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Exploring Siwa Lakes: A Study on the Distribution and Abundance of Wild "Waterbirds"

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ABSTRACT

This study investigated the waterbird communities at Siwa Lakes, focusing on the period from November 2021 to May 2023. A diverse array of 26 waterbird species, comprising three resident and 23 migratory species, was recorded across seven orders and twelve families. Charadriiformes dominated, showing significant representation across four families and thirteen species, while Pelecaniformes ranked second. The relative abundance analysis highlighted key species such as the greater flamingo and little egret. Variations in bird species diversity were observed among lakes, with a significant difference between Fatnas and Zamory Lakes compared to Dehaba Lakes. Seasonal patterns of bird abundance consistently highlighted Phoenicopteriformes as the most abundant order, with Charadriiformes peaking during spring. The diversity indices revealed higher numbers and richness in migratory waterbirds compared to residents, emphasizing the ecological significance of migratory populations. This study provided valuable insights into the dynamic waterbird communities, their distribution, and relative abundances, contributing to the broader understanding of ecosystem health and functioning.

INTRODUCTION

In the realm of environmental science, water bodies stand as intricate and ecologically vital ecosystems. They assume a pivotal role, serving as both critical wintering grounds for migratory birds and essential breeding sites for rare and endangered species within the vast Palearctic region and on a global scale, as observed by **Bouaguel (2021)**. These habitats fulfill the fundamental requisites necessary for the sustenance and survival of migratory birds during their migration seasons, offering essential resources, such as food, nesting materials, and shelter, as elucidated by research conducted by **Francesiaz *et al.* (2017)** and **Xia *et al.* (2017)**. The intricate ecological dynamics governing avian populations, encompassing both general bird communities and specific waterbird species inhabiting the North African wetlands, remain shrouded in substantial gaps in our comprehension, highlighting an urgent need for comprehensive exploration **(Elafri *et al.,* 2017)**. This highlights the importance of furthering our comprehension of the selective forces acting upon the waterbirds within the North African wetland environment, which serves as a crucial habitat for several taxonomic categories **(Hamza & Selmi, 2018)**. The outermost limits of their geographic range, as elucidated in scholarly research conducted by **Chenchouni (2012)** and in a study conducted by **Sayoud *et al*. (2017)**.

Waterbirds, such as waterfowl and wading birds, are of utmost importance in the ecological dynamics and functioning of wetland ecosystems. Wetlands are widely recognized for their paramount role in providing ecosystem services, serving as significant contributors to these services, and acting as valuable biological indicators (**Amat & Green, 2010; Green & Elmberg, 2014)**.

Remarkably, considering their relatively modest spatial footprint, North African wetlands harbor an astonishing congregation of avian life. Approximately, 2 million wintering waterbirds, representing an impressive array of around 150 distinct species, find sanctuary within these ecosystems (**Wetlands International, 2014; Sayoud *et al.,* 2017**). This remarkable statistic takes on added significance when considering that these wetlands cover a mere 1.5% of the total global wetland surface, a revelation conveyed by the **Mediterranean Wetlands Observatory (2012)**. Furthermore, the North African regions, comprising Morocco, Algeria, Tunisia, Libya, and Egypt, play a crucial role as migratory routes for waterbirds within the wider African-Eurasian framework. This recognition is supported by reputable experts, including **Samraoui and Samraoui (2008)**, **Squalli *et al.* (2020)** and **Hamza *et al.* (2022)**.

Siwa Oasis, situated in the Northwestern corner of Egypt's Western Desert, is renowned for its captivating landscapes and cultural heritage (**Amara, 2010; Salman *et al.,* 2010)**. This oasis is not only a historical gem but also a crucial habitat for a diverse array of bird species, both migratory and resident **(Goodman *et al*., 1989)**. Siwa Oasis lies along one of the primary flyways for bird migration from the Palearctic to Africa, serving as a crucial corridor between Europe, Asia and Africa **(Cottridge & Porter 2001; Newton, 2008)**. The presence of water bodies, lakes, and wetlands within Siwa Oasis plays a vital role in supporting avian biodiversity. These areas serve as essential stopover and wintering sites for migratory birds, which heavily rely on water bodies. Changes in water levels can particularly impact migratory birds **(Bancroft *et al*., 2002)**. Water bodies, such as lakes and wetlands, provide diverse benefits to water bird species, serving as crucial sites for roosting, foraging, and nesting **(Erwin & Beck, 2007)**. Avifauna is an important component of the Egyptian biological resources; indeed, it is the most diverse and prominent of all the country's non-aquatic vertebrate fauna **(Baha El Din, 1999)**. More than 470 bird species were recorded in Egypt. The majority are non-breeding seasonal visitors **(Fishpool & Evans, 2001)**. In Egypt, about 150 species are breeding residents, found all year round **(Baha El Din, 1999)**. Egypt has an international importance for birds with globally significant populations of breeding, wintering and migrating birds. It is home to 34 sites declared as Important Bird Areas **(Baha El Din, 1999**, hosting approximately 19 globally threatened species **(IUCN 2000)**.

Understanding the role of the water bodies of Siwa Oasis and diversity of the migratory bird populations is of utmost importance. Studying the presence, distribution, and abundance of migratory bird species in relation to these water features can provide valuable insights into their migration patterns, habitat preferences, and the ecological significance of Siwa Oasis as a critical stopover site. This knowledge is essential for the conservation and management of migratory bird populations, as well as the preservation of their habitats.

MATERIALS AND METHODS

Study area and bird monitoring

Siwa Oasis, located in the Western Desert of Egypt, is the smallest among the main oases in the region, covering only 0.15% (1175km2) of the Western Desert's total area. Its shape is elongated and irregular, tapering toward the west **(Rashed, 2016)**. Moreover, it is located between longitudes 25° 16'- 26° 7' E and latitudes 29° 7' - 29° 21' N **(Ibrahim, 2011)**. The oasis is bordered to the north by the Marmarica Plateau, which extends to the Mediterranean Sea, and to the south by the dunes of the Great Sand Sea.

Topographically, Siwa Oasis features five distinct local depressions that lie below the sea level, with altitudes ranging from -1 to -18 meters. These depressions are home to several significant lakes within the oasis, including Maraqi, Siwa, Aghourmy, and Zeitoun lakes, which are recognized from the west to the east (**Abdulaziz & Faid, 2013)**. The climate of Siwa Oasis is classified as arid to semi-arid, characterized by minimal rainfall, high evaporation rates, and moderate to high humidity levels **(Parsons, 1963)**.

Bird monitoring was conducted in Siwa Lake. The monthly surveys were carried out at three main parts of the lake, namely Fatnas, Dehaba, and Zamory Lakes, as shown in Fig. (1).

The study, initiated in November 2021 and extended until May 2023, spanned different seasons, including migration and breeding seasons. At each part of the lake, bird species were identified and counted. The collected data were analyzed to determine the bird diversity and abundance in Siwa Lake. During the study period, the count operations were carried out from dawn to sunset utilizing the recording of sighting data during routine field visits at the research.

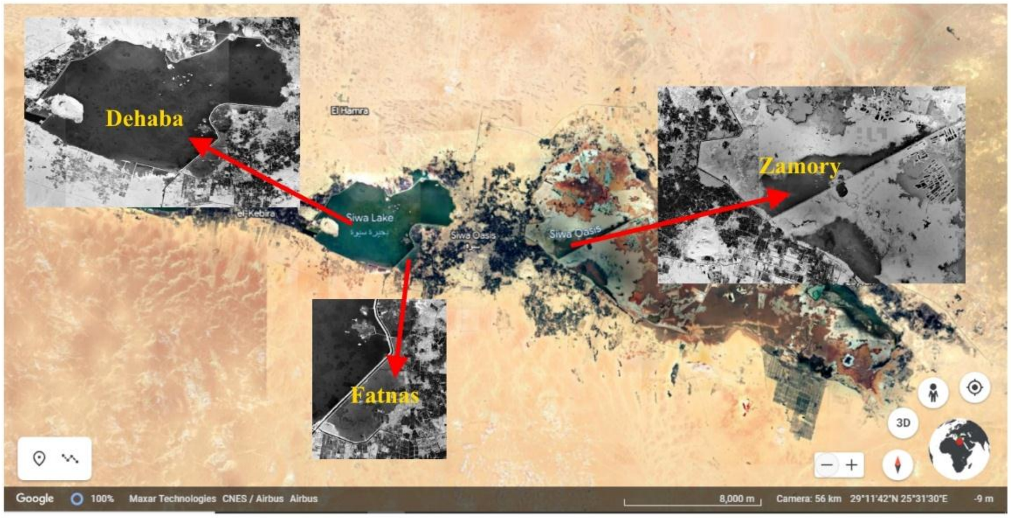

Fig. 1. The study site of Fatnas, Dehaba, and Zamory Lakes
(Google Earth 2022)

The observations of avian species were conducted using a 10*50X binocular, while photographic documentation was obtained using a Canon PowerShot SX60 HS Digital Camera equipped with a 65X optical zoom lens (21- 1365mm, full-frame equivalent). The confirmation of bird species identification was achieved through the utilization of field guides (**Bruun, & Baha El Din, 1985; Mullarney *et al.*, 1999; Cottridge & Porter, 2001; Svensson & Grant, 2001; HBW & BirdLife International, 2022)**. The avian census, conducted through point counts from the shorelines, adhered to the protocols described earlier.

Data analysis

Data were arranged to obtain the following parameters:

I) The relative abundance of bird species per habitat/ district was determined using:

$$Relative\ abundance = \frac{n}{N}$$

Where, n is the total number of birds of a particular , and *N* is the total number of birds of all species.

II) Bird species diversity:

Species richness is the number of different species present in an area **(Deitmers *et al.*, 1999)**. Species richness was estimated for each lake.

Shannon-Weiner Index (*H′*) was calculated in order to know the species diversity **(Hutcheson, 1970)** by employing the formula established by **Shannon and Weaver (1949)** based on species abundance as follows:

$$H' = -\sum_{i=1}^{n} p_i \ln p_i$$

Where, H' is the Diversity Index, P_i is the proportion of each species in the sample, and $(\ln p_i)$ is the natural logarithm of this proportion.

Evenness of birds species compares the similarity of the population size of each species. Evenness Index (J') was calculated using the ratio of observed diversity to maximum diversity using the equation of **Kiros *et al.* (2018)**, as follows:

$$J' = \frac{H'}{H_{max}}$$

Where, H' is the Shannon Wiener Diversity index, and H_{max} is the natural log of total number of species.

Simpson Diversity Index (D) measures the probability of any two individuals drawn from noticeably large community belonging to different species **(Simpson, 1949)**. It was measured by the following formula:

$$D = 1 - \frac{\sum_i^s n_i(n_i - 1)}{N(N-1)}$$

Where, n is the total number of birds of a particular species S and N is the total number of birds of all species.

RESULTS AND DISCUSSION

Waterbird species records

The structure of waterbird communities recorded at Siwa Lakes was varied. The checklist in Table (1) showed bird species recorded at Fatnas (App. I), Dehaba (App. II), and Zamory (App. III) during the period from November 2021 to May 2023 inclusively. The obtained data showed that the total number of waterbird species detected was twenty-six; three resident and twenty-three migratory, belonging to seven orders and twelve families. Charadriiformes was the dominant one represented by four families including thirteen species. Furthermore, order Pelecaniformes was in the second rank with three families including six species. Moreover, order Anseriformes and order Gruiformes were represented by one family with two species, each. While, the lowest orders in numbers were Phoenicopteriformes, Podicipediformes, and Coraciiformes, each represented by one species.

Few studied surveys done on the birds in Siwa oases confirm the above finding. **Al Hussaini (1938)** recorded 18 species in spring and winter. Furthermore, **Moreau (1940)** through his research in Ornithology of Siwa Oasis mansion recoded 71 different species of birds. **Goodman *et al.* (1986)** documented in their study that there are seasonal occurrences of breeding and nonbreeding birds in the Siwa Oasis. In their review on biodiversity resources, **El-Ramady and Abdalla (2021)** mentioned that Siwa supports a diverse range of birds species.

Table 1. Water bird species recorded from Siwa Lakes during the study period from November 2021 to May 2023 inclusively

Order	Family	English name	Scientific name	Status	Red list (IUCN)	Fa	De	Za
Anseriformes	Anatidae	Ferruginous duck	*Aythya nyroca*	M	NT	+		
		Shoveler	*Spatula clypeata*	M	LC	+	+	
Charadriiformes	Recurvirostridae	Black winged stilt	*Himantopus himantopus*	M	LC	+		+
	Charadriidae	Ringed plover	*Charadrius hiaticula*	M	LC			+
	Scolopacidae	Marsh sandpiper	*Tringa stagnatilis*	M	LC	+		+
		Dunlin	*Calidris alpina*	M	LC	+		+
		Little stint	*Calidris minuta*	M	LC			+
		Bar tailed Godwit	*Limosa lapponica*	M	NT			+
		Common Sandpiper	*Actitis hypoleucos*	M	LC	+		+
		Sanderling	*Calidris alba*	M	LC	+		+
		Common snipe	*Gallinago gallinago*	M	LC	+		+
	Laridae	Audouin's Gull	*Ichthyaetus audouinii*	M	VU	+	+	+
		Slender gull	*Chroicocephalus genei*	M	LC	+	+	+
		Arctic tern	*Sterna paradisaea*	M	LC	+		
		Common tern	*Sterna hirundo*	M	LC			+
Gruiformes	Rallidae	Eurasian coot	*Fulica atra*	M	LC	+	+	
		Common moorhen	Gallinula chloropus	R	LC	+		
Pelecaniformes	Ardeidae	Grey heron	*Ardea cinerea*	M	LC	+	+	+
		Great egret	*Egretta alba*	M	LC	+	+	+
		Squacco heron	*Ardeola ralloides*	M	LC	+		+
		Littele Egred	*Egretta garzetta*	R	LC	+		+
	Threskiornithidae	Gloosy ibis	*Plegadis falcinellus*	M	LC	+		+
	Phalacrocoracidae	Cormorant	*Phalacrocorax carbo*	M	LC	+		
Phoenicopteriformes	Phoenicopteridae	Greater Flamingo	*Phoenicopterus roseus*	M	LC	+	+	+
Podicipediformes	Podicipedidae	Black necked grebe	*Podiceps nigricollis*	M	LC	+	+	
Coraciiformes	Alcedinidae	Piad kingfisher	*Ceryle rudis*	R	LC	+	+	+

Where, R= Resident species, M = Migratory species, VU = Vulnerable, LC= Least concern, NT= Near threatened, Fa= Fatnas, De=Dehaba, and Za= Zamory.

Additionally, other nine bird species were recorded outside the studied lakes (Table 2, App. IV). Passeriformes was the largest order with five species, then order

Coraciiformes with two species. This agrees with the study of **Omar (2020)** on wild birds in Assiut governorate. The highest number recorded was the blue cheeked bee eater in spring and summer seasons. It was first recorded in April 2022 which is considered as one of the common migratory birds in Egypt. These birds were also recorded by **Moreau (1940)** in Siwa.

Table 2. Other birds recorded at Siwa Oasis

Order	Family	English name	Scientific name	Status	Red list (IUCN)	Number in sample (count)
Accipitriformes	Accipitridae	Common buzzard	*Buteo buteo*	M	LC	1
Coraciiformes	Upupidae	Hoodpoe	*Upupa epops*	R	LC	16
	Meropidae	blue cheeked bee eater	*Merops persicus*	M	LC	65
Passeriformes	Motacillidae	White Wagtail	*Motacilla alba*	M	LC	29
	Motacillidae	western yellow wagtail	*Motacilla flava*	M	LC	30
	Muscicapidae	white-crowned wheatear	*Oenanthe leucopyga*	R	LC	14
	Muscicapidae	northern wheatear	*Oenanthe oenanthe*	M	LC	5
	Phylloscopidae	willow wabler	*Phylloscopus trochilus*	M	LC	4
Pelecaniformes	Ardeidae	Cattal egret	*Bubulucus ibis*	R	LC	20

Relative abundance of waterbird species

The relative abundance of waterbird species is a crucial aspect to consider when studying the ecological dynamics of ecosystems. Understanding the distribution and population sizes of different waterbird species provides valuable insights into the overall health and functioning of these habitats.

Assessing the relative abundance of the numerical data regarding the waterbird species is presented in Table (3). The observed species were arranged in a descending order, reflecting their ecological significance: The greater flamingo, little egret, shoveler, ringed plover, common sandpiper, and marsh sandpiper. The highest counts were quantified as 1449, 255, 213, 188, 172, and 158 individuals, respectively, based on numerical values. The relative abundances of these counts were calculated to be 0.47, 0.88, 0.07, 0.06, 0.06, and 0.05, respectively, indicating the distribution of these counts in the ecosystem. The avian specimens recorded for both the common tern and cormorant species were observed in a minimum count of three each, indicating a relative frequency of 0.001. The analysis of variance of the bird species diversity showed no significant difference between bird species in Fatnas and Zamory Lakes ($P< 0.611$), while there are high significant difference between two lakes and Dehaba Lakes ($P< 0.001$) in the number of waterbird species. According to **Sheta (2019)** and **Sheta *et al.* (2023)**, there was a notable variation in the observed bird population among the different habitat types of Burullus Lake. **Mengesha (2014)** also observed significant differences in bird species diversity in his study on birds in and around Lake Zeway, Ethiopia, among various species.

Table 3. Relative abundance of waterbirds observed at Siwa Lakes

	English name	Number in sample (count)	Relative abundance (Pi)	LN(Pi)	Pi* LN(Pi)
Migratory species	Ferruginous duck	4	0.001	-6.654	-0.009
	Shoveler	213	0.069	-2.679	-0.184
	Black winged stilt	135	0.043	-3.135	-0.136
	Ringed plover	188	0.061	-2.804	-0.170
	Marsh sandpiper	158	0.051	-2.978	-0.152
	Dunlin	25	0.008	-4.822	-0.039
	Little stint	16	0.005	-5.268	-0.027
	Bar tailed godwit	31	0.010	-4.606	-0.046
	Common sandpiper	172	0.055	-2.893	-0.160
	Sanderling	52	0.017	-4.089	-0.069
	Common snipe	101	0.033	-3.425	-0.111
	Audouin's gull	110	0.035	-3.340	-0.118
	Slender gull	5	0.002	-6.431	-0.010
	Arctic tern	8	0.003	-5.961	-0.015
	Common tern	3	0.001	-6.942	-0.007
	Eurasian coot	150	0.048	-3.030	-0.146
	Grey heron	111	0.036	-3.331	-0.119
	Great egret	30	0.010	-4.639	-0.045
	Squacco heron	4	0.001	-6.654	-0.009
	Gloosy ibis	126	0.041	-3.204	-0.130
	cormorant	3	0.001	-6.942	-0.007
	Greater flamingo	1449	0.467	-0.762	-0.356
	Black necked grebe	10	0.003	-5.738	-0.018
Total		3104	1	-100.327	-2.083
Resident species	Piad kingfisher	31	0.107	-2.236	-0.239
	Common moorhen	4	0.014	-4.284	-0.059
	Little egred	255	0.879	-0.129	-0.113
Total		290	1	-6.648	-0.411

Pi proportion of each species (relative abundance), LNPi natural logarithm of Pi.

Fig. (2) illustrates the mean percentage of waterbird order. Throughout the study periods, including winter 2022, winter 2023, summer 2022, and autumn 2022, the order

Phoenicopteriformes displayed the highest level of abundance, with corresponding percentages of 53, 51, 56, and 53%, respectively. On the other hand, it was observed that Charadriiformes exhibited the greatest prevalence during the spring seasons of 2022 and 2023, with proportions of 40 and 70%, correspondingly. The study revealed that the orders Podicipediformes and Coraciiformes demonstrated the least amount of order richness throughout all seasons analyzed. This is in line with the observation of **Sheta *et al.* (2023)** who reported that in winter waterbird abundance, particularly that of Charadriiformes, Anseriformes, and Suliformes, reaches its peak. **Pittock *et al.* (2003)** and **Romano *et al.* (2005)** concluded that fluctuations in species richness and abundance during different months may be due to the influence of seasonal variations, local migration patterns, reproductive behaviors, agricultural practices in the surrounding area, water level in addition to climatic and environmental changes. Furthermore, **Assefa (2023)** and **Khatsuriya *et al.* (2023)** documented that the diversity of species can be influenced by various environmental factors, such as weather patterns, temperature fluctuations, rainfall levels, and the overall productivity of the habitat.

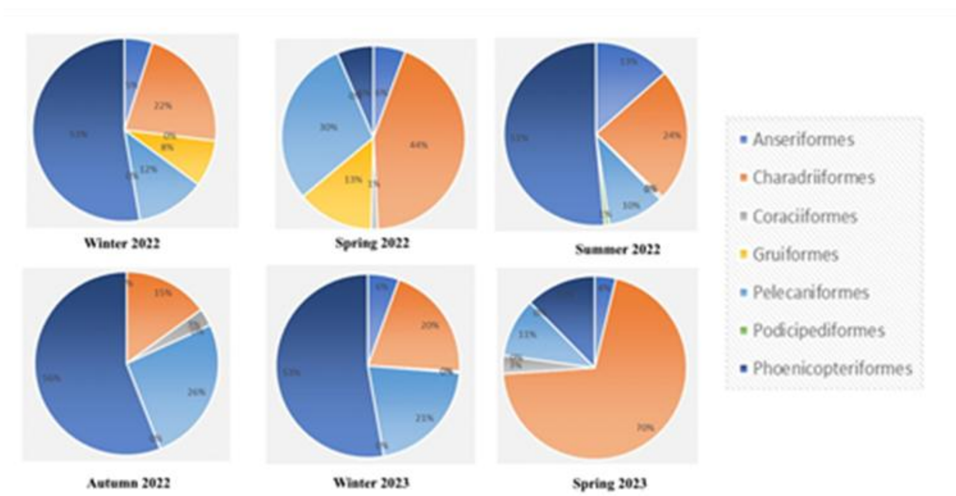

Fig. 2. The mean percentage of waterbird order variety throughout the study period from winter 2022 to spring 2023 inclusively

Diversity indices for resident and migratory waterbird species

Table (4) shows some variables related to the diversity of water bird species. The total number of resident bird species was 290 individuals, which is lower than the migratory water birds (3104 individuals). Moreover, species richness for resident was r= 3, which is also lower than migratory water birds (r= 23). Similarly, resident water bird had the lowest values of Shannon-Weiner Diversity Index (H′= 0.411) and Simpson's Diversity (D= 0.216), then migratory water bird (H′ = 2.083) and (D = 0.758). However, evenness (J′) was higher in the migratory water bird (J′= 0.664) than the resident water bird (J′= 0.374). According to **Mengesha and Bekele (2008)**, the presence of a diverse avian community can serve as a valuable indicator of the ecological variety within a given habitat. The abundance of species and individuals within a particular area reflects the significance of that area, while each habitat possesses a unique array of microenvironments that cater to the specific needs of different species. **Bibi and Ali (2013)**observed that , the values of the Shannon-Weiner Diversity Index typically range from 1.5 to 3.5 in most cases, with instances of exceeding 4.5 being quite rare. Furthermore, **Issa (2019)** recorded the diversity indices pertaining to the overall populations of avian species in two distinct habitats. Hence, the Diversity Index is regarded as a quantitative measure of the range of species present, serving as a valuable instrument for comprehending the biodiversity composition within designated research sites **(Bibi & Ali, 2013)**.

Table 4. Diversity indices for resident and migratory water birds at Siwa Lakes

Diversity index	Resident species	Migratory species	All species
Overall abundance	290	3104	3394
Species richness (r)	3	23	26
Evenness (J′)	0.374	0.664	0.757
Shannon-Weiner (H′)	0.411	2.083	2.494
Simpson diversity (D)	0.216	0.758	0.792

CONCLUSION

Siwa Oasis stands as a vital hub for bird migration, attracting numerous species during their long-distance journeys. The water bodies and lakes within the oasis play a significant role in supporting avian biodiversity and providing essential resources for birds throughout the year. However, the sustainable management of water resources, and the conservation of these habitats are of a paramount importance to ensure the well-being of the avian population in Siwa Oasis. This study highlights the need for further research and conservation efforts to preserve this unique ecosystem and its avian inhabitants.

REFERENCES

Abdulaziz, M. A. and Faid, A. M. (2013). Evaluation of the groundwater resources potential of Siwa Oasis using three-dimensional multilayer groundwater flow model, Mersa Matruh Governorate, Egypt. Arab J Geosci. 24:56-73.

Al-Hussaini A. H. (1938). An ornithological trip to Siwa Oasis. In: Bulletin de l'Institut d'Egypte, tome 21:145-152; doi : https://doi.org/10.3406/bie.1938.3520.

Amara, D. F. (2010). Tourism as a tool of development: the case study of Siwa Oasis–Egypt Western Desert. WIT Transactions on Ecology and the Environment, 139: 537-549.

Amat, J.A. and Green, A.J. (2010). Waterbirds as Bioindicators of Environmental Conditions. In: Hurford, C., Schneider, M., Cowx, I. (eds) Conservation Monitoring in Freshwater Habitats. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9278-7_5.

Samraoui B. and Samraoui F. (2008). An ornithological survey of Algerian wetlands: Important BirdAreas, Ramsar sites and threatened species. Wildfowl, 58: 71–96.

Baha El Din S.M. (1999). Directory of Important Bird Areas in Egypt. Palm Press, Cairo.

Bancroft, G.T.; Gawlik, D.E. and Rutchey, K., (2002). Distribution of wading birds relative to vegetation and water depths in the northern Everglades of Florida, USA. Waterbirds, 25(3):.265-277.

Bouaguel, L.; Charchar, N. and Houhamdi, M. (2021). Phenology and diurnal behavior of common shelduck Tadorna tadorna at Sebkhet Bazer (El-Eulma, Nouth-East of Hauts Plateaux, Algeria). Acta Biologica Sibirica, 7 :293-306.

Bruun, B. and El Din, B. (1985). Common birds of Egypt. American University in Cairo Press.

Chenchouni, H. (2012). Diversité floristique d’un lac du bas-sahara algérien. Flora diversity of a lake at algerian low-sahara. Acta Botanica Malacitana, 37: 33-44.

Cottridge, D. and Porter, R. (2001). A photographic guide to birds of Egypt and the Middle East. New Holland.

Deitmers, R.; Buehler, D. A.; Bartlett, J. G. and Klaus, N. A. (1999). Influence of point count length and repeated visits on habitat model performance. The Journal of Wildlife Management, 63(3): 815–823.

Elafri, A.; Belhamra, M. and Houhamdi, M. (2017). Comparing habitat preferences of a set of waterbird species wintering in coastal wetlands of North Africa: implication for management. Ekológia (bratislava), 36(2):.158-171.

El-Ramady, H. and Abdalla, N. (2021). Biodiversity Resources: A case Study of Egyptian Natural Reserves and Botanical Gardens. Environment, Biodiversity and Soil Security, 5: 221-234.

Erwin, R.M. and Beck, R.A. (2007). Restoration of waterbird habitats in Chesapeake Bay: Great expectations or Sisyphus revisited?. Waterbirds, 30(sp1):163-176.

Fishpool, L. D. C. and Evans, M. (2001) Important Bird Areas in Africa and associated islands: priority sites for conservation. Cambridge, UK: Pisces Publications/BirdLife International.

Francesiaz, C.; Guilbault, E.; Lebreton, J.D.; Trouvilliez, J. and Besnard A. (2017). Colony persistence in waterbirds is constrained by pond quality and land use. Freshwater Biology. 62 (1): 119–132.

Galewski, T. (2012). Biodiversity: Status and trends of species in Mediterranean wetlands. Tour du Valat.

Goodman S.M.; Meininger P.L. and Mullié W.C. (1986). The birds of the Egyptian Western Desert. Misc. Publ. Univ. Michigan Mus. Zool. 172: 1-91.

Goodman, S.M.; Meininger, P.L.; Baha El Din, S.M. Hobbs, J.J. and W.C. Mullie (1989). The birds of Egypt. Oxford University Press, UK.

Green, A.J. and Elmberg, J. (2014). Ecosystem services provided by waterbirds. Biological reviews, 89(1):105-122.

Hamza, F. and Selmi, S. (2018). Diversity of waterbirds wintering in Douz wetlands (south Tunisia): factors affecting wetland occupancy and species richness. Ecological research, 33(5):.917-925.

Hamza, F.; Kahli, A.; Almalki, M. and Chokri, M.A. (2022). Distance from industrial complex, urban area cover, and habitat structure combine to predict richness of breeding birds in southeastern Tunisian oases. Environmental Science and Pollution Research, :1-14.

HBW and BirdLife International (2022) Handbook of the Birds of the World and BirdLife International digital checklist of the birds of the world. Version 7. Available at: http://datazone.birdlife.org/userfiles/file/Species/Taxonomy/HBW-BirdLife_Checklist_v7_Dec22.zip.

Hutcheson, K. (1970). A test for comparing diversities based on the Shannon formula. Journal of Theoretical Biology, 29: 151–154.

Ibrahim, W. A. L. (2011). An overview of bird migration studies in Egypt. The Ring, 33(1-2): 55-75.

IUCN. The IUCN Red List of Threatened Species. Version, 2021, 1. https://www.iucnredlist.org; 2021 Aug 22.

Kiros, S.; Afework, B., and Legese, K. (2018). A preliminary study on bird diversity and abundance from Wabe fragmented forests around Gubre subcity and Wolkite town, southwestern Ethiopia. International Journal of Avian & Wildlife Biology, 3(5): 333–340.

Mediterranean Wetlands Observatory Biodiversity (2012): Status and trends of species in Mediterranean wetlands (Thematic collection, Special Issue #1).

Mengesha G.; Mamo, Y. and Bekele, K. S. C. E. A. (2014). Effects of land-use on birds' diversity in and around Lake Zeway, Ethiopia. Journal of Science & Development, 2, 2.

Moreau R. E. (1940). The Ornithology of Siwa Oasis, with particular reference to the results of the Armstrong College Expedition, 1935, In: Bulletin de l'Institut d'Egypte, tome 23, fascicule 2: 247-261; doi : https://doi.org/10.3406/bie.1940.3602.

Mullarney, K.; Svensson, L.; Zetterström, D. and Grant, P.J. (1999). Bird Guide (the most complete field guide to the birds of Britain and Europe). HarperCollins Publishers Ltd., London.

Newton I. (2008). The Migration Ecology of Birds. Acad. Press, London.

Omar, M. A. A. (2020). Survey of some wild birds and their feeding habits in three types at Assiut governorate, Egypt. Archives of Agriculture Sciences Journal, 3(2):137-144.

Parsons, R.M. (1963) Siwa Oasis area, final report, New Valley Project, Western Desert of Egypt, report to Egyptian Desert Development Organized by The Ralf Parsons Engineering Company, Los Angeles, CA, USA.

Radwan, A. R. and Latfy, I. M. (2002). On the pollution of Burullus lake water and aedimemts by heavy metals Egypt. Aquat. Biol. Fish., 6(4): 147 - 164.

Rashed S. A. Heba (2016). Change Detection in Land Degradation and Environmental Hazards Sensitivity in Some Soils of Siwa Oasis, Egypt. J. Soil Sci. 56(3):433-451.

Salman, A.B.; Howari, F.M.; El-Sankary, M.M.; Wali, A.M. and Saleh, M.M. (2010). Environmental impact and natural hazards on Kharga Oasis monumental sites, Western Desert of Egypt. Journal of African Earth Sciences, 58(2):.341-353.

Sayoud, M.S.; Salhi, H.; Chalabi, B.; Allali, A.; Dakki, M.; Qninba, A.; El Agbani, M.A.; Azafzaf, H.; Feltrup-Azafzaf, C.; Dlensi, H. and Hamouda, N. (2017). The first coordinated trans-North African mid-winter waterbird census: the contribution of the International Waterbird Census to the conservation of waterbirds and wetlands at a biogeographical level. Biological Conservation, 206:11-20.

Shannon, C. E. and Weaver, W. (1949). The mathematical theory of communication, (144pp.). Urbana: University of Illinois, Press.

Sheta B. M. (2019). Biodiversity and habitat use of wintering and breeding waterbirds in Burullus Lake (Ramsar site), Egypt. Catrina: The International Journal of Environmental Sciences, 19(1): 47-54.

Sheta B.M.; Adnan A.A.; Elgyar E.E.; Mohamed A.K. and Mohamed F.A. (2023). Wetland Habitat Suitability and Diversity for Migratory and Resident Birds in the Ramsar Site Lake Burllus, Egypt. Egyptian Journal of Aquatic Biology & Fisheries ISSN 1110 – 6131, 27 (1): 253 - 274.

Simpson, E. H. (1949). Measurement of diversity. Nature, 163, 688.

Squalli, W.; Mansouri, I.; Dakki, M. and Fadil, F. (2020). Nesting habitat and breeding success of Fulica atra in tree wetlands in Fez's region, central Morocco. Journal of Animal Behaviour and Biometeorology, 8(4):.282-287.

Svensson, L. and P.J. Grant. (2001). Bird Guide: The Most Complete Field Guide to the Birds of Britain and Europe (Paperback). HarperCollins, UK.

Xia, S.; Yu, X.; Millington, S.; Liu, Y.U.; Jia, Y.; Wang, L.; Hou, X. and Jiang, L. (2017). Identifying priority sites and gaps for the conservation of migratory waterbirds in China's coastal wetlands. Biological Conservation, 210:72-82.

Wetlands International. (2014). IWC Online Database. http://iwc.wetlands.org.

Appendix (I)

Appendix (II)






Appendix (III)

Appendix (IV)