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Diversity and abundance of migratory waterbird communities in natural and artificial agricultural wastewater habitats of New Valley Governorate, Egypt

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ABSTRACT

This work aims to study the diverse migrating waterbirds in the New Valley area at the natural lakes in Dakhla, Mut and at the artificial agricultural wastewater in Kharga during the period from December 2022 to April 2023. This study focused on the winter and spring migration seasons and 32 different bird species were recorded, of which 29 were migratory. The observed birds belong to 8 different orders and 12 families. The largest group was the Charadriiformes order with 14 bird species. Also, Near Threatened Ferruginous Duck was recorded in Dakhla and relative abundance analysis spotlighted two key species the little stint and marsh sandpiper. The results shed light on the ecological importance of shallow water zones comparison to deep water zones, which had 84.4% from total recorded birds. Dakhla is characterized by higher overall abundances, richer species numbers, and a more diverse Shannon-Weiner index, 2.611 pointing to a more varied and populous avian community compared to Kharga. While Dakhla boasted greater diversity indices, the measurements from both sites similarly suggested that the bird species were evenly spread throughout each location. Both locations exhibited substantial increases in the diversity and populations of species, underscoring the valuable role of agricultural wastewater habitats as resting habitats of migrating waterbirds.

Keywords: Migratory birds, Abundance, Agricultural Wastewater, shallow and deep water.

INTRODUCTION

Wetlands are proven ecosystems that are all indispensable; as they meanwhile avail many places where different waterbird species can live and provide suitable habitats necessary for global biodiversity. On the other hand, the conservation of these biodiversity hotspots is also undermined by human activities and climatic changes at the planetary scale which result into the worldwide degradation or loss of wetlands (Shine & Klemm, 1999; Turner *et al.,* 2000; Froneman *et al.,* 2001). Considerably, the Earth loses almost 50% of the wetlands in near difference because these are being used for agricultural production and the development of the towns and cities, hence it is bound to have higher priority conservation programs to prevent and restore these valuable ecosystems.

Recently the tendency to save the now poorly represented wetlands has been replaced by the rehabilitation of formerly artificial wetlands to give these habitats to the waterbirds who were forced from their original grounds (Maeda, 2001; Múrias *et al.,* 2002; Elphick, & Oring, 2003). In the past, artificial aquatic environment was created for purposes like farming or mining. Though, in recent years, together with protecting biodiversity, these water reserves are gaining a lot of importance. Research has proven that artificial wetlands with characteristics of salt marshes, fish culture ponds and mine impoundments may become a viable habitat for waterbird communities and other related species (Knutson *et al.*, 2004; Taft and Haig, 2005; Julian *et al*., 2006; Almeida *et al.,* 2020).

Although artificial wetlands may provide habitat for only a few individuals, they can still play an important role in maintaining specific species and offsetting the effects of wetland loss (Tourenq *et al.*, 2001; Elphick & Oring, 2003; Ma *et al.*, 2004). One example is the irrigation ponds that have been shown to host greater numbers of some waterbird species than their nearby natural wetlands (Mohamed & Zeid 2015; Donnelly *et al.*, 2020; Rajpar *et al.,* 2022). Also, the stability observed in waterbird populations in some created wetlands implies their crucial contribution in the conservation of wildlife under deteriorating environmental conditions (Fan *et al.,* 2021; Rajpar *et al.*, 2022).

Artificial wetlands are important, although their ecological dynamics and long-term effectiveness in bird groups are unclear. The association between landscape form and connectivity and waterbird habitat selection at manmade wetlands deserves more study (Sebastián-González *et al.,* 2010). This study is aimed at filling knowledge gaps by monitoring the spatial shifts of habitat use by water birds in a wetland complex, in the New Valley region that is located on the southern part of the Western Desert of Egypt. This area, comprising those oases like Dakhla and Kharga, depends mainly on agriculture that gives rise to significant drainage of water and sewage from the groundwater (Mohallal & Ahmed 2018; Elbeih & Zaghloul 2021; Darwish 2020). Also, this research involves extensive field surveys and analysis to show how the artificial wetlands are supporting waterbird populations and ascertaining their possible role in conservation efforts, in the face of environmental challenges.

MATERIALS AND METHODS

Study area and Bird monitoring:

Bird monitoring was undertaken in two distinct types of habitats; natural lakes in Dakhla, specifically Mut lakes, and artificial agricultural wastewater stations in Kharga. These study sites are situated in the southern region of the Western Desert of Egypt, within the New Valley area. The Mut lakes in Dakhla (Fig. 1 A) and the artificial agricultural wastewater stations in Kharga (Fig. 1 B) are focal points of the study.

These oases rely predominantly on agricultural activities supported by groundwater, resulting in significant volumes of agricultural drainage and wastewater that accumulate in ponds. The placement of many of these ponds in elevated terrain poses a risk of structural failure and subsequent flooding of adjacent cultivated lands and residential areas.

The study extends From December 2022 to April 2023, and focusing on the winter and spring bird migration at each lake. Bird species were identified and counted after Mohallal (2023) method for four days every month for each site.

The confirmation of bird species identification was achieved through the utilisation of field guides (Bruun, and Baha El Din, 1985; Mullarney *et al.*, 1999; Cottridge and Porter, 2001; Svensson and Grant, 2001; HBW & BirdLife International, 2022).

A

B

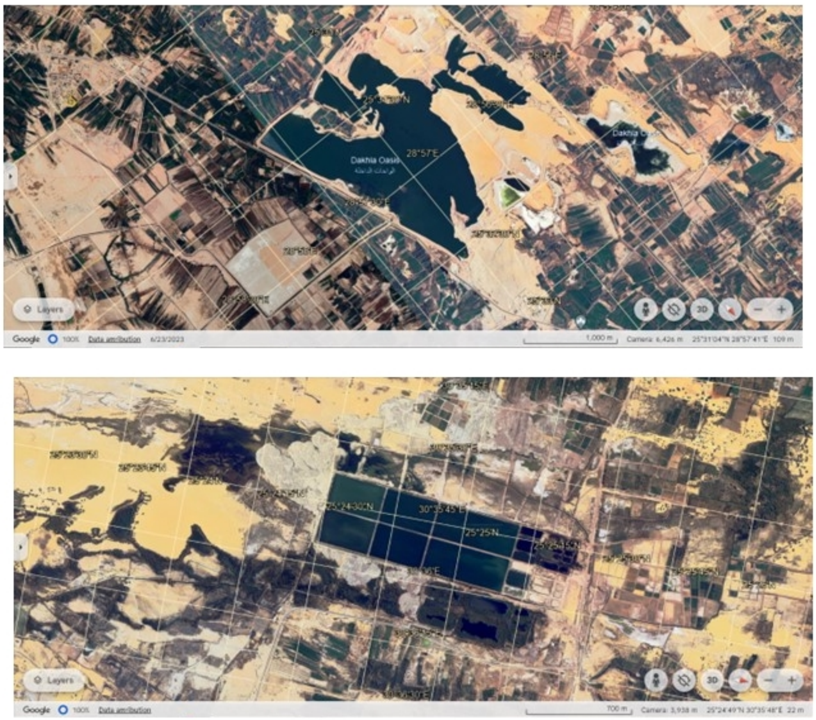

Fig. 1. Show the study site The Mut lakes in Dakhla (A) and artificial lakes in Kharga (B). (Google Earth 2023.)

Data analysis:

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 species

N is the total number of birds of all species).

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

Shannon-Weiner Index (*H′*) using the Shannon & Weaver (1949) formula:

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

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 Index (*J′*) using Kiros *et al.*(2018) was calculated using the equation: $J' = \frac{H'}{H_{max}}$

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

Simpson Diversity Index (*D*) (Simpson, 1949) 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* ; *N* is the total number of birds of all species).

RESULTS

Waterbird species records:

The checklist in Table (1) showed variation in structure of waterbird communities recorded at Natural and Artificial Agricultural Wastewater during the investigation period. Bird species recorded at Dakhla, Mut lakes are shown in (App. I), while those at Kharga agricultural wastewater stations in (App.

II). The obtained data showed that the total number of waterbird species found was thirty-two; four resident species, are distributed across eight orders and twelve families. Charadriiformes was the dominant one represented by four families and a total of fourteen species. Order Pelecaniformes, on the other hand, has two families including five species. While the lowest orders in numbers were Suliformes and coraciiformes, which were represented by one species for each. Near Threatened Ferruginous Duck was recorded in Dakhla.

Table 1. Waterbird species recorded in natural and artificial agricultural wastewater habitats of New Valley Governorate during the study period from December 2022 to April 2023.

Order	Family	English Name	Scientific Name	Status	Red list (IUCN)	D	K
Coraciiformes	Alcedinidae	Pied kingfisher	*Ceryle rudis*	*R*	*LC*	+	+
Anseriformes	Anatidae	Mallard	*Anas platyrhynchos*	*M*	*LC*	+	-
Anseriformes	Anatidae	Northern shoveler	*Spatula clypeata*	*M*	*LC*	+	-
Anseriformes	Anatidae	Green winged teal	*Anas carolinensis*	*M*	*LC*	+	-
Anseriformes	Anatidae	Ferruginous duck	*Aythya nyroca*	*M*	*NT*	+	-
Charadriiformes	Charadriidae	Little ringed plover	*Charadrius dubius*	*M*	*LC*	+	+
Charadriiformes	Charadriidae	White taild lapwing	*Vanellus leucurus*	*M*	*LC*	+	-
Charadriiformes	Charadriidae	Spur-winged Plover	*Vanellus spinosus*	*M*	*LC*	+	+
Charadriiformes	Laridae	Whiskered tern	*Chlidonias hybrida*	*M*	*LC*	+	+
Charadriiformes	Laridae	Black headed gull	*Chroicocephalus ridibundus*	*M*	*LC*	-	+
Charadriiformes	Laridae	Slender billed gull	*Chroicocephalus genei*	*M*	*LC*	+	+
Charadriiformes	Laridae	Common tern	*Sterna hirundo*	*M*	*LC*	+	+
Charadriiformes	Laridae	Gull billed tern	*Gelochelidon nilotica*	*M*	*LC*	+	+
Charadriiformes	Recurvirostridae	Black-winged stilt	*Himantopus himantopis*	*R*	*LC*	+	+
Charadriiformes	Scolopacidae	Common snipe	*Gallinago gallinago*	*M*	*LC*	+	+
Charadriiformes	Scolopacidae	Little stint	*Calidris minuta*	*M*	*LC*	+	+
Charadriiformes	Scolopacidae	Marsh sandpiper	*Tringa stagnatilis*	*M*	*LC*	+	+
Charadriiformes	Scolopacidae	Ruff	*philomachus pugnax*	*R*	*LC*	+	+
Charadriiformes	Scolopacidae	Redshank	*Tringa totanus*	*R*	*LC*	+	+
Passeriformes	Motacillidae	Yellow wagtail	*Motacilla flava*	*M*	*LC*	+	-
Passeriformes	Motacillidae	White wagtail	*Motacilla alba*	*M*	*LC*	+	+
Suliformes	Phalacrocoracidae	Cromorant	*Phalacrocorax carbo*	*M*	*LC*	+	-
Podicipediformes	Podicipedidae	Little grebe	*Tachybaptus ruficollis*	*M*	*LC*	-	+
Podicipediformes	Podicipedidae	Black necked grebe	*Podiceps nigricollis*	*M*	*LC*	-	+
Gruiformes	Rallidae	Eurasian coot	*Fulica atra*	*M*	*LC*	-	+
Gruiformes	Rallidae	The common moorhen	*Gallinula chloropus*	*M*	*LC*	+	-
Gruiformes	Rallidae	Baillon's crake	*Porzana pusilla*	*M*	*LC*	+	-
Pelecaniformes	Ardeidae	Squacco hern	*Ardeola ralloides*	*M*	*LC*	+	+
Pelecaniformes	Ardeidae	Grey heron	*Ardea cinerea*	*M*	*LC*	+	+
Pelecaniformes	Ardeidae	Cattle Egret	*Bubulcus ibis*	*M*	*LC*	+	+
Pelecaniformes	Ardeidae	Little Egret	*Egretta garzetta*	*M*	*LC*	+	+
Pelecaniformes	Threskiornithidae	Glossy ibis	*Plegadis falcinellus*	*M*	*LC*	+	+

Where, R= Resident species, M = Migratory species, LC= least concern, NT = near threatened, D= Dakhla and K=Kharga

Relative abundance of waterbird species:

Assessing the relative abundance of the numerical data regarding the waterbird species is presented in Table (2), the little stint, Marsh Sandpiper was on both location and Eurasian coot in Kharga. The highest counts were quantified as 100 individuals and more based on numerical values. The relative abundances of these counts were calculated to be 0.160 in Dakala and 0.174 in Kharga, indicating the distribution of these counts in the ecosystem. The avian specimens recorded for White tailed lapwing, Cormorant and Baillon’s crake species were observed in a minimum count each, indicating a relative frequency of 0.002. Only two spices were recorded in both deep an shallow water zoon in Dakhla and Kharga and their relative abundance was 0.081, 0.013 for Gray horn and 0.108, 0.020 for Raff. Pied kingfisher has 0.0405 relative abundance in deep water in Dakala, while Eurasian coot has 0.533 relative abundance in deep water in Kharga.

Table 2. Relative abundance of waterbirds observed in Dakhla Mut lakes and Kharga agricultural wastewater stations.

English Name	Dakhla				Kharga			
	Number	Relative abundance (Pi)	LN(Pi)	Pi* LN(Pi)	Number	Relative abundance (Pi)	LN(Pi)	Pi* LN(Pi)
Pied kingfisher	15	0.024	-3.730	-0.090	6	0.010	-4.563	-0.048
Mallard	60	0.096	-2.343	-0.225	-	-	-	-
Northern shoveler	47	0.075	-2.588	-0.195	-	-	-	-
Green winged teal	20	0.032	-3.442	-0.110	-	--	-	-
Ferruginous duck	10	0.016	-4.135	-0.066	-	-	-	-
Little ringed plover	25	0.040	-3.219	-0.129	27	0.047	-3.059	-0.144
White tailed lapwing	1	0.002	-6.438	-0.010	-	-	-	-
Spur-winged Plover	20	0.032	-3.442	-0.110	30	0.052	-2.953	-0.154
Whiskered tern	4	0.006	-5.051	-0.032	3	0.005	-5.256	-0.027
Black headed gull	-	-	-	-	4	0.007	-4.968	-0.035
Slender billed gull	2	0.003	-5.745	-0.018	2	0.003	-5.661	-0.020
Common tern	2	0.003	-5.745	-0.018	3	0.005	-5.256	-0.027
Gull billed tern	3	0.005	-5.339	-0.026	2	0.003	-5.661	-0.020
Black-winged stilt	50	0.080	-2.526	-0.202	40	0.070	-2.665	-0.185
Common snipe	8	0.013	-4.358	-0.056	5	0.009	-4.745	-0.041
Little stint	100	0.160	-1.833	-0.293	100	0.174	-1.749	-0.304
Marsh sandpiper	100	0.160	-1.833	-0.293	100	0.174	-1.749	-0.304
Ruff	40	0.064	-2.749	-0.176	30	0.052	-2.953	-0.154
Rredshank	25	0.040	-3.219	-0.129	20	0.035	-3.359	-0.117
Yellow wagtail	6	0.010	-4.646	-0.045	-	-	-	-
White wagtail	10	0.016	-4.135	-0.066	12	0.021	-3.869	-0.081
Cromorant	1	0.002	-6.438	-0.010	-	-	-	-
Little grebe	-	-	-	-	30	0.052	-2.953	-0.154
Black necked grebe	-	-	-	-	25	0.043	-3.135	-0.136
Eurasian coot	-	--	-	-	100	0.174	-1.749	-0.304
The common moorhen	3	0.005	-5.339	-0.026	-	-	-	-
Baillon's crake	1	0.002	-6.438	-0.010	-	-	-	-
Squacco hern	8	0.013	-4.358	-0.056	10	0.017	-4.052	-0.070
Grey heron	11	0.018	-4.040	-0.071	4	0.007	-4.968	-0.035
Cattle Egret	20	0.032	-3.442	-0.110	8	0.014	-4.275	-0.059
Little Egret	30	0.048	-3.037	-0.146	10	0.017	-4.052	-0.070
Glossy ibis	3	0.005	-5.339	-0.026	4	0.007	-4.968	-0.035
Total	625	1	-114.945	-2.744	575	1	-88.619	-2.525
deep water zone	37	1	-22.335	-1.871	150	1	-31.915	-1.476
shallow water zone	588	1	-95.649	-2.611	425	1	-63.794	-2.314

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

Waterbird feeding guild:

It was obvious from Figure (2) the presence of variation in dietary preferences between the Kharga and Dakhla bird species. Kharga birds appear to have a higher preference for carnivorous diets compared to Dakhla birds, with 259 individuals classified as carnivores compared to 289 for Dakhla. On the other hand, Dakhla birds seem to favor more insectivorous diets, with 180 individuals falling into this category compared to 204 for Kharga. Interestingly, both species show a preference for omnivorous diets, with Kharga having 112 individuals and

Dakhla having 156 individuals categorized as omnivores.

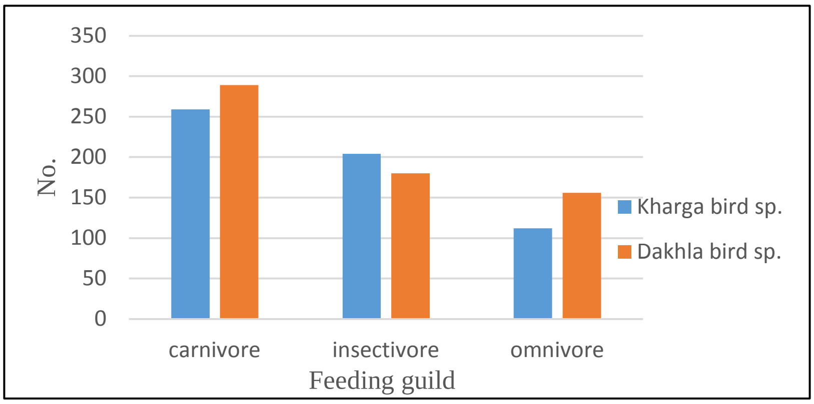

Fig. 2. The mean percentage of waterbird Feeding guild variety throughout the study period extends from winter 2022 to spring 2023.

Diversity indices waterbird species:

Table (3) shows some variables related to the diversity of water bird species. The total number of bird species was 1200 individuals, which is (187 individual) in deep water zone lower than Migratory water birds in shallow water zoon (1013 individuals). Also, species richness for Dakhla was (r = 28), which is also higher than Kharga water birds (r = 23). At the same trend, Dakhla waterbird had the highest values of Shannon-Weiner diversity index (H′ = 2.744) and Simpson's Diversity (D = 0.914), than Migratory water bird (H′ = 2.083) and (D = 0.758). While evenness (J′) was higher in Kharga waterbird (J′ = 2.525) than resident water bird (J′ = 0.891). The Analysis of variance of the bird species diversity showed that there was no significant difference between bird species in natural lake and Artificial lakes ($p<0.823$) in number of waterbird species.

Table 3. Diversity indices for waterbird species recorded in agricultural wastewater habitats of New Valley Governorate.

Diversity Index	Dakhla bird sp.			Kharga bird sp.			Total Bird sp.
		Deep water zone	Shallow water zone		Deep water zone	Shallow water zone	
Overall abundance	625	37	588	575	150	425	1200
Species richness (r)	28	9	24	23	10	18	32
Evenness (J′)	0.823	0.852	0.822	0.805	0.641	0.801	1.520
Shannon-Weiner (H′)	2.744	1.871	2.611	2.525	1.476	2.314	5.269
Simpson diversity (D)	0.914	0.808	0.905	0.891	0.665	0.862	0.952

DISCUSSION

The study recorded a wide variety of waterbird species in both natural and man-made agricultural wastewater environments in the New Valley Governorate. 32 waterbird species, were observed encompassing both resident and migratory species. The Charadriiformes order was the most prevalent, with a significant presence in four families. Two families and five species of Pelecaniformes were observed in proximity. While several orders were abundant in species, others, such as Suliformes and Coraciiformes, had a limited representation, each consisting of only one species. Several research studies conducted on bird surveys in the New Valley region support the current results (Goodman *et al.,* 1986; Churcher *et al.,* 2008; Ibrahim, 2011; Mohallal & Ahmed, 2018). Numerous researchers found that the artificial wetlands are effective and important habitats for waterbirds throughout different seasons, including wintering and migrating (Paracuellos & Telleria 2004; Rendon *et al.,* 2008; Sebastián-González *et al.,* 2010; Pérez-García *et al.,* 2014; Pandiyan & Nagarajan 2014). Also, some studies indicated that well-maintained artificial habitats and other semi-natural wetlands such as traditional saline and rice fields can provide valuable habitats for several species (Mu´rias *et al.,* 2002; Masero *et al.,* 2017; Lei *et al.,* 2021). In addition, ponds may promote the interconnection of wetlands within the research area (Qiu *et al.,* 2024).

Comprehending the comparative prevalence of waterbird species is crucial for evaluating their ecological importance within environments. In the present study the little stint, marsh sandpiper and Eurasian coot were observed in significant numbers, particularly in the Kharga region. This suggests that these species play an important role in the ecological dynamics of agricultural wastewater systems. In contrast, certain species, such as the pied kingfisher and ferruginous duck, exhibited reduced relative abundances, suggesting potential variations in habitat preference or utilization of ecological niches. Man-made wetlands can significantly impact certain environments and particular species (Froneman *et al.,* 2001; Afdhal *et al.,* 2013). Artificial wetlands typically exhibit lower population densities than natural wetlands, as were observed in many studies (Tourenq *et al.,* 2001; Ma *et al.,* 2004; Rajpar *et al.,* 2022).

The specific characteristics of irrigation ponds have a direct correlation with the population and diversity of waterbirds. However, the specific impacts can differ among different species groups (guilds), as noted by Sánchez-Zapata *et al.* (2005) and Wiens (1989). Multiple studies have examined the correlation between environmental factors and wetland bird populations in man-made wetlands located in agricultural areas (Choi *et al.,* 2015; S'anchez-Zapata *et al.,* 2005; Sebastian-Gonz'alez *et al.,* 2010; Almeida *et al.,* 2020).

In the current investigation the analysis of variance did not indicate any statistically significant differences between bird species in natural settings compared to artificial habitats, or between deep and shallow water zones. This ay indicated that the distribution and diversity of waterbird species remained largely stable across various habitats and water depths during the study period.

Various studies have indicated that the depth of water plays a crucial role in influencing the use of wetland habitats by waterbirds (Colwell & Taft 2000; Isola *et al.,* 2002; Liang *et al.,* 2022). The depth of the water has a direct impact on the availability of waterbirds. This is because their physical characteristics, such as the lengths of their tarsometatarsi, impose limitations, as observed in studies by Collazo *et al.* (2002) and Darnell & Smith (2004). The community of waterbirds has a favorable correlation with the regulation of water level (Isola et al., 2002; Sebastian-Gonzalez & Green 2014; Larson *et al.,* 2020).

The study emphasized the divergent feeding preferences observed among waterbird species in Dakhla and Kharga. Kharga birds exhibited a greater inclination towards consuming meat-based diets, while Dakhla birds displayed a predilection for diets primarily consisting of insects. Nevertheless, both populations displayed a substantial number of omnivores, suggesting their capacity to adapt. Even within species, waterbirds exhibit significant variation in their dietary choices, and their dietary patterns vary based on patterns of land use (Adhurya *et al*., 2020; Rajpar *et al.*, 2022; Mott *et al.*, 2023). In addition, waterbirds could alter their dietary composition based on the season and their location (Almeida *et al.*, 2020; Antón-Tello *et al.*, 2021) Red knot feeds on hard shelled mollusks during the winter and soft-bodied arthropods during the summer (Davis & Smith, 2001).

Diversity indices offer valuable insights into the organization and makeup of waterbird groups. In comparison to Kharga, Dakhla displayed greater species richness, Shannon-Weiner diversity, and Simpson diversity. Nevertheless, Kharga exhibited greater evenness, indicating a more equitable distribution of species abundances. These findings emphasize the significance of using different diversity indices to thoroughly evaluate the dynamic of waterbirds. Community-level studies indicated that both local and regional landscape characteristics influence the diversity of species in a particular area as mentioned by Yifei *et al.* (2020).

Implications for Conservation

Conservation efforts should focus on maintaining the ecological integrity of the studied habitats to support resident and migratory waterbird populations. Additionally, continued monitoring and research are essential for understanding long-term trends and implementing effective management strategies.

CONCLUSION:

Waterbird communities play vital roles in ecosystem dynamics and reflect the health and vitality of aquatic habitats. The current work explores the structure, abundance, and diversity of waterbird species recorded in natural and artificial agricultural wastewater habits within the New Valey Governorate. Through a comprehensive analysis of species composition, relative abundance, food guild diversity, and divergent indices, this study elucidates key insights into the ecological dynamics of these local ecosystems. Understanding the distribution and behavior of waterbird populations is fundamental for developing conservation strategies aimed at preserving biodiversity and the overall health of aquatic ecosystems in the investigated Egyptian habitats.

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Appendix (I)


Marsh sandpiper


White taild lapwing


Northern shoveler


Ferruginous duck


Rredshank


Cromorant


Marsh sandpiper and Glossy ibis


Teal


Baillons crake


Yellow wagtail

Appendix (II)


Eurasian coot


Little stint


Eared grebe


Black necked grebe


Marsh sandpiper


Glossy ibis


Ruff


Common tern


Little stint and Common snipe


Black-winged stilt

Diversity and abundance of migratory waterbird communities in natural and artificial agricultural wastewater habitats of New Valley Governorate, Egypt

تنوع ووفرة مجتمعات الطيور المائية المهاجرة في موائل مياه الصرف الزراعي الطبيعية والصناعية بمحافظة الوادي الجديد، مصر

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المستخلص

يهدف هذا العمل إلى دراسة الطيور المائية المهاجرة المتنوعة في منطقة الوادي الجديد فى البحيرات الطبيعية في الداخلة بحيرة موط وفي وبحيرات الصرف الزراعية الاصطناعية في الخارجة خلال الفترة من ديسمبر ٢٠٢٢ إلى أبريل ٢٠٢٣. ركزت هذه الدراسة على مواسم الهجرة الشتوية والربيعية وسُجِّلت ٣٢ نوعًا مختلفًا من الطيور، منها ٢٩ كانت مهاجرة. تنتمي الطيور المرصودة إلى ٨ رتب مختلفة و ١٢ عائلة. كانت أكبر مجموعة هي رتبة Charadriiformes التي تضم ١٤ نوعًا من الطيور. كما تم تسجيل بَطَّةٌ كُمَيْتٌ في الداخلة وهى مسجله كقريب من التهديد بالانقراض ، وقد سلط تحليل الوفرة النسبية الضوء على نوعين رئيسيين هما طائر الطيطوي الصغير وطائر رمل المستنقعات. ألقت النتائج الضوء على الأهمية البيئية للمناطق المائية الضحلة مقارنة بالمناطق العميقة، حيث بلغت ٨٤.٤% من إجمالي الطيور المسجلة. تتميز الداخلة بوجود كثافات عامة أعلى وأعداد أنواع أغنى ومؤشر شانون - وينر المتنوع أكثر، بنقطة ٢.٦١١ تشير إلى مجتمع طيور متنوع وأكثر ازدحامًا مقارنة بالخارجة. وفي حين أن منطقة الداخلة كانت تتمتع بمؤشرات تنوع أكبر، فإن القياسات من كلا الموقعين تشير بالمثل إلى أن أنواع الطيور كانت منتشرة بالتساوي في كل موقع. وأظهر كلا الموقعين زيادات كبيرة في تنوع الأنواع وأعدادها، مما يؤكد على الدور القيّم الذي تلعبه موائل مياه الصرف الزراعية باعتبارها موائل راحة للطيور المائية المهاجرة.

الكلمات المفتاحية: الطيور المهاجرة- الوفرة - مياه الصرف الزراعية،- المياه الضحلة والعميقة.