SEAGRASS AND MANGROVES AS WATER-ASSOCIATED BIRD HABITAT IN THE SOUTHERN RED SEA COASTS OF SAUDI ARABIA

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ABSTRACT

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Studies on water-associated bird communities within seagrass and mangrove habitats, especially in arid environments, are limited. Here, we studied a pristine mangrove forest with associated seagrass meadows in the Jazan City for Primary and Downstream Industries (JCPDI) on the southern Red Sea coast of Saudi Arabia. Our objectives were to (1) determine the differences in the diversity and distribution of water-associated bird communities between three sampling stations—S1 (a mixture of mangroves and seagrass beds), S2 (an open coast adjacent to mangroves), and S3 (an open coast without vegetation)—and across three seasons (March for spring, July for summer, and November for fall), and (2) identify the key climatological variables influencing variations in waterbird community composition. Point count surveys detected 29 water-associated bird species from 14 families. The Common Gull *Larus canus* and the Kentish Plover *Anarhynchus alexandrinus* were the most commonly observed waterbird species. Station S1 exhibited higher species richness, diversity, and dominance compared to stations S2 and S3, with a downward trend from S1 to S3, except in summer. The non-metric multidimensional scale (nMDS) and the analysis of similarity (ANOSIM) showed that seasonality was a major factor in avifaunal composition. A distance-based linear model (DISTLM) revealed that air temperature was the most influential factor affecting species composition. We concluded that the synergistic effects of a partially enclosed embayment, dominated by seagrass meadows and mangrove forests, support greater bird diversity than exposed, less vegetated coastal habitats.

Key words: *Avicennia marina*, feeding, habitat, *Halophila stipulacea*, intertidal zone, waterbirds, wave

INTRODUCTION

In coastal areas, seagrass meadows and mangrove forests are the most productive and carbon-sequestering ecosystems (Fourqurean *et al*., 2012; Nellemann, 2009). These coastal environments, located at the interface between land and sea, provide habitats for a variety of water-associated birds, including seabirds, waterbirds, and even some land birds. Recent studies have revealed that seagrass meadows not only serve as a direct food source for herbivorous birds, but also support various invertebrates and juvenile fishes, which indirectly supplies food for coastal and offshore birds (Unsworth & Butterworth, 2021). However, there is a paucity of available information on water-associated bird communities in seagrass-mangrove habitats. Assemblages of birds—waterbirds—which occasionally or permanently feed in the marine environment (Ashmole, 1971; Evans 1987; Newton, 2006), play a crucial role in maintaining the stability of marine biodiversity and the ecological integrity of the coastal system in several ways (Cairns, 1987; Piatt et al., 2007). These roles include acting as predators in the food web (Cairns, 1987), contributing to the influx of allochthonous materials through their migratory and staging behavior (Linhares & Bugoni, 2023), disturbing soil and vegetation while digging burrows and constructing and maintaining nests (Anderson et al., 2017), and fertilizing coastal vegetation through their feces and urine, particularly in oligotrophic environments (Adame et al., 2015; Graham et al., 2018; Ismael, 2015; Otero et al., 2018; Qurban et al, 2019). In addition, waterbirds serve as important bio-indicators for assessing overall marine ecosystem health (Cairns, 1987).

In Saudi Arabia, most previous studies have focused on the importance of islands for breeding seabirds in the northern (Shobrak & Aloufi, 2014) and southern Red Sea (AlRashidi et al., 2011; Gaucher et al., 1988; Goldspink et al., 1995; Jennings, 1988; Newton & Suhaibany, 1996; Ormond et al., 1984; Ostrowski et al., 2005). To date, no studies in Saudi Arabia have addressed the coastlines where mangroves and seagrasses coexist, particularly in the Red Sea. Understanding the intricate interrelationships between the structure of avian communities, habitat types, and environmental variables is necessary for effective conservation planning in the region (Shobrak et al., 2003).

The coastal area of Jazan City for Primary and Downstream Industries (JCPDI) on the southern Red Sea coast of Saudi Arabia, which is characterized by a harsh and arid environment, is known to harbour a variety of uniquely adapted animals, including birds (Khoury & Al-Shamlih, 2006; Tieleman et al., 2003). Recently, the Saudi Arabian government launched the "Saudi Green Initiative," a nationwide program aimed at promoting biodiversity, fisheries, and carbon sequestration capacity along the Red Sea coasts (www.vision2030.gov.sa). As part of this initiative, actions were taken to support the planting of three to five million seedlings for a mangrove afforestation program in this area. Given the growing public interest in sustainability in this region, it is necessary to increase our understanding of the local ecosystem. In this coastal area, study of the ecology of marine benthic fauna (e.g., macrobenthos) along vegetated habitats, especially mangroves and seagrasses, has already received attention (Abrogueña et al., 2021, 2023; Qurban et al., 2019). However, there is still a need to improve our understanding of the ecological value of these habitats, particularly by studying how top predators, such as birds, use these areas as feeding and nursery grounds.

In this study, we investigated the capacity of coastal mangroves and seagrasses of the coastal area of JCDPI to serve as potential habitat for various water-associated birds. To achieve our objective, we compared the seasonal diversity, abundance, and distribution of avian communities between mangrove and seagrass habitats. In addition, we explored key environmental variables to identify which factors most influence variation in bird communities.

STUDY AREA AND METHODS

Description of the study site

The study site is a semi-enclosed bay within the Jazan City for Primary and Downstream Industries (JCPDI) on the southern coast of the Red Sea in Saudi Arabia (Fig. 1). The vegetation consists of mangroves and seagrasses. The mangroves encompass a monospecific forest of *Avicennia marina*, covering approximately 120 ha (1.2 km^2) (Abrogueña et al., 2022). The seagrasses occur within the mangrove forests, mostly along the mangrove fringes and shorelines, and consist mainly of five species: *Halodule pinifolia*, *Halodule uninervis*, *Halophila stipulacea*, *Halophila ovalis*, and *Thalassia hemprichii* (Qurban et al., 2019). The most abundant seagrass species is *H. stipulacea* (Qurban et al., 2019). The study site is a marine protected area and is relatively pristine due to the absence of human (e.g., construction works) and recreational (e.g., fishing, invertebrate gleaning, and picnicking) activities that could lead to disturbance.

Sampling

The study site was represented by three sampling stations (Table 1): S1 (17.32019°N, 42.32896°E), S2 (17.3382°N, 42.30896°E), and S3 (17.3587°N, 42.31417°E). The distances between S1 and S2, S2 and S3, and S1 and S3 were approximately 2.88, 2.30, and 4.55 km, respectively. Station S1 was located at the mouth of a semi-enclosed bay, in the immediate vicinity of extensive seagrass meadows and mangroves, and contained a shallow, muddy substrate, and low wave exposure (Abrogueña et al., 2021; Qurban et al., 2019) (Table 1). Station S2 was located closer to the mangroves but further away from the seagrass meadows (Table 1). This site is exposed to wind and waves and its sediment consists of a mixture of mud and sand. Station S3 was designated as a control station and is characterized by a finer substrate, lack of vegetation, and strong wind and wave influence (Table 1).

Daytime and low tide point count surveys (Volpato et al., 2009) were conducted during the morning between 07h00 and 09h00 along the three sampling stations on 04 and 11 March, 02 and 21 July, and 05 November 2022. Sampling was conducted on a Friday to avoid disturbance by weekend human activities, especially road traffic and construction work in neighboring areas. Friday is a rest day for most workers in the area. The fieldwork was carried out

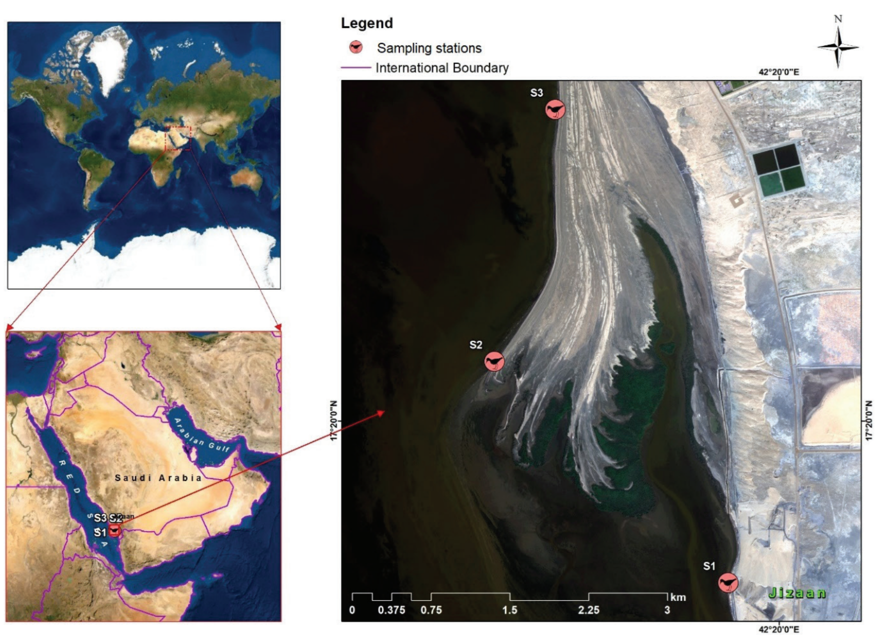

Fig. 1. Map of the study site showing the locations of the avifaunal sampling stations (S1 to S3) in the southern Red Sea, Saudi Arabia.

TABLE 1
Physical and biological characteristics of the waterbird sampling stations (S1 to S3) in the southern Red Sea, Saudi Arabia

Physical and biological component	Sampling station		
	S1	S2	S3
Seagrass	Present	Absent	Absent
Mangrove	Present	Present	Absent
Wind and wave exposure	Low	Medium	High
Substrate	Mud and silt	Fine sand	Fine sand

by an experienced avifaunist and one of the co-authors, Anthony Doyle. Observers stood at a designated point at each station and used 10×50 binoculars; thus, our range was limited to about 300 m. Species identification was performed by the same observer throughout the study and was performed using a smartphone-based application called "The eGuide to Birds of the Middle East." Data on wind speed, direction, air temperature, relative humidity, and barometric pressure were obtained from an adjacent air quality monitoring station (AQMS) in March and July to investigate the relationship between climate conditions and avifaunal composition (Shobrak & Aloufi, 2014). No data were collected in November due to maintenance work on the AQMS.

The behaviour of species (e.g., feeding, preening, loafing, and flyover), and the habitat in which they were observed (seagrass, seagrass die-off, mud, coastline, man-made structures), were recorded in March and July. The number of each species was estimated by visual count.

Data analysis

We determined species diversity, Shannon–Wiener Index, H'; species evenness, Pielou's Evenness Index, J'; and species dominance, Simpson's Dominance Index, λ'. These indices were applied to spatial (station S1 to S3) and temporal distributions (March as spring, July as summer, and November as winter) using Plymouth Routines in Multivariate Ecological Research (PRIMER, version 6.1.5). In addition, differences in abundance between the spatial and temporal distributions were tested using a permutation analysis of variance (PERMANOVA), with 999 permutations. Pairwise comparison by post hoc test examined specific groups between sampling location and time. The multidimensional scale (nMDS) examined any spatial and temporal heterogeneity based on bird abundance (Kruskal, 1964; Shepard, 1962). Prior to the actual nMDS analysis, a logarithmic transformation and normalization of the data was performed using the Euclidean distance matrix. A similarity analysis (ANOSIM) was subsequently performed to test the differences between the seasonal groups. The statistic 'R' was calculated according to the following formula:

$$R = (rB - rW)/(M/2)$$

where, rB = the average of the rank similarities resulting from all pairs of replicates between different stations; rW = the average of all rank similarities between replicates within stations; and $M = n(n-1)$ (n is the total number of samples considered).

Similarity percentage (SIMPER) was used to determine which of the bird species had the highest probability of occurrence during the specific sampling period. A distance-based linear model (DISTLM) was used to determine the degree of relationship between the environmental variables (wind speed, wind direction, air temperature, relative humidity, and barometric pressure) and the abundance and diversity of waterbirds. A sequential test (conditional test) was then carried out. The data on the environmental parameters were logarithmically transformed and normalized before the similarity was calculated, using Euclidean distance to compare them with the biota.

RESULTS

Environmental variables

Wind speed was similar in the two sampling months (March and July; Fig. 2A), but wind direction gradually changed from south in March to southwest in July (Fig. 2B). Air temperature increased from March (26°C to 27°C) through July (32°C to 33°C) (Fig. 2C). Relative humidity and barometric pressure also decreased during the study period (Figs. 2D, E). Although the data used in this study were snapshot measurements taken on the sampling days, the trends closely matched and reflected the seasonal variability patterns in this region.

Spatial and temporal distribution of bird communities

Twenty-nine bird species from 14 families were identified (Table 2). More than half (n = 18; 62%) belonged to four families: Laridae (n = 5), Scolopacidae (n = 5), Ardeidae (n = 4), and Charadriidae (n = 4). Two species accounted for half of the 514 individuals: Common Gull *Larus canus*, with 39% (n = 202), and Kentish Plover *Anarhynchus alexandrinus*, with 9.9% (n = 51) (Table 2).

Only six species (21%) from four families were found at all three sampling stations (S1 to S3): Common Ringed Plover *Charadrius hiaticula*, Kentish Plover, Common Gull, Black-winged Stilt *Himantopus himantopus*, Sanderling *Calidris alba*, and Eurasian Curlew *Numenius arquata*. Common Ringed Plover was absent in July, occurred only as a single individual in March, but was abundant at all stations in November (Table 2). In contrast, Kentish Plover was present at all stations, with numbers declining starting in March and the species completely absent by November (Table 2). Common Gull was abundant at S2 and S3 and appeared in very low numbers in November (Table 2). Black-winged Stilt was present in very low numbers in March, absent in July, and appeared only at S1 (n = 1) in November (Table 2). Sanderling appeared once at S1 in March, was absent in July, and then became abundant at all stations in November (Table 2). Eurasian Curlew was consistently found at S1 and occasionally at S2 and S3 in all sampling months (Table 2). In addition, the following species were exclusively observed at S1 and S2: Western Reef Heron *Egretta gularis*, Greater Sand Plover *Anarhynchus leschenaultii*, Caspian Gull *Larus cachinnans*, and Osprey *Pandion haliaetus*.

Species richness was highest in March, with 20 species, followed by July (12 species) and November (10 species). Only three species were present in all three sampling months: Western Reef Heron, Common Gull, and Eurasian Curlew. The number of species common to both March and July, March and November, and July and November was similar, six species each. However, the species composition varied across these month pairs. The proportion of unique species was highest in March (38%; n = 11), followed by July (17%; n = 5), and was lowest in November (7%; n = 2).

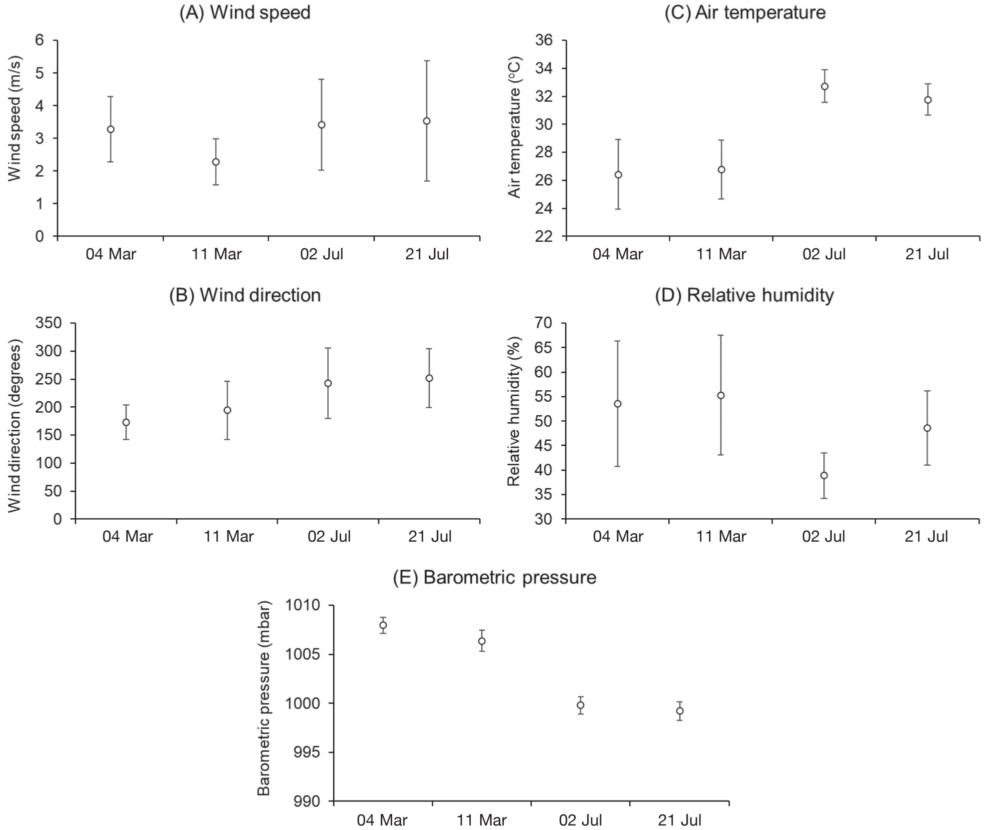

Fig. 2. Daily averages of selected meteorological data for the study site on the sampling days in March and July 2022: (A) wind speed (m/s), (B) wind direction (°), (C) air temperature (°C), (D) relative humidity (%), and (D) barometric pressure (mbar).

Avifaunal characteristics

Species richness differed significantly between stations (PERMANOVA: $F = 15.454$, $P < .05$), with significant differences between pairs S1 and S2 ($t = 3.536$, $P < .05$), and S1 and S3 ($t = 3.9196$, $P < .05$). Similarly, species diversity differed significantly across stations (Shannon-Wiener Index; PERMANOVA: $F = 13.334$, $P < .05$), with significant differences between S1 and S2 ($t = 3.536$, $P < .05$), and S1 and S3 ($t = 8.355$, $P < .001$) (Table 3). Species dominance also differed significantly across stations (Simpson Dominance Index; PERMANOVA: $F = 9.758$, $P < .05$), with significant differences between S1 and S2 ($t = -2.850$, $P < .05$), and S1 and S3 ($t = -3.254$, $P < .05$) (Table 3). In contrast, there were no spatial differences in species evenness (Table 3).

The multidimensional scale (MDS) showed a significant heterogeneous distribution of species richness in relation to seasonality (PERMANOVA: $F = 3.76$; $P < .05$). This observation was also confirmed by the analysis of similarity (ANOSIM), which revealed a significant dissimilarity of species richness as a function of the sampling season (global $R = 0.728$). Similarity percentage (SIMPER) showed the characteristic species for each season. For spring, the characteristic species were Common Gull, Pallas's Gull *Ichthyaetus ichthyaetus*, Kentish Plover, and Black-winged Stilt. In summer, the characteristic species were Great White Pelican *Pelecanus onocrotalus*, White-eyed Gull *Ichthyaetus leucophthalmus*, and Kentish Plover. In winter, the characteristic species were Sanderling, Common Ringed Plover *C. hiaticula*, Greater Sand Plover, and Caspian Gull.

Waterbird species and environmental variables

The distance-based linear model (DISTLM) revealed that the sequential test explained 82% of the variability in the relationship between species composition and environmental variables (Table 4). Of the environmental variables, only air temperature showed a significant relationship with species composition ($P = .0006$), accounting for 32% of the total variance (Table 4). Other variables, such as wind direction (17.6%), relative humidity (11.8%), wind speed (10.2%), and barometric pressure (10.5%), explained smaller proportions of the variance (Table 4).

Behavioral patterns and habitats of waterbird species

Most species were found foraging, approximately 72.2% ($n = 13$) in March and 45.4% in July ($n = 5$) (Fig. 4). Birds were primarily found in the intertidal area, which is typically muddy and characterized by a low tide regime (Fig. 5). In July, birds at S2 and S3 fed on small organisms and detritus found on the drifted seagrass that had been washed away due to coastal die-off.

DISCUSSION

The present study provides an assessment of the abundance, diversity, and distribution of birds, and their relationship with selected environmental variables, in coastal seagrass and mangrove areas in the Saudi Arabian Red Sea. Unlike previous studies, which focused on island habitats (in the north, Shobrak & Aloufi, 2014; in the south, Bijlsma et al., 2023; Gaucher et al, 1988; Goldspink et al., 1995;

TABLE 2
Distribution and abundance of waterbird species in a mangrove/seagrass habitat observed at the stations (S1 to S3) within the study site on the southern Red Sea coast, Saudi Arabia in March, July, and November 2022

Family	Species	Common Name	04 Mar			11 Mar			02 Jul			21 Jul			05 Nov		
			S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Accipitridae	*Milvus migrans*	Black Kite	5														
Apodidae	*Apus apus*	Common Swift	2														
Ardeidae	*Ardea alba*	Great Egret	2														
	Ardea cinerea	Gray Heron	1														
	Egretta gularis	Western Reef Heron	1						2	2					4		
	Ardeola ralloides	Squacco Heron													1		
Alcedinidae	*Todiramphus chloris*	Collared Kingfisher									1	1					
Charadriidae	*Charadrius hiaticula*	Common Ringed Plover				1									8	7	12
	Anarhynchus alexandrinus	Kentish Plover	10	4	3	18	5		2	4	4		1				
	Pluvialis apricaria	European Golden Plover							1		1						
	Anarhynchus leschenaultii	Greater Sand Plover													7	9	
Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove							2						2		
Dromadidae	*Dromas ardeola*	Crab Plover	1		1			2		1			1				
Hirundinidae	*Hirundo rustica*	Barn Swallow							2								
Laridae	*Ichthyaetus leucophthalmus*	White-Eyed Gull							4	2							
	Larus canus	Common Gull		2			50	100	1	44			1		2	2	
	Ichthyaetus ichthyaetus	Pallas's Gull					60										
	Larus sp.	Herring Gull					1										
	Larus cachinnans	Caspian Gull													3	25	
Pandionidae	*Pandion haliaetus*	Osprey	1	1					1								
Passeridae	*Passer domesticus*	House Sparrow	1														
Pelecanidae	*Pelecanus rufescens*	Pink Backed Pelican						2									
	Pelecanus onocrotalus	Great White Pelican							17								
Recurvirostridae	*Himantopus himantopus*	Black Winged Stilt	1				1	2							1		
Scolopacidae	*Calidris alba*	Sanderling				2									5	10	19
	Calidris alpina	Dunlin	1			2											
	Gallinago gallinago	Common Snipe	1														
	Numenius arquata	Eurasian Curlew	3		2	2			5	2					2		
	Tringa totanus	Common Redshank	2														
	Grand total		32	7	6	25	117	106	37	55	6	1	3	0	35	53	31

TABLE 3
Diversity indices (Pielou's Evenness [J'], Shannon-Wiener Diversity [H'], and Simpson's Dominance [λ']) for waterbird communities at stations (S1 to S3) and across seasons (spring, summer, and winter) at the study site on the southern Red Sea coast, Saudi Arabia

Variables	J'	H' (log2)	λ'
Spring S1	0.833	3.330	0.140
Spring S2	0.526	1.361	0.482
Spring S3	0.268	0.694	0.812
Summer S1	0.778	2.693	0.222
Summer S2	0.428	1.108	0.665
Summer S3	0.790	1.252	0.400
Winter S1	0.907	3.014	0.119
Winter S2	0.846	1.964	0.292
Winter S3	0.963	0.963	0.510

Jennings, 1988; Newton & Suhaibany, 1996; Ormond et al., 1984), this research is unique in its focus on the mainland coastline.

Twenty-nine water-associated bird species were recorded despite the small size of the surveyed site. This number should be considered a minimum estimate because our sampling times were relatively short, and the observation range with binoculars is limited (e.g., compared to spotting scopes). The number of species observed at the study site (15 species) is comparable to the total species count for the entire southern Red Sea (16 species) as reported by Evans (1987). This is notable given that the study site is a relatively small mangrove patch, especially when compared to other areas of the Red Sea and mangrove ecosystems (Aloysius et al., 2023; Siddiq et al., 2023). The high species richness in the southern Red Sea was likely related to the diversity of habitats, including seagrass, mangroves, tidal flats, as well as nutrient input from the Indian Ocean (Evans, 1987; Raitsos et al., 2015). In addition, the study area is located on an important migratory route for waterbirds, with approximately 90% (n = 26) of the total species considered migratory and only 10% (n = 3) classified as resident (West Asian–East African flyway: Aloysius et al., 2023; BirdLife International, 2011; Boere et al., 2006).

Species richness was strongly influenced by habitat type, with significantly higher values recorded in the presence of coastal vegetation (station S1). This may be partly due to variations in food availability, as the majority of birds were observed feeding at these sites. While the present study did not directly assess food availability, it is well documented that vegetated ecosystems offer greater diversity of food resources (Abrogueña et al., 2021; Alsaffar, 2018; Alsaffar et al., 2020; Al-Sofyani & El-Sherbiny, 2018; Shaban & Abdel-Gaid, 2020). In addition, the seagrass communities observed at station S1 are more diverse compared to other seagrass areas within the study site (Qurban et al., 2019). Furthermore, Abrogueña et al. (2021) found that seagrass meadows in S1 supported higher species diversity within microbenthic communities compared to other areas of the forest. This variation probably explains the occurrence of birds that mainly reside and feed in the vicinity of seagrass meadows in this area, as has also been reported for other climatic regions (Herrera et al., 2024).

Station S1's natural, semi-enclosed structure and mangrove forest reduce the influence of wind and waves from the north and northwest side, making the area a more favorable habitat for various bird communities (Aloysius et al., 2023; McNicholl, 1985). This sheltered environment allows birds to settle and utilize the available resources without the disturbance and stress caused by these physical factors. Additionally, seagrass can reduce sediment desiccation, especially at low tide, which, in turn, brings invertebrates close to the surface, increasing the availability of prey (Spruzen et al., 2008; Unsworth & Buterworth, 2021). In contrast, stations S2 and S3, which are heavily exposed to wind and waves, present a different environment altogether.

The declining trends in both total species richness and the number of unique species across the sampling months (March, July, and November) indicate seasonal fluctuations in the overall structure of the waterbird communities in this area. These variations are strongly influenced by meteorological factors, particularly air temperature (Aloysius et al., 2023). The present study found that the diversity and abundance of waterbirds were higher during the colder months (March) and decreased with rising air temperatures, especially in summer when intense atmospheric heat occurs. This pattern aligns with the findings of Able (1973), who showed that declining temperatures and northerly winds are often used to predict large-scale bird migration. In addition to increasing temperatures, weather factors such as onshore winds, low but increasing humidity, and low barometric pressure also lead to a decrease in bird migration (Chen et al., 2020; Nisbet & Drury, 1968). However, in this study, only air temperature had a significant influence on the variation of waterbird communities. This may be due to the latitudinal differences between the study stations and their position along migration routes.

The variability in species richness and abundance across seasons suggests an important ecological role of the study area in the southern Red Sea as a habitat for migratory bird species on the West Asian–East African Flyway (Almalki et al., 2015). It is

TABLE 4
Sequential test results of the distance-based linear model (DISTLM) between the abundance of waterbird species and environmental variables

Variable	R^2	SS (trace)	Pseudo-F	P	Proportion	Cumulative	% of variance explained
Wind speed	0.10	2,654	0.80	.68	0.10	0.10	10.2
Wind direction	0.28	4,575	1.47	.16	0.18	0.28	17.6
Air temperature	0.60	8,408	4.11	.006	0.33	0.60	32.5
Relative humidity	0.72	3,052	1.70	.15	0.12	0.72	11.8
Barometric pressure	0.83	2,740	1.85	.15	0.11	0.83	10.5

[a] SS = sum of squares

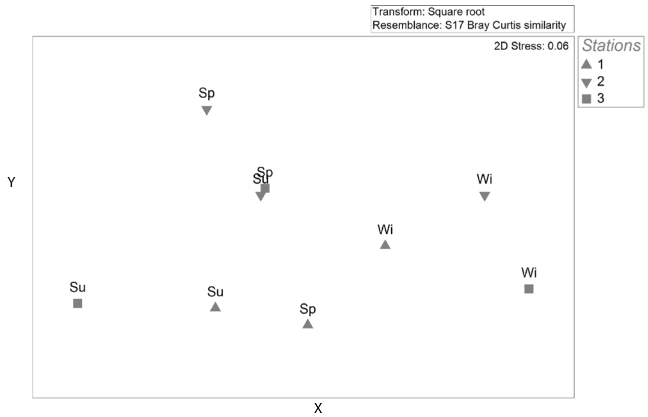

Fig. 3. Multidimensional scaling (MDS) of bird abundance sampled at three stations within the study site, with season (Su = summer, Sp = spring, Wi = winter) and station (S1 to S3) used as factors.

noteworthy that most of the bird species observed are migratory (Shamna et al., 2023), with only a few, such as the Common Gull, Eurasian Curlew, and Western Reef Heron (https://www.iucnredlist.org/), being resident to any significant extent during the sampling months. Therefore, the current study has demonstrated that the study area is a critical habitat for migratory and resident waterbird species. However, the present census of resident species may represent an underestimation of the actual resident and migratory bird communities because the field sampling was limited to an observation area, birds may migrate rapidly on a daily basis, and some of the resident birds may have been in nearby areas but were not seen during the field survey.

Of the 28 species identified in this study, seven (25%) have special conservation status: four species (14%) are Near Threatened, one (4%) is Vulnerable, and three species (7%) are High Conservation Priority (HCP) (Table 5). The Kingfisher was excluded from the

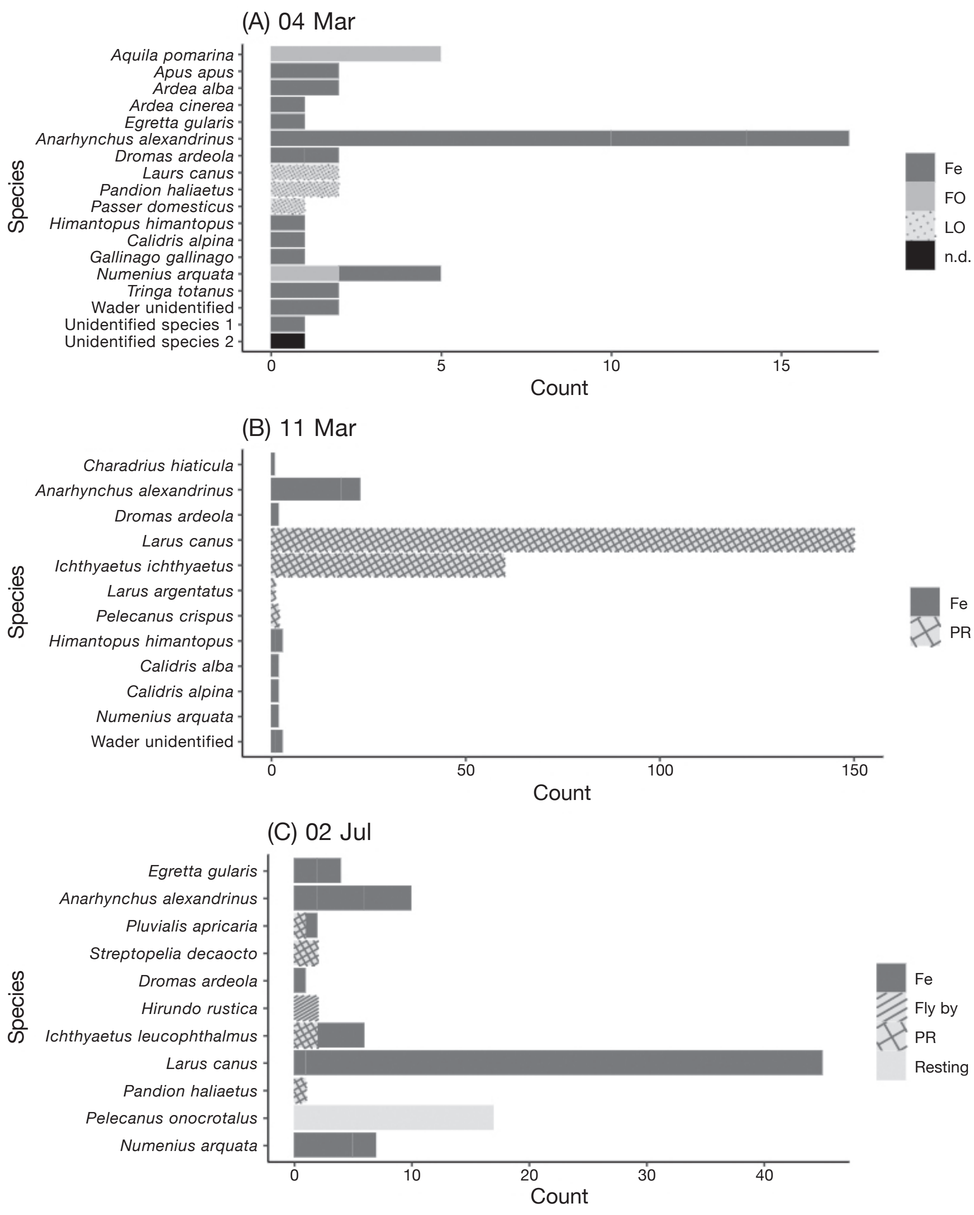

Fig. 4. Behavioral patterns of bird species sampled in the study site (southern Red Sea, Saudi Arabia) at all stations (S1 to S3) on (A) 04 Mar, (B) 11 Mar, and (C) 02 Jul 2022. Fe = feeding, FO = flyover, PR = preening. See Table 2 for species common names.

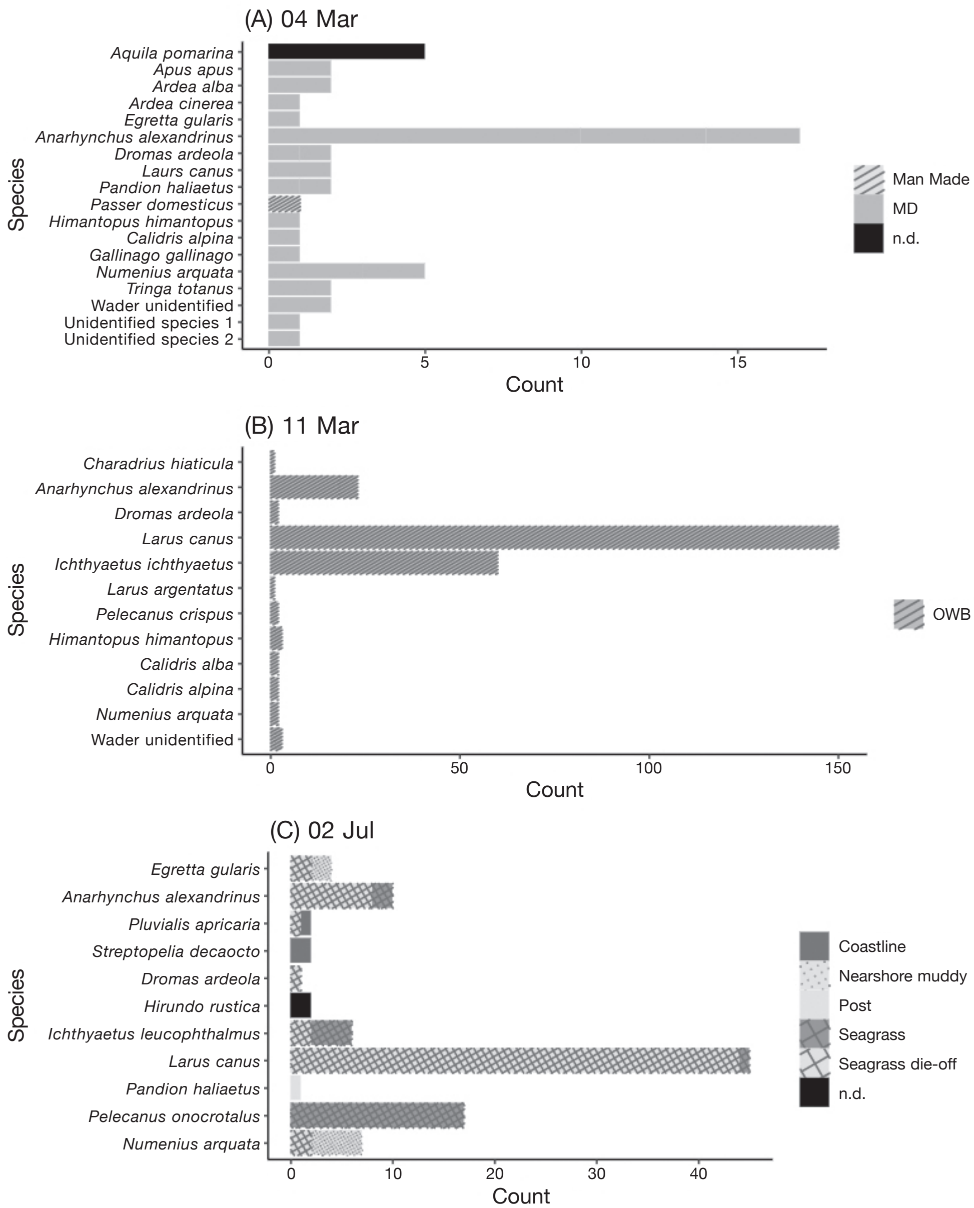

Fig. 5. Habitats of the bird species observed in the study site (southern Red Sea, Saudi Arabia). The survey data at stations S1, S2, and S3 on (A) 04 Mar, (B) 11 Mar, and (C) 02 Jul 2022. MD = mud, OWB = open water beach, n.d. = no data. See Table 2 for species common names.

classification due to the inability of the observer to identify it to species level; therefore, only 28 of the 29 species were categorized. Of the four Near Threatened species identified, two were listed on the IUCN Red List: the Dalmatian Pelican *Pelecanus crispus* and Eurasian Curlew. The other two species—Grey Heron *Ardea cinerea* and Greater Sand Plover— are included on the Arabian Peninsula List. The only Vulnerable species identified was Crab Plover *Dromas ardeola*. The three HCP species were Crab Plover, White-eyed Gull, and Osprey.

Waterbird species diversity appears to be higher in the southern Red Sea compared to the northern regions. For example, Shobrak & Aloufi (2014) recorded 16 species in the north, whereas the present study identified 29 species in the south, and Ostrowski et al. (2005) recorded 34 species on Umm al-Qamari Island. This study is the first to report the presence of the Dalmatian Pelican, Eurasian Curlew, and Grey Heron in the southern Red Sea, as only one species, Pink-backed Pelican *Pelecanus rufescens*, was recorded in the southern Red Sea in 1987 by Evans (1987) and in 1996 by Newton & Symens (1996). Crab Plover is a local bird found on the Red Sea coast, White-eyed Gull is a rare gull species endemic to the region (Avibase, n.d.), and Osprey feeds mainly on coastal fish (Evans, 1987). Interestingly, several islands at varying distances from the study site share some of the same species, including the islands of Umm al-Qamari and Farasan, both of which are protected areas in the southern Red Sea of Saudi Arabia (AlRashidi et al., 2011; Ostrowski et al., 2005).

Although the mangrove and seagrass cover at this study site is relatively low compared to other mangrove forests in the southern Red Sea, it provides an important habitat for waterbirds, warranting special attention in conservation and management efforts. Notably, a

TABLE 5
Conservation status of the water-associated bird species based on the Global and Regional (Arabian Peninsula) IUCN Red Lists and their classification for high conservation priority (HCP)

Family	Species	Common Name	IUCN[a]	Arabian Peninsula (Symes et al., 2015)[a]	HCP (Abuzinada et al., 2004)[b]	HCP (Boland & Burwell, 2020)[c]
Accipitridae	*Clanga pomarina*	Lesser Spotted Eagle	LC	–	–	–
Apodidae	*Apus apus*	Common Swift	LC	LC	–	–
Ardeidae	*Ardea alba*	Great Egret	LC	–	–	–
	Ardea cinerea	Grey Heron	LC	NT	–	–
	Egretta gularis	Western Reef Heron	LC	LC	–	–
	Ardeola ralloides	Squacco Heron	LC	LC	–	–
Charadriidae	*Charadrius hiaticula*	Common Ringed Plover	LC	–	–	–
	Anarhynchus alexandrinus	Kentish Plover	LC	LC	–	–
	Pluvialis apricaria	European Golden Plover	LC	–	–	–
	Anarhynchus leschenaultii	Greater Sand Plover	LC	NT	–	–
Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove	LC	LC	–	–
Dromadidae	*Dromas ardeola*	Crab Plover	LC	VU	1,3	5
Hirundinidae	*Hirundo rustica*	Barn Swallow	LC	LC	–	–
Laridae	*Ichthyaetus leucophthalmus*	White-Eyed Gull	LC	LC	1,3	3
	Larus canus	Common Gull	LC	–	–	–
	Ichthyaetus ichthyaetus	Pallas's Gull	LC	–	–	–
	Larus argentatus	Herring Gull	LC	–	–	–
	Larus cachinnans	Caspian Gull	LC	–	–	–
Pandionidae	*Pandion haliaetus*	Osprey	LC	LC	1,5,7	–
Passeridae	*Passer domesticus*	House Sparrow	LC	LC	–	–
Pelecanidae	*Pelecanus crispus*	Dalmatian Pelican	NT	–	–	–
	Pelecanus onocrotalus	Great White Pelican	LC	–	–	–
Recurvirostridae	*Himantopus himantopus*	Black Winged Stilt	LC	LC	–	–
Scolopacidae	*Calidris alba*	Sanderling	LC	–	–	–
	Calidris alpina	Dunlin	LC	–	–	–
	Gallinago gallinago	Common Snipe	LC	–	–	–
	Numenius arquata	Eurasian Curlew	NT	–	–	–
	Tringa totanus	Common Redshank	LC	–	–	–

[a] LC = Least Concern; NT = Nearly Threatened; VU = Vulnerable.
[b] In Abuzinada et al. (2015), "1" indicates species that are critically endangered, endangered, or vulnerable; "3" indicates species for which conservation of populations within Saudi Arabia is essential to the conservation of the taxon (e.g., near-endemics and migrants for which Saudi Arabia represents a critical range); "5" indicates species of ecological importance (e.g., fulfilling a vitally important function in an ecosystem, such as providing key habitat for other species serving as indicator species); "7" indicates species with "flagship" function (e.g., high profile species of cultural value, the protection of which will also protect large numbers of other species that share their habitats).
[c] In Boland & Burwell (2020), "3" indicates stable and "5" indicates vulnerable.

quarter of the species recorded here are classified as having special conservation status (e.g., Near Threatened, Vulnerable, or High Conservation Priority). Additionally, Crab Plover, one of the waterbird species identified in this study, is experiencing a regional population decline (Boland & Burwell, 2020; Symes et al., 2015). Conservation and improvement of this area through mangrove protection and other conservation strategies (e.g., mangrove afforestation) would create a more suitable habitat for waterbirds (Byju et al., 2024). It is also important to note that the species inventory in this study may be underestimated, and that other species that were not identified during sampling may also be present.

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