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Avifauna diversity and phenology in a Ramsar site: Lake Tonga (Northeastern Algeria)

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Abstract

Avifauna diversity and phenology in a Ramsar site: Lake Tonga (Northeastern Algeria). Between 2013 and 2016 we conducted an inventory and characterization of aquatic avifauna at Lake Tonga, a Ramsar site. We identified 61 species belonging to 17 families, dominated by Anatidae with 14 species. The inventoried species have different phenological status. Some are known for their regular wintering and some for their summer concentrations, while others are residents year round. Population analysis showed the presence of endangered species such as *Oxyura leucocephala, Marmaronetta angustirostris and Aythya nyroca,* that are protected by national and/or international laws. Bird counts showed monthly variations in total abundance and richness, peaking during winter. Peak numbers were recorded in February and January, reflecting gatherings to prepare for prenuptial migration. Analysis of diversity and equitability indices indicated that maximum values were generally recorded during the pre– and post–nuptial passages (H'= 3.51 and E = 0.72). Our results reflect the importance of this wetland as a wintering site and nesting site for numerous waterbirds species.

Checklist dataset published through GBIF (Doi: 10.15470/vwujvf)

Key words: Lake Tonga, Water birds, Inventory, Count, Ecological indices, Spatial distribution

Resumen

Diversidad y fenología de la avifauna en un sitio Ramsar: el lago Tonga (noreste de Argelia). Se estudiaron el inventario y la caracterización de la avifauna acuática del lago Tonga, un sitio Ramsar, entre 2013 y 2016. Se identificaron 61 especies pertenecientes a 17 familias dominadas por Anatidae, con 14 especies. Las especies inventariadas presentan diferentes estados fenológicos, siendo conocidas algunas de ellas por su invernada regular, como los patos, o sus concentraciones estivales, mientras que otras están presentes todo el año. El análisis poblacional muestra la presencia de especies en peligro de extinción protegidas por leyes nacionales y/o internacionales como *Oxyura leucocephala*, *Marmaronetta angustirostris* o *Aythya nyroca*, entre otras. Los recuentos de aves mostraron cambios mensuales en la abundancia y riqueza totales, alcanzando los valores máximos durante el

periodo de invernada. De hecho, dichos valores máximos se registraron en los meses de febrero y enero del periodo de estudio, reflejando los agrupamientos para la preparación de la migración prenupcial. El análisis de los índices de diversidad y equitatividad indicó que sus valores máximos se registraron generalmente durante los pasos prenupciales y posnupciales (H' = 3,51 y E = 0,72). Los resultados obtenidos durante el presente estudio muestran la importancia de este humedal como lugar de invernada y nidificación de numerosas especies de aves acuáticas.

Lista de datos publicada en GBIF (Doi: 10.15470/vwujvf)

Palabras clave: Lago Tonga, Aves acuáticas, Inventario, Recuento, Índices ecológicos, Distribución espacial

Resum

Diversitat i fenologia de l'avifauna en un lloc de Ramsar: el llac Tonga (nord–est d'Algèria). Es van estudiar l'inventari i la caracterització de l'avifauna aquàtica del llac Tonga, un lloc Ramsar, entre el 2013 i el 2016. Es van identificar 61 espècies pertanyents a 17 famílies dominades per Anatidae, amb 14 espècies. Les espècies inventariades presenten diferents estats fenològics i algunes són conegudes per la hivernada regular, com els ànecs, o per les concentracions estivals, mentre que d'altres hi són presents durant tot l'any. L'anàlisi poblacional mostra la presència d'espècies en perill d'extinció protegides per lleis nacionals i/o internacionals com ara *Oxyura leucocephala*, *Marmaronetta angustirostris* o *Aythya nyroca*, entre d'altres. Els recomptes d'ocells van mostrar canvis mensuals en l'abundància i la riquesa totals que van assolir els valors màxims durant el període d'hivernada. De fet, aquests valors màxims es van registrar els mesos de febrer i gener del període d'estudi i reflecteixen les reunions per a la preparació de la migració prenupcial. L'anàlisi dels índexs de diversitat i equitabilitat va indicar que els valors màxims es van registrar generalment durant els passos prenupcials i postnupcials (H' = 3,51 i E = 0,72). Els resultats obtinguts durant l'estudi mostren la importància d'aquest aiguamoll com a lloc d'hivernada i nidificació de nombroses espècies d'ocells aquàtics.

Llista de dades publicada a GBIF (Doi: 10.15470/vwujvf)

Paraules clau: Llac Tonga, Aus aquàtiques, Inventari, Recompte, Índexs ecològics, Distribució espacial

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Introduction

North Africa is home to a great diversity of wetlands that provide wintering and stopover sites for Palearctic migratory birds. Within this vast group, and among the countries of the Western Palearctic, Algeria occupies a privileged place for a large number of migratory

bird species (Bensaci et al., 2013). Its most predominant wetlands are located on the main migration route of the East Atlantic corridor and play an important relay role between the Mediterranean Sea and the Sahara Desert, the two obstacles for migratory fauna (Lazli et al., 2018). This region in the northeast of Algeria comprises 72 wetland complexes.

The El Kala wetland complex, which consists of a set of exceptionally large sites, stands out for the diversity of its fauna and flora (Stevenson et al., 1988). Its wetlands regularly receive a remarkable diversity of birds due to the favorable conditions during wintering and nesting seasons (Ledant et al., 1981; Isemann and Moali, 2000).

Lake Tonga, one of the most famous wetlands within this complex, has been the subject of much research, mainly relating to the ecology and reproductive biology of many waterbirds species (Boumezbeur, 1993; Lazli et al., 2011a, 2011b, 2012, 2014; Athamnia et al., 2015; Gherib and Lazli, 2016, 2017; Menasria and Lazli, 2017; Rizi et al., 2019; Mecif et al., 2020). However, documentation of the avifaunistic diversity of this Ramsar site is incomplete and the inventories require review (Elafri et al., 2016; Loucif et al., 2020).

The present study was conducted at Lake Tonga (north–east Algeria), a wintering and nesting site for various species of water birds. Our aim was to diagnose the state of health of this Ramsar site as in recent years it has been subjected to several degradation factors –such as poaching, disturbance, and unregulated pumping– that could be responsible for the loss of biodiversity and quality of its habitats. Research is needed to improve our knowledge of the lake's richness, to monitor the status and phenology of species, and to determine the trends of its avian populations. With this objective in mind, we aimed to create an inventory and quantify the aquatic avifauna. We analyzed their structure by calculating various ecological indices that allowed us to understand the wintering strategy and typology, distinguish the status of the birds, and explain their abundance and diversity throughout their annual cycle. These datasets could contribute to the development of a management and preservation strategy for the biodiversity and habitats of this protected area.

Material and methods

Study area

The study was carried out at Lake Tonga, a Ramsar site and wilderness area in El Kala National Park (annex 1 and checklist dataset published through GBIF: Doi: 10.15470/vwujvf). Located in the extreme Northeast of Algeria, this freshwater marsh covers an area of 2,600 ha. It occupies a large coastal depression and communicates with the sea by means of an artificial channel (fig. 1, 2). Eighty percent of the park is covered in a mosaic consisting of emergent vegetation composed of helophyte (notably bulrushes, phragmites and typhas), with a large open water area largely occupied by the white water lily *Nymphaea alba*. This lily is becoming increasingly invasive, especially during the nesting period of the water birds (Lazli, 2011). Lake Tonga is considered the most important wintering and nesting site in North Africa for a multitude of species, such as the white–headed duck *Oxyura leucocephala*, the ferruginous duck *Aythya nyroca*, the purple swamp hen *Porphyrio porphyrio*, the great crested grebe *Podiceps cristatus*, and the glossy ibis *Plegadis falcinellus* (Lazli et al., 2011a, 2011b, 2012; Gherib and Lazli, 2016, 2017; Menasria and Lazli, 2017; Mecif et al., 2020).

Regarding halieutic diversity, four species have been identified: *Barbus callensis*, *Anguilla anguilla*, *Gambusia affinis* and *Pseudophoxinus callensis* (Benmetir et al., 2020). The lake also hosts 22 Odonata species and several species of reptiles and amphibians (Lazli, 2011; Gherib, 2018).

Despite its international importance and the essential role it plays in maintaining high biodiversity, this wetland is under increasing pressure from issues such as poaching, eutrophication, urbanization, and recreational summer activities, all of which increase the difficulties of carrying out local conservation actions (Lazli et al., 2014; Gherib and Lazli, 2017; Menasria and Lazli, 2017; Mecif et al., 2020).

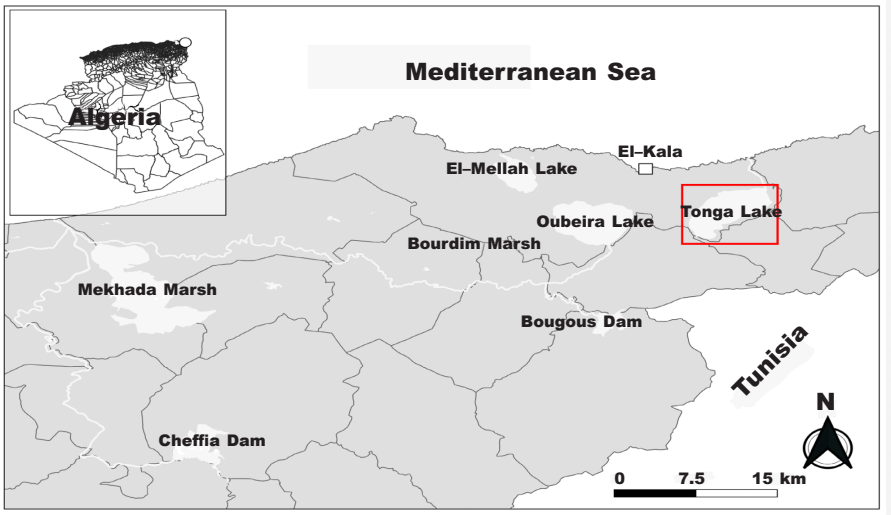

Fig. 1. Location of the study site, Lake Tonga, in Northeastern Algeria.

Fig. 1. Localización geográfica del lugar de estudio, el lago Tonga, en el noreste de Argelia.

Fig. 2. View of Lake Tonga.

Fig. 2. Vista del lago Tonga.

Inventory and count of waterbirds

Fieldwork was conducted twice monthly, from September 2013 until August 2016 using a KONUS–SPOT telescope (20 x 60) and a pair of binoculars (10 x 50). We conducted individual counts when the total number of birds was fewer than 200, and made a visual estimate when the number of birds was greater than 200. In this case, we divided the flock into small equal parts and counted the number of birds in each part. This is the most commonly used method in winter counts because the number of individuals and the observation distances are often large (Lamotte and Bourlière, 1969; Blondel, 1975; Tamisier and Dehorter, 1999).

To avoid disturbing the birds, observations were made from the banks, from around the lake, and from natural promontories. We also used the two watchtowers of 'Meizila' and 'Oued El Hout' as observation points.

Analysis of avian population structure

To characterize the aquatic avifauna population, we determined several ecological indices, namely: (i) total abundance, which consisted of a count of the total number of birds that visited Lake Tonga on a specific date (Baziz, 2012). (ii) The frequency of occurrence (*fi*) according to Dajoz in Elafri et al. (2016), by dividing the number of surveys during which the species was recorded by the total number of conducted surveys. (iii) Specific richness, which is the number of bird species observed on a specific date; this also allows determination and characterisation of the periods when bird numbers are richest and poorest (Blondel, 1969; Legendre and Legendre, 1979; Lindström and Piersma, 1993). (iv) Simpson index, *D* (according to the formula: $D = 1 - \{\Sigma ni\ (ni - 1)/N\ (N - 1)\}$, where *ni* is the total number of birds of each individual species; *N* is the total number of birds of all species. (v) Shannon and Weaver diversity index H' (according to the formula $H' = [\Sigma Pi\ ln\ Pi\ ]$, where Pi = is the proportion of each species in the sample (Daget, 1979); H' value varies from 0 when the community is composed of only one species to 4.5 or 5 bits for the most diverse communities; the lowest values, less than 1.5 bits, are associated with communities dominated by 01 or a few species (Faurie et al., 2003). (vi) As well as the Equitability index or Evenness (E) according to the formula H'/H' max, where (H′) is the Shannon diversity index and $H'_{max} = lnS$, is the maximum diversity and S is the specific richness recorded during each visit; when E is close to 1, the diversity observed reflects an abundance distribution close to equilibrium (Legendre and Legendre, 1979). Conversely, when E is close to 0, the observed diversity is low and illustrates a highly hierarchical distribution of abundance, which reflects a simple, restrictive environment in which few factors structure the settlement (Gherib, 2018).

Spatio–temporal distribution

In parallel with the monitoring of numbers, we visually noted the locations of waterbirds on grid maps, including all species regularly frequenting the lake and its immediate surroundings, whether wintering or nesting. The location of birds across the water body will later allow us to establish a distribution map of bird families observed throughout the wetland.

Statistical data analysis

Statistical analyses were carried out using Minitab 17 Ink. Because the data followed a normal distribution, we used the analyses of variance (one–way ANOVA) to determine whether there was a difference in ecological indices between the three years. The significance level used was $p < 0.05$.

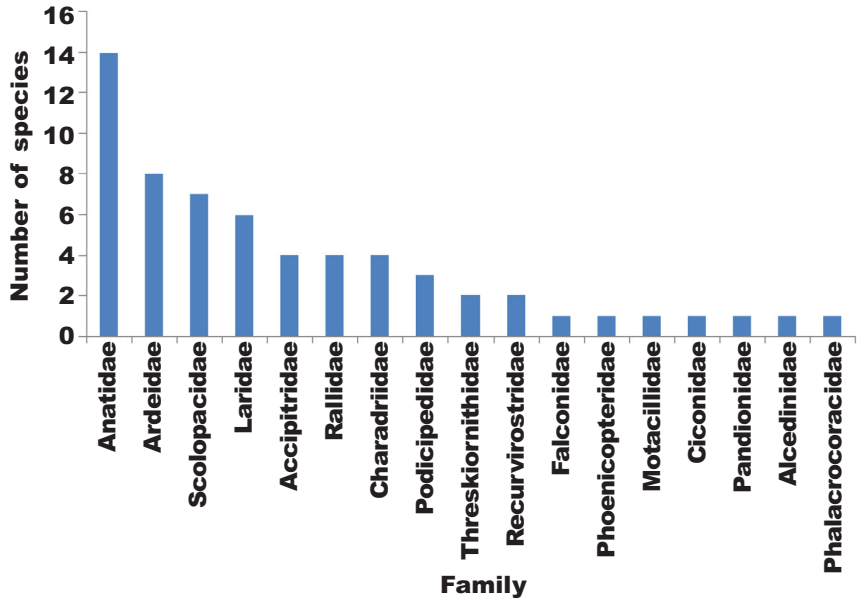

Fig. 3. Composition of waterbirds in Lake Tonga (2013–2016).

Fig. 3. Composición de las aves acuáticas en el lago Tonga (2013–2016).

Results

Population composition

Fieldwork allowed us to identify 61 species belonging to 17 families and 44 genera (annexes 1, 2; fig. 3). This number includes all species regularly present in the lake and its immediate surroundings throughout the year. The most highly represented family was Anatidae with 14 species, followed by Ardeidae, Scolopacidae, and Larids, with 8, 7, and 6 species, respectively. There were four species of Accipitridae, Rallidae and Charadriidae. Other families were represented by one to three species (fig. 3).

Ecological status of species

Species observed at Lake Tonga during the study period exhibited different phenological status: winterers, sedentary breeders, passing migrants, sedentary non–breeders, and summer breeders (annex 2, fig. 4).

Wintering birds represented 38 % of the species surveyed, and breeders accounted for 39 %, including sedentary birds and summer breeders. Approximately 15 % of the species were reported as passing visitors and were using Lake Tonga as a migratory stopover. Finally, 8 % of the species were sedentary non–breeders (fig. 4).

Based on the frequency of occurrence, 4 waterbird species were defined as omnipresent in the lake, 13 species as common, 11 as moderately common, 14 as uncommon, 12 as rare species, and 7 as exceptional (annex 2).

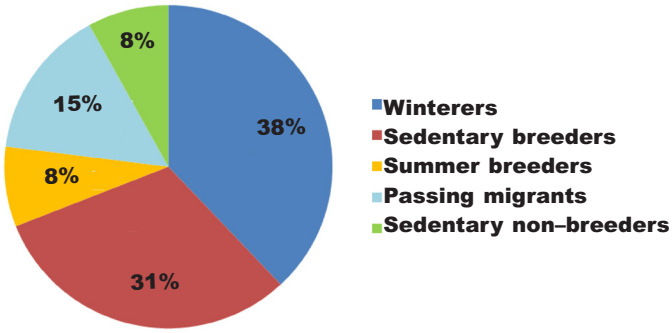

Fig. 4. Phenological status of waterbird species observed in Lake Tonga.

Fig. 4. Estatus fenológico de las especies de aves acuáticas encontradas en el lago Tonga.

Six of the species recorded are listed on the IUCN Red List (Isenmann and Moali, 2000; Birdlife International, 2017, 2019), representing almost 10 % of the settlement; those protected by Algerian legislation account for over 47 %, and AEWA, CMS and CITES listed species account for almost 43 % of the surveyed waterbirds (annex 2).

Analysis of settlement structure

Total abundance

During our fieldwork, there were considerable fluctuations in the avian population at Lake Tonga. Maximum numbers were recorded in February 2014 with sightings of 12,297 individuals, in January 2015 with 21,403 and in January 2016 with 27,815 individuals (fig. 5). The difference between bird numbers for the three years of the study was not significant (F = 1.99; p = 0.153).

Numbers in the avian population at Lake Tonga were highest from September to mid–March (> 5,000 – >12,000), corresponding to the highest specific richness recorded (fig. 5, 6). In contrast, abundance and species richness were lowest in the second half of March to the end of August (fig. 5, 6).

Calculation of the relative abundance of individuals for 2013–2016 showed that the common coot *Fulica atra* was the most dominant bird, representing 29 % of the birds counted throughout this period, followed by the Eurasian wigeon *Anas penelope* (22 %), the ferruginous duck *Aythya nyroca* (10 %), the common teal *Anas crecca* (6.8 %) and the Northern shoveler *Spatula clypeata* (5.7 %). Other species had a relative abundance of less than 2 % (annex 2).

To display the relative abundance of species and to visualize species richness and species equitability, we used a rank abundance curve (Whittaker plots) (fig. 7). The curves showed great similarity in slope for the three years of the study with a constant finding during the wintering and breeding seasons indicating the predominance of one species occupying rank 1 in the Whittaker diagram. Some of the following species are rare and had a low relative abundance (fig. 7). Thus, we noted a steep gradient in winter seasons, showing a high Simpson index (> 0.5) and low equitability (≤ 0.5) as the high–ranking spe-

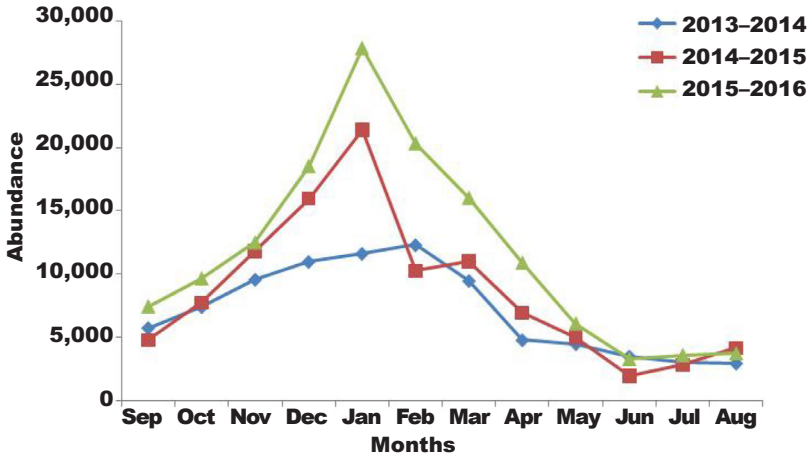

Fig. 5. Changes in waterbird abundance in Lake Tonga during the study period.

Fig. 5. Variación de la abundancia de aves acuáticas en el lago Tonga durante el periodo de estudio.

cies have much higher abundance. Coots, for example were notably dominant during the two first annual cycles, and the Eurasian was the dominant species (rank 1 on Whittaker plots) in the annual cycle third year in the third year of the study. In breeding seasons, we recorded a shallow gradient equity (> 0.5) and here the ferruginous duck was the dominant species (rank 1 on Whittaker plots) in all three annual cycles, followed by coot, whiskered tern, and garganey.

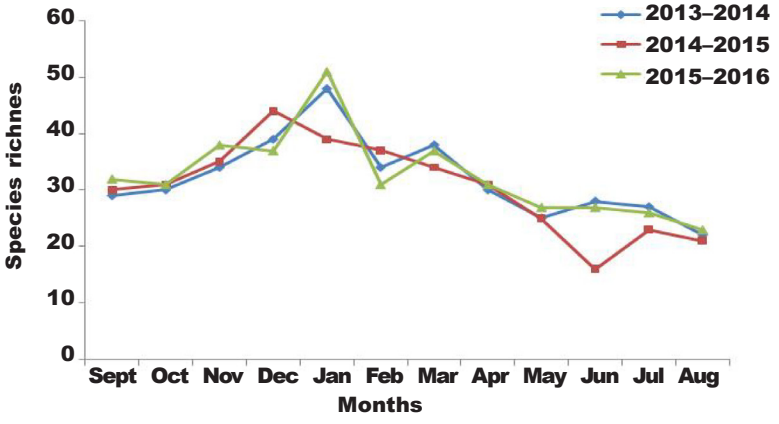

Fig. 6. Changes in waterbird species richness in Lake Tonga during the study period.

Fig. 6. Variación de la riqueza específica de aves acuáticas en el lago Tonga durante el periodo de studio.

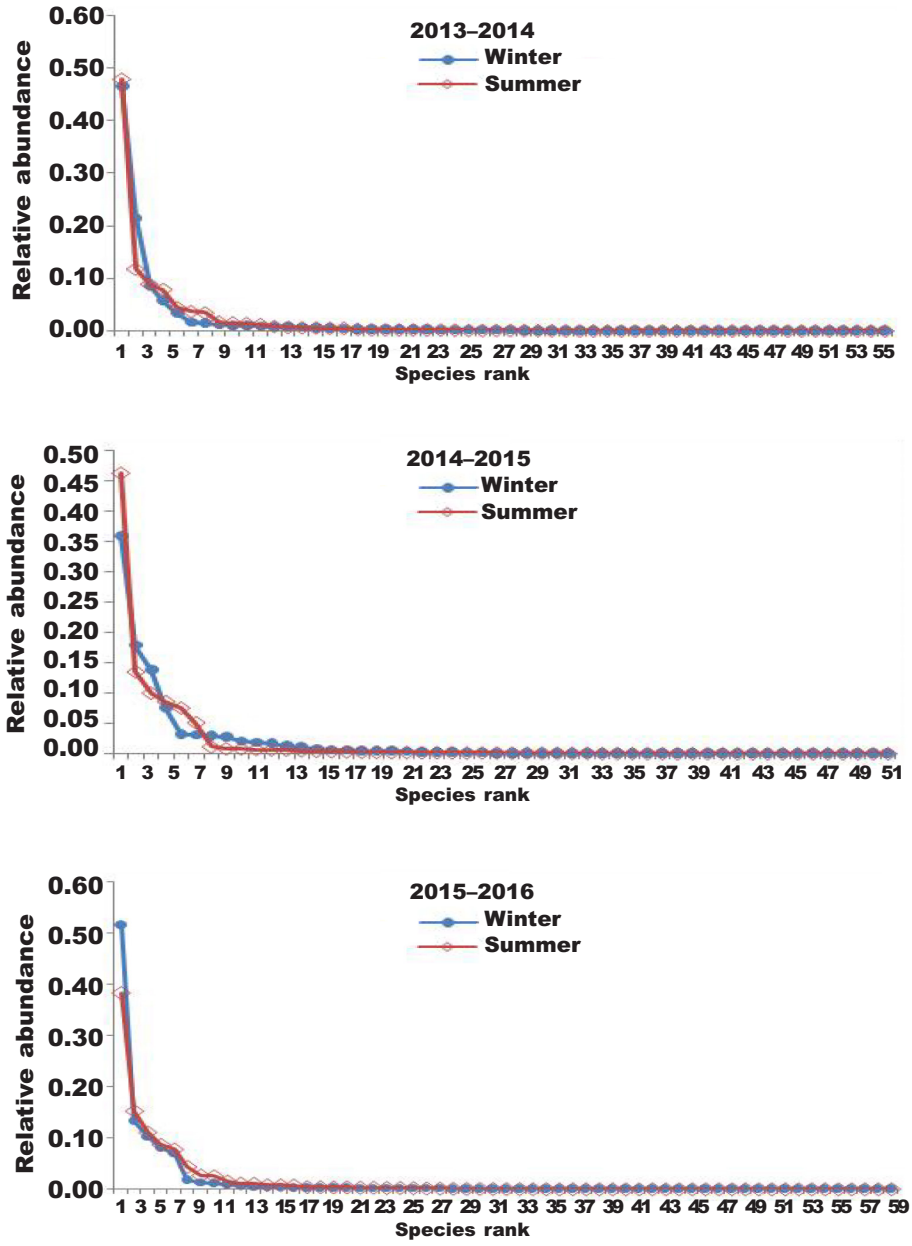

Fig. 7. Species rank/relative abundance diagram (Whittaker plots) of breeding and wintering bird communities at Lake Tonga during the three annual cycles studied.

Fig. 7. Diagrama de rango de especies/abundancia relativa (gráficos de Whittaker) de las comunidades de aves reproductoras e invernantes en el lago Tonga durante los tres ciclos anuales estudiados.

Species richness

Sixty–one species of waterbirds were recorded at Lake Tonga (annex 1). In general, species richness was highest during the wintering season. The maximum number of species was observed in January 2014 (48 species). In December 2014 the maximum number was 44 species and in January 2016 it was 51 species (fig. 6). Towards the end of the wintering season, species richness decreased to values between 16 and 28 species in May and August, corresponding to the nesting period (fig. 6). No significant difference was recorded for species richness between the three study (F = 0.22; p = 0.802).

Analysis of the data collected during the wintering and nesting seasons indicated a richness of 40 waterbirds species for the 3 winters. In comparison, data for the 3 nesting seasons were lower and varied between 21 and 26 species (annex 3).

Diversity (H') and equitability (E) indices

The two ecological indices reflecting the equilibrium of the populations showed similar patterns. In general, the maximum values of the two indexes were recorded in the second study year, and particularly in September 2014: H' = 3.51 and E = 0.72, corresponding to a balanced abundance distribution (fig. 8).

During the three study years, Shannon diversity, Simpson indexes, and equitability varied in wintering and breeding seasons according to avifauna richness and abundance at Lake Tonga (annex 3), but generally showed a diversified settlement.

Throughout our study, Shannon diversity index exhibited values exceeding 2 bits and Simpson index showed values above 0.6. The equitability index showed values on average ≥ 0.5 across the 3 years (annex 3).

In January 2014, the maximum value of the index was 3.04 bits corresponding to a high species richness of 48 for 11,617 individuals. During the 2014–2015 season, the maximum was recorded in September (3.51 bits), corresponding to a richness of 26 species for a population of 4,778 individuals. Throughout the third season, the highest value was recorded in September, with 3.47 bits, reflecting a richness of 32 species corresponding to 7,402 waterbirds (fig. 8A).

The equitability index varied depending on the number of each species. Maximum values were recorded at the beginning of the three wintering seasons with 0.68, 0.72 and 0.69, recorded respectively in September. Minimum values (0.43, 0.44 and 0.45) were noted in January and February 2016 (fig. 8B). Other maximum values were recorded during July and August when the avian population is mainly dominated by breeding species (such as coot, Anatidae, and Ardeidae).

Spatio–temporal distribution of avian population in Lake Tonga

During the study period, Anatidae occupied the centre of the lake and western and southern parts. Rallidae and Podicipedidae were observed throughout the waterbody together with other bird species. Ardeidae were noted in the northern, western and southern parts of the lake, but a few individuals were also observed in the centre of the lake where they were associated with Anatidae, Rallidae and Podicipedidae. Laridae and shorebirds were mainly observed in the northern, western and southern parts of the wetland but a few were also seen in the centre (fig. 9).

Discussion

The data collected during this study at Lake Tonga revealed high avifauna diversity. Sixty–one waterbird species were recorded, representing about 62 % of the species identified

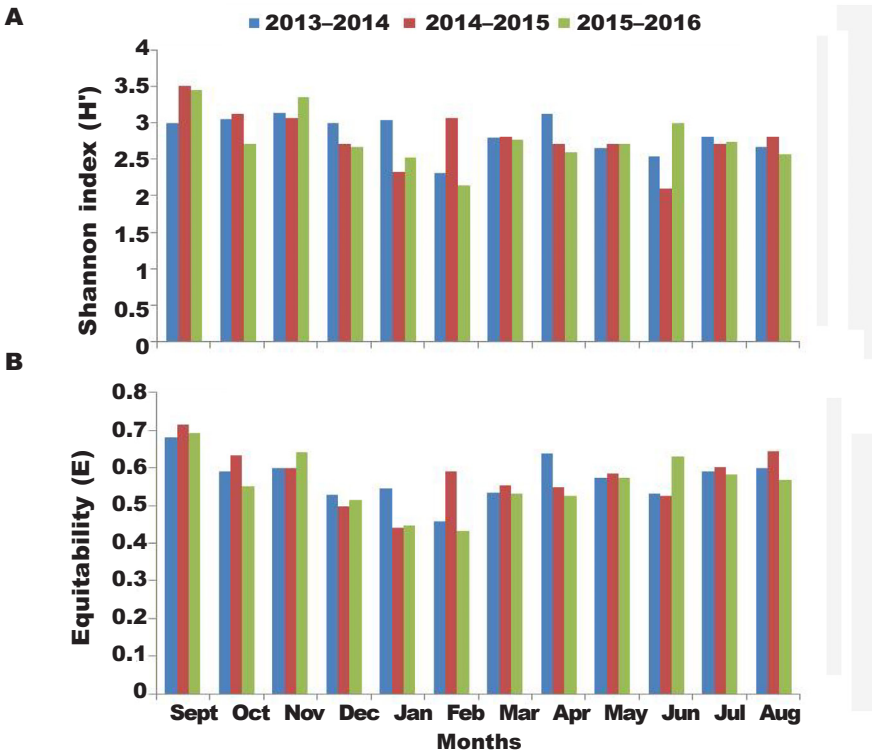

Fig. 8. Changes in ecological indices of waterbirds in Lake Tonga during the study period: A, Shannon–Weaver index; B, evenness.

Fig. 8. Variación de los índices ecológicos de las aves acuáticas en el lago Tonga durante el periodo de estudio: A, índice de Shanon–Weaver; B, equidad.

in Algerian wetlands by Samraoui et al. (2011). At the same site, Elafri et al. (2016) and Loucif et al. (2020) described a rich avian population with 52 and 35 species, respectively. This difference in species number could be due to poor vision because of the unfavorable climatic conditions during wintering seasons, to a low sampling effort, or to the study covering a limited area. Various studies carried out on the aquatic avifauna in northeastern Algeria have reported a census of a large number of species. Houhamdi (2002) recorded 46 species at Lake des Oiseaux, located about 50 km from the study site. At Garaet Hadj–Tahar, an ecological study of the wintering aquatic avifauna showed the presence of 47 species belonging to 15 families (Metlaoui and Houhamdi, 2010). At the Boussedra marsh, Boudraa et al. (2014) identified 53 species belonging to 15 families. Lazli et al. (2018) listed 52 species at Lake Oubeira belonging to 16 families throughout three wintering seasons. Not far away at the Mekhada marsh, Bediaf et al. (2020) counted 53 species between 2015 and 2017). In concordance with our results, various fieldworks in Algerian wetlands, and notably at Lake Tonga, reported the high representatation of Anatidae compared to other waterbird families (Metlaoui and Houhamdi, 2010; Baaziz et al., 2011; Boudraa et al., 2014; Guellati et al., 2014; Guergueb et al., 2014; Elafri et al., 2016; Lazli et al., 2018; Bediaf et al., 2020).

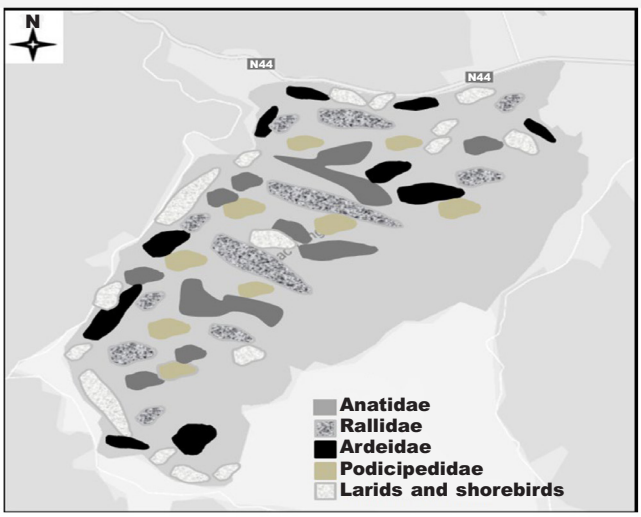

Fig. 9. Spatial occupation of waterbirds at Lake Tonga during the study period.

Fig. 9. Ocupación espacial de las aves acuáticas en el lago Tonga durante el periodo de estudio.

During this study, we recorded various phenological statuses of the listed species: wintering, sedentary (breeding or non–breeding), summering, migratory. Among these, 15 % of the species were considered to be passing visitors using Lake Tonga as a migratory stopover, such as the greater flamingo, the common shelduck, the garganey, species that winter or breed in the High Plains (Hauts plateaux) of eastern Algeria and the Sahara (Saheb et al., 2006; Boulekhssaim et al., 2006a, 2006b; Samraoui et al., 2006; Baaziz et al., 2011; Seddik et al., 2012; Bouzid et al., 2018, 2019); 8 % of the species were sedentary non–breeding. These results denote the importance of this wetland as a nesting site for a rich and diverse avifauna and as a wintering area for many migratory species, probably due to the diversity of habitats and the availability of trophic resources (Elafri et al., 2016; Menasria and Lazli, 2017). Several studies have reported various statuses of the species inventoried across the country's wetlands such as the Oued Righ depression, the wetland complex of Souk Ahras, Chott El Hodna, Boussedra marshes, Lake Oubeira and Mekhada marsh (Bensaci et al., 2013; Boudraa et al., 2014; Guellati et al., 2014; Guergueb et al., 2014; Lazli et al., 2018; Bediaf et al., 2020; Bouali et al., 2021).

It is important to note that the status of some species has yet to be monitored, and even confirmed in some cases, as their presence has been reported even outside the periods we observed during our surveys. This is the case for the gadwall *Mareca strepera*, the common pochard *Aythya ferina* and the common snipe *Gallinago gallinago,* observed during summer, and for the black–necked grebe *Podiceps nigricollis,* considered by some observers as wintering in Lake Tonga (PNEK, 2011). The black–winged stilt *Himantopus himantopus* and the black–headed gull *Larus ridibundus* are also noted as breeding species, although no sign of this was found at the study site during our study. Several questions therefore remain to be clarified. Elafri et al. (2016) reported personal observations of the symptomatic behavior of breeding status of a few waterbirds, such as the black–winged stilt *Himantopus himantopus*, the grey heron *Ardea cinerea*, and the great egret.

Also of note is the absence of certain species observed on the site during previous work or monitoring campaigns by the forestry department, such as the lesser spotted eagle *Clanga pomarina* (Isenmann and Moali, 2005), the booted eagle *Hieraaetus pennatus*, the Egyptian vulture *Neophron percnopterus*, and the blacked–winged kite *Elanus caeruleus*. These birds were observed in the southern part of Lake Tonga (Oued El Hout). Their absence in the present study could be attributed to the fact that they were occasional during the counts or that the sampling effort was insufficient. It could also be due to unfavourable climatic conditions, especially in winter (heavy rain, wind, low luminosity), which would have greatly diminished observations.

The analysis of the monthly variation in bird numbers at Lake Tonga showed that the wintering season in general began in September when abundance varied between 4,778 and 7,402 individuals during the study period. The species observed were sedentary, mainly being Podicipedidae (great crested grebe *Podiceps cristatus*, little grebe *Tachybaptus ruficollis*), Anatidae (mallard *Anas platyrhynchos,* white–headed duck *Oxyura leucocephala,* ferruginous duck *Aythya nyroca*), Rallidae (coot *Fulica atra*, common moorhen *Gallinula chloropus,*…) and Ardeidae (little egret *Egretta garzetta*, cattle egret *Bubulcus ibis*, grey heron *Ardea cinerea*). In early October, the number started to increase gradually, reflecting the arrival of early winterers, mostly Anatidae (gadwall *Mareca strepera* and Northern pintail *Anas acuta)* and Recurvirostridae (pied avocet *Recurvirostra avosetta*, black–winged stilt *Himantopus himantopus*) and Charadriidae (Northern lapwing *Vanellus vanellus*, little ringed plover *Charadrius dubius)*.

Between November and early December, numbers continued to increase, reflecting the arrival of numerous other wintering birds such as coots, Eurasian wigeon *Mareca penelope*, common teal *Anas crecca*, and common pochard *Aythya ferina*. These gatherings during January reflect the preparation for the pre–breeding migration and have also been reported by various studies conducted in Algerian wetlands (Metlaoui and Houhamdi, 2010; Seddik et al., 2012; Bensaci et al., 2013; Boudraa et al., 2014; Elafri et al., 2016; Halassi et al., 2016; Lazli et al., 2018; Bediaf et al., 2020). Peak numbers were observed in February 2014 and January 2015 and 2016. After these dates, the total number of birds gradually declined, reflecting the departure of wintering and migratory species towards the breeding grounds in the Palearctic and sub–Saharan Africa (Elafri et al., 2016; Loucif et al., 2020). In April, only sedentary and summer breeding species –such as little grebes, great crested grebes, little egrets, squacco herons, mallards, ferruginous ducks, coots, and common moorheen– remained on the lake. This observation was also reported by Elafri et al. (2016).

In contrast, species richness increased progressively as of September with the arrive of wintering birds such as species of Anatidae (tufted duck *Aythya fuligula,* greylag goose *Anser anser,* common shelduck *Tadorna tadorna,*...), Phalacrocoracidae (great cormoran *Phalacrocorax carbo*), and certain passing species, such as the common snipe *Gallinago gallinago*, spotted redshank *Tringa erythropus*, the black–necked grebe *Podiceps nigricollis*, and the Eurasian spoonbill *Platalea leucorodia*. The number of species and abundance reached a maximum December or January, depending on the year. This species richness remained similar in March, but numbers decreased thereafter, reflecting the departure of wintering species and the start of the nesting season with the arrival of breeding summer birds such as the whiskered tern *Chlidonias hybrida* and the white stork *Ciconia ciconia*, and a few migratory species, notably the greater flamingo, passing through. In effect, throughout the year Lake Tonga provides rich and varied habitats for several waterbird species. Such areas consist of dense vegetation scattered across the water body, composed of a variety of floating plants such as *Salix pedicellata, Scirpus lacustris, Typha* spp., emergent vegetation largely *Phragmites australis* and shallow riparian areas with mixed emergent vegetation (*Scirpus lacustris, Sparganium erectum*) (Elafri et al., 2016; Menasria and Lazli, 2017). This high amount of dense vegetation provides better conditions for nesting and shelter from predators, notably birds of prey (Rouibi et al., 2013; Gherib and Lazli, 2016, 2017; Elafri et al., 2016).

This variation in the pattern of waterbird abundance and richness between wintering and breeding seasons in Lake Tonga was also described by Elafri et al. (2016) and Loucif et al. (2020), but numbers were considerably lower than those reported in this study.

Various studies have reported the evolution of species richness across Algerian wetlands, such as that at Garaet Hadj Tahar (Skikda, north–east Algeria) (Metlaoui and Houhamdi, 2010) or at Boussedra and Mekhada marshes (Boudraa et al., 2014; Bediaf et al., 2020). In other humid sites in the country, highest richness of species has been reported in November and February (Ledant et al., 1981; Metallaoui and Houhamdi, 2008, 2010; Seddik et al., 2010, 2012). These two months correspond to the pre– and post–nuptial assembly and passage periods for many waterbirds in North Africa (Lazli et al., 2018).

Values of diversity indices recorded throughout the study period varied. One particular pattern was that Shannon and equitability indexes were highest during autumn, displaying a perfect balance throughout this period and corresponding to the arrival of several wintering and migrating birds (such as tufted duck, greylag goose, marbled teal, common shelduck, pied avocet, and Northern lapwing). Values obtained during this autumnal season were close to those of studies in other coastal wetlands such as Garaet Hadj Tahar (Metallaoui and Houhamdi, 2010), Lake Beni–Belaid and El Kennar Marsh (Mayache, 2008) but higher compared to those of Elafri et al. (2016) and Loucif et al. (2020) in the same site. Through wintering period Shannon diversity index and Equitability were lower comparared with Simpson index which was due to the high abundance of coot in the two first wintering seasons as reported by Elafri et al. (2016) and the Eurasian wigeon in the third one. These two species are recorded as the most abundant waterbirds in the Algerian wetlands (Elafri et al., 2016; Lazli et al., 2018; Bediaf et al., 2020; Chabou et al., 2020; Loucif et al., 2020). Diversity indexes (Shannon and Simpson indices) were lower during the spring–summer period, corresponding to a decrease in richness and abundance due to the departure of wintering and migrant waterbirds. However, equitability values were higher or lower depending on the presence of sedentary species (such as the ferruginous duck, white–headed duck, mallard, coot, great crested grebe) and summer nesters (garganey spatula querquedula, black–winged stilt, whiskered tern).

Monitoring the spatial distribution of waterbirds in Lake Tonga showed that occupation of the water body during the study period depended mainly on the biology and ecology of the species surveyed, but also on requirements such as food availability, safety, and quietness. Podicipedidae were observed in all areas of the lake but showed a preference for the central, deeper parts, which are covered, in particular during the breeding period, with stands of varied vegetation. These patches of vegetation vary in size. They provide shelter, quietness, nesting sites, and important food resources, for water birds such as the little grebe and the great crested grebe. At Sebkha de Bazer–Sakra, Baaziz et al. (2011) observed great crested grebes in the deepest sectors. Gherib and Lazli (2017) and Mecif et al. (2020) also reported this species selected these locations Lake Tonga during the breeding season.

Throughout our fieldwork, Rallidae frequented all parts of Lake Tonga, showing a preference for proximity to emergent vegetation during the breeding season. This type of emplacement has also been reported in the wetlands of the semi–arid highlands (Hauts plateau) in northeast Algeria (Samraoui and Samraoui, 2007; Samraoui et al., 2013; Meniaia et al., 2014; Gherib and Lazli, 2016).

Anatidae and coots, the most abundant species observed during the study period, were observed mainly in the central and southern parts of the lake. Some species frequented the deepest areas, such as the white–headed duck, the ferruginous duck, the common pochard, and the tufted duck, while others frequented shallow areas, such as the Northern pintail and teals, and areas near banks, such as the Northern shoveler and mallard. The choice of these environments is especially justified by the availability and ease of access to food, such as macro–invertebrates, amphibians, seeds, and varied aquatic vegetation.

Anatidae dispersal behaviour has been mentioned in other studies in wetlands of the region (Menasria and Lazli, 2017; Lazli et al., 2018; Bediaf et al., 2020).

Shorebirds and waders, such as Northern lapwing, great white egret, glossy ibis, and white stork, generally occupied the wet meadows and banks of the lake, but some were also observed in the wooded banks or in the high, dense vegetation located inside the lake or in the nearby mobile islets, such as black–crowned night heron, squacco heron, Schrenck's bittern, and the little egret.

Larids, such as the European herring gull, lesser black–backed gull, and common tern, were generally gathered in colonies in the western part of the lake. Other species also observed near the western banks of the lake were the black–headed gull and the yellow–legged gull. Lake Tonga appears to be a wetland that serves as a resting place and feeding ground for this species in this region.

Finally, raptors were often seen flying over the lake, on perches inside the lake, or on residential fence poles on the outskirts of Lake Tonga, awaiting prey, such as fish, small birds, snakes, and small rodents). Such raptors included Western osprey, long–legged buzzard, and the Western marsh harrier. This latter raptor nests on the lake in the large tufts of dense and inaccessible vegetation –mainly consisting of *Typha*, Bulrush and reeds. For these raptor species, Lake Tonga is a prime feeding ground as its many habitats harbor a rich and varied biodiversity.

Conclusion

In this study of the avian population of Lake Tonga we documented 61 species belonging to 17 families and 44 genera. The most highly represented family was the Anatidae. Phenological status varied and included winterers, sedentary breeders, passing visitors, sedentary non–breeders and summer resident breeders. Among the species recorded, six are on the IUCN Red List and others are protected by Algerian legislation or listed in international conventions and agreements (AEWA, CITES, CMS).

Monitoring of bird population dynamics in Lake Tonga showed that total abundance and species richness peaked during the wintering period, with maximum numbers recorded in January and February, reflecting gatherings in preparation for pre–breeding migration. The decline in numbers from March onwards reflects the departure of wintering and migratory species to the breeding grounds. At the end of the wintering season, only sedentary or summer breeding species remain on the lake.

Our results show the importance of this wetland as a wintering area for many migratory species and as a nesting site for many other bird species. The high value of this wetland is also demonstrated by the presence of certain species that benefit from national and international legal protection. However, despite its protected status and the important role it plays for the biodiversity it hosts, Lake Tonga faces many unfavourable factors, such as poaching, the development of recreational activities during the breeding season, and the erosion of its catchment area which is gradually contributing to its silting.

Data collected in this study needs to be completed in order to improve our knowledge of the status of certain species yet to be monitored or confirmed because their presence has been reported outside the periods when we observed them during our fieldwork. Conservation efforts are needed for the protection and sustainable management of this ecosystem. In particular, there is a need to monitor the water level in winter so as to preserve wintering areas from flooding, and the lake's drawbridge require repair. In addition, agropastoral installations are needed to avoid the pressure exerted by cattle on the herbaceous vegetation surrounding the lake as many species of birds, such as certain Ardeidae, Charadriidae, and Scolopacidae, were regularly observed on the banks and wet meadows of the lake, either at rest or in search of food.

These findings will serve as a database for future research and contribute to the development of an adequate management plan for the safeguard and preservation of the biodiversity and habitats of this particular ecosystem.

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Annex 1. Checklist of species and wintering chronology of waterbirds at Lake Tonga (2013–2016). Checklist dataset published through GBIF (Doi: 10.15470/vwujvf)

Anexo 1. Lista de especies y cronología de invernada de las aves acuáticas en el lago Tonga (2013–2016). Lista de especies publicada en GBIF (Doi: 10.15470/vwujvf)

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Max.	Min.
Podiceps nigricollis	X	X	X	X	X	X	X	X					51	2
Tachybaptus ruficollis	X	X	X	X	X	X	X	X	X	X	X	X	278	7
Podiceps cristatus	X	X	X	X	X	X	X	X	X	X	X	X	53	2
Phalacrocorax carbo	X	X	X	X	X	X	X	X	X	X	X		290	1
Egretta garzetta	X	X	X	X	X	X	X	X	X	X	X	X	146	5
Nycticorax nycticorax				X	X	X	X		X		X		15	1
Ixobrychus minutus				X			X	X	X	X	X		6	1
Ardeola ralloides	X	X	X	X	X	X	X	X	X	X	X	X	95	1
Ardea alba	X	X	X	X	X	X	X	X	X	X	X	X	68	1
Bubulcus ibis	X	X	X	X	X	X	X	X	X	X	X	X	194	15
Ardea purpurea	X		X	X	X			X	X	X	X	X	7	1
Ardea cinerea	X	X	X	X	X	X	X	X	X	X	X	X	48	1
Ciconia ciconia							X	X	X	X	X		36	1
Plegadis falcinellus	X	X	X	X	X	X	X	X	X	X	X	X	90	6
Platalea leucorodia		X			X		X						84	15
Phoenicopterus roseus					X								2	0
Anas strepera	X	X	X	X	X	X	X	X					2,700	137
Anas platyrhynchos	X	X	X	X	X	X	X	X	X	X		X	840	2
Anas acuta		X	X	X	X	X	X	X	X				1,650	7
Anas penelope	X	X	X	X	X	X	X	X	X				15,000	28
Spatula clypeata	X	X	X	X	X	X	X	X					2,900	89
Oxyura leucocephala	X	X	X	X	X	X	X	X	X	X	X	X	278	2
Aythya ferina	X	X	X	X	X	X	X	X	X	X		X	640	4
Aythya fuligula				X	X	X	X	X					198	10
Aythya nyroca	X	X	X	X	X	X	X	X	X	X	X	X	1,947	3
Anser anser		X	X	X	X	X	X	X					92	1
Anas querquedula	X								X	X	X	X	1,200	12
Anas crecca	X	X	X	X	X	X	X	X					3,800	85
Marmaronetta angustirostris	X												71	52
Tadorna tadorna	X	X	X	X	X	X	X						39	1
Circus aeruginosus	X	X	X	X	X	X	X	X	X	X	X	X	10	1
Buteo rufinus		X		X	X		X						2	1
Accipiter nisus					X								1	0

Annex 1. (Cont.)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Max.	Min.
Milvus migrans	X		X	X	X	X	X	X	X	X	X	X	18	1
Pandion haliaetus		X	X	X	X	X	X	X	X	X	X		9	1
Fulica atra	X	X	X	X	X	X	X	X	X	X	X	X	12,154	252
Gallinula chloropus	X	X	X	X	X	X	X	X	X	X	X	X	1,003	16
Rallus aquaticus					X								2	0
Porphyrio porphyrio	X	X	X	X	X	X	X	X	X	X	X	X	420	2
Recurvirostra avosetta	X	X	X	X		X							18	2
Himantopus himantopus	X		X		X								43	5
Charadrius hiaticula				X			X	X					108	1
Charadrius dubius		X	X	X			X						260	1
Pluvialis apricaria					X								74	0
Vanellus vanellus	X	X	X	X	X	X	X	X	X				280	5
Limosa limosa					X								11	0
Calidris minuta	X	X	X	X	X	X	X						61	7
Calidris alpina	X		X	X	X	X	X						93	3
Gallinago gallinago				X	X	X	X						11	2
Tringa nebularia			X	X	X		X	X		X	X		31	3
Tringa erythropus		X	X	X	X	X							51	7
Numenius phaeopus												X	17	2
Motacilla alba	X	X	X	X	X	X	X						14	3
Alcedo atthis				X	X	X	X	X	X				5	1
Larus argentatus	X												5	11
Larus fuscus					X								12	4
Larus michahellis					X	X	X	X	X	X	X		221	2
Chlidonias hybrida	X				X	X	X			X	X	X	890	8
Chroicocephalus ridibundus					X				X				220	11
Sterna hirundo					X								49	25
Falco tinnunculus			X										1	0

Annex 2. Ecological status and relative abundance of waterbirds occurring at Lake Tonga (2013–2016) values are given as means of the three years): phenological status (PM, passing migrant; W, wintering; SB, sedentary breeding; SNB, sedentary non–breeding; SN, summer nesting; Ed, endangered; Vul, vulnerable; NT, near–threatened). Local status (O, species omnipresent, fi = 100 %; C, constant or common, 75 % < fi < 100 %; MC, moderately common, 50 % < fi < 75 %; UC, uncommon, 25 % < fi < 50 %; R, rare, 5 % < fi < 25 %; E, exceptional, < 5 %. Conservation status (A.L, Algerian legislation).

Anexo 2. Estado ecológico y abundancia relativa de las aves acuáticas presentes en el lago Tonga (2013–2016) los valores se dan como medias de los tres años: estado fenológico (PM, migrante de paso; W, invernante; SB, sedentaria reproductora; SNB, sedentaria no reproductora; SN, nidificante de verano; Ed, en peligro; Vul., vulnerable; NT, casi amenazada). Estado local (O, especies omnipresentes, fi = 100 %; C, constantes o comunes, 75 % < fi < 100 %; MC, moderadamente comunes, 50 % < fi < 75 %; UC, poco comunes, 25 % < fi < 50 %; R, raras, 5 % < fi < 25 %; E, excepcionales, < 5 %. Estado de conservación (A.L, legislación argelina).

	Phenological status	Local status	Conservation status	Annual relative abundance (%)
Podiceps nigricollis	PM	MC	AEWA	0.1
Tachybaptus ruficollis	SB	C	AEWA	0.9
Podiceps cristatus	SB	C	AEWA	0.2
Phalacrocorax carbo	W	C	AEWA / A.L	0.5
Egretta garzetta	SB	O	AEWA / A.L	0.6
Nycticorax nycticorax	SN	UC	AEWA / A.L	0.02
Ixobrychus minutus	SN	R	AEWA/ CMS (A.II) / A.L	< 0.01
Ardeola ralloides	SB	C	AEWA / A.L	0.2
Ardea alba	SNB	C	CMS (A.II) / A.L	0.1
Bubulcus ibis	SB	O	AEWA	1.4
Ardea purpurea	SN	MC	AEWA / CMS (A.II) / A.L	0.02
Ardea cinerea	SB	O	AEWA	0.1
Ciconia ciconia	SN	UC	AEWA / CMS (A.II) / A.L	0.05
Plegadis falcinellus	SB	MC	AEWA / CMS (A.II) / A.L	0.3
Platalea leucorodia	PM	R	CITES (A.II) / AEWA / CMS (A.II) / A.L	0.07
Phoenicopterus roseus	PM	E	CITES (A.II) / CMS (A.II) / A.L	< 0.01
Mareca strepera	W	MC	AEWA / CMS (A.II)	8.5
Anas platyrhynchos	SB	C	AEWA / CMS (A.II)	1.5
Anas acuta	W	MC	AEWA / CMS (A.II)	1.7
Anas penelope	W	C	AEWA / CMS (A.II)	22
Spatula clypeata	SB	MC	AEWA / CMS (A.II)	5.7
Oxyura leucocephala	SB	C	UICN (End.) / CITES (A.II) / AEWA / CMS (A.I, A.II) / A.L	0.8
Aythya ferina	W	MC	UICN (Vul.) / AEWA / CMS (A.II)	1.1
Aythya fuligula	W	UC	AEWA / CMS (A.II)	0.4
Aythya nyroca	SB	O	UICN (Q.m.) / AEWA / CMS (A.I, A.II) / A.L	10
Anser anser	W	UC	AEWA / CMS (A.II) / A.L	0.2
Anas querquedula	PM	UC	AEWA / CMS (A.II)	1.5
Anas crecca	W	MC	AEWA / CMS (A.II)	6.8

Annex 2. (Comt.)

	Phenological status	Local status	Conservation status	Annual relative abundance (%)
Marmaronetta angustirostris	PM	R	UICN (Vul.) / AEWA / CMS (A.I) / A.L	0.04
Tadorna tadorna	PM	UC	AEWA / CMS (A.II) / A.L	0.1
Circus aeruginosus	SB	MC	CMS (A.II) / A.L	0.03
Buteo rufinus	SNB	R	CMS (A.II) / A.L	< 0.01
Accipiter nisus	SNB	E	CMS (A.II) / A.L	< 0.01
Milvus migrans	SB	C	CMS (A.II) / A.L	0.04
Pandion haliaetus	SB	MC	CMS (A.II) / A.L	0.03
Fulica atra	SB	C	AEWA / CMS (A.II)	29
Gallinula chloropus	SB	C	AEWA	1.8
Rallus aquaticus	SB	E	AEWA / A.L	< 0.01
Porphyrio porphyrio	SB	C	A.L	0.3
Recurvirostra avosetta	W	R	AEWA / CMS (A.II) / A.L	0.02
Himantopus himantopus	SNB	UC	AEWA / CMS (A.II) / A.L	0.1
Charadrius hiaticula	W/PM	UC	AEWA / CMS (A.II) / A.L	0.05
Charadrius dubius	W	UC	AEWA / CMS (A.II)	0.3
Pluvialis apricaria	PM	E	AEWA / CMS (A.II)	0.02
Vanellus vanellus	W	C	UICN (Q.m.) / AEWA/ CMS (A.II)	0.7
Limosa limosa	W	E	UICN (Q.m.) / AEWA/ CMS (A.II)	< 0.01
Calidris minuta	W	UC	AEWA / CMS (A.II)	0.1
Calidris alpina	W	UC	AEWA / CMS (A.II)	0.1
Gallinago gallinago	W	E	AEWA / CMS (A.II)	< 0.01
Tringa nebularia	W	UC	AEWA / CMS (A.II)	0.1
Tringa erythropus	W	R	AEWA / CMS (A.II)	0.07
Numenius phaeopus	PM	R	AEWA / CMS (A.II)	0.01
Motacilla alba	W	UC	–	0.02
Alcedo atthis	SB	R	A.L	< 0.01
Larus argentatus	W	R	AEWA	0.01
Larus fuscus	W	R	AEWA	0.01
Larus michahellis	W	MC	–	0.2
Chlidonias hybrida	SN	UC	AEWA / A.L	1.6
Chroicocephalus ridibundus	W	R	–	0.06
Sterna hirundo	W	R	AEWA / CMS (A.II)	0.03
Falco tinnunculus	SNB	E	CITES (A.II) / CMS (A.II) / A.L	< 0.01

Annex 3. Assessment of the diversity of waterbirds at Lake Tonga over the seasons studied: wintering season (December to February) and breeding season (May to August): n, number of visits.

Anexo 3. Evaluación de la diversidad de aves acuáticas en el lago Tonga a lo largo de las tres temporadas estudiadas: temporada de invernada (diciembre a febrero) y temporada de reproducción (mayo a agosto): n, número de visitas.

	2013/2014		**2014/2015**		**2014/2015**	
Parameter	**Wintering (n = 6)**	**Breeding (n = 8)**	**Wintering (n = 6)**	**Breeding (n = 8)**	**Wintering (n = 6)**	**Breeding (n = 8)**
Species richness	40	26	40	21	40	26
Shannon diversity index (H′)	2.79	2.68	2.71	2.59	2.45	2.76
Simpson index	0.72	0.74	0.74	0.81	0.69	0.8
Equitability (E)	0.51	0.57	0.51	0.59	0.46	0.59