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Avian Species Diversity in Terrestrial and Aquatic Habitats in Certain Areas of Egypt

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ABSTRACT

Ecologically, the presence of avifauna is a crucial indicator of ecosystem equilibrium. The diversity of bird species and their community structure serves as an essential tool for assessing ecological impacts. This study aimed to evaluate the species composition, evenness, and diversity of wild bird species across different habitats in Egypt from May 2023 to February 2024. The study identified 17,387 individuals from 40 resident bird species belonging to 25 families and 10 orders. The house sparrow exhibited the highest relative abundance among resident bird species, followed by the western cattle egret, barn swallow, house crow, rock pigeon, little egret, hooded crow, laughing dove, and common myna. In terms of migratory birds, 6,050 individuals from 39 species across 22 families and 11 orders were observed. The slender-billed gull, little stint, great cormorant, common ringed plover, the European bee-eater, black-winged stilt, and white wagtail had the highest relative abundances among migratory species. The distribution of bird species across different sites revealed that the coastal area (CA) and the Suez Canal & Gulf Suez (SCGS) each harbored 25% of the total number of resident species, followed by the Nile Delta (ND) with 21%, the Nile Valley (NV) with 16%, and the Faiyum (F) area with 13%. For migratory birds, the CA accounted for 48% of all migratory species, followed by the F area at 23%, ND at 13%, SCGS at 11%, and NV at 5%. The highest species richness was recorded in the CA, followed by SCGS, ND, F, and NV. The highest values for the Shannon and Simpson indices were found in the CA, NV, ND, SCGS, and F areas, respectively. It can be concluded that the Egyptian environment, especially aquatic habitats, is a valuable resource for the Egyptian avifauna by providing food sources and nesting sites.

INTRODUCTION

The habitat heterogeneity type is very critical to bird diversity since it has a great effect on the existence, dominations of bird species, and their interactions with the surrounded ecosystem. Moreover, they are sensitive to habitat type **(Sharma & Kumar,**

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2023). Some habitats exhibit a positive impact on bird abundance and diversity such as the availability of food resources **(Kath *et al.*, 2009; Wuczyński, 2016)**, nesting sites and shelter from predators **(Soto *et al.*, 2017)**, as well as suitable environmental factors **(Sheta, 2019)**. The interactions with the surrounding ecosystem include pollination, pest control in agriculture, seeds dispersal and cleaning environment viz. scavenger **(Shah, 2021)**.

Egypt's diverse landscapes create a rich habitat heterogeneity, supporting a wide array of resident bird species and serving as crucial stopover points for migratory birds. Countless flyways of migratory birds pass through Egypt; the Mediterranean/Black Sea and East Africa-West Asia flyways are among them, where birds migrate from their homes in north Europe (Palearctic) and western & central Asia to the tropical Africa in winter **(Council, 2011)**. Egyptian birds are comprised of 515 species including 300 migratory species and 186 resident species, while the remaining species range from 12 extinct species to 17 endemic species **(Tharwat, 1997; EEAA, 2016)**.

Despite Egypt's rich avifauna, studies on bird diversity across its various habitats remain limited. Recent research has focused on specific locations, revealing intriguing patterns. For instance, in the agricultural and coastal areas of Damietta Governorate, **Sheta *et al.* (2010)** recorded 154 bird species, totaling 197,568 individuals. In contrast, a Ramsar site in Lake Burullus yielded only 49 species with 34,425 individuals **(Sheta, 2019)**, highlighting the variability in bird diversity across different habitats. Bird species diversity vary temporally, as mentioned by **Sheta *et al.* (2023)** for the same lake in Burllus, where 60 bird species holding 6888 individuals were recorded. The spatial heterogeneity affects bird diversity; aquatic habitat hosts a highest number of birds compared to the field crop habitat **(Issa, 2019)**. Protected areas provide more suitable habitats, offering essential resources such as foraging and nesting sites, shelter, and reduced human disturbance. This is reflected in the high bird diversity observed in Saint Catherine Protectorate, South Sinai, where 3,884 individuals from 73 bird species have been recorded **(Soliman *et al.*, 2022)**.

Biodiversity is a radical measurement for the significance of the ecosystem ascribed to its relation with the fineness of life and human welfare.

The diversity is a term referring to species members that achieve an ecological function according to its exploitation of the available resources at the community **(Ricklefs, 2010)**. The biodiversity is the variation amongst the species, thus it’s an important method to monitor the condition of the ecosystem **(Yu & Yoo, 2015)**, various indices and methods can be utilized to draw picture for biodiversity through field observations **(Herrmann *et al.*, 2022)**. These indices are measured through classical statistical indices, such as evenness, species richness, relative abundance, Shannon-Wiener index and Simpson's index **(Yu & Yoo, 2015; Asmare *et al.*, 2023)**. These indices help us enrich our knowledge about the diversity of the ecosystem such as bird

species populations, dispersal in addition to the interaction between species and the surrounding environment.

The objective of the current study was to investigate bird species composition, assess the bird species evenness, studying the distribution and diversity indices for the wild bird species through habitat heterogeneity in Egypt, in order to understand the bird diversity of the Egyptian ecosystem, viz. populations, dispersal, and the interaction between species & the surrounding environment.

MATERIALS AND METHODS

Study areas

The current study was conducted in 22 different locations in different governorates covering Egypt. In each location, different habitats were chosen to perform bird count; these habitats varied between natural habitat (agricultural area, rural area, urban area) and artificial habitat as (places contain garbage boxes and garbage collection area). The different locations, representing the Egyptian habitat heterogeneity, were stratified into 5 main regions;

1. Coastal area (CA): including governorates of North Sinai, Port said, Damietta, Kafr El-sheikh, Alexandria and El-Hamam City in Matrouh Governorate, the Burullus and Manzala lakes.
2. Nile Delta (ND): including governorates of Sharkia, Dakahlia, Gharbia, Monofia, El Qalubia, Giza in additional to Sadat and Wadi El- natron districts.
3. Nile Valley (NV): includes Assuit and Qina governorates.
4. Suez canal & Gulf Suez (SCGS): including governorates of the Red Sea, Ismailia, the Suez and El- sokhna area.
5. Faiyum (F): Faiyum Governorate, known as a place for migratory birds, has a unique character as Qarun Lake (big saline lake) and agricultural lands, where lots of crops are found.

Bird counts

Two skilled observers cooperated to achieve the work by visiting each location three times (every three month) during the period from May 2023 to February 2024. Birds were counted using the line transects method, as the observer walked in a route of 500m length and 100m width (50m on both sides) **(Bibby *et al.*, 2000)**. The walking speed was around 1km per hour, thus the line was achieved in 30min. Birds seen or heard within the line transect were counted. No counts were detected in windy or rainy weather. Counts were scored within two hours after sunrise, because at this time bird is most active.

A 10×42 binocular was used for counting bird species, with identifications determined using the *Collins Bird Guide* **(Svensson *et al.*, 2009)**. Bird classification followed the criteria outlined by **Clements *et al.* (2023)**. Additionally, classification into resident or migratory species was based on the works of **Sheta *et al.* (2010), Issa (2019), Sheta (2019), Soliman *et al*. (2022)** and **Sheta *et al.* (2023)**.

Data analysis

The data were classified to conduct the following parameters:

1- Relative abundance of different bird species for the different locations through the succeeding formula:

$$\text{Relative abundance} = (n / N) \times 100$$

Where, n is the total number of recorded birds for specific specie in the area, and N is the total numbers for all bird species.

2- The diversity parameters:

- Species richness (S) which reflects the number of all species found in the area **(Morris *et al.*, 2014; Abdul Razak *et al.*, 2019)**.
- Shannon diversity index (H´): was calculated according to Shannon and Weaver (1949) formula:

$$H' = - \Sigma Pi * LN (Pi)$$

Where, Pi = proportion of every specie in the sample; LN (Pi) = the natural logarithm for this proportion.

- Simpsons index (D): values were calculated according to **Simpson, 1949**, as follows:

$$D = 1- \Sigma n(n-1) / N(N-1)$$

Where, n = total numbers for every species; N = total number for all bird species.

- The distinctness or dissimilarity of the different species in the area is referring to evenness index (J') and was calculated according to the instructions of **Abdul Razak *et al.*, 2019,** as follows:

$$J' = H' / H_{max}$$

Where, H'= Shannon diversity index, H_{max}= the natural log for the total number of species.

- Menhinick's index and Margalef's richness index were calculated according to **Abdul Razak *et al.* (2019)** as follows:

$$\text{Menhinick's index} = S / \sqrt{N}$$

Where, S= Species richness, $\sqrt{N}$ = SQRT for the total number of bird species.

$$\text{Margalef's index} = (S-1) / \text{In } (n)$$

Where, S= Species richness, In (n) = log for the total number of bird species.

RESULTS

Species composition

Resident bird species

The resident bird species composition during the study is illustrated in Table (1), indicating that there were 17387 individuals of 40 bird species belonging to 25 families and 10 orders. The order Passeriformes was the most abundant, representing 12 families (Alaudidae, Acrocephalidae, Cisticolidae, Columbidae, Corvidae, Hirundinidae, Estrildidae, Muscicapidae, Motacillidae, Pycnonotidae**,** Passeridae, and Sturnidae) with 20 species. The aforementioned order was followed by order Charadriiformes represented by 4 families (Burhinidae, Charadriidae, Laridae, Rostratulidae) with 6 species, then order Coraciiformes was represented with 2 families (Alcedinidae, Meropidae) and 3 species. While, for orders Pelecaniformes and Psittaciformes, each was represented by only one family, where Ardeidae (order Pelecaniformes represented by 4 species, Psittaculidae (order Psittaciformes) was represented by 2 species. On the other hand orders Accipitriformes, Bucerotiformes, Cuculiformes, Falconiformes, Gruiformes were at the last rank, with one family and 1 species for each.

Regarding the relative abundance, the house sparrow gives the highest value (30.16%), followed by the western cattle egret (15.30%), the barn swallow (10.06%), house crow (9.44%), rock pigeon (8.91%), little egret (4.8%), hooded crow (4.39%), laughing dove (3.84%) and (2.67%) the common myna which is an invasive species spread over Egypt. In the other hand, the lowest value was (0.01%) for the white-crowned wheatear, the Alexandrine parakeet and the rose-ringed parakeet (the last two species are also established in Egypt).

Table 1. List of resident bird species recorded across different habitats in Egypt

Birds name	Scientific name	Family	Order	Count	Relative abundance
Black-winged Kite	*Elanus caeruleus caeruleus* Desfontaines, 1789	Accipitridae	Accipitriformes	6	0.03
Eurasian Hoopoe	*Upupa epops epops* Linnaeus, 1758	Upupidae	Bucerotiformes	96	0.55
Senegal Thick-knee	*Burhinus senegalensis* Swainson, 1837	Burhinidae	Charadriiformes	34	0.20
Spur-winged Lapwing	*Vanellus vanellus* Linnaeus, 1758	Charadriidae	"	303	1.74
Whiskered Tern	*Chlidonias hybrida hybrida* Pallas, 1811	Laridae	"	28	0.16
Gull-billed Tern	*Gelochelidon nilotica nilotica* Gmelin, 1789	"	"	64	0.37
Little tern	*Sternula albifrons albifrons* Pallas, 1764	"	"	396	2.28
Greater painted-snipe	*Rostratula benghalensis* Linnaeus, 1758	Rostratulidae	"	8	0.05
Rock Pigeon	*Columba livia schimperi* Bonaparte, 1854	Columbidae	Columbiformes	1549	8.91
Laughing Dove	*Spilopelia senegalensis aegyptiaca* Latham, 1790	"	"	667	3.84
Eurasian Collared-Dove	*Streptopelia decaocto Frivaldszky,* 1838	"	"	163	0.94
Pied Kingfisher	*Ceryle rudis rudis* Linnaeus, 1758	Alcedinidae	Coraciiformes	64	0.37
White-throated Kingfisher	*Halcyon smyrnensis smyrnensis* Linnaeus, 1758	"	"	22	0.13
Green Bee-eater	*Merops viridissimus cleopatra* Nicoll, 1910	Meropidae	"	29	0.17
Senegal Coucal	*Centropus senegalensis*	Cuculidae	Cuculiformes	12	0.07

	aegyptius Gmelin, 1788				
Eurasian kestrel	*Falco tinnunculus tinnunculus* Linnaeus, 1758	Falconidae	Falconiformes	33	0.19
Eurasian Moorhen	*Gallinula chloropus chloropus* Linnaeus, 1758	Rallidae	Gruiformes	55	0.32
Clamorous Reed Warbler (Clamorous)	*Acrocephalus stentoreus stentoreus* Hemprich & Ehrenberg, 1833	Acrocephalidae	Passeriformes	5	0.03
Crested lark	*Galerida cristata* Linnaeus, 1758	Alaudidae	"	68	0.39
Zitting Cisticola	*Cisticola juncidis cisticola* Temminck, 1820	Cisticolidae	"	21	0.12
Graceful prinia	*Prinia gracilis* Lichtenstein, 1823	"	"	95	0.55
Hooded crow	*Corvus cornix pallescens* Madarász, 1904	Corvidae	"	764	4.39
House crow	*Corvus splendens* Vieillot, 1817	"	"	1641	9.44
Common raven	*Corvus corax* Linnaeus, 1758	"	"	7	0.04
Fan-tailed Raven	*Corvus rhipidurus* Hartert, 1918	"	"	56	0.32
Brown-necked Raven	*Corvus ruficollis* Lesson, 1831	"	"	37	0.21
Indian silverbill	*Euodice cantans orientalis* Lorenz von Liburnau & Hellmayr, 1901	Estrildidae	"	7	0.04
Sand martin (Bank Swallow)	*Riparia riparia shelleyi* Sharpe, 1885	Hirundinidae	"	27	0.16
Barn Swallow	*Hirundo rustica savignii* Stephens, 1817	"	"	1750	10.06
Western Yellow	*Motacilla flava* Linnaeus, 1758	Motacillidae	"	9	0.05

Wagtail					
White-crowned Wheatear	***Oenanthe leucopyga ernesti* Meinertzhagen, 1930**	**Muscicapidae**	"	**1**	**0.01**
House Sparrow	***Passer domesticus niloticus* Nicoll & Bonhote, 1909**	**Passeridae**	"	**5244**	**30.16**
Common bulbul	***Pycnonotus barbatus* Desfontaines, 1789**	**Pycnonotidae**	"	**92**	**0.53**
Common Myna	***Acridotheres tristis* Linnaeus, 1766**	**Sturnidae**	"	**464**	**2.67**
Squacco Heron	***Ardeola ralloides* Scopoli, 1769**	**Ardeidae**	**Pelecaniformes**	**43**	**0.25**
Western Cattle Egret	***Bubulcus ibis* Linnaeus, 1758**	"	"	**2660**	**15.30**
Little Egret	***Egretta garzetta garzetta* Linnaeus, 1766**	"	"	**834**	**4.80**
Black-crowned Night Heron	***Nycticorax nycticorax nycticorax* Linnaeus, 1758**	"	"	**30**	**0.17**
Alexandrine Parakeet	***Psittacula eupatria* Linnaeus, 1766**	**Psittaculidae**	**Psittaciformes**	**2**	**0.01**
Rose-ringed Parakeet	***Psittacula krameri* Scopoli, 1769**	"	"	**1**	**0.01**
		Total		**17387**	**100**

Migratory bird species

The migratory bird species (Table 2) were represented with 11 orders: Accipitriformes, Anseriformes, Charadriiformes, Ciconiiformes, Coraciiformes, Gruiformes, Passeriformes, Pelecaniformes, Suliformes, Phoenicopteriformes, and Podicipediformes, with 6050 individuals of 22 family and 39 species. The highest value of relative abundance for migratory birds were recorded for the slender-billed gull (57.31), little stint (12.88), great cormorant (8.88), common ringed plover (4.51), the European bee-eater (3.12), black-winged stilt (2.78), and white wagtail (1.44). While, montagu's harrier, yellow-legged gull and marsh sandpiper had the lowest value (0.02).

Table 2. List of resident bird species recorded in Egypt with the taxonomic classification

Birds name	Scientific name	Family	Order	Count	Relative abundance
Common Buzzard (Steppe)	*Buteo buteo vulpinus* Gloger, 1833	Accipitridae	Accipitriformes	3	0.05
Black Kite	*Milvus migrans migrans* Boddaert, 1783	''	''	6	0.10
Montagu's Harrier	*Circus pygargus* Linnaeus, 1758	''	''	1	0.02
Eurasian green-winged teal	*Anas crecca crecca* Linnaeus, 1758	Anatidae	Anseriformes	5	0.08
Mallard	*Anas platyrhynchos platyrhynchos* Linnaeus, 1758	''	''	6	0.10
common pochard	*Aythya ferina* Linnaeus, 1758	''	''	4	0.07
Eurasian Wigeon	*Mareca penelope* Linnaeus, 1758	''	''	4	0.07
Northern Shoveler	*Spatula clypeata* Linnaeus, 1758	''	''	7	0.12
Kentish plover	*Anarhynchus alexandrinus alexandrinus* Linnaeus, 1758	Charadriidae	Charadriiformes	47	0.78
Common Ringed Plover	*Charadrius hiaticula* Linnaeus, 1758	''	''	273	4.51
Slender-billed Gull	*Chroicocephalus genei* di Brème, 1839	Laridae	''	3467	57.31
Black-headed Gull	*Chroicocephalus ridibundus* Linnaeus, 1766	''	''	60	0.99
Common Gull	*Larus canus canus* Linnaeus, 1758	''	''	3	0.05
Yellow-legged Gull	*Larus michahellis michahellis* Naumann, 1840	''	''	1	0.02
Black-winged Stilt	*Himantopus himantopus*	Recurvirostridae	''	168	2.78

	Linnaeus, 1758				
Common Snipe	*Gallinago gallinago gallinago* Linnaeus, 1758	Scolopacidae	''	31	0.51
Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	''	''	62	1.02
Little stint	*Calidris minuta* Leisler, 1812	''	''	779	12.88
Marsh Sandpiper	*Tringa stagnatilis* Bechstein, 1803	''	''	1	0.02
Common Redshank	*Tringa totanus* Linnaeus, 1758	''	''	9	0.15
White stork	*Ciconia ciconia ciconia* Linnaeus, 1758	Ciconiidae	Ciconiiformes	50	0.83
Common Kingfisher	*Alcedo atthis atthis* Linnaeus, 1758	Alcedinidae	Coraciiformes	32	0.53
European bee-eater	*Merops apiaster* Linnaeus, 1758	Meropidae	''	189	3.12
Eurasian Coot	*Fulica atra atra* Linnaeus, 1758	Rallidae	Gruiformes	6	0.10
Greater Short-toed Lark	*Calandrella brachydactyla hermonensis* Tristram, 1865	Alaudidae	Passeriformes	17	0.28
European Turtle-Dove	*Streptopelia turtur rufescens* Brehm, 1845	Columbidae	''	8	0.13
European Goldfinch	*Carduelis carduelis niediecki* Reichenow, 1907	Fringillidae	''	16	0.26
Western House-Martin	*Delichon urbicum* Linnaeus, 1758	Hirundinidae	''	26	0.43
white wagtail	*Motacilla alba* Linnaeus, 1758	Motacillidae	''	87	1.44
Common Chiffchaff	*Phylloscopus collybita collybita* Vieillot, 1817	Phylloscopidae	''	23	0.38
Willow Warbler	*Phylloscopus trochilus trochilus* Linnaeus, 1758	''	''	8	0.13
European Starling	*Sturnus vulgaris* Linnaeus, 1758	Sturnidae	''	15	0.25

Great Egret	***Ardea alba alba* Linnaeus, 1758**	**Ardeidae**	**Pelecaniformes**	**11**	**0.18**
Gray Heron	***Ardea cinerea cinerea* Linnaeus, 1758**	"	"	**7**	**0.12**
Little Bittern	***Ixobrychus minutus minutus* Linnaeus, 1766**	"	"	**3**	**0.05**
Glossy Ibis	***Plegadis falcinellus* Linnaeus, 1766**	**Threskiornithidae**	"	**28**	**0.46**
Great Cormorant	***Phalacrocorax carbo* Linnaeus, 1758**	**Phalacrocoracidae**	**Suliformes**	**537**	**8.88**
Greater Flamingo	***Phoenicopterus roseus* Pallas, 1811**	**Phoenicopteridae**	**Phoenicopteriformes**	**45**	**0.74**
black-necked grebe	***Podiceps nigricollis* Brehm, 1831**	**Podicipedidae**	**Podicipediformes**	**5**	**0.08**
		Total		**6050**	**100**

Distribution of bird species among different sites

The distribution of bird species across different sites was based on the comparison for the total number of birds found in each habitat. Fig. (1) illustrates that, the CA and SCGS areas harbor 25% of the total number of resident bird species. In the second rank comes the ND area with 21%, then NV area with 16%, while F area was the least with 13% of the total bird species. In the same trend, 48% of the total species of migratory birds were founded in CA area, followed by F area with 23%, ND with 13%, SCGS with 11% and finally NV area with 5% of the total migratory species.

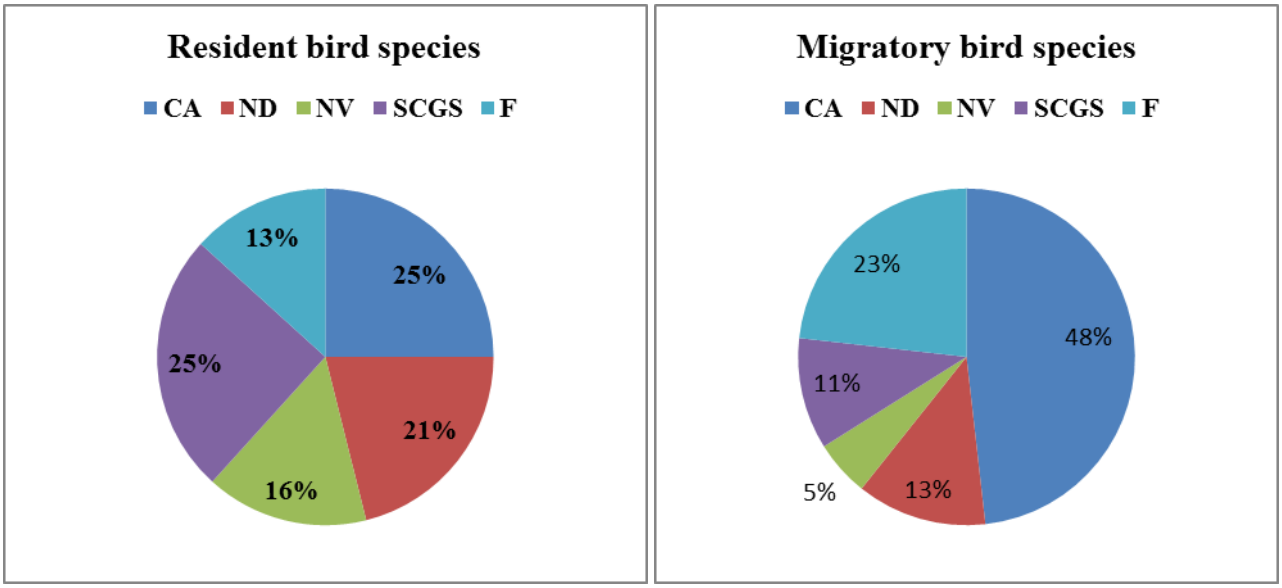

Fig. 1. Percentage of resident and migratory bird species among the different sites

Dominant birds

Dominant bird species differed according to the site area and the status of the bird species (resident or migratory). The data exhibited in Table (3) refer to the five dominant species at every site. The dominant resident birds at CA site were the house sparrow with 31.05%, the barn swallow with 15.23%, the western cattle egret with 10.81%, the rock pigeon with 8.17%, and the hooded crow with 6.57%. A similar trend was observed at the ND site, where the dominant species included the house sparrow (38.30%), western cattle egret (26.96%), rock pigeon (8.39%), barn swallow (7.06%), and hooded crow (6.09%). At the NV site, the dominance shifted slightly, with the house sparrow (31.58%), rock pigeon (24.58%), laughing dove (13.06%), barn swallow (11.53%), and western cattle egret (7.06%). For the SCGS site, the house crow (41.56%) took the lead, followed by the house sparrow (24.47%), rock pigeon (7.71%), barn swallow (7.51%), and western cattle egret (6.54%). Meanwhile, the F site was recorded with the little egret (45.65%) as the dominant species, accompanied by the little tern (22.62%), barn swallow (12.48%), house sparrow (3.54%), and spur-winged lapwing (3.46%).

For dominant migratory birds, each site had a different dominant species; at CA site, the dominant birds were the great cormorant (58.05%), white wagtail (9.41%), back-headed gull (6.49%), slender-billed gull (6.27%), and the European bee-eater (3.78%). Whereas at the ND site, the dominant species included the European bee-eater (56.0%), white stork (18.18%), common kingfisher (11.64%), European goldfinch (5.82%), and European starling (5.45%). In contrast, the NV site featured only three dominant species: the western house-martin (54.17%), glossy ibis (41.67%), and common chiffchaff (4.17%). The SCGS site had five dominant migratory birds, with the European bee-eater (50.72%), greater short-toed lark (24.64%), black kite (8.70%), European turtle-dove (7.25%), and common buzzard (4.35%). Finally, at the F site, known for its abundance of migratory species, the dominant birds were the slender-billed gull (71.04%), little stint (16.0%), common ringed plover (5.69%), black-winged stilt (2.81%), and common sandpiper (1.19%).

Table. 3. Resident and migratory dominant bird species in the different habitats

Site	Resident bird		Migratory bird	
	Bird Species	%	Bird Species	%
CA	House Sparrow	31.05	Great Cormorant	58.05
	Barn Swallow	15.23	White Wagtail	9.41
	Western Cattle Egret	10.81	Black-headed Gull	6.49
	Rock Pigeon	8.17	Slender-billed Gull	6.27
	Hooded crow	6.57	European bee-eater	3.78
ND	House Sparrow	38.30	European bee-eater	56.00
	Western Cattle Egret	26.96	White stork	18.18
	Rock Pigeon	8.39	Common Kingfisher	11.64
	Barn Swallow	7.06	European Goldfinch	5.82
	Hooded crow	6.09	European Starling	5.45
NV	House Sparrow	31.58	Western House-Martin	54.17
	Rock Pigeon	24.58	Glossy Ibis	41.67
	Laughing Dove	13.06	Common Chiffchaff	4.17
	Barn Swallow	11.53	-	0.00

	Western Cattle Egret	**7.06**	**-**	**0.00**
SCGS	**House crow**	**41.56**	**European bee-eater**	**50.72**
	House Sparrow	**24.47**	**Greater Short-toed Lark**	**24.64**
	Rock Pigeon	**7.71**	**Black Kite**	**8.70**
	Barn Swallow	**7.51**	**European Turtle-Dove**	**7.25**
	Western Cattle Egret	**6.54**	**Common Buzzard (Steppe)**	**4.35**
F	**Little Egret**	**45.65**	**Slender-billed Gull**	**71.04**
	Little tern	**22.62**	**Little stint**	**16.00**
	Barn Swallow	**12.48**	**Common Ringed Plover**	**5.69**
	House Sparrow	**3.54**	**Black-winged Stilt**	**2.81**
	Spur-winged Lapwing	**3.46**	**Common Sandpiper**	**1.19**

Diversity indexes

The diversity indices of bird species were recorded in Table (4). The highest value of species richness was recorded with CA (59), followed by SCGS (38), ND (34), F (30) and NV (23species) respectively. In contrast, ND gave the highest number of bird species with 6892 individuals, followed by F with 6041, then CA with 5292 and SCGS with 3984, while the lowest value was with NV with 1549 individuals.

Shannon and Simpson diversity indexes refer that the maximum diversity was recorded in CA (H´ =2.73, D =0.89), followed NV (H´ =2.05, D =0.81), ND (H´ =2.00, D = 0.78) and SCGC (H´ =1.88, D =0.76), while the lowest diversity was recorded in F (H´=1.67, D =0.65). In the same trend, evenness (J′) recorded higher in CA (J′=0.67), NV (J′=0.65), ND (J′=0.57), SCGC (J′=0.52), and the recorded lowest in F (J′=0.49). Margalef index in CA was had the highest value followed by SCGC, ND, F and NV. From this result, CA harbors the highest diversity and evenness of species.

Table 4. Diversity indexes in the different habitats

Diversity Index	CA	ND	NV	SCGS	F
Species Richness (S)	**59**	**34**	**23**	**38**	**30**
Number of Individuals (N)abundance	**5292**	**6892**	**1549**	**3984**	**6041**
Shannon Index (H´)	**2.73**	**2.00**	**2.05**	**1.88**	**1.67**
Simpson Index (D)	**0.89**	**0.78**	**0.81**	**0.76**	**0.65**
Species Evenness (J')	**0.67**	**0.57**	**0.65**	**0.52**	**0.49**
Menhinick Index	**0.81**	**0.41**	**0.58**	**0.60**	**0.39**
Margalef Index	**6.76**	**3.85**	**3.00**	**4.46**	**3.33**

CA= Coast area, ND= Nile Delta, NV= Nile Valley, SCGS= Suez Canal & Gulf Suez, F= Faiyum Governorate.

DISCUSSION

The bird species diversity is an essential factor in the maintenance and stability of the environment. Meanwhile, the habitat types determine the bird species composition in the environment.

The current study spans a vast region in Egypt, providing insights into bird species composition across different areas. A total of 15 orders, encompassing 35 families and 79 bird species, were recorded, accounting for 23,758 individuals. This diversity highlights the abundance and heterogeneity of essential resources in the Egyptian environments, including agricultural crops, vegetables, horticulture, dense vegetation, wetland habitats, and coastal areas. Variations in vegetation structure contribute to a rich supply of food resources **(Ghosh *et al.*, 2022)**, influencing the diversity, composition, and abundance of bird species **(Issa, 2019; El Sayed *et al.*, 2024)**.

The bird species richness observed in the current study (79 species) surpasses several previous records: **Omar (2020)** reported 23 species in Assiut Governorate; **Rizk *et al.* (2020)** recorded 28 species in Giza Governorate; **Issa (2019)** documented 33 species in Sharkia Governorate; **Abd-Ellatif *et al.* (2024)** noted 50 species in Ashtoum

El-Gamil Protected Area; and **Sheta *et al.* (2023)** found 60 species at Lake Burullus in northern Egypt.

The variation in species numbers may be attributed to factors such as observer expertise, time of day, and environmental conditions **(Bibby *et al.*, 2000)**. Additionally, the impacts of human settlements, which can create disturbances that repel birds **(Masoud *et al.*, 2011)**, as well as the habitat heterogeneity and biotic interactions at different sites **(Issa, 2019)**, may also play significant roles in these differences.

The order Passeriformes was the most dominant among resident bird species, highlighting that two out of three bird species are passerines **(Schmitt & Edwards, 2022)**. Approximately, 60% of all living birds belong to this order **(Oliveros *et al.*, 2019)**. Passeriformes are notable for their ability to adapt to various environments **(Baptista & Trail, 1992)**, exhibiting diverse feeding strategies, including granivory, carnivory, insectivory, nectivory, omnivory, and frugivory **(Smith, 2015)**. Consequently, it is the dominant bird order in nearly all geographic regions of the world **(Slud, 1976)**.

The highest relative abundance of resident wild birds was recorded for the house sparrow, followed by the western cattle egret, barn swallow, house crow, rock pigeon, little egret, hooded crow, laughing dove, and common myna, consistent with the findings of **Issa (2019)**. **Attia (2013)** identified the house sparrow, rock dove, palm dove, house crow, and hooded crow as the most dominant resident species in Ismailia Governorate. In St. Katherine City, South Sinai, **White *et al.* (2007)** noted that the rock dove, laughing dove, and Sinai rose finch were the most abundant species.

Among migratory bird species, the highest relative abundance was that of the slender-billed gull, little stint, great cormorant, common ringed plover, European bee-eater, black-winged stilt, and white wagtail. This partially aligns with the findings of **Sheta *et al.* (2023)**, who reported that migratory birds, particularly the cormorants and various gull species, represented the highest abundance at Lake Burullus. In Sharkia Governorate, **Issa (2019)** assessed that the most abundant migratory species were recorded to be the white wagtail, blue-cheeked bee-eater, bluethroat, lesser whitethroat, and kingfisher. Variations in species richness and relative abundance across studies can be attributed to habitat heterogeneity, the living requirements of each species **(Issa, 2019; Sheta, 2019)**, as well as factors like food availability, habitat conditions, and breeding seasons **(Asmare *et al.*, 2023)**. Additionally, predation and disturbances impact the relative abundance of bird species.

Bird species distributions across different sites are influenced by habitat types. In the CA and SCGS areas, resident bird species accounted for 50% of the total number, with NV ranked third, followed by NV and F. These differences stem from variations in food resources across the study sites. Environments with water bodies and wetlands

provide abundant vegetation, offering food (aquatic plants, grains, insects, and fish), shelter, and nesting opportunities, consistent with the findings of **Sheta *et al.* (2023)**.

For migratory birds, the CA area hosted 48%, followed by F with 23%. This distribution is associated with the presence of migratory water birds and suitable foraging areas **(Sheta, 2019)**. In addition, these varied percentages are ascribed to the reduced disturbances in these areas compared to others impacted by human activity **(Frid & Dill, 2002)**.

Species dominance refers to abundant species, characterized by high individual counts compared to others in the same community **(Avolio *et al*., 2019)**. There is a clear relationship between habitat type and dominant species, as habitat structure influences species abundance. The house sparrow and barn swallow were dominant residents across all surveyed habitats, indicating that these habitats meet their essential requirements **(Chenchouni, 2010)**. These results align with those of **Sheta *et al*. (2023)**, who identified the house sparrow as the dominant resident species at Lake Burullus and noted its prevalence across various Egyptian governorates. Among those governorates were the new reclaimed lands in Alexandria **(El-Danasory *et al*., 2016)** and the diverse habitats in Sohag Governorate **(El-Danasory *et al*., 2020)**.

In the F and CA areas, water birds were dominant migratory species, underscoring their importance for migratory birds (**EMU & EEAA, 2008; Sheta *et al*., 2010)**. At the ND site, dominant migratory birds included the European bee-eater, white stork, common kingfisher, European goldfinch, and European starling. The SCGS site had five dominant species: the European bee-eater, greater short-toed lark, black kite, European turtle-dove, and common buzzard. The NV site featured the western house-martin, glossy ibis, and common chiffchaff. Variations in dominant species are influenced by habitat differences and environmental conditions, as specific habitat characteristics can attract certain bird species by providing food, nesting sites, and shelter from predators **(Palomino & Carrascal, 2006; Ceresa *et al*., 2012; Avolio *et al*., 2019; Tu *et al*., 2020)**. Both biotic and abiotic factors impact species distribution and abundance **(Xu *et al*., 2022; Liang *et al*., 2017)**.

Shannon's index is employed to assess species richness, while Simpson's index measures evenness and relative abundance **(Nagendra, 2002)**. The CA, SCGS, ND, and F areas positively impacted species richness, reflecting the availability of food resources. The highest diversity (Shannon index) corresponds to the increased richness, indicating a stable surrounding ecosystem where primary life needs are met **(Issa, 2019; Sheta, 2019)**.

Maximal evenness indicates that all species in a community are represented evenly, while low evenness suggests some species are numerically dominant **(Gregorius & Gillet, 2022)**. Higher values of Simpson's Index indicate greater diversity. The CA area recorded the highest Simpson diversity index and evenness, followed by NV, ND, and SCGS areas, while the lowest diversity was noted in the F area. This reflects the diversity of foraging areas, various food sources, shelter, roosting habitats, and nesting sites.

The Menhinick index compares diversity across different habitats, while the Margalef index measures species diversity, with higher values indicating greater richness **(Kitikidou *et al.*, 2024)**. Margalef diversity index values were 6.76 at CA and 3.0 at NV, while Menhinick index values ranged from 0.39 at F to 0.81 at CA.

CONCLUSION

The current study sheds light on bird species composition and bird diversity in a wide range of the Egyptian environment at the same time. The results clarified that the studied areas as a component of the Egyptian environment are rich in basic resources which are necessary for life of wild birds, such as food, shelter, and nesting places. The aquatic environment had a positive impact on bird species; this was illustrated through the increases in the species richness and diversity index. Thus, the study would enrich the knowledge about the diversity of wild birds and factors affecting diversity in order to help preserve it as a component of the Egyptian ecosystem.

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ABBREVIATIONS

Coastal area (CA); Nile Delta (ND); Nile Valley (NV); Suez Canal & Gulf Suez (SCGS) ; Faiyum (F).

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