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Ornithological importance and phenological status of the avifauna population of the Idriss 1st dam in semi-arid climate Morocco

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Abstract: This study evaluates the ornithological diversity and phenological status of bird species at Idriss I Dam, located 21 km northeast of Fez, Morocco. From 2022 to 2024, avifaunal monitoring was conducted on a monthly to bimonthly basis, accounting for both seasonal and interannual variations. Observation points were selected based on water-level fluctuations, and bird counts were carried out using 12×50 binoculars and a Nikon P1000 camera. The avifaunal structure was analyzed using ecological indices, including total abundance, species richness, and the Shannon–Wiener diversity index. Seventy-eight waterbird species from 21 families were recorded, with Anatidae (20%) and Scolopacidae (15%) being the most represented, followed by Ardeidae (11%) and Laridae (9%). Diversity indices indicated high species richness, with Shannon index values ranging from 2.83 to 3.02 bits per individual, confirming the site's importance as a wintering, resting, and breeding habitat. Seven dominant species were identified: black-headed gull, mallard, green-winged teal, common crane, great cormorant, northern shoveler, and ruddy shelduck. Occasional records of endangered or vulnerable species, such as the Egyptian vulture and common pochard, were also documented. Principal Component Analysis revealed three main phenological phases: post-nuptial migration, wintering, and pre-nuptial migration, underscoring the site's ecological significance and supporting its potential designation as a Ramsar site.

Keywords: *Biodiversity, Bird population, Idriss 1st Dam, Morocco, Phenological status.*

1. Introduction

Wetlands are ecosystems that play an irreplaceable role in regulating the climate, maintaining hydrological cycles, conserving biodiversity and safeguarding human well-being [1]. They provide a multitude of ecosystem services, including flood regulation, water purification, carbon storage and habitats for a diverse range of wildlife, particularly waterbirds [2]. These species depend on wetlands throughout their life cycle, whether for breeding, feeding or as resting sites during their migrations [3, 4]. These ecosystems are crucial for migratory species, some of which are threatened or in decline, making wetlands vital refuges for their conservation [5].

In recent decades, a significant proportion of wetlands have been lost or degraded as a result of urbanisation, intensive agriculture and, in particular, the effects of climate change [5-7]. This phenomenon has a direct impact on avifauna, whose migratory behaviour and phenology are disrupted [8-10]. The phenology of migratory birds, which includes the timing of their migration and their reproductive behaviour, is thus affected by changes in climatic conditions [11, 12] which call for in-depth research.

In Morocco, the situation of wetlands is of particular concern. The country is home to around 300 wetlands, both natural and artificial, spread between the Mediterranean coast in the north and the Saharan areas in the south [13]. Of these, 38 are classified as RAMSAR sites due to their specific and ornithological richness. Because of Morocco's strategic geographical position, these wetlands provide

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crucial winter stopovers for many migratory species, serving as a refuge for birds from Europe and tropical Africa. However, these ecosystems are now under threat, with a significant impact on the species that depend on them [14, 15].

In view of this situation, it is becoming essential to monitor changes in the phenology of waterfowl, particularly in continental wetlands with a semi-arid climate, such as the Idriss I dam. This dam, which is located some thirty kilometres from Fez and plays a key role in energy production and irrigation in the Gharb Plain, has already been the subject of winter censuses [16, 17] but without any study of the phenological dynamics of its avifauna. In response to this situation, our research topic is part of a monthly monitoring programme over three consecutive years (2022–2024) involving waterbirds censuses, the main objective of which is to determine their phenological behaviour as a function of environmental factors.

2. Materials and Methods

2.1. Presentation of the Study Site

The ldriss First Dam is located 21 km NE of the city of Fez in the Inaouen river watershed which covers an area of 3600 km². It was flooded in 1973 from the Inaouène river which is a tributary of the Sebou river (Figure 1). Its capacity is 1186 Mm³ over an area of approximately 18000 hectares at the normal coast of 217 NGM. Since 1992, this dam has also received approximately 600 Mm³.year⁻¹ of water from the upper Sebou from the Allal El Fassi dam via the Matmata gallery, taking advantage of the topographical difference in altitude for the production of electricity [17]. The prevailing climate is semi-arid with annual rainfall varying between 400 mm and 600 mm and an average minimum temperature of 10°C and maximum of 25°C.

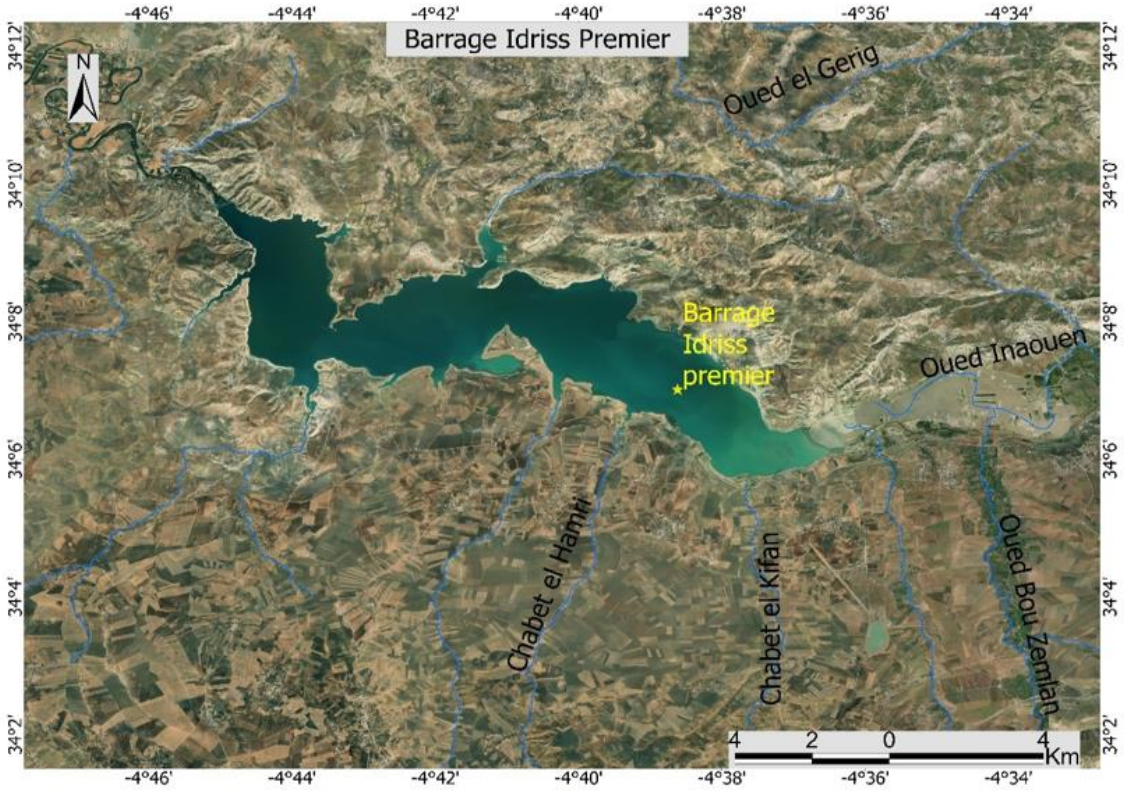

Figure 1.
Geographical and morphological situation of the Idriss 1st dam.

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The geomorphology indicates two types of substratum, the first on the right bank desolate and poor in vegetation, the second on the left bank where agricultural activities dominate with the sowing of cereals, legumes and the marshes irrigated by the waters of the dam where develop with the water level.

2.2. Bird Census

For the phenological monitoring of the avifauna of the Idriss First Dam, census campaigns were carried out from January 2022 to August 2024 at a regular bimonthly to monthly frequency depending on the nesting, migration and/or wintering periods. Several observation points are chosen on the left bank of the dam, point 1 is considered the most representative of the effective point of view mainly for waders (Figure 1). During the study period, the dam experienced fluctuations in the water level due to the drought that prevailed during this period.

The direct counting method used is that of Lamotte and Bourlière [18] which consists of an individual count when the group does not exceed 200 individuals or the subdivision of the visual field into equal bands when the group is greater than 200 individuals. The census is based on the visual counting of birds by two observers using binoculars (12×50) and a high-magnification camera (Nikon Coolpix P1000). Various ornithological guides were used for species identification, including the Ornitho guide, Birds of Morocco and African East Atlantic flyway guide [19-21].

2.3. Structure of the Bird Population

The structure of the stands in the study area was assessed using various ecological indices that reflect the balance of the stands: total abundance, species richness, diversity index of Shannon and Weaver [22].

The Shannon index was calculated using the following formula:

$H' = -\sum (ni/N) \times Log_2 (ni/N)$

Where:

N = Sum of the numbers of all species

ni = Population size of species i

The results are expressed in Bits/individual.

2.4. Correspondence Factorial Analysis

During the census, the multivariate statistical method PCA was used to analyse annual variations in waterbird species in the study site and to establish a correlation between the presence of bird species (observed variables) and observations (census dates). Table I shows the number given to each observation and the code used for each waterbird species in this analysis.

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Table 1.
Observations numbers and species codes used in PCA.

Observations numbers				Species codes			
1	17/01/2022	21	31/07/2023	*Ac-hy*	*Actitis hypoleucos*	*Li-la*	*Limosa lapponica*
2	19/02/2022	22	19/08/2023	*An-cr*	*Anas crecca*	*Li-li*	*Limosa limosa*
3	24/02/2022	23	10/09/2023	*An-pl*	*Anas platyrhynchos*	*Ma-st*	*Mareca strepera*
4	29/03/2022	24	19/10/2023	*Ar-ci*	*Ardea cinerea*	*Ph-pu*	*Philomachus pugnax*
5	18/04/2022	25	21/10/2023	*Ay-fe*	*Aythya ferina*	*Ph-ca*	*Phalacrocorax carbo*
6	15/05/2022	26	28/10/2023	*Ca-al*	*Calidris alpina*	*Ph-ro*	*Phoenicopterus roseus*
7	16/06/2022	27	19/11/2023	*Ca-fe*	*Calidris ferruginea*	*Pl-le*	*Platalea leucorodia*
8	20/07/2022	28	10/12/2023	*Ca-mi*	*Calidris minuta*	*Po-cr*	*Podiceps cristatus*
9	19/08/2022	29	01/01/2024	*Ca-te*	*Calidris temminckii*	*Re-av*	*Recurvirostra avosetta*
10	17/09/2022	30	15/01/2024	*Ch-al*	*Charadrius alexandrinus*	*Sp-cl*	*Spatula clypeata*
11	14/10/2022	31	17/02/2024	*Ch-du*	*Charadrius dubius*	*St-al*	*Sternula albifrons*
12	15/11/2022	32	19/03/2024	*Ch-hi*	*Charadrius hiaticula*	*Ta-ru*	*Tachybaptus ruficollis*
13	17/12/2022	33	20/04/2024	*Ch-ri*	*Chroicocephalus ridibundus*	*Ta-fe*	*Tadorna ferruginea*
14	01/01/2023	34	18/05/2024	*Ci-ci*	*Ciconia ciconia*	*Ta-ta*	*Tadorna tadorna*
15	15/01/2023	35	21/06/2024	*Eg-ga*	*Egretta garzetta*	*Tr-gl*	*Tringa glareola*
16	19/02/2023	36	30/06/2024	*Fu-at*	*Fulica atra*	*Tr-ne*	*Tringa nebularia*
17	15/03/2023	37	13/07/2024	*Ge-ni*	*Gelochelidon nilotica*		
18	16/04/2023	38	27/07/2024	*Hi-hi*	*Himantopus himantopus*		
19	19/05/2023	39	31/08/2024	*La-mi*	*Larus michahellis*		
20	15/06/2023						

3. Results

3.1. Specific Composition of the Bird Population

Monthly monitoring of avifauna at the Idriss 1st Dam over the three-year study period (2022–2024) identified 78 species of waterbirds across 21 families. The Anatidae and Scolopacidae families were the most abundant, comprising 22% and 14% of the surveyed species, respectively, followed by Ardeidae at 10% and Laridae at 9%.

The species richness within these families accounted for a significant proportion of the nationally reported species counts: 82.60% for Scolopacidae, 80% for Ardeidae, 66.66% for Charadriidae, 47.61% for Anatidae, and 44.44% for Rallidae.

Census data also recorded the presence of internationally significant species, including the Egyptian vulture (endangered), the common pochard (vulnerable), as well as marbled teal, bar-tailed godwit, black-tailed godwit, red knot, eurasian oystercatcher, ruddy turnstone and curlew sandpiper (near threatened) (Table II).

Additionally, coastal-origin species were present at the site, such as the oystercatcher, ruddy turnstone, whimbrel, sanderling, great ringed plover, black-backed gull, and yellow-legged gull (Table 2).

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Table 2.
List of bird species with their phenological and conservation status in the study site during the three-year monitoring (2022 to 2024). * Species with important conservation status; ** Species of coastal origin; Phenological status: (RB: Resident breeder, WV: Winter visitor, PM: Passage migrant, BM Breeding migrant, OB: Occasional Breeder; PAV: Palearctic Accidental Visitor) and IUCN conservation status (EN: Endangered, LC: Least Concern, NT: Near Threatened).

Orders	Families	Common names	Scientific names	Phenological status	Conservation status	2022	2023	2024	Total	Percentage
Anseriformes	Anatidae	Pintail	*Anas acuta* Linnaeus, 1758	WV; PM; OB	LC	0	5	0	5	0.01%
		Northern shoveler	*Spatula clypeata* Linnaeus, 1758	WV; PM; OB	LC	554	1286	535	2375	5.22%
		Winter teal	*Anas crecca* Linnaeus, 1758	WV; PM	LC	893	2837	1090	4820	10.59%
		Mallard	*Anas platyrhynchos* Linnaeus, 1758	RB; WV	LC	2468	2960	661	6089	13.38%
		Garganey	*Spatula querquedula* Linnaeus, 1758	PM; OW	LC	2	6	0	8	0.02%
		Gadwall	*Mareca strepera* Linnaeus, 1758	WV; PM; OB	LC	607	1135	233	1975	4.34%
		Common pochard*	***Aythya ferina*** Linnaeus, 1758	**WV; PM; OB**	**VU**	**217**	**385**	**25**	**627**	**1.38%**
		Ruddy shelduck	*Tadorna ferruginea* Pallas, 1764	RB	LC	842	1158	356	2356	5.18%
		Common shelduck	*Tadorna tadorna* Linnaeus, 1758	WV	LC	123	198	100	421	0.92%
		Marbled teal*	***Marmaronetta angustirostris*** Ménétries, 1832	**RB; WV; PM**	**NT**	8	3	0	**11**	**0.02%**
		Total				**5714**	**9973**	**3000**	**18687**	**41.05%**
Ciconiiformes	Ardeidae	Great egret	*Ardea alba* Linnaeus, 1758	WV; PM	LC	0	1	0	1	0.01%
		Grey heron	*Ardea cinerea* Linnaeus, 1758	PM; WV; OB	LC	202	147	41	390	0.86%
		Purple heron	*Ardea purpurea* Linnaeus, 1766	PM; BM; OW	LC	0	0	6	6	0.01%
		Black-crowned night heron	*Nycticorax nycticorax* Linnaeus, 1758	PM; BM; WV	LC	0	0	12	12	0.03%
		Cattle egret	*Bubulcus ibis* Linnaeus, 1758	RB; PM; WV	LC	230	155	77	462	1.01%
		Little egret	*Egretta garzetta* Linnaeus, 1766	RB; PM; WV	LC	82	160	63	305	0.67%
		Squacco heron	*Ardeola ralloides* Scopoli, 1769	BM; RB? PM; W	LC	2	1	5	8	0.02%
		Total				**516**	**464**	**204**	**1184**	**2.60%**
	Ciconiidae	White stork	*Ciconia ciconia* Linnaeus, 1758	PM; BM; WV	LC	78	362	80	520	1.14%
		Total				**78**	**362**	**80**	**520**	**1.14%**
	Phoenicopteridae	Great flamingo	*Phoenicopterus roseus* Pallas, 1811	PM; WV; RB	LC	457	635	283	1375	3.02%
		Total				**457**	**635**	**283**	**1375**	**3.02%**
	Threskiornithidae	Eurasian spoonbill	*Platalea leucorodia* Linnaeus, 1758	PM; WV; RB	LC	356	405	303	1064	2.34%
		Glossy ibis	*Plegadis falcinellus* Linnaeus, 1766	PM; WV; OB	LC	6	1	7	14	0.03%
		Total				**362**	**406**	**310**	**1078**	**2.37%**
Gruiformes	**Gruidae**	Common crane	*Grus grus*	WV	LC	1620	1660	1086	4366	9.9%
		Total				**1620**	**1660**	**1086**	**4366**	**9.59%**
	Rallidae	Coot	*Fulica spp*			29	69	12	110	0.24%
		Eurasian coot	*Fulica atra* Linnaeus, 1758	RB; WV	LC	96	70	114	280	0.62%
		Wattled coot	*Fulica cristata* Gmelin, 1789	RB	LC	0	5	0	5	0.01%
		Common moorhen	*Gallinula chloropus* Linnaeus, 1758	RB; WV	LC	0	0	39	39	0.09%
		Western swamphen	*Porphyrio porphyrio* Linnaeus, 1758	WV; PM; OB	LC	0	0	2	2	<0.01%
		Total				**125**	**144**	**167**	**436**	**1.02%**
Charadriiformes	Laridae	Black tern	*Chlidonias niger* Linnaeus, 1758	PM	LC	1	0	18	19	0.04%

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		Whiskered tern	*Chlidonias hybrida* Pallas, 1811	PM; WV; OB	LC	9	0	2	11	0.02%
		Caspian tern **	*Hydroprogne caspia* Pallas, 1770	PM; WV	LC	1	1	0	2	<0.01%
		Gull-billed tern	*Gelochelidon nilotica* Gmelin, 1789	PM	LC	33	6	38	77	0.17%
		Black-headed gull	*Chroicocephalus ridibundus* Linnaeus, 1766	WV; PM; RB	LC	2503	2765	1206	6474	14.22%
		Little tern	*Sternula albifrons* Pallas, 1764	BM; PM; OW	LC	6	20	50	76	0.17%
		Black-backed gull**	*Larus fuscus* Linnaeus, 1758	PM; WV	LC	0	0	0	8	0.02%
		Yellow-legged gull**	*Larus michahellis* Naumann, 1840	RB; WV	LC	1	3	4	14	0.03%
		Total				**2554**	**2795**	**1318**	**6681**	**14.67%**
	Scolopacidae	Sandpipers	*Calidris spp*			95	36	4	135	0.30%
		Sanderling**	*Calidris alba* Pallas, 1764	PM; WV	LC	20	19	20	59	0.13%
		Dunlin	*Calidris alpina* Linnaeus, 1758	PM; WV	LC	108	162	54	324	0.71%
		Red knot*	***Calidris canutus*** Linnaeus, 1758	**PM; WV**	**NT**	**0**	**8**	**4**	**12**	**0.03%**
		Curlew sandpiper*	***Calidris ferruginea*** Pontoppidan, 1763	**PM, WV**	**NT**	**64**	**75**	**11**	**150**	**0.33%**
		Purple sandpiper**	*Calidris maritima* Brünnich, 1764	PAV	LC	0	0	0	1	<0.01%
		Little stint	*Calidris minuta Leisler, 1812*	PM; WV	LC	67	85	34	186	0.41%
		Temminck's stint	*Calidris temminckii* Leisler, 1812	PM; WV	LC	33	68	32	133	0.29%
		Shanks	*Tringa spp*			14	30	9	53	0.12%
		Spotted redshank	*Tringa erythropus* Pallas, 1764	PM; WV	LC	6	2	3	11	0.02%
		Wood sandpiper	*Tringa glareola* Linnaeus, 1758	PM; WV	LC	79	46	34	159	0.35%
		Greenshank	*Tringa nebularia* Gunnerus, 1767	PM; WV	LC	54	117	25	196	0.43%
		Green sandpiper	*Tringa ochropus* Linnaeus, 1758	PM; WV	LC	2	24	8	34	0.07%
		Common redshank	*Tringa totanus* Linnaeus, 1758	PM; WV; OB	LC	25	14	1	40	0.09%
		Common sandpiper	*Actitis hypoleucos* Linnaeus, 1758	PM; WV	LC	88	164	31	283	0.62%
		Common snipe	*Gallinago gallinago* Linnaeus, 1758	PM; WV	LC	7	10	6	23	0.05%
		Ruff	*Calidris pugnax* Linnaeus, 1758	PM	LC	101	231	84	416	0.91%
		Bar-tailed godwit*	***Limosa lapponica*** Linnaeus, 1758	**PM; WV**	**NT**	**52**	**59**	**14**	**125**	**0.27%**
		Black-tailed godwit*	***Limosa limosa*** Linnaeus, 1758	**PM; WV**	**NT**	**115**	**92**	**44**	**251**	**0.55%**
		Whimbrel**	*Numenius phaeopus* Linnaeus, 1758	PM	LC	0	1	0	2	<0.01%
		Ruddy turnstone**	***Arenaria interpres* Linnaeus, 1758**	**PM; WV**	**NT**	**0**	**1**	**0**	**1**	**<0.01%**
		Total				**930**	**1244**	**418**	**2594**	**5.69%**
	Charadriidae	Kentish plover	*Charadrius alexandrinus* Linnaeus, 1758	RB; PM; WV	LC	165	115	45	325	0.71%
		Little ringed plover	*Charadrius dubius* Scopoli, 1786	RB; PM; WV	LC	574	369	54	997	2.19%
		Common ringed plover**	*Charadrius hiaticula* Linnaeus, 1758	PM; WV	LC	115	65	8	188	0.41%
		Grey plover**	*Pluvialis squatarola* Linnaeus, 1758	PM; WV	LC	1	0	0	2	<0.01%
		Total				**855**	**549**	**107**	**1512**	**3.32%**
Charadriiformes	**Glareolidae**	Collared pratincole	*Glareola pratincole* Linnaeus, 1758	PM; BM; OW	LC	286	105	0	391	0.86%
		Total				**286**	**105**	**0**	**391**	**0.86%**
	Haematopodidae	**Oystercatcher**	***Haematopus ostralegus* Linnaeus, 1758**	**PM; WV**	**NT**	**0**	**1**	**0**	**1**	**<0.01%**
		Total				**0**	**1**	**0**	**1**	**<0.01%**

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	Recurvirostridae	Black winged stilt	*Himantopus Himantopus* Linnaeus, 1758	BM/RB; PM; WV	LC	503	356	128	987	2.17%
		Elegant avocet	*Recurvirostra avosetta* Linnaeus, 1758	PM; WV; OB	LC	622	597	150	1369	3.01%
		Total				**1125**	**953**	**278**	**2356**	**5.18%**
Pelecaniformes	**Phalacrocoracidae**	Great cormorant	*Phalacrocorax carbo* Linnaeus, 1758	WV	LC	441	853	1848	3142	6.90%
		Total				**441**	**853**	**1848**	**3142**	**6.90%**
Podicipediformes	Podicipedidae	Great crested grebe	*Podiceps cristatus* Linnaeus, 1758	RB; WV	LC	7	119	72	198	0.43%
		Black-necked grebe	*Podiceps nigricollis* Brehm, 1831	RB	LC	4	14	32	50	0.11%
		Little grebe	*Tachybaptus ruficollis* Pallas, 1764	RB	LC	189	92	27	308	0.68%
		Total				**200**	**225**	**131**	**556**	**1.22%**
Pandioniformes	Pandionidae	Osprey	*Pandion haliaetus* Linnaeus, 1758	PM; WV; RB	LC	1	1	0	2	<0.01%
		Total				**1**	**1**	**0**	**2**	**<0.01%**
Falconiformes	Accipitridae	**Egyptian vulture**	***Nephron percnopterus*** Linnaeus, 1758	**RB; WV; PM**	**EN**	**0**	**0**	**1**	**1**	<0.01%
		Marsh harrier	*Circus aeruginosus* Linnaeus, 1758	RB; WV; PM	LC	14	15	9	38	0.08%
		Booted eagle	*Hieraaetus pennatus* Gmelin, 1788	RB	LC	0	2	2	4	0.01%
		Total				**14**	**17**	**12**	**38**	**0.08%**
	Falconid	Peregrine falcon	*Falco peregrinus* Tunstall, 1771	RB	LC	0	1	0	1	<0.01%
		Kestrel	*Falco tinnunculus* Linnaeus, 1758	RB	LC	2	1	2	5	0.01%
		Total				**2**	**2**	**2**	**6**	**0.01%**
Burhiniformes	Burhinidae	Stone curlew	*Burhinus oedicnemus* Linnaeus, 1758	RB; WV; PM	LC	12	16	9	37	0.08%
		Total				**12**	**16**	**9**	**37**	**0.08%**
Pteroclidiformes	Pteroclidae	Black-bellied sandgrouse	*Pterocles orientalis* Linnaeus, 1758	RB	LC	0	58	0	58	0.13%
		Total				**0**	**58**	**0**	**58**	**0.13%**
Passeriformes	Motacillidae	White wagtail alba	*Motacilla alba* Linnaeus, 1758	WV; RB; PM	LC	85	67	35	187	0.41%
		White Wagtail supersonata	*Motacilla alba subpersonata* Meade-Waldo, 1901	RB	LC	34	11	6	51	0.11%
		Grey Wagtail	*Motacilla cinerea* Tunstall, 177	PM; RB; WV	LC	61	76	18	155	0.34%
		Western yellow wagtail	*Motacilla flava* Linnaeus, 1758	PM; BM/RB; WV	LC	33	53	18	104	0.23%
		Total				**213**	**207**	**77**	**497**	**1.09%**
		TOTAL				**15503**	**20639**	**9330**	**45472**	**100%**

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The Shannon-Weaver diversity index yielded values of 3.02 bits per individual in 2022, 2.96 bits per individual in 2023, and 2.83 bits per individual in 2024.

This indicates that species are evenly distributed, though some degree of dominance by certain species may still exist. Such a range reflects a balanced level of diversity, often associated with a stable and healthy ecosystem.

These results indicate that the study site supports significant avian diversity, facilitated by favourable environmental conditions that attract a wide variety of bird species.

Furthermore, the study revealed that the observed and recorded species belong to different phenological categories, including winterers, summer visitors, migrants, breeders, and non-breeders, which can be described as follows:

3.1.1. Migratory, Wintering and Summering

This category includes species that are present on the site year-round but do not breed there. Examples of such species are the white spoonbill, greater flamingo, little egret, grey heron, and little ringed plover.

3.1.2. Migratory and Wintering

These species are absent during the summer months and are typically present in autumn, winter, and spring. Notable species in this group include the green-winged teal, northern shoveler, black-headed gull, greenshank, avocet, and ruff.

3.1.3. Strict Winterers

Strict winterers are species observed exclusively during the winter season. Examples include the common crane, great cormorant, elegant avocet, and common shelduck.

3.1.4. Migratory Nesters

These are breeding summer visitors that have been observed only during the summer. This is the case for the little tern, the Kentish plover and the collared pratincole.

3.1.5. Non-Nesting Summer Visitors

This group is similar to the previous group, except that they do not nest. This is the case for the gull-billed tern, the whiskered tern and the black tern.

3.1.6. Sedentary, Migratory and Wintering Nesters

In this category, it was noted that these species are present all year round. But unlike the first group, they reproduce in the site where they present a population to which are most probably added passing migrants and wintering birds, this is the case of the mallard, the ruddy shelduck and the black-winged stilt.

3.1.7. Strict Migrants

These are species that have been observed during postnuptial migration from July to October and prenuptial migration from March to May. This is the case of the dunlin, Temminck's sandpiper, curlew sandpiper, common sandpiper and wood sandpiper.

3.2. Interannual Variation in Bird Numbers

Ornithological monitoring showed a very significant interannual variation in the number of each species observed during the study period. The highest percentages of the numbers are attributed to the Black-headed gull (14%), the Mallard (13%), the Green-winged Teal (11%), the Common Crane (10%) and the Great Cormorant (7%), the Ruddy Shelduck (5%) and the Northern Shoveler (5%). These seven species alone account for 65% of the total of the bird population (Table II).

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The other species have much smaller numbers, not exceeding a cumulative percentage of 35%, mainly consisting of waders.

Figure 2 shows the annual and interannual monitoring of the numbers of the main species observed during the study period.

3.2.1. Black-headed Gull Chroicocephalus ridibundus Gmelin, 1789

The first individuals of this species are observed at the end of July each year, a period that corresponds to the beginning of the postnuptial migration until March-April, the period of the beginning of the prenuptial migration. This result shows that it is a species that winters at the site. The highest number is recorded during the winter season and can exceed 700 individuals (Figure 2a). During the breeding season, a few individuals in nuptial plumage were observed, but no nesting was recorded at the site.

3.2.2. Mallard Anas platyrhynchos Linnaeus, 1758

The mallard is present all year round with a significant variation in numbers. It increases during the post-nuptial migration to reach 410 individuals in January 2024 and decreases to 40 individuals during the pre-nuptial migration (Figure 2b). Its continuous presence indicates that the population of this species is composed of two types of populations: a partial migratory one that migrates during the breeding season and another sedentary one that nests at the site.

3.2.3. Winter teal Anas crecca Linnaeus, 1758

Monitoring of this species shows that it is present between the two migration periods with more or less significant numbers. A maximum of 830 individuals is recorded in December 2023 (Figure 2c). This typical wintering species disappears completely from the site during the summer.

3.2.4. Common Crane Grus grus Linnaeus, 1758

Common cranes are regularly present from November to April. The largest number of 700 individuals is noted in January 2023 (Figure 2d). This is a species that winters at the site.

The presence of this species on the site is favoured by the suitable conditions prevailing in the environment: the marshy aspect upstream of the dam offers a safety perimeter against predators and human disturbance. Similarly, the presence of land with high agricultural potential offers the species the food necessary to survive during the winter period.

3.2.5. Great Cormorant Phalacrocorax Carbo Linnaeus, 1758

The great cormorant is present from October to March each year. The largest number is 820 individuals recorded in March 2024 (Figure 2e). This massive presence can be explained by the abundance of fish fauna in the site offering food sources to these divers who organize themselves to carry out collective fishing operations in order to fatten up even more before the big return to the North.

3.2.6. Ruddy Shelduck Tadorna Ferruginea Pallas, 1764

Like the mallard, monitoring of the ruddy shelduck shows that it is present at the site throughout the study period with a population that can reach 290 individuals in August 2024. It is a sedentary breeding species with an irregular population (Figure 2f). This species is dominant in the natural lakes of the Middle Atlas. After the latter dried up, it migrated to the reservoirs of dams to seek favourable habitat and food conditions for its settlement.

3.2.7. Northern Shoveler Spatula Clypeata Linnaeus, 1758

It is a wintering duck at the site level. The numbers are much higher during the year 2023, where the maximum of 390 individuals is recorded in December 2023 (Figure 2g). This phenological status is

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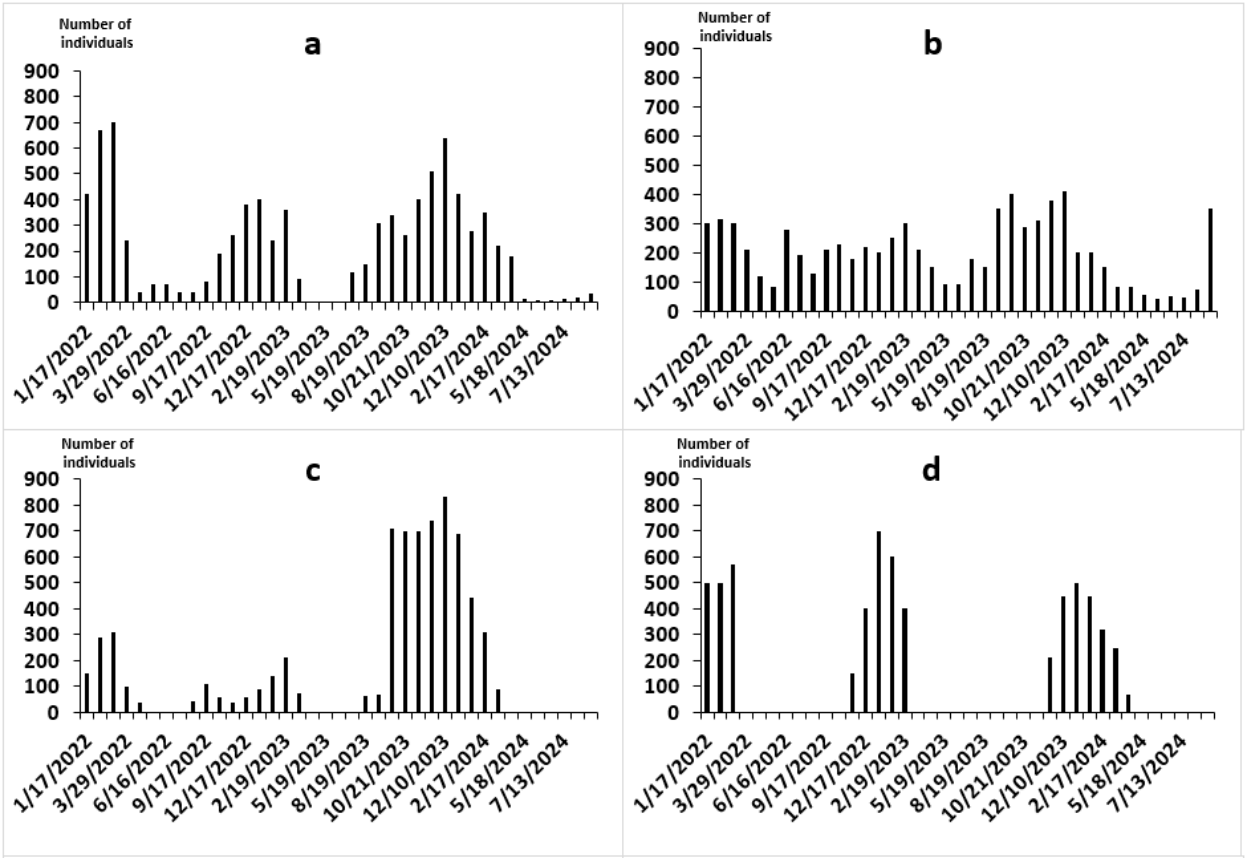
similar to that of the green-winged teal, the great cormorant, the common crane, the black-headed gull and the pied avocet.



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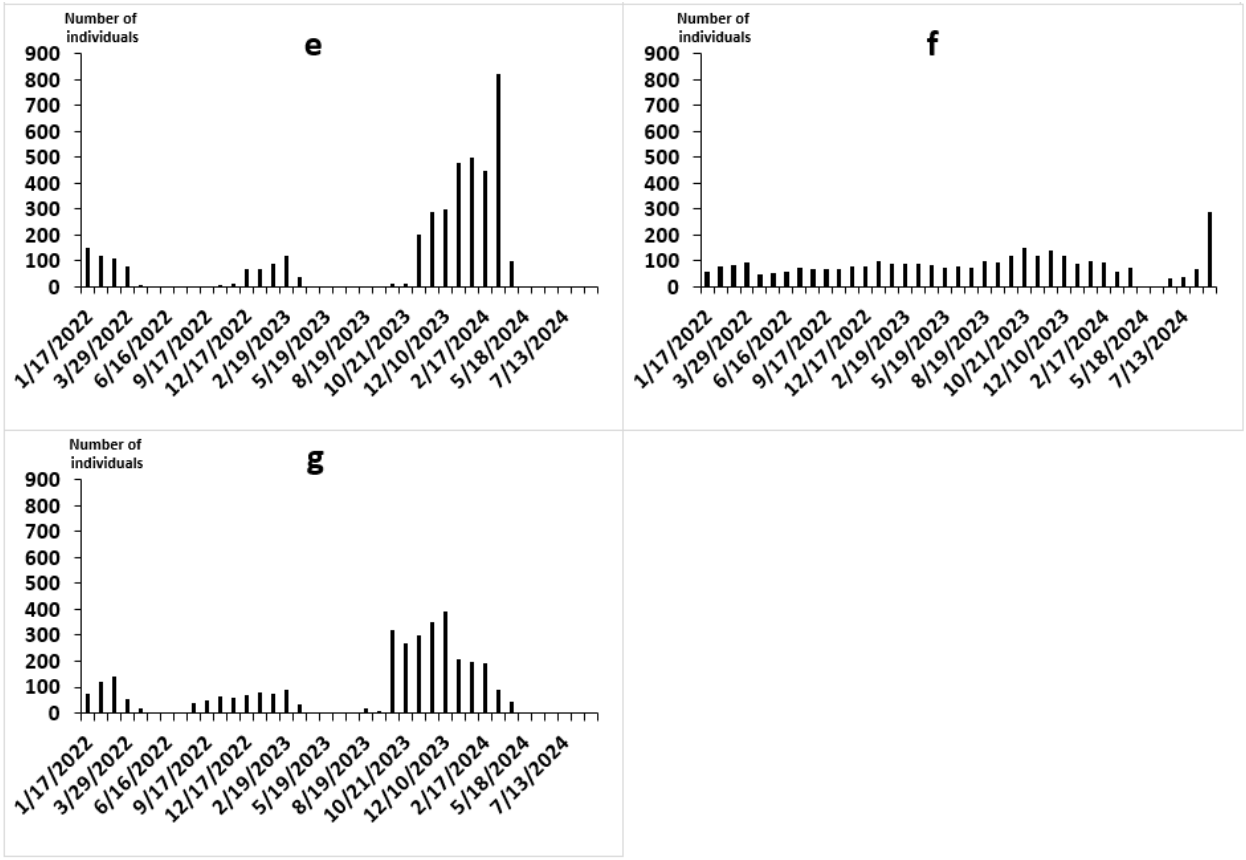

Figure 2.
Temporal variation in the number of individuals of dominant species.
Source: (a) *Chroicocephalus ridibundus*; (b) *Anas platyrhynchos*; (c) *Anas crecca*; (d) *Grus grus*; (e) *Phalacrocorax carbo*; (f) *Tadorna ferruginea*; (g) *Anas clypeata*.

3.3. Typological Structure of the Bird Population

In order to synthesise the results obtained, Principal Component Analysis was used, applied to the different variables to determine the phenological status of bird species of this hydro-system. The data matrix includes 78 species and 39 observations, the latter representing the dates of the outings carried out. The first two axes accumulate 44% of the total inertia. The axis 1 accounts for 29.36% of the total information and the axis 2 with 14.70%.

Axis 1 positively selects the group of ducks and large waders (grp1). This group include the mallard, the northern shoveler, the gadwall, the green-winged teal, the greater flamingo and the spoonbill (Figure 3a). It corresponds to a period that extends from November to February of each year (Figure 3b). These are strict wintering species that are present from the beginning of the postnuptial migration to the prenuptial migration.

Furthermore, this axis negatively selects the group of terns (grp4). The gull-billed tern, the little tern, the black tern, the whiskered tern and the coot (Figure 3a), represents this group. These are summer species including nesters such as the little tern. It corresponds to a period that extends from March to July (Figure 3b). This presence is noted during all summer observation periods.

Axis 2 positively selects the group of sandpipers and the sandpipers (grp3), among the species found, the leach's sandpiper, the curlew sandpiper, and the kentish plover (Figure 3a). It corresponds to a period that extends from July to November (Figure 3b). It represents two migration periods, the first is a mixture of early and delayed postnuptial migration, the second is a delayed prenuptial migration.

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Axis 2 negatively selects the group of pochard and common crane (grp5), among these species we find the common crane, the shelduck, the pochard and the little grebe (Figure 3a). It corresponds to a period that extends from December to March (Figure 3b). It is the duration of the winter presence for late migrants.

On the other hand, the two axes positively select another group of sandpipers and snipes (grp2), they include the dunlin, Temminck's sandpiper, little sandpiper, ruff, greenshank and white stork (Figure 3a). They correspond to a period that extends from August to October (Figure 3b). It represents the postnuptial migration period.

Furthermore, the observation graph allows us to find the broad outlines of the phenological succession of the avifauna of the studied site. It allows a good interpretation of this succession which follows a well-defined orientation, passing from the summer period, then by a postnuptial migration, then by a wintering period and finally by a prenuptial migration.

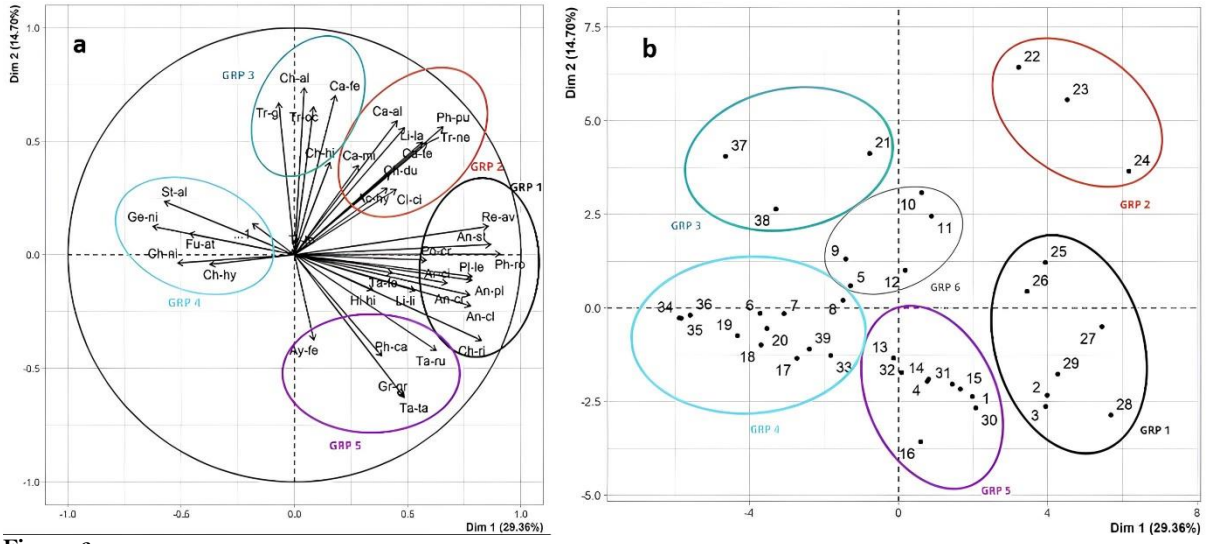

Figure 3.
Principal component analysis of the bird population of the Idriss 1st dam.
Note: (a) Observed variables on factorial plan 1-2, (b) Observations on factorial plan 1-2.

4. Discussion

This study, which aims to highlight the importance of the Idriss 1st dam as a wintering, stopover and nesting site for sedentary and migratory Afro-Palearctic birds, provided recent and detailed data on the avifauna populations frequenting this dam lake. The results obtained made it possible to identify, during three years of census study, 78 species of waterbirds belonging to 21 families. The avifauna is mainly dominated by two families of waders (22%), namely, the Scolopacidae and the Charadriidae, the Anatidae (16%), such as the mallard, the green-winged teal and the ruddy shelduck as well as the Laridae (10%), such as the black-headed gull.

In 2023, the Idriss 1st dam recorded the highest number of individuals, with 20639, followed by 2022 with 15509. Finally, 2024 recorded the lowest count, with 9350 individuals, as the count was conducted only until August 2024. Furthermore, the analysis of avian communities based on specific richness did not reveal any notable differences between the different years of study, which indicate the phenological stability of the site.

These results show the infrastructure of the Idriss 1st dam lake constitutes a panoply of species between passing migrants, winterers, sedentary and summer visitors. This ornithological diversity is due to the exceptional characteristics of the site, offering a suitable habitat for sedentary birds, a migratory stopover for migrants and a source of fattening for winterers. Habitat quality is recognised

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for its impact on population trends of sedentary and migratory waterbirds [23, 24]. This perspective operates under the assumption that the abundance of waterbirds serves as an indicator of habitat quality. However, this is not always accurate [25] the abundance of waterbirds at staging areas is generally linked to food supply levels [24]. This later encourages the presence of other species groups, illustrated by mammals like the European otter (personal observation).

As a result, when compared to other aquatic systems in Morocco and North Africa, the number of waterbird species (S = 78) is higher than that of other wetlands. For example, the Smir wetland complex in northern Morocco had 58 species during the 2005–2009 seasons [26] 47 species are reported in Morocco's north-central region [16] while the Midelt region's reservoirs and lakes, which are situated on the southern borders of the Middle Atlas, are home to 24 species [27] and 93 species of waterbirds have been found in the two Mediterranean coastal wetlands in the Martil plain (Tangier-Tetouan Region, Northern Morocco) [28] indicating that this number surpasses our findings. In Algeria, there are 68 species in Batna region [29] 62 species at Gareat Hadj-Taher (Skikda province) [30] 59 species at Lake Beni Belaid and El Kennar Marsh (Jijel province) during the fourteen-year period (2008–2021) [31] 53 species were discovered at Kef Doukhane (Ghardaïa, Algerian Sahara) between November 2017 and October 2019 [32] and 52 in the central Algerian wetlands [33]. In Tunisia, 41 wetlands together support 73 species [34] and 34 species with waders dominating in the southern Tunisian wetlands of Douz [35].

The PCA form groups that move towards the lake following a well-defined chronological cycle that is regularly from one year to the next, mainly for the grey cranes, the mallard, the wintry duck, the shelduck, the great flamingo, the great cormorant and the avocet.

The dam lake studied in the present work is also home to species of heritage interest such as the ruddy shelduck, the white spoonbill, the glossy ibis, the black-crowned night heron and the squacco heron, as well as other emblematic species, including the white stork, and other species considered globally vulnerable, such as the marbled teal and the black-tailed godwit, the bar-tailed godwit and the common pochard.

We also recorded the presence of several species of coastal origin, including the oystercatcher, ruddy turnstone, whimbrel, sanderling, ringed plover, herring gull, lesser black-backed gull, and yellow-legged gull. The occurrence of these species inland may be attributed to the degradation of their natural habitats in coastal wetlands [36].

Additionally, the presence of a group of black-bellied sandgrouse, a species typically found in arid bioclimatic zones, was observed. The occurrence of this species at this site may be explained by its inability to tolerate the extreme summer temperatures in arid and desert regions [37]

In addition to rare species such as the purple sandpiper, which was observed at our site, this species has been recorded 18 times in Moroccan coastal wetlands. However, this is the first time it has been reported in an inland wetland. The purple sandpiper is a rare visitor from subarctic and arctic regions. Of the 18 known records, nine have been analysed by the Moroccan Records Committee, with sightings primarily distributed across the Strait of Gibraltar and along the Atlantic coast up to Essaouira. The coastline of the Rabat region appears particularly suitable for this species, with five of the sightings documented there [38].

Throughout the non-breeding season, large groups of shorebird species gather on intertidal mudflats within coastal wetlands to actively forage for benthic macrofauna [39-41] especially bivalves in our site study. In spite of the fact that this dam constitutes a continental wetland, it offers fluctuations favoured by the inflows from the Sebou and Inaouene catchment areas, which are exported to irrigate the Ghareb basin and to produce electricity. As a result, it constitutes an important intertidal zone for waders, offering optimal feeding areas.

On the other hand, the site offers favourable conditions for the presence of an endangered species which is the Egyptian vulture, as well as another vulnerable one which is the common pochard. The reproduction of the little tern, the collared pratincole, the kentish plover, the ruddy shelduck, the mallard, the coot and the wattled coot, the moorhen, shows the importance of the site as a nesting site.

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This nesting can be attributed to the abundance of different food sources in the environment [33, 35]. For the little tern, mentioned as nesting in the Moroccan coastal areas by Hanane, et al. [42] is listed in our study in 2023 as a summer visitor. While in 2024, it is listed as a nesting summer visitor.

The presence of the endangered Egyptian vulture in the site is due to its proximity to the Allal El Fassi dam, which contains nesting sites for this species (personal observation). It has declined sharply since the 1970s, mainly as a result of poisoning [37].

We note also the presence of Moroccan wagtail, an endemic subspecies native to Northwest Africa, primarily bred in western and northeastern Morocco until the 1960s. Since then, it has expanded its range southward, eastward, and northward [43].

However, ornithological monitoring of this site noted the absence of two species of international importance, the white-headed duck and the ferruginous duck, although these two species were observed in the same site during the winter of 2018 for the white-headed duck and the winters of 2018, 2019 and 2020 for the ferruginous duck [16].

The anthropogenic impact is always observed at the site due to agricultural activities and fishing. This can significantly affect the site's biodiversity and may lead to species extinction [44].

5. Conclusion

The ornithological monitoring carried out at the Idriss 1st dam over three successive years (2022, 2023 and 2024) made it possible to identify 78 species belonging to 22 families, the most abundant of which, in terms of specific richness, are the Anatidae and the Scolopacidae.

The diversity calculated using the Shannon index revealed a greater diversity with the presence of species of phenological status of different categories: wintering, breeding, summering and migrating. This allows us to conclude that the study site constitutes a panoply of species between passing migrants, winterers, sedentary and summer visitors, which gives it a status for the conservation and protection of avifauna.

In addition, the site hosts bird species with important conservation status, such as the Egyptian vulture (endangered species), the common pochard (vulnerable species), as well as marbled teal, bar-tailed godwit, black-tailed godwit, red knot, ruddy turnstone, Eurasian oystercatcher and curlew sandpiper (near threatened species). Species of coastal origin are also recorded on the site, namely the oystercatcher, the ruddy turnstone, the Caspian tern, the whimbrel, the sanderling, the great ringed plover, the black-backed gull and the yellow-legged gull.

The fruit of this ornithological work is a reference for biodiversity managers to prioritise and guide conservation efforts in continental aquatic environments in Morocco. Given that the site is home to a near-threatened species of mammal, the European otter (*Lutra lutra*). Special attention must be given to this dam lake to classify it among the RAMSAR sites of international importance, in particular by validating two criteria; criterion 2: presence of vulnerable species such as the marbled teal, the black-tailed godwit and the common pochard, criterion 5: Numbers exceeding 20000 individuals.

Effective wetland management in Morocco's Idriss 1st dam should incorporate specific adjustments to dam operations to meet the unique environmental requirements and protection needs of waterbird communities. This will ensure that seasonal water levels, vegetation, and food resources are maintained to support biodiversity and sustain this key habitat along the North African migratory route.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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References
[1] S. Hu, Z. Niu, Y. Chen, L. Li, and H. Zhang, "Global wetlands: Potential distribution, wetland loss, and status," *Science of the Total Environment*, vol. 586, pp. 319-327, 2017. https://doi.org/10.1016/j.scitotenv.2017.02.001
[2] R. Costanza *et al.*, "The value of the world# s ecosystem services and natural capital," *Ecological Economics*, vol. 25, no. 1, pp. 3-15, 1998. https://doi.org/10.1016/s0921-8009(98)00020-2
[3] U. Özesmi, *Review of wetland birds: Habitat resources and conservation implications, by Milton W. Weller*. Cambridge, UK: Cambridge University Press, 2001.
[4] E. Gaget *et al.*, "Assessing the effectiveness of the ramsar convention in preserving wintering waterbirds in the mediterranean," *Biological Conservation*, vol. 243, p. 108485, 2020. https://doi.org/10.1016/j.biocon.2020.108485
[5] D. Pavon-Jordan *et al.*, "Positive impacts of important bird and biodiversity areas on wintering waterbirds under changing temperatures throughout Europe and North Africa," *Biological Conservation*, vol. 246, p. 108549, 2020. https://doi.org/10.1016/j.biocon.2020.108549
[6] M. Khaffou and A. Chahlaoui, "Impacts of climate change on the dysfunction of Mediterranean wetlands: Case of aguelmam afennourir-ramsar site-the middle Atlas–Morocco," presented at the IOP Conference Series: Earth and Environmental Science, 2022.
[7] F. Verniest *et al.*, "Anticipating the effects of climate warming and natural habitat conversion on waterbird communities to address protection gaps," *Biological Conservation*, vol. 279, p. 109939, 2023. https://doi.org/10.1016/j.biocon.2023.109939
[8] C. Parmesan and G. Yohe, "A globally coherent fingerprint of climate change impacts across natural systems," *Nature*, vol. 421, no. 6918, pp. 37-42, 2003. https://doi.org/10.1038/nature01286
[9] S. Pimm, P. Raven, A. Peterson, Ç. H. Şekercioğlu, and P. R. Ehrlich, "Human impacts on the rates of recent, present, and future bird extinctions," *Proceedings of the National Academy of Sciences*, vol. 103, no. 29, pp. 10941-10946, 2006. https://doi.org/10.1073/pnas.0604181103
[10] P. A. Stephens *et al.*, "Consistent response of bird populations to climate change on two continents," *Science*, vol. 352, no. 6281, pp. 84-87, 2016. https://doi.org/10.1126/science.aac4858
[11] M. F. Knudsen, M.-S. Seidenkrantz, B. H. Jacobsen, and A. Kuijpers, "Tracking the atlantic multidecadal oscillation through the last 8,000 years," *Nature Communications*, vol. 2, no. 1, p. 178, 2011. https://doi.org/10.1038/ncomms1186
[12] L. Y. Pomara, *Recent literature book review effects of climate change on birdspeter O.Dunn and anders papemøller(eds.)*. Oxford, UK: Oxford University Press, 2019.
[13] M. Dakki, "Ecological classification of wetlands in Morocco," *Travaux de l'Institut Scientifique, Rabat*, vol. 9, pp. 1–124, 2021.
[14] M. Dakki, "Wetlands of Northeastern Morocco," 2020.
[15] M. Dakki, F. Hamman, and S. Hammada, "Mapping of natural habitats in a Mediterranean coastal wetland: The Smir marshes (Tetouan region, Morocco)," *Ecosystèmes sensibles de la Méditerrané: Cas du littoral de Smir*, vol. 4, pp. 9-15, 2005.
[16] W. Squalli *et al.*, "Diversity and population sizes of wintering waterbirds in the wetlands of the saïss–middle atlas region (North–central Morocco): Main survival factors and evaluation of habitat loss," *Animals*, vol. 14, no. 9, p. 1352, 2024. https://doi.org/10.3390/ani14091352
[17] H. d. S. A. Du Bassin, "Dams of the sebou basin," 2016.
[18] M. Lamotte and F. Bourlière, *Problems of ecology: Sampling of animal populations in terrestrial environments*. Paris: Masson et Cie, 1969.
[19] G. d. O. d. Maroc, M. c. Holcim, J. Franchimont, V. Schollaert, and B. Maire, *Birds of Morocco: Identification guide*. Paris: Ibis Press, 2010.
[20] P. J. Svensson, L. Mullarney, K. Zetterström, and D. Grant, *The bird guide: The most comprehensive guide to the birds of Europe*. Delachaux: d'Afrique du Nord et du Moyen-Orient, 2021.
[21] C. R. e. T. D. Barlow, "African east atlantic flyway guide," 2015.
[22] C. E. Shannon and W. Weaver, "The theory of mathematical communication," *International Business*, vol. 131, pp. 164-174, 1949.
[23] J. A. Gill, K. Norris, P. M. Potts, T. G. Gunnarsson, P. W. Atkinson, and W. J. Sutherland, "The buffer effect and large-scale population regulation in migratory birds," *Nature*, vol. 412, no. 6845, pp. 436-438, 2001. https://doi.org/10.1038/35086568
[24] J. A. Gill, W. J. Sutherland, and K. Norris, "Depletion models can predict shorebird distribution at different spatial scales," *Proceedings of the Royal Society of London. Series B: Biological Sciences*, vol. 268, no. 1465, pp. 369-376, 2001. https://doi.org/10.1098/rspb.2000.1386

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 8: 1285-1300, 2025
DOI: 10.55214/2576-8484.v9i8.9595

[25] B. Van Horne, "Density as a misleading indicator of habitat quality," *The Journal of Wildlife Management*, vol. 47, no. 4, pp. 893-901, 1983. https://doi.org/10.2307/3808148
[26] A. Qninba, A. Benhoussa, M.-A. El Agbani, M. Dakki, and M. Thevenot, "Phenological study and interannual variability of abundance of Charadriidae (Aves, Charadrii) in a Ramsar site in Morocco: The Merja Zerga," *Bulletin de l'Institut Scientifique*, vol. 28, pp. 35-47, 2006.
[27] I. Mansouri *et al.*, "Avifauna diversity in the gate between humid atlas and saharan desert: Midelt province, Morocco," *International Journal of Zoology*, vol. 2021, no. 1, p. 5557921, 2021. https://doi.org/10.1155/2021/5557921
[28] N. Mars, O. Haddad, M. Jaouani, A. Maouni, and R. Saïdi, "A review of the avifauna visiting the wetland environments of the martil plain (Tetouan region, northern Morocco): Preliminary results," presented at the E3S Web of Conferences (Vol. 412, p. 01068). EDP Sciences, 2023.
[29] A. Bezzalla *et al.*, "Species diversity within ecosystem diversity of wetlands within drylands: Waterbird ecological attributes in an ecological complex of wetland habitats," *Estuarine, Coastal and Shelf Science*, vol. 313, p. 109103, 2025. https://doi.org/10.1016/j.ecss.2024.109103
[30] S. Metallaoui, *Ecology of the aquatic avifauna of Garaet Hadj-Tahar*. Annaba: Univ. Badji Mokhtar, 2010.
[31] B. Mayache, "Inventory and ecological study of the aquatic avifauna of the Jijel wetland ecocomplex," State Doctoral Thesis, Name of University, 2008.
[32] A. Chedad, D. Bendjoudi, and O. Guezoul, "Biodiversity of aquatic avifauna in an artificial wetland in Kef Doukhane (Ghardaia, Algerian Sahara)," *Bulletin de la Société Zoologique de France*, vol. 145, no. 4, pp. 383-400, 2020.
[33] E. Bensaci, A. Zoubiri, Y. Nouidjem, F. Mimeche, B. Gasmi, and M. Saheb, "Diversity and distribution pattern of waterbirds in wetlands of Algerian steppe region," presented at the International Biodiverstiy & Ecology Sciences Symposium, 2019.
[34] F. Hamza and S. Selmi, "Diversity of waterbirds wintering in Douz wetlands (south Tunisia): Factors affecting wetland occupancy and species richness," *Ecological Research*, vol. 33, no. 5, pp. 917-925, 2018. https://doi.org/10.1007/s11284-018-1587-z
[35] F. Hamza *et al.*, "Landscape context and wetland attributes influence wintering waterbirds in important bird and biodiversity areas: Implications for conservation and management," *Landscape Ecology*, vol. 39, no. 8, pp. 1-19, 2024. https://doi.org/10.1007/s10980-024-01942-9
[36] C. D. Santos, T. Catry, M. P. Dias, and J. P. Granadeiro, "Global changes in coastal wetlands of importance for non-breeding shorebirds," *Science of the Total Environment*, vol. 858, p. 159707, 2023. https://doi.org/10.1016/j.scitotenv.2022.159707
[37] F. Mougeot, M. Fernández-Tizón, R. Tarjuelo, A. Benítez-López, and J. Jiménez, "Population decline of the black-bellied Sandgrouse Pterocles orientalis in continental Spain, a main western Palearctic stronghold," *Bird Conservation International*, vol. 34, p. e11, 2024. https://doi.org/10.1017/S0959270924000066
[38] P. J. Franchimont and Q. A. Lemsaadi, "Rare birds in Morocco (report of the Moroccan approval commission)," *Go-South Bull*, vol. 11, pp. 104-107, 2015.
[39] J. Van de Kam, B. Ens, T. Piersma, and L. Zwarts, "Shorebirds: An illustrated behavioural ecology," Brill, 9004277994, 2017. https://api.semanticscholar.org/CorpusID:89803244
[40] M. A. Colwell, *Shorebird ecology, conservation, and management*, 1st ed. Berkeley, CA: University of California Press, 2010.
[41] F. Touhami, H. Bazaïri, B. Badaoui, and A. Benhoussa, "The impact of wader predation on benthic macrofauna in Merja Zerga lagoon, Morocco: An exclosure experiment," *Wader Study*, vol. 124, pp. 225-237, 2017. https://doi.org/10.18194/ws.00093
[42] S. Hanane, M. Dakki, M. Maghnouj, T. Benazzou, and M. Thevenot, "Status and breeding biology of the Little Tern Sterna albifrons on a rocky section of the North Atlantic coast of Morocco," *Alauda*, vol. 73, no. 1, pp. 9-20, 2005.
[43] M. Thévenot, R. Vernon, and P. Bergier, *The birds of Morocco: An annotated checklist (BOU Checklist No. 20)*. Tring, UK: British Ornithologists' Union, 2003.
[44] E. Golzar, B. S. Esfandabad, J. Morshedi, M. Naderi, and S. Jozi, "Effect of human-induced activities on waterbirds diversity and abundance in three wetlands of international importance in Iran," *Contemporary Problems of Ecology*, vol. 12, no. 6, pp. 658-666, 2019. https://doi.org/10.1134/S199542551906012X