Ecological status interactions for assessing bird diversity in relation to a heterogeneous landscape structure

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ABSTRACT

Avian diversity is used to assess the functionality of diverse types of habitats around Salt Lake Djendli, North-east Algeria. The landscape is stratified into five habitat types in a gradient from wetland to forested mountains. Bird species found in these habitats can be classified into four ecological groups with decreasing degrees of aquatic specialisation and increasing forest specialisation. For each surveyed species, five ecological status were assigned. Overall, there was lower species richness in urban areas compared to other "natural" habitats. Birds have a biogeographical affinity to the western Palaearctic according to the dominant faunal types. Interactions of ecological status with phenological traits reveal that water birds are different from non-aquatic species because most of them are migrants. Moreover, overall, there is no worrying conservation status for surveyed birds. Bird diet is dependent on the ecological status that differentiate bird groups from each other due to differences in the food resources of the habitats they frequent. Phenological categories tend to link together birds of urban and open-lands. These two groups are affected by seasonal human activities. Our findings emphasise the importance of using combinations within the birds' ecological status, which would give information on the actual state of avifauna. This approach is relevant for future programmes and conservation actions.

Keywords: Salt Lake Djendli, birds, biodiversity, ecological status, landscape

1. INTRODUCTION

Knowledge of species diversity is particularly useful in monitoring biodiversity because it depends on a set of characteristic habitats that are adequately anastomosed (Breininger *et al.*, 2002). As a biological model, we chose ecological groups of birds to assess the level of biodiversity in wetland ecosystems and the surrounding areas. Birds are particularly useful because they are mobile and, depending on species, require a wide variety of habitats on different spatial scales (Angelstam *et al.*, 2004).

Since birds are relatively easy to study, several avifaunal surveys were performed in Algerian wetlands especially in the East of the country. Several bird species/populations were used: (i) to investigate the conditions of the bird populations and (ii) to give an indication of the health of the habitats (Ledant and Van Dijk, 1977; Ledant *et al.*, 1981; Van Dijk and Ledant, 1983; Isenmann and Moali, 2000; Saheb *et al.*, 2006; Samraoui *et al.*, 2006; Samraoui and Samraoui, 2008; Samraoui *et al.*, 2011). Since it provides information for managers and conservationists, the investigation of relationships between ecological niches of avian populations across landscape heterogeneity patterns represent a key tool for assessing the ecological value of wetlands and their surrounding habitats (Martensen *et al.*, 2008; Concepción and Díaz, 2011).

This study aims to give an updated assessment of avian populations by addressing some ecological status. This work consists of a multi-criteria database gathering both systematic and bio-ecological status (faunal type, phenological traits, trophic status, occurrence and protection state) of bird species.

Since this study is on the heterogeneity of landscape and its relevance to bird diversity, it is an important tool for both planners and managers of wetlands, particularly as there is a lack of synthetic studies on these aspects not only in Algerian wetlands but also on a North African scale. From this perspective, we evaluate the distribution of birds, divided into different ecological groups, and

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their connectivity, along an environmental gradient going from the inside of a wetland (salt lake) to the neighbouring mountain ecosystems crossing over open environments characterised by cereal crops, halophytic low-vegetation, and urban conglomerates.

2. METHODS

2.1 Study area

This study was carried out in the Salt Lake Djendli, which is a temporary saline wetland located in northeastern Algeria, 46 km northeast of Batna city (Figure 1). The lake covers 3700 ha of area at an average altitude of 833 m (a.s.l.). It is fed mostly by rainwater collected from the sub-watershed of Oued Chemora that belongs to the "Hauts Plateaux Constantinois" watershed.

The climate of the region is not uniform, great inter-annual fluctuations are observed. Long-term data (1974–2006) show that the coldest month was January with average temperatures of 5.3°C and the warmest month was July with average temperatures of 25°C. Rainfall was also irregular with an annual average of 350.8 ± 76.3 mm. The bioclimate is semiarid Mediterranean-type with cool winters. Furthermore, the main economical activities of Salt Lake Djendli are cereal crops, fruit growing and sheep-farming (Chenchouni, 2007).

2.2 Ecological unit composition and landscape structure

The landscape was stratified into five coarse landscape types, hereafter referred to as ecological units, in a gradient from the lake to the surrounding forested mountains, namely waterbody and flooded area, halophytic rangeland, urban urea, cereal crops and sparse vegetation, mountain and sub-forest habitats.

Waterbody and its flooded area

The lake covers a large area with low water depth, rarely exceeding 0.5 m, even in wet years. The low water level of the lake is due to low rainfalls and to the low slope of the ground that disperses water over a large surface. Water is alkaline (pH = 8.4 ± 0.2) and salt (salinity at 25°C = 58.4 ± 4.0 g L^{-1}) with a turbidity ranging between 41.1 and 53.3 Nephelometric Turbidity Unit (Chenchouni, 2007). The flooded area includes bare lands on which the water level settles. The soil is impervious and salty due to repeated evaporation of salt water. When drought occurs in summer, the waterbody disappears completely.

Halophytic rangelands

The immediate vicinity of flooded areas is occupied by belts of vegetation dominated by halophytic plants such

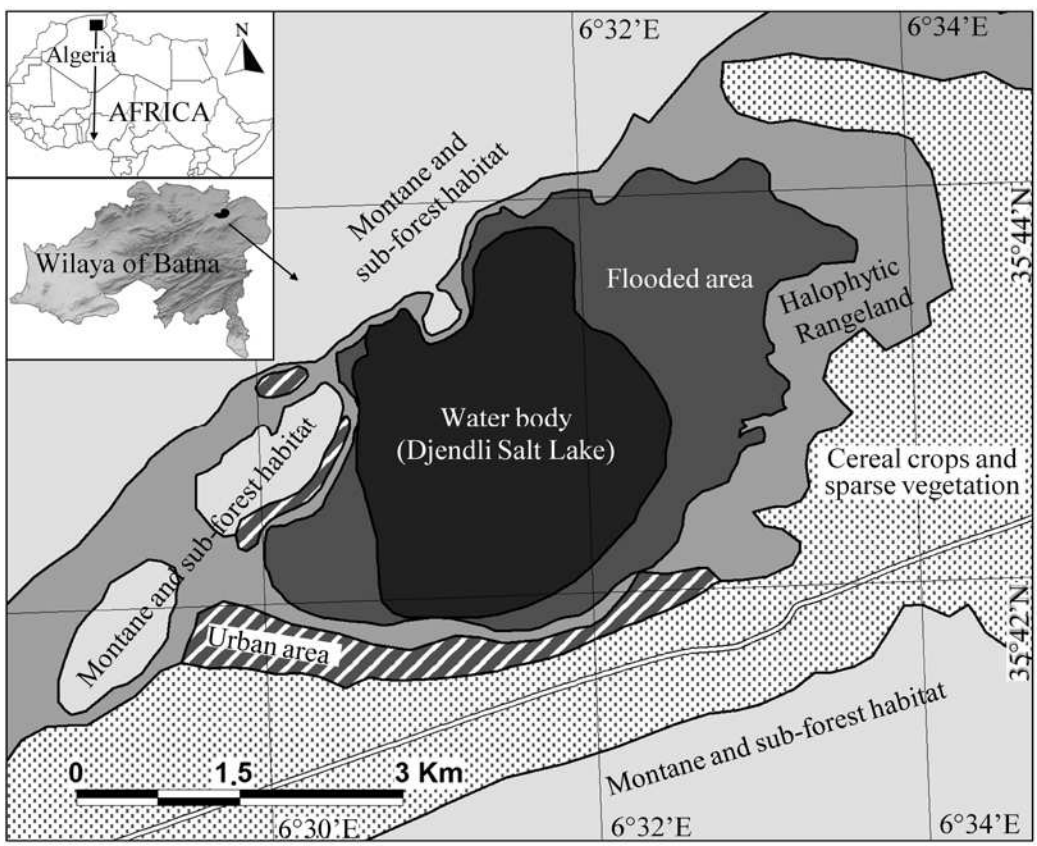

Figure 1 Study area with the sampled ecological units (*i.e.* coarse landscape types) of Djendli Salt Lake (Batna, Northeastern Algeria).

as *Salicornia fruticosa* (Forssk.), *Suaeda vermiculata* (Forssk.), *Suaeda fruticosa* (Forssk.), *Atriplex halimus* (L.). These environments are often over-trampled following overgrazing by sheep and cattle. Characteristic hydrophilic plant-species such as *Juncus maritimus* (L.), *Phragmites communis* (Trin.), *Cyperus laevigatus* (L.) and *Scirpus lacustris* (L.) do exist frequently between the halophytic belts.

Urban area

The urban areas consist of country houses scattered along the south and west side of the lake. The houses are often located inside small fruit orchards or among parcels of forage crops. Cereal crops and livestock farming are the main activities of the community.

Fields of cereal crops and sparse vegetation

Cereal growth is a widespread agricultural activity all around the area. Major crops include barley, durum and bread wheat. At the borders of these cultivated plots and in other adjacent lands, spontaneous sparse vegetation of *Artemisia herba alba* (Asso), *Tamarix gallica* (L.), *Ziziphus lotus* (L.) and *Retama retam* (Fossk.) was recorded.

Mountain and sub-forest habitats

The Salt Lake Djendli and its surrounding plains are circumvented by the Bouarif Mountain Range (altitude 1744 m a.s.l.) in the south, Jebel Toumbait (1116 m a.s.l.) and Yeddou (884 m a.s.l.) in the North, and Jebel Takouist (915 m a.s.l.) in the Northwest. These mountains are covered with rupicolous and shrub-forest vegetation. The main tree species include Phoenician Juniper (*Juniperus phoenicea* L.), Holm Oak (*Quercus ilex* L.) and Oleaster (*Olea europaea* L.).

2.3 Bird surveys

Waterbirds were counted regularly with fortnightly visits during winter and spring (from November to May) between 2005 and 2009. The method used in the salt lake (*i.e.* waterbody and its surrounding flooded areas) is as follows: waterfowl groups located at a distance of less than 200 m, and that did not exceed 200 individuals were processed by a single count. However, if the bird population size was more than 200 individuals or if the group was more than 200 m away, a quantitative estimation was considered. In this case, the visual field was divided into several bands, then the average number of birds in a mid-band count was often reported as the number (Bibby *et al.*, 1992).

Other birds frequenting the halophytic rangelands, crop fields, urban area and the foothills of bordering mountains were also sampled. In these habitats, birds were surveyed using the EFP technique (Echantillonnage Fréquentiel Progressif) which is a point count (Blondel *et al.* 1981). The EFP method was performed in eight sampling points randomly distributed along a route covering each of the four ecological units cited above (apart from the waterbody and flooded areas) during the spring and summer (*i.e.* March to August) from 2006 to 2009. All bird species seen or heard at every point were recorded. The technique estimates species richness regardless of species abundances provided it is applied under favourable weather conditions (Bibby *et al.*, 1992).

2.4 Data analysis

The data collected from censuses were reported in a database in which five ecological status were assigned to each species:

1. Faunal type (FT), according to Voous (1960) to investigate the biogeographical origin.
2. Trophic status (TC), were assigned according to the diet categories (Müller, 1997): carnivorous (Cv), carrion-feeder (Cr), granivorous (G), invertebrate-feeder (Inv) and polyphagous (Pp).
3. The phenology of species (PHC) was considered as well as the reproductive status in the Haut-Plateaux region (Heim de Balzac and Mayaud, 1962; Isenmann and Moali, 2000; Samraoui and Samraoui, 2008). Phenological types used were (i) resident (R) species present all year; (ii) winter migrant (WM) species observed exclusively during the rainy season; (iii) summer migrant (SM) migratory species in summer; (iv) breeder (B) species that nested in the region of Hauts-Plateaux at least once; and (v) probable breeder ([B]) species suspected of breeding.
4. The frequency of occurrence (FO) was determined by the number of surveys in which the species occurred/ total number of conducted surveys (Dajoz, 2006). An index varying from (I) to (V) was given for each species to express its FO. Occasional species (I) have an occurrence of less than 20%; rare species (II) are those whose occurrence varies between 20 and 39%; common species (III) are present in 40–59% of records; constant species (IV) are present in 60–79% of the observations; and abundant species (V) are present in 80% or more of the conducted surveys.
5. Protection status (PRC) was determined nationally according to species citations in Algeria legislation (OJAR, 1995), and internationally, following their citations in appendices of various international conventions and treaties: the Washington Convention "CITES" (CITES, 1994), the IUCN Red list (Baillie *et al.*, 2004), the African–Eurasian Waterbird Agreement "AEWA" (AEWA, 2008), and conventions of Bonn

(Vagg, 2009), Berne (AFS, 2007) and Barcelona (CEC, 1999).

We investigated the diversity of bird species classified into four partly overlapping ecological groups according to the type of ecological unit in which the species is mostly dependent on. Hence, these ecological groups were defined along a gradient ranging from wetlands to mountain forests passing through intermediary ecosystems including urban areas. The ecological units "halophytic rangelands" and "fields of cereal crops and sparse vegetation" are grouped together as a single category to characterise the open-habitats of mainly herbaceous low height vegetation.

Then the four bird ecological groups were water birds and waders (W), bird species related to open habitats (O), urban birds (U) and forest birds (F).

2.5 Statistical analysis

A qualitative presentation was performed by spineplots in order to combine in pairs the investigated ecological status. This approach also aimed to highlight bird group distribution according to their diet, phonology and frequency of occurrence.

Multiple factor analysis (MFA) is a multi-table factorial method. It highlights the relationship between ecological status (included as variables) grouped into categories (blocks), looking for common factors of differentiation of bird species (recognised as statistical individuals). Only the presence or absence of a species in each survey was used in the calculations. To test for differences in species richness between the four ecological groups of birds previously defined, the MFA was used to simultaneously analyse categories of ecological status, and then plot them to study elements that explain the differences and/or similarities between these ecological groups (Escofier and Pagès, 1994). Statistical analyses were performed using the software XL-Stat version 2012.

3. RESULTS

3.1 Inventory and ecological status of birds

The study area included an avian community composed of 108 bird species including 42 passerines, 66 non-passerine birds with 46 waterbirds. This avifauna can be classified into 13 orders, 35 families and 72 genera. The Passeriformes order was the best represented with 42 species and 13 families, followed by Charadriiformes with 20 species and five families, then came Anseriformes with 12 species (Table 1).

The surveyed avifauna belonged to 15 faunal types following the classification of Voous (1960). The Palaearctic faunal type dominated with more than a quarter of all counted species (28.7%). It was followed by Holarctic (10.2%) then the Turkesto–Mediterranean type (8.3%), then came the Mediterranean type with 7.4%. Passerines were dominant in the Mediterranean faunal type with seven species against one non-passerine species. Palaearctic and Holarctic faunal types were characterised by non-passerine birds (Table 2).

Regarding trophic categories, Invertebrate feeders represented 45.4% (49 species) of the total avifauna, where Passeriformes including mainly bird of open habitats (19 species) dominated this category with 54.7%. In addition, 20 species in this category were waterbirds (17 Charadriiformes). Polyphagous were listed with 30 species (27.8%) dominated by 22 waterbirds (11 Anseriformes). Granivorous included 19 species, 17.6% of all recorded birds. These species were mostly forest or open-environment birds (10 Passeriformes and four Columbiformes) (Figure 2A). Carnivores have eight species; all belonging to the order of Falconiformes. Carrion feeders were represented by two species; Black Kite *Milvus migrans* and Egyptian Vulture *Neophron percnopterus* (Table 1).

Migratory species represented 59% of all recorded birds, they were either winter migrant (44%) or summer visitors (15%). Resident species were noted with 41% and were dominated by birds from open environments which held nearly half the recorded species of this group. Breeding species (48 species) were better represented by the ecological group which occupied the open-habitats (55%). Winter migrants were mainly waterbirds (83%), while summer migrants were best characterised by forest birds. Also, nearly all forest birds and those of open habitats were resident breeders (Figure 2B).

Wintering migrant birds were well represented by invertebrate feeders and polyphagous birds with 25 and 20 species respectively. For resident birds, granivorous and invertebrate feeders have the most species (17 and 16 species respectively). All carrion eaters were summer migrants (Figure 2C). Phenological groups of both resident and winter migrants have an equal distribution in the different classes of occurrence. Summer migrants were occasional and rare. Occasional birds were the most frequent with 29 species (27% of all birds). Abundant species were represented by the lowest rate (12% of all birds, Figure 2D). Invertebrate feeders over all classes of occurrence were dominant. The polyphagous species came in second position (Figure 2E). Urban and forest birds were rarer but waterbirds and those of open-habitats were quite abundant. Waterbirds were the most numerous in the category of abundant, rare and occasional birds, and forest birds were most abundant in the classes of occasional, rare and common species (Figure 2F).

The salt lake Djendli had 29 birds protected in Algeria, of which 10 are Falconiformes. The most identified species (95.4%) were of "Least Concern" according to the IUCN Red List (Table 3), while only one species (Marbled Teal) has the "Vulnerable" status and another is

Table 1 Systematic list of bird species recorded in Salt Lake Djendli with their ecological status[a]

	Ecological status					
Scientific name	EG	FT	PHC	TC	PRC	FO
Bubulcus ibis	W	IA	RB	[Inv]	LC,T³,E²,A	V
Egretta garzetta	W	OW	WM	[Inv]	LC,T³,E²,A	II
Ciconia ciconia	U	P	WMB	[Inv]	LC,N²,D,E²,A	V
Phoenicopterus roseus	W	–	WMB	Pp	LC,T²,N²,L²,D,E²,A	V
Tadorna tadorna	W	S	WMB	Pp	LC,N²,D,E²,A	V
Tadorna ferruginea	W	PX	WMB	Pp	LC,N²,D,E²,A	II
Anas penelope	W	P	WM	Pp	LC,T³,N²,E³,A	IV
Anas strepera	W	H	WM	Pp	LC,N²,E³,A	IV
Anas acuta	W	P	WM	Pp	LC,T³,N²,E³,A	IV
Anas crecca	W	H	WM	G	LC,T³,N²,E³,A	IV
Anas platyrhynchos	W	H	WMB	Pp	LC,N²,E³,A	V
Anas clypeata	W	H	WM	Pp	LC,T³,N²,E³,A	V
Anas angustirostris	W	[S]	WM	Pp	VU,N¹,D,E²,A	I
Aythya fuligula	W	P	WM	Pp	LC,N²,E³,A	II
Aythya ferina	W	P	WM	Pp	LC,N²,E³,A	II
Aythya nyroca	W	TM	WM	Pp	NT,T³,N¹,E³,A	III
Milvus migrans	F	OW	SM[B]	Cr	LC,T²,N²,D,E²	III
Neophron percnopterus	F	IA	SM	Cr	EN,T²,N²,D,E²	II
Circaetus gallicus	O	IA	SM	Cv	LC,T²,N²,D,E²	I
Circus aeruginosus	W	P	WM	Cv	LC,T²,N²,D,E²	I
Buteo buteo	F	H	SM	Cv	LC,T²,N²,D,E²	I
Buteo rufinus	F	PX	RB	Cv	LC,T²,N²,D,E²	I
Hieraaetus fasciatus	F	IA	RB	Cv	LC,T²,N²,D,E²	II
Pandion haliaetus	W	C	WM	Cv	LC,T²,N²,L²,D,E²	I
Falco tinnunculus	O	OW	RB	Cv	LC,T²,N²,D,E²	III
Falco biarmicus	O	ETH	RB	Cv	LC,T²,N²,D,E²	III
Alectoris barbara	O	M	RB	G	LC,E³	I
Coturnix coturnix	O	OW	RB	G	LC,E³	III
Rallus aquaticus	W	P	WM	Inv	LC,E³,A	I
Fulica atra	W	P	RB	Pp	LC,E³,A	II
Grus grus	O	P	WM	Pp	LC,T²,N²,D,E²,A	V
Himantopus himantopus	W	C	RB	Inv	LC,N²,D,E²,A	V
Recurvirostra avosetta	W	[TM]	WMB	Inv	LC,N²,D,E²,A	V
Burhinus œdicnemus	W	[TM]	WM[B]	Inv	LC,N²,E²	III
Glareola pratincola	W	IA	WM	Inv	LC,N²,E²,A	II
Charadrius dubius	W	P	WM	[Inv]	LC,N²,E²,A	III
Charadrius hiaticula	W	ARC	WM	[Inv]	LC,N²,E²,A	II
Charadrius alexandrinus	W	C	WMB	[Inv]	LC,N²,E²,A	V
Vanellus vanellus	W	P	WM	[Inv]	LC,N²,E³,A	I
Calidris minuta	W	ARC	WM	Inv	LC,N²,E²,A	IV
Calidris alpina	W	ARC	WM	Inv	LC,N²,E²,A	III
Lymnocryptes minimus	W	SB	WM	Inv	LC,N²,E³,A	II
Philomachus pugnax	W	P	WM	Inv	LC,N²,E³,A	I
Gallinago gallinago	W	H	WM	Inv	LC,N²,E³,A	I
Limosa limosa	W	P	WM	Inv	NT,N²,E³,A	I
Numenius arquata	W	P	WM	Pp	NT,N²,E³,A	II
Tringa erythropus	W	SB	WM	Inv	LC,N²,E³,A	IV
Tringa totanus	W	P	WM	Pp	LC,N²,E³,A	III
Tringa nebularia	W	SB	WM	Inv	LC,N²,E³,A	II
Tringa ochropus	W	P	WM	Inv	LC,N²,E²,A	II
Actitis hypoleucos	W	–	WM	Pp	LC,N²,E²,A	II
Larus ridibundus	W	P	WM	Pp	LC,E³,A	IV
Larus genei	W	[S]	SMB	Pp	LC,N²,E²,A	I
Larus michahellis	W	–	WM	Pp	LC,E³,A	I

Table 1. Contd.

	Ecological status					
Scientific name	EG	FT	PHC	TC	PRC	FO
Chlidonias niger	W	H	WM	Pp	LC,E^2,A	I
Chlidonias leucopterus	W	P	WM	Pp	LC,N^2,E^2,A	I
Sterna nilotica	W	C	SMB	Pp	LC,E^3	I
Pterocles orientalis	O	PX	RB	G	LC,E^2	I
Pterocles alchata	O	PX	RB	G	LC,E^2	I
Columba livia	U	[TM]	RB	G	LC,T^3,E^3	IV
Streptopelia decaocto	U	IA	RB	G	LC,E^3	IV
Streptopelia turtur	F	ET	SM	G	LC,E^3	III
Streptopelia senegalensis	F	ET	RB	G	LC,T^3,E^3	II
Apus apus	U	P	SM	Inv	LC,E^3	I
Merops apiaster	O	TM	RB	Inv	LC,N^2,D,E^2	III
Upupa epops	F	OW	RB	Inv	LC,D,E^2	IV
Melanocorypha calandra	O	M	RB	Inv	LC,E^2	III
Calandrella brachydactyla	O	TM	RB	Inv	LC,E^2	III
Calandrella rufescens	O	TM	RB	Inv	LC,E^2	I
Galerida cristata	O	P	RB	G	LC,E^3	IV
Alauda arvensis	O	P	RB	Pp	LC,E^3	V
Ptyonoprogne rupestris	O	PXM	SM	Inv	LC,E^2	I
Hirundo rustica	U	H	SMB	Inv	LC,E^2	IV
Delichon urbica	U	P	SMB	Inv	LC,E^2	III
Anthus pratensis	O	E	WM	Inv	LC,E^2	I
Motacilla flava	O	P	WM	Inv	LC,E^2	III
Motacilla alba	O	P	WM	Inv	LC,E^2	IV
Erithacus rubecula	O	E	R[B]	Pp	LC,E^2	IV
Phoenicurus moussieri	O	–	RB	Inv	LC,E^3	III
Phoenicurus ochruros	F	PXM	RB	Inv	LC,E^2	III
Saxicola torquata	O	P	WM[B]	Inv	LC,E^2	II
Oenanthe oenanthe	F	P	WM[B]	Inv	LC,E^2	I
Oenanthe leucopyga	O	M	R[B]	Inv	LC,E^3	II
Oenanthe leucura	O	M	RB	Inv	LC,E^2	IV
Turdus merula	F	P	RB	Pp	LC,E^3	II
Cisticola juncidis	O	IA	RB	Inv	LC,E^2	IV
Hippolais polyglotta	O	M	SM	Inv	LC,N^2,E^2	I
Sylvia melanocephala	F	TM	SM	Inv	LC,N^2,E^2	II
Sylvia atricapilla	F	E	SM	Inv	LC,N^2,E^2	I
Phylloscopus collybita	O	P	SM	Inv	LC,N^2,E^2	IV
Ficedula hypoleuca	F	E	SM	Inv	LC,N^2,E^2	III
Parus caeruleus	F	E	RB	Pp	LC,E^2	I
Lanius excubitor	O	H	RB	[Inv]	LC,E^2	V
Lanius meridionalis	O	H	RB	Inv	LC,E^2	II
Lanius senator	O	M	RB	Inv	LC,E^2	III
Corvus corax	O	H	RB	Pp	LC,E^3	IV
Sturnus vulgaris	O	ET	WM	Inv	LC	III
Passer domesticus	U	P	RB	Pp	LC	V
Passer hispaniolensis	O	TM	RB	G	LC,E^3	III
Passer montanus	U	P	RB	Pp	LC,E^3	II
Fringilla coelebs	F	E	RB	G	LC,E^3	III
Serinus serinus	U	M	RB	G	LC,D,E^2	IV
Carduelis chloris	F	ET	RB	G	LC,E^2	II
Carduelis carduelis	O	ET	RB	G	LC,E^2	III
Carduelis cannabina	F	ET	RB	G	LC,E^2	I
Emberiza cirlus	F	M	RB	G	LC,E^2	II
Emberiza cia	F	P	RB	G	LC,E^2	I
Miliaria calandra	O	ET	RB	G	LC,E^3	IV

[a]See Appendix 1 for abbreviation details.

Table 2 Distribution of bird species numbers by faunal types in Sebkha Djendli

Faunal types (symbol)	Non-passerines	Passerines	Total	%
Arctic (Arc)	3	0	3	2.8
Holarctic (H)	7	4	11	10.2
Siberian (SB)	3	0	3	2.8
Palearctic (P)	19	12	31	28.7
European (E)	0	6	6	5.6
Europeo–Turkestanian (ET)	2	5	7	6.5
Turkesto–Mediterranean (TM)	5	4	9	8.3
Mediterranean (M)	1	7	8	7.4
Sarmatic (S)	3	0	3	2.8
Paleoxeric (PX)	4	0	4	3.7
Palaeo-xero-mountain (PXM)	0	2	2	1.9
Ethiopien (Eth)	1	0	1	0.9
Old world (OW)	5	0	5	4.6
Indo–African (IA)	6	1	7	6.5
Cosmopolitan (C)	4	0	4	3.7
Not defined (–)	3	1	4	3.7
Total	66	42	108	100

"Endangered" (Egyptian Vulture). There were three species with "Near Threatened" status, following the IUCN Red List: Ferruginous Duck, Black-tailed Godwit and Eurasian Curlew (Table 1). Regarding species protected by Washington Convention (CITES), 21 species are noted in Appendices 2 and 3. According to the Bonn Convention, 53 species were recorded with a predominance of waterbirds (38 species) of which two are in Appendix 1 (*i.e.* Marbled Teal and Ferruginous Duck). Based on the AEWA bird list, 43 waterbirds were present in the Salt Lake Djendli with "Near Threatened" conservation status. Only two species of waterbirds are listed in Appendix 2 of the Barcelona Convention (Great Flamingo and Osprey). Virtually all species are listed in Appendixes 2 and 3 of the Berne Convention, except for two not-retained species (*Sturnus vulgaris* and *Passer domesticus*) (Tables 1 and 3).

3.2 Multiple-analysis of ecological status

MFA results shown that all tested status-types were well weighted in the four categories of ecological status. All parameters had high values (~1) on the factorial map F1×F2 which revealed a total inertia of 82.09%. The ecological status of birds was distributed over three of the four quadrants of the correlation circle (Figure 3) and the graph of the gravity centres of MFA factorial plot (Figure 4). The winter migrants and polyphagous birds with an abundant frequency of occurrence "V" were highly correlated on the first axis of the FMA. Protection status "VU, LT, L, A, N" also appear to be associated with these categories of birds. Carrion feeders were associated with the protection status "Endangered". In addition, most of breeders were resident and most of the polyphagous species were protected under Bonn Convention "N". Invertebrate feeders seemed to be constant "IV" and were related to protection status "LC, E, D". Moreover, the second factorial axis (F2) was strongly weighted with carnivores (resident breeders) that seem to belong to the class of common birds "III" regarding their occurrence. Furthermore, winter migrants were negatively associated with granivorous birds that were linked with summer migrants (Figure 3).

Distribution of gravity centres (agglomerates of ecological status) in the MFA distinguished a cyclic distribution of ecological collections of birds at the

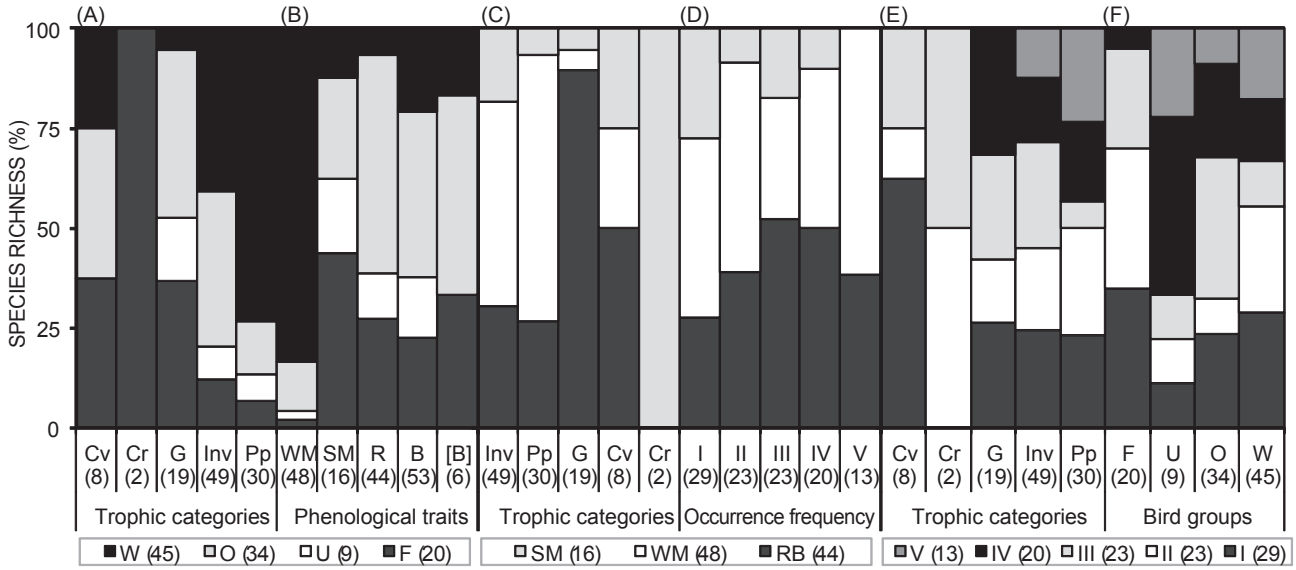

Figure 2 Distribution of species richness "number of bird species in %" according to their ecological status combined in pairs. (A): EG *versus* TC, (B): EG *versus* PHC, (C): PHC *versus* TC, (D): PHC *versus* FO, (E): FO *versus* TC, (F): FO *versus* EG. See Appendix 1 for abbreviations; numbers in parentheses are the total number of bird species of each ecological status.

Table 3 Distribution of the number of species by ecological bird groups following their protection state nationally and internationally

Treat and convention on bird protection		Code	Forest birds	Urban birds	Open-habitat birds	Water birds	Total	%
Red List of IUCN	Least Concern	LC	19	9	41	34	103	95.4
	Near Threatened	NT	0	0	3	0	3	2.8
	Vulnerable	VU	0	0	1	0	1	0.9
	Endangered	EN	1	0	0	0	1	0.9
Convention of Washington (CITES)	Appendix 1	T²	5	0	4	3	12	11
	Appendix 2	T³	1	1	0	7	9	8.3
Convention of Bonn	Appendix 1	N¹	0	0	0	2	2	1.9
	Appendix 2	N²	8	1	7	35	51	47.0
Convention of Barcelona	Appendix 2	L²	0	0	2	0	2	1.9
Convention of Berne	Appendix 2	E²	16	4	24	22	66	61
	Appendix 3	E³	4	4	9	23	40	37
AEWA Agreement		A	0	1	41	1	43	40
Algerian law		D	6	2	8	5	21	19

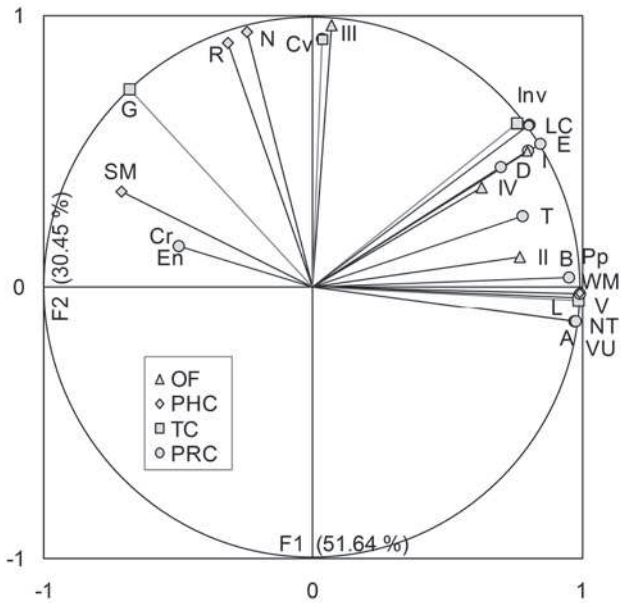

Figure 3 Representation of the correlation circle for all ecological statutes tested in the MFA. Although these dimensions were not normalised in the construction of axes, here, they are normalised in order to show their correlation with the two first factors of the MFA. See Appendix 1 for abbreviations.

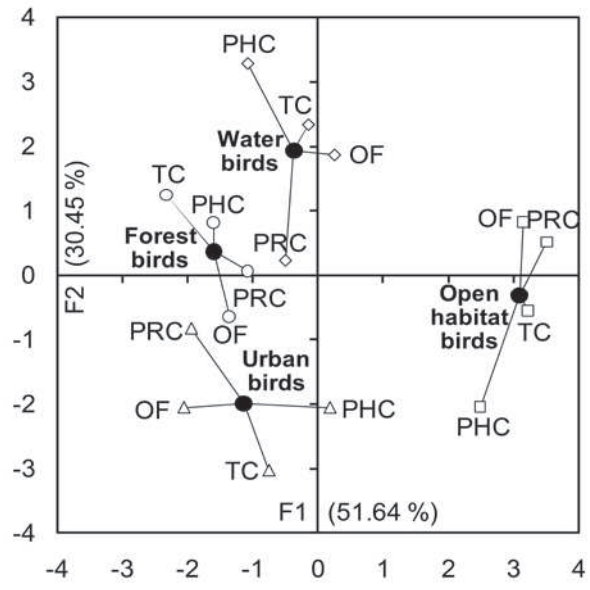

Figure 4 Superimposed representation of centroids of the four ecological bird groups on common factorial 1–2 of the multiple factor analysis. Each group is represented by five points: a representative average point and one point for each studied ecological group. See Appendix 1 for abbreviations.

factorial plot. Starting from top to bottom and from right to left of the plot (from positive to negative values of axes F2 and F1), we distinguish respectively, waterbirds, birds of open habitats, urban birds, and forest birds (Figure 4).

4. DISCUSSION AND CONCLUSION

4.1 Ecological status of surveyed bird species

Despite the limited area of this study, the surveyed avifauna is diverse. It represents over a quarter of Algeria birds (406 species cited by Isenmann and Moali, 2000) and covers more than half of the orders and families described in the country (Ledant *et al.*, 1981). Whereas waterbirds with 46 species, are quite diverse compared to those counted in main Algerian wetlands [99 species identified by Samraoui and Samraoui (2008) and 97 species by Samraoui *et al.* (2011)]. This biodiversity assessment indicates the regional importance of wetland "Chott know also as Sebkhat" Djendli and also supports and justifies its classification as an Important Bird Area "IBA" because of the importance and abundance of avian species it shelters and hosts (BirdLife International, 2002).

The dominance of some faunal types (P, TM, M, E and ET) provides information on the relationship of

the surveyed avifauna to the biogeographical zone of Western Palaearctic; as it applies to all North Algeria and North Africa (Lebreton and Ledant, 1980; Isenmann and Moali, 2000). According to Bonter *et al*. (2010), the biogeographical position and structure of landscapes and habitats are some of the causes that support the invasion of some bird species. Indeed, expanding the range of some invasive species such as Eurasian Collared Dove (*Streptopelia decaocto*) (Benyacoub, 1998; Moali *et al*., 2003) and Cattle Egret (*Ardeola ibis*) (Si Bachir *et al*., 2011) became evident not only in the study area but also in all Algeria.

The predominance of migratory birds in the region indicates the ecological importance of this site. It provides abundant food resources in both quality and quantity for a large variety of birds, particularly waterfowl that find it an ideal refuge to fatten during the winter. Indeed eco–ethological studies on several waterbird species have shown a dominance in feeding behaviour on other diurnal activities (Houhamdi and Samraoui, 2002; Baaziz and Samraoui, 2006; Boulakhssaim *et al*., 2006a).

The importance of invertebrate feeders also provides information on the health of habitats which offer an abundant biomass (i) of insect species which represent the food of choice for many passerines and (ii) of aquatic invertebrates that feed waterfowl (Chenchouni, 2007; Martensen *et al*., 2008). Although granivorous species feed on the seeds of several herbaceous and bushy plants located around the lake or in mountain foothills, they can also forage grain fields which sometimes experience high damage, in particular, by sparrows.

Birds occasionally encountered on sites whose phenological and trophic behaviour varies over other sites or surrounding landscapes of eastern Algeria, may testify to the effect of landscape connectivity and interactions between neighbouring sites at multi-continental scales (Roshier *et al*., 2001; Martensen *et al*., 2008; Concepción and Díaz, 2011; Samraoui *et al*., 2011). Recently created man-made ecosystems (dams, reforestation, crops, orchards, *etc*.) has favoured the evolution of trophic categories of bird species, as they contain abundant and permanent food resources (Mwaura, 2010; Concepción and Díaz, 2011).

It is important to mention here that bird-breeding status is the most misunderstood feature of the identified birds' biology. Moreover, apart from reproduction studies on waterbirds in eastern Algeria (Baaziz and Samraoui, 2006; Boulakhssaim *et al*., 2006b; Saheb *et al*., 2006; Samraoui *et al*., 2006; Samraoui and Samraoui, 2007), studies on the breeding of passerine birds, especially in forest and fields, are totally lacking for the region.

Following the IUCN Red List, the identified birds are not, overall, in an alarming situation since nearly all surveyed species (95.4% of all birds) are of least concern (LC). Only two of 108 species (1.8% of all birds) are currently threatened. These are marbled teal (*Marmaronetta angustirostris*) and Egyptian Vulture (*Neophron percnopterus*) which are classified as "Vulnerable" and "Endangered" respectively. These two species are also protected nationally and by other conventions and treaties (Table 1). Our study highlights that local conservation status does not match international protection status, and a better understanding of the local population status would ensure better protection.

4.2 Combined analysis of ecological status

The analysis that combined ecological statutes in pairs indicates that characteristic birds are either invertebrate feeders or polyphagous, but can be also partly winter migrants or resident breeders. Indeed, searching for current or future food resources is often the main cause of bird migration (Blondel, 1969). Dajoz (2006) also indicates that the diet of bird species closely determines its migratory or sedentary phenology. Moreover, wetlands are indeed characterised by the presence of wintering bird species that search there for their food resources (Dajoz, 2006; Samraoui and Samraoui, 2008). In addition, birds of mountain-forest environments and open-habitats are largely resident-breeders with a granivorous or insectivorous diet (Blondel, 1969).

Urban birds include anthropophilic species that are often considered as invasive (Marzluff, 2001) due to their wide ecological and trophic niches, and because of their ability to adapt quickly to changes in habitat (Barnard and Thuiller, 2008). Consequently, little conservation attention is given by bird protection treaties and conventions to this category of species due to their increasing abundance and geographic expansion (AEWA, 2008).

MFA can visualise how each single ecological category could influence the position of a given group of birds according to the heterogeneity of the landscape. Indeed, phenological status within waterbirds tend to distinguish them from non-aquatic species because they are largely migratory (Chenchouni, 2007). Regarding urban birds, it is mainly the trophic categories and classes of occurrence that distinguish this group of birds from others. Furthermore, the trophic status of forest birds makes this group distinctive in relation to urban birds and to birds of open lands. Moreover, this criterion (trophic status) differentiates these three groups from each other. This demonstrates how the heterogeneity of landscapes may influence the partitioning of species in and around Lake Djendli according to food availability/abundance in each habitat and trophic niches of the bird species sharing that habitat. Phenological categories tend to link birds frequenting urban and open areas. These two categories are often affected by seasonal human activities (Beissinger and Osborne, 1982; Marzluff, 2001). Landscape connectivity effects may play a key-role in explaining the similar traits between bird species (Martensen *et al*., 2008; Concepción and Díaz, 2011).

Protection status seems to be the criterion that describes most bird groups except for those from open habitats.

Amongst the latter, passerine birds have often escaped to local and/or regional conservation considerations since: (i) main bird protection efforts are often determined by international treaties for global strategies and perspectives (Bowman, 1999a, 1999b), and (ii) there is a lack of accurate data based on monitoring and mid/long-term surveys for assessing their population dynamics.

With an increasing human impact on natural environments, birds of Salt lake Djendli have various threats such as disturbances and habitat degradation. Understanding ecological trends in bird groups and outlining their interactions is undoubtedly an indispensable tool for scientists and managers of natural environments for effective conservation.

When investigating a complex range of variables for assessing threats and possible areas of conservation action within heterogeneous landscape, this study could help in the understanding of the ecological niches in each type of habitats and with the surrounding environment. Although this study aims to provide knowledge of the bird life of the area, it is also important from the point of view of showing how valuable a single waterbody can be to a wide range of species with different needs. The biggest advantage, of course, of Lake Djendli and its surroundings is the variety of landscape features within such a contained area. It might be expected to exhibit the richness of species in North Africa because of the heterogeneity of this habitat.

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APPENDIX 1: LIST OF ABBREVIATIONS

Phenological categories (PHC)	***Faunal types (FT)***	***Ecological bird groups (EG)***
SM: summer migrant WM: winter migrant R: resident B: breeder [B]: probable breeder	Arc: Arctic C: Cosmopolitan E: European ET: Europeo-turkestanian Eth: Ethiopian H: Holarctic IA: Indo–African M: Mediterranean OW: Old world P: Palearctic PX: Paleoxeric PXM: Palaeo-xero-mountain S: Sarmatic SB: Siberian TM: Turkesto-mediterranean –: Not defined	F: forest birds O: open-habitat birds U: urban birds W: water birds
Trophic categories (TC)		***Protection categories (PRC)***
Cv: carnivorous G: granivorous Inv: invertebrate feeder, Pp: polyphagous Cr: carrion feeder [ ]: principally		IUCN's red list categories: EN: Endangered LC: Least Concern NT: Near Threatened VU: Vulnerable A: AEWA agreement N: Convention of Bonn D: Algerian law L: Convention of Barcelona E: Convention of Berne T: CITES Convention [1]: Appendix 1 [2]: Appendix 2 [3]: Appendix 3
Frequency of occurrence (FO)		
I: occasional species II: rare species III: common species IV: constant species V: abundant species		