

AVIFAUNA OF M'ZAB REGION (GHARDAÏA, ALGERIAN SAHARA): CHECKLIST AND OVERVIEW OF THE CURRENT STATUS


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Abstract. Despite the lack and irregularity of rainfall, high temperatures, and limited food resources, desert areas, with their oases and wetlands, are considered to be an essential stopover for birds and an important place for their wintering and breeding. In this study, we made a list of all the birds recorded in the M'Zab region at Ghardaïa (Algerian Sahara) from 2015 to 2022 using the point count method. We found 203 species (69 of which were waterbirds), belonging to 23 orders and 48 families. The most abundantly represented were Passeriformes, with 18 families and 91 species (44.83%). 84.24% of the species occurred in wetlands, followed by pre-urban areas (40.39%), palm groves and agricultural crops (39.90%). As for the phenological status of the recorded birds, 51 are breeding species, of which 38 are sedentary, 10 are migratory, and three are occasionally nesting waterbirds. There are 122 non-breeding species, of which 81 are passage visitors and 41 are wintering species. Status of the remaining 30 species is uncertain.

INTRODUCTION

Currently, there are 10980 living species and subspecies of birds, and 160 species are known to be extinct. They are split into 44 orders, 253 families, and 2385 genera (Gill et al. 2023). Birds are considered to be bioindicators, since changes in their population size, behaviour, and ability to breed reflect the health of the ecosystem (Schrag et al. 2009; Harisha and Hosetti 2009; Zhang and Ma 2011; Kurniawan and Arifianto 2017; Egwumah et al. 2017). Bird diversity is important for the environment because they help pollinate flowers, spread seeds, get rid of pests, and control rodent populations. Also, scavengers get rid of dead animals, which helps keep the environment clean (Klein et al. 2007; Whelan et al. 2008; Şekercioğlu et al. 2016; Jha 2021).

The Algerian desert covers nearly 2 million km², or about 85% of Algeria's total land area (Medioni 1997). Its climate is characterized by low and irregular rainfall and large temperature differences between day and night and between months (Doumandji and Doumandji-Mitiche 1994). It contains various types of water bodies

as well as oases, palm groves, and daias (shallow basins that temporarily accumulate nearby rainwater), which makes it an important stopover site as well as a wintering and breeding area for many bird species (Chedad 2021; Chedad et al. 2020a, 2021a).

Numerous researchers have been studying the M'Zab avifauna in various biotopes throughout the last century, with their studies focusing primarily on the inventory of the bird population (Heim De Balsac 1926, 1962; Ledant et al. 1981; Isenmann and Moali 2000; Guezoul et al. 2012, 2017; Ababsa et al. 2013; Shirihai and Svensson 2018 a, b; Chedad 2021; Chedad et al. 2020a, 2021a, b, c, f, g). Other authors began to focus on the biology of reproduction in such species as the House Bunting *Emberiza sahari*, the Little Egret *Egretta garzetta*, and the Desert Sparrow *Passer simplex* (Bouzid et al. 2021; Chedad et al. 2021d, 2022a). A lot of other work has been done on the enlargement of species' ranges and other phenomena such as albinism and commensalism in several species, such as the White-crowned Wheatear *Oenanthe leucopyga*, the Hybrid Sparrow *Passer domesticus* X *Passer hispaniolensis*, the Common Starling *Sturnus vulgaris*, the European

Turtle Dove *Streptopelia turtur* (Chedad et al. 2018, 2019, 2020 b, c, 2021f, 2022b).

The present study aimed to compile the first full list of birds inhabiting the M'Zab region (Ghardaïa, Algerian Sahara) and compare their diversity in various biotopes. We also report their phenological and protection status based on laws at national and international levels.

MATERIALS AND METHODS

Study area

The study was conducted in the northern Algerian Sahara at Ghardaïa, in an area called “M'Zab” (Figure 1). This region has a Saharan bioclimate, which is characterized by mild winters (mean temperature of the coldest month is 11.5° C), very hot summers (mean peak temperature in July is 35.5° C), and low annual rainfall (~50–70 mm) (Chedad et al. 2021d). As we move from north to south in the study area, we find an important landscape diversity represented by different forms of biotopes, including both natural and artificial ecosystems: e.g., (i) daia shallow basins where rainwater from nearby heights temporarily accumulates; (ii) palm groves and oases, which are mainly composed of palm trees, in addition to citrus and vegetable crops; (iii) wadis, which are generally dry riverbeds except during the rainy season and have an important vegetation cover; (iv) waterbodies, including lakes, sebkhas, wastewater, and springs; (v) agricultural crops such as wheat, barley, corn, and alfalfa. Also, the surveys included other habitats such as rocky plateaus, desert pavement (Reg), dunes (Erg), green strips and spaces, Ksour (fortresses) and urban environments.

Data collection and statistical analysis

Land birds were surveyed and recorded using the point count method with unlimited distance, where the observer records only the presence or absence of species at the onset of dawn during each 5 to 6 hour-long transect (Blondel 1975; Mansouri et al. 2021). Advantages of this method are as follows: it is inexpensive and simple in its application; it can be used at any time of the day and even outside the breeding period. However, it gives only an avian inventory, not the population density of the study area (Ochando 1988). We did a count of waterbirds by setting up fixed observation points around the wetlands. (Ramade 1984). We carried out an individual count when a group of birds numbering less than 200 individuals was near the observation point, and a visual estimate when the number was higher and the birds were at a significant distance (e.g., Lamotte and Bourlière 1969; Blondel 1975).

Between 2015 and 2022, direct observation was conducted with a telescope (20 × 50) mounted on a tripod and a Nikon Coolpix P900 camera (×83). The counts were performed on a regular basis, monthly surveys being reinforced with additional surveys, especially during the main postnuptial and prenuptial bird migration seasons in various biotopes (Chedad et al. 2021a). Identification of bird species was facilitated using ornithological guidebooks (Svensson 2010).

The organization of the species was established according to an alphabetical classification of the systematic orders according to the latest version of nomenclature [IOC World Bird List] (Gill et al. 2023).

Algeria follows the Executive Fiat 12–235 of 24 May 2012, which establishes the list of protected non-domestic animal species, and the Ordinance n° 06–05

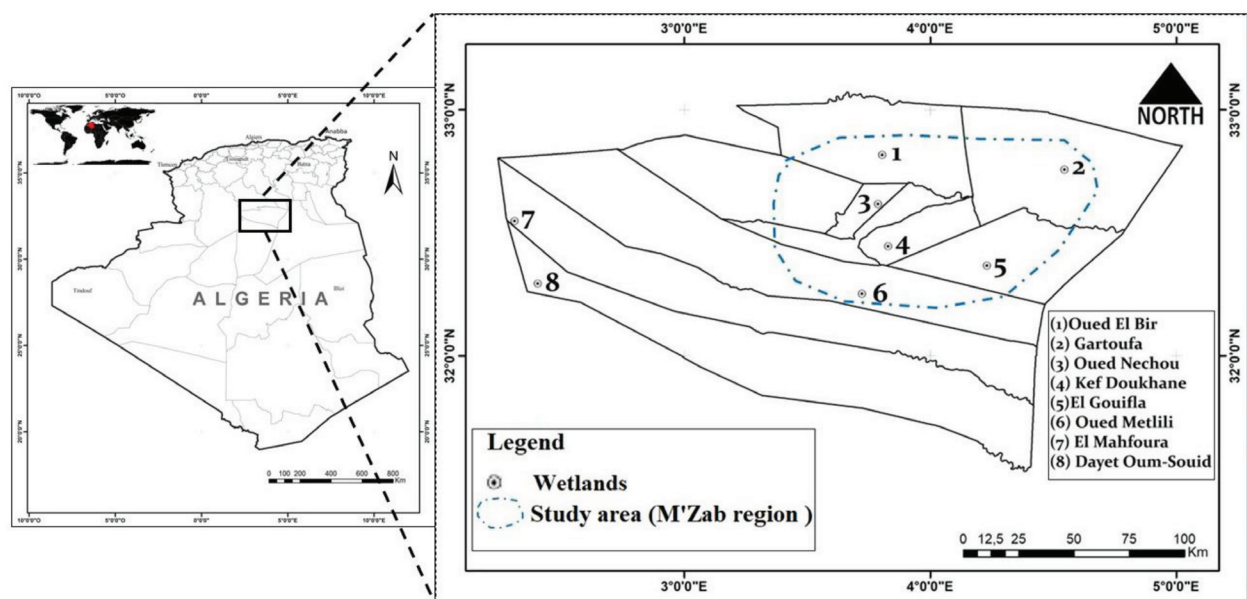


Figure 1. Map showing the location and the outline of the study area in the M'Zab region (Ghardaïa, northern Algerian Sahara).

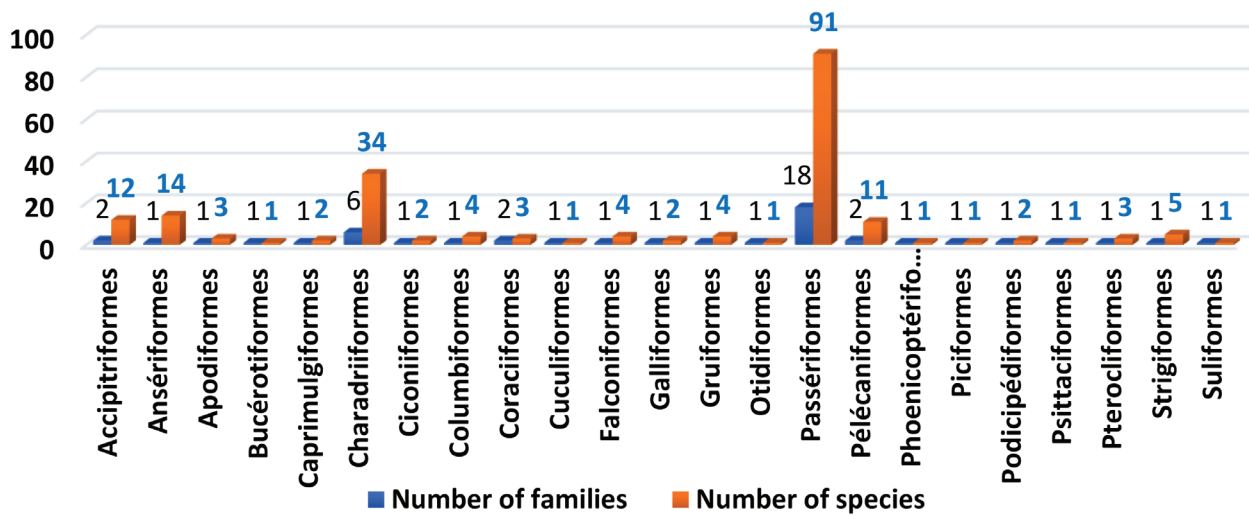


Figure 2. Number of avian families and species in the M'Zab region.

of 15 July 2006, which deals with the protection and preservation of certain endangered animal species, when it comes to the conservation status of bird species on a national level. At the international level, we based our assessment on the IUCN Red List (IUCN 2022).

The R software (R Development Core Team 2022) was used to perform statistical analyses. The association between the specific richness and the monthly distribution as well as with the biotopes was evaluated using the Pearson's Chi-Square (χ^2) Test (Heumann et al. 2016), as well as the “vegan” and “specpool” packages, to obtain the species-accumulation curve and richness estimate.

RESULTS

Systematic list of M'Zab avifauna

During the study, we found 203 species, 69 of which were waterbirds. These species belong to 23 orders and 48 families (Table 1). With 18 families and 91 species, or 44.83% of all the species, Passeriformes is the most common order. Charadriiformes with six families and 34 species come second. As for Muscipidae, Scolopacidae, and Anatidae, these are the families with the highest number of species, i.e., 22, 17, and 14, respectively (Figure 2).

Abundance and specific richness of species of the M'Zab Avifauna

Monthly specific richness values for 2015–2022 range between 67 and 116 species (Figure 3), with January exhibiting the highest specific species richness in winter (105 species), April in spring (116 species), September in summer (102 species), and October in autumn (100 species). The Pearson's Chi-Square (χ^2) Test showed

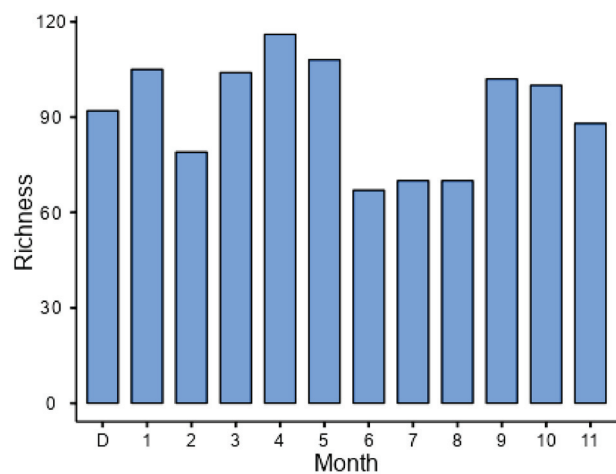


Figure 3. Monthly specific richness values for 2015–2022 in the M'Zab region.

that there was a significant association recorded between the specific richness and the distribution over the months ($\chi^2 = 33.64$, $df = 11$, $p < 0,001$).

Firstly, of all the species recorded, 65 are regular, with small numbers of individuals observed, representing 32.02%. Secondly, the regular species with large numbers represent 25.62%; subsequently, the accidental, occasional, and rare species represent 16.75%, 9.36%, and 7.39% sequentially. Finally, 19 species (9.36%) were not observed during this study and were only mentioned in previous studies (Ledant et al. 1981; Isenmann and Moali 2000) (Table 2). Among the accidental species recorded, 16 were observed only once, of which three are protected by the IUCN (the Egyptian Vulture, Black-tailed Godwit, and the Eurasian Curlew).

Figure 4 shows the curve of species accumulation between 2015 and 2022 with the total richness ranging from 83 to 159 species during this period. However,

Table 1. Systematic list of M'Zab avifauna.

Order–Family		Annual distribution	Abn.	Ph. St.	Pr. St.			Ref.																						
N°	Scientific name				A	B	C	1	2	3																				
A-1		Accipitriformes–Accipitridae																												
1	<i>Aquila chrysaetos homeyeri</i>										Acc	PV	0	1	LC	1	1	1												
2	<i>Aquila f. fasciata</i>																				Acc	PV	0	1	LC	0	0	0		
3	<i>Hieraaetus pennatus</i>																					Rsn	PV	0	1	LC	0	0	1	
4*	<i>Neophron p. percnopterus</i>																						Acc	PV	0	1	EN	0	0	1
5	<i>Circus a. aeruginosus</i>																						Rsn	RB	0	1	LC	1	1	0
6	<i>Circus pygargus</i>																						Occ	PV	0	1	LC	1	0	1
7	<i>Buteo rufinus cirtensis</i>																						R	PV	0	1	LC	1	1	1
8	<i>Circaetus g. gallicus</i>																						Occ	PV	0	1	LC	1	1	1
9*	<i>Milvus m. migrans</i>																						Acc	PV	0	1	LC	1	1	1
10*	<i>Elanus c. caeruleus</i>																						Acc	PV	0	1	LC	0	0	0
11	<i>Pernis apivorus</i>																						Rsn	PV	0	1	LC	0	0	1
A-2		Accipitriformes–Pandionidae																												
12+	<i>Pandion h. haliaetus</i>																						M	U	0	1	LC	0	1	0
B		Anseriformes–Anatidae																												
13	<i>Anas acuta</i>																						Rln	W	0	0	LC	0	0	0
14	<i>Spatula clypeata</i>																						Rln	W	0	0	LC	0	0	0
15	<i>Anas p. platyrhynchos</i>																						Rln	RB	0	0	LC	1	1	0
16	<i>Mareca s. strepera</i>																						R	PV	0	0	LC	0	0	0
17	<i>Mareca penelope</i>																						R	W	0	0	LC	0	0	0
18	<i>Tadorna ferruginea</i>																						Rln	RB	0	1	LC	0	0	0
19	<i>Tadorna tadorna</i>																						Rsn	W	0	1	LC	0	0	0
20	<i>Anas crecca</i>																						Rln	W	0	0	LC	1	1	0
21	<i>Spatula querquedula</i>																						Rln	PV	0	0	LC	0	0	0
22	<i>Marmaronetta angustirostris</i>																						Rln	RB	0	1	VU	0	0	1
23	<i>Aythya ferina</i>																						R	W	0	0	VU	0	0	0
24	<i>Aythya nyroca</i>																						Rln	RB	0	1	NT	0	0	1
25	<i>Aythya fuligula</i>																						Occ	PV	0	0	LC	0	0	0
26*	<i>Aythya collaris</i>																						Acc	U	0	0	LC	0	0	0
C		Apodiformes–Apodidae																												
27	<i>Apus a. apus</i>																						Rln	PV	0	0	LC	1	0	0
28	<i>Apus pallidus brehmorum</i>																						Rpn	PV	0	0	LC	1	1	1
29*	<i>Tachymarptis melba</i>																						Acc	PV	0	0	LC	0	0	0
D		Bucérotiformes–Upupidae																												
30	<i>Upupa e. epops</i>																						Rsn	RB	0	1	LC	1	1	1
E		Caprimulgiformes–Caprimulgidae																												
31	<i>Caprimulgus aegyptius saharae</i>																						Rsn	MB	0	1	LC	1	1	1
32+	<i>Caprimulgus ruficollis desertorum</i>																						M	U	0	1	NT	0	1	1
F-1		Charadriiformes–Burhinidae																												
33	<i>Burhinus oedicnemus saharae</i>																						Rsn	MB	0	1	LC	0	0	1
F-2		Charadriiformes–Charadriidae																												
34	<i>Charadrius a. alexandrinus</i>																						Rln	RB	0	0	LC	0	0	0
35	<i>Charadrius dubius curonicus</i>																						Rsn	RB	0	0	LC	0	0	0
36	<i>Charadrius hiaticula</i>																						Rsn	W	0	1	LC	0	0	0
37*	<i>Pluvialis apricaria</i>																						Acc	PV	0	0	LC	0	0	0
38+	<i>Vanellus vanellus</i>																						M	U	0	0	NT	1	1	1
F-3		Charadriiformes–Glaréolidae																												
39	<i>Cursorius c. cursor</i>																						Rsn	MB	0	0	LC	1	1	1
40	<i>Glaireola p. pratincola</i>																						Acc	PV	0	1	LC	0	0	0

Order–Family		Annual distribution										Abn.	Ph. St.	Pr. St.			Ref.								
N°	Scientific name													A	B	C	1	2	3						
F-4	Charadriiformes–Laridae																								
41	<i>Chlidonias leucopterus</i>																	Acc	PV	0	0	LC	0	0	1
42	<i>Chlidonias h. hybrida</i>																	Occ	PV	0	1	LC	0	0	0
43	<i>Chlidonias n. niger</i>																	Rsn	PV	0	0	LC	1	0	0
44	<i>Gelochelidon n. nilotica</i>																	Rsn	PV	0	1	LC	1	0	0
45	<i>Sternula a. albifrons</i>																	Acc	PV	0	1	LC	0	0	1
46	<i>Larus michahellis atlantis</i>																	Acc	PV	0	0	LC	0	0	0
47	<i>Chroicocephalus ridibundus</i>																	Acc	PV	0	0	LC	1	1	0
F-5	Charadriiformes–Recurvirostridae																								
48	<i>Himantopus himantopus</i>																	Rln	RB	0	1	LC	1	1	0
49	<i>Recurvirostra avosetta</i>																	Rsn	W	0	1	LC	0	0	0
F-6	Charadriiformes–Scolopacidae																								
50	<i>Calidris a. alba</i>																	Occ	PV	0	0	LC	0	0	0
51	<i>Calidris minuta</i>																	Rln	W	0	0	LC	0	1	0
52	<i>Calidris alpina arctica</i>																	Rsn	W	0	0	LC	0	0	0
53	<i>Calidris temminckii</i>																	Occ	PV	0	0	LC	0	0	0
54	<i>Calidris ferruginea</i>																	Occ	PV	0	0	NT	0	0	0
55	<i>Calidris c. canutus</i>																	Occ	PV	0	0	NT	0	0	0
56	<i>Gallinago g. gallinago</i>																	Rsn	W	0	0	LC	0	1	0
57	<i>Lymnocyptes minimus</i>																	Rsn	W	0	0	LC	0	0	0
58	<i>Calidris pugnax</i>																	Occ	PV	0	0	LC	1	1	0
59	<i>Tringa erythropus</i>																	Occ	PV	0	0	LC	0	0	0
60	<i>Tringa glareola</i>																	Rsn	W	0	0	LC	0	0	0
61	<i>Tringa nebularia</i>																	R	PV	0	0	LC	0	1	0
62	<i>Tringa ochropus</i>																	Rsn	W	0	1	LC	1	0	1
63	<i>Actitis hypoleucos</i>																	Rsn	W	0	0	LC	0	0	0
64	<i>Tringa totanus</i>																	Occ	PV	0	0	LC	0	0	1
65*	<i>Limosa limosa</i>																	Acc	U	0	0	NT	0	0	1
66*	<i>Numenius arquata</i>																	Acc	U	0	1	NT	0	0	1
G	Ciconiiformes–Ciconiidae																								
67	<i>Ciconia c. ciconia</i>																	Rln	PV	0	1	LC	1	1	1
68	<i>Ciconia nigra</i>																	Occ	PV	0	1	LC	0	0	0
H	Columbiformes–Columbidae																								
69	<i>Columba livia</i>																	Rln	RB	0	0	LC	0	1	0
70	<i>Streptopelia t. turtur</i>																	Rln	MB	0	0	VU	1	1	1
71	<i>Spilopelia senegalensis phoenicophila</i>																	Rln	RB	0	0	LC	1	1	1
72	<i>Streptopelia decaocto</i>																	Rln	RB	0	0	LC	0	0	0
I-1	Coraciiformes–Coraciidae																								
73	<i>Coracias g. garrulus</i>																	Rsn	PV	0	1	LC	0	1	1
I-2	Coraciiformes–Méropidae																								
74	<i>Merops persicus chrysocercus</i>																	Rln	MB	0	1	LC	1	1	0
75	<i>Merops apiaster</i>																	Rln	PV	0	1	LC	1	1	1
J	Cuculiformes–Cuculidae																								
76*	<i>Clamator glandarius</i>																	Acc	PV	0	1	LC	0	0	0
K	Falconiformes–Falconidae																								
77	<i>Falco t. tinnunculus</i>																	Rln	RB	0	1	LC	1	1	1
78	<i>Falco peregrinus peleginoides</i>																	Acc	PV	0	1	LC	1	0	1
79	<i>Falco peregrinus peregrinus</i>																	Occ	PV	1	0	LC	0	1	1
80+	<i>Falco biarmicus erlangeri</i>																	M	U	0	1	LC	0	1	1
L	Galliformes–Phasianidae																								
81	<i>Alectoris barbara</i>																	Rsn	RB	0	0	LC	1	1	1
82	<i>Coturnix c. coturnix</i>																	Occ	U	0	0	LC	1	1	1

N°	Order–Family Scientific name	Annual distribution	Abn.	Ph. St.	Pr. St.			Ref.		
					A	B	C	1	2	3
M		GRUIFORMES–RALLIDAE								
83	<i>Fulica a. atra</i>		Rln	RB	0	0	LC	0	0	1
84	<i>Gallinula c. chloropus</i>		Rln	RB	0	0	LC	1	1	1
85	<i>Rallus a. aquaticus</i>		Rsn	RB	0	1	LC	1	1	0
86+	<i>Porzana porzana</i>		M	U	0	1	LC	1	0	1
N		OTIDIFORMES–OTIDIDAE								
87+	<i>Chlamydotis u. undulata</i>		M	U	1	0	VU	1	1	1
O-1		Passériformes–Acrocephalidae								
88	<i>Iduna pallida reiseri</i>		Rln	MB	0	0	LC	1	1	1
89	<i>Hippolais polyglotta</i>		Rln	MB	0	0	LC	1	1	1
90	<i>Hippolais icterina</i>		Acc	VP	0	0	LC	0	0	1
91	<i>Acrocephalus schoenobaenus</i>		Rln	W	0	0	LC	1	1	1
92	<i>Acrocephalus a. arundinaceus</i>		Rsn	PV	0	0	LC	0	1	1
93	<i>Acrocephalus s. scirpaceus</i>		Acc	VP	0	0	LC	0	1	1
94+	<i>Acrocephalus palustris</i>		M	U	0	0	LC	0	1	0
O-2		Passériformes–Alaudidae								
95	<i>Galerida cristata</i>		Rln	RB	0	0	LC	1	1	1
96	<i>Galerida m. macrorhyncha</i>		R	U	0	0	LC	0	0	0
97	<i>Galerida theklae</i>		R	PV	0	0	LC	1	1	1
98	<i>Ramphocoris clotbey</i>		Rsn	RB	0	0	LC	1	1	1
99	<i>Eremophila bilopha</i>		R	U	0	0	LC	1	1	1
100	<i>Calandrella brachydactyla</i>		Rln	PV	0	0	LC	1	1	1
101+	<i>Alaudala rufescens minor</i>		M	U	0	0	LC	1	1	1
102	<i>Ammomanes cinctura arenicolor</i>		Rsn	RB	0	0	LC	0	1	1
103	<i>Ammomanes deserti</i>		Rsn	RB	0	0	LC	1	1	1
104	<i>Alaemon a. alaudipes</i>		Rsn	RB	0	0	LC	1	1	1
105+	<i>Chersophilus duponti</i>		M	U	0	1	VU	1	1	1
O-3		Passériformes–Cettiidae								
106	<i>Cettia c. cetti</i>		Acc	PV	0	0	LC	1	1	0
O-4		Passériformes–Corvidae								
107	<i>Corvus ruficollis</i>		Rln	RB	0	0	LC	1	1	1
108+	<i>Corvus corax tingitanus</i>		M	U	0	0	LC	1	1	0
O-5		Passériformes–Emberizidae								
109	<i>Emberiza s. sahari</i>		Rln	RB	0	0	LC	1	1	1
O-6		Passériformes–Fringillidae								
110	<i>Serinus serinus</i>		Rsn	U	0	1	LC	0	0	0
111	<i>Coccothraustes c. buvryi</i>		Acc	W	0	1	LC	0	0	0
112	<i>Spinus spinus</i>		Rsn	W	0	0	LC	1	1	0
113	<i>Bucanetes githagineus zedlitzi</i>		Rln	RB	0	0	LC	1	1	1
114	<i>Linaria cannabina mediterranea</i>		Rsn	W	0	0	LC	1	1	0
115	<i>Chloris chloris voousi</i>		Rsn	W	0	0	LC	0	0	0
O-7		Passériformes–Hirundinidae								
116	<i>Delichon urbicum meridionale</i>		Rln	W	0	0	LC	1	1	1
117	<i>Riparia r. riparia</i>		Rln	W	0	0	LC	1	0	0
118	<i>Hirundo r. rustica</i>		Rln	W	0	0	LC	0	0	0
119*	<i>Cecropis daurica rufula</i>		Acc	PV	0	1	LC	0	0	0
120	<i>Ptyonoprogne obsoleta</i>		Acc	U	0	0	LC	0	0	1
O-8		Passériformes–Laniidae								
121	<i>Lanius s. senator</i>		Rsn	PV	0	0	NT	1	1	1
122	<i>Lanius excubitor</i>		Rsn	RB	0	0	LC	1	1	1
O-9		Passériformes–Laniidae								
123	<i>Turdoides f. fulva</i>		Rln	RB	0	0	LC	1	1	1

Order–Family		Annual distribution	Abn.	Ph. St.	Pr. St.			Ref.								
N°	Scientific name				A	B	C	1	2	3						
O-10	Passériformes–Motacillidae															
124	<i>Anthus t. trivialis</i>								Rsn	PV	0	0	LC	1	1	1
125	<i>Anthus s. spinoletta</i>								Rsn	W	0	0	LC	1	1	1
126	<i>Anthus cervinus</i>								Rsn	W	0	0	LC	0	0	0
127	<i>Anthus campestris</i>								Occ	PV	0	0	LC	0	1	1
128	<i>Anthus pratensis</i>								Rsn	W	0	0	LC	0	1	0
129	<i>Motacilla alba</i>								Rln	W	0	0	LC	1	1	1
130	<i>Motacilla flava</i>								Rln	PV	0	0	LC	0	1	1
O-11	Passériformes–Muscicapidae															
131	<i>Ficedula albicollis</i>								R	PV	0	0	LC	0	1	0
132	<i>Muscicapa s. striata</i>								Rln	PV	0	0	LC	0	1	0
133	<i>Ficedula h. hypoleuca</i>								Rln	PV	0	0	LC	0	1	1
134	<i>Saxicola r. rubicola</i>								Rsn	W	0	0	LC	1	1	1
135	<i>Saxicola rubetra</i>								Rsn	W	0	0	LC	1	1	0
136	<i>Cercotrichas galactotes</i>								Rsn	MB	0	0	LC	0	1	1
137	<i>Luscinia m. megarhynchos</i>								Acc	PV	0	0	LC	1	0	0
138	<i>Erithacus rubecula</i>								Rsn	W	0	0	LC	1	1	1
139	<i>Phoenicurus p. phoenicurus</i>								Rsn	U	0	1	LC	1	1	1
140	<i>Phoenicurus moussieri</i>								Rsn	RB	0	1	LC	1	1	1
141	<i>Phoenicurus ochruros gibraltariensis</i>								Occ	W	0	1	LC	1	1	1
142+	<i>Luscinia svecica</i>								M	U	0	0	LC	1	1	1
143	<i>Oenanthe l. leucopyga</i>								Rln	RB	0	0	LC	1	1	1
144	<i>Oenanthe oenanthe</i>								Rln	PV	0	0	LC	1	1	0
145	<i>Oenanthe deserti homochroa</i>								Rln	RB	0	0	LC	1	1	1
146	<i>Oenanthe hispanica</i>								Rln	PV	0	0	LC	1	1	1
147	<i>Oenanthe isabellina</i>								Occ	PV	0	0	LC	1	1	0
148	<i>Oenanthe moesta</i>								R	PV	0	0	LC	1	1	1
149	<i>Oenanthe l. lugens</i>								Occ	PV	0	0	LC	1	1	1
150*	<i>Oenanthe seebohmi</i>								Acc	PV	0	0	LC	0	0	0
151	<i>Monticola s. solitarius</i>								Occ	PV	0	0	LC	0	1	0
152*	<i>Monticola saxatilis</i>								Acc	PV	0	1	LC	0	0	1
O-12	Passériformes–Oriolidae															
153	<i>Oriolus oriolus</i>								VP	R	0	1	LC	1	1	1
O-13	Passériformes–Passeridae															
154	<i>Passer h. hispaniolensis</i>								Rsl	W	0	0	LC	1	1	1
155	<i>Passer domesticus</i>								Rsl	RB	0	0	LC	1	1	1
156	<i>Passer simplex saharae</i>								Rsl	RB	0	0	LC	1	1	0
157+	<i>Petronia petronia barbara</i>								M	U	0	0	LC	1	1	1
O-14	Passériformes–Phylloscopidae															
158	<i>Phylloscopus collybita</i>								Rln	W	0	0	LC	1	1	1
159	<i>Phylloscopus sibilatrix</i>								R	PV	0	0	LC	1	1	1
160	<i>Phylloscopus trochilus</i>								Rsn	PV	0	0	LC	1	1	1
161	<i>Phylloscopus bonelli</i>								Acc	PV	0	0	LC	0	1	1
O-15	Passériformes–Scotocercidés															
162+	<i>Scotocerca inquieta saharae</i>								M	U	0	0	LC	1	1	1
O-16	Passériformes–Sturnidae															
163	<i>Sturnus vulgaris</i>								Rsn	W	0	0	LC	1	1	0
O-17	Passériformes–Sylviidae															
164	<i>Curruca undata toni</i>								Rsn	PV	0	0	LC	1	1	0
165	<i>Curruca c. conspicillata</i>								R	W	0	0	LC	1	1	1
166	<i>Curruca h. hortensis</i>								Rsn	PV	0	0	LC	0	0	1
167	<i>Curruca cantillans</i>								Rln	W	0	0	LC	1	1	1

N°	Order–Family Scientific name	Annual distribution										Abn.	Ph. St.	Pr. St.			Ref.		
		A	B	C	1	2	3	1	2	3	1			2	3				
168	<i>Curruca c. communis</i>											Rln	PV	0	0	LC	1	1	1
169	<i>Curruca m. melanocephala</i>											Rln	W	0	0	LC	1	1	1
170	<i>Sylvia atricapilla</i>											Rsn	PV	0	0	LC	1	1	1
171	<i>Curruca d. deserticola</i>											Acc	PV	0	0	LC	1	1	1
172	<i>Sylvia b. borin</i>											Acc	PV	0	0	LC	0	1	1
173*	<i>Curruca subalpina</i>											Acc	PV	0	0	LC	0	0	1
174+	<i>Curruca sarda</i>											M	U	0	0	LC	1	1	0
175+	<i>Curruca deserti</i>											M	U	0	0	LC	1	1	1
O-18	Passériformes–Turdidae																		
176+	<i>Turdus torquatus</i>											M	U	0	0	LC	1	1	1
177+	<i>Turdus philomelos</i>											M	U	0	0	LC	1	1	1
178+	<i>Turdus iliacus</i>											M	U	0	0	NT	1	1	0
P-1	Péléciformes–Ardeidae																		
179	<i>Ardea c. cinerea</i>											Rsn	W	0	0	LC	1	1	0
180	<i>Ardea p. purpurea</i>											Rsn	PV	0	1	LC	0	0	0
181	<i>Ardeola ralloides</i>											Rsn	CB	0	1	LC	0	1	1
182	<i>Bubulcus ibis</i>											Rsn	U	0	0	LC	1	1	0
183	<i>Ardea alba melanorhynchus</i>											R	PV	0	1	LC	0	0	0
184	<i>Egretta g. garzetta</i>											Rln	CB	0	1	LC	0	0	0
185	<i>Nycticorax n. nycticorax</i>											Rsn	CB	0	1	LC	1	1	0
186*	<i>Egretta g. gularis</i>											Acc	PV	0	0	LC	0	0	0
187	<i>Ixobrychus m. minutus</i>											Rln	MB	0	1	LC	1	1	0
P-2	Péléciformes–Ardeidae																		
188	<i>Platalea l. leucorodia</i>											Rsn	W	0	1	LC	0	0	0
189	<i>Plegadis falcinellus</i>											Rsn	PV	0	1	LC	0	0	0
Q	Phoenicoptérimorphes–Phoenicoptéridae																		
190	<i>Phoenicopterus roseus</i>											Rsn	W	0	1	LC	0	0	0
R	PICIFORMES–PICIDAE																		
191	<i>Jynx torquilla mauretanicus</i>											Rsn	PV	0	1	LC	1	1	0
S	Podicipédiformes–Podicipedidae																		
192	<i>Tachybaptus r. ruficollis</i>											Rsl	RB	0	0	LC	1	1	1
193*	<i>Podiceps c. cristatus</i>											Acc	PV	0	0	LC	0	0	0
T	Psittaciformes–Psittacidae																		
194	<i>Psittacula krameri</i>											Acc	U	0	0	LC	0	0	0
U	Pteroclitiformes–Pteroclitidae																		
195	<i>Pterocles senegallus</i>											Rln	RB	0	0	LC	1	0	1
196	<i>Pterocles c. coronatus</i>											Rln	RB	0	0	LC	1	1	1
197+	<i>Pterocles alchata caudacutus</i>											M	U	0	0	LC	1	1	1
V-1	Strigiformes–Strigidae																		
198	<i>Athene noctua saharae</i>											Rsn	RB	0	1	LC	1	1	1
199	<i>Bubo ascalaphus</i>											Rsn	RB	0	1	LC	1	1	1
200	<i>Otus scops mallorcae</i>											Rsn	W	0	1	LC	1	1	1
201*	<i>Asio f. flammeus</i>											Acc	PV	0	1	LC	1	0	0
V-2	Strigiformes–Tytonidae																		
202	<i>Tyto a. alba</i>											Rsn	RB	0	1	LC	0	0	1
W	Suliformes–Phalacrocoracidae																		
203	<i>Phalacrocorax carbo maroccanus</i>											Acc	PV	0	1	LC	0	0	0

Abn.: abundance (Rln: regular in large numbers, Rsn: regular in small numbers, R: rare, Occ: occasional, Acc: accidental, M: missing); Ph. St.: phenological status (W: wintering, RB: resident breeder, MB: migrant breeder, CB: casual breeder, PV: passage visitors, U: status uncertain); Pr. St.: protection status, A: Ordinance n° 06–05 of 15 July 2006; B: Executive Decree n° 12–235 of 24 May, 2012; C: The International Union for Conservation of Nature, IUCN (LC: Least Concern; NT: Near Threatened; VU: Vulnerable; EN: Endangered); Ref.: References (1: Ledant et al. 1981; 2: Isenmann and Moali, 2000; 3: BirdLife International); *: a single observation; +: old documentation; 0: no, 1: yes.

Table 2. Species abundance of the M'Zab avifauna.

Type \ Abn.	Rln	Rsn	R	Occ	Acc	M	Total
Waterbirds	17	23	5	10	12	2	69
Land birds	35	42	9	9	22	17	134
Total	52	65	15	19	34	19	203

Abn.: Abundance, Rln: Regular in large numbers (species that can be observed every year in large numbers); Rsn: Regular in small numbers (species that can be observed every year, but in very low numbers); R: Rare (species not being observed every year); Occ: Occasional (species not being observed every year); Acc: Accidental (species with a maximum of three observational data); M: Missing (species that have not been observed since 2000).

Table 3. Phenological status of the M'Zab avifauna.

Type \ Ph. St.	Breeder			Non-breeding		U	Total
	RB	MB	CB	W	PV		
Waterbirds	11	3	3	18	28	6	69
Land birds	27	7	00	23	53	24	134
Total	38	10	3	41	81	30	203
	51			122		30	203

Ph. St.: phenological status; RB: resident breeder; MB: migrant breeder; CB: casual breeder; W: wintering; PV: passage visitors; and U: uncertain status.

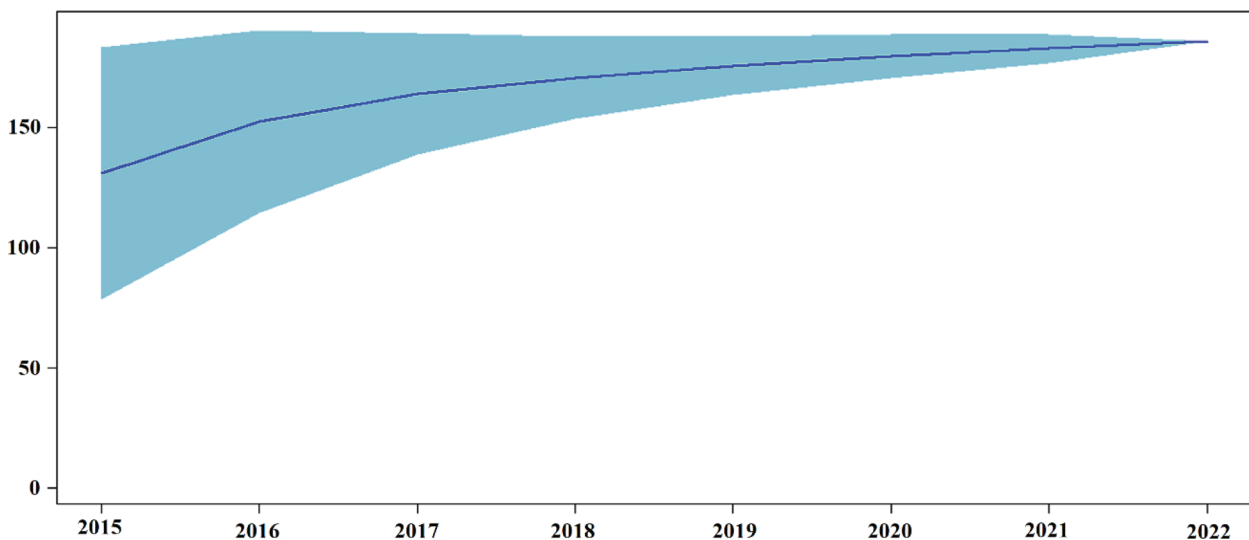


Figure 4. Species-accumulation curve of M'Zab region between 2015–2022.

the cumulative richness varies, being 131.13 ± 26.31 in 2015 and 186 ± 00 in 2022. Since 2018, we have recorded some stability, which indicates completeness of the sampling. Future sampling is expected to yield the following richness estimate: 186 species, $\text{chao} = 205.28 \pm 10.72$, $\text{jackknife 1} = 206.12 \pm 10.91$, $\text{jackknife2} = 215.66 \pm 00$, $\text{bootstrap} = 195.41 \pm 6.67$, $n = 8$.

The Pearson's Chi-Square (χ^2) Test showed that there was a significant association recorded between specific richness and biotopes ($\chi^2 = 145.54$, $df = 4$, $P < 0.001$). The richest biotope is the waterbody, where 84.24 % of the species were encountered, followed by the pre-urban biotope (40.39%), and palm groves with agricultural crops (39.90%). The urban biotope accounts for only 9.36% of total species.

Phenology of M'Zab avifauna

There are 51 bird species breeding in M'Zab. Of these, 38 are sedentary (11 waterbirds and 27 land birds), 10 are migratory (seven land birds and three waterbirds), and three are occasional breeding waterbirds. Non-breeding birds are represented by 122 species, 81 of which are passage visitors (28 waterbirds and 53 land birds). Wintering species represent 41 species (18 waterbirds and 23 land birds). Finally, 30 species have an uncertain phenological status (six waterbirds and 24 land birds) (Table 3).

Protection statutes of the M'Zab avifauna

Nationally, in Algeria, the Executive Fiat 12–235 of 24 May 2012, which establishes the list of protected

non-domestic animal species, protects 59 species, or 32% of the species found during this study. Most of these species are from the families Accipitridae and Ardeidae, which have 12 and 6 species, respectively. But only the Peregrine Falcon and the Houbara Bustard are protected by the Ordinance 06–05 of 15 July 2006, which is concerned with the protection and preservation of endangered animal species. Internationally, 92.12% of the counted species have a status of “least concern”, according to the IUCN Red List. Ten species have a “near threatened” status, and five have a “vulnerable” status. Finally, one species (Egyptian Vulture) is in the “endangered” category.

DISCUSSION

This study investigated the avifaunal diversity in various biotopes of the M'Zab region (northern Algerian Sahara). These data are valuable because they fill the gap in the information on the avifauna in Algeria, especially in the Sahara. The richness of avian species in the M'Zab region (203 species belonging to 23 orders and 48 families) is considerable accounting for more than 50% of the Algerian avifauna. Between 2015 and 2022, we recorded 184 species, belonging to 22 orders and 45 families; this number is significant compared to the data (95 species belonging to 19 orders and 40 families) reported for the same area by Ledant et al. (1981), and by Isenmann and Moali (2000) (104 species belonging to 19 orders and 41 families). In addition, it should be noted that in Zibans (northeast of the Algerian Sahara), Farhi and Belhamra (2012) identified 136 species belonging to 18 orders and 44 families.

Most of the species recorded in M'Zab belong to the Muscipidae (22 species), Scolopacidae (17 species), and the Anatidae (14 species). According to Isenmann and Moali (2000), nationally, there are 37 species of Sylviidae, 34 species of Anatidae, 29 species of Accipitridae, and 26 species of Scolopacidae in Algeria. Among the 203 species reported, 69 are waterbirds, belonging to 14 families and 8 orders, frequenting wetlands, springs, and oases. The most abundantly represented families are the Scolopacidae (17 species), Anatidae (14 species), and the Ardeidae (9 species). Indeed, 71 species were recorded at Ghardaïa and El Ménéa, 67 species at Ouargla (Bouzig 2017; Chedad 2021; Chedad et al. 2020a, 2021a), the number of species recorded at Lake Ayata (Oued Righ Valley) by Chenchoumi (2010) being 55. The diversity of birds in this study area indicates the abundance of food resources (Sommerfeld and Hennicke 2010; Barger et al. 2016), and the differences found in species richness among the surveyed regions are certainly due to microclimatic, floristic, and faunal differences (Guezoul et al. 2002).

Studies into recent changes in the distribution ranges of some species, which were initiated by Heim de Balsac (1979), show that avian species with a Saharan distribution have shifted north of Algeria. Simultaneously, from north to south, which is explained by a number of such factors as climate change, drought, urban development, fires, overexploitation of natural resources, different types of pollution, agricultural expansion, creation of green spaces, and appearance of new wetlands, especially the artificial ones (Chedad et al. 2020b, c). In the M'Zab region, several species were discovered for the first time: *Coccothraustes coccothraustes*, *Serinus serinus*, *Chloris chloris*, *Pluvialis apricaria*, *Ciconia nigra*, *Egretta gularis*, and *Aythya collaris* (Chedad et al. 2020c, 2021b). During this study period, we recorded the presence of an invasive species (Rose-ringed Parakeet), posing a real problem in the countries where it has been introduced. As reported by (Bendjoudi et al. 2005a, b), some adult individuals of this species, which probably escaped from an aviary at the Botanical Garden Hamma (Algiers), kept themselves in the wild in this garden and its immediate surroundings. It should be noted that this area hosts three species endemic to North Africa, i.e., *Alectoris barbara*, *Phoenicurus moussieri* and *Sylvia deserticola*.

We found that the biotope with the highest species richness is the waterbody (84.24%) because it is home to both waterbirds and land birds largely due to the abundance of food resources and tranquility. Followed by the pre-urban biotope, the palm grove and its agricultural crops represented 40.39% and 39.90%, respectively, of all the birds counted. Only 9.36% of all the avian species were recorded in the urban biotope. This is due to different forms of pollution, limited food resources, and the lack of habitats and shelter for these species. Similarly, Aouissi et al. (2021) mentioned that urban green spaces are important biodiversity hotspots in North Africa, and on the other hand, Mounir et al. (2022) recorded a high number of birds in pine and oak forests compared to that in open habitats (High Atlas Mountains, Morocco).

The avifauna of M'Zab consists of 122 non-breeding species, of which 81 are strictly migratory (53 land birds and 28 waterbirds), and they only stopover in different biotopes. Similarly, Farhi and Belhamra (2012) reported 74 species, which are typically migratory, in the oasis of Ziban. In similar surveys, Bruderer and Salewski (2008) showed that in autumn, about 200 species of migratory passerines annually cross the Palearctic to reach Sub-Saharan Africa. The Ghardaïa region receives an important part of the avifauna, crossing the Palearctic during the two post- and prenuptial passages. This fact shows the importance of this territory since it is on the migratory routes between Europe and Africa (Chedad et al. 2020a, b; Chedad 2021).

There are 38 species of breeding residents, of which 27 species are land birds. According to Farhi and Belhamra (2012), in the oasis of Ziban, breeding residents are represented by 47 species. 13 migratory species come to nest in M'Zab, and this low number is explained by the competition between migratory and sedentary species. In the Kef Doukhane wetland, three sporadic species (*Ardeola ralloides*, *Egretta garzetta*, and *Nycticorax nycticorax*) were confirmed nesting by Chedad et al. (2022a). Nationally, 103 breeding passerine species out of a total of 214 species represent almost half of the avifauna (48.1%), showing the general dominance throughout the Palearctic zone (Isenmann and Moali 2000). There are 41 species of wintering birds (18 waterbirds and 23 land birds). The phenological status of 30 species (6 waterbirds and 24 land birds) is uncertain because of the scant evidence of breeding, random dispersal, and unstable numbers.

The executive Fiat 12–235 of May 24, 2012, which establishes the list of protected non-domestic animal species, lists a total of 59 species (32.02%) as protected, which accounts for 47.20% of the protected Algerian avifauna. Two species, the Peregrine Falcon and the Houbara Bustard, are protected by the Ordinance 06–05 of July 15, 2006, relating to the protection and preservation of certain endangered animal species. At the international level, 92.12% of the recorded species have the status of “Least Concern”, according to the IUCN Red List. Ten others have the “Near Threatened” status, five have the “Vulnerable” status, and one species is “Endangered”. These statuses are determined according to the criteria based on different biological factors that are associated with the extinction risk: population size, rate of decline, geographical range, degree of settlement, and fragmentation of the distribution (UICN 2020).

Protection status of the M'Zab avifauna reflects the national and international importance of this region, in particular that of the Kef Doukhane wetland, which meets four Ramsar Convention (Wetlands International 2022) criteria (2, 3, 4, and 6), which is mostly enough for identifying wetlands of international importance: (i) Criterion 2, this site hosts three vulnerable species: *Marmaronetta angustirostris*, *Aythya ferina* and *Streptopelia turtur*; (ii) Criterion 3, it shows that this site plays an important role in maintaining the Mediterranean biological diversity and that of the northern Algerian Sahara by sheltering nine species listed in the IUCN Red List, (iii) Criterion 4, Kef Doukhane shelters avian species at a critical stage of their life cycle (especially during the breeding and wintering periods), *Marmaronetta angustirostris*, *Aythya ferina* and *Streptopelia turtur*; (iv) Criterion 6, the site hosts at least 1% of the waterbird populations of North-west Africa and West Africa of the following three species: *Tadorna ferruginea*, *Marmaronetta angustirostris* and *Aythya nyroca*.

CONCLUSIONS

The M'Zab region falls into the Saharan bioclimatic zone characterized by mild winters, irregular and low annual rainfall, and high temperatures. However, this has not prevented the presence of an important biodiversity of flora and fauna. Our study shows that M'Zab contains 203 bird species (including 69 species of waterbirds), belonging to 23 orders and 48 families, which accounts for more than half of the Algerian avifauna. Simultaneously, it confirms that this area is an essential stopover for land- and waterbird species, as well as an important wintering and breeding zone. Further bird counts could provide additional results and further update the bird list for this region. Studies of the bioecology of some protected species may provide valuable information on their phenological status. The information gathered on the avifauna of this area could contribute to the elaboration of the management plan, particularly for wetlands, with the aim of classifying them as sites of international importance under the Ramsar Convention, as in the case of the Kef Doukhane wetland.

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Conflict of interests

The co-authors report no conflicts of interest.

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Data availability

The data used to support the findings of this study are included within the article.

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