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# AVIAN ECOLOGICAL STATUS IN THE GADAÏNE ECO-COMPLEX (BATNA, NE ALGERIA)

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**Abstract.** Wetlands represent ecosystems of great importance through their ecological and socio-economic functions and biological diversity, even if they are most threatened by anthropization. This study aimed to contribute to the creation of an inventory of bird species in the Gadaïne eco-complex (Batna, Algeria) from 2019 to 2021. Counts were carried out from 8:00 to 19:00 using a telescope (20 × 60) and a pair of binoculars (10 × 50) and by employing absolute and relative methods. Birds were categorized by phenology, habitat, biogeography, and diet. A total of 80 species in 58 genera and 19 families were observed. Migratory birds were dominant (38%) phenologically, and the birds of Palearctic origin dominated (26.25%) biogeographically. Invertivorous and carnivorous species were most common (35%). Ecologically, the majority of species were waterbirds (73.75%), which are protected in Algeria. This study highlights the need for the preservation of ecosystem components and enhancement of biological resources of protected, rare, and key species. We observed 43797 individuals of *Marmaronetta angustirostris* during our study and reported the nesting of *Podiceps nigricollis*, *Porphyrio porphyrio,* and *Tadorna ferruginea*. For this reason, it is recommended to propose the area as a Ramsar site.

## INTRODUCTION

Waterbirds are biologically dependent on wetlands; therefore, they have developed wetlands-specific adaptations and habits. Wetlands are where they feed and breed (Betts et al. 2019). In general, ecologists used to focus on key groups and birds (specifically waterbirds) that have always been considered important bioindicators of the ecological condition of wetland ecosystems because they respond immediately to habitat changes (Rajpar et al. 2018). Wetlands host several avian species and constitute a stopover area due to their high biological productivity, providing a wide variety of wintering and breeding habitats and a source of food (Green and Elmberg 2013; Betts et al. 2019).

In the eastern Algerian highlands, the wetland eco-complex is a vital stopover for wintering avian populations in the north-east of Algeria or returning to the usual nesting biotopes. The biodiversity of wetlands, including vegetation belts, attracts many breeding populations. In Algeria, there is some evidence of the ecological role of wetlands in maintaining migratory bird populations (Mayache et al. 2008; Metallaoui and Houhamdi 2008; Metallaoui et al. 2009; Bensaci et al. 2013; Chedad et al. 2020; Meziane et al. 2014). Only the Oum El-Bouaghi wetlands are studied in the highlands of eastern Algeria (Bezzalla et al. 2019).

The wetlands of the Batna province are characterized by a very important biodiversity, which makes them of scientific, social, economic, touristic, cultural, and ecological interest. Thus, their conservation is essential (Houhamdi et al. 2009; Boulkhssaim et al. 2009; Seddik et al. 2010). These wetlands play an important role in the wintering and nesting of waterbirds, as well as in the breeding of rare and endangered species (Samraoui and Samraoui 2008; Bouaguel 2014). The water level

in these areas depends primarily on weather conditions, particularly heavy rain and snow; therefore, most of these ecosystems are ephemeral and only fill up with water for a short period of the year, often in winter (Houhamdi et al. 2009).

Batna includes 21 continental wetlands, including two Ramsar classified areas, namely Chott El Beïdha-Hammam Essoukhna and Chott El Hodna, as well as the dam of the Gazelle Fountain and an area proposed by the Directorate General of Forests, Chott Djendli (D.G.F. 2019, 2020, 2021).

In general, there is a lack of animal-related studies in North Africa, specifically those concerning ornithology (Belabed et al. 2013; Aouissi et al. 2017; Aouissi et al. 2021; Farhi et al. 2022). In fact, our study is the first in the Gadaïne eco-complex. Thus, it fills an important gap in our knowledge of avian biodiversity in north-eastern Algeria. This study aims to highlight the importance of these wetlands for the aquatic avifauna, the structure and dynamics of this avian population, and their bioecological status (phenological status, ecological group, wildlife type, trophic category, and protection status).

## MATERIALS AND METHODS

### *Study area*

The Gadaïne eco-complex is located in the Batna province. The total area of the site, including its surroundings, stretches over 2647 ha and forms a film of water formed by five sub-chotts (to facilitate the monitoring and counting of the observed species): Draâ Boultif, Teniet Saïda, Taricht, Saboune, and Gamra. Chotts are saline lakes typical of the Maghreb region of North Africa.

This wetland is situated at an average altitude of 813 m, longitude 35°44' and 35°45' North and latitude 6°14' and 6°15' East (Figure 1A). This water film is mainly fed by the rainwater from the Oued El Madher and Oued Zana. Its water is brackish with low salinity, alkaline PH, and a depth that varies fairly regularly between 0.2–1 m. Our study area has an average temperature of 31°C, rainfall of 334.5 mm, a medium slope is low and covered by halophytic plants growing on clay-limestone soil (D.G.F. 2019). Actually, it is a temporary natural wetland that only fills during the winter season, with the exception of the Saboune sub-chott (D.G.F. 2020, 2021).

A: Geographic location of the Gadaïne eco-complex, B: Draâ Boultif sub-chott (taken on: 12/02/20), C: Teniet Saïda sub-chott (taken on: 20/03/21), D: Taricht sub-chott (taken on: 17/06/21), E: Saboune sub-chott (taken on: 11/07/20), F: Gamra sub-chott (taken on: 09/08/21), and G: Gamra sub-chott (taken on: 30/07/20).

### *Data collection*

Birds were studied for two consecutive years, from September 2019 to December 2021, with four inventories per month for the winter season. Nevertheless, in the summer breeding season, counts were made every week (12 surveys per month). Counts were based on two methods. We conducted an individual count (absolute method) for the groups of birds that include less than 200 individuals and are at a distance of less than 200 m. However, we also conducted estimates of the total number of birds (relative method or estimation technique) that are at more than 200 m and with more than 200 individuals in a group (Blondel 1979). This method is the most widely used in winter surveys of aquatic avifauna (Lamotte and Bourlière 1969). Hence, we divided the visual field into several bands, counted the number of birds in a medium band, and reported as many times as we had bands (Bibby et al. 1992).

The counts were carried out with a KONUS-SPOT tripod (20 × 60) telescope, a pair of HIRSCH binoculars (10 × 50), a Nikon P 1000 digital camera (18–105 mm), a SONY camcorder (HDR-CX240), and a Garmin Map 73CSx GPS. A European, North African, and Middle Eastern bird guide (Heinzel et al. 2004) and a European, North African, and Middle Eastern bird guide (Gensbol 2005) were used for identification.

### *Ecological status*

Ecological statuses were assigned to each species listed and observed to characterize their bioecology according to the contexts of the study region.

The phenological status of our study area includes six classes: resident breeder (RB), migrant breeder (MB) summer migrant breeder (SM), migrant breeder with a sedentary population (MBSP), summer migrant with a sedentary population (SMSP), and occasional visitor (OV) (Isenmann and Moali 2000; Bezzalla 2019; Boubekeur et al. 2020; Loucif et al. 2020).

Birds were represented by four ecological groups: waterbirds (WB), forest birds (FB), open habitat birds (OHB), and urban habitat birds (UHB) (Bensizerara et al. 2013).

The determination of the faunal type of each identified species was made based on the classification of Voous (1960). The birds were subdivided into 13 faunal types: Old World (OW), Ethiopian (Eth), Arctic (Arc), Cosmopolitan (C), Mediterranean (M), Holarctic (H), Palearctic (P), Indo-African (IA), Paleoxeric (Px), Sarmatic (S), Siberian (Sb), European-Turkestanian (ET), and Turk-Mediterranean (TM).

The trophic status of the species was based on an average diet during the considered season. Referring to Benyacoub (1993), Milla (2008), Chenchouni (2010a), Farhi

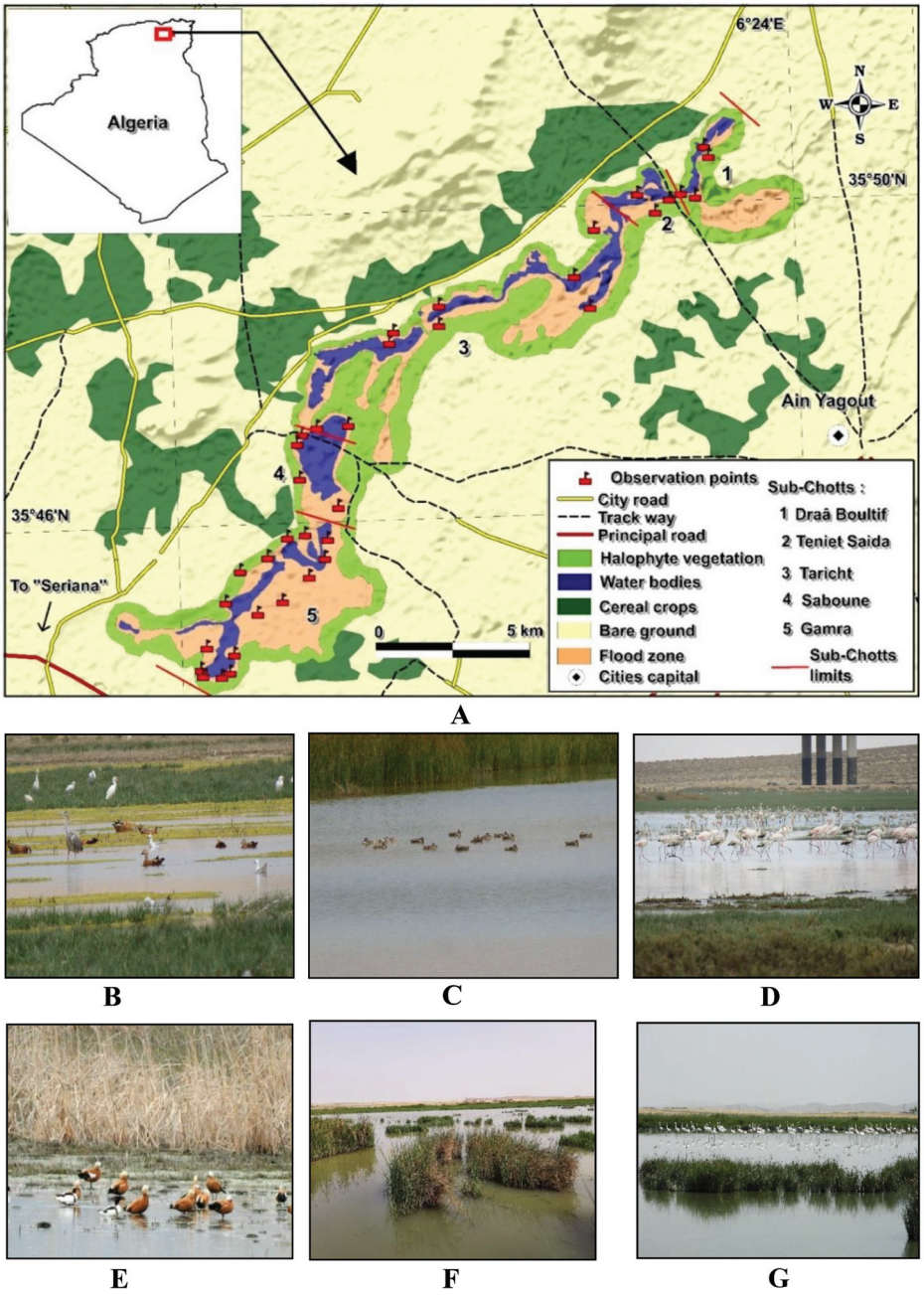


Figure 1. General views and geographical location of the Gadaïne eco-complex:

and Belhamra (2012), Bensizerara et al. (2013), Farhi (2014), and Bezzalla (2019). Seven trophic categories were distinguished: herbivores (Hb), carnivores (Cv), insectivores (Ins), polyphagous (Pp), omnivores (Om), piscivores (P), and invertivores (Inv) (Bensizerara 2014; Bezzalla 2019).

In Algeria, the protection categories are based on the list of species protected by Ordinance Nº 06–05 of 15 July 2006, which deals with the protection and preservation of certain endangered animal species, and by Executive Fiat N° 12–235 of 24 May 2012, which establishes the list of protected non-domestic animal species (Joradp 2018). Internationally, we referred to the IUCN Red List (Vié et al. 2008; IUCN 2017).

### *Statistical analyses*

Two annual cycles of observations at the Gadaïne eco-complex were processed using a multivariate analysis and the Multifactorial Statistical Analysis (MFSA), using the XLSTAT statistical software (Ver. 2021.3.1). This statistical analysis involved determining the number and percentage of bird species, focusing on the distribution of ecological groups according to their bioecological status (phenological, faunal, trophic, and protection categories).

In order to test if there is a significant dependence between the abundance of species and time variations of 2019/2020 and 2020/2021, we performed a $\chi^2$ test using the two hypotheses:

H0: there is no significant difference between the number of species recorded during the two observation periods (2019/2020 and 2020/2021) at level 0.05 and

H1: there is a significant difference between the abundance of species recorded during the two observation periods (2019/2020 and 2020/2021) at level 0.05.

In order to apply this test, we calculated the statistical value of the $\chi^2$ for the observed frequencies and compared it with the critical $\chi^2$ value at the level 0.05 and a degree of freedom 76.

## RESULTS

### *Systematic inventory*

Eighty species were recorded, fifty-nine of which were waterbirds. These species belong to nineteen families and fifty-eight genera (Table 1).

Scolopacidae was the dominant family. It was represented by fourteen species (17.95%), with a maximum of 242 individuals of *Tringa glareola*. Scolopacidae was followed by Accipitridae and Anatidae with eleven (14.29%) and ten (12.82%) species, respectively. Among Anatidae, *Tadorna tadorna* represented a maximum of 4651 individuals. Ardeidae was represented by seven species (8.97%) and Charadriidae by six species (7.69%), while Laridae and Rallidae were represented by five species (6.41%) each. Falconidae was represented by four species (5.13%) and Podicipedidae by three species (3.85%), of which *Podiceps nigrocollis* nested with success; Motacillidae, Recurvirostridae and Threskiornithidae were represented by two species (2.56%) each. The Western Swamphen, *Porphyrio porphyrio*, was noted for the first time (four individuals observed on 29/06/20 and 10/07/21).

Finally, the remaining families (Burhinidae, Ciconiidae, Corvidae, Strigidae, Greudae, Phoenicopteridae, and Phalacrocoracidae) were represented by a single species (1.28%) each. *Phoenicopterus roseus* was represented by a maximum of 2743 individuals observed on 07/08/20 and a failure of an attempt at nesting (Figure 2 and Table 1)

**Phenological status (PhS):** resident breeder (RB), migrant breeder (MB), summer migrant breeder (SM), migrant breeder with a sedentary population (MBSP), summer migrant with a sedentary population (SMSP), and occasional visitor (OV).

**Faunal type:** Old World (OW), Ethiopian (Eth), Arctic (Arc), Cosmopolitan (C), Mediterranean (M), Holarctic (H), Palearctic (P), Indo-African (IA), Paleoxeric (Px), Sarmatic (S), Siberian (Sb), European-Turkestanian (ET), and Turk-Mediterranean.

**Trophic status:** herbivores (Hb), carnivores (Cv), insectivores (Ins), polyphagous (Pp), omnivores (Om), piscivores (P), and Invertivores (Inv).

**Ecological group (EG):** waterbirds (WB), open habitat birds (OHB), forest birds (FB), urban habitat birds (UHB).

**Protection categories (CPr):** A: Algiers Convention (AU,1969), C: CITES Convention (CITES, 1994), D: Algerian laws, L: Barcelona Convention (CEC, 1999), N: Bonn Convention (Vagg, 2009), R: Berne Convention (COE, 1982), W: AEWA (AEWA, 2008), IUCN Red List Categories (IUCN, 2017), LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered, 1: Appendix I, R2: Appendix II, R3: Appendix III.

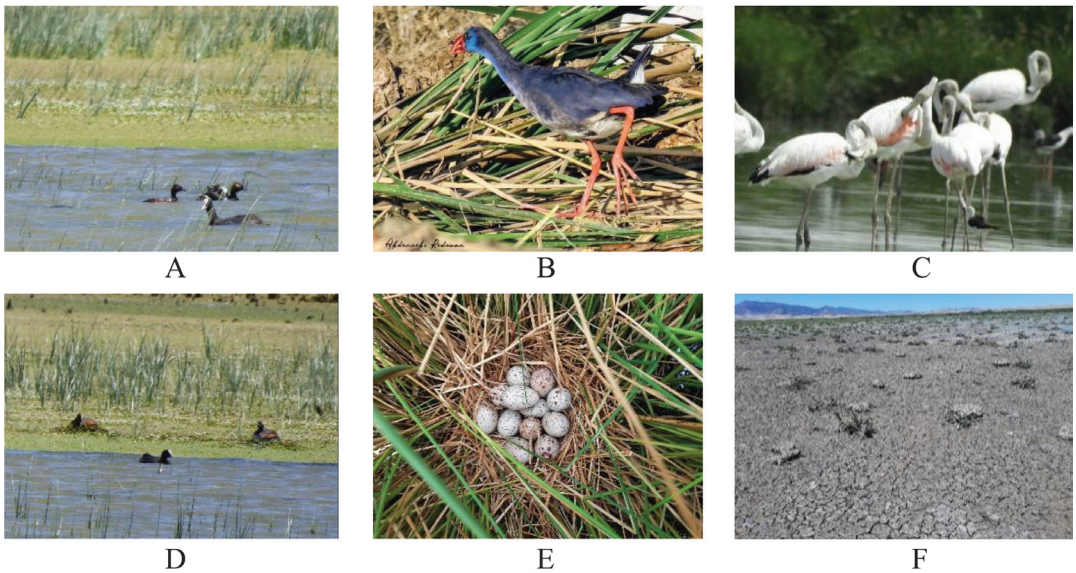


Figure 2. Some species observed in the Gadaïne eco-complex: A: *Podiceps nigrocollis*, B: *Porphyrio porphyrio*, C: *Phœnicopterus roseus*, D: Nest of *Podiceps nigricollis*, E: Nest of *Porphyrio porphyrio*, and F: Nest of *Phœnicopterus roseus*. Photos taken by C. Marref and A. Abdennebi.

Table 1. Binomial classification of the avifauna recorded in the Gadaïne eco-complex and its distribution according to the phenological status (PhS), ecological groups (EG), faunal types (FT), trophic status (TS), and protection categories (PrC). The percentage associated with families represents the relative richness of the species relative to all the species identified. The figures in the table represent the maximum number of individuals observed at a given date (dd/m/year).

| English names | Scientific names (descriptors) | Families | Ecological status | | | | | Maximum number of individuals (date of maximum number) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | PhS | EG | FT | TS | Pr C | 2019–2020 | 2020–2021 |
| Booted Eagle | *Hieraaetus pennatus* (Gmelin, JF, 1788) | Accipitridae | SM | FB | IA | Cv | D, LC, C2, N2, B, R2 | 0 | 5(17/04/21) |
| Bonelli's eagle | *Aquila fasciata* Vieillot, 1822 | | RB | FB | M | Cv | D, LC, C2, N2, B, R2 | 0 | 3(12/06/21) |
| Golden Eagle | *Aquila chrysaetos* Linnaeus, 1758 | | RB | FB | H | Cv | D, LC, C2, N2, B, R2 | 0 | 3(24/05/21) |
| Western Marsh Harrier | *Circus aeruginosus* Linnaeus, 1758 | | RB | WB | P | Cv | D, LC, C2, N2, B, R2 | 7(29/06/20) | 9(03/04/21) |
| Long-legged Buzzard | *Buteo rufinus cirtensis* (Cretzschmar, 1829) | | RB | FB | Px | Ins | D, LC, C2, N2, B, R2 | 4(29/04/20) | 7(12/03/21) |
| Common Buzzard | *Buteo buteo* Linnaeus, 1758 | | RB | FB | P | Ins | D, LC, C2, N2, B, R2 | 6(17/08/20) | 3(28/0921) |
| Short-toed Snake Eagle | *Circaetus gallicus* (Gmelin, JF, 1788) | | SM | OHB | IA | Cv | D, LC, C2, N2, B, R2 | 0 | 9(30/07/21) |
| Red Kite | *Milvus milvus* Linnaeus, 1758 | | RB | OHB | M | Cv | D, NT, C2, N2, B, R2 | 0 | 4(28/11/20) |
| Black Kite | *Milvus migrans* (Boddaert, 1783) | | SM | FB | OW | Cv | D, LC, C2, N2, B, R2 | 3(21/06/20) | 4(24/05/21) |
| Black-winged kite | *Elanus caeruleus* (Desfontaines, 1789) | | OV | OHB | IA | Cv | D, LC, C2, N2, R3 | 0 | 2(09/11/20) |
| Egyptian Vulture | *Neophron percnopterus* Linnaeus, 1758 | | SMSP | OHB | IA | Cv | D, EN, C2, N1, A, R2 | 9(21/05/20) | 11(10/12/21) |
| Gadwall | *Mareca strepera* Linnaeus, 1758 | Anatidae | MB | WB | H | [Hb] | LC, N2, W, R3 | 0 | 481(30/01/21) |
| Mallard | *Anas platyrhynchos* Linnaeus, 1758 | | MBSP | WB | H | Om | LC, N2, W, R3 | 1331(14/02/20) | 4175(18/01/21) |
| Northern pintail | *Anas acuta* Linnaeus, 1758 | | MB | WB | H | Hb | LC, C3, N2, W, R3 | 0 | 37(03/04/21) |
| Eurasian wigeon | *Mareca penelope* Linnaeus, 1758 | | MB | WB | H | Pp | LC, C3, N2, W, R3 | 159(14/02/20) | 557(18/01/21) |
| Northern shoveler | *Spatula clypeata* Linnaeus, 1758 | | MB | WB | H | Pp | LC, C3, N2, W, R3 | 184(14/02/20) | 3354(02/01/21) |
| Common pochard | *Aythya ferina* Linnaeus, 1758 | | MB | WB | P | Pp | VU, N2, W, R3 | 7(15/03/20) | 22(10/12/21) |
| Eurasian teal | *Anas crecca* Linnaeus, 1758 | | MB | WB | H | Pp | LC, C3, N2, W, R3 | 1257(17/08/20) | 1870(18/01/21) |
| Marbled duck | *Marmaronetta angustirostris* (Ménétrés, 1832) | | MBSP | WB | H | Pp | D, VU, N1, N2,W, R2 | 1600(27/12/19) | 375(30/01/21) |
| Ruddy shelduck | *Tadorna ferruginea* (Pallas, 1764) | | MBSP | WB | Px | Om | D, LC, N2, W, R2 | 1257(17/08/20) | 820(30/01/21) |
| Common shelduck | *Tadorna tadorna* Linnaeus, 1758 | | MBSP | WB | S | Ins | D, LC, N2, W, R2 | 1600(27/12/19) | 4651(18/01/21) |
| Ferruginous duck | *Aythya nyroca* (Güldenstädt, 1770) | | OV | WB | P | Pp | D, NT, C3, N1, N2, W, R3 | 4(27/12/19) | 7(18/01/21) |
| Little egret | *Egretta garzetta* Linnaeus, 1766 | Ardeidae | MB | WB | OW | Pp | D, LC, C3, W, A, R2 | 5(16/06/20) | 6(02/01/21) |
| Black-crowned Night Heron | *Nycticorax nycticorax* Linnaeus, 1758 | | MB | WB | C | [P] | D, LC, W, R2 | 0 | 4(10/05/21) |
| Squacco heron | *Ardeola ralloides* (Scopoli, 1769) | | SM | WB | P | Cv | D, LC, W, A, R2 | 6(10/06/20) | 4(13/12/20) |
| Great egret | *Ardea alba* Linnaeus, 1758 | | MB | WB | P | Pp | D, LC, C3, N2, W, R2 | 7(17/06/20) | 15(11/10/21) |
| Grey heron | *Ardea cinerea* Linnaeus, 1758 | | MB | WB | P | Pp | LC, W, A, R3 | 7(02/06/20) | 13(09/11/20) |
| Cattle egret | *Bubulcus ibis* Linnaeus, 1758 | | RB | WB | IA | Inv | LC, C3, W, A, R2 | 1541(15/06/20) | 1123(01/05/21) |
| Purple Heron | *Ardea purpurea* Linnaeus, 1766 | | OV | WB | P | Inv | D, LC, N2, W, A, R2 | 0 | 4(30/11/21) |

| English names | Scientific names (descriptors) | Families | Ecological status | | | | | Maximum number of individuals (date of maximum number) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | PhS | EG | FT | TS | Pr C | 2019–2020 | 2020–2021 |
| Eurasian Stone-curlew | *Burhinus oedicnemus* Linnaeus, 1758 | Burhinidae | RB | OHB | [TM] | Inv | D, LC, N2, R2 | 0 | 102(13/02/21) |
| White stork | *Ciconia ciconia* Linnaeus, 1758 | Ciconiidae | SM | UHB | P | Cv | D, LC, N2, W, A, R2 | 578(10/07/20) | 235(01/05/21) |
| Northern Raven | *Corvus corax* Linnaeus, 1758 | Corvidae | OV | WB | H | Cv | LC, R3 | 0 | 12(27/03/21) |
| Common Ringed Plover | *Charadrius hiaticula* Linnaeus, 1758 | Charadriidae | MB | WB | H | Inv | D, LC, N2, W, R2 | 145(29/04/20) | 67(28/12/20) |
| Kentish plover | *Charadrius alexandrinus* Linnaeus, 1758 | | MBSP | WB | C | Inv | LC, N2, W, L2, R2 | 170(04/05/20) | 214(20/02/21) |
| Little ringed plover | *Charadrius dubius* (Scopoli, 1786) | | MB | WB | P | Inv | LC, N2, W, R2 | 84-29/06/20 | 131(30/01/21) |
| Grey Plover | *Pluvialis squatarola* (Linnaeus, 1758) | | MB | WB | H | Inv | LC, N2, W, R3 | 0 | 311(30/01/21) |
| European golden plover | *Pluvialis apricaria* Linnaeus, 1758 | | MB | WB | H | Inv | LC, N2, W, R3 | 0 | 1014(02/01/21) |
| Northern lapwing | *Vanellus vanellus* Linnaeus, 1758 | | MB | OHB | P | Inv | NT, N2, W, R3 | 151(20/02/20) | 1160(18/01/21) |
| Sandwich Tern | *Thalasseus sandvicensis* (Latham, 1787) | | OV | WB | C | P | LC, W, L2, R2 | 4(16/09/20) | 2(30/11/21) |
| Common Kestrel | *Falco tinnunculus* Linnaeus, 1758 | Falconidae | SM | OHB | OW | Cv | D, LC, C2, N2, B, R2 | 6(07/02/20) | 11(08/08/21) |
| Lesser Kestrel | *Falco naumanni* (Fleischer, 1818) | | SM | OHB | M | Cv | D, LC, C2, N2, A, R2 | 3(18/01/20) | 3(12/12/20) |
| Eurasian Hobby | *Falco subbuteo* Linnaeus, 1758 | | OV | OHB | OW | Cv | D, LC, C2, N2, A, R2 | 4(09/09/20) | 4(31/12/21) |
| Peregrine Falcon | *Falco peregrinus* Tunstall, 1771 | | RB | FB | C | Cv | D, LC, C1, N2, B, R2 | 4(20/02/20) | 3(12/06/21) |
| Common crane | *Grus grus* (Linnaeus, 1758) | Gruidae | MB | OHB | P | Om | D, LC, C2, N2, W, R2 | 6(17/06/20) | 287(27/10/21) |
| White Wagtail | *Motacilla alba* Linnaeus, 1758 | Motacillidae | MBSP | OHB | P | Inv | LC, R2 | 211(19/06/20) | 349(18/01/21) |
| Western Yellow Wagtail | *Motacilla flava* Linnaeus, 1758 | | SM | OHB | P | Inv | LC, R2 | 0 | 236(01/05/21) |
| Yellow-legged gull | *Larus michahellis* (Naumann, 1840) | Laridae | OV | WB | [M] | Pp | LC, W, R3 | 142(15/05/20) | 5()30/12/21 |
| Slender-billed gull | *Chroicocephalus genei* (Breme, 1839) | | OV | WB | [S] | Pp | LC, N2, W, L2, R2 | 31(10/06/20) | 8(30/01/21) |
| Black-headed gull | *Chroicocephalus ridibundus* Linnaeus, 1766 | | OV | WB | P | Pp | LC, W, R2 | 14(21/06/20) | 21(09/11/21 |
| Gull-billed tern | *Gelochelidon nilotica* (Gmelin, JF, 1789) | | OV | WB | C | Cv | D, LC, N2, W, L2, R2 | 51(15/06/20) | 21(12/01/21) |
| Little Tern | *Sternula albifrons* (Pallas, 1764) | | OV | WB | C | [P] | D, LC, N2, W, L2, R2 | 4(02/06/20) | 11(1/01/21) |
| Curlew Sandpiper | *Calidris ferruginea* (Pontoppidan, 1763) | Scolopacidae | MB | WB | Sb | Inv | NT, N2, W, R2 | 31(19/06/20) | 25(27/03/21) |
| Little stint | *Calidris minuta* (Leisler, 1812) | | MB | WB | Arc | Inv | LC, N2, W, R2 | 31(20/06/20) | 520(18/01/21) |
| Temminck's Stint | *Calidris temminckii* (Leisler, 1812) | | MB | WB | Arc | Inv | LC, N2,W, R3 | 4(08/06/20) | 25(30/11/21) |
| Dunlin | *Calidris alpina* Linnaeus, 1758 | | MB | WB | Arc | Inv | LC, N2, W, R2 | 4(08/06/20) | 311(30/01/21) |
| Common snipe | *Gallinago gallinago* Linnaeus, 1758 | | MB | WB | P | Inv | LC, N2, W, R3 | 27(31/01/20) | 77(13/03/21) |
| Green sandpiper | *Tringa ochropus* Linnaeus, 1758 | | MB | WB | P | Inv | D, LC, N2, W, R2 | 167(15/05/20) | 97(20/02/21) |
| Common greenshank | *Tringa nebularia* (Gunnerus, 1767) | | MB | WB | Sb | Inv | LC, N2, W, R3 | 158(21/05/20) | 48(27/02/21) |
| Spotted Redshank | *Tringa erythropus* (Pallas, 1764) | | OV | WB | P | Inv | LC, N2,W, R2 | 0 | 68(30/01/2021) |
| Common Redshank | *Tringa totanus* Linnaeus, 1758 | | MB | WB | P | Inv | LC, N2, W, R3 | 0 | 53(30/01/21) |
| Common sandpiper | *Actitis hypoleucos* Linnaeus, 1758 | | MB | WB | H | Inv | LC, N2, W, R2 | 122(29/06/20) | 217(20/02/21) |
| Wood sandpiper | *Tringa glareola* Linnaeus, 1758 | | MB | WB | Arc | Inv | LC, N2, W, R2 | 0 | 242(30/01/21) |
| Ruff | *Calidris pugnax* Linnaeus, 1758 | | SM | WB | OW | Inv | LC, N2, W, R3 | 0 | 147(01/06-21) |
| Eurasian curlew | *Numenius arquata* Linnaeus, 1758 | | MB | WB | P | Inv | D, NT, N2, W, R3 | 35(31/01/20) | 11(10/12/21) |
| Eurasian Whimbrel | *Numenius phaeopus* Linnaeus, 1758 | | MB | WB | H | Inv | LC, N2, R3 | 5(08/03/20) | 11(30/11/2)1 |

| English names | Scientific names (descriptors) | Families | Ecological status | | | | | Maximum number of individuals (date of maximum number) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | PhS | EG | FT | TS | Pr C | 2019–2020 | 2020–2021 |
| Little Owl | *Athene noctua* (Scopoli, 1769) | Strigidae | RB | OHB | P | [Ins] | D, LC, N2, C2, B, R2 | 0 | 4(05/12/20) |
| Eurasian coot | *Fulica atra* Linnaeus, 1758 | Rallidae | MBSP | WB | P | Hb | LC, N2, W, R3 | 1071(10/07/20) | 2411(27/02/21) |
| Common moorhen | *Gallinula chloropus* Linnaeus, 1758 | | MBSP | WB | C | Om | LC, W, R3 | 232(13/07/20) | 852(03/04/21) |
| Little Crake | *Porzana parva* (Scopoli, 1769) | | MB | WB | P | Ins | LC, N2, W, R2 | 0 | 4(24/04/21) |
| Water rail | *Rallus aquaticus* Linnaeus, 1758 | | MB | WB | P | Pp | D, LC, W, R3 | 0 | 9(27/03/21) |
| Western swamphen | *Porphyrio porphyrio* Linnaeus, 1758 | | SM | WB | C | Om | LC, D, N2, W, R2 | 4(29/06/20) | 4(10/07/21) |
| Pied avocet | *Recurvirostra avosetta* Linnaeus, 1758 | Recurvirostridae | MB | WB | [TM] | Pp | D, LC, N2, W, R2 | 222(20/07/20) | 5(17/04/21) |
| Black-winged stilt | *Himantopus himantopus* Linnaeus, 1758 | | MB | WB | C | Inv | D, LC, N2, W, R2 | 2009(13/7/20) | 3059(18/01/21) |
| Greater flamingo | *Phoenicopterus roseus* (Pallas, 1811) | Phoenicopteridae | MBSP | WB | H | Pp | D, LC, C2, N2, W, A, L2, R2 | 2743(07/08/22) | 1764(27/02/21) |
| Great cormorant | *Phalacrocorax carbo* Linnaeus, 1758 | Phalacrocoracidae | OV | WB | OW | [P] | D, LC, W, A, R3 | 0 | 75(28/12/20) |
| Black-necked grebe | *Podiceps nigricollis* (Brehm, 1831) | Podicipedidae | SM | WB | Eth | Inv | LC, W, A, R2 | 9(29/04/20) | 9(10/07/21) |
| Little grebe | *Tachybaptus ruficollis* (Pallas, 1764) | | MBSP | WB | OW | P | LC, W, A, R2 | 30(08/06/20) | 24(12/12/20) |
| Great crested grebe | *Podiceps cristatus* Linnaeus, 1758 | | OV | WB | OW | [P] | LC, W, A, R3 | 111(29/04/20) | 12(12/12/20) |
| Glossy ibis | *Plegadis falcinellus* Linnaeus, 1766 | Threskiornithidae | OV | WB | OW | Inv | D, LC, N2, W, A, R2 | 9(10/06/20) | 37(17/04/21) |
| Eurasian spoonbill | *Platalea leucorodia* Linnaeus, 1758 | | MB | WB | P | Pp | D, LC, C2, N2, W, A, R2 | 11(10/06/20) | 10(06/03/21) |

## Ecological statuses

### Phenological status

Avifauna in the Gadaïne eco-complex was represented by 40 migratory species (50% of the population surveyed). Overwintering migratory birds (31 species, or 38.75%) dominated this phenological category. In addition, sedentary species were represented by 11 species (13.75%), of which most abundant were Accipitridae, followed by occasional visitors, which represented 18.75% (15 species). The number of migrant breeder species with sedentary populations was 13 (16.25%), and the number of summer migrant species was 9 (11.25%). It is noted that *Neophron percnopterus* is the only species (1.28%) classified as a summer migrant with a sedentary population; while *Ardeola ralloides*, *Falco naumanni,* and *Philomachus pugnax* are classified as summer migrant species (Table 1).

### Ecological group

Four ecological groups were represented, with the dominance of waterbirds. The latter represented 73.75% (59 species) of the observed bird species followed by open habitat birds (OHB; 16.25%, or 13 species), forest birds with seven species (8.75%), and finally urban habitat birds with one species (*Ciconia ciconia*, 1.25%).

### Faunal type

The birds observed at the Gadaïne eco-complex belonged to 13 faunal types according to Voous (1960). The Palearctic faunal type dominated the other types with a percentage of 26.25%. It was followed by the Holarctic (17.5%), Cosmopolitan (10%), Indo-African and Old World (8.75% each), Mediterranean (7.5%), Sarmatic (6.25%), Arctic (5%), Turk-Mediterranean (3.75%), and Ethiopian (2.5%) types. The Paleoxeric, Siberian, and Turkestanian-European types were each represented by one species (1.25%).

### Trophic category

Avian species recorded at the Gadaïne eco-complex were grouped into seven distinct trophic categories, with invertivores and carnivores best represented with 28 (35%) and 19 species (23.75%), respectively. They were followed by polyphagous species, with 16 species (20%) of all registered birds. Piscivores were represented by six species (7.5%). Five species (6.25%) belonged to insectivores and omnivores. Herbivores were poorly represented with only three species (3.75%).

### *Protection status*

Of the 80 species listed in the study area, 32 species (40%) were protected in Algeria by Executive Fiat No 12-235 of 24 May 2012, of which 18 were waterbirds. The majority of the species listed (59 species) were Least Concern birds in the IUCN Red List Categories and seven species (7.69%) were Near Threatened birds. *Aythya ferina* and *Marmaronetta angustirostris* were considered Vulnerable and *Neophron percnopterus* was considered Endangered.

### *Pearson's Chi-square ($\chi^2$) test*

We obtained the following results regarding the $\chi^2$ test:

Chi-square for the observed frequencies =
$= \sum_{k=0}^{n}$ (observed – expected)$^2$ / expected = 10364;

Critical value = 97.

Therefore, we have 10364 > 97; then we reject H0 and accept H1: there is a significant relationship between the abundance of species and the time variation of 2019/2020 and 2020/2021 at alpha level 0.05. Therefore, the abundance of species in the Gadaïne eco-complex significantly differed among monitoring periods.

### *Multifactorial analysis of ecological statuses*

The Multifactorial Statistical Analysis (MFSA) of our wetland showed that all types of bioecological status tested were well weighted across the four ecological groups of birds. All bioecological status parameters had high values on the factorial biplots F1 × F3 and F1 × F5. (Figure 3).

The MFSA distinguished a scattered distribution of ecological categories of birds in the factorial biplot (Figure 3). From the right and from the top to the bottom of the biplot (i.e., the positive values of the F1 axis and the positive to negative values of the F3 axis), waterbirds, forest birds, open habitat birds and urban habitat birds were distinguished respectively (Figure 3).

Waterbirds and open habitat birds had the same phenological status, while the majority of forest birds were sedentary species. Urban habitat birds were represented by a single species, *Ciconia ciconia*, which is a summer migrant species.

Polyphagous, piscivorous, and invertivorous birds appeared to have a direct relationship with the waterbird ecological group. Carnivorous or scavenger species were present in open habitats. The majority of forest

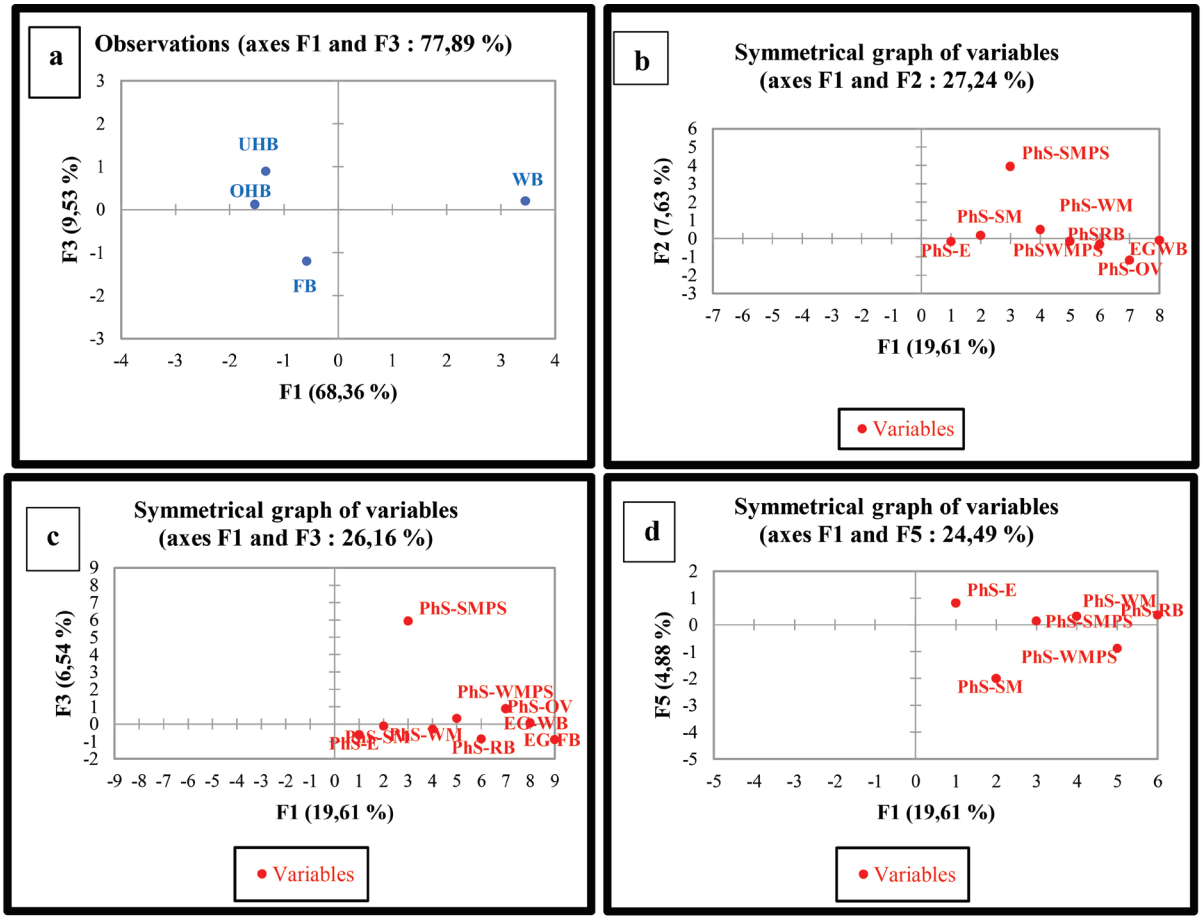


Figure 3. Superimposed representation of the centres of the four groups of ecological birds on the common factors 1–3 and 1–5 of the analysis of the Multifactorial Statistical Analysis (MFSA); a, b, c, and d: coordinates of the partial clouds (axes F1 and F3) of the bioecological statutes for the observations and families of the avifauna observed in our site.

birds were carnivorous, and urban birds were consumers of invertebrates. Similarly, the faunal types Cosmopolitan, Old World, Siberian, Indo-African, Sarmatic and Mediterranean were found to be associated with the ecological group of waterbirds. The scavengers were exclusively associated with the Endangered protection status of the IUCN Red List because it is specific to *Neophron percnopterus*, which is an estimated summer migrant species with a sedentary population and open habitat. Whereas sedentary species are associated with forest birds and open habitats. They were strongly correlated with the trophic statuses of invertivores, carnivores and insectivores (Figure 4).

In addition, most summer migrant birds with sedentary populations were carrion-feeders and protected by the Bonn, Bern and Algiers Convention "Bonn Convention, CITES Convention, Bern Convention". Invertivores seemed to be bound by the protection categories Least Concern, Bern Convention, AEWA, IUCN Red List Categories, Bonn Convention, CITES Convention, Algiers Convention, Bern Convention, which means that birds of this trophic status are well preserved. It is worth mentioning that four species belonging to waterbirds (*Numenius arquata*, *Aythya nyroca*, *Calidris ferruginea,* and *Porphyrio porphyrio*) were found to be associated with the protection status Near Threatened. The scavengers and most of the carnivores, which appear to belong to the class of forest birds, were significantly weighted on the third factorial axis (F3).

Ethiopian and Turkestanian-European birds were associated with migratory birds with sedentary population and nesting birds, respectively, while they helped determine that waterbirds have almost all biogeographical origins (Figure 4).

## DISCUSSION

The number of bird species recorded at the Gadaïne eco-complex is 80. This community represents 19.70%

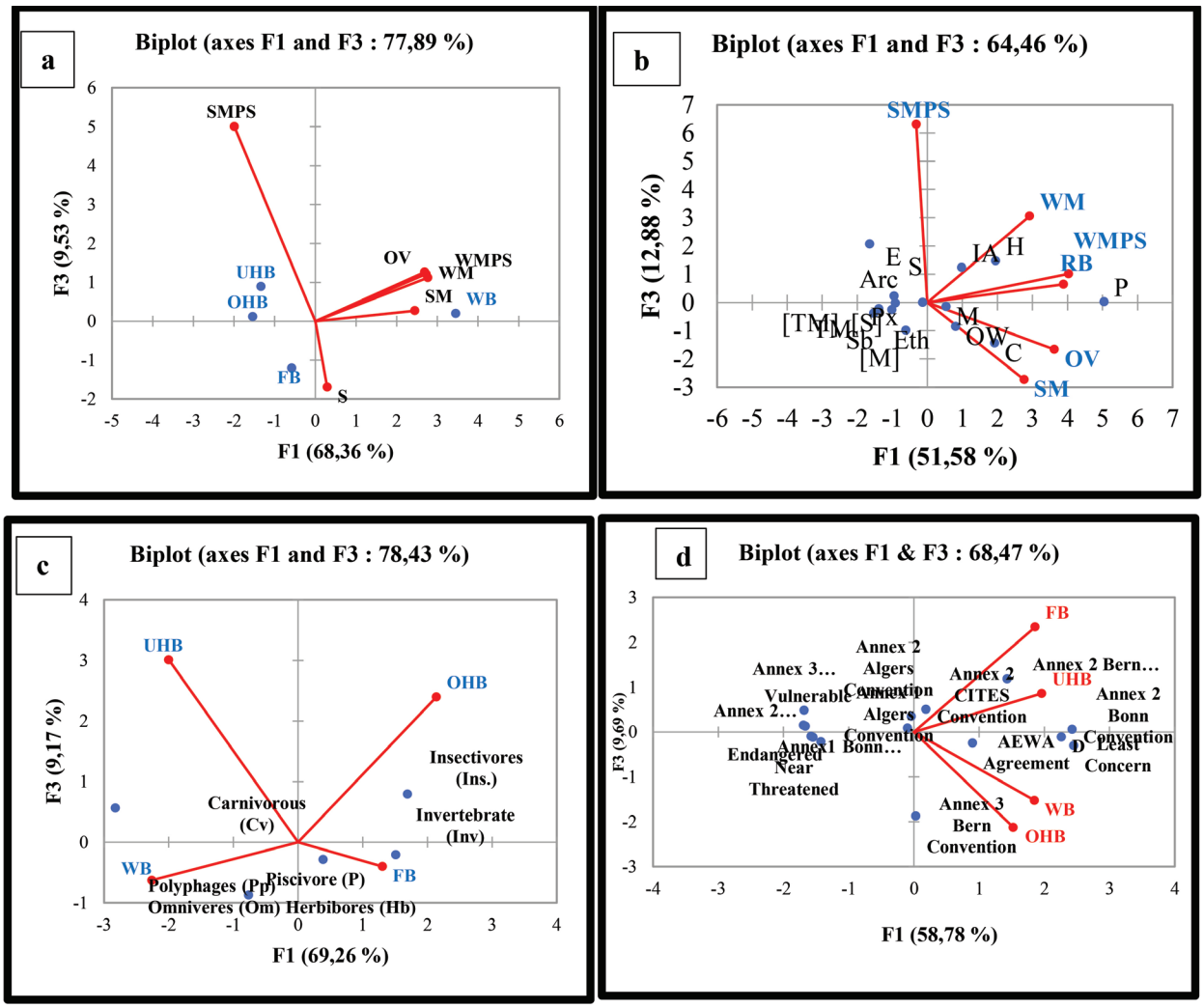


Figure 4. Primary component (PDA) analytical biplots (correlation biplot) associated with the MFSA detailing the phenological status (PhS), trophic status (TS), ecological groups (EG), faunal type (FT), and protection categories (PrC) of the enumerated avian populations.

of Algeria's avifauna (Isenmann and Moali 2000). The wealth of bird species is good compared to the other salt wetlands located in the north-east of Algeria. In Sebkhet Djendli (Batna), 51 species were listed by Bensizerara (2014) and 73 species by Chenchouni (2007). At the Setif eco-complex, Baaziz et al. (2011) counted 79 species; at Chott El Hodna (M'sila), 39 species were counted by Guergueb (2015). Bendahmane (2015) at Dayet El Fard (Telemcen) inventoried 110 species Bezzalla (2019) counted 29 species in Chott Tinsilt and 23 species in Sebkhet Ezzemoul. Fifty-three species were recorded in Boussedra marsh (Boudraa 2016), 10 species in Oued El-Alleug, Blida (Ouarab et al. 2018), 53 species in the Oases of the Algerian North Sahara (Lasad et al. 2021), 35 species at Lake Tonga (Loucif 2020), and 41 species at Lake El Golea in Ghardai (Biad et al. 2022).

Other ornithological studies, such as those of Samraoui and Samraoui (2008) on Algerian wetlands, Bendahmane (2015) on Dayet El Ferd, and Gourari et al. (2021) on Chott Ech Chergui Oriental, showed a higher specific richness compared to our results. We followed waterbirds and birds of prey for a short period (two annual cycles), while previous studies covered several wetlands for a long period, and some reported all the observed avifauna, including visiting species that frequent adjacent and remote habitats.

The predominance of wintering birds reflects the importance of our study area for the reception of such birds. It provides a safe and suitable refuge for waterfowl which make up more than half of the reported bird species. The studied wetlands also provide a high quality and quantity of trophic resources for resident breeder species, which are poorly represented in comparison to migratory birds (Bendahmane 2015; Hamli 2020; Bara 2020). In addition, these saline ecosystems, with their urban habitats, provide highly diversified trophic resources for birds of open habitats and forest-dwellers (Chenchouni et al. 2015; Chenchouni 2017a, b; Gourari et al. 2021).

In our study area, we observed the predominance of Palearctic species. Our results are consistent with the biogeographical affinity of the avian communities of the Mitidja plain (northern Algeria) (Bendjoudi et al. 2013), with the avifauna of Sebkhet Djendli (Bensizerara et al. 2013), and Sebkhet Ezzemoul and Chott Tinsilt (Bezzalla 2019). Moreover, our results are only partially consistent with those of Chenchouni (2010a), who studied bird life in a Saharan wetland. The latter is located along the border between two biogeographical zones: Palearctic and Afrotropical.

In fact, the biogeographical characteristics of birds counted and recorded in our sub-chott are similar to those of the Mediterranean region in general (Lebreton and Ledant 1980), although the location of the semi-arid region in north-eastern Algeria is located in a transition zone between two different biogeographical zones (Blondel 1979). As a result, the different types of fauna are grouped into three main biogeographical categories (Bellatreche 1994): Mediterranean avifauna, which includes Mediterranean, Paleoxeric, Indo-African, Sarmatic, Ethiopian, and Turk-Mediterranean fauna; Boreal/European avifauna, which includes Palearctic, Siberian, and European-Turkestanian faunal types; and Holarctic/Old World avifaunal, which is widely distributed in our study area with the Cosmopolitan and Arctic faunal types added.

It should be noted that the Boreal/European category was represented by Palearctic, Siberian, and European-Turkestanian avifauna (23 species), and the Holarctic/Old World category represented 41.25% of all birds inventoried, whereas the Mediterranean category was listed with 30% (24 species). This is because North Africa belongs to the greater Palearctic region, forming its south-western boundary (Blondel 1979). In fact, the low proportion of Afrotropical avifauna in our study area provides reliable information on the location of Gadaïne within the boundary between the Palearctic and Afrotropical biogeographical areas.

Polyphagous and insectivorous species were dominant, especially aquatic species, reflecting the richness of our study area in aquatic macroinvertebrates and tadpoles, which form the main diet for many winter species, including Charadriidae (Viani 2011; Bezzalla 2019) and Scolopacidae. Polyphagous species are the most abundant in winter because they comprise wintering species with higher numbers for Anatidae, Charadriidae, Gruidae, Rallidae, Phoenicopteridae, and Scolopacidae. As for carnivorous, the majority of these species in this category are diurnal birds of prey (*Hieraetus pennatus Aquila fasciata*, *Aquila chrysaetos*, *Circus aeruginosus*, *Circaetus gallicus,* and *Elanus caeruleus)*. But *Buteo rufinus* and *Buteo buteo* are insectivores. It should be noted that at the Gadaïne eco-complex, *Circus aeruginosus* and *Buteo rufinus* are almost common, with a more or less stable number throughout the study period. These species frequent the red beds and often fly over in search of their prey, mainly composed of small vertebrates (Chenchouni 2010a).

Awareness of the need to protect birds is critical in the fight against species extinction. The aim is to mitigate the threats they face through a multi-scale conservation strategy (Fishpool and Evans 2001). In Algeria, regulations and laws constitute the functional core for the protection of natural resources and bird species, in particular (Chenchouni 2010b). The best way is to protect the habitats where these birds live through the creation of national parks and natural reserves (D.G.F 2006) and by classifying wetlands as Ramsar sites (D.G.F 2002, 2004). These measures were followed by the ratification of multinational agreements and conventions (Chenchouni 2010b; Loucif 2020).

Additionally, the strategic geographical location of our study wetland (Gadaïne eco-complex) adds importance to the location of wetlands in the Batna province of the eastern highlands of Algeria. These areas should gain international importance for the conservation of bird species, especially migratory birds (Ledant et al. 1985; Samraoui and Samraoui 2008; Boulkhssaim et al. 2009). Several studies highlighted the importance of Algerian wetlands for migratory and nesting waterbirds and highlighted urgent conservation plans that consider the current state of wetland degradation (Bezzalla et al. 2018; Hamli 2020; Loucif 2020; Gourari et al. 2021).

Currently, declining wetlands affect the abundance of aquatic bird populations and ecosystem services, hence the value of monitoring programmes (Samraoui et al. 2011). The threat assessment of the species observed in our site reveals a situation that is not of concern overall, since six species of the 80 species listed on our site are currently Near Threatened (*Milvus milvums*, *Aythya nyroca*, *Vanellus vanellus*, *Calidris ferruginea*, *Numenius arquata,* and *Porphyrio porphyrio*) and two are Vulnerable (*Hieraaapetus ennatus* and *Aythya ferina*). However, one species is Endangered, which is *Neophron percnopterus*. These species have a very good international conservation status (Bird Life International 1979). *Neophron percnopterus* is also protected on a national scale. Contrary to the results of Loucif (2020), which showed that Anatidae species were dominant, *Aythya nyroca* and *Oxyura leucocephala* are waterbirds with a Near Threatened protection status. In addition, most species observed (71.75%) at the Gadaïne eco-complex are of Least Concern. It should be noted that with the exception of the works of Dupuy (1967), Ledant and Jacob (1982), and Chenchouni (2010b), virtually no regional or national assessment has been carried out to define the national statutes of the conservation of the birds according to the criteria of the IUCN Red List. This would probably have given a more concrete imitation of the threats that really weigh on the Algerian avifauna.

Climate change, exacerbated by strong anthropogenic disturbances, has led to dramatic changes and significant environmental degradation in Algerian wetlands in recent decades (Samraoui et al. 2011). These disturbances will result in radical changes in the spatial and temporal structure, organization, and dynamics of the avian populations, these habitats, and, consequently, the landscape. The combination of these threats would result in a significant long-term decline in many bird populations, including waterbirds, which represent the most important ecological model used both for the assessment of these ecosystems and as bio-indicators of their quality, balance and habitat health (Sayoud et al. 2017; Loucif 2020; Gourari et al. 2021).

The Multifactorial Statistical Analysis serves to distinguish the different categories of birds (Bensizerara et al. 2013; Bezzalla 2019), establish ecological traits, phenological status, ecological groups, faunal type, trophic status, and protection status, and characterize each group of avian species. It is noted that open habitat and urban habitat birds have been assigned to one group, while waterbirds and forest birds form separate groups. The Multifactorial Statistical Analysis (MFSA) has shown that there is a close affinity between nesting, sedentary, and wintering migratory birds with sedentary populations, resident breeder birds with wintering occasional visitors, and migratory birds. In addition, the MFSA has demonstrated an affinity of occasional visitors, wintering migratory birds, summer migrant breeder birds, and summer migratory birds with sedentary populations in faunal type terms, which is the opposite with sedentary birds and wintering migratory birds with sedentary populations.

The statistical results which combine ecological status indicate that the majority of the birds counted are invertivores, polyphagous, or carnivorous, a large proportion of which are overwintering migrants (more than 50% of the population surveyed). The search for trophic resources is the main driver of bird species migration (Baldassarre and Bolen 1994). Dajoz (2006) determined that the trophic regime of bird species determines their migratory or sedentary phenology. Mediterranean and North African wetlands are characterized by the dominance of overwintering bird species that feed on multiple trophic resources that are deficient in their winter breeding areas (Dajoz 2006; Chenchouni 2010a). In addition, open forest and habitat birds are largely sedentary with carnivorous diets or invertebrate feeders (Bensizerara et al. 2013; Chenchouni 2017b, c). In the studied wetland, our results show that forest and open habitat birds are largely carnivores or carrion-feeders that are similar to those of Bezzalla (2019). The MFSA can visualize how each ecological category influences the positioning of a bird group in relation to the ecological units for which it is responsible within our study area.

The trophic status of forest birds (carnivorous and scavengers) makes this group different from open or urban waterfowl and habitats. This status differentiates the four groups from each other, which highlights the influence of species distribution on the heterogeneity of the ecological landscape. In our study area, the availability and abundance of food favour the presence of avian species and enhance the trophic niches of the bird species that inhabit our wetland (Martensen et al. 2008; Concepción and Díaz 2011; Bensizerara and Chenchouni 2019; Bezzalla 2019). Protection status is the criterion that describes all groups of birds recorded at our site studied, since the main efforts to protect birds are often determined by international treaties on global strategies and perspectives (Chenchouni 2010b; Gourari et al. 2021).

Finlay, the Gadaïne eco-complex is a preferred place for the maintaining of the biodiversity of fauna and flora. It is an ideal and obligatory stopping place for birds during their pre- and post-nuptial migrations. During the two seasons of the study, it played an important role for many avian species wintering and/or transiting in the north-east of Algeria.

## CONCLUSION

In the Gadaïne eco-complex we determined over two years the presence of 80 bird species (59 of which were waterbirds), belonging to nineteen families and fifty-eight genera. The observed birds were represented by herbivores, carnivores, insectivores, polyphagous, omnivores, piscivores, and invertivores. This indicates that the investigated water body provides a rich food source during the whole period of their presence, which sometimes exceeds the winter period. Overall, Anatidae was the dominant group in this wetland. *Marmaronetta angustirostris*, *Tadorna ferruginea*, *Tadorna tadorna*, *Fulica atra*, *Gallinula chloropus*, *Porzana parva*, *Porphyrio porphyrio*, *Himantopus himantopus*, *Podiceps nigricollis,* and *Anas platyrhynchos* were nesting in this area, including *Phoenicopterus roseus* which was represented by a failed nesting.

This study allowed us to understand the ecological niches of birds frequenting various types of habitats. While it is intended to provide information on the ecology of the birds in our wetland, it has also shown how important the study site can be. It is essential and useful for a wide range of species with different ecological needs and uses such as migration, reproduction, and feeding. The most important benefit of our wetland and its environment for birds is a wide variety of habitat features. The extent of our study area and the ignorance of the dynamics of the avian populations of these habitats, combined with their fragility in the face of climate change and anthropogenic threats, make these issues of great importance and need to be addressed for sustainable preservation.

Rehabilitation of breeding areas should consider the elimination of access to breeding sites by predators and livestock. The conservation of this wetland can only be achieved if it is integrated into a more comprehensive concept of sustainable development of all the resources of the catchment area to which it belongs and the rational use of rural areas. Regular updates are needed to adapt and update legislation to meet the current needs for the protection and sustainable conservation of our avian biodiversity. Finally, it is recommended to propose classifying the Gadaïne eco-complex as a Ramsar site, due to its specific wealth and its bioecological value.

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