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Diversity of Wader across various wetland ecosystems in Jamnagar city, Gujarat, India

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Abstract
Wader birds, or shorebirds, inhabit wetlands, coastal zones, and shallow waters, using their long legs to wade while feeding on invertebrates like insects, molluscs, and small fish. Their name derives from this foraging behaviour. Despite this, these populations face threats from hunting, poaching, and habitat loss. The present study was conducted in Jamnagar city various wetland ecosystem. For this baseline study, two specific wetlands were selected 1. Saltpans area, (22°30' 43.5" N 70°03'16.1" E) 2. Dhinchda Lake (22°30'24.0 N 70°01'32.5" E). Methodology includes regular field visits, twice a month early morning (7:30 to 10:00 AM) and evening (3:30 to 6:00 PM). Statistical Analysis was employed using different diversity indices accordingly. A total of 63 avian species were recorded across site 1 and site 2. The maximum abundance of waders was recorded in February and the minimum abundance was recorded in October. We Found 35 species of migratory birds, 3 species of non-migratory, and the remaining species are resident at both sites. The family Scolopacidae was identified as the most prevalent. The comparatively higher diversity indices observed at Dhinchda Lake ranging from 0.80 to 0.93 suggest that Dhinchda potentially harbour's a more ecologically robust ecosystem. Given the importance of these areas as critical habitats for wader birds and the threats posed by anthropogenic activities, there is an urgent need for comprehensive conservation measures to safeguard bird diversity in these ecosystems.

Keywords: Waders, wetlands habitat, diversity, Dhinchda lake, INS valsura, Jamnagar, Gujarat

Introduction

Wader birds, commonly referred to as shorebirds, constitute a classification of avian species that predominantly inhabit regions adjacent to wetlands, coastal zones, mudflats, marsh ecosystems, and various other shallow aquatic environments. These birds are characterized by their elongated legs, which facilitate their ability to wade through water while foraging for nourishment, thereby leading to the designation "waders." Waders primarily consume diminutive invertebrates, including insects, mollusks, crustaceans, and small fish, typically located within mud or shallow aquatic settings. Birds act as scavengers, pollinators, seed dispersers, and ecosystem indicators, reflecting environmental changes like pollution and habitat disruption [7]. Out of 1266 species of birds, 302 species are water birds, 57 are endemic, 3 are breeding endemic, and 85 are threatened [2]. They can also identify changes in both waters and on land. They migrate over great distances; shorebirds are a highly diversified group of migratory animals that use a lot of energy [11, 01, 14, 03]. A wetland is an area of marshes, peatlands, or aquatic environments, either natural or man-made, with permanent or temporary water, ranging from fresh to saline, and not exceeding a depth of 6 meters. Seabirds and coastal avifauna constitute a fundamental component of marine and coastal ecosystems, typically functioning as apex predators within the trophic hierarchy. They integrate into ecosystems across various trophic levels. During peak migratory periods each year, numerous avian species traversing the Central Asian-Indian Flyway congregate in India's coastal wetlands in pursuit of habitat and sustenance. Many wetland birds use Jamnagar as a home; however, no comprehensive study has been done on the season, diversity, evenness, richness, and density of wetland birds. Therefore, the main goal of this effort was to list the wetland birds in Jamnagar.

Materials & methods

1. Study Site

The present study was conducted in Jamnagar city. Jamnagar, situated on the western coast of India in the state of Gujarat within the Saurashtra region, serves as the focal point for our baseline study on the diversity of waders. Notably, India's largest private company, Reliance Industries, has established the world's largest Oil Refining and Petrochemicals Complex in the Jamnagar district, contributing significantly to the economic landscape. The city lies just south of the Gulf of Kutch, featuring two vital ports – Rozi Port along the Gulf of Kutch shore and Bedi Port inland on the Rangamati River.

Jamnagar experiences a hot semi-arid climate, characterized by three distinct seasons. In terms of wetland significance, Jamnagar ranks second in Gujarat, following Kachchh, due to its extensive coastal wetlands. These wetlands, constituting 5.72% of Gujarat's total wetland area, showcase a diverse ecosystem, featuring coral and mangroves.

For this baseline study, two specific wetlands sites were selected:

Site 1: Saltpans area: INS Valsura road (22°30' 43.5" N 70°03'16.1" E). Saltpans area, INS Valsura Road covers an area of 10 sq. km. It is managed by Halar Salt Company it is in proximity to the Navy Base Station.

Site 2: Dhinchda Lake: (22°30'24.0 N 70°01'32.5" E). Dhinchda Lake covers an area of 7 sq. km and is away from Jamnagar City for 11 km. Near to Rozi-port. These selected wetlands provide diverse environments for the survey of waders, allowing for a complete knowledge of the factors influencing their diversity and distribution in the Jamnagar region.

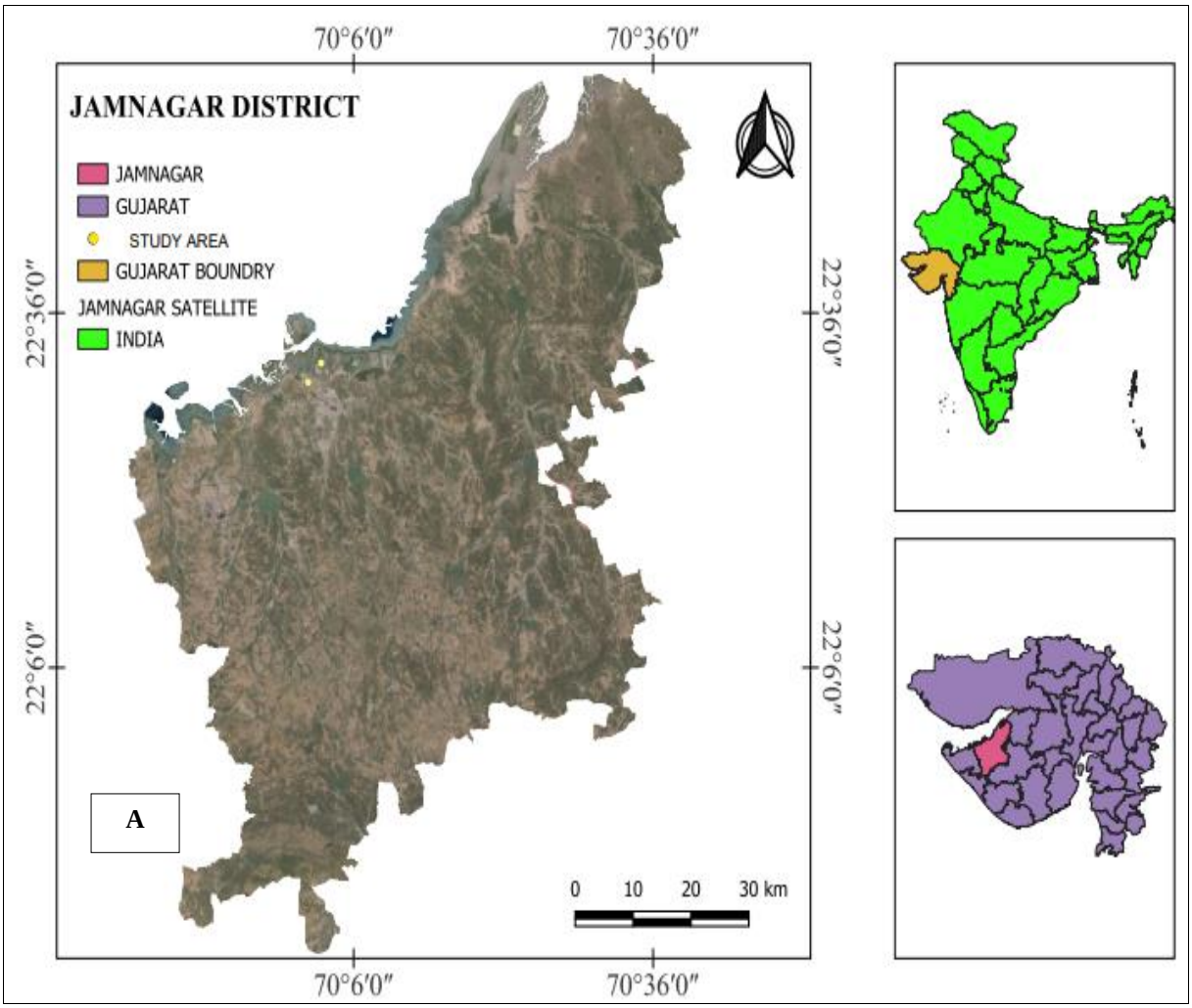

Fig 1: A. Location of Jamnagar District in Gujarat and Study site location point. **B**. Google Earth image of saltpans area, INS Valsura. **C.** Google Earth image of Dhinchda Lake.

2. Methods

The study was conducted from September 2023 to February 2024 and included regular field visits, twice in a month, and a prepared checklist. Photography and observation were done by using Canon 1100D, 50-250MM lens, and Canon 10×50 binoculars. The time selected for the survey was early morning (7:30 to 10:00 AM) and evening (3:30 to 6:00 PM).

During the study, a 3 km transect was established at Saltpans area, INS Valsura road, with intervals on both edges observations made at 300 feet of the transect. Additionally, point stations were established at predetermined distances along the transect. At each station, a 10-minute observation period was utilized to count, employing a checklist for systematic data collection., given the unique characteristics of the Dhinchda Lake, the total count method and direct observation techniques were adopted as the transect was 0.84 km only. (Bibby, Jones, *et al* 1998).

3. Statistical Analysis

Simpson's Diversity Index (SDI) (D): The formula for Simpson's Diversity Index is.

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

Were,
n = the number of organisms of the individual species
N = the combined count of individuals across all species
Simpson's Diversity Index provides an indicator of species dominance within a population. A low value indicates high dominance, meaning that a few species are highly abundant relative to others. Conversely, a high value indicates more evenly distributed species abundance, indicating greater diversity.

Shannon-Weiner Diversity Index (SWDI) (H): The formula for the Shannon Diversity index is.

$$H = -\sum_{i=1}^{s} pi\ ln(pi)$$

Were,
H=the Shannon index value
Pi=is the proportion of species found in the species.
ln=the natural logarithm
s=the number of individuals in the community
High values of the Shannon Diversity Index suggest high diversity, indicating that species are more. Evenly distributed, and there is a greater variety of species present.

Result and discussion

In this section, the discussion pertains to the findings of our research and the interpretation of their significance. Our observation focused on key objectives, and through a thorough analysis of collected data and experimental outcomes, numerous significant patterns and insights were revealed. These findings contribute to our understanding of the fundamental principles learned.

Site: 1 (saltpans area, INS Valsura)

During the current observation, a total 63 avian species were recorded across site 1 these species were distributed across 24 distinct families. and 13 different orders. The study (Table 1) includes an assessment of the avian studies in Site 1, where 9 species of birds were identified as Near Threatened (NT), according to the International Union for Conservation of Nature (IUCN) classification (BirdLife International, 2024). 52 species are classified under the Least Concern (LC) and 2 species are Endangered (EN). (Table 1).

Apart from 63 avian species, I have recorded 39 species of wader birds were exemplified by species such as the Great White Egret (*Casmerodius albus*), Painted Stork (*Mycteria leucocephala*), Indian Cormorant (*Phalacrocorax fuscicollis*), Eurasian Spoonbill (*Platalealeucorodia*), Lesser flamingo (*Phoenicopterus minor*), Greater flamingo (*Phoenicop terusroseus*) and the Rosy Starling etc. (Table 1).

They belong to 13 families *viz*. Ardeidae, Charadriidae, Ciconiidae, Jacanidae, Laridae, Rallidae, Motacillidae, Phalacrocoracidae, Phoenicopteridae, Recurvirostridae, Rostratulidae, Scolopacidae, Threskiornithidae. they belong to orders *viz*. Phoenicopteriformes, Charadriiformes, Ciconiiformes, Suliformes (Table 1).

Table: 1: Checklist of Birds observed during the field visit at both sites.

No.	Common name	Scientific name	Valsura	Dhinchda	Resident/ Migratory	IUCN Status
	Order: Phoenicopteriformes					
	Family: Phoenicopteridae					
1	Greater Flamingo	*Phoenicop terusroseus*	Yes	Yes	Migratory	LC
2	Lesser Flamingo	*Phoenicopterus minor*	Yes	Yes	Migratory	NT
	Order: Aciipitriformes					
	Family: Accipitridae					
1	Pallas fish eagle	*Haliaeetus leucoryphus*	Yes	Yes	Resident	EN
	Order: Anseriformes					
	Family: Anatidae					
1	Indian Spott-billed duck	*Anas zonorhyncha*	Yes	Yes	Non-Migratory	LC
2	Northern Shoveler	*Spatula clypeata*	Yes	Yes	Migratory	LC
	Order: Bucerotiformes					
	Family: Upupidae					
1	Common Hoopoe	*Upupa epops*				
	Order: Charadriiformes					
	Family: Scolopidae					
1	Black-Tailed Godwit	*Limosa limosa*	YES	NO	Migratory	NT
2	Common Redshank	*Tringa tetanus*	YES	NO	Migratory	LC
3	Sanderling	*Calidris alba*	NO	YES	Migratory	LC
4	Bar-Tailed Godwit	*Limosa lapponica*	NO	NO	Migratory	NT
5	Little Stint	*Calidris minute*	YES	NO	Migratory	LC
6	Ruddy Turnstone	*Arenaria interpres*	YES	NO	Migratory	LC
7	Terek Sandpiper	*Xenus cinereus*	NO	YES	Migratory	LC
8	spotted Sandpiper	*Actitis macularius*	NO	YES	Migratory	LC
9	Common Sandpiper	*Actitiis hypoleucos*	YES	YES	Migratory	LC
10	Marsh Sandpiper	*Tringa stagnatilis*	YES	YES	Migratory	LC
11	Red-necked Stint	*Calindris ruficollis*	YES	YES	Migratory	NT
12	Ruff	*Philomachus pugnax*	YES	NO	Migratory	LC
13	Curlew Sandpiper	*Calidris ferruginea*	YES	NO	Migratory	NT
14	Spotted Redshank	*Tringa erythropus*	YES	NO	Migratory	LC
15	Marsh Sandpiper	*Tringa stagnatilis*	YES	YES	Migratory	LC
	Family: Laridae					

1	Black-headed Gull	*Chroicocephalus ridibundus*	YES	NO	Migratory	LC
2	slender-billed Gull	*Chroicocephalus genei*	YES	NO	Migratory	LC
3	Caspian Tern	*Hydroprogone caspia*	YES	YES	Migratory	LC
4	Brown-headed Gull	*Chroicocephalus brunnicephalus*	YES	YES	Migratory	LC
5	Indian Skimmer	*Rynchops albicollis*	NO	YES	Migratory	EN
	Family: Burhinidae					
1	Great Thick-Knee	*Esacus recurvirostris*	YES	NO		
	Order: Ciconiiformes					
	Family: Ciconiidae					
1	Black-Necked Stork	*Ephippiorhynchus asiaticus*	NO	YES	Migratory	LC
2	Painted Stork	*Mycteria leucocephala*	YES	YES	Resident	LC
3	Asian Openbill	*Anastomus oscitans*	NO	NO	Migratory	LC
4	Greater Adjuvent	*Leptoptilos dubious*	NO	NO	Migratory	NT
	Order: Columbiformes					
	Family: Columbidae					
1	Eurasian Collared Dove	*Streptopelia decaocto*	YES	YES	Resident	LC
2	Pied Imperial Pigeon	*Ducula bicolor*	NO	NO	Resident	LC
3	Common Pigeon	*Columbia livia*	YES	YES	Resident	LC
	Order: Coraciiformes					
	Family: Alcedinidae					
1	Oriental Dwarf Kingfisher	*Ceyx erithaca*	NO	NO	Resident	NT
2	Common Kingfisher	*Alcedo atthis*	YES	YES	Resident	LC
	Family: Meropidae					
1	Green Bee-eater	*Merops orientalis*	YES	YES	Resident	LC
	Order: Gruiformes					
	Family: Rallidae					
1	Common Moorhen	*Gallinula chloropus*	NO	YES	Resident	LC
2	Eurasian Coot	*Fulica atra*	NO	NO	Migratory	LC
	Order: Passeriformes					
	Family: Alaudidae					
1	Creasted Larks	*Galerida cristata*	YES	NO	Resident	LC
2	Indian Buslark	*Mirafra erythroptera*	YES	NO	Resident	LC
	Family: Pycnonotidae					
1	Red-vented Bulbul	*Pycnotus cafer*	YES	YES	Resident	LC
2	white eared Bulbul	*Pycnotous leucotis*	YES	YES	Resident	LC
3	Red Wattled Lapwing	*Vanellus indicus*	YES	YES	Nonmigratory	LC
	Family: Corvidae					
1	House Crow	*Corvus splendens*	YES	YES	Resident	LC
2	Indian Jungle Crow	*Corvus culminates*	YES	YES	Resident	LC
3	Black Drongo	*Dicrurus macrocercus*	YES	YES	Resident	LC
	Family: Strunidae					
1	Common Myna	*Acridotheres tristis*	YES	NO	Migratory	LC
2	Rosy Starling	*Pastor roseus*	YES	YES	Resident	LC
	Family: Motallicidae					
1	Yellow Wagtail	*Motacilla flava*	YES	YES	Resident	LC
	Family: Nectoriniidae					
1	Purple Sunbird	*Cinnyris asiaticus*	YES	YES	Resident	LC
	Family: Hirundinidae					
1	Wire Tailed Swallow	*Hirundo smithii*	YES	YES	Resident	LC
	Order: Pelecaniformes					
	Family: Ardeidae					
1	Great White Egret	*Casmerodius albas*	YES	YES	Migratory	LC
2	Reef Egret	*Egretta gularis*	YES	YES	Resident	LC
3	Grey Heron	*Ardea cinerea*	YES	YES	migratory and resident	LC
4	Indian Pond Heron	*Ardeola graylii*	YES	NO	Nonmigratory	LC
	Family: Pelecanidae					
1	Rosy Pelican	*Pelecanus onocrotalus*	NO	YES	Migratory	LC
2	Dalmatian Pelican	*Pelecanus crispus*	NO	YES	Migratory	NT
	Family: Threskiornithidae					
1	Eurasian Spoonbill	*Platalea leucorodia*	YES	YES	Migratory	LC
2	black-headed Ibis	*Threskiornis melanocephalus*	YES	NO	Migratory	NT
3	Glossy Ibis	*Plegadis falcinellus*	yes	NO	Migratory	LC
	Order: Psittaciformes					
	Family: Psittaculidae					
1	Rose-ringed Parakeet	*Psittacula eupatria*	YES	YES	Resident	LC
	Order: Suliformes					
	Family: Phalacrocoracida					
1	Indian Cormorantas	*Phalacrocorax fucicollis*	YES	YES	Migratory	LC

LC = Least Concern**, NT** = Near Threatened**, EN** = Endangere

Month-wise Abundance of wader birds at Site-1 (Saltpan area, INS Valsura)

The monthly abundance of waders at the Saltpans study area along INS Valsura road varies significantly from October to February. In October, the area exhibits relatively low numbers, with species like the Great white egret (34.67 ± 32.67), Greator flamingo (35.33 ± 3.76), and Black-tailed godwit (64.33 ± 49.90) being the most prominent (Table-2).

During the November sees a slight increasing in bird populations, particularly with the emergence of the Lesser Flamingo (13.67 ± 0.88) and Greator flamingo (31.00 ± 1.00). December experiences a significant rise in bird numbers, notably the Lesser Flamingo (233.00 ± 17.10) and Black-tailed godwit (5.00 ± 3.21) (Table-2).

January marks the peak season with a substantial increase in various species, including the Lesser Flamingo (101.67 ± 10.67), Indian jungle crow (94.00 ± 38.84), and Black-tailed godwit (94.33 ± 46.46). February shows a slight decreasing in abundance compared to January but remains relatively high, with significant numbers of species like the Lesser Flamingo (101.67 ± 10.67) and Greator flamingo (57.00 ± 33.95) still present. (Table-2) Overall, the data illustrates the dynamic fluctuations in bird populations across the winter months, highlighting the diverse avian life in the Saltpans area (Table-2).

In the Saltpans area, the data reveals a pattern of increasing bird abundance from October to January, with a slight decrease in February. October starts with relatively low numbers, gradually building up in November and December. January emerges as the peak season, marked by a substantial increase in various species, including the Lesser Flamingo, Indian jungle crow, and Black-tailed godwit. February, while showing a slight decline compared to January, still maintains relatively high numbers of certain species like the Lesser Flamingo and Greator flamingo. This variation in abundance reflects the seasonal changes and ecological factors influencing bird migration and habitat use in the Saltpans area (Table-2).

Table 2: Monthly abundance of waders at Saltpans area, INS Valsura road

Common Name	OCT.	NOV.	DEC.	JAN.	FEB.
Greator flamingo	35.33 ± 3.76	31.00 ± 1.00	65.00 ± 7.77	35.33 ± 14.72	57.00 ± 33.95
Lesser Flamingo	0.00	13.67 ± 0.88	0.00	233.00 ± 17.10	101.67 ± 10.67
Great white egret	34.67 ± 32.67	1.00 ± 0.58	12.67 ± 6.39	0.67 ± 0.67	2.00 ± 1.00
black-tailed Godwit	64.33 ± 49.90	11.67 ± 6.01	5.00 ± 3.21	0.00	71.33 ± 11.84
Common redshank	0.00	0.00	1.67 ± 0.88	0.00	0.00
Black-necked stork	0.67 ± 0.33	0.00	0.33 ± 0.33	0.00	0.00
Eurasian Spoonbill.	1.00 ± 0.58	0.00	0.00	0.00	2.00 ± 1.00
Indian Cormorantas	2.33 ± 1.45	4.33 ± 4.33	0.00	4.67 ± 2.03	8.67 ± 6.23
black-headed Ibis.	41.67 ± 32.17	0.00	3.33 ± 0.88	0.00	4.67 ± 2.60
Black-winged stilt	19.67 ± 4.33	8.67 ± 2.91	37.33 ± 16.90	9.00 ± 4.04	26.33 ± 1.76
Eurasian collared dove	2.33 ± 1.45	4.00 ± 2.08	4.33 ± 2.60	3.33 ± 2.03	6.00 ±3.00
Ruddy turnstone	0.00	0.00	0.00	0.00	0.33 ±
Common Sandpiper	1.33 ± 0.67	1.67 ± 1.67	0.00	0.00	0.00
Marsh sandpiper	0.33 ± 0.33	0.00	0.00	0.00	1.00 ± 1.00
Ruff	13.00 ± 7.51	27.33 ± 3.71	70.00 ± 39.05	82.67 ± 46.77	120.00 ± 60.00
Curlew sandpiper	0.00	0.00	0.00	0.00	0.33 ± 0.33
Indian jungle crow	0.00	0.00	94.00 ± 38.84	0.00	3.00 ± 3.00
Painted stork	4.67 ± 1.45	4.67 ± 1.20	2.00 ± 0.58	2.67 ± 0.67	6.00 ± 3.00
slender billed gull	0.00	0.00	175.33 ± 87.95	0.00	145.67 ± 83.72
Indian spot-billed duct	14.67 ± 8.37	19.67 ± 7.86	4.00 ± 1.15	7.33 ± 2.33	13.00 ± 4.04
rosy starling	6.00 ± 3.06	9.33 ± 3.38	8.67 ± 4.98	22.67 ± 6.17	51.67 ± 34.84
Black-tailed godwit	5.67 ± 2.96	17.00 ±13.20	0.67 ± 0.67	94.33 ± 46.46	2.33 ± 2.33
Reef egret	1.33 ± 0.33	0.33 ± 0.33	1.33 ± 0.33	1.00 ± 0.58	2.33 ± 0.88
Caspian tern	0.00	0.00	0.00	0.00	0.67 ± 0.67
Glossy ibis	0.00	0.00	0.00	0.33 ± 0.33	0.00
Northern shoveler	4.00 ± 2.08	0.00 ± 0.00	0.00 ± 0.00	4.00 ± 1.15	10.67 ±5.33
Yellow wattled lapwing	7.33 ± 4.06	0.00 ± 0.00	0.00 ± 0.00	6.67 ± 5.24	0.00 ± 0.00
Grey heron	2.00 ± 0.58	0.00 ± 0.00	0.00 ± 0.00	5.33 ± 3.53	1.00 ± 1.00
Indian pond heron	0.33 ± 0.33	0.67 ± 0.33	0.00 ± 0.00	0.67 ± 0.33	1.00 ± 1.00
Great thick-knee	0.33 ± 0.33	0.33 ± 0.33	0.00 ± 0.00	0.33 ± 0.33	1.00 ± 0.58
White egret	1.67 ± 0.33	1.00 ± 0.58	0.00 ± 0.00	0.33 ± 0.33	0.33 ± 0.33
Red vented lapwing	2.00 ± 1.53	1.00 ± 1.00	0.00 ± 0.00	6.00 ± 6.00	6.67 ± 6.67
Indian pond heron	0.33 ± 0.33	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.33 ± 0.33
Eurasian spoonbill	4.00 ± 2.08	3.00 ± 1.73	0.00 ± 0.00	4.00 ± 4.00	1.00 ± 1.00
Common moorhen	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.33 ± 0.33	0.67 ± 0.67

Simpson Diversity Index (SDI) and Shannon-Weiner Diversity Index (SWDI) Diversity index at site 1:

During study, I have calculated SDI values ranged from 0.08 to 0.17 and these values are indicating a moderate species diversity over the study period. The highest SDI value was recorded in January (0.17) which are indicating according to SDI the slightly increased species richness and evenness of total avian fauna. (Table 4).

The SWDI for site 1 ranged from 4.03 to 6.27, with the highest value observed in February (6.27), indicating a higher degree of biodiversity of total avian fauna. (Table 5).

SDI values for wader birds at site-1 were fluctuated between 0.10 and 0.26, indicating varying levels of species diversity over the five months. In October and November, site 1 exhibited relatively lower diversity with SDI values of 0.10 and 0.26 respectively, suggesting a moderate and less

evenly distributed species composition during these months. However, from November onwards, the SDI values declined steadily, reaching their lowest point in November at 0.10, indicating a potential decrease in both species' richness and evenness during the winter months. (Table 6).

Moving on to the Shannon-Weiner Diversity Index (SWDI) for wader birds' site 1 exhibited values ranging from 3.56 to 5.23 across the months. The highest diversity was observed in February (5.23), indicating a period of increased species richness and evenness. Conversely, the lowest diversity was recorded in December (3.56), suggesting a decline in biodiversity during that month (Table 7).

Site: 2 (Dhinchda lake)

During the study a total 64 avian species were recorded at site- 2 these species were distributed in 24 different families and 14 different orders. Apart from these many species were found that are like site 1 like Grater Flamingo (*Phoenicop terusroseus*), Lesser flamingo (*Phoenicopterus minor*), Cormorant (*Phalacrocorax fuscicollis*), Eurasian Spoonbill (*Platalealeucorodia*), painted stork (*Mycteria leucocephala*). Indian skimmer (*Rynchopsalbicolli*) is only found on this site where 8 species of birds were identified as Near Threatened (NT), according to the International Union for Conservation of Nature (IUCN) classification (BirdLife International, 2024) (Table 1).

They belong to 12 families *viz*. Ardeidae, Charadriidae, Ciconiidae, Jacanidae, Laridae, Rallidae, Motacillidae, Phalacrocoracidae, Phoenicopteridae, Recurvirostridae, Rostratulidae, Scolopacidae, Threskiornithidae. they belong to orders *viz*. Phoenicopteriformes, Charadriiformes, Ciconiiformes, Suliformes (Table 1).

During the study period at site- 2 Greater Flamingo, Lesser flamingo, Common Sandpiper Terek Sandpiper, Marsh Sandpiper, Spotted Sandpiper, Red-vented lapwing, and Indian skimmer found in site 2, some species of waders are found in Endangered (EN) like Indian skimmer, and some are near threatened like a lesser flamingo, black-tailed godwit, etc. according to the International Union for Conservation of Nature (IUCN) classification (BirdLife International, 2024). During the study I found 35 species are migratory, 3 species are non-migratory, and the remaining species are resident at both sites because sites 1 and site 2 are near to each other (Table 1).

The family Scolopacidae was identified as the most prevalent, and succeeded in dominance by the families Laridae, Charadriidae, and Ciconiidae, in that order. Conversely, Accipitridae, Burhinidae, and Hirundinidae were recorded with the lowest frequency. Furthermore, when considering the broader taxonomic categorization into orders, 12 different orders were observed. Within this classification, Charadriiformes emerged as the most represented order, followed by Passeriformes. The orders Accipitriformes, Psittaciformes, Bucerotiformes, and Suliformes, on the other hand, were among the least represented in the study.

Month-wise Abundance of wader birds at Site-2 (Dhinchda Lake)

The monthly abundance of waders at the Dhinchda lake site displays varied populations from October to February. In October, the area with minimal bird activity, with notable species such as the Indian jungle crow (9 ± 3.33) and Northern shoveler (31 ± 4.10) being among the few observed. November shows a slight increase in bird numbers, with species like the Indian spot billed duct (6 ± 2.03) and Northern shoveler (36 ± 5.51) becoming more prevalent. December sees a notable rise in bird populations, particularly with the presence of species like the Eurasian Spoonbill (17 ± 1.45) and Black-headed Ibis (17 ± 1.45). January marks a significant peak in avian activity, with substantial numbers of species such as the Black-headed gull (90 ± 37.86) and Lesser Flamingo (22 ± 9.39) observed. February exhibits a decline in abundance compared to January but remains active, with species like the Northern shoveler (62 ± 29.25) and Lesser Flamingo (44 ± 21.55) still prominent. Overall, the data reflects the dynamic fluctuations in bird populations across the months, showcasing the diverse avian community at the Dhinchda lake site.

October begins with minimal bird activity, gradually increasing in November and December. January stands out as the peak season, characterized by significant avian activity, including species like the Black-headed gull and Lesser Flamingo. February witnesses a decline in abundance compared to January but remains active, with certain species like the Northern shoveler and Lesser Flamingo still prominent. This fluctuation in bird populations highlights the importance of understanding seasonal patterns and habitat preferences to effectively conserve and manage bird communities in diverse ecosystems like lakes and wetlands.

Table 3: Monthly abundance of waders at Dhinchda lake site

BIRD SPECIES	OCT	NOV	DEC	JAN	FEB
Greator flamingo	98 ± 11.37	118 ± 12.72	6 ± 0.67	153 ± 72.47	56 ± 23.71
Lesser Flamingo	0	0	0	22 ± 9.39	44 ± 21.55
Great white egret	0	0	0	0	1 ± 0.58
black-tailed Godwit	0	0	2 ± 1.53	35 ± 12.58	28 ± 14.00
Black-necked stork	0	0	0	6 ± 2.08	1 ± 0.58
Eurasian Spoonbill.	15 ± 2.89	15 ± 7.57	16 ± 2.33	19 ± 9.54	0
Indian Cormorantas	9 ± 3.33	13 ± 3.53	146 ± 83.03	30 ± 2.89	26 ± 4.98
black-headed Ibis.	0	0	17 ± 1.45	19 ± 5.46	2 ± 1.20
Black-headed gull	0	0	2 ± 1.67	90 ± 37.86	30 ± 7.54
Black-winged stilt	0	0	12 ± 4.91	25 ± 12.45	28 ± 11.46
Common Sandpiper	15 ± 2.03	10 ± 2.03	0	5 ± 0.67	2 ± 0.33
Ruff	6 ± 1.76	6 ± 1.45	5 ± 2.73	52 ± 24.21	47 ± 2.91
Painted stork	3 ± 1.45	3 ± 1.45	4 ± 1.76	0	4 ± 1.76
Indian spot-billed duct	0	0	2 ± 0.88	12 ± 1.45	6 ± 2.03
rosy starling	0	0	128 ± 14.81	204 ± 149.88	9 ± 0.88

black-tailed godwit	0	0	0	35 ± 12.58	36 ± 14.97
Crested lark	3 ± 0.88	1 ± 0.58	1 ± 0.58	0	1 ± 0.58
Red-vented bulbul	5 ± 1.67	4 ± 2.08	4 ± 2.08	9 ± 1.45	3 ± 2.08
Reef egret	1 ± 0.67	1 ± 0.67	1 ± 0.67	1 ± 0.67	1 ± 0.67
Yellow wedged tail	0	0	0	0	1 ± 0.67
Northern shoveler	31 ± 4.10	36 ± 5.51	9 ± 0.88	24 ± 13.01	62 ± 29.25
Yellow wattled lapwing	4 ± 1.20	4 ± 1.20	5 ± 3.18	2 ± 0.88	8 ± 3.84
Grey heron	0	1 ± 0.33	1 ± 0.33	1 ± 0.33	1 ± 0.33
Indian pond heron	1 ± 0.33	1 ± 0.33	1 ± 0.33	0	1 ± 0.33
Great thick-knee	0	1 ± 0.33	0	0	1 ± 0.33
White egret	0	1 ± 0.33	0	1 ± 0.33	1 ± 0.33
Red vented lapwing	5 ± 0.88	4 ± 1.15	6 ±	12 ± 1.45	12 ± 1.45
Indian pond heron	1 ± 0.33	1 ± 0.33	0	1 ± 0.33	1 ± 0.33
Eurasian spoonbill	24 ± 2.91	12 ± 5.24	17 ± 1.45	20 ± 8.95	11 ± 0.67
Wire Tailed swallow	0	0	0	1 ± 0.33	1 ± 0.33
Marsh sandpiper	5 ± 0.88	7 ± 1.33	3 ± 1.00	9 ± 4.16	4 ± 2.03
Common myna	13 ± 8.57	13 ± 8.57	0	0	0
plover sp.	0	0	0	0	4 ± 2.19
Common Sandpiper	0	0	1 ± 0.33	0	2 ± 0.67

Simpson Diversity Index (SDI) and Shannon Weiner Diversity Index (SWDI) Diversity index at site 2

SDI values ranged from 0.80 to 0.93. These values are near site 1, indicating a moderate to high level of species diversity over the study period. The highest SDI value was recorded in February (0.93) suggesting increased species richness and evenness of total avian fauna (Table 4).

The SWDI for site 2 ranged from 4.55 to 6.21, with the highest value observed in February (6.21), indicating a higher degree of biodiversity of total avian fauna (Table 5).

SDI values for wader birds at site 2 fluctuated between 0.10 and 0.36, indicating varying levels of species diversity over the five months. In October and November, site 2 exhibited relatively higher diversity with SDI values of 0.27 and 0.36 respectively, suggesting a richer and more evenly distributed species composition during these months. However, from December onwards, the SDI values declined steadily, reaching their lowest point in February at 0.10, indicating a potential decrease in both species' richness and evenness during the winter months (Table 6).

Moving on to the Shannon-Weiner Diversity Index (SWDI) for wader birds at site 2. exhibited values ranging from 2.21 to 4.70 across the months. The highest diversity was observed in February (4.70), indicating a period of increased species richness and evenness. Conversely, the lowest diversity was recorded in December (2.21), suggesting a decline in biodiversity during that month (Table 7).

In summary, the biodiversity indices reveal fluctuating patterns of species diversity at both the Saltpan area, INS Valsura (site-1), and Dhinchda Lake (site-2) over the five months. While site 2 exhibited higher diversity in the initial months, site-1 generally showed higher diversity towards the end of the study period. Further observation of the underlying ecological factors driving these dynamics could provide valuable insights into the conservation and management of these ecosystems.

Table 4: Simpson Diversity Index (SDI)of total avian fauna

	Simson Diversity Total				
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**
Dhinchda	0.87	0.84	0.80	0.89	0.93
Saltpan area, INS valsura	0.09	0.08	0.15	0.17	0.09

Table 5: Shannon Weiner diversity Index (SWDI) of total avian fauna

	Shannon Weiner Diversity Total				
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**
Dhinchda	4.63	5.21	4.55	5.40	6.21
Saltpan area, INS valsura	4.03	5.39	4.18	5.78	6.27

Table 6: Simpson Diversity Index (SDI)of wader birds

	Only Waders Simson Diversity				
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**
Dhinchda	0.27	0.36	0.28	0.16	0.10
Saltpan area, INS Valsura	0.12	0.10	0.23	0.26	0.15

Table 7: Shannon Weiner diversity Index (SWDI) of wader birds

	Only Waders Shannon Weiner Diversity				
	Oct	**Nov**	**Dec**	**Jan**	**Feb**
dhinchda	3.30	3.75	2.21	4.41	4.70
Saltpan area, INS valsura	4.14	4.05	3.56	4.37	5.23

The findings of this observation yield significant insights into avian diversity patterns within the wetlands of Jamnagar, Gujarat. The presence of a diverse assemblage of wader species underscores the critical role of these wetland ecosystems as pivotal habitats for both resident and migratory avifauna. [5] Reported a total of 223 bird species from Bortalav and Victoria Park Reserve Forest, representing 61 different families. In India, the Order Passeriformes is the most dominant avian taxon [10] with Muscicapidae being the largest family [6]. A similar study conducted in the Kumbharvada Marshland, another productive wetland in Bhavnagar city, reported 71 bird species from 27 families [8]. Additionally, a study on the avifauna of selected sites in Visnagar city, North Gujarat [9] recorded 96 bird species from 40 families, while research on the Chhaya Rann Wetland in Porbandar [13] identified 70 waterbird species from 21 families. A total of 103 species of birds were recorded belonging to 42 families, 81 genera and 19 orders recoded in Jamnagar [4]. In Amreli district A total of 155 species of birds distributed in 20 order, 63 families

and 130 genera were recorded from the seven sites [12]. Bortalav and its surrounding areas host a rich avifaunal diversity, protecting important bird species within the urban landscape. However, ongoing anthropogenic pressures such as construction, mining, and cropland expansion threaten this highly diverse bird habitat.

The identification of near-threatened wader species accentuates the imperative for conservation endeavours aimed at safeguarding these habitats. Diminishing wader populations may serve as indicative of environmental degradation, accentuating the exigency for implementing sustainable management strategies to counter threats such as habitat encroachment, pollution, and anthropogenic disturbance.

Temporal variations in avian populations at both study sites reflect the dynamic nature of wetland ecosystems, subject to seasonal fluctuations in environmental parameters and resource availability. A comprehensive understanding of these fluctuations is essential for effective conservation planning and management, ensuring the perpetuation of wader populations over the long term. The comparatively higher diversity indices observed at Dhinchda Lake suggest that Dhinchda potentially harbors a more ecologically robust ecosystem. Factors encompassing habitat complexity, water quality, and prey abundance likely underpin the disparities in species richness and evenness between the two locales.

Conclusion

The study conducted in the Saltpans area, INS Valsura, and Dhinchda revealed a notable abundance and diversity of wader birds across these locations. Both study site saltpan area, INS Valsura and Dhinchda Lake exhibited a rich diversity based Bondiversity indices (Simpson Diversity Index (SDI), and Shannon Weiner Diversity Index (SWDI)) waders, especially during February, attributed to the significant influx of migratory bird species. Conversely, lower bird diversity was observed from September to October, primarily due to the absence of migratory birds during this period. This temporal variation underscores the seasonal dynamics influencing bird diversity in these ecosystems.

The total bird diversity recorded at Dhinchda Lake is better than that of the Saltpans area, INS Valsura, underscoring the significance of habitat characteristics in shaping bird diversity within both study sites. Habitat attributes such as the availability of suitable feeding grounds, nesting sites, and water resources likely contribute to the observed variations in bird diversity among the study areas.

However, despite the natural habitat suitability observed in these locations, anthropogenic activities pose a significant threat to bird diversity in both the Saltpans area and INS Valsura. Human-induced disturbances such as habitat degradation, pollution, and disturbance from recreational activities may disrupt crucial ecological processes and habitat suitability for wader birds, potentially leading to declines in bird populations.

Given the importance of these areas as critical habitats for wader birds and the threats posed by anthropogenic activities, there is an urgent need for comprehensive conservation measures to safeguard bird diversity in these ecosystems. Conservation efforts should be categorizedas habitat restoration, management of human activities, and the establishment of protected areas to ensure the long-term survival of wader bird populations.

By addressing these conservation challenges, we can mitigate the impacts of anthropogenic disturbances and promote the conservation of avian biodiversity in the Saltpans area, INS Valsura, and Dhinchda, thereby contributing to the overall ecological integrity of these ecosystems.

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Conflict of Interest Statement

The authors affirm that there is no conflict of interest associated with this research.

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Plate 1: Waders foraging at study sites

Plate 2: A. Black-tailed Godwit **B**. Black-headed Ibis, Greater Flamingo, and spoonbill **C.** Indian Skimmer **D.** Black-headed gull

Plate 3: A. Intermediate egret **B**. Great White Pelican **C**. Black-necked Stork

Plate 4: Footprint of wader birds at study site 2

Plate 5: Greater Flamingo, Indian cormorant with intermediate egret, black-headed gull with Black-tailed godwit.

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