

Water bird Diversity, Distribution, and Habitat Associations in the Wetlands of Taounate Region, Northern Morocco

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ABSTRACT

Wetlands constitute a primary resource for both human and animal life and irreplaceable habitats for a wide range of flora and fauna, especially water birds. The Taounate region in Morocco contains various wetlands that are important as staging posts and wintering for multiple bird species. The present study aims to determine the status and distribution of water bird species in the wetlands of the Taounate region. A survey was carried out for four successive years (2022, 2023, 2024, and 2025) at four distinct sites (Al-Wahda dam, Sahla dam, Bouhouda dam, and Oued Ouaregha). This study allowed the evaluation of 25 species representing 18 families. Ardeidae are the most abundant bird representing four species with high frequency, especially in the Al-Wahda dam and Oued Ouaregha (599 and 278 for *Bubuleus ibis*, respectively, 29 and 31 for *Ardea alba*, respectively). In addition, the status conservation changed between the studied sites according to the climatic characteristics of each station. Statistical analysis demonstrated that there is a positive correlation between site area and the number of bird species, as well as the number of families. Generally, the Al-Wahda dam is the preferred wetland for different species of birds for different reasons, including the surface and availability of nutrition.

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Authors' Contribution

Both authors contributed to the data curation, conceptualization of the study, formal analysis, investigation, methodology, visualization and writing of the original draft, and read and approved the final manuscript.

Key words

Water birds, Wetland ecology, Biodiversity, Climatic variables, Ardeidae, Conservation

INTRODUCTION

Wetlands play a central role as reservoirs of biodiversity and sustain various species of all main categories of creatures. However, natural wetlands are rapidly losing and degrading in the Mediterranean area, which has serious repercussions on the condition of aquatic organisms, including plants and animals (Green *et al.*, 2002b). Within this framework, there is an urgent need for more research on wetland loss and prioritization of remaining wetlands for conservation efforts. Recently, various efforts have been made to quantify the rates of wetland loss and their consequences for biodiversity conservation (Bertassello *et al.*, 2025; Biswas *et al.*, 2025; Kenmegne *et al.*, 2025; Strzȳciwilk and Grygoruk, 2025; Sharma *et al.*, 2026).

In Morocco, wetlands are threatened by multiple disorders, such as direct drainage, groundwater overexploitation, dam construction upstream, pollution, introduction of foreign species and heavy grazing and reed cutting (Addou *et al.*, 2025; Ait Kacem *et al.*, 2025; Bouregbi *et al.*, 2025; Ennabili *et al.*, 2025). They serve as a stopover for different migrants and wintering birds, while the perturbation of these wetlands enhances the habitat loss of various inhabited birds and nesting ones.

The Taounate region is located in the Sebou river basin in the central part of the Rif Mountains, north of Morocco, and is characterized by multiple wetlands, including the Al-Wahda Dam, the Bouhouda and Sahla reservoirs, and the Ouergha river and its tributaries. These sites are of particular scientific interest and are dominated by the vast Al-Wahda reservoir, playing a pivotal role for Morocco's waterfowl, especially for wintering and potentially nesting. Beyond direct anthropogenic pressures, habitat features intrinsic to each wetland such as water depth and surface extent strongly determine water bird use of these sites (Mouhaya *et al.*, 2025). Despite the opportunity of this approach to mitigate climate change, it can affect the stability of water bird ecosystems directly or indirectly (Hernandez *et al.*, 2025). Furthermore, the depth of the wetland water plays a crucial role in the use of wetland by water birds (Bolduc and Afton, 2008). The abundance

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of species has been found to be highly associated with water depth and surface (Bolduc and Afton, 2008). The assessment of species richness in a particular environment and the size of wetland patches plays a pivotal role and depends highly on the taxonomic group (Cerdeña-Peña and Rau, 2023).

Within this framework, the present study was carried out to evaluate the ornithological attributes and abundance of water birds in different wetlands in the Taounate region, including the Al-Wahda dam, Bouhouda and Sahla reservoirs, oued Ouergha and their tributaries. Second, the study aimed to determine the variability of water birds in different wetlands in the Taounate region during 2022-2025. Specifically, we addressed the following questions: (1) How do the composition, richness, diversity, and abundance of waterbird species vary among the major wetlands in the Taounate region; (2) whether waterbird communities differ significantly among Al-Wahda, Bouhouda, Sahla, the Ouergha River, and its tributaries; and (3) whether the abundance of waterbirds and the composition of their communities show significant temporal variations between 2022 and 2025? The hypothesis was that waterbird communities would differ from one wetland to another due to differences in habitat characteristics and water availability, that each species would exhibit site-specific habitat preferences, and that the abundance of waterbirds and community composition would vary over time in response to changing environmental conditions. Overall, this study provides a comparative assessment of waterbird communities across the major wetlands of the Taounate region and contributes to a better understanding of their ecological importance for waterbird conservation and wetland management in northern Morocco.

MATERIALS AND METHODS

Study site description

The Sebou basin is located in northwestern Morocco and is considered one of the largest Moroccan basins. It drains an area of 40,000 km², which represents 5.5% of the total area of Morocco. The basin is characterized by a highly diverse geographical context, named: The Rif Mountains to the north, the Middle Atlas Mountains

to the southeast and the Meseta plateau to the south, the Ghareb Maamoura basin to the west, and the Fez-Taza corridor which forms the center of the basin. The climate prevailing throughout the basin is Mediterranean with oceanic influence. The average rainfall in the basin is 700 mm, with significant variation ranging from 400 mm in the upper Sebou and the Steep-sided valleys of Beht to 1200 to 1800 mm in the Rif Mountains. Temperatures are the highest in July and August and the lowest in January. Average annual temperatures range between 10 and 20 °C depending on altitude. The temperature range is significant, fluctuating between 20 and 30 °C. The present study aimed to investigate the abundance of birds in Oued Ouergha and different dams including Al-Wahda, Sahla and Bouhouda in the Taounate region (Table I and Fig. 1).

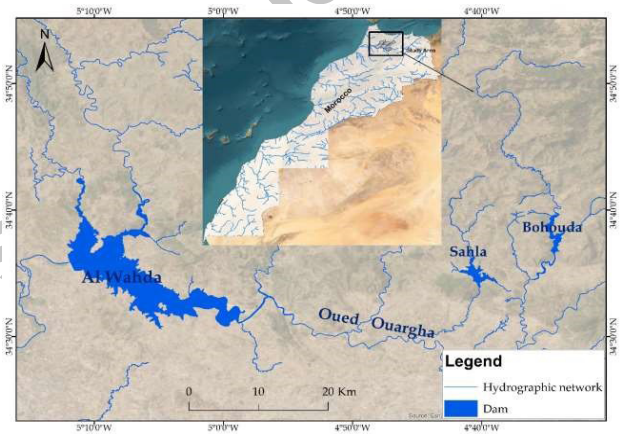


Fig. 1. Geographical localization of studied sites.

Data collection

The monitoring of water birds was made at four different sites, including Al-Wahda dam, Bouhouda dam, Sahla dam, and Oued Ouergha. It was held between 2022 and 2025 focusing our interest on different bird species in order to cover the variability between different studied sites. Surveys were conducted from December 2022 to March 2025, each site was surveyed on a weekly basis throughout the study period, yielding a cumulative sampling effort of approximately 250 visits (mean $\pm$ SD: 62.5 $\pm$ 3.06 visits per site). Two complementary census methods were applied

Table I. Main characteristics of the investigated aquatic ecosystems of studied wetlands.

Site	Altitude (m)	Latitude (N) (W)	Longitude	Area (ha)	Annual rainfall
Al-Wahda dam	140	34°35'56	5°11'54	9000-12300	600
Bouhouda dam	893	34°37'16	4°33'58	350-600	650
Sahla dam	325	34°34'20.48	4°39'35.01	300-500	650
Oued Ouaregha	200-500	34°16'55.08	5°20'59.96	400-1800	600

according to site configuration. At the three reservoir sites, bird counts were performed using the point-count method from elevated vantage points offering an unobstructed panoramic view of the water body; points were spaced at least 300 m apart to minimize the risk of double-counting, with a standardized observation duration of 10 min per point (Bibby *et al.*, 2000). At Oued Ouergha, whose linear configuration was incompatible with the point-count approach, birds were surveyed along fixed-transect walks conducted at a constant pace following the watercourse. All surveys were conducted between 09:00 and 16:00, coinciding with the period of peak avian activity, to minimize detectability bias associated with circadian variation in bird behavior.

Species identification in the field was based on Svensson (2010) (Delachaux et Niestlé field guide), supplemented where necessary by the digital identification platforms eBird and BirdNET. All field data were recorded and standardized in real time using the MaghrebBirds mobile application.

The wetlands of the Taounate region, including the Al-Wahda Dam, Bouhouda Reservoir, Sahla Reservoir, and the Oued Ouergha hydrosystem, represent essential aquatic ecosystems for the conservation of water birds in northern Morocco. These wetlands provide critical ecological functions such as water storage, nutrient cycling, flood regulation, and maintenance of breeding, wintering, and migratory habitats for numerous avian species, particularly Anatidae, Ardeidae, Rallidae, and Charadriiformes. Wetland ecosystems are widely recognized as reliable indicators of environmental quality because their ecological integrity directly influences bird diversity, abundance, and spatial distribution (Green *et al.*, 2002a; Ennabili *et al.*, 2025).

However, these wetlands are increasingly exposed to anthropogenic pressures associated with agricultural intensification, overgrazing, urban expansion, dam sedimentation, wastewater discharge, and excessive water abstraction. Such disturbances alter the hydrological functioning and physicochemical characteristics of wetlands, leading to habitat degradation and loss of biodiversity. Several studies conducted in Moroccan wetlands have shown that increasing human disturbance negatively affects species richness and abundance, particularly among sensitive and specialist water bird species (Ennabili *et al.*, 2021, 2025). Anthropogenic activities also contribute to eutrophication processes through nutrient enrichment and sediment runoff, resulting in changes in the structure of aquatic vegetation and the food resource availability for birds (Arabi *et al.*, 2024). Consequently, monitoring quantitative ecological indicators such as bird density, species richness, Shannon

diversity index, vegetation cover percentage, water quality variables, and anthropogenic disturbance indices constitute an effective approach for evaluating wetland health and biodiversity conservation status in the Taounate region.

Environmental characteristics of the sites studied

The environmental characterization of the studied wetlands was carried out in order to assess the ecological conditions that influence the distribution of water birds and habitat suitability in the Taounate region. Several abiotic and habitat-related parameters were measured or estimated throughout the study period, including air temperature, relative humidity, altitude, precipitation, water surface area, vegetation cover and hydrological characteristics of each site. These environmental variables are considered essential indicators for understanding the ecological functioning of wetlands and their capacity to support avian biodiversity (Paracuellos and Tellería, 2004; Cherkaoui *et al.*, 2015; Ennabili *et al.*, 2025).

Air temperature and relative humidity were recorded seasonally because climatic conditions strongly influence water availability, primary productivity, and bird activity patterns. Variations in temperature affect evaporation rates and consequently water depth and wetland persistence, particularly during dry periods characteristic of Mediterranean and semi-arid ecosystems (Paracuellos and Tellería, 2004; Wen *et al.*, 2016). Precipitation data were also considered since rainfall directly controls hydrological dynamics, seasonal flooding, and the extent of aquatic habitats available to migratory and wintering water birds. In years with low precipitation, reductions in water levels may lead to habitat fragmentation and a decline in food resources for aquatic fauna.

Topographic parameters such as altitude were included because they influence local climatic conditions, vegetation structure, and hydrological connectivity between wetlands. The estimated water surface area of each site was determined to assess the availability of habitat and the carrying capacity of water birds. Larger wetlands generally provide greater habitat heterogeneity and support higher species richness and abundance due to the diversity of feeding and nesting microhabitats (Cherkaoui *et al.*, 2015). Additionally, vegetation cover around wetlands and along shorelines was assessed because emergent and riparian vegetation plays an important role in shelter provision, nesting opportunities, and the availability of trophic resources for birds.

Other environmental characteristics, including water turbidity, anthropogenic disturbance, and land use patterns surrounding wetlands, were also considered when possible. Human activities such as agriculture, grazing, water extraction, and wastewater discharge can

significantly alter wetland quality through eutrophication, sedimentation, and habitat degradation (Cherkaoui *et al.*, 2015). Therefore, the combined analysis of the climatic, hydrological and anthropogenic parameters provides a comprehensive understanding of the ecological status of the wetlands and their influence on the structure of the water bird community in the Taounate region.

Water bird census protocol in the studied sites

Water bird surveys in the studied wetlands were conducted using a standardized direct count method adapted to the ecological characteristics of the wetlands in the Taounate region. Field observations were carried out from strategically selected fixed observation points along the shores of dams, reservoirs, and river sections to ensure maximum visibility of open water surfaces and surrounding riparian habitats. Counts were generally conducted during the early morning hours, when bird activity and detectability are the highest and weather conditions are more favorable for observation.

All observed birds were identified using binoculars and, when necessary, a spotting scope. Individuals were identified at the species level and the number of birds per species was recorded. To minimize the risk of double counting, the movements of bird flocks were carefully monitored and counts were conducted progressively in a single direction around each site. When population sizes were small, exhaustive individual counts were performed, whereas large flocks were estimated using block counting methods based on groups of 5, 10, or 50 individuals.

For each survey, several variables were recorded, including site name, date, start and end time of count, global positioning system (GPS) coordinates of observation points, species identity, abundance, habitat type, dominant behavior, and weather conditions. Anthropogenic disturbances observed during the census,

such as fishing activities, grazing, agricultural practices, vehicle circulation, hunting or waste accumulation, were also noted to evaluate their potential influence on bird distribution and habitat use.

This census protocol provides comparable quantitative data between sites and seasons, allowing the assessment of species richness, total abundance, relative density, frequency of occurrence, and diversity indices. Consequently, it constitutes a reliable methodological framework for analyzing the structure of the water bird community and evaluating the ecological status of wetlands in the Taounate region.

Statistical analysis

Statistical analysis was performed using PAST 3 software, comparing available water bird species during four successive years with the one-way analysis of variance (ANOVA) test. In addition, the Pearson's correlation coefficient was used to determine the correlation between the climatic conditions of the studied sites and the distribution of various water bird species in the vision to characterize their interannual variability.

RESULTS AND DISCUSSION

Water bird diversity during the study period

Table II displays the results of water bird monitoring conducted in four distinct wetlands, including Al-Wahda Dam, Bouhouda Dam, Sahla Dam and Oued Ouaregha. Clearly, there is a high diversity of bird species between the different wetlands studied, particularly in the Al-Wahda dam (Table II). Handling of the findings obtained revealed that *Phalacrocorax carbo*, *Fulica atra*, *Himantopus himantopus*, *Pycnonotus barbatus*, and *Anas platyrhynchos* were recorded across all sites studied completed the survey period, albeit with varying abundances and occasional

Table II. Distribution of different bird species in various studied sites.

S. No	Bird species	Families	Site	Average number of bird species				P value	Total	Aver-age	Min	Max
				2022	2023	2024	2025					
1	<i>Ciconia ciconia</i>	Ciconiidae	Al-Wahda dam	3	152	35	23	<0.05	213	53.25	3	152
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	0	13	8	15	>0.05	36	9	0	15
			Oued Ouaregha	26	23	34	29	>0.05	112	90.25	23	34
2	<i>Podiceps nigricollis</i>	Podicipedidae	Al-Wahda dam	3	9	4	2	>0.05	18	4.5	2	9
			Bouhouda dam	6	12	8	9	>0.05	41	10.25	6	12
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-

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S. No	Bird species	Families	Site	Average number of bird species				P value	Total	Average	Min	Max
				2022	2023	2024	2025					
3	<i>Plegadis falcinellus</i>	Threskiornithidae	Al-Wahda dam	12	4	8	2	>0.05	26	6.5	2	12
			Bouhouda dam	3	8	2	5	>0.05	18	4.5	2	8
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
4	<i>Platalea leucorodia</i>		Al-Wahda dam	34	105	60	22	>0.05	221	55.25	22	105
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
5	<i>Bubulcus ibis</i>	Ardeidae	Al-Wahda dam	69	330	80	120	<0.05	599	149.75	69	330
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	72	44	24	195	<0.05	335	83.75	24	195
			Oued Ouaregha	54	46	100	78	>0.05	278	69.5	46	100
6	<i>Ardea cinerea</i>		Al-Wahda dam	7	3	10	5	>0.05	25	6.25	3	10
			Bouhouda dam	15	7	7	4	>0.05	33	8.25	4	15
			Sahla dam	13	1	6	7	>0.05	27	6.75	1	13
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
7	<i>Ardea alba</i>		Al-Wahda dam	11	6	4	8	>0.05	29	7.25	4	11
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	10	7	4	10	>0.05	31	7.75	4	10
8	<i>Egretta garzetta</i>		Al-Wahda dam	19	3	8	6	>0.05	36	9	3	19
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	6	22	34	25	>0.05	87	21.75	6	34
9	<i>Phalacrocorax carbo</i>	Phalacrocoracidae	Al-Wahda dam	162	76	88	123	<0.05	449	112.25	76	162
			Bouhouda dam	15	10	12	8	>0.05	45	11.25	8	15
			Sahla dam	4	12	8	7	>0.05	31	7.75	4	12
			Oued Ouaregha	22	-	24	14	>0.05	60	15	14	24
10	<i>Pandion haliaetus</i>	Pandionidae	Al-Wahda dam	3	2	1	1	>0.05	7	1.75	1	3
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
11	<i>Circus aeruginosus</i>	Accipitridae	Al-Wahda dam	4	2	5	2	>0.05	13	3.25	2	5
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
12	<i>Buteo rufinus</i>		Al-Wahda dam	3	2	1	1	>0.05	7	1.75	1	3
			Bouhouda dam	5	8	10	8	>0.05	31	7.75	5	10
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	2	2	2	5	>0.05	11	2.75	2	5

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S. No	Bird species	Families	Site	Average number of bird species				P value	Total	Average	Min	Max
				2022	2023	2024	2025					
13	<i>Falco tinnunculus</i>	Falconidae	Al-Wahda dam	1	2	3	2	>0.05	10	2.5	1	3
			Bouhouda dam	3	14	7	6	>0.05	30	7.5	3	14
			Sahla dam	1	2	2	3	>0.05	6	1.5	1	3
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
14	<i>Fulica cristata</i>	Rallidae	Al-Wahda dam	16	16	22	18	>0.05	72	58.5	16	22
			Bouhouda dam	8	14	22	18	>0.05	62	15.5	8	22
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
15	<i>Fulica atra</i>		Al-Wahda dam	77	90	82	12	>0.05	261	65.25	12	90
			Bouhouda dam	23	46	35	26	>0.05	130	32.5	23	46
			Sahla dam	151	15	12	22	<0.05	200	50	12	151
			Oued Ouaregha	8	15	21	16	>0.05	60	15	8	21
16	<i>Himantopus himantopus</i>	Recurvirostridae	Al-Wahda dam	102	105	51	0	<0.05	258	64.5	0	105
			Bouhouda dam	18	32	41	30	>0.05	121	30.25	18	41
			Sahla dam	33	23	12	8	>0.05	76	19	8	33
			Oued Ouaregha	7	9	5	8	>0.05	29	7.25	5	9
17	<i>Recurvirostra avosetta</i>		Al-Wahda dam	10	6	3	4	>0.05	23	5.75	3	10
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
18	<i>Charadrius dubius</i>	Charadriidae	Al-Wahda dam	3	1	5	5	>0.05	14	3.5	1	5
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	-	-	-	-	-	-	-	-	-
			Oued Ouaregha	-	-	-	-	-	-	-	-	-
19	<i>Milvus migrans</i>	Accipitridae	Al-Wahda dam	-	-	-	-	-	-	-	-	-
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	0	2	3	1	>0.05	6	1.5	0	3
			Oued Ouaregha	8	12	9	5	>0.05	34	8.5	5	12
20	<i>Columba livia</i>	Columbidae	Al-Wahda dam	15	12	20	12	>0.05	59	14.75	12	20
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	8	12	23	32	>0.05	75	18.75	8	32
			Oued Ouaregha	13	23	35	17	>0.05	88	22	13	35
21	<i>Columba palumbus</i>		Al-Wahda dam	12	23	54	160	<0.05	249	62.25	12	160
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	6	13	27	44	<0.05	90	22.5	6	44
			Oued Ouaregha	5	11	8	12	>0.05	36	9	5	12
22	<i>Streptopelia turtur</i>		Al-Wahda dam	-	-	-	-	-	-	-	-	-
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	2	5	12	3	>0.05	22	5.5	2	12
			Oued Ouaregha	-	-	-	-	-	-	-	-	-

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S. No	Bird species	Families	Site	Average number of bird species				P value	Total	Average	Min	Max
				2022	2023	2024	2025					
23	<i>Corvus splendens</i>	Corvidae	Al-Wahda dam	100	250	134	160	<0.05	644	161	100	250
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	2	12	23	16	>0.05	53	13.25	2	23
			Oued Ouaregha	22	17	26	18	>0.05	83	20.75	17	22
24	<i>Pycnonotus barbatus</i>	Pycnonotidae	Al-Wahda dam	12	6	14	22	>0.05	54	13.5	6	22
			Bouhouda dam	35	5	18	12	>0.05	70	17.5	5	35
			Sahla dam	7	10	13	8	>0.05	38	9.5	7	13
			Oued Ouaregha	18	10	24	18	>0.05	70	17.5	10	24
25	<i>Motacilla alba</i>	Motacillidae	Al-Wahda dam	10	20	13	11	>0.05	44	11	10	20
			Bouhouda dam	-	-	-	-	-	-	-	-	-
			Sahla dam	0	2	5	9	>0.05	16	4	0	9
			Oued Ouaregha	4	9	6	12	>0.05	31	7.75	4	12
26	<i>Anas platyrhynchos</i>	Anatidae	Al-Wahda dam	43	302	125	90	<0.05	560	140	43	302
			Bouhouda dam	23	18	13	20	>0.05	74	18.5	13	23
			Sahla dam	12	20	16	23	>0.05	71	17.75	12	23
			Oued Ouaregha	12	10	14	19	>0.05	65	16.25	10	19

year-specific absences at individual sites (e.g., *H. himantopus* was not recorded at Al-Wahda dam in 2025). This widespread occurrence contrasts with several species showing a more restricted distribution. However, other species of birds occupied specific areas, such as *Platalea leucorodia*, *Pandion haliaetus*, *Circus aeruginosus*, *Recurvirostra avosetta*, and *Charadrius dubius* detected in the Al-Wahda dam, while *Streptopelia turtur* was found only in the Bouhouda dam. Water birds play a pivotal role in ecosystem stability as excellent long-distance dispersal vectors of other organisms and provide connectivity across terrestrial-aquatic boundaries (Green *et al.*, 2023). However, there are increasing threats to water birds from indirect and direct human interventions, including wetland degradation, illegal hunting, and climate change (Wang *et al.*, 2018). In arid and semi-arid environments with considerable geographical and temporal variability in rainfall, environmental managers face a significant challenge to provide water birds with sufficient habitat (Wen *et al.*, 2016; Wang *et al.*, 2018) proposed various recommendations for water bird conservation, including strengthening the wildlife conservation law and control of illegal hunting, restoration of degraded areas, restoration of threatened bird species, and sharing information and data in water birds and their conservation strategies (Wang *et al.*, 2018). Variability in the abundance of bird species enhanced orderly extinction of the wetland complex at the same rate as the ponds shrank in size (Paracuellos and Telleria, 2004).

Mounting evidence demonstrates the impact of climate change and anthropization on ecosystems in

Taounate region (Laftouhi *et al.*, 2022; El-Bakouri *et al.*, 2019). Laftouhi *et al.* (2022) proclaimed that the forest area in the Taounate region experienced weighed pressure from environmental and human factors, leading to a strong deterioration of the cover plant, thus affecting the composition of birds (Kurnia *et al.*, 2021; Laftouhi *et al.*, 2022). Clarifying habitat use patterns and targeting conservation investment will be made easier with a better understanding of the links between water bird occurrence and habitat state under changing climatic conditions and anthropogenic stresses (Wen *et al.*, 2016).

Multivariate analysis

Principal component analysis (PCA) is considered an excellent mathematical tool to determine the distribution of water birds based on their repartition across various studied sites. The analysis of the results obtained showed that most of the bird species were concentrated in a single group (Fig. 2). Figure one shows the repartition of different species at various sites studied. The principal components PC1 and PC2 accounted for 82.08 % and 8.46%, respectively. The first component was characterized by the accumulation of most bird species in the negative part that occupied the Bouhouda dam, Oued Ouaregha and Sahla dam. However, the positive part of the same component represented a positive correlation with multiple bird species that characterized the Al-Wahda dam, including W5 (*Bubulcus ibis*), W9 (*Phalacrocorax carbo*), W21 (*Chroicocephalus ridibundus*), W28 (*Corvus ruficollis*), W30 (*Galerida cristata*), W33 (*Delichon urbicum*), W38 (*Passer montanus*), W45 (*Aythya ferina*).

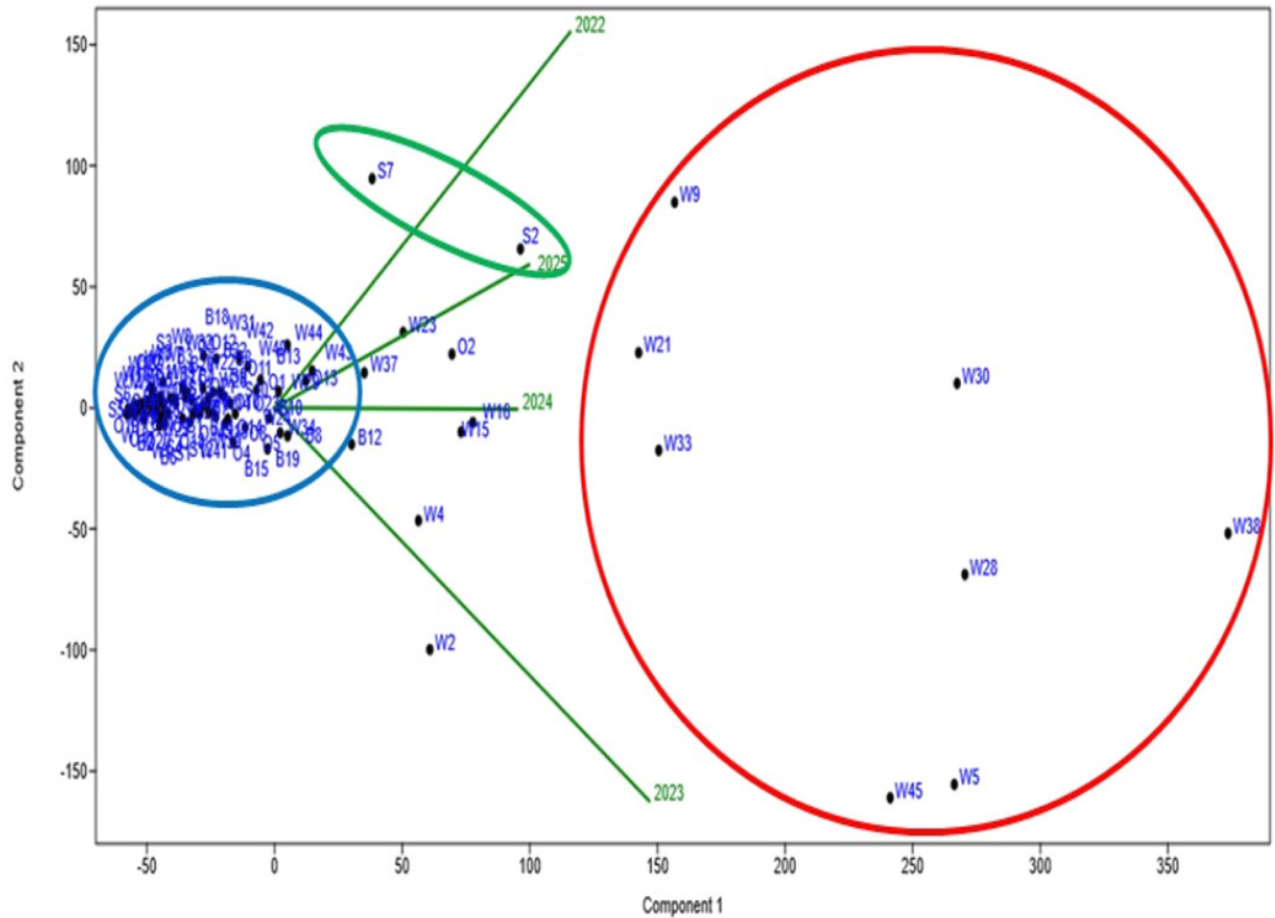


Fig. 2. Principal component analysis of the studied water bird species at different geographical locations using their distribution density.

W: species found in Al-Wahda dam. W1: *Podiceps nigricollis*; W2: *Ciconia ciconia*; W3: *Plegadis falcinellus*; W4: *Platalea leucorodia*; W5: *Bubulcus ibis*; W6: *Ardea cinerea*; W7: *Ardea alba*; W8: *Egretta garzetta*; W9: *Phalacrocorax carbo*; W10: *Pandion haliaetus*; W11: *Circus aeruginosus*; W12: *Buteo rufinus*; W13: *Falco tinnunculus*; W14: *Fulica cristata*; W15: *Fulica atra*; W16: *Himantopus himantopus*; W17: *Recurvirostra avosetta*; W18: *Charadrius dubius*; W19: *Actitis hypoleucos*; W20: *Calidris alpina*; W21: *Chroicocephalus ridibundus*; W22: *Columba livia*; W23: *Columba palumbus*; W24: *Streptopelia decaocto*; W25: *Lanius senator*; W26: *Corvus monedula*; W27: *Corvus splendens*; W28: *Corvus ruficollis*; W29: *Corvus corax*; W30: *Gallerida cristata*; W31: *Pycnonotus barbatus*; W32: *Hirundo rustica*; W33: *Delichon urbicum*; W34: *Phylloscopus collybita*; W35: *Sturnus unicolor*; W36: *Turdus merula*; W37: *Passer domesticus*; W38: *Passer hispaniolensis*; W39: *Passer montanus*; W40: *Motacilla alba*; W41: *Serinus serinus*; W42: *Carduelis carduelis*; W43: *Emberiza citrinella*; W44: *Anas platyrhynchos*; W45: *Aythya ferina*; W46: *Podiceps cristatus*; W47: *Plegadis falcinellus* **B:** species identified in Bouhouda dam. B1: *Ardea cinerea*; B2: *Phalacrocorax carbo*; B3: *Buteo rufinus*; B4: *Falco tinnunculus*; B5: *Fulica cristata*; B6: *Fulica atra*; B7: *Grus grus*; B8: *Himantopus himantopus*; B9: *Actitis hypoleucos*; B10: *Chroicocephalus ridibundus*; B11: *Streptopelia decaocto*; B12: *Cuculus canorus*; B13: *Garrulus glandarius*; B14: *Cyanistes caeruleus*; B15: *Parus major*; B16: *Pycnonotus barbatus*; B17: *Turdus merula*; B18: *Motacilla cinerea*; B19: *Carduelis carduelis*; B20: *Anas platyrhynchos*; B21: *Anas crecca*; B22: *Ciconia ciconia*; B23: *Bubulcus ibis* **S:** species identified in Sahla dam. S1: *Ardea cinerea*; S2: *Phalacrocorax carbo*; S3: *Milvus migrans*; S4: *Falco tinnunculus*; S5: *Fulica atra*; S6: *Himantopus himantopus*; S7: *Columba livia*; S8: *Columba palumbus*; S9: *Streptopelia turtur*; S10: *Corvus splendens*; S11: *Pycnonotus barbatus*; S12: *Motacilla alba*; S13: *Anas platyrhynchos*; S14: *Ciconia ciconia*; S15: *Bubulcus ibis* **O:** species identified in Oued Ouergha dam. O1: *Ardea cinerea*; O2: *Egretta garzetta*; O3: *Phalacrocorax carbo*; O4: *Buteo rufinus*; O5: *Himantopus himantopus*; O6: *Columba livia*; O7: *Columba palumbus*; O8: *Streptopelia decaocto*; O9: *Corvus corax*; O10: *Pycnonotus barbatus*; O11: *Sturnus vulgaris*; O12: *Turdus merula*; O13: *Motacilla alba*; O14: *Ardea alba*; O15: *Milvus milvus*; O16: *Milvus migrans*; O17: *Aquila fasciata*; O18: *Gallinula chloropus*; O19: *Anas platyrhynchos*; O20: *Alcedo atthis*; O21: *Corvus monedula*; O22: *Fulica atra*.

Table III. Spearman correlation coefficients among climatic factors, habitat area, and water bird diversity parameters in the studied sites.

	Temperature (°C)	Area (ha)	Rainfall	Species number	Family number
Temperature °C	1	0.952	0.967	0.848	0.183
Area (ha)	-0.047	1	0.130	0.350	0.544
Precipitation (mm)	-0.030	0.896	1	0.087	0.777
Species number	-0.151	0.649	0.912	1	0.907
Family number	-0.816	0.455	0.222	0.092	1

It has been reported that *Bubulcus ibis* occupied different agroecosystems searching for its food across pastures, public waste and water bodies (Mohammedi and Ababou, 2020). This bird plays an important auxiliary role in pest control in regions with intensive agricultural activities such as Taounate region (Mohammedi and Ababou, 2020). Multiple bird species are known for their periodic modification of feeding areas under the impact of various factors, such as the kind and availability of prey, accessibility, and the placement of the natural environment in relation to the heronry (Si Bachir *et al.*, 2012).

The wetlands of the Taounate region by this remarkable biodiversity have remained underexplored. During the survey period through four successive years; it has been shown that the distribution pattern of water bird species via families has changed between the studied sites; these variations could be explained by various factors, including climatic ones. In the vision to determine the correlation between climatic conditions, such as temperature, site area, and rainfall. In fact, a positive correlation between site area and abundance of bird species has been detected ($r=0.640$ and 0.455 , respectively, for species number and family number) (Table III). The previous report proclaimed that habitat availability and ecological needs account for the variances in the repartition pattern of the family of wetland species and family between stations (Zoubiri *et al.*, 2018).

CONCLUSIONS

This study represents the first comprehensive and long-term investigation of water birds and associated wetlands in the Taounate region of northern Morocco, providing original ecological data from an area that has remained largely underexplored despite its strategic hydrological and biogeographical importance. Through four consecutive years of monitoring (2022–2025), the present work documented the composition, abundance, and spatial distribution of water bird communities in four major wetlands: Al-Wahda Dam, Bouhouda Reservoir, Sahla Reservoir, and Oued Ouergha. The findings clearly demonstrate that Taounate wetlands constitute highly

valuable habitats for resident, migratory, and wintering bird species, confirming their ecological significance within the Moroccan wetland network and the western Mediterranean flyway. Among the studied wetlands, Al-Wahda Dam exhibited the highest species richness and abundance, supporting large populations of ecologically important taxa, including *Bubulcus ibis*, *Phalacrocorax carbo*, *Fulica atra*, *Himantopus himantopus* and *Anas platyrhynchos*. The positive relationships observed between wetland size, climatic variables, and avian diversity further emphasize the key role of habitat availability and ecological stability in the maintenance of water bird communities in semi-arid Mediterranean ecosystems. In addition, multivariate analysis highlighted clear ecological differentiation between wetlands, reflecting the influence of local environmental conditions and habitat complexity on species distribution patterns.

Finally, the present study strongly recommends the establishment of long-term ecological monitoring programs, the strengthening of wetland protection policies, the restoration of degraded habitats, and the integration of biodiversity conservation into regional water resource management strategies. Protecting Taounate's wetlands is essential not only to conserve water bird populations, but also to maintain ecosystem services, hydrological balance, and ecological resilience in the face of accelerating climate change and anthropogenic pressures.

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Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Statement of conflict of interest

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