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Diversity patterns and seasonal variation of the waterbird community in Mediterranean wetlands of Northeastern Algeria

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ABSTRACT

During two annual cycles (from September 2012 to August 2014), we analysed structural patterns (provided and compared data on diversity metrics) of bird assemblages in coastal wetlands of Northeastern Algeria. Annual and seasonal differences in relative species abundance were analysed from the viewpoint of diversity/dominance. Bird assemblages vary only in the number of species (35 recorded species during the wintering season against 23 during the breeding season). Values of the relative abundance in both seasons were similar, curves in the diversity/dominance diagram were analogous (not significantly different; both $p > 0.05$). Indeed, the seasonal structure of waterbird communities indicates highly dominated assemblages manifesting themselves in reduced species diversity and increased dominance of certain species. Simpson's index was never recorded below 0.50, thus indicating evidently lower evenness. The Eurasian Coot *Fulica atra* and the Little Grebe *Tachybaptus ruficollis* were highly dominant species together accounting for more than 50% of waterbird communities. This atypical organisation (highly dominated structure) is mainly due to anthropogenic or natural stresses. The marked decline in bird species diversity recorded during the study period (approximately two years long) may be of concern to wetland managers as causes and consequences of the increased number of widespread species and factors behind the increasing species diversity are likely to be felt in both seasons.

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Bird assemblages; diversity indices; widespread species; rank/abundance plot; waterfowl monitoring

Introduction

Waterbirds are an important component of the biotic community of wetland ecosystems (Green and Elmberg 2014). Since waterbirds are relatively large species and tend to concentrate in very large numbers, they play key functional roles in many aquatic habitats, acting as major herbivores or predators. Responding rapidly to habitat changes, they are generally recognised as valuable bioindicators of the ecological status of wetland ecosystems (Green and Elmberg 2014). Waterbird community dynamics are complex and are influenced by natural factors, bird life cycle (migration, breeding and moulting), water availability and anthropogenic constraints, such as hunting, water extraction and agricultural activities (Mundava et al. 2012). At the time of global change, most studies have pointed out marked effects of climate change exacerbated by anthropogenic pressures on species and communities (Samraoui et al. 2011). Hence, there is a growing need for the development and application of appropriate conservation strategies (Vasilios 2010), which in turn require quantitative information on dispersed bird populations and population monitoring methods and techniques. Almost all studies into North-African waterbirds were focused on single species, especially on endangered ones, such as the White-headed Duck *Oxyura leucocephala*, the Ferruginous Duck *Aythya nyroca* and the Marbled Duck *Marmaronetta angustirostris* (Boumezbeur 1993; Green and Hamzaoui 2000; Aissaoui, Houhamdi, and Samraoui 2009; Lazli et al. 2011; Lazli, Boumezbeur, and Moali 2012; Chettibi et al. 2013; Meziane, Samraoui, and Samraoui 2014); or on small families such as Ardeidae (Belhadj, Chabi, Chalabi, and Gauthier-Clerc 2007). Meanwhile, monitoring studies analysing yearly patterns of diversity metrics (abundance, frequency, species richness and diversity) of large, multi-species assemblages are currently less documented. In this regard, the main goal of this study was to give an updated ecological assessment of coastal wetlands (Lake Tonga) of northeastern Algeria 30 years after they were given the conservation status [RAMSAR site since 1983 (Boumezbeur 1993)]. In pursuance of this goal, the following tasks were undertaken: (1) to inventory aquatic avifauna and assess its ecological status, (2) to conduct population monitoring and analyse structural patterns (presentation and comparison of data on diversity metrics) of bird assemblages during breeding and wintering seasons.

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Materials and methods

Site description

Lake Tonga (36°51′ N, 8°30′ E) is a freshwater marsh covering an area of 2,600 ha. It is situated in the extreme north-east of Algeria near the Algerian–Tunisian border 3 km from the Mediterranean Sea (Figure 1). Almost 80% of its area is covered by helophytes and aquatic plants dominated by *Scirpus lacustris*, *Typha angustifolia*, *Nymphaea alba*, *Salix atrocinerea* and *Phragmites australis*. It has been designated as a RAMSAR site since 1983 and is part of the El Kala National Park (Wilaya of El-Taref) (Lazli et al. 2011). The climate in the region is typically Mediterranean, characterised by warm to hot, dry summers and mild to cool, wet winters (Boumezbeur 1993).

Bird survey

The bird community was sampled by performing counts of waterbirds from vantage points with unlimited distance (Blondel 1975; Legendre and Legendre 1979). Ten sampling points were chosen for the count of birds because of their relative accessibility and unhindered view. A total of 80% of the study area was scanned. When the number of birds was small, birds were counted individually. When this number exceeded 200, the estimation of the population size was carried out by dividing the flock into small equal parts, counting the number of birds in each part and then finding the sum of the counts (Blondel 1975; Legendre and Legendre 1979). The study area was visited twice a month from September 2012 to August 2014; the total time spent in the field amounting to 288 h, about 6 h being spent per each visit. Bird counts were done using a 20–40 × 60 telescope (Konus Spotting Scope).

Data analysis

For each count session, we calculated species richness, relative abundance and local occurrence status (frequency of occurrence). During each visit, the relative abundance (%) of bird species was estimated according to the following expression: $n/N \times 100$, where n is the count of a particular bird species and N is the total number of individuals counted for all species (during each count session). To describe the frequency of occurrence (f_i) according to Dajoz (2006), we divided the number of surveys during which the species was recorded by the total number of conducted surveys. We also calculated classical diversity indices, such as the Simpson index, D (according to the formula $D = 1 - \{\Sigma n_i\,(n_i - 1)/N\,(N-1)\}$, where n_i is the total number of birds of each individual species; N is the total number of birds of all species), the Shannon diversity index H' (according to the formula $H' = [\Sigma P_i \ln P_i]$, where, H' = Diversity Index; P_i = is the proportion of each species in the sample; and Evenness (E) (Pielou index) (Shannon diversity index (H') divided by the maximum diversity ($\ln S$), S being the total number of species recorded during each visit). The index of evenness shows the number of individuals distributed among species (Okpiliya 2012). When all species in a sample are equally abundant, the value of the evenness index is one, but it decreases towards zero when the relative species abundance becomes uneven (Okpiliya

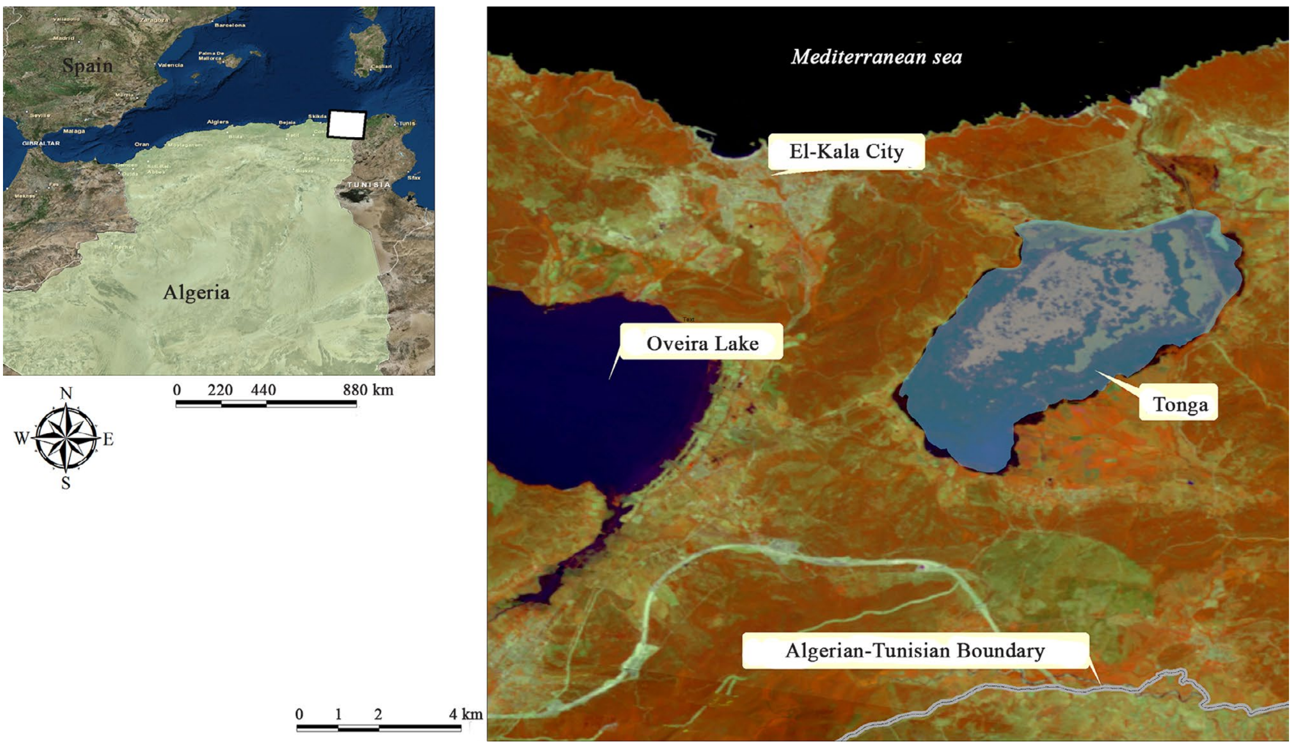

Figure 1. Location of Lake Tonga. (source: ArcMap 10 and Arcgis online open data from Land/Water Boundary 1990/2010 (Owner Esri))

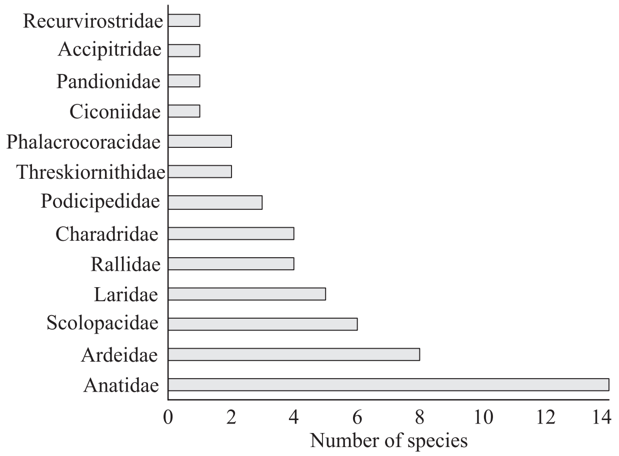

Figure 2. Species richness of aquatic birds belonging to different families during the study period at Lake Tonga.

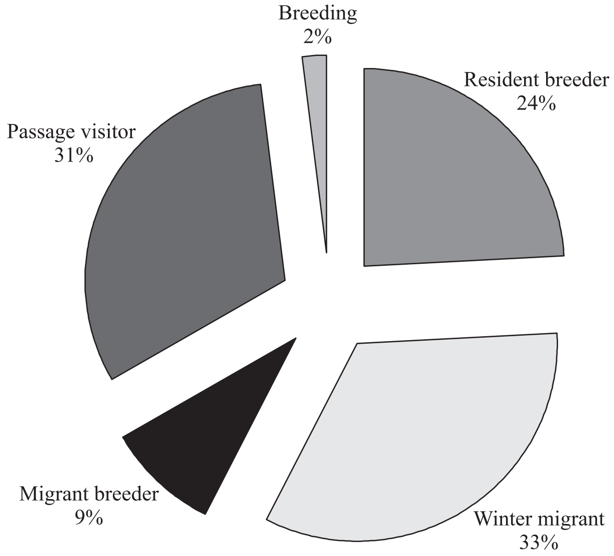

Figure 3. Status of waterbirds at Lake Tonga from 2012 to 2014.

2012). The species abundance distribution was visualized on the rank/abundance plot with species plotted from the most to the least abundant (Magurran 2004; Battisti et al. 2006; Battisti, Malavasi, and Carpaneto 2009). The analysis of variance (One-way ANOVA) was carried out using the SPSS 15.0 version for Windows with $p < 0.05$ as significance level to look at differences in the relative abundance of waterbird species among different seasons. Multivariate analyses such as the correspondence analysis (CA) map were performed using the mean number of individuals per species per month (combining the two years of observation) with XLSTAT.2014.5 to illustrate the temporal assemblage of birds in this area as in Metallaoui and Houhamdi (2010) and Boudraa, Bouslama, and Houhamdi (2014).

Results

Inventory and ecological status of birds

The study revealed that the avian community of this wetland is composed of a total of 52 species belonging to 13 families. The family Anatidae with 14 species was found to be the richest in species number, followed by Ardeidae (8 species), Scolopacidae (6 species), Laridae (5) and Rallidae (4). Ciconiidae, Pandionidea, Accipitridae and Recurvirostridae with only 1 species each (Figure 2). Migratory species accounted for 74% of all the recorded birds. They were represented by winter migrants (33%), summer (migrant) breeders (9%) and passage visitors (32%). Sedentary species constituted only 24% of all the recorded birds (Figure 3).

Based on the percentage of occurrence frequency, 10 waterbird species were defined as omnipresent in the lake area, 13 species were considered to be common and moderately common, 8 to be uncommon and 11 to be rare species (Table 1).

In accordance with the BirdLife Checklist Version_7 (2014), only the White-headed Duck has the Endangered species status, while the Ferruginous Duck and the Black-tailed Godwit *Limosa limosa* are considered to be Near Threatened, and the Marbled Duck to be Vulnerable. The remaining species were assigned the status of 'Least Concern' (Table 1).

As for the relative abundance of individuals (Table 1), the Eurasian Coot *Fulica atra* was highly dominant with 53.9% of the birds recorded throughout the year, followed by several species such as the Little Grebe *Tachybaptus ruficollis* (7.2%), the Cattle Egret *Bubulcus ibis* (7.2%), the Ferruginous Duck (4.7%) and the Gadwall *Anas strepera* (4.4%) with intermediate frequency, while other species had the relative abundance less than 2%.

Quantitative evolution and phenology of avian communities

The average number of birds recorded at the study site (all species including) each month ranged from 2000 to 9000 individuals (Figure 4). We counted over 2000 individuals between September and February, the period during which the average number of species was also the highest ranging from 24 to 30. On the factorial map of CA (Figure 5) containing 69.38% of the information, this period was represented by birds showing a positive correlation with autumn-winter months. In contrast, the second period lasting from March to August exhibited the lowest number of species and individuals (less than 2000) (Figures 4 and 5). Representative of this period were the bird species that are dominant in spring and summer months (Figure 5). Furthermore, this ordination demonstrates the actual temporal succession of this lake occupation by waterbirds. Aquatic birds were divided into four groups based on their dominance period in the annual cycle. Thus, waterbird species that are dominant in autumn and early-winter months (September–December) (Figure 5) formed the first group and those showing a positive correlation with winter months

Table 1. Ecological status and relative abundance of aquatic birds occurring at Lake Tonga from September 2012 to August 2014 (values are given as means of the two years).

Scientific name (abbreviation)	Phenological status[a]	Conservation status[b]	Local status[c]	Annual relative abundance (%)
Fulica atra (EC)	RB	LC	O	53.9
Gallinula chloropus (CM)	RB	LC	O	1.2
Porphyrio porphyrio (PS)	RB	LC	O	0.3
Rallus aquaticus (WR)	AV	LC	E	0.0
Tachybaptus ruficollis (LG)	RB	LC	O	7.2
Podiceps cristatus (GCG)	RB	LC	O	2.5
Podiceps nigricollis (BNG)	WV	LC	UC	0.9
Bubulcus ibis (CE)	RB	LC	O	7.2
Casmerodius albus (GE)	RB	LC	O	0.3
Ardea cinerea (GH)	RB	LC	O	0.3
Ardea purpurea (PH)	MB	LC	MC	0.1
Egretta garzetta (LE)	RB	LC	O	2.1
Ixobrychus minutus (LB)	MB	LC	R	<0.01
Ardeola ralloides (SH)	MB	LC	MC	0.9
Nycticorax nycticorax (BNH)	MB	LC	MC	0.3
Anser anser (GG)	AV	LC	R	<0.01
Tadorna tadorna (CS)	AV	LC	E	<0.01
Anas platyrhynchos (ML)	RB/WV	LC	C	0.4
Anas penelope (EW)	WV	LC	R	0.1
Anas strepera (GD)	WV	LC	MC	4.4
Anas clypeata (NS)	WV	LC	MC	2.3
Anas acuta (NP)	AV	LC	E	<0.01
Oxyura leucocephala (WHD)	RB/WV	EN	MC	0.5
Aythya ferina (CP)	WV	LC	MC	0.2
Aythya fuligula (TD)	WV	LC	UC	0.1
Aythya nyroca (FD)	RB/WV	NT	O	4.7
Anas crecca (ET)	WV	LC	UC	2.0
Anas querquedula (GA)	AV	LC	R	<0.01
Marmaronetta angustirostris (MD)	AV	VU	E	<0.01
Chroicocephalus genei (SBG)	WV	LC	MC	0.7
Larus michahellis (YLG)	WV	NR	UC	0.5
Chroicocephalus ridibundus (BHG)	WV	LC	MC	0.5
Chlidonias hybrida (WT)	MB	LC	MC	2.5
Gelochelidon nilotica (GBT)	WV	LC	UC	0.1
Tringa ochropus (GS)	AV	LC	E	<0.01
Tringa stagnatilis (MS)	PV	LC	R	<0.01
Tringa totanus (CR)	AV	LC	R	<0.01
Limosa limosa (BTG)	AV	NT	R	0.2
Gallinago gallinago (CS)	PV	LC	R	0.5
Lymnocryptes minimus (JS)	AV	LC	E	<0.01
Charadrius hiaticula (CRP)	AV	LC	E	<0.01
Charadrius alexandrinus (KP)	AV	LC	E	<0.01
Charadrius dubius (LRP)	PV	LC	R	<0.01
Vanellus vanellus (NL)	WV	LC	R	<0.01
Phalacrocorax carbo (GC)	WV	LC	UC	<0.01
Phalacrocorax aristotelis (ES)	WV	LC	UC	1.6
Plegadis falcinellus (GI)	RB	LC	C	0.7
Platalea leucorodia (ES)	AV	LC	E	<0.01
Ciconia ciconia (WS)	PV	LC	R	0.1
Circus aeruginosus (WMH)	RB(NCB)	LC	C	<0.01
Pandion haliaetus (WO)	WV	LC	UC	0.2
Himantopus himantopus (BWS)	NCB	LC	C	<0.01

Notes:
[a]RB = Resident breeder; NCB = No confirmed breeding; MB = Migrant breeder; WV = Winter migrant and PV = Passage visitor;
[b]Bird Life Checklist Version_7 (2014)
CR = Critically; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern;
[c]Species Omnipresent (O) (fi = 100%); Constant or Common (C) (75% < fi < 100%); Moderately Common (MC) (50% < fi < 75%); Uncommon (UC) (25% < fi < 50%); Rare (R) (5% < fi < 25%) and exceptional (E) (5%).

(January and February) fell into the second. The third group comprised species that are characteristic of spring and early summer months (March, April, May and June), and the fourth group included birds that are dominant in summer months, i.e. in July and August.

Diversity patterns

Species richness and other metrics of diversity are given in Table 2. Bird assemblages vary greatly in the total number of species, the maximum of 35 species being recorded in the wintering season compared to the minimum of 23 species recorded in the breeding period. Variation in other diversity metrics was low (H′; D and J). Hence, only the number of species fluctuated between seasons in both yearly cycles of the study period, which is visualized in the rank/relative abundance diagram, where the curve for wintering seasons shows a steep slope compared to that for the breeding seasons (Figure 6). Furthermore, the trend and shape of the diagram lines revealed a noteworthy community organisation during wintering and breeding seasons characterised by the

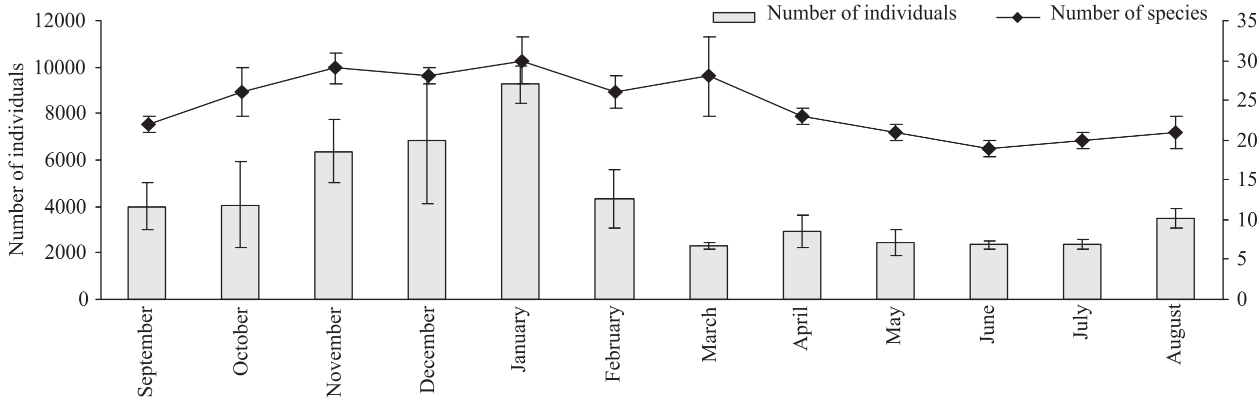

Figure 4. Average monthly count (±SE) of individuals and number of species at Lake Tonga between September 2012 and August 2014.

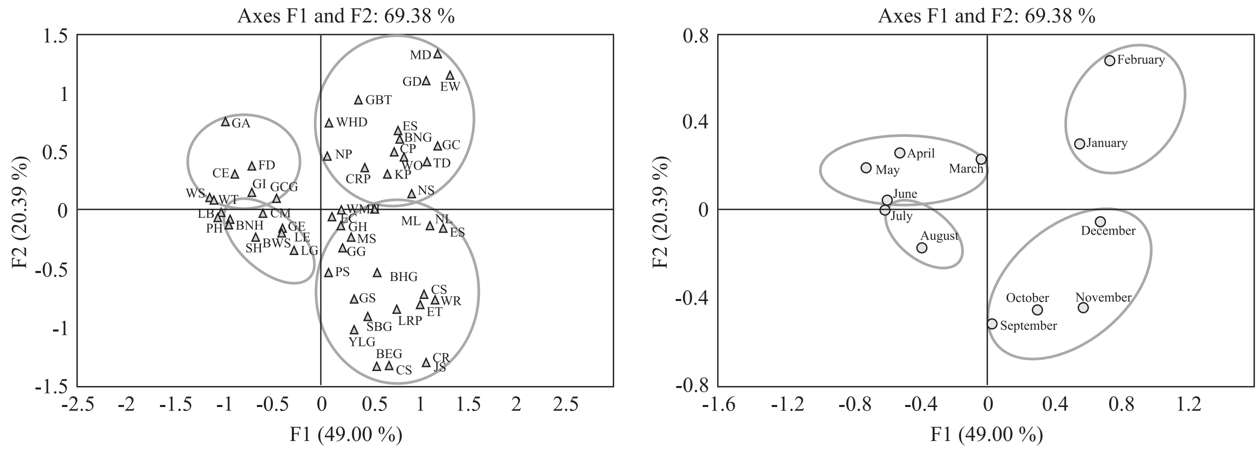

Figure 5. Correspondence analysis map (CA) of waterfowl species abundance at Lake Tonga from September 2012 to August 2014: 12 mean months × 52 species. (Abbreviations in Table 1).

Table 2. Univariate metrics of waterbird diversity at Lake Tonga grouped into two seasons: wintering season (from December to February) and breeding season (from May to August) (n = number of visits).

	2012/2013		2013/2014	
Parameter	Wintering ($n=6$)	Breeding ($n=8$)	Wintering ($n=6$)	Breeding ($n=8$)
Species richness	34	23	35	23
Shannon diversity index (H′)	1.57	1.89	1.52	1.87
Simpson index (D)	0.65	0.73	0.53	0.74
Equitability or evenness (E or J)	0.45	0.6	0.42	0.6

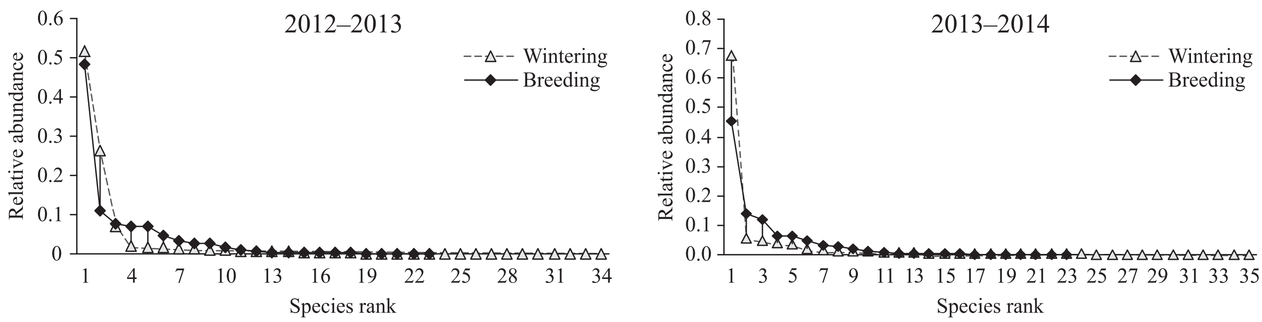

Figure 6. Species rank/relative abundance diagram (Whittaker plots) of breeding and wintering bird assemblages at Lake Tonga during two yearly cycles of the study period.

following patterns: one dominant species (the Eurasian Coot, rank 1 on Whittaker plots), a few species with intermediate occurrence frequency ranging from 0.1 to 0.3 and, finally, many rare species with the relative abundance lower than 0.1 (Figure 6). In the course of the two yearly cycles of the study period, the curves showed great similarity in slope level. All of them had a very steep slope without significant differences in relative abundance distributions of wintering and breeding curves (One-way ANOVA: $F = 0.18$; df = 57.69 and $p = 0.9$). Hence, communities shared a similar structural organisation pattern in different seasons: one dominant species (Eurasian Coot) with the higher proportion of dominance (53.9% of the birds recorded throughout the year) increasing Simpson's index, which has never been recorded below 0.50, thus indicating an evidently lower evenness (Table 2).

Discussion

Although the study covered a limited area, the surveyed avifauna was found to be diverse. It was represented by more than half of the waterbird species described in Algerian wetlands [99 species identified by Samraoui and Samraoui (2008) and 97 species by Samraoui et al. (2011)]. This biodiversity assessment indicates that since its designation as a RAMSAR site in 1983 (Boumezbeur 1993), the discussed area has retained regional importance for the aquatic avifauna (resident and migrant species). It is important to point out that our study has revealed that the phenological status of some species at this lake has changed. Some of the species that were not reported as breeding in previous waterbird studies in eastern Algeria (Skinner and Smart 1984; Stevenson, Skinner, and Smart 1988; Samraoui and Samraoui 2008; Samraoui et al. 2011), e.g. the Mallard *Anas platyrhynchos*, the Black-winged Stilt *Himantopus himantopus,* the Grey Heron *Ardea cinerea*, the Great Egret *Casmerodius albus* and the Western Marsh Harrier *Circus aeruginosus*, were found to be breeding. We observed several behavioural patterns symptomatic of the breeding status, i.e. particular aggression (intra- and inter-specific interactions) and carrying of nest building material (pers. obs.). However, only the Marbled Duck and the Common Pochard *Aythya ferina* were observed during wintering periods.

Two univariate metrics: waterbird abundance and species richness showed seasonal changes among-years with the highest values recorded in autumn-winter months when from September a large number of migratory birds such as Ducks, Shorebirds and Coots start arriving in the area (see Figure 5). The gathering and abundance of numerous Duck species (Anatidae) and Coots are conditioned by the diversity of the existing vegetation. Almost 80% of the lake area is covered by various helophytes and hydrophytes, such as *Oryza sativa*, *Echinochloa* sp., *Scirpus maritimus* and *Potamogeton pusillus* (Boumezbeur 1993; Lazli et al. 2011), which are the main source of food and a major element of their habitats (Brochet, Mouronval, and Aubry 2012). In contrast, these metrics reached their lowest values in spring-summer months due to the departure of all wintering and staging migrant birds that return to their breeding sites in the Palearctic and sub-Saharan Africa (Samraoui et al. 2011). So the lake becomes virtually empty and only sedentary and breeding migrant species such as Herons (Little Egret *Egretta garzetta*, Squacco Heron *Ardeola ralloides*, Cattle Egret and Grey Heron); Ibises (Glossy Ibis *Plegadis falcinellus*); Grebes (Little Grebe and Great Crested Grebe *Podiceps cristatus*) and Common Moorhen *Gallinula chloropus* (see Figure 5) remain in the lake area. The dense vegetation and the rich production of submerged aquatic macrophytes create ideal nesting conditions for these birds: all of them nest amidst tall vegetation, which covers more than 30% of the study area, providing shelter from aerial predation (Belhadj, Chabi, Chalabi, Yves et al. 2007; Nedjah et al. 2010; Rouibi et al. 2013; Samraoui, Alfarhan, and Samraoui 2013).The composition of waterbird community (total abundance and species richness) in autumn-winter months showed less similarity with that in other months, which is, perhaps, due to higher mobility of birds during this period in response to environmental stressors (e.g. weather; changes in water level and in food resources) and others factors such as bird phenology and differences in the timing of arrival and departure of different species (Kershaw and Cranswick 2003; Carvalho et al. 2013).

As to the remaining univariate metrics of diversity (relative abundance, evenness and diversity indices), we did not observe any significant differences among them. Low values of diversity indices (Shannon and evenness) and high values of Simpson index were due to the high abundance of the Eurasian Coot, a monogamous species, highly gregarious in these wintering areas and very territorial during the breeding season (Zitouni et al. 2014). Additionally, Coot numbers are more influenced by the availability of suitable habitat (food resources) than by the distance to human settlements (Kamburova and Michev 2003). This bird was omnipresent even in the study area (in open water zone, vegetation zone, shore zone and riparian area) and was observed to compete with other species for food resources. The indices (Shannon and evenness) obtained during this study were much lower than those recorded in similar coastal wetlands of North-eastern Algeria during the wintering period, Garaet Hadj-Tahar ($H' = 3.5$ and $E = 0.7$) (Metallaoui and Houhamdi 2010), Lake Beni-Belaid ($H' = 3.58$ and $E = 0.7$) and El-Kennar marsh ($H' = 3.5$ and $E = 0.7$) (Mayache 2008).

The shape and slope of a diversity/dominance curve contain information on the community structure (Battisti, Luiselli, and Frank 2009; Battisti, Malavasi, and Carpaneto 2009). The shape and slope of the diversity/dominance curve vary with human-induced changes in the relative abundance, richness and evenness of the species (Battisti, Luiselli, and Frank 2009; Battisti, Malavasi, and Carpaneto 2009). Specifically, curves with shallower slopes indicate higher evenness and diversity than curves with steeper ones (Magurran 2004). Our curves showed a steeper slope during both seasons pointing out atypical conditions: (1) one dominant species (Eurasian Coot, rank 1 in Whittaker plots); (2) a small group of species with intermediate occurrence frequency; and (3) many rare species. According to Frontier (1976); Battisti, Malavasi, and Carpaneto (2009); Battisti, Luiselli, and Frank (2009), structural patterns indicate that the ecosystem has suffered an anthropogenic or natural stress or it has reached the ageing state. Indeed, it is well known that disturbed (anthropogenic or natural stress) habitats are usually dominated by a very small number of species compared to undisturbed sites (Frontier 1976; Magurran 2004; Battisti, Luiselli, and Frank 2009). Illegal hunting, fishing, edge building and wetland eutrophication due to agriculture and domestic activities were the main anthropogenic factors recorded during the study period (pers. obs.).

On the whole, our results demonstrated that Coots and Little Grebes (both of which always accounted for more than 50% of all the individuals) made up the bulk of bird communities at Lake Tonga in all seasons. Ducks, especially Dabbling ducks, are abundant in winter, and Herons and some diving ducks such as the Ferruginous Duck are abundant in summer. Therefore, since its designation as a RAMSAR site in 1983 (Boumezbeur 1993), Lake Tonga has retained its regional importance for migrant and resident waterbirds. However, it may be of concern that species diversity has reduced. The lake may lose its resilience in the face of the changing environment due to the decreasing species diversity and species homogenisation.

The marked decline in species diversity highlighted in this study as well as seasonal persistence of dominant assemblages should be of serious concern to wetland managers. The data derived from this study should be supplemented by those from further research aimed at explaining the causes and consequences of increased numbers of widespread species over a broader span of time. What is more, factors behind increasing species richness and diversity are likely to operate both in breeding and wintering seasons. This can be of help in the implementation of conservation and management programs in the wetland biodiversity aimed to reach more equilibrated waterbird assemblages in this and other coastal wetlands of the Mediterranean region as well as in similar areas around the world.

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