Western Yellow Wagtail	*Motacilla flava*	W	I		LC
	Phylloscopidae	Common Chiffchaff	*Phylloscopus collybita*	W	I		LC
		Willow Warbler	*Phylloscopus trochilus*	W	I		LC
		Wood Warbler	*Phylloscopus sibilatrix*	W	I		LC
	Prunellidae	Alpine Accentor	*Prunella collaris*	W	G.I	P	LC
	Acrocephalidae	Melodious Warbler	*Hippolais polyglotta*	W	I		LC

Phenological status: S – sedentary, W – wintering, M – migratory, V – Visiting; Feeding habits: G – Granivorous, I – insectivorous, C – Carnivorous, O – Omnivorous, G.I – Granivorous + insectivorous, C.I – Carnivorous + insectivorous; Protection status (Nationally): P – protected by the Executive Fiat 12–235 of 24 May 2012; (UICN): LC- least concern, NE – not evaluated, VU – vulnerable, NT – near threatened.

13%. Omnivorous birds accounted for 7% of the observed feeding habits. Additionally, species classified as granivorous + insectivorous represented 24% of the feeding guilds, while those classified as carnivorous + insectivorous made up 4%.

Conservation status

Of the 94 species recorded in the survey, 29 species (31%) are protected according to Executive Fiat 12-235 of 24 May 2012, which establishes the list of protected non-domestic animal species in Algeria. Notably, 13 of these protected species are raptors. This highlights Algeria's commitment to safeguarding its biodiversity *(Table 2)*.

In addition, 89 or 94.7% of the species recorded in the surveys are listed as "Least Concern" according to the IUCN Red List, which is reassuring because this indicates that these species currently are not facing a high risk of extinction. However, two species (Dartford Warbler *Curruca undata,* Redwing *Turdus iliacus)* are listed as "Near Threatened", indicating that they could become vulnerable if specific threats are not addressed. One species (European Turtle Dove *Streptopelia turtur*) has a "Vulnerable"" status, indicating a higher risk of extinction in the wild *(Table 2)*. Two species (Atlas Flycatcher *Ficedula speculigera*, European Stonechat *Saxicola rubicola*) remain unassessed, which poses a significant challenge to conservation due to the absence of essential data.

Discussion

Species composition

This study investigated bird species composition in Djebel Aïssa National Park of Southwestern Algeria (Northern Sahara Atlas Mountains). These data are valuable because they fill the gap in the information on the avifauna in Algeria, especially in semi-arid and arid protected regions. In addition, until now, no data were available for Djebel Aïssa National Park because previous studies investigated larger regions such as the Ksour Mountains or Naama Province, where the national park is located. The number of species detected (94) suggests relatively high diversity, which can probably be related to the location of the park in the northern part of the Atlas Mountains of the Sahara, the various climatic conditions and vegetation types (Benaradj *et al.* 2021). This number of species corresponds to 28% of the 336 species documented across Algeria by Ledant *et al.* (1981) and 23.2% of the species reported to occur in Algeria by Isenmann and Moali (2000).

This study shows that the species richness of Djebel Aïssa National Park is high compared to other regions. Blondel (1962) reported 58 bird species in the Ksour Mountains of Naama Province. Mostefai and Grenot (2006) recorded 100 bird species for the whole of Naama Province. More recently, Youcefi and Marouf (2022) noted a total of 179 species for Naama province, with only 20 species from the forest and mountain regions of the province. In the pre-Saharan steppes of the Zibans, Farhi *et al*. (2016) recorded 42 species and in Boussada, Chiheb *et al.* (2021) reported 53 species. Moreover,

Guezoul *et al.* (2013) recorded 59 species from a much larger area covering three different localities of the Northern Algerian Sahara (Biskra: 47, Oued Souf: 33 and Ouargla: 44). A more comprehensive recent study of the M'Zab region in the Northern Algerian Sahara reported 203 species, which corresponds to more than 50% of the Algerian avifauna. The highest richness of arid land birds in Algeria was recorded in the Timimoun region in Southwestern Algeria, where 100 species belonging to 59 genera, 28 families and 12 orders were observed (Boukhemza 1990). The richness found in this study was also higher than that reported for southern Tunisia, i.e. 86 species in 13 families and orders (Selmi 2002).

The order Passeriformes is prominently represented in all avian communities that are present in the oasis (69% of the assessed species). This is in line with previous studies on pre-desertic birds of Algeria (Farhi & Belhamra 2012, Guezoul *et al.* 2013).

The diversity of birds in this study area indicates the abundance of food resources (Sommerfeld & Hennicke 2010, Barger *et al.* 2016), and the differences found in species richness among the surveyed regions are certainly due to altitudinal, microclimatic, floristic and faunal differences (Habibi *et al.* unpublished data).

Studies into recent changes in the distribution range of some species, show that the range of avian species with a Saharan distribution have shifted north in Algeria (Heim de Balsac 1979). There are multiple factors that contribute to the simultaneous movement of species ranges such as climate change, drought, urban development, fires, overexploitation of natural resources, different types of pollution and agricultural expansion. Generally, habitat fragmentation (Brotons & Herrando 2001, Santos *et al.* 2002) and land abandonment following the rural exodus, timber harvesting, and overgrazing are the main reasons for biodiversity losses in the Mediterranean (Suárez-Seoane *et al.* 2002, Sirami *et al.* 2008).

In a comparable region in North Sahara, Farhi & Belhamra (2012) have recorded a total of 136 bird species that represent 33.5% of the Algerian avifauna, which has a total of 406 species (164 passerines, 242 non-passerines) (Isenmann & Moali 2000). The importance of passerine birds (67 species) in Djebel Aïssa agrees with other data originating from a semi-arid and arid region, namely the Ziban region in Southeastern Algeria, where 14 families with 63 bird species were found, which corresponds to 46.3% of the total bird fauna of Algeria (Isenmann & Moali 2000). In the Ziban region, Turdidae and Sylvidae were the most frequent families, with 18 and 13 species, respectively. However, for the other families, this number varied between 1 and 10 species (Farhi & Belmhamra 2012). Nevertheless, it seems that the dominance of these two families of passerines is likely related to their high species richness on a Palearctic scale.

Our data are relatively similar to those obtained from neighboring countries. In natural ecosystems in the High Atlas region of Morocco, Wakass *et al.* (2023) reported the dominance of Passeriformes, with 68 species grouped in 16 families, and Accipitriformes, with 13 species in one family. The families Muscicapidae, Accipitridae, Fringillidae, and Alaudidae were the most prevalent. These results agree with those of Mansouri *et al.* (2021) from the Eastern High Atlas and those of Mounir *et al.* (2022) from the Central High Atlas. These authors also reported Passeriformes and Accipitriformes orders and Accipitridae and Muscicapidae families as dominant. In this context, we agree that the

ecosystems of those investigated regions are favorable to a diverse avifauna dominated by Passeriformes, which likely reflects their global importance. They are globally represented by 5,700 species and 96 families, or ~60% of all avian species (Blondel & Mourer-Chauvier 1998, Aliabadian *et al.* 2005).

Trophic status and feeding habits

The findings of our study indicate that insectivorous birds are the most prevalent dietary group within the park. We hypothesize that the geographic isolation of the bird populations, the characteristics of the habitats within the park, and the structural features of the habitats are primary contributors to this dominance, which should be tested in future researches. Despite the degradation, the vegetation cover in the park supports a diverse plant life that attracts a significant bird population. Pine forests and open steppe areas, identified as critical habitats by Maire (1916) and Thiollay and Mostefai (2004), remain particularly important for avian species. In contrast, *Juniperus* forests attracted birds only during the flowering season; however, this should not restrict conservation efforts to restore this typical local habitat type. For the three "Vulnerable" or "Near Threatened" species, sub-forest habitats, water sources and open areas were the most important. It is generally recognized that insectivorous bird populations decline following environmental disturbances. However, it is crucial to note that broad classifications such as 'insectivorous' obscure significant variation among species in terms of habitat preferences, behaviour, and ecological roles (Gray *et al.* 2007, Boucif *et al*. 2022).

Species categorized as granivorous and insectivorous accounted for 24.5% of all observed species, while carnivorous and insectivorous species contributed 4.3%. Such intricate dietary patterns underscore the adaptive strategies employed by avian populations to exploit the diverse resources available within this park.

Conservation status

The executive decree 12-235 of May 24, 2012, established the list of protected non-domestic animal species. It lists 29 species as protected, which accounts for 23.2% of the protected Algerian avifauna. Notably, 13 of these protected species belong to the raptor group.

At the international level, 94.7% of the recorded species have the status of "Least Concern", according to the IUCN Red List. Dartford Warbler (according to criteria A2bc+3bc+4bc) and Redwing (according to criteria A2b+3b+4b) are listed as "Near threatened", meaning their populations might decline and become more vulnerable in the future. European Turtle-Dove is also classified as "Vulnerable" (according to criteria A2bcd+3bcd+4bcd), highlighting a higher threat level. These statuses are determined according to the criteria based on different biological factors that are associated with the extinction risk: population size, rate of decline, geographical range, degree of settlement, and fragmentation of the distribution (IUCN 2023).

Compared to Blondel's (1962) work entitled "The Ecology of Birds in the Ksours Mountains", we found noteworthy absences during our research period. We did not

detect several species reported by Blondel (1962), such as Egyptian Vulture *(Neophron percnopterus),* Great Tit *(Parus major),* Western Bonelli's Warbler *(Phylloscopus bonelli),* and Eurasian Wren *(Troglodytes troglodytes)*. The potential local extinction of these species possibly reflects habitat alterations induced by recent climate shifts, which may have blocked the adaptability of these species.

Furthermore, Blondel's (1962) report on the abundance of Northern Raven *(Corvus corax)* contrasts with our findings, because we did not detect this species at all. Instead, we found that Brown-necked Raven *(C. ruficollis)* pervaded numerous habitats throughout the park, which may have resulted from potential competition between the two species.

Finally, it should be noted that Blondel's (1962) mention of Blue Tit *(Cyanistes caeruleus)*, can be problematic because this species is absent from Africa, whereas we found African Blue Tit *(Cyanistes teneriffae),* which was not recorded by Blondel. Similarly, Rock Bunting *(Emberiza cia)* was a resident species in our observations, whereas Striolated Bunting *(E. striolata)*, reported by Blondel (1962), is currently absent from the region. These discrepancies underscore the need to revise bird species records and to document observations with techniques for enhanced accuracy beyond past methodologies. Differences between past and current observations can also indicate the evolving nature of avian populations and the necessity for up-to-date assessments to inform conservation strategies effectively.

Conclusion

We found that Djebel Aïssa National Park supports many resident and migratory bird species. We detected 94 species of bird in the area, belonging to 11 orders and 27 families, which represent a substantial proportion of the avifauna of Algeria. One species is classified as "Vulnerable" and two species are "Near Threatened" based on the IUCN Red List, which supports the role of Djebel Aïssa National Park in their conservation.

Our bird species inventory of Djebel Aïssa National Park serves as a valuable baseline for future monitoring and for the development of management strategies. Moreover, the high diversity of bird species within these national parks underscores their critical role as bastions of biodiversity in the face of mounting anthropogenic pressures and habitat degradation and calls for continued efforts at biodiversity conservation within the landscapes of Djebel Aïssa and beyond.

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Ecological and life history aspects of the Kalij Pheasant *(Lophura leucomelanos)* (Latham, 1790): An in-depth review

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Abstract The Kalij Pheasant *(Lophura leucomelanos)* is a widely distributed galliform and an important indicator species of the Himalayan ecosystems. It demonstrates remarkable ecological adaptability, occupying diverse habitats ranging from subtropical forests to temperate mountain regions across the Himalayas and Southeast Asia. This review synthesizes current knowledge on its distribution, population status, morphology, habitat preferences, feeding habits, social structure, breeding behaviour, and conservation challenges, while highlighting critical research gaps. Although classified as Least Concern globally, the species remains poorly studied across its distributional range with emerging evidence of localized declines due to anthropogenic pressures. It exhibits pronounced sexual dimorphism, with males showing conspicuous plumage and females relying on cryptic coloration. Kalij Pheasant typically inhabit mid-elevation zones (up to 2,500 m), preferring dense understory vegetation and proximity to water sources, but may also be found at lower and higher elevations depending on resource availability and human disturbances. The omnivorous diet of Kalij Pheasant includes seeds, fruits, leaves, insects and small invertebrates, reflecting its role in forest ecosystem dynamics. Although territorial and vocal behaviours are well documented, their mating system remains unclear, with studies implicating both monogamous and facultatively polygynous tendencies. Hybridization between subspecies is reported across its range, however, the genetic consequences of this phenomenon remain unexplored. Despite its ecological flexibility, the species faces increasing threats from habitat degradation, hunting, and human encroachment. Conservation efforts should incorporate advanced technologies such as GPS tracking, remote sensing, and molecular techniques to gain deeper insights into the species' behaviour, movement patterns, habitat use, and genetic diversity. Addressing these gaps will enhance our understanding of the Kalij Pheasant's ecology and help inform conservation strategies for this important bird species.

Keywords: conservation, Galliformes, ecology, Kalij Pheasant, Himalayas

Összefoglalás Az ördögfácán *(Lophura leucomelanos)* egy széles körben elterjedt fácánfaj, amely élőhelyein indikátorfajként működik. Figyelemre méltó ökológiai alkalmazkodóképességgel rendelkezik, a Himalája és Délkelet-Ázsia szubtrópusi erdőin át a mérsékelt égövi régiókig különböző élőhelyeken fordul elő. Áttekintő cikkünkben részletesen megvizsgáltuk a faj ökológiáját, különös tekintettel elterjedésére, morfológiájára, élőhelypreferenciáira, táplálkozási szokásaira, szociális kapcsolataira, szaporodási viselkedésére és a természetvédelmi problémáira, miközben kiemeljük a fajjal kapcsolatos kutatások legfontosabb hiányosságait. A fajra ivari dimorfizmus jellemző, a hímek feltűnő tollazatot viselnek, míg a tojók rejtőzködő színezete az álcázást szolgálja. Az ördögfácán elsősorban a középmagasságú zónákban (2500 méterig) él, ahol a sűrű aljnövényzetet és a vízforrások közelségét kedveli, de az erőforrások elérhetőségétől és az emberi zavarástól függően alacsonyabb és magasabb tengerszint feletti magasságokban is előfordulhat. Széles a táplálkozási spektruma, magvakat, gyümölcsöket, leveleket, rovarokat és kisebb gerinctelenek fogyaszt, ami tükrözi az erdei ökoszisztéma dinamikájában betöltött szerepét. A megfigyelések bonyolult vokális és territoriális viselkedésről árulkodnak, de a párválasztási rendszer továbbra is tisztázatlan, mivel a vizsgálatok szerint a faj monogám és fakultatív poligám tendenciákat

egyaránt mutat. Az alfajok közötti hibridizációról az egész elterjedési területéről beszámoltak, azonban e jelenség genetikai következményeit még nem vizsgálták. Alkalmazkodóképessége ellenére a faj egyre nagyobb veszélynek van kitéve az élőhelyének romlása, a vadászat és az emberi jelenlét miatt, különösen az alacsonyabban fekvő területeken. Annak érdekében, hogy a faj mozgási szokásainak, élőhelyhasználatának és genetikai sokféleségének megismerésével hatékony természetvédelmi intézkedéseket lehessen bevezetni, fejlett technológiát (GPS nyomkövetés, távérzékelés, molekuláris technológiák) kell alkalmazni.

Kulcsszavak: természetvédelem, tyúkalakúak, ökológia, ördögfácán, Himalája

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Introduction

Pheasants (Galliformes: Phasianidae) represent a fascinating suite of ground-dwelling birds in their ecosystems (Fuller & Garson 2000). The family Phasianidae is a vast and ancient family of gallinaceous birds distributed all over the world, comprising of over 180 species and 54 genera, including pheasants, grouses, turkeys, chickens, junglefowls, and quails. The higher diversity of the family occurs in Southeast Asia and Africa (del Hoyo *et al.* 1994, McGowan & Garson 1995, Fuller & Garson 2000). To date, 51 species of pheasants have been recognized in the world (IUCN 2024), of which 50 species are endemic to Asian countries (Fuller & Garson 2000). The sole exception is the Congo Pheasant *(Afropavo congensis)* which is restricted to Zaire in Central Africa (Crowe *et al.* 1986).

Pheasants occupy diverse habitat types ranging from lowland tropical forests (e.g. Crested Fireback *Lophura ignita*), coniferous forests, scrubs, deserts to alpine regions (e.g. Chinese Monal *Lophophorus lhuysii*) in the Himalayas (Ramesh 2003, Sathyakumar *et al.* 2010). They play a phenomenal role in maintaining the food webs of high-altitude ecosystems by forming the primary prey base for raptors and carnivores (Johnsgard 1999) and also acting as excellent seed dispersers. They prefer fragile and undisturbed habitats, exhibiting intense predilection for their environments. By acting as valuable ecological indicators, pheasants determine the health status of an ecosystem (Bhattacharya *et al.* 2009, Grainger *et al.* 2018).

Given the radical land-use changes and habitat disturbances in many parts of the Himalayas, pheasants are facing precipitous population declines over the years owing to several anthropogenic factors (Lawes *et al.* 2006, Bhattacharya *et al.* 2009, Miller 2010, Storch 2013, Zhou *et al.* 2015, Furqan & Ali 2022). Around 20% of pheasant species are threatened with extinction (IUCN 2024). Habitat degradation, hunting, and increased urbanization being the primary drivers of this decline (Ramesh 2003, McNew *et al.* 2013, Gray *et al.* 2018), and these may lead many more species to the verge of extinction in the wild in near future (Dunn *et al.* 2016, Chhetri *et al.* 2018).

The Kalij Pheasant *(Lophura leucomelanos)* belongs to a group of pheasants commonly monikered as the Gallopheasants. Nine subspecies – native to the Southeast Asian and Himalayan forests – have been identified so far, differing morphologically and geographically (Johnsgard 1999). Despite its wide distribution and ecological significance,

the various aspects of the Kalij Pheasant remain understudied (Andleeb *et al.* 2012). Listed as Least Concern by the International Union for Conservation of Nature (IUCN) (BirdLife International 2021), the global population status of the Kalij Pheasant is declining due to various factors such as habitat degradation, illegal hunting, and forest fires (Hussain *et al.* 2002, Andleeb *et al.* 2012, Furqan & Ali 2022). The mapped range of the species has declined by 11.2% over the past three generations, leading to a population decline of between 1–19% during the same period (BirdLife International 2021).

Given its vital role in ecosystems, its adaptability to various habitat types and the conservation issues it faces across its distributional range, a detailed and comprehensive review of the Kalij Pheasant is necessary. This paper aims to synthesize existing knowledge on its various ecological aspects (distribution, population status, habitat preferences, feeding habits, breeding behaviour, social structure, and conservation status) to highlight research gaps and guide future studies. By consolidating the available literature, this review will contribute to a better understanding of the Kalij Pheasant and support evidence-based conservation strategies.

Material and Methods

To ensure a thorough and comprehensive review of the existing information, we conducted an extensive literature survey mainly focusing on research articles from 1970 to 2024. Our search strategy involved the use of multiple academic databases and search engines including Google Scholar, Scopus, PubMed, Web of Science, ResearchGate, and JSTOR. We employed a range of relevant keywords such as 'Galliformes', 'Pheasants', 'Kalij Pheasant habitat', 'Kalij Pheasant diet', 'Kalij Pheasant behaviour', 'Kalij Pheasant threats' and 'Kalij Pheasant conservation' to retrieve all pertinent studies related to the species. This systematic and comprehensive search yielded over 1,000 research papers. After critical investigation of the collected literature, we identified around 180 papers that focused on pheasants in general. From this subset, 60 papers were found directly relevant to our research topic, providing essential information on various ecological aspects of the Kalij Pheasant, including its distribution, status, habitat selection, dietary ecology, behavioural patterns, and conservation challenges. These selected studies formed the scientific foundation of our research, enabling a more detailed understanding of the species and its ecological interactions.

Discussion

Distribution

The Kalij Pheasant has the widest distribution among all the pheasant species. Its natural range extends from western Himalayas in Pakistan, through northern India, Nepal, Bhutan, Sikkim, Assam and parts of Myanmar, reaching as far east as western Thailand *(Figure 1)* (McGowan & Panchen 1994, Johnsgard 1999, BirdLife International 2016, Akhter 2023).

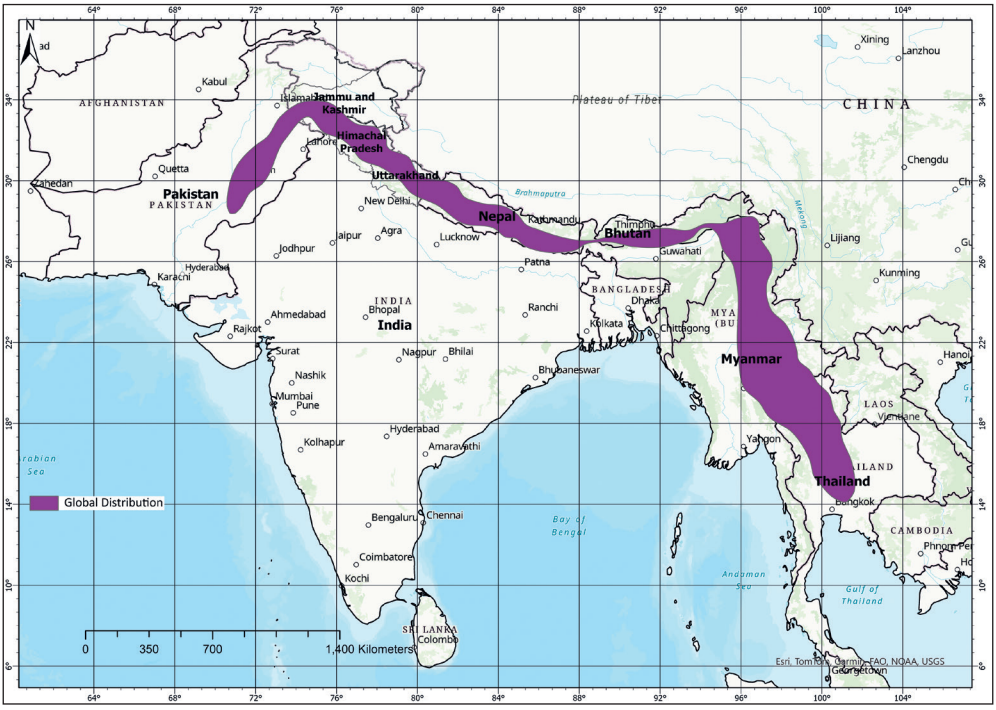


Figure 1. Global distribution of the Kalij Pheasant
1. ábra Az ördögfácán globális elterjedése

The species has also been introduced outside its native range, particularly in the Hawaiian Islands and parts of the United States, where it has adapted well to captivity and semi-wild conditions (Pratt 1976). The Kalij Pheasant is primarily found on the western side of the Himalayan mountains (Barnes 1981), generally adapted for sedentary lifestyles and occurring along foothills, woodland roads, forest clearings, bushy ravines and frequently encountering human habitations (Bump & Bohl 1961, Ali & Ripley 1983, Bisht *et al.* 2002). In India, four subspecies of Kalij Pheasant are known, which inhabit almost all forest types with a thick undergrowth of shrubs (Grimmett *et al.* 2016).

Despite their extensive distribution, the Kalij Pheasant show considerable geographical variation across their range, leading to the recognition of nine subspecies *(Table 1)*. Among these, the White-crested Kalij Pheasant *(L. l. hamiltoni)* is the westernmost subspecies found in the Indian states of Jammu and Kashmir, Uttarakhand, and Himachal Pradesh. On 21st October 2021, the Government of Jammu and Kashmir declared the White-crested Kalij Pheasant as its Union Territory (UT) bird.

Morphology and adaptations

As one moves from west to east across the Kalij Pheasant's distributional range, the male's plumage gradually changes. Generally, subspecies in the western and central parts of their range (White-crested Kalij, Nepal Kalij, Black-backed Kalij, Black Kalij, Horsefield's

Table 1. Various subspecies of the Kalij Pheasant and their distributional range
1. táblázat Az ördögfácán különböző alfajai és azok elterjedési területe

S. No.	Subspecies	Common name	Distribution
01.	*Lophura leucomelanos hamiltoni*	White-crested Kalij	Western Himalayas
02.	*Lophura leucomelanos leucomelanos*	Nepal Kalij	Forests of Nepal
03.	*Lophura leucomelanos melanota*	Black-backed Kalij	Sikkim and Bhutan
04.	*Lophura leucomelanos moffiti*	Black Kalij	Central Myanmar
05.	*Lophura leucomelanos lathami*	Horsefield's Pheasant	Eastern Bhutan and northern India to Myanmar
06.	*Lophura leucomelanos williamsi*	Williams' Kalij	Western Myanmar
07.	*Lophura leucomelanos oatesi*	Oates' Kalij Pheasant	Southern Myanmar
08.	*Lophura leucomelanos crawfurdi*	Crawfurd's Pheasant	Southeastern Myanmar to Thailand
09.	*Lophura leucomelanos lineata*	Lineated Pheasant	Southern Myanmar to northwestern Thailand

Pheasant) have a glossy bluish-black plumage with white rumps, while those in the eastern regions (Williams' Kalij, Oates' Kalij Pheasant, Crawfurd's Pheasant, Lineated Pheasant) exhibit thicker vermiculation and more extensive white markings on the tail and upperparts (Herman 1986, McGowan 1994). The westernmost subspecies (White-crested Kalij) is distinguished from the rest of the subspecies by its white crest, while all other subspecies have a bluish-black crest *(Figure 2)*. In contrast, females of all subspecies exhibit less variation and are uniformly brownish. Despite these morphological variations, all Kalij Pheasants share key characteristics, such as a red facial patch and grey legs, a feature that differentiates them from the closely related Silver Pheasant *(Lophura nycthemera)*, which has red legs (McGowan & Panchen 1994). Further studies on subspecies variation, especially in relation to environmental factors and potential genetic divergence, would be valuable for refining conservation strategies for this widely distributed species.

Despite distinct morphological differences and geographical preferences (Johnsgard 1999), hybridization between different subspecies has been reported in areas where subspecies' ranges overlap (Herman 1986). This is particularly evident in introduced populations such as those in Hawaii, where individuals show mixed characteristics of White-crested Kalij Pheasant and Horsefield's Kalij (Pratt 1976). However, the genetic implications of such hybridization on survival and adaptability remain poorly studied, indicating a critical research gap that could be explored using molecular phylogenetics.

The Kalij Pheasant exhibits pronounced sexual dimorphism, with males displaying striking bluish-black plumage, a prominent white/bluish black crest, and a contrasting white rump, while females have cryptic brownish coloration that blends seamlessly with their surroundings (Zeng *et al.* 2016). This sexual dichotomy may play a crucial role in survival strategies, as the subdued plumage of females provides effective camouflage, reducing predation risk, especially during nesting and chick-rearing periods. In contrast, the conspicuous appearance of males, though advantageous for attracting mates, and establishing dominance also makes



Figure 2. White-crested Kalij Pheasant (A: Male with a white crest, B: Female, © Arif Nabi)
2. ábra Ördögfácán (A: hím fehér koronával, B: tojó, © Arif Nabi)

them more visible to predators and hunters. This increased vulnerability is particularly pronounced in winter when reduced foliage cover exposes them further, likely contributing to higher hunting pressures on males compared to females (Lone *et al.* 2024).

While the adaptive significance of these morphological differences is well recognized, several knowledge gaps remain. The extent to which male plumage variation influences mating success or dominance hierarchies in Kalij Pheasant has not been thoroughly examined. Furthermore, while the cryptic coloration of females is assumed to enhance survival, quantitative studies assessing its effectiveness in different habitat types and levels of disturbance are lacking. Additionally, the role of environmental factors, such as seasonal changes and habitat degradation, in influencing plumage maintenance, and survival strategies warrants further investigation. Understanding these aspects could provide deeper insights into the adaptive evolution of sexual dimorphism in Kalij Pheasant and its implications for their conservation in varying ecological conditions.

Population status

Despite its wide distribution, the population status of the Kalij Pheasant remains largely understudied across much of its range, particularly in the western Himalayas. The species is currently categorized as Least Concern by the IUCN (BirdLife International 2021) due to its extensive distribution; however, localized population trends suggest varying degrees of decline, primarily attributed to anthropogenic pressures such as habitat degradation, illegal hunting, and increasing human encroachment (Hussain *et al.* 2002, Furqan & Ali 2022, Lone *et al.* 2024). Studies by Selvan *et al.* (2013) reported a population density of 6.7 birds/km^2 of Kalij Pheasant in the eastern Himalayas of Arunachal Pradesh, India. Similarly, Subedi (2006) while working on the Nepal Kalij in central Himalayas of Nepal, documented population densities ranging from 8.9 birds/km^2 in October to 1.94 birds/km^2 in March.

Furqan *et al.* (2024) while working on habitat suitability of Kalij Pheasant in Mirpur Division of Azad Jammu and Kashmir, Pakistan, reported a maximum population density of 2.33 birds/ha from Gaian area followed by Glater palian with 1.67 birds/ha.

In regions like Jammu and Kashmir, reliable population estimates remain scarce and are often inferred through indirect methods such as field sightings. Preliminary observations from protected areas suggest that while the Kalij Pheasant may be locally common in undisturbed habitats, its populations are fragmented and potentially declining in degraded landscapes (Hussain *et al.* 2002). A recent study by Lone *et al.* (2024) on population status of White-crested Kalij Pheasant in Limber Wildlife Sanctuary of western Himalayas recorded the highest mean encounter rate of 2.25 birds/km of transect walk. They also observed male-biased sex ratio for the Kalij Pheasant, with the highest mean flock size of 3.38 individuals. There is a pressing need for systematic, long-term population monitoring using standardized techniques such as distance sampling, call counts, and camera trapping to better understand population dynamics of the Kalij Pheasant and inform conservation strategies.

Habitat and altitudinal preferences

The Kalij Pheasant exhibits remarkable ecological plasticity, inhabiting a wide range of habitats from subtropical forests to temperate montane regions. It is largely sedentary, preferring forested foothills and mountainous areas between 600 m and 3,400 m altitude (Delacour 1977, Johnsgard 1999). The species is commonly associated with broad-leaved forests, temperate deciduous and mixed forests, riparian zones, grassy slopes and even agricultural landscapes near human settlements (Ali & Ripley 1983, McGowan & Panchen 1994, Zeng *et al.* 2016, Lone *et al.* 2024). However, it shows strong preference for habitats with dense shrub understory, which provides essential cover for foraging and protection (Madge *et al.* 2002, Grimmett *et al.* 2016). The species flourishes in dense undergrowth in subtropical and temperate forests, often near water sources (Sathyakumar & Kaul 2007). The presence of dense undergrowth is necessary for the species' foraging and nesting behaviour, besides offering protection from predators (Lone *et al.* 2024). Shrub density appears to be a critical factor in habitat selection, as studies have documented that Kalij Pheasant favours areas with abundant understory vegetation and minimal tree or grass cover (Sathyakumar *et al.* 1992). Additionally, the species frequently occurs near water sources, especially in drier seasons, suggesting that water availability is a key determinant of habitat suitability (Sathyakumar & Kaul 2007, Dohling & Sathyakumar 2011, Furqan *et al.* 2024).

In terms of altitudinal distribution, the Kalij Pheasant is generally found at mid-elevations, with most sightings occurring below 2,500 m. It is frequently observed between 450 m and 2,150 m (Lewin & Lewin 1984), with similar trends reported from the upper Beas Valley of Himachal Pradesh (1,200–2,500 m) (Gaston *et al.* 1981) and Garhwal Himalayas (< 2,400 m) (Chandola-Saklani *et al.* 1988). Studies by Hussain and Sultana (2013) likewise observed Kalij Pheasant occurring below 2,700 m in Kumaon Himalayas, Uttarakhand. Recent study from Jammu and Kashmir confirms a higher occurrence of Kalij Pheasant below 2,300 m (Lone *et al.* 2024). This altitudinal preference is likely shaped by a combination of biotic and abiotic factors. At lower elevations, habitat fragmentation, livestock grazing and hunting

pressure increases, while higher elevations pose challenges related to food scarcity and harsh climatic conditions (Herzog *et al.* 2003). The species, therefore, appears to favour mid-elevation zones where moderate temperatures, adequate shrub cover, and sufficient food resources provide optimal conditions for survival. However, studies quantifying the effects of habitat fragmentation and climate change on the species' distribution remain scarce. Furthermore, while some populations have been recorded at higher elevations (Lewin & Lewin 1984), the extent of their seasonal movements and the factors influencing such altitudinal shifts require further investigation. Given the increasing anthropogenic pressures on montane ecosystems, long-term monitoring of habitat changes and their impact on Kalij Pheasant populations is crucial for effective conservation planning.

Feeding habits

Pheasants play a crucial ecological role in mountain ecosystems as prey base for large carnivores and raptors as well as seed dispersers that facilitate plant regeneration. However, despite their ecological significance, the dietary ecology of the pheasants remains poorly studied in the wild. Their secretive behaviour and preference for dense and often inaccessible forested habitats make direct observation and dietary analysis challenging (Hill 1985). Additionally, the seasonal variation in food availability due to dynamic climatic conditions in high-altitude ecosystems further influences their feeding ecology, which remains largely undocumented (McShea 2000).

The Kalij Pheasant is an omnivore primarily adapted for ground scratching, allowing it to forage efficiently. It uses its stout bill to displace small stones, dig into the soil, and extract invertebrates, which constitute a major portion of its diet during the breeding season to fulfil the protein demands of growing chicks (Lewin & Lewin 1984). Diet studies reveal a diverse spectrum of food items including grasses, herbs, seeds, roots, flowers, tubers, earthworms, crustaceans and even small vertebrates such as reptiles (Johnsgard 1986). Stomach content analysis by Lewin and Lewin (1984) identified 19 plant species, while Furqan and Ali (2022) documented 45 plant species in the diet of Kalij Pheasant in Pakistan which included trees, shrubs, herbs, grasses and one climber. However, studies on the seasonal variability of their diet across different altitudes and habitats are scanty, limiting our understanding of how food resource fluctuations impact their foraging behaviour and nutritional ecology.

The Kalij Pheasant follows a distinct diurnal feeding pattern, with peak foraging activity occurring during early morning and late afternoon, periods with minimal human disturbance. Mid-day feeding is significantly reduced, likely due to higher human activity levels (Johnsgard 1986). Feeding groups vary in composition, with individuals foraging alone, in male-female pairs, or in family groups with chicks. Males have been observed to perform lateral displays and offer food to females as part of courtship behaviour (Johnsgard 1986). Seasonal movements in response to food availability have also been reported, with Kalij Pheasant descending from higher elevations in autumn to forage near agricultural fields, roads and trails, where they form loose aggregations of two to ten individuals (Lewin & Lewin 1984). These foraging sites are typically located close to forest cover and near water sources, indicating a strong association between feeding activity and water availability

(Furqan & Ali 2022). Despite these observations, there is a lack of detailed studies on their foraging behaviour across different habitat types and elevations, particularly in response to human disturbances such as agriculture expansion and habitat fragmentation.

Unlike other pheasant species that avoid human settlements, Kalij Pheasant frequently exploit agricultural fields adjacent to forests, particularly during late autumn and winter when food scarcity at higher elevations forces the pheasants to migrate lower areas (Kaul *et al.* 2004) to seek alternative food sources. They primarily feed on leftover grains such as paddy in cultivated fields but exhibit strict temporal feeding patterns, restricting foraging to early morning and late evening to avoid human disturbances. Feeding ceases at dawn when visibility increases and resumes at dusk before roosting. This behaviour suggests an adaptation to human presence, yet the extent to which agricultural landscapes contribute to their overall diet and survival during food-scarce periods remains unexplored. Furthermore, their reliance on agricultural crops raises concerns about potential human-wildlife conflicts, which have not been systematically documented.

An important aspect of the Kalij Pheasant's feeding ecology is its role in seed dispersal. While consuming seeds, the species also ingests small pebbles and grit, which aid in grinding food in the gizzard. However, not all seeds are digested, and many pass through the digestive tract intact, contributing to seed dispersal across their habitats (Lewin & Lewin 1984). Additionally, seeds may adhere to their feathers and be transported to new locations, promoting plant diversity and aiding forest regeneration. This underscores the species' ecological importance in maintaining habitat integrity. Despite these observations, there is limited research quantifying the effectiveness of Kalij Pheasant as seed dispersers, including germination rates of dispersed seeds and their impact on plant community dynamics.

Social structure

The social structure of the Kalij Pheasant is characterized by communal roosting, group foraging and complex vocal communication. Larger aggregations of the species have been observed post-monsoon, likely due to the presence of chicks accompanying their mothers (Hussain *et al.* 2002). Studies in Kedarnath Wildlife Sanctuary have reported a higher occurrence of males than females, with a consistent sex ratio across seasons (Sathyakumar *et al.* 1993). This could be attributed to the more conspicuous plumage of males, making them easier to detect than females (Delacour 1977). The male-biased sex ratio was also documented by Zeng *et al.* (2016) and reported an average ratio of 2.1 males to 1.0 females. However, it remains unclear whether the apparent male-biased detection is due to actual differences in abundance or behavioural factors such as habitat use and predator avoidance strategies. The occurrence of more males than females in a group might also be attributed to the cooperative breeding shown by the Kalij Pheasant (Zeng *et al.* 2016). Moreover, unlike males which are quite agile, females – being less active – become more susceptible to hunting and predation, resulting in the higher occurrence of males in a group (Lone *et al.* 2024).

Although the Kalij Pheasant is considered territorial, the extent of its territory and seasonal variations remains undocumented (Johnsgard 1986). Males assert dominance through loud crowing calls and wing-whirring displays, which serve as territorial warnings (Ali & Ripley

1983). However, quantitative studies on call frequency, propagation distance and the role of habitat structure in territorial communication are lacking. Kalij Pheasant also exhibit a range of vocalizations for social cohesion and predator avoidance, including contact calls during foraging and alarm calls in response to threats (Bump & Bohl 1961, Ali & Ripley 1983). Despite these observations, the acoustic structure of these calls and their functional significance remain unexplored. Additionally, the species shows strong fidelity for its roosting sites, typically perching on tree branches at heights of 4.5 to 8 meters in small groups of four to five individuals (Gautam 1999). These sites are used consistently unless disturbed by predators or human activity, yet the specific factors influencing roost-site selection remain unclear (World Pheasant Association 1980). While faecal accumulation beneath roosts provides an indicator of site fidelity, the potential role of communal roosting in disease transmission or predator avoidance has not been studied. Further research is needed to understand the behavioural and ecological factors driving group formation, the role of social interactions in survival and reproduction, and how habitat disturbances influence these dynamics.

Breeding behaviour

The breeding behaviour of the Kalij Pheasant remains poorly understood, particularly its mating system, which is debated between monogamy and polygyny. Ali and Ripley (1983) suggested that the species is primarily monogamous, with polygamy occurring only under specific conditions, while Lewin and Lewin (1984) observed both monogamous and polygynous tendencies based on group compositions. Johnsgard (1986) hypothesized facultative polygyny, wherein males may mate with multiple females in a breeding season if the opportunity arises and abandon one female post egg laying to assist another in brood-rearing. However, field evidence for this hypothesis remains limited, and more detailed behavioural studies are needed to determine the extent and ecological drivers of different mating strategies in Kalij Pheasant. Zeng *et al.* (2016) while studying the introduced population of Kalij Pheasant in Hawaiian Islands observed that the species exhibits cooperative breeding, which may have arisen as a result of overcrowding and shortage of breeding opportunities in an insular environment. Compared to what is known in their native ranges, the complex social and breeding system of Kalij Pheasant in Hawaii reflects the overall flexibility of its mating patterns in response to environmental conditions. Understanding the factors influencing monogamy or polygyny – such as resource availability, habitat conditions, or population density – would provide valuable insights into the species' reproductive ecology.

The breeding season of the Kalij Pheasant commences from March and may extend into late July. However, their breeding associations in their native areas are not well documented (Delacour 1977, Ali & Ripley 1983). A study by Chandola-Saklani *et al.* (1988) in Garhwal reported that the breeding season of Kalij Pheasant varies with the altitude. They observed that at higher elevations (> 2,100 m), it started from April to June, whereas, at lower elevations (< 2,100 m) it extends from May to August. This variation could be due to the reason that the hatching occurs at a time when the food supply and

invertebrate content in the soil is abundant to meet the protein requirements of the growing chicks. Male Kalij Pheasants usually begin courting females in April which initiate nesting shortly thereafter (Zeng *at al.* 2016). The female usually lays 7–10 eggs per clutch (Wayre 1969, Johnsgard 1986). The nesting period can prolong into July, and the chicks hatch after ~25 days (Johnsgard 1986, Zeng *et al.* 2016), and subsequently remain in the group. Only female incubates and guards the nest from predators and unfavourable conditions (Chandola-Saklani *et al.* 1988). Males appear to play no role in the incubation or protection of nests. The juveniles become sexually mature adults by the start of the next breeding season (March – April) (Zeng *et al.* 2016).

During courtship, females typically initiate interactions and males respond with a series of elaborate displays including 'wing-fluttering,' 'rum-jump' and 'tail-fanning' (Lewin & Lewin 1984). These displays, characterized by rapid wing strokes, running towards the female and fanning tail feathers, are thought to reinforce pair bonds and signal male fitness. Interestingly, 'wing-fluttering,' previously believed to be exclusive to paired males, has also been observed in unmated males and, on rare occasions, in females (Lewin & Lewin 1984). While these behaviours likely play a crucial role in mate selection, their specific functions, hormonal influences and evolutionary significance remain unclear. Additionally, the impact of environmental factors such as habitat fragmentation, hunting pressure, or climatic variations on breeding success and mate selection remains unstudied. Future research should focus on long-term field observations and experimental studies to clarify the mating system, the influence of social and environmental factors on courtship displays, and their implications for reproductive success in Kalij Pheasant.

Threats and predators

The Kalij Pheasant, despite its ecological adaptability, faces multiple anthropogenic and natural threats that have led to localized population declines (Andleeb *et al.* 2012). Habitat destruction and hunting are the primary factors affecting the species' survival across its distributional range. Rapid deforestation due to agricultural expansion, infrastructure development and illegal logging has led to the degradation of critical habitats, particularly dense understory vegetation essential for breeding and foraging (Sathyakumar *et al.* 1992, Lone *et al.* 2024). Studies from the western Himalayas indicate that large-scale deforestation, particularly of oak (*Quercus* spp.) forests, has significantly reduced habitat suitability for the species by depleting essential cover and food resources (Hussain *et al.* 2002, Kaul *et al.* 2004). However, long-term data on habitat loss and its direct impact on Kalij Pheasant populations remain limited.

Illegal hunting is another major threat to the species, with reports of widespread trapping and shooting, particularly in the western Himalayas (Khan 1997, Hussain *et al.* 2002). After habitat degradation, overhunting has immensely contributed to the recent animal extinctions (Diamond & Case 1986, Reid 1992), and may continue to lead future species extinctions. Hunting pressure remains highest in late autumn and winter when heavy snowfall forces the birds to lower elevations, making them more vulnerable (Kaul *et al.* 2004). A study in Azad Jammu and Kashmir, Pakistan, recorded 142 hunting incidents over two years, with the

primary hunting methods involving nylon snares and direct shooting (Furqan & Ali 2022). Despite these observations, there is a lack of quantitative studies assessing the impact of hunting on population demographics and reproductive success.

Livestock grazing and non-timber forest product collection, particularly mushroom harvesting, also pose significant threats by degrading the forest floor and trampling nesting sites. Excessive livestock grazing has been negatively correlated with the Kalij Pheasant abundance in the Kumaon Himalayas (Hussain *et al.* 2002), but studies quantifying grazing-induced habitat degradation in different parts of the pheasant's range are scarce. Similarly, mushroom collection overlaps with the critical breeding season, potentially disturbing nesting females and reducing chick survival, yet there is little empirical data on its specific impact on Kalij Pheasant populations.

Forest fire, whether natural or anthropogenic, is another emerging threat to the Kalij Pheasant. Fires during the breeding season may destroy nests, eggs and even adult birds, further reducing reproductive success (Kimothi & Jadhav 1998). A study by Furqan and Ali (2022) in Pakistan identified forest fires as the most significant threat (41.2% of reported cases), but data from other parts of its range, particularly in India and Nepal, remain limited. There is a critical need for studies assessing the frequency, extent and direct impact of forest fires on Kalij Pheasant populations and their nesting success.

Natural predation by carnivores such as the Red Fox *(Vulpes vulpes)*, Yellow-throated Marten *(Martes flavigula)*, and Leopard *(Panthera pardus)* is a part of the species' ecological interactions (Bahuguna & Mallick 2010). However, habitat fragmentation and hunting may be amplifying predation pressure by reducing available cover and forcing birds into suboptimal habitats with higher predator densities (Furqan & Ali 2022). Despite anecdotal reports of predation on both chicks and adults, detailed studies on predator-prey dynamics involving Kalij Pheasant remain lacking.

While several studies have documented the threats to Kalij Pheasant, key knowledge gaps persist. There is limited long-term monitoring data to assess population trends in response to habitat degradation, hunting pressure and climate-induced changes such as forest fires. The species' response to habitat fragmentation and landscape-level changes remains poorly understood. Quantitative assessments of human-induced threats, such as livestock grazing and mushroom collection, are needed to determine their direct effects on breeding success and survival. Additionally, studies on predator-prey interactions and how hunting pressure alters predation risk for Kalij Pheasant would enhance conservation strategies. Addressing these gaps is crucial for developing targeted conservation measures and ensuring the long-term survival of the species.

Conclusion

This review provides a comprehensive synthesis of the ecology, behaviour, status, and conservation challenges of the Kalij Pheasant. As a native species of the Himalayan and Southeast Asian forests, the Kalij Pheasant exhibits remarkable adaptability, thriving in diverse habitats due to its flexible diet, which includes leaves, tubers, seeds, fruits and

small invertebrates. Its complex social structure, characterized by monogamous pairs and elaborate courtship displays, further underscores its ecological significance.

The species shows a strong affinity for dense understory shrubs and mixed forest environments, highlighting the importance of preserving these critical habitats. However, increasing habitat degradation – driven by deforestation, firewood collection, timber extraction and agricultural expansion – poses significant threats to its populations. Despite some studies on the species' habitat preferences and threats, major research gaps remain, particularly in its ecology, conservation genetics and long-term population dynamics. Addressing these gaps is crucial for developing effective conservation and management strategies.

Future research should incorporate advanced technologies such as GPS tracking, remote sensing and molecular techniques to gain deeper insights into the species' behaviour, movement patterns, habitat use and genetic diversity. Additionally, integrating traditional ecological knowledge from local communities could provide valuable context for conservation efforts.

As an indicator species, the Kalij Pheasant reflects the health of its forest ecosystems. Protecting this species not only preserves its unique genetic heritage but also contributes to broader biodiversity conservation. A multi-faceted approach – combining scientific research, habitat protection, community involvement, and policy interventions – is essential to ensuring the long-term survival of this species. Proactive conservation measures, backed by robust scientific research, will be key to mitigating threats and securing viable populations of the Kalij Pheasant in its natural habitat.

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Winged stewards of the rivers: A systematic review of avian ecosystem services in the Ganga River basin

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Abstract Birds are one of the prominent classes of vertebrates, occurring worldwide in nearly all habitat types, and providing a wide range of ecological functions, which in turn, generate a wide array of ecosystem services. While ornithological research on ecosystem services has become more prevalent, studies specifically focusing on the contributions of waterbirds in aquatic ecosystems have been largely overlooked.

We undertook a review of the ecosystem services provided by the waterbirds inhabiting the Ganga River, which is home to a wide variety of waterbirds that compete with the human-induced developments for habitat, and therefore, their survival is dependent on human understanding of their critical role within the ecosystem. The review highlighted that the waterbirds are efficacious bioindicators of different ecological conditions, control pests, maintain the diversity of other organisms, act as predators, herbivores, vectors of aquatic plants, invertebrates, and nutrients, and also play the role of ecosystem engineers. Furthermore, they provide cultural services to human society. Understanding the functional role of waterbirds, through natural history research, can inform conservation-oriented decision making by policymakers as well as public. The findings of this study would increase public support for the conservation of biodiversity in a holistic manner.

Keywords: waterbirds, ecosystem services, bioindicator, ecosystem engineer, seed dispersal, freshwater ecosystem

Összefoglalás A madarak a gerincesek egyik jelentős osztályát alkotják, világszerte csaknem minden élőhelytípusban előfordulnak, és számos ökológiai funkciót látnak el, amelyek révén sokféle ökoszisztéma-szolgáltatást nyújtanak. Bár az utóbbi időben egyre gyakoribbá váltak az ökoszisztéma-szolgáltatásokat vizsgáló ornitológiai kutatások, a vízimadarak szerepével, kifejezetten az édesvízi rendszerekben, továbbra is kevés tanulmány foglalkozik.

Tanulmányunkban áttekintettük a Gangesz folyó mentén élő vízimadárfauna által nyújtott ökoszisztéma-szolgáltatásokat. A térségben számos vízimadárfaj él, melyek élőhelyeit egyre inkább veszélyeztetik az emberi tevékenységek, így fennmaradásuk nagymértékben azon múlik, hogy az ember felismeri-e ökológiai jelentőségüket. Az áttekintés rávilágított arra, hogy a vízimadarak hatékony bioindikátorai a különféle ökológiai állapotoknak, szerepet játszanak a kártevők gyérítésében, más élőlények diverzitásának fenntartásában, továbbá ragadozóként, növényevőként, valamint vízi növények, gerinctelenek és tápanyagok terjesztőiként is funkcionálnak. Emellett ökoszisztéma-mérnök szerepet is betöltenek. A vízimadarak ezen túlmenően kulturális szolgáltatásokat is nyújtanak az emberi társadalom számára.

A vízimadarak funkcionális szerepének természetrajzi kutatásokon alapuló mélyebb megértése segítheti a természetvédelmi célú döntéshozatalt, mind a szakpolitikai szinten, mind a lakosság körében. Jelen tanulmány eredményei hozzájárulhatnak a biodiverzitás megőrzését célzó társadalmi támogatottság erősítéséhez, holisztikus szemléletben.

Kulcsszavak: vízimadarak, ökoszisztéma-szolgáltatások, bioindikátor, ökoszisztéma-mérnök, magterjesztés, édesvízi ökoszisztéma

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Introduction

Birds are one of the most diverse groups of vertebrates, with more than 10,000 extant species distributed globally (BirdLife International 2004). They occupy an extensive range of ecological niches and range, and widely vary in size from the Ostrich *(Struthio camelus)* (~2.4–2.7 m) to the Cuban Bee Hummingbird *(Mellisuga helenae)* (~5.7 cm) (Pettingill 2013). Birds occupy almost all the ecosystems and have association with forest vegetation, agroecosystem, riverine habitat, grassland, and marine ecosystems, involving a wide range of feeding niches (Whelan *et al.* 2008, Wenny *et al.* 2011, Mariyappan *et al.* 2023). Being a diverse group occupying diverse habitats and niches the birds' diversity signifies environmental stability (Şekercioğlu 2006). They play an important role in biogeographical cycling, nutrient, and energy transfer; thus, they are critically important in regulating and supporting ecosystem services. Some of the services provided by the birds include pest control, seed dispersal, pollination, nutrient cycling, soil formation, waste management, and ecosystem engineering (Bock & Jones 2004, Şekercioğlu 2006, Whelan *et al.* 2008, Wenny *et al.* 2011, DeVault *et al.* 2016, Chain-Guadarrama *et al.* 2019, Díaz-Siefer *et al.* 2022, Valkó *et al.* 2022, Green *et al.* 2023).

With the growing concern to conserve natural ecosystems, it is becoming impertinent to document the avian ecological functions that sequentially bring about ecosystem services that are of immense value to human beings (Whelan *et al.* 2008, 2015).

The functions provided by birds and the methodologies to quantify their values are well-studied in terrestrial ecosystems (Bock & Jones 2004, Şekercioğlu *et al.* 2004, Şekercioğlu 2006, Whelan *et al.* 2008, Wenny *et al.* 2011, Karp *et al.* 2013, Lindell *et al.* 2018, Grilli *et al.* 2019, Chain-Guadarrama *et al.* 2019), but there is a lack of consolidated information for their role in aquatic ecosystems. Birds that are ecologically dependent on wetlands have been identified as 'waterbirds' by Ramsar Convention (Wetlands International 2012). They have many fascinating features in their biology that include long-distance migration, large congregation, colonial breeding and ground nesting. Though waterbirds are one of the best-studied groups of birds, from the view of ecosystem services, however, the studies focusing on their role are largely overlooked (Green & Figuerola 2005, Green & Elmberg 2014, Green *et al.* 2016, 2023, Sebastián-González *et al.* 2020).

Wide altitudinal range from sea level extending up to the summit pinnacle of the Himalayas, highly varied climate and corresponding diversified vegetation, and overlapping of three biogeographical provinces namely, the Indo-Malayan, Palearctic and Afrotropical realms, make the Indian subcontinent one of the unique hotspots for birds (Grimmett *et al.* 2014). Due to these features, three flyways namely, Central Asian, East Asian Australian, and Asian East African Flyway, pass through the Indian subcontinent. India is known to have about 243 species of waterbirds and 1,383 avian species in total (Avibase 2024), and has a strategic role in the Central Asian Flyway, as it provides critical stopover sites to over 90% of the bird

species known to use this migratory route (MoEFCC 2018). The Ganga River basin in the Indian subcontinent harbors many of these important aquatic avian species. This basin is the largest and most diverse river basin in India, and encompasses five ecologically different biogeographical regions, namely, Himalayan, Semi-arid, Deccan Plateau, Gangetic Plains, and Coastal Region (Rodgers & Panwar 1988). Due to copious rainfall in the Gangetic plains and the Himalayas, this region comprises numerous floodplain wetlands, which are extremely productive in terms of vegetation biomass and avian diversity (Rawat 2004). Out of 467 Important Bird and Biodiversity Areas (IBAs), 12 are present here with significant populations of waterfowls (Islam & Rahmani 2004, BNHS-ENVIS 2021). Being an integral part of Central Asian Flyway, all these wetlands in the basin are not only the crucial habitat for resident breeders but also provide wintering ground to many migratory waterbirds. The Ganga basin has approximately 128 species including 52 species of migratory and 76 species of resident water- and water-associated birds, which are indicators of the health of the fragile riverine ecosystem (WII-GACMC 2018). According to the IUCN Red List of threatened species, 15 of these species are globally threatened, of which one is critically endangered, five are endangered and seven are vulnerable.

The Government of India's (GOI) initiative to restore the ecological and hydrological integrity of the Ganga River through its ambitious Namami Gange Program, with biodiversity as one of its thrust areas, calls for a comprehensive understanding of the role the avian species play in ecological functioning of the Ganga River and its surrounding areas. Understanding the functional role of waterbirds, through natural history research can aid in informed decision-making. Such studies would also increase public support for conservation of the waterbirds and their habitats, in a holistic manner. Thus, the aim of this paper is to review the aquatic avian ecology literature, congruent with the species found in the Ganga River area, to assess the ecosystem services generated from their functional role.

Material and Methods

This review focused on the ecosystem services provided by waterbirds. 128 species of waterbirds found in the Ganga River area have been restricted in the study. Peer-reviewed papers published from 1990 to 2024 were searched using the search engines of Google Scholar and Publish or Perish software (Harzing 2007). General search statistics are reported in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analysis) guidelines (Page *et al.* 2021) *(Figure 1)*. The keywords related to supporting and regulating services provided by birds through their functional roles were used for literature search. The Publish or Perish database was searched with a combination of keywords such as "Ecosystem services" and "waterbirds", which resulted in a total of 493 records. Functional roles of different waterbird species were also searched in the Google Scholar database to obtain species-wise information, which resulted in another 132 records. All these 625 publications were screened for repetitive articles, titles and abstracts to check the adequacy of the study's aim. The screening further reduced the number of articles to 174.

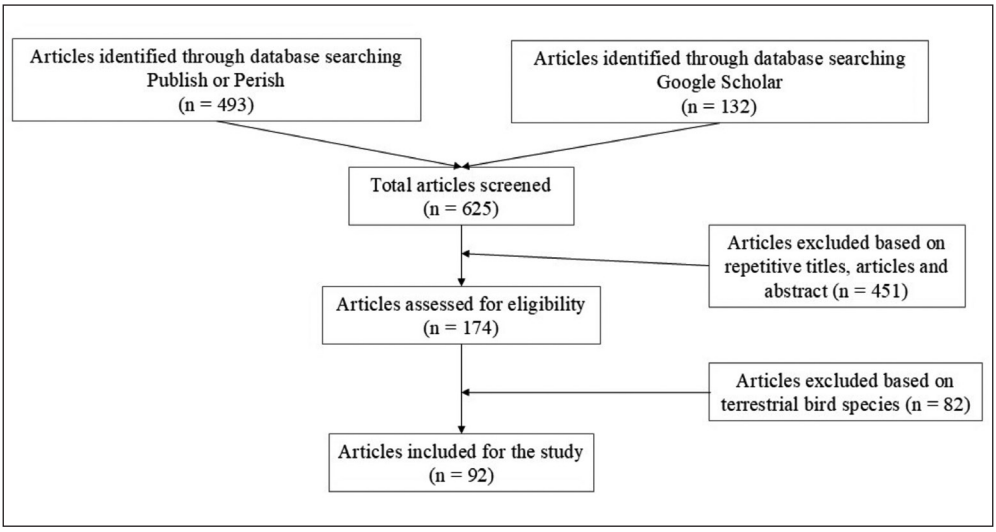


Figure 1. PRISMA flowchart summarizing the workflow adopted for this review
1. ábra Az áttekintő tanulmány munkafolyamatát összefoglaló PRISMA-folyamatábra

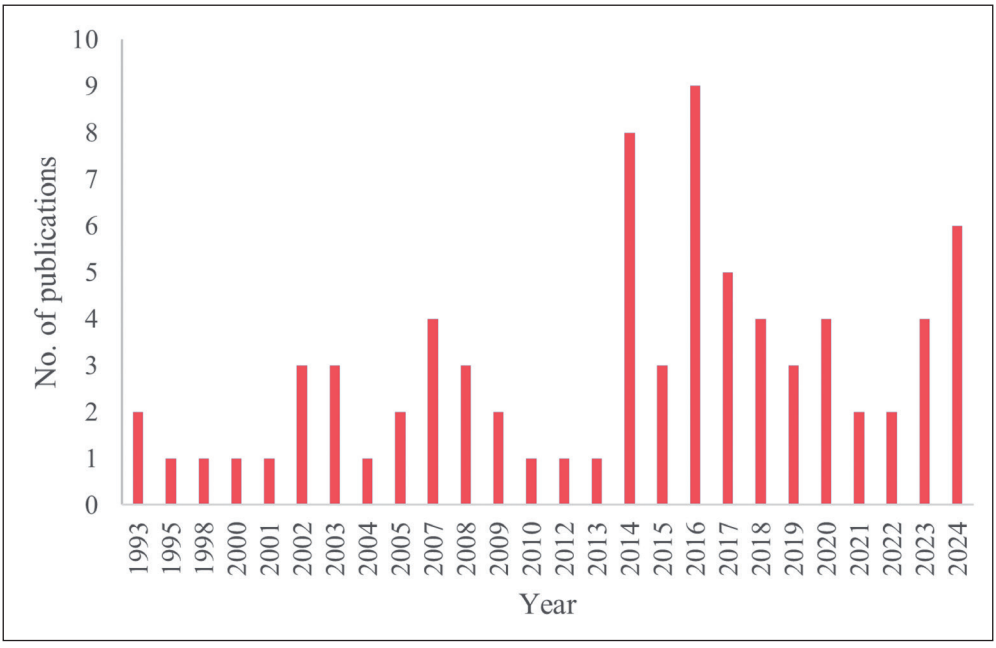


Figure 2. Number of publications on ecosystem services of waterbirds
2. ábra A vízimadarak ökoszisztéma-szolgáltatásait elemző cikkek száma

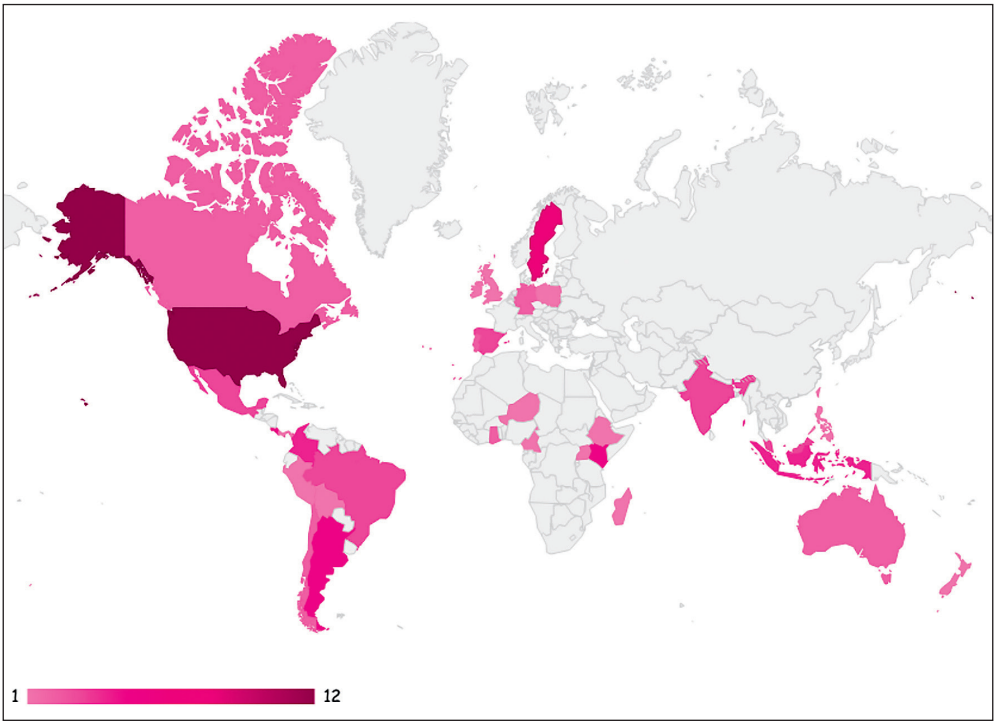


Figure 3. World map showing country-wise publications on ecosystem services provided by birds
3. ábra A madarak általi ökoszisztéma-szolgáltatásokat elemző cikkek országonkénti megoszlása, világtérképen ábrázolva

Scientific publications on ecosystem services of waterbirds were scant prior to the Millennium Ecosystem Assessment in 2003. Thereafter, there was an increase in the number of publications on ecosystem services of waterbirds, which was brought about by the concept of ecosystem services to the vanguard of the global policy debate *(Figure 2)*. Of 174 articles, a total of 92 publications described the functions and services provided by both waterbirds and terrestrial birds; of these, only 77 were specific to the functions of waterbirds, and the remaining 15 described both aquatic and terrestrial birds. Papers with the most relevance to Ganga River, in terms of similar species or genus, were segregated further for in-depth study. These 92 articles on avian ecosystem services were mapped to show the country of origin of these articles *(Figure 3)*.

Results and Discussion

The functional role of waterbirds determined through their feeding, and the behavioral pattern suggests that there is a close relationship between the feeding guilds and the ecosystem services provided by different families *(Table 1)*. They have a profound positive effect on aquatic biodiversity, contribute to biological pest control, act as indicators of conditions of

Table 1. Feeding guild and family-wise delivered services
1. táblázat Táplálkozási guildek és családonkénti szolgáltatásaik

Family	Feeding guild	Ecosystem Service	References
Podicipedidae	Piscivorous	Bioindicator of absence of large predatory fish (Avoid water with large predatory fish)	Konter 2001
Phalacrocoracidae	Piscivorous	Biological pest control, Indicator of regime shift of wetland	Engström 2001
Anhingidae	Piscivorous	Indicator of unpolluted and deep waterbody, Indicator of presence of fish	Rahmani 2005
Ardeidae	Insectivorous	Biological pest control, Seed dispersal, Dispersal of aquatic invertebrates	Nachuha *et al.* 2014, IUCN-SCC Heron Specialist Group 2021
Pelecanidae	Piscivorous	Secondary dispersers of propagules, Nutrient cycling	Michel *et al.* 2020, Green *et al*. 2023
Threskiornithidae	Carnivorous	Indicator of spatial variability of prey availability, Indicator of habitat condition	Frederick *et al.* 2009
Ciconiidae	Carnivorous/ Omnivorous	Biological pest control, Seed dispersal, Animal propagule dispersal	Nachuha *et al.* 2014
Anatidae	Herbivorous/ Omnivorous	Animal propagule dispersal, plant propagule dispersal, Biological pest control, Indicator of presence of fish, Indicator of presence of healthy riverine habitat, Birdwatching and ecotourism, Nutrient recycling	Ormerod & Tyler 1993, Green *et al.* 2002, Charalambidou & Santamaria 2005, Green & Figuerola 2005, Frisch *et al.* 2007, Navedo *et al.* 2015, Boros *et al.* 2016
Accipitridae	Carnivorous/ Piscivorous	Biological pest control, Nutrient cycling, Waste removal, Disease control, Religious symbol	Grande *et al.* 2018
Pandionidae	Piscivorous	Nutrient cycling	Green & Elmberg 2014
Falconidae	Carnivorous	Biological pest control, Religious and cultural symbol	Wilkinson 2003, Grande *et al.* 2018
Gruidae	Omnivorous	Nutrient recycling; Religious and cultural symbol	Navedo *et al.* 2015, Green *et al.* 2016
Rallidae	Herbivorous, Omnivorous	Indicator of presence of macrophyte, Indicator of regime shift of wetland	Mitchell & Perrow 1998, Frisch *et al.* 2007, Green *et al.* 2016
Charadriidae	Carnivorous	Seed dispersal	Green *et al.* 2002
Scolopacidae	Carnivorous	Seed dispersal, Animal propagule dispersal, Indicator of presence of wet grassland habitat, Indicator of alteration of physical structure of mudflat habitat, Nutrient recycling	Green *et al.* 2002, Green & Figuerola 2005, Fisher *et al.* 2011, Navedo *et al.* 2015, Boros *et al.* 2016

Family	Feeding guild	Ecosystem Service	References
Recurvirostridae	Carnivorous	Biological pest control, Disease control, Indicator of presence of polluted water	Ueng *et al.* 2009, Singh *et al.* 2016
Burhinidae	Carnivorous	Seed dispersal	Green *et al.* 2002
Glareolidae	Carnivorous/ Insectivorous	Seed dispersal	Green *et al.* 2002
Laridae	Carnivorous, Omnivorous	Regulation of intertidal food web, Secondary dispersers of propagules, Bioindicator of plastic pollution	Ellis *et al.* 2007, Green *et al.* 2023, Mansfield *et al.* 2024
Alcedinidae	Carnivorous/ Piscivorous	Ecosystem engineering, Nutrient cycling, Bioindicators of plastic pollution	Whelan *et al.* 2015, Belaústegui *et al.* 2018, Winkler *et al.* 2020, Qaiser *et al.* 2023
Hirundinidae	Insectivorous	Sediment transport and biodeposition	Belaústegui *et al.* 2018, McLendon 2019 Tokunaga *et al.* 2023

freshwater ecosystems, help in nutrient influx from terrestrial to aquatic ecosystem, and contribute to waste removal and disease control.

Members of the family Phalacrocoracidae (Cormorants) are chiefly piscivorous and are represented by three species in the mainstream Ganga. Since the early 1990s, rapid increase in cormorant population in Europe and North America (Carss 2003) led to numerous studies on fish consumption by these birds, to reduce the negative conception of the local fishermen who consider these birds responsible for fish exploitation (Zydelis & Kontautas 2008). Studies proved that cormorants are generally predators of artificially stocked fish which are considered a pest to the fishery industry (Bzoma 1998, Engström 2001, Carss 2003). They also increase water transparency by predating on benthivorous fish (Dirksen *et al.* 1995). Reduction of benthivorous fish is necessary to get macrophytes which keep the algal biomass low. Thus, cormorants act as indicators of regime shift of wetlands.

The Little Grebe *(Tachybaptus ruficollis)*, a member of the Podicipedidae family, serves as bioindicator by avoiding waterbodies with large predatory fish (Konter 2001). Oriental Darter *(Anhinga melanogaster)* is the only representative of the family Anhingidae in India. Being an obligate piscivorous bird, its presence indicates the presence of fish species in the waterbody (Ryan 2007, Niangthianhoi & Khudsar 2015). They are also indicators of unpolluted and deep-water bodies (Rahmani 2005).

Agricultural fields – specifically the rice paddies – are favorable foraging grounds for Ciconiidae and Ardeidae, represented by seven and eleven species, respectively, in the Ganga River area. These birds – particularly egrets, herons and storks – feed extensively on rats, snails, crayfish, and tadpole shrimps, and thus, control potential pests in rice paddies (Hafner & Britton 1983, Negro *et al.* 2000, Green & Elmberg 2014, Nachuha *et al.* 2014). By predating upon snails, Asian Openbill *(Anastomus oscitans)* indirectly reduces the incidence of schistosomiasis infection in humans working in agricultural fields (Nachuha *et al.* 2014). Yellow Bitterns *(Ixobrychus sinensis)* also help in pest control by catching flying insects and stem-boring crickets from rice fields (Lansdown & Rajanathan 1993,

IUCN SSC Heron Specialist Group 2021). Other valuable representatives of the order Ciconiiformes are Greater Adjutants *(Leptoptilos dubius)*, having an important role in scavenging discarded waste material including unburied corpses as well as large carrions, thus saving the populace from pestilence (BirdLife International 2016). Now having only a few records from the Gangetic basin, the Greater Adjutants were once common in the streets of Kolkata, West Bengal, and even figured prominently in the first emblem of Calcutta Municipal Corporation (1896).

Ibises (Threskiornithidae) are colonially nesting waders and tactile feeders, hence they require concentrated prey in shallow water. That is why they are important indicators of spatial variability of prey abundance, because they quickly abandon feeding sites when prey availability begins to decline due to longer patterns of precipitation or drying (Frederick *et al.* 2009). Though their conservation status is Least Concern, their population trend is decreasing globally owing to ongoing habitat destruction.

Sarus Crane *(Antigone antigone)*, one of the important members of the family Gruidae, is traditionally protected in India due to its association with the Hindu scriptures and is thus considered sacred. The earliest literary evidence of Sarus Crane is in the ancient Sanskrit literature Ramayana (Sundar & Choudhury 2003). The ubiquitousness of sarus in the Gangetic floodplains, their unison calls, and the legends of life-long pair-bonds have given the species an eminent position in Indian culture and folklore. This crane aids in nutrient cycling and pest management in the agricultural fields (Sundar 2018). Another member of this family, Common Crane *(Grus grus)* has proved to be helpful in nutrient recycling in rice agroecosystems through guanotrophication (Navedo *et al.* 2015).

Due to their widespread distribution and abundance, Anatids (ducks and geese) are important for the dispersal of aquatic plant and animal propagules, employing ecto- and endozoochory (Green *et al.* 2002, Frisch *et al.* 2007). They are responsible for the dispersal of some keystone species of aquatic ecosystems like *Daphnia* sp. (Green & Elmberg 2014), which are abundant in the Ganga River basin too (Padhye *et al.* 2016). These crustaceans cannot move between wetlands or river catchments on their own and depend largely on ducks for their dispersal. Studies have provided evidence that they are dominant zooplanktons that regulate phytoplankton abundance, and thus, also help to reduce the turbidity of water (Wurtsbaugh 1992, Scheffer 2001), and promote the growth of aquatic macrophyte population and associated benthic invertebrate communities (Leah *et al.* 1980). Herbivorous dabbling ducks including Eurasian Teal *(Anas crecca)*, Mallard *(Anas platyrhynchos),* Northern Pintail *(Anas acuta)*, Northern Shoveler *(Spatula clypeata)*, and Gadwall *(Mareca strepera)* play a crucial role in dispersing viable plant propagules, many of which are important components of the ecosystem and offer valuable indirect benefits to humans (Green *et al.* 2016). The Gangetic basin is one of the important wintering grounds of Anatidae (Grimmett *et al.* 2014, WII-GACMC 2018), and their presence in the agricultural fields, specifically in the rice paddies, can reduce the biomass of weeds during harvest times and increase the rate of residue decomposition (van Groenigen *et al.* 2003), and also help in nutrient recycling through defecation (Navedo *et al.* 2015). Besides, ducklings also help to control the mosquito population by feeding on their larvae (Miles *et al.* 2002). There is a positive correlation between the presence of piscivorous Anatids like Goosander *(Mergus*

merganser) and the smaller fish population in the large lotic water body because they feed mostly on larger fish. They also need an adequate supply of fish population to raise many ducklings (McNicol *et al.* 1995, Kajtoch *et al*. 2014). Furthermore, their existence is congruent with the healthy riverine habitat, as they avoid the river stretch altered due to bank regulation or, dam or barrage construction (Kajtoch & Figarski 2013). It has been reported that the distribution of aquatic mammals, like Eurasian Otter *(Lutra lutra)*, is positively influenced by Goosander (Kajtoch *et al.* 2014).

Apart from all these functions, Anatidae and colonially nesting waders are also valuable from the perspective of bird watching and ecotourism (Edgell & Williams 1992, MacMillan & Leader-Williams 2008), and thus, have the potential to contribute to the rural economy and also to the conservation of the species and their habitat (Şekercioğlu 2002, Green & Elmberg 2014, Gaston *et al.* 2018). Furthermore, the presence of ducks and geese is revered in the ancient Indian scriptures where their long migratory flight and family loyalties have been mentioned (Kumar *et al.* 2005).

Many of the raptor species inhabiting the Gangetic basin have a globally decreasing population trend due to habitat loss and degradation. Some of them inhabit agricultural ecosystems and control the population of rodents and other small mammals (Korpimaki *et al.* 1996, Kross *et al.* 2018). Their presence also helps to control rodent activity in the respective agricultural fields (Abramsky *et al.* 1996). This evidence suggests that they have the potential to contribute to biological pest control services. Other birds of prey like Fish-eagles (*Icthyophaga* spp.) and Osprey *(Pandion haliaetus)* are chiefly piscivorous, and they help in transporting nutrients from aquatic to terrestrial ecosystems. The input of their phosphate-rich guano influences wetland productivity and fish production (Green & Elmberg 2014, Whelan *et al.* 2015). Obligate scavengers like Egyptian Vultures *(Neophron percnopterus)* have a potential role in transporting a large amount of energy and nutrients from carcasses to the food web, and thus, they contribute to waste removal, disease control, and also nutrient cycling (Whelan *et al.* 2015, DeVault *et al.* 2016). Their decreasing population in India, particularly in the Ganga basin could have increased the population of facultative scavengers like feral dogs, which have a negative impact on predation on other wildlife (Pain *et al.* 2003, DeVault *et al.* 2016) and also serve as reservoirs and vectors of several zoonotic diseases (Pain *et al.* 2003). This near extirpation of vultures also disrupted the sky burial tradition of the Parsi and Tibetan Buddhists in which human corpses are exposed to open area to be consumed by sacred vultures, which are symbolized for purification and resurrection (DeVault *et al.* 2016, Bhusal *et al.* 2020). Another predatory bird, the Peregrine Falcon *(Falco peregrinus)* has religious importance for being present in the history of Ancient Egypt (Wilkinson 2003).

The decline in Eurasian Coot *(Fulica atra)* population indicates the decreasing abundance of submerged macrophytes caused by eutrophication (Mitchell & Perrow 1998, Green & Elmberg 2014). Hence, they serve the role of bioindicator of the presence of macrophyte and regime shift of wetland. This species also aids in dispersing viable diaspores of several aquatic plants and is reported to consume more seeds than one of the Anatids, Gadwall (Green *et al.* 2016). The Common Moorhen *(Gallinula chloropus)*, another species within the Rallidae family, serves as vectors of seeds of birdcatcher tree

(Pisonia grandis) which has a wide distribution in India (Green *et al.* 2016). All the members of the family Scolopacidae are winter visitors to the Gangetic basin. Owing to their long-distance migration, their role in seed and invertebrate propagule dispersal is globally important (Green *et al.* 2002, 2005), and they help to maintain the biotic connectivity between the world's wetlands (Amezaga *et al*. 2002). Some of them like Common Snipe *(Gallinago gallinago)* and Common Redshank *(Tringa totanus)* also serve the function of indicator species of the presence of wet grassland habitat (Fisher *et al.* 2011). By grazing on epibenthic biofilm, sandpipers are estimated to be turning over tons of sediments. Thus, biofilm grazing by large flocks of scolopacids results in bioturbation, which can potentially alter the physical structure of mudflat ecosystem (Mathot *et al.* 2018, Beninger & Elner 2020). The presence of another Scolopacid, Black-tailed Godwit *(Limosa limosa)*, in paddy fields, aids in nutrient recycling (Navedo *et al.* 2015).

Black-winged Stilt *(Himantopus himantopus)* helps to control malaria by preying upon mosquito larvae (Ueng *et al.* 2009). It also feeds on chironomid midges, and thus, may have a role in preventing the allergic response in humans caused by chironomid larvae (Ueng *et al.* 2009, Nandi *et al.* 2014). Besides, stilts act as indicators of the presence of polluted water and can easily be seen foraging in the water just beside the source of pollution (Singh *et al.* 2016). They have a globally increasing population trend and are also well distributed throughout the Gangetic basin, which may be due to their tolerance to contaminated water.

Represented by three species in the Ganga River area, members of the Burhinidae and Glareolidae families help in the dispersal of seeds (Green *et al.* 2002); ecosystem functions of these families at species level still have not been quantified.

Gulls (Laridae) are one of the prominent bioindicators of plastic pollution (Mansfield *et al*. 2024). Being predatory, they facilitate the secondary dispersal of propagules either inside or attached to their prey (Green *et al.* 2023). Additionally, gulls play a role in regulating intertidal food webs by consuming highly mobile predators and augmenting the population of other mesopredators during low tide (Ellis *et al*. 2007).

Kingfishers and martins are primary tunnel nesters. These 'ready-made nesting tunnels' are often used by secondary nesters (Goodfellow 2011, Smalley *et al.* 2013, Belaústegui *et al.* 2018), and thus, these species shape the microenvironment for other species (Ali *et al.* 2010, Smalley *et al.* 2013). Such tunnel nests also help in bioturbation (Belaústegui *et al.* 2018). Being largely piscivorous, all the representatives of the family Alcedinidae have an important role in nutrient influx from terrestrial to aquatic ecosystem (Whelan *et al.* 2015). Among them, Common Kingfisher *(Alcedo atthis)* and White-throated Kingfisher *(Halcyon smyrnensis)* also act as a bioindicator of plastic pollution (Winkler *et al.* 2020, Qaiser *et al.* 2023) by feeding on plastic-bioaccumulating prey (Mansfield *et al.* 2024). Furthermore, swallows (Hirundinidae) transport sediment and play role in biodeposition while building their nests with sediment and saliva (Belaústegui *et al*. 2018, McLendon 2019). Barn Swallows *(Hirundo rustica)* function as bioindicators of air-borne microplastic pollution (Tokunaga *et al.* 2023). The members of these families are widely distributed along the Ganga River.

The literature suggests that waterbirds are extremely valuable from the perspective of ecosystem functions they provide, yet the roles of many families are still not clear and require

further studies. As Asia represents only 11.43% of studies on avian ecosystem services, there is an urgent need to qualitatively study the ecosystem services of the waterbirds in India, particularly in the context of the Ganga River.

The sheer diversity of waterbirds in India is primarily due to the diversity of aquatic habitats, hence understanding the linkage between aquatic habitat and waterbirds is crucial. Any threats to the aquatic ecosystem will affect waterbirds that are dependent on these. The population trend of many of these waterbirds is decreasing due to the decline in their habitat and other threats they face in their foraging and breeding grounds and stopover sites. The expansion of human habitation and consequent land use changes along the river bank, river bed, and the associated wetlands, use of mechanized boats, commercial exploitation of the birds, disturbances in the nesting and foraging ground of birds in the floodplains due to extensive loss of vegetation cover, and use of chemical pesticides have resulted in the population decline of migratory as well as resident birds of the Ganga River (Sinha *et al.* 2009). About 10% of waterbirds of Ganga are threatened and have been placed under several threatened categories by IUCN (WII-GACMC 2018).

Conclusion

Understanding the functional role of waterbirds, through natural history research, can aid in informed decision-making by the policymakers as well as the public. It has been documented that biodiversity has a pivotal role in all the levels of the ecosystem service hierarchy, hence combining biodiversity with the ecosystem services implies that managing one will enhance the other (Mace *et al.* 2012). Higher biodiversity stabilizes and diversifies the ecosystem functions which in turn ensures the delivery of ecosystem services (Jacobs *et al.* 2013). Hence for effective ecosystem management, it is required to identify and analyze the roles of biodiversity in optimization of ecosystem service delivery and conservation of species and their habitat.

Ecosystem service co-benefits are a lens through which the conservation of birds, and the habitat they rely on, can illuminate potential options for maintaining a larger suite of services derived to people now and into the future. Globally, over 60% of the ecosystem services are already degenerating or overused (Millennium Ecosystem Assessment 2005). An understanding of the functional roles of waterbirds and the resultant ecosystem services will aid in informed decision making, particularly in the wake of United Nations' call for decade of Ecological Restoration and the "nature-based solution" to achieve the restoration. Avian ecologists can demonstrate that maintaining diversity can be useful for building resilience of the ecosystem and adaptive capacity of the communities. The findings of this study would increase public support for the conservation of biodiversity in a holistic manner. National Mission for Clean Ganga's objective of intensifying and augmenting the conservation efforts at Ganga and its tributaries, for aquatic biodiversity conservation and maintenance of ecosystem services for a clean Ganga, also provides a gateway for research on ecosystem services delivered by waterbirds.

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Burning or cutting? Comparing methods for bird conservation in the reedbeds of Lake Neusiedl/Fertő

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Abstract Lake Neusiedl/Fertő has Europe's second-largest reed area (180 km^2), and it is home to some of the largest populations of reed birds on the continent. In recent years, reed die-back and the extensive formation of a thick litter layer of broken reed have led to a dramatic decline in some reed bird species. Management measures to renew reedbeds and conserve their avifauna include reed burning, but this practice faces legal challenges in Austria. To get a first assessment of the feasibility of fire management, we compared reedbeds that had been burnt one year before with old reedbed sites and regularly harvested sites based on abundance indices of a set of characteristic reed bird species. This was achieved by conducting point counts in burnt and old reedbeds, and by comparing our results with counts in harvested areas, which involved a total of 88 point count locations. Our results show that the abundance patterns of the focal species in the burnt area are similar to those in the cut areas. However, there were differences as well, for example, the Water Rail *(Rallus aquaticus)* was significantly more abundant at the burnt site. As expected, we found fewer "old reed specialists" in the burnt area compared to the old reed sites. Although this study provides only a snapshot of the spatio-temporal processes in the reed belt, our findings suggest that burning does not have a negative impact on the bird assemblage compared to reed harvesting.

Keywords: fire management, reed die-back, reed age, *Phragmites australis*, controlled burning

Összefoglalás A Fertő-tó/Neusiedler See Európa második legnagyobb egybefüggő nádasával (180 km^2) rendelkezik, és a kontinens legjelentősebb nádi madárpopulációinak ad otthont. Az elmúlt években a nádpusztulás és az avas nád vastag rétegben való felhalmozódása bizonyos nádi madárfajok jelentős állomány-csökkenéséhez vezetett. A nádas megfiatalítására és madárvilágának megőrzésére irányuló kezelési intézkedések közé tartozik a nádégetés, de ez a gyakorlat Ausztriában jelenleg jogi korlátokba ütközik. Ezen élőhely-kezelési gyakorlat megvalósíthatóságának felmérése céljából összehasonlítottunk egy előző évben leégett nádterületet rendszeresen aratott és idősebb nádas területekkel, kiválasztott madárfajok abundanciája alapján. Az adatfelvételezést 88 mintavételi helyszínen pontszámlálással végeztük, beleértve a leégett, idős és aratott nádasokat. Eredményeink azt mutatják, hogy a leégett területeken megfigyelt madárfajok abundanciája hasonló az aratott területekéhez. Voltak azonban különbségek is, például a guvat *(Rallus aquaticus)* szignifikánsan gyakoribb volt a korábban leégett területen. A várakozásoknak megfelelően kevesebb „öregnád-specialistát" találtunk az égetett területen, mint az idősebb nádasokban. Bár ez a tanulmány csak egy pillanatfelvételt nyújt a nádasban lejátszódó tér- és időbeli folyamatokról, eredményeink arra utalnak, hogy a nádégetésnek nincs negatív hatása a madárvilágra a nádaratáshoz képest.

Kulcsszavak: tűzmenedzsment, nádpusztulás, nádas kora, *Phragmites australis*, kontrollált égetés

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Introduction

Europe has lost 80% of its wetlands in the past millennium (Verhoeven 2014). Thus, it is crucial to protect such remaining habitats and to restore lost ones (Čížková *et al.* 2013, Hu *et al.* 2017). Common reed *(Phragmites australis)* is a characteristic colonizer of numerous wetland habitats, and reedbeds are also known to have shrunk Europe-wide (Graveland 1998), posing a threat to numerous species that are evolutionarily adapted to, and thus, dependent on them. The Lake Neusiedl/Fertő is the westernmost steppe lake in Europe, located in Austria and Hungary (Dinka *et al.* 2010, Tolotti *et al.* 2021) with an average water depth of 1.2 meters (Soja *et al.* 2013). It is surrounded by an extensive reed belt (180 km^2), the second-largest contiguous reed area in Europe, following the Danube Delta (Csaplovics 2019), and it is home to numerous species of conservation concern (Dvorak *et al.* 2024). This unique ecosystem at the western edge of the Pannonian Ecoregion is especially vulnerable to the impacts of climate change (Soja *et al.* 2013, Dokulil *et al.* 2021). Considering its size and the bird populations it sustains, it is evident that the reed belt of Lake Neusiedl/Fertő requires protection and management in an ecologically reasonable way. Management measures should be designed carefully based on a scientific basis, taking into account the characteristics of this fragile lake ecosystem (Nemeth *et al.* 2022).

After the last dry-up in 1865–1870, the reed belt around Lake Neusiedl/Fertő has expanded dramatically, mainly due to the lowering and stabilization of formerly highly variable water levels. A major influence on the extension of the reed areas resulted from the construction of a drainage channel called Hansági-főcsatorna (Einserkanal) in 1909, and later from the weir system at Mekszikópuszta in 1965. In the last century, reed growth had been influenced by increased nutrient input from unmanaged sewage from nearby municipalities, and it is still impacted by agricultural activities around the lake (Wolfram *et al.* 2014, Csaplovics 2019, Nemeth *et al.* 2022). Consequently, the water regime of Lake Neusiedl/Fertő has been dramatically altered by technical interventions.

Currently, the lake is facing the issue of reed die-back and a massive accumulation of biomass. Reed die-back can be seen as a natural succession state that offers, at least for some time, niches for different fungal, insect, and bird species, such as the old-reed specialist Moustached Warbler *(Acrocephalus melanopogon)*. However, the recent breakdown of reed stands has an overall devastating effect on reed birds (Nemeth & Dvorak 2022). Reed stands have collapsed in one direction, forming a thick litter layer (hereinafter: mats) up to one meter high *(Figure 1)*. According to Perlinger (2022), the area covered by mats of broken reed reached 17 km^2 on the Austrian side in 2019. However, based on aerial images taken between 2020 and 2024, the extent may well have increased since then (E. Nemeth *pers. obs.*).

Reed die-back is a phenomenon that has been reported from various locations across Europe (Armstrong & Armstrong 2001, Engloner 2009, Dinka *et al.* 2010, Tóth 2016). At Lake Neusiedl/Fertő, die-back processes of reed have been reported since the 1970s (Csaplovics 1985, Dinka & Szeglet 1999, Dinka *et al.* 2010). Armstrong *et al.* (1996) describe the process and causes of reed die-back, which includes an environment flooded by stagnant water, the accumulation and microbial decomposition of organic matter (fallen leaves, decaying



Figure 1. Aerial photo of mats of broken reed ©Erwin Nemeth 2024
1. ábra Légifelvétel a felhalmozódott avas nádrétegekről ©Erwin Nemeth 2024

stems, dead rhizomes), and subsequent oxygen depletion. This is followed by anaerobic decomposition, which leads to the production of phytotoxins (sulfides, ammonia, and organic acids) that damage rhizomes and prevent aeration through the aerenchyma, resulting in reduced growth and die-back. It has been reported that mechanical damage to reed rhizomes causes and exacerbates the effect of reed die-back (Armstrong & Armstrong 2001).

Several strategies exist for managing reed habitats, including cutting, prescribed burning, and grazing (Ostendorp 1987, Báldi & Moskát 1995, Vadász & Csörgő 2009, Biró *et al.* 2020). Reed harvesting, once widespread around the lake, traditionally took place on frozen surfaces, which prevented mud compaction and rhizome damage (Dvorak *et al.* 2024). However, global warming has reduced suitable ice conditions, limiting this practice (Führer 2010). Additionally, prescribed burning, which was formerly used to prepare areas for cutting, is now prohibited. As stated in the Austrian Air Pollution Control Act (BGBl. I Nr. 137/2002), the burning of materials is only permitted in incineration plants (Bundeskanzleramt Österreich 2025). Therefore, climate change combined with socioeconomic changes over the past centuries has altered the harvesting practices.

Today, reed cutting is performed using heavy machinery. At previously unused sites, the process involves flattening reed vegetation in winter to prepare it for mowing the following year (Nemeth *et al.* 2022). Flattening and mowing can cause ground compaction and damage to reed buds in more deeply flooded reedbeds. This results in diminished regrowth and ultimately leads to reed die-back. By examining satellite imagery, it is evident how the harvesting machines damage the reedbed *(Figure 2),* and how certain parts of the contiguous

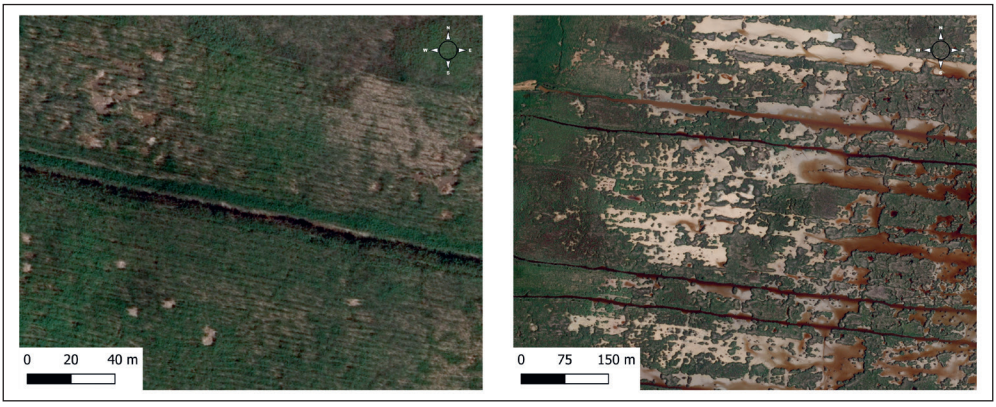


Figure 2. Marks of reed harvesting machines (left) and patchy vegetation due to reed die-back (right) near Mörbisch (Fertőmeggyes) Source: ESRI Satellite Imagery

2. ábra A nádarató gépek nyoma (balra) és a nádpusztulás által gyérré vált növényzet (jobbra) Mörbisch (Fertőmeggyes) közelében Forrás: ESRI Satellite Imagery

reed area have transformed into a habitat with patchy reed growth surrounded by open water. Conversely, in older uncut areas of the reedbelt, the formation of mats of broken reed creates unfavorable conditions. To address both issues, the reintroduction of fire management has been proposed (Nemeth *et al.* 2022).

Several studies have investigated the ecological impacts of reed cutting and reed burning on birds (Báldi & Moskát 1995, Ostendorp 1995, Goc *et al.* 1997, Graveland 1999, Valkama *et al.* 2008, Vadász & Csörgő 2009, Moga *et al.* 2010, Mérő *et al.* 2015, Antoniazza *et al.* 2018). The meta-analytical review by Valkama *et al.* (2008) concluded that long-term management leads to a reduction of avifauna by approximately 60%, mainly due to the decline of invertebrates and the absence of certain structural elements. Nonetheless, there is a fundamental difference between long-term and short-term management: while long-term management (i.e. yearly recurring management practices over many years) reduces bird densities, short-term management (1–2 years) enhances habitat quality (Valkama *et al.* 2008, Vadász & Csörgő 2009).

Several studies have focused on the ecological effects of burning in older reedbeds (Báldi & Moskát 1995, Valkama *et al.* 2008, Mester *et al.* 2015). Although the necessity for such a project has been emphasized (Nemeth *et al.* 2022, Nemeth & Dvorak 2022), no study has yet been conducted on this topic at Lake Neusiedl/Fertő. To address this gap, we compared burnt, cut, and old reedbeds based on their bird assemblage within the framework of a project initiated by the Federal State of Burgenland (Land Burgenland) to evaluate the effects of prescribed burning (Land Burgenland 2024). Since the area of the initial test burning in Jois (Nyulas) was considerably smaller than anticipated (Berner *et al.* 2025), we used a larger, accidentally burnt area in Breitenbrunn (Fertőszéleskút) in our assessment *(Figure 3)*.

We focus on eight passerine species and two non-passerine species that breed in the reed belt of Lake Neusiedl/Fertő. The objective of our study is to examine differences in this set of characteristic bird species between previously burnt reed areas, cut reed of similar age, and older reedbeds similar to the reed stands that existed before the fire.

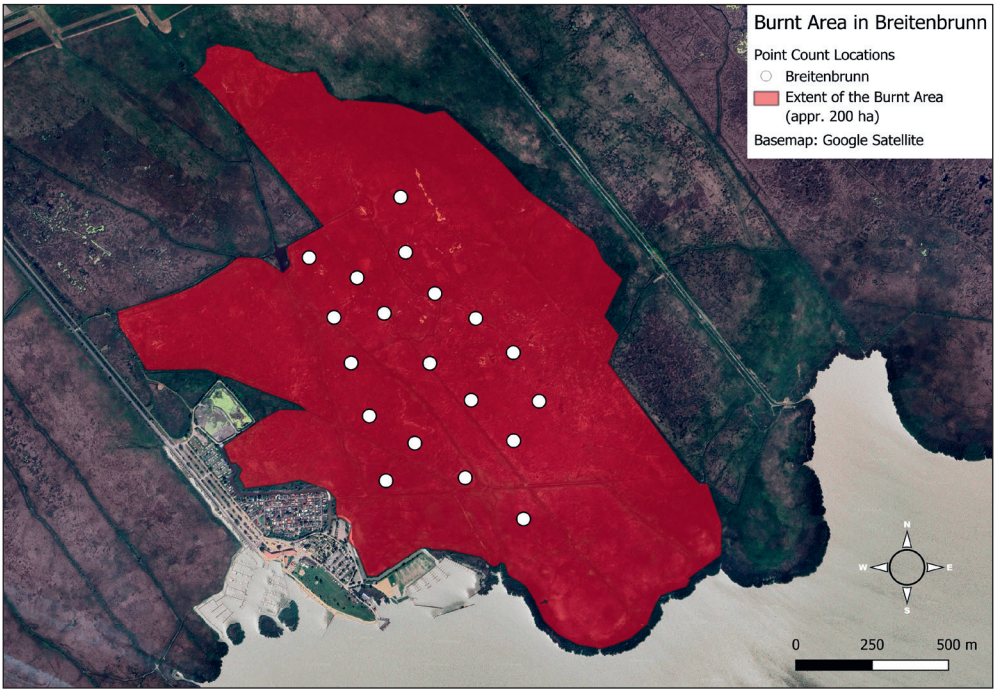


Figure 3. Extent of the burnt areas and locations of the point counts near Breitenbrunn (Fertőszéleskút)
3. ábra A leégett területek kiterjedése és a mintavételi pontok helyszínei Breitenbrunn (Fertőszéleskút) közelében

Material and Methods

Study area

The study area encompasses the Austrian part of the reed belt surrounding Lake Neusiedl/Fertő. During the fieldwork in 2024, two sites were surveyed: a one-year-old reedbed that had previously burnt in Breitenbrunn and an old reedbed (over 15 years old) in Illmitz. In 2019, counting points were distributed throughout the entire Austrian portion of the reed belt, excluding the national park area.

Number of points and their selection

Observation data from a total of 88 points were used in our analysis. The locations in 2024 (Breitenbrunn and Illmitz) included 19 and 10 point count locations, respectively. Data from 2019 consisted of 30 points from old reed sites, 16 points from cut reedbeds aged one to four years, and 13 points from a cut reedbed less than one year old. In the two survey years, we chose different sites with no overlap of the counted areas (see *Figure 4*). A minimum distance of 150 meters was kept between neighboring points to prevent spatial overlap and to guarantee independent sampling. The point count locations in Breitenbrunn

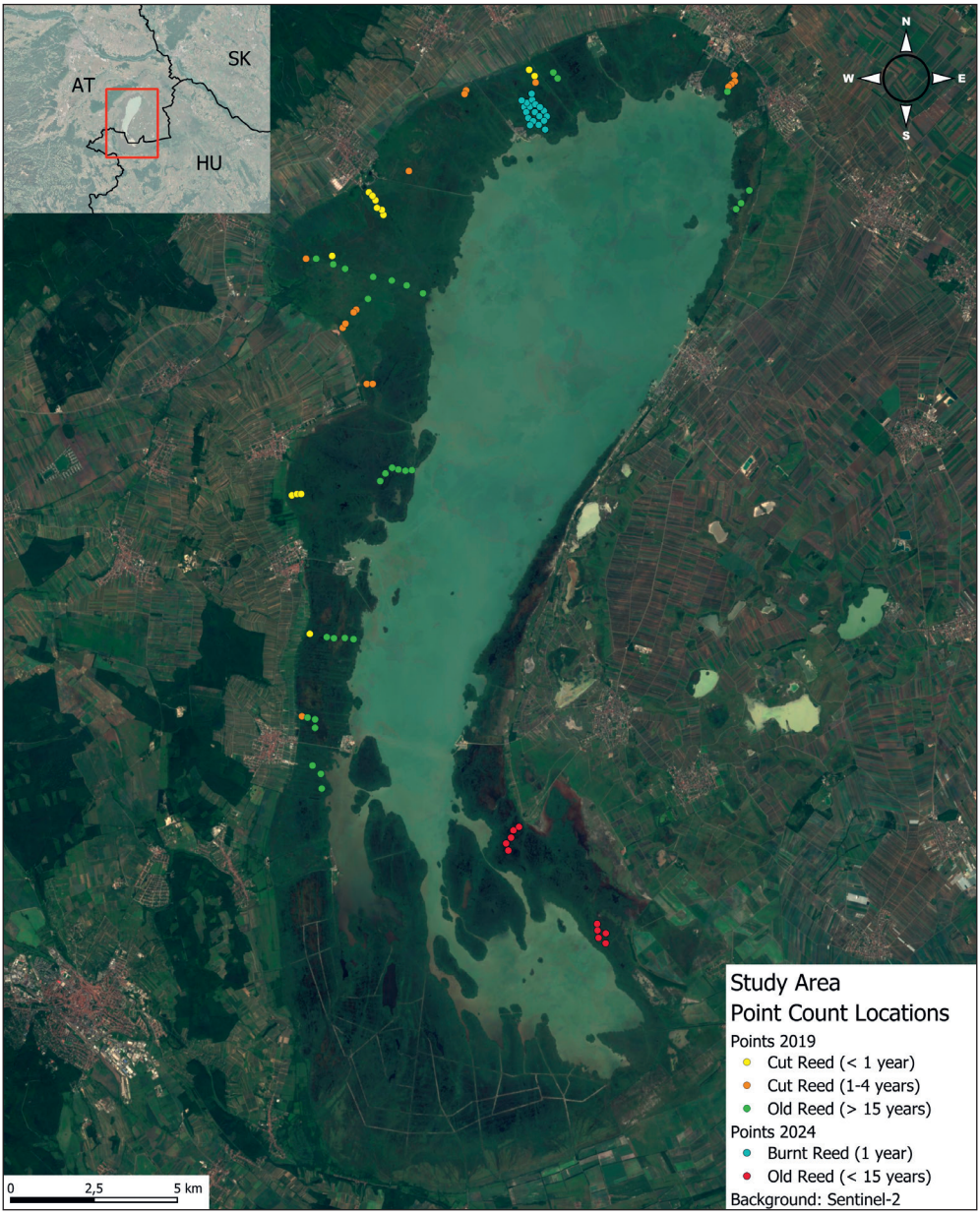


Figure 4. Study area and point count locations (2019–2024)
4. ábra A kutatási terület és a pontszámlálás helyszínei (2019–2024)

were preferentially selected using GIS software, with the aid of Sentinel-2 satellite imagery (European Space Agency 2023), to ensure they were situated in areas where reed had not been cut since the fire event.

Bird species

The Water Rail *(Rallus aquaticus)* is a short-distance migrant found in its breeding ground between mid-March and the beginning of October, although overwintering has also been reported (Csörgő *et al.* 2009, Dvorak *et al.* 2024). It prefers reedbeds, fens, and marshes with shallow water and dense vegetation (Dvorak *et al.* 2024).

The Little Crake *(Zapornia parva)* is a long-distance migrant, and it can be found between the end of March and the end of September at Lake Neusiedl/Fertő (Csörgő *et al.* 2009, Dvorak *et al.* 2024). It prefers old reedbeds with a mosaic of reed patches, open water, and channels (Nemeth *et al.* 2022).

The Bluethroat *(Luscinia svecica)* is a long-distance migrant that can be observed between the end of March and October in Central Europe (Csörgő *et al.* 2009, Dvorak *et al.* 2024). At Lake Neusiedl/Fertő, it is now bound to anthropogenically altered habitats, such as channels and dams, or to dried-up open water areas within the reed belt in years with low water levels (Grüll 2001, Dvorak *et al.* 2024).

The Savi's Warbler *(Locustella luscinioides)* is a long-distance migrant found in Europe between April and October (Csörgő 1995b, Csörgő *et al.* 2009). It prefers extensive, unmanaged reedbeds occasionally with Typha (Csörgő 1995b, Haraszthy 2019b), and it is known to use higher reed stands along channels as singing posts (Dvorak *et al.* 2024).

The Moustached Warbler is a short-distance migrant that returns from its wintering ground in March and can be observed until October, occasionally even in November (Csörgő 1995b, Csörgő *et al.* 2009, Dvorak *et al.* 2024). It breeds in extensive reedbeds with dense, old reed (Nemeth *et al*. 2022).

The Sedge Warbler *(Acrocephalus schoenobaenus)* is a sub-Saharan migrant found in its breeding grounds between April and October (Csörgő *et al.* 2009, Dvorak *et al.* 2024). It breeds in the transition zone of reedbeds with sedges and low shrubs (Csörgő 1995b, Haraszthy 2019b, Dvorak *et al* 2024).

The Common Reed Warbler *(Acrocephalus scirpaceus)* is a long-distance migrant present in its breeding grounds between April and October (Csörgő *et al.* 2009). It prefers homogenous reedbeds (Csörgő 1995b), and its distribution was found to be relatively equal among reed age classes at Lake Neusiedl/Fertő (Nemeth & Dvorak 2022).

The Great Reed Warbler *(Acrocephalus arundinaceus)* is a long-distance migrant found in European reedbeds from April until September (Csörgő *et al.* 2009). It prefers tall, dense, young reed stands with thick reed stems near open water (Leisler 1981, Leisler & Schulze-Hagen 2011, Dvorak *et al.* 2024). Nests are mostly found near the waterside edge of reed stands, typically within 2 m from open water (Csörgő 1995b).

The Bearded Reedling *(Panurus biarmicus)* is mainly non-migratory (Csörgő *et al.* 2009, Dvorak *et al.* 2024). It favors medium-height reed stands and a bent layer of broken stems, and old reed patches that have not been cut or burnt for years (Haraszthy 2019b).

The Reed Bunting *(Emberiza schoeniclus)* is sedentary in the southern edge of its range, while the northern individuals are migratory; the Central European population is partly migratory (Csörgő *et al.* 2009). It requires dry ground for breeding and is typically found in the dry edge zones rather than in the inner parts of extensive reedbeds (Haraszthy 2019b, Dvorak *et al.* 2024).

Bird counts

The point count methodology, which utilizes distance estimation for each bird, follows the approach described by Buckland *et al*. (2001), also employed in the study by Nemeth and Dvorak (2022). The surveys were conducted by two individuals proficient in identifying bird vocalizations. Prior to the start of the project, a joint mapping session was organized with other field experts to assess and ensure consistency between counters.

All counting points were surveyed three times over a two-month period, from the 30th of April till the 30th of June. The mapping was conducted between 4:50 and 11:00 a.m. from a 3.5 m tall ladder, which provided an elevated vantage point for observation. A laser rangefinder (Nikon Laser 550/550) was used to estimate the distance to the locations around each counting point where birds were seen or heard. The counting interval lasted five minutes to maximize the likelihood of registering birds and to minimize the chance of double-counting. During this interval, birds were identified acoustically and, when possible, visually. When birds moved within the counting interval, we measured the distance to the first sighting. Apart from the Bearded Reedling, all species were counted based on territorial song or calls. Since Bearded Reedlings have no conspicuous territorial song, they were recorded at the first location seen. For Water Rail and Little Crake, a 1-minute playback of their territorial calls was played from a speaker after the counting interval to elicit a response from them. The distance to the first response was recorded, and the playback was stopped if a response was heard before the end of the recording. Each observation was recorded in a field notebook, along with the corresponding distance estimate, and later digitized.

For each species, we used the data with the highest number of observations from the three mapping dates for each point. Next, we categorized the observations into three classes: 0–50 meters, 0–100 meters, and all distances within 150 m. Histograms were generated to identify the most appropriate distance class based on the distribution of the observation distances of each species for further statistical analysis. While observation data of the Little Crake and the Common Reed Warbler were analyzed within 0–50 m, the 0–100 m distance class was chosen for the rest of the species.

Statistical analyses

Due to the small sample size (e.g. n = 10 for old reed from 2024), the non-parametric Kruskal–Wallis test was used to assess differences in abundance among the reedbed types (burnt, cut, and old). If significant results or at least a trend ($p < 0.1$) were observed, Dunn's *post-hoc* test with Bonferroni correction was conducted to identify pairwise differences.

Since the data came from two different years with varying water levels in the lake, the mean water depth at each point was calculated using a digital lakebed model (Bácsatyai *et al.* 1997). We utilized mean water level data for Lake Neusiedl/Fertő (Wasserportal Burgenland 2024) from May to June of the respective years to compare the water levels (see *Figure 5*). As we were primarily interested in the relative differences between the water levels from the study years, we derived data from the lakebed model that includes the mud layer. The Kruskal–Wallis and Dunn's *post hoc* tests were used to identify differences between the mean water levels. We applied a generalized linear model (GLM) with a Poisson distribution to assess the effect of water depth on bird species abundance. In this model, the number of individuals served as the predicted values, and water level as the predictor. We checked the models for overdispersion. If the dispersion parameter exceeded the value of 1.2, we addressed it by refitting the model using quasi-Poisson errors.

Data analyses were conducted using R v. 4.3.3 (R Core Team 2024) and R Studio (RStudio Team 2024). We used QGIS (QGIS.org 2009) to calculate water depth at various points and to create maps.

Results

Water levels

The analysis revealed significant differences in water depth among several reedbed types (Kruskal–Wallis, $\chi^2 = 58.47$, $p < 0.001$). The burnt site (B1) had the greatest mean water depth, followed by the old reed site from 2019 (O19), with a non-significant difference. This was followed by the cut reed sites younger than a year (C0), old reed from 2024 (O24), and 1–4-year-old cut reed (C1–4). O24 and the cut sites (C0 and C1–4) did not differ significantly from each other *(Table 1, Figure 5)*. The results of the Poisson regressions to test the influence of water levels on different bird species showed no significant effect of water level on any species except the Sedge Warbler. Here, the species were found significantly more often at sites with lower water levels (Poisson regression, $n = 88$, coeff. $= -1.19$, $p = 0.0013$).

Comparison of burnt and cut reedbeds

The comparison of bird abundances from B1, C0, and C1–4 showed that five of the ten species had significant differences in abundance based on the results of the Kruskal–Wallis test *(Table 2, Figure 6)*.

Species that showed the highest abundance in B1, with significant differences, include Water Rail and Bluethroat. The Water Rail was nearly twice as abundant in B1 as in C1–4, and more than five times more abundant than in C0. The number of Bluethroats was more than twice as high in B1 compared to C0 and over ten times higher than in C1–4.

The species with the lowest abundance in B1 were Savi's Warbler, Moustached Warbler, and Common Reed Warbler. Savi's Warbler exhibited the same abundance in C1–4 and C0,

Table 1. Comparison of Water Depths Across Survey Sites using the Kruskal–Wallis test and the *post-hoc* Dunn's test with Bonferroni correction. Significant differences are indicated in bold. B1 = 1-year-old burnt reed, C0 = cut reed (< 1 year), C1–4 = 1–4-year-old cut reed, O19 = old reed from 2019, O24 = old reed from 2024 (Kruskal–Wallis, $\chi^2 = 58.47$, $p < 0.001$)

1. táblázat A vízmélységek összehasonlítása a megfigyelési területeken a Kruskal–Wallis-próba és a *post hoc* Dunn-próba eredményei alapján, Bonferroni-korrekcióval. A szignifikáns különbségek félkövér betűvel jelölve. B1 = egyéves leégett nád, C0 = vágott nád (< 1 év), C1–4 = 1–4 éves vágott nád, O19 = öreg nád 2019-ből, O24 = öreg nád 2024-ből (Kruskal–Wallis, $\chi^2 = 58.47$, $p < 0.001$)

Reedbed type	Mean Depth±SD (cm)	Comparison	Dunn's p
B1	129.25±5.51	C0 vs C1-4	1.00
C0	79.73±28.15	C0 vs O19	**<0.001**
C1-4	66.59±26.71	C1-4 vs O19	**<0.001**
O19	124.84±25.36	C0 vs B1	**<0.001**
O24	73.73±18.53	C1-4 vs B1	**<0.001**
		O19 vs B1	1.00
		C0 vs O24	1.00
		C1-4 vs O24	1.00
		O19 vs O24	**<0.001**
		B1 vs O24	**<0.001**

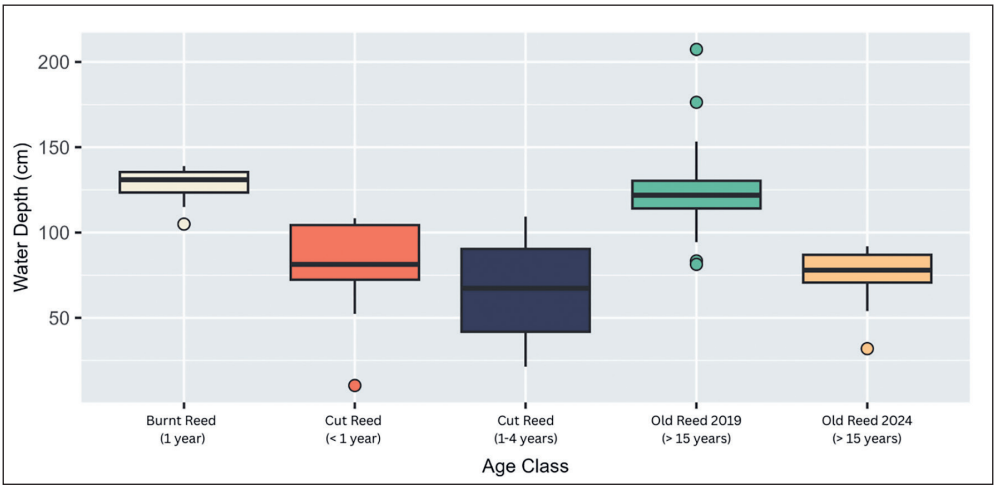


Figure 5. Distribution of water depths at survey points of different reed age classes
5. ábra A vízmélységek eloszlása a különböző korosztályú nádasok mintavételi pontjainál

significantly higher than in B1. The Moustached Warbler could not be observed in B1 and C0, but it was present in C1–4, albeit in very low numbers. For this species, Dunn's test indicated a significant difference between C1–4 and C0 and between C1–4 and B1. The Common Reed Warbler had the highest abundance in C1–4 compared to all other species and habitat classes, but the difference was significant only between B1 and C1–4.

Table 2. Comparison of the number of individuals of the respective species (means±standard deviation) counted at the one-year-old burnt reedbed (B1, n = 19), the less-than-one-year-old cut reed areas (C0, n = 13), and the 1–4-year-old cut reed areas (C1–4, n = 16) using Kruskal–Wallis tests and *post-hoc* Dunn's tests with Bonferroni correction. Significant differences are indicated in bold

2. táblázat Az egyéves leégett nádas (B1, n = 19), a kevesebb mint egyéves vágott nádas (C0, n = 13) és az 1–4 éves vágott nádas területek (C1–4, n = 16) pontjainál regisztrált egyedszámok fajonkénti összehasonlítása (átlag±szórás) a Kruskal–Wallis-próba és a *post hoc* Dunn-próba eredményei alapján, Bonferroni-korrekcióval. A szignifikáns különbségek félkövér betűvel jelölve

Species	B1	C1-4	C0	χ^2	Kruskal–Wallis p	Dunn's p (B1 vs C1-4)	Dunn's p (B1 vs C0)	Dunn's p (C0 vs C1-4)
Rallus aquaticus	2.37±1.26	1.31±1.20	0.46±0.78	16.73	**<0.001**	**0.04**	**0.001**	0.10
Zapornia parva	0.47±0.84	0.38±0.72	0.31±0.48	0.15	0.93	1.00	1.00	1.00
Luscinia svecica	1.42±0.61	0.13±0.34	0.69±0.85	22.84	**<0.001**	**<0.001**	**0.02**	0.09
Locustella luscinioides	0.63±0.68	1.69±0.79	1.69±1.18	13.48	**0.001**	**0.001**	**0.08**	1.00
Acrocephalus melanopogon	0.00±0.00	0.25±0.58	0.00±0.00	6.26	**0.04**	**0.04**	1.00	0.06
Acrocephalus schoenobaenus	0.47±0.70	0.81±1.22	0.77±0.93	0.70	0.70	0.86	0.63	1.00
Acrocephalus scirpaceus	2.26±1.24	3.63±0.81	2.77±1.09	11.77	**0.003**	**0.001**	0.42	0.06
Acrocephalus arundinaceus	1.84±0.96	1.56±1.55	1.69±1.25	1.77	0.41	0.28	0.68	0.96
Panurus biarmicus	0.32±0.48	0.63±0.72	0.69±0.63	3.32	0.19	0.28	0.13	0.98
Emberiza schoeniclus	2.47±1.22	1.81±0.83	1.62±0.87	5.22	0.07	0.17	0.05	0.77

Species that displayed no significant differences across habitat classes include Little Crake, Great Reed Warbler, Sedge Warbler, Bearded Reedling, and Reed Bunting. However, the Little Crake and Great Reed Warbler had their highest abundance in B1, while the Sedge Warbler and Bearded Reedling were most abundant in C1–4. The Bearded Reedling was nearly half as abundant in B1 compared to the other cut areas, a pattern that was similar for the Sedge Warbler. While the Great Reed Warbler had higher numbers in C0 than in C1–4, the Little Crake showed the opposite. The Reed Bunting was most abundant in B1, followed by approximately one-third lower values in C1–4 and C0.

Comparison of burnt and old reedbeds

Data from B1 was also compared to the two old reed habitats (O19 and O24). The results revealed that nine of the ten species showed significant differences in abundance *(Table 3, Figure 7)*.

Species such as the Water Rail, Bluethroat, Great Reed Warbler, and Reed Bunting had the highest counts in B1. The Water Rail exhibited a pronounced difference between the survey years rather than between reedbed types. For instance, B1 had nearly four times higher abundance than O19. The Bluethroat exhibited the lowest abundance in O19, which

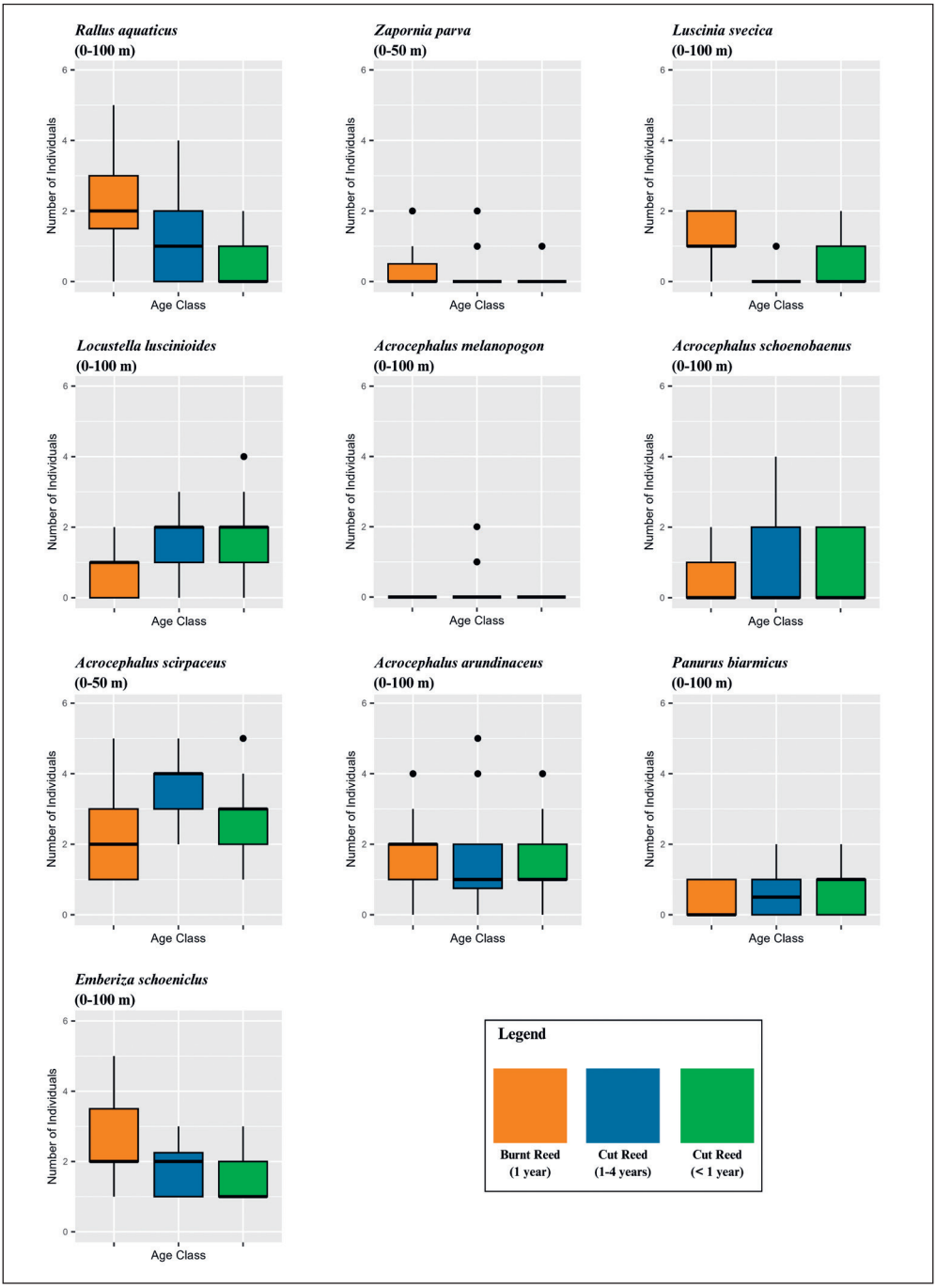


Figure 6. Distribution of the number of observations in burnt and cut reed areas by species using a box plot. Common Reed Warbler and Little Crake within a 50 m radius

6. ábra A leégett és vágott nádterületeken észlelt megfigyelésszámok eloszlása fajonként, dobozdiagramm segítségével. A cserregő nádposzáta és a kis vízicsibe 50 m sugarú körön belül

Table 3. Comparison of the number of individuals counted for each species (mean±standard deviation) among the points of the burnt reedbed (B1, n = 19), the old reedbed from 2024 (O24, n = 10), and the old reedbed from 2019 (O19, n = 30), using the Kruskal–Wallis tests and *post-hoc* Dunn's tests with Bonferroni correction. Significant differences are indicated in bold

3. táblázat Az egyével leégett nádas (B1, n = 19), a 2024-es öreg nádas (O24, n = 10) és a 2019-es öreg nádas területek (O19, n = 30) pontjainál regisztrált egyedszámok fajonkénti összehasonlítása (átlag±szórás) a Kruskal–Wallis-próba és a *post hoc* Dunn-próba eredményei alapján, Bonferroni-korrekcióval. A szignifikáns különbségek félkövér betűvel jelölve

Species	B1	O24	O19	χ^2	Kruskal-Wallis p	Dunn's p (B1 vs O24)	Dunn's p (B1 vs O19)	Dunn's p (O24 vs O19)
Rallus aquaticus	2.37±1.26	2.20±1.62	0.63±0.81	23.84	**<0.001**	0.92	**<0.001**	**0.003**
Zapornia parva	0.47±0.84	1.20±1.03	0.50±0.57	5,54	0.063	**0.03**	0.79	0.08
Luscinia svecica	1.42±0.61	1.30±1.06	0.03±0.18	39.08	**<0.001**	0.68	<0.001	<0.001
Locustella luscinioides	0.63±0.68	1.90±0.74	2.77±1.38	28.14	**<0.0001**	**0.009**	**<0.001**	0.29
Acrocephalus melanopogon	0.00±0.00	1.30±0.82	1.00±1.08	20.44	**<0.001**	**<0.001**	**<0.001**	0.27
Acrocephalus schoenobaenus	0.47±0.7	1.40±1.07	0.50±0.94	8,61	**0.01**	**0.02**	1.00	**0.006**
Acrocephalus scirpaceus	2.26±1.24	2.20±1.32	3.53±1.33	12,86	**0.002**	1.00	**0.002**	**0.01**
Acrocephalus arundinaceus	1.84±0.96	0.40±0.52	0.50±0.78	23.61	**<0.001**	**<0.001**	**<0.001**	1.00
Panurus biarmicus	0.32±0.48	2.10±1.10	1.13±0.78	23.61	**<0.001**	**<0.001**	**0.001**	**0.04**
Emberiza schoeniclus	2.47±1.22	2.10±0.57	0.63±0.93	27.87	**<0.001**	1.00	**<0.001**	**<0.001**

significantly differs from O24 and B1, with B1 showing a slightly higher abundance than B24. The abundance of the Great Reed Warbler in O19 and O24 did not differ significantly; there was a negligible difference between the reedbed types. However, B1 differed highly significantly from both old reed classes. The Reed Bunting was present in much higher numbers in 2024, with no significant difference between B1 and O24, the former being the highest. O19 showed values more than three times lower compared to O24 and was nearly four times lower compared to B1.

The Moustached Warbler, Sedge Warbler, and Bearded Reedling exhibit the highest populations in O24, with all three species ranking second in abundance in O19, followed by B1. The Moustached Warbler was not observed in B1, and the difference between O19 and O24 was not significant. The Sedge Warbler was almost three times less abundant in B1 and O19 compared to O24. The Bearded Reedling was nearly twice as abundant in O24 as in O19 and more than six times more abundant in O24 than in B1.

Savi's Warbler and Common Reed Warbler exhibit the highest counts in O19. No significant difference could be detected between the two old reed sites for Savi's Warbler; however, B1 had nearly 4.4 times and three times lower abundances compared to O24 and O19, respectively. Conversely, the abundance of the Common Reed Warbler in B1 and O24 did not differ significantly, while a significant difference was observed between O19 and the other two categories, with O19 showing about 1.5 times lower values.

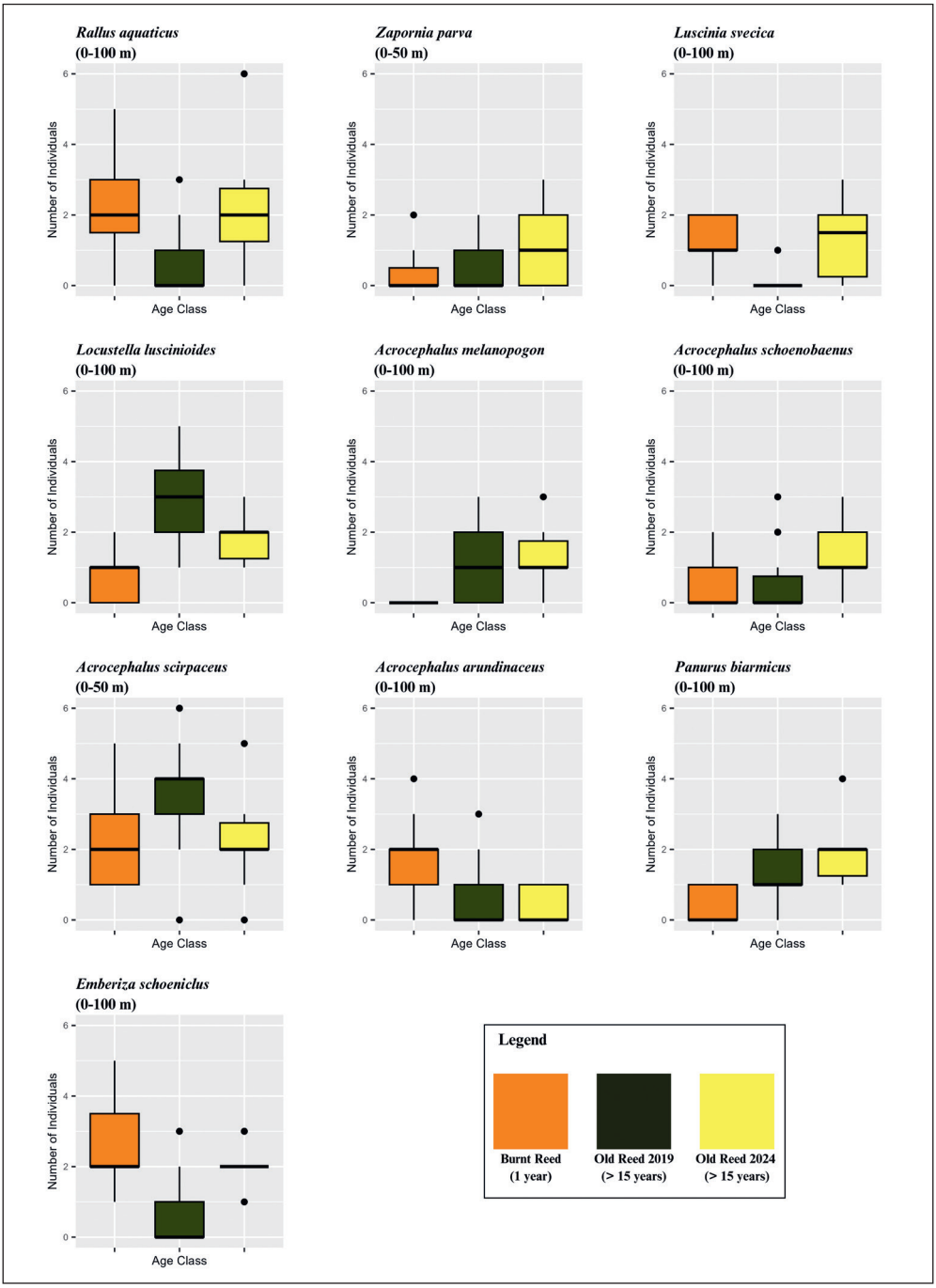


Figure 7. Distribution of the number of observations in burnt and old reed areas by species using a box plot. Common Reed Warbler and Little Crake within a 50 m radius

7. ábra A leégett és idős nádterületeken észlelt megfigyelésszámok eloszlása fajonként, dobozdiagramm segítségével. A cserregő nádposzáta és a kis vízicsibe 50 m sugarú körön belül

The Little Crake was the only species without significant differences based on the Kruskal–Wallis test. Still, the species showed the highest abundance in O24, followed by O19 and then B1. O24 had a slightly more than 2.5 times higher abundance compared to B1, whereas the difference between B1 and O19 was negligible.

Presence-absence data and additional observations

Presence-absence data for the target species are shown in *Table 4*. The Water Rail, the Bluethroat, the Savi's Warbler, the Great Reed Warbler, the Sedge Warbler, the Common Reed Warbler, the Bearded Reedling and the Reed Bunting were detected at all survey sites. The Moustached Warbler was not detected in the burnt reedbed and the young cut reedbed.

Table 4. Presence-absence of species across survey sites
4. táblázat A fajok jelenléte vagy hiánya a megfigyelési helyszíneken

Target species	Burnt reed (B1)	Cut reed (C0)	Cut reed (C1–4)	Old reed (O19)	Old reed (O24)
Rallus aquaticus	+	+	+	+	+
Zapornia parva	+	+	+	+	+
Luscinia svecica	+	+	+	+	+
Acrocephalus schoenobaenus	+	+	+	+	+
Acrocephalus melanopogon	-	-	**+**	**+**	+
Locustella luscinioides	+	+	+	+	+
Acrocephalus scirpaceus	+	+	+	+	+
Acrocephalus arundinaceus	+	+	+	+	+
Panurus biarmicus	+	+	+	+	+
Emberiza schoeniclus	+	+	+	+	+

Discussion

The results of the point counts partially corroborate the already known preference of particular reed bird species towards reed age, as described in Nemeth and Dvorak (2022). Our results demonstrate that the differences between the burnt and old reedbeds are more pronounced than those between the cut and burnt ones. This is evident in the number of significant differences observed in the Kruskal–Wallis tests. While nine out of ten species showed significantly different abundances in the burnt and old reedbeds, only five species differed significantly in the burnt-cut comparison. The species composition of the burnt reedbed resembles that of very young reed areas and shows substantial differences from old ones. The results are interpreted separately for each species.

Water Rail

The Water Rail is less likely to occur in reedbeds younger than five years or older than 15 years (Nemeth *et al.* 2022, Nemeth & Dvorak 2022), while Antoniazza *et al.* (2018) found the higher number of territories in 3-year-old reedbeds. In the reed belt of Lake Neusiedl/Fertő, it tends to colonize the shallowly flooded, dense, older reedbeds with or without sedge undergrowth (Nemeth *et al.* 2022). The results of the counts from 2024 are similar to the occurrence probability indicated in Nemeth and Dvorak (2022), as no significant difference was detected between the burnt and the old reed site. In 2019, however, significantly lower numbers were observed compared to 2024, which may have been caused by higher water levels in previous years, as the species requires shallowly inundated reedbeds (Nemeth *et al.* 2022). Burnt reed showed significantly higher numbers than cut reed, and it also exhibited greater abundance compared to the old reed data from 2024. Additionally, a nest with eight eggs was found at the previously burnt site. This evidence of breeding further supports the conclusion that previously burnt reed can provide suitable conditions for breeding; however, additional monitoring is necessary to study the habitat use of the Water Rail in this reedbed.

Little Crake

The Little Crake is known to inhabit old, inundated reed habitats with a dense layer of broken, old reed stems (Dvorak 1985, Haraszthy 2019a, Dvorak *et al.* 2024). Our comparison between burnt and cut sites, where the species is very rare, did not reveal any significant differences. In the comparison of burnt reed to old reed, the Little Crake was the only species that exhibited no significant difference but only a trend in the Kruskal–Wallis test; however, as expected, the burnt reedbed had substantially lower abundance compared to old reed from 2024. Our results suggest that the one-year-old, previously burnt area provided slightly higher suitability than cut reed sites for this species, while old reed is potentially the most suitable, even if the 2019 abundance data was close to the level of the burnt site. In the burnt area, some old reed patches may have been unaffected by the fire, which may have led to the prevalence of some suitable habitat elements.

Bluethroat

The Bluethroat was more abundant in both the burnt and old reedbeds in 2024 compared to 2019. The Bluethroat requires habitats that combine open water surfaces, dry ground, and reed (Nemeth *et al.* 2022, Dvorak *et al.* 2024). The high numbers in 2024 are hypothesized to be a legacy effect of very low water levels present in previous years, especially in 2022. The Bluethroat typically inhabits anthropogenically modified habitats at Lake Neusiedl/Fertő, such as channels and dams (Grüll 2001, Haraszthy 2019a, Dvorak *et al.* 2024). During the breeding season of 2024, several locations along the dams and channels were not inundated, which, combined with the legacy effect mentioned above, may have facilitated breeding. The findings of Báldi and Moskát (1995) are in contrast with ours, as they found

no Bluethroats in the control and burnt areas, while densities in mowed and homogeneous areas (i.e. transition zones with reed and shrubs) were higher.

Savi's Warbler

The Savi's Warbler is known to exhibit an even distribution across various reed age classes, with the exception of the rather unsuitable one-year-old reed (Nemeth & Dvorak 2022). The results from the old-burnt comparison indicate that the species prefers older reed over recently burnt reed, a pattern also noted by Zwicker and Grüll (1985). We found significant differences between burnt and cut sites, with higher abundance in cut sites. This pattern aligns with the findings of Báldi and Moskát (1995) and is likely due to the more effective removal of the litter layer (including bent stems) by the fire. The Savi's Warbler is the only species that displayed a positive correlation with the presence of mats of broken reed; the abundance of the Savi's Warbler only declines when mats of broken reed cover more than half of the reed area (Nemeth *et al.* 2022). The significance of a layer of horizontal stems is reported by Grüll and Zwicker (1993). Furthermore, high densities are also observed in tall, strong, and healthy stands located in the outer lake margin zone and along channels (Dvorak *et al.* 1997). Our results suggest that even a very young cut reedbed supports higher abundance than one-year-old burnt reed, and the lower numbers at the burnt site can be interpreted as a result of effective removal of the bent layer/litter through prescribed burning.

Moustached Warbler

There was no record of the species in the burnt area, nor in the very young cut site, but the 1–4-year-old previously cut reedbed did have a low number of sightings. The Moustached Warbler requires a bent layer of old reed stems, small open water surfaces, but also reed stems with leaves that serve as cover over the bent layer are essential (Haraszthy 2019b, Nemeth *et al.* 2022). Reedbeds less than 5 years old are known to be rather unsuitable for the species, followed by an optimum in the 5–9-year age class, and then a slowly declining suitability in reedbeds older than 15 years (Nemeth & Dvorak 2022). Zwicker and Grüll (1985) reported maximum densities at an eight-year-old, previously burnt site characterized by the presence of the lesser reedmace *(Typha angustifolia)*. When comparing the burnt reed and the old reed sites, a significant preference is evident towards the old reed sites, supporting previous findings (Leisler 1981, Nemeth *et al.* 2001), and indicating that even old reedbeds beyond their optimum age are more suitable than young reeds. These results are also in line with the findings of Báldi and Moskát (1995), which showed that burning led to the absence of species, while unmanaged sites supported the highest densities.

Sedge Warbler

The Sedge Warbler is a characteristic species of the transition zone between wet reedbeds and lower herbaceous vegetation with reed patches (Cramp *et al.* 1992, Nemeth *et al.* 2022). Our findings did not reveal any significant difference between burnt and cut reed sites; however,

cut reedbeds exhibited higher abundances. The old reed area from 2024 was seemingly more suitable than the burnt area, although it did not differ significantly from it. Because parts of the landward side of the reed area are more accessible for cutting machines, the slightly higher abundance in cut areas may have resulted from a greater overlap of the regularly cut zones with the Sedge Warbler's range. According to the results of the Poisson regression, this was the only species in our analysis that is significantly affected by water levels, as Sedge Warblers generally avoid reedbeds with standing water and require periodically dry ground (Dyrcz 2020). It is plausible that the time-lagged effects of the dry years in 2022 and 2023 contributed to the increased numbers in the old reedbed in 2024. Our results are consistent with the findings of Báldi and Moskát (1995), who reported the highest numbers in a heterogeneous habitat, followed by old and cut reed, while noting the lowest counts at a burnt site.

Common Reed Warbler

The Common Reed Warbler is regarded as a reed generalist species and is known to be the most common reed warbler in the reed belt around Lake Neusiedl/Fertő (Nemeth *et al.* 2022). Our results indicate that the burnt area is less suitable for the species than cut areas. Compared to the old reed habitats, the burnt reedbed differed significantly only from the 2019 old reed site. After cutting or burning, this species reoccupies these areas immediately after the regrowth of young reed in early summer, making it impossible to show any statistical differences between reed age classes after the first year (Nemeth *et al.* 2022). Our findings show that the Common Reed Warbler was present in the 1–4-year-old age reed (C1–4) in higher abundance than at the cut site (C0), which aligns with the results reported by Nemeth and Dvorak (2022). The burnt and old reed site from 2024 exhibited the lowest abundances, differing from the findings presented by Báldi and Moskát (1995), who reported the highest numbers in unmanaged areas and the lowest in cut reedbeds (see also Grüll & Zwicker 1993). The greater abundance in the very young cut area compared to the one-year-old burnt area may suggest a negative impact of burning. However, the non-significant difference between the burnt area and the old reed site from 2024 implies that differences in environmental conditions between the two survey years are likely to have played a more decisive role.

Great Reed Warbler

The Great Reed Warbler is one of the species that did not show any significant differences between burnt and cut sites; however, the burnt area was characterized by a slightly higher abundance of this species. The presence of well-spaced, tall and healthy reed stems in the edge zone between the reedbed and the water surface complies with the habitat requirement of this species reported by numerous studies (Leisler 1981, Grüll & Zwicker 1993, Graveland 1998, Báldi 2004, Kennerley & Pearson 2010, Mérő & Žuljević 2014, Haraszthy 2019b, Nemeth *et al.* 2022). It is likely that suitable habitat patches either remained intact or could quickly recover after the fire event. Additionally, inundation is also a crucial factor

(Leisler 1981, Leisler & Schulze-Hagen 2011, Mérő *et al.* 2014). At Lake Neusiedl/Fertő, such conditions are often found at the waterside edge of the reed belt and along dams and channels (Dvorak *et al.* 1997). The species does not favor old reedbeds (Nemeth *et al.* 2022), which aligns with our findings that indicate significantly lower numbers in the older reed sites compared to the others. Nemeth and Dvorak (2022) described 1–4-year-old reed as the most suitable breeding habitat, which is also consistent with our results. The higher abundance in the burnt area may have resulted from the positive effects of burning compared to cutting with heavy machinery. However, in the study by Báldi and Moskát (1995), the Great Reed Warbler was recorded in lower numbers in a burnt habitat than in a cut and an unmanaged site, which contradicts our findings.

Bearded Reedling

The Bearded Reedling is reported to show preference towards reed age classes of 5–9 and 10–14 years, with a slight decline in stands older than 15 years (Nemeth & Dvorak 2022). This species is more frequently found in areas with medium reed height and deeper water (Cramp *et al.* 1994, Nemeth & Dvorak 2022). In response to burning, the species was absent from burnt sites and occurred at higher densities in mowed sites, with the highest densities recorded in unmanaged sites in the study by Báldi and Moskát (1995). Our analysis did not reveal any significant differences across burnt and cut sites, but in old reed, significantly higher numbers of individuals were recorded (both in 2019 and 2024). Despite the fact that reed growth is denser at previously burnt sites (Valkama *et al.* 2008), which is described as an important habitat requirement (Cramp *et al.* 1994, Haraszthy 2019b), it did not affect the abundance of the Bearded Reedling positively in the burnt site we surveyed.

Reed Bunting

The Reed Bunting was found to be the most abundant in the burnt area. While Dunn's test showed a significant difference between the old reed site from 2019 and the burnt one, no significant differences were detected between cut and burnt sites, and between burnt and old reed from 2024. Nemeth and Dvorak (2022) reported higher suitability of young reed age classes for the species than old reed. In the study by Báldi and Moskát (1995), the burnt areas exhibited the lowest mean number of individuals, while mowed areas had slightly higher values; the highest numbers were found in the control areas with older reed. Our results differ from the findings of Báldi and Moskát (1995), as we observed the highest numbers in the burnt area. The old reed site from 2024 had the second highest mean overall and did not differ significantly from the burnt site. Consequently, Reed Buntings had a higher overall abundance in 2024 compared to 2019. This was likely to be influenced by differences in water levels, with lower levels in 2024 than in 2019 (Wasserportal Burgenland 2024), resulting in more suitable conditions, as the species requires dry ground for breeding (Cramp *et al.* 1994, Copete & Christie 2021). Burnt reed still had the highest mean number of observations in both the burnt-cut and burnt-old comparisons, indicating the high suitability of previously burnt one-year-old reed.

Conclusion

Although water level differences and varying environmental conditions between the two survey years pose a limitation to the interpretation of the results of our study, the core findings demonstrate that differences between burnt and cut reed sites were less pronounced than those between burnt and old reed sites; five species differed significantly in the former comparison, while nine did so in the latter. It is essential to focus on the long-term effects of burning and cutting, as these effects become relevant for certain bird species only in subsequent years following a fire. To achieve a more comprehensive understanding of this matter, it is necessary to conduct monitoring over a longer period and to include more sites with varying ecological conditions. Nonetheless, as an initial step toward this, our findings clearly indicate that prescribed burning is a possible alternative to reed cutting as a management tool for reed bird conservation.

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Impact of road improvements on the distribution and demography of rupicolous birds on the corniche of Jijel in Algeria

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Abstract Our study aims to identify the impact of road improvement works on rupicolous birds on the corniche of Jijel in Algeria between two periods: before the works began and after they were completed. The results show a large decline in nesting pairs of rupicolous birds between the two periods (2007: 307 pairs vs. 2017: 135 pairs). Thus, more than half of the breeding pairs disappeared between the start and the end of the work. The decline in the number of nesting pairs mainly concerned the most adapted and demanding species nesting on coastal cliffs: Pallid Swift *(Apus pallidus)*, Common Kestrel *(Falco tinnunculus)*, Peregrine Falcon *(Falco peregrinus brookei)*, Eurasian Crag Martin *(Ptyonoprogne rupestris)* and Blue Rock Thrush *(Monticola solitarius)*. The main factor in reducing the number of nesting pairs of species on cliffs and rocks is the degradation or loss of nesting sites due to developmental work. System restoration measures are proposed to encourage the return of nesting birds.

Keywords: road development works, coastal cliffs, breeding birds, Algeria

Összefoglalás Tanulmányunk célja, hogy azonosítsa az algériai Jijel környékén végzett útfejlesztési munkálatok hatását a sziklákon költő madarak állományaira a munkálatok megkezdése előtti és azok befejezése utáni időszakban. Az eredmények azt mutatják, hogy a két időszak között nagymértékben csökkent a fészkelő madarak állománya (2007: 307 pár – 2017: 135 pár); vagyis a fészkelő állománynak több mint a fele eltűnt a munkálatok befejeztére. A fészkelő párok számának csökkenése elsősorban a parti sziklákon fészkelő, ahhoz alkalmazkodó és azoktól függő fajokat érintette: halvány sarlósfecske *(Apus pallidus)*, vörös vércse *(Falco tinnunculus)*, vándorsólyom *(Falco peregrinus brookei)*, szirtifecske *(Ptyonoprogne rupestris)*, kék kövirigó *(Monticola solitarius)*. A fészkelő párok számának csökkenésének fő oka a fészkelőhelyek leromlása vagy elvesztése a fejlesztési munkák következtében. A szerzők élőhely-rekonstrukciós intézkedéseket javasolnak a fészkelő madarak visszatérésének ösztönzésére.

Kulcsszavak: Algéria, fészkelő madarak, tengerparti sziklák, útfejlesztési munkák

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Introduction

Facing with increasing urbanization, avian habitats are undergoing radical transformations (Shochat *et al.* 2006). These modifications represent both challenges for the survival of birds and opportunities for their adaptation to new ecological niches (Evans *et al.* 2018).

The Algerian coastline, which extends over more than 2,000 km, is characterized by a succession of cliffs, rocky areas and beaches, either sand, pebble or mixed. It should be noted that the rocky habitats are quite dominant. The presence of coves, mouths of small wadis, some coastal wetlands and island environments should also be noted.

These different coastal habitats are home to a significant diversity of birds, particularly coastal and sea birds, as well as waterbirds (Samraoui *et al.* 2011, Bougaham & Moulaï 2013). Certain coastal environments such as cliffs and rocky areas attract specialized avifauna called rupicolous or rupestral birds, for example Pallid Swift *(Apus pallidus)*, Common Peregrine Falcon *(Falco peregrinus brookei)*, Eurasian Crag Martin *(Ptyonoprogne rupestris)* and Blue Rock Thrush *(Monticola solitarius)*.

In recent years, Algeria has experienced major projects of public interest, notably the construction of highways, bridge roads, tunnels, intended to develop and improve infrastructure with a socio-economic and sustainable development goal. These various works have exerted consequences on wildlife in general, and birds in particular, because several natural habitats have been destroyed or modified (Mouhoub-Sayah *et al.* 2009).

Therefore, here we aim to assess the impact of road development works on the rupicolous birds of the Jijel corniche (National Road 43) in Algeria by comparing the diversity and distribution of the main species of rupicolous birds before the start of the work in 2007 (Bougaham & Moulaï 2013) and after its completion in 2017.

Methods

Study area

Our work is carried out along National Road 43, which extends from El-Aouana to Melbou, over a length of approximately 35 km *(Figure 1)*. The region is part of the coastal range of the Babors chain and the eruptive massif of Cavallo. From Jebel M'saada to the west to Taza, the chains form an extrusion of Liassic limestone. From the place called Aftis to Cavallo, the chain seems to make an intrusion of dacite and volcanic projections. Beyond that, towards the east, the range forms an intrusion made up of Oligocene sandstones and clays (Duplan 1952). This portion of coast is made up of landscape units which include a succession of cliffs, rocky areas, beaches either sandy or pebble, with the predominance of the rocky character. Certain portions of cliffs and rocky areas are covered with thin soil, which support flora characteristic of rupicolous environments such as European fan palm *(Chamaerops humilis)*, perennial hyoseris *(Hyoseris radiata)* and caper bush *(Capparis orientalis)*.

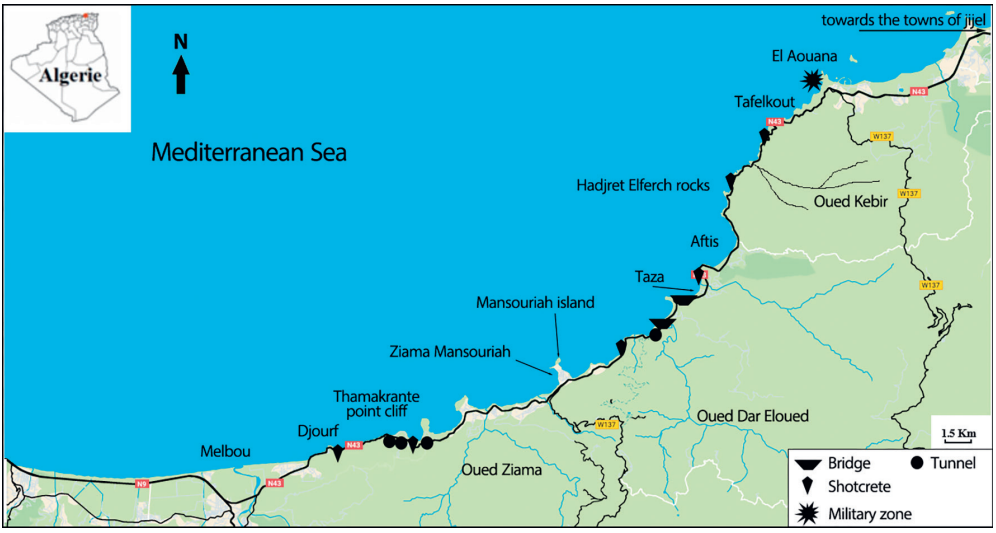


Figure 1. Geographical location of the study area and the main road developments along national road 43 in Algeria

1. ábra A kutatási terület földrajzi elhelyezkedése és a legfontosabb útfejlesztések az algériai 43. számú út mentén

Methodology

In the study area and along National Road 43 on the Jijel corniche, the location and counting of nesting pairs of rupicolous birds (Pallid Swift, Yellow-legged Gull *Larus michahellis*, Long-legged Buzzard *Buteo rufinus cirtensis*, Peregrine Falcon, Common Kestrel, Northern Raven *Corvus corax*, Eurasian Crag Martin, Blue Rock Thrush) were carried out during the period from March to June in year 2017. Observations were generally made using a pair of binoculars and from a distance of 50 to 500 metres. Nesting is established when the nest is accurately located for each species. Each nest spotted is geo-located to avoid any double counting during the breeding season.

During the period from 2007 to 2016, we noted the widening of the roadway extending from El-Aouana to Melbou over a distance of 35 km, with various engineering structures; notably the construction of a



Figure 2. Sprayed concrete at the level of the Cliffs of the Jijel cornice (Photo A. Birouk)

2. ábra Porlasztott beton a Jijel-sziklák párkányának magasságában (felvétel: A. Birouk)

tunnel in Dar El-Oued over 600 m, the construction of three tunnels in Melbou with a respective length of 880 m, 635 m and 268 m. In addition, a 137 m emergency tunnel was built. We also noticed the installation of an engineering structure over 102 linear metres and the construction of two bridges, one in Ghar Elbaz and the other in Dar Eloued. Along the way, reinforcement of mountain slopes with shotcrete was observed, aimed at preventing rockfalls and landslides on the road *(Figure 2)*. It is also noted that in the Tafalkout region a military barracks of the coast guard was established during this period with the presence of a shooting range *(Figure 1)*. These engineering structures that may affect the habitat and nesting sites of rupicolous birds are listed in *Figure 1*.

Our data obtained on the nesting of rupicolous birds at the Jijel corniche during the season in 2017 are compared to those of Bougaham and Moulaï (2013) obtained in 2007, i.e. before the start of road development works in order to identify the impact of this work on the number of nesting pairs of rupicolous birds and their distribution within the study area.

To evaluate the differences between the two periods (2007 vs 2017) and test the effect of human activities, we used the Wilcoxon signed-rank test implemented in the XLSTAT software version 2014. The species names followed the IOC World Bird List version 14.2 (Gill *et al.* 2024).

Results and Discussion

Table 1 shows large decreases in the nesting pairs of rupicolous birds between the two periods (2007 vs 2017), which amounts to 135 estimated pairs. Accordingly, more than half of the breeding pairs disappeared between the start and the end of the work. The road development work had a confirmed overall impact on the establishment of birds dependent on the cliffs and rocky escarpments of the region. The reduction in the number of nesting pairs mainly affected the species most adapted and most demanding to nest on coastal cliffs: Pallid Swift *(Figure 3)*, Peregrine Falcon *(Figure 4)*, Eurasian Crag Martin *(Figure 5)*, Blue Rock Thrush (*Figure 6)*. We also note a decrease in the number of pairs of the Yellow-legged Gull *(Table 1)*. Only one species was able to increase numbers during this period, the Common Raven. The numbers were zero for this species in 2007 and, in 2017 we found 12 pairs *(Table 1)*.

The main factor in reducing the number of nesting pairs

Table1. Number of nesting pairs of rupicolous birds between 2007 (before the works) and after the works in 2017 on National Road 43 in Algeria

1. táblázat A sziklákon költő madarak fészkelő párjainak száma 2007 (a munkálatok előtt) és a 2017-es munkálatok után az algériai 43-as számú úton

Species	2007	2017
Pallid Swift	120	71
Yellow-legged Gull	143	31
Long-legged Buzzard	1	2
Common Kestrel	7	4
Peregrine Falcon	3	1
Northern Raven	0	12
Eurasian Crag Martin	16	10
Blue Rock Thrush	17	4
Total	**307**	**135**

of species characteristic of cliffs and rocks is the degradation or loss of nesting sites following development work. The crevices, orifices, cavities and areas of rocky overhang were filled by spraying concrete onto the cliff or completely destroyed following the smoothing of the cliff to avoid rockfall. Another significant factor is the disruption linked to public works machinery, particularly during the construction phases of various structures, such as tunnels and bridges. The coast guard barracks with its shooting range also had an impact on the disturbance level of the birds during the breeding period. These disturbances lasted several years, which had a significant effect on the safety and well-being of rupicolous birds during the sensitive nesting period. The Common Raven did not appear to nest in the study region before the work period *(Figure 7)*. It ended up with a number of 12 pairs in 2017. This situation is probably linked to the decrease in the number of pairs of Yellow-legged Gull *(Figure 8)*. Gulls are known to be very aggressive towards other species of birds, particularly those which may nest nearby, such as Common Ravens, which may establish their nests on cliff ledges. The drop in numbers of Yellow-legged Gulls following the works may have been favourable to Common Ravens (Philo & Wilbert 2000, Whatmore 2002, Moulaï 2007). By performing the Wilcoxon signed-rank test at a significance level of 5%, with eight observations, with a critical value of 3, we obtained $W+=15$. Compared to $Wcrit=3$, $W+$ is much greater than $Wcrit$. This indicates that there is a significant difference in the average population of bird species between 2007 and 2017.

Pallid Swift *(Apus pallidus)*

The declining trend in the number of nesting pairs of Pallid Swift was more significant for this species as compared to that of Eurasian Crag Martin, because the latter species

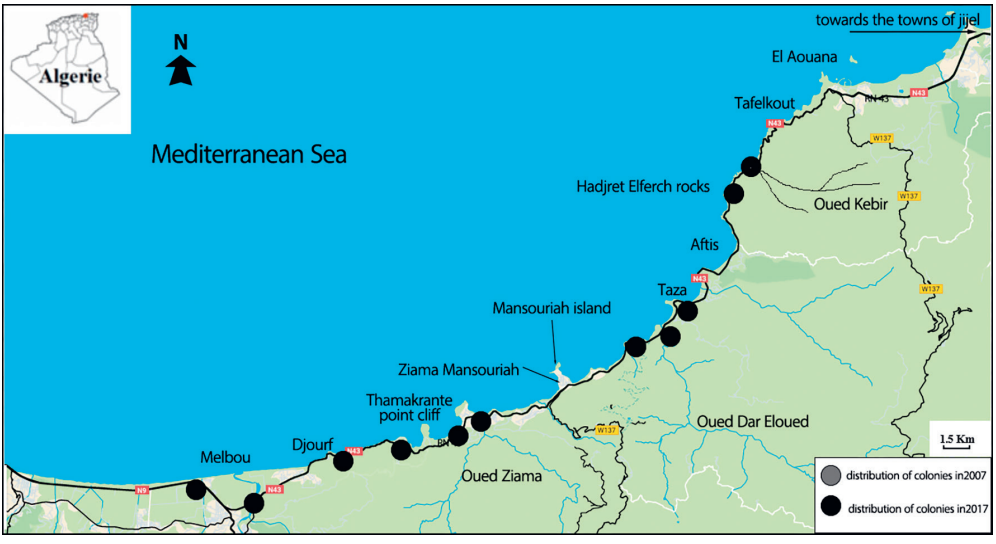


Figure 3. Distribution of Pallid Swift colonies along the west coast of Jijel between 2007 and 2017
3. ábra A halvány sarlósfecske kolóniáinak eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

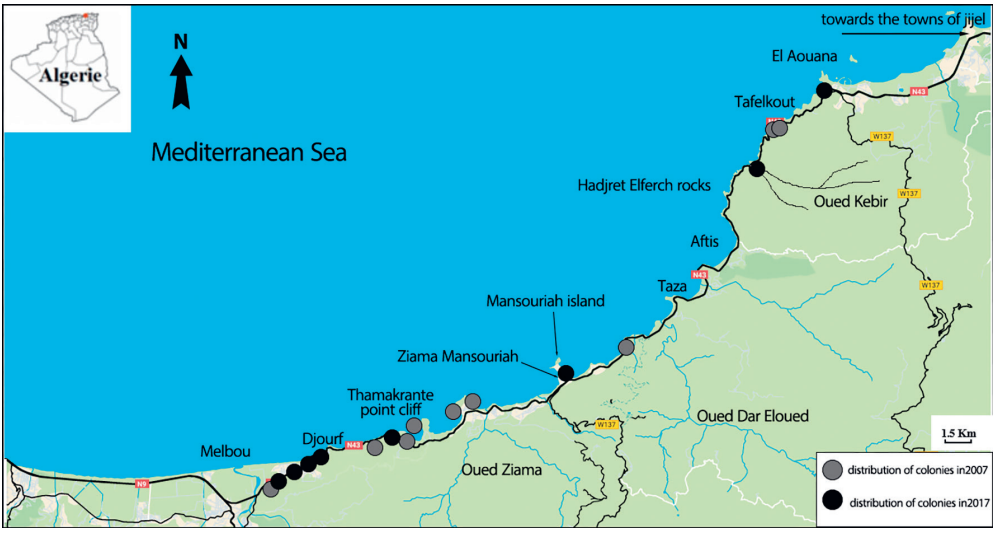


Figure 4. Distribution of Peregrine Falcon nesting pairs along the west coast of Jijel between 2007 and 2017

4. ábra A fészkelő vándorsólyom párok eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

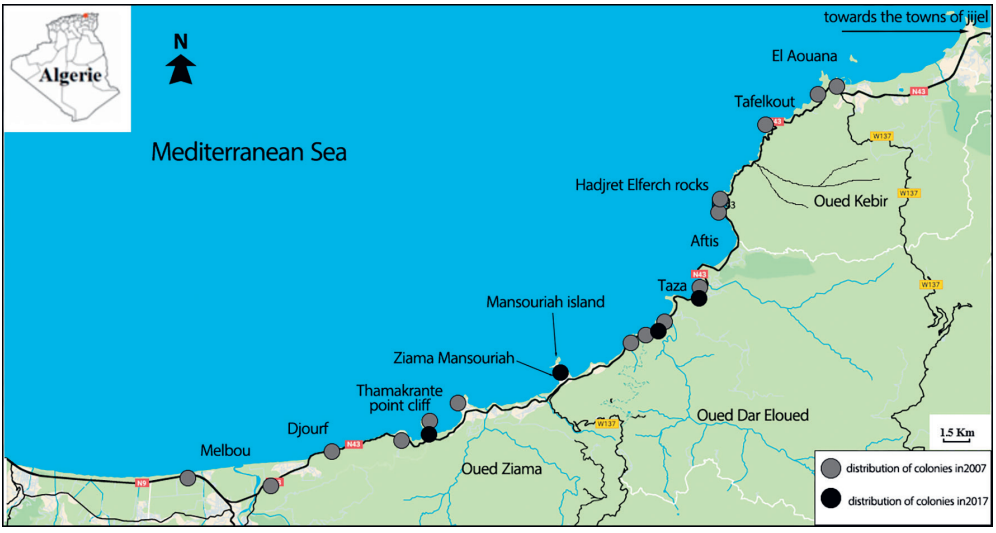


Figure 5. Distribution of Eurasian Crag Martin colonies along the west coast of Jijel between 2007 and 2017

5. ábra A szirtifecske kolóniáinak eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

generally nests in small colonies of a few pairs, which is not the case for Pallid Swift, or the colony may contain more than tens of pairs (Thorup 2001, Davies 2013).

Before the start of the work, Bougaham and Moulaï (2013) identified approximately fifteen colonies distributed between Melbou and El Aouana. In 2017, only three colonies remained at the cliffs of Pointe Thamakrante, at Ziama Mansouriah and Taza *(Figure 3)*. The same

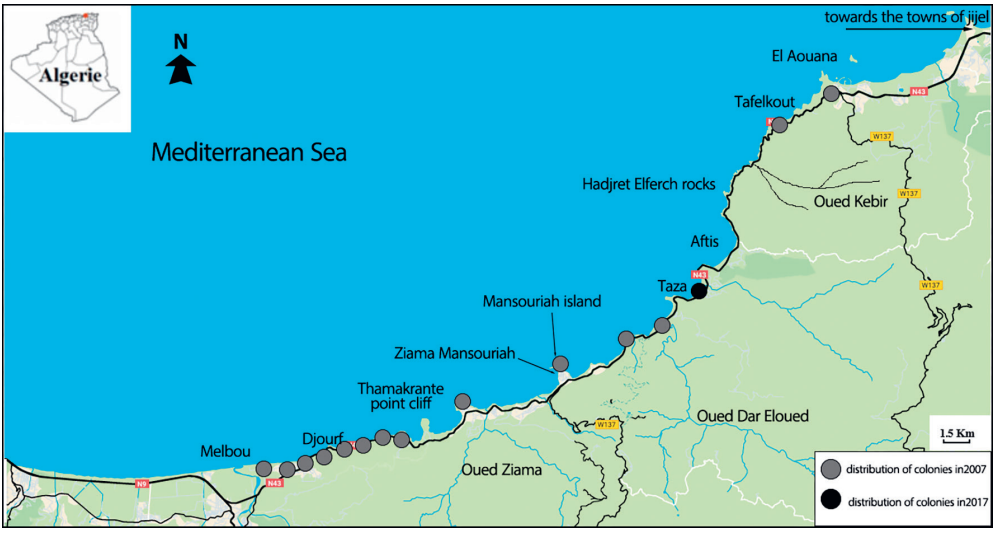


Figure 6. Distribution of breeding pairs of Blue Rock Thrush along the west coast of Jijel between 2007 and 2017.

6. ábra A fészkelő kék kövirigó párok eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

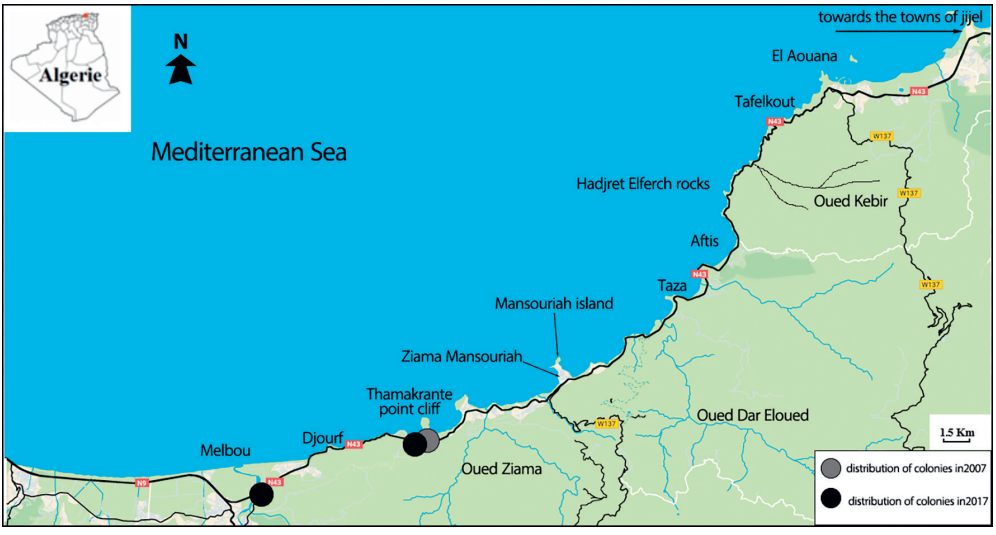


Figure 7. Distribution of Northern Raven nesting pairs along the west coast of Jijel between 2007 and 2017

7. ábra A fészkelő holló párok eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

causes observed for the Eurasian Crag Martin are valid for the Pallid Swift, because the two species have a similar reproductive ecology in the natural environment. The decrease in the number of nesting pairs of Pallid Swifts is linked to the loss of nesting sites on the cliffs and rocky areas of the region, following the smoothing of the cliffs and the projection of concrete on the walls.

Yellow-legged Gull *(Larus michahellis)*

The number of pairs of Yellow-legged Gulls also experienced a drastic decline between 2007 and 2017 *(Table 1)*. The number of colonies also decreased from 10 colonies in 2007 to seven colonies in 2017 *(Figure 8)*. The smoothing of the cliffs and the projection of concrete on the cliffs has greatly reduced the nesting sites favourable to the Yellow-legged Gull. The decrease in the nesting population of Yellow-legged Gulls may also be linked to changes in the behaviour of this species following the closure of illegal dumps, most of which are located near the large urban area of Jijel. In this context, we noted a shift in the nesting population from natural environments (cliffs and islands) towards the urban environment of Jijel, certainly to compensate for the lack of trophic resources following the closure of landfills (Birouk & Moulaï 2021, Hussein *et al.* 2021).

Long-legged Buzzard *(Buteo rufinus cirtensis)*

Between 2007 and 2017, we noted the appearance of a new reproduction site at the Melbou cliffs, in an area little affected by development work. The first pair recorded in 2007 kept the same location in 2017 at the Cliffs of Pointe Thamekrante *(Figure 9)*. It is reported that Long-legged Buzzard is a common species in Algeria which can tolerate a certain degree of disturbance in its habitat, in addition, it is less linked to rock habitats than the Common Kestrel or the Peregrine Falcon (Moulaï & Mostefai 2015, Elafri *et al.* 2020, Hachour *et al.* 2021).

Common Kestrel *(Falco tinnunculus)*

The kestrels in the region seem to have been impacted by the road development works. Before the work began, the pairs were distributed between the Melbou area and Taza. While in 2017, we found them confined to the region between Melbou and the cliffs of the Thamekrante points *(Figure 10)*. The influence that the work may have had on the nesting of this raptor is understandable, given that this species is linked to rocky cliffs in Algeria (Moulaï & Mostefai 2015, Elafri *et al.* 2020, Hachour *et al.* 2021).

Peregrine Falcon *(Falco peregrinus brookei)*

Similar to the Common Kestrel, we note a decrease in the number of nesting pairs of Peregrine Falcon. In 2007, there were three areas of this raptor: in El Djourf, near Ziama-Mansouriah and in Taflakout. In 2017, only the pair of El Djourf cliffs maintained their presence *(Figure 4)*.

Here, the impact of the road development work is also clear, besides the disturbance factor linked to the presence of a significant number of Northern Ravens, not present when the work began *(Table1, Figure 9)*. Latter must have exerted hounding and harassment pressure on the Peregrine Falcons, causing them to abandon their nesting areas (Ratcliffe 1993, Monneret 2000).

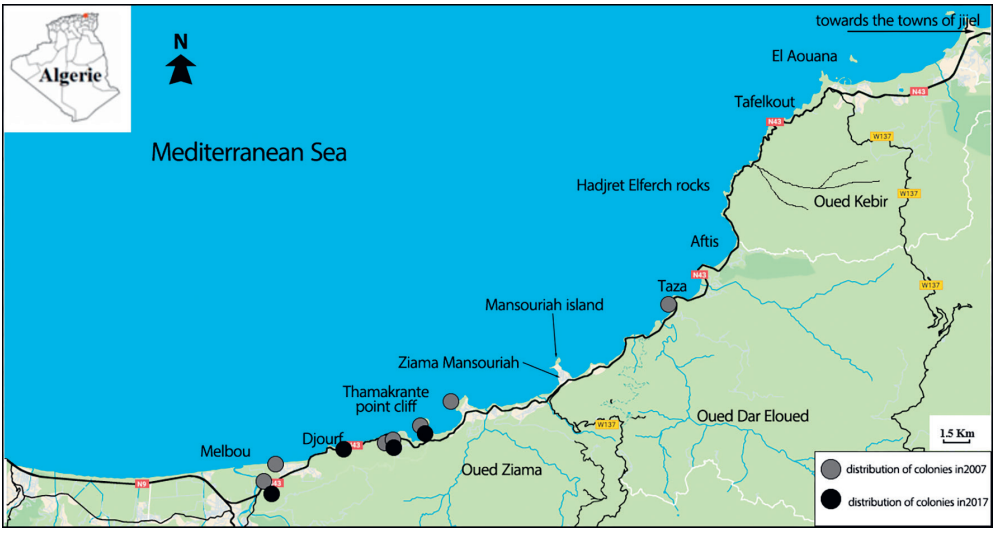


Figure 8. Distribution of Yellow-legged Gull colonies along the west coast of Jijel between 2007 and 2017

8. ábra A sárgalábú sirály kolóniáinak eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

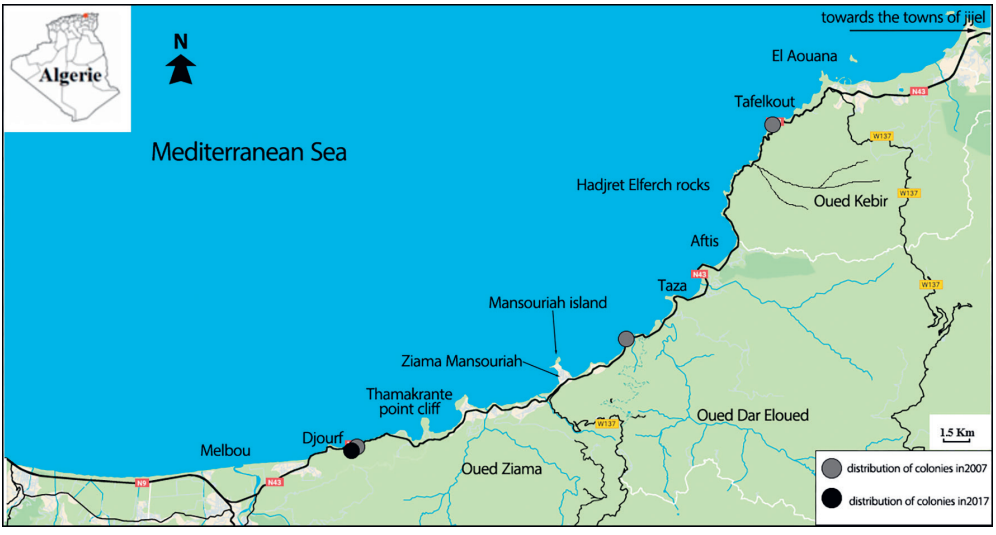


Figure 9. Distribution of breeding pairs of the Long-legged Buzzard along the west coast of Jijel between 2007 and 2017

9. ábra A fészkelő pusztai ölyv párok eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

Northern Raven *(Corvus corax)*

We counted 12 pairs of Northern Ravens, distributed between Oued Kebir and Melbou *(Figure 7)*. Most nests are established on cliffs and rocky areas in the region (Cramp & Perrins 1994, Aberkane *et al.* 2011). Note that no nesting event of this species was recorded

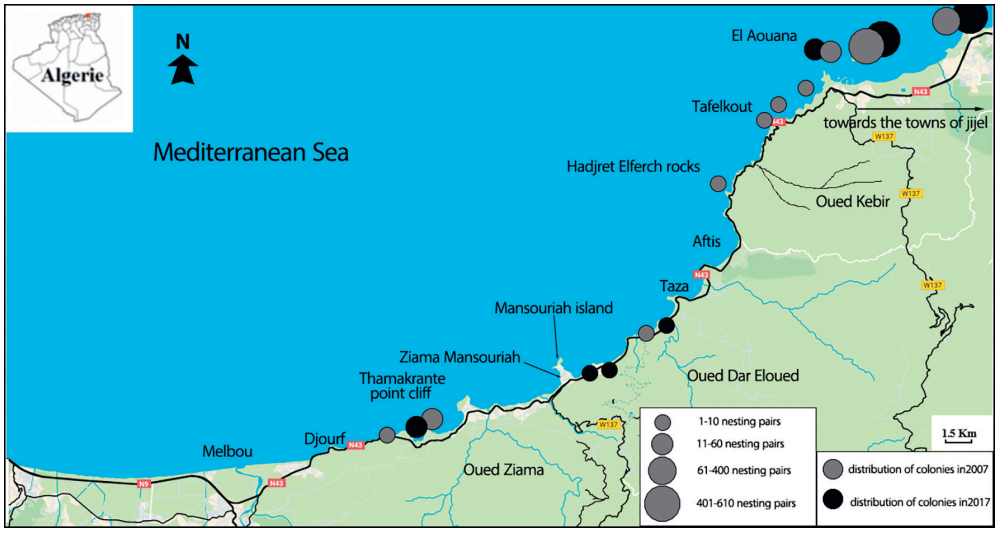


Figure 10. Distribution of breeding pairs of the Common Kestrel along the west coast of Jijel between 2007 and 2017

10. ábra A fészkelő vörös vércse párok eloszlása Jijel nyugati partvidéke mentén 2007 és 2017 között

during the period preceding the work (Bougaham & Moulaï 2007). It is likely that Northern Ravens have occupied the cliffs of the study region as a result of the decrease in the number of nesting pairs of Yellow-legged Gulls between 2007 and 2017 *(Table 1)*.

Eurasian Crag Martin *(Ptyonoprogne rupestris)*

The number of breeding pairs of Eurasian Crag Martins decreased between the two periods. Whereas in 2007 the breeding pairs were distributed all along the length of the study area, between the region of Melbou and Tafelkout *(Figure 4)*. In 2017, we noticed that breeding Eurasian Crag Martins disappeared from most sites observed in 2007, to the benefit of the Melbou region which was little affected by the impact of road development works *(Figure 4)*. The widespread use of sprayed concrete along the cliffs has resulted in the closure of most of the openings that served as nesting sites for swallows, resulting in a lack of favourable breeding sites in the areas affected by the spraying *(Figure 4)*.

Blue Rock Thrush *(Monticola solitarius)*

It is the bird that has been most impacted by road development work. Before the work began, this rupicolous bird had spread throughout the coastal stretch affected by the developments. In 2017, the pairs were located only at the Taza cliffs *(Figure 6)*.

Apparently, the work started has blocked most of the rocky crevices necessary for the nesting of the Blue Rock Thrush (Choi *et al.* 2011, Nayak 2020).

In conclusion, we can say that the road development work started in 2007 (Bougaham & Moulaï 2013) on National Road 43 in Algeria had a significant impact on the number of birds nesting on the cliffs and the rocky areas of the region. The strongest effect is observed on the species most adapted to and most dependent on the rocky habitat. All species have a high heritage value at least on a local or regional scale. These birds are, for example, protected by the Algerian legislator (Executive Decree No. 12-235 of 3 Rajab 1433 corresponding to May 24, 2012 establishing the list of protected non-domestic animal species (JORA No. 35)) hence a loss for the regional and national diversity.

In the future, it would be useful to integrate into the specifications for road development work on rupicolous habitats in Algeria, environmental impact studies which consider the possible impact of the work on the diversity and presence of birds from cliffs and rocks, in particular those with the label, species of high heritage value. We recommend the restoration of the natural rock ecosystem, by providing for maintaining a certain number of cracks and orifices in the rock and the establishment of artificial cement nest boxes suitable for certain rupicolous species, more particularly: Pallid Swift, Eurasian Crag Martin and Blue Rock Thrush.

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Distribution, habitat shift, and conservation needs of Jerdon's Babbler *(Chrysomma altirostre)*: A study of a vulnerable grassland specialist

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Abstract Grassland ecosystems are vital for global biodiversity but are increasingly threatened by habitat loss, agricultural expansion, urbanization, and climate change. Jerdon's Babbler *(Chrysomma altirostre)*, a vulnerable grassland specialist, serves as a model species to assess the impacts of habitat degradation and fragmentation. This study analysed historical and current distributions, revealing a significant contraction from 326,263 km^2 to 173,071 km^2, representing a 47% reduction in the species' historical range. The overlap between historical and current ranges was limited to 71,623 km^2, while 101,448 km^2 of new areas were identified as potential habitat gain, indicating possible range shifts. The centroids of the distributions of the three subspecies shifted significantly: Indian and Saharo-Sindian subspecies moved northeast by 361 km and 444 km, respectively, while the Burmese subspecies shifted 490 km south. Populations in the Indo-Bangladesh region remain uncertain due to a lack of recent records. These findings underscore extensive habitat loss, reduced connectivity, and the persistence of fragmented populations primarily within protected areas. Conservation priorities include grassland restoration, habitat connectivity enhancement, and mitigating disturbances such as unauthorized playback and seasonal fires. While Jerdon's Babbler exhibits adaptability to degraded habitats, its long-term viability remains uncertain without targeted interventions. This study highlights the necessity of expanded conservation efforts to safeguard populations beyond protected zones and to preserve this species as an indicator of grassland ecosystem health.

Keywords: kernel density, temporal distribution, niche dynamics, climate change, grassland ecosystems

Összefoglalás A füves területek létfontosságúak a globális biológiai sokféleség szempontjából, de az élőhelyek elvesztése, a mezőgazdaság terjeszkedése, az urbanizáció és az éghajlatváltozás egyre inkább veszélyezteti őket. A Jerdon-timália *(Chrysomma altirostre)*, a füves területek sérülékeny specialista madárfaja szolgál modellként az élőhelyek pusztulásának és feldarabolódásának értékeléséhez. A szerzők tanulmányukban elemezték a faj történelmi és a jelenlegi elterjedését. A faj elterjedési területének kiterjedése 47%-os csökkenést mutatott, 326 263 km^2-ről 173 071 km^2-re esett vissza. A történelmi és a jelenlegi elterjedési terület közötti átfedés 71 623 km^2-re korlátozódott, míg 101 448 km^2-nyi potenciálisan új élőhelyen jelent meg a faj. Ez az elterjedési terület áthelyeződésére utalhat. Az alfajok elterjedésének központjai jelentősen, az indiai 361, a burmai 490, míg a szaharo-szindiai 444 km-rel eltolódtak. Az indo-bangladesi régió populációinak helyzete bizonytalan maradt, mivel nincsenek friss feljegyzések. Megállapításaik hangsúlyozzák az élőhelyek nagymértékű csökkenését és ezek elszigetelődését. Az elszigetelt populációk fennmaradása elsősorban a védett területeken belül lehetséges. A természetvédelmi prioritások közé tartozik a gyepterületek helyreállítása, az élőhelyek folytonosságának biztosítása, valamint az olyan zavaró tényezők mérséklése, mint az engedély nélküli hívóhang lejátszás és a szezonális tüzek. Bár a Jerdon-timália képes alkalmazkodni a leromlott élőhelyekhez, hosszú távú fennmaradása célzott beavatkozások nélkül bizonytalan marad. Ez a tanulmány rávilágít a védett területeken kívüli populációk megőrzését célzó, kiterjesztett védelmi erőfeszítések szükségességére.

Kulcsszavak: füves területek, időbeli elterjedés, kernel denzitás, klímaváltozás, niche dinamika

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Introduction

Grassland ecosystems are among the most threatened habitats globally, often overshadowed by conservation efforts prioritizing forests and wetlands (Siebert *et al.* 2024). These ecosystems play a vital role in biodiversity preservation, supporting a unique array of flora and fauna. However, they are increasingly at risk due to habitat conversion for agriculture (Banerjee *et al.* 2023, Douglas *et al.* 2023), urbanization, and climate change (Nandintsetseg *et al.* 2021). Jerdon's Babbler *(Chrysomma altirostre)*, a small passerine bird, is a grassland specialist whose survival is intricately linked to the availability of quality grassland ecosystems. As a grassland specialist, Jerdon's Babbler is particularly vulnerable to habitat degradation and fragmentation. As grassland habitats degrade, the species faces growing threats to its existence, making it as a significant conservation concern (BirdLife International 2020).

The bird, historically distributed across riverine grasslands in South and Southeast Asia, is currently classified as "Vulnerable" by the IUCN (BirdLife International 2020) and is increasingly affected by habitat fragmentation and human activities.

Biodiversity monitoring and the study of species distribution patterns are essential for understanding ecosystem dynamics and informing conservation strategies. For habitat-sensitive species such as the Jerdon's Babbler, these assessments are particularly crucial. Belonging to the family Paradoxornithidae, Jerdon's Babbler is native to subtropical and tropical grasslands and wetlands in the floodplains of South Asia. Its elusive behaviour, restricted distribution, and high sensitivity to habitat changes make it an important indicator of grassland ecosystem health. The species holds ecological significance as it occupies a unique niche within its habitat, relying on tall grasses dominated by species like kans grass *(Saccharum spontaneum)*, ravennagrass *(Tripidium ravennae)*, etiver *(Vetiveria zizanioides)*, tall reed *(Phragmites karka),* and Indian reed-grass *(Typha elephantina)*.

Three subspecies of Jerdon's Babbler are recognized (Cai *et al.* 2019), reflecting ecological variation and geographic separation. The nominate subspecies, *C. a. altirostre*, primarily inhabits the wetlands of Myanmar and adjacent regions (Harington 1913, Rheindt *et al.* 2014). The second subspecies, *C. a. scindicum*, is found in the drier grasslands of Pakistan (Ali & Ripley 1971) and Punjab, India (Sawant & Sudhagar 2013), while *C. a. griseigulare* is distributed across the wetter regions of the Himalayan foothills, including Bhutan and northeastern India (Sadanandan *et al.* 2018). These subspecies illustrate the species' adaptability to diverse grassland types, although they remain poorly studied and their ranges fragmented.

Jerdon's Babbler was first described in 1862 by Jerdon T. C. from the Ayeyarwady floodplain in Myanmar. Over time, historical records have documented its presence across the lowland floodplains of India, Nepal, Bangladesh, and Myanmar, where it was closely associated with grass-dominated ecosystems along rivers (Poudyal *et al.* 2020, Iqbal *et al.* 2023). However, inconsistencies in early records, including taxonomic discrepancies and limited field observations, have created ambiguities in understanding the exact historical range of the species. For instance, *C. a. scindicum* was variably referred to as "*scindicum*" or "*scindicus*" in earlier literature, while *C. a. griseigulare* was synonymized with *Pyctorhis altirostris griseigularis* (Baker 1923). The taxonomy of Jerdon's Babbler is marked by ambiguities due to historical classifications and overlapping morphological traits among its subspecies. The three recognized subspecies exhibit subtle plumage differences, with unclear distribution boundaries and potential intergradation zones. Discrepancies in type specimen descriptions and frequent synonymities (e.g. *Moupinia altirostris*, *Pyctorhis griseigularis*) further complicate taxonomy (Harington 1913, Deignan 1964). Morphological variability, possibly influenced by habitat, raises questions about the validity of current subspecies, while limited genetic studies and outdated distribution data hinder comprehensive conservation efforts. Resolving these issues requires integrative taxonomic approaches using genetic, ecological, and historical data.

Jerdon's Babbler is facing significant population declines across its range, with local extinctions reported in several regional pockets. In the Ayeyarwady-Sitaung plain, the species was believed to be locally extinct for over 73 years due to widespread agricultural expansion and the loss of wetland habitats. Remarkably, it was rediscovered after this long absence (Rheindt *et al.* 2014). Similarly, sightings across Pakistan and Myanmar became more sporadic (Poudyal *et al.* 2020), suggesting severe population declines driven by habitat fragmentation and degradation.

However, these grasslands are increasingly threatened by human activities. Agriculture, infrastructure development, and overgrazing have led to significant habitat loss, while invasive plant species and changes in flooding regimes further degrade habitat quality. Seasonal flooding, once a natural feature supporting grassland regeneration, now poses challenges due to climate change. Additionally, the potential construction of dams poses further risks by altering hydrological patterns, potentially undermining the ecological balance essential for the survival of these unique ecosystems (Sheth 2020).

The conservation of Jerdon's Babbler is further complicated by its fragmented distribution and the lack of large, continuous grassland patches. Even within protected areas like Kaziranga National Park and Manas National Park, habitat fragmentation due to seasonal flooding and fire events. Outside these protected zones, grassland patches in regions like Arunachal Pradesh remain vulnerable to unregulated human activities, including unsustainable agriculture and ecotourism (Dhyani 2024).

Another pressing issue is the unauthorized use of playback calls in ecotourism areas, particularly during breeding seasons. These practices disturb the species' natural behaviours, including mating and territorial displays, potentially affecting reproductive success (Harris & Haskell 2013). Combined with habitat degradation, such disturbances amplify the challenges of conserving Jerdon's Babbler.

This study aims to understand Jerdon's Babbler's distribution, and conservation needs by analysing historical records, mapping current distributions through field surveys and secondary data. The findings of this study are expected to contribute significantly to conservation planning for the species. Regular monitoring, habitat restoration, and public awareness are essential components of any successful conservation strategy, and this study aims to provide a scientific foundation for these efforts.

Methods

Study area

This study was conducted in Northeast India, focusing primarily on the Brahmaputra floodplains, particularly Assam and Arunachal Pradesh, where Jerdon's Babbler has been historically prevalent. The Brahmaputra River, one of South Asia's major rivers, flows through diverse landscapes across India, China, and Bangladesh, forming an extensive floodplain ecosystem that supports variety of grassland-dependent species. Secondary data were collected from various known population sites of Jerdon's Babbler across its range to complement field surveys, providing a broader perspective on the species' historical and current distribution.

Survey methodology

The study employed a two-pronged approach: field data collection and secondary data analysis. Field surveys were carried out in the Brahmaputra's islands and neighbouring grassland ecosystems within its drainage basin during two separate seasons in 2020 and 2021. The study area was systematically gridded using a 1-km buffer, and only grids containing grassland habitats were selected for survey efforts. Within each grid, survey points were established with a minimum distance of 500 metres between them to avoid overlap. Rainy and other unfavourable weather conditions were avoided to ensure accurate observations, and accessible points with clear visibility of the surrounding environment were prioritized.

To assess Jerdon's Babbler populations, two main methods were used: point counts and call playback. These methods provided complementary insights into the species' presence, behaviour, and population density.

Fixed point count surveys

Fixed point count methods (Hutto *et al.* 1986) were employed to assess sympatric species and habitat interactions, despite the inherent challenge of reduced detection probabilities in grassland habitats. A total of 746 survey sites were examined across the Brahmaputra floodplains, encompassing the historical range of the species. Surveys were conducted during early morning and evening hours to maximize bird activity and detection likelihood.

Observations were made within a 25-metre radius over a 10-minute period using binoculars. Data collected included the species observed, distance, perch height, and the number of individuals. Adverse weather conditions were strictly avoided to minimize observation biases.

Call listening and playback

The call playback method, widely recognized for its effectiveness in surveying elusive and vocally responsive bird species (Conway & Gibbs 2005), was used to specifically target Jerdon's Babbler. Call playback was integrated into all fixed point count locations to maximize detection rates. Initially, vocalizations were recorded during preliminary field observations and then played back at predetermined survey points within the species' habitat. Playback sessions were conducted during optimal times, considering diurnal and seasonal variations.

Each session involved a structured protocol: a 2-minute listening period followed by 2-minute playback and one repetition as needed to enhance detection chances. Observers recorded vocal responses, territorial behaviours, and other activity cues. Call directions and frequencies were analysed to estimate the number of individuals.

Secondary data collection

Extensive literature reviews were undertaken to gather historical distribution data for Jerdon's Babbler, enabling comparisons between past and present occurrences. Spatial data were collected to evaluate habitat shifts over time, with a focus on identifying trends and potential

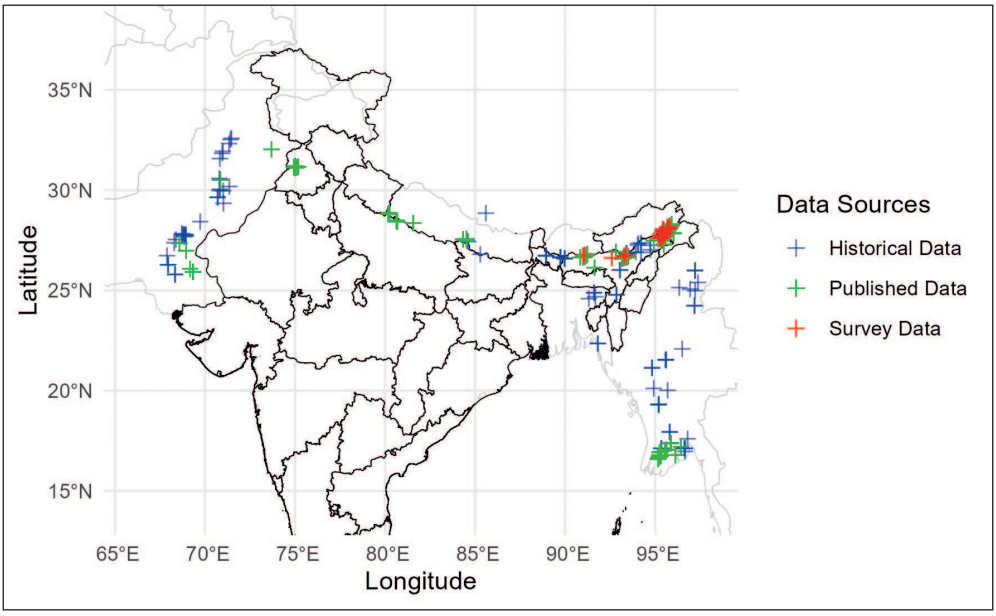


Figure 1. Occurrence map of Jerdon's Babbler based on multiple data sources
1. ábra A Jerdon-timália elterjedési térképe különböző adatforrások alapján

habitat changes. Search keywords included "Jerdon's Babbler", "Sind Babbler", "Hume's Babbler", "*Chrysomma altirostre*", "*Pyctorhis altirostris*", and "*Moupinia altirostris*".

Additionally, eBird records (eBird Basic Dataset 2024) for Jerdon's Babbler, including its three subspecies, were sourced from the December 2023 dataset. Both vetted and unvetted records were merged to create a comprehensive dataset, with entries lacking coordinates or containing spatial errors exceeding 10 km excluded. Historical data (pre-1980s) and recent occurrences (post-2000) were georeferenced *(Figure 1)*, while records between these periods were omitted to focus on distinct temporal comparisons.

Habitat shifts and kernel density estimation

To examine habitat shifts over time, historical and current occurrence points were analysed using kernel density estimation (KDE) (Kim & Scott 2012). KDE was employed to generate heatmaps that identified areas with high concentrations of Jerdon's Babbler occurrences. This technique helped visualize shifts in population density and habitat preferences between historical and current periods.

Kernel bandwidths were determined based on the spatial spread of the occurrence data, ensuring an appropriate balance between smoothing and detail preservation. KDE analysis highlighted regions of habitat contraction, expansion, and shifting centroids, providing critical insights into changes in the species' spatial distribution.

Centroid calculations and shift measurements

Centroid calculations were used to capture the central tendency of species distribution within each subspecies zone. Historical and current distributions were grouped by subspecies, and centroids were computed using the st_centroid function in R. Habitat shifts were quantified by measuring the distance between historical and current centroids with the st_distance function. Directional movements were visualized with arrows pointing from historical to current centroids, clearly illustrating spatial shifts.

The analysis employed R version 4.4.2 (R Core Team 2024) with packages such as **sf** for spatial data processing, **ggplot2** for visualization, and **raster** for geospatial data handling. Kernel Density Estimation (KDE) and centroid analyses offered insights into habitat shifts, with trends visually examined for conservation implications. Additionally, a 50 km buffer was applied to expand coverage, and polygon areas were calculated using st_area and converted to square kilometres to quantify spatial changes.

Results

Current distribution

Observations confirmed the presence of the species in 129 sites, reflecting its restricted and fragmented current distribution compared to historical records. A literature review yielded

119 historical locations, but after rigorous vetting, 106 GPS locations were deemed reliable and selected for analysis.

Indian zone

Historically, Jerdon's Babbler was predominantly found in the Terai-Duar grasslands and Brahmaputra Valley grasslands. Its distribution in the past was more uniform and widespread, indicative of stable habitat conditions and relatively unfragmented ecosystems. Notably, no historical records were reported from Arunachal Pradesh, suggesting either limited distribution in this region or under-surveyed areas.

The current distribution shows a significant eastward shift in the centroid, approximately 361 km from its historical centroid location *(Figure 2)*, now concentrated in the upper Brahmaputra Valley and parts of Arunachal Pradesh. This shift likely reflects habitat loss and fragmentation in its historical range, driving populations into more isolated and potentially less disturbed regions. Current population densities are highest in smaller, fragmented

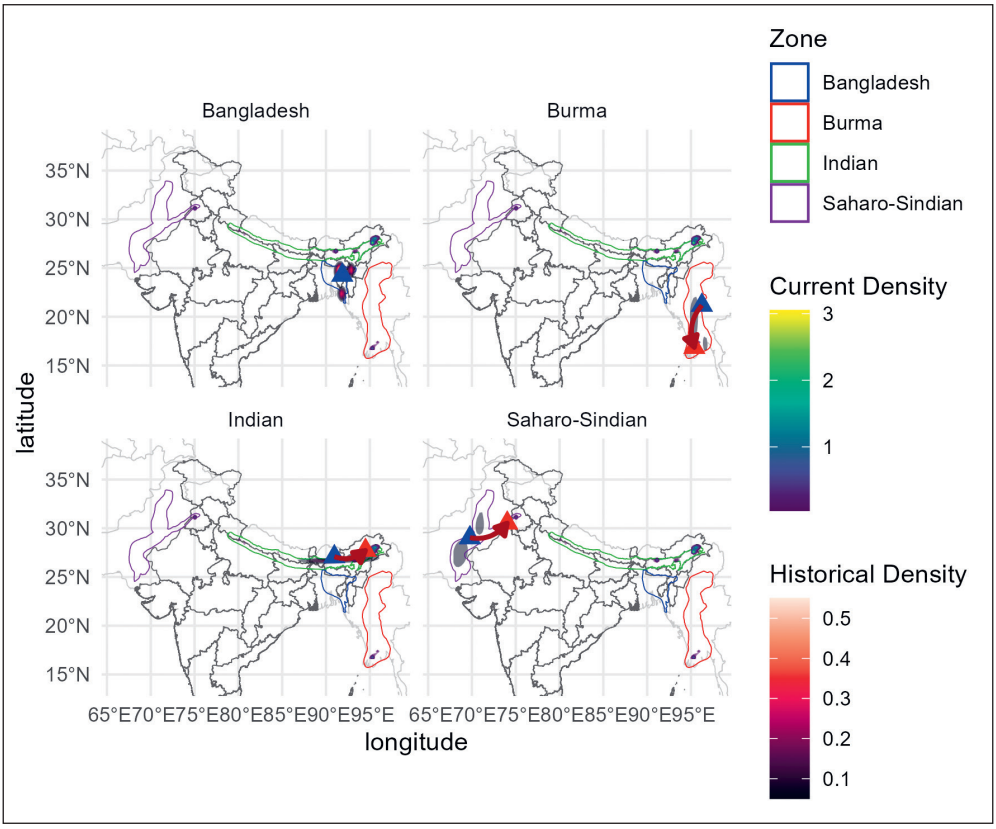


Figure 2. Map depicting range shifts of Jerdon's Babbler across subspecies zones, highlighting historic (blue triangles) and current (red triangles) centroids

2. ábra A Jerdon-timália elterjedési területének eltolódása az alfajok zónái között, kiemelve a történelmi (kék háromszögek) és a jelenlegi (piros háromszögek) középpontokat

patches, contrasting with the broader and more contiguous historical ranges. Protected areas like Kaziranga National Park and Manas National Park support relatively stable populations, particularly in the grasslands dominated by kans grass.

Burmese zone

In Myanmar, Jerdon's Babbler historically exhibited a broader and more contiguous range across riverine grasslands, supported by stable ecosystems with well-distributed density gradients. These conditions suggest that the habitats were once robust and less influenced by habitat loss.

Presently, the centroid of Jerdon's Babbler distribution in the Burmese Zone has shifted approximately 490 km southwestward *(Figure 2)*. The high-density populations are now restricted to grassland patches in areas such as Shwelaung, particularly near water bodies and marshlands. This shift indicates a reduction in habitat connectivity, likely driven by agricultural expansion, urbanization, and changes in hydrology. Fragmentation within these regions poses significant challenges to the long-term viability of the species in Myanmar.

Saharo-Sindian zone

Historically, the Saharo-Sindian zone encompassed the floodplains of the Indus River and adjacent desert-edge grasslands, characterized by reed-dominated habitats. The distribution in this zone was relatively extensive, suggesting suitable ecological conditions in the past.

Currently, the centroid of the species' range in this zone has shifted approximately 444 km northwestward *(Figure 2)*, now centroid is near Jalandhar in Northern India. Interestingly, historical records do not include observations from this specific region, suggesting either recent expansion or improved detection due to focused survey efforts. However, the density in this zone is notably low, reflecting extensive habitat degradation and loss, particularly in its historical range. Though the recent sightings from this region highlight the need for further investigation to understand the species population status.

Indo-Bangladesh zone

The Indo-Bangladesh zone historically supported populations of Jerdon's Babbler, with records indicating significant presence in areas such as Sylhet and the Surma Valley. However, no recent sightings of the species have been reported from this region, suggesting local extirpation. The loss of populations in this zone may be attributed to widespread habitat conversion for agriculture, urbanization, and wetland degradation, which have drastically altered the landscape.

Observations from Northeast India

Extensive surveys in northeastern India revealed that the populations of Jerdon's Babbler are now majorly confined to protected areas and less accessible regions, such as the islands

of the Brahmaputra River. These areas serve as refuges, providing relatively undisturbed habitats crucial for the species' persistence. Arunachal Pradesh, Kaziranga National Park, and Manas National Park emerged as key strongholds, with populations thriving in grasslands dominated by kans grass. Despite these pockets of stability, the overall range remains fragmented, with limited connectivity between populations.

Distribution patterns

The analysis of historical and current occurrence data revealed distinct patterns of distribution across the subspecies zones of the species. Kernel density estimation highlighted areas of concentrated occurrences, identifying high-density zones across the species' range. These findings underscore the stark differences between historical and current distributions, marked by areas of overlap and divergence.

The analysis revealed a significant reduction in the species' distribution. The historical distribution spanned 326,263 km^2, while the current distribution covered only 173,071 km^2,

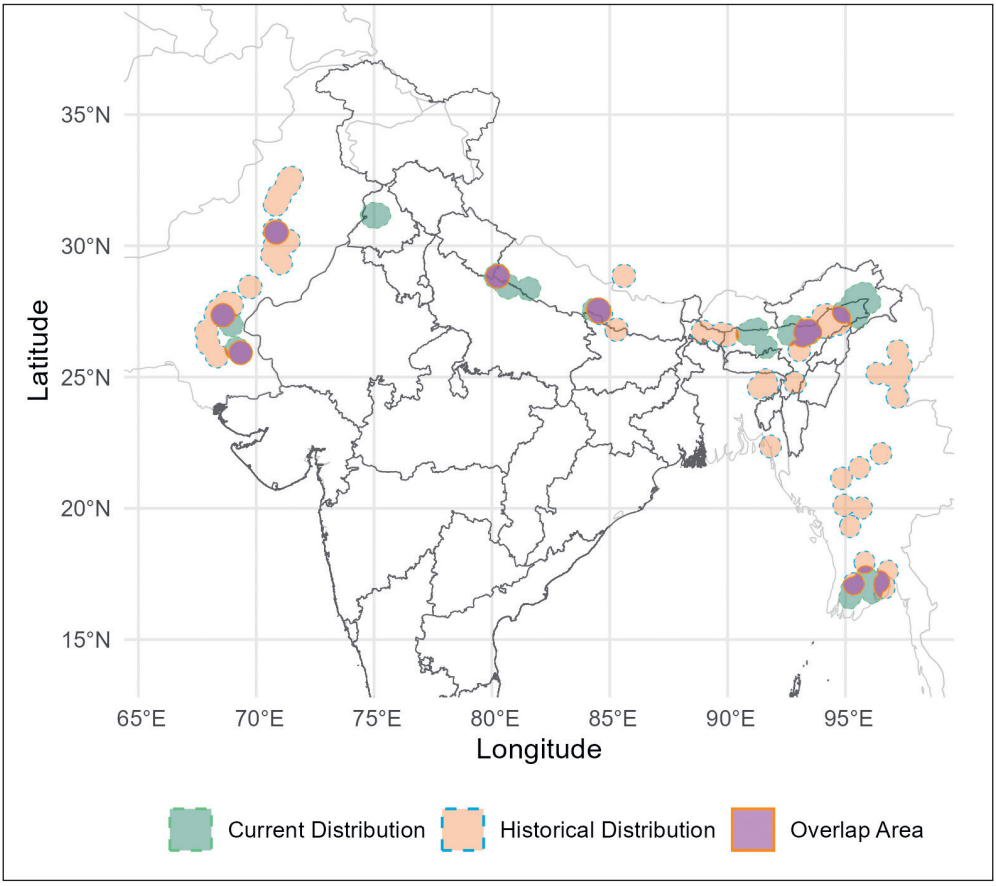


Figure 3. Map showing the historical distribution, current distribution, and overlap area of the species
3. ábra A faj egykori és jelenlegi elterjedése, valamint a kettő közötti átfedési terület térképe

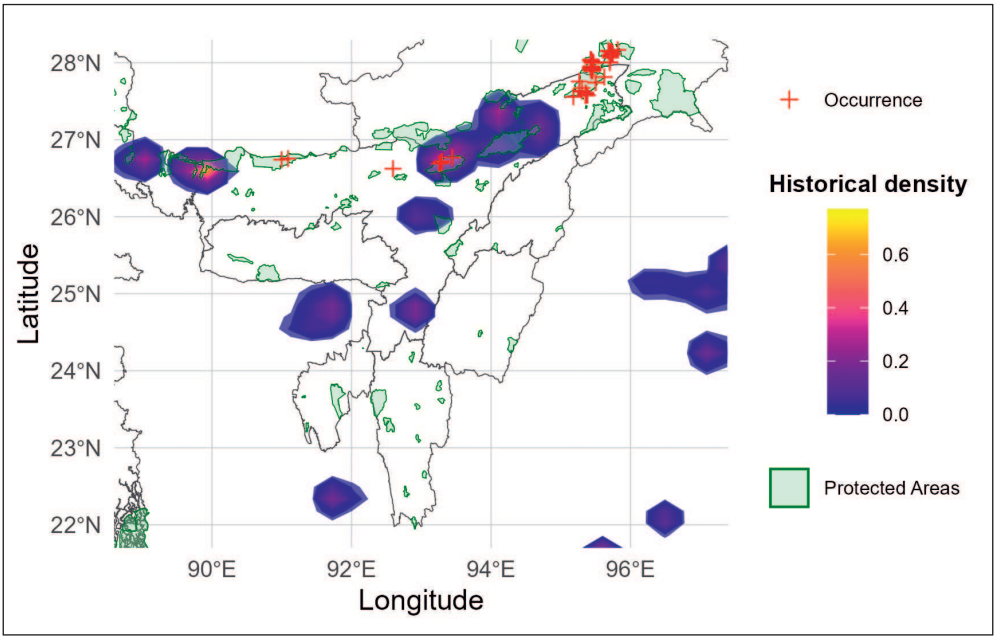


Figure 4. Map of the intensive study area depicting the current distribution of Jerdon's Babbler, historical records, and protected areas

4. ábra Az intenzíven vizsgált terület térképe, amely a Jerdon-timália jelenlegi elterjedését, a történelmi adatokat és a védett területeket ábrázolja

reflecting a loss of 254,639 km^2. Overlap between historical and current areas was limited to 71,623 km^2, indicating zones of persistence *(Figure 3)*. However, 101,448 km^2 of new areas were identified as potential habitat gain, suggesting possible range expansion.

While historical data depict a more uniform and contiguous range, current patterns indicate severe fragmentation and habitat contraction. The kernel density heatmap clearly illustrates these changes, with high-density populations now confined to isolated patches within each subspecies' range *(Figure 4)*. These shifts reflect the combined effects of habitat degradation, anthropogenic pressures, and environmental changes, emphasizing the urgent need for targeted conservation measures to preserve the remaining populations and restore degraded habitats.

Discussion

Habitat challenges and conservation needs

This study underscores the critical challenges facing Jerdon's Babbler, including habitat degradation, population decline, and increased dependence on disturbed environments. Habitat loss, largely driven by agricultural expansion, infrastructure development, and climate change, has reduced the availability of suitable grassland habitats. Fires during

breeding seasons (June–July) exacerbate this problem, disrupting reproductive success and long-term viability (Murphy *et al.* 2010, Long *et al.* 2023, Peltzer *et al.* 2023). Additionally, unauthorized use of playback calls in ecotourism areas further interferes with the species' natural behaviours, such as mating calls and territorial displays, particularly in grassland patches along the Brahmaputra River.

Environmental changes such as proposed dam constructions, mining activities, and the degradation of grassland ecosystems present significant threats not only to Jerdon's Babbler but also to the broader biodiversity of riverine systems like the Brahmaputra. These ecosystems are vital for many grassland-dependent species, underscoring the urgency for targeted habitat restoration and protective measures.

Although the species demonstrates some adaptability by transitioning to novel environments, the long-term suitability of these alternative habitats remains uncertain. Conservation measures must prioritize the restoration of traditional grassland ecosystems, minimize disturbances during critical periods, and address broader ecological challenges such as climate change and unsustainable tourism practices.

Status and distribution

Our findings reveal a significant contraction in the distribution range of Jerdon's Babbler compared to historical records, particularly in key habitats like the floodplains of Assam and Myanmar. This aligns with trends observed in other passerine species facing similar anthropogenic pressures (Rushing *et al.* 2020). However, the identification of new populations in previously undocumented regions suggests that the species might exhibit ecological plasticity, albeit inconsistently across its range. The absence of recent observations in historically dense areas highlights the need for further, comprehensive surveys to accurately define the species' current distribution.

Habitat shifts

The findings underscore extensive habitat loss, with the current distribution comprising only 52% of the historical extent. The overlap region represents critical zones for species survival and conservation prioritization. While the 50 km buffer and simplified geometries facilitate analysis, they may overgeneralize dispersal or omit fine-scale habitat details. The species increasingly observed in fragmented or degraded grasslands characterized by proximity to protected areas (Pacifici *et al.* 2020) and high-quality grasslands. These shifts are likely driven by habitat degradation, climate change, and agricultural encroachment, which have rendered traditional habitats less suitable.

This trend mirrors patterns observed in other avian species that exploit disturbed environments as a survival strategy (Newcombe *et al.* 2023). While this adaptability indicates ecological resilience, it raises concerns about long-term population viability if such habitats fail to provide adequate resources for reproduction and survival.

Effectiveness of conservation measures

Protected areas such as Kaziranga and Manas National Parks have proven effective in preserving populations of the species, offering relatively undisturbed environments dominated by kans, vetiver, and tall reed grasslands. High population densities within these zones highlight the importance of habitat management and protection. Regular monitoring programs within these areas provide a framework for assessing population trends.

However, challenges persist even within protected zones. Seasonal flooding, uncontrolled fire, invasive plant species, and insufficient enforcement against unauthorized activities degrade habitat quality and disrupt the species behaviour. Furthermore, many critical grassland patches, particularly in Arunachal Pradesh, lie outside protected areas, leaving these populations vulnerable to unregulated human activities.

This study acknowledges several limitations that could impact the robustness of its findings. One significant issue is the reliance on secondary data, as historical distribution records often lack consistency due to taxonomic revisions, vague descriptions about location, and the absence of standardized reporting methods. Another limitation lies in survey coverage, as field surveys were confined to northeastern portion of India.

To address these limitations, future research should adopt several measures to improve data quality and comprehensiveness. Longitudinal studies are crucial for monitoring dynamic changes in habitat and population trends across multiple seasons. Advanced technologies, such as remote sensing for habitat mapping and bioacoustic (Hobi *et al.* 2021) methods for accurate species detection, can enhance data precision (Toenies & Rich 2021). Engaging local communities in data collection and conservation initiatives, particularly in under-surveyed regions, can improve coverage and integrate valuable traditional knowledge. Lastly, genetic studies should be conducted to evaluate population connectivity, clarify subspecies classifications, and identify potential bottlenecks caused by habitat fragmentation.

Implications for conservation

The observed distribution shifts and habitat contractions underline the urgency of targeted conservation measures. Efforts must prioritize restoring and protecting traditional grassland habitats while exploring the viability of newly adopted habitats as supplementary refuges. Enhancing landscape connectivity through habitat corridors could sustain genetic diversity and mitigate local extinctions.

Conclusion

This study highlights the ecological and conservation challenges confronting Jerdon's Babbler, emphasizing both its resilience and its vulnerability. While the species demonstrates adaptability, the contraction of its traditional range and increasing reliance on fragmented habitats raise concerns about its long-term viability. Our findings reveal significant habitat contraction, with the current distribution encompassing only 52% of its historical range.

Effective conservation efforts must prioritize the restoration of these habitats, coupled with landscape-scale strategies to mitigate fragmentation and enhance connectivity.

Key conservation measures should prioritize the restoration of traditional grassland ecosystems, enhance connectivity through habitat corridors, and mitigate disturbances, especially in unprotected areas. Protected zones like Kaziranga and Manas National Parks remain crucial refuges, but conservation efforts must extend beyond these areas to address regional threats and ensure species persistence.

This study underscores the urgency of targeted conservation actions to protect Jerdon's Babbler and its threatened grassland habitats. While facing significant threats, the species' resilience offers hope, provided informed actions, continued monitoring, and research are prioritized to secure its future amidst ongoing environmental changes.

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Breeding biology of Rufous-bellied Woodpecker *(Dendrocopos hyperythrus)* in Rudraprayag District (Western Himalayas), Uttarakhand, India

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Abstract Cavity nesting species such as woodpeckers comprise a major component of many forest communities and play an important role in forest ecosystems. To conserve the population of these species, proper field observations on their breeding ecology are required. On the Indian subcontinent, there has been almost no scientific study about the breeding ecology of Rufous-bellied Woodpecker (RBW) *(Dendrocopos hyperythrus)*. We studied the breeding ecology of RBW from February 2018 to July 2020 in Rudraprayag (Western Himalayas), Uttarakhand, India. Results indicated that the breeding season of RBW extends from March to July. RBW is a primary cavity excavator in which the pair excavates the nest cavity in various tree species, such as rhododendron *(Rhododendron arboreum)*, Nepalese alder *(Alnus nepalensis)*, brown oak *(Quercus semecarpifolia)*, walnut *(Juglans regia)*, and moru oak *(Quercus floribunda)*. The most often selected tree for nest cavities in the study species was rhododendron (n=8). The average depth of the nest chamber was 29.5±6.67 cm (22–45 cm) and the diameter of the cavity entrance was 7.09±0.067 cm (7.0–7.2 cm). Nests were located at heights between 2–14 m above ground level with an average of 6.7±4.7 m. All the nesting sites found were between range 1800–2589 m a.s.l. Nests were orientated in all directions except for the North and Northeast. Twelve active nests were located on tree trunks (n=7) and branches (n=5). One nest was found abandoned before completion by the pair due to conflict with Himalayan Woodpecker *(Dendrocopos himalayensis)* which excavated a nesting cavity on the same tree. Clutch size ranged from 2–3 with an average of 2.90±0.30 (n=32). The incubation period ranged between 16–18 days (16.72±0.78 days). A total of 28 eggs hatched successfully with a success rate of 87.5%. The average fledgling period was 25.81±1.40 days (range 24–28 days). Nesting success was estimated at 81.25%.

Keywords: Indian subcontinent, breeding ecology, nesting, clutch size, breeding success, woodpecker

Összefoglalás Az odúban fészkelő fajok, mint például a harkályok, számos erdei életközösség fontos részét képezik, és fontos szerepet játszanak az erdei ökoszisztémákban. E fajok megőrzése érdekében szükség van a költési ökológiájuk tanulmányozására. Az indiai szubkontinensen szinte semmilyen tanulmány nem készült a vöröshasú fakopáncs *(Dendrocopos hyperythrus)* költési ökológiájáról, melyet 2018 februárjától 2020 júliusáig vizsgáltunk Rudraprayagban (Nyugat-Himalája), Uttarakhandban, Indiában. Az eredmények azt mutatták, hogy a szaporodási időszak márciustól júliusig tart. A vöröshasú fakopáncs elsődleges odúkészítő, különböző fafajokban készíti odúját, mint például *Rhododendron arboreum*, *Alnus nepalensis*, *Quercus semecarpifolia*, *Juglans regia* és *Quercus floribunda*. A vizsgált fajok közül a leggyakoribb fafaj a *Rhododendron arboreum* volt (n=8). A fészekkamra átlagos mélysége 29,5±6,67 cm (22–45 cm), a röpnyílás átmérője pedig 7,09±0,067 cm (7,0–7,2 cm) volt. Az odúk a talajszint felett 2–14 m (átlagosan 6,7±4,7 m) magasságban helyezkedtek el. Az összes költőhely 1,800–2,589 m tengerszint feletti magasságon volt (terjedelem: 1800–2589 m). Az odúk tájolására az északi és északkeleti irány kivételével minden égtáj jellemző volt. Tizenkét aktív odút találtunk fatörzseken (n=7) és ágakon (n=5). Egy odút a pár az odúkészítés befejezése előtt elhagyott, mert konfliktusba került egy himalájai fakopáncscsal *(Dendrocopos himalayensis)*, amely ugyanazon a fán készítette odúját. A fészekalj mérete 2–3 között változott, átlagosan 2,90±0,30 (n=32) volt. A keltetési idő 16–18 nap volt (16,72±0,78 nap). Összesen 28 tojás kelt ki

sikeresen, a sikerességi arány 87,5% volt. Az átlagos időtartam 25,81±1,40 nap volt (24–28 nap). A fészekrakás sikerességét 81,25%-ra becsülték.

Kulcsszavak: indiai szubkontinens, szaporodási ökológia, költés, fészekalj méret, költési siker, harkály

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Introduction

Woodpeckers are important components of forest communities and play a vital role in forest ecosystems. They are mainly insectivorous, and help in controlling the populations of bark living invertebrate pests by direct predation and by altering the micro-climatic conditions on tree bark (McCambridge & Knight 1972, Kroll & Fleet 1979, Otvos 1979, Kroll *et al.* 1980, Mendel *et al.* 1984). Woodpeckers are susceptible to habitat changes and act as indicators of forest biodiversity and specific forest bird species (Mikusiński *et al.* 2001). Habitat requirements and breeding success are poorly studied for many species of woodpeckers in India and particularly in the Western Himalayas, Uttarakhand, India.

As primary cavity users excavating holes in trees, woodpeckers provide nesting opportunities for secondary hole-users that often depend upon woodpecker cavities (Short 1979, 1982, Gorman 2020a). By providing sites for secondary cavity nesters such as parakeets, tits, owlets, and others, woodpeckers interact with many species and act as keystone species (Smith 2006, Diamond 2019). The conservation of keystone species is very important since a loss of them can lead to cascading negative effects in many other species from different taxonomic groups. As mentioned above, woodpeckers, as insectivores have an important role in controlling bark beetles and other insects, and ultimately in the restoration processes of natural habitats. It is known that the Rufous-bellied Woodpecker *(Dendrocopos hyperythrus)* is also a sap-sucking species (Gorman 2014, Shahabuddin *et al.* 2018).

Avian reproduction represents an integral and energetically demanding phase within the life history strategy of birds. This period necessitates substantial investment of time and metabolic energy directed towards critical reproductive behaviors, including nest site selection, nest construction, egg incubation, and the provisioning of altricial or precocial young (Fargallo *et al.* 2001, de León & Mínguez 2003, Mänd & Tilgar 2003). Unfortunately, there is limited data available on the breeding biology of the woodpeckers of the Indian subcontinent in general and of the Himalayan region in particular. Woodpeckers excavate their own nest holes, and it is difficult to locate their nests during nest making stage. As a result, there is little data available on their breeding ecology in India with only anecdotal evidence existing on the breeding phenology, number of fledglings and breeding/nesting success of the woodpeckers occurring in the country. The Rufous-bellied Woodpecker is thinly distributed and often uncommon in the study area (personal observation). Habitat varies across the range but is mainly damp subtropical jungle and upland temperate

coniferous, broadleaved and mixed forests (Gorman 2014). The range stretches across SE Asia with breeding in the Himalayas, SE Russia and NE China (possibly NW Thailand) to Indochina (Gorman 2014, Heim *et al.* 2016). Altitudinal movements in the Himalayas from 500 m to over 4,000 m are made.

Materials and Method

Study area

This study was conducted in the Kedarnath Wildlife Sanctuary (KWLS) of Rudraprayag, Uttarakhand (Western Himalayas). KWLS was established in 1972 and is situated in the north-eastern part of the Garhwal Himalayas between 30°250–30°410 N; 78°550–79°220 E *(Figure 1)*. The sanctuary falls under the IUCN management Category IV (Managed Nature Reserve) in the biogeographical province 2.38.12 of the Himalayan highlands. KWLS is one of the largest protected areas with 975.178 km^2 in the Western Himalaya. The sanctuary lies in the upper catchment of the Alaknanda and Mandakini Rivers, which are major tributaries of Ganges. It is bordered by high mountain peaks. The highest temperature recorded was 25 °C during summer and the lowest temperature observed was −10 °C during the winter seasons (IMD web). There is heavy snowfall during the winter (December–February) in the study area. A total of 485.7 km^2 area was covered during the study.

Field data collection

The study was conducted from 2018 to 2020, from the pre-breeding period until the end of the breeding season, and nests were located and marked. At each nest site, the presence of a Rufous-bellied Woodpecker was confirmed by two observers. Nesting locations of the woodpecker were located by listening to the drumming and vocalizations. It was observed that both males and females excavate many nests before the start of the breeding season and only a few are occupied by the pair for nesting purposes. Field observations were made during early morning (6:30 am to 11:30 am) and late afternoon (4:00 pm to 6:30 pm). We observed the activities of each breeding pair using Nikon binoculars (10×50mm), Canon 70 D still image camera (100–400 mm zoom lens), and a LED camera (RC_51001715 7 mm 6 LED Endoscope Waterproof Inspection Borescope Camera) was used for the inspection of nest contents. We marked nest trees with red-colored ribbons and local villagers were requested not to approach the nest trees. The number of cavities (occupied or unoccupied) was noted during the breeding season and the number of active woodpecker nests was also confirmed. Subsequently, the following nest/breeding parameters were recorded: entrance diameter, nest height above ground, depth of the nest cavity, altitude of nesting site, tree species on which cavities were found, cavity status (occupied or unoccupied), breeding parameters (clutch size, incubation period, nestling numbers and number of fledgling) and losses (eggs and nestlings). Tree cavities were measured using a collapsible ruler and a flashlight bulb, fixed with a flexible wire only after the nestlings fledged. The egg laying

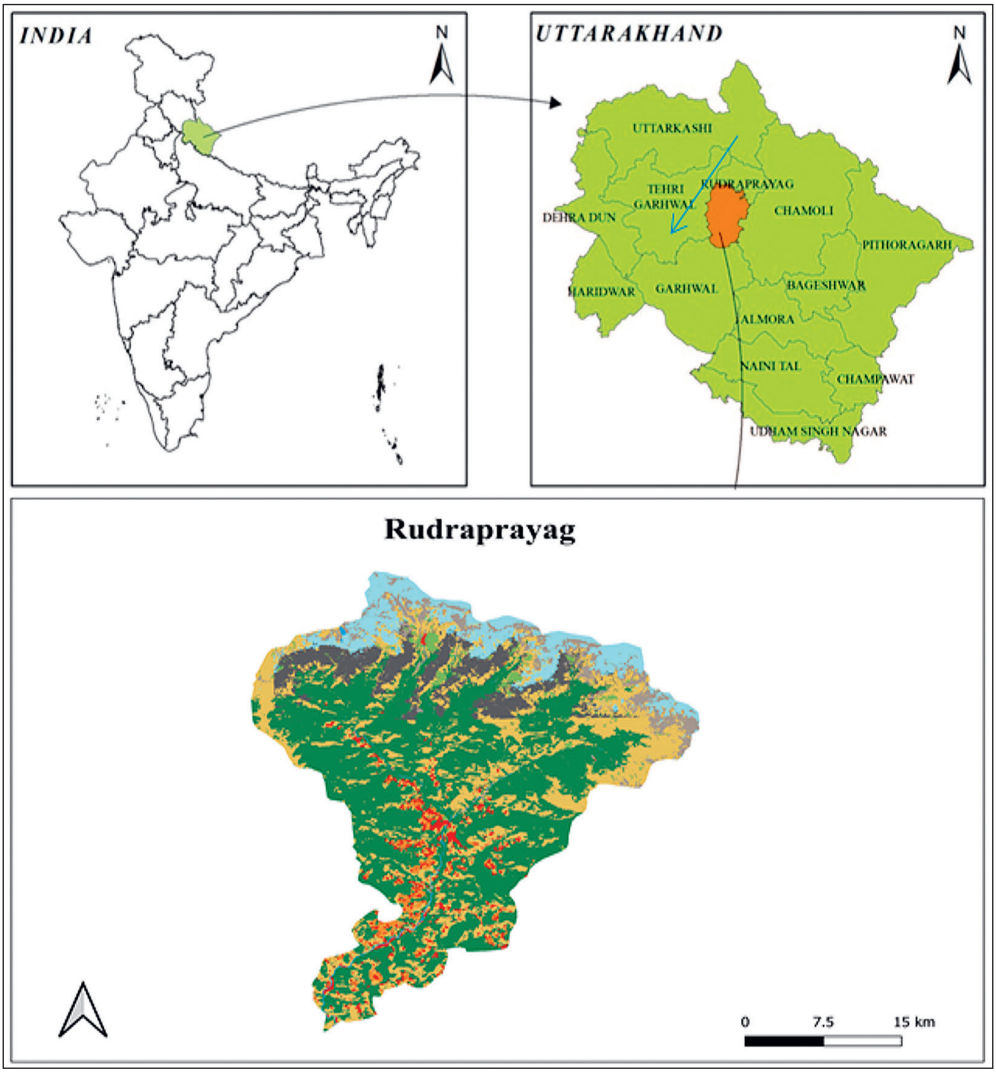


Figure 1. Map of the study area (Rudraprayag, Western Himalayas, India). Red dots represent the locations of nest sites in the lower map

1. ábra A vizsgálati terület térképe (Rudrapraang, Nyugat-Himalája, India). A piros pontok a felmért költőhelyek helyzetét mutatják

was observed through daily visit in different sites. The authors and volunteers visited each nesting cavity seven times in a week during the breeding season.

Data analysis

Nests were included only if they were truly active (i.e. had at least one egg or nestling). We began counting days, starting from zero, on the day the first egg was laid. Daily survival rate and nesting success were calculated following Mayfield's method (Mayfield 1975).

For nests whose outcome, successful or failed, was known, we stopped counting the days between the last date observed active and the subsequent nest check. For nests whose outcome was unknown, we stopped counting on the last active check. The nesting period was calculated by adding total exposure days (i.e. egg laying, incubation and nestling). In nests in which nestlings were not observed, the number of young fledged from the nests was assumed to be equal to the number of nestlings observed on the last nest visit only if the fledglings were found around the nest as the young do not leave the territory before 30 to 40 days after fledging (Kumar 1999).

Hatching success was also calculated using the traditional method formula:

$$\text{Hatching success} = (\text{No.of eggs hatched}) \div (\text{Total No.of eggs laid}) \times 100$$

MS Office Excel (version 10) was used for the data analysis.

Results

Nest tree use

Nest cavity entrances were found to be orientated in line with the direction from which direct sunlight arrived, more precisely nests were orientated in all directions except for the north and northeast *(Table 1)*.

It was also observed that slightly tilted trees were preferred for cavities and in every breeding season, the pairs created a new cavity for nesting. It is interesting to note that in the study site where rainfall was frequent. So, the RBW preferred those trees for nesting where the growth of the fungus *Trametes versicolor*, a common species in the study area was found.

Twelve cavities were excavated by the RBW during the study period on five tree species such as rhododendron *(Rhododendron arboreum)*, Nepalese alder *(Alnus nepalensis)*, brown oak *(Quercus semecarpifolia)*, walnut *(Juglans regia)*, and moru oak *(Quercus floribunda) (Table 1)*. The most often used tree species for nest building were rhododendron (n=8) and walnut (n=3) *(Table 1)*. Among the years of study, all the tree species selected for nests were close to small patches of grassland.

All the nest sites were found between 1,800–2,589 m a.s.l. The height of the nest varied between 2 and 14 m above ground level. Nests were located by inspecting all approachable snags. Nest cavities were completed in 4 to 6 weeks, and chips were more abundant as excavation proceeds. The average nest height from the ground was 6.7±4.8 m (n=12 nests). The depth of tree cavities ranged between 22 and 45 cm with an average of 29.5±6.67 cm (n=12 nests). The entrance diameter of the nests was between 7.0 and 7.2 cm with a mean of 7.09±0.07 cm. During this study 50% of the nests (n=6) were either east or southeast facing and the rest of the nest were in southwest directions. Most nests were found in March (n=5) throughout the study period *(Figure 2)*. Out of twelve cavities excavated, eleven nests were successful to raise the young, while one pair built the nest but abandoned it before egg-laying due to a conflict/fight with a Himalayan Woodpecker *(Dendrocopos himalayensis)*.

Table 1. Nesting and breeding parameters of RBW in the study site

1. táblázat A vizsgált költések paraméterei. Az oszlopok balról jobbra: fafaj, tengerszint feletti magasság, a röpnyílás tájolása, a röpnyílás talajszint feletti magassága, az odú mélysége, a röpnyílás átmérője, fészekalj méret, kotlási időszak hossza, kikelt tojások száma, fiókanevelési időszak hossza, kirepült fiatalok száma

S. No.	Tree species	Altitude of nesting site in meters	Nest cavity orientation	Height of the nest above ground (m)	Depth of cavity (cm)	Entrance diameter (cm)	Clutch size	Incubation period	Eggs hatched	Provisioning period	No. of youngs fledged
1.	*Quercus semecarpifolia*	2230	W	10	30	7.1	3	15	3	26	3
2.	*Juglans regia*	2150	NW	7	23	7.1	3	17	3	25	3
3.	*Rhododendron arboreum*	1800	E	2	40	7.0	3	17	3	25	2
4.	*Lyonia ovalifolia*	1906	SE	4	26	7.1	3	16	2	24	2
5.	*Rhododendron arboreum*	2100	NW	2.4	30	7.2	3	17	2	25	2
6.	*Juglans regia*	2200	SE	8.3	28	7.1	2	16	2	24	2
7.	*Alnus nepalensis*	2300	SW	14	45	7.2	3	17	3	28	3
8.	*Quercus floribunda*	2320	E	13	28	7.0	3	17	3	27	3
9.	*Rhododendron arboreum*	2470	W	2.1	25	7.1	3	17	2	26	2
10.	*Rhododendron arboreum*	2500	SW	2.1	29	7.1	3	18	3	26	2
11.	*Rhododendron arboreum*	2560	E	2.8	28	7.1	3	17	2	28	2
12.	*Juglans regia*	2110	SE	13	22	7.0	0	0	0	0	0
	Mean	**2220.50**	–	6.725	**29.500**	**7.091**	**2.900**	**16.727**	**2.540**	**25.818**	**2.360**
	Standard Deviation	**219.80**	–	4.780	**6.667**	**0.066**	**0.300**	**0.786**	**0.520**	**1.401**	**0.50**

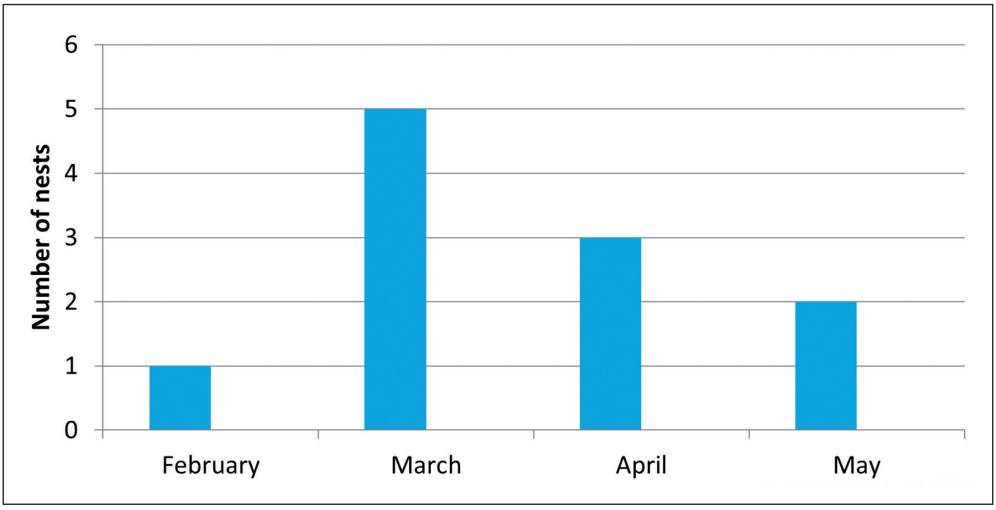


Figure 2. Monthly variation in number of nests found during the breeding season
2. ábra A talált költőodúk számának hónapok szerinti eloszlása

Clutch size and hatching success

The RBW laid a total of 32 eggs in all the nests observed during the study period. The mean clutch size of the 11 successful nests was 2.90±0.30 eggs (n=11) and ranged between 2 and 3 eggs. Out of the total 32 eggs laid 28 eggs hatched successfully. The hatching success during the study period was 87.5%

Fledgling success

Out of a total of 28 eggs hatched only 26 were fledged successfully. The fledgling success was calculated 92.85%

Nesting success

Out of a total of 32 eggs laid, only 26 young were fledged successfully from the nest. The nesting period was 35 days. The daily survival probability was 0.982 and the nesting success 81.25%

Discussion

Field observations revealed that cavities for nesting were excavated by the RBW on six tree species and the most frequently used tree species seems to be *Rhododendron arboreum*. The preference may simply be because the wood is softer where a big fungus growth takes place in the tree which makes this place more attractive. This would also explain why the RBW

makes a new cavity each year as the ones used for nesting in one year are probably not re-usable the next year due to the rotten and decaying wood.

Woodpeckers, renowned for their arboreal life stages, exhibit remarkable adaptations for excavating nesting and roosting cavities in trees, a behavior critical to their reproductive success and often beneficial to a host of secondary cavity users (Martin & Li 1992, Cornelius *et al.* 2008). This behavior has been documented for other *Dendrocopos* woodpeckers, too (Gorman 2020b, 2021). The selection of specific tree species and cavity characteristics varies considerably across woodpecker taxa, influenced by factors such as wood hardness, decay presence, and microclimatic conditions (Kozma & Kroll 2012). For instance, species like the Hairy Woodpecker *(Picoides villosus)* and Downy Woodpecker *(Dryobates pubescens)* are known to prefer softer, often decaying wood for excavation, enhancing construction efficiency (Kilham 1974). Similarly, the Black-backed Woodpecker *(Picoides arcticus)* frequently utilizes snags killed by fire, as the wood is softer and more amenable to excavation (Murphy & Lehnhausen 1998). Our field observations on the RBW further underscore the influence of wood characteristics on cavity site selection. During our study, RBW cavities were excavated on six tree species, with rhododendron being the most frequently utilized. This preference for rhododendron may be attributed to the prevalence of significant fungal growth in these trees, which softens the wood and makes it more attractive for excavation, aligning with observations in other woodpecker species where decay facilitates cavity creation (Elchuk & Wiebe 2003). This hypothesis is further supported by the RBW's tendency to excavate a new cavity each year, suggesting that the previously used sites, likely composed of extensively rotted and decaying wood, become unsuitable for subsequent nesting attempts.

This work presents the first detailed information regarding the various breeding ecology parameters of RBW including nesting success in its natural habitat. The nesting success of RBW in the study area was slightly higher (81.25%) as compared to other woodpeckers such as Lesser Spotted Woodpecker *(Dryobates minor)* (LSW). Rossmanith *et al.* (2007) reported 74.2% nesting success in LSW in German forest near Frankfurt. In general, cavity-nesting birds are known for their relatively high probability of nesting success (Martin & Li 1992). In this study, we observed very few occasions of nest predation. However, there was competition for nesting with Himalayan Woodpecker because of the same habitat they share and same tree was frequently used for nest making (Elchuk & Wiebe 2003).

According to Hogstad (2006), the mean incubation period of the woodpeckers (12.4±2.2 days) does not differ significantly from that of the secondary hole-nesters (17.6±6.3 days). In our study, the mean incubation period was 16.72±0.78 days which appears to be close to secondary hole nesters. However, when woodpeckers are compared with passerine species, they are seen to have a significantly longer nestling period (Hogstad 2006). A nestling period of about four weeks (24–28 days) was observed in this study which is higher than that of the Lesser Spotted Woodpecker (21–25 days) (Rossmanith *et al*. 2007) and passerine species in general. But clutch size was higher (mean 5.4 eggs) in LSW compared to RBW (mean 2.90 eggs). The mean nestling period of the woodpeckers (25.81±1.40 days) does not differ significantly from that of the secondary hole-nesters (22.7±6.9 days; p=0.57). However, the RBW has a longer nestling period (25.81 days) than LSW (23.2 days) and passerines

(18.5 days) (Hogstad 2006). It is generally perceived that compared with open nesters, woodpeckers have relatively small clutches (Winkler & Christie 2002). Similar observations have been made in the present study. Future studies about the role of acoustic signals in breeding biology and provisioning behavior in RBW would be important to understand the complete breeding behaviors and ecology of this species.

The breeding biology findings for the Rufous-bellied Woodpecker in Rudraprayag District, Western Himalayas, offer crucial insights for conservation and forest management practices in this ecologically sensitive region. The species' strong preference for rhododendron and other tree species exhibiting significant fungal decay for nesting cavities highlights the importance of maintaining a diversity of tree ages and health stages within the forest ecosystem.

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Diet of a breeding population of South Polar Skuas *(Stercorarius maccormicki)* of the Schirmacher Oasis, Central Dronning Maud Land, East Antarctica

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Abstract The first detailed study on the diet of a breeding population of South Polar Skuas *(Stercorarius maccormicki)* at Schirmacher Oasis is based on the collection and analysis of prey remains and pellets from the 2024/2025 breeding season and food samples from previous seasons near active skua nests (n=8) and old breeding territories (n=2). The diet composition of the skua population and its changes in the context of human activity were determined. The diet included five bird species, fish, squid, and food scraps and garbage from Antarctic stations and bases. The diet was dominated by Snow Petrels *(Pagodroma nivea)*, with subdominants being Antarctic Petrels *(Thalassoica antarctica)* and Adélie Penguins *(Pygoscelis adeliae)*. Native marine fish and squid were likely incidental dietary components, introduced into pellets along with the skuas' prey. Human activities have influenced the diet of skuas on a population-wide scale by introducing imported food and garbage into their diet. Food waste was found in seven of eight surveyed breeding territories and in one of two old breeding territories. Diet composition and behaviour of skuas in areas of human activity in Antarctica can be used as an indicator of the quality of local human waste management, as well as an indicator of the health of the ecosystem.

Keywords: predation, scavenging, kleptoparasitism, cannibalism, feeding

Összefoglalás Jelen tanulmány az első, ami a Schirmacher-oázisban költő délsarki halfarkasok *(Stercorarius maccormicki)* táplálkozását vizsgálta a 2024/2025-ös költési szezonból származó zsákmánymaradványok és köpetek, valamint a korábbi szezonokból származó táplálékminták alapján, aktív halfarkas-fészkek (n=8) és régi költőhelyek (n=2) közelében. Meghatároztuk a halfarkas-populáció táplálékösszetételét és annak változását az emberi tevékenységgel összefüggésben. Az étrend öt madárfajt, halat, tintahalat, valamint az antarktiszi állomásokról és bázisokról származó ételmaradékot és szemetet tartalmazott. A táplálékban a hóhojszák *(Pagodroma nivea)* domináltak, a szubdomináns fajok az antarktiszi hojszák *(Thalassoica antarctica)* és az Adélie-pingvinek *(Pygoscelis adeliae)* voltak. Az őshonos tengeri halak és a tintahalak valószínűleg véletlenül kerültek a köpetekbe a halfarkasok zsákmányával együtt. Az emberi tevékenységek a populáció egészére kiterjedően befolyásolták a halfarkasok étrendjét azáltal, hogy behozott táplálékot és szemetet vittek be a táplálékukba. A nyolc vizsgált költőterületből hétben, és a két régi költőterületből egyben találtak élelmiszerhulladékot. Az antarktiszi emberi tevékenységgel érintett területeken élő halfarkasok táplálékösszetétele és viselkedése a helyi emberi hulladékgazdálkodás minőségének, valamint az ökoszisztéma egészségének mutatójaként is használható.

Kulcsszavak: predáció, szemét eltakarítás, kleptoparazitizmus, kannibalizmus, táplálkozás

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Introduction

At the scale of Antarctica, the human footprint is much smaller than in most other regions of the Earth (Pertierra *et al.* 2017), but human activities can influence Antarctic flora and fauna at different levels of biological organization (Tin *et al.* 2009). The presence of more permanent settlements in Antarctica will increase, and this will likely bring conservation challenges (Chown *et al.* 2012). Research into Antarctic oases is of particular interest. They occupy an insignificantly small area of the ice continent, where most Antarctic stations are located and tourism is developing (Sokratova 2009). At the same time, the seasonal and year-round human settlements in Antarctica suggest the longest and closest contacts with biota and birds, in particular.

After the discovery of the Schirmacher Oasis (hereinafter the Oasis) on 3 February 1939, its territory was first visited in 1959 by members of the Fourth Soviet Antarctic Expedition (Konovalov 1962a, Fritzsche & Bormann 1995). Subsequently, the Oasis experienced increasing anthropogenic influence, which was expressed in the construction and then continuous year-round operation of Antarctic stations (Fritzsche & Bormann 1995, AARI Press Service 2011, Aleksandrov 2014, Tiwari 2017) and annually functioning seasonal tourist bases (White Desert 2020). In 1961, the Novolazarevskaya Station was opened, the infrastructure of which included the George Forster base from 1976 to 1996 (AARI Press Service 2011). In 1988/1989, the Maitri Station opened (Tiwari 2017). From 2006 to the present time, commercial tourism has been organized on the basis of the White Desert Antarctic Camp (White Desert 2020). Thus, the permanent human population in the Oasis is now a reality, and in fact, human activity does not allow it to be considered a virgin habitat for the biota inhabiting it.

Despite a long history of bird records at Oasis (Ryan 2024), many aspects of bird life remain unclear due to insufficient research. One of the relevant aspects is the study of the diet and feeding behaviour of the South Polar Skua *(Stercorarius maccormicki)* (hereinafter SPS), an avian predator and food generalist. They breed on the periphery of Antarctica (Higgins & Davies 1996, Ritz *et al.* 2008). In the interior mountainous regions of the continent, there are small colonies of this species (Furness *et al.* 2020).

SPS is a migratory species, a seasonal resident, whose reproduction occurs throughout the land of the Oasis. Nests are located in lake basins or at some distance from them. There are 1–2 eggs in a clutch. The distance between the nearest nests varies from several hundred meters to several kilometres (data of the authors). The total size of the breeding population varies from a few pairs to more than 10 pairs (Pande *et al.* 2020).

SPS arrive at their breeding grounds in October (Richter & Bormann 1995, Venkataraman 1998, Chupin 2001, Voevodin 2002, Venkataraman & Hazra 2005, Pande *et al.* 2020) and leave the Oasis in March–April (Chupin 2001, Voevodin 2002, Chupin 2019, Pande *et al.* 2020). Thus, they spend about half of their annual cycle at sea and the other half at their breeding grounds on land. The foraging habitats and foraging behaviour of SPS have not been sufficiently studied. In search of food, they explore the entire territory of the Oasis and its environments and visit Antarctic stations and bases (observations by the authors). The main foraging strategy of SPS is predation, and the dominant prey items are petrels. During

the historical period, SPS also received food waste mainly from the Antarctic stations Novolazarevskaya, George Forster and Maitri (Venkataraman 1998, Venkataraman & Hazra 2005, Surwade 2006–2007, Pande *et al.* 2020), where scavenging was the food procurement strategy.

In the Oasis, SPS predation affects breeding and visiting seabirds (Chandra 2007, Chupin 2019, Pande *et al.* 2020). However, the decline in SPS prey such as Snow Petrels *(Pagodroma nivea)* and Wilson's Storm Petrels *(Oceanites oceanicus)* may affect SPS breeding success (Venkataraman 1998, Venkataraman & Hazra 2005). On the shores of the Oasis lakes, where SPS nests are located and which are exposed to the influence of Antarctic stations and tourist camps, a slight increase in the trophicity of water bodies was recorded (Smirnova *et al.* 2020), which is also important to study from a hydrobiological point of view.

Opportunistic observations of SPS diet at Oasis have been published sporadically (Mathew 1986, Chaturvedi & Tripathi 1999, Chandra 2007). Detailed studies and analyses of diet and feeding behaviour data of breeding SPS on a population-wide scale have not been undertaken. Furthermore, previous efforts to study SPS diet have been inconclusive in assessing the extent of dietary diversity, the importance of certain prey categories in SPS diets, and the influence of available food scraps on dietary variation in the local breeding population. Our study is a continuation of SPS population monitoring at this Antarctic land mass, with some emphasis on examining SPS diets in relation to distances from different Antarctic stations and bases (Bhatnagar 1999, Ryan 2024).

The aim of this study was to answer the question related to the diet composition of the SPS breeding population at the Oasis and how it has changed in the face of increasing human activity. Objectives: (1) to determine the size of the SPS breeding population in the 2024/2025 breeding season; (2) to establish the survival rate of SPS chicks during the study period; (3) to identify the diet of SPS breeding pairs in the current and past breeding seasons; (4) to compile data from the 2024/2025 season and historical information (1960–2023); (5) to identify feeding strategies that ensure SPS survival.

Material and Methods

Study area

The Oasis is located on the edge of the Antarctic continent, on land free of continuous snow and ice cover (Princess Astrid coast of central Dronning Maud Land, 70°44′ – 70°46′ S, 11°26′ – 11°49′ E). It is separated from the Lazarev Sea by an ice shelf. The Oasis is below the continental ice but above the shelf ice. It is a low hillock about 17 km long and 3 km wide, with a maximum height of 228 m above sea level and an area of about 34 km^2. There are up to 180 lakes in the Oasis, ranging in depth from 3 to 120 m; according to other estimates, there are more than 200 stagnant and running bodies of water there. The climate of the area is predominantly continental. The average annual air temperature is about -10 °C, the average annual precipitation is 250–300 mm. In summer, the surface of the rocks can heat up to 26 °C, the temperature of the ground layer of air rises to 5 °C. The relative

humidity of the air, on average throughout the year, does not exceed 52% (Fritzsche & Bormann 1995, Aleksandrov 2014, Smirnova *et al.* 2020).

The flora of the Oasis around the Novolazarevskaya Station is the richest in continental Antarctica. It includes 75 species of lichens and 13 species of mosses (Andreev & Kurbatova 2019). In the water bodies of the Oasis, 309 species and intraspecific taxa of algae were recorded: 179 species and intraspecific taxa of cyanoprokaryotes (Cyanophyta/Cyanobacteria/Cyanoprokaryota), 64 species of diatoms (Bacillariophyta), 46 species of green algae (Chlorophyta), 11 species and 3 intraspecific taxa of desmid algae (Charophyta, Zygnematophyceae, Desmidiales), 4 species of yellow-green algae (Ochrophyta, Xanthophyceae) and 1 species each of dinophytes (Dinoflagellata) and golden algae (Ochrophyta, Chrysophyceae) (Smirnova *et al.* 2020).

There are no marine mammals in the Oasis (Richter 1995) and no fish. Birds are represented by 7 species: the Adélie Penguin *(Pygoscelis adeliae)*, the Southern Fulmar *(Fulmarus glacialoides)*, the Snow Petrel and Antarctic Petrel *(Thalassoica antarctica)*, the Wilson's Storm Petrel, the South Polar Skua and the Kelp Gull *(Larus dominicanus)*. Five bird species occur annually in the Oasis and four species have been recorded breeding. The Southern Fulmar and Kelp Gull are classified as vagrants (Gerbovich 1963, Artem'ev 1964, Richter 1995, Pande *et al.* 2020, Ryan 2024). To study the impact of climate change on glaciers, as well as to study algae, mosses, cyanobacteria and lichens, Antarctic Specially Protected Area №163 Dakshin Gangotri Glacier was established on an area of 4.53 km^2.

Field work

The field survey was conducted from 5 December 2024 to 10 January 2025. The Oasis was divided into three equal areas: eastern, central and western. The main bases of our research were located at the Russian Antarctic Novolazarevskaya Station (eastern area), the Indian Antarctic Maitri Station (central area) and a temporary field camp (western area).



Figure 1. Images of some active nests of South Polar Skuas found during the 2024/2025 season at Oasis: A – adult bird on the nest, Lake Glubokoe; B – clutch of eggs in the nest on the shore of the lake in the north-central part of the Oasis; C – downy chick in the vicinity of the nest near the lake to the south-east of Lake Zub

1. ábra Képek néhány aktív fészekről, amelyeket a 2024/2025-ös szezonban találtak az Oasis területén: A – öreg madár a fészken, Glubokoe-tó; B – tojásos fészek a tó partján, az Oasis északi-középső részén; C – pelyhes fióka a fészek mellett a Zub-tótól délkeletre fekvő tó közelében

The size of the breeding SPS population in the Oasis during the 2024/2025 breeding season was estimated by searching for active nests or territorial pairs. A nest was classified as active if (1) there were one or two adults on the nest, (2) there was a clutch of eggs or chick(s) in the nest *(Figure 1)*. A nest was considered abandoned during the incubation stage if the eggs in the nest disappeared along with the breeding adults.

We explored the entire land area of the Oasis on foot in varying detail, with the greatest survey in the eastern part. In addition to the 2024/2025 season, one of the authors (I. I. Chupin) briefly visited Novolazarevskaya Station during the 2001 and 2019 seasonal work to collect some ornithological material on the state of the local avifauna and the impact of Antarctic stations on birds. We partially used the data from surveys of polar explorers from these studies.

Outside the Antarctic stations, our focus was on surveying the shores of all the large lakes of the Oasis and smaller lakes where SPS had historically nested. Eleven main routes were completed, ranging in length from 5 to 27 km. The total length of the routes was 123.5 km. Among them were the nunatak Aerodromnyy/Vetehia Hills, the Rock (nunatak) Palets, and three small unnamed islets north of Nadezhdy Island/Lanka *(Figure 2)*.

The survival of chicks in the SPS population was established by continuous monitoring of six active SPS nests (nests №1–№6), located mainly to the east of the Oasis. Nests №7–№9, located in the centre and west of the Oasis, were not monitored further. The timing

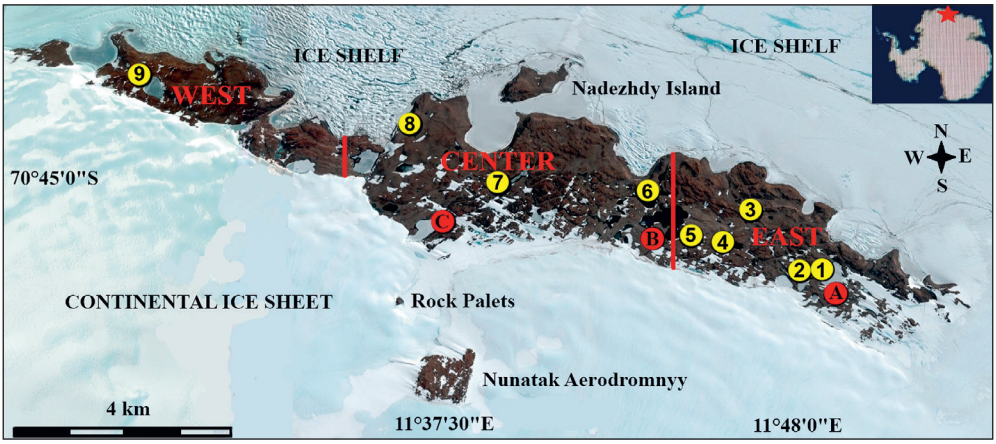


Figure 2. Spatial distribution of active nests of South Polar Skuas (yellow circles with numbers) at Oasis during the 2024/2025 breeding season: nest №1 – Lake Glubokoe; nest №2 – Lake Pomornik; nest №3 – Lake Chernoe; nest №4 – Lake Melkoe; nest №5 – lake to the southeast of Lake Zub; nest №6 – lake to the northwest of Lake Zub; nest №7 – Lake Dlinnoe; nest №8 – lake in the north-central part of the Oasis; nest №9 – Lake Zapadnoe. A – the Novolazarevskaya Station, B – the Maitri Station, C – the White Desert Antarctic Camps. The vertical red lines show the conditional boundaries of the three main sites of the Oasis

2. ábra A délsarki halfarkasok aktív fészkeinek (sárga körök számokkal) területi eloszlása az Oasis területén a 2024/2025-ös költési szezonban. Fészkek: 1. számú: – Glubokoe-tó; 2. számú: – Pomornik-tó; 3. számú: – Chernoe-tó; 4. számú: – Melkoe-tó; 5. számú: – a Zub-tótól délkeletre fekvő tó; 6. számú: – a Zub-tótól északnyugatra fekvő tó; 7. számú: – Dlinnoe-tó; 8. számú: – az Oasis északi-középső részén lévő tó; 9. számú: – Zapadnoe-tó. A – a Novolazarevszkaja állomás, B – a Maitri állomás, C – a White Desert antarktiszi táborai. A függőleges piros vonalak az Oasis három fő helyszínének feltételes határait mutatják

of establishing the survival rate of chicks in the SPS population corresponded to the stage of incubation of eggs, hatching of chicks and their subsequent growth. The final breeding success in the SPS population is not indicated in this work. It was limited by the timing of our fieldwork.

Food samples of SPS prey were collected only at sites of their concentrations in the Oasis – on SPS-defended breeding territories (n=8) and on SPS-undefended old breeding territories (n=2), i. e. breeding sites used for breeding until the 2024/2025 season. The old nesting territories were distant from each other. One was located in the eastern sector of the Oasis, the other in the western. The eastern old nesting territory was located 50 meters from nest №4 on Lake Melkoe. The western old nesting territory was located at some distance from nest №9 on Lake Zapadnoe.

Food samples included regurgitated pellets and prey remains of SPS prey. Prey remains (wings, feet, skulls and other bones and body fragments of animals), which did not pass through the digestive tract of SPS, but were important for studying their diet, were analysed separately from regurgitated pellets. Each prey remains belonged to only one species of wild birds, introduced animals and marine fish, in contrast to pellets, which could contain inclusions of one or more animal species *(Figure 3)*.

All nest sites included old (Ryan 2024) and/or very old bone remains of petrels (Venkataraman 1998, Venkataraman & Hazra 2005), and occasionally penguins and SPS. In addition, remains of recent SPS victims were found in, near and in the immediate vicinity of nests. Thus, food samples from SPS collected in their breeding territories consisted predominantly of samples from previous SPS breeding seasons and rare fresh samples from the current breeding season. The number of fresh samples was low and did not form a representative sample. Therefore, we combined them with food samples from previous seasons into a single sample.

The technique for collecting samples and processing them was carried out using the methodological guidelines of Voronetsky and Kuzmenko (2013). It included direct observations and collection of prey remains and pellets near nests. Outside the protected areas, food samples were usually visually recorded at a lower density but were not analysed. Pellets and prey remains were collected within a 10-metre radius from the centre of the active nest. The wings of petrels and SPS were collected within a 25-metre radius from the centre of the nest. In some cases, the radius of wing collection could be larger. In laboratory conditions, samples were measured with a calliper with an accuracy of 0.1 mm. Large fragments of samples were measured with a tape measure with an accuracy of 1 mm. The frequency of occurrence (FO) was calculated using the formula

$$FO = \left(\frac{f_i}{N}\right) x100$$

where f_i is the number of pellets with item i and N is the total number of pellets (De Villa-Meza *et al.* 2002). Each pellet was crushed into small fractions after measurements to allow detailed identification of its contents. Bones, feathers, wings, feet, mummified carcasses, and eggshells of birds were identified to species level. Bones of local marine fish and squid beaks were not identified to species level. From 10 categories of SPS prey remains,



Figure 3. Feeding, prey remains and pellets of South Polar Skuas collected at Oasis during the 2024/2025 field season: A – eating by SPS Snow Petrel *(Pagodroma nivea)*, vicinity of nest №8; B – prey remains from a Snow Petrel, nest №9; C – prey remains from an Antarctic Petrel, nest №9; D – wings and skeleton of a juvenile SPS as evidence of cannibalism, nest №3; E – SPS pellet from Adélie Penguin *(Pygoscelis adeliae)* feathers, nest №4; F – fragment of the skeleton of the head of a non-native (introduced) fish near nest №6; G – bone fragments of imported animals near nest №2; H – ceramic fragment in an SPS pellet of Adélie Penguin feathers and food waste near nest №8; I – green plastic in an SPS pellet near nest №6

3. ábra A 2024/2025-ös terepi szezonban az Oasis területén gyűjtött, délsarki halfarkasoktól származó táplálék, zsákmánymaradványok és köpetek: A – délsarki halfarkas hóhojsza- *(Pagodroma nivea)* zsákmánya a 8. számú fészek közelében; B – egy hóhojsza maradványai a 9. számú fészekből; C – egy antarktiszi hojsza zsákmánymaradványai a 9. számú fészekből; D – egy fiatal délsarki halfarkas szárnya és csontváza a kannibalizmus bizonyítékaként a 3. számú fészekből; E – Adélie-pingvin *(Pygoscelis adeliae)* tollából álló köpet a 4. számú fészekből; F – egy nem őshonos (behurcolt) hal koponyájának töredéke a 6. számú fészek közelében; G – behurcolt állatok csonttöredékei a 2. számú fészek közelében; H – kerámiatöredék egy Adélie-pingvin tollából és táplálékmaradványokból álló köpetben a 8. számú fészek közelében; I – zöld műanyag egy délsarkihalfarkas-köpetben a 6. számú fészek közelében

we measured Snow Petrel wings and skulls or skull fragments with or without cervical vertebrae, i. e. skulls as body fragments of Snow and Antarctic Petrels. To identify Snow Petrel morphs hunted by SPS within the Oasis, we collected only fresh petrel wings and measured their length as an important diagnostic parameter. All SPS food samples after laboratory testing were subjected to thermal disposal in a high-temperature incinerator ИУ-300 at the Novolazarevskaya Station.

The compilation of historical data is based on the study of available information resources collected until the 2024/2025 breeding season. Based on this, we compiled a general list of prey categories and attempted to identify the foraging strategy for each prey category. Historical data on SPS diet in 1960–2023 were obtained from scientific literature and unpublished reports. Primary historical data without exact dating, i. e. before the 2024/2025 season and data from the 2024/2025 season were collected by us in SPS nesting areas. They contained 704 food samples – 298 pellets, 406 prey remains including bone fragments from Antarctic stations and tourist bases from imported animals and marine fish.

Nests, nesting territories, and encounters of adult SPS at a distance from breeding sites or individuals with unclear status were mapped using a GPS navigator. All digital images of adults on the nest, clutches, chicks, feeding, prey remains, and SPS pellets collected in the Oasis during the 2024/2025 field season were obtained by S. V. Golubev. We consider four feeding strategies characteristic of southern hemisphere skuas: predation, scavenging, cannibalism and kleptoparasitism (Reinhardt *et al.* 2000).

Equipment

Binoculars, laptops, GPS navigators, mobile phones, radio communication devices were used in the field work. Computer programs MS Excel, SASPlanet, Adobe Photoshop CC were used for data storage, processing and visualization.

Results and Discussion

SPS population size

We found nine SPS active nests in the 2024/2025 breeding season. Nests were located on the shores of lakes and in their immediate vicinity inside the Oasis. The number of nests increased from west to east. In the western sector of the Oasis, one nest was found, in the central sector three nests, and in the eastern sector five nests *(Table 1, Figure 2)*. The distance from the nest to the nearest Antarctic station or tourist base varied from 470 m to 7,000 m, on average 1,871 m (n=9). The affinity of SPS towards human settlements in the Oasis is confirmed by the spatial distribution of their nests, i. e. an increase in the number of active nests from west to east against the background of an increase in human activity in this direction.

From 3–5 to 11 pairs of SPS have bred at the Oasis each year (e. g. Pande *et al.* 2020, Ryan 2024). Our actual estimates of nine breeding pairs for the 2024/2025 season are close to the upper limit of the historical total SPS breeding population size. Early estimates of

Table 1. Spatial distribution parameters of active nests of South Polar Skuas in the Oasis in the 2024/2025 breeding season, considering the distances to the nearest Antarctic stations and bases. The nest numbering in *Table 1* corresponds to the nest numbering in *Figure 2* and the captions to it.

1. táblázat A délsarki halfarkas aktív fészkeinek térbeli eloszlási paraméterei az Oasis területén a 2024/2025-ös költési időszakban, figyelembe véve a legközelebbi antarktiszi állomásoktól és bázisoktól mért távolságokat. A fészkek számozása megfelel a 2. ábrán szereplő számozásnak és a hozzá tartozó feliratoknak

Nest №	Coordinates	Date of discovery	Distance between the nest and the nearest station or base
1	70°46′216″ S, 11°49′041″ E	06.12.2024	470 m from the Novolazarevskaya Station
2	70°46′233″ S, 11°48′376″ E	06.12.2024	570 m from the Novolazarevskaya Station
3	70°45′452″ S, 11°46′502″ E	22.12.2024	2.2 km from the Novolazarevskaya Station and 1.9 km from the Maitri Station
4	70°46′028″ S, 11°46′128″ E	10.12.2024	2.2 km from the Novolazarevskaya Station and 1.4 km from the Maitri Station
5	70°46′011″ S, 11°45′051″ E	19.12.2024	700 m from the Maitri Station
6	70°45′345″ S, 11°43′381″ E	22.12.2024	800 m from the Maitri Station
7	70°45′293″ S, 11°38′499″ E	18.12.2024	1.2 km from the White Desert Antarctic Camp
8	70°44′542″ S, 11°36′066″ E	14.12.2024	2.8 km from the White Desert Antarctic Camp
9	70°44′190″ S, 11°27′086″ E	13.12.2024	7 km from the White Desert Antarctic Camp

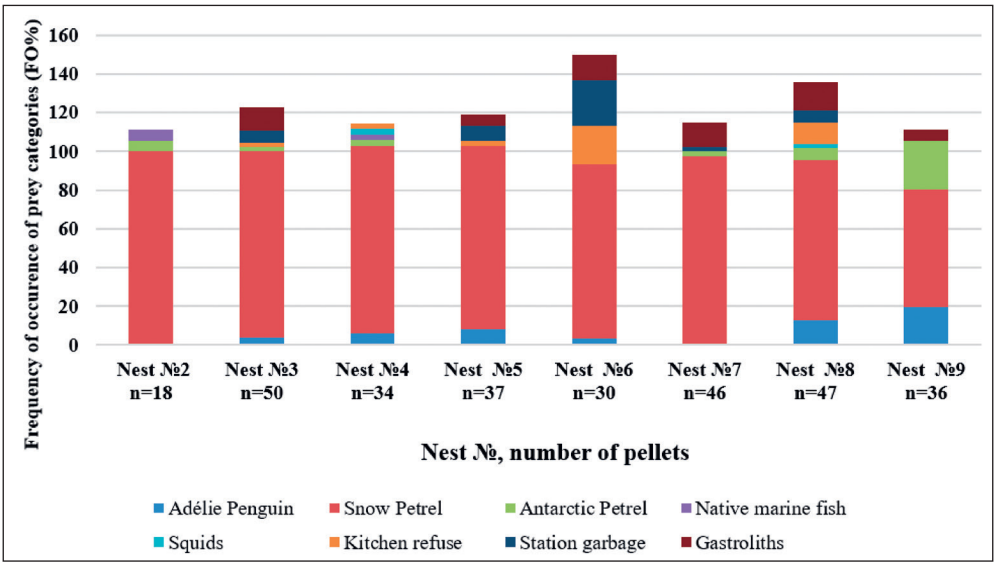


Figure 4. Frequency of occurrence of prey categories (FO%) in pellet samples from eight breeding territories of South Polar Skuas, based on data from past seasons and the 2024/2025 season combined

4. ábra A zsákmánykategóriák előfordulási gyakorisága (FO%) a délsarki halfarkasok nyolc fészkelőhelyéről származó köpetmintákban, az előző szezonok adatai és a 2024/2025-ös terepi szezon adatai alapján

Table 2. Survival of chicks in the population of South Polar Skuas in Oasis on 10 January 2025. The nest numbers in *Table 2* correspond to the nest numbers in *Figure 2* and the legends to it.

2. táblázat Az Oasis területén fészkelő délsarki halfarkas fiókák túlélése 2025. január 10-én. A 2. táblázatban szereplő fészkek számozása megfelel a 2. ábrán szereplő fészekszámozással és a hozzá tartozó ábraaláírással

Nest №	Date of nest discovery	Number of eggs/ chicks in the nest	Date of last nest visit	Number of eggs/ chicks in the nest	Survival rate of chicks, %
1	06.12.2024	2 eggs	16.12.2024	the eggs are gone	0
2	06.12.2024	2 eggs	10.01.2025	1 chick	50
3	22.12.2024	1 egg, 1 chick	10.01.2025	1 chick	50
4	10.12.2024	2 eggs	10.01.2025	1 chick	50
5	19.12.2024	1 chick	10.01.2025	1 chick	100
6	22.12.2024	1 egg, 1 chick	10.01.2025	1 chick	100
7	18.12.2024	1 egg	–	?	?
8	14.12.2024	2 eggs	–	?	?
9	13.12.2024	2 eggs	–	?	?

the SPS breeding population size (≤ 11 breeding pairs) in the Oasis, dating back to the 1970s and 1980s (Pande *et al.* 2020), could already bear the imprint of the influence of imported food on the diet and habits of SPS. Most likely, the natural size of the SPS population was lower than historical values.

Survival rate of SPS chicks

The results of the study showed that the breeding success of SPS in the early postembryonic period is low in the 2024/2025 breeding season. The survival rate of chicks by the end of the first 10 days of January *(Table 2)* was 0.83 chicks per breeding pair. This could be due to weather conditions during the current breeding season, but is more likely due to a decrease in the abundance of available food. In the 2000/2001 breeding season, three monitored nests at Oasis contained two eggs per clutch, but subsequently (date not given) one fledged flightless chick was found near each nest, where

Table 3. Quantitative distribution of pellets and prey remains across surveyed nests/ nesting territories of South Polar Skuas in the Oasis. Food samples from the SPS 2024/2025 breeding season are shown in parentheses, and those from previous breeding seasons are shown without parentheses

3. táblázat A köpetek és zsákmánymaradványok mennyiségi eloszlása az Oasis területén lévő délsarki halfarkasok vizsgált fészkeiben/fészkelőhelyein. A 2024/2025-ös költési szezonból származó táplálékminták zárójelben, a korábbi szaporodási szezonokból származó minták zárójel nélkül szerepelnek

Nest №	Pellets	Prey remains	Σ
1	0	0	0
2	14(4)	39(21)	53(25)
3	38(12)	48(7)	86(19)
4	34	43(3)	77(3)
5	35(2)	60(1)	95(3)
6	30	27(7)	57(7)
7	46	54(8)	100(8)
8	46(1)	13(21)	59(22)
9	32(4)	48(6)	80(10)
Σ	275(23)	332(74)	607(97)

the survival rate was one chick per breeding pair (Chupin 2001). In the 2001/2002 breeding season, the four nests containing relevant information contained a total of seven eggs, and by 10 January six chicks had survived, i. e. 1.5 chicks per breeding pair (Voevodin 2002, authors' calculations).

Compilation of data from the 2024/2025 field season

Sample sizes from the studied active SPS nests are presented in *Table 3*. A total of 42 food samples (32 pellets and 10 prey remains) were collected from the old nesting territories *(Table 4)*. In general, old nesting territories, as places of concentration of SPS prey remains, were not a common phenomenon in the feeding territories of SPS. Fresh pellets and prey remains of SPS in old nesting territories indicate that SPS occasionally use them to cut up and consume prey.

Table 4. Quantitative distribution of pellets and prey remains across surveyed old breeding territories of South Polar Skuas in the 2024/2025 field season in Oasis. Note: EONT – eastern old breeding territory; WONT – western old breeding territory. Numbers in parentheses indicate SPS food samples belonging to the 2024/2025 breeding season, numbers without parentheses – previous breeding seasons

4. táblázat A köpetek és zsákmánymaradványok mennyiségi eloszlása a délsarki halfarkasok régi költőterületein a 2024/2025-ös terepi szezonban az Oasis területén. Megjegyzés: EONT – régi keleti költőterület; WONT – régi nyugati költőterület. A zárójelben lévő számok a 2024/2025-ös szaporodási időszakhoz tartozó táplálékmintákat jelzik, a zárójel nélküli számok a korábbi szaporodási időszakokét

Old nesting territories	Pellets	Prey remains	Total
EONT	18(1)	9(1)	27(2)
WONT	9(4)	0	9(4)
Total	27(5)	9(1)	36(6)

A data compilation based on the analysis of SPS pellet contents is presented in *Figure 4*. It includes data from the 2024/2025 season combined with data from previous breeding seasons. The histogram shows the contribution of a specific prey category to the overall spectrum of identified prey categories for each active nest studied as frequency of occurrence (%).

A similar data visualization is presented in the histogram in *Figure 5* from two old SPS breeding territories. The pellet sizes (mm) from active SPS nests (mean±SD (min–max), n=295) were 67.2±21.5 (23–203) × 28.8±8.6 (15–84). The pellet sizes (mm) from old SPS breeding territories (n=32) were 74.5±27.7 (40–156) × 27.7±7 (17–43). Ten categories of prey remains were found in the breeding territories and the eastern old breeding territory of SPS. The results of prey collection and analysis are presented in *Table 5*.

Compilation of historical data (1960-2023) on the diet of the SPS breeding population

Two foraging strategies were identified: predation and scavenging. In some cases, the foraging strategy of some prey categories was not identified. The results of the data compilation and foraging strategy identification are presented in *Table 6*. The compilation of SPS prey categories derived from historical and our recent data is currently the most comprehensive study of the qualitative composition of their diet at Oasis. The results of this research effort are presented in *Table 7*.

Table 5. Distribution and sample size of prey remains in 8 breeding territories and the eastern old breeding territory of South Polar Skuas in the 2024/2025 breeding season

5. táblázat A zsákmánymaradványok eloszlása és mintanagysága a délsarki halfarkasok nyolc költőterületén és a régi keleti költőterületen a 2024/2025-ös költési időszakban

Nest № and name of old nesting territory	Nest №2	Nest №3	Nest №4	Nest №5	Nest №6	Nest №7	Nest №8	Nest №9	Eastern old breeding territory
Name of prey remains/ number of samples in the sample	**n=60**	**n=55**	**n=46**	**n=61**	**n=34**	**n=62**	**n=34**	**n=53**	**n=7**
Snow Petrel skull		+	+	+	+	+	+	+	+
Antarctic Petrel skull	+	+	+	+	+	+		+	
Snow Petrel wing/wings	+	+				+	+	+	
Antarctic Petrel wing/ wings	+					+	+	+	
South Polar Skua wing/ wings							+		
Adélie Penguin leg								+	
Snow Petrel's leg		+	+	+	+	+	+	+	
Antarctic Petrel leg		+		+		+		+	+
South Polar Skua leg		+		+	+	+			
Bone remains of imported animals	+	+	+			+	+		+

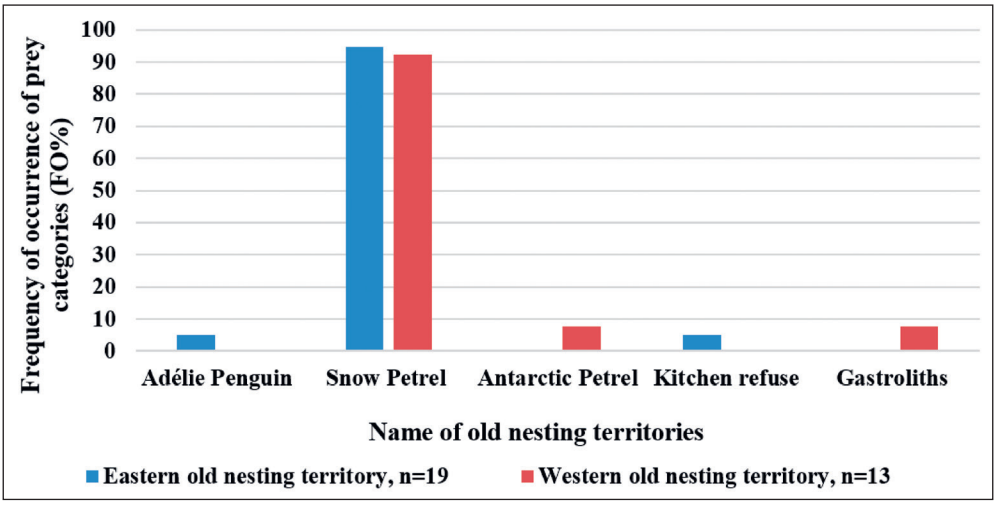


Figure 5. Frequency of occurrence of prey categories (FO%) in pellet samples from two old breeding territories of South Polar Skuas, based on data from previous seasons and the 2024/2025 field season combined

5. ábra A zsákmánykategóriák előfordulási gyakorisága (FO%) a délsarki halfarkasok két régi fészkelőhelyéről származó köpetmintákban, az előző szezonok adatai és a 2024/2025-ös terepi szezon adatai alapján

Table 6. Identification of feeding strategies and compilation of historical (published and unpublished reports) dietary qualitative data for South Polar Skuas from Oasis, 1960–2023

6. táblázat A táplálkozási stratégiák azonosítása és a történeti táplálékminták minőségi összetétele az Oasis területéről származó délsarki halfarkasok adatai alapján 1960 és 2023 között

Name of species/ category of prey	Feeding strategy	References
BIRDS		
Pygoscelis adeliae		
Adults	?,P,S	Chaturvedi & Tripathi 1999, Voevodin 2002, Chupin 2019
Thalassoica antarctica		
Adults	?,P	Richter 1995, Voevodin 2002, Chupin 2019
Pagodroma nivea		
Adults	?,P	Mathew 1986, Richter 1995, Voevodin 2002, Chandra 2007, Chupin 2019, Pande *et al.* 2020, Ryan 2024
Oceanites oceanicus		
Adults	?,P	Mathew 1986, Richter 1995, Chupin 2001, 2019
Stercorarius maccormicki		
Adults	?	Richter 1995
Chicks	?	Mathew 1986
Eggs	?	Richter 1995
Faeces	S	Surwade 2006–2007
Anthropogenic items		
Station garbage	S	Venkataraman 1998, Venkataraman & Hazra 2005
Kitchen refuse	S	Venkataraman 1998, Voevodin 2002, Venkataraman & Hazra 2005, Surwade 2006–2007, Chandra 2007, Chupin 2019

Legend: P – predation; S – scavenging; ? – feeding strategy is not clear

Compilation of historical information (1960–2023) and identification of the diet of each specific breeding pair of SPS in the 2024/2025 season

The results of the studies have established the important role of Snow and Antarctic Petrels in the diet of SPS during the historical period (Mathew l986, Richter 1995, Voevodin 2002, Chandra 2007, Chupin 2019, Pande *et al.* 2020, Ryan 2024). Snow Petrels are the main, most abundant prey species of SPS. Antarctic Petrels, together with Adélie Penguins, occupy a subdominant position in the diet with a significantly lower abundance in food samples.

Adélie Penguins have visited the Oasis throughout history and have occasionally made unsuccessful breeding attempts (e. g. Gerbovich 1963, Artem'ev 1964, Chaturvedi & Tripathi 1999, Pande *et al.* 2020, Ryan 2024, authors' observations). In contrast, some penguins have not attempted to breed there.

In April 2019, the Adélie Penguin accounted for 4.5% of the prey remains at one of the SPS nests (Chupin 2019). In the 2024/2025 field season, the average frequency of Adélie Penguin inclusions in SPS pellets was 8.8%. In nests remote from human settlements, it increased significantly.

Table 7. General list of qualitative diet composition of the South Polar Skuas population at Oasis (1960–2024), based on historical data (published and unpublished reports) and food sampling data from the 2024/2025 season by the authors of this article

7. táblázat Az Oasis területén élő délsarki halfarkas populáció táplálékösszetételének általános listája (1960–2024) történelmi adatok (publikált és nem publikált jelentések) és a 2024/2025-ös szezonban a jelen cikk szerzői által végzett táplálékmintavétel adatai alapján

Prey categories /Data	Historical data, 1960–2023	Authors' collection, season 2024/2025	
	Published data and unpublished reports	Food samples until the 2024/2025 season	Food samples, season 2024/2025
Birds			
Pygoscelis adeliae			
Adults	+	+	+
Thalassoica antarctica			
Adults	+	+	+
Pagodroma nivea			
Adults	+	+	+
Oceanites oceanicus			
Adults	+	–	–
Stercorarius maccormicki			
Adults	+	+	+
Chicks	+	–	–
Eggs	+	–	–
Faeces	+	–	–
Fish			
Local marine fish	–	+	–
Invertebrates			
Squid	–	+	–
Minerals			
Stones and pebbles	–	+	+
Anthropogenic items			
Station garbage	+	+	+
Kitchen refuse	+	+	+

Legend: "+" – presence of prey categories in the sample; "–" – absence of prey categories in the sample. Historical data 1960–2023 are based on the sources of information in Table 6.

Adélie Penguins served as food for SPS throughout the entire historical period. The importance of this category of prey varies greatly between the nests studied. It increased with distance from the centre of the Oasis to the periphery of the western sector and generally decreased from the centre of the Oasis to the east, where anthropogenic influence on the island land increased.

Snow Petrels bred in the Oasis in the 1959/1960 season (Konovalov 1962b). Their breeding subsequently ceased and was not confirmed (Bhatnagar 1999, Chupin 2001, Voevodin 2002, Pande *et al.* 2020). Although there is an opinion about possible modern breeding of Snow Petrels in the Oasis in small numbers (Chupin 2019). In fact, after 1960, SPS predated on transient Snow Petrels, which bred outside the Oasis if they did. This is supported by historical evidence and our data from the 2024/2025 field season.

Throughout the historical period, Snow Petrel remains have been consistently recorded near SPS nests and their vicinity (Mathew l986, Bhatnagar 1999, Surwade 2006–2007). They were the main component of SPS chicks' food (Chandra 2007). In the second half of the 20th century, Snow Petrels accounted for more than 95% of SPS prey in summer (Richter 1995). At the beginning of the 21st century, Snow Petrels were also the main prey of SPS (Ryan 2024). For example, in April 2019, skulls and wings of Snow Petrels were found at two SPS nesting sites; at one nest, they accounted for 74% of the prey remains (Chupin 2019).

The results of the 2024/2025 field season demonstrate the absolute dominance of Snow Petrels in SPS prey. Snow Petrel inclusions in SPS pellets were found in all nests surveyed and in pellets from both old breeding territories. The frequency of Snow Petrel inclusions in pellet samples from all SPS breeding territories, based on data from past seasons and the 2024/2025 season combined, averaged 89.9%, and 93.5% from the two old breeding territories. Prey remains (skulls, wings and feet of Snow Petrels) were found in all breeding territories surveyed and in the eastern old breeding territory.

It has recently been established that the wings of living Snow Petrels are much longer than those of mummies or isolated wings (Rümmler *et al.* 2024). All the wings of the SPS prey that we measured did not belong to living Snow Petrels. The duration of existence of isolated wings hardly exceeded 1.5–2 months. In recent SPS prey, the wing length (mm) of Snow Petrels was (n=46): 244.5±19.7 (194–273). The results of measurements did not exceed the lower threshold of wing length of 280 mm, which corresponds to the large morph *(P. n. major)* of Snow Petrels. The results of the morphometric analysis of the Snow Petrel wings did not indicate belonging to the large morph. Therefore, the Oasis and its surroundings are visited by Snow Petrels belonging to the small morph *(P. n. minor)*. However, in this regard, we cannot deny the mixed breeding of Snow Petrel morphs on Lake Untersee, which was previously assumed (Rümmler *et al.* 2024). The range of extreme values of Snow Petrel wing lengths that we measured was 79 mm, which could also be explained by the fact that SPS prey belonged to different geographical populations, different age classes, or the duration of existence of isolated wings after killing the prey. However, these hypotheses require further testing. The sizes of the skulls as body fragments of Snow Petrels (mm) were (n=133): 60.2±13.1 (24–92) × 27.1±3 (10–46). Antarctic Petrels have not been recorded breeding at the Oasis during the historical period (Ryan 2024). Therefore, only transient adults were targeted by SPS. In the second half of the 20th century, SPS rarely fed on Antarctic Petrels in summer (Richter 1995). In the early 21st century, various types of Antarctic Petrel bones were found in SPS nests along with bones of other Antarctic bird species (Survade 2006–2007). In April 2019, Antarctic Petrel skulls and wings were found at two SPS nesting sites, accounting for 10% of SPS prey remains at one nest (Chupin 2019).

The results of the 2024/2025 field season showed that inclusions of Antarctic Petrels in SPS pellets were found in six of the eight nesting territories studied. The frequency of occurrence of inclusions of Antarctic Petrels in pellets from different nests averaged 7.3%. In the nests most remote from human settlements it increased significantly. Remains of the prey of these petrels (skulls, wings and paws) were found in all studied nesting territories of SPS and in the eastern old nesting territory.

Thus, Antarctic Petrels served as food for SPS throughout the entire historical period. The importance of this prey category varies greatly between the nests studied. It increases with distance from the centre of the Oasis to the periphery and from human settlements in its western sector *(Figure 6)*. The sizes of the skulls as body fragments of Antarctic Petrels (mm) were (n=48): 84.3±15.3 (44–99) × 32.9±2.2 (28–39).

Wilson's Storm Petrels were probably rare in SPS food samples in the past, based on historical publications (Mathew l986, Richter 1995, Chupin 2001, 2019). In April 2019, Wilson's Storm Petrel fragments were found at two SPS breeding sites, and in one of the examined nests, they occupied 7% of SPS prey remains (Chupin 2019). The prey remains and pellets analysis data from eight SPS breeding sites in the 2024/2025 season, together with the data from previous breeding seasons that we collected, did not contain Wilson's Storm Petrels. Inclusions were also absent from pellets from two old SPS breeding territories. Thus, Wilson's Storm Petrels, like other petrel species, have been found in SPS prey throughout the historical period, but very rarely and in small numbers. Depending on the abundance of SPS prey, Wilson's Storm Petrels were not a constant component of the SPS diet, varying from season to season. The lack of detail in the observations does not allow us to confidently judge the age of the birds taken and the feeding strategies used by SPS when hunting Wilson's Storm Petrels.

Among the three species of petrels, only fledged individuals fell victim to SPS, since in the local natural conditions of the Oasis SPS do not have the habit of extracting petrel eggs and chicks from nesting crevices in rocks and feeding on them for a long time. In addition, SPS breed openly, and if necessary, they use both adult birds and chicks and eggs of their own species as food (Mathew l986, Richter 1995, our data). Moreover, we observed cases (n=4) when adult SPS refused to consume their own recently dead downy chicks (n=1) or downy chicks of Adélie Penguins in abandoned nests (n=1) and from recently dead adult Adélie Penguins (n=2). A fact has also been established when SPS ignored feeding on a dead chick and an egg in a nest abandoned by Adélie Penguins (Voevodin 2002). There is an observation when SPS abandoned a clutch of 2 eggs, which were subsequently covered with snow, but did not use the eggs for food, although they were near the nest (Voevodin 2002). Such behaviour may indicate individual food habits of some individuals or pairs that avoid cannibalism, and the degree of their physiological satiety. We found chicken eggshells in only 6 pellets out of 330 pellets examined, but no eggshells of local breeding bird species were found in the pellets. In fact, eggs and chicks were rarely used for food by the breeding SPS population.

SPS breeding on the Antarctic coast and islands are also known to occasionally consume seal excrement (authors' observations). SPS use of their own excrement as food in the Oasis (Surwade 2006–2007) is likely to be an exceptionally rare phenomenon not only for this area but also for SPS breeding populations elsewhere around Antarctica and adjacent islands.

Native marine fish and squid were not mentioned in historical documents. Bones of local marine fish were found in pellets (n=2) in two SPS nesting territories. They were present in 0.61% of the pellets from the total number of pellets examined. A similar picture was established for squid beaks in pellets (n=2), also from two SPS nesting territories.

Bones of native marine fish and squid beaks found in SPS pellets containing Snow Petrels and Adélie Penguins may have originated from their stomachs. The exceptional rarity of native marine fish bones and squid beaks in the pellets we examined indicates that the SPS do not feed at sea during the breeding season, relying on food resources obtained inside the Oasis. In contrast, bone fragments of fish introduced from stations and bases were much more common in SPS food samples *(Figure 3F)*.

Gastroliths (stone and gravel fragments) were not mentioned in historical documents. We found gastroliths in pellets from nests of the current and previous breeding seasons, as well as in pellets from one of the two old nesting territories. Gastroliths were contained in 8.48% of pellets (n=28) of the total number of pellets examined. This ratio of gastroliths content is apparently sufficient for the utilization of victims by SPS, which abundantly use the flesh of Snow Petrels as food. The largest stones could have been captured accidentally together with food. Dimensions (mm) of the largest stones (average (min-max), n=15)): 12.9 (6–25) × 8 (3–16).

Anthropogenic items included bones and feathers of introduced animals, chicken eggshells, and fruits of agricultural plants. In the 2024/2025 season, they were found in 19 pellets (frequency of occurrence 5.76%) out of 330 examined. Waste was contained in pellets from 5 active nests out of 8 examined nests and in 1 of 19 pellets (frequency of occurrence 5.26%) from the eastern old nesting territory. The frequency of occurrence of food waste in pellets from 5 nests averaged 9.6%. Bone fragments of introduced animals were common. Plant components were rarely found among anthropogenic food inclusions (e. g. nut shells, watermelon seeds). Natural vegetation was not found in food samples. Most breeding SPS used food waste.

Station garbage and food waste were present in the SPS diet, apparently, throughout the entire historical period *(Table 7)*. There are records of feeding of large numbers of SPS at Novolazarevskaya, George Forster, Maitri stations (Venkataraman 1998, Chupin 2001, 2019, Voevodin 2002, Venkataraman & Hazra 2005, Surwade 2006–2007, Chandra 2007) and near them (Richter 1995, Chupin 2001). At the Novolazarevskaya Station in 2001, for example, up to 16 SPS fed (Voevodin 2002), in the 2000/2001 season at a garbage dump in the eastern part of the Oasis up to 14 individuals (Chupin 2001). In addition, SPS received food from seasonal research staff at a distance from the stations (Voevodin 2002). At least half (n=4) of the nesting territories in 2002 contained bones of introduced animals (Voevodin 2002). In 2019, they were also found near SPS nests, and in one of the nesting territories, remains of introduced animals accounted for 4.5% of the total amount of remains of SPS prey (Chupin 2019).

In fact, food scraps such as chicken, meat and fish (Venkataraman 1998, Venkataraman & Hazra 2005, Chandra 2007) from human activity sites in the Oasis are attracted only by SPS. Currently, access to food resources and feeding of SPS are not practiced at the Maitri Station. We have visited this station many times, now free of SPS. Only once did we observe

a solitary SPS that had not received food, sitting at the western entrance to the main building of the station. SPS were absent from the White Desert Antarctic Camps area visited by us on 14 December 2024. Surveys of active nests in the vicinity of these human settlements did not reveal fresh food scraps from introduced animals.

At the Novolazarevskaya Station, SPS access to food was stopped in the 2024/2025 season. In the 2024/2025 season, SPS visited the station daily, and the maximum number of individuals observed simultaneously during the day varied from 1 to 4. The station was primarily visited by birds that bred closest to it – on the shores of Glubokoe and Pomornik lakes. Sometimes SPS with unclear status were encountered.

Station litter included fragments of plastic, paper, and ceramics. The frequency of occurrence of station debris in pellets from different nests averaged 9.1%. The most common type of station litter present as inclusions in pellets was plastic. It was contained in 14 pellets (4.2% of the total number of pellets from all nests studied). The pellets included fragments of wrapping material (n=14), a piece of rubber rope (n=1), and of unknown purpose (n=1). The colour of the plastic in the pellets was green (n=8), black (n=4), white (n=2), or colourless (n=2). Paper was found in four pellets, accounting for 1.2% of the total number of pellets in all nests examined. A ceramic fragment was found in one of the pellets (0.3% of the total number of pellets in the nests examined).

Potentially, marine mammals (seals) could have been used as food by SPS in the historical past. Isolated, extremely rare cases of seal wandering have been repeatedly recorded in the Oasis. Mummies and carcasses of the crabeater seal *(Lobodon carcinophagus)* and the Weddell seal *(Leptonychotes weddelli)* have been found here (Bardin 1961, Der & Richter 1983, Richter 1995). However, direct evidence of the use of marine mammals in the diet of local SPS has not been obtained.

In general, it should be noted that in the Dronning Maud Land mountains, Snow Petrels are the main food resource in the prey of SPS (Løvenskiold 1960, Ryan & Watkins 1988, Steele & Cooper 2012). A distinctive feature of the diet of the Oasis SPS is the dominance of Snow Petrels in the diet, which over the course of the historical period ceased to be identified as breeding residents, becoming its visitors.

Identification of foraging strategies of the breeding SPS population

Kleptoparasitism is not supported by research or historical records. The identification of the other three feeding strategies (predation, scavenging and cannibalism) was possible based on our observations.

SPS are capable of covering large distances to hunt Snow Petrels and Wilson's Storm Petrels (Chandra 2007). During the 2024/2025 breeding season, we did not observe foraging trips of SPS from the Oasis north to the sea and back. Our observations also did not confirm foraging flights of SPS in the southern direction. During the search flight, SPS were repeatedly observed (the number of registrations was not considered) flying along the Oasis. In one case, a SPS crossed the Oasis with a Snow Petrel in its bill from the southeast to the northwest in the direction of the nest. All the above convinces us that SPS searches for and obtains prey exclusively within the Oasis. The absence of relatively large

colonies of Adélie Penguins, Snow and Antarctic Petrels in the Oasis is a determining factor in the choice of food obtaining strategies by SPS and their combination, which ensures autonomous seasonal survival of adults and a certain number of chicks until the stage of full plumage and the beginning of autumn migrations.

The results of the pellet and prey remains of SPS studies, historical data and thematic video evidence of a SPS catching a Snow Petrel by pinning it to the ground (video fragment shown to us by a staff member of White Desert Antarctic Camps, 2023) convince us that the main foraging strategy of SPS in the Oasis was and remains predation. It is believed that high levels of SPS predation hinder successful nesting of Adélie Penguins in the Oasis (Pande *et al.* 2020). However, historical evidence and our studies did not find confirmation of this. Only weakened, dying penguins fall prey to SPS (Chaturvedi & Tripathi 1999), but this requires further verification.

Scavenging is a less common but effective supplementary food-obtaining strategy. It is useful to distinguish between scavenging on native and anthropogenic resources. The main source of available native carrion for SPS are Adélie Penguins visiting the Oasis and attempting to breed there (Chaturvedi & Tripathi 1999). However, as mentioned above, weakened Adélie Penguins can be utilized by SPS (Chaturvedi & Tripathi 1999), and sometimes in such cases it is difficult to draw a line between predation and scavenging. The annual volumes of native carrion utilization by SPS have not been determined. Undoubtedly, the role of scavenging increases if SPS depend more on imported food than on local, native food. According to the results of our study, breeding pairs of SPS demonstrated different dependence on food waste – from complete disregard for anthropogenic resources to a deep dependence on them. In the past, SPS, which feed largely on food waste, reduce the pressure of predation on native prey items and vice versa *(Figure 6)*.

We did not record cannibalism by direct observations. However, given the low overall size of the breeding population of SPS and the level of their reproductive potential in the Oasis, we note that this strategy is undoubtedly used to a minimum extent by adult SPS for short-term replenishment of energy expenditure during a deficit of food resources. Thus, on several (the number was not considered) bodies of dead fledglings or partially fledged chicks that we examined, as well as on the carcasses of fully fledged young or adult SPS, ruptures of soft tissue on the abdomen and the absence of internal organs in the abdominal cavity were identified. We also repeatedly found carcasses of adult SPS completely cleared of flesh. In such cases, the wings with fragments of the SPS carcass were identical to those of Snow and Antarctic petrels *(Figure 3)*, which indicated obvious cannibalism of SPS, since other avian predators were not recorded in the Oasis. No evidence was obtained during the 2024/2025 season of other avian predators, potential food competitors of SPS – Southern Giant Petrels *(Macronectes giganteus)* and Brown Skuas *(Stercorarius antarctica lonnbergi)*. Historical evidence from Oasis supports SPS cannibalism (Mathew l986). However, SPS remains at nests both historically (Surwade 2006–2007) and in the 2024/2025 season do not always prove cannibalism in individual breeding pairs. It is also unclear whether SPS kill their chicks or consume dead ones.

The increase in the SPS population at Oasis may have been due to the use of abundant food waste from the stations (Bhatnagar 1999). Past and current impacts of SPS affect petrels

and Adélie Penguins, but the magnitude of the impact overall requires further verification. The change in breeding status was primarily documented for Snow Petrels, the main prey of SPS. Increased predation pressure by SPS may explain the loss of a small number of potential preys, nesting Snow Petrels, at Oasis (Ryan 2024). The disappearance of the Snow Petrel as a breeding species at Oasis may be a result of increased SPS and subsequent nest predation (Chattopadhyay 1995, Bhatnagar 1999, Pande *et al.* 2020), where direct human intervention may have played a role (Ryan 2024). We believe that the balance between the top predator and its main prey was upset by the influx of food subsidies from humans. This could have led to the disappearance of Snow Petrels breeding in the Oasis and, as a consequence, to compensatory hunting of background prey by SPS already in the status of non-breeding transients. It should be noted that by the beginning of the 1959/1960 field season and the onset of human activity, Snow Petrels could breed in the Oasis in small numbers (Konovalov 1962a, Ryan 2024) and, apparently, gradually reduced breeding there.

The continued coexistence of humans and SPS in the Oasis should aim to achieve a prehistoric balance of interactions between avian predators and their prey by eliminating access to imported food resources from areas of human activity and strictly adhering to the requirements of the Madrid Protocol on the Protection of the Antarctic Environment.

Limitations of our study include that prey remains and pellets collected prior to the 2024/2025 season cannot be accurately dated to a specific past breeding season. At the same time, fresh samples from the 2024/2025 season were rare and not representative in the samples for each SPS nest studied. Therefore, we were forced not to separate all collected material into food samples from the 2024/2025 season and historical food samples, which could be several, ten or more years old since the 2023/2024 season. This research approach allowed us to confirm the presence of some already established prey categories and supplement the historical data with new prey categories not listed in known sources, thereby expanding the already established dietary spectrum of SPS in the Oasis.

The small size of the Oasis allows for monitoring to be carried out throughout its entire territory during one field season. However, in reality this does not always happen. In this paper we demonstrate and propose to researchers to use the differentiation of the Oasis into western, central and eastern sectors with specific boundaries. In the long term, such differentiation will allow us to increase the potential of comparable scientific data and have consistent time series of observations for some of them, if an ornithological survey of all land sectors in a specific breeding season is impossible.

In the future, it will be important to study in detail the diet of SPS during the pre-breeding, breeding and post-breeding periods and to identify seasonal changes in diet composition, or lack thereof. Periodic inspection of active SPS nests under monitoring may also shed light on the dynamics of Antarctic and Snow Petrel records at specific geographical locations in the Oasis. To date, this aspect remains poorly understood. Although prey remains and pellets around SPS nests, together with field observations, provide very valuable and relatively abundant information on the composition of SPS food, it would be important to deploy video cameras and camera traps to better understand the daily rhythms of adult SPS and their prey throughout the breeding season. This information may shed new light on the scarce data on SPS foraging strategies.

The question remains, what would the diet of the SPS be without human food subsidies? What would be the size of the breeding population of SPS without full access to imported food resources? Would the size of the breeding population of SPS be stable if SPS access to food scraps were completely cut off? What changes would occur in the bird population of the Oasis if human-predator interactions tended to the natural background of prehistoric levels?

Conclusion

1. In the Oasis conditions, the diet of SPS was limited in the spectrum of diversity of prey categories compared to the potential diversity on the coast of Antarctica. It included five species of birds, fish, squid, as well as food waste and garbage from Antarctic stations and bases. Native marine fish and invertebrates (squid) were likely incidental dietary components that were included in the pellets along with the SPS prey – Snow Petrels and Adelie Penguins. Anthropogenic inclusions were found in 32 pellets out of 330 examined. Plastic fragments were found in 14 SPS pellets, a ceramic fragment was found in one pellet, and paper in four pellets. Gastroliths were found in 28 pellets.
2. Antarctic bird species are the main component of the diet of Oasis SPS, where the diet is completely dominated by visiting non-breeding Snow Petrels, which distinguishes the Oasis SPS population from populations that hunt breeding Snow Petrels elsewhere in Queen Maud Land.
3. Predation is the dominant foraging strategy of SPS. Scavenging plays a secondary role. Cannibalism is rare.
4. During the historical period, human activities have affected the diet of the Oasis-wide breeding SPS by introducing imported food and garbage into their diet. Food garbage from stations and bases was found in seven of the eight surveyed breeding territories and in one of the two old SPS breeding territories. Food garbage was not recorded at the active SPS nest in the west of the Oasis, which is the furthest from the stations and bases.
5. Analysis of pellets and prey remains of SPS and direct observations indicate that breeding SPS do not fly to feed at sea, relying on food resources within the Oasis and possibly in its surroundings.
6. Diet composition and behaviour of SPS at sites of human activity in Antarctica can be used as an indicator of the quality of local human waste management and as an indicator of overall ecosystem health.

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Orthopteran prey sources of Red-footed Falcon *(Falco vespertinus)* on grasslands near their nesting sites in Serbia

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Abstract Red-footed Falcons *(Falco vespertinus)* in the breeding period feed mainly on orthopteran insects. Theoretically, the availability of this food source may affect the size of the colonies of nesting birds and breeding success. We hypothesized that in the grassland habitats around larger colonies, sources of the orthopteran prey are richer in quality and quantity than around smaller colonies or solitary nests. Furthermore, we predicted that during the growth of the nestlings, the individuals of orthopteran species that are potential prey also grow over time. Orthopteran assemblages living in grasslands near 19 Red-footed Falcon nesting sites were sampled with sweep-nets in the northern province of Serbia, Voivodina, in June and July 2003. A total of 1,454 individuals of 25 Orthoptera species were identified in the study area, 21 species from the samples in Bachka (region between the Danube and Tisa River), while 24 species were collected in the Banat (areas east of the Tisa River). Individuals of larger orthopteran species were found only sporadically. At the same time with growths of Red-footed Falcon nestlings, from June to July, neither the potentially available orthopteran species nor the number of their individuals changed significantly. The body length of the most common orthopteran species Common Straw Grasshopper *(Euchorthippus declivus)* was significantly larger in July than in June. We could not detect relationship between the size of the Red-footed Falcon colonies and the number of species and individuals of the orthopterans. The proper management and conservation of these overgrazed and degraded grasslands should be a priority task, since these are hunting areas for Red-footed Falcons and at the same time, the habitats of several rare and in Serbia protected Orthoptera species e.g. Steppe Spiny Bush-cricket *(Gampsocleis glabra)*, Veysel's Slender Bush-cricket *(Tessellana veyseli)* and Cone-headed Grasshopper *(Acrida ungarica)*.

Keywords: food supply, sweep-netting, Orthoptera, overgrazing, Voivodina

Összefoglalás A kék vércsék *(Falco vespertinus)* a szaporodásuk időszakában főként egyenesszárnyú (Orthoptera) rovarokkal táplálkoznak. Ennek a táplálékforrásnak az elérhetősége elméletben befolyásolhatja a madarak fészkelő telepeinek nagyságát és költési sikerét. Azt feltételeztük, hogy a nagyobb telepek körüli füves élőhelyeken gazdagabb az egyenesszárnyú fajok minőségi és mennyiségi kínálata, mint a kisebb telepek vagy magányos fészkek körül, valamint a fészkekben nevelkedő fiókák növekedésével a táplálékul szolgáló egyenesszárnyú fajok egyedei is idővel nőnek. A kék vércse 19 fészkelőhelye közelében található füves területeken élő egyenesszárnyú-együttesekből fűhálóval vettünk mintát Szerbia északi tartományában, a Vajdaságban, 2003 júniusában és júliusában. A vizsgált területen összesen 25 egyenesszárnyú-fajt (1454 egyed) mutattunk ki: Bácskában (a Duna-Tisza közén) 21 faj, míg Bánátban (a Tiszától keletre eső területeken) 24 egyenesszárnyú-faj egyedeit gyűjtöttük be. A nagyobb testű egyenesszárnyú-fajok egyedei csak elvétve kerültek elő. A kék vércse fiókák növekedésével egyidőben, júniustól júliusig, sem a potenciálisan elérhető egyenesszárnyúak fajszáma, sem azok egyedszáma nem változott jelentősen. Azonos mintavételi helyeken a leggyakoribb egyenesszárnyú-faj a rövidszárnyú rétisáska *(Euchorthippus declivus)* testhossza júliusban azonban szignifikánsan nagyobb volt, mint júniusban. A kék vércse telepek nagysága és az egyenesszárnyúak faj- és egyedszáma között nem tudtunk statisztikailag jelentős összefüggést kimutatni. A vizsgált füves területek többsége túllegeltetett és degradált, de a kék vércsék vadászterületei és egyúttal több Szerbiában ritka és védett Orthoptera fajnak, mint pl. a tőrös szöcské-

nek *(Gampsocleis glabra)*, a sávos rétiszöcskének *(Tessellana veyseli)* és a sisakos sáskának *(Acrida ungarica)* is az élőhelyei, ezért megőrzésük és megfelelő kezelésük prioritást kell, hogy élvezzen.

Kulcsszavak: táplálék kínálat, fűhálózás, Orthoptera, túllegeltetés, Vajdaság

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Introduction

The population of the mainly insectivorous Red-footed Falcon *(Falco vespertinus)*, which breeds in the steppe and forest-steppe areas of the temperate zone of the Palearctic region, is showing a declining trend (Cramp & Simmons 1980, Tomialojc 1994, BirdLife International 2024). The primary reason for this is the lack of suitable nesting sites (Bagyura & Palatitz 2004) and the scarcity of insects that serve as food, which is caused by the destruction of natural steppic habitats and use of pesticides (Snow & Perrins 1998, Ham & Rašajski 2000). The southwestern limit of the distribution of the Red-footed Falcon is in the southeastern part of the Carpathian Basin (Pannonian Plain), in the plains of northern part of Serbia, where from May to the end of July it breeds in pairs or in small or large colonies in abandoned nests of crows (Corvidae), mainly Rooks *(Corvus frugilegus)* (Ham & Rašajski 2000, Purger & Lukács 2022). The breeding success of Red-footed Falcons is significantly influenced by availability of food supply in the vicinity of nesting areas (Fehérvári *et al.* 2011, Krištín *et al.* 2017). Moreover, larger colonies can only be formed near large pastures, where they have enough food to raise their young (Bagyura & Palatitz 2004, Palatitz *et al.* 2011, Fehérvári *et al.* 2012). The food composition of Red-footed Falcon was examined during nesting and migration based on the content of their spits and stomach (e.g. Csiki 1910, Budnithshenko 1950, Keve & Szijj 1957, Fülöp & Szlivka 1988), as well as from food residues collected from nests (e.g. Haraszthy *et al.* 1994, Purger 1998, Szövényi 2015, Tulis *et al.* 2017), and at resting places (e.g. Budnithshenko 1950, Balát & Bauer 1955, Bezzel & Hölzinger 1969, Gjerkeš & Lipej 1992, Alivizatos & Kassinis 2021). The larger prey carried by the bird parents can also be determined based on camera recordings (e.g. Horváth 1955, 1964, Chavko & Krištín 2017, Tulis *et al.* 2017). During the nesting period, they feed mainly on orthopterans (Szövényi 2015), but they often carry small vertebrates to the nestlings (e.g. Horváth 1955, 1964, Fülöp & Szlivka 1988, Purger 1998). These studies showed the share of prey species in the food of adult birds and nestlings (Szövényi 2015), but what is less known is where and under what conditions Red-footed Falcons catch their prey (Palatitz *et al.* 2015). During the growing of nestlings, they primarily hunt on grasslands near the breeding site and most of the prey is caught on the ground or nearby (Haraszthy *et al.* 1994). The management of pastures greatly affects the composition and populations of the orthopterans (e.g. Batáry *et al.* 2007, Qin *et al.* 2017, Gardiner 2018). Gustin and Ferrarini (2021) found that almost 40% of hovering and perching activity of adult Red-footed Falcons occurred within a 50 m radius around the nests. In addition to grasslands, they also regularly

visit agricultural fields, and in years with a shortage of food, they even hunt at several kilometers distance (Palatitz *et al.* 2015). With the growth of the nestlings especially in the second part of the fledging period, large bodied and later smaller Orthoptera appear in the food (Horváth 1955, 1964). Little is known about the food resources near nesting sites (Szövényi 2015, Krištín *et al.* 2017) and even less of its relationship with the formation of colonies (Haraszthy *et al.* 1994), but this knowledge is essential for the conservation and survival of the Red-footed Falcon.

Our aim was to reveal, based on sampling in the orthopteran communities living in the grasslands near the nesting sites of Red-footed Falcon: 1) the richness of the othopteran species assemblages, the abundance of certain species, and the presence of rare or protected species; 2) the relationship between the size of the colonies and the richness of the prey; 3) the temporal change of the food supply and the average body size of the potential orthopteran prey items during the breeding season progresses.

Materials and Methods

Study area

The study was performed in the southern part of Central Europe, in the northern part of Serbia, in Voivodina province (approximately 21,500 km^2) which is divided by the Danube and the Tisa rivers into three regions: Bachka (Bačka) in the northwest, Banat in the east and Srem in the southwest (Bezdan *et al.* 2024). The area of Voivodina is mostly flat, and more than 60% is covered by loess and loess-like sediments (Gavrilov *et al.* 2015), on which fertile chernozem soil has formed, and therefore, approx. 75% of its area is arable land with very intensive agricultural production (Galic *et al.* 2019). However, in the area with seminatural and natural habitats sub-pannonic and pannonic steppe grasslands are distributed. In the southern part of the Carpathian Basin, there are also saline soils, on which pannonic salt steppes and salt marshes can be found (Bagi *et al.* 2011). In total, the grasslands cover about 1,500 km^2, and two-thirds of them are used as pasture. About 80% of these grasslands are east of the Tisa River in Banat (Erić *et al.* 2003). Due to their low productivity, saline soils are less affected by agricultural production, thus preserving many relict components of the natural landscape (Zeremski *et al.* 2021). Even so, only 6.4% (1,380 km^2) of the area of Voivodina is protected (Puzović *et al.* 2015). The known nesting sites of Red-footed Falcons (less of which is located in Bachka, but most of them in Banat) overlap with the distribution of saline soils and steppic grasslands (Ham & Rašajski 2000, Purger 2008, Barna 2015, Purger & Lukács 2022).

The climate of Voivodina is moderate continental with cold winters and hot and humid summers, and with a huge range of extreme temperatures featuring inconsistent amounts of rainfall over the course of months (Gavrilov *et al.* 2015). In the period between 1949 and 2006, the mean annual air temperature was 11.1 °C and annual amount of precipitation was 606 mm (Tošić *et al.* 2014).

Sampling methods

The sampling of insects was carried out in the summer of 2003 in the grasslands near the nesting sites of Red-footed Falcons *(Figure 1)*, in the places where we observed the adult birds hunting. Vegetation was low in most of the sampling sites due to intensive grazing *(Figure 2)*. In all locations, sweep-net sampling was conducted between 10 and 16 hours on windless sunny days. A transect consisted of 25 sweeps taken on 25 consecutive strides using a 40-cm diameter sweep-net with a white canvas net bag (e.g. O'Neill *et al.* 2002).

We took 13 samples near 12 nesting sites in 2003 in the period June 20–24. Of these, 6 samples (*Table 1*, samples: 1, 10, 14, 25, 31, 37) are from the vicinity of solitary breeding pairs (or small colonies of 2–5 pairs), while another 6 samples (*Table 1*, samples: 4, 18, 21, 28, 33, 39) were taken near larger colonies (7–24 pairs nested). Based on these samples, in the first step, we checked the normal distribution of the data series using the Shapiro–Wilk test for the number of breeding pairs (colony size), the number of species and individuals of detected orthopterans. In the case of all three parameters, the test confirmed the normal distribution, so

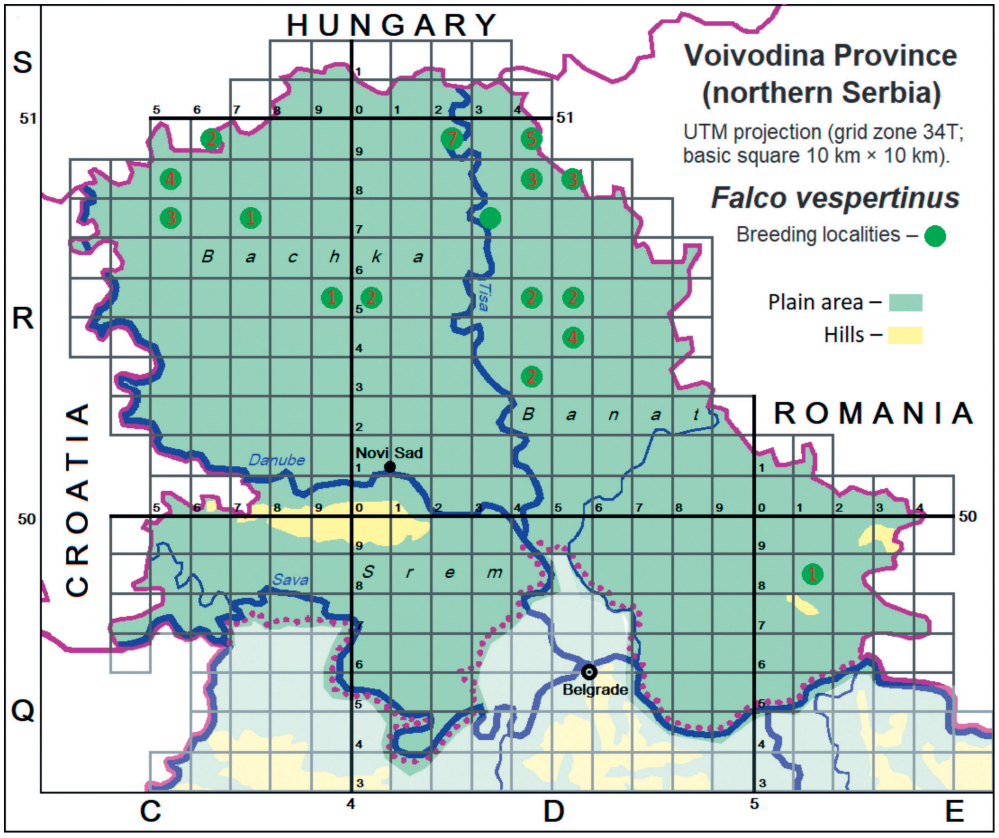


Figure 1. Red-footed Falcon breeding localities in Voivodina in 2003 (green circles), with numbers of sweep-net samplings

1. ábra A kék vércsék fészkelőterületei Vajdaságban 2003-ban (zöld körök) a fűhálózások mintavételi számával



Figure 2. Most of the pastures were overgrazed and degraded, so the number of species and individuals of orthopteran insects were smaller than expected. Red-footed Falcons breeded in the Rook nests on the black-locust trees, Mokrin (Vašarište), 10 July 2003 (Photo by J. J. Purger)

2. ábra A legelők többsége a túllegeltetés miatt degradált volt, így az egyenesszárnyúak faj- és egyedszáma kisebb volt mint várható. Az akácokon lévő vetési varjú fészkekben költöttek a kék vércsék. Mokrin (Vašarište), 2003. július 10. (Fotó: Purger J. J.)

a two-sample t-test was used to test the assumed differences in the distribution of the number of Red-footed Falcon breeding pairs and the number of species and individuals of orthopterans (Hammer *et al.* 2001, Zar 2010). We also took an additional sample at Zimonjić site from the narrow strip of saline meadow along the channel crossing the pasture, from which we saw Red-footed Falcon hunting several times (*Table 1*, sample 15).

Sampling was carried out in the same year at 29 locations near 18 nesting sites, between 7 and 11 of July. In most places we took two samples in July, as there were more Red-footed Falcons hunting, and since the low numbers of catches in June, we considered additional sampling to be justified *(Table 1)*. The collected material was placed in a plastic freezer bag filled with 70% ethanol with zip closure and transported to the laboratory. The material was determined to species level by using identification keys (Harz 1969, 1975, Harz & Kaltenbach 1976). After the determination, we measured the body length of each orthopteran individual.

We compared the body lengths of the two most common species Common Straw Grasshopper *(Euchorthippus declivus)* and Meadow Grasshopper *(Pseudochorthippus*

Table 1. Breeding sites and number of breeding pairs (BP) of Red-footed Falcon in Voivodina in 2003, with the date and location of sweep-netting and the number of collected orthopteran species (Sp) and specimens (N)

1. táblázat A kék vércse költőhelyei és a költő párok száma (BP) Vajdaságban 2003-ban, a fűhálózások dátumával és helyével, a befogott egyenesszárnyúak fajszámával (Sp) és egyedszámával (N)

UTM	Locality/Sample, Date	Latitude °N	Longitude °E	Alt.	BP	Sp	N
CR57	Obzir	45.8387	19.1669	85	3		
	1. 21.06.2003.	45.8387	19.1672	85		3	27
	2. 07.07.2003.	45.8385	19.1671	86		3	17
	3. 07.07.2003.	45.8389	19.1671	85		2	13
CR58	S-W part of Stanišić	45.9275	19.1567	88	7		
	4. 20.06.2003.	45.9278	19.1556	87		3	11
	5. 07.07.2003.	45.9281	19.1562	88		4	14
	6. 07.07.2003	45.9295	19.1553	86		3	7
CR58	N-E part of Stanišić	45.9458	19.1746	94	3		
	7. 07.07.2003.	45.9450	19.1732	94		5	27
CR69	3km N-E of Stanišić	45.9484	19.2314	100	1		
	8. 07.07.2003.	45.9489	19.2309	100		2	17
	9. 07.07.2003.	45.9476	19.2310	99		5	6
CR77	2.5 km W of Gornja Rogatica	45.7937	19.4327	110	5		
	10. 20.06.2003.	45.7945	19.4330	109		3	4
CR95	3 km S of Feketić	45.6361	19.6996	90	2		
	11. 07.07.2003.	45.6363	19.7019	90		2	20
DR05	4 km E of Feketić	45.6876	19.7623	94	7		
	12. 07.07.2003.	45.6869	19.7621	94		7	35
	13. 07.07.2003.	45.6865	19.7615	94		6	32
DR29	2.5 km N-W of Zimonjić	46.0495	19.9594	83	2		
	14. 20.06.2003.	46.0499	19.9609	79		5	44
	15. 20.06.2003. *Juncus*	46.0490	19.9614	79		10	347
	16. 11.07.2003.	46.0505	19.9601	80		3	19
	17. 11.07.2003. *Juncus*	46.0491	19.9615	79		9	83
DR29	3 km S-W of Mali Pesak	46.0556	19.9624	81	24		
	18. 21.06.2003.	46.0572	19.9658	79		5	25
	19. 11.07.2003.	46.0548	19.9609	80		4	6
	20. 11.07.2003.	46.0535	19.9581	80		8	47
DR37	2 km N-W of Padej	45.8406	20.1384	74	1		
DR43	Okanj, 3 km S-W of Melenci	45.4911	20.2965	77	10		
	21. 23.06.2003.	45.4906	20.2970	75		4	34
	22. 10.07.2003.	45.4906	20.2940	75		7	38
DR45	10 km E of Novi Bečej	45.6247	20.2634	75	13		

UTM	Locality/Sample, Date	Latitude °N	Longitude °E	Alt.	BP	Sp	N
	23. 10.07.2003.	45.6251	20.2641	75		9	34
	24. 10.07.2003.	45.6242	20.2641	75		11	62
DR48	2 km S-E of Jazovo	45.8894	20.2427	75	3		
	25. 23.06.2003.	45.8891	20.2423	76		3	40
	26. 11.07.2003.	45.8894	20.2418	75		6	49
	27. 11.07.2003.	45.8883	20.2423	75		5	76
DR48	Jazovo (N part)	45.9038	20.2243	75	1		
DR49	2 km S-W of Vrbica	45.9973	20.2944	73	12		
	28. 23.06.2003.	45.9971	20.2943	73		4	27
	29. 10.07.2003.	45.9969	20.2942	73		4	18
	30. 10.07.2003.	45.9975	20.2935	73		5	23
DR49	1 km E of Banatski Monoštor	45.9631	20.2909	73	1		
	31. 21.06.2003.	45.9638	20.2904	73		2	3
	32. 10.07.2003.	45.9625	20.2895	74		6	12
DR54	Torda (S-E part)	45.5797	20.4677	73	13		
	33. 10.06.2003.	45.5795	20.4679	73		3	18
	34. 10.07.2003.	45.5794	20.4678	73		4	17
	35. 10.07.2003.	45.5793	20.4675	73		2	22
DR54	2 km S of Torda	45.5672	20.4648	72	1		
	36. 10.07.10.	45.5660	20.4667	72		6	56
DR55	1 km S-E of Bašaid	45.6365	20.4236	79	2		
	37. 23.06.2003.	45.6367	20.4216	78		3	5
	38. 10.07.2003.	45.6379	20.4226	78		8	35
DR58	Mokrin (Vašarište)	45.9421	20.3954	72	15		
	39. 21.06.2003.	45.9416	20.3955	73		1	3
	40. 10.07.2003.	45.9424	20.3939	70		4	52
	41. 10.07.2003.	45.9415	20.3963	73		6	24
EQ18	Potporanj	45.0301	21.2399	86	2		
	42. 12.07.2003.	45.0307	21.2398	86		3	5
	Total number of nesting Red-footed Falcon pairs in 2003:				**128**		
	Number of collected orthopteran species and specimens:					**25**	**1454**

parallelus) from June (*Table 1*, samples: 1, 4, 14, 18, 21, 25, 28, 31, 33, 37, 39) and July (*Table 1*, samples: 2, 5, 16, 19, 22, 26, 29, 32, 34, 38, 41) samples from the same 11 sampling locations. Since the two species were present in different numbers in the June and July samples, we randomly selected the same number of individuals for comparison. In the next step, we performed a normality test, and since the measured body length did not fit the normal distribution for any of the species, we used a non-parametric Wilcoxon paired-rank test to test for differences in the measured parameters (Hammer *et al.* 2001, Zar 2010).

Table 2. Threat category of the orthopteran species in Europe (and in Serbia) according to IUCN criteria (End. – Endemic, * – strictly protected in Serbia), and number of collected specimens in region Bachka and Banat

2. táblázat Az egyenesszárnyú fajok veszélyezettségi kategóriája Európában (és Szerbiában) az IUCN kritériumai szerint (End – endemikus, * – Szerbiában fokozottan védett) és a begyűjtött példányok Bácskában és Bánátban

Species	Status	Bachka	Banat	Total
Ensifera				
Conocephalus fuscus (Fabricius, 1793)	LC	12	2	14
Ruspolia nitidula (Scopoli, 1786)	LC	4	5	9
Leptophyes albovittata (Kollar, 1833)	LC	7	19	26
Gampsocleis glabra (Herbst, 1786)	NT (VU) *		1	1
Bicolorana bicolor (Philippi, 1830)	LC	4	4	8
Roeseliana roeselii (Hagenbach, 1822)	LC	1	1	2
Platycleis grisea (Fabricius, 1781)	LC	4	5	9
Tessellana veyseli (Kocak, 1984)	LC (NT) *	5	12	17
Oecanthus pellucens (Scopoli, 1763)	LC	0	3	3
Caelifera				
Acrida ungarica (Herbst, 1786)	LC (End.) *	1	5	6
Calliptamus italicus (Linnaeus, 1758)	LC	18	5	23
Pezotettix giornae (Rossi, 1794)	LC	15		15
Chorthippus oschei Helversen, 1986	LC	25	4	29
Chorthippus biguttulus (Linnaeus, 1758)	LC	1	9	10
Chorthippus brunneus (Thunberg, 1815)	LC	7	18	25
Chorthippus dichrous (Eversmann, 1859)	LC	20	2	22
Chorthippus dorsatus (Zetterstedt, 1821)	LC	32	8	40
Pseudochorthippus parallelus (Zetterstedt, 1821)	LC	78	71	149
Dociostaurus brevicollis (Eversmann, 1848)	LC		1	1
Dociostaurus maroccanus (Thunberg, 1815)	LC	1	5	6
Euchorthippus declivus (Brisout de Barneville, 1848)	LC (End.)	549	442	991
Omocestus haemorrhoidalis (Charpentier, 1825)	LC	2	3	5
Omocestus rufipes (Zetterstedt, 1821)	LC	1	2	3
Stenobothrus crassipes (Ocskay in Charpentier, 1825)	LC (End.)		6	6
Aiolopus thalassinus (Fabricius, 1781)	LC	14	20	34
Total number of individuals		**801**	**653**	**1454**
Number of species		**21**	**24**	**25**

Results

A total of 42 samples were taken from the Orthoptera assemblages of the grassland areas near the 19 nesting sites of the Red-footed Falcon *(Figure 1, Table 1)*. The average number of species detected in each sample was 4.7 (SD=2.36), and the average number of individuals was 34.6 (SD=53.03). We caught a total of 1,454 individuals of 25 orthopteran species *(Table 2)*. Most of the species are considered common but there were three species endemic to Europe, the Cone-headed Grasshopper *(Acrida ungarica)*, the Common Straw Grasshopper *(Euchorthippus declivus)* and the Pygmy Toothed Grasshopper *(Stenobothrus crassipes)* (Hochkirch *et al.* 2016). We detected in the samples three species in the samples, which are strictly protected in Serbia *(Table 2)*. A single specimen of the Steppe Spiny Bush-cricket *(Gampsocleis glabra)* was collected in the pasture in Mokrin *(Figure 2, Table 3d)*; individuals of Veysel's Slender Bush-cricket *(Tessellana veyseli)* were found in ten samples *(Table 3b, c, d)*; the only large-bodied species (with body length exceeding 30 mm) was the Cone-headed Grasshopper from which we collected 6 specimens from four samples in the vicinity of Stanišić, Novi Bečej and Jazovo *(Table 3a, c)*.

The number of species (3 species) and the number of individuals (20 individuals) of Orthoptera in the vicinity of breeding sites of solitary Red-footed Falcons (or 1–5 pairs) were likely to be those in grassland habitats near larger colonies (7–24 pairs) *(Table 4)*.

In Bachka, 801 individuals of 21 Orthoptera species were found in 20 samples *(Figure 1, Table 3a)* and one species, Common Maquis Grasshopper *(Pezotettix giornae)* was collected only in Bachka. In Banat, we collected 653 individuals of 24 species from 22 samples *(Table 3c, d)* and we detected individuals of four species: Steppe Spiny Bush-cricket, Tree-cricket *(Oecanthus pellucens)*, Intermediate Cross-backed Grasshopper *(Dociostaurus brevicollis)* and Pygmy Toothed Grasshopper that were found only in Banat.

Table 3a Number of orthopteran species and specimens collected at sampling sites (1–10)
3a táblázat A mintavételi helyeken (1–10) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Conocephalus fuscus		1			1		4			
Ruspolia nitidula			1							
Leptophyes albovittata										2
Bicolorana bicolor	1			1					1	1
Acrida ungarica									1	
Calliptamus italicus					1	1	1			
Chorthippus brunneus							2			
Chorthippus dichrous									1	
Pseudochorthippus parallelus	1	9		3	4	2	4	6	2	
Euchorthippus declivus	25	7	12	7	8	4	16	11	1	
Aiolopus thalassinus										1
Number of species	**3**	**3**	**2**	**3**	**4**	**3**	**5**	**2**	**5**	**3**
Number of specimens	**27**	**17**	**13**	**11**	**14**	**7**	**27**	**17**	**6**	**4**

Table 3b Number of orthopteran species and specimens collected at sampling sites (11–20)
3b táblázat A mintavételi helyeken (11–20) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	**11.**	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
Conocephalus fuscus							6			
Ruspolia nitidula		3								
Leptophyes albovittata		3	1					1		
Roeseliana roeselii					1					
Platycleis grisea					4					
Tessellana veyseli		1	1		2		1			
Calliptamus italicus		10	1		2		2			
Pezotettix giornae							11	4		
Chorthippus oschei				2	9	1	7			6
Chorthippus biguttulus										1
Chorthippus brunneus		2	3							
Chorthippus dichrous				5	9		1			4
Chorthippus dorsatus					2	8	12		1	9
Pseudochorthippus parallelus	1	8	16	6	12		1	1	1	1
Dociostaurus maroccanus				1						
Euchorthippus declivus	19	8	10	30	300	10	42	18	3	18
Omocestus haemorrhoidalis									1	1
Omocestus rufipes								1		
Aiolopus thalassinus					6					7
Number of species	**2**	**7**	**6**	**5**	**10**	**3**	**9**	**5**	**4**	**7**
Number of specimens	**20**	**35**	**32**	**44**	**347**	**19**	**83**	**25**	**6**	**47**

In June, we detected individuals of 19 species from the 13 samples, among them the Moroccan locust *(Dociostaurus maroccanus)*, which was absent from the samples collected in July *(Table 2, 3a, b, c, d)*. In July, we detected the presence of 24 species out of 29 samples and individuals of six species: Long-winged Conehead *(Conocephalus fuscus)*, Large Conehead *(Ruspolia nitidula)*, Steppe Spiny Bush-cricket, Tree-cricket, Intermediate Cross-backed Grasshopper and Orange-tipped Grasshopper *(Omocestus haemorrhoidalis)* were collected only in this month *(Table 2)*. We could not detect any significant differences ($\chi^2 = 0.296$, df = 1, P = 0.586) in the numbers of orthopterans in samples collected in June and July (237 individuals of 15 species vs. 249 individuals of 17 species) near the 11 Red-footed Falcon breeding sites *(Table 5)*.

The average body length (16.91 mm) of the most common Common Straw Grasshopper individuals (n = 142) collected in July was significantly greater (Wilcoxon test, z = 3.51, P = 0.0001) than that of the individuals (n = 142) collected in June (15.70 mm) *(Figure 3)*. The body length of the second most common species, Meadow Grasshopper, did not show any significant differences when comparing samples collected in June (17.76 mm, n = 29) and July (16.90 mm, n = 29) (Wilcoxon test, z = 1.43 P = 0.15).

Table 3c Number of orthopteran species and specimens collected at sampling sites (21–31)
3c táblázat A mintavételi helyeken (21–31) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	**21.**	**22.**	**23.**	**24.**	**25.**	**26.**	**27.**	**28.**	**29.**	**30.**	**31.**
Conocephalus fuscus				1							
Ruspolia nitidula			1						3		
Leptophyes albovittata			1				1	2	1	6	
Bicolorana bicolor			1								
Platycleis grisea			2	1						2	
Tessellana veyseli		3	1								
Oecanthus pellucens						1					
Acrida ungarica			1	3	1						
Calliptamus italicus		1						1		2	
Chorthippus oschei		3		1							
Chorthippus biguttulus	1	7					1				
Chorthippus brunneus	1	5		1		1	2				1
Chorthippus dorsatus		5		2							
Pseudochorthippus parallelus			1		1	2	2	11	11	12	
Dociostaurus brevicollis				1							
Dociostaurus maroccanus	5										
Euchorthippus declivus	27	14	25	43	38	43	70	13	3	1	2
Omocestus haemorrhoidalis				2							
Omocestus rufipes						1					
Stenobothrus crassipes			1	1							
Aiolopus thalassinus				6		1					
Number of species	**4**	**7**	**9**	**11**	**3**	**6**	**5**	**4**	**4**	**5**	**2**
Number of specimens	**34**	**38**	**34**	**62**	**40**	**49**	**76**	**27**	**18**	**23**	**3**

Discussion

We confirmed the presence of individuals of 25 orthopteran species in grasslands near nesting sites of Red-footed Falcons in the lowland areas of Voivodina, which is 22.5% of the 111 species occurring in this north Serbian province (Ivković 2014–2024). Most of the species that we detected are common, but there were also rare and endangered species e.g. the xerothermic habitat specialist Steppe Spiny Bush-cricket (Grzędzicka & Vahed 2020), which in Serbia is Vulnerable (VU) and Veysel's Slender Bush-cricket, which is Near Threatened (NT) (Pavićević *et al.* 2018).

During a similar study in the Vásárhelyi Plain in Hungary using sweep-net sampling and soil traps, 26 species were detected (Szövényi 2015). In Slovakia, individuals of 46 orthopteran species were collected on several sites during the Red-footed Falcon breeding season (Krištín

Table 3d Number of orthopteran species and specimens collected at sampling sites (32–42)
3d táblázat A mintavételi helyeken (32–42) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	**32.**	**33.**	**34.**	**35.**	**36.**	**37.**	**38.**	**39.**	**40.**	**41.**	**42.**
Conocephalus fuscus					1						
Ruspolia nitidula			1								
Leptophyes albovittata					5	1	2				
Gampsocleis glabra									1		
Bicolorana bicolor		3									
Roeseliana roeselii					1						
Tessell ana veyseli	1						2		4	1	
Oecanthus pellucens	1									1	
Calliptamus italicus			1								
Chorthippus brunneus	1						4			1	1
Chorthippus dichrous	2										
Chorthippus dorsatus							1				
Pseudochorthippus parallelus	1	5	1	8	10	1	1		2		2
Euchorthippus declivus	6	10	14	14	38		15		45	19	2
Omocestus haemorrhoidalis							1				
Omocestus rufipes										1	
Stenobothrus crassipes								3		1	
Aiolopus thalassinus					1	3	9				
Number of species	**6**	**3**	**4**	**2**	**6**	**3**	**8**	**1**	**4**	**6**	**3**
Number of specimens	**12**	**18**	**17**	**22**	**56**	**5**	**35**	**3**	**52**	**24**	**5**

Table 4. Comparison of the average species and number of individuals (SD – standard deviation and SEM – standard error of the mean) of orthopterans caught in June in the grassland habitats near the smaller and larger colonies of Red-footed Falcons
4. táblázat A kisebb és nagyobb kék vércse telepek közelében lévő füves élőhelyeken júniusban fogott egyenesszárnyúak átlagos faj- és egyedszámának (±SD – standard deviation and SEM – standard error of the mean) összehasonlítása

Mean of:	**colony size**	**number of species**	**number of individuals**
1–5 pair	2.67 (SD=1.37, SEM=0.56)	3.17 (SD=0.98, SEM=0.40)	20.50 (SD=18.94, SEM=7.73)
7–24 pair	13.50 (SD=5.82, SEM=2.38)	3.33 (SD=1.37, SEM=0.56)	19.67 (SD=11.34, SEM=4.63)
t-test	4.4371	0.2425	0.0925
df	5	5	5
P-value	0.0013	0.8133	0.9282

Table 5. Number of individuals and average body length±SD (mm) of orthopteran species collected at the same 11 Red-footed Falcon nesting sites during sweep-netting sampling in June and July of 2003

5. táblázat A júniusi és júliusi fűhálózások során ugyanazon a 11 kék vércse költőhelynél gyűjtött orthoptera fajok egyedszáma és átlagos testhossza±SD (mm)

Species	June	Mean±SD	July	Mean±SD
Conocephalus fuscus			2	10.00±0.00
Ruspolia nitidula			4	20.75±2.50
Leptophyes albovittata	4	12.75±4.27	3	15.00±0.00
Bicolorana bicolor	5	15.40±3.65		
Tessellana veyseli			7	16.28±0.49
Oecanthus pellucens			3	13.00±2.65
Acrida ungarica	1	18.00±0.00		
Calliptamus italicus	1	17.00±0.00	3	14.00±4.00
Pezotettix giornae	4	16.75±2.50		
Chorthippus oschei	2	15.00±0.00	4	15.00±1.63
Chorthippus biguttulus	1	20.00±0.00	7	16.57±1.13
Chorthippus brunneus	2	17.50±3.54	12	18.00±2.77
Chorthippus dichrous	5	14.80±0.84	2	19.00±4.24
Chorthippus dorsatus			15	15.87±1.96
Pseudochorthippus parallelus	29	17.76±3.01	30	16.87±2.01
Dociostaurus maroccanus	6	18.00±3.10		
Euchorthippus declivus	170	15.56±3.05	142	16.91±2.37
Omocestus haemorrhoidalis			2	15.50±2.12
Omocestus rufipes	1	14.00±0.00	2	14.50±2.12
Stenobothrus crassipes	3	15.67±1.53	1	12.00±0.00
Aiolopus thalassinus	3	14.67±1.15	10	17.20±4.08
Number of individuals	**237**		**249**	
Number of species	**15**		**17**	

et al. 2017). More than half of the species detected in both the Hungarian and Slovakian samples were proven to be on the prey list of Red-footed Falcon (Szövényi 2015, Krištín *et al.* 2017). In our study, the number of individuals of the Orthoptera collected was much smaller (1,454 specimens) than in the samples collected both in Hungary (3,504 specimens) and Slovakia (ap. 14,500 specimens). This can be explained by the fact that our study lasted one year, while sampling was more intensive in Hungary and Slovakia lasted two and three years, respectively (Szövényi 2015, Krištín *et al.* 2017). In addition, in most of our sampling locations, the vegetation was very low due to the overgrazing. Our sampling could have been more effective if the sweep-neting method had been combined, for example, with vacuum sampling, which can more effectively collect smaller invertebrates (e.g. < 5 cm), but this method was not widely used at the time of our survey (Doxon *et al.* 2011). Our samples did

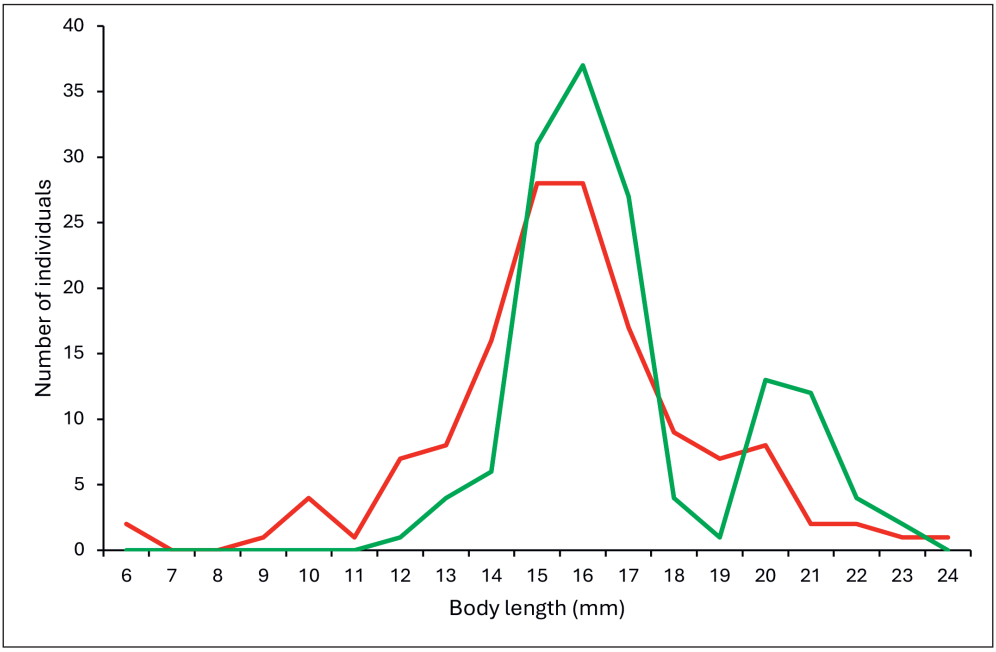


Figure 3. Changes in the body length of the Common Straw Grasshopper *(Euchorthippus declivus)* individuals collected in June (red line) and July (green line)

3. ábra A júniusban (piros vonal) és júliusban (zöld vonal) begyűjtött rövidszárnyú rétisáska *(Euchorthippus declivus)* egyedek testhosszának változása

not contain the Wart-biter *(Decticus verrucivorus)* or the Great Green Bushcricket *(Tettigonia viridissima)* which are the typical large-bodied orthopteran prey of the Red-footed Falcon (Szövényi 2015, Krištín *et al.* 2017, Tulis *et al.* 2017). The sampling method and intensity of grazing have a demonstrable effect on the pasture and on the straggler, communities living there (e.g. Báldi & Kisbenedek 1997, Batáry *et al.* 2007, Báldi *et al.* 2013, Török *et al.* 2016, Gardiner 2018, Almásy *et al.* 2021, Milić *et al.* 2024). With the disappearance of the species typical of tall grasslands, the diversity of orthopteran often decreases (Qin *et al.* 2017, Gardiner 2022, Stefanidis *et al.* 2024). A significant positive correlation between the species richness of Orthoptera and vascular plants was also shown (Essl & Dirnböck 2012).

In the study area, we could not demonstrate a correlation between the size of the Red-footed Falcon colonies and the abundance of orthopteran insects as the potential food resources in the grassland patches near the nesting sites. The low number of orthopterans in our samples primarily reflects the overgrazing of the grasslands, which can be supported by the fact that we found them in significant numbers in non-grazed patches (e.g. in a saline meadow dominated by *Juncus* sp.). Grasslands maintained with moderate grazing are important hunting areas and sources of food for Red-footed Falcon (Fehérvári *et al.* 2009, Palatitz *et al.* 2011, 2015), but overgrazing can result in impoverishment of grassland habitats. Some agricultural crops (e.g. alfalfa or grain fields) may have richer assemblages of Orthoptera than overgrazed grasslands in the Pannonian lowlands (e.g. Arnóczkyné Jakab & Nagy 2021, 2022). Red-footed Falcon is an opportunistic raptor, making use of local abundances and seasonal variations in prey,

with orthopterans as its most abundant food (Cramp & Simmons 1980, Szövényi 2015). In the year of our study, there were no large colonies of 40–50 pairs of Red-footed Falcons in Voivodina (Purger 2008). Keve and Szijj (1957) uncorrectly reported information from the reference in Serbian language (Marčetić & Medaković 1954) that in 1950, there was a colony of 100–200 pairs in Bachka in Voivodina near Bačko Gradište. However, in the cited publication (Marčetić & Medaković 1954) it is stated that „in 1950, 3 pairs nested in a 100–200 m wide black-locust forest at Biserno Ostrvo next to the dead Tisa". The conditions for the formation of large colonies were only present in a few places, but in 1990, 147 pairs nested on the banks of the Tisa tributary Zlatica near Jazovo (Purger 1996). Unfortunately, due to illegal logging and disturbance, in later years there were much fewer pairs breeding in this colony (Purger 2008, Purger & Lukács 2022). Around the settlement, there is vast grassland, a significant part of which is now under the protection of the Special Nature Reserve "Pasture of the Great Bustard – Pašnjaci velike droplje", Important Bird Area (Serbia) (Zeremski *et al.* 2021), and the corresponding due to the management, there are still a significant number of Red-footed Falcons nesting in the area (Barna 2015, Purger & Lukács 2022). The formation of larger colonies is primarily related to the number of available rook nests (e.g. Végvári *et al.* 2002, Barna 2015). However, if the number of nests is not a limiting factor and large colonies are not formed, we presume that it can be explained more by the lack of birds, the lack of adequate food supply and the complex effect of background factors. Near those nesting sites, where grassland habitats are not protected and intensive grazing continues, low-intensity extensive farming should be returned as soon as possible. Improving the condition of grasslands not only helps the naturalness of the habitats, but also the conservation of endangered animal species living there (Baldock 1999, Grdović *et al.* 2012). The condition of grasslands is also important for maintaining populations of common insect (e.g. orthopteran species), amphibian (e.g. Common Spadefoot *Pelobates fuscus*), reptile (e.g. Sand Lizard *Lacert agilis*) and small mammal (e.g. Common Vole *Microtus arvalis*) species, several of which are potential prey for Red-footed Falcons (e.g. Fülöp & Szlivka 1988, Haraszthy *et al.* 1994, Krištín *et al.* 2017). The diversity of orthopterans depended on habitat quality rather than the size of area and connection with similar habitats (Löffler *et al.* 2020). To preserve diversity, it is essential to maintain large patches with traditional land use practices (i.e. rough grazing or mowing once a year) and to restore former habitats to promote species dispersal across fragmented landscapes (Löffler *et al.* 2020). Even less natural grasslands that remain stable elements over long time in an agricultural landscape have extremely important role in conserving orthopterans and other grassland-dwelling insects (Purger & Vadkerti 2004, Riggi & Berggren 2020).

We could not find significant difference in the number of potentially available orthopteran species and individuals in June and July in the studied grassland patches near the Red-footed Falcon nesting sites. As time progressed, the average body length of the individuals of dominant orthopteran species, the Common Straw Grasshopper, increased by more than one millimeter. The Red-footed Falcons needed more food to raise their chicks, while the availability of orthoptera resources in grassland patches was limited. This could probably be the reason for the well-known phenomenon that hunting shifts from natural habitats to agricultural and even arable habitats during the late fledgeling period (Palatitz *et al.* 2011).

To meet the increased food needs of the chicks, the hunting of Common Voles on agricultural areas is more profitable than hunting small orthopterans on grasslands. In the entire sample that we collected, the average body length of the individuals exceeded 16 mm. Despite the lack of large-bodied orthopteran species, Red-footed Falcons could find it worthwhile to hunt individuals of small species if the grassland is close to the nesting site. In the study performed in Hungary, the body length of the insects preyed upon by Red-footed Falcons, breeding in Hortobágy, was only 5–10 mm, and during nestling, one locust was preyed on average every 30 seconds (Haraszthy *et al.* 1994). In the southwestern part of Slovakia, the feeding of 14–26-day-old chicks was studied using cameras and 97% of the prey were insects, more than half of which was Italian Locust *(Calliptamus italicus)*, the frequency of feeding of the chicks was also high, 9.9 feedings per hour (Chavko & Krištín 2017).

Orthoptera, in addition to being an important source of food for Red-footed Falcons, are also good indicators of disturbance and naturalness (Báldi & Kisbenedek 1997). Their monitoring is also important because small habitat island systems include a large proportion of the regional orthopteran species pool in arable landscapes (Riggi & Berggren 2020). Often smaller and more disturbed habitats are unable to support resident insectivore populations, this bottom-up mechanism may underlie the disproportionate sensitivity of insectivores to land-use intensification (Razeng & Watson 2015)

Conclusion

Based on our results, the small number of individuals of orthopteran insects reflects the disturbed, overgrazed state of the grassland patches near breeding sites of the Red-footed Falcons. It may indicate that this food source was not enough for the breeding period and therefore they needed additional food sources. Because of that, we could not show a correlation between orthopteran insects as the food source with the size of the Red-footed Falcon colonies. Due to the presence of rare and protected species detected during the survey, it would be important to place additional grassland areas under protection as soon as possible and to take measures that would regulate the intensity of grazing in such a way that the diversity of the orthopteran species pool and a rich source of food for the Red-footed Falcons are both preserved. A long time has passed since our survey, most of the Red-footed Falcon breeding sites as well as the landscape use changed considerably, therefore it would be worthwile to make similar research in the future.

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Diet composition of Barn Owl *(Tyto alba)* and Spotted Owlet *(Athene brama)* in an agricultural landscape of Central Assam, India

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Abstract This study examined the food habits of coexisting Barn Owls *(Tyto alba)* and Spotted Owlets *(Athene brama)* from January 2021 to January 2022 in two agricultural landscapes in Nagaon district, Assam, India. Pellet analysis at two sites, Nonoi and Puranigudam, revealed that Barn Owls primarily preyed on small mammals, such as Asian House Shrew *(Suncus murinus)* (42.05%) and Black Rat *(Rattus rattus)* (9.88%), with some avian species like Common Myna *(Acridotheres tristis)* and Oriental Magpie-robin *(Copsychus saularis)*. In contrast, Spotted Owlets predominantly consumed insects (Coleoptera, 50.47%) and small mammals (House Mouse *Mus musculus*, 16.19%). The dietary niche breadth was wider for Barn Owls (4.9) compared to Spotted Owlets (3.3). Both species contribute significantly to pest management in agricultural ecosystems, emphasizing their role as natural biocontrol agents.

Keywords: Barn Owl *(Tyto alba)*, Spotted Owlet *(Athene brama)*, Nagaon, Assam, dietary niche breadth, pellet analysis, agricultural pest control, coexistence

Összefoglalás A tanulmány az együtt élő gyöngybagoly *(Tyto alba)* és a brama kuvik *(Athene brama)* táplálkozási szokásait vizsgálta két mezőgazdasági tájban az indiai Assam állam Nagaon régiójában 2021 januárja és 2022 januárja között. A két területen, Nonoiban és Puranigudamban végzett bagolyköpet elemzés kimutatta, hogy a gyöngybagoly elsősorban kisemlősöket zsákmányolt, mint a Távol-keleti pézsmapatkány *(Suncus murinus)* (42,05%) és a házi patkány *(Rattus rattus)* (9,88%), valamint néhány madárfajt, mint például a pásztormejnót *(Acridotheres tristis)* és a Dayal-rigót *(Copsychus saularis)*. Ezzel szemben a brama kuvik túlnyomórészt rovarokat (Coleoptera, 50,47%) és kisemlősöket (házi egér *Mus musculus*, 16,19%) fogyasztott. A gyöngybagoly táplálék niche-szélessége nagyobb volt (4,9), mint a brama kuviké (3,3). Mindkét faj jelentősen hozzájárul a kártevők elleni védelemhez a mezőgazdasági ökoszisztémákban, hangsúlyozva a természetes biokontrollban betöltött szerepüket.

Kulcsszavak: gyöngybagoly *(Tyto alba)*, brama kuvik *(Athene brama)*, Nagaon, Assam, táplálkozási niche-szélesség, köpetvizsgálat, mezőgazdasági kártevő kontroll, együttélés

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Introduction

Owls are a prevalent group of avian fauna that inhabit rural, semi-urban, and urban landscapes. Primarily nocturnal, these birds of prey often roost in tall trees during the day (Lewis 2015). In India, the Spotted Owlet *(Athene brama)* and the Barn Owl *(Tyto alba)* are common species, particularly in Northeast India (Ali & Ripley 1983). Each owl species has specific prey preferences: Scops and Screech Owls primarily feed on insects, Barn Owls prefer rodents such as mice, shrews, and voles. Eagle Owls (*Bubo* sp.) hunt hares, young foxes, and birds up to the size of ducks, while Fish Owls (*Ketupa* sp.) are adept at catching fish. However, most owls exhibit opportunistic feeding behaviour, adapting their diet to the available prey in their habitat.

Owls, classified under the order Strigiformes, have a unique feeding habit of swallowing their prey whole and later regurgitating indigestible parts as compact pellets. Analyzing these pellets provides valuable insights into their diet and serves as a primary method for studying their feeding habits (Goguen 2016). This analysis also yields data on the small vertebrate fauna present in a given area (Heisler *et al.* 2016), making it a crucial tool that supplements traditional small mammal trapping methods. Pellets can capture data on species that typically avoid traps due to elusive behaviour or low population densities (Rocha *et al.* 2015).

Owls play a critical role in maintaining ecological balance, as they occupy the apex of trophic levels in both terrestrial and aquatic ecosystems (Sergio *et al.* 2008). They are particularly noted for their role in pest control (Pande & Dahanukar 2011, Kross *et al.* 2016, Moysi *et al.* 2018). Among India's owl species, Barn Owls and Spotted Owlets are frequently found in agricultural and human-dominated landscapes. Barn Owls are generalist predators, primarily preying on rodents (Taylor 1994). Similarly, the Spotted Owlet is a generalist predator, consuming a wide variety of prey, including rodents, small birds, reptiles, amphibians, and invertebrates such as insects and annelids (Jadhav & Parasharya 2003, Pande *et al.* 2007).

Due to their nocturnal and elusive nature, the population status and basic biology of many owl species remain largely unknown. In Northeast India, particularly, there is limited understanding of the distribution and habitat preferences of various owl species. Understanding the owl species co-occurrence in a given area and identifying the key habitat attributes they rely on are essential for comprehending how owls utilize their environment.

This study highlights the role of owls in controlling agricultural pests, specifically rodents, which pose significant threats to crops. As natural predators, owls help manage rodent populations in different geographical regions (Kross *et al.* 2016, Moysi *et al.* 2018), with over twenty species identified as major agricultural pests in India (Sridhara & Tripathi 2006). Conserving owls not only enhances rodent control, thereby preventing substantial crop losses, but also reduces the need for chemical interventions, contributing to the preservation of ecological diversity. This study also aims to investigate the diet composition and seasonal dietary variations in an agricultural landscape of Nagaon District, Assam.

Material and Methods

The study was conducted in Nagaon District of Assam, India, from January 2021 to January 2022, covering all four seasons. The focus was on two primary sites: Nonoi Agricultural Field (26.268651° N, 92.713536° E) and Puranigudam Agricultural Field (26.376473° N, 92.780771° E) *(Figure 1)*. These sites were chosen due to the presence of sacred fig *(Ficus religiosa)* trees, which provide ideal nesting sites for the Barn Owl and Spotted Owlet. Additional sites, including Samaguri Beel Par, Jaysagar Doloni, and Teliagaon, were also surveyed to broaden trophic ecological understanding.

Nesting and roosting sites were identified using modified protocols from Pande *et al.* (2011) and Mehta and Kulkarni (2018). These protocols included direct observations for owls, pellets, prey remains, excreta, and feathers, as well as monitoring potential nesting trees, conducting auditory surveys during late evening hours (19:00–21:00 hrs), and engaging residents through structured interviews. Data collection focused on the two primary sites where both owl species coexisted in the same nesting trees. Key parameters for data collection included gathering regurgitated pellets, prey remains, and feathers from beneath nesting trees during morning from 06.00 to 11.00 and evening from 15.30 to 19.30 sampling slots.

The study comprised 105 field days and a total of 158 hours of data collection. Spotted Owlet's pellets were collected during early morning hours (06.00–07.00) to minimize

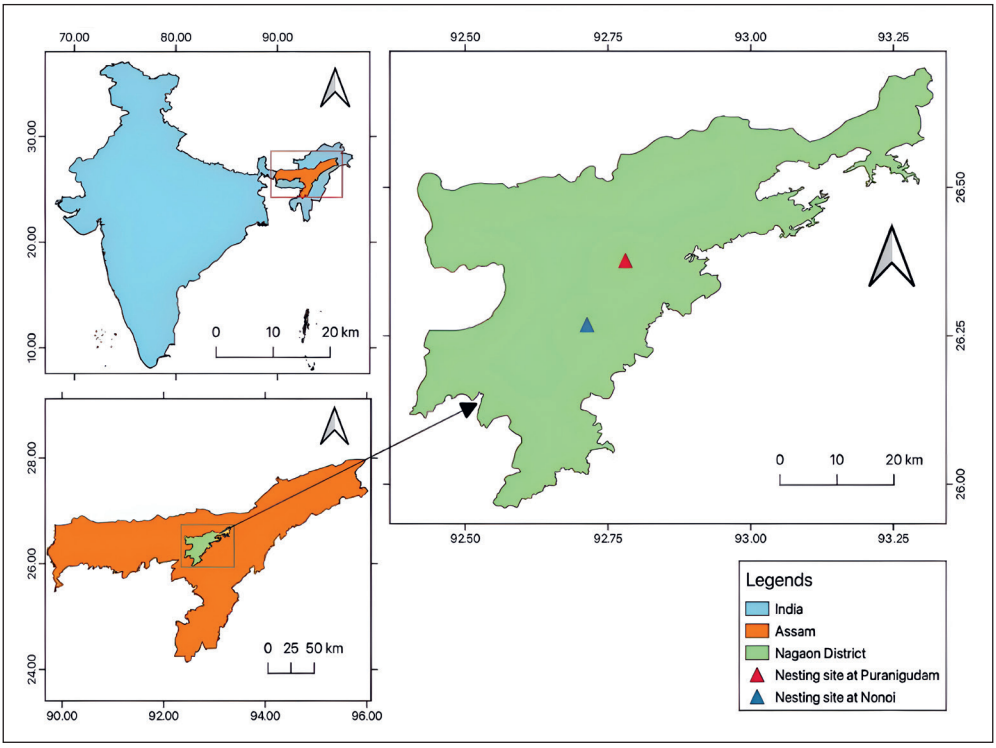


Figure 1. Map of the study area showing the investigated nesting sites of the two owl species
1. ábra A kutatási terület térképe a két bagolyfaj vizsgált fészkelőhelyeivel

disintegration risks, especially during the monsoon season. They were carefully handled, measured using a Vernier calliper, sun-dried for six hours to eliminate parasitic insect larvae, and stored in labelled plastic bags for analysis. Nikon P900 and Nikon D500 cameras were used to capture photographic evidence of owl activity and nesting sites.

For analysis, pellet samples were rehydrated in warm water and separated into identifiable components using tweezers, including bones, hair, feathers, and insect exoskeletons, following methods from Talmale and Pradhan (2009) and Mehta *et al.* (2020). Key prey items were identified based on skeletal elements; rodent pest species were identified from Sridhara and Tripathi (2006). To find out the association between pellet shape and dominant prey type Chi-square test was carried out. The food niche breadth (NB) was calculated using Levins' (1968) formula:

$$NB = (\sum Pi^2)^{-1}$$

where 'Pi' is the percentage of prey 'i' in the diet. Seasonal variations in diet composition were visualised using Microsoft Excel 2021, and geographic maps illustrating study sites were created using QGIS software, version 3.14, providing spatial context for the findings.

Results

Diet of Barn Owl

A total of 312 Barn Owl pellets were collected from the nesting habitat, revealing 517 distinct prey items, resulting in an average of 1.6 prey items per pellet. These pellets contained a total of 25 different prey species *(Table 1)*. The average pellet length was 43.26 mm (range: 31.1–68.6 mm, n=312), and the average width was 26.87 mm (range: 19.5–34.5 mm, n=312). The pellets exhibited various shapes, including cylindrical, oval, and irregular structures, and were dark brown and grey in colour. They were often covered with undigested parts of prey, such as fur, feathers, and small bone fragments.

Furthermore, a Chi-square test of independence revealed a significant association between pellet shape and dominant prey type ($\chi^2 = 76.20$, df = 2, $p < 0.001$). Cylindrical and oval pellets primarily contained small mammals, whereas pellets with undigested bird parts lacked a defined geometric shape. The vertebrate prey species identified in the pellets included two insectivores from the Soricidae family: Asian House Shrew *(Suncus murinus)* and an unidentified *Crocidura* species. The Barn Owl's diet also comprised two species of Microchiroptera, one of which was identified as a Greater False Vampire Bat *(Megaderma lyra)*. Additionally, the pellets contained seven species of Rodentia from the family Muridae, including Greater Bandicoot Rat *(Bandicota indica)*, Lesser Bandicoot Rat *(B. bengalensis*), Black Rat *(Rattus rattus)*, Sikkim Rat *(R. sikkimensis)*, an unidentified *Rattus* sp., Little Indian Field Mouse *(Mus booduga)*, and House Mouse *(Mus musculus)*, collectively accounting for 39% of the overall Barn Owl prey base in the study area.

Seven avian species were identified in the pellets, six of which were specified to the species level: Indian Pied Myna *(Gracupica contra)*, Jungle Myna *(Acridotheres fuscus)*,

Table 1. Seasonal relative percentage values of prey species in the Barn Owl's diet
1. táblázat A gyöngybagoly zsákmány fogyasztásának szezonális gyakorisági értékei

Prey items	Year around (%) (n=517)	Pre-monsoon (%) (n=142)	Monsoon (%) (n=149)	Retreating monsoon (%) (n=94)	Winter (%) (n=132)
Mammals					
Suncus murinus	41.97	53.52	40.94	42.55	30.30
Crocidura sp.	5.41	5.63	0.67	3.19	12.12
Megaderma lyra	0.19	0	0.67	0	0
Unidentified bat sp.	0.19	0	0	1.06	0
Bandicota indica	5.03	5.63	3.35	4025	6.82
Bandicota bengalensis	6.38	7.04	5.37	3.19	9.10
Rattus rattus	9.86	9.15	12.75	8.51	8.33
Rattus sikkimensis	8.70	6.34	9.39	8.51	10.61
Mus booduga	3.87	3.52	4.70	0	6.10
Mus musculus	5.22	3.52	8.72	0	6.82
Birds					
Gracupa contra	0.19	0	0	0	0.76
Acridotheres fuscus	0.38	0.70	0.67	0	0
Sturnia malabarica	0.97	0.70	1.34	2.13	0
Passer domesticus	1.16	0.70	0.67	4.25	0
Psilopogon asiaticus	0.19	0	0.67	0	0
Psilopogon haemacephalus	0.58	0	0.67	1.06	0.76
Acridotheres tristis	2.71	1.41	1.34	8.51	1.51
Copsychus saularis	3.28	0.70	2.68	9.57	2.27
Amphibians					
Unidentified *Anura* sp. 1	0.77	0	1.34	0	1.51
Unidentified *Anura* sp. 2	1.16	0	1.34	1.06	2.27
Reptiles					
Unidentified reptile sp.	0.19	0	0	1.06	0
Insets					
Hemiptera sp.	0.19	0.70	0	0	0
Coleoptera sp.	1.16	0.70	2.01	1.06	0.76
Orthoptera sp.	0.19	0	0.67	0	0

Chestnut-tailed Starling *(Sturnia malabarica)*, House Sparrow *(Passer domesticus)*, Blue-throated Barbet *(Psilopogon asiaticus)*, and Coppersmith Barbet *(Psilopogon haemacephalus)*. The observed pellets also contained herpetofauna (amphibians and reptiles) from the order Anura (specific species not identified), while the reptilian species could not be determined. Furthermore, the Barn Owl pellets included insect species belonging to the orders Coleoptera, Hemiptera, and Orthoptera, although these constituted only a minor portion of the Barn Owl's diet *(Figure 2)*.

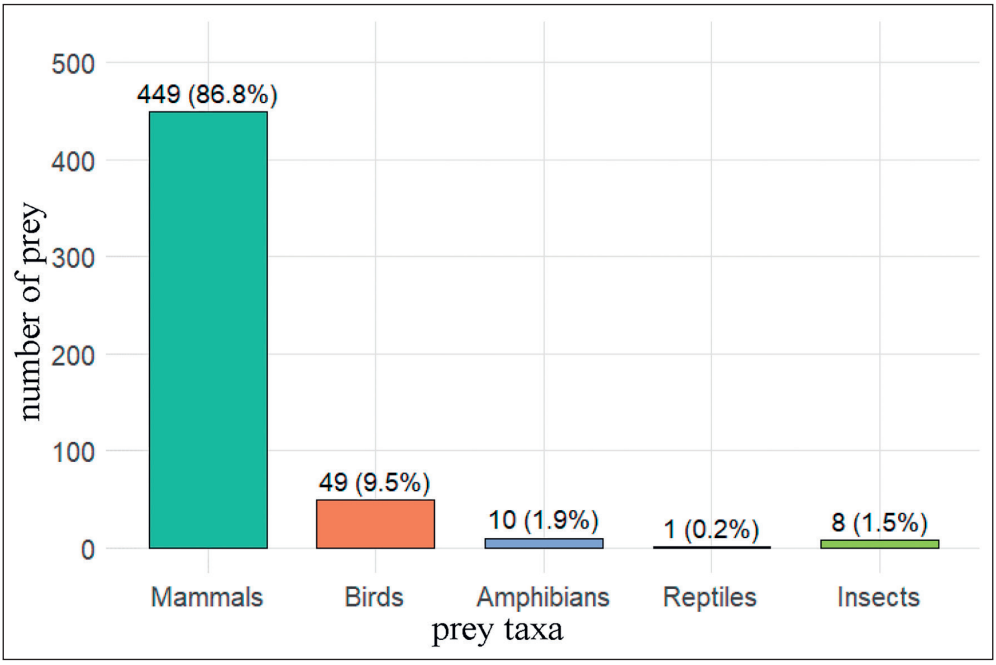


Figure 2. Distributioin of larger prey groups in the Barn Owl's diet during the year-round observation
2. ábra A gyöngybagoly fő zsákmánykategóriáinak megoszlása a teljes vizsgálati év adatai alapján

Seasonal variation of Barn Owl diet

During the pre-monsoon season (March–May), a total of 94 Barn Owl pellets were collected, yielding 142 identified prey items. Analysis revealed that small mammals dominated the diet, accounting for 94.3% of the total prey items observed in this season *(Table 1)*. The most common prey species included Asian House Shrew (53.5%), Greater Bandicoot Rat (5.6%), Lesser Bandicoot Rat (7%), and Black Rat (9.1%).

In the monsoon season (June–September), 87 pellets were collected, yielding 149 prey items, with small mammals again predominant at 87%. The Barn Owls most frequently hunted Asian House Shrew (40.9%), followed by Black Rat (12.7%) and Sikkim Rat (9.4%).

During the retreating monsoon season (October–November), 60 Barn Owl pellets were collected, revealing 94 prey items. Of these, small mammals constituted 71.3% of the diet, while birds made up 25.5%. Asian House Shrew was the most frequently hunted prey, comprising 42.5% of the diet.

In the winter season (December–February), 71 pellets were collected, from which 132 prey items were identified. Mammals were the most dominant prey group at 90.2%, followed by birds at 5.3%, with Asian House Shrew remaining the most frequently hunted species at 30.3%.

Overall, the analysis clearly indicated that the Barn Owl's diet is primarily composed of small mammalian species across all four seasons, with mammals consistently being the dominant prey group. Among small mammals, rodents are particularly significant, peaking at 90.2%

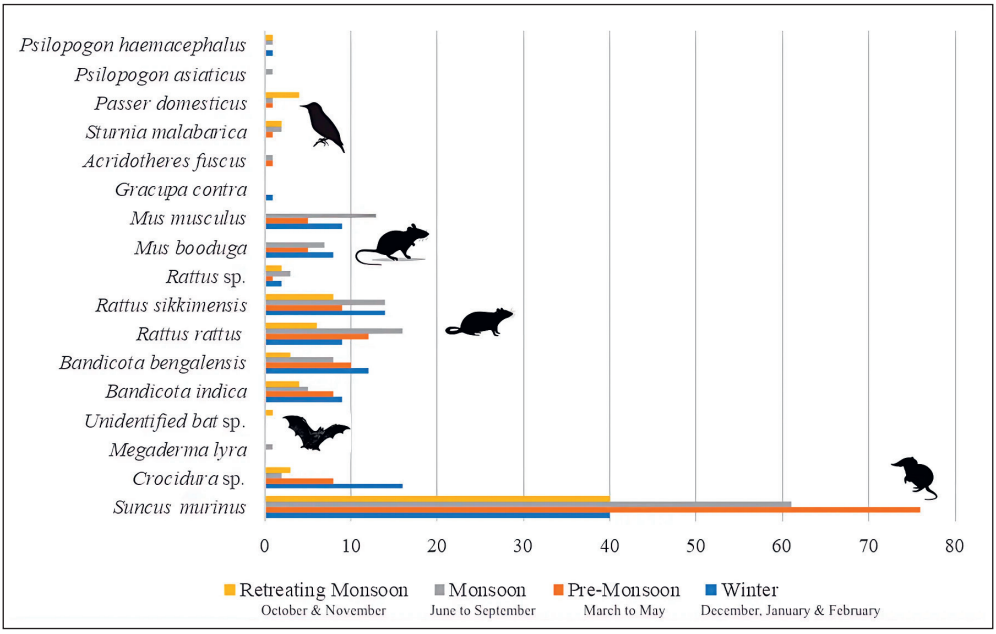


Figure 3. Distribution of prey species consumed by the Barn Owl in different seasons
3. ábra A gyöngybagoly által fogyasztott zsákmányfajok megoszlása a különböző évszakokban

during the winter season. Birds also contribute to the diet, with consumption increasing during the retreating monsoon. While amphibians constitute a minor component, their consumption shows a surprising increase in winter. Insects form a negligible part of the Barn Owl's diet, with their consumption rising slightly during the monsoon season *(Figure 3)*.

Diet of Spotted Owlet

The pellets of the Spotted Owlet exhibit consistent size and shape characteristics. The average length of the pellets is 25.08 mm (range: 21–34.1 mm, n=72), and the average width is 14.02 mm (range: 12–17.2 mm, n=72). These pellets are elongated and cylindrical, dark brown when dried, and covered with undigested prey remains such as insect exoskeletons and bone fragments from small mammals.

Analysis of 72 Spotted Owlet pellets revealed 105 prey items (1.5 prey items per pellet) belonging to 10 species *(Table 2)*. The diet of the Spotted Owlet predominantly consists of arthropods, which make up 55.2% of the diet. Among these, beetles (order Coleoptera) and grasshoppers (order Orthoptera) are the most frequently consumed. Mammals constitute 40% of the diet, followed by amphibians (2.9%) and birds (1.9%) *(Figure 4)*. The pellets contained remains of mammals primarily from the orders Insectivora and Rodentia. Within Insectivora, species from the family Soricidae and the genus *Crocidura* were identified. In the order Rodentia, four species from the Murinae family – Lesser Bandicoot Rat, Sikkim Rat, Little Indian Field Mouse, and House Mouse – were recorded. Additionally, amphibian remains from the order Anura, and one bird species were found.

Table 2. Seasonal relative percentage values of prey species in the Spotted Owlet's diet
2. táblázat A brama kuvik zsákmányfogyasztásának szezonális gyakorisági értékei

Prey Items	Year around (%) (n=105)	Pre-monsoon (%) (n=29)	Monsoon (%) (n=22)	Retreating monsoon (%) (n=13)	Winter (%) (n=41)
Mammals					
Crocidura sp.	9.52	6.9	9.1	7.7	12.2
Bandicota bengalensis	0.95	0	0	0	2.4
Rattus sikkimensis	2.86	0	4.5	15.4	0
Mus booduga	16.19	17.2	13.6	0	4.9
Mus musculus	10.48	20.7	13.6	0	22
Birds					
Orthotomus sutorius	1.90	0	0	7.7	2.4
Amphibians					
Unidentified *Anura* sp.	2.86	0	4.5	0	4.9
Insects					
Coleoptera	50.48	55.20	45.4	61.5	46.3
Hymenoptera	3.81	0	9.1	0	4.9
Orthoptera	0.95	0	0	7.7	0

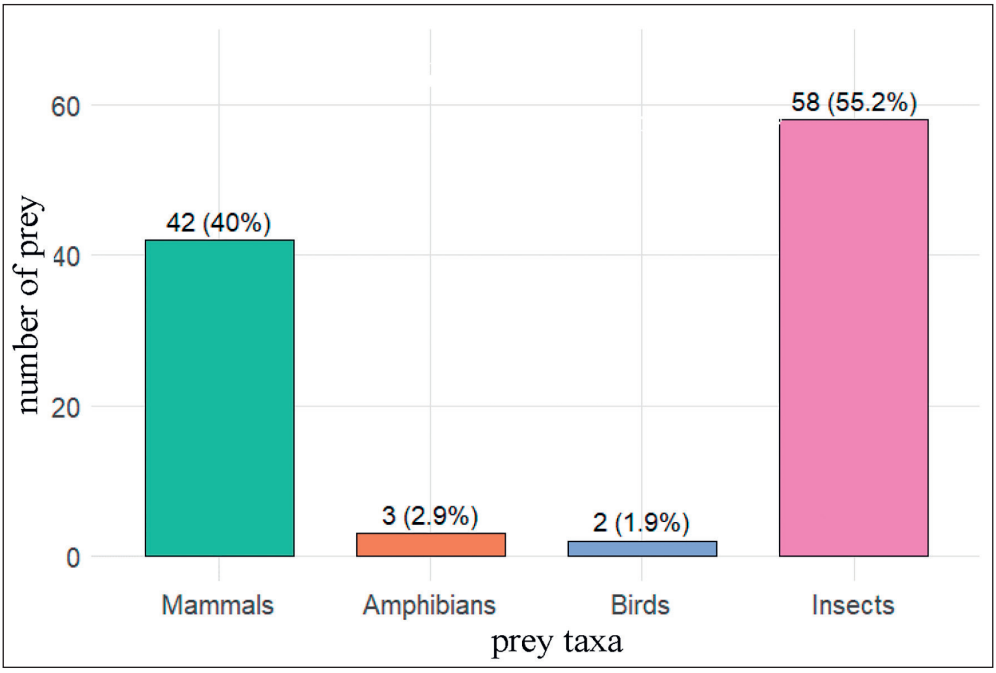


Figure 4. Distribution of larger prey groups in the Spotted Owlet's diet during the year-round observation
4. ábra A brama kuvik fő zsákmánykategóriáinak megoszlása a teljes vizsgálati év adatai alapján

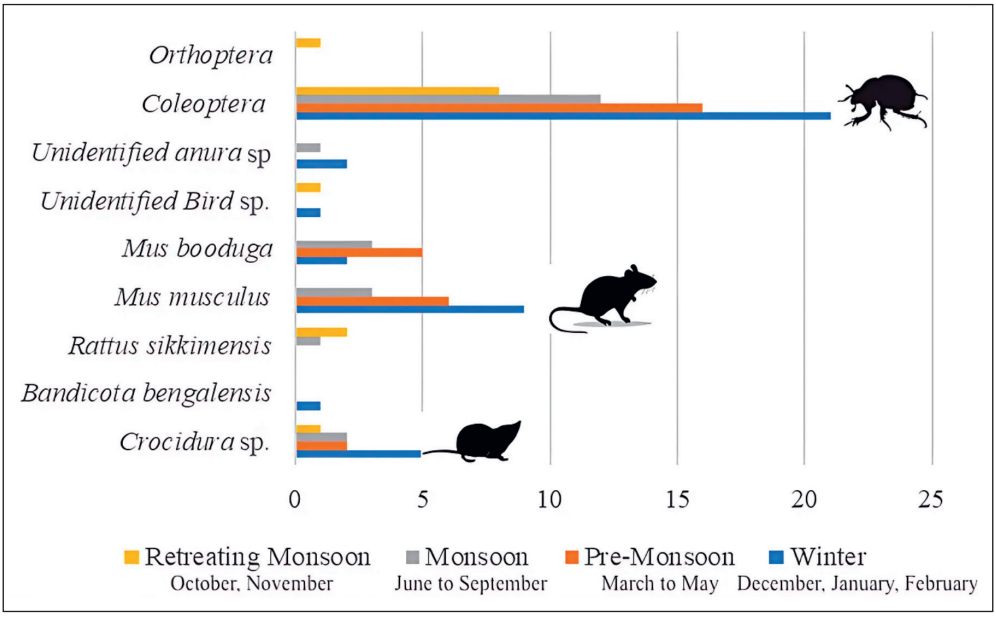


Figure 5. Distribution of prey species consumed by the Spotted Owlet in different seasons
5. ábra A brama kuvik által fogyasztott zsákmányfajok megoszlása a különböző évszakokban

Seasonal variation in Spotted Owlet diet

Analysis of Spotted Owlet pellets collected across different seasons shows variations in diet composition *(Table 2)*. During the pre-monsoon season (March–May), 19 pellets yielded 29 prey items, with insects making up 55.2% of the diet, particularly coleopterans. In the monsoon season (June–September), 15 pellets contained 22 prey items, with insects constituting 54.5% of the diet, again with coleopterans being the preferred prey. During the retreating monsoon season, 11 pellets revealed 13 prey items, with insects being predominant (69.2%) and coleopterans the most frequently consumed. In winter (December–February), 27 pellets yielded 41 prey items, with insects comprising 51.2% of the diet. Other prey items included Lesser Bandicoot Rat and House Mouse, with coleopterans remaining the most preferred prey *(Figure 5)*. Overall, the diet of the Spotted Owlet is primarily composed of insects and small mammals, with rodents being particularly important during the pre-monsoon season (44.8%).

Rodent pests in owl diet

A total of six rodent species were identified from the Barn Owl and Spotted Owlet pellets and all are considered as major agricultural pests. Analysis of 312 Barn Owl pellets revealed the remains of six rodent pest species, including Greater Bandicoot Rat (13%), Lesser Bandicoot Rat (16%), Black Rat (25%), Sikkim Rat (22%), Little Indian Field Mouse (10%), and House Mouse (14%). A total of 202 rodent prey were identified in Barn Owl pellets during the study period. Similarly, analysis of 72 Spotted Owlet pellets showed the

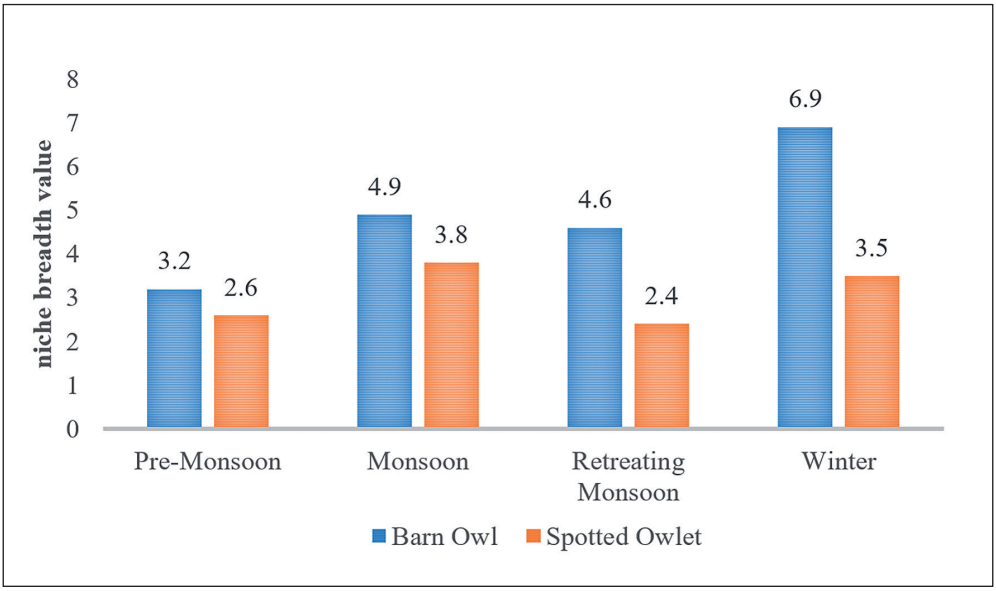


Figure 6. Seasonal variation of niche breadth of Barn Owls and Spotted Owlets
6. ábra A gyöngybagoly és a brama kuvik táplálék niche-szélességének szezonális eltérése

remains of Lesser Bandicoot Rat (3.1%), Sikkim Rat (9.3%), Little Indian Field Mouse (34.3%), and House Mouse (53.1%). In total, 32 rodent preys belonging to 4 species were identified in Spotted Owlet pellets during the study period.

Trophic niche breadth of the owl species

The trophic niche breadth of the Barn Owl was determined to be 4.9, exhibiting seasonal variation. The narrowest niche breadth was recorded during the pre-monsoon season (3.2), followed by an increase to 4.9 in the monsoon, a slight decline to 4.6 during the retreating monsoon, and a peak of 6.9 in winter. In contrast, the Spotted Owlet displayed a trophic niche breadth of 3.3, with seasonal fluctuations. The niche breadth was at its lowest during the retreating monsoon (2.4), reached its highest point in the monsoon (3.8), and measured 2.6 in the pre-monsoon and 3.5 in winter *(Figure 6)*.

Discussion

The morphometric measurements of Barn Owl pellets in this study show notable variation when compared to previous research. Studies by Ali and Santhanakrishnan (2012), Santhanakrishnan *et al.* (2010), Almeida *et al.* (2021), and Nadeem *et al.* (2012) reported pellet lengths of 37±8.8 mm (range: 10–80 mm) and widths of 25±5.3 mm (range: 8–40 mm); 37±9.1 mm (range: 10–80 mm) and widths of 24.7±5.4 mm (range: 8–40 mm); and 48.2±0.82 mm (range: 39.7–55.4 mm) and widths of 38.2±0.46 mm (range: 33.8–40.8 mm),

respectively. The variation in pellet size observed throughout the year is consistent with previous findings by Stegeman (1957) and Hardy (1977), who suggested that pellet size is influenced by diet composition, prey size, and prey nutritive value. Our study also found that Barn Owl pellets containing multiple prey items were generally smaller than those with a single prey item, contrasting with the findings of Nadeem *et al.* (2012), who reported larger pellets in areas where Barn Owls primarily preyed on avian species.

The average number of prey items per pellet was 1.6, differing from other studies (Travaini *et al.* 1997, Bellocq 1998, Neelanarayanan 2007, Magrini & Facure 2008, Charter *et al.* 2009, Nadeem *et al.* 2012). Consistent with research from various regions (Glue 1974, Marti 1974, Lovari *et al.* 1976, Taylor 1994, Pezzo & Morimando 1995, Travaini *et al.* 1997, Bose & Guidali 2001, Leonardi & Arte 2006, Magrini & Facure 2008), small mammals were the primary contributors to the Barn Owl's prey biomass, a pattern supported by numerous studies (Marti 1974, Gubanyi *et al.* 1992, Pezzo & Morimando 1995, Travaini *et al.* 1997, Bose & Guidali 2001, Leonardi & Arte 2006, Magrini & Facure 2008). The most frequently hunted and significant prey species was Asian house shrew, likely due to its abundance and nocturnal behavior, in line with previous studies (Santhanakrishnan *et al.* 2010, Nadeem *et al.* 2012).

While other studies noted a significant proportion of bats in the Barn Owl's diet (Bellocq 2000, Escarlate-Tavares & Pessoa 2005, Sommer *et al.* 2005, Nadeem *et al.* 2012), this study recorded only a negligible amount, with just two individuals consumed. Birds made up 5.4% of the diet, and other studies have suggested that Barn Owls may specialize to birds when other prey is scarce (Bose & Guidali 2001, Leonardi & Arte 2006, Nadeem *et al.* 2012). Reptiles and amphibians were consumed in smaller numbers, accounting for 0.19% and 1.93% of the diet, respectively, consistent with previous research (Pezzo & Morimando 1995, Sommer *et al.* 2005, Neelanarayanan 2007, Santhanakrishnan *et al.* 2010). Insects from the orders Coleoptera, Hemiptera, and Orthoptera constituted 1.54% of the Barn Owl's diet, which aligns with findings from other regions where arthropods comprise less than 2.5% of the diet (Rifai *et al.* 1998, Santhanakrishnan *et al.* 2010).

Seasonal variation was observed in the Barn Owl's diet, though small mammals remained dominant throughout the year. Rodents were particularly prevalent during the winter season, likely due to the agricultural cycle in Assam, where paddy fields are harvested in December and January, exposing small mammals to predation. Additionally, the cessation of breeding among small mammals, except for the black rat, in the colder months (December–January) may have contributed to this pattern. The reproductive cycles and changes in vegetation cover significantly influence the availability and abundance of small mammals, including Asian house shrew, which remained a staple diet item across all four seasons.

In contrast, the Spotted Owlet's diet was characterized by a higher proportion of insect prey, consistent with previous studies (Santhanakrishnan *et al.* 2011, Patki *et al.* 2016. Mehta *et al.* 2018). Coleoptera were the most frequently consumed insects, followed by Hymenoptera and Orthoptera. Despite the prevalence of insect consumption, small mammals, particularly those weighing less than 30 g (such as *Crocidura* and *Mus* species), were important prey items, corroborating earlier research (Nadeem *et al.* 2012). Seasonal variation was also observed in the Spotted Owlet's diet, with small mammals forming a larger part of the prey biomass during the winter and pre-monsoon seasons when agricultural fields are cleared,

exposing small mammals to predators. Insect consumption increased during the monsoon and retreating monsoon seasons, corresponding to a rise in insect abundance.

The findings suggest that the Barn Owl is a more generalist predator, with a prey base comprising 25 species, compared to the Spotted Owlet. Levin's index for the Barn Owl was smaller than reported by Petrovici *et al.* (2013) but larger than in Nadeem *et al.* (2012). The Barn Owl's niche breadth varied across seasons, peaking in winter, likely due to the increased availability of rodents. For the Spotted Owlet, Levin's index was larger than that reported by Nadeem *et al.* (2012), with seasonal variations, and the widest niche breadth occurring in winter, again likely due to the availability of small mammals.

This study provides valuable insights into the prey base and dietary variations of the Barn Owl and Spotted Owlet in Assam. Given the limited research conducted in Northeast India, these findings underscore the ecological importance of owls. Barn Owls are potential predators of rodent pests, and their role as biological pest controllers in agricultural areas could be harnessed to reduce the use of harmful chemical pesticides. Farmers in some western countries already use Barn Owls for this purpose (Meyrom *et al*. 2009, Kross *et al.* 2016), and installing artificial nest boxes in agricultural fields could further promote this practice in India. Raising awareness among local communities about the ecological role of owls is essential. Owl pellet analysis also serves as an efficient method for studying small mammal populations, such as rodents and shrews, which are otherwise difficult to monitor using conventional trapping methods. The frequent presence of certain species in owl pellets indicates high population densities in the study area, making this a valuable tool for ecological monitoring.

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The diet of the European Bee-eater *(Merops apiaster)* in Višnjička Kosa, Belgrade, Serbia

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Abstract We examined the diet of the European Bee-eater *(Merops apiaster)* within a suburban colony in Belgrade (Serbia). From 68 pellets, we identified 1236 prey individuals. The predominant prey was the Honey Bee *(Apis mellifera)*, representing 59.0% of all extracted prey individuals, followed by ants (11.4%), bumble bees (*Bombus* spp.) (9.3%), other bees (8.6%), diverse other hymenopteran taxa (5.3%), coleopterans (3.4%), and dragonflies (1.5%). Honey bees and other bee taxa were present in the diet of bee-eaters significantly more in May than in June, while the opposite was true for other prey categories. This diet composition may be a result of local prey availability and the selective choice of prey categories during the chick provisioning period.

Keywords: Honey Bee, Hymenoptera, insectivorous birds, prey composition

Összefoglalás A gyurgyalag *(Merops apiaster)* táplálékválasztását vizsgáltuk Belgrád egyik külvárosi területén található költőtelepen. A 68 köpetből 1236 zsákmányállat-egyedet azonosítottunk. A házi méh *(Apis mellifera)* volt a leggyakoribb zsákmány, amely az összes egyed 59,0%-át tette ki. Ezt követték a hangyák (11,4%), poszméhek (9,3%), egyéb méhek (8,6%), egyéb hártyásszárnyúak (5,3%), bogarak (3,4%) és a szitakötők (1,5%). A házi méh és más méhtaxonok szignifikánsan nagyobb arányban voltak jelen a gyurgyalagok étrendjében májusban, mint júniusban. A többi zsákmányállat esetében ennek ellenkezőjét állapítottuk meg. A helyi, fiókanevelés idején jellemző táplálék-összetétel a költőtelep környékén élő zsákmányállatok elérhetőségének és a gyurgyalagok szelektív táplálékválasztásának lehetett az eredménye.

Kulcsszavak: házi méh, Hymenoptera, rovarevő madarak, zsákmányösszetétel

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Introduction

Many birds rely on insects as important prey – around 60% of avian species worldwide, to a certain extent, depend on insects in their diet (Morse 1971). The loss of insect biomass, documented over the last couple of decades (Hallmann *et al*. 2017, Wagner 2020), has thus negatively affected populations of insectivorous birds on a global scale (Bowler *et al*. 2019, Spiller & Dettmers 2019, Møller *et al*. 2021). For example, populations of insectivorous birds in Europe declined by 13% from 1990 to 2015, while populations of omnivorous species remained stable over the same period (Bowler *et al*. 2019). Similarly, terrestrial insectivorous birds declined by 2.9 billion individuals across North America over the last

50 years, whereas population abundances of species in which insects are not principal prey have increased (Tallamy & Shriver 2021). Since the reproductive success of birds depends not only on food availability but also on prey type (Tallamy & Shriver 2021), detailed knowledge of prey composition and dietary preferences of insectivorous species is necessary for the planning and implementation of future conservation strategies.

Here, we examined the diet of an insectivorous bird, the European Bee-eater *(Merops apiaster)* (hereafter "bee-eater"), within a suburban colony in Belgrade, Serbia. The bee-eater is a long-distance migrant with a breeding range across Europe, Asia, the Mediterranean, and southern Africa. It winters in western, central, and southern Africa (Bastian & Bastian 2024). Its population in Serbia is estimated at 5,200–8,500 breeding pairs, with a stable short-term trend and an increasing long-term trend (BirdLife International 2021). The bee-eater is an obligate insectivore that captures its prey in flight (Bastian & Bastian 2024). While hymenopterans are its most common prey, the bee-eater is an opportunistic forager whose diet varies regionally and seasonally (Cramp 1985, Bastian & Bastian 2024). As the diet of the bee-eater has never been studied in Serbia, the information presented in this study contributes to the understanding of this species within the European part of its range.

Methods

The study was conducted in Višnjička Kosa, a suburban area of Belgrade, Serbia, in 2021. The study area is characterized by a mosaic of agricultural and ruderal habitats, forests, thickets, and hedgerows, with steep, bare loess slopes originating from past clay excavation (Jakovljević *et al*. 2008). Around 300 pairs of bee-eaters breed here, in a 500-meter-long bank with a height of 2–8 meters, in a mixed colony with Starlings *(Sturnus vulgaris)* and Common Swifts *(Apus apus)* (Raković *et al*. 2024).

We investigated the bee-eaters' diet by analyzing their pellets, which were collected near the colony, typically under perches that the birds used for hunting and resting. Since the pellets were gathered along a 200-meter stretch of the bank containing over 100 active bee-eater nests, we assume that the sampled pellets reflect the diet of a representative number of individuals. We conducted pellet sampling in 18, 21 and 23 May and 7, 19 and 23 June 2021. Samples were stored at below -15 °C, and before analysis, pellets were submerged in a mixture of warm water and alcohol to facilitate the safe extraction of undigested prey remains. Remains of hymenopterans were typically identified to family or genus level, based on forewing size, shape, and distinctive details of wing venation. We quantified prey based on the number of extracted forewings, rounding to the nearest whole number if necessary. For the identification of Hymenoptera, we used keys to various aculeate subgroups, focusing on bee genera (Scheuchl 2000, Macek *et al*. 2010), and compared the material with the extensive collection of the Centre for Bee Research at the Faculty of Biology. Identification of the other insect orders (Hemiptera, Diptera, Odonata and Coleoptera) was primarily conducted at a coarser taxonomic level, for which we used general entomological guides (Chinery 1993, Brock 2017).

Table 1. Diet composition of European Bee-eaters: number of prey items consumed in May and June, the total number of prey items, and frequency of occurrence of prey taxa in bee-eaters' pellets

1. táblázat A gyurgyalagok táplálék-összetétele: a májusban és júniusban elfogyasztott zsákmányállatok száma, a zsákmányállatok teljes száma és a taxonok előfordulásának gyakorisága a köpetekben

Prey taxa	Number of prey items in May	Number of prey items in June	Number of prey items	Frequency of occurrence
Hymenoptera	**738**	**420**	**1158**	**100%**
Apoidea: Apidae – apid bees	599	274	873	94.1%
Apis	551	179	730	86.8%
Bombus	30	85	115	52.9%
Solitary nonparasitic Apidae (mostly *Eucera* and *Anthophora*)	11	9	20	17.6%
Solitary parasitic Apidae (mostly *Nomada*)	7	1	8	8.8%
Apoidea – other bees	62	16	78	36.8%
Andrenidae: *Andrena*	43	8	51	32.4%
Colletidae: *Colletes*	8	3	11	10.3%
Halictidae: mostly *Halictus* and *Lasioglossum*	10	1	11	8.8%
Melittidae: *Dasypoda*	0	4	4	2.9%
Megachilidae	1	0	1	1.5%
Ants and wasps	77	130	207	61.8%
Formicidae	48	93	141	33.8%
Apoidea – spheciform wasps	8	19	27	22%
Ichneumonidae	11	9	20	22%
Vespidae	10	8	18	22%
Scolidae (*Scolia*)	0	1	1	1.5%
Other insect orders	**27**	**51**	**78**	**52.9%**
Coleoptera	15	27	42	36.8%
Odonata	2	16	18	22%
Diptera	9	5	14	19.1%
Hemiptera	1	3	4	2.9%

For each prey category, we calculated the frequency of occurrence in the pellets and the proportion of total prey individuals *(Table 1)*. Differences among prey categories were examined using binomial tests for proportions (Crawley 2013), applied to the major prey groups – Honey Bee *(Apis mellifera)*, other hymenopterans and other insects – with Bonferroni adjustments for pairwise comparisons (McDonald 2014). To examine changes in diet composition during the breeding season, we compared prey consumed in May with prey from June, also using binomial tests for proportions. We tested the following prey

categories: *A. mellifera*, *Bombus* spp. other bee taxa, Formicidae, other hymenopteran taxa (excluding bees and ants), Coleoptera, and Odonata *(Table 1)*. Statistical analysis was carried out with R v4.3.3, using the stats package (R Core Team 2024).

Results

We collected and analyzed the content of 68 pellets, from which we identified 1236 prey individuals. The number of individuals per pellet ranged from 7 to 78 individuals. In our study, bee-eaters fed almost exclusively on hymenopterans, the remains of which were found in all analyzed pellets, while other insect orders were present in about 53% of the pellets and accounted for only 6.4% of the analyzed prey items *(Table 1)*. The predominant prey was the Honey Bee (identified in 59 pellets, i.e. 86.8%), followed by bumble bees (*Bombus* spp.) in 36 pellets (52.9%) and ants (Formicidae) in 23 pellets (33.8%) *(Table 1)*. In terms of total prey abundance, Honey Bees accounted for 59.0% of all extracted prey individuals, followed by ants with 11.4% and bumble bees with 9.3%. The sum of other bee taxa represented 8.6% of the total prey abundance, other diverse hymenopteran taxa (excluding bees and ants) accounted for 5.3%, coleopterans

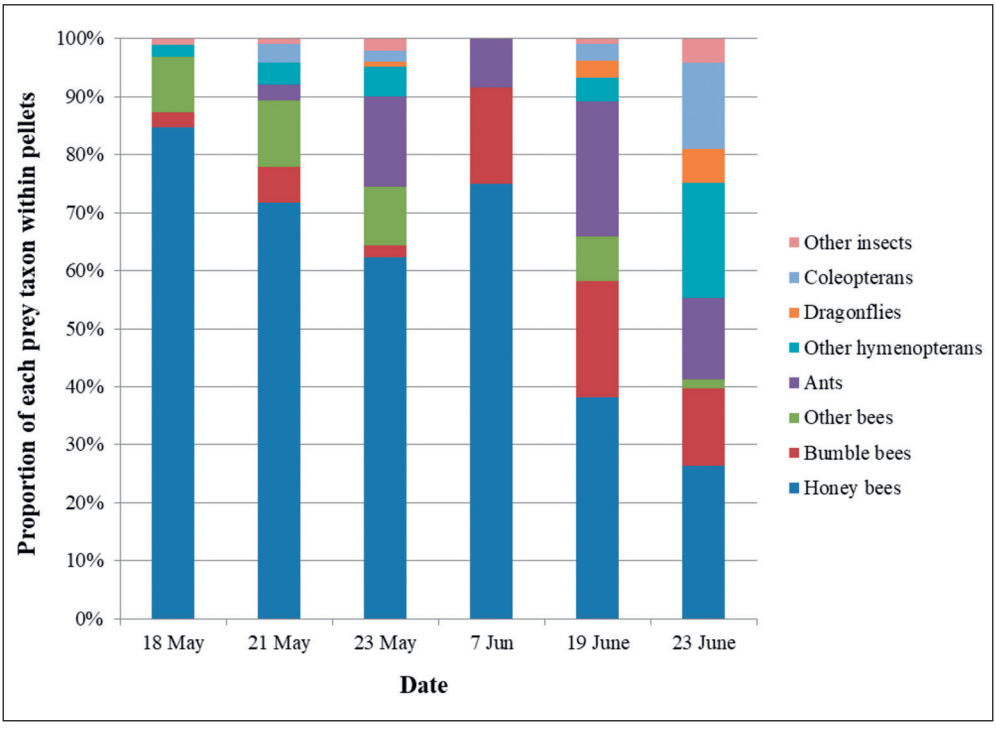


Figure 1. The proportion of various prey categories (less represented taxa shown subsumed) in bee-eaters' pellets by sampling days

1. ábra A különböző zsákmánykategóriák (a kevésbé reprezentált taxonok összeadva) aránya a gyurgyalag köpetekben mintavételi napok szerint

(Coleoptera) for 3.4%, dragonflies (Odonata) for 1.5%, and all other insects constituted 1.5% of the bee-eaters' diet *(Table 1)*. The proportion of Honey Bees in the analyzed pellets was significantly higher than that of other prey categories (binomial tests: $p < 0.001$), constituting over 90% of the total prey individuals in some of the analyzed pellets. Similarly, all other hymenopterans were more represented in the bee-eaters' diet than the sum of all non-hymenopteran insects (binomial test: $p < 0.001$). Bee-eaters consumed significantly more Honey Bees and other bee taxa in May than in June, while the opposite was true for all other tested taxa (binomial tests: $p < 0.01$) *(Figure 1)*.

Discussion

Hymenopterans are the main prey of adult bee-eaters in many parts of their range (Fuisz *et al*. 2013, Arbeiter *et al*. 2014, Ullmann *et al*. 2017). Among hymenopterans, the Honey Bee was the predominant prey in our study. The proportion of Honey Bees in the bee-eaters' diet varies among regions and seasons, and is typically higher in colonies close to beehives (Costa 1991, Galeotti & Inglisa 2001, Arbeiter *et al*. 2014, Farinós-Celdrán *et al*. 2016). In Sardinia, for example, the proportion of Honey Bees in the bee-eaters' diet ranged from 3.9% to 19.9% in areas without beehives, whereas it was considerably higher, 46.2% to 62.5%, in areas near beehives (Galeotti & Inglisa 2001). Similarly, a study in Portugal found that Honey Bees comprised 50% of the diet of bee-eaters hunting near beehives, but only 10% in those foraging away from beehives (Costa 1991). Although we did not observe any beehives near the study site, the high proportion of Honey Bees in the diet suggests that beehives were likely located in close proximity to the bee-eater colony. Additionally, managed apiaries have previously been reported within a 2 km radius of the bee-eater colony (Bila Dubaić *et al*. 2021). Finally, a remarkable presence of free-living Honey Bees was documented in many parts of Belgrade, with numerous colonies and frequent swarming in some years (Bila Dubaić *et al*. 2021). Accordingly, some Honey Bee colonies were undoubtedly available as an easily accessible food source near the study site. The proportion of consumed Honey Bees decreased as the breeding season progressed *(Figure 1)*, indicating a shift toward other prey categories during the chick provisioning period (Inglisa *et al*. 1993, Arbeiter *et al*. 2014), which may be due to phenological changes in activity and the relative availability of different groups.

In addition to Honey Bees, the closely related bumble bees also represented attractive prey for bee-eaters, as their remains were detected in more than half of the examined pellets. However, the share of bumble bees in the total number of identified prey was considerably lower than in some other studies. For example, bumble bees were the most important prey in the north and northwest of Europe, presumably due to the favorable influence of the oceanic climate, while hot summers may pose challenges in more continental areas (Krüger 2018, Bastian & Bastian 2024). In such areas (from central through eastern Europe), bumble bees were recorded as common prey in colonies close to suitable habitats, e.g. clover fields and flowering grasslands (Fry 1984), but also later in the summer (Krištín 1994). Bumble bees are well known for their generalist and highly opportunistic foraging behavior, as well as

for local differences and seasonal variation in population abundance (Goulson *et al*. 2008, Goulson 2010, Pyke *et al*. 2011), which may affect their availability and attractiveness to bee-eaters. Our previous long-term observations in the wider Belgrade area indicate that the abundance and local activity of bumble bees are strongly affected by the availability of more favorable habitats, and the Višnjička Kosa study site does not represent a favorable area in that respect (Ćetković, unpublished data). The number and relative share of bumble bee prey items were significantly higher in June, likely due to the seasonal growth of their colonies.

In our study, bee-eaters also captured a considerable number of ants. These hymenopterans are also common prey for bee-eaters in Europe, as the timing of the nuptial flight period in the life cycle of many ant species overlaps with the birds' breeding season (Fry 1984, Seifert 2017). For example, ants were identified as the second most frequently consumed prey at a study site in Slovakia, being more prevalent in the diet of nestlings than adults (Goffová *et al*. 2022). We recorded only a few individuals of ants per sample, with the exception of two pellets in which ants were the most abundant prey, suggesting that some bee-eaters succeeded to detect local ant swarming.

Although some research indicates that bee-eaters generally prefer hymenopterans, which may dominate their diet even when not the most abundant flying insects (Fry 1984, Inglisa *et al*. 1993), bee-eaters typically capture the most abundant insect species in higher proportions, depending on the season and habitat (Fry 1983, Bastian & Bastian 2024). For example, dragonflies are the dominant prey of bee-eaters whose colonies are located close to aquatic habitats (Fuisz *et al*. 2013, Bastian & Bastian 2024). In addition, a recent study revealed that the proportion of hymenopterans in the diet of bee-eaters is overestimated if the diet is assessed only through analysis of pellets, i.e., without direct observations or photographic surveys of birds; weakly sclerotized insects, such as lepidopterans and dragonflies may be largely digested to unrecognizable remains and thus underrepresented in pellets (Bastian & Bastian 2023). A photographic survey of prey delivered to nests in a colony near wetland habitats revealed a high consumption of dragonflies (Fuisz *et al.* 2013), with their proportion comparable to that of all hymenopterans combined. These soft-bodied insect groups were poorly represented (e.g. dragonflies, dipterans) or completely absent (e.g. lepidopterans) in our study, which may, in part, be due to the methodology we applied.

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An avifaunal inventory of the Kazinag National Park and adjoining areas: Conservation implications

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Abstract The present study was undertaken in Kazinag National Park – an important protected area in the Northwestern Himalayan region of India – from March 2023 to February 2024, to compile a comprehensive avifaunal inventory of the park. Field surveys were systematically carried out during early morning and late afternoon hours, coinciding with peak bird activity. Birds were identified following standard field guides, expert consultations, and online sources. A total of 127 bird species, distributed across 10 orders and 35 families were documented, many of which are of conservation concern. The family Muscicapidae exhibited the highest representation of 19 species, followed by Corvidae with 11 species. The high avian diversity observed in the park can be attributed to its diverse habitat types, ranging from mixed forests, coniferous forests to riverine areas and alpine meadows. Of the 127 species recorded, four are listed as 'Threatened' by the IUCN (Western Tragopan *Tragopan melanocephalus,* Cheer Pheasant *Catreus wallichii,* Mountain Hawk-Eagle *Nisaetus nipalensis* and Bearded Vulture *Gypaetus barbatus*). Increasing urbanisation and human encroachment into the park pose significant threats to the survival of key avian species. Illegal hunting, particularly of pheasants, warrants urgent conservation attention.

Keywords: birds, species richness, Kazinag National Park, Kashmir, Northwestern Himalaya

Összefoglalás A vizsgálatot India északnyugat-himalájai régiójának egyik jelentős védett területén, a Kazinag Nemzeti Parkban végezték 2023 márciusa és 2024 februárja között azzal a céllal, hogy átfogó madárfaj-felmérést végezzenek össze a park területéről. A terepi felmérések rendszeresen zajlottak a kora reggeli és késő délutáni órákban, amikor a madarak aktivitása a legintenzívebb. A madárfajok meghatározása terepi határozók, ornitológus szakértőkkel való konzultáció, valamint online források alapján történt. Az eredmények alapján összesen 127, 10 rendből és 35 családból származó madárfajt dokumentáltak, amelyek közül több természetvédelmi szempontból is jelentős. A legtöbb fajt a légykapófélék (Muscicapidae) családja képviselte 19 fajjal, ezt követték a varjúfélék (Corvidae) 11 fajjal. A nemzeti parkban tapasztalt magas fajgazdagság elsősorban az élőhelyek változatosságának tudható be, melyek a vegyes lombú és tűlevelű erdőktől a folyó menti élőhelyeken át a hegyi rétekig terjednek. A felmért 127 faj közül négy szerepel a Természetvédelmi Világszövetség (IUCN) veszélyeztetettségi listáján: nyugati tragopán *(Tragopan melanocephalus)*, bóbitás fácán *(Catreus wallichii)*, hegyi héjasas *(Nisaetus nipalensis)*, szakállas saskeselyű *(Gypaetus barbatus)*. A nemzeti parkot érintő fokozódó urbanizáció és emberi zavarás komoly fenyegetést jelent több kulcsfontosságú madárfaj fennmaradására nézve. A fácánfajok illegális vadászata különösen sürgős beavatkozást igényel.

Kulcsszavak: madarak, fajgazdagság, Kazinag Nemzeti Park, Kasmír, Himalája

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Introduction

Birds represent a well-known class of vertebrates that occur globally in nearly all habitat types (Sekercioglu 2006, Whelan *et al.* 2008). They are one of the most widely distributed and extensively studied taxa, owing to their ecological importance and sensitivity to environmental changes (Browder *et al.* 2002, Perrow & Davy 2002). Birds inhabit a vast array of environments, and occupy diverse ecological niches (Kahl *et al.* 2021), playing a significant role in biodiversity conservation and environmental monitoring (Chettri *et al.* 2001, Byju *et al.* 2024). As vital ecological indicators, their presence or absence often reflects the habitat quality and the overall health of an ecosystem (Piersma & Lindström 2004, Mahmood *et al.* 2021). Birds contribute immensely to ecosystem functioning by providing a multitude of essential ecosystem services. They function as long-range pollinators, scavengers, ecosystem engineers, and also as bio-control agents for a plethora of crop pests (Klein *et al.* 2007, Wenny *et al.* 2011, Malik & Sheikh 2020). Fluctuations in bird populations are closely linked to the ecological condition of an area, making them valuable bio-indicators for assessing the impacts of climate change (Loreau *et al.* 2001, Pearce *et al.* 2014).

The Union Territory (UT) of Jammu and Kashmir, nestled in the Northwestern Himalaya, hosts a remarkable bird diversity driven by its unique physiographic features and climatic conditions. Positioned at the junction of two bio-geographic realms (Oriental realm and Palearctic realm), the Jammu and Kashmir boasts a diverse and unique assemblage of bird species (Roberts 1991). The region lies within the West Himalayan Endemic Bird Area (EBA 128, Rahmani *et al.* 2012) and is home to 11 restricted range species (Stattersfield *et al.* 1998). Furthermore, it serves as an important migratory corridor for birds traveling from Central Asia and Eastern Europe into the Indian subcontinent, passing through Iran, Afghanistan, and Pakistan (Ali & Ripley 1983). Known for its rich bird diversity, the UT of Jammu and Kashmir contains 28 Important Bird and Biodiversity Areas (IBAs) (Islam & Rahmani 2004, Rahmani *et al.* 2012, Sohil & Sharma 2019).

The recent IUCN assessment has placed 32 bird species of Jammu and Kashmir under different threat categories (Suhail *et al.* 2020). Additionally, 25 more species have been Red Listed as Near Threatened (Kichloo *et al.* 2024). Seven species documented from Jammu and Kashmir – Cheer Pheasant *(Catreus wallichii)*, Western Tragopan *(Tragopan melanocephalus)*, White-throated Tit *(Aegithalos niveogularis)*, Kashmir Nuthatch *(Sitta cashmirensis)*, White-cheeked Nuthatch *(Sitta leucopsis)*, Orange Bullfinch *(Pyrrhula aurantiaca)* and Spectacled Finch *(Callacanthis burtoni)* – are endemic to the Western Himalayas (Praveen & Jayapal 2024).

The Indian avifaunal checklist currently recognizes 1,348 bird species, accounting for approximately 12% of the world's avian diversity (Praveen *et al.* 2019, Praveen & Jayapal 2022). Of these, nearly 80% of the Indian bird species are found in the Himalayas (Naithani & Bhat 2010). Birds inhabiting mountainous regions display distinct distribution patterns, with some species inhabiting lower altitudes and others adapted to higher elevation zones (Price *et al.* 2011). Their spatial distribution within an area is predominantly shaped by the availability and quality of food resources, and also by the presence of suitable roosting and

breeding sites (MacArthur & MacArthur 1961, Malik *et al.* 2023). Additionally, climatic factors such as temperature, humidity, and oxygen availability significantly influence species diversity and density, with mountain areas often showing higher species turnover and diversity at certain elevations (Graham *et al.* 2014).

Establishing baseline data is a fundamental prerequisite for understanding the impacts of habitat degradation and climate change on species and ecosystems, and for formulating effective conservation strategies (Llanos *et al.* 2011). Bird surveys play a crucial role in generating ecological insights, identifying priority conservation areas (Daniels *et al.* 1991, Peterson *et al.* 2000), evaluating ecosystem health, and informing management interventions (McComb *et al.* 2010, Fitzpatrick & Rodewald 2016). Biodiversity inventories and species checklists serve as essential repositories for documenting species distributions and conservation statuses. The Kazinag National Park (hereafter KNP), situated in the Northwestern Himalayan region of India, is celebrated for its rich biodiversity wealth, including a diverse assemblage of avian species. Despite its ecological significance, systematic information on the bird fauna of the park remains sparse. This study aims to address this knowledge gap by presenting a comprehensive avifaunal inventory of the KNP, intended to serve as a template for future ornithological research and conservation planning.

Materials and Methods

Study area

The KNP (34°10' N and 74°2' E), located in Baramulla district of Jammu and Kashmir, falls within the Northwestern Himalayan region of India. It has been designed by demarcating upper adjoining parts of three protected areas – Limber Wildlife Sanctuary, Lachipora Wildlife Sanctuary, and Naganari Conservation Reserve *(Figure 1)*. Covering an area of 89 km^2, the elevation of the park ranges from 2,500–4,500 m a.s.l (Lone *et al.* 2025). The park features a typical temperate climatic condition and the vegetation is primarily coniferous. Deodar cedar *(Cedrus deodara)* and Himalayan pine *(Pinus wallichiana)* dominate the lower reaches of the park whereas pindrow fir *(Abies pindrow)* and morinda spruce *(Picea smithiana)* are prevalent at middle elevations. The higher reaches are characterized by *Betul*a, *Juniper*, and *Acer* species. Alpine regions are dominated by meadows. The various habitat types found in the KNP include mixed forests, coniferous forests, broadleaved deciduous forests, riverine areas, alpine scrub, and alpine meadows.

The KNP is the only surviving place of the famous mountain goat – Markhor *(Capra falconeri)* in India. Besides Markhor, the notable fauna of the park includes Himalayan Goral *(Naemorhedus goral)*, Kashmir Musk Deer *(Moschus cupreus)*, Brown Bear *(Ursus arctos)*, Himalayan Black Bear *(Ursus thibetanus)*, Yellow-throated Marten *(Martes flavigula)*. The prominent avifaunal species include Himalayan Monal *(Lophophorus impejanus)*, Western Tragopan *(Tragopan melanocephalus)*, Himalayan Snowcock *(Tetraogallus himalayensis)*, Cheer Pheasant *(Catreus wallichii)*, Himalayan Griffon *(Gyps himalayensis)*, Bearded

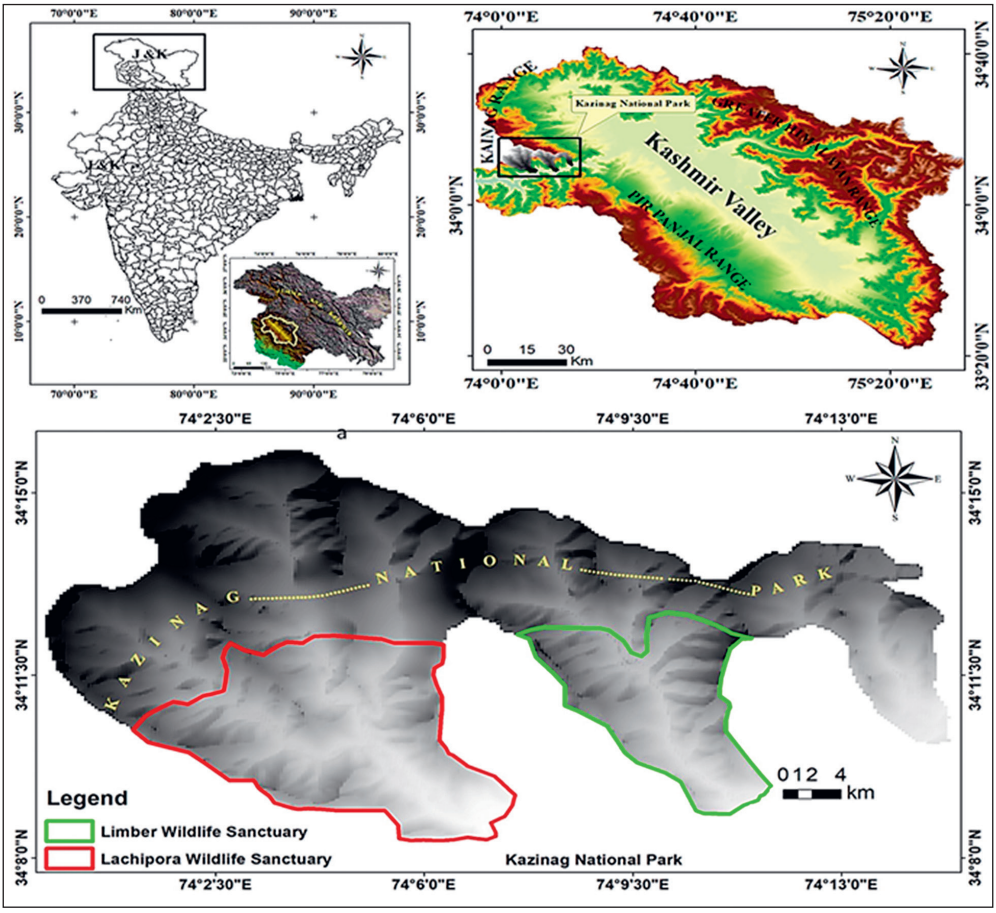


Figure 1. Map of the study area and adjoining areas
1. ábra A kutatási terület és a szomszédos területek térképe

Vulture *(Gypaetus barbatus)*, and White-crested Kalij Pheasant *(Lophura leucomelanos hamiltoni)*. The latter has been declared as the Union Territory (UT) bird of Jammu and Kashmir (Lone *et al.* 2024).

Data collection

The present study was undertaken in KNP from March 2023 to February 2024, for a period of one year. To develop a comprehensive checklist of the bird species, systematic field surveys were conducted in the early morning (7:00) and late afternoon (17:00) aligning with the birds' most active periods to maximise sightings (Thakur 2010). Fieldwork involved walking the transects and point counts. Additional data was collected from local birdwatchers to prepare the checklist. Field binoculars (Nikon 10 × 50) and digital camera (Nikon D-850 24 MP with 200–500 mm lens) were respectively employed for observing birds and taking photographs.

Identification of birds was done using standard field guides such as Ali and Ripley (1983) and Grimmett *et al.* (2016). Furthermore, avian experts, verified birding groups and clubs were also consulted for species validation (Sharma *et al.* 2018). The conservation status of the birds is provided according to the recent IUCN Red List (2024) and the categorisation of birds into 'Abundant' (A – sighted >30 times), 'Common' (C – sighted ≥15 times), 'Occasional' (O – sighted <10 times), and 'Rare' (R – sighted <5 times) was carried out following Quyoom *et al.* (2024).

Results

The present avifaunal survey of the KNP recorded a total of 127 bird species, belonging to 10 orders and 35 different families *(Table 1)*. Family Muscicapidae exhibited the highest number of species diversity comprising of 19 species, followed by Corvidae with 11 species. Accipitridae and Fringillidae each had nine species. Phasianidae was represented by eight species, while Paridae and Picidae had six species each. Four species – Western Tragopan, Cheer Pheasant, Mountain Hawk-Eagle *(Nisaetus nipalensis)* and Bearded Vulture – are Red Listed as 'Threatened' by the International Union for Conservation of Nature (IUCN). The study also revealed variations in species abundance, with some species being recorded frequently, while others were observed sporadically. Of the 127 species, 30 were abundant, 44 common, 42 occasional and 11 rare.

Discussion

The present avifaunal survey of the KNP recorded 127 bird species, distributed across 10 orders and 35 families, underscoring the park's significance as a key biodiversity hotspot in the Northwestern Himalaya. Such a good number is likely associated with the diverse habitat types present in the park, ranging from riverine ecosystems, coniferous forests, and broadleaved forests to alpine meadows. This habitat heterogeneity acts as the primary driver of rich avifaunal diversity, catering to the ecological requirements of a gamut of avian species (Price *et al.* 2011). The dominance of the Muscicapidae family, comprising 19 species, aligns with the previous findings in montane ecosystems where insectivorous passerines flourish due to diverse microhabitats and abundant prey availability (Singh *et al.* 1990, Price 2003, Quyoom *et al.* 2024). Additionally, the relatively high representation of Corvidae, Fringillidae, Accipitridae, and Phasianidae highlights the varied ecological niches present within the park, supporting both resident and migratory species.

Of the 592 bird species known from the Jammu and Kashmir (Kichloo *et al.* 2024), 127 birds – representing 21.45% – were reported from the KNP in our study. This number is much higher compared with other protected areas of the Kashmir Himalaya reflecting the park's immense potential for supporting bird species. For instance, Price *et al.* (2003) prepared a checklist of the Overa-Aru Sanctuary, and reported 70 species of birds from the sanctuary. Our findings closely match with the recent study carried by Quyoom *et al.* (2024)

Table 1. Comprehensive avifaunal checklist (IOC World Bird List) of the Kazinag National Park and adjoining areas

1. táblázat A Kazinagi Nemzeti Park és a szomszédos területek fajlistája

S. No.	Common name	Scientific name	IUCN Status	Abundance	Habitat
Order: Galliformes					
Family: Phasianidae					
1.	Western Tragopan	*Tragopan melanocephalus* (J. E. Gray, 1829)	VU	R	AS, BD
2.	Himalayan Monal	*Lophophorus impejanus* (Latham, 1790)	LC	C	BD, CF, AS
3.	Koklass Pheasant	*Pucrasia macrolopha* (R. P. Lesson, 1829)	LC	O	BD, CF,
4.	Cheer Pheasant	*Catreus wallichii* (Hardwicke, 1827)	VU	O	AS, RC, CF
5.	White-crested Kalij Pheasant	*Lophura leucomelanos hamiltoni* (J. E. Gray, 1829)	LC	O	CF, AL
6.	Himalayan Snowcock	*Tetraogallus himalayensis* (G. R. Gray, 1843)	LC	R	RC, AM, AS
7.	Chukar Partridge	*Alectoris chukar* (J. E. Gray, 1830)	LC	O	RC, AS
8.	Snow Partridge	*Lerwa lerwa* (Hodgson, 1833)	LC	R	AS
Order: Cuculiformes					
Family: Cuculidae					
9.	Jacobin Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	LC	R	BD, CF
10.	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	LC	O	CF, AL
11.	Common Cuckoo	*Cuculus canorus* (Linnaeus, 1758)	LC	C	BD, CF
Order: Columbiformes					
Family: Columbidae					
12.	Rock Dove	*Columba livia* (J. F. Gmelin, 1789)	LC	A	AL, CF
13.	Snow Pigeon	*Columba leuconota* (Vigors, 1831)	LC	O	RC
14.	Oriental Turtle Dove	*Streptopelia orientalis* (Latham, 1790)	LC	C	BD, CF
15.	Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky, 1838)	LC	O	BD, CF, AL
16.	Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)	LC	O	AL, BD, CF

S. No.	Common name	Scientific name	IUCN Status	Abundance	Habitat
Order: Accipitriformes					
Family: Accipitridae					
17.	Bearded Vulture	*Gypaetus barbatus* (Linnaeus, 1758)	NT	C	CF, RC, AM
18.	Himalayan Griffon Vulture	*Gyps himalayensis* (Hume, 1869)	LC	A	RC, CF, RA
19.	Mountain Hawk-eagle	*Nisaetus nipalensis* (Hodgson, 1836)	NT	O	CF, BD, RC
20.	Golden Eagle	*Aquila chrysaetos* (Linnaeus, 1758)	LC	C	AM, RC,
21.	Eurasian Sparrowhawk	*Accipiter nisus* (Linnaeus, 1758)	LC	O	CF, AL, RC
22.	Black Kite	*Milvus migrans* (Boddaert, 1783)	LC	A	CF, RC, AL
23.	Crested Honey Buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	LC	O	AL, CF
24.	Common Buzzard	*Buteo buteo* (Linnaeus, 1758)	LC	C	AL, BD, CF,
25.	Himalayan Buzzard	*Buteo refectus* (Portenko, 1935)	LC	C	BD, CF, AL
Order: Strigiformes					
Family: Strigidae					
26.	Asian Barred Owlet	*Glaucidium cuculoides* (Vigors, 1830)	LC	O	CF
Order: Bucerotiformes					
Family: Upupidae					
27.	Eurasian Hoopoe	*Upupa epops* (Linnaeus, 1758)	LC	A	AL
Order: Piciformes					
Family: Picidae					
28.	Speckled Piculet	*Picumnus innominatus* (E. Burton, 1836)	LC	R	CF, BD
29.	Brown-fronted Woodpecker	*Dendrocoptes auriceps* (Vigors, 1831)	LC	C	CF
30.	Himalayan Woodpecker	*Dendrocopos himalayensis* (Jardine & Selby, 1831)	LC	A	CF, AL
31.	Lesser Yellownape	*Picus chlorolophus* (Vieillot, 1818)	LC	O	CF, BD
32.	Scaly-bellied Woodpecker	*Picus squamatus* (Vigors, 1831)	LC	C	CF, AL
33.	Grey-headed Woodpecker	*Picus canus* (J. F. Gmelin, 1788)	LC	O	CF, AL
Family: Megalaimidae					
34.	Great Barbet	*Psilopogon virens* (Boddaert, 1783)	LC	C	CF, AL

S. No.	Common name	Scientific name	IUCN Status	Abundance	Habitat
Order: Falconiformes					
Family: Falconidae					
35.	Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	LC	O	AL, CF
Order: Psittaciformes					
Family: Psittaculidae					
36.	Slaty-headed Parakeet	*Psittacula himalayana* (R. P. Lesson, 1831)	LC	C	AL, CF
37.	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	LC	C	AL, CF
Order: Passeriformes					
Family: Aegithalidae					
38.	Black-throated Bushtit	*Aegithalos concinnus* (Gould, 1855)	LC	C	BD, CF, AS
39.	White-throated Bushtit	*Aegithalos niveogularis* (Gould, 1855)	LC	C	BD, CF, AS
Family: Campephagidae					
40.	Long-tailed Minivet	*Pericrocotus ethologus* (Bangs & Philips, 1914)	LC	C	CF, BD
Family: Certhiidae					
41.	Bar-tailed Treecreeper	*Certhia himalayana* (Vigors, 1832)	LC	C	CF, BD
Family: Cinclidae					
42.	Brown Dipper	*Cinclus pallasii* (Temminck, 1820)	LC	O	RA, AS
Family: Corvidae					
43.	Eurasian Jay	*Garrulus glandarius* (Linnaeus, 1758)	LC	O	BD, CF
44.	Black-headed Jay	*Garrulus lanceolatus* (Vigors, 1830)	LC	O	CF, BD, AL
45.	Yellow-billed Blue Magpie	*Urocissa flavirostris* (Blyth, 1846)	LC	A	CF, BD, AL
46.	Kashmir Nutcracker	*Nucifraga multipunctata* (Gould, 1849)	LC	O	CF
47.	Red-billed Chough	*Pyrrhocorax pyrrhocorax* (Linnaeus, 1758)	LC	C	AS, AM
48.	Alpine Chough	*Pyrrhocorax graculus* (Linnaeus, 1766)	LC	O	AS, AL, RC,
49.	Western Jackdaw	*Coloeus monedula* (Linnaeus, 1758)	LC	C	AL
50.	House Crow	*Corvus splendens* (Vieillot, 1817)	LC	A	AL, CF, RA
51.	Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	LC	A	AL, CF, BD

S. No.	Common name	Scientific name	IUCN Status	Abundance	Habitat
52.	Carrion Crow	*Corvus corone* (Linnaeus, 1758)	LC	C	AL, CF
53.	Northern Raven	*Corvus corax* (Linnaeus, 1758)	LC	C	CF, AL, RA
Family: Dicruridae					
54.	Ashy Drongo	*Dicrurus leucophaeus* (Vieillot, 1817)	LC	A	CF, AL
55.	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	LC	A	AL, CF
Family: Emberizidae					
56.	Crested Bunting	*Emberiza lathami* (J. E. Gray, 1831)	LC	O	CF, AS, AL
57.	Rock Bunting	*Emberiza cia* (Linnaeus, 1766)	LC	A	RC, AL
58.	Chestnut-eared Bunting	*Emberiza fucata* (Pallas, 1776)	LC	O	RC, CF
Family: Fringillidae					
59.	Eurasian Chaffinch	*Fringilla coelebs* (Linnaeus, 1758)	LC	R	CF, AL
60.	Black and Yellow Grosbeak	*Mycerobas icterioides* (Vigors, 1830)	LC	O	CF, AS
61.	White-winged Grosbeak	*Mycerobas carnipes* (Hodgson, 1836)	LC	O	AS
62.	Plain Mountain Finch	*Leucosticte nemoricola* (Hodgson, 1836)	LC	O	AS, CF, BD
63.	Common Rosefinch	*Carpodacus erythrinus* (Pallas, 1770)	LC	C	AL, AS
64.	Pink-browed Rosefinch	*Carpodacus rodochroa* (Vigors, 1831)	LC	O	AS, CF
65.	Yellow-breasted Greenfinch	*Chloris spinoides* (Vigors, 1831)	LC	C	AL
66.	European Goldfinch	*Carduelis carduelis* (Linnaeus, 1758)	LC	C	AL
67.	Red-fronted Serin	*Serinus pusillus* (Pallas, 1811)	LC	O	AL
Family: Hirundinidae					
68.	Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	LC	O	AL, RA
Family: Laniidae					
69.	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	LC	A	AL, AS
Family: Leiothrichidae					
70.	Streaked Laughing Thrush	*Trochalopteron lineatum* (Vigors, 1831)	LC	A	AL, CF
71.	Variegated Laughing Thrush	*Trochalopteron variegatum* (Vigors, 1831)	LC	A	AL, CF, BD

S. No.	Common name	Scientific name	IUCN Status	Abundance	Habitat
72.	Rufous Sibia	*Heterophasia capistrata* (Vigors, 1831)	LC	O	BD, CF
73.	Red-billed Leiothrix	*Leiothrix lutea* (Scopoli, 1786)	LC	O	BD, CF
Family: Monarchidae					
74.	Indian Paradise Flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)	LC	A	CF, AL
Family: Motacillidae					
75.	Western Yellow Wagtail	*Motacilla flava* (Linnaeus, 1758)	LC	C	RA
76.	Citrine Wagtail	*Motacilla citreola* (Pallas, 1776)	LC	O	RA
77.	Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	LC	C	RA
78.	White Wagtail	*Motacilla alba* (Linnaeus, 1758)	LC	C	RA
79.	Olive-backed Pipit	*Anthus hodgsoni* (Blackwelder, 1907)	LC	R	AS, AM
Family: Muscicapidae					
80.	Dark-sided Flycatcher	*Muscicapa sibirica* (J. F. Gmelin, 1789)	LC	R	AS, CF
81.	Verditer Flycatcher	*Eumyias thalassinus* (Swainson, 1838)	LC	C	AL, CF
82.	Bluethroat	*Luscinia svecia* (Linnaeus 1758)	LC	O	CF
83.	Himalayan Rubythroat	*Calliope pectoralis* (Gould, 1837)	LC	O	AS, CF
84.	Little Forktail	*Enicurus scouleri* (Vigors, 1832)	LC	C	RA
85.	Spotted Forktail	*Enicurus maculatus* (Vigors, 1831)	LC	C	RA
86.	Blue Whistling Thrush	*Myophonus caeruleus* (Scopoli, 1786)	LC	A	CF, RA
87.	Indian Blue Robin	*Larvivora brunnea* (Hodgson, 1837)	LC	R	CF, BD
88.	Ultramarine Flycatcher	*Ficedula superciliaris* (Jerdon, 1840)	LC	C	BD, CF
89.	Himalayan Bluetail	*Tarsiger rufilatus* (Hodgson, 1845)	LC	C	CF, BD
90.	Blue-fronted Redstart	*Phoenicurus frontalis* (Vigors, 1831)	LC	A	AS, RA
91.	Blue-capped Redstart	*Phoenicurus coeruleocephala* (Vigors, 1831)	LC	A	RA, CF
92.	Plumbeous Water Redstart	*Phoenicurus fuliginosus* (Vigors, 1831)	LC	A	RA
93.	White-capped Redstart	*Phoenicurus leucocephalus* (Vigors, 1831)	LC	C	RA

S. No.	Common name	Scientific name	IUCN Status	Abundance	Habitat
94.	Blue-capped Rock Thrush	*Monticola cinclorhyncha* (Vigors, 1831)	LC	R	CF, BD
95.	Blue Rock Thrush	*Monticola solitarius* (Linnaeus, 1758)	LC	C	RC, CF
96.	Chestnut-bellied Rock Thrush	*Monticola rufiventris* (Jardine & Selby, 1833)	LC	O	RC, CF
97.	Grey Bush Chat	*Saxicola ferreus* (J. E. Gray, 1847)	LC	A	CF, AL
98.	Siberian Stonechat	*Saxicola maurus* (Pallas, 1773)	LC	O	AL, CF, BD
Family: Oriolidae					
99.	Indian Golden Oriole	*Oriolus kundoo* (Sykes, 1832)	LC	C	CF
Family: Paridae					
100.	Rufous-naped Tit	*Periparus rufonuchalis* (Blyth, 1849)	LC	C	CF
101.	Rufous-vented Tit	*Periparus rubidiventris* (Blyth, 1847)	LC	C	CF, BD
102.	Coal Tit	*Periparus ater* (Linnaeus, 1758)	LC	A	CF, BD
103.	Cinerous Tit	*Parus cinereus* (Vieillot, 1818)	LC	A	CF, BD
104.	Green-backed Tit	*Parus monticolus* (Vigors, 1831)	LC	A	CF
105.	Himalayan Black-lored Tit	*Machlolophus xanthogenys* (Vigors, 1831)	LC	O	CF, BD
Family: Passeridae					
106.	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	LC	A	AL
107.	Russet Sparrow	*Passer cinnamomeus* (Gould, 1836)	LC	A	AL
Family: Phylloscopidae					
108.	Hume's Leaf Warbler	*Phylloscopus humei* (W. E. Brooks, 1878)	LC	A	CF, AS
109.	Western Crowned Warbler	*Phylloscopus occipitalis* (Blyth, 1845)	LC	C	CF
110.	Blyth's Leaf Warbler	*Phylloscopus reguloides* (Blyth, 1842)	LC	C	CF, BD
111.	Grey-hooded Warbler	*Phylloscopus xanthoschistos* (J. E. Gray & G. R. Gray, 1847)	LC	O	CF
Family: Prunellidae					
112.	Alpine Accentor	*Prunella collaris* (Scopoli, 1769)	LC	R	AS, AM
113.	Rufous-breasted Accentor	*Prunella strophiata* (Blyth, 1843)	LC	O	AS, BD

S. No.	Common name	Scientific name	IUCN Status	Abundance	Habitat
Family: Pycnonotidae					
114.	Black Bulbul	*Hypsipetes leucocephalus* (J. F. Gmelin, 1789)	LC	A	CF, AL
115.	Himalayan Bulbul	*Pycnonotus leucogenys* (J. E. Gray, 1835)	LC	A	CF, AL
Family: Sittidae					
116.	White-cheeked Nuthatch	*Sitta leucopsis* (Gould, 1850)	LC	C	CF, BD
117.	Kashmir Nuthatch	*Sitta cashmirensis* (Brooks, 1871)	LC	O	CF, BD
Family: Sturnidae					
118.	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	LC	C	AL, CF
119.	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	LC	A	AL
120.	Common Starling	*Sturnus vulgaris* (Linnaeus, 1758)	LC	C	AL, CF
Family: Tichodromidae					
121.	Wallcreeper	*Tichodroma muraria* (Linnaeus, 1766)	LC	O	RC, RA
Family: Troglodytidae					
122.	Eurasian Wren	*Troglodytes troglodytes* (Linnaeus, 1758)	LC	A	CF, BD
Family: Turdidae					
123.	Mistle Thrush	*Turdus viscivorus* (Linnaeus, 1758)	LC	C	CF, AS
124.	Common Blackbird	*Turdus merula* (Linnaeus, 1758)	LC	O	CF, RA
125.	Tickell's Thrush	*Turdus unicolor* (Tickell, 1833)	LC	C	BD, CF, RA
126.	Tibetan Blackbird	*Turdus maximus* (Seebohm, 1881)	LC	O	AS, CF
127.	Chestnut Thrush	*Turdus rubrocanus* (J. E. Gray, 1847)	LC	C	CF, BD

Abbreviations used: **A** – Abundant, **O** – Occasional, **C** – Common, **R** – Rare, **AL** – Agricultural land, **RA** – Riverine areas, **CF** – Coniferous forest, **BD –** Broadleaved deciduous, **AS** – Alpine scrub, **AM** – Alpine meadow

in the Bani Wildlife Sanctuary, a similar temperate landscape, in the Jammu division of Jammu and Kashmir. They compiled an avifaunal inventory of the sanctuary, identifying 135 bird species. This higher species count was attributed to the diverse habitat types and tree species present in the sanctuary, which offer optimal sites for feeding, nesting and breeding purposes. A more comprehensive and systematic study of birds in the future could potentially expand the current avifaunal inventory of the KNP.

Notably, several species of conservation importance were documented from this study. The presence of four IUCN Red Listed threatened species – Western Tragopan, Cheer Pheasant, Mountain Hawk-eagle and Bearded Vulture – reinforces the park's conservation importance. These species are sensitive to habitat fragmentation, anthropogenic disturbances and poaching, necessitating the need for immediate conservation intervention. The Western Tragopan, endemic to the Western Himalayas, is particularly vulnerable to habitat degradation caused by anthropogenic pressures, including livestock grazing and deforestation (Fuller & Garson 2000, Keane *et al.* 2005). Similarly, the Cheer Pheasant, a globally threatened species, faces threats from habitat fragmentation and hunting (Bhattacharya *et al.* 2007, Grimmett *et al.* 2016). The Bearded Vulture is a critical scavenger species that plays a vital role in maintaining ecosystem integrity. Its population decline in the Himalayas has been attributed to poisoning, food scarcity, and habitat loss (Virani *et al.* 2011).

Several studies have indicated that Himalayan bird communities exhibit altitudinal stratification, with different assemblages occupying specific elevation zones (Graham *et al.* 2014). Our findings corroborate this pattern, as high-altitude species such as Western Tragopan and Cheer Pheasant were restricted to montane forests, whereas lower and mid-elevation areas were dominated by Muscicapidae species. Seasonal variation in bird sightings was also evident, with greater species richness recorded during spring and summer compared to autumn and winter. These seasonal fluctuations in bird sightings are obviously due to alterations in food sources, weather conditions and habitat quality (Loiselle & Blake 1991, Norris & Marra 2007).

Despite covering only an area of 89 km^2, the KNP harbours five Himalayan pheasant species: Western Tragopan, Himalayan Monal, Cheer Pheasant, Koklass *(Pucrasia macrolopha)* and Kalij Pheasant. These species are globally known for their dwindling populations, driven by habitat loss, illegal hunting and climate-induced changes in their ranges. Their presence in the KNP suggests that the park provide crucial habitats for these taxa, making its protection vital for the survival of these species. However, these species face the highest risk of hunting pressure within the park. Among pheasants, the Kalij Pheasant is usually restricted to lower, human-dominated elevations of the park, where it experiences greater hunting pressure (Lone *et al.* 2025).

Given the presence of threatened species, alongside a diverse assemblage of avifaunal community, it is essential to prioritize conservation efforts in the KNP. To mitigate the potential threats, conservation priorities should focus on alleviating habitat degradation particularly in forest areas and curbing illegal hunting. Involving local communities in conservation efforts will prove helpful in protecting the park's biodiversity. Establishing regular bird monitoring programmes, to track changes in species diversity and population

trends, need to be organised especially in response to ongoing climate change. Additionally, long-term ecological monitoring and avian research focusing on breeding patterns, habitat preferences, and climate induced changes would enhance our understanding of the bird ecology of KNP.

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The occurrence of the Great Grey Shrike *(Lanius excubitor)* in Hungary, with special reference to the Csanádi-hát region

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Abstract The Great Grey Shrike *(Lanius excubitor)* is a regular breeding and overwintering species in Hungary. The nesting population is concentrated in a small part of the country, but during winter, it occurs countrywise. Despite this fact, only occasional reports of migration and wintering of this species can be found in the literature. The aim of our work was to collect the sporadic occurrence data published or collected by the BirdLife Hungary Monitoring Centre, and to determine an accurate occurrence period of the species in Hungary. In addition, we processed 240 field observation data from the area of the Csanádi-hát (SE Hungary) between 1991 and 2025. It was not possible to determine the most important wintering sites of the species based on the national-level observaion data, but it was possible to examine the temporal distribution of the data. Based on data from the last 130 years, the first individuals of the species typically arrived in Hungary in the second half of September, while in spring the last individuals left the country by the end of March – beginning of April. Earlier records in autumn and later records in spring are very rare, with observations at extreme times probably referring to nesting birds. Most individuals were seen during the autumn migration period in October–November, after which they overwintered in varying numbers from year to year, but its number typically declined gradually until late spring. The standard data available from the Csanádi-hát indicate that in some years, records were high, while in others, far fewer individuals were seen. This is probably due to the annual fluctuation of food and the different weather conditions in the breeding and wintering grounds year to year.

Keywords: Laniidae, Passeriformes, escape migration, winter visitors, Maros–Körös köze region, Tiszántúl, Great Hungarian Plain

Összefoglalás A nagy őrgébics *(Lanius excubitor)* rendszeres, kisszámú fészkelő és rendszeres téli vendég Magyarországon. A fészkelőállomány az ország kis részére koncentrálódik, télen viszont országszerte előfordul. Ennek ellenére a magyarországi szakirodalomban csak alkalmi közléseket találhatunk a faj vonulásáról és teleléséről. Munkánk célja az volt, hogy összegyűjtsük a szakirodalomban publikált szórványos előfordulási adatokat, illetve feldolgozzuk a Magyar Madártani és Természetvédelmi Egyesület Monitoring Központjának adatbázisát, és ezek alapján meghatározzuk a faj jellemző magyarországi előfordulási időszakait. Emellett feldolgoztunk 240 saját megfigyelési adatot is, amelyek a Csanádi-hát kistáj területéről származnak az 1991 és 2025 közötti időszakból. A faj országos megfigyelési adatai alapján nem volt lehetséges meghatározni a legfontosabb előfordulási helyeit, azonban az adatok időbeli eloszlását meg tudtuk vizsgálni. Az elmúlt közel 130 évből származó adatok alapján elmondható, hogy a faj első egyedei jellemzően szeptember második felében érkeztek Magyarországra, míg tavasszal az utolsók március végéig – április elejéig hagyták el az országot. Ősszel az ennél korábbi és tavasszal az ennél későbbi adatai nagyon ritkák, a szélsőséges időpontokban történt megfigyelések minden bizonnyal fészkelő madarakra vonatkoznak. A legtöbb példányt az október–novemberi őszi vonulási időszakban látták, ezt követően évenként változó mennyiségben telelt át, de jellemzően tavasz végéig fokozatosan csökkent a számuk. A Csanádi-hátról elérhető standard adatok alapján megállapítható, hogy bizonyos években kimagasló mennyiségben észleltük, míg máskor ennél jóval kevesebb példány jelent meg. Ennek oka valószínűleg az évenként eltérő időjárási körülmények, illetve a költő- és telelőterületeken az eltérő mennyiségben rendelkezésre álló táplálék lehet.

Kulcsszavak: gébicsfélék, énekesmadarak, vonulás, téli vendégek, Maros–Körös köze, Tiszántúl, Alföld

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Introduction

The Great Grey Shrike (*Lanius excubitor* Linnaeus, 1758) is a polytypic species with 12 subspecies, of which four subspecies are found in Europe. In western, central and north-eastern Europe, the nominate *L. e. excubitor*, in southeastern Europe and southwestern Siberia the *L. e. homeyeri*, in the Caspian Sea area and Kazakhstan the *L. e. pallidirostris*, and on the Canary Islands the *L. e. koenigi* occurs (Yosef *et al*. 2020). The latter two subspecies are resident, while the wintering grounds of individuals of the other two subspecies are located in the southern part of the breeding range (Panov 2011). Scandinavian birds migrate mainly southwestwards and winter in central Europe, but a few individuals have been found in the British Isles and Greece. Birds nesting in central Europe also show a southwesterly migratory direction (Spina *et al*. 2020). The largest populations are found in Norway, Sweden, Finland, Poland, Belarus and northern Ukraine, while in the other parts of Europe patchy populations can be found. In western Europe, a significant part of the population has disappeared in recent decades, while in the east and north, the population is increasing or stable, and the species has colonised new areas. Increasing intensification of agricultural cultivation may be behind the decline, which may also affect eastern populations in the future (Nijssen 2020).

It nests in open, tree-studded subarctic and low-cultivation agricultural areas rich in prey species (Yosef *et al*. 2020). Semi-open areas and mowed fields are found around its nest. It is particularly sensitive to habitat modification. In Hungary, it is increasingly found nesting in wooded pastures, mowed fields and extensively used ploughland, and is a regular winter visitor throughout the country, while individuals of the subspecies *L. e. homeyeri* have been observed twice (Hadarics & Zalai 2008, Lovászi 2021).

The first nesting of Great Grey Shrike in Hungary was detected in the Vas–Sopron Plain in 2000 (Hadarics 2008). From 2003, increasing number of nesters appeared in the Szatmári Plain, and in 2008 and 2011, it was detected in Nógrád County (Barna & Török 2013). According to Barna and Török (2013), these geographically distinct population were settled due to the dispersal of different (Austrian: Sachslehner *et al*. 2004, Slovakian: Kristin 1998, Romanian and Ukrainian: Barna & Török 2013) populations. Nowadays, it breeds in the Ipoly Valley, on the Szatmár–Beregi Plain, in the Nyírség, and in the northern part of the Berettyó–Körös Plain, in a total of 80–125 pairs (Lovászi 2021). The fragmented farmland structure, more extensive agriculture and sufficient prey may be the reasons for the high density of population in the Szatmár–Beregi Plain (Barna & Török 2013).

It builds its nests on solitary trees, bushes or hedges, forest edges, orchards. They may start building their nests very early, sometimes as early as the end of February, but this is usually not until March. They breed once a year, but may also make a replacement brood

(or even a second replacement brood). The main egg-laying period is April (Barna & Török 2013, Haraszthy 2019). The young birds do not return to their hatching site afterwards (Marcum & Yosef 1998).

The wintering birds sometimes appear as early as the end of August, but mainly arrive after mid-September (Hadarics & Zalai 2008, Török 2009, Lovászi 2021). The earliest ever autumn arrival of the Hortobágy was recorded on 10 September 1976. In a few cases, it occurred before mid-September, but the main period of arrival was between 19 and 23 September (Oláh & Kovács 2004). Their movements are strongest in October–November and January–February (Török 2009), but wintering in the Hortobágy is steady after the migration peak between 25 October and 3 November (Oláh & Kovács 2004). They winter in much smaller numbers in Hungary in milder winters (Török 2009), but the same is true when winters are extremely cold and snowy (Oláh & Kovács 2004). In the latter case, the amount of their avian prey increases and they sometimes even visit inhabited areas and bird feeders to hunt (Oláh & Kovács 2004). Numbers can be extremely high in years of vole gradations (Hadarics & Zalai 2008). Field observations suggest that birds may return to their wintering grounds for years (Oláh & Kovács 2004). They are usually seen solitarily, but flocks of a few (up to 110 abroad) have been observed (Oláh & Kovács 2004, Török 2009). Overwinterers typically leave the country by the end of March, but rarely in early April, exceptionally in mid-April, a few late individuals can be seen (Oláh & Kovács 2004, Török 2009, Lovászi 2021). Numbers increase in the Hortobágy after 10 February and remain so until 20 March (Oláh & Kovács 2004).

The origin of the birds that appear in Hungary is unknown due to a lack of recaptures, but they are likely to come from eastern Scandinavia, the Baltic, Poland, Russia and the Carpathians. Colour ring markings indicate that part of the local nesting population winters in Hungary (Török 2009).

Historical data indicate that not only its taxonomic position but also its distribution within the Carpathian Basin was disputed (Beretzk & Keve 1972). Csató (1884) mentioned the occurrence of *L. e. homeyeri* and *L. e. major* in Transylvania, in addition to the nominate race. He later wrote that *L. e. homeyeri* was breeding near Nagyenyed in 1889 (Csató 1891). Further investigations finally led to the result that only the breeding and occurrence of the nominate race was officially recognised in the Carpathian Basin (Schenk 1939). In Transylvania and Felvidék, it was a regular breeder (Schenk 1920), but within the present borders of Hungary, its nesting was not proven even in the early 1970s (Beretzk & Keve 1972). The greatest uncertainty about its movements within the year was caused by its similarity to the Lesser Grey Shrike *(L. minor)*. This questioned the reliability of the late summer-early autumn and late spring data. For this reason, Beretzk and Keve (1972) used only their own data from the area of Szeged and Lake Balaton in their first detailed study of the migration and wintering of the species in Hungary. They found that the birds arrived only rarely before October and were seen only once in Szeged in August. In spring, apart from one observation on 4 April, they left the wintering grounds until the end of March. The most important result of the study was that the occurrence of the subspecies *L. e. homeyeri* in Hungary was not confirmed in any case.

A few years later, Andrési (1988) assessed the national occurrence of the species based on 496 observations published in the journal of Madártani Tájékoztató between 1974 and 1982. These data showed that winter observations were made throughout the country, but while

53% of the data were from Transdanubia and 34% from the Great Hungarian Plain, a much smaller proportion (13%) was found in the Northern Mountains. In terms of the temporal distribution of observations, the birds were typically seen in September, but were rarely seen in July and August. Most records were from November. In spring, records in April and especially in May were exceptionally rare. There was considerable variation in the number of annual observations. However, it was stressed that the distribution of the monitoring network within the country and the steady increase in the number of observers meant that the results obtained did not necessarily give an accurate picture of the spatial and temporal distribution of the species.

Since Andrési (1988), only the northeastern Hungarian nesting has been studied in detail (Barna & Török 2013), summary evaluations of its migration have been published only in books (Hadarics & Zalai 2008, Török 2009, Lovászi 2021), and regional study has been published only for the Hortobágy region (Oláh & Kovács 2004).

In the present study, we investigated the autumn and spring migration and wintering of the species in the Csanádi-hát area in southeastern Hungary. We also analysed the national distribution of the species based on literature data and the dataset of the BirdLife Hungary Monitoring Centre.

Material and Methods

A total of 240 data come from the area of the Csanádi-hát region from 1991 to 2025, a geographic sub-region located in the southern part of the present-day Békés County *(Figure 1)*. Regular observations were made in three settlements, Battonya, Kevermes and Lőkösháza, while in the other settlements (Almáskamarás, Csanádapáca, Dombegyház, Dombiratos, Elek, Kaszaper, Kisdombegyház, Kunágota, Magyarbánhegyes, Magyardombegyház, Medgyesbodzás, Medgyesegyháza, Mezőhegyes, Mezőkovácsháza, Nagybánhegyes, Nagykamarás, Pusztaottlaka, Végegyháza), we recorded occurrences mainly along the busier roads and railway lines.

Nowadays, the area is dominated by farmlands, which typically accounts for around 90% of the total area with the exception of a few more forested settlements, such as Mezőhegyes (Hevesi 2005). Woody-shrubby habitats can be found along the banks of the Száraz-ér river, along artificial drainage channels and mine lakes, and in populated areas (Bozó 2018). Of particular importance for the Great Grey Shrike are the power lines, which often run alongside roads. Sightings in Battonya, Kevermes and Lőkösháza were mainly made on foot or by bicycle using binoculars, while elsewhere sightings were mainly made from cars, buses and trains, often without the use of binoculars. In all cases, only the data of clearly identified individuals were recorded. In any case, the occurrence time of the two species do not overlap in the area.

Data are available for Battonya from 1991, Kevermes from 2002 and Lőkösháza from 2010. Regular, standard field surveys started in Battonya in 2009 and in Kevermes and Lőkösháza in 2012. Since then, the number of days spent in the field annually has remained roughly constant in all three settlements. For this reason, only data from 2012 onwards

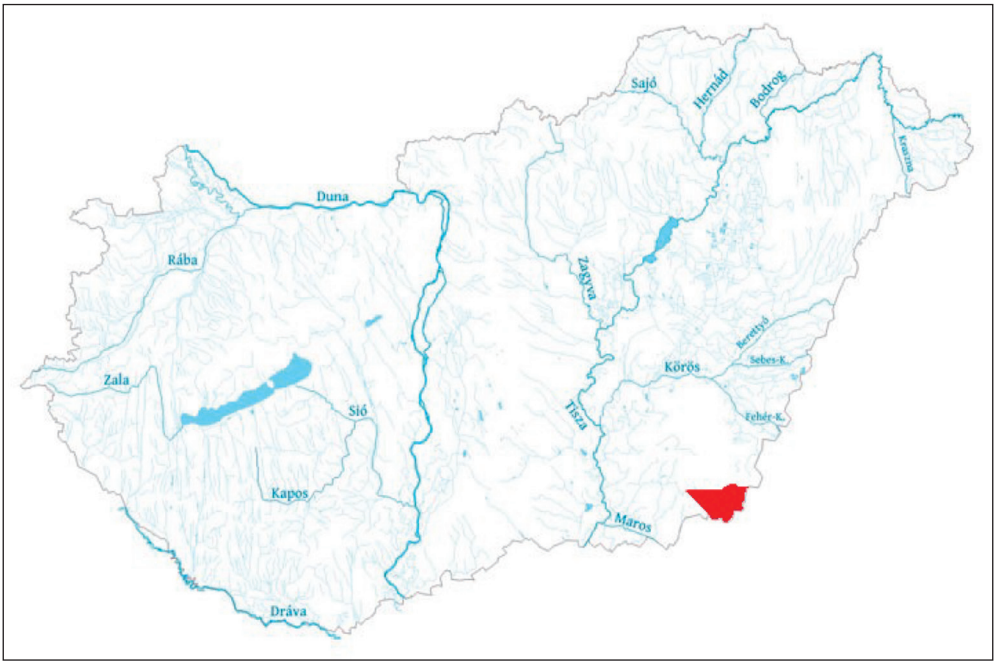


Figure 1. The location of the Csanádi-hát region within Hungary
1. ábra A Csanádi-hát elhelyezkedése Magyarországon

were used when we analysed the number of annual observations, ten-day intervals, the length of the seasons as well as the earliest and latest observations. In Kevermes, undated observations are known for the winter of 2002–2003. These have not been included in the data analysis and data counts, but because of their importance, some of these sightings have been mentioned in the context of the more interesting observations of the species.

We first looked at the distribution of the data between years and then within years in ten-days intervals. To do this, the data were plotted. In order to evaluate the results obtained, we used literature data to determine the spring (15 February – 15 April) and autumn (1 August – 30 November) migration periods and the wintering period (1 December – 15 February). We calculated the median date of observations for the whole database and also gave the earliest ever and seasonally earliest autumn and latest spring data. The latter could be determined for the period starting from 2013. Weather data (average monthly minimum temperature) for four seasons between 2016 and 2020 were also available from Dombegyház, Nyéki-major meteorological station in the Csanádi-hát. We examined whether there was a significant relationship between temperature data and the length of season between the 2016–2017 and the 2019–2020 seasons by using Spearman correlation. We also wanted to see if there was a relationship between the date of seasonal first observations and the lenght of the season. We have also published the more interesting observations concerning birds singing, bird predation and highlighted the occurrences in the interior areas of the villages and cities.

National observational data reported in the literature were then processed. The national data are mainly from three periods.

1. 1914–1927. 58 records from this period with exact dates and locations were found in the spring migration reports of the journal Aquila, and 11 wintering records were also published there (Schenk 1915, 1919, 1921, Warga 1922, 1924, 1926, 1928). Unfortunately, unlike other migratory species, no records of the Great Grey Shrike were collected between 1894 and 1914, and only a few data were provided by later reporters. Similar to the data for the Csanádi-hát region, these data are presented by year and by month within a year. In this case, the ten-day assessment was not used due to the low sample size.

2. 1974–1982. 496 record from this period is known. The data published in the journal Madártani Tájékoztató have already been processed by Andrési (1988). He summarised the data in a table, while we – as before – presented the information in graphs by year and by month within the year. Some early summer and late spring occurrences are also included in the database.

3. 1996–2000. The journal Túzok published 2,510 data on the species for each month between 1 January 1996 and 31 October 2000 (except for the three months between 1 November 1999 and 31 January 2000) (Hadarics 1996a, 1996b, 1996c, 1996d, 1997a, 1997b, 1997c, 1997d, 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d, 2000a, 2000b, 2000c, 2000d). Within-year comparisons were only possible for the three years between 1996 and 1998 due to missing data. Within-year, the data are presented in ten-day periods. Data from 1 January to 31 January are from 1996 to 1999, data from 1 February to 31 October are from 1996 to 2000, and data from 1 November to 31 December are from 1996 to 1998.

Finally, data from the BirdLife Hungary Monitoring Centre for the period 2000–2024 were also processed. As the methodology and geographical distribution of the data collection raised several issues (occasional observations linked to certain survey days distort the results, separation of breeding birds from non-breeding birds), the available data were selected according to the following criteria. The counties (Borsod-Abaúj-Zemplén, Győr-Moson-Sopron, Hajdú-Bihar, Heves, Nógrád, Pest, Szabolcs-Szatmár-Bereg) where the species was confirmed to breed were not included. Also, occasional data uploads were not taken into account, only data from complete species lists were used. This resulted in a total of 2,418 observations. There was an unusal peak in the second decade of January, which was an artificial product of increased field activity due to the annual bird of prey counts. For this reason, we decided to remove these data from the figure, and used the average number of observations of the first and the third decades of January.

Results

Data from the Csanádi-hát region

Between the 2012–2013 and 2024–2025 seasons (n = 209), the lowest number of observations was in 2014–2015 (n = 2), while the highest number (n = 30) was in 2018–2019 *(Figure 2)*.

Since 1991, the earliest autumn observation is from 20 September 2024 from the Tompapuszta grassland in Battonya, while the latest spring observation is from 30 March 2008 from the Vajda-dűlő area in Battonya.

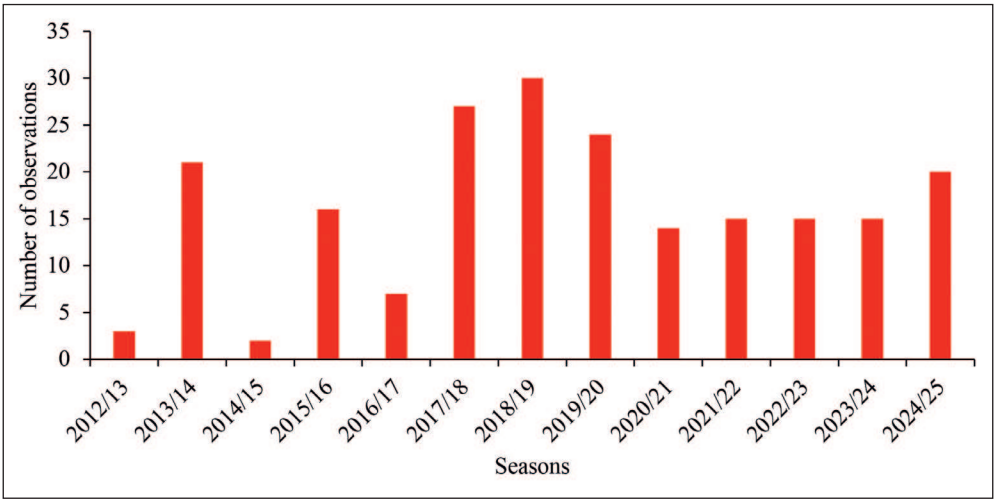


Figure 2. Number of seasonal observations between 2012–2013 and 2024–2025 in the Csanádi-hát region

2. ábra A szezononkénti megfigyelések száma 2012–2013 és 2024–2025 között a Csanádi-háton

The ten-day distribution of the data from 1991 shows that the first individuals rarely arrived in the region as early as the last third of September. After a small peak in mid-October, the number of sightings then fell again at the end of November. The number of records then fluctuated throughout the winter. Most sightings were recorded in mid-February. It was still regularly observed in early March, but after that it was extremely rare *(Figure 3)*.

Between the 2012–2013 and 2024–2025 seasons, an average of 138 days (SD = 19.8 days) passed between the first and the last observations of the given season *(Table 1)*. The results are

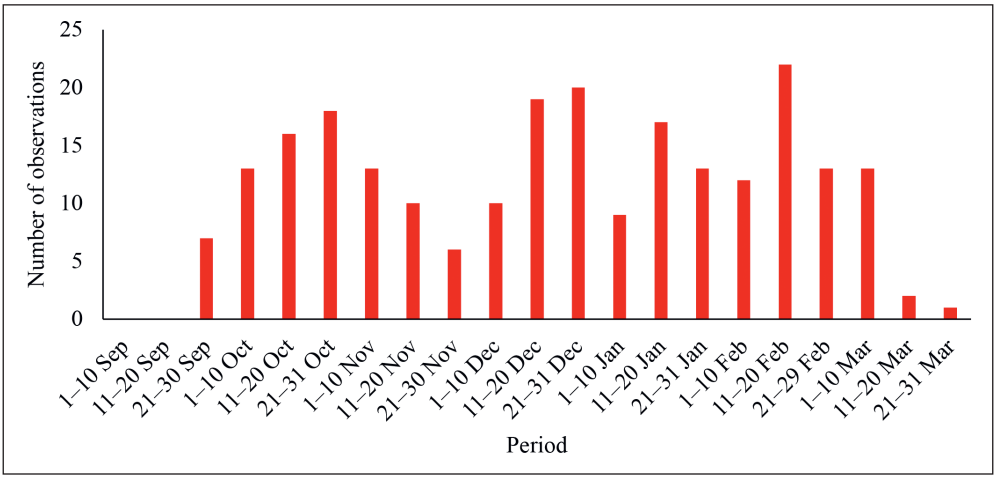


Figure 3. Ten-day distribution of the Great Grey Shrike observations in the Csanádi-hát region between 1 September and 31 March

3. ábra A nagyőrgébics-megfigyelések tíznapos eloszlása a Csanádi-háton szeptember 1. és március 31. között

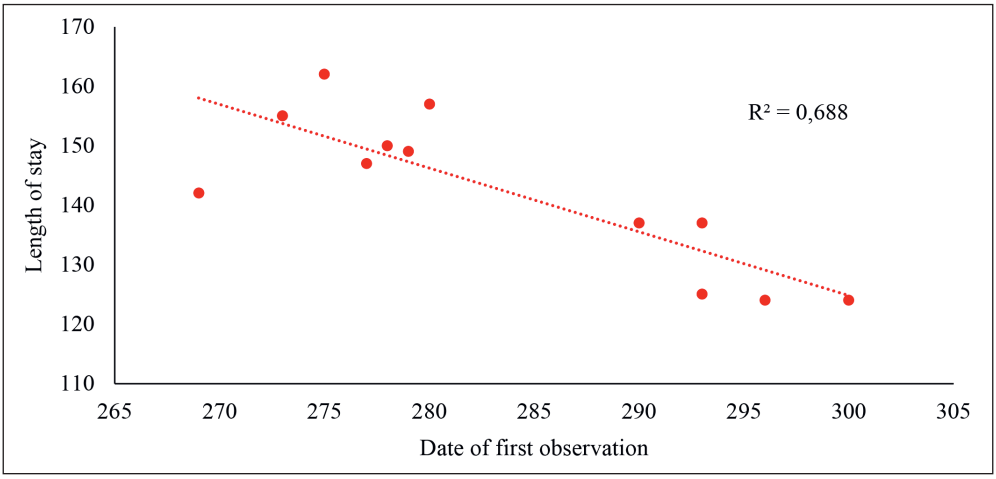


Figure 4. Relationship between the date of seasonal first observations and days spent between the seasonal first and last observations

4. ábra A szezonális első megfigyelések és az első és utolsó megfigyelések között eltelt idő közötti összefüggés

significantly skewed by the 2012–2013 season, when the last observation was extremely early, on 29 December. Apart from this, the average number of days spent in the area was 142 (SD = 13.2 days). On average, the first individuals appeared on 9 October (SD = 11.3 days) and the last individuals disappeared on 2 March (SD = 6.6 days), excluding the extremely early departure date of the 2012–2013 season. There was a significant negative correlation between the date of seasonal first observations and days spent between the seasonal first and last observations ($R = -0.739$, $p = 0.006$) *(Figure 4)*. However, the average monthly minimum temperatures between October and March did not affect the length of the season as well as there was no significant correlation between the date of first observations and the length of the season ($R = -0.093$, $p = 0.671$).

Considered all data from 1991, in most observations

Table 1. The earliest and latest observations by seasons, and the number of days spent in the Csanádi-hát region

1. táblázat A szezonkénti legkorábbi és legkésőbbi megfigyelések időpontjai, illetve a Csanádi-háton töltött napok száma

Season	Date of first observation	Date of last observation	Period that the birds spent in the area
2012/13	3 October	29 December	87
2013/14	4 October	1 March	147
2014/15	20 October	7 March	137
2015/16	30 September	5 March	155
2016/17	23 October	25 February	124
2017/18	27 October	1 March	124
2018/19	17 October	4 March	137
2019/20	5 October	5 March	150
2020/21	20 October	23 February	125
2021/22	7 October	14 March	157
2022/23	26 September	16 February	142
2023/24	6 October	5 March	149
2024/25	20 September	2 March	162

(224 cases; 93.3%), a single individual, and in 14 cases (5.8%) two individuals were seen in the same area. Three individuals were observed on two occasions (0.8%), on 20 October 2014 and 14 October 2024 in Kevermes.

In the interiors, it was recorded in Battonya (the western edge of the town) on 27 February 2016 and in Kevermes in the winter of 2002–2003. In the latter winter, due to thick snow cover and prolonged cold weather, solitary birds or 2–3 individuals were regularly observed in the village. In one case, we also recorded the predation of Eurasian Tree Sparrow *(Passer montanus)* in the cemetery of Kevermes.

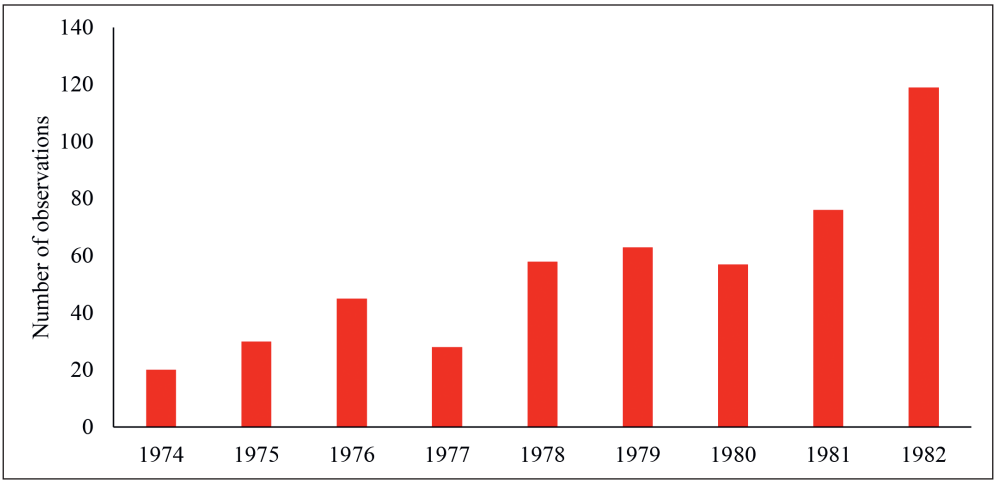


Figure 5. Annual number of Great Grey Shrike observations published between 1974 and 1982 in Hungary

5. ábra A szakirodalomban közölt nagyőrgébics-megfigyelések éves mennyisége 1974 és 1982 között Magyarországon

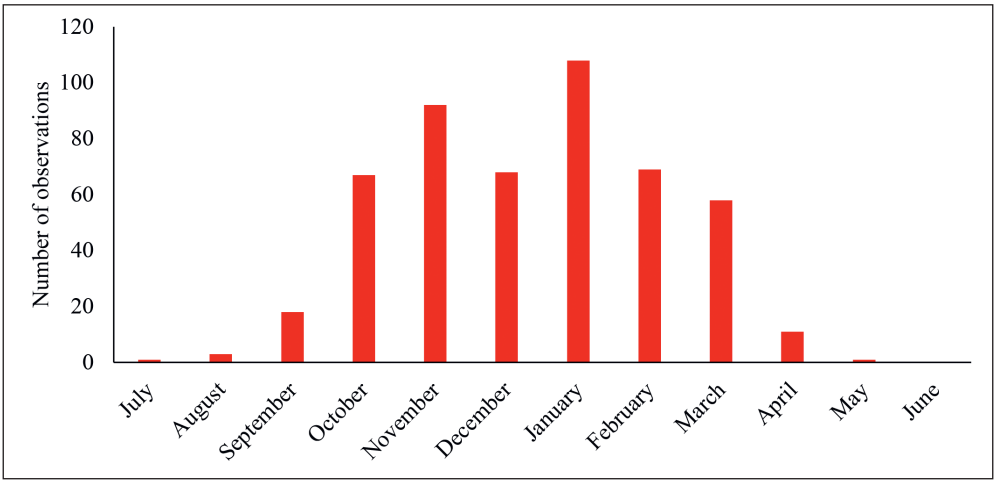


Figure 6. Monthly distribution of the Great Grey Shrike observations between 1974 and 1982 in Hungary

6. ábra A nagyőrgébics-megfigyelések havi eloszlása 1974 és 1982 között Magyarországon

Singing birds were observed in Battonya on 16 January 2019, in Kevermes on 2 November 2011, 2 November 2018 and 4 November 2022.

Carpathian Basin data between 1914 and 1927

In terms of the distribution of the data between years, the highest number of data was from 1926 (n = 15), while no records were available from 1920. However, the data collection was random during this period.

Within a season, the earliest autumn observation was on 11 September 1926 and the latest spring observation on 23 May 1914. It was very rare in September, but birds were regularly seen in October, and then fluctuated in numbers throughout the winter. There was a new peak in March, after which it became rare again. The observations in Szombathely on 2 May 1914, in Tarnaméra on 23 May 1914 and in Eperjes (Prešov) on 8 May 1918 could all have been of nesting birds, but also of Lesser Grey Shrikes. Except for these, the latest, and most definite Great Grey Shrike sighting was in Budapest on 14 April 1925.

Data for Hungary between 1974 and 1982

In terms of the distribution of data between years, the highest number of data came from 1982 (n = 119), while the lowest number of data (n = 20) came from 1974 *(Figure 5)*.

Most observations within year were made in November and January. Apart from some very early summer sightings, the first individuals appeared in September, but the species was only seen in greater numbers in October. Again, only small numbers were seen in April *(Figure 6)*.

Of the occurrences defined as late spring by Andrési (1988), only two stand out from the data (29 April 1980 Gyirmót and 15 May 1982 Kiskunfélegyháza), while the summer occurrences (26 July 1980 Tokod; 2 August 1976 Nyírtelek; 5 August 1978 Polgár; 9 August 1980 Császárszállás) are really interesting.

Observations between 1996 and 2000

Between 1996 and 2000, a total of 2,464 observations were reported, of which 665 observations were from 1996, 592 fom 1997, 487 from 1998, 392 from 1999 and 328 from 2000.

Apart from a few summer occurrences, the number of observations started to increase in the second half of September and peaked in October. Thereafter, it was recorded in constant numbers until March. By April it was rare *(Figure 5)*.

Great Grey Shrike observations between 2000 and 2024 (BirdLife Hungary Monitoring Centre data)

Between the 2015–2016 and 2023–2024 seasons (n = 2,018), the lowest number of observations was in 2018–2019 (n = 149), while the highest number (n = 295) was in 2020–2021 *(Figure 8)*.

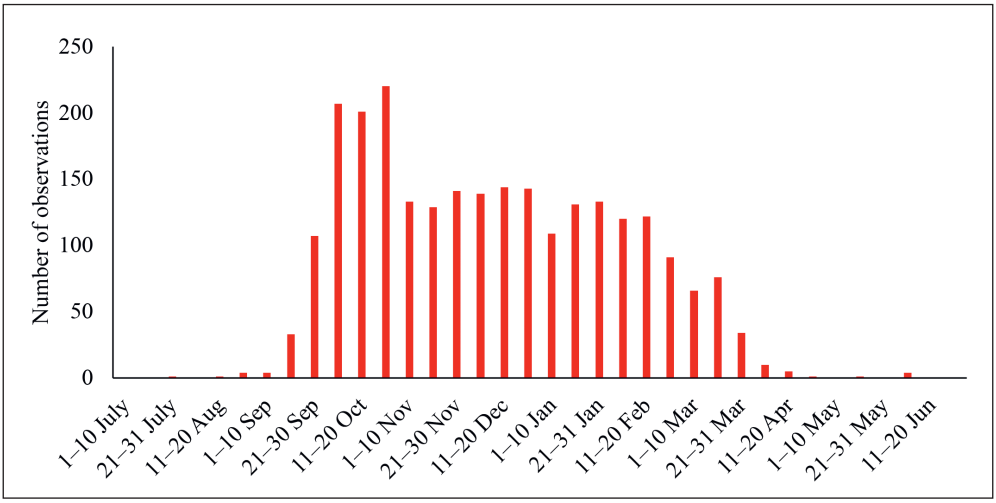


Figure 7. Ten-day distribution of the Great Grey Shrike observations published in Hungary between 1996 and 2000

7. ábra A szakirodalomban közölt nagyőrgébics-megfigyelések tíznapos eloszlása a Magyarországon 1996 és 2000 között

The first individuals were typically observed in mid-September. By mid-October, the number of sightings had reached the level that was typical throughout the winter. There was a peak in late-October. The number of sightings started to decrease in the second half of February and the species was quite rare by the end of March. There is also three sightings

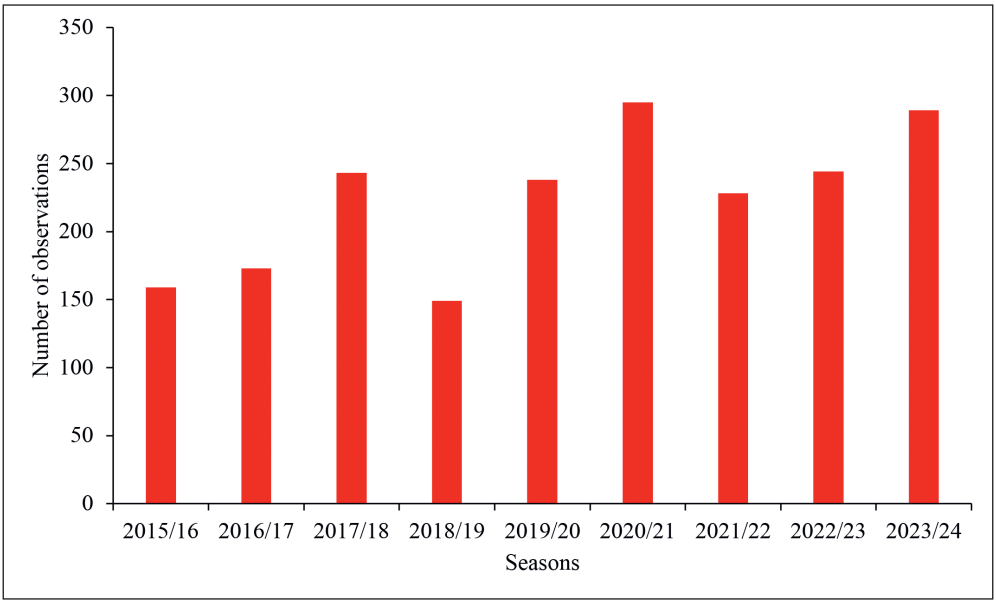


Figure 8. Number of seasonal observations between 2015–2016 and 2023–2024 in Hungary

8. ábra A szezononkénti megfigyelések száma 2015–2016 és 2023–2024 között Magyarországon

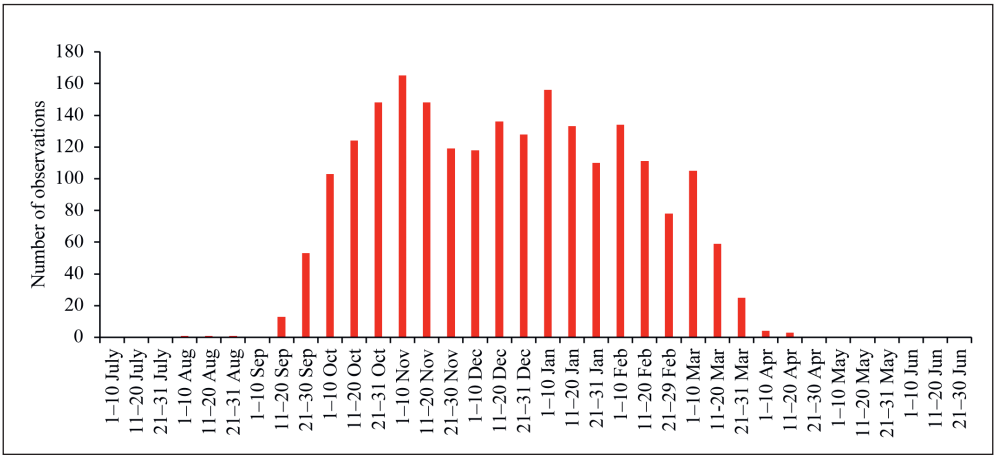


Figure 9. Ten-day distribution of the Great Grey Shrike observations based on the dataset of the BirdLife Hungary Monitoring Centre

9. ábra A nagyőrgébics-megfigyelések tíznapos eloszlása a Magyar Madártani és Természetvédelmi Egyesület Monitoring Központjának adatbázisa alapján 2000 és 2024 között

in August (earliest: 7 August 2006, Szatymaz, Csongrád-Csanád County) and seven in April (latest: 16 April 2015, Vértestolna, Komárom-Esztergom County) *(Figure 9)*.

In 92.9% of the cases, 1, 6.0% 2, 1.0% 3 individuals were observed, and there were two data when 4 birds were observed in one UTM quadrat.

Discussion

According to the data we have processed, the Great Grey Shrike was a regular winter visitor to Hungary in all periods in the last century, and occasionally in small numbers, it was a rare breeder. National data collection was not standard even in the years when the Hungarian Ornithological Centre and later BirdLife Hungary/MME were expecting data from observers on the occurrence of migratory birds and rarer, scattered species. At the beginning of the 20th century, this was because they were mainly interested in the spring return of birds, and the Great Grey Shrike was not a migratory species in the classical sense. The data started to increase after the First World War, when it became important to clarify questions about the bird life of the Carpathian Basin, including the status of the Great Grey Shrike. The main problem with the observations from 1970 to 1980 and from 1996 to 2000 is that the spatial distribution of the data is random from year to year, with only one Great Grey Shrike observation from some sites and several years from others. Comparison of data between years does not give a realistic picture of the true status of the species. For this reason, the difference in the number of data between years could only be evaluated for the Csanádi-hát region. In this region, the number of observations was much higher than average in some years and much lower in others. The number of observations was particularly high in 2015, but the situation was probably similar in the winter of 2001–2002.

The number of Great Grey Shrikes away from nesting sites is related to the weather, and they are also conspicuously abundant during the gradation years of the Common Vole *(Microtus arvalis)* (Oláh & Kovács 2004). In both periods were cold winters, and in 2001–2002 the landscape was covered with the thickest snow cover in decades. Observations (presence in the interior areas, bird predation, movements in flocks) that were otherwise uncharacteristic were also made during this period. Bird predation has been observed by several authors (Bod 1901, Nozdroviczky 1907, Rácz 1907, Vasvári 1942, Bechtold 1977, Radetzky 1919, Bank 1985, Wágner 1999), and in exceptional cases even bats (Gorman 1997). They were also rare in the Hortobágy in inhabited areas, and even then they only moved to the outskirts of settlements (Oláh & Kovács 2004), which is confirmed by our own observations in the Chanádi-hát region. The occurrence in flocks was also considered exceptional (Oláh & Kovács 2004).

The timing of the first birds' appearance and the last birds' departure is broadly similar in each period and in different parts of the country. In autumn, the first individuals were typically observed from mid-September onwards. Sightings in August are likely to be of Lesser Grey Shrikes, possibly members of the local breeding population. In the Hortobágy, where the species also did not breed, the earliest sighting was on 10 September 1976, but they only appeared in greater numbers in the last third of the month (Oláh & Kovács 2004). A similar pattern is also typical of the Csanádi-hát region, but here, the first individuals arrived even later. Sightings were high at all periods during the migration periods in October and March, as in other parts of the country, but were typically most frequent in winter. In March, sightings were quite rare on the Csanádi-hát region, and there were no records at all in April, although they were still regularly observed throughout the country at that time. It is possible that the birds that appeared here came from areas to the north of the Carpathian Basin, and therefore, arrived later in the autumn due to the longer migration route, leaving earlier in spring.

The early autumn arrival resulted in a later spring departure, but this did not depend on the local weather. Additionally, earlier arrival did not resulted longer season. For this reason, it is likely that the movement of the species is mainly influenced by the weather at the breeding sites.

The possibility of confusion with the Lesser Grey Shrike is often not completely ruled out, so the use of summer data is severely limited. It is, however, striking that between May and August, Great Grey Shrikes were observed mainly in western, northwestern and northeastern Hungary and in the Kiskunság region. In those regions – with the exception of the Kiskunság – where there was evidence of nesting later (Lovászi 2021), it cannot be excluded that it was already nested in the first decades of the 20th century.

We have not been able to quantify the numbers, but it seems that the timing of the occurrence of the species has not changed over the last century. According to Busse (1995), a decline and fluctuation in the abundance of migratory birds in Europe was already detectable from the mid-20th century, but this probably did not significantly affect the timing of bird migration.

It is also not proven, but it is likely that individuals may overwinter in a given area and return there years later (Oláh & Kovács 2004). This is supported by our observations of singing individuals. Three quarters of these observations occurred in early November, when the birds were occupying their winter territories and protecting them with territorial song.

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Breeding range expansion of White Storks *(Ciconia ciconia)* in the Algerian Sahara: Adaptation to hot hyper-arid environments

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Abstract The breeding population of the White Stork in Algeria has historically been confined to the northern part of the country. During the 2025 breeding season (February to June), confirmed nesting occurred in El Oued (2 nests), Ouled Djellal (1 nest), and Menea (1 breeding attempt in 2003) provinces. The observed Southward expansion of the White Stork breeding population into the hot and hyper-arid climate of the Sahara represents a notable ecological shift in its known breeding range. Moreover, old datasets and historical records further indicate significant expansions of migratory flyways into southeastern Saharan regions. These findings highlight the White Storks' adaptability to climate change and anthropogenic pressures under extreme aridity conditions, but also underscore the rapid ecological transformations occurring under climate change and human activity. They emphasized the critical role of Saharan ecosystems in providing foraging resources and optimal nesting sites for this resilient population.

Keywords: climate change, migration, avifauna, nesting success, phenology, wetland

Összefoglalás A fehér gólya algériai költőpopulációja történelmileg az ország északi részére korlátozódott. A 2025-ös költési időszak alatt (február–június) bizonyított fészkelés történt El Oued (2 fészek), Ouled Djellal (1 fészek) és Menea (1 költési kísérlet 2003-ban) tartományokban. A fehér gólya költőpopulációjának megfigyelt déli irányú terjeszkedése a Szahara forró és rendkívül száraz éghajlatába jelentős ökológiai változást jelent ismert költési területén. Ezen kívül régi adatbázisok és történelmi feljegyzések további jelentős vonulási útvonal-bővüléseket jeleznek a délkeleti szaharai régiókba. Ezek a megállapítások kiemelik a fehér gólyák alkalmazkodóképességét az éghajlatváltozáshoz és az antropogén nyomásokhoz szélsőséges szárazság körülményei között, ugyanakkor rámutatnak a gyors ökológiai átalakulásokra, amelyek az éghajlatváltozás és az emberi tevékenység hatására zajlanak. Kiemelték a szaharai ökoszisztémák kritikus szerepét a táplálkozási erőforrások és optimális fészkelőhelyek biztosításában ezen ellenálló populáció számára.

Kulcsszavak: éghajlatváltozás, vonulás, madárvilág, fészkelési siker, fenológia, vizes élőhely

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Introduction

Climate is a fundamental determinant controlling the spatial distribution of biodiversity (Pecl *et al.* 2017). Climate change manifests in shifting rainfall and temperature patterns (Coumou & Rahmstorf 2012, Robinson *et al.* 2021), profoundly impacting life on Earth (Khezzani 2021). They are intensifying other simultaneous anthropogenic threats to wildlife, like habitat loss and land use alteration, thereby amplifying the challenges confronted by species and their ecosystems (Kim & Weaver 1994, Greening *et al.* 2025). These changes cause degradations in habitats and geographical redistribution for many animal species (Stocker *et al.* 2014, Pecl *et al.* 2017), imposing them to change their distribution ranges by migrating to newly suitable climatic habitats (Koufaki *et al.* 2024). Avifauna, mainly migratory birds, are influenced by environmental conditions across their distribution ranges (Arizaga *et al.* 2006). These species exhibit high vulnerability to habitat modifications (Thongsoulin *et al.* 2019) and their phenological patterns are shifting in response to climate change (McDermott & DeGroote 2017). Consequently, populations of migratory birds with limited adaptive capacity or those failing to exhibit behavioral plasticity in response to shifting ecological factors are declining and augmenting their extinction risk (Møller *et al.* 2008). Long-distance migrant birds, including trans-African migratory, appear to be more susceptible to climate change (Both & Visser 2001, Both *et al.* 2010). Undoubtedly, avian species, particularly waterbirds, serve as good bioindicators of environmental and ecosystem health in the context of climate change, urbanization and anthropogenic modifications (Gregory & Strien 2010, Bensizerara *et al.* 2013).

Algeria is a vast North African country encompasses a bioclimatic gradient from the Mediterranean coastline to hyper arid Saharan zones, where rainfall values increase from west to east (longitudinal gradient) and from north to south (latitudinal gradient) (Bouaoune & Dahmani-Megrerouche 2010, Chenchouni *et al.* 2025). This geographic location within the Palearctic region's migration network establishes the country as a critical role in the trans-Saharan migrations interconnecting between Eurasia and tropical Africa and an important habitat for 406 migratory and sedentary birds (Isenmann & Molai 2000).

Recent ornithological studies in the Saharan region, particularly in the northeastern Algerian Sahara, has revealed that these regions, with their oasis and wetlands, function as essential sites for maintaining both resident and migratory avian species (Farhi & Belhamra 2012, Guezoul *et al.* 2013, Chedad *et al*. 2023a). Consequently, new observation of several bird taxa across Saharan regions (Chedad *et al.* 2022b, 2023b, Bouzid *et al.* 2023a), and shifting in wintering or breeding geographical distribution of other species have documented (Chedad *et al.* 2022a, 2022b, 2022c, 2023c, 2023d, Bouzid *et al.* 2023b, 2023c, Gueddoul *et al.* 2024). Nevertheless, significant knowledge gaps persist regarding the ecology of Algerian avifauna, particularly for waterbirds, where there are deficiencies in data on population status, seasonal migration dynamics, current range distribution and habitat use (Samraoui & Samraoui 2008).

Urban growth patterns significantly influence the functioning of ecological systems in local and global Earth, offering appropriate foraging and nesting habitats for many bird species globally (Alberti 2005, Mainwaring 2015). The White Stork *(Ciconia ciconia)*, is a

long-distance, trans-African migratory bird breeding in a variety of habitats across Europe and North Africa, and wintering in sub-Saharan regions (BirdLife International 2024). They exhibited a feeding strategy adapted to severe conditions of aridity and anthropogenic landscapes, and phenological flexibility in breeding ground arrival times in response to climate change across its migratory range (Ptaszyk *et al.* 2003, Chenchouni 2017, Athamnia *et al.* 2022). Their nesting, particularly the success of reproduction is influenced by the quality of habitat (Moali-Grine *et al.* 2013).

The present research investigates the ecological situation of the White Stork in Algeria, with a focus on its first nesting success in hot hyper-arid environments, evaluating its resilience to harsh climatic conditions in the northeastern Saharan region, and providing updated range distribution data for Algerian White Stork breeding populations.

Nest monitoring and data collection

The study was conducted during 2024 and 2025 in El Oued province, locally known by Oued Souf located in Northeastern Algerian Sahara *(Figure 1)*. The region has a hyper-arid climate characterized by hot and dry summers and mild winters (Barkat *et al.* 2023).

In late breeding period (June) 2024, we documented the nest of White Stork for the first time. To assess their breeding success, a monitoring of the nest was conducted during the subsequent breeding season, from February 2025 to July 2025. We employed direct counts for flocks under 200 individuals and visual estimation for larger or distant groups (Blondel 1975).

Breeding success is determined by counting the number of fledglings standing on the nest and able to fly. Additional insights have been provided through interviews with citizens and farmers inhabiting in areas adjacent to the nesting site.

We mapped the recent range expansion of the White Stork in Algeria by integrating the known geographic distribution from BirdLife International (2016), studies reported on White Stork nesting beyond historical breeding limits (Farhi 2014, Zoubiri *et al.* 2018), and species presence records in Algeria during the period 1962–2025, with geographical coordinates obtained from observations by international network members in the Global Biodiversity Information Facility database (GBIF.org 2025).

Results

During international census of migratory waterbirds in Algeria (January 2024), we have observed important flock of White Storks in El Oued province (estimated at 350 individuals), using wetlands, waste discharges and agricultural zones as foraging and stopover sites during its migratory passage across the Sahara. Individuals (5–10) remain during the breeding period, were observed in urban wetland "Chott El Oued" and wastewater treatment plant of Kouinine.

During the 2025 season, we confirmed successful breeding of the White Stork in the northeastern part of Algerian Sahara *(Figure 2A)*. The nest was built on a mobile phone pole at the top of the communication antenna *(Figure 2B)*, in an urbanized area in El Oued province, northeastern Algerian Sahara (33°23'33.72" N, 6°52'5.33" E, alt.: 68 m). Potential

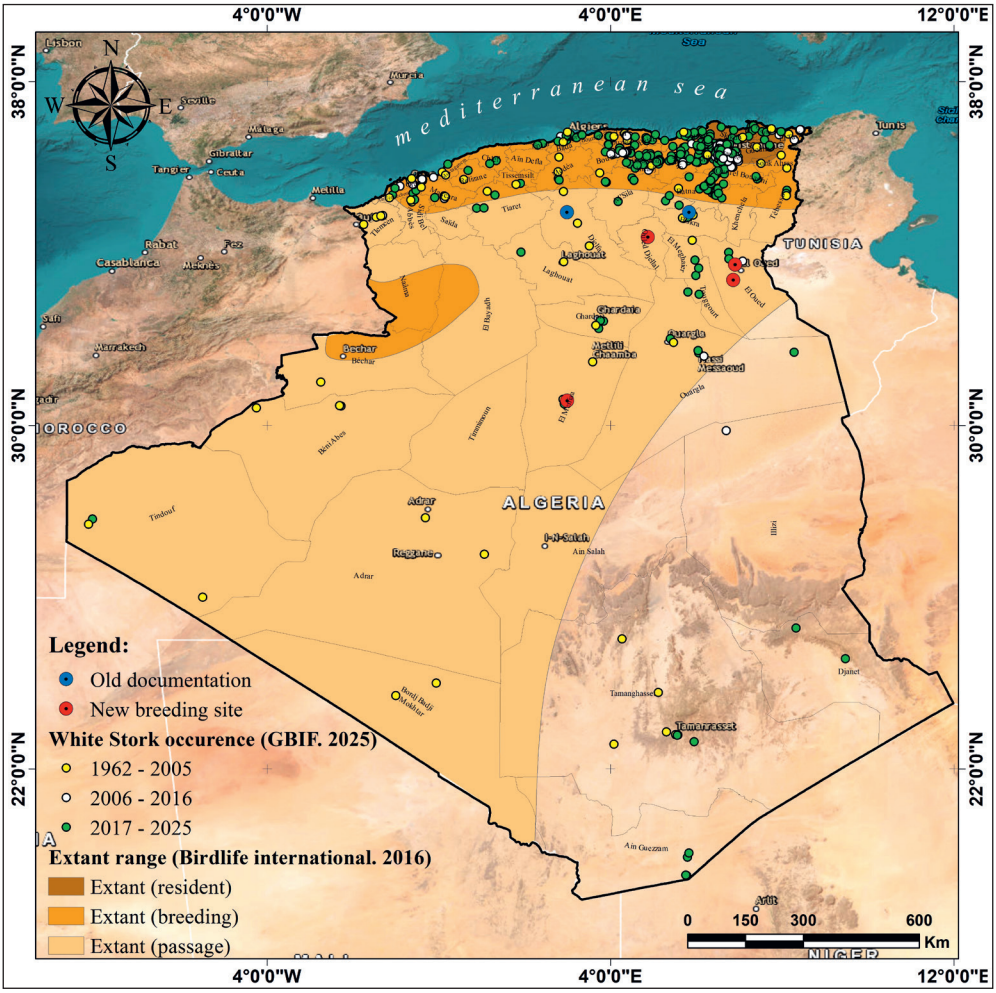


Figure 1. Geographical situation of the new breeding site in El Oued province, Northeastern Sahara and known and new range of White Stork in Algeria

1. ábra Az új költőhely földrajzi helyzete El Oued tartományban (Északkelet-Szahara), és a fehér gólya ismert és új elterjedési területe Algériában

feeding areas near the nest included Chott El Oued, a natural urban wetland located 900 meters away, the Kouinine wastewater treatment plant located 3.5 kilometers from the nest, and the Oued El Alenda public waste disposal site 11 kilometers away.

The arrival of the pair on its nest (nest occupancy confirmed) was in mid-February (15 February), and the start of incubation began in late-March (observed on 21 March). The increase in adult activity began on 13 April, indicating the hatching of eggs. The appearance of two juveniles, with black flight feathers indicated successful breeding *(Figure 2C)*. Fledging took place on 10 June 2025, all the juveniles fledged steadily and the nest was completely vacated over the following days (successful fledging). In addition, a second nest was observed on a high-voltage electricity pylon (33°44'41.91" N, 6°54'28.94" E, alt.: 10 m)

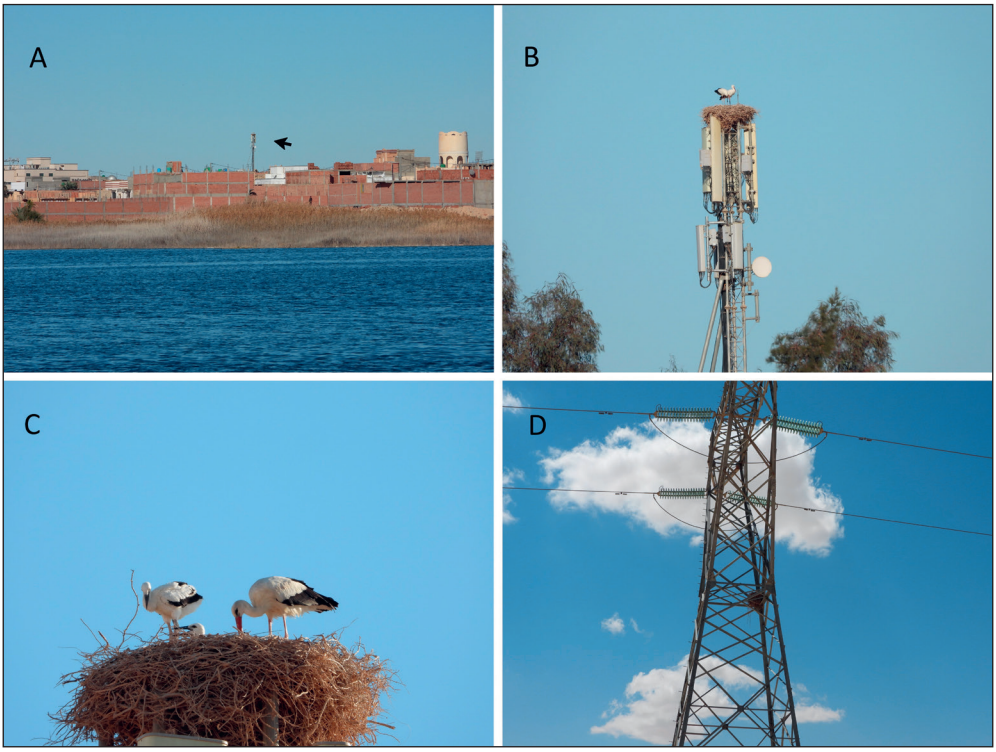


Figure 2. Nesting site in urban habitat near urban wetland chott El Oued (A), nest on a mobile phone base station (B), adult with two juveniles (C), nest on a high-voltage electricity pylon (D)

2. ábra Fészkelőhely városi élőhelyen a Chott El Oued közeli vizes élőhelynél (A), fészekrakó hely mobiltelefon bázisállomáson (B), felnőtt példány két fiókával (C), fészek nagyfeszültségű távvezeték oszlopán (D)

near an artificial wetland namely Chott E'Dhiba wastewater outlet *(Figure 2D)*, although it remained incomplete. The nest was located 4 km from the Chott E'Dhiba wastewater outlet, 11 km from agricultural areas, and 19 km from the Hassi Khalifa public waste disposal site.

Our findings were supported by a confirmed successful nesting case during 2025 breeding season in Ouled Djellal province, representing westernmost of our study area (5°3'53.81" E, 34°25'30.28" N, alt.: 194 m) and an old breeding attempt since 2003 documented in Menea province in southwest of our study area (2°55'0.20" E, 34°25'17.86" N, alt.: 371 m). All these sites situated in northeastern part of Algerian Sahara.

Discussion

White Stork breeding distribution in Algeria follows a bioclimatic gradient from Mediterranean coastal plains (Tell region) through semi-arid regions (High Plateaus) to the extreme border of Northern Sahara, when two pair observed during the census in 1993 in Biskra (Isenmann & Molai 2000). In 2008, seven breeding pairs were documented by Farhi (2014) in some

regions in Biskra province (El Kantra, Biskra, Lioua and Saada). National censuses were conducted since 1995 to 2007 as part of a project to study avian population dynamics in Algeria (Moali-Grine 2007, Moali-Grine *et al.* 2013). These surveys focused on quantifying breeding populations of White Stork across their distribution range, highlighted a substantial growth in Algerian population size and increasing gradient of their abundance from west to east with higher densities recorded in eastern regions, which are primarily influenced by climatic conditions, and anthropogenic pressures affecting their breeding habitat quality. These demographic trends are driven not only by migratory breeding populations but also by the expansion of resident breeders (local population), given the significant range-wide population increase recorded in recent years (Moali-Grine 2007, Thomsen & Brust 2025).

As a synanthropic species exploiting human-altered ecosystems for nesting and opportunistic feeder while maintaining wild population dynamics. Algerian White Storks demonstrate facultative habitat plasticity, employing both natural (wetlands, floodplains), and anthropogenic (irrigated farmlands, landfills) sites as foraging grounds, and adopting available artificial structures in urban or suburban areas (rooftops, electricity poles, pylons, mobile phone base stations) as nesting supports, owing to the decrease of natural nesting structure (Moali-Grine *et al.* 2013, Si Bachir *et al.* 2013, Benharzallah *et al.* 2015, Mammeria *et al.* 2019, Babouri *et al.* 2020, Soualah *et al.* 2021, Sakraoui *et al.* 2023).

The frequency of these feeding areas varied seasonally and directly correlated to the abundance and the reproductive phenology of prey species (Boukhemza *et al.* 2006). The diversity of prey in White Stork diets decreased significantly with increasing aridity, showing higher richness in sub-humid and semi-arid climates compared to arid regions defined by low productivity (Chenchouni 2017). The White Stork exhibits a highly opportunistic feeding strategy, adapting its diet to environmental constraints by foraging across diverse habitats, including waste discharges, to secure a stable food supply. This flexibility allows the species to balance prey abundance and diversity, ensuring nutritional adequacy despite challenges such as climatic aridity and anthropogenic pressures (Chenchouni *et al.* 2015). The dietary composition analysis reveals a large trophic spectrum, which the invertebrates dominate the diet in terms of the number of individuals consumed (mostly arthropod insects), and at the same time, scavenged chicken remains from landfills and small mammals (mainly rodents) predominate in terms of biomass and energy (Cheriak *et al.* 2014, Chenchouni 2017). Landfills offer a consistent resource and easy accessibility to food sources for both resident and migratory birds, including the White Stork, throughout the year (Soualah *et al.* 2021).

The important flock of White Stork reported in our study area represent the return of wintering populations from tropical Africa to Eurasia and North Africa breeding grounds. This post-wintering storks are crossing the Sahara during December, January, and February through the significant flyway migration along eastern Algeria via Menea, Ain Salah, Arak and Tamanrasset (Isenmann & Molai 2000). The El Oued region in the northeastern Sahara located within this trajectory. They feature diverse categories of land use, including irrigated farmlands and pastoral lands, expanding urbanization with anthropogenic pressures and both natural and artificial wetlands. These landscape alterations have made our region a new suitable habitat for the distribution range of a variety of species and stopover for migrant White Stork populations.

The documented breeding success of White Storks in a new breeding range represents a significant latitudinal range expansion into the south of the known distribution limit in Algeria, by approximately 220 km compared to previous records in Biskra and an adaptation to the hot and hyper-arid conditions of Saharan ecosystems. However, a systematic survey across all Saharan regions in Algeria during the breeding season, especially those that sustain suitable nesting features for White Storks, would fill significant gaps in our understanding of White Stork population dynamics and their geographical distribution in these poor environments. Furthermore, these ecological significances contribute to updating the breeding distribution range of White Storks in Algeria and Northwest Africa. This expansion of breeding range are mentioned by Azafzaf (2002) in Tunisia from northwest to east and south.

Recently, Algerian Saharan regions (particularly the study area) have experienced rapid agricultural transformation characterized by the development of irrigated crops through the exploitation of groundwater (Ouendeno 2019, Djouhri *et al.* 2023). The population in the Souf region has depended on groundwater resources for their needs and activities, particularly agriculture. The unsustainable extraction of groundwater resources by intensive irrigation practices have driven a rising water phenomenon, that has affected densely populated localities, notably El Oued, El Bayadha and Kouinine (Diaf *et al.* 2024). Consequently, several water bodies have emerged in these urban areas such as Chott El Oued. Moreover, artificial wetlands were established, encompassing wastewater treatment plants and final wastewater outfalls like Chott E'Dhiba. In addition, numerous legal or illegal landfills were established around urban sites, as a result of the growth of human activities (mostly greater is the public discharges in Oued El Alenda). These anthropogenic modified habitats support significant biodiversity such as small mammals (rodents) and insects (Selmane & Benslama 2015, Selmane *et al.* 2016, Alia *et al.* 2025), and serve as a foraging, wintering or breeding habitats for several bird species (Guezoul *et al.* 2013, Gueddoul *et al.* 2024). Consequently, these local key habitat features support White Stork populations and directly affect their reproductive success by providing both diversified foraging resources and optimal nesting opportunities. Generally, bird species exhibited varied responses to recent environmental changes, some rapidly changed their ecological needs, while others preserved stable niches. These patterns were partially predictable based on the physical and behavioral characteristics of species, underscoring how biodiversity adapts to global change (Avidad *et al.* 2025).

Undoubtedly, the reproductive success of the White Stork in the northeastern Algerian Sahara offers new insights into the geographical distribution of species and reveals a significant southward range expansion than its traditional breeding range. Our findings underscore the critical role of both natural and artificial habitats, especially wetlands in sustaining migratory bird populations across the Sahara. In addition, suggests adaptive responses to climate change and increasing resilience to extreme desert conditions.

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Ornis Hungarica 2025. 33(2): 357–379.
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So far undetermined Middle Miocene (Badenian) bird fossils from the Mátraszőlős 3 site (Nógrád county), Part II. (Ardeidae, Scolopacidae, Columbidae, Apodidae, Picidae, Strigidae and Passeriformes)

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Abstract This article is a continuation of the previous article (Horváth 2023. Description of representatives of the family Phasianidae from Mátraszőlős 3 (Nógrád county, Hungary) by means of recent finds of Badenian age – Ornis Hungarica: DOI: 10.2478/orhu-2023-0024), which also presents the new finds from the Mátraszőlős 3 site. In the previous article, 4 extinct taxa of the order Galliformes, including the family Phasianidae, were described, while in the sequel members of the families Ardeidae, Scolopacidae, Columbidae, Strigidae, Apodidae, Picidae, and members of the order Passeriformes, Alaudidae, Hirundinidae, Sittidae, Muscicapidae, Turdidae, Prunellidae, Laniidae, Sturnidae, Fringillidae and Emberizidae, are described. This article discusses the identification of 58 bone fragments.

Keywords: Mátraszőlős 3, Middle Miocene, fossil birds, Hungary

Összefoglalás A cikk folytatása a korábbi cikknek (Horváth 2023. Description of representatives of the family Phasianidae from Mátraszőlős 3 (Nógrád county, Hungary) by means of recent finds of Badenian age – Ornis Hungarica: DOI: 10.2478/orhu-2023-0024), amely szintén a Mátraszőlős 3-as lelőhelyről előkerült újabb leleteket mutatja be. A korábbi cikkben a Galliformes rend, azon belül is a Phasianidae család 4 kihalt taxonja került bemutatásra, míg a folytatásban az alábbi családok tagjai kerültek meghatározásra: Ardeidae, Scolopacidae, Columbidae, Strigidae, Apodidae, Picidae, valamint a Passeriformes rend tagjai közül pedig az Alaudidae, Hirundinidae, Sittidae, Muscicapidae, Turdidae, Prunellidae, Laniidae, Sturnidae, Fringillidae és Emberizidae. Jelen cikk 58 csonttöredék azonosítását tárgyalja.

Kulcsszavak: Mátraszőlős 3, középső miocén, fosszilis madarak, Magyarország

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Introduction

The village of Mátraszőlős is located in the south-eastern part of Nógrád County, in the Zagyva valley. The village and its surroundings are well known in both geological and palaeontological literature. Three sites have been excavated in the vicinity of the village, but only the one marked with the number 3 will be of importance for this article, the Mátraszőlős 1 and 2 sites are described in the previous article (Horváth 2023):

Mátraszőlős (3): The swan species *Cygnopterus neogradensis* Kessler *et* Hír, 2009, and the material of *Paleolodus ambiguus /crassipes* Milne-Edwards, 1863, *Tadorna minor* Kessler *et* Hír, 2012; Anatidae gen. *et* sp. indet, *Miocorvus larteti* Milne-Edwards, 1871, *Turdicus minor* Kessler *et* Hír, 2012; Aves indet. also originate from here (Kessler & Hír 2009, 2012 a, b). The species list indicates a typical wetland area, in whose coastal zone the small crow and thrush may have lived. The waterbirds all indicate highly typical habitats: both the swan and the little flamingo, as well as the shoveler. All three of these materials are in the possession of the Municipal Museum of Pásztó.

Abbreviations: MN6-MN8 – Middle Miocene; †-extinct/fossil species-subspecies; A-total lengths; B-partial lengths; C-breadth of proximal epiphysis; D-thickness of proximal epiphysis; E-breadth of diaphysis; E1-partial breadth of diaphysis; F-breadth of distal epiphysis; G-thickness of distal epiphysis; H-height of distal epiphysis.

Anatomical terminology: after Lambrecht (1933), Baumel *et al.* (1979), Gilbert *et al.* (1981), Kessler (2013)

Systematics

Ord. Ardeiformes (Wagler, 1830)
Fam. Ardeidae Vigors, 1825
***Ixobrychus* Billberg, 1828**
cf. *Ixobrychus* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 right *humerus* proximal fragment *(Figure 1/1–2)*; 1 left *carpometacarpus* distal fragment *(Figure 1/3–4.)*.

Dimensions (in mm): *humerus*: B-7.53, C-8.68, D-4.18, E-2.54; *carpometacarpus*: E-1.86, F-3.65, G-2.36.

Main anatomical characters: *humerus*: *caput humeri* asymmetrically rounded, *tuberculum ventrale* prominent, *crista bicipitalis* truncate, rounded. Distal edge of *crista bicipitalis* flatly curved, *fossa pneumotricipitalis* divided. The *carpometacarpus*: *facies articularis digitalis majoris* has an undulating shape and the *syntiosis* is low. In terms of bone size and anatomy, it is clearly a member of the heron family (Ardeidae).

Comparative material: *Ixobrychus minutus* (L. 1766) *(Figure 1/5–8)*.

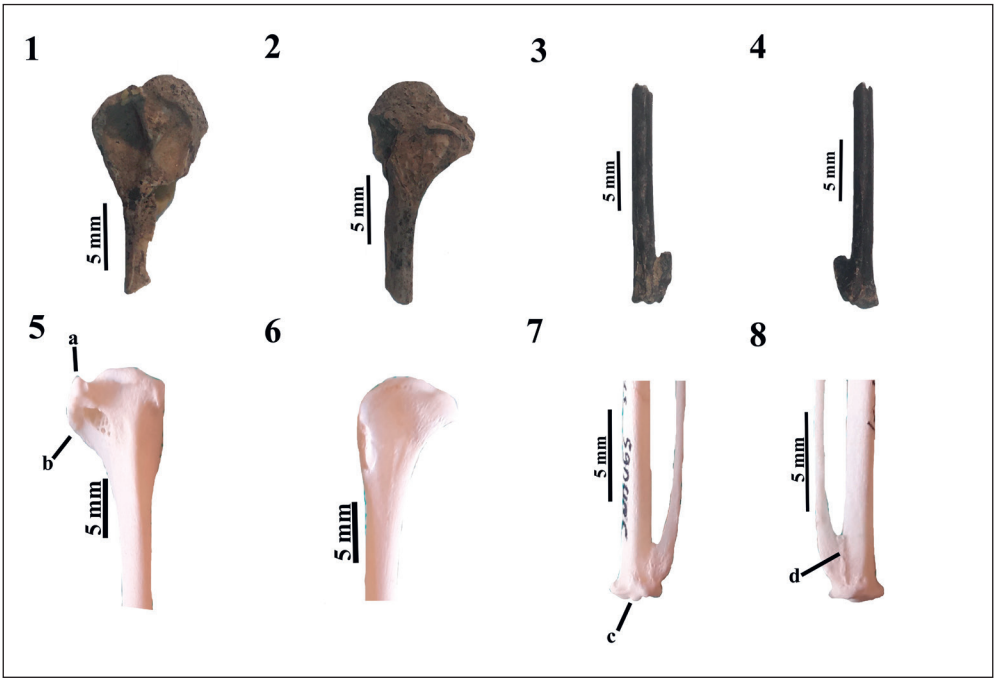


Figure 1. *Ixobrychus* sp. n. – Mátraszőlős 3. 1- right *humerus*, proximal end, caudal view; 2 – right *humerus*, proximal end, cranial view; 3 – left *carpometacarpus*, distal end; ventral view; 4 – left *carpometacarpus*, distal end; dorsal view; 5 – *Ixobrychus minutus* (L. 1766) right *humerus*, distal end, caudal view; a. *tuberculum ventrale*; b. *crista bicipitalis*; 6 – *Ixobrychus minutus* (L. 1766) right *humerus*, proximal end, cranial view; 7 – *Ixobrychus minutus* (L. 1766) left *carpometacarpus*, proximal end; ventral view; c – *facies articularis digitalis minor*; 8 – *Ixobrychus minutus* (L. 1766) left *carpometacarpus*, distal end; d – *synostosis metacarpalis distalis*

1. ábra *Ixobrychus* sp. n. – Mátraszőlős 3. 1 – jobboldali felkarcsont, proximális vég, caudális nézet; 2 – jobboldali felkarcsont, proximális vég, craniális nézet; 3 – baloldali kézközépcsont, disztális vég; ventrális nézet; 4 – baloldali kézközépcsont, disztális vég; dorzális nézet; 5 – *Ixobrychus minutus* (L. 1766) jobboldali felkarcsont, disztális vég, caudális nézet; a. *tuberculum ventrale*; b. *crista bicipitalis*; 6 – *Ixobrychus minutus* (L. 1766) jobboldali felkarcsont, proximális vég, craniális nézet; 7 – *Ixobrychus minutus* (L. 1766) baloldali kézközépcsont, proximális vég; ventrális nézet; c – *facies articularis digitale minor;* 8 – *Ixobrychus minutus* (L. 1766) baloldali kézközépcsont, disztális vég; dorzális nézet; d – *synostozis metacarpalis distalis*

Ord. Charadriiformes (Huxley, 1867)

Fam. Scolopacidae Vigors, 1825

***Tringa* Linnaeus, 1758**

cf. *Tringa* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 left *carpometacarpus* distal fragment *(Figure 2/1–2)*

Dimensions (in mm): *carpometacarpus*: E-4.45, E1-2.09, F-5.03, G-3.31

Main anatomical characters: on the metacarpal fragment, only the distal end is visible, and only the *facies articularis digitalis majoris* and the *spatium intermetacarpale* are

visible on the bone. The *facies articularis digitalis majoris* is slightly wavy and the *spatium intermetacarpale* is narrow and U-shaped.

Comparative material: *Tringa ochropus* (L. 1758) *(Figure 2/9–10)*.

Ord. Columbiformes (Latham, 1790)

Fam. Columbidae Illiger, 1811

***Columba* Linnaeus, 1758**

cf. *Columba* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 left *carpometacarpus* proximal fragment *(Figure 2/3–4)*

Dimensions (in mm): *carpometacarpus*: C-9.94, D-4.11, E1-3.43

Main anatomical characters: the *trochlea carpalis* is asymmetrical, small cone-shaped, the *processus extensorius* is large, prominent, upwardly curved and the *processus alularis* is small. The *facies articularis ulnocarpalis* is large, semicircular.

Comparative material: *Columba livia* Gmelin, 1789 *(Figure 2/11)*.

Figure 2. 1. *Tringa* sp. – Mátraszőlős 3 – left *carpometacarpus*, distal end; dorsal view; 2. *Tringa* sp. – Mátraszőlős 3 – left *carpometacarpus*, distal end, ventral view; 3. *Columba* sp. – Mátraszőlős 3 – left *carpometacarpus*, proximal end, dorsal view; 4. *Columba* sp. – Mátraszőlős 3. – left *carpometacarpus*, proximal end, ventral view; 5. *Alcedo* sp. – Mátraszőlős 3. – left *carpometacarpus*, proximal end, dorsal view; 6. *Alcedo* sp. – Mátraszőlős 3 – left *carpometacarpus*, proximal end, ventral view; 7. *Dendrocopos* sp. – Mátraszőlős 3 – right *carpometacarpus*, proximal end, ventral view; 8. *Dendrocopos* sp. – Mátraszőlős 3. – right *carpometacarpus*, proximal end, dorsal view; 9. *Tringa ochropus* L. 1758 – left *carpometacarpus*, distal end, dorsal view; 10. *Tringa ochropus* L. 1758 – left *carpometacarpus*, distal end, ventral view; 11. *Columba livia* Gmelin, 1789 – left *carpometacarpus*, proximal end, dorsal view; 12. *Apus apus* (L. 1758) – left *carpometacarpus*, proximal end, ventral view; 13. *Jynx torquilla* L. 1758 – right *carpometacarpus*, proximal end, ventral view; 14. *Jynx torquilla* L. 1758 – right *carpometacarpus*, proximal end, dorsal view

2. ábra 1. *Tringa* sp. – Mátraszőlős 3. – baloldali kézközépcsont, disztális vég, dorzális nézet; 2. *Tringa* sp. – Mátraszőlős 3. – baloldali kézközépcsont, disztális vég, ventrális nézet; 3. *Columba* sp. – Mátraszőlős 3. – baloldali kézközépcsont, proximális vég, dorzális nézet; 4. *Columba* sp. – Mátraszőlős 3. – baloldali kézközépcsont, proximális vég, ventrális nézet; 5. *Alcedo* sp. – Mátraszőlős 3. – baloldali kézközépcsont, proximális vég, dorzális nézet; 6. *Alcedo* sp. – Mátraszőlős 3. – baloldali kézközépcsont, proximális vég, ventrális nézet; 7. *Dendrocopos* sp. – Mátraszőlős 3. – jobboldali kézközépcsont, proximális vég, ventrális nézet; 8. *Dendrocopos* sp. – Mátraszőlős 3. – jobboldali kézközépcsont, proximális vég, dorzális nézet; 9. *Tringa ochropus* L. 1758 – baloldali kézközépcsont, disztális vég, dorzális nézet; 10. *Tringa ochropus* L. 1758 – baloldali kézközépcsont, disztális vég, ventrális nézet; 11. *Columba livia* Gmelin, 1789 – baloldali kézközépcsont, proximális vég, dorzális nézet; 12. *Apus apus* (L. 1758) – baloldali kézközépcsont, proximális vég, ventrális nézet; 13. *Jynx torquilla* L. 1758 – jobboldali kézközépcsont, proximális vég, ventrális nézet; 14. *Jynx torquilla* L. 1758 – jobboldali kézközépcsont, proximális vég, dorzális nézet


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Ord. Apodiformes Peters, 1940
Fam. Apodidae Olphe – Galliard, 1887
***Apus* Scopoli, 1777**
cf. *Apus* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 left *carpometacarpus* proximal fragment *(Figure 2/5–6)*

Dimensions (in mm): *carpometacarpus*: C-3.49, D-2.71, E1-2.75

Main anatomical characters: The *trochlea carpalis* is conical and symmetrical, the *processus extensorius* is prominent, rounded and obtuse, and the *processus alularis* is also rounded and rectangular.

Comparative material: *Apus apus* (L. 1758) *(Figure 2/12)*.

Ord. Piciformes (Meyer *et* Wolf), 1810
Fam. Picidae Vigors, 1825
***Dendrocopos* Koch, 1816**
cf. *Dendrocopos* sp. indet

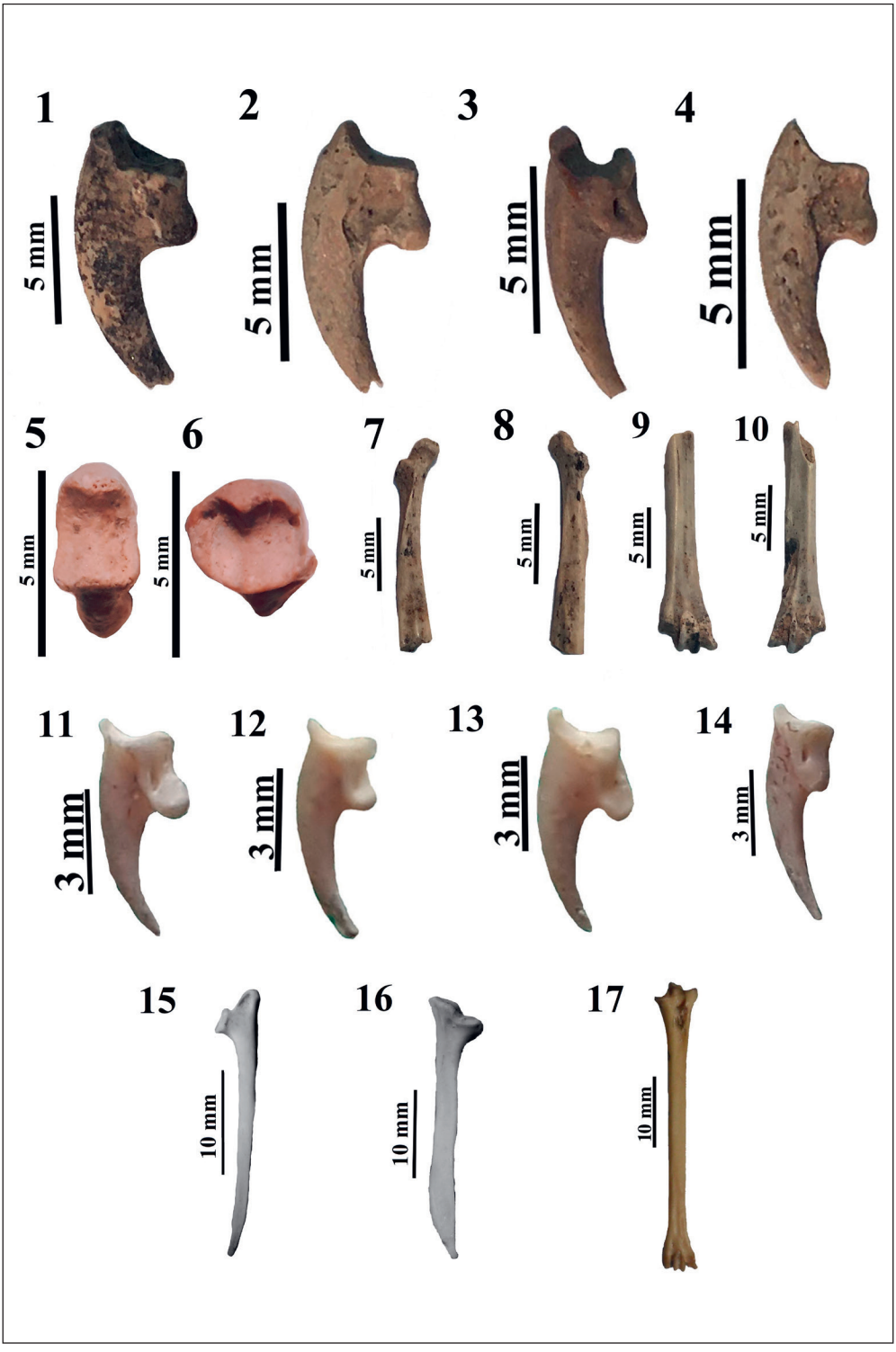
Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 right *carpometacarpus* proximal fragment *(Figure 2/7–8)*

Dimensions (in mm): *carpometacarpus*: C-3.98, D-1.23, E1-1.62

Figure 3. 1. *Glaucidium /Otus* sp. – Mátraszőlős 3. – claw bone, I finger/2 *phalanges*; 2. *Glaucidium /Otus* sp. – Mátraszőlős 3. – claw bone, II finger/3 *phalanges*; 3. *Glaucidium /Otus* sp. – Mátraszőlős 3. – claw bone, III finger/4 *phalanges*; 4. *Glaucidium /Otus* sp. – Mátraszőlős 3 – claw bone, IV phalanx/5 *phalanges*; 5. *Glaucidium /Otus* sp. – Mátraszőlős 3 – left *scapula*, lateral view; 6. *Glaucidium /Otus* sp. – Mátraszőlős 3 – left *scapula*, medial view; 7. *Glaucidium /Otus* sp. – Mátraszőlős 3. – claw bone, plantar view; 8. *Glaucidium /Otus* sp. – Mátraszőlős 3. – claw bone, plantar view; 9. *Corvus* sp. – Mátraszőlős 3. – left *tarsometatarsus* distal end, ventral view; 10. *Corvus* sp. – Mátraszőlős 3. – left *tarsometatarsus* distal end, plantar view; 11. *Otus scops* (L. 1758) – claw bone, I phalanx/2 *phalanges*; 12. *Otus scops* (L. 1758) – claw bone, II phalanx/3 *phalanges*; 13. *Otus scops* (L. 1758) – claw bone, III phalanx/4 *phalanges*; 14. *Otus scops* (L. 1758) – claw bone, IV phalanx/5 *phalanges*; 15. *Glaucidiumn passerinum* (L 1758) – left *scapula*, lateral view; 16. *Glaucidiumn passerinum* (L 1758) – left *scapula*, ventral view; 17. *Corvus monedula* (L. 1758) – right *tarsometatarsus*, distal end, dorsal view

3. ábra 1. *Glaucidium /Otus* sp. – Mátraszőlős 3. – karomcsont, I ujj/2 ujjperc; 2. *Glaucidium /Otus* sp. – Mátraszőlős 3. – karomcsont, II ujj/3 ujjperc; 3. *Glaucidium /Otus* sp. – Mátraszőlős 3. – karomcsont, III ujj/4 ujjperc; 4. *Glaucidium /Otus* sp. – Mátraszőlős 3. – karomcsont, IV ujj/5 ujjperc; 5. *Glaucidium /Otus* sp. – Mátraszőlős 3. – baloldali lapockacsont, laterális nézet; 6. *Glaucidium /Otus* sp. – Mátraszőlős 3. – baloldali lapockacsont, mediális nézet; 7. *Glaucidium /Otus* sp. – Mátraszőlős 3. – karomcsont, plantáris nézet; 8. *Glaucidium /Otus* sp. – Mátraszőlős 3. – karomcsont, plantáris nézet; 9. *Corvus* sp. – Mátraszőlős 3. – baloldali csüd, disztális vég, ventrális nézet; 10. *Corvus* sp. – Mátraszőlős 3. – baloldali csüd, disztális vég, plantáris nézet; 11. *Otus scops* (L. 1758) – karomcsont, I ujj/2 ujjperc; 12. *Otus scops* (L. 1758) – karomcsont, II ujj/3 ujjperc; 13. *Otus scops* (L. 1758) – karomcsont, III ujj/4 ujjperc; 14. *Otus scops* (L. 1758) – karomcsont, IV ujj/5 ujjperc; 15. *Glaucidiumn passerinum* (L 1758) – bal lapocka, laterális nézet; 16. *Glaucidiumn passerinum* (L 1758) – bal lapocka, ventrális nézet; 17. *Corvus monedula* (L. 1758) – jobb csüd, disztális vég, dorzális nézet


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Main anatomical characters: The *trochlea carpalis* is conical and asymmetrical, the *processus extensorius* is straight, elongated and bluntly rounded, the *processus alularis* is rectangular and the *processus intermetacarpalis* is very distinct and possibly triangular.

Comparative material: *Jynx torquilla* L. 1758 *(Figure 2/13–14)*.

Ord. Strigiformes (Wagler)
Fam. Strigidae Vigors (1825)
***Glaucidium* Boie, 1826**
cf. *Glaucidium* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 5 *phalanx ungularis* (*Figure 3/1–6)*; 1 left *scapula* proximal fragment *(Figure 3/7–8)*.

Dimensions (in mm): *phalanx ungularis*: A-6.86–10.52, B-3.67–5.87, C-1.68–4.79, D-1.46– 4.18; *scapula*: B-3.98, E-2.55.

Main anatomical characters: the *phalanx ungularis*: The *tuberculum extensorium* is straight and prominent, rounded at the end, slightly downright. The *cotyla articularis* is strongly concave in all 5 bones, however, if one observes the bones articulately *(Figure 3/5–6)*, one notices that there are 2 around the 5 bones which are narrower in shape. And the *tuberculum flexorium* is concave and protrudes obtusely downwards. The curvature of the *margo plantaris* is strongly curved, and the shape of the apex is squat and curves downwards. *scapula*: the stems of the *acromion* are different, rounded. The *processus articularis humeralis* is truncate. *Corpus scapulae* is straight.

Comparative material: *Otus scops* (L. 1758) *(Figure 3/11–14)*; *Glaucidiumn passerinum* (L. 1758) *(Figure 3/15–16)*.

Ord. Passeriformes (Linnaeus), 1758
Fam. Corvidae Vigors, 1825
***Corvus* Linnaeus, 1758**
cf. *Corvus* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 left *tarsometatarsus* distal end *(Figure 3/9–10)*

Dimensions (in mm): *tarsometatarsus*: E-2.32, F-4.69, G-3.11

Main anatomical characters: the character of the *margo medialis* is prominent, protuberant, the shape of the *troclea metatarsi* II. is rounded, the shape of the *trochlea metatarsi* III. is concave, the shape of the *trochlea metatarsi* IV. is incomplete.

Comparative material: *Corvus monedula* (L. 1758) *(Figure 3/17)*.

Fam. Alaudidae (Vigors), 1825
***Alauda* Linnaeus, 1758**
cf. *Alauda* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 left *coracoideum (Figure 4/1);* 1 right *humerus* distal fragment *(Figure 4/2)*

Dimensions (in mm): *coracoideum*: A-11.84, B-11.34, C-2.29, D-3.51, E-0.98, F-4.09; *humerus:* E-1.52, F-4.29, G-2.26

Main anatomical characters: the shape of the coracoideum: *processus acrocoracoidalis* short and blunt and hook shaped, the shape of the *acrocoracoideum* asymmetrical, the form of the *sulcus musculus supracoracoidei*: semicircular and the existence of the *processus procoracoidalis* missing. *Humerus*: the form of the *tuberculum supracondylare ventrale* is protuberant, the shape of the *processus flexorius* is with a strongly overhanging, rounded end and the form of the *processus supracondylaris dorsalis* is 2 branches and unequal.

Comparative material: *Alauda arvensis* (L. 1758) *(Figure 4/9); Galerida cristata* (L. 1758) *(Figure 4/10)*.

Fam. Hirundinidae Vigors, 1825

***Hirundo* Linnaeus, 1758**

cf. *Hirundo* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 right *humerus* proximal fragment *(Figure 4/3)*; 1 right *humerus* distal fragment *(Figure 4/4)*; 1 right *ulna* distal fragment *(Figure 4/5–6)*; 2 left *tarsometatarsus* intact bone *(Figure 4/7–8)*.

Dimensions (in mm): *humerus* proximal fragment: B-4.18, C-6.49, D-4.99, E-1.93; *humerus* distal fragment: E-1.41, G-1.64; *ulna*: E-1.24, F-3.05, G-2.08; *tarsometatarsus*: A-11.57–12.34, C-2.33–2.44, E-1.16–1.57, F-1.98–2.08, G-0.99–1.28.

Main anatomical characters: *humerus* proximal fragment: the shape of the *tuberculum ventrale* is highly prominent, the form of the *crista bicipitalis* is prominent and rounded, the form of the distal edge of the *crista bicipitalis* is strongly curved and the character of the *fossa pneumotricipitalis* is no division. In case of distal fragment of *humerus* the form of the *tuberculum supracondylare ventrale* is protuberant, the shape of the *processus flexorius*; asymmetrically strongly protruding and the form of the *processus supracondylaris dorsalis* two branched, unequal. *Ulna*: the shape of the *condylus dorsalis* is pointed cone, the form of the *sulcus intercondylaris* is asymmetrically curved, the shape of the *condylus ventralis* is conical and the form of the *tuberculum carpale* is asymmetrical. In the case of *tarsometatarsus*: the *margo medialis* is straight, the *trochlea metatarsi* II with truncated end, the *trochlea metatarsi* III is slightly concave, the *trochlea metatarsi* IV rounded and conical, and the *incisura intertrochlearis medialis* is narrow. A small size difference is visible between the 2 bones of the *tarsometatarsus*. It may be due to sexual dimorphism.

Comparative material: *Hirundo rustica* L. 1758 *(Figure 4/11–15)*.

Fam. Sittidae (Bonaparte, 1831)

***Sitta* Linnaeus, 1758**

cf. *Sitta* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 left *coracideum* intact bone *(Figure 5/8)*

Dimensions (in mm): *coracoideum*: C-2.56, D-3.11, E-1.08

Main anatomical characters: the shape of the *processus acrocoracoidalis* are short and blunt, the shape of the *acrocoracoideum* are symmetrical, the form of the *sulcus musculus*

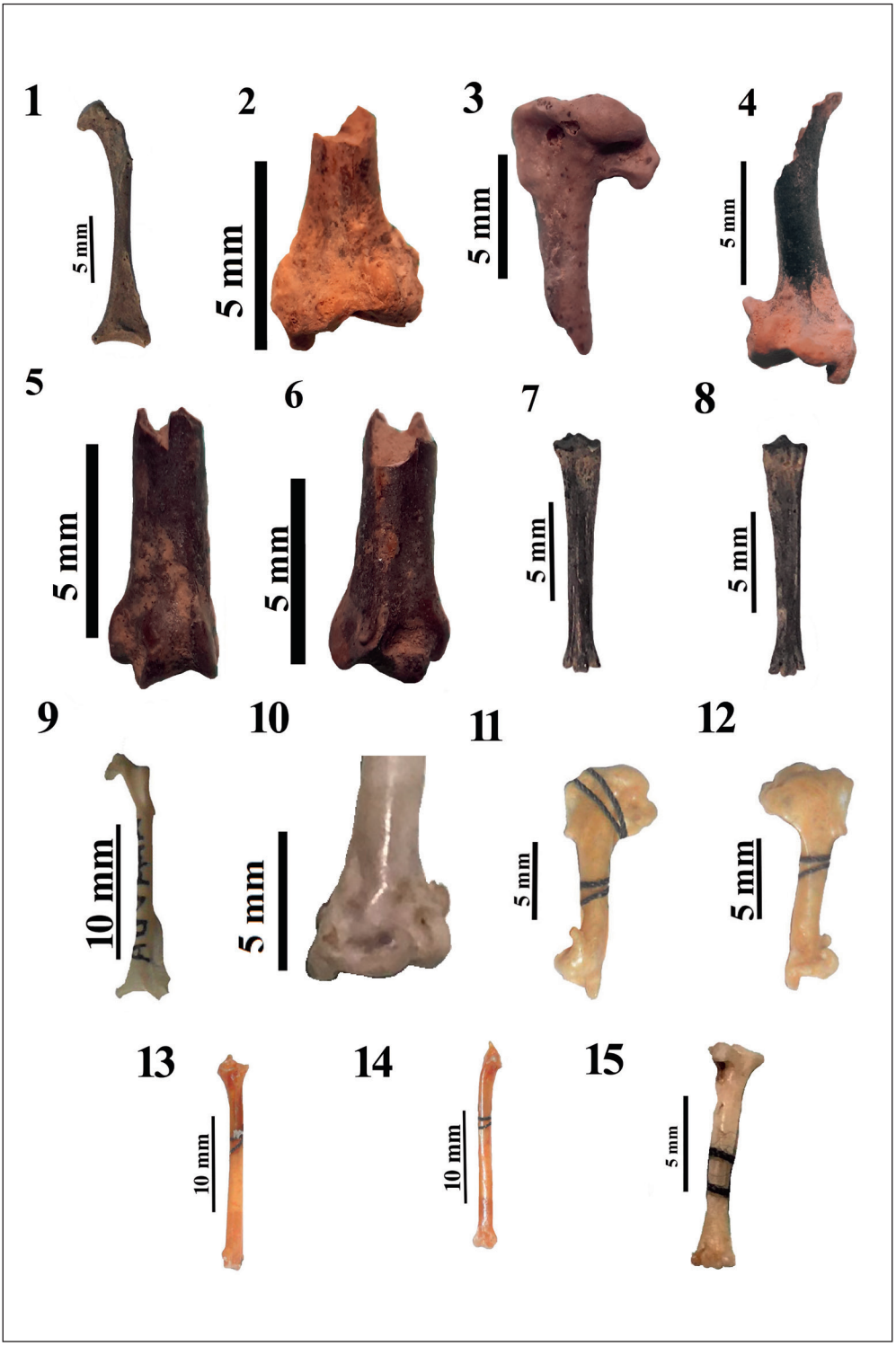

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Figure 4. 1. Alaudidae sp. – Mátraszőlős 3. – left *coracoideum*, dorsal view; 2. Alaudidae sp. – Mátraszőlős 3. – right *humerus*, distal end, cranial view; 3. Hirundinidae sp. – Mátraszőlős 3. – right *humerus*, proximal end, cranial view; 4. Hirundinidae – Mátraszőlős 3. – right *humerus*, distal end, caudal view; 5. Hirundinidae sp. – Mátraszőlős 3. – right *ulna*, distal end, dorsal view; 6. Hirundinidae sp. – Mátraszőlős 3. – right *ulna*, distal end, ventral view; 7. Hirundinidae sp. – Mátraszőlős 3. – left *tarsometatarsus*, dorsal view; 8. Hirundinidae sp. – Mátraszőlős 3. – left *tarsometatarsus*, plantar view; 9. *Alauda arvensis* L. 1758 – left *coracoideum*, dorsal view; 10. *Galerida cristata* (L. 1758) – right *humerus*, distal end, cranial view; 11. *Hirundo rustica* L. 1758 – right *humerus*, cranial view; 12. *Hirundo rustica* L. 1758 – left *humerus*, caudal view; 13. *Hirundo rustica* (L. 1758) – right *ulna*, dorsal view; 14. *Hirundo rustica* L. 1758 – right *ulna*, ventral view; 15. *Hirundo rustica* L. 1758 – left *tarsometatarsus*, dorsal view

4. ábra 1. Alaudidae sp. – Mátraszőlős 3. – baloldali hollócsőrcsont, dorzális nézet; 2. Alaudidae sp. – Mátraszőlős 3. – jobbboldali felkarcsont, disztális vég, craniális nézet; 3. Hirundinidae sp. – Mátraszőlős 3. – jobboldali felkarcsont, proximális vég, craniális nézet; 4. Hirundinidae – Mátraszőlős 3. – jobboldali felkarcsont, disztális vég, caudális nézet; 5. Hirundinidae sp. – Mátraszőlős 3. – jobboldali singcsont, disztális vég, dorzális nézet; 6. Hirundinidae sp. – Mátraszőlős 3. – jobboldali singcsont, disztális vég, ventrális nézet; 7. Hirundinidae sp. – Mátraszőlős 3. – baloldali csüd, dorzális nézet; 8. Hirundinidae sp. – Mátraszőlős 3. – baloldali csüd, plantáris nézet; 9. *Alauda arvensis* L. 1758 – baloldali hollócsőrcsont, dorzális nézet; 10. *Galerida cristata* (L. 1758) – jobboldali felkarcsont, disztális vég, craniális nézet; 11. *Hirundo rustica* L. 1758 – jobboldali felkarcsont, craniális nézet; 12. *Hirundo rustica* L. 1758 – baloldali felkarcsont, caudális nézet; 13. *Hirundo rustica* L. 1758 – jobboldali singcsont, dorzális nézet; 14. *Hirundo rustica* L. 1758 – jobboldali singcsont, ventrális nézet; 15. *Hirundo rustica* L. 1758 – baloldali csüd, dorzális nézet

supracoracoidei are asymmetrically semi-circular and the existence of the *processus procoracoidalis* are missing.

Comparative material: *Sitta europaea* (L. 1758) *(Figure 5/16)*.

Fam. Prunellidae Richmond, 1908

***Prunella* Vieillot, 1818**

cf. *Prunella* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 right *humerus* proximal fragment *(Figure 5/7)*

Dimensions (in mm): *humerus*: B-5.37, C-6.11, D-3.98

Main anatomical characters: the shape of the *tuberculum ventrale* is prominent, the form of the *crista bicipitalis* prominent, rounded, the form of the distal edge of the *crista bicipitalis* is flatly curved and the character of the *fossa pneumotricipitalis* is not divided.

Comparative material: *Prunella modularis* (L. 1758) *(Figure 5/15)*.

Fam. Muscicapidae Vigors, 1825

***Erithacus* Cuvier, 1801**

cf. *Erithacus* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 right *humerus* proximal fragment *(Figure 5/1–2)*; 5 right *carpometacarpus* proximal fragment *(Figure 5/5–6)*

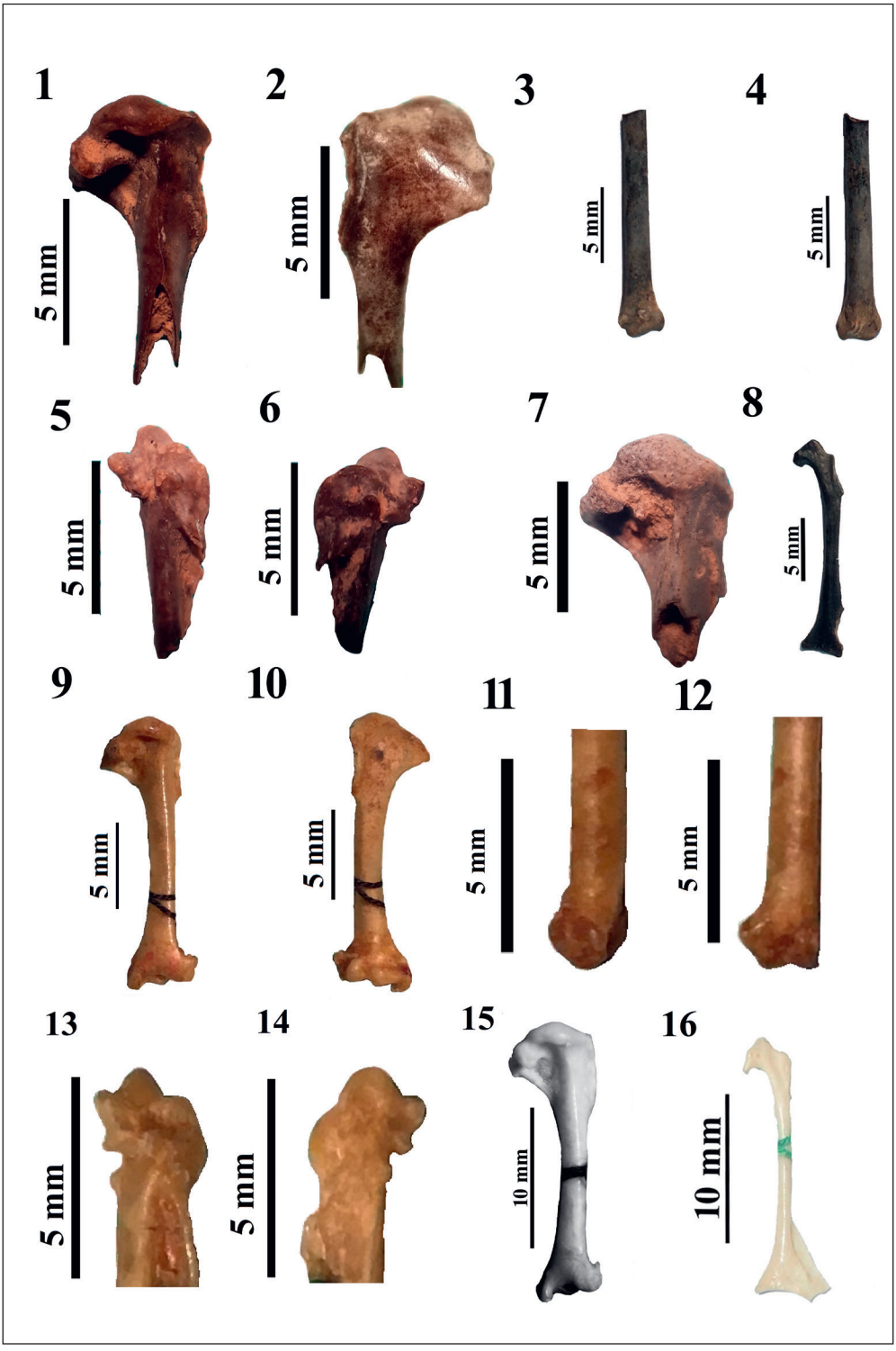

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Figure 5. 1. Muscicapidae sp. – Mátraszőlős 3 – right *humerus*, proximal end, caudal view; 2. Muscicapidae sp. – Mátraszőlős 3 – right *humerus*, proximal end, cranial view; 3. Muscicapidae sp. – Mátraszőlős 3 – left *ulna*, distal end, ventral view; 4. Muscicapidae sp. – Mátraszőlős 3. – left *ulna*, distal end, dorsal view; 5. Muscicapidae sp. – Mátraszőlős 3. – right *carpometacarpus*, proximal end, ventral view; 6. Muscicapidae sp. – Mátraszőlős 3. – right *carpometacarpus*, proximal end, dorsal view; 7. Prunellidae sp. – Mátraszőlős 3. – right *humerus*, proximal end, caudal view; 8. Sittidae sp. – Mátraszőlős 3. – left *coracoideum*, dorsal view; 9. *Erithacus rubecula* L. 1758 – right *humerus*, caudal view; 10. *Erithacus rubecula* L. 1758 – right *humerus*, cranial view; 11. *Erithacus rubecula* L. 1758 – left *ulna*, distal end, ventral view; 12. *Erithacus rubecula* L. 1758 – left *ulna*, distal end, dorsal view; 13. *Erithacus rubecula* L. 1758 – right *carpometacarpus*, proximal end, ventral view; 14. *Erithacus rubecula* L. 1758 – right *carpometacarpus*, proximal end, dorsal view; 15. *Prunella modularis* (L. 1758) – right *humerus*, caudal view; 16. *Sitta europaea* (L. 1758) – left *coracoideum*, dorsal view

5. ábra Muscicapidae sp. – Mátraszőlős 3. – jobboldali felkarcsont, proximális vég, caudális nézet; 2. Muscicapidae sp. – Mátraszőlős 3. – jobboldali felkarcsont, proximális vég, craniális nézet; 3. Muscicapidae sp. – Mátraszőlős 3. – baloldali singcsont, disztális vég, ventrális nézet; 4. Muscicapidae sp. – Mátraszőlős 3. – baloldali singcsont, disztális vég, dorzális nézet; 5. Muscicapidae sp. – Mátraszőlős 3. – jobboldali kézközépcsont, proximális vég, ventrális nézet; 6. Muscicapidae sp. – Mátraszőlős 3. – jobboldali kézközépcsont, proximális vég, dorzális nézet; 7. Prunellidae sp. – Mátraszőlős 3. – jobboldali felkarcsont, proximális vég, caudális nézet; 8. Sittidae sp. – Mátraszőlős 3. – baloldali hollócsőrcsont, dorzális nézet; 9. *Erithacus rubecula* L. 1758 – jobboldali felkarcsont, caudális nézet; 10. *Erithacus rubecula* L. 1758 – jobboldali felkarcsont, craniális nézet; 11. *Erithacus rubecula* L. 1758 – baloldali singcsont, disztális vég, ventrális nézet; 12. *Erithacus rubecula* L. 1758 – baloldali singcsont, disztális vég, dorzális nézet; 13. *Erithacus rubecula* L. 1758 – jobboldali kézközépcsont, proximális vég, ventrális nézet; 14. *Erithacus rubecula* L. 1758 – jobboldali kézközépcsont, proximális vég, dorzális nézet; 15. *Prunella modularis* (L. 1758) – jobboldali felkarcsont, caudális nézet; 16. *Sitta europaea* (L. 1758) – baloldali hollócsőrcsont, dorzális nézet

Dimensions (in mm): *humerus*: C-3.73, D-1.79; B-4.91, *carpometacarpus*: C-5.45, D-4.26, E-1.89

Main anatomical characters: *humerus*: the shape of the *tuberculum ventrale* is prominent, the shape of *crista bicipitalis* is truncate, the shape of distal edge of *crista bicipitalis* is strongly curved and shape of the *pneumotricipital fossa* is divided. *Carpometacarpus*: the shape of the a *trochlea carpalis* are symmetrical blunt cone, the form ofthe *processus extensorius* are oblique, obtuse cone, upright and the shape of the *processus alularis* are rectangular, rounded.

Comparative material: *Erithacus rubecula* L. 1758 *(Figure 5/9–14)*;

***Luscinia* Forster, 1817**

cf. *Luscinia* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 2 *ulna* distal fragments *(Figure 5/3–4)*; 1 *phalanx proximalis digiti majoris (Figure 6/1–2)*; 1 *tarsometatarsus* proximal fragment *(Figure 6/5)*; 1 *tarsometatarsus* proximal fragment *(Figure 6/6–7)*; 1 *phalanx ungularis (Figure 6/8)*.

Dimensions (in mm): *ulna*: E-1.56–1,72, F-3.24–3.34, G-1.81–2.09; *phalanx proximalis digiti majoris*: A-4.96, C-1.36, E-1.69, F-1.32; *tarsometatarsus*: D-3.25, F-1.65; *tarsometatarsus*: E-1.51, F-2.55; *phalanx ungularis*: A-6.64

Main anatomical characters: *ulna*: the shape of the *condylus dorsalis* are blunt cone, the form of the *sulcus intercondylaris* are curved, the shape of the *condylus ventralis* are rounded and the form of the *tuberculum carpale* are semicircular. *Phalanx proximalis digiti majoris:* the form of the *margo proximalis* is wavy, the form of the *tuberculum ventralis* is rounded, the form of the *tuberculum dorsalis* is rounded, the character of the *margo dorsalis* is wavy and the character of the *margo distalis* is wavy. *Tarsometatarsus*: *enimentia intercotylaris* prominent, rounded, the *tuberositas m. tibialis cranialis* is long, the *crista medialis hypotarsi* is rounded. *Tarsometatarsus*: the character of the *margo medialis* is wavy, the shape of the *troclea metatarsi* II. is with cut ends, the shape of the *trochlea metatarsi* III. is slightly concave, the shape of the *trochlea metatarsi* IV. is missing, the form of the *incisura intertrochlearis medialis* is missing and the form of the *incisura intertrochlearis lateralis* is wide. *Phalanx ungularis*: the direction and the form of the *tuberculum extensorium* is posteriorly elevated, blunt, the character of the *cotyla articularis* is concave but weakly, the shape of the *tuberculum flexorium* is protrudes obtusely, the elbow of the *margo plantaris* is strongly curved, symmetrically and the form of the *apex* is squat.

Comparative material: *Luscinia luscinia* (L. 1758) *(Figure 6/9)*;

***Phoenicurus* Forster, 1817**

cf. *Phoenicurus* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 *tibiotarsus* distal fragment *(Figure 6/3–4)*;

Dimensions (in mm): *tibiotarsus*: E-1.83. F-2.99, G-1,89

Main anatomical characters: *tibiotarsus*: the shape of the *epicondylus lateralis* is bluntly conical, the shape of the *epicondylus medialis* is conical, the form of the *incisura intercondylaris* is curved, asymmetrical and the character of the *tuberositas retinaculi* is protruding, highly rounded.

Comparative material: *Muscicapa striata* (Pallas, 1764) *(Figure 6/10–12)*.

Figure 6. 1. Muscicapidae sp. – Mátraszőlős 3. – left phalanx, dorsal view; 2. Muscicapidae sp. – Mátraszőlős 3. – left phalanx, ventral view; 3. Muscicapidae sp. – Mátraszőlős 3. – left *tibiotarsus*, distal end, ventral view; 4. Muscicapidae sp. – Mátraszőlős 3 – left *tibiotarsus*, distal end, caudal view; 5. Muscicapidae sp. – Mátraszőlős 3 – right *tarsometatarsus*, proximal end, plantar view; 6. Muscicapidae sp. – Mátraszőlős 3. – right *tarsometatarsus*, distal end, ventral view; 7. Muscicapidae sp. – Mátraszőlős 3. – right *tarsometatarsus*, distal end, plantar view; 8. Muscicapidae sp. – Mátraszőlős 3. – claw bone, lateral view; 9. *Luscinia luscinia* (L. 1758) – left phalanx, dorsal view; 10. *Muscicapa striata* (Pallas, 1764) – left *tibiotarsus*, distal end, ventral view; 11. *Muscicapa striata* (Pallas, 1764) – right *tarsometatarsus*, ventral view; 12. *Muscicapa striata* (Pallas, 1764) – claw bone, lateral view

6. ábra 1. Muscicapidae sp. – Mátraszőlős 3. – baloldali kézujjperc, dorzális nézet; 2. Muscicapidae sp. – Mátraszőlős 3. – baloldali kézujjperc, ventrális nézet; 3. Muscicapidae sp. – Mátraszőlős 3. – baloldali lábszárcsont, disztális vég, ventrális nézet; 4. Muscicapidae sp. – Mátraszőlős 3. – baloldali lábszárcsont, disztális vég, caudális nézet; 5. Muscicapidae sp. – Mátraszőlős 3. – jobboldali csüd, proximális vég, plantáris nézet; 6. Muscicapidae sp. – Mátraszőlős 3. – jobboldali csüd, disztális vég, ventrális nézet; 7. Muscicapidae sp. – Mátraszőlős 3. – jobboldali csüd, disztális vég, plantáris nézet; 8. Muscicapidae sp. – Mátraszőlős 3. – karomcsont, laterális nézet; 9. *Luscinia luscinia* (L. 1758) – baloldali kézujjperc, dorzális nézet; 10. *Muscicapa striata* (Pallas, 1764) – baloldali lábszárcsont, disztális vég, ventrális nézet; 11. *Muscicapa striata* (Pallas, 1764) – jobboldali csüd, ventrális nézet; 12. *Muscicapa striata* (Pallas, 1764) – karomcsont, laterális nézet

Fam. Turdidae Rafinesque, 1815

***Turdus* Linnaeus, 1758**

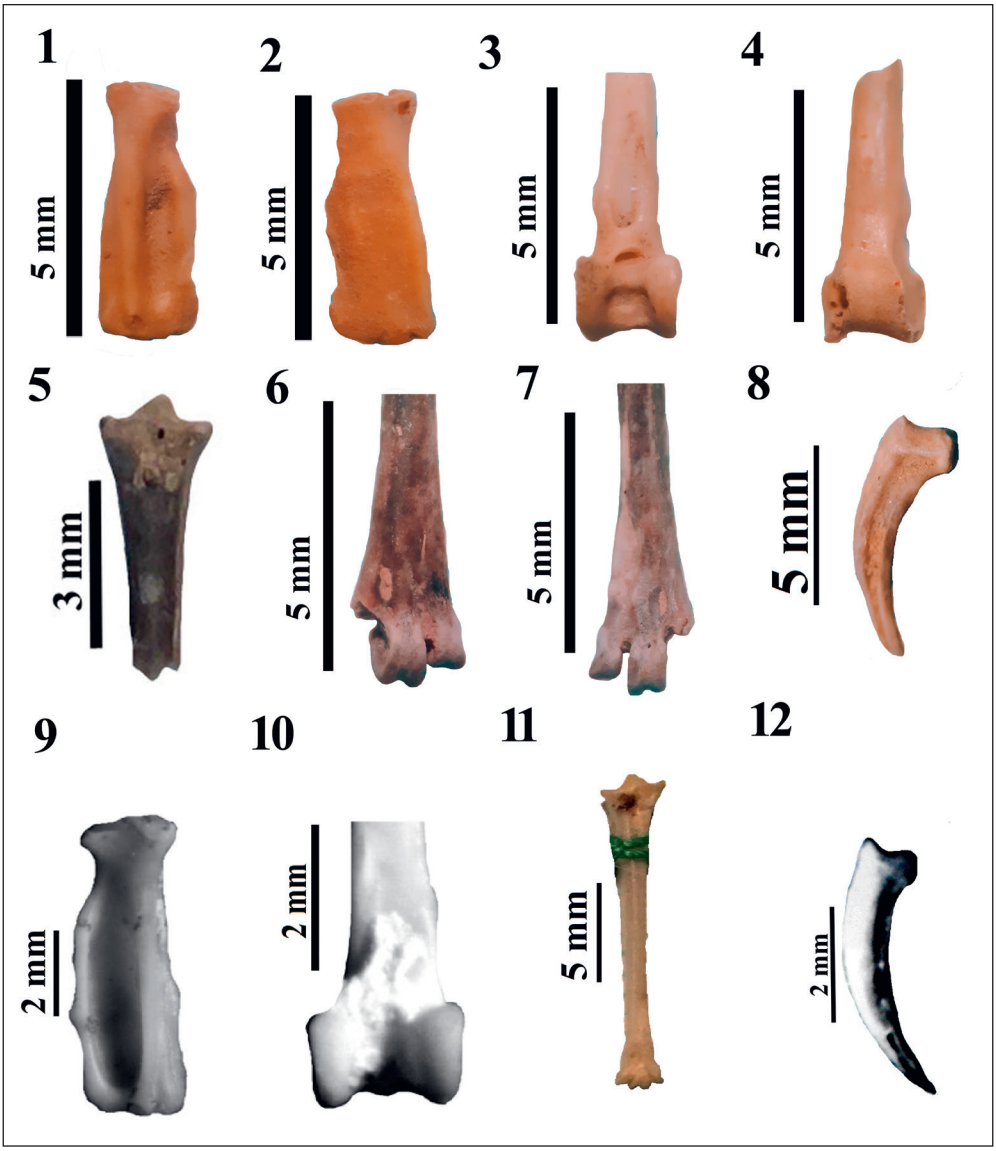
cf. *Turdus* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 *ulna* distal fragment *(Figure 7/1–2)*; 2 *humerus* distal fragment *(Figure 7/3–4)*

Dimensions (in mm): *ulna*: F- 7.41, G-3.71; *humerus*: E- 2,86–3.16, F- 5,07–6.31, G-3,55–3.57

Main anatomical characters: *ulna*: the shape of the *condylus dorsalis* is pointed cone, the form of the *sulcus intercondylaris* is curved, the shape of the *condylus ventralis* is



rounded and the form of the *tuberculum carpale* is semicircular. *Humerus*: the form of the *tuberculum supracondylare ventrale* are prominent, the shape of the *processus flexorius* are strongly protruding, rounded and the form of the *processus supracondylaris dorsalis* are 1 branch, and strongly protruding. There is a small difference in size between the 2 bones. They are identical in character, although the *condylus dorsalis* on one of the bones is larger and rounder. The *condylus dorsalis* rounded on both bones.

Comparative material: *Turdus torquatus* (L. 1758) *(Figure 7/9–10)*.

Fam. Laniidae Swainson, 1834

***Lanius* Linnaeus, 1758**

cf. *Lanius* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 *carpometacarpus* complete, intact *(Figure 7/7–8)*

Dimensions (in mm): *carpometacarpus*: A-23.77, B-20.84, C-4.97, D-2.86, E1-2.14, F-4.57, G-2.46

Main anatomical characters: *carpometacarpus*: the shape of the a *trochlea carpalis* is symmetrical blunt cone, the form of the *processus extensorius* is missing, the shape of the *processus alularis* is rectangular, conical, the form of the *fovea subalularis* is possibly trapezoidal, the character of the *protuberantia metacarpale* majus is missing and the shape of the *facies articularis digitale minor* is concave.

Comparative material: *Lanius collurio* (L. 1758) *(Figure 7/12)*.

Figure 7. 1. Turdidae sp. – Mátraszőlős 3. – left *ulna*, distal end, ventral view; 2. Turdidae sp. – Mátraszőlős 3. – left *ulna*, distal end, dorsal view; 3. Turdidae sp. – Mátraszőlős 3. – left *humerus*, distal end, cranial view; 4. Turdidae sp. – Mátraszőlős 3. – left *humerus*, distal end, caudal view; 5. Sturnidae sp. – Mátraszőlős 3. – right *coracoideum*, proximal end, dorsal view; 6. Sturnidae sp. – Mátraszőlős 3 – right *coracoideum*, proximal end, ventral view; 7. Laniidae sp. – Mátraszőlős 3. – left *carpometacarpus*, ventral view; 8. Laniidae sp. – Mátraszőlős 3. – left *carpometacarpus*, dorsal view; 9. *Turdus torquatus* L. 1758 – left *ulna*, ventral view; 10. *Turdus torquatus* L. 1758 – left *humerus*, cranial view; 11. *Sturnus vulgaris* L. 1758 – right *coracoideum*, proximal end, ventral view; 12. *Lanius collurio* L. 1758 – left *carpometacarpus*, ventral view

7. ábra 1. Turdidae sp. – Mátraszőlős 3. – baloldali singcsont, disztális vég, ventrális nézet; 2. Turdidae sp. – Mátraszőlős 3. – baloldali singcsont, disztális vég, dorzális nézet; 3. Turdidae sp. – Mátraszőlős 3. – baloldali felkarcsont, disztális vég, craniális nézet; 4. Turdidae sp. – Mátraszőlős 3. – baloldali felkarcsont, disztális vég, caudális nézet; 5. Sturnidae sp. – Mátraszőlős 3. – jobboldali hollócsőrcsont, proximális vég, dorzális nézet; 6. Sturnidae sp. – Mátraszőlős 3. – jobboldali hollócsőrcsont, proximális vég, ventrális nézet; 7. Laniidae sp. – Mátraszőlős 3. – baloldali kézközépcsont, ventrális nézet; 8. Laniidae sp. – Mátraszőlős 3. – baloldali kézközépcsont, dorzális nézet; 9. *Turdus torquatus* L. 1758 – baloldali singcsont, ventrális nézet; 10. *Turdus torquatus* L. 1758 – baloldali felkarcsont, craniális nézet; 11. *Sturnus vulgaris* L: 1758 – jobboldali hollócsőrcsont, proximális vég, ventrális nézet; 12. *Lanius collurio* L. 1758 – baloldali kézközépcsont, ventrális nézet

Fam. Sturnidae Vigors, 1825

***Sturnus* Linnaeus, 1758**

cf. *Sturnus* sp. indet

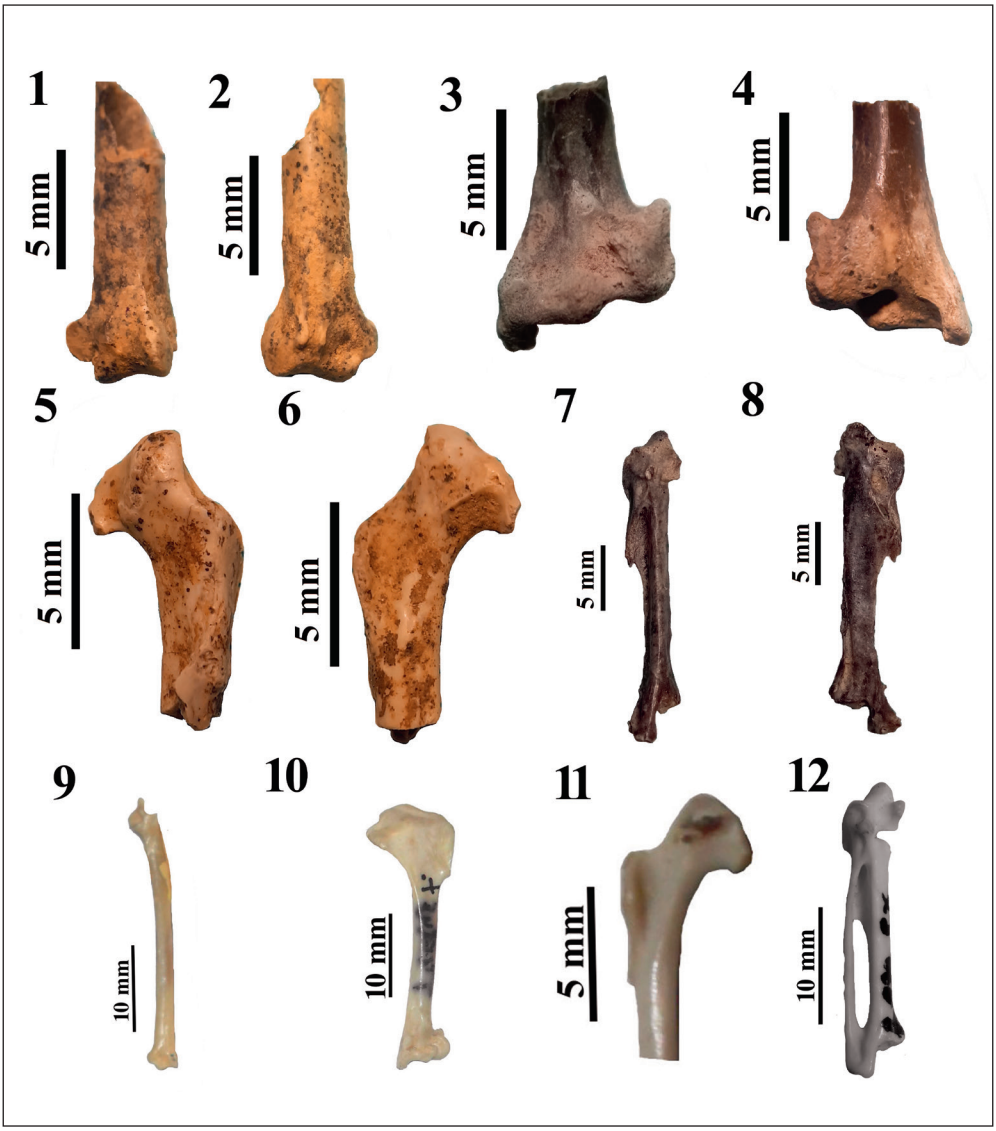
Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 *coracoideum* proximal fragment *(Figure 7/5–6)*

Dimensions (in mm): *coracoideum*: C-4.18, D-5.33, E-2.49

Main anatomical characters: the shape of the *processus acrocoracoidalis* is short and blunt, the shape of the *acrocoracoideum* is asymmetrical and the form of the *sulcus musculus supracoracoidei* symmetrically semi-circular.

Comparative material: *Sturnus vulgaris* (L. 1758) *(Figure 7/11)*.



Fam. Fringillidae Leach, 1820

***Fringilla* Linnaeus, 1758**

cf. *Fringilla* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

Material: 1 *coracoideum* intact bone *(Figure 8/1–2)*; 1 *humerus* intact bone *(Figure 8/3–4)*; 1 *ulna* intact bone *(Figure 8/5–6)*; 1 *femur* intact bone *(Figure 8/7–8)*.

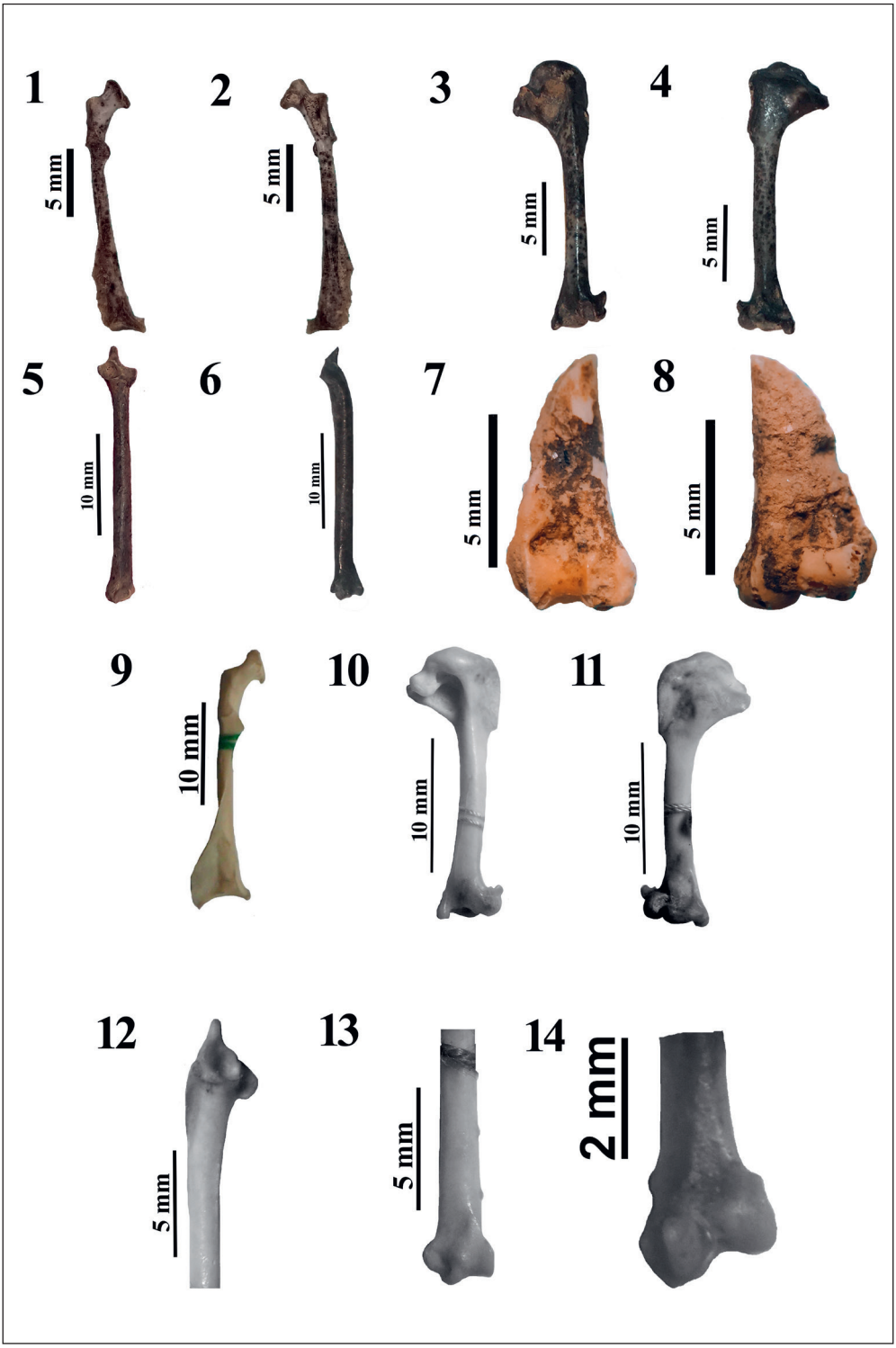
Dimensions (in mm): *coracoideum*: A-17.92, B-16.64, C-2.86, D-3.43, E- 1.17, F-3.75; *humerus*: A-20.75, B-5.97, C-6.26, D-5.16, E-2.18, F-4.57, G-2.56; *ulna*: A-21.74, B-3.05, C-3.58, E-1.57, F-2.88, G-2.45; *femur*: F-3.88. G-2.75.

Main anatomical characters: *coracoideum*: the shape of the *processus acrocoracoidalis* is short and blunt, the shape of the *acrocoracoideum* is asymmetrical, the form of the *sulcus musculus supracoracoidei* is flat and the existence of the *processus procoracoidalis* is strongly protruding. *Humerus*: the shape of the *tuberculum ventrale* is not prominent, the form of the *crista bicipitalis* is prominent and rounded, the form of the distal edge of the *crista bicipitalis* is more strongly curved, the character of the *fossa pneumotricipitalis* is divided, the form of the *tuberculum supracondylare ventrale* is prominent, the shape of the *processus* flexorius is protruding and rounded and the form of the *processus supracondylaris dorsalis* is two-branched and unequal. *Ulna*: the shape of the *olecranon* is long and blunt, the form of the *cotyla dorsalis* is semicircular, the existence of the *tuberculum ligamentum collateralis ventralis* is undeveloped, the shape of the *condylus dorsalis* is pointed cone, the form of the *sulcus intercondylaris* is asymmetrically curved, the shape of the *condylus ventralis* is conical and the form of the *tuberculum carpale* is asymmetrical. *Femur*: the shape of the *condylus medialis* is blunt cone, the character of the *sulcus intercondylaris* is deeply concave, the shape of the *condylus lateralis* is missing, the form of the *epicondylus medialis* is rounded and the form of the *epicondylus lateralis* is missing.

Comparative material: *Fringilla coelebs* (L. 1758) *(Figure 8/9–14)*.

Figure 8. 1. Fringillidae sp. – Mátraszőlős 3. – left *coracoideum*, dorsal view; 2. Fringillidae sp. – Mátraszőlős 3. – left *coracoideum*, ventral view; 3. Fringillidae sp. – Mátraszőlős 3. – right *humerus*, caudal view; 4. Fringillidae sp. – Mátraszőlős 3 – right *humerus*, cranial view; 5. Fringillidae sp. – Mátraszőlős 3. – right *ulna*, ventral view; 6. Fringillidae sp. – Mátraszőlős 3. – right *ulna*, dorsal view; 7. Fringillidae sp. – Mátraszőlős 3 – right *femur*, dorsal view; 8. Fringillidae sp. – Mátraszőlős 3 – left *femur*, distal end, cranial view; 9. *Fringilla coelebs* L. 1758 – left *coracoideum*, dorsal view; 10. *Fringilla coelebs* L. 1758 – right *humerus*, caudal view; 11. *Fringilla coelebs* L. 1758 – right *humerus*, cranial view; 12. *Fringilla coelebs* L. 1758 – right *ulna*, ventral view; 13. *Fringilla coelebs* L. 1758 – right *ulna*, dorsal view; 14. *Fringilla coelebs* L. 1758 – left *femur*, distal end, caudal view

8. ábra 1. Fringillidae sp. – Mátraszőlős 3. – baloldali hollócsőrcsont, dorzális nézet; 2. Fringillidae sp. – Mátraszőlős 3. – baloldali hollócsőrcsont, ventrális nézet; 3. Fringillidae sp. – Mátraszőlős 3. – jobboldali felkarcsont, caudális nézet; 4. Fringillidae sp. – Mátraszőlős 3. – jobboldali felkarcsont, craniális nézet; 5. Fringillidae sp. – Mátraszőlős 3. – jobboldali singcsont, ventrális nézet; 6. Fringillidae sp. – Mátraszőlős 3. – jobboldali singcsont, dorzális nézet; 7. Fringillidae sp. – Mátraszőlős 3. – baloldali combcsont, disztális vég, caudális nézet; 8. Fringillidae sp. – Mátraszőlős 3. – baloldali combcsont, disztális vég, craniális nézet; 9. *Fringilla coelebs* L. 1758 – baloldali hollócsőrcsont, dorzális nézet; 10. *Fringilla coelebs* L. 1758 – jobboldali felkarcsont, caudális nézet; 11. *Fringilla coelebs* L. 1758 – jobboldali felkarcsont, craniális nézet; 12. *Fringilla coelebs* L. 1758 – jobboldali singcsont, ventrális nézet; 13. *Fringilla coelebs* L. 1758 – jobboldali singcsont, dorzális nézet; 14. *Fringilla coelebs* L. 1758 – baloldali combcsont, disztális vég, caudális nézet


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Fam. Emberizidae Vigors, 1831

***Emberiza* Vigors, 1831**

cf. *Emberiza* sp. indet

Location and age: Mátraszőlős 3; Middle Miocene (MN6–8)

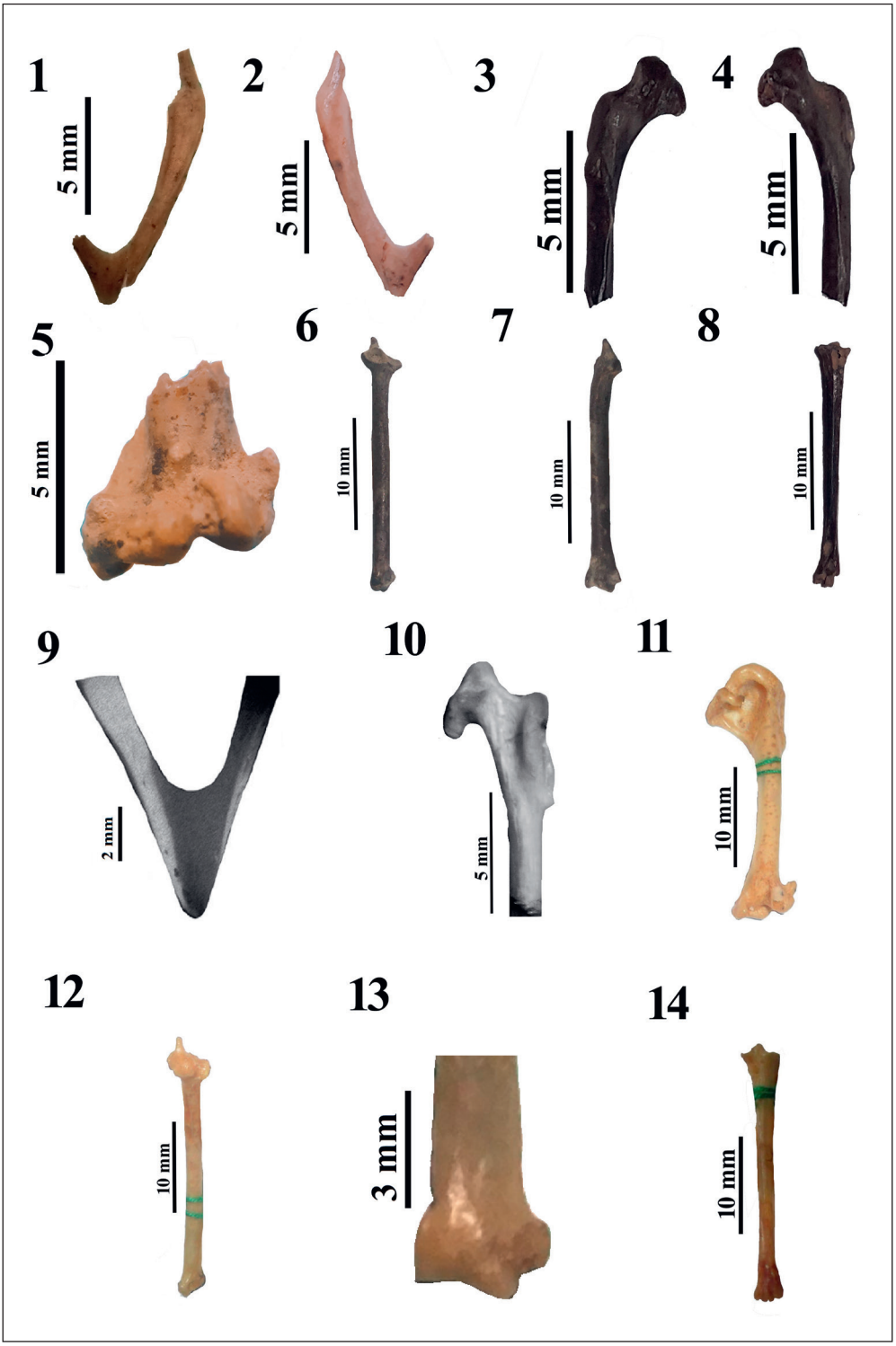
Material: *mandibula (Figure 9/1–2)*; 1 *coracoideum* proximal fragment *(Figure 9/3–4)*; 1 *humerus* distal fragment *(Figure 9/5)*; 6 *ulna* (2 intact bone and 4 proximal fragment) *(Figure 9/6–7)*; 1 *tarsometatarsus* intact bone *(Figure 9/8)*.

Dimensions (in mm): *mandibula*: B-3.11; *coracoideum*: B-6.69, C-2.41, D-3.44, E-0.93; *humerus*: F-5.22, G-2.13; *ulna*: A-21.99–26.15, B-2.91–3.69, C-3.58–4.12, E-1.59–2.51, F-3.04–3.07, G-1.78–2.65; *tarsometatarsus*: A-20.01, C-2.78, E-1.01, F-2.23.

Main anatomical characters: *mandibula*: the end of the beak is short and wide, the slot of the beak is semicircular, the stem of the beak is strongly protruding. *Coracoideum*: the shape of the *processus acrocoracoidalis* is long and blunt, the shape of the *acrocoracoideum* is symmetric, the form of the *sulcus musculus supracoracoidei* is flat and the existence of the *processus procoracoidalis* is strongly protruding. *Humerus*: the form of the *tuberculum supracondylare ventrale* is prominent, the shape of the *processus flexorius* is strongly protruding, rounded, the *incisura intercondylaris* is concave and wide and the form of the *processus supracondylaris dorsalis* is two branched, unequal. *Ulna*: the shape of the *olecranon* are long and blunt, the form of the *cotyla dorsalis* are semicircular, the existence of the *tuberculum ligamentum collateralis ventralis* are undeveloped, the shape of the *condylus dorsalis* are pointed cone, the form of the *sulcus intercondylaris* are asymmetrically curved, the shape of the *condylus ventralis* are conical and the form of the *tuberculum carpale* are asymmetrical. *Tarsometatarsus*: the character of the *margo medialis* is straight, the shape of the *troclea metatarsi* II. is cut end, the shape of the *trochlea*

Figure 9. 1. Emberizidae sp. – Mátraszőlős 3. – lower jaw, upper view; 2. Emberizidae sp. – Mátraszőlős 3. – lower jaw, lower view; 3. Emberizidae sp. – Mátraszőlős 3. – left *coracoideum*, proximal end, dorsal view; 4. – left *coracoideum*, proximal end, ventral view; 5. Emberizidae sp. – Mátraszőlős 3. – left *humerus*, distal end, cranial view; 6. Emberizidae sp. – Mátraszőlős 3. – right *ulna*, ventral view; 7. Emberizidae sp. – Mátraszőlős 3. – right *ulna*, dorsal view; 8. Emberizidae sp. – Mátraszőlős 3. – right *tarsometatarsus*, dorsal view; 9. *Emberiza calandra* L. 1758 – *mandibula*, upper view; 10. *Emberiza calandra* L. 1758 – left *coracoideum*, proximal end, ventral view; 11. *Emberiza calandra* L. 1758 – left *humerus*, caudal view; 12. *Emberiza calandra* L. 1758 – right *ulna*, ventral view; 13. *Emberiza calandra* L. 1758 – right *ulna*, distal end, dorsal view; 14. *Emberiza calandra* L. 1758 – right *tarsometatarsus*, dorsal view

9. ábra 1. Emberizidae sp. – Mátraszőlős 3. – alsó álkapocs, felső nézet; 2. Emberizidae sp. – Mátraszőlős 3. – alsó álkapocs, alsó nézet; 3. Emberizidae sp. – Mátraszőlős 3. – baloldali hollócsőrcsont, proximális vég, dorzális nézet; 4. Emberizidae sp. – Mátraszőlős 3. – baloldali hollócsőrcsont, proximális vég, ventrális nézet; 5. Emberizidae sp. – Mátraszőlős 3. – baloldali felkarcsont, disztális vég, craniális nézet; 6. Emberizidae sp. – Mátraszőlős 3. – jobboldali singcsont, ventrális nézet; 7. Emberizidae sp. – Mátraszőlős 3. – jobboldali singcsont, dorzális nézet; 8. Emberizidae sp. – Mátraszőlős 3. – jobboldali csüd, dorzális nézet; 9. *Emberiza calandra* L. 1758 – alsó állkapocs, felső nézet; 10. *Emberiza calandra* L. 1758 – baloldali hollócsőrcsont, proximális vég, ventrális nézet; 11. *Emberiza calandra* L. 1758 – baloldali felkarcsont, caudális nézet; 12. *Emberiza calandra* L. 1758 – jobboldali singcsont, ventrális nézet; 13. *Emberiza calandra* L. 1758 – jobboldali singcsont, disztális vég, dorzális nézet; 14. *Emberiza calandra* L. 1758 – jobboldali csüd, dorzális nézet


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metatarsi III. is slightly concave, the shape of the *trochlea metatarsi* IV. is missing, the form of the *incisura intertrochlearis medialis* and *lateralis* is wide.

Comparative material: *Emberiza calandra* (L. 1758) *(Figure 9/9–14)*.

Conclusions

The article describes 7 orders, 16 families and 18 genera. Taking into account the habitat preference of the species, it can be said that several species with different ecological requirements may have lived in the Middle Miocene at Mátraszőlős 3. *Ixobrychus* are smaller members of the heron family, occurring mainly in inaccessible marshy areas. Their habitats are mainly along rivers/lakes, as are the redshank within the Scolopacidae family, which, like the *Ixobrychus*, prefer wet, moist habitats. While all other species found in the fossil record may have lived primarily in wooded, woody, shrubby areas. Woodpeckers are birds with a very special morphology and habits. As they are a forest-associated species (especially in older stands), their fossil presence suggests that it is very likely that a large area of forest may have been present in Mátraszőlős 3 in the Middle Miocene (Kessler 2013). Members of the family Picidae (with some exceptions) have a predominantly arboreal distribution. Many are also habitat specialists (Kerpez & Smith 1990). In fact, now we know that their choice of habitat is not only related to their feeding method, but also to the presence of certain cranial elements (Pecsics *et al.* 2023).

The majority of the material, however, consists of songbirds. Probably on the slowly receding western shore of Lake Pannon, habitats may have ranged from coastal marshes, reedbeds and gallery forests to more open grasslands and wooded cliffs. The order is the richest in species and artefacts, except for the warblers. They are also known from warmer climates, such as aningas, bustards, flamingos and tropical swallows (Gál *et al.* 2000, Kessler 2009b, Kessler & Hír 2012a, b, Kessler 2013). The species list composition indicates a wide range of ecological conditions.

As the bones in this paper have only been identified to genus level, it is expected that species identification will be carried out at a later stage, if possible.

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Ornis Hungarica 2025. 33(2): 380–387.
DOI: 10.2478/orhu-2025-0040

Chewing lice (Phthiraptera) species infesting the Lesser Spotted Eagle *(Clanga pomarina)* in Türkiye: First record of *Craspedorrhynchus naevius* (Giebel, 1861) (Ischnocera: Philopteridae)

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Abstract Ornitho-parasitological studies in Türkiye began in the early 2000s, focusing on chewing lice, and have continued to increase to the present day – new studies, records, and host-parasite associations – are published each year. Despite this progress, the chewing lice fauna of many wild bird species in Türkiye remains poorly known, especially among raptor species (Accipitriformes and Falconiformes). Faunistic records of birds of prey are still limited, and each novel record or novel host-parasite association provides valuable data for understanding host specificity and ectoparasite distribution. The material of this study consists of chewing lice specimens collected from the Lesser Spotted Eagle *(Clanga pomarina)* and were mounted on slides using standard clearing and mounting techniques and examined under a light microscope for identification. As a result, the specimens were identified as *Colpocephalum impressum* Rudow, 1866, *Craspedorrhynchus naevius* (Giebel, 1861), *Degeeriella fulva* (Giebel, 1874), and *Falcolipeurus suturalis* (Rudow, 1869). Among these species, *Craspedonhynchus naevius* represents a new record for the chewing lice fauna of Türkiye. This study contributes to the understanding the ectoparasite biodiversity of birds of prey in Türkiye and emphasises the importance of continued parasitological studies of wild avian species.

Keywords: Accipitriformes, avian parasitology, Phthiraptera, Psocodea

Összefoglalás A madárparazitológiai vizsgálatok Törökországban a 2000-es évek elején kezdődtek, főként a tolltetvekre összpontosítva, és napjainkig folyamatosan bővülnek – évente új kutatások, adatok és gazda-parazita kapcsolatok – kerülnek közlésre. E fejlődés ellenére sok vadon élő madárfaj tolltetűfaunája még mindig kevéssé ismert Törökországban, különösen a ragadozó madarak (Accipitriformes és Falconiformes) körében. A ragadozó madarak faunisztikai adatai továbbra is korlátozottak, ezért minden új adat vagy új gazda-parazita kapcsolat értékes információt nyújt a gazdaspecificitás és az ektoparaziták elterjedésének megértéséhez. A vizsgálat anyagát a békászó sas *(Clanga pomarina)* egyedeiről gyűjtött tolltetvek alkotják. A tárgylemezes preparátumokat standard macerálási és beágyazási technikákkal készítettük, majd fénymikroszkóp alatt identifikáltuk. Ennek eredményeként a következő fajokat azonosítottuk: *Colpocephalum impressum* Rudow, 1866, *Craspedorrhynchus naevius* (Giebel, 1861), *Degeeriella fulva* (Giebel, 1874), és *Falcolipeurus suturalis* (Rudow, 1869). Ezek közül a *Craspedorrhynchus naevius* új fajt képvisel Törökország tolltetű-faunájában. Tanulmányunk hozzájárul a ragadozó madarak ektoparazita-biodiverzitásának megértéséhez, és hangsúlyozza a vadon élő madárfajok további parazitológiai vizsgálatainak fontosságát.

Kulcsszavak: Accipitriformes, madárparazitológia, Phthiraptera, Psocodea

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Introduction

The ectoparasite fauna of diurnal birds of prey of the orders Accipitriformes and Falconiformes primarily includes chewing lice, ticks, mites, fleas, and louse flies (Philips 2000, de Oliveira *et al.* 2021, Gherardi *et al.* 2021, Dik *et al.* 2022). Chewing lice (Psocodea, Phthiraptera) represent the most extensively studied group among these parasitic arthropods worldwide. Diurnal predators are associated with members of the families Menoponidae and Laemobothriidae (suborder Amblycera), and Philopteridae (suborder Ischnocera) (Price *et al.* 2003).

Türkiye has a species-rich raptor fauna, the order Accipitriformes comprises 31 species belonging to the families Accipitridae and Pandionidae, whereas the order Falconiformes includes 10 species belonging to the family Falconidae (Karataş *et al.* 2021). Ornitho-parasitological studies conducted in Türkiye to date suggest that diurnal birds of prey are relatively well studied. In these studies, ectoparasite examinations were conducted on 28 (68.29%) of the 41 diurnal predator species, and chewing lice infestations were detected in 22 (53.65%) of them. As a result, 29 species of chewing lice were reported from diurnal predatory bird species (Dik 2006, 2010, Gülanber *et al.* 2006, Dik & Aydenizöz Özkayhan 2007, 2013, 2015, 2017, Dik & Yamaç 2008, Dik & Uslu 2009, 2011, İnci et *al.* 2010, Ulutaş Esatgil *et al.* 2012, Girisgin *et al.* 2013, 2023, Göz et *al.* 2015, Dik & Kandir 2021). Of these, 13 species from the genus *Colpocephalum* and one species from the genus *Kurodaia* (family Menoponidae), as well as three species from the genus *Laemobothrion* (family Laemobothriidae), belong to the suborder Amblycera. The remaining species – three from *Craspedorrhynchus*, seven from *Degeeriella*, and two from *Falcolipeurus* – belong to the family Philopteridae in the suborder Ischnocera.

This study aims to report the chewing lice species identified on the Lesser Spotted Eagle *(Clanga pomarina)* subjected to ectoparasitic examination in Türkiye, and also aims to contribute to the avian ectoparasitological studies in Türkiye and globally.

Material and Methods

In July 2025, chewing lice specimens were collected using blunt-ended forceps during the ectoparasitological examination of a Lesser Spotted Eagle brought to the clinics of the Department of Wild Animal Diseases, Faculty of Veterinary Medicine, Ondokuz Mayıs University (Samsun, Türkiye). The collected specimens were preserved in microtubes containing 70% ethanol until microscopic identification. In the laboratory conditions, all lice specimens were initially cleared in 10% potassium hydroxide (KOH), rinsed with distilled water, and then immersed in transparent lactophenol for 24–48 hours to enhance

transparency. Following this, they were dehydrated by sequentially transferring them through 70%, 80%, 90%, and 99% ethanol solutions (each for 24 hours), and finally mounted in Canada balsam (Palma 1978) on microscope slides. Finally, permanent slides of all specimens were examined under a light microscope (Nikon Eclipse 80i, Tokyo, Japan), and species identification was carried out based on the descriptions and illustrations provided in the relevant literature (Rudow 1869, Price & Beer 1963, Tandan 1964, Mey 2001). Following identification, high-resolution images of the specimens were captured with the integrated camera of the stereo microscope (Mshot Mdx4-t, Guangzhou, China). All permanent glass slides are deposited in the Parasitology Museum of the Parasitology Laboratory, Faculty of Veterinary Medicine, Ondokuz Mayıs University.

Results and Discussion

The chewing lice specimens were identified as *Colpocephalum impressum* Rudow, 1866 *(Figure 1 A, B)*, *Craspedorrhynchus naevius* (Giebel, 1861) *(Figure 1 C–E)*, *Degeeriella fulva* (Giebel, 1874) *(Figure 1 F, G)*, and *Falcolipeurus suturalis* (Rudow, 1869) *(Figure 1 H)*. The number of specimens and life stages of the identified species are presented in *Table 1*. Among these, only *C. naevius* represents a new record for the chewing lice fauna of Türkiye.

Ornithoparasitological studies on diurnal raptors worldwide and in Türkiye have reported numerous species belonging to six genera: *Laemobothrion* spp., *Colpocephalum* spp., and *Kurodaia* spp. from the suborder Amblycera, and *Craspedorrhynchus* spp., *Degeeriella* spp., and *Falcolipeurus* spp. from the suborder Ischnocera (Price *et al.* 2003, Dik *et al.* 2022).

Current parasitological literature indicates that the chewing lice diversity of the Lesser Spotted Eagle includes *Colpocephalum impressum* Rudow, 1866, *Craspedorrhynchus naevius* (Giebel, 1861), *Degeeriella aquilarum* Eichler, 1943, *D. fulva* (Giebel, 1874), *Falcolipeurus suturalis* (Rudow, 1869), and *Laemobothrion vulturis* (Fabricius, 1775) (Price *et al.* 2003). In ornitho-parasitological studies conducted in Türkiye, the chewing lice species *Falcolipeurus*

Table 1. Chewing lice species detected on a Lesser Spotted Eagle in this study
1. táblázat A vizsgálat során a békászó sasból gyűjtött tolltetű-fajok

Chewing lice species and taxonomic status			Number of specimens and life stages
Amblycera	Menoponidae	*Colpocephalum impressum*	♀ (n: 3) – ♂ (n: 5)
Ischnocera	Philopteridae	*Craspedorrhynchus naevius**	♀ (n: 1) – ♂ (n: 2) – N (n: 2)
		Degeeriella fulva	♀ (n: 2) – ♂ (n: 1)
		Falcolipeurus suturalis	♀ (n: 3) – ♂ (n: 1)

*new record for chewing lice fauna of Türkiye
Abbreviations: ♀: female, ♂: male, and N: nymph

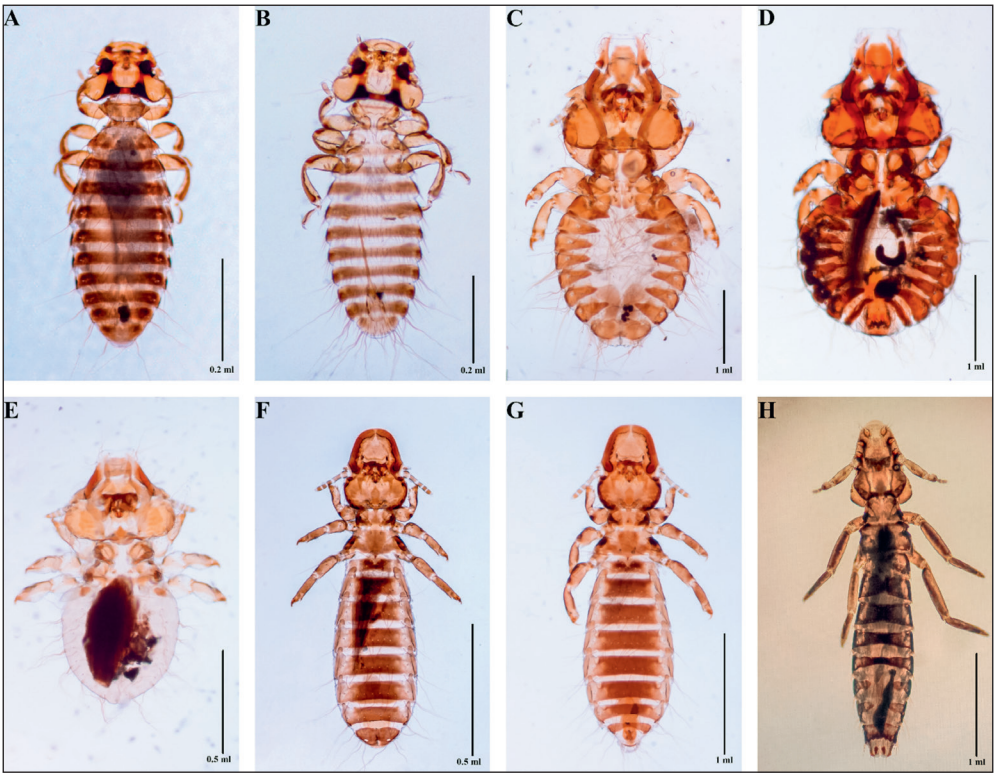


Figure 1. Original micrographs of chewing lice detected on the Lesser Spotted Eagle *(C. pomarina)*: *Colpocephalum impressum* ♀ (A) and ♂ (B); *Craspedorrhynchus naevius* ♀ (C), ♂ (D), and nymph (E); *Degeeriella fulva* ♀ (F) and ♂ (G); and *Falcolipeurus suturalis* ♀ (H)

1. ábra A békászó sasból gyűjtött tolltetvek eredeti mikroszkópos felvételei: *Colpocephalum impressum* ♀ (A) és ♂ (B); *Craspedorrhynchus naevius* ♀ (C), ♂ (D), és lárva (E); *Degeeriella fulva* ♀ (F) és ♂ (G); és *Falcolipeurus suturalis* ♀ (H)

suturalis, *Colpocephalum impressum*, and *Degeeriella fulva* have been reported on the Lesser Spotted Eagle (Dik & Yamaç 2024). In addition, *Laemobothrion maximum*, a common ectoparasite of diurnal raptors, has also been reported (Zerek *et al.* 2024).

The genus *Colpocephalum* comprises approximately 100 species associated with birds of prey (Accipitriformes, Falconiformes), as well as various other bird orders, including Ciconiiformes, Columbiformes, Cuculiformes, Galliformes, Gruiformes, Pelecaniformes, Passeriformes, Piciformes, and Strigiformes (Price *et al.* 2003). According to the literature, the genus *Colpocephalum* is represented by 16 species in Türkiye: *Colpocephalum apivorus*, *C. ecaudati*, *C. eucarenum*, *C. heterosoma*, *C. impressum*, *C. milvi*, *C. nanum*, *C. napiforme*, *C. nigrae*, *C. percnopteri*, *C. polonum*, *C. subzerafae*, *C. trachelioti*, *C. turbinatum*, *C. zebra*, and *C. zerafae* (Dik *et al.* 2022, Eren *et al.* 2022, Dik & Yamaç 2024, Zerek *et al.* 2024). *Colpocephalum impressum*, detected on the Lesser Spotted Eagle in the present study, has previously been reported from various eagles belonging to the genera *Aquila*, *Hieraaetus*, and *Nisaetus* in studies conducted both in Türkiye and worldwide (Price & Beer 1963, Morishita *et al.* 2001, Price *et al.* 2003, Dik *et al.* 2022, Bahiraei *et al.* 2024, Talabante *et al.* 2024).

The genus *Craspedorrhynchus* currently includes 41 described species associated with birds of prey (Accipitriformes, Falconiformes) (Gállego Berenguer *et al.* 1987, Mey 2001, Price *et al.* 2003, Gustafsson *et al.* 2024). Prior to the present study, this genus was represented in Türkiye by three species: *Craspedorrhynchus aquilinus* from the Golden Eagle *(Aquila chrysaetos)*, *C. fraterculus* from the Imperial Eagle *(Aquila heliaca)*, and *C. platystomus* from the Common Buzzard *(Buteo buteo)* and the Long-legged Buzzard *(Buteo rufinus)* (Dik *et al.* 2022, Eren *et al.* 2022). *Craspedorrhynchus naevius*, a new record for the fauna of Türkiye, was originally described from the Lesser Spotted Eagle in Germany (Giebel 1861). Subsequent studies have also reported *Craspedorrhynchus naevius* on the same host in several countries, including Italy, Hungary, Romania, and Slovakia (Picaglia 1885, Rékási & Kiss 1980, Solt 1998, Ošlejšková *et al.* 2021). The *Craspedorrhynchus naevius* specimens detected in the present study *(Figure 1, Table 2)* are consistent with the morphological descriptions and morphometric measurements reported in the literature (Giebel 1861, Picaglia 1885, Mey 2001).

The genus *Degeeriella* comprises approximately 40 species, primarily associated with diurnal predators (Accipitriformes, Falconiformes) (Price *et al.* 2003). To date, studies conducted in Türkiye have reported seven species of this genus: *Degeeriella aquilarum* from the Imperial Eagle; *D. fulva* from the Lesser Spotted Eagle, the Common Buzzard, and the Long-legged Buzzard; *D. fusca* from the Western Marsh Harrier *(Circus aeruginosus)*; *D. leucopleura* from the Short-toed Snake Eagle *(Circaetus gallicus)*; *D. nisus* from the Eurasian Sparrowhawk *(Accipiter nisus)* and the Common Buzzard; *D. phlyctopygus* from the Osprey *(Pandion haliaetus)* and the European Honey Buzzard *(Pernis apivorus)*; and *D. rufa* from the Eurasian Hobby *(Falco subbuteo)* (Dik *et al.* 2022, 2024, Eren *et al.* 2022). Similar to previous studies, *Degeeriella fulva* was also detected on the Lesser Spotted

Table 2. Comparative morphometric measurement of *Craspedorrhynchus naevius*
2. táblázat A *Craspedorrhynchus naevius* összehasonlító morfológiai mérései

	Present study (Samsun, Türkiye)							**Picaglia (1885) (Modena, Italy)**	
	Female (n: 1)	**Male (n: 2)**			**Nymph (n: 2)**			**Female (n: ?)**	**Male (n: ?)**
	–	**Min.**	**Max.**	**Avg.**	**Min.**	**Max.**	**Avg.**	**Avg.**	**Avg.**
CL	0.88	0.78	0.88	0.83	0.57	0.62	0.59	0.80	0.83
CW	0.91	0.79	0.79	0.79	0.68	0.75	0.71	0.94	0.82
CI	1.03	0.89	1.00	0.94	1.19	1.20	1.19	–	–
TL	0.55	0.40	0.48	0.44	0.38	0.38	0.38	0.43	0.43
TW	0.48	0.44	0.60	0.52	0.48	0.54	0.51	0.80	0.62
AL	1.00	0.86	0.88	0.87	0.73	0.79	0.76	1.31	1.07
AW	0.99	1.00	1.08	1.04	0.79	0.82	0.80	1.18	1.10
ToL	2.43	2.14	2.14	2.14	1.68	1.79	1.73	–	–
CoI	2.45	1.98	2.14	2.06	2.12	2.18	2.15	–	–

Abbreviations: CL: Cephalic length; CW: Cephalic width; CI: Cephalic index (CW/CL); TL: Thoracic length; TW: Thoracic width; AL: Abdominal length; AW: Abdominal width; ToL: Total length; and CoI: Corporal index (ToL/AW).

Eagle in the present study. *Degeeriella fulva*, a heteroxenous species of chewing louse, has been reported from various species of buzzards *(Buteo, Geranoaetus)*, eagles *(Aquila, Hieraaetus, Icthyophaga, Lophaetus, Pandion, Spilornis)*, hawks *(Accipiter, Melierax)*, and kites *(Milvus)* in Türkiye and worldwide (Price *et al.* 2003, Gonzalez-Acuña *et al.* 2008, Gherardi *et al.* 2011, Dik *et al.* 2022, Lade *et al.* 2023).

The genus *Falcolipeurus* comprises 19 species associated with diurnal raptors belonging to the orders Accipitriformes and Falconiformes (Price *et al.* 2003). In Türkiye, this genus is represented by two species, including *Falcolipeurus suturalis* from the Common Buzzard and the Lesser Spotted Eagle, and *F. quadripustulatus* from the Cinereous Vulture *(Aegypius monachus)* and the Short-toed Snake Eagle (Dik *et al.* 2022, Dik & Yamaç 2024). *Falcolipeurus suturalis*, detected on the Lesser Spotted Eagle in the present study, has also been reported from various eagle species belonging to the genera *Aquila*, *Hieraaetus*, *Nisaetus*, and *Terathopius* in previous studies conducted worldwide (Tandan 1964, Ledger 1980, Price *et al.* 2003, Gaponov 2023, Bahiraei *et al.* 2024).

Conclusion

This study is based on the identification of chewing lice specimens obtained during ectoparasitic examination of a Lesser Spotted Eagle. As a result, one of the four identified species is a new record for Türkiye. Given the diversity of the ornithofauna of Türkiye and the large number of bird species that have not yet been examined, future ornitho-parasitological studies are likely to yield new records, host-parasite associations, and even new species for the chewing lice fauna of Türkiye.

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Glass traps: Investigating bird mortality at glass-fronted buildings in the Nilgiris

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Abstract Bird-window collisions pose a significant but underexplored threat to the avian biodiversity in India. This study, the first of its kind in the Nilgiris, South India, documents bird collisions with glass surfaces over a year. A total of 35 incidents were recorded across two locations, Forestdale and Coonoor, involving 22 species from 15 families. Among these, 16 birds were found dead, 18 were injured, and one managed to fly away. Migratory species, particularly the Indian Blue Robin, had the highest number of collisions, while among resident birds, the White-cheeked Barbet and Spotted Dove were most affected. Collisions peaked during winter, highlighting seasonal vulnerability. Building architecture, especially reflective glass surfaces, played a crucial role in increasing collision risks. These findings underscore the urgent need for mitigation measures such as UV-reflective films, window modifications, and strategic landscaping. Promoting bird-friendly urban designs and raising awareness are essential to reducing avian mortality in expanding human settlements.

Keywords: bird-glass collision, Nilgiris, Western Ghats, urban bird conservation

Összefoglalás A madarak ablaknak ütközése India madárvilágára is jelentős hatással bíró, de alulkutatott tényező. Ez a tanulmány, amely az első ilyen jellegű vizsgálat a dél-indiai Nilgiris területén, egy éven át dokumentálja az üvegfelületeken történő madárütközéseket. Két helyszínen, Forestdaleben és Coonoorban összesen 34 esetet rögzítettek, amelyek 15 család 22 faját érintették. Ezek közül 16 madarat elpusztulva találtak, 18 megsérült, és egynek sikerült elrepülnie. Az ütközések jelentős része vonuló fajokra – különösen a narancsszínű fülemülére – vonatkozott, míg az állandó fajok közül a fehérarcú bajszika és a gyöngyösnyakú gerle volt a leginkább érintett. Az ütközések csúcsa télen volt, ami rávilágít a szezonális veszélyeztetettségre. Az épületek építési módja, különösen a fényvisszaverő üvegfelületek jelentősen növelték az ütközés kockázatát. Ezek az eredmények hangsúlyozzák az olyan megelőző intézkedések szükségességét, mint az UV-tükröző fóliák, az ablakok módosítása és a stratégiai tereprendezés. Az egyre inkább terjeszkedő városokban alapvető fontosságú a madárbarát várostervezés és a tudatosság növelése a madárpusztulás csökkentése érdekében.

Kulcsszavak: madár – üveg ütközés, Nilgiris, Nyugati-Ghátok, városi madárvédelem

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Introduction

Bird-window collisions are primarily driven by anthropogenic pressure, with urbanization playing a significant role in wildlife mortality (Loss *et al.* 2015, Adams *et al.* 2021, Riding *et al.* 2021, Żmihorski *et al.* 2022). The transformation of natural habitats into urban areas due to human population growth has profound negative effects on biodiversity (Rebolo-Ifrán 2019). Habitat fragmentation is a major factor contributing to biodiversity decline, as it isolates populations and disrupts ecological balance (Fischer & Lindenmayer 2007, Rodríguez-Loinaz *et al.* 2012). In urban environments, glass reflections deceive birds by creating the illusion of open space or natural habitats, leading to fatal collisions. Globally, an estimated one billion birds die each year due to window collisions (Klem 1989, Klem 2006, Bayne *et al.* 2012). Key habitat factors influencing collision risks include the presence of trees and shrubs near buildings or their reflections in windows, both of which significantly increase the likelihood of bird strikes (Klem 2009, Borden *et al.* 2010, Rosenberg *et al.* 2019, Brown *et al.* 2020). In the United States alone, rough estimates suggest that 100 million to one billion birds perish annually due to window collisions (Kornreich *et al.* 2024). Despite the growing concern over bird-window collisions worldwide, research on this issue in India remains limited (Sekhsaria 2020). This study represents the first-ever investigation of bird-window collisions in South India, specifically in the Nilgiris region. This study analyses seasonal bird-window collisions, the time of day they occur, bird outcomes (dead, injured, or flown away), and the residency status (resident vs. migratory) over a year.

Methods

This study was conducted over a one-year period, from January to December 2024, at two locations in and around Coonoor: Coonoor (11.346, 76.81529) and Forestdale (11.3654, 76.79919) *(Figure 1)*. Bird collision data was collected opportunistically throughout the year, documenting instances where birds sustained fatal injuries upon striking windows. Data were categorised for the seasonal analysis as summer (March to June), monsoon (July to October) and winter (November to February) and for the time period of the collisions morning (06.00 AM to 12.00 PM), afternoon (12.00 PM to 4.00 PM), evening (4.00 PM to 8.00 PM). Mapping was done using QGIS (version 3.40) and data visualization was performed using R Studio (2020), utilizing the "ggplot2", "patchwork" and "RColorBrewer" packages for analysis and graphical representation.

Both study sites featured commercial buildings surrounded by gardens, with nearby forested areas comprising semi-evergreen forests and shola, while non-forest areas primarily consisted of tea plantations. The architectural characteristics of the buildings varied, potentially influencing the frequency and severity of bird-window collisions. At Coonoor, buildings are in a two-storied structure, with the first and second stories featuring transparent glass panels facing east and measuring 6 × 4 feet, installed uniformly at a two-foot interval. The reflective nature of the second-story glass panels mirrors the sky and the

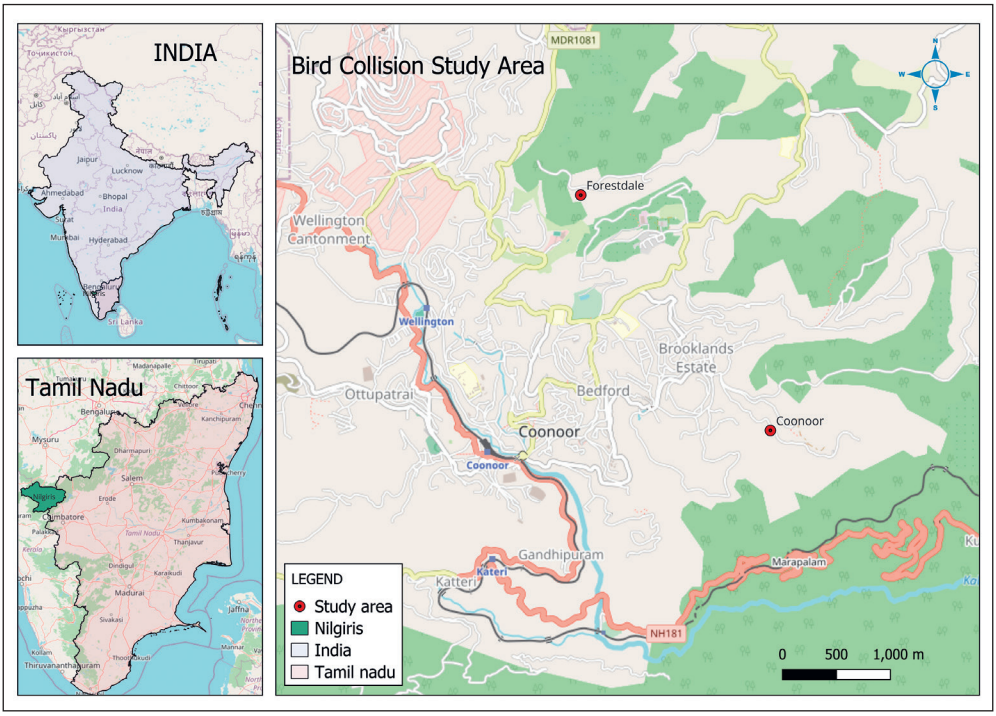


Figure 1. The map of the study area
1. ábra A kutatási terület térképe

garden in front. At Forestdale, the structure is similar but differs in its design: the first floor lacks transparent or reflective glass, while the second floor features a continuous transparent glass panel facing east and measuring 20 × 10 feet, which reflects both the adjacent garden and the sky.

Result

Bird-window collisions were recorded at two locations, Forestdale (n = 19) and Coonoor (n = 16), totalling 35 collisions across 22 bird species *(Table 1, Figure 2)*. These incidents affected 15 families, with Muscicapidae (n = 4) and Columbidae (n = 3) being the most impacted. Of the recorded collisions, 16 birds were found dead, 18 were injured, and one managed to fly away *(Figure 2)*. Monsoon had the highest number of collisions (n = 15), followed by summer (n = 11) and winter (n = 9). Most collisions occurred in the morning (n = 18), followed by the afternoon (n = 12) and evening (n = 5). A total of 18 resident and four migratory bird species were affected. Among migratory species, the Indian Blue Robin *(Luscinia brunnea)* (3 fatalities, 1 injury) had the highest number of collisions, followed by the Greenish Warbler *(Phylloscopus trochiloides)*, Kashmir Flycatcher *(Ficedula subrubra)* (1 male, 1 female), and Grey Wagtail *(Motacilla cinerea)*. Among residents, the White-cheeked Barbet *(Megalaima viridis)* and Spotted Dove *(Spilopelia chinensis*) were most

Table 1. Results of glass collisions including family, scientific name, common name, number of collisions, IUCN status, and residency status of species
1. táblázat Az üvegnek ütközött fajok listája

Family	Scientific Name	Common Name	N	IUCN Status	Residency Status
Tytonidae	*Tyto alba* (Scopoli, 1769)	Barn Owl	2	LC	Resident
Strigidae	*Strix leptogrammica* (Temminck, 1832)	Brown Wood Owl	2	LC	Resident
Columbidae	*Chalcophaps indica* (Linnaeus, 1758)	Common Emerald Dove	1	LC	Resident
	Columba elphinstonii (Sykes, 1832)	Nilgiri Wood Pigeon	1	VU	Resident
	Spilopelia chinensis (Scopoli, 1786)	Spotted Dove	3	LC	Resident
Megalaimidae	*Psilopogon viridis* (Boddaert, 1783)	White-cheeked Barbet	3	LC	Resident
Corvidae	*Corvus macrorhynchos* (Wagler, 1827)	Large-billed Crow	1	LC	Resident
Hirundinidae	*Hirundo domicola* (Jerdon, 1841)	Hill Swallow	2	LC	Resident
	Ptyonoprogne concolor (Sykes, 1832)	Dusky Crag Martin	1	LC	Resident
Motacillidae	*Motacilla cinerea* (Tunstall, 1771)	Grey Wagtail	1	LC	Migratory
Pycnonotidae	*Pycnonotus cafer* (Linnaeus, 1766)	Red-vented Bulbul	1	LC	Resident
	Pycnonotus jocosus (Linnaeus, 1758)	Red-whiskered Bulbul	2	LC	Resident
Phylloscopidae	*Phylloscopus trochiloides* (Sundevall, 1837)	Greenish Warbler	2	LC	Migratory
Paridae	*Parus cinereus* (Vieillot, 1818)	Cinereous Tit	1	LC	Resident
Zosteropidae	*Zosterops palpebrosus* (Temminck, 1824)	Indian White-eye	1	LC	Resident
Sturnidae	*Acridotheres fuscus* (Wagler, 1827)	Jungle Myna	1	LC	Resident
Turdidae	*Turdus simillimus* (Jerdon, 1839)	Indian Blackbird	1	LC	Resident
Muscicapidae	*Copsychus saularis* (Linnaeus, 1758)	Oriental Magpie-robin	1	LC	Resident
	Cyornis tickelliae (Blyth, 1843)	Tickell's Blue Flycatcher	1	LC	Resident
	Ficedula subrubra (Hartert & Steinbacher, 1934)	Kashmir Flycatcher	2	VU	Migratory
	Larvivora brunnea (Hodgson, 1837)	Indian Blue Robin	4	LC	Migratory
Passeridae	*Passer domesticus* (Linnaeus, 1758)	House Sparrow	1	LC	Resident

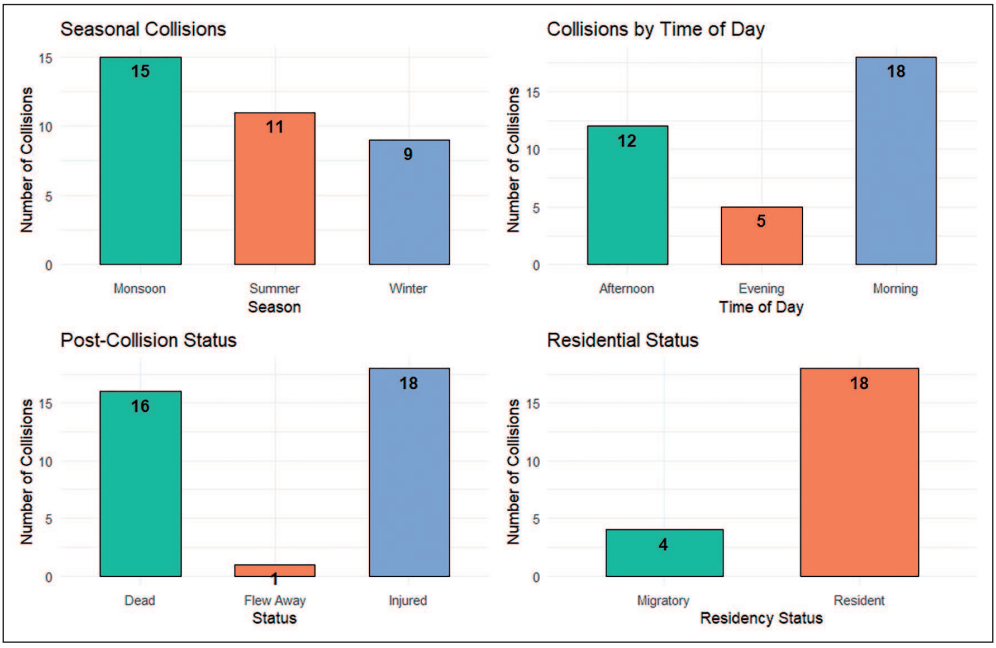


Figure 2. Analysis of bird-window collisions based on season, time of day, post-collision status, and residency status

2. ábra A madarak ablaknak ütközésének elemzése a szezon, a napon belüli időpont, az ütközés utáni státusz és a vonulási típus alapján

affected, followed by the Brown Wood Owl *(Strix leptogrammica)*, Common Barn Owl *(Tyto alba)*, Hill Swallow *(Hirundo domicola),* and Red-whiskered Bulbul *(Pycnonotus jocosus)*, each with two collisions. Additionally, single collisions were observed for 12 species.

Discussion

This study provides valuable insights into bird-window collisions in the Nilgiris, a region where such research has been limited. Our findings highlight that multiple factors including seasonality, species residency status, and building structure significantly influence collision occurrences (Longcore *et al.* 2012, Calvert *et al.* 2013, Loss *et al.* 2015, 2019). With increasing urbanization, habitat fragmentation and glass reflections pose serious risks to birds, making these collisions an emerging conservation concern (Klem 2010, 2014). The data indicate that resident birds, White-cheeked Barbet and Spotted Dove, experience more collisions than other migratory species, likely due to their year-round presence and frequent interactions with human-altered environments. The Indian Blue Robin, an important winter migratory bird in the Nilgiris, was involved in three collisions, resulting in two fatalities and one injury. Notably, this study also recorded fatalities of the Nilgiri Wood Pigeon a Near Threatened (NT) species endemic to the Western Ghats (BirdLife International 2025). We also observed a male and female Kashmir Flycatcher *(Ficedula subrubra)*, a vulnerable

winter migrant in the Nilgiris (Moinudheen & Samson 2021, BirdLife International 2025), collided in Forestdale but were able to recover and fly away. While migratory species are also vulnerable, their collision rates are lower due to their seasonal presence. Seasonality played a crucial role in collision rates, with monsoon recording the highest number of incidents. This trend may be attributed to reduced visibility, increased bird activity, and possibly higher food availability near human settlements during rainy seasons. The relatively lower number of collisions in summer suggests that birds may either adapt to their surroundings or avoid high-risk areas during this period. The architectural design of buildings significantly influenced collision frequency. Forestdale recorded a higher number of collisions compared to Coonoor, likely due to its continuous transparent glass panel on the second floor, which reflects the surrounding garden and sky.

The findings from this study highlight the urgent need for mitigation measures in urban and peri-urban areas. Simple interventions, such as window films, external screens, and modifications to glass transparency, can significantly reduce bird mortality. Additionally, altering landscape features such as relocating vegetation away from reflective surfaces can help minimize collision risks. Birds possess a broader visual spectrum than humans, extending into the ultraviolet range (Jacobs 1992, Hart 2001, Lind *et al.* 2013). Research indicates that UV-reflective films, such as BirdShades, can effectively reduce collisions by enhancing glass visibility to birds while remaining mostly unnoticed by humans (Goldsmith & Butler 2005, Aidala *et al.* 2012, Swaddle *et al.* 2020). Our findings align with previous studies suggesting that UV-reflective treatments and circular-shaped decals serve as effective deterrents against bird-window collisions (Ribeiro *et al.* 2020). This underscores the importance of incorporating bird-friendly glass solutions in urban planning and conservation efforts to mitigate avian mortality from glass-pane collisions. Despite being the first study of its kind in South India, this research serves as an essential starting point for further investigation. Expanding studies across different landscapes and building types can help refine mitigation strategies tailored to Indian urban environments. Long-term monitoring, public awareness campaigns, and policy-level interventions are crucial steps toward addressing this growing conservation issue.

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Colonisation and nest site selection in the urban landscape of Poltava, Ukraine by Eurasian Jay *(Garrulus glandarius)*: A case report study

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Abstract In recent decades, the Eurasian Jay *(Garrulus glandarius)* has been actively colonising urban areas; however, its adaptation to living near humans has been understudied. This study examines the nesting density, habitat preferences and the impact of urban landscape elements on nest site selection of Eurasian Jays in Poltava, Ukraine. The study covered over a 16.46 km^2 area in Poltava, comparing the coverage around Eurasian Jay nests to that of randomly selected points. Statistical analyses, including the Kruskal–Wallis-test and Bayesian logistic regression, suggested that tree cover slightly influences nest site selection, though no strong correlations with other urban variables were detected. Additionally, the distance of nests to roads and buildings did not significantly differ from random points, suggesting a tolerance of urban infrastructure. However, the overall low density of Eurasian Jays compared to other corvids in the city highlights their relatively limited adaptation to urban environments.

Keywords: birds, Eurasian Jay, urban landscape, habitat selection

Összefoglalás Az elmúlt évtizedekben a szajkó *(Garrulus glandarius)* benépesítette a városi területeket; az emberi környezethez való alkalmazkodását azonban kevéssé vizsgálták. Ez a tanulmány a szajkó fészkelési denzitását, élőhelypreferenciáját és a városi tájképi elemek fészelőhely-választására gyakorolt hatását vizsgálja az ukrajnai Poltavában egy 16,46 km^2-es területen. A kutatás során összehasonlították a fészkek körüli lefedettséget a véletlenszerűen kiválasztott pontokéval. A statisztikai elemzések, beleértve a Kruskal–Wallis-tesztet és a Bayes-féle logisztikus regressziót, azt mutatták, hogy a fák borítása enyhén befolyásolja a fészkek helyének kiválasztását, míg más változókkal nem mutattak erős korrelációt. Emellett a fészkek utaktól és épületektől való távolsága nem különbözött szignifikánsan a véletlenszerűen kiválasztott pontoktól, ami arra utal, hogy a madarak tolerálják a városi infrastruktúrát. Mindazonáltal a szajkók más varjúfélékhez képest alacsony denzitása rávilágít arra, hogy a városi környezethez való alkalmazkodásuk viszonylag korlátozott.

Kulcsszavak: madarak, szajkó, városi környezet, élőhelyválasztás

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Introduction

The Eurasian Jay *(Garrulus glandarius)* is a common sedentary and nomadic species with an extremely large range in Europe. It usually nests in various types of forest biotopes. The European population is estimated at 7,480,000–14,600,000 pairs, which equates to 15,000,000–29,300,000 mature individuals. In Ukraine, there are 225,000–320,000 estimated pairs, which accounts for about 2.2% of the European population (BirdLife International 2015). In Europe, the Eurasian Jay also usually chooses forests during the breeding season but can settle in windbreaks and urban areas (Gianpasquale & Meriggi 2019).

Approximately since the end of the 1960s, the species began to adapt to dwelling in anthropogenic landscapes, inhabiting green areas of settlements of various sizes and residential quarters (Knysh *et al.* 2010). This was reflected in the increase in population size and expansion of nesting sites in populated areas (Zimaroeva 2012). For example, in the city of Melitopol, the nesting of the species was first recorded in 2008, and by 2017–2019, the total number of breeding pairs reached 60–70 (Koshelev *et al.* 2020). In Lviv, during the late 1990s and early 2000s, an increase in the number of Eurasian Jays was also observed (Bokotey 2008). The exploitation of non-typical nesting places by Eurasian Jays was also documented. For example, in 2014 in the city of Melitopol, one pair built a nest behind the balcony cladding, on the third floor of a five-story residential building in the city centre (Koshelev *et al.* 2020). Nesting of Eurasian Jays on buildings was also recorded in other parts of their range (Krivickij 1989, Nadtochij & Ziomenko 1989, Rezanov & Rezanov 2007). However, compared to other corvid species such as the Hooded Crow *(Corvus cornix)*, Rook *(Corvus frugilegus)*, Western Jackdaw *(Coloeus monedula)* and Eurasian Magpie *(Pica pica)*, the Eurasian Jay is less synanthropic and remains primarily a forest species, preferring woodlands (Zimaroeva 2012, Gianpasquale & Meriggi 2019, Koshelev *et al.* 2020).

The biology and population aspects of common corvid species in cities that have rapidly colonised and inhabited anthropogenic landscapes have been studied over a large area of their range (Jerzak 2001, Vogrin 2003, Wang *et al.* 2008, Kövér *et al.* 2015, Jokimäki *et al.* 2017, Benmazouz *et al.* 2021). However, little is known about the gradual expansion of Eurasian Jays into cities and the processes of their urbanisation have received little attention.

For Poltava, the Eurasian Jay was a common bird during the winter in the first half of the 20th century. The first documented nesting of the species in the city dates back to 1954, when a pair built a nest in a spruce tree at the Fruit and Berry Technical College. Up to 1958, only one nesting pair was regularly observed there (Gavrilenko 1970). Currently, the Eurasian Jay is one of the most numerous forest-nesting species in the arboretum, which is located on the outskirts of the city (Slusar 2017). However, since the mid-20th century, no research has been conducted on the territory of residential areas of the city, and we lack data on the level of urban adaptation of this species.

The available literature on the distribution and abundance of the Eurasian Jay, especially in urban areas, is rather limited. Additionally, the extent to which Eurasian Jays have settled in cities and the preferences of their habitat choice in cities remain unclear.

In this preliminary study, we aim to analyse how the species exploits urban landscapes, identify their habitat preferences, and assess the influence of urban landscape elements on nest-site selection.

Material and Methods

The research was carried out in the territory of Poltava city. A complete survey of the area of 16.46 km^2, which is 15.8% of the entire city territory, was conducted. The surveyed territory of the city included its centre and central streets, the main green areas of the city and a significant part of the private buildings sector. The research was conducted from late March to mid-April in 2021 and 2022 by mapping Eurasian Jay nests, sometimes nesting pairs. The study area was surveyed at least once during the breeding season each year. The survey effort was evenly distributed across the area to ensure comparable detectability; every yard and every green space was inspected. Due to the conspicuous behaviour of Eurasian Jays during the breeding period, we estimated that the probability of detecting an active nest or nesting pair was high, although some nests may have been missed in densely vegetated or inaccessible areas, such as those concealed in mistletoe clusters. Nest coordinates were recorded in the field using the open navigation system of Google Maps.

To find out the characteristics of the distribution of the species' nesting sites, the survey area was divided into three categories according to different urban landscapes, types of vegetation, and anthropogenic pressure:

(I) Areas with high-rise buildings (more than two floors) and commercial buildings (7.71 km^2, 46.84% of the study area). These areas are often close to the main streets of the city (with continuous and regulated traffic) and have high traffic intensity. Dense low-rise buildings, such as city markets and garage cooperatives are also included in this category.

(II) Private sectors with one- and two-storey buildings (6.68 km^2, 40.56%). This category of sites includes suburbs, away from main roads with heavy and regulated traffic.

(III) Parks and green spaces (2.07 km^2, 12.6%), also including cemeteries and the university botanical garden.

To estimate the area of land cover type around nests we used land cover map created in our previous study (Dupak & Telizhenko 2023). Six habitat variables were chosen for the analysis: (i) proportion of tree cover, (ii) proportion of grass and ground, (iii) proportion of artificial ground covers, i.e. asphalt and tiles, (iv) proportion of high-rise buildings, which was defined as having more than two floors, (v) proportion of low buildings (up to 2 floors) and (vi) proportion of water surface. In this case, we relied on the classifications proposed in the studies of Jokimäki *et al.* (2017) and Sakhvon and Kövér (2020). In addition, we categorized buildings into high-rise (multistorey, higher than two floors) and low-rise, considering that, depending on height, they might create distinct 3D environments for birds.

To investigate bird nesting habitat selection, we used 75-m radius plots around the nests and control points. Such a radius was used by Jokimäki *et al.* (2017) for similar studies

of nest-site selection by Eurasian Magpies. The relatively small area for the analysis of habitat selection is explained by the fact that the foraging activity of solitary corvid birds is concentrated, first of all, around the nest, and the staying of birds in this area is necessary for its protection (Högstedt 1980). Therefore, in our opinion, birds are guided by surrounding landmarks in a relatively small range during the choice of a nest site.

Thirty random control points were generated within the tree cover layer (to account for the fact that Eurasian Jays build nests only in trees) using the "Random Points Inside Polygons" tool in QGIS 3.26.3. The percentage of each habitat variable was calculated and visualized using 'Field Calculator' in QGIS and custom Python scripts.

We measured the distance from the Eurasian Jay nesting site to the nearest road and the building to investigate the effects of buildings and roads on the location of nest sites. Such measurements were also performed for randomly generated points (n = 30).

Statistical analyses

To compare breeding densities in different urban areas, the Kruskal–Wallis H-test (Kruskal & Wallis 1952) with Dunn's *post hoc* test and Bonferroni adjustment (Dunn 1961) were used. The kernel density estimation of Eurasian Jay nesting in Poltava city was calculated using the STATS package in R v4.4.0 (R Core Team 2023).

We then evaluated differences in habitat (land cover) variables between the nesting sites of Eurasian Jay and random control points. To examine how close the sample data fitted a normal distribution the Shapiro–Wilk-test (Shapiro & Wilk 1965) was performed. Since the Shapiro–Wilk-test revealed that the data were not normally distributed, we used the Mann–Whitney U-test for further analysis.

Additionally, we modelled the probability that a sampling point represents an Eurasian Jay nest (versus a randomly selected control site) using Bayesian logistic regression implemented in R via the 'brms' package (Bürkner 2017, Carpenter *et al.* 2017). A Bayesian approach was adopted because it often provides more reliable estimates than traditional methods when dealing with relatively small sample sizes. We modelled whether a point is an Eurasian Jay nest (1) or a control site (0) based on the land cover percentages (scaled from 0 to 1). Weakly informative normal priors (mean = 0, SD = 1) were specified for both the intercept and regression coefficients. Model estimation was performed using Markov Chain Monte Carlo sampling with four chains, each run for 10,000 iterations, including a 4,000-iteration burn-in. Convergence was assessed using R-hat values and effective sample sizes (ESS), and model fit was evaluated through posterior predictive checks.

Finally, the distances from Eurasian Jay's nests to the nearest road and building were compared with those from randomly generated points in the tree cover to the nearest road and building. Since the data did not follow a normal distribution, the Mann–Whitney U-test was used to compare these distances. Additionally, rank-biserial correlation was calculated to assess the strength of the differences between groups. The analysis and visualisations were performed using the 'ggstatsplot' package (Patil 2021).

Results

Number and density

A total of 16 Eurasian Jay pairs were registered in the study area. The largest number of nests, 8 (50.0%) was found in parks and green spaces. In private sector plots, 7 pairs (43.7%) were recorded, and 1 pair (6.3%) was in the first zone (plots with high-rise, industrial, and commercial buildings).

The average nesting density of the species in the study area was 0.97 pairs/km^2. The highest density in parks and green spaces was 3.8 pairs/km^2. In the private sector plots, the density was 1.05 pairs/km^2, and the lowest one was for territories covered by high-rise buildings and by industrial and commercial buildings, the estimated nesting density here was 0.1 pair/km^2.

More than half of the nests found (55.5%) were built inside the mistletoe.

Breeding density differed significantly among site categories (Kruskal–Wallis-test: $H = 24.153$, $p < 0.01$). *Post hoc* pairwise comparisons using Dunn's test with Bonferroni adjustment showed that breeding densities in green areas were significantly higher than in both high-density ($Z = 4.91$, $p < 0.01$) and low-density building areas ($Z = 3.96$, $p = 0.01$). No significant difference was found between high-density and low-density sites ($Z = –1.36$, $p = 0.52$).

Habitat selection

The analysis of land cover variables within a 75 m radius around nests *(Figure 1A)* showed that Eurasian Jays prefer habitats with a higher percentage of water (Mann–Whitney U-test: $U = 515$, $p < 0.05$). Among all cover types, only water exhibited significantly higher values around nests compared to random points. Additionally, the test suggested a tendency toward a preference for tree cover, although this was not statistically significant.

The Bayesian analysis *(Figure 1B)* of Eurasian Jay nest presence suggests slightly positive effects of tree cover on nesting probability, as indicated by posterior distribution shifted above zero. However, credible intervals for these variables overlap zero, indicating uncertainty in the effect sizes. Other habitat variables show high uncertainty, with their distributions spanning both negative and positive values, suggesting that they do not strongly influence nest selection in our dataset. The trace plots that support Bayesian analysis are in the Supplementary Data.

Our analysis revealed no significant difference in the median distances between nests and random points to the nearest road or building *(Figure 2)*.

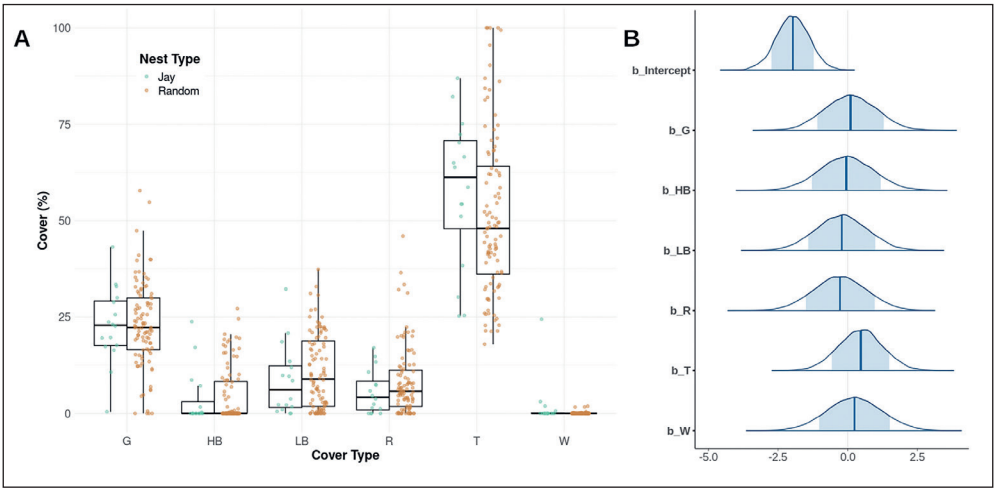


Figure 1. Analysis of habitat variables. A – Differences in habitat variables between Eurasian Jay nest sites and random points. B – Posterior distributions of regression coefficients for habitat variables in the Bayesian model predicting Jay nest presence. The density curves represent the posterior distributions of each coefficient, with shaded areas indicating 80% uncertainty intervals. G – grass/ground, HB – high buildings, LB – low buildings, R – roads/pavements, T – tree cover, W – water

1. ábra Az élőhelyváltozók elemzése. A – Különbségek az élőhelyváltozókban a random pontok és a szajkó fészkek között. B – Az élőhelyváltozók regressziós együtthatóinak eloszlása a szajkó fészkek jelenlétét előrejelző Bayes-i modellben. A sűrűségi görbék az egyes együtthatók becsült értékének eloszlásait mutatják, az árnyékolt területek a 80%-os bizonytalansági intervallumokat jelzik. G – fű, talaj, HB – magas épület, LB – alacsony épület, R – utak, járdák, T – faborítás, W – víz

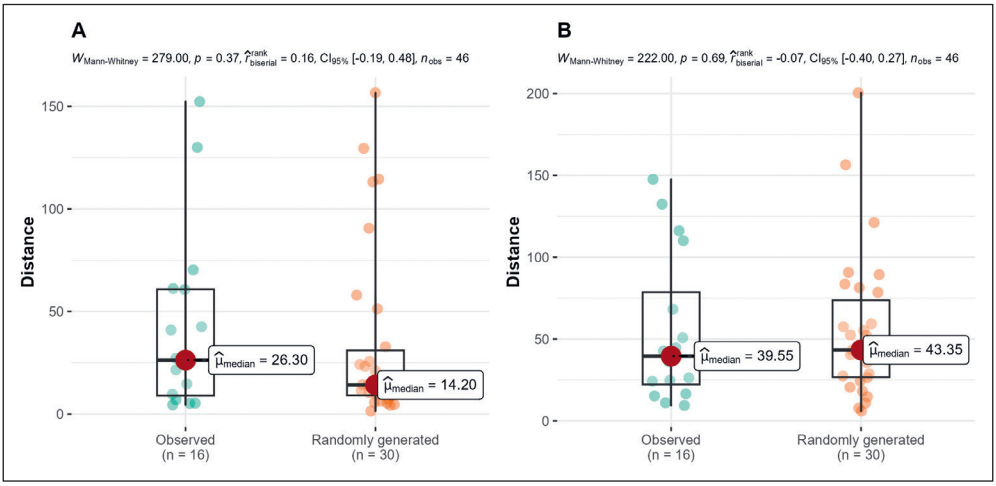


Figure 2. Comparative analysis of median distances from observed nests and randomly generated points to the nearest road (A) and to the nearest building (B)

2. ábra A megfigyelt fészkek és a véletlenszerűen generált pontok legközelebbi úthoz (A) és legközelebbi épülethez (B) mért távolságának mediánjainak összehasonlítása

Discussion

The total density of Eurasian Jays (0.97 pairs/km^2) in the surveyed area was the lowest compared to other corvid species found in this monitoring area. At the same time, the highest number and density of nesting was recorded for Eurasian Magpies (368 nests; the average nesting density of 22.4 pairs/km^2), the next most numerous were Western Jackdaws (147 pairs; 9.8 pairs/km^2) and Hooded Crow (41 nests; 2.5 pairs/km^2) (Dupak & Telizhenko 2023, unpublished data). In the number gradation of corvids in the city of Sumy (Ukraine) in the 2000s, the Eurasian Jay also took ranked place after the Western Jackdaw, Rook and Eurasian Magpie (Knysh *et al.* 2010).

The Eurasian Jay demonstrated a strong tendency to camouflage its nests, as evidenced by 55.5% of nests being built in mistletoe. Such a high percentage was not observed for other corvid species in the study area; for the Hooded Crow, it was 14.6%, and for the Eurasian Magpie, only 1.6% (unpublished data). While this nesting behaviour likely provides effective camouflage from predators, it may also reduce nest detectability during field surveys. Although the area was thoroughly surveyed and the observer carefully inspected tree crowns, it is possible that some nests concealed within dense mistletoe clusters were overlooked. This potential detection bias should be taken into account when interpreting the results or conducting similar studies.

The Eurasian Jay is the only one of the "urban" species of Corvidae of Ukraine (Eurasian Magpie, Western Jackdaw, Hooded Crow, Rook), whose numbers in natural biotopes exceed its population in anthropogenic landscapes. For example, in the ravine forests of the Sumy region in the 1960s, the recorded number of this species was 40 individuals/km^2, and in mixed and pine forests 20–26 individuals/km^2 (Matvienko 2009). At least as of the 2000s, this state of the number of Eurasian Jays for these territories has been preserved (Knysh *et al.* 2010). The species' density in Europe can also be quite high. For example, a record number of Eurasian Jays was registered in July in a pine forest in the Maremma Natural Park (Tuscany, Italy) ranged from 347 to 676 (on average 484) birds per km^2 (Patterson *et al.* 1991). In a mixed forest in Sweden in the 1980s, for 5 years, the density of the species fluctuated around 8–13 birds km^2 (average 11) (Grahn 1990).

Half of all nesting pairs of Eurasian Jays in the city of Poltava (50%) were in parks and green squares where the density of birds was significantly higher compared to building areas. The concentration of Eurasian Jays in parks and green areas was also observed in other settlements. In the 1980s, during the growth of the number of Eurasian Jays in the city of Kharkiv, most of the birds were concentrated in the central city park. Nesting of the species was also recorded in building areas of the city, but these were rare cases, mainly in the areas adjacent to the park (Nadtochij & Ziomenko 1989). In Zhytomyr, the Eurasian Jay nests were most densely located in the green areas surrounding the city, with 3.5 pairs/km^2. In the city of Zhytomyr, most nests were in old blocks of high-storey buildings. These blocks had numerous trees, and the average density of its nests here comprised 0.75 pair/km^2 (Zimaroeva 2012).

On the one hand, no significant difference was observed in the distances between nests and random points when analysing their proximity to the nearest roads and buildings. According

to our data, Eurasian Jays tolerate buildings and roads with their associated traffic. On the other hand, nesting habitat selection analysis showed that the birds prefer habitats with a higher percentage of water. However, due to the low number of water bodies in the city and their rare occurrence near nests, this association cannot be considered reliable.

The Mann–Whitney U-test and Bayesian analysis of habitat variables indicate that most habitat types do not significantly influence nest site selection in Eurasian Jays. Both methods revealed an insignificant but clear tendency toward selecting tree-covered areas. However, high uncertainty in the posterior distributions suggests that the effects of habitat variables remain inconclusive, likely due to a limited sample size or overlapping habitat preferences.

In our opinion, this suggests that the Eurasian Jay is tolerant of urban landscape elements. However, the presence of a high number of trees remains a key factor in nest site selection, which should be considered in the management and planning of urban forest and park areas. Further research on synanthropization in different regions is crucial for attracting this species to green spaces and urban outskirts. Additionally, Jays may play an important role in the dispersal of oak trees in these areas (Kurek *et al.* 2018, Mitrus & Szabo 2020). Therefore, we believe that future research should focus on the role of the Eurasian Jay in urban ecosystems.

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Plumage aberration in Chestnut-bellied Sandgrouse *(Pterocles exustus)* from Rajasthan, India

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Abstract Individuals with color aberrations are distinguished in species with cryptic colouration, which may also affect their social interactions. Color aberrations in birds have been extensively studied in the scientific community, however, aberrations in many species are unknown or poorly understood. In this study, we present the first record of plumage aberration in Chestnut-bellied Sandgrouse *(Pterocles exustus)*. A female with brown aberration was recorded in Jaisalmer, Rajasthan, India.

Keywords: avian plumage aberration, brown colour aberration, Chestnut-bellied Sandgrouse, plumage variation, Rajasthan

Összefoglalás Színezeti aberrációval rendelkező egyedek a rejtőszínű fajoknál is megfigyelhetőek, és az aberráció náluk is hatással lehet a társas interakciókra is. A madarak színaberrációit a tudományos közösség széles körben tanulmányozza, ugyanakkor e színezeti formák számos fajnál még feltáratlanok vagy kevéssé ismertek. Ebben a tanulmányban a barnahasú pusztaityúk *(Pterocles exustus)* tollazati színaberrációjának első feljegyzését mutatjuk be egy Jaisalmerben (Rajasthan, India) észlelt, barna aberrációjú tojó esetét tárgyalva.

Kulcsszavak: tollazati aberráció, barna színaberráció, barnahasú pusztaityúk, színezeti változatosság, Rajasthan

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Background

The striking nature and ease of tracking of abnormal plumages have led to their detection in numerous wild bird species. Color aberrations develop from the deficiency or excess of specific pigments in feathers and skin, lead to various forms of color variation that deviate from the original plumage pattern. In birds, there are multiple forms of color aberrations mostly caused by mutations (van Grouw 2013, 2018). The commonly reported aberrations are albinism, brown, dilution, leucism, melanism and progressive greying (Sage 1963, van Grouw 2006, 2011, 2012, Koprade *et al.* 2014, Mahabal *et al.* 2016).



Figure 1. (A, C) Female Chestnut-bellied Sandgrouse with normal colouration; (B, D) female with 'brown aberration'

1. ábra Barnahasú pusztaityúk tojó normális színezettel (A, C) és barna aberrációval (B, D)

The qualitative reduction of eumelanin (responsible for black, grey and/or dark brown colors) results in 'brown aberration'. Because of partial oxidization of eumelanin, the black pigments remain dark brown while red-yellow and reddish brown stays unaffected (van Grouw 2013). Aberrations from partially oxidized eumelanin are sensitive to sunlight and bleach quickly. Plumage that is in direct exposure thus becomes almost white. Feet and bill become paler, but eyes remain unaffected (van Grouw 2012). The brown mutation could be induced by a single gene and passed down recessively via the female sexual chromosome (van Grouw 2006, 2012) increasing the probability that females are more likely to have brown plumage.

The Chestnut-bellied Sandgrouse *(Pterocles exustus)* is native to Africa and Asia, and it is found across India except in the northeast region of the country. The species favors open habitats such as rangelands, shrubland, grassland, and desert. The Chestnut-bellied Sandgrouse is sexually dichromatic. Males are more consistent on the head and breast, with a distinct black band across the upper breast. The face and throat are yellowish. Females have extensively mottled breasts and necks, with thin black line across the breasts. Females' upperparts are less brightly colored and more streaked than males (Khil *et al.* 2012).

Observation

On 6 December 2024, we located a Chestnut-bellied Sandgrouse flock with ~20 individuals, among which we spotted an adult female with remarkable pale plumage. The observation occurred at Silotara Pond, Jaisalmer, Rajasthan (26°59'28.7"N 71°45'03.0"E) falling in arid region of India. The unusual individual probably had 'brown aberration' *(Figure 1)*. The typical sandy brown color turned to beige shade. The dark breast band was not visible, and the streaks on the throat, which are a distinguishing trait in females, were lighter and barely visible. Dark bars on the back turned to brighter shades. However, black bars on the belly and black underwings turned to dark brown and were least affected as that region is unexposed to sun. The yellowish-brown head was unaffected. The bird was photographed at 11:00 in the morning.

Discussion

To extent of the information we have, no cases of unusual plumage color were recorded in Chestnut-bellied Sandgrouse throughout their distribution range. Among other sandgrouse species, we found two examples in the scientific literature; 'brown' in Black-bellied Sandgrouse *(Pterocles orientalis)* from Israel (Smith 2010), and 'progressive greying' in Pin-tailed Sandgrouse *(Pterocles alchata)* from Spain (Benítez-López & García-Egea 2015). Recent plumage abnormalities reported from Rajasthan, India in various bird species that includes 'intersex plumage' in Plum-headed Parakeet *(Psittacula cyanocephala)* (Choudhary *et al.* 2024), 'erythrism' in House Sparrow *(Passer domesticus)* (Jangir *et al.* 2024a), 'progressive greying' in White-eared Bulbul *(Pycnonotus leucotis)* (Jangir *et al.* 2024b), 'melanism' in Black-headed Ibis *(Threskiornis melanocephalus)* (Sharma & Tripathi 2024), 'brown aberration' in Indian Pied Starling *(Gracupica contra)* (Jangir *et al.* 2023), and 'leucism' in Western Yellow Wagtail *(Motacilla flava)* (Bhardwaj 2020) suggests that shared environmental stressors or genetic factors may be contributing to abnormal occurrences in this geographical region.

Cases of 'brown aberration' are reported in a variety of birds that includes Eastern Wood-Pewee *(Contopus virens)* and a White-collared Manakin *(Manacus candei)* from Costa Rica (Lopez *et al.* 2024), Lava Gull *(Leucophaeus fuliginosus)* from Galapagos Islands, Ecuador (Reyes & Ortiz-Catedral 2023), Red-vented Bulbul *(Pycnonotus cafer)* (Thapa *et al.* 2023), Fulvous-breasted Woodpecker *(Dendrocopos macei)* (Pathania *et al.* 2020), House Crow *(Corvus splendens)* (Mahabal *et al.* 2015) and Gadwall *(Anas strepera)* from India (Patel *et al.* 2019), House Sparrow (van Grouw 2012), and Common Buzzard *(Buteo buteo)* from Poland (Ciach *et al.* 2011).

The documented individual's brown plumage differs from the usual cryptic coloration of the Chestnut-bellied Sandgrouse, which could influence the individual's fitness as coloration plays an essential role in survival in arid and semi-arid environments. Predators are likely to spot a bird with abnormal coloration more easily, increasing risk and making survival more difficult (Olea *et al.* 2010). Color aberrations in wild bird species are still insufficiently

recorded in many regions. This case study aims to contribute a new species in existing knowledge pool of color aberration in wild birds.

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Exploring anomalies in urban avifauna: Bald Indian House Crow (*Corvus splendens* Vieillot, 1817) observations in Kerala, India

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Abstract The Indian House Crow *(Corvus splendens)*, commonly observed in urban habitats, is the subject of this study presenting opportunistic observations of three bald individuals in coastal urban habitats, shedding light on their behaviour and potential causes of baldness. Furthermore, the absence of scientific literature on baldness in Indian House Crows highlights the novelty of this report. The lack of comprehensive studies on this topic underscores the need for further investigation into the causes and implications of bird baldness.

Keywords: Indian House Crow, baldness, deformities, plumage anomalies, urban birds

Összefoglalás Az indiai varjú *(Corvus splendens)*, amely madárfaj gyakran megfigyelhető városokban, adja tárgyát jelen tanulmányunknak. Három hiányos tollazatú (kopasz) egyedet is megfigyeltünk egy tengerparti város nyújtotta élőhelyen. A madarak viselkedése mellett a kopaszság okának lehetséges magyarázatait is tárgyaljuk. Az irodalomban nagyon kevés információ áll rendelkezésre a témában, ami tovább emeli rövid közleményünk fontosságát. Átfogó tanulmányok hiányában a madarak kopaszságának okai és következményei alig ismertek, ezért további vizsgálatok indokoltak.

Kulcsszavak: indiai varjú, kopaszság, tollazati eltérések, városi madarak

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Introduction

Baldness in birds poses interesting concerns regarding the health, behaviour, and ecology of birds, even if it may not be as common or obvious as in mammals. Birds' plumage serves a variety of purposes, including insulation, water resistance, flight facilitation, camouflage, and participation in aggressive and sexual displays (Dawson 2015). Unlike human baldness linked to aging, avian baldness stems from different causes, with birds experiencing brief periods of feather loss. Bird baldness is a unique abnormality that is significant due to its rarity attributed to its transient nature and its effects on several plumage-related processes.

These anomalies have the potential to have a substantial impact on affected birds, with implications on their general well-being, social connections, and chances of survival. In this report, we document the observations of baldness in Indian House Crows *(Corvus splendens)*, a synanthropic bird species flocking urban and rural habitats in Kerala, India (Jayapal *et al.* 2022). Its general look earned it the scientific name, *Corvus splendens*, which translates to 'shining raven'.

The Indian House Crow is a slender bird with a long neck and relatively large bill. It is glossy black except for a well-defined smoky-grey "collar", from the hind crown to mantle and breast, the shade of which varies among the five subspecies. Sexes are alike, with males being slightly larger (Rasmussen & Anderton 2005). It is an omnivorous and highly opportunistic scavenger that feeds heavily on human food remains and is generally confined to man-made habitats and conurbations due to its highly commensal nature. The Indian House Crow has successfully invaded tropical and subtropical regions well beyond its native range, reaching pest proportions in many areas (Brook *et al.* 2003). This species presents great ecological flexibility, as well as an obligate association with human presence, to the extent that no populations are known to live independently of man (Nyári *et al.* 2006). They are highly social, staying in a locality for perhaps their whole life. Movement into new areas is often because of major disturbances (e.g. attempted unorganised control) on nest or roost sites, however, adult birds regularly travel up to 20 km per day to known feeding areas (Global Invasive Species Database 2024).

Observation

During a bird-watching trip on Kollam Beach (8°52'32.6"N – 76°35'23.6"E) on 25th March 2024, the team spotted a bald Indian House Crow among a murder and several Little Egrets *(Egretta garzetta)* foraging near a hauled fishing net. The bizarre bird with a vulture-like appearance, seen walking and occasionally hopping could be easily identified from its size, shape and colour. Photographs were taken to record the abnormalities in its plumage *(Figure 1)*. The neck was devoid of feathers and bore remnants of feathers. The head was sparsely feathered with several bare patches around the nape, beak and orbital region. Ears and nostrils were partially covered. However, the bird had normal plumage from the breast downwards. We could see other crows in the flock with missing feathers on the throat and breast. We could also see most of the crows in the vicinity with gaps in the outline of the tail and wings, pointing to the moulting season. The baldness in the crow could be caused either by moulting or some feather parasites. The bird #1 documented is presumed to be an adult as we could see the bird carrying food on its beak while flying away.

Another partially bald Indian House Crow was spotted almost 500 m from the beach on 3rd April 2024 nesting on a sacred fig tree *(Ficus religiosa)*. The bird's nape appeared shaven, and the rest of the head was thinly plumaged with a ruffled appearance *(Figure 1)*. The remaining plumage of the bird appeared normal except for a few missing flight feathers. It was frequently spotted in pairs, flying short distances from tree to tree or utility poles. The accompanying bird was its juvenile which was discerned from the calls and appearance and was seen feeding the pestering bird.



Figure 1. a – bald crow (bird #1) on the beach; b and c – partially bald crow (bird #2) with its pair; d – another partially bald crow (bird #3)
1. ábra A kopasz varjak fotói

While photographing bird #2, we could see a different individual (bird #3) flying around in the locality with incomplete plumage on its head. The crow had an almost bare neck and bald patches on its head *(Figure 1)*. Unlike the other two birds, we could not determine the reproductive status of the bird. The bird is assumed to be an adult from its size and behaviour.

A Google image search with key words "Bald bird," "Baldness in birds" and "bald crow" yielded some images, mostly Blue Jays *(Cyanocitta cristata)*, Northern Cardinals *(Cardinalis cardinalis)* and couple of crows *(Table 1)*.

Table 1. Google image search result of bald birds
1. táblázat Google képkeresés eredményei kopasz madarakra

No	Species	Source
1	Blue Jays *(Cyanocitta cristata)*, Northern Cardinals *(Cardinalis cardinalis)* and couple of crows	u/AcidRotten 2022
2	Male pattern baldness (MPB) in the Wattled Starling *(Creatophora carunculate)* and Ruff *(Philomachus pugnax)*	van Oordt & Junge 1936, u/MilkshakePoultry 2024,
3	Gouldian Finches *(Erythrura gouldiae)*	Marshall 2009
4	Gouldians	Gelis 2003
5	Blue Jays and Northern Cardinals	Burtt 2004, Kieffer 2014, Project Feeder Watch (a) (n.d.), Cornell Lab 2024
6	Hooded Oriole *(Icterus cucullatus)*	Project Feeder Watch (b) (n.d.)
7	Wattled Starling *(Creatophora carunculate)*	Chapin 1954

Discussion

There is energy costs associated with feather loss. Fewer feathers mean less efficient flight leading to incompetence with prey and predators, and reduced insulation thereby loss of body heat and other fitness consequences (Tucker 1991, Murphy & King 1992, Swaddle & Witter 1997, Dawson 2015). The phenomenon of baldness in birds has been ascribed to various factors, encompassing genetic disorders, hormonal imbalances, ectoparasite infestation, nutritional deficiencies, or moulting (Kasambe *et al.* 2010, Surender *et al.* 2015).

In laboratory settings, some birds exhibit baldness, seemingly induced by androgenic stimulation (Hamilton 1959) as evidenced by examination of preserved specimens from diverse species at the American Museum of Natural History that revealed pronounced male pattern baldness (MPB) in the Wattled Starling *(Creatophora carunculate)* (Chapin 1954) and the Ruff *(Philomachus pugnax)* (van Oordt & Junge 1936). A syndrome of baldness and facial feather loss commonly seen in Gouldian Finches *(Erythrura gouldiae)* (Gelis 2003). A common disease, the Airsac Mite *(Sternostoma tracheacolum)* infection results in baldness in gouldieans (Marshall 2009). The presence of mycobacteria in the dermis in some finches which have exhibited feather loss in the head and face also points to the underlying microbial roles (Bauck & Brash 1999).

Conspicuously, there has been a lack of scientific studies in this field, leaving the exact causes behind such cases yet to be revealed. It is uncommon to come across a bald bird in the wild. Plumage colouration is of great importance to birds as it helps them in camouflage (Barragán-Farías *et al.* 2019), mate selection (Hill *et al.* 1999), social signaling (Senar

2006) and various other physiological and behavioural processes. When the colour of the plumage itself is very important for the fitness of a bird, loss of feathers on the head or any other part could have greater negative consequences for the bird (Sarlin *et al*. 2024).

It turns out that bird baldness is common in Blue Jays *(Cyanocitta cristata)* and Northern Cardinals *(Cardinalis cardinalis)*. According to Cornell Lab (Project Feeder Watch 2024), many of these strange-looking birds may be juveniles undergoing their first prebasic moult, which produces the first winter adult plumage. For Blue Jays, this moult pattern is considered normal, and this moult pattern also happens with enough frequency in Northern Cardinal populations to be considered within the normal range.

In India, reports of baldness in birds are predominantly confined to Common Mynas *(Acridotheres tristis)*, and Rose-ringed Parakeets *(Psittacula krameri)* (Kasambe *et al.* 2010). Multiple instances of bald Common Mynas have been documented in diverse locations across India, including Maharashtra, Chandigarh, Tamil Nadu, and Madhya Pradesh (Kasambe *et al.* 2010, Ali *et al.* 2013, Sagar *et al.* 2013, Kumar & Kushwaha 2019). Additionally, a bald Pied Starling *(Gracupica contra)* sighting was reported in the Nalgonda District, Telangana, in 2012 (Surender *et al.* 2015).

Conclusion

While baldness in birds has been reported in other species across India, its occurrence in Indian House Crows is relatively unexplored. Astonishingly, no report of baldness in Indian House Crow, a common species in Kerala exists in the scientific literature. It must be noted that Kerala had conducted systematic surveys of various bird species with the participation of over 1,000 volunteer bird watchers as a citizen science-driven exercise spread over 60 days a year for five years (2015–2020) releasing The Kerala Bird Atlas (KBA), the first-of-its-kind state-level bird atlas in India (Kerala Bird Atlas 2022). We believe that it must be due to non-detection and the Least Concern status in the International Union for Conservation of Nature (IUCN) red data book of such birds. Had anyone observed such unusual birds, they might have naturally reported it in scientific journals, or in the Bird Watchers forum, which are active on multiple social media platforms. To the best of our knowledge, this note describes the first confirmed sighting of a bald Indian House Crow from Kerala, India.

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