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Assessment of Diversity of Wading Birds and Shorebirds on Aden Lagoons, Yemen

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Abstract. Almost all habitats on the planet are home to birds, from the lowest deserts to the highest mountains. Birds have proved to be excellent indicators of biodiversity as they are easily observed and are relatively well known compared to other animals. This study aims to assess wading birds and shorebirds diversity in the Aden lagoons from October 2021 to December 2022. Fifty four species belong to one order and six families of shorebirds and three orders and four families of wading birds were recorded in the study area. A highest relative abundance 14.78 % was recorded in June 2022, while the lowest was 3.03 % recorded in April 2022. The highest values of Simpson diversity index and Shannon-Weiner index were 0.95 and 3.25, respectively. Species richness index reached 5.432, while an evenness index was 0.862. Dominance index recorded a high value in November 2021, July 2022, August 2022, September 2022and November 2022. The assemblage of wading birds and shorebirds at Aden lagoons was moderate, whereas showed disturbed and semi-balanced assemblage in terms of the richness and evenness respectively.

Keywords: wetland, wading birds, shorebirds, Aden lagoons, Yemen.

1. Introduction

Birds are highly mobile animals and spread around the world, because their morphological and structural adaptation features. Some bird species are residence in certain area during breeding period to produce generation successfully, while others migrate for long distances of thousands of miles in certain seasons then return to their original home for breeding (Newton, 2008).

It was recognized that water birds are highly dependent on wetland habitat (Zakaria & Rajpar, 2013). Wetlands support a high diversity of resident and migrant water birds (Gibru & Biru 2022; Gibru *et al*. 2023). They exhibit wide variation due to differences in soil, terrain, climate, water regime, water chemistry, vegetation and other factors. They include swamps, bogs, marshes and other similar areas (Neal *et al.*, 2008).One of the basic benefit of wetlands is providing suitable habitat for plants and animals that live primarily in these regions. For example, migratory birds are considered the main users of wetlands for foraging, resting, and roosting sites (Zhijun *et al*, 2010).

Evans (1994) mentioned detailed inventory of 57 sites, which are of vital importance for the conservation of birds in Yemen. These 57 sites, covering a total area of 7 300 sq. km or about 1.4 % of the area of the country contain all the endemic or near-endemic bird species, as well as other rare, significant or limited-range species. These sites, distributed around the country (including Socotra Island), also represent prime eco-tourism destinations in Yemen since, apart from containing important and interesting avifauna,

many of them consist of relatively undisturbed natural areas and are of great botanical interest. Some of them also contain other interesting types of animals (Evans 1994). However, none of these sites are legally protected for nature conservation purposes and many of them are in serious risk of degradation or destruction.

There are many studies were conducted on the birds in Yemen by Baily (1966, 1968), Brooks *et al*. (1987), Evans (1987), Al-Saghier& Porter (1996), Porter & Al-Saghier (1998), Al-Saghier *et al.* (1999), Al-Saghier (2000, 2002), Taleb (2002), Abdull-Hakeem (2007), Kardash (2009), Raweeh (2010), Kaboob (2012) and Balem and Al-Zokary (2014). PERSGA / GIF (2003) described 37 sites in Yemen considered as important bird areas; 10 are in the Red Sea and 27 are in the Gulf of Aden, of the latter Aden wetlands.

Aden wetlands are amongst the most important wetlands in Yemen and the region, and support unique marine biodiversity and host a large number of water bird species, sea grasses, crustaceans, Mollusca, and fish, and are considered an important wintering area for migratory waterfowl (Bawazir, 2009).

Aden Wetlands are complex of habitats adjacent to Aden city which together form one of the most important areas for wading birds and other waterfowl in southern Arabia. The site regularly holds over 10,000 waterfowl including 12 species with regionally important populations and three globally threatened species (*Larus leucophthalmus, Aquila clanga* and *Aquila helicaca*). The site is relatively free of disturbance and provides extensive feeding areas for a huge variety of birds (Al-Saghier& Porter, 1996).

Al-Thalabi (2005) mentioned some of natural resources (biotic and non-biotic) in the wetlands of Aden, and how local people utilized them and he put management plan to conserve these natural resources including wading and shorebirds by putting practical objectives to monitor birds of conserved wetlands and create bird database, but his plan didn't get attention except built three small towers around wetlands to monitor birds, Although there are some studies conducted on waterfowl of Aden in particular, none of these studies conducted on temporal and spatial changes of sea birds along four Al-Memlah lagoons, Aden. This study aims to assess bird species diversity, richness, evenness, dominance and relative abundance in Aden lagoons, as a contribution to creating a bird database of Aden wetlands.

2. Materials and Methods

2.1 Study Area

Aden is located at the south western end of Yemen and the Arabian Peninsula. It is stretch on the southern part of the Yemeni coast of the Gulf of Aden, between latitude N 12°.70 - 12°.90 and longitude E 044°.78 - 045°.08. Aden lies on the main world trade route through the Suez Canal. Aden had a chain of communities that stretch around a well-protected bay. These include Crater, Mua'alla, Tawahi, Khor Maksar, Sheikh Othman, Al-Mansoura, Dar Saad, and Little Aden (Saleh *et al*. 2018). In addition to its port related activities, Aden is in known for its marine tourism, marine traffic, fishing industry, oil and gas exploitation (Al-Shwafi 2007).The Directorate of Khor Maksar is located to the north of the ancient city of Aden and extends with sandy land linking the volcanic peninsula to the dry land from the coast. It is a narrow neck called Khor Maksar. It is bordered on the east by the Abyan coast in the Arabian Sea, on the north by Tawahi Bay and Salt Pans area, on the south by Sirah district, and on the west by the Sheikh Othman district (UNDP 2016).

The Directorate of Khor Maksar occupies about 5680 hectares. Based on meteorological data at Aden International Airport, we find that the governorate of Aden is located within the

arid and semi-arid region, with warm summer and moderate winters (UNDP 2016).

2.2 Sampling Sites

With careful observations for the most common habitats among the Marshes area of Aden, which are commonly visited by birds, four lagoons were selected within Khor Maksar district (Table 1).

2.3 Aden Lagoons

The Marshes of Aden consist of four lagoons as commonly called Buhairat Al-Memlah, they are of seawater separated from each other by narrow barriers. The total area of the lagoons is 110 hectares. The water level in it fluctuates according to the movement of the tide, with a maximum depth of one meter. Sandy soils of marine origin, resulting from the disintegration of rocks and seashells, prevail. Silicates and calcium carbonate are the main components of them, and mica is found, especially in dark sands (Bawazir, 2009).

Site1

It is called Pelican lagoon, it is bordered on the north by Aden International Airport and is separated from Tawahi Bay by the road linking KhorMaksar, Sheikh Othman District and Aden Minor District to the west. The southern edge of the lake extends with Badr Road, and to the east the lake abuts Badr Camp and the Khor Maksar power station and pilots' residences, the maximum length The lake is 1.7 kilometers and the maximum width is about 0.9 kilometers. The lake is not connected to the rest of the lakes because of the airport runway that cuts its northern border. The lake is connected to the sea water through pipelines that pass under the highway.

Site 2

It is called Flamingo lagoon**;** it is located next to Lake 1 adjacent to the runway of Aden airport. The length of this lake is 1 km and its width is 0.8 km. It connects with Lake 3 through pipelines in the northwest corner and from the west side parallels the highway that connects the Khor Maksar district, the Little Aden district and the Mansoura district. To the east, it is adjacent to the facilities of Aden Airport and is linked to the Tawahi Pay by pipelines pass under the highway.

Site 3

It is considered one of the largest lagoon of Al-Memlah lagoons, with a length of 1.4 km and a width of 2.8 km. It is bounded on the northern part by the forth lagoon and the salt Pans sector facilities, from the south by Flamingo lagoon, and from the west by the highway that connects the Khor Maksar district, Mansoura district and the Little Aden district, while it is bordered to the east by the salt pans sector facilities and residential area.

Site 4

Its length is 1 km and its width is 0.5 km. It is bounded on the north by the Al Memelah (Salt pans), on the south by the highway that connects Khor Maksar district, Mansoura district, and Little Aden district, on the east by Lagoon 3, and on the west by the Royal Hotel and Al-Burihi Hospital (Fig. 1).

2.4 Bird's Survey

The surveys were conducted from October 2021 to December 2022. Birds surveys were performed during the peak of bird activity from 7 am to 1 pm, they were carried out under appropriate climatic conditions, (no survey was made on rainy or windy days) so that the birds activity was directly affected by bad climatic conditions reducing the ability of seeing or hearing birds during the counting time that may leads to lower the efficiency and reliability of collecting data (Bibby *et al*., 2000). Bird survey was carried out during the low tide when the mudflats are appearing. According to Bibby *et al.* (2000) and Sutherland *et al.* (2004). Point survey

method was used with six replicates; each point was the center of a circle with a 50 m radius. One visit per month for all stations was accomplished. During the survey work, birds were observed by binoculars (Opticron7X50) and a professional camera (Sony N50). All bird back-up was recording by photography, the data were checked by contacting with experts in bird and sent some of the pictures that diagnosis doubtful via the Web Internet, as well as using some good references in birds identification (Allouse, 1960, 1961; Porter *et al*., 1996; Ali, 2002), in addition to the Cornell Lab. of Ornithology website (www.birdsoftheworld.org).

2.5 Data Analysis

To assess the wading birds and shorebirds assemblage, we applied relative abundance and biodiversity indices to analyze the composition of communities of these organisms. The relative abundance (Ra) refers to the percentage of one species in relation to the total number of different species in a specific community, formula [Ra% = ni / N * 100], the diversity indices were calculated by using the Shannon Weiner index explain in formula [H′ = - Σ pi Ln pi] and Simpson's index formula [D = 1- Σ (pi)2] and richness were estimated by using the Margalef's index formula [S = S-1/ Ln N] for evenness we used, the Pielou evenness index indicated in formula [J = H′/Ln S] and dominance index (Berger and Parker index) using formula [d= Nmax / N] [17,16]. Diversity indices were determined by using the PAST program (Paleontological statistics software package for education and data analysis) statistical software (v. 2.17c). Statistical analysis using SPSS (V.21) software was used. One - way ANOVA was applied to test whether the abundance and number of species (species richness) among the stations.

3. Results

A total of fifty four species of wading and shorebirds have been observed in this study, which belong to 29 genera and ten families and four orders (Phoenicopteriformes, Pelecaniformes, Charadriiformes and ciconiiformes). The highest percentage of observed birds belonged to Charadriiformes (70.35%), followed by Phoenicopterifomes (18.81%), then Ciconiiformes and the lowest percentage of observed birds were belonging to Pelecaniformes (Fig. 2). Number of species in the study sites were 52, 49,48 and 21 in site 1, site 2, site 3 and site 4 respectively (Table 2).

The abundance of birds observed during the monitoring period in the four Al-Memlah lagoons was 17954 birds. The highest abundance of birds was observed in the site 1 (7488 birds) with mean 83 birds/ point(SE ±15), followed by the site 2 (7235 birds) with mean 80 birds/point(SE ±10), while the lowest number of birds was observed in site 4 (877 birds) with mean 10 birds/point(SE ±3)followed by site 3 (2354 birds) with mean 26 birds/point(SE ±6) (Fig. 3 & 4).When comparing the effect of place (stations) on the presence and distribution of seabirds, it was also found that there were significant differences in the presence and distribution of seabirds, as station 1 recorded the highest average number of birds, amounting to 83.20 individuals, compared to station 4, in which the value of the average number of birds decreased, reaching 9.74. An individual. With a significant decrease estimated at 88.29%, which is higher than the percentage value of L.S.D, which reached 30.43% (Table 3).

Results of relative abundance of birds of each family showed that family Laridae forms the highest percentage of all birds observed during study period, followed by family Phoennicopteridae, then Scolopacidae, while birds of Charadriidae occur with 8.13% relative abundance (Fig. 5). Larian and Phoeninicopterian birds were observed with high abundance at sites 1 and 2 and observed at low abundance at sites 3 and 4, mainly by

species Great Crested Tern (*Sterna bergii*) and Greater Flamingo (*Phoenicopterus rubber*) respectively. While Scolopacian birds in site 2 mainly by Common Sandpiper (*Actitis hypoleucos*) and Marsh Sandpiper (*Tringa stagnatilis*), whereas Charadrian birds occurred in the three sites (sites 1, 2 and 3) at moderate abundance, mainly by Lesser Sandpiper (*Charadrius mongolus*), Greater Sandpiper (*C. lechenaultii*) and Little Ringed Plover (*C. dubius*)(Fig. 6) (Table 4).

While birds of four families (Haematopodidae, Threskiornihidae, Recurviorostridae and Dromadidae) occurred at low abundant and form only 3.71%. Whereas, two families (Ardeidae and Pelecanidae) occurred at satisfied levels (Fig. 7).Ardeian birds were observed highly in site 3followed by sites 2and 1, composed mainly by Western Reef Heron (*Egretta gularis)* and little Egret (*E. garzetta*), while only one species of Pelecanian, Pink backed Pelican (*Pelecanus rufescens*) was observed highly in site 4 (and were dominant birds in the site) followed by sites 1 and 2, whereas a few pelicans were observed during study period at site 3. In addition, only one species of family Haematopodidae, Oyster catcher (*Haematopus ostralegus*) was observed in three sites, 1, 2 and 3, while two families, Recurvirostridae and Dromadidae, were mainly some of migratory birds, composed only by one species for each, Black winged Stilt (*Himantopus himantopus*), Crab Plover (*Dromasardeola*),respectively. And last family Threskiorniihidae which presented by two species Spoon Bill (*Platalea leucorodia*) occurs only in sites 2 and 3 only, while African Sacard Ibis (*Threskiornis aethiopicus*) occurs in all study sites (Fig. 8) (Table 4).

The current study showed that there are variations in the presence and abundance of seabirds during the months of study. Means of seabird number during study period showed that the highest number of birds were observed during June 2022, whereas the lowest number were observed during April 2022l (Fig. 9). The results of Least Significance Differences (L.S.D.) (Table 5) to test significant difference in the means of bird numbers indicate that there are significant differences in the presence and distribution of seabirds, as the number of seabirds increased during the month of June 2022, as it reached its highest average, which reached 111 individuals/transect. While the number of seabirds decreased to its lowest average, reaching 22.7 individuals/transect during the month of April, with a significant decrease of 79.55%, which is higher than the L.S.D. value that reached 44.18%, also they indicate that there are significant differences between mean of birds numberin June 2022 and all other months except January 2022 and December 2022, and there are significant differences between December 2022 and April 2022, September 2022, July 2022 and February 2022, whereas no significant differences between other months.The number of observed birds and species number in each study sites during study period showed in Fig. (10).

The monthly relative abundance of wading birds and shorebirds in study sites during study period illustrated in Fig. (11).In the site (1), the highest relative abundance in site 1 was 21.86% during June 2022, and the lowest was0.19 % recorded in April 2022. And in the site (2), the highest relative abundance was 13.27% during June 2022, whereas, the lowest abundance was1.8%recorded in December 2022. While in site (3), the highest relative abundance was 22.13% during January 2022, whereas the lowest was 0.85% during August 2022. In the site (4), the highest relative abundance was during May 2022, whereas there were no shorebirds observed during June and September 2022, and followed by July 2022 with relative abundance 0.34%.

Results of biodiversity indices for shorebirds in Aden lagoons showed temporal

and spatial variations. The monthly variations in Shannon – Weiner diversity index values were showed in Fig. (12), and the monthly variations in Simpson index showed in Fig. (13). Results of these indices were high in site (1) during September 2022, in site (2) during February 2022, in site (3) during December 2021, while in site (4) were high during December 2022. Whereas these indices were low during November 2022, June 2022 and September 2022 in sites (1), (2) and 3, respectively. Site (4) had low diversity of birds and showed low values of Shannon and Simpson's indices (Zero) during November 2021, June, July, August, September and November 2022.

The monthly fluctuations in richness index (Margalef index) values for wading birds and shorebirds in study sites during study period illustrated in Fig. (14).The fluctuations values in richness index Aden lagoons, ranged between the highest values were 5.43 in February 2022 in site 2, followed by 5.38 during December 2021 in site 3, followed by 4.65 during December 2022 and 1.7 during December 2022 in site (1) and site (4), respectively, and the lowest values were 1.31 during June 2022 in site 2, then 0.38 during April 2022 in site (1) and it were 0 during September 2022 in site 3 and November 2021, July, August and November 2022 in site 4, while no observed birds in site 4 during June and September 2022 and these reflected on Margalef index values in these months.

The evenness index in each study sites illustrated in Fig. (15). The highest value was 1 that recorded in September 2022 in site 3 during November2021,July, August and November 2022in site 4, when only one bird was observed.Whilethe lowest value was zero in June, September 2022 in site4, when no birds were observed.

The monthly variations in dominance index were showen in Fig. (16). The highest valuerecorded was 1 which recorded in September 2022 in Site 3, only one species (Lesser Flamingo *Phoenicopterus minor*) was observed and during November2021 only Greater flamingo was observed, July 2022 only Pink backed pelican was observed, August 2022 only Pink backed pelican was observed and November 2022 only Black head gull was observed 2022 in site 4. While the lowest value was 0, which recorded in June and September 2022.

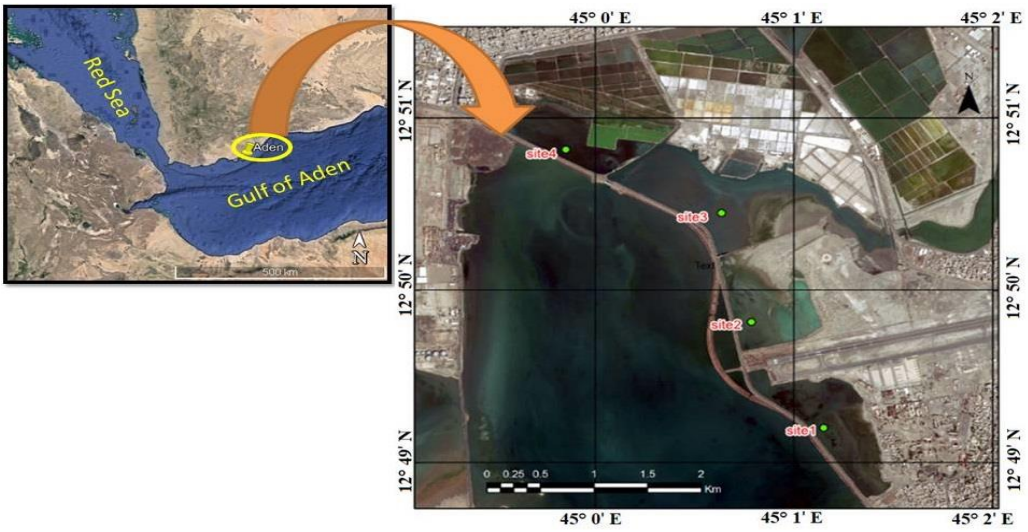

Fig. 1. Map of the study sites in Aden,Yemen.

Table 1. The GPS coordinate of studied sites in Khor Maksar district.

Site	GPS Coordinates	
	Latitude (North)	Longitude (East)
1	12º 49' 12"	45º 01' 09"
2	12º 49' 49"	45º 00' 47"
3	12º 50' 27"	45º 00' 38"
4	12º 50' 49"	44º 59' 51"

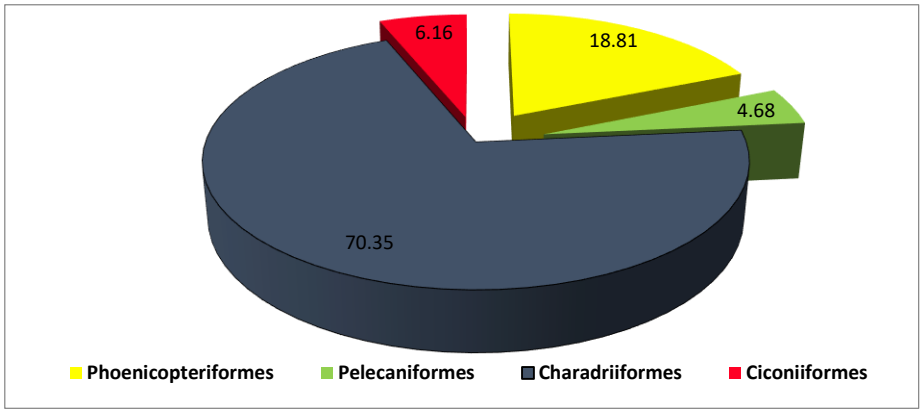

Fig. 2. Percentages of observed birds in each order.

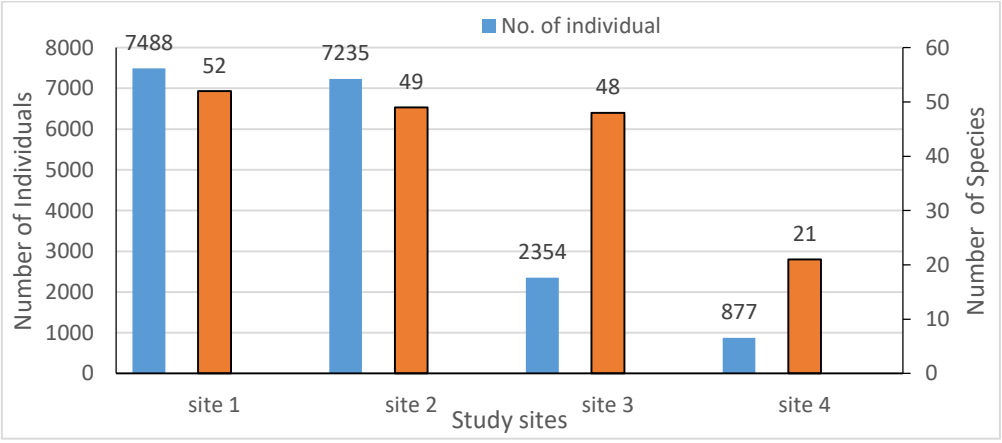

Fig. 3. Number of observed bird species and individuals at study sites.

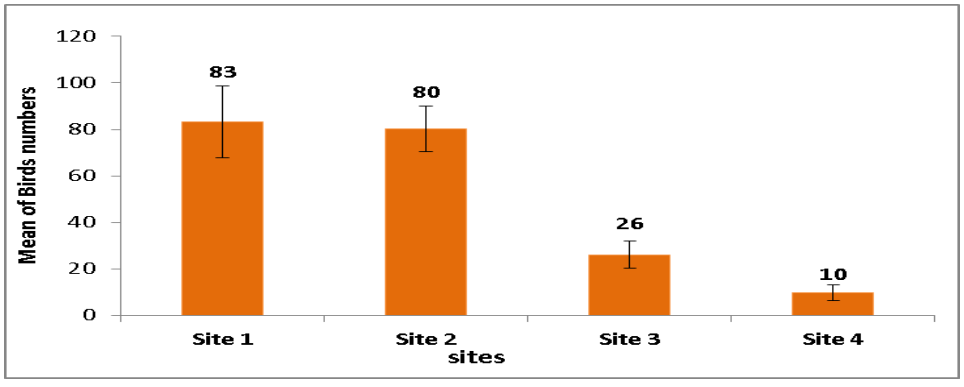

Fig. 4. Means of number of birds and standard errors (n = 90) in study sites.

Table 2. Occurrence of wading birds and shorebirds in study sites during monitoring period.

Order	Family	Scientific name	English name	Stations			
				1	2	3	4
Phoenicopteriformes	Phoennicopteridae	*Phoeniconaias minor*	Lesser Flamingo	+	+	+	+
		Phoenicopterus rubber	Greater Flamingo	+	+	+	+
Pelecaniformes	Pelecanidae	*Pelecanus rufescens*	Pink Backed Pelican	+	+	+	+
Charadriiformes	Recurvirostridae	*Himantopus himantopus*	Black Winged Stilt	+	+	+	+
	Laridae	*Larus fuscus fuscus*	Lesser Black Backed Gull	+	+	+	+
		Larus fuscus heuglini	Heuglin's Gull	+	-	-	-
		Larus marinus	Great Black Backed Gull	+	+	+	-
		Larus ridibundus	Black Headed Gull	+	+	+	+
		Larus hemprechi	Sooty Gull	+	-	+	+
		Larus michahellis	Yellow Legged Gull	+	+	+	+
		Larus cachinnans	Caspian Gull	+	+	-	-
		Larus armenicus	Armenian Gull	+	-	-	-
		Larus argentatus	Herring Gull	+	-	+	-
		Chroicocephalus genei	Slender billed Gull	+	+	+	-
		Hydrocoloeus minutus	Little Gull	+	+	+	-
		Gelochelidon nilotica	Gull Billed Tern	+	+	+	-
		Hydroprogne caspia	Caspian Tern	+	+	+	-
		Sternula saundersi	Saunders Tern	+	+	-	-
		Sternula albifrons	Little Tern	+	+	-	-
		Sterna bengalensis	Lesser Crested Tern	+	+	+	+
		Sterna sandvicensis	Sandwich Tern	+	+	+	+
		Sterna bergii	Greater Crested Tern	+	+	+	+
	Dromadidae	*Dromas ardeola*	Crab Plover	-	+	+	-
	Haematopodidae	*Haematopus ostralegus*	Oystercatcher	+	+	+	-
	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	+	+	+	+
		Calidris alba	Sanderling	+	+	+	-
		C. minuta	Little Stint	+	+	+	-
		C. alpina	Dunlin	+	+	+	-
		Numenius arquata	Curlew	+	+	+	+
		Numenius tenuirostris	Slender billed Curlew	+	+	+	+
		N. phaeopus	Whimbrel	+	+	+	-
		Limicola falcinellus	Broad billed Sandpiper	+	+	+	+
		Tringa ochropus	Green Sandpiper	+	+	+	-
		T. stagnatilis	Marsh Sandpiper	+	+	+	-
		T. totanus	Red Shank	+	+	+	-
		Limosa lapponica	Bar Tailed Godwit	+	+	+	+
		Calidris ferruginea	Curlew Sandpiper	+	+	+	-
		C. temminckii	Timminck's Stint	+	+	+	-
		Arenaria interpres	Ruddy Turnstone	+	+	+	+
	Charadriidae	*Charadrius dubius*	Little Ringed Plover	+	+	+	-
		C. hiaticula	Great Ringed plover	+	+	+	-
		C. leschenaultii	Greater Sandpiper	+	+	+	-
		C. asiaticus	Caspian Plover	+	+	-	-
		C. mongolus	Lesser Sandpiper	+	+	+	-
		C. alexandrinus	Kentish Plover	+	+	+	-
		Vanellus spinosis	Spur-winged Lapwing	+	-	-	-
		Pluvialiss quatarola	Grey Plover	+	+	+	-
Ciconiiformes	Threskiornithidae	*Platalea leucorodia*	Spoonbill	-	+	+	-
		Threskiornis aethiopicus	African Sacred Ibis	+	+	+	+

	Ardeidaee	*Ardea alba*	Great white Egret	+	+	+	-
		Ardea melanocephala	Black Head Heron	+	+	+	+
		Ardea cinerea	Grey Heron	+	+	+	-
		Egretta garzetta	Little Egret	+	+	+	+
		Egretta gularis	Western Reef Egret	+	+	+	+

+ Recorded, - not recorded

Table 3. Results of least significant difference test (LSD) between means of number of birds in study sites.

Months	averages	L.S.D	Site 4	Site 3	Site 2
			9.74	26.16	80.39
Site 1	83.20	25.32	73.46*	57.04*	2.81ns
Site 2	80.39		70.65*	54.23*	

*: indicates a significant difference at a significant level of 0.05 (P < 0.05).
ns: denotes no significant difference at a significant level of 0.05 (P < 0.05).

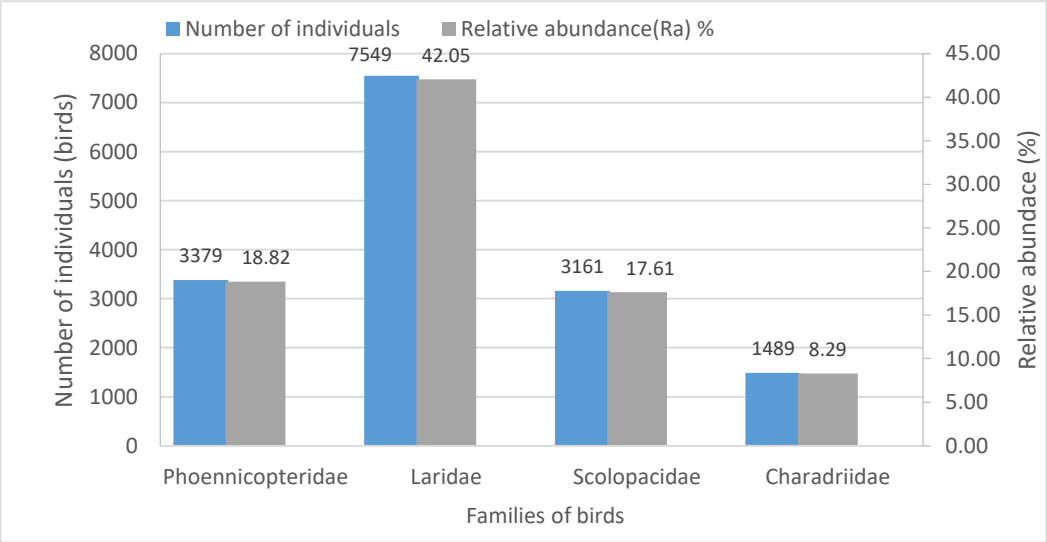

Fig. 5. Relative abundance of each family that more dominant during study period.

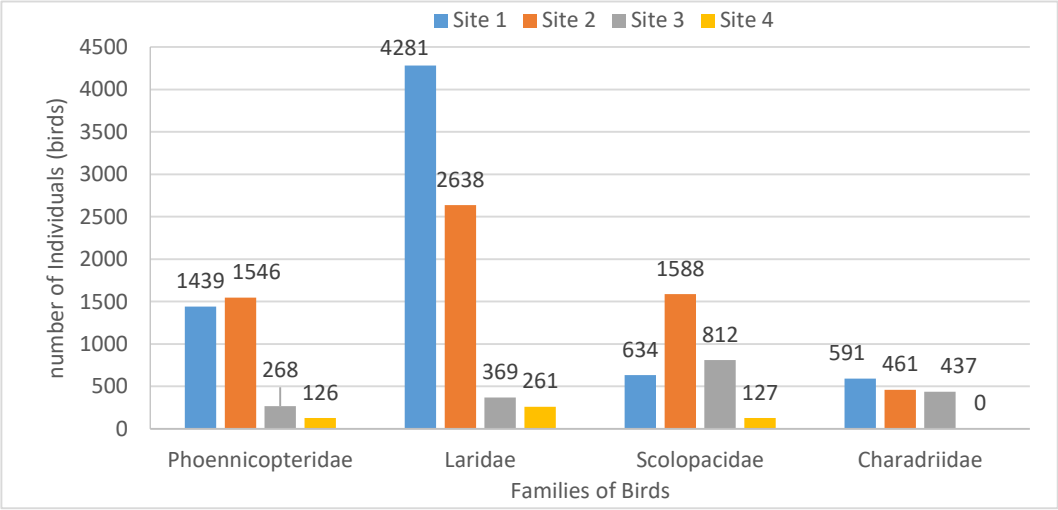

Fig. 6. Number of high dominant birds in different study sites.

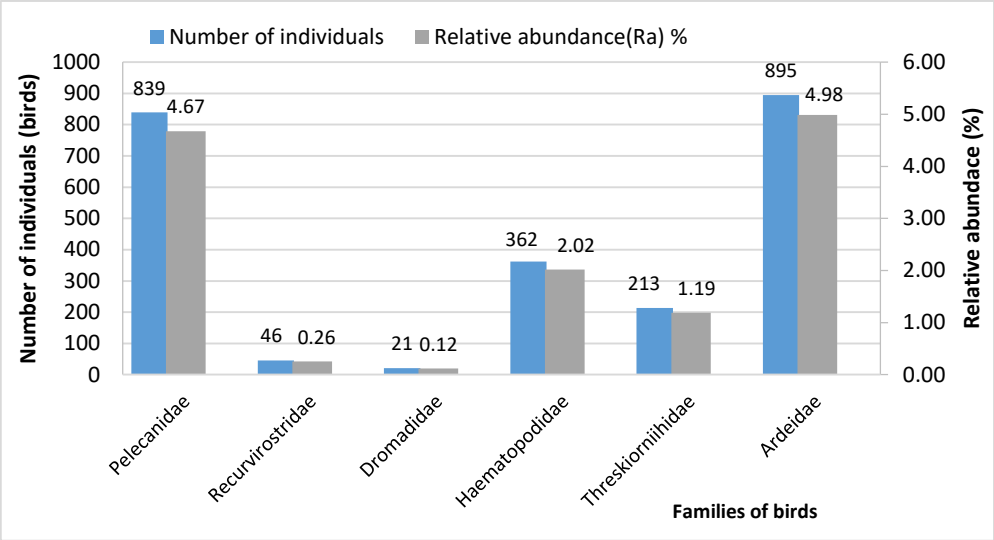

Fig. 7. Relative abundance of each family that have low abundance during study period.

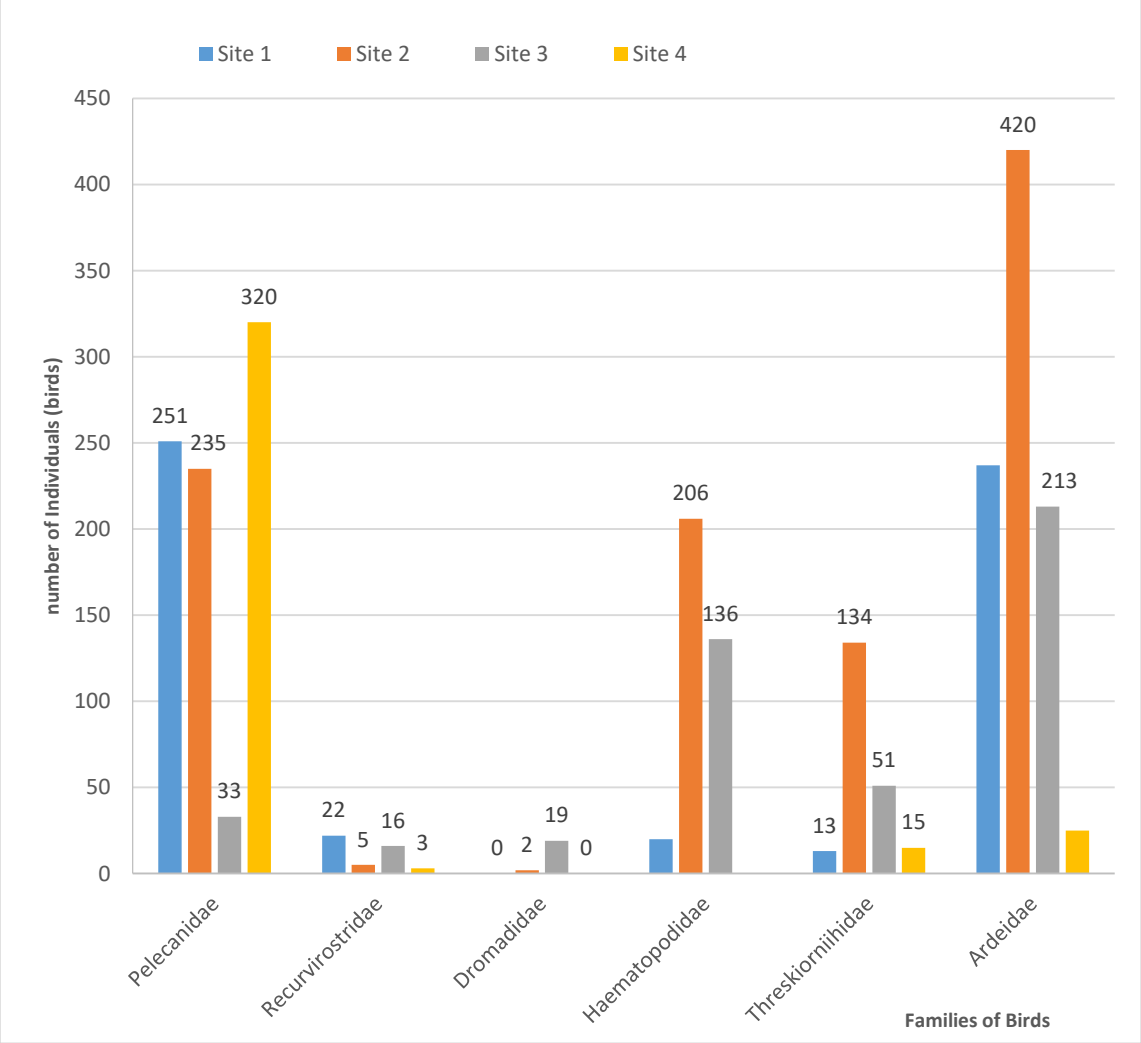

Fig. 8. Number of birds for low abundance families in different study sites.

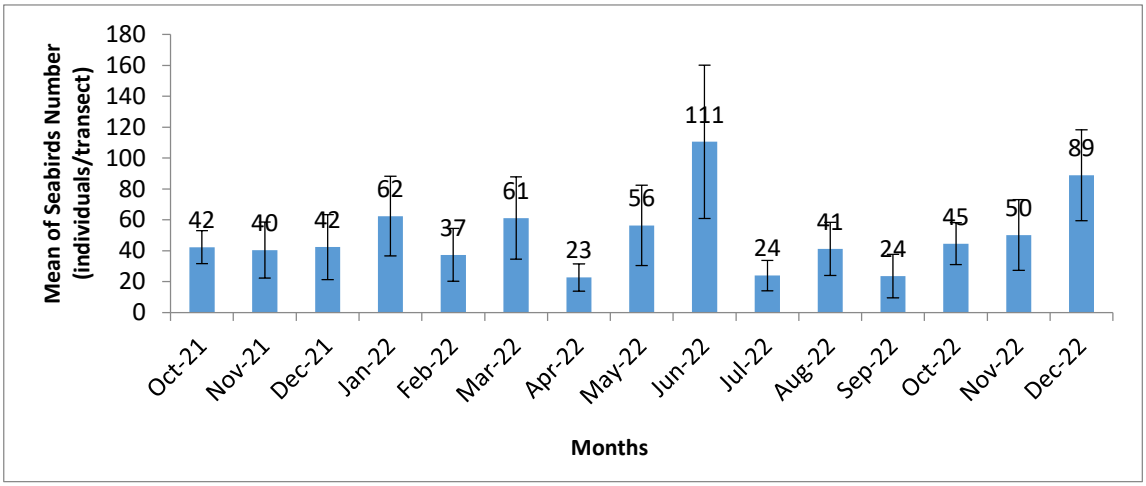

Fig. 9. Means and standard errors (n=24) for shorebirds number during months of study.

Table 4. Relative abundance percentage of all species recorded in monitoring period.

Order	Family	Scientific name	English name	Stations			
				1	2	3	4
Phoenicopteriformes	Phoennicopteridae	*Phoeniconaias minor*	Lesser Flamingo	7.68	6.44	2.29	3.42
		Phoenicopterus rubber	Greater Flamingo	11.54	14.93**	9.09**	10.95
Pelecaniformes	Pelecanidae	*Pelecanus rufescens*	Pink Backed Pelican	3.35	3.25	1.40	36.49**
Charadriiformes	Recurvirostridae	*Himantopus himantopus*	Black Winged Stilt	0.29	0.07	0.68	0.34
	Laridae	*Larus fuscus fuscus*	Lesser Black Backed Gull	0.79	1.27	0.47	0.91
		Larus fuscus heuglini	Heuglin's Gull	1.58	0.00	0.00	0.00
		Larus marinus	Great Black Backed Gull	0.97	0.51	0.30	0.00
		Larus ridibundus	Black Headed Gull	4.77	2.16	0.76	0.46
		Larus hemprechi	Sooty Gull	0.23	0.00	0.13	4.10
		Larus michahellis	Yellow Legged Gull	3.00	1.11	0.17	20.07
		Larus cachinnans	Caspian Gull	0.55	0.26	0.00	0.00
		Larus armenicus	Armenian Gull	0.80	0.00	0.00	0.00
		Larus argentatus	Herring Gull	0.17	0.00	0.68	0.00
		Chroicocephalus genei	Slender billed Gull	13.68	4.55	4.80	0.00
		Hydrocoloeus minutus	Little Gull	0.31	0.77	0.51	0.00
		Gelochelidon nilotica	Gull Billed Tern	1.64	3.84	0.08	0.00
		Hydroprogne caspia	Caspian Tern	1.59	2.43	0.98	0.00
		Sternula saundersi	Saunders Tern	0.45	2.9	0	0
		Sternula albifrons	Little Tern	0.81	1.71	0	0.00
		Sterna bengalensis	Lesser Crested Tern	4.23	1.48	0.55	0.91
		Sterna sandvicensis	Sandwich Tern	4.59	3.03	0.25	1.03
		Sterna bergii	Greater Crested Tern	17.00**	10.42	5.99	2.28
	Dromadidae	*Dromas ardeola*	Crab Plover	0	0.03	0.81	0
	Haematopodidae	*Haematopus ostralegus*	Oystercatcher	0.27	2.85	5.78	0
	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	1.44	4.06	7.18	2.39
		Calidris alba	Sanderling	0.4	1.15	2.34	0.00
		C. minuta	Little Stint	0.67	1.27	1.57	0.00
		C. alpina	Dunlin	0.51	0.44	0.13	0
		Numenius arquata	Curlew	0.71	1.51	0.81	1.14
		Numenius tenuirostris	Slender billed Curlew	0.71	1.85	0.34	0.46
		N. phaeopus	Whimbrel	0.31	0.86	1.02	0.0
		Limicola falcinellus	Broad billed Sandpiper	0.28	0.3	5.27	7.75

		Tringa ochropus	Green Sandpiper	0.31	1.66	1.4	0
		T. stagnatilis	Marsh Sandpiper	0.93	2.99	1.06	0
		T. totanus	Red Shank	0.44	2.54	1.95	0
		Limosalapponica	Bar Tailed Godwit	0.17	0.86	5.18	1.71
		Calidris ferruginea	Curlew Sandpiper	0.65	1.04	3.06	0
		C. temminckii	Timminck's Stint	0.87	1.05	0.42	0
		Arenaria interpres	Ruddy Turnstone	0.07	0.37	2.76	1.03
	Charadriidae	*Charadrius dubius*	Little Ringed Plover	1.46	0.32	2.55	0
		C. hiaticula	Great Ringed plover	0.69	0.36	3.36	0
		C. leschenaultii	Greater Sandpiper	1.63	1.48	5.01	0
		C. asiaticus	Caspian Plover	0.11	0.17	0	0
		C. mongolus	Lesser Sandpiper	1.94	1.26	4.8	0.00
		C. alexandrinus	Kentish Plover	0.79	1.16	2.21	0.00
		Vanellus spinosis	Spur-winged Lapowing	0.48	0	0	0.00
		Pluvialiss quatarola	Grey Plover	0.8	1.63	0.64	0.00
Ciconiiformes	Threskiornithidae	*Platalea leucorodia*	Spoonbill	0.00	1.77	0.51	0.00
		Threskiornis aethiopicus	African Sacred Ibis	0.17	0.08	1.66	1.71
	Ardeidaee	*Ardea alba*	Great white Egret	0.28	0.64	0.47	0.00
		Ardea melanocephala	Black Head Heron	0.13	0.07	0.42	0.68
		Ardea cinerea	Grey Heron	0.52	0.52	2.34	0.0
		Egretta garzetta	Little Egret	0.44	2.13	1.44	0.8
		Egretta gularis	Western Reef Egret	1.79	2.45	4.38	1.37

*** Low** ****High**

Table 5. Resutls of least significant difference (LSD) Test between mean of birds number during study period (October 2021-December 2022).

Months	**Averages**	**LSD**	**Months**													
			Apr. 22	**Sep. 22**	**Jul. 22**	**Feb. 22**	**Nov. 21**	**Aug. 22**	**Dec.21**	**Oct. 21**	**Oct. 22**	**Nov. 22**	**May 22**	**Mar22**	**Jan. 22**	**Dec. 22**
			22.7	23.6	24.0	37.3	40.5	41.2	42.0	42.4	44.5	50.2	56.3	61.2	62.4	88.9
			The difference between the average numbers of birds in the months													
June 22	**111.0**	**49.04**	88. 3*	87.4*	87.0*	73.7*	70.5*	69.8*	69.0*	68.6*	66.5*	60.8*	54.7*	49.8*	48.6ns	22.1ns
Dec. 22	**88.9**		66.2*	65.3*	64.9*	51.6*	48.4ns	47.7ns	46.9ns	46.5ns	44.4ns	38.7ns	32.6ns	27.7ns	26.5ns	
Jan. 22	**62.4**		39.7ns	38.8ns	38.4ns	25.1ns	21.9ns	21.2ns	20.4ns	20.0ns	17.9ns	12.2ns	6.1ns	1.2ns		
Mar. 22	**61.2**		38.5ns	37.6ns	37.2ns	23.9ns	20.7ns	20.0ns	19.2ns	18.8ns	16.7ns	11.0ns	4.9ns			
May 22	**56.3**		33.7ns	32.7ns	32.3ns	19.0ns	15.8ns	15.1ns	14.3ns	13.9ns	11.8ns	6.1ns				
Nov. 22	**50.2**		27.5ns	26.6ns	26.2ns	12.9ns	9.7ns	9.0ns	8.2ns	7.8ns	5.7ns					
Oct. 22	**44.5**		21.8ns	20.9ns	20.5ns	7.2ns	4.0ns	3.3ns	2.5ns	2.1ns						
Oct. 21	**42.4**		19.7ns	18.8ns	18.4ns	5.1ns	1.9ns	1.2ns	0.4ns							
Dec. 21	**42.0**		19.3ns	18.4ns	18.0ns	4.7ns	1.5ns	0.8ns								
Aug. 22	**41.2**		18.5ns	17.6ns	17.2ns	3.9ns	0.7ns									
Nov. 21	**40.5**		17.8ns	16.9ns	16.5ns	3.2ns										
Feb. 22	**37.3**		14.6ns	13.7ns	13.3ns											
Jul. 22	**24.0**		1.3ns	0.4ns												
Sep. 22	**23.6**		0.9ns													

*indicates a significant difference at a significant level of 0.05 ($P < 0.05$)

ns: denotes no significant difference at a significant level of 0.05 ($P < 0.05$)

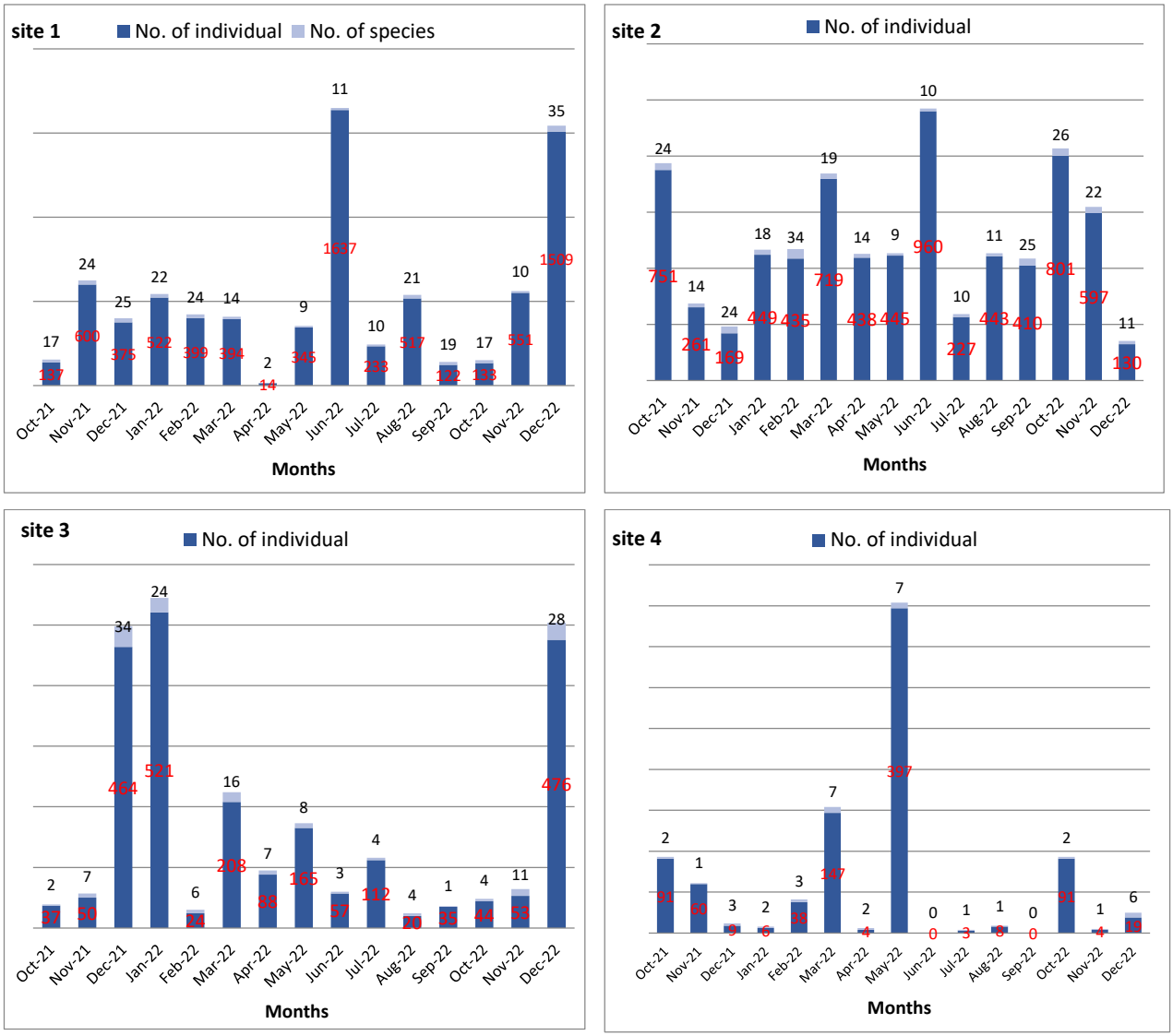

Fig. 10. Number of observed birds (individuals) and number of bird species at each sites during study period.

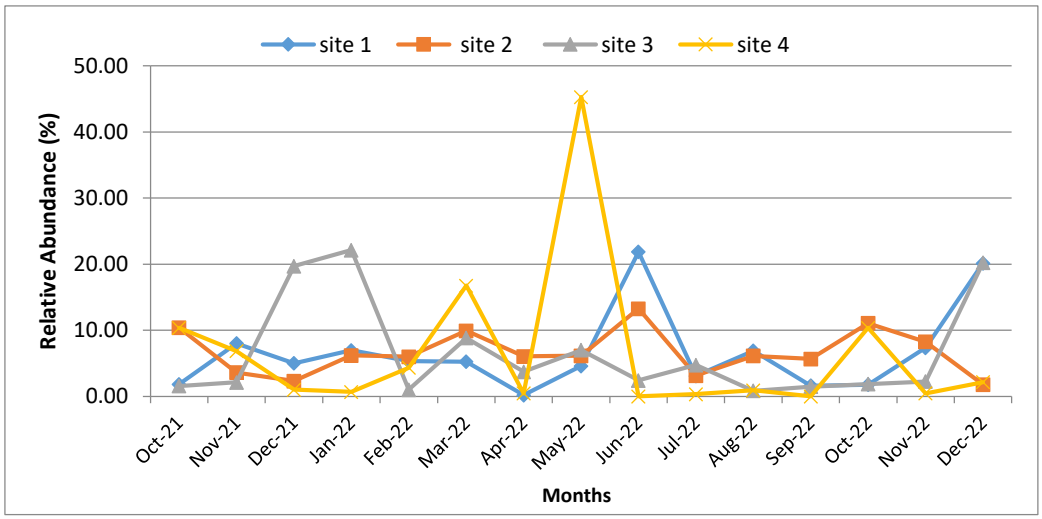

Fig. 11. Monthly relative abundance of wading birds and shorebirds in Aden lagoon.

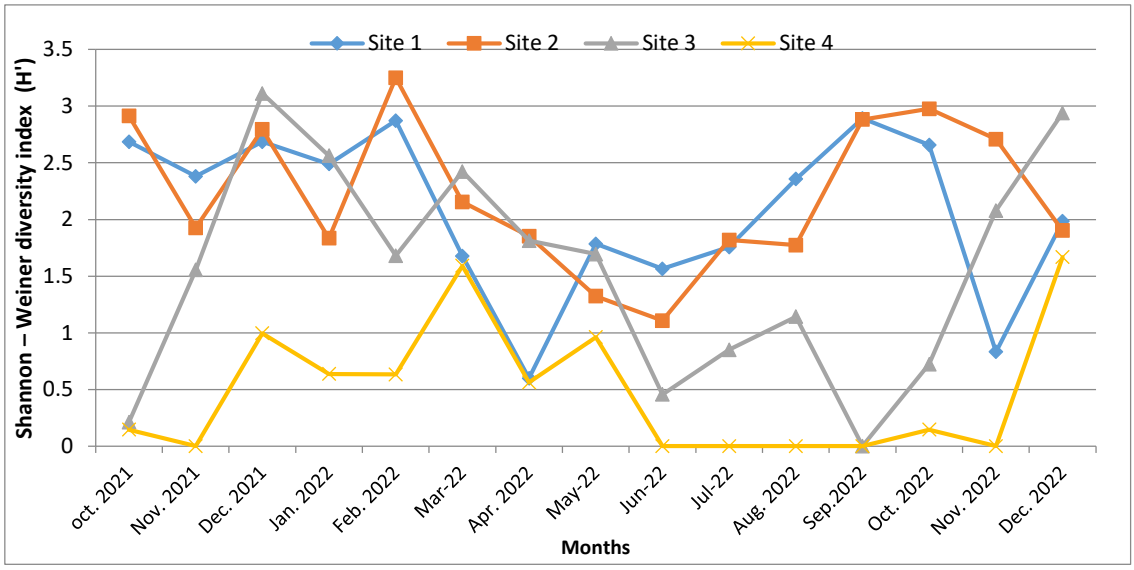

Fig. 12. Monthly variations in Shannon - Weiner diversity index in Aden lagoons.

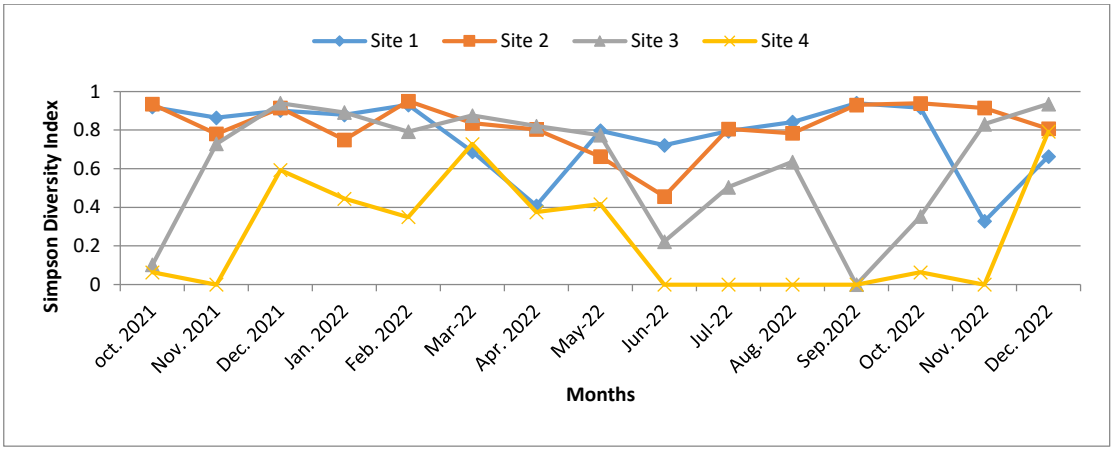

Fig. 13. Monthly variations in Simpson diversity index in Aden lagoons.

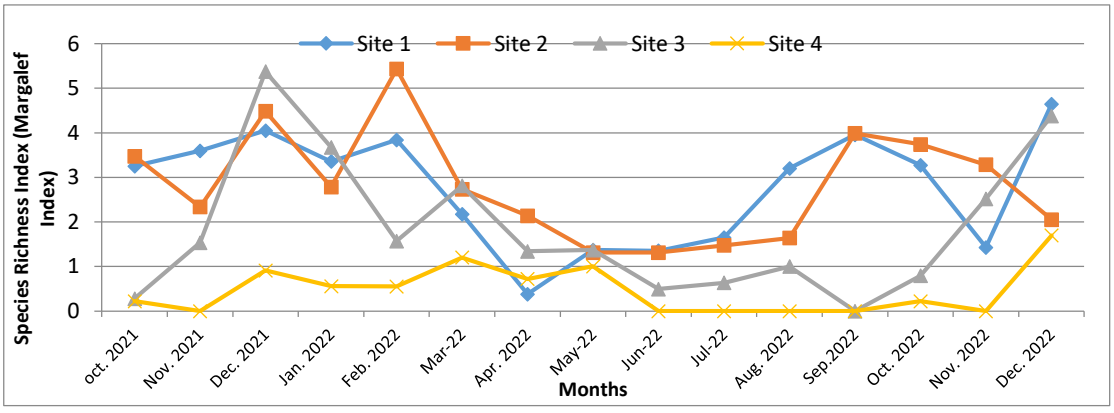

Fig. 14. Monthly variations in Species richness index (Margalef index)in study sites during study period.

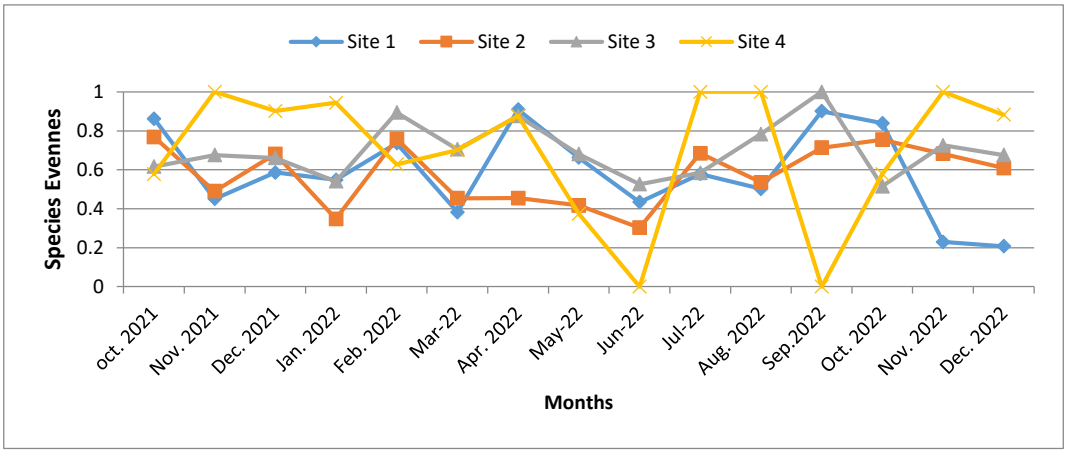

Fig. 15. Monthly variations in evenness index in study sites during study period.

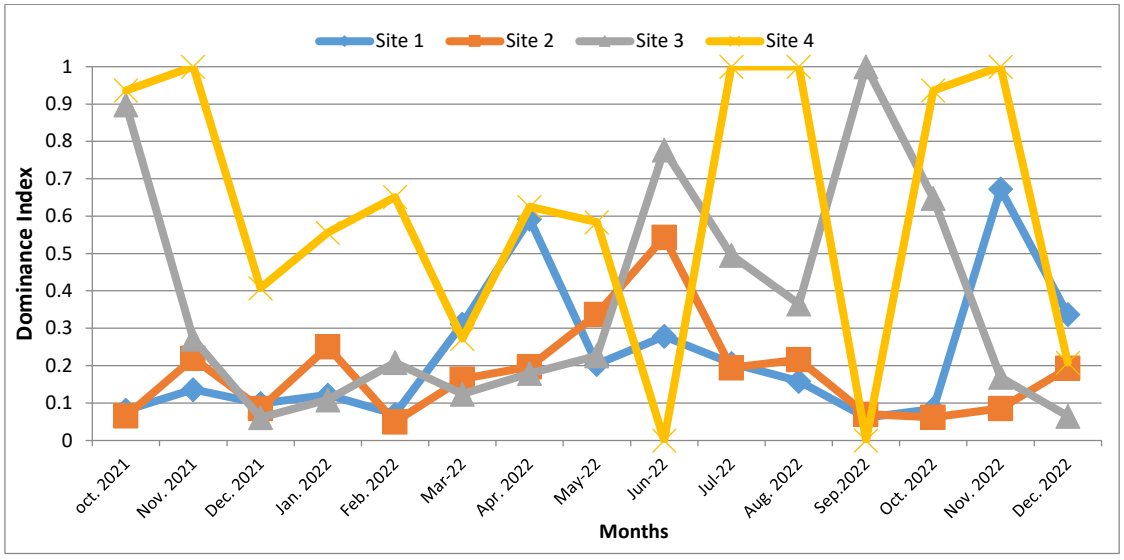

Fig. 16. Monthly variations in dominance index in study sites during study period.

4. Discussion

Lagoons of Aden provide ideal habitats for many seabirds, in addition to the availability of sites unaffected by harmful tidal changes. They are nurseries for fish and other Marine organisms and they also provide feeding habitats for birds (Bawazir, 2009).

Aden lagoon characterized by huge avifauna including large number of shorebirds and wading birds as stated by previous surveys (Abdull-Hakeem, 2007). One of the major group is the migrating birds. Several studies pointed out the importance Aden lagoon habitat for the migrating birds, which prefer these lagoons. Birds mostly come from Europe and central Asia during winter season when force hard weather as well as a scarcity of food at the original homeland. Thus, many migrating species refuge to Aden lagoons and other marshes in Aden governorate (Evans, 1994; Scott, 1995; Raweeh, 2010).

The present survey recorded 54 species of wading birds and shorebirds that occurred in Aden lagoons. The total number of individuals

reached 17954 birds through the monitoring period. There is obviously an increase in the number of individuals and species in winter due to arrival of migratory species as well as residents compared with other seasons (Al-Ballam, 2005). Station 1 is considered as more diverse compared with other stations, because it is one of the biggest lagoons in terms of area, and to the area of mud flats extending to the port of the free zone, and this extension made it an important feeding area for birds especially when the water recedes.

The relative abundance of wading birds and shorebirds might be relevant to availability of food, habitat conditions and migration season of the species. Therefore, it showed an increase in abundance of these birds in the winter season. Simpson index and Shannon-Weiner index were used to assess the bird species diversity, the values of Simpson index ranged between 0 to 1, while the values of Shannon- Weiner 0 to 5, but the typical values are generally between 1.5 to 3.5 and the index is rarely it exceed 4 (Magurran, 2004; Krebs, 2014). The calculated values of the Simpson index fluctuated between (0 to 0.95) in all stations during the survey, while the average annual value of this index reached to 0.62, it is dependent on how individuals are distributed to the species of the community. The values of Shannon-Weiner index ranged between 0 to 3.25 in all sites through the monitoring period, while the average annual value reached to 1.58 in Aden lagoons. Shannon - Weiner value close 4.5 would indicate that the individuals are equally distributed among all the species (Bibi & Ali, 2013). The values over 3.0 indicate that the composition of habitat is stable and balanced; the values under 1.0 indicate the habitat is unstable where pollution and degradation occurs accordingly, in this case, the status of wading birds and shorebirds community are of moderate status and the habitat of these birds is not degradation.

The values of species richness index fluctuated between 0 to 5.43, while the average annual value was 1.98 during the survey. The Margalef index determines the diversity relating certain richness to all individuals, the major problem when applying this index is the absence of a limit value, so it is very difficult to raise reference values (Jorgensen, *at al*. 2005). Ros and Cardell (1991) pointed out the values less than 4 as typically polluted (disturbed), on the contrary, while Bellan and Santini(1980) considered that it is limited when this index takes values less than 2.05. In this situation, the wading birds and shorebirds assemblage and their habitat are considered disturbed.

Evenness is directly proportional to diversity. When the high value of evenness means high value of diversity. The values are ranged between 0 to 1. When the values are reaching near 1, it means that the individuals of all species are distributed evenly, while the low value of evenness means there is an extreme distribution of individuals, in other words there is a dominance of one species or a few on other species of community (Magurran, 2004; Krebs, 2014).

The evenness values in present study fluctuated between 0 to1, this is attributed to the low value of evenness in September and June 2022 that resulted from dominance of *Phoenicopterus rubber* on other species, but the high value means all individuals distributed closer equally. The average annual value of evenness in Aden lagoons reached 0.64 from this value the community of wading birds and shorebirds in Aden lagoons can be described as semi-balanced.

The Berger- Parker index expresses the proportional abundance of the dominant species (most abundant). In large assemblages, the dominance index (more than 100 species) is independent of number of species, while in smaller communities, its values will tend to

reduce with increasing species richness (Magurran, 2004). The values of the dominance index are inversely proportional to the values of diversity, when the Berger- Parker value increases the diversity decreases. The dominance index values in this study ranged between 0 to 0.69, the increase in value attributed to the dominance of *Phoenicopterus rubber* in June and September 2022. The values of dominance index in present survey refer to dominance of a few species on other species in the bird's community.

5. Conclusion

The present study supports the idea that Aden lagoons are precious buffer wetlands habitat for migratory wading birds and shorebirds, plays as alternate feeding habitats and therefore, for this characteristic, they attracted many birds, especially in winter season. We can conclude that Aden lagoons are rich in bird species with relative diversity.

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تقييم تنوع الطيور الخواضة وطيور الشاطئ في بحيرات عدن – عدن/اليمن

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المستخلص. تعد جميع الموائل الموجودة على هذا الكوكب تقريبًا موطنًا للطيور، بدءًا من الصحاري الأدنى وحتى أعلى الجبال. لقد أثبتت الطيور أنها مؤشرات ممتازة للتنوع البيولوجي حيث يمكن ملاحظتها بسهولة وهي معروفة نسبيًا مقارنة بالحيوانات الأخرى. هدفت هذه الدراسة إلى تقييم تنوع الطيور الخواضة وطيور الشاطئ في بحيرات عدن خلال الفترة من أكتوبر ٢٠٢١ إلى ديسمبر ٢٠٢٢. تم تسجيل أربعة وخمسين نوعًا تنتمي إلى رتبة واحدة وست عائلات لطيور الشاطئ وثلاث رتب وأربعة عائلات من الطيور الخواضة في منطقة الدراسة. وسجلت أعلى وفرة نسبية ١٤,٧٨٪ في يونيو ٢٠٢٢، بينما سجلت أدنى نسبة٣,٠٣ ٪ في أبريل ٢٠٢٢. وكانت أعلى قيم لمؤشر سيمبسون للتنوع ومؤشر شانون وينر ٠,٩٥ و٣,٢٥ على التوالي. وبلغ مؤشر ثراء الأنواع ٥,٤٣٢، في حين بلغ مؤشر التكافؤ ٠,٨٦٢. سجل مؤشر السيادة قيمة عالية في نوفمبر ٢٠٢١ ويوليو ٢٠٢٢ وأغسطس ٢٠٢٢ وسبتمبر ٢٠٢٢ ونوفمبر ٢٠٢٢. وكان تجمع طيور الخوض والطيور الساحلية في بحيرات عدن معتدلاً، في حين أظهر تجمعاً مضطرباً وشبه متوازن من حيث الثراء والتساوي على التوالي.

الكلمات المفتاحية: التنوع، الطيور الساحلية، الطيور الساحلية، بحيرات عدن، اليمن.