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Wetland Habitat Suitability and Diversity for Migratory and Resident Birds in the Ramsar Site Lake Burllus, Egypt

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ABSTRACT

Burllus wetland is one of the ideal places for overwintering migratory and resident birds in Egypt. This study aimed to assess the bird diversity and habitat suitability at one of the important bird areas (IBAs) and Ramsar sites at the Burllus Lake in northern Egypt. Waterbird diversity was assessed at 16 random sites in the lake representing four different habitats; reedbed, lakeshore, open water and islet from autumn 2019 to summer 2020. Species richness, abundance, composition, species diversity and evenness were addressed. Bird species diversity varied spatially and temporally among different sites during the study period. The estimated species richness was 60 species. Migratory birds were represented by 47%, while resident birds were 53%. Birds occupied all lake habitats. The highest diversity of birds was recorded in winter. The evidence of breeding was recorded, such as collecting nest material, nesting, hatching of eggs and food-collecting for juveniles. The lake sites were divided into four distinct habitats based on the hierarchical cluster analysis; lakeshores, open water, islets and reedbeds. Five bird species showed significant affinities with different habitat types: moorhen (*Gallinula chloropus*), and common kingfisher (*Alcedo atthis)* were significantly associated with reedbed. House sparrows (*Passer domesticus niloticus*) and white wagtail (*Motacilla alba)* favored the lakeshore habitat. The northern shoveler (*Spatula clypeata*) was recorded as an indicator species in open-water habitats. No significant indicator bird species was recorded in the islet habitats. The current results emphasized the significance of Burullus Lake as a wintering and breeding habitat for birds. Thus, more conservation and management strategies should be implemented.

INTRODUCTION

Wetlands are areas with shallow openwater or land that is regularly flooded **(Matthews, 1993)**. They are crucial for both biodiversity preservation and long-term economic generation **(Mulongoy, 2016)**. Urbanization, agriculture, and natural land have experienced changes affecting the quality and quantity of the world's wetlands **(Zhao *et al*., 2006).** Wetlands are the primary habitat for water birds and are well-known for their importance in feeding, resting and breeding grounds for waterfowl **(Pöysä, 1983; BirdLife International, 2004; Connor & Gabor, 2006)**. These habitats provide all the basic requirements for migrating birds throughout the migration seasons, such as food, nesting materials and shelter **(Xia *et al*., 2017; Francesiaz *et al*., 2017)**. **Ma *et al.* (2010)** noted that, more than half of the world's wetlands have been lost due to severe land use and human activities, which, in turn, threatens all biodiversity, especially waterbirds. The Ramsar convention is one of several remarkable efforts made to safeguard the world's wetlands (**Ramsar Convention Secretariat, 2016)**. A total of 2000 wetlands all over the world have been designated as Ramsar sites, covering an area of about 215 million hectares of wetland locations designated as protected areas (PA). The Convention on Biological Diversity (CBD), on the other hand, recommended the participating nations' concerned authorities manage their PA primarily for the protection and sustainable use of ecosystems and biodiversity **(Tiega, 2011)**. One of the Ramsar convention on wetlands' recommendations is wetland management, which entails reviewing and monitoring the changes made to assist wetland managers in dealing with the many challenges they face **(Finalyson & Pollard, 2009)**.

Wetlands are vital economic assets because they are significantly affecting and supporting biodiversity; they provide ecosystem services such as water purification and sediment flow management. In addition, they are considered a cultural heritage and sometimes have moral values (**Robledano *et al*., 2010; Alikhani *et al*., 2021)**.

Wetlands are eco-complex and important habitats that play a critical role as a wintering ground for migratory birds and breeding grounds for rare and endangered species in the Palearctic and the world **(Bouaguel, 2014)**. The ecological status of birds in general and specific waterbirds in North African wetlands is far from being completely understood and fully addressed. It is therefore important to better understand the selective pressures exerted on waterbirds in North African wetlands, which for many taxa represent the extreme limit of their range **(Chenchouni, 2012; Sayoud *et al*., 2017)**. The monitoring of waterbirds has become an even more pressing global concern as the role of waterbirds in wetland ecosystems becomes clearer. Waterbirds are now recognized as important ecosystem service providers, acting as a biological proxy for the condition of wetlands, seed dispersers or sentinels of potential epidemics **(Amat & Green, 2010; Green & Elmberg, 2014)**. With a potential, 2 million wintering waterbirds belonging to about 150 different species are hosting only 1.5% of the total surface of wetlands worldwide **(Mediterranean Wetlands Observatory, 2012)**. Yet, North Africa (including Morocco, Algeria, Tunisia, Libya and Egypt) represents highly significant flyways for waterbirds of the African-Eurasian **(Meininger & Atta, 1994; Dakki *et al*., 2002; Isenmann *et al*., 2005; Samraoui & Samraoui, 2008; EGA - RAC/SPA waterbird census team, 2012)**.

During both autumn and spring migrations, North African wetlands provide the last refueling stopover for millions of migratory waterbirds before they cross the Sahara or the Mediterranean Sea **(Green *et al.*, 2002)**; both crossings can be energetically demanding. Hundreds of thousands of waterbirds spend the winter in these wetlands. Conserving and managing these waterbird populations, as well as the North African wetlands that support them, necessitates, among other things, filling knowledge gaps on species population sizes and distribution patterns on a regional scale **(Galewski *et al*., 2011; Samraoui *et al*., 2011)**.

Biodiversity, natural resource conservation, and management plan are becoming more and more important priorities of the environmental community of Egypt to maintain the natural heritage of the nation, a dedicated law for the natural reserve was issued by the Egyptian Parliament in 1983 and designed as low 102/1983. The Egyptian government's National Biodiversity Strategy and Action Plan (NBSAP) for the years 2015 to 2030 has been revised by Egypt's Ministry of Environment. The NBSAP (1997-2017) is regarded as the principal instrument for responding to the Biodiversity Convention (CBD). The new analysis examines the long-term usage of wetlands as well as the protection of wetlands environments **(Egyptian Environmental Affair Agency, 2016)**.

The Burullus Lake wetland is a coastal lake and is considered one of the five northern lakes in Egypt; it is the second largest lake in the Nile delta located in Kafr El-Sheikh Governorate. Burullus wetland is among the four Egyptian Ramsar sites and has been declared as a natural protectorate in 1998 by Prime Ministerial decree number 1444, which was modified later by decree number 330/2018 including about 410 km^2 **(Kassas, 2002)**. The Burullus Lake is a coastal bar (i.e. sand bar) separating the Mediterranean coast in the north from the lakeshore in the south. Its area is about 165 km^2. The lake lost about 49% of its area over the past 112 years (from 1092 km^2 in 1801 to 556 km^2 in 1913) and about 62.5% by the year 1997 **(Eid *et al*., 2012)**. Though the surface of this bar is relatively flat, it possesses many geomorphological characteristics which have been formed upon it due to the evolution and development of the geomorphological processes (sand flats, tidal flats, sand dunes, salt marshes and sea outlets). Some of these characteristics were attributed to the sedimentation process such as sand flats and sand dunes, while some others were related to fluctuations in sea level including salt marshes and tidal flats **(Nassar, 2014)**. Numerous islets (about 30 islets) of different sizes are scattered in the Burullus Lake. These islets consist mostly of mud and sometimes sand. Most of these islets are oriented from north to south and the others are located parallel to the coast. Due to the geomorphological processes, such as sedimentation, erosion, and water flooding, the locations, size, number and dimensions of these islets change over time. Some examples of the Burullus Lake’s islets are Dibar, El-Kom El-Akhdar, El-Zanka, Deshimi, Shishet Al-Agoza, El-Zoaya and Absak **(Dumont, 2007)**.

Burullus is an important wetland for wintering waterbirds on a global scale; for these and other reasons, it has been recognized as an important Bird Area (IBAs) by BirdLife International, which indicates that Egypt has legally enforceable duties to maintain and repair Lake Burullus. Lake Burullus was designated as a protected area, even though the protected area has a wide range of environmental concerns and challenges, it is widely believed that it can be saved since it still has some remnants of wildness that have been destroyed elsewhere in the country. As a result, the Burullus protected area needed a management plan. Lake Burullus has a high degree of biodiversity and a high proportion of endemism due to numerous conditions of water, soil and vegetation. The sand dunes and salt marshes of the sand bar, as well as the islets (particularly El-Kom El-Akhdar and Dechimi) are characterized by high species diversity of fauna and flora species due to a variety of microhabitats. Although reedbeds are not unique to Burullus, they are essential for resident and migrating birds in addition to providing food and refuge for several fish species **(Egyptian Environmental Affair Agency, 2005)**.

The aim of this work was to assess the current ecological status of avian communities frequenting Ramsar sites and important bird areas 'IBAs' (Burllus lake) in the north of Egypt via addressing different habitats during different seasons and identify the habitat suitability for both resident birds and passage migrants.

MATERIALS AND METHODS

Study area

The Burullus Lake is located in the Nile Delta between the two Nile River branches, Damietta and Rosetta, between longitude 30° 30' and 31° 10' E and latitude 31° 21' and 31° 35' N. It is located along the Mediterranean coast in the northern part of the Nile Delta. The Burullus Lake is a shallow basin with water depths ranging from 0.5m near the lake shores to 2.5m near the lake-sea contact (El-Boughaz) **(Dewidar, 2004)**. It is connected to the sea at its northeastern edge through the Burullus inlet (El-Boughaz). The width of the lake varies from one site to another and it reaches an average of 13km in the middle part, while it decreases to about 5km in the western part. The shoreline of the Burullus Lake is about 53km long, and it takes many forms according to its origin, formation and evolution. The main basin of the Burullus Lake is classified into three parts, including the western, eastern and the middle, each of which has its own hydrological, geomorphological and biological characteristics. The islets are distributed in the lake form physical isolations between these parts **(Shaltout & Al-Sodany, 2008)**. The lake gets a yearly water volume of around 4.1 milliard cubic meters through an arrangement of eight drains and a freshwater canal. In Burullus, the air temperature ranges from 11.2°C in January to 23.6°C in August, with a mean yearly temperature of around 17.3°C.

Bird survey

Bird monitoring was conducted seasonally at randomly 16 sites around the lake. Each site was a representative of an area of 1km^2 (Fig. 1) and all of which represent different habitats (Reedbed, lakeshore, openwater and Islet) in the lake; each habitat represent four sites according to **Sheta (2019)**. The study was started in the autumn of 2019 until the summer of 2020, covering different seasons; migration and breeding seasons. At each site, all birds observed were recorded. The habitat structure in each site was assessed. Stainer (10×42) Binocular, Kite (SP65) telescope was used to survey and species identification according to **Svensson *et al*. (2010)**. The evidence of breeding behavior including carrying nesting material, nesting, hatching eggs and feeding fledglings was recorded.

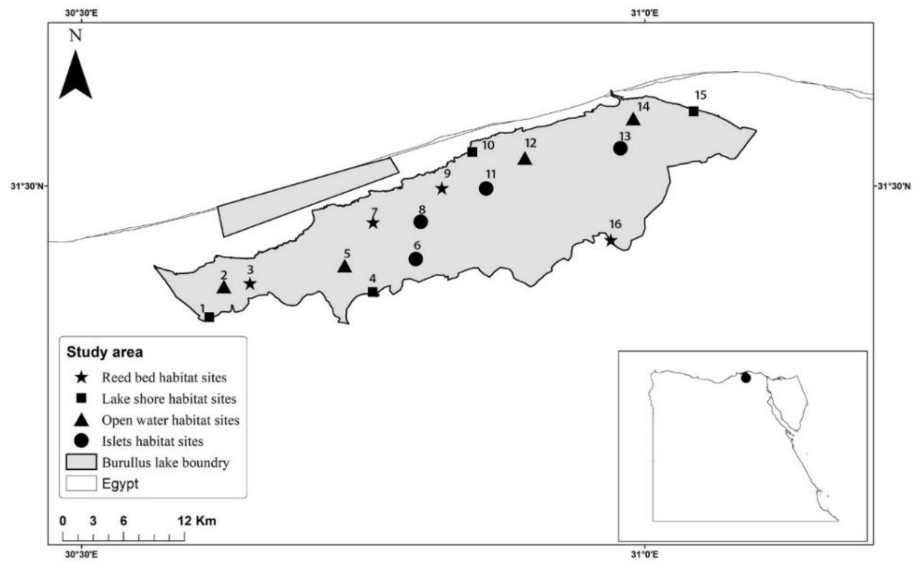

Fig. 1. Map of Burllus wetland showing the sampling sites in the different habitats of the lake

Data analysis

Data were represented as mean ± SE unless otherwise indicated. The spatial data has been divided into four habitat categories: lakeshores, openwater, islets and reedbed. The temporal data were divided into four seasons. Species richness, mean abundance, evenness, Shannon's diversity index, and Simpson's index were calculated using PAST, a software package for paleontological data analysis V4.08 **(Hammer *et al*., 2001)**, PC-ORD software version 6.12, and Arc map version 10.8 **(McCune & Mefford, 2011)**. Diversity t-test was used in the comparison of the Shannon and Simpson diversities in two samples as described by **Magurran (1988)**. Hierarchical cluster analysis was used to arrange locations based on the mean abundance of bird species. The analysis of indicator species has been done according to **Duferne and Legendre (1997)**. The method to determine which species are related to or with the inductive group was used according to **Bakker (2008)**. The statistical differences across habitat groups were compared using one and two-way analysis of variance (ANOVA); if there was a significant difference between groups, Tukey's (HSD) post hoc comparisons among different groups were performed with a significance level of $P< 0.05$. Minitab software package version 19.0, and Microsoft Excel 365 were used for other statistical analyses.

RESULTS

1. Community structure and abundance of bird species

A total of 60 bird species were recorded in the lake during the study period covering the four seasons at 16 sites and representing the different habitats of the lake, with a total abundance of 6888 individuals, belonging to 23 families and 12 orders (Table 1). Waterbirds were the most abundant species (51 species with a total abundance of 6009 individuals), representing 87.24 % of the total bird community, most of them inhabiting the islet habitat with a high and great percentage in spring and autumn seasons. On the other hand, passerines and raptors accounted for the remaining 12.76 % (9 species with a total abundance of 879 individuals) of the bird community (Figs. 2a, b); most of them are resident species inhabiting islet habitat. In contrast, the highest annual total species abundance was recorded in lakeshore habitats, followed by openwater, islets and reedbed habitats with a total abundance of 2255 (32.7%), 2006 (29.1), 1600 (23.2%) and 1027 (14.9%) individual, respectively (Table 1). The highest number of individuals (2876) represented 41.7% of the total individuals recorded in winter, while the lowest number of individuals (976) recorded in summer represented 14.1% of the total abundance (Table 1).

In this study, migratory bird species (40 spp.) represented 46.49% of all bird abundance observed in diverse habitats; the highest percentage was recorded in openwater habitats (25.1%) (Fig. 3a). The highest abundance of migratory birds was recorded in winter (1954 ind.), while the lowest was estimated in summer (173 ind.) (Fig. 3b). On the other hand, the resident species (20 spp.) represented 53.51% of the total bird abundance; the highest abundance was recorded in spring (1117 ind.) in the islet habitat. Generally, the result showed that winter was represented by the highest percentage of all birds (41.8%), followed by spring, autumn and summer with percentages of 22.5%, 21.5% and14.1%. respectively (Figs. 3a, b). Table (2) and Fig. (4) showed that the total bird abundance in diverse habitats throughout the different seasons was statistically not significant ($P > 0.05$).

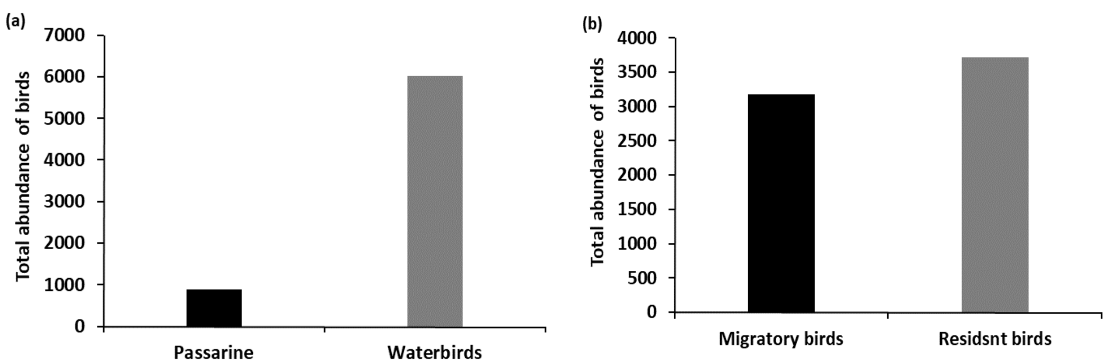

Fig. 2. (a) Total abundance of passerine and waterbirds; **(b)** Total abundance of migratory and resident birds

Cormorant waterbirds represent the highest abundance of migrant species in the lake during winter (1023 ind.), forming 35% of total winter birds. Six species of gull waterbirds represented 15 % of the total abundance of migrant species in the lake (1038 ind.). However, ducks represented by 8 species accounted for 9.8% of the total abundance of migrant species in the lake (680 ind.). Resident bird species whisked tern, squacco heron, little egret, pied kingfisher, barn swallow and sand martin were the most abundant resident birds with a total number of individuals 715, 678, 661, 448, 403, and 287 accounting for 10.4%, 9.8%, 9,6%, 6,5%, 5.8%, and 4.8%, respectively. Insectivorous and breeder birds have been associated with reedbeds, viz. Passeriformes and marsh harriers. Birds are distributed in all lake habitats during the autumn.

Table 1. List of the recorded bird species and their abundance in Burullus wetland during the study period in different seasons and habitats

Order (Family)	Scientific name (Common name)	IUCN Red list	R/M	Habitat (Abundance)					Seasons (Abundance)					Total abund.	R.C%
				LS	OW	Is	RB	F.	aut.	win.	spri.	sum.	F.		
Accipitrimorphae (Accipitriformes)	*Circus aeruginosus* (Marsh harrier)	LC	M	13	0	8	18	3	12	27	0	0	2	39	0.57%
Anseriformes (Anatidae)	*Anas querquedula* (Gargany)	-	M	0	85	0	0	1	0	15	0	70	2	85	1.23%
Anseriformes (Anatidae)	*Anas crecca* (Green-winged Teal)	LC	M	0	5	0	5	2	0	0	10	0	1	10	0.15%
Anseriformes (Anatidae)	*Anas platyrhynchos* (Mallard)	LC	M	0	9	0	2	2	9	2	0	0	2	11	0.16%
Anseriformes (Anatidae)	*Anas acuta* (Northern Pintail)	LC	M	0	7	2	0	2		9	0	0	1	9	0.13%
Anseriformes (Anatidae)	*Spatula clypeata* (Northern Shoveler)	LC	M	0	434	10	0	2	60	134	250	0	3	444	6.45%
Anseriformes (Anatidae)	*Aythya ferina* (Pochard)	VU	M	0	0	3	0	1	0	3	0	0	1	3	0.04%
Anseriformes (Anatidae)	*Anas* sp. (un. Identifyed duc)	-	M	0	75	15	25	3	3	42	70	0	3	115	1.67%
Anseriformes (Anatidae)	*Mareca penelope* (Wigeon)	LC	M	0	3	0	0	1	3	0	0	0	1	3	0.04%
Bucerotiformes (Upupidae)	*Upupa epops* (Hoopoe)	LC	R	2	0	0	0	1	2	0	0	0	1	2	0.03%
Charadriiformes (Recurvirostridae)	*Recurvirostra avosetta* (Avocet)	LC	M	28	17	0	0	2	45	0	0	0	1	45	0.65%
Charadriiformes (Laridae)	*Larus ridibundus* (Black-headed Gull)	LC	M	11	15	30	0	3	34	7	0	15	3	56	0.81%
Charadriiformes (Recurvirostridae)	*Himantopus himantopus* (Black-winged Stilt)	LC	M	2	5	0	0	2	5	0	0	2	2	7	0.10%
Charadriiformes (Scolopacidae)	*Calidris* sp. (calidris sp.)	LC	M	0	0	30	0	1	0	30	0	0	1	30	0.44%
Charadriiformes (Laridae)	*Larus canus* (common gull)	LC	M	3	16	8	0	3	4	0	0	23	2	27	0.39%
Charadriiformes (Scolopacidae)	*Gallinago gallinago* (Common Snipe)	LC	M	12	0	0	0	1	12	0	0	0	1	12	0.17%
Charadriiformes (Laridae)	*Larus* spp. (Different immature gull)	-	M	0	0	9	12	2	0	9	12	0	2	21	0.30%
Charadriiformes (Scolopacidae)	*Calidris alpina* (Dunlin)	LC	M	0	0	0	3	1	0	3	0	0	1	3	0.04%
Charadriiformes (Scolopacidae)	*Tringa nebularia* (Greenshank)	LC	M	0	0	3	0	1	3	0	0	0	1	3	0.04%
Charadriiformes (Charadriidae)	*Charadrius alexandrinus* (Kentish Plover)	LC	M	15	0	0	0	1	15	0	0	0	1	15	0.22%
Charadriiformes (Laridae)	*Larus fuscus* (Lesser Black-backed Gull)	LC	M	0	5	3	1	3	2	7	0	0	2	9	0.13%
Charadriiformes (Scolopacidae)	*Calidris minuta* (Little stint)	LC	M	35	0	0	0	1	30	0	5	0	2	35	0.51%
Charadriiformes (Scolopacidae)	*Tringa stagnatilis* (Marsh Sandpiper)	LC	M	0	0	0	2	1	2	0	0	0	1	2	0.03%
Charadriiformes (Scolopacidae)	Tringa totanus (redshank)	LC	M	0	0	3	0	1	0	3	0	0	1	3	0.04%

Order (Family)	Scientific name (Common name)	IUCN Red list	R/M	Habitat (Abundance)					Seasons (Abundance)					Total abund.	R.C%
				LS	OW	Is	RB	F.	aut.	win.	spri.	sum.	F.		
Charadriiformes (Charadriidae)	*Charadrius hiaticula* (Ringed Plover)	LC	M	34	0	0	0	1	17	0	17	0	2	34	0.49%
Charadriiformes ( )	*Charadriiformes* sp. (Shorebird sp.)	-	M	50	0	0	0	1	50	0	0	0	1	50	0.73%
Charadriiformes (Laridae)	*Larus genei* (Slender-billed Gull)	LC	M	0	15	0	0	1	0	0	15	0	1	15	0.22%
Charadriiformes (Charadriidae)	*Vanellus spinosa* (spur-winged lapwing)	LC	R	20	0	38	28	3	22	8	38	18	4	86	1.25%
Charadriiformes (Laridae)	*Larus* sp. (unidentified gulls)	-	M	542	121	65	182	4	243	600	17	50	4	910	13.21%
Charadriiformes (Laridae)	*Chlidonias hybrida* (Whiskered Tern)	LC	R	304	66	186	159	4	203	146	112	254	4	715	10.38%
Charadriiformes (Scolopacidae)	Tringa glareola (Wood Sandpiper)	LC	M	0	17	2	0	2	19	0	0	0	1	19	0.28%
Columbiformes (Columbidae)	Streptopelia senegalensis (Laughing dove)	LC	M	0	0	2	0	1	0	2	0	0	1	2	0.03%
Columbiformes (Columbidae)	*Streptopelia turtur* (Turtle dove)	VU	M	0	0	2	10	2	0	5	7	0	2	12	0.17%
Coraciiformes (Meropidae)	*Meropus persicus* (Blue checked bee-eater)	-	R	2	0	0	0	1	0	0	2	0	1	2	0.03%
Coraciiformes (Alcedinidae)	*Alcedo atthis* (Common Kingfisher)	LC	M	1	0	0	6	2	4	1	2	0	3	7	0.10%
Coraciiformes (Alcedinidae)	*Ceryle rudis* (Pied Kingfisher)	LC	R	46	31	316	55	4	48	90	259	51	4	448	6.50%
Coraciiformes (Alcedinidae)	*Halcyon smyrnensis* (White-throated kingfisher)	LC	R	3	0	6	3	3	0	1	3	8	3	12	0.17%
Cuculiformes (Cuculidae)	*Centropus senegalensis* (Senegal coucal)	LC	R	0	0	0	2	1	1	1	0	0	2	2	0.03%
Gruiformes (Rallidae)	*Fulica atra* (Common Coot)	LC	M	5	0	4	11	3	9	11	0	0	2	20	0.29%
Gruiformes (Rallidae)	*Gallinula chloropus* (Moorhen)	LC	R	4	0	6	23	3	12	8	4	9	4	33	0.48%
Gruiformes (Rallidae)	*Porphyrio porphyrio* (Purple Swamphen)	LC	M	2	0	3	1	3	1	0	2	3	3	6	0.09%
Passeriformes (Hirundinidae)	*Hirundo rustica* (Barn swallow)	LC	R	116	11	174	102	4	72	85	222	24	4	403	5.85%
Passeriformes (Acrocephalidae)	*Acrocephalus stentoreus* (Clamorous reed warbler)	LC	R	0	0	5	2	2	0	0	0	7	1	7	0.10%
Passeriformes (Pycnonotidae)	*Pycnonotus barbatus* (common bulboul)	-	R	0	0	2	0	1	0	2	0	0	1	2	0.03%
Passeriformes (Cisticolidae)	*Prinia gracilis* (Graceful prinia)	LC	R	22	0	35	21	3	5	22	30	21	4	78	1.13%
Passeriformes (Corvidae)	*Corvus corone cornix* (Hooded crow)	U	R	15	0	2	5	3	5	13	4	0	3	22	0.32%
Passeriformes (Passeridae)	*Passer domesticus niloticus* (House sparrow)	LC	R	51	0	2	2	3	3	17	6	29	4	55	0.80%
Passeriformes (Hirundinidae)	*Riparia riparia* (sand martin)	LC	R	10	40	237	0	3	45	30	210	2	4	287	4.17%
Passeriformes (Motacillidae)	*Motacilla alba* (white wagtail)	LC	M	18	0	0	1	2	8	10	1	0	3	19	0.28%
Passeriformes (Motacillidae)	*Motacilla flava* (yellow wagtail)	LC	M	5	0	1	0	2	2	4	0	0	2	6	0.09%
Pelecaniformes (Ardeidae)	*Nycticorax nycticorax* (Black-crowned Night-heron)	LC	R	80	0	0	0	1	0	80	0	0	1	80	1.16%

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				LS	OW	Is	RB	F.	aut.	win.	spri.	sum.	F.		
Pelecaniformes (Ardeidae)	*Bubulcus ibis* (Cattle Egret)	LC	R	71	35	0	0	2	52	30	5	19	4	106	1.54%
Pelecaniformes (Threskiornithidae)	*Plegadis falcinellus* (Glossy ibis)	LC	M	0	5	0	0	1	0	0	5	0	1	5	0.07%
Pelecaniformes (Ardeidae)	*Ardea cinerea* (Grey Heron)	LC	M	30	0	0	0	1	30	0	0	0	1	30	0.44%
Pelecaniformes (Ardeidae)	*Ixobrychus minutus* (Little Bittern)	LC	M	9	6	0	0	2	0	5	0	10	2	15	0.22%
Pelecaniformes (Ardeidae)	*Egretta garzetta* (Little Egret)	LC	R	248	38	189	186	4	218	193	108	142	4	661	9.60%
Pelecaniformes (Threskiornithidae)	*Platalea* sp. (spoonbil)	LC	M	0	7	0	0	1	0	0	7	0	1	7	0.10%
Pelecaniformes (Ardeidae)	*Ardeola ralloides* (Squacco Heron)	LC	R	301	54	180	143	4	152	195	112	219	4	678	9.84%
Podicipediformes (Podicipedidae)	*Tachybaptus ruficollis* (little grebe)	LC	M	0	0	0	3	1	0	3	0	0	1	3	0.04%
Suliformes (Phalacrocoracidae)	*Phalacrocorax carbo (*Great Cormorant)	LC	M	145	884	19	14	4	20	1023	19	0	3	1062	15.42%
	Total abundance			2255	2006	1600	1027		1482	2876	1554	976		6888	100%
	Species richness			35	26	34	29		40	39	29	20			
	Dominance (D)			0.118	0.251	0.117	0.124		0.090	0.187	0.111	0.154			
	Simpson (1-D)			0.882	0.749	0.883	0.877		0.910	0.813	0.889	0.847			
	Shannon (H)			2.576	1.988	2.452	2.408		2.827	2.255	2.478	2.251			
	Evenness_e^H/S			0.376	0.281	0.341	0.383		0.423	0.245	0.411	0.475			

IUCN Red list; LC: Least concern; VU: Vulnerable; U: Unidentified population trend.
R.C% = Relative contribution. M; Migrant species, R; Resident species.

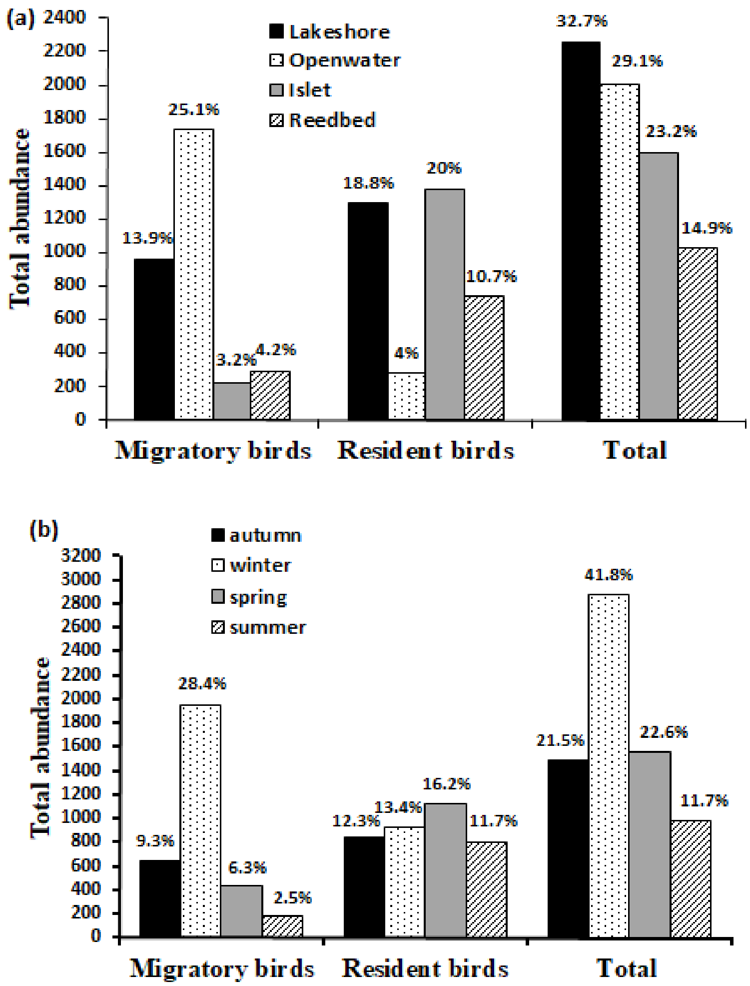

Fig. 3. Total abundance of migratory and resident birds **(a)** in different habitats and **(b)** in different seasons

Table 2. Total abundance of bird species in four habitats during different seasons Expressed as (Mean ± SE).

Season	Habitat types			
	Lakeshore	**Openwater**	**Islet**	**Reedbed**
Autumn	116.5 ± 27.6	63 ± 22.4	80.8 ± 29.5	110.3 ± 29.4
Winter	306.5 ± 127.3	283.5 ± 250.8	68 ± 12.2	61 ± 13.7
Spring	56.3 ± 17.2	108 ± 74.5	186 ± 114.2	38.3 ± 11.9
Summer	72 ± 31	59.5 ± 42.3	66 ± 5.7	46.5 ± 16.3
F-value	2.92	0.63	0.94	2.85
P- value	0.078 n.s	0.61 n.s.	0.452 n.s.	0.082 n.s.

One-way ANOVA statistical analyses revealed no significant differences in mean abundance among different habitat during collecting seasons ($P > 0.05$).

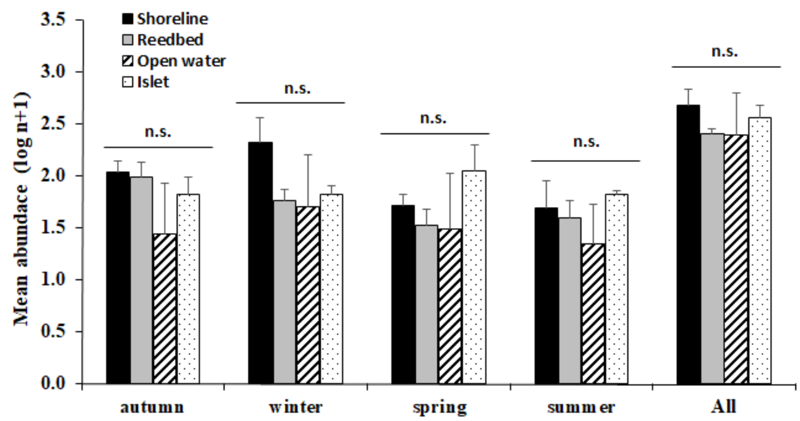

Fig. 4. Mean abundance of total birds in different seasons among different habitats in Burllus wetland during the study period

2. Spatial and temporal distribution of bird community

Fig. (5) shows the spatial distribution of bird abundance during the studied season in Burllus lake. In the winter and summer seasons birds occupied the western part of the lake (Figure 5 b,d); In winter the sites with high abundance were 5; openwater habitat with a total abundance of 1034 individuals represented 6 species, and 4; lakeshore habitat with a total abundance of 568 individuals represented 10 species. On the other hand, in summer, sites 2 and 1 recorded the highest abundance, with 183 individuals (7 species) and 155 individuals (6 species), respectively. In spring, they occupied the middle and east parts of the lake (sites 11 and 14 with a total abundance of 525 and 328, respectively); 5 species were recorded in each site (Fig. 5c).

In autumn, site 15 in the east of the lake showed high species richness (15 species), with a total abundance of 178 individuals. However, the highest abundance was recorded at site 3 in the west of the lake, representing 5 species. The eastern part of the lake recorded an equal distribution of birds during summer and spring. The lakeshore habitat type attracted bird species, but the western part of the middle had the highest individual richness.

3. Bird species richness and diversity

Table (1) and Figs. (6a, b, c & d) show that bird richness was spatially different across the different habitats. Lakeshore and islet habitats registered the highest species richness, with 35 and 34, respectively, followed by reedbed habitat (29 species) and openwater (26 species). However, total abundance was at its highest in the lakeshore habitat (2255), followed by openwater (2006) and islet (1600); whereas, the lowest abundance was recorded in reedbed habitat. The highest species richness was observed in autumn and winter with 40 and 39 species, respectively, and reached 29 species in spring; while, the lowest abundance was detected in summer (20 species). Resident birds occupied lakeshore and islets habitats but openwater showed a low occupation. For migratory birds' abundance, the beak occupied the openwater compared to the islet habitat. By using spatial analysis of sites, bird richness reveals that birds occupied the lakeshore and east part of the lake in the autumn season, and winter richness tends to be in the west part of the lake. In spring, bird richness was detected in the middle and the east parts of the lake; whereas, in summer, birds tend to occupy the middle part of the lake. The lakeshore habitat showed the highest bird species total abundance. Splitting the data showed that resident birds were found mainly in islet habitats, while migratory birds were mainly in the openwater. Generally, individuals' richness is concentrated in the west and middle parts of the lake, respectively. Passerine birds represent the most species in all habitats in all seasons (Figs. 6c, d).

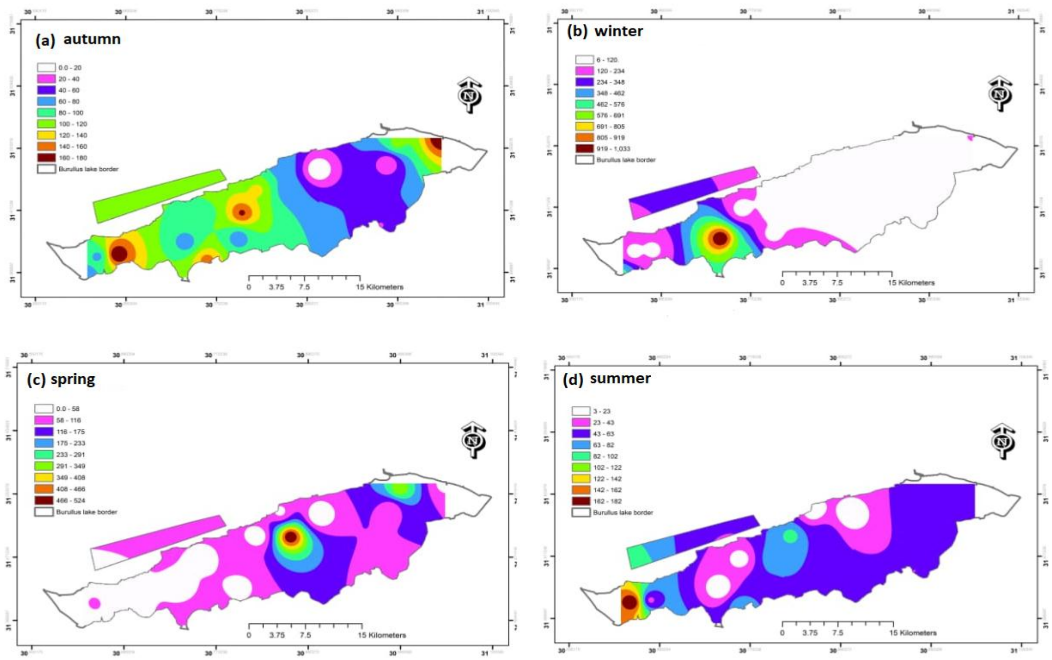

Fig. 5. Spatial distribution of bird communities among the studied seasons in the Burllus Lake

For bird species diversity, Shannon and Simpson diversity indices indicated that the highest diversity was recorded in lakeshore habitat, followed by islet and reedbed habitats, while the lowest diversity was observed in openwater habitat (Table 1 & Figs. 7a, 8a). Shannon and Simpson diversity indices were significantly higher in autumn than all other seasons. (2.8 and 0.91, respectively) ($P< 0.001$), followed by spring. The lowest species diversities were recorded in winter and summer (Table 1 & Figs. 7b, 8b).

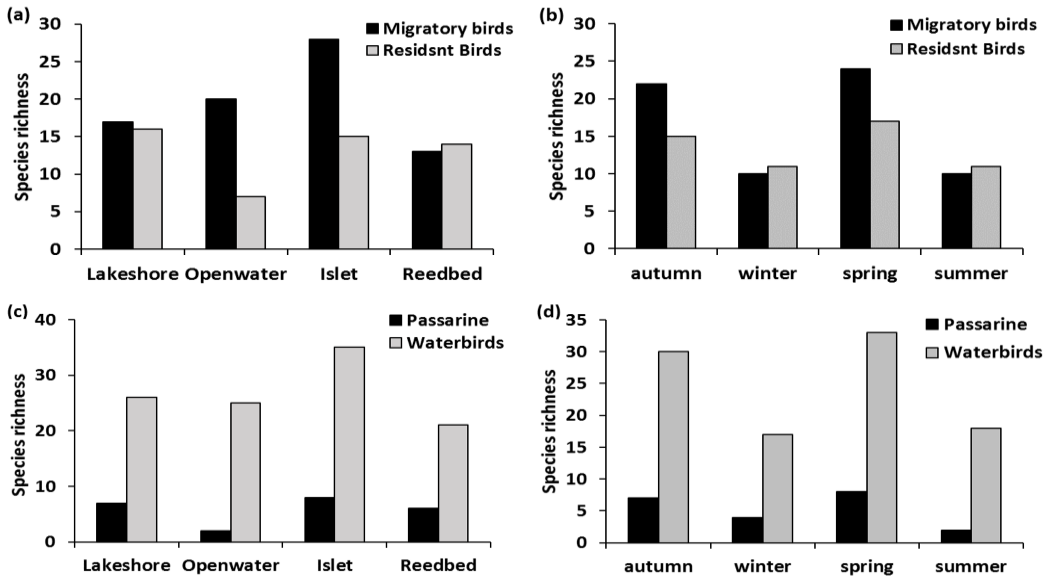

Fig. 6. Species richness of migratory and resident birds in **(a)** different habitats and **(b)** different seasons; species richness of passerine and waterbirds in **(c)** different habitats and **(d)** different seasons in the Burllus Lake

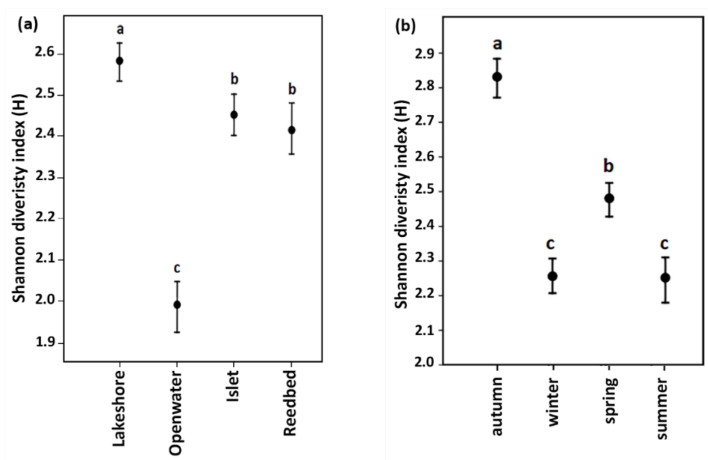

Fig. 7. Shannon species diversity index in **(a)** different habitat types, and **(b)** different seasons. Values that do not share a letter are significantly different ($P < 0.05$).

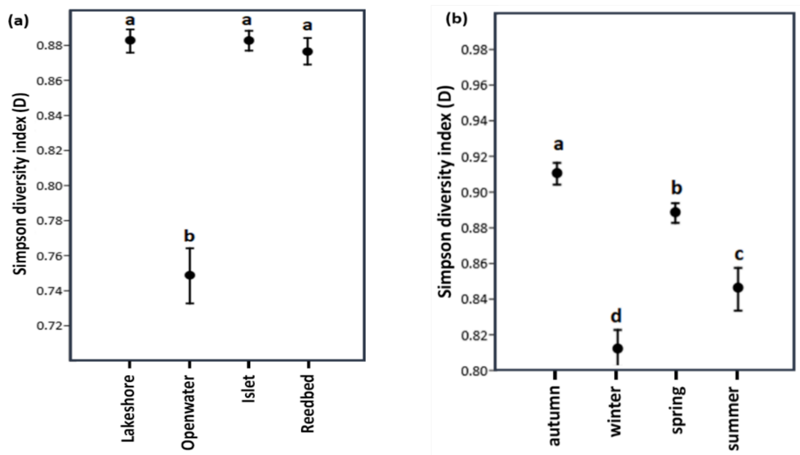

Fig. 8. Simpson species diversity index in **(a)** different habitat types and **(b)** different seasons.

Values that do not share a letter are significantly different ($P< 0.05$).

4. The trend in assemblage: Hierarchical cluster analysis

The relationship between the habitat type of studied locations and the bird community assemblage is represented in cluster analysis based on bird abundance.The resulting cluster separated each habitat type inside the lake from the related bird community. The first level separated the lakeshore sites and openwater sites groups from the islet and reedbed sites groups (Fig. 9). In the second level, every two similar groups from the previous level were further separated.

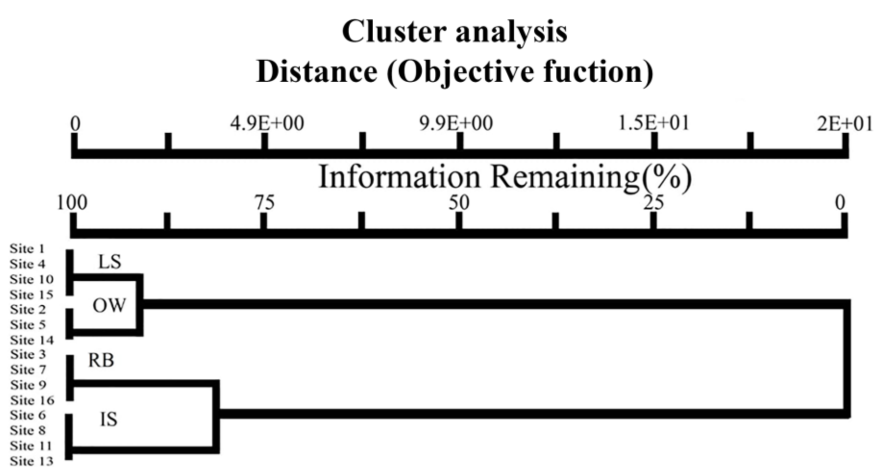

Fig. 9. Dendrogram showing the 16 sites interpreted from the Hierarchical Cluster Analysis Classification of the study sites according to their avifauna.

The scale represents dissimilarity (1-Sorensen). (LS) Lakeshores group, (OW) openwater group, (Is) Islet group, (R) reedbeds group.

5. Bird-indicator species analysis

An indicator species analysis was calculated based on the habitat types. The results showed five bird species with significant indicator values (Table 3). Lakeshores, openwater, and reedbed groups reflected more unique bird species composition. The abundance and occurrence of moorhen (*Gallinula chloropus*) (*P*< 0.003), and common kingfisher (*Alcedo atthis) (P*< 0.066) were significantly associated with reedbeds. House sparrows (*Passer domestics niloticus*) (*P*<0.03) and white wagtail (*Motacilla alba)* (*P*< 0.035) favored the lakeshore habitat. While, the northern shoveler (*Spatula clypeata*) favored the openwater habitats and was recorded as indicator species at *P*< 0.03. Remarkably, no significant indicator species was recorded for the islet habitats (Table 3).

Table 3. Indicator species of birds recorded from different study sites according to CCA analysis

Bird species	Bird common name	Habitat	indicator value	*P-value*
Passer domesticus niloticus	House sparrow	LS	69.5	0.03
Motacilla alba	White wagtail	LS	71.1	0.035
Spatula clypeata	Northern shoveler	OW	73.3	0.03
Gallinula chloropus	Common moorhen	RB	69.7	0.003
Alcedo atthis	Common kingfisher	RB	64.3	0.066
Circus aeruginosus	Marsh harrier	RB	46.2	0.119
Riparia riparia	Sand martin	IS	61.9	0.139

Habitat; (LS) Lakeshores site, (OW) openwater site, (RB); Reedbeds site and (IS) Islets site. *P*< 0.05 is considered significant.

DISCUSSION

The significance of this work lies in the fact that it goes beyond a systematic bird study at one of the most significant water bird locations in Burullus Lake, Egypt to assess its ecological importance. Lake Burullus worldwide and its local location, as well as its ecosystems have resulted in a diverse spectrum of water bird community composition. The present results revealed the importance of the lake; the number of bird species recorded in this study represented 60 species; this community represents 12% of the Egyptian avifauna, **(Isenmann & Moali, 2000)** recorded 31 species at an important site IBAs and Ramsar site this record represented by 7.6% of Algeria avifauna. Moreover, the lake acts as a foraging area for all bird species, notably fish-eating water birds. Moreover, the lake provides a great habitat for both migratory and resident birds that require specialized habitat. The wintering migratory birds (water birds) reflect the significance of these Ramsar sites for carrying massive migratory waterfowl. Indeed, these wetlands offer a safe and secure heaven for water birds, which account for more than half of the reported birds. Both water bodies have rich food resources, both in quality and quantity, for sedentary birds, which are less represented compared to migratory birds. Besides, the lake act as a refueling and resting habitat for migratory water birds. Reedbeds provide these birds with concealment from predators, as well as a place to sleep and nest for resident birds. Large flocks of ducks, gulls and terns might be found in openwater regions.

However, there were no big breeding colonies at this crucial Ramsar site, contrary to predictions. This finding agrees with that of **Brandisa *et al*. (2018)**, who realized a great decline in colonial breeding birds in different Ramsar sites. **Meininger *et al*. (1986)** attributed the elimination of remote, calm regions and the great amount of disturbance in the Nile Delta caused by the presence of a large number of small fishing boats and human settlements to the lack of big colony breeders in Egypt's Nile Delta (e.g. herons). Numerous factors including the significant human effect inside the lake and human habitation inside the lake's boundary can explain the striking absence of large breeding colonies in the current study. Additionally, the lake suffers from pollution uncontrolled and untreated water swage inside the lake (**El-Kafrawy *et al.*, 2015)**. Such anthropogenic activity has short- and long-term impacts on wildlife by inducing changes in behavior, physiology and reproduction **(Burger & Gochfeld, 1991; Frid & Dill, 2002)**.

Numerous variables influence the distribution and abundance of bird species, including the layout of specific habitats and the availability of critical requirements for them, such as a wide food supply, access to a dry or muddy environment and nest materials **(Chenchouni, 2010a)**. Variations in soil and water quality define Lake Burullus, influencing each ecological type **(El-Kafrawy *et al*., 2015)**. The observed bird population varied significantly across the various habitat categories. The present results showed the diverse habitat of Burullus Lake and how it hosts wide waterbird species. Waterbirds that migrate through the area predominated during the winter, whereas the season of summer observed a lack of migrants and a dominance of resident breeders within the lake. This finding coincides with that of **Ericia *et al.* (2005)** who suggested that differences in bird composition depend on the nature of habitat type, shape, suitability and human land use in the environment. The results of temporal patterns in relative abundance for the individual species or how these changes spatially are of concern for the conservation strategies and management **(Harrison *et al*., 2014)**. The study showed that the migration reached its peak in February (41.8% of total birds recorded). The abundance of waterbirds, especially Charadriiformes, Anseriformes and Suliformes reached their maximum in winter.

Resident water birds, especially Coraciiform, Hirundinidae and Pelecaniformes showed the highest counts in the spring season with a courtship behavior. The breeder birds were the dominant birds in the lake, and many birds were collecting nest materials and were observed carrying food to return to feed the juvenile. The location of Basic islet recorded many nests for pied kingfisher with many stages laying eggs (about 6 eggs showing in many nests, hatching eggs and small juveniles about 5 juveniles seeing). Temporal change in bird species differing in diversity, community assemblage, and richness may be related to the availability of food and resources. The number of available resources may be determined by a lot of environmental factors such as temperature and precipitation **(O'Brien, 1998; Currie, *et al*, 2004)**.

For the abundance of species richness variation among different habitats, no significant difference was detected between different orders of bird species in the number of species and among habitat types. The highly represented orders were Charadriiformes and Passeriformes since most Charadriiformes are water birds; this group recorded the most abundant one inside the lake.

Many wintering birds such as Charadriiformes rely on aquatic invertebrates for their nutrition throughout the cold seasons; the number of polyphagous species and invertebrate feeders is indicative of the quantity of these food sources **(Viani, 2011)**. This order was followed by Passeriformes which mostly inhabited the lakeshore. Orders of Cuculiformes and Columbiformes were represented by senegal coucal and laughing dove,, respectively inhabiting reedbeds habitat.

In terms of the number of individuals, polyphagous have the most plentiful numbers in winter because they are composed of wintering species with the largest numbers (Anatidae, Charadriidae and Scolopacidae). For carnivores, all species in this category are diurnal raptors (*Circus aeruginosus*,). It should be noted that, *Circus aeruginosus* is almost the frequently observed species. The species individuals frequent the reedbed and often fly over water bodies searching for prey, mainly composed of small vertebrates (this is computable) **(Chenchouni, 2010a)**.

The awareness needed to protect birds is an ancient phenomenon that emerged as part of a larger movement to prevent the extinction of species and lessen the impact of the threats they face **(Fishpool & Evans, 2001)**. In some regions, regulations and laws constitute the functional core for the protection of natural resources and birds in particular **(Chenchouni, 2010b)**. This is the best achieved through the protection of habitats where these birds live via IBAs **(Fishpool & Evans, 2001; Samraoui & Samraoui, 2008)**, the classification of wetlands as Ramsar sites **(DGF, 2002, 2004)**, as well as establishing national parks and nature reserves **(DGF, 2006)**. These measures were followed by the ratification of multinational agreements and conventions **(Chenchouni, 2010b)**.

The results of the Hierarchical cluster analysis of the bird species community separated the bird assemblages according to the type of habitat inside the lake into four distinctive habitats: lakeshores, reedbeds, openwater areas and islets. The clustering and the indicator species analysis provide the opportunity to identify several species as indicative of a specific class of sites **(Bakker, 2008)**. Such species, including common moorhen (*Gallinula chloropus*), common kingfisher (*Alcedo atthis)* and marsh harrier (*Circus aeruginosus*) were significantly associated with reedbeds, which are safe for birds, hiding them from enemies as foraging areas. Reedbeds are considered a refuge habitat due to their ability to colonize many species including birds **(Godet *et al*., 2018)**. In Japan, **Hattori and Mae (2001)** found that, the high waterbird diversity is associated with reedbeds habitat in lakes, especially in those with people who live and work inside. The islet habitats group showed marked numbers of indicator species, sand martin (*Riparia riparia*), barn swallow (*Hirundo rustica*), spur-winged lapwing (*Vanellus spinosa*) and pied kingfisher (*Ceryle rudis*), which offers flat surfaces for birds and may help in roosting for ground nester and attract carnivore birds for hunting and waders' birds who feed on mud surfaces **(Masero *et al*., 2000)**, nesting detective during this study. House sparrows (*Passer domesticus niloticus)* and white wagtail (*Motacilla alba)* favor the lakeshore habitat since this area is suitable for food and roosting **(Ameta *et al*., 2014)**. Northern shoveler *Spatula clypeata* favors openwater habitats thus it was an indicator species for it. The northern shovelers prefer open shallow water areas with rich submerged vegetation, where forage is on sub-emergent and emergent vegetation **(Pöysä, 1983; Holm & Clausen, 2014)**.

CONCLUSION

Lake Burullus has great importance at all levels; For a global level, it is considered one of the important sites for migratory and resident waterbirds. Therefore, Egypt has joined international agreements to protect these areas such as the Ramsar Convention. In addition, this area contributes to the mitigation of global warming. At the national level, this area is considered a bank of biodiversity and works in reducing storms, and preserving the groundwater. Notably, it is one of the sources of protein production and heavy metal precipitant. The results of this study confirm the importance of Burullus Lake for migratory and resident waterbirds, providing suitable habitat. The improvement in the future management of the Burullus Lake environment is recommended combined with a continuous monitoring of waterbirds in the lake to keep it safe.

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