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DISTRIBUTION OF BREEDING WATERBIRDS IN RELATION TO WETLAND CHARACTERISTICS IN THE OUED RIGH VALLEY IN THE ALGERIAN SAHARA

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Abstract

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In the framework of this study 14 breeding species were identified in the wetland complex of the Oued Righ valley in the Algerian Sahara. Six species of breeding Anatidae were reported, two of which are classified as vulnerable and threatened, namely, the ferruginous duck *Aythya nyroca* and the marbled teal *Marmaronetta angustirostris*. For shorebirds, we noted reproduction of the pied avocet *Recurvirostra avosetta*, the black-winged stilt *Himantopus Himantopus,* and the Kentish plover *Charadrius alexandrinus* in most of the wetlands studied. We report for the first time nesting of the slender-billed gull *Chroicocephalus genei* at Chott Merouane with 72 pairs recorded during the breeding season 2018. This colony was associated with the larger colony of greater flamingo *Phoenicopterus roseus* composed of 640 pairs. Principal component analysis (PCA), gathering 69.74% of the information, showed a significant correlation between the distribution of different bird species and the main environmental factors, that is, vegetation, water surface area, water depth, and salinity, and a strong correlation between the species of Annatidae and Rallidae, which are associated with less-saline environments rich in vegetation and deep water, with the exception of shelducks, which prefer large surface areas with less-dense vegetation and more holomorphic water. For the shorebirds such as *R. avosetta* and *H. himantopus,* there was a clear preference for large wetlands with shallow water and relatively high salinity. A remarkable correlation was also noted for *P. roseus,* where a strong distribution of breeding populations was observed in areas with the highest salinity levels and a vast surface area.

Key words: wetlands, waterbirds, Anatidae, shorebirds, Sahara.

Introduction

The wetlands of the Oued Righ valley are recognized for their role in the migration and reproduction of water birds and the economic values generated by mineral extraction, agriculture, and tourism activities (Demnati et al., 2017).

The aquatic avifauna of the Oued Righ depression has been little studied, despite its potential interest in view of its geographic location on the southern margins of the Western Palearctic (Heim de Balsac, Mayaud, 1962; Ledant et al., 1981; Isenmann, Moali, 2000).

Earlier research has focused on the study of some targeted species at some of the major wetlands within this Oued without considering the whole complex of wetlands. For example, the eco-ethology and breeding of the greater flamingo (*Phoenicopterus roseus*) was studied at Chott Merouane (Bensaci, 2011; Bensaci et al., 2011; Houhamdi et al., 2008). Inventories of aquatic avifauna were taken by Bouzegag (2008) and Chenchouni (2011), but limited to the wetland of Lake Ayata. A study on the ecology of the marbled teal *Marmaronetta angustirostris* conducted between 2009 and 2011 in the Oued Righ valley is reported by Bouzegag et al. (2013).

The aim of this contribution is, therefore, to update knowledge on the breeding avifauna in these Saharan wetlands and to identify the influence that certain environmental factors (vegetation, water depth, surface of water, and salinity) may have on the distribution of waterbirds.

Breeding waterbirds tend to choose the environment according to specific requirements that differ from one species to another. Depending on their diet, species tend to distribute themselves according to different salinity and depth gradations. For nest building, birds choose their environment according to the ethology, manner, and materials used to build their nests, and this is directly related to the area of water and the density of surrounding vegetation, as well as the depth.

Water surface and depth, vegetation, and salinity are the structuring parameters in the biology of aquatic organisms (Green, Figuerola, 2003; Kushlan, 1993). Salinity is one of the main drivers of vegetation structure and fauna and flora species diversity (Koull, Chehma, 2016; Ysebaert et al., 2000), particu-

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Table 1. Characteristics of the wetlands studied.

	Halomorphic status	Depth, m	Water area, ha	Vegetation(reedbed), ha	Date of sampling
Chott Merouane	Hyperhaline >40‰	0.4–3	1500	20	01/21/2019
Oued Kherouf	Polyhaline, euhaline 18‰–40‰	0.8–3	1200	70	01/24/2019
Lake Sidi Khelil	Polyhaline 18‰–30‰	2.5	20	80	01/26/2019
Chott Tendla	Hyperhaline, euhaline >30‰	0.2–0.4	600	5	01/27/2019
Lake Ayata	Oligohaline, mesohaline 0.5‰–18‰	0.2–1.3	155	70	02/02/2019
Lake Merdjadja	Mesohaline 5‰–18‰	3	16	15	02/03/2019

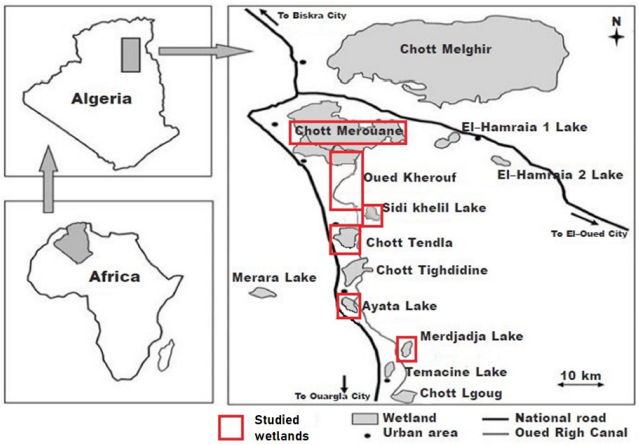


Fig. 1. Location of the studied wetlands.

larly under arid conditions. It should also be mentioned that increasing the salinity level of water will affect the food of waterbirds, whose diet includes a range of fauna items and aquatic plants, particularly for ducks (Telailia et al., 2017). Salinity drives the choice of feeding, resting, and breeding sites for many waterbird species. It is also a main factor influencing the distribution of wintering waterfowl in the Oued Righ valley in the Algerian Sahara (Khirani-Betrouche, Moulaï, 2021).

Study area

The valley of Oued Righ includes a complex of wetlands, among which three are classified as Ramsar sites: Chott Merouane, Oued Kherouf, and Chott Sidi Slimane. This valley of southeastern Algeria occupies an area of 11,738 km^2 (Khechana et al., 2010). It is part of the whole basin of the lower Sahara. It is a vast depression elongated between El Goug (32°54´N) in the administrative district of Ouargla in the south and Oum El Thyour (34°9´N) in the administrative district of El Oued in the north. Our study focuses on the six most important wetlands in terms of biodiversity and for waterbird populations: Chott Merouane and Oued Kherouf (Ramsar sites since February 2, 2001), Lake Sidi Khelil, Chott Tendla, Lake Ayata, and Lake Merdjadja (Fig. 1).

Chott Merouane (34°02.433'N, 5°58.748'E): This covers 337,700 ha, with areas in open water all year round. It is classified as a Ramsar site since February 2, 2001. This wetland receives, via Oued Kherouf, all the excess water from the irrigation of palm groves and wastewater from all the communes of the valley; it hosts the largest concentrations of flamingos in eastern Algeria (Fig. 2).

Oued Kherouf (33°53.332'N, 06°01.125'E) belongs to the municipality of Ain Chikh (560 km south of Algiers) and is classified as a Ramsar site since February 02, 2001. Its outflow represents the end reached by the waters of the valley of Oued Righ (Fig. 1). It is dominated by stands of *Phragmites australis* of about 1200 ha, which opens on the Chott Merouane with a maximum depth of up to 3 m (Houhamdi et al., 2008).

Lake Sidi Khelil (33°29.867'N, 05°59.403'E): With an area of 20 ha, it is characterized by its relatively dense vegetation. This lake seems to be permanent and has its origin in irrigation channels, ditches, sakia (local drain channels), and neighboring palm groves. Its depth reaches 2.5 m.

Chott Tendla (33°39.787'N, 06°02.815'E) is a wetland of 600 ha located near the town of Tindla, 80 km north of the wilaya of El Oued. It is shallow (20–30 cm depth) and fed by wastewater overflowing from the drainage channels of the southern region of the valley. This easily accessible site, rich in *P. australis*, is dotted with small islands (Fig. 3).

Lake Ayata (33°29.867'N, 05°59.403'E) is located about 600 km south of Algiers. The site covers an area of about 155 ha with an average altitude of 31 m. It has surface water during all the year.

Lake Merdjadja (33°03'08"N, 06°03'55'E) is a permanent lake surrounded by palm groves and a dune cordon. A belt of reed surrounds the lake on its immediate edges. The submersed and emergent macrophytes are abundant and diverse.

The main characteristics of the wetlands studied are summarized in Table 1.

Methodology

The field study was conducted for two breeding seasons, 2018 and 2019. It required 48 trips during the two breeding seasons, which represent approximately a total of 385 h of observation for the six sites. Counts were conducted by direct observation of the different waterbird species using a spotting scope (KITE SP 82 ED) and a pair of binoculars. The whole open water area was surveyed for waterbirds at all the study locations, except Chott Merouane. Due to its large surface, we focused our bird survey on the three most accessible locations at Chott Merouane for a total open water surface of about 1500 ha. We proceeded to a complete counting of individuals when the distance was less than 200 m and the number of individuals was less than 200. When the group was larger than 200 individuals or if it was located at more than 200 m, we proceeded by dividing the visual field into several sections. We



Fig. 2. Chott Merouane.



Fig. 3. Chott Tendla.

counted the number of birds in an average section and reported it as many times as there were sections (Altmann, 1974).

The identification and counting of breeding birds was done between March and June. The protocol used was the EBCC European Bird Census Council (Hagemeijer, Blair, 1997); of the three main breeding categories, only the "certain" criteria was considered to determine the number of breeding pairs.

For the measurement of salinity of the Oued Rign valley wetlands, we opted for the direct method using a portable optical refractometer brand Autoutlet, whose measurement interval varies from 0 to 100‰. Eleven stations in each of the six wetlands studied were analyzed and classified according to the salinity categorization of Mediterranean wetlands proposed by Farinha et al. (1996), namely, freshwater <0.5‰, oligosaline (0.5‰–5‰), mesosaline (5‰–18‰), polysaline (18‰–30‰), eusaline (30‰–40‰), and hypersaline >40‰. For vegetation, water depth, and area, direct measurements were conducted.

To determine inter-site variation for the different breeding species, we used the nonparametric Kruskal–Wallis test. Principal component analysis (PCA; Spearman; correlation biplot) was used to assess and compare factors influencing abundance and distribution at different study sites during the monitoring peri-

Table 2. Status and numbers (number of pairs) of breeding species in the different wetlands studied for the period 2017–2019.

Family ***Species***	**Phenological status**	**CM**	**OK**	**LS**	**CT**	**LA**	**LM**
Annatidae							
Anas platyrhynchos	Sedentary breeder	0	4	8	0	16	11
Spatula querquedula	Occasional breeder	0	1	2	0	0	0
Aythya nyroca	Sedentary breeder	0	9	12	0	17	9
Marmaronetta angustirostris	Sedentary breeder	0	22	31	0	34	0
Tadorna ferruginea	Sedentary breeder	4	2	0	5	0	0
Tadorna	Sedentary breeder	26	7	0	18	0	0
Podicipedidae							
Tachybaptus ruficollis	Migratory breeder	0	0	3	0	4	3
Rallidae							
Fulica atra	Sedentary breeder	0	6	15	0	14	11
Gallinula chloropus	Sedentary breeder	0	24	12	0	18	0
Recurvirostridae							
Recurvirostra avosetta	Sedentary breeder	0	0	0	29	8	0
Himantopus himantopus	Sedentary breeder	33	0	0	48	39	0
Charadriidae							
Charadius alexandrinus	Sedentary breeder	8	0	0	43	40	0
Phoenicopteridae							
Phoenicopterus ruber	Sedentary breeder	640	0	0	0	0	0
Laridae							
Chroicocephalus genei	Occasional breeder	72	0	0	0	0	0

Notes: CM – Chott Merouane; OK – Oued Kherouf; LS – Lake Sidi Khelil; CT – Chott Tendla; LA – Lake Ayata; LM – Lake Merdjadja.



Fig. 4. Duckling of *Marmaronetta angustirostris* at the Oued Righ wetlands.



Fig. 5. Nest of *Himantopus*.

ods. PCA was performed with XLSTAT software version 2016. The significance level used for statistical analysis was $p < 0.05$.

Results

Of the 14 breeding species, the Anatidae are represented by six species: the mallard *Anas platyrhynchos*, the ferruginous duck *Aythya nyroca*, the garganey *Spatula querquedula*, the marbled teal *Marmaronetta angustirostris* (Fig. 4), the ruddy shelduck *Tadorna ferruginea*, and the shelduck *T. tadorna*. For this family, the most important breeding numbers were noted for marbled teal with 34 pairs at Lake Ayata and 31 pairs at Lake Sidi Khelil, observed between the end of April and the beginning of June 2018.The number of breeding pairs of *T. tadorna* was 26 at Chott Merouane and 18 at Chott Tendla (Table 2).

Three species of shorebirds were found breeding: the black-winged stilt *Himantopus* (Fig. 5), the avocet *Recurvirostra avosetta*, and the Kentish plover *Charadrius alexandrinus*. Thirty-three pairs of black-winged stilt were noted at Chott Merouane, 48 at Chott Tendla, and 39 at Lake Ayata. For the avocet, we counted 29 breeding pairs at Chott Tendla and eight at Lake Ayata. For Kentish plover, 43 pairs were counted at Chott Tendla and 40 at Lake Ayata (Table 2). The Rallidae are represented by two breeding species: the coot *Fulica atra* and the common moorhen *Gallinula chloropus*, while Podicipedidae involve only the little grebe *Tachybaptus ruficollis*.

The most important breeding numbers were noted for the common moorhen with 24 pairs at Oued Kherouf and 18 at Lake

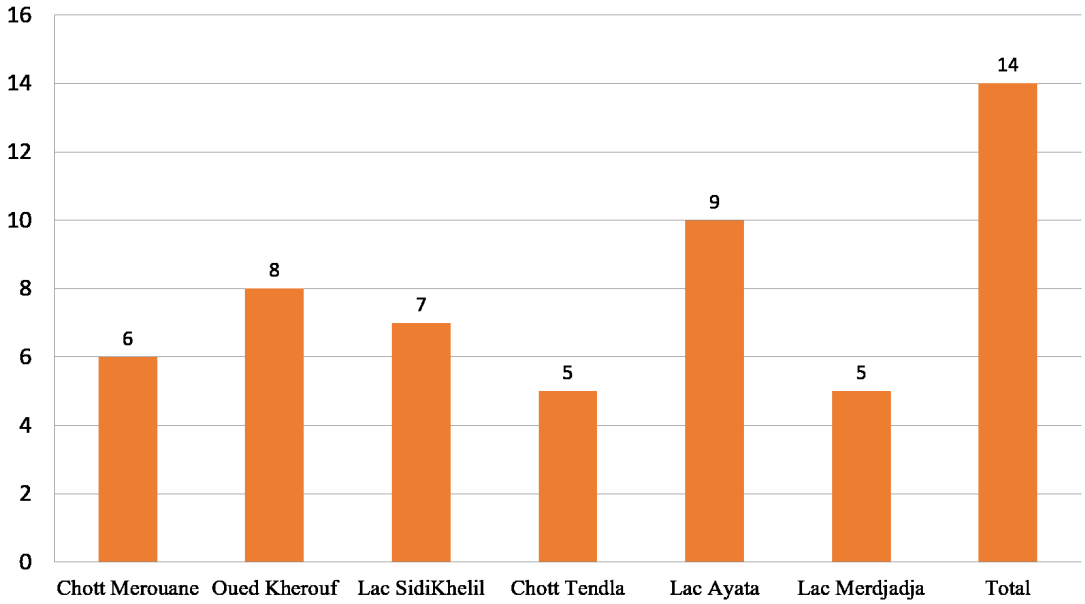


Fig. 6. Number of breeding waterbird species in the wetlands of the Oued Righ valley for the two pooled breeding seasons, 2018 and 2019.

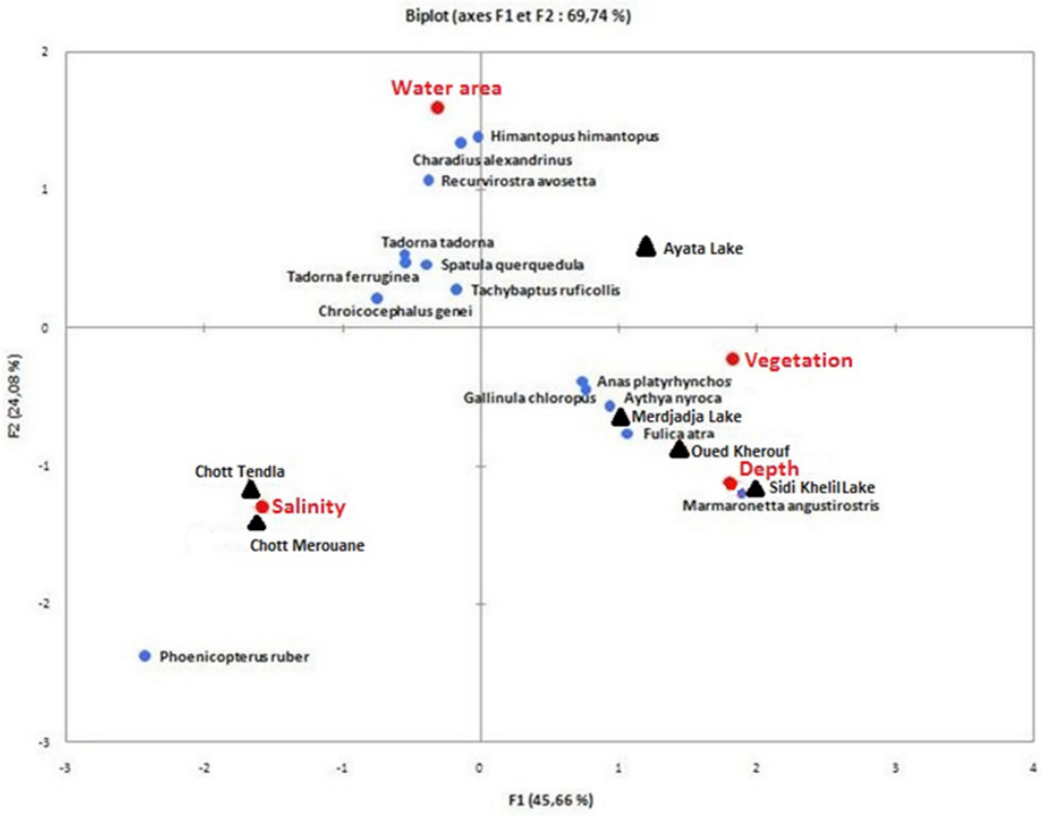


Fig. 7. PCA (correlation biplot) representing the breeding waterbirds' distribution across the different wetlands of the Oued Righ valley.

Ayata, followed by the coot with 15 pairs at Lake Sidi–Khelil and 14 at Lake Ayata (Table 2). Regarding gulls, we noted for the first time in the valley of Oued Righ nesting of the slender-billed gull *Chroicocephalus genei* at Chott Merouane, on an islet located near the village of Oum Thyour. For the breeding season 2018, we counted 72 breeding pairs. The colony of the slender-billed gull was associated with the larger colony of the greater flamingo with 640 breeding pairs, counted between March and June

2018 at Chott Merouane (Table 2). As to species diversity, Lake Ayata is considered the most diverse with nine breeding species, followed by Oued Kherouf and Lake Sidi Khelil with eight and seven nesters, respectively. Chott Tendla and Lake Merdjadja had only five and four breeding species for each site, respectively (Fig. 6). Concerning the status of the breeding aquatic birds, we noted that the vast majority were sedentary breeders. Occasional nesters were represented by only two species (*Spatula querquedula* and *Chroicocephalus genei*). Little grebe seemed to be the only representative of migratory breeders (Table 2).

The PCA (Fig. 7) (factorial design 1 × 2 gathering 69.74% of the information) showed a significant correlation between the distribution of the different breeding waterbird species and the four environmental variables studied, namely, vegetation, salinity, depth, and surface area of the water body characterizing the six wetlands. We distinguished four main groupings (Fig. 7). The sites characterized by a great depth, dense vegetation, and low salinity, namely, Lake Sidi Khelil, Oued Kherouf, and Lake Merdjadja, are distinguished mainly by the regular presence of nesting Anatidae, such as *Anas platyrhynchos*, *Aythya nyroca,* and *Marmaronetta angustirostris.* This is to note that the same conditions are associated with the breeding of Rallidae and Podicipedidae, such as *Galinulla chloropus*, *Fulica atra*, and *Tachybaptu sruficollis.* On the other hand, the shelducks *Tadorna ferruginea* and *T. tadorna* tend to breed at the most open sites (less-dense vegetation), with large surface area and relatively high salinity. Nouidjem et al. (2015) were the first to mention the breeding status of *T. ferruginea* in this region.

Recurvirostridae and Charadriidae, represented by *Recurvirostra avosetta*, *Himantopus himantopus,* and *Charadius alexandrinus*, prefer shallow sites with less-dense vegetation. Their habitat distribution showed no influence of the salinity level. The majority of their nests were found on the mudflats of Lake Ayata and Chott Tendla.

The sites of large area, shallow water, and very high salinity (Chott Merouane and Chott Tendla) appeared as the preferred nesting sites for the slender-billed gull *Chroicocephalus genei* and the greater flamingo *Phoenicopterus roseus* (Fig. 7).

Discussion

The number of breeding waterbirds in the wetlands of the Oued Righ valley in the Algerian Sahara amounts to 14 species, which represents nearly 34% of the breeding waterbird species in Algeria (Samraoui et al., 2011). Regarding the breeding birds with high conservation values, we could count 22, 31, and 34 pairs of marbled teal *Marmaronetta angustirostris* at Oued Kherouf, Lake Sidi Khelil, and Lake Ayata, respectively, between April 21 and June 25, 2018. Bouzegag et al. (2013) found between 28 and 54 pairs in all wetlands of the depression of Oued Righ in 2011. For the ferruginous duck *Aythya nyroca*, a species that nests in many sites in northeastern Algeria but with limited numbers (Aissaoui et al., 2009), we noted a significant reproduction in our study area with 17 pairs at Lake Ayata, 12 at Sidi Khelil, and nine at Lake Merdjadja. The presence of the marbled teal and the ferruginous duck at several sites in the Oued Righ valley indicates high ecological value and biological integrity of both sites. The ecological value and biological integrity can be assessed for wetlands by the presence and abundance of bird species whose conservation value is considered high (Green et al., 2002).

Three species of waders bred in our study areas: the black-winged stilt *Himantopus himantopus*, the pied avocet *Recurvirostra avosetta*, and the Kentish plover *Charadrius alexandrinus*. These birds inhabited most of the mudflats of the studied wetlands where they were more abundant at Chott Tendla, Chott Merouane, and Lake Ayata.

The greater flamingo is considered as the emblematic species of the wetlands of the high plateaus of eastern Algeria and the Saharan Chott because it is observed throughout the year and regularly nests there (Saheb et al., 2006; Boulkhssaïm et al., 2006, 2009; Samraoui et al., 2006, 2008, 2009). Not less than 602 breeding pairs were counted in 2019 at Chott Merouane. This colony can currently be considered the largest in the eastern part of the Algerian Sahara, followed by Sebkhate Safioune in the Ouargla basin with 120 breeding pairs in 2008 (Bouzid et al., 2009). Further north in the highlands of the east of the country, the number of breeding pairs was much higher in Sebkhate Ezemoul (Oum El-Bouaghi), where the colonies may contain between 5000 and 6000 pairs (Saheb et al., 2006; Boulkhssaïm et al., 2009).

The nesting of the slender-billed gull is reported for the first time in the Saharan wetlands of eastern Algeria at Chott Merouane with 72 pairs. The first mention of the nesting of this species in Algeria was given by Seddik et al. (2010) at the Lake Timerganine in Oum El Bouaghi on the eastern highlands. A second mention relates to the central highlands of Algeria (Cherief-Boutera et al., 2013).

The results of the PCA (Fig. 7) on the breeding waterbirds data in the different wetlands showed that remarkable variations in abundance and diversity of breeding species existed across the different wetlands studied under the influence of different ecological parameters such as vegetation, salinity, water surface area, and depth. Anatidae, which are strict waterbirds, are relatively sensitive to hydrological regimes, which explains their abundance in deeper wetlands with minimum changes in the water surface area (Liang et al., 2002), as is the case of Lake Merdjadja, Sidi Khelil, and Oued Kherouf. This may relate also to fairly abundant vegetation and higher floristic richness. In addition to serving as a direct food source for herbivorous birds and indirectly for birds feeding on invertebrates, the vegetation cover plays a role in providing shelter and nesting sites (Hargeby et al., 1994).

The presence of breeding waders *Recurvirostra avosetta*, *Himantopus himantopus*, and *Charadrius alexandrinus* in the shallow environments of the mudflats of Lake Ayata and Chott Tendla can be explained both by the relatively high tolerance of these birds to high levels of salinity recorded at these two wetlands and by the fact that in these environments, water levels vary between 5 and 20 cm, which provides a favorable habitat for these birds.

The remarkable presence of the greater flamingo and the slender-billed gull breeding at Chott Merouane, where some stations show salinity rates higher than 80‰, may be explained by the fact that their staple food – the crustacean *Artemia salina*– finds there an optimum habitat for its development (Van Stappen, 2002; Bouzegag, 2008).

The breeding of some species with high conservation value, such as the greater flamingo, the marbled teal, the ferruginous duck, and the slender-billed gull, at the Saharan wetlands of the Oued Righ valley points to the robust adaptation of these species to extreme environmental conditions, especially during periods of great heat and certainly adds the ecological and biological value of these wetlands located in the middle of the arid desert area.

These wetlands suffer from various disturbances and threats such as hydrological changes induced by hydraulic development work and other human activities, necessitating the development of a conservation plan and more effective protection of these wetlands, especially in Ramsar sites such as Chott Merouane and Oued Kherouf.

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