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Can Annual Rainfall Influence the Presence and Structure of Waterbirds in Semi-Arid Regions of Algeria?

Ghezal Hassiba[1], Ziouani Khawla[1], Zehraoui Rabia[1], Dahmani Rachid[1], Benelkadi Hadj Aissa[1], Kerzabi Rachida[1], Boumakhleb Abdallah[1], Sassoui Dallal[1], Moulaï Riadh[2].

[1] AgroPastoral Research Center (CRAPast - Djelfa - Algeria) 17000
[2] Laboratory of Applied Zoology and Ecophysiology, FSNV, University of Bejaia, Algeria, 17000.
Corresponding author; GHEZAL Hassiba 1 Email ; Hassiba.ghezal@crapast.dz

Abstract
This work has been concerns the inventory of nesting waterbirds in semi-arid environments in Algeria (north Africa), including the parameters studied, namely water level, water quality,conducted during spring in 2023, 2024, and 2025 at three wetlands: Dayas Louguila, Selouine, and Malha. In 2025, 19 species of nesting waterbirds were observed, belonging to 7 families. The wealthiest family in the species is Ardeidae, with 05 species, followed by Scolopacidae, with 04 species; The most abundant species is Ardea Ibis with 103 individuals; 17 nesting waterbirds were observed; in the Daya , de Malha; 04 nesting waterbirds in the; Daya Louguila; and 06 nesting waterbirds in the; Daya Malha, for a total of in 2023, 12 species were observed, divided into seven families, of which the Ardeidae family is the most represented in species, with 03 species, followed by Anatidae and Ciconidae with 02 species each, while the families of Phoenicopteridae, Charadridae, and Rallidae are represented by 01 species each. No nesting species has been recorded in 2024. These results highlight the crucial role of Dayas as breeding habitats in Algerian semi-arid zones, despite annual fluctuations linked mainly to rainfall.
Keywords: *Breeding waterbirds, semi-arid environments, wetlands, Dayas, Algeria.*

INTRODUCTION

Wetlands are complex, fragile, and diverse environments. Classified among the richest ecosystems on the planet, in terms of biological diversity and natural productivity, just after tropical forests (PEARCE and CRIVELLI, 1994).

They serve as feeding, breeding, resting, and nesting areas for various species of sedentary and migratory birds throughout the year (BROYER and CALENGE, 2010), and provide essential habitat for wildlife, particularly for the conservation of waterbird species (BEZZALLA et al., 2025). However, these ecosystems are considered among the most threatened in the world due to their intrinsic environmental vulnerability (ZHOU et al. 2020). In Mediterranean regions, particularly in North Africa, wetlands host exceptional but declining biodiversity (BOULDJEDRI et al., 2011). The Dayas wetlands are very unique wetlands located in arid and semi-arid environments in Algeria; they include large geomorphological groups composed of vast erosion surfaces with alluvium terrain (BOUMEZBEUR, 2004).

North Africa is home to a great diversity of wetlands that serve as wintering sites and stopovers for migratory birds from the Palearctic (STEVENSON et al., 1988; FISHPOOL and EVANS, 2001; BOULKHSSAÏM et al., 2006). Nevertheless, several wetlands along the southern Mediterranean coast in North Africa, particularly those in inland regions such as Chott El Oued in the northeast of the Algerian Sahara, have been poorly studied, and insufficient data exist to characterize these ecosystems comprehensively (Hamza and Selmi 2018). In Algeria, several studies on birds and Dayas include the works of MOULAY et al and DAHMANE et al on the Dayet Elferd..

The structuring parameters of the biology of aquatic organisms include water surface and depth, vegetation, and salinity (GREEN and FIGUEROLA, 2003; KUSHLAN, 1993). In Algeria, the North-Central region occupies second place with 1,479 sites (SAIFOUNI and BELLATRACHE, 2020).

The main objective of this work is to assess the influence of annial rainfall on the presence, diversity and community structure of waterbirds in semi-arid regions of Algeria.

METHODOLOGY

Study Area

This study was carried out in the Djelfa region, located in the central part of Northern Algeria, beyond the southern foothills of the Tellian Atlas from the north, where the chief town of the Wilaya is 300 kilometres south of the Capital, which is between 2 ° and 5 ° east longitude and between 33 ° and 35 ° north latitude. Its total area is 32,280 km², or 8.33% of Algeria's total area, with an average altitude of 1,200 m. (Figure 1).

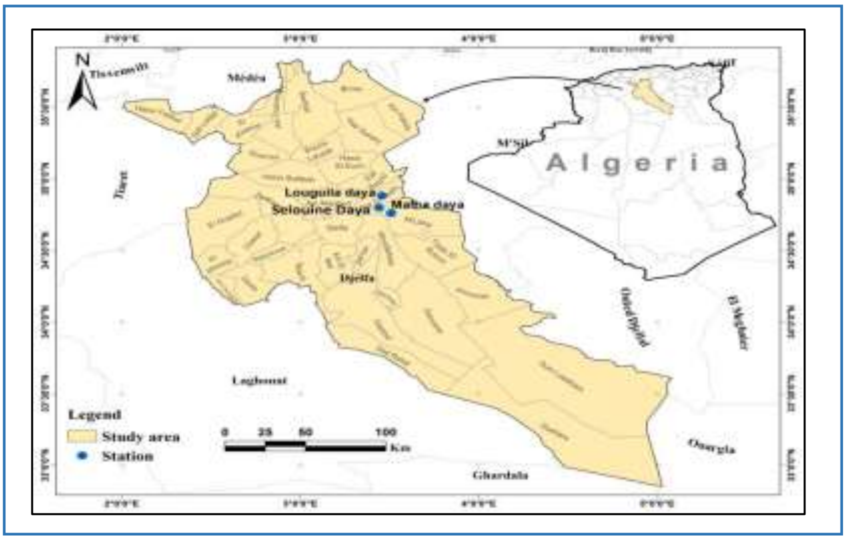

Figure 1 - Location map of the study area

Presentation of the study area

The choice of areas for the inventory of nesting waterbirds including the parameters studied, namely water level, water quality, focused on three days: Louguila (Fig. 02), Selouine (Fig. 03), and Malha (Fig. 04), located near the agglomeration of Dar Chioukh, 37 km south of the wilaya of Djelfa. Dar chioukh is limited to the north by the commune of Sidi Baizid, to the east by the wilaya of M'sila, to the west by the communes of Ain Maabed and Djelfa, and to the south by the commune of M'liliha and Moudjebara.

The Louguila daya (X: 34.882667°, Y: 3.456944°), located approximately 25 km away, extends over an area of 70 Ha, the Selouine daya (X: 34.073705°, Y: 3.502884°) with an area of 834 Ha, and the Malha daya (X: 34.760503°, Y: 3.508650°) with an area of 30 Ha.

Among the criteria considered for selecting these stations, the depth of the water, the distribution of nesting birds, and the vegetation are retained.

Figure 2 - Genaral view of Daya Louguila.

Figure 3 - Genaral view of Daya Selouine

Figure 4 - Genaral view of Daya Malha

MATERIAL AND METHOD

Many methods and techniques are used to observe and monitor nesting waterbird populations. Still, they often come up against factors linked to the biology of these species and the physiognomic transformations of biotopes, influenced by the seasons and annual variations (BLONDEL 1969, LAMOTTE and BOURLIÈRE 1969).

The study was carried out in three wetlands in the steppe zone: the dayas of Louguila, Selouine, and Malha. The surveys took place in spring (May) from 2023 to 2025, with a sampling effort of 3 visits per site and a total of 09 trips.

The equipment used included a pair of tripods with spotting scopes (20X60X), a second tripod for the Nikon Coolpix P1000 digital camera (optical zoom 125x24-3000 m; for visual documentation), and the waterbird identification guide from Henzel (2015). The cots were carried out by direct observation. For groups of individuals, we conducted a complete enumeration when the distance was less than 200 m and the group size was less than 200 individuals. When the group exceeded 200 individuals or was located more than 200 m away, the visual field was divided into equal sections; the number of birds in an average section was counted and multiplied by the number of sections (Altmann, 1974).

RESULT.

Table 01: Characteristics of wetlands during the year 2023, 2024 and 2025

Année	Daya	Area type	Depth(Mettre)	Water level	Water quality	Temperature (°C)
2023	Louguila	Naturel	1 - 1.7	Medium	Disturbed	22
	Selouine		00	Dry	--	25
	Malha		00	Dry	--	26
2024	Louguila	Naturel	00	Dry	--	22
	Selouine		00	Dry	--	19
	Malha		00	Dry	--	16
2025	Louguila	Naturel	0,1 - 0,5	Hight	Polluted	16
	Selouine		0,1 - 0,7	Medium	Disturbed	18
	Malha		0,1 - 0,8	Hight	Disturbed	15

Table 02: Systematic list of nesting waterbirds in the year 2023 in the three wetlands.

Families	Common name	Scientific name	Number of individuals		
			Daya Louguila	Daya Selouine	Daya Malha
Anatidae	Tadorne casarca	Tadorna ferruginea	18	--	--

	Tadorne de belon	Tadorna tadorna	04	~	~
Phoenicopteridae	Flamant rose	Phoenicopterus roseus	67	~	~
Charadridae	Petit gravelot	Charadrius dubius	35	~	~
Ardeidae	Héron garde bœuf	Ardea ibis	19	~	~
	Canard colvert	Anas platyrhyncos	23	~	~
	Héron cendré	Ardea cinerea	03	~	~
Recurvirostridae	Échasse blanche	Himantopus himantopus	16	~	~
	Avocette élégante	Recurvirostra avostta	20	~	~
Ciconidae	Cigogne blanche	Ciconia ciconia	02	~	~
Scolopacidae	Becassine des marais	Gallinago gallinago	01	~	~
Rallidae	Foulque macroule	Fulica atra	10	~	~

The enumeration of nesting waterbirds during the year 2023 in the three Dayas made it possible to identify seven families, those of Anatidae, Phoenicopteridae, Charadridae, Ardeidae, Recurvirostridae, Ciconidae, and Rallidae. (Table 2). It should be noted that the family of Ardeidae is the best represented in species with 03 species, followed by Anatidae and Ciconidae with 02 species, as well as the family of Phoenicopteridae, Charadridae and Rallidae in last position with 01 species for each family,
No nesting birds were observed in the two study stations Daya Selouine and Malha due to the absence of water (Table 01 and 04)

Table 03: Systematic list of nesting waterbirds in the year 2024 in the three wetlands.

Families	Common name	Scientific name	Number of individuals		
			Daya Louguila	Daya Selouine	Daya Malha
Nothing					

No nesting birds were observed due to the absence of water (Tab. 02 and 05)

Table 04: Systematic list of nesting waterbirds in the year 2025 in the three wetlands.

Families	Common name	Scientific name	Number of individuals		
			Daya Louguila	Daya Selouine	Daya Malha
Anatidae	Tadorne casarca	Tadorna ferruginea	5	2	6
	Tadorne de belon	Tadorna tadorna	2	~	~

Charadridae	Petit gravelot	Charadrius dubius	19	17	2
	Gravelot à collier interrompu	Anarhyncus alexandrinus	~	4	~
	Grand Gravelot	Charadrius hiaticula	3	~	~
Ardeidae	Héron garde bœuf	Ardea ibis	103	~	~
	Aigrette garzette	Egretta garzetta	7	~	~
	Canard colvert	Anas platyrhyncos	3	~	2
	Fuligule nyroca	Aythya nyroca	3	~	~
	Héron cendré	Ardea cinerea	1	~	~
Recurvirostridae	Échasse blanche	Himantopus himantopus	31	20	17
	Avocette élégante	Recurvirostra avostta	9	~	11
Ciconidae	Cigogne blanche	Ciconia ciconia	89	~	~
Scolopacidae	Chevalier guignette	Actitis hypoleucos	1	~	~
	Bécasseau minute	Calidris minuta	21	~	~
	Bécasseau cocorli	Calidris ferruginea	5	~	~
	Chevalier cul blanc	Tringa ochropus	7	~	~
Rallidae	Poule d'eau	Gallinula chloropus	~	~	3
	Foulque macroule	Fulica atra	45	~	~

In 2025, the direct observation method identified seven families of nesting waterbirds in the three Dayas: Anatidae, Charadridae, Ardeidae, Recurvirostridae, Ciconidae, Scolopacidae, and Rallidae. (Tab. 2) It should be noted that the family of Ardeidae is the best represented in species, with 05 species, Scolopacidae in second position with 04 species, and Charadridae in third position with 03 species. The families Anatidae, Recurvirostridae, and Rallidae rank fourth, each with two species. As for the Ciconiidae family, it ranks last and is represented by a single species (Tab. 2).

1/Generalized Linear Mixed Model – GLMM (Negative Binomial)

The results in Table 1 of the GLMM model revealed a highly significant statistical effect of environmental factors on nesting density (NbI) between the three sites over the two years (2023 and 2025), as follows:

* Water depth had a positive and statistically significant effect ($p = 0.0013$; $p < 0.05$), indicating that increased water depth improves nesting opportunities for most bird species.

* Conversely, temperature and water level (water level index) yielded negative values for the coefficients (estimate), which could indicate the existence of specific thermal or hydrological thresholds that, when exceeded, lead to decreased nesting opportunities. These results are statistically significant, given the "p" values , which reached approximately $p=0.0014$.

1. Statistical Analysis (NMDS) of Environmental Variations at Study Stations and Nesting Seasons

NMDS analysis was performed to reduce dimensionality of the environmental data and to visualize the degree of variation and similarity in climatic conditions (temperature, depth, water quality, etc.) across the three study periods and the different stations.

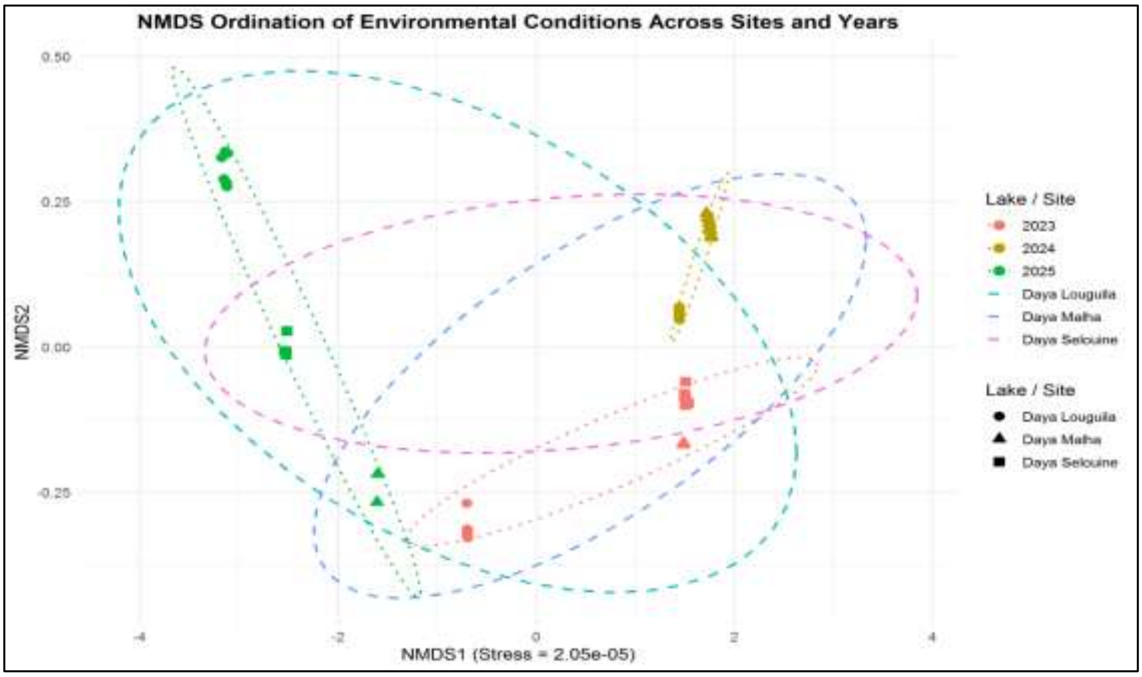

Figure 5: NMDS representation of the ecological distance between study stations and nesting seasons.

The NMDS analysis yielded a very low stress value of 1.24×10^{-6}, indicating that the environmental distances among the study station samples are accurately represented. The spacing of the stations on the diagram (Figure 1) reflects a significant variation in the hydraulic and climatic footprint for 2025 compared to 2023 and 2024, where the 2025 samples are completely separated along the axis (NMDS1) at all study stations.

The large area of the Daya Lougila site (large blue circle) also indicates strong environmental resilience and significant temporal changes in environmental factors. This explains its capacity to support large and diverse breeding populations, unlike the other two sites, Daya Malha and Daya Selouine, which exhibit more compact clusters, indicating relative stability in their ecological footprints.

Using this diagram (NMDS), we demonstrate that these factors (temperature and depth) have, in fact, varied considerably from year to year and from site to site, creating entirely different "environments" that have led to variations in the number of nests.

2. Generalized Linear Mixed Model (GLMM) (Negative Binomial) of Environmental Factors and Nesting Density

The results in Table 7 of the GLMM model revealed a highly significant statistical effect of environmental factors on nesting density (NbI) between the three sites over the two years (2023 and 2025), as follows:

* Water depth had a positive and statistically significant effect ($p = 0.0013$; $p < 0$), indicating that increased water depth improves nesting opportunities for most bird species.

* Conversely, temperature and water level (water level index) yielded negative values for the coefficients (estimate), which could indicate the existence of specific thermal or hydrological thresholds that, when exceeded, lead to decreased nesting opportunities. These results are statistically significant, with p-values approximately 0.0014.

Table 05: Values of the generalised linear mixed model (GLMM) for estimating the effect of environmental factors on nesting density.

facteurs	estimate	p.value	CI 95%
Temperature (Scaled)	8.34-09	0.0014	[0.000, 0.001]
Water Depth (Scaled)	1.2 *1010	0.0013	[21526.06, 6.67×1017]
Water Level Index (Scaled)	2.63-06	0.0014	[0.000, 0.007]

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

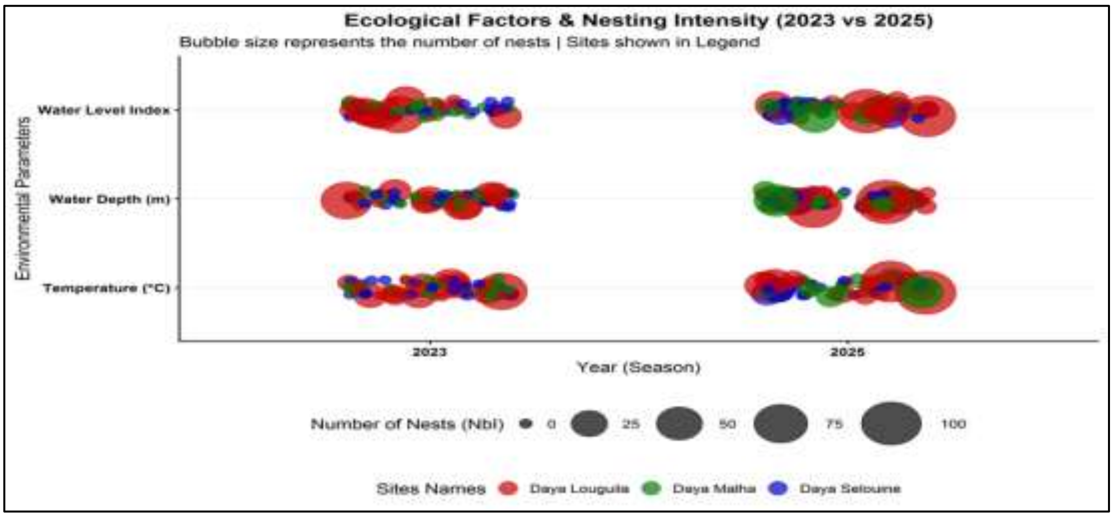

Figure 6: Spatio-temporal distribution of nesting and the relationship with environmental factors in the sites studied (2023 and 2025).

The bubble plot (Figure 8) confirms the statistical results reported in Table 1, which show an apparent variation in nesting density across sites and years. The size of the circles indicates that 2025 experienced more intense nesting activity at most sites than 2023, particularly at the Daya Louguila site (in red, Figure 8). The moderation of water levels and temperatures can explain this.

The graph also shows that the highest nesting density was associated with medium- to high-water depths and levels. In contrast, the absence of water in 2024 (excluded from the model because there was no nesting) resulted in a complete cessation of biological activity. This demonstrates that the presence of water is the determining factor for nesting at these sites.

The graph also shows that the highest nesting density was associated with medium- to high-water depths and levels. In contrast, the absence of water in 2024 (excluded from the model because there was no nesting) resulted in a complete cessation of biological activity. This demonstrates that the presence of water is the determining factor for nesting at these sites.

3. Descriptive bar graph model of nesting as a function of site water level over the three years:

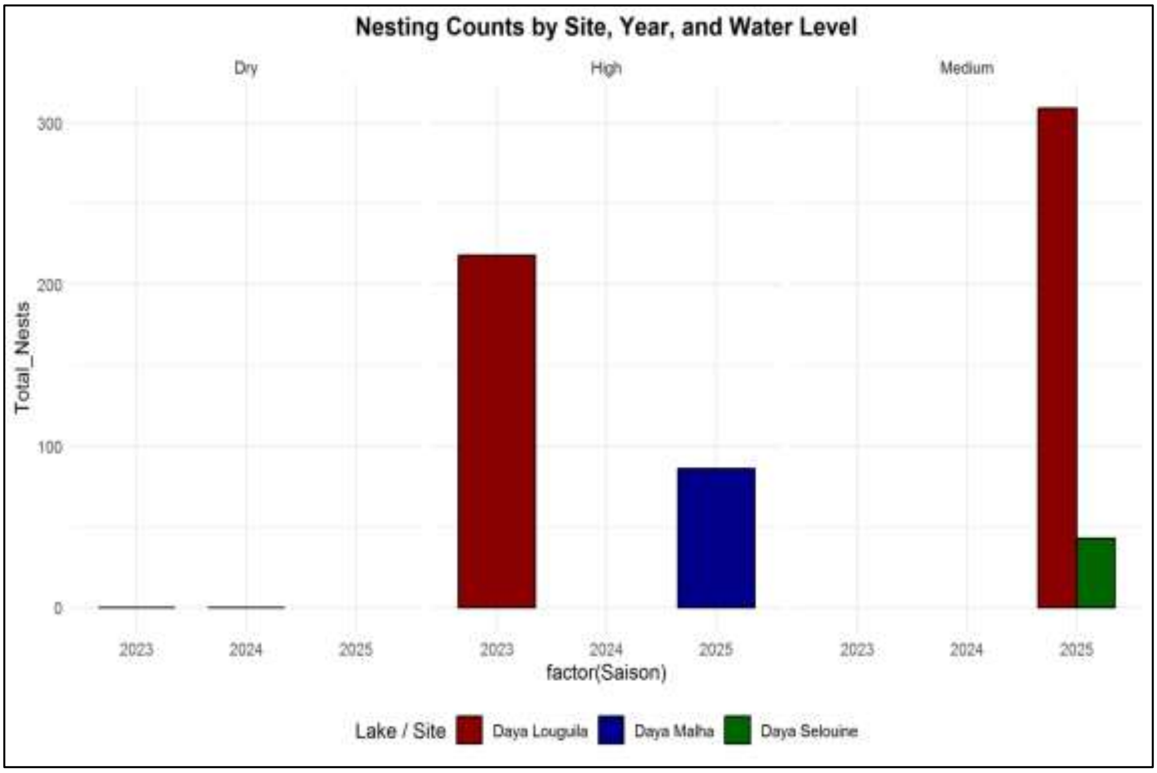

Figure 7: Impact of water levels on nesting in the study sites during the three periods "2023-2024-2025".

This graph corroborates our previous analysis that the highest nesting density is more closely linked to average water levels, particularly at the Daya Louguila site in 2025.
4. Descriptive bar graph model of nesting as a function of site water quality over the three years:
This descriptive graph shows substantial variation in the number of nests with respect to water quality.

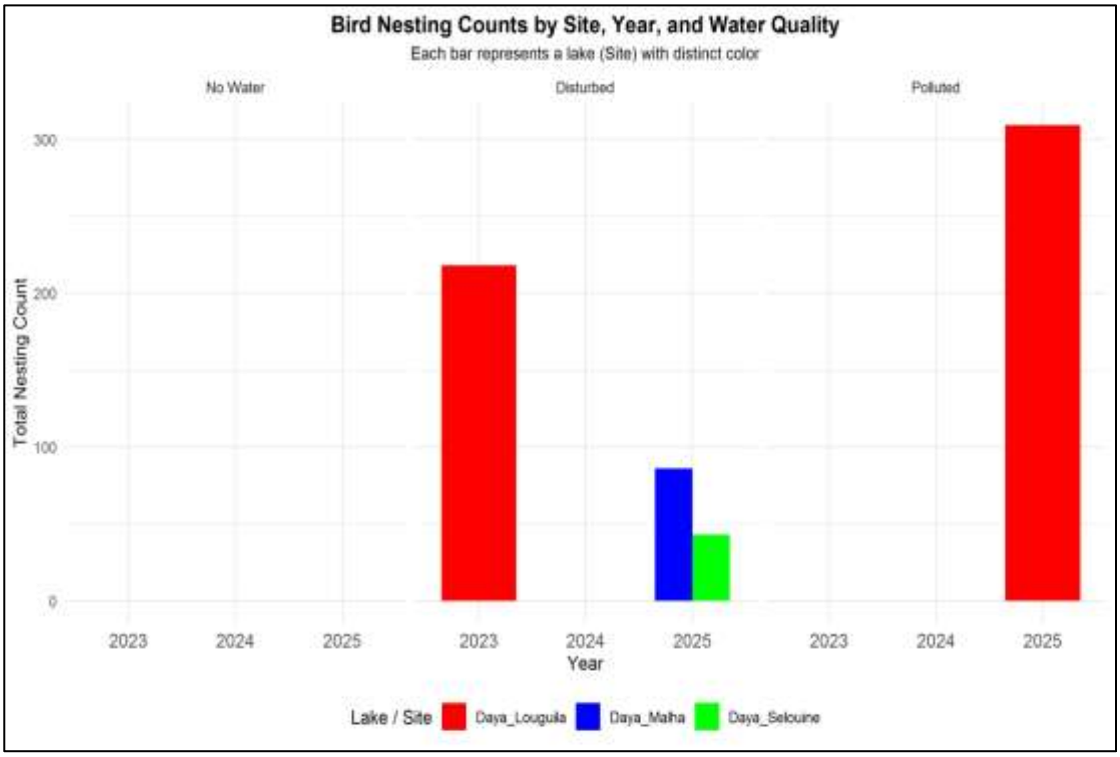

Figure 8: Impact of water quality on nesting at the study sites during the three periods "2023-2024-2025".

The highest nesting density was recorded in the waters classified as “polluted” at the Daya Louguila site in 2025 (more than 300 nests). This was followed by waters classified as “disturbed” in 2023 (more than 200 nests) and again in 2025 for the Daya Malha and Daya Selouine sites (Figure 10). This could indicate that polluted waters offer more favorable nesting conditions than disturbed waters, for example, in terms of food resource availability, or that the birds in this region have adapted to polluted waters.
5. Visual Analysis of Nesting Plasticity and Waterbird Abundance Across the 2025 Environmental Gradient at Study Stations
This graph illustrates the spatial distribution and abundance of breeding bird species (coded on the horizontal axis) at the three stations in 2025.
The results of the 2025 abundance-plasticity graph revealed apparent variation in nesting strategies and environmental preferences among the studied species. Species such as Himantopus himantopus: Hh, Charadrius dubius: Cd, and Tadorna ferruginea: Tf exhibited strong ecological plasticity in nesting, despite variable and low nesting rates (approximately 5 to 30 nests). This indicates the adaptability of these species to different environmental factors. The species Anas platyrhyncos: Ap and Recurvirostra avostta: Ra showed moderate ecological plasticity, as they were able to nest at two sites (Daya Lougila and Daya Malha).
The majority of other species appear on the diagram with low ecological flexibility, as they are confined to nesting in Lake Daya Lougila (except Gallinula chloropus: Gc at Daya Malha and Anas acuta: Aa at Daya Selouine) and occur at highly variable densities. The species Ardea ibis (Ai) recorded the highest nesting density, with 103 nests, followed by the species Ciconia ciconia (Cc) with 89 nests, and then the species Fulica atra (Fa) with 45 nests, all concentrated exclusively in this lake.

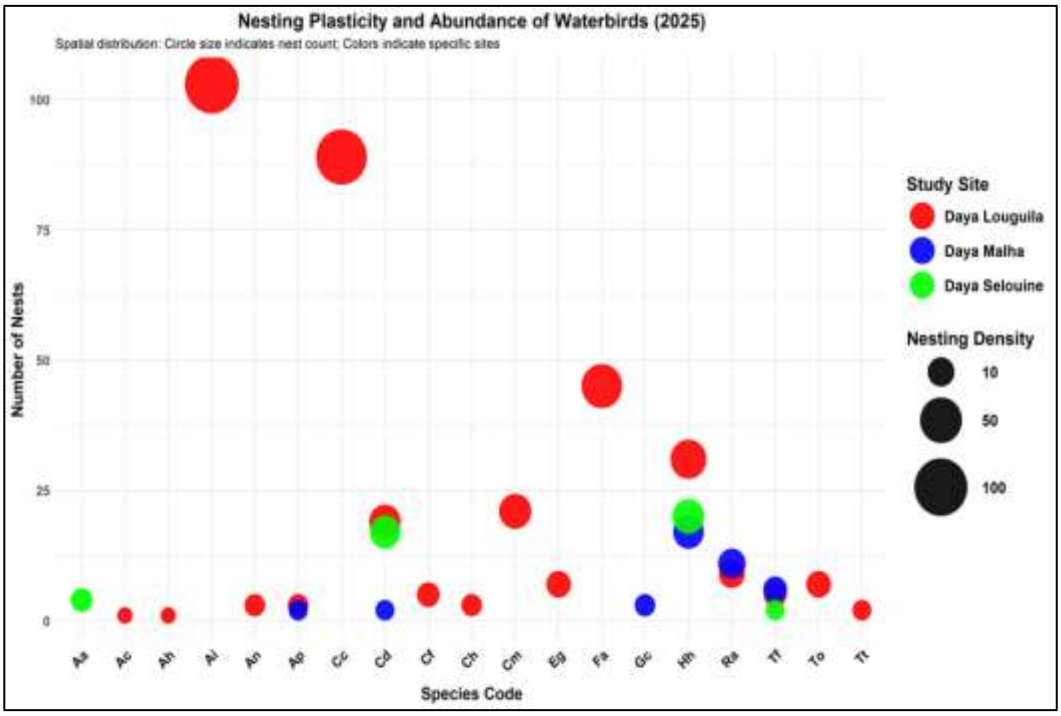

Figure 9: Nest abundance and spatial distribution of birds at the three stations in 2025.

Nesting dynamics at the Daya Luogela station between 2023 and 2025 in relation to environmental factors. This graph (Figure 12) presents a direct comparison between 2023 and 2025 for the nesting bird species (coded on the horizontal axis).

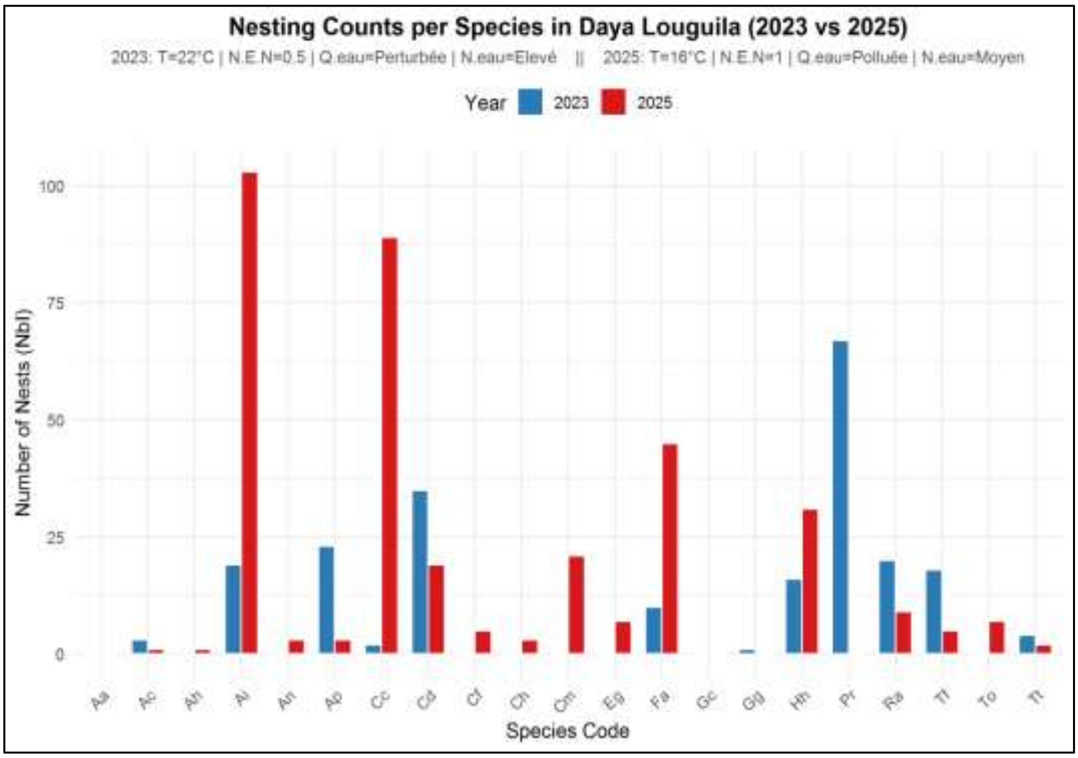

Figure 10: Hydro-climatic analysis of nesting by species at Daya Louguila (2023 vs. 2025)

Graph 4 shows a direct comparison between the bird species that nested at Daya Luogela in 2023 and 2025 (Figure 12). The horizontal axis shows 20 coded bird species, while the number of nests is indicated on the vertical axis. This graph highlights the specific dynamics of the Daya Louguila site, in which most species recorded a significant numerical increase during the 2025 season relative to 2023. In particular, we observed a surge in the number of nests for species such as Ardea ibis (Ai) and Ciconia ciconia (Cc). In 2025, the AI species exceeded 100 nests, and Cc exceeded 80 nests. In contrast, in 2023, there were

only 19 nests for Ardea ibis and only 2 for Ciconia ciconia. This is likely because the environmental conditions that year (temperature of 16°C and water level) were particularly favorable for these species.
Similarly, in 2025, nesting was observed for species that did not nest in 2023, such as *Calidris minuta* (Cm), *Egretta garzetta* (Eg), and *Calidris ferruginea* (Cf), indicating that the site has become an attractive environment for greater biodiversity, despite its classification as a polluted site.
We also note that the species *Phoenicopterus roseus* (Pr) was dominant in 2023 with approximately 65 nests, but had disappeared entirely by 2025. This reflects species turnover, which may be due to a shift in water quality from disturbed to polluted conditions, or to changes in temperature and relatively low water levels.
The data recorded above the graph clearly show that the temperature drop from 22°C to 16°C and the average water level in 2025 had a cumulative positive effect on the total number of nesting aquatic species.

DISCUSSION

The enumeration of nesting waterbirds in the three Dayas in 2023, using the direct observation method, identified 12 species; none in 2024; and 19 in 2025.
The 21 species recorded represent 05.17% of the Algerian avifauna (406 species) reported by Isenmann and Molaï (2000). In the northern Algerian (Farhi and Blhamra 2012; Farhi 2014).
KHIRANI-BETROUCHE and MOULAÏ (2022) identified 14 nesting species in complex wetland of Oued Righ valley, in Algerian .
In Daya Louguila, the pink flamingo is the most abundant species during the year 2023 with 67 individuals, while the species Cattle Heron is the most abundant during the year 2025 with 103 individuals.
The greater flamingo is considered the emblematic species of the wetlands of the eastern Algerian highlands and the Saharan Chott, as it is observed year-round and nests there regularly (SAHEB et al., 2006; BOULKHSSAÏM et al., 2006, 2009; SAMRAOUI et al., 2006, 2008, 2009).
Wetlands in steppe zones, particularly the Dayas, play a role in conserving natural ecosystems and supporting the reproduction of nesting waterbirds. These wetlands are subject to various threats, such as pollution and drought. It is essential to develop a conservation, restoration, and protection plan to achieve sustainable development.

CONCLUSION

Dayas are depressions where rainwater and runoff accumulate due to their soil structure. They are considered wetlands and habitats for migratory, nesting, and resident birds, thus playing a crucial role in the diversity and distribution of these birds.
According to our results, temperature and water level are limiting factors, unlike water quality. However, these wetlands face threats related to urbanization, human activities, and climate change. Our spring inventory (2023-2025) in the dayas of Louguila, Selouine, and Malha highlights marked variability: 19 nesting species in 2025 (Ardeidae being dominant with 5 species, and Ardea ibis reaching 103 individuals in Louguila), 12 species in 2023, and a total absence in 2024 due to environmental factors such as drought. These fluctuations highlight the critical influence of vegetation, water depth, and salinity on the distribution of waterbirds, aligned with Palearctic dynamics.
However, these vulnerable ecosystems face accelerating threats: rapid urbanization, human activities (overgrazing, agricultural pollution), and above all, climate change. To counter this, we propose measures that will not only preserve Algerian bird biodiversity but also strengthen the overall resilience of North African wetlands to future crises.

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