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Conservation status, feeding guilds and diversity of birds in Khijadiya Bird Sanctuary, Jamnagar, Gujarat, India

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ABSTRACT

Khijadiya Bird Sanctuary (KBS) near Jamnagar in Gujarat is positioned under the Indo-Asian Flyway and declared as the fourth wetland of Gujarat's Ramsar site; these wetlands serve as important wintering and stopover sites for birds. The present study aimed to collect information regarding the species richness, status, and feeding guilds of avifauna at KBS, Jamnagar City, Gujarat, India from April to December 2019. The point count and box line transect method was employed under a total of 28 surveys (Samplings N=56). A total of 146 bird species, 106 genera, 50 families, and 20 orders were recorded; of which 75 species were terrestrial and 71 water birds. Nonpasserine birds were more prevalent (97 species, 66%) than Passerine (49, 34%). Birds of Order Passeriformes (49/19 species/families), family Scolopacidae (17 species), and species *Fulica atra* –Common Coot (45.14 Mean/survey) were the most superior during the survey. The majority of the 92 species were resident (63%) and 45 species were winter migrants (31%); very rare species (89) had the highest abundance status. 11 species of birds are considered Near Threatened, and 01 Vulnerable category; 01 species in Appendix – App I, 12 in App II and 02 in App III; 10 species in Schedule – Sch I, 134 in Sch II and 02 in Sch IV. Carnivores (52 species) and omnivores (45) feeding guilds have the most number of species out of the 12 avian feeding guilds. The study areas reveal high species richness (d = 14.81) and diversity (H′ = 4.016, α = 21.74) during the survey. This study provides baseline data for future research in monitoring the avifauna in the sanctuary and demonstrates the importance of the area in bird conservation.

Keywords: Avifauna, diversity, status, feeding guild, India, Gujarat, Khijadiya Bird Sanctuary.

1. INTRODUCTION

India ranks among the top ten countries in the world in terms of most number of bird species Lepage, (2024); covering 2.2% of the world's terrestrial landmass; India shares 12.5% of the total avifaunal richness of the world Praveen et al., (2016), Praveen and Jayapal, (2024) represented with 1364 bird species. Among them, a total of 615 bird

species have been recently updated from Gujarat state (Ganpule, 2022). Birds are key indicators of habitat quality Pradhan et al., (2023), and also serve as pollution indicators, pollination, seed dispersal, and pest control (Nason, 1992; Bibi and Ali, 2013; Jha, 2021). The diversity of birds is directly connected to the environmental conditions of any landscape Loreau et al., (2001), also involved in various ecological functions (Abie et al., 2019; Jha, 2021). The vegetation mainly manipulates the diversity, abundance, and distribution of birds (Gregory et al., 2010; Balodi et al., 2018). Birds are quite sensitive to changes in habitat structure and composition, and stresses in the urban ecosystem Savard and Falls (1982), Clergeau et al., (1998); birds play an important role in the development of various countries' economies through the tourism industry (Areaya et al., 2013).

The present work deals with protected areas using birds as a target group; regarding their diversity, species community, feeding guilds, and status. Despite previous research on Khijadia Wildlife Sanctuary – KBS's avifauna has listed 104 species of birds in a single day at Khijadiya Ali, (1954), 136 species of wetland and wetland-dependent birds Kumar, (2013) from 2005 to 2008; reported 257 avian species by. Further, only freshwater records from June 2015 to 2016 reveal 49 species of water birds, the most recent contribution of 2016 to 2017 terrestrial (45), freshwater (65), Marine (44), and saline (11) water birds reveal a total of 165 species of birds Jambu, (2017), 152 species of Salt Marsh habitat only and recent checklists of KBS report 304 species Birds (e-Bird, 2024). This study presents a checklist of birds with updated systematic, familial distribution, abundance status, species composition, conservation status, and feeding guilds in birds of KBS including ecological indices.

2. MATERIALS AND METHODS

Study area

KBS (Ramsar site No. 2464), a freshwater wetland is geographically located between 22°30'51.4" N and 70°09'16.1"E at a distance of about 13 km north-east of Jamnagar city on the southern coast of the Gulf of Kutch in the western state of Gujarat (Figure 1A - C). Bio-geographically, the area falls in the 4B Gujarat-Rajwara biotic province of the semi-arid zones (Rodgers and Panwar, 1988). KBS is spread over 6.05 km2 (604.86 hectares) having a unique habitat with freshwater lakes, salt, and freshwater marshlands. The area experiences an annual rainfall of 1,311 mm, average temperature varies between 26.5°C and 36.6 °C, and average humidity ranges between 67.32 - 88.03 % in the morning and 28.65-75% evening (Year, 2019). The freshwater of the rain and rivers Ruparel and Kalindri on one side flows through the areas before it enters the sea and on the other side a saltwater of a large tidal creek flowing from the Gulf of Kutch; which supports mangroves and marine diversity.

The KBS is divided into 2 major parts: Part 1 and Part 2 mainly dividing salt waters and fresh waters. The Khijadiya freshwater lakes Part 1 (western - Site 1) and Part 2 (eastern – Site 2) were dominated by mangrove vegetation mainly represented by *Avicennia marina* (Grey Mangrove), *Avicennia officinalis* (Indian Mangrove), *Salicornia* sp. (Glasswort), *Suaeda nudiflora* (Seep weeds) and *Suaeda fruticosa* (Alkali Seep weed) with scattered patches of *Aeluropus lagopoides* (Mangrove Grass), near bund side margin *Prosopis juliflora* (Algaroba), endemic mangrove species *Urochondra setulosa* (Creek Rat-Tail Grass) in few patches on drying ground and submerged flora mainly leaf of lotus (*Nymphaea* sp.) was distributed (Kumar, 2013). Salt marsh habitat (Site 3) near the Southern Gulf of Kachchh has a dense mangrove forest dominated by *Salvadora persica* (Pilu shrub or Miswak) and more intertidal mudflats with creek water areas.

Field Methods

The survey was conducted from April to December 2019. To encompass all of the study areas (i.e., Site 1, Site 2, and Site 3) and various habitat types, the box line transects (1km long and 3m broad by road right and left using binocular); and some places at water reservoirs point count methods Urfi et al., (2005) was used. Data records on bird sightings, the birds present in and around all sites at KBS; including overflying individuals or flocks, resting on trees, feeding on the ground, and some individuals as well as large flocks by photos also.

The study includes a total of 28 field surveys (S=28) with an average of 3 to 4 visits per month and 3 to 4 transects per visit in each site, undertaking 28 box line transects and 28-point count samplings (Samplings N=56) in the morning (06:00 to 12:00 hrs) depending on the season when birds were most active. The birds were identified through direct observations using binoculars (Olympus, 12 x 50) and photographs were captured by Canon EOS 1300D (DSLR camera). The identification of birds was done using field guides such as (Ali and Ripley, 1983; Grimmett et al., 2014). For taxonomy updates followed, common and scientific names as per (Praveen et al., 2016; Praveen et al., 2020; Praveen and Jayapal, 2022; Praveen and Jayapal, 2023; Praveen and Jayapal, 2024).

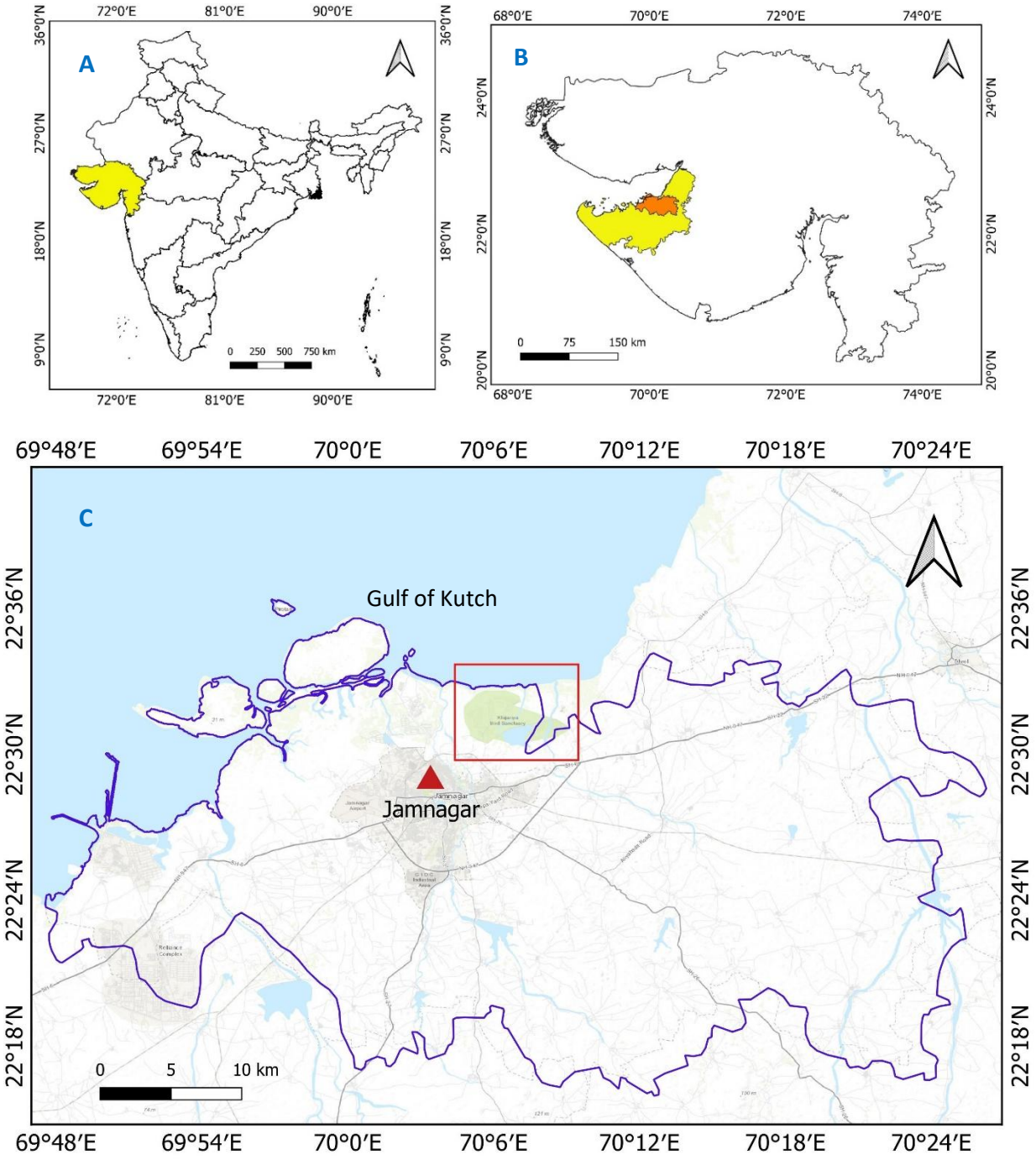

Figure 1 Map showing study areas: A—Location of Gujarat (yellow) state and Western India, B—Location of Jamnagar Taluka (orange) and Jamnagar district (yellow) in Gujarat state of Western India | C—Location of Khijadiya Bird Sanctuary (red square) in Jamnagar city and Jamnagar Taluka (blue line areas). (Mapping by QGIS 3.28.3 Prepared by VMT).

Data Analysis

The abundance status is based on the frequency (%) of bird sightings and is categorized as VR—Very Rare (1–20%), R—Rare (21–40%), O—Occasional (41–60 %), C—Common (61–80 %), and VC—Very Common (81–100 %) and calculated (i.e. total no of occurrence/total no of samplings x 100) and mean calculated per survey (Table 1, Figure 3). Conservation status of each species was noted according to their IUCN Red List categories IUCN, (2023), Schedule under the Wildlife Protection Act (IWPA, 2023). The status of the bird in Gujarat was noted (Ganpule, 2020).

The feeding guilds (FG) of bird species were classified into C- Carnivore, F- Frugivore, G – Graminivore, H – Herbivore, I – Insectivore, I/C – Prime insectivore occasional animal matters, I/O – Prime insectivore occasional plant matters, N – Nectarivore, O – Omnivore, P – Piscivore, P/C - Prime piscivore occasional animal matters, R/C - Prime rodents occasional animal matters (IUCN, 2023). Family-wise individual birds, genera, and species were analyzed (Table 2), and number of family and species per order (Figure 2). Shannon diversity-H`, evenness - e^H/S, Margalef's species richness (d), and Fisher alpha diversity (α) were computed using PAST software Hammer et al., (2001) and their interpretations followed (Magurran, 2004).

3. RESULTS AND DISCUSSION

A total of 146 species of birds, belonging to 106 genera, 50 families, and 20 orders were recorded from the KBS. Nonpasserine birds dominated with 97 species (66%) than 49 species of passerine (34%). Order-wise species diversity and number of families were greater in Passeriformes (49 species, 19 family) and Charadriiformes (37, 6) (Figure 2).

Out of 50 families, Scolopacidae dominated with 17 species (12%) and most abundant species was *Limosa limosa* - Black-tailed Godwit support with Kumar, (2013); thereafter 10 species (7%) in Ardeidae and most populated species *Ardea alba* - Great Egret, Laridae with 09 species (6%), Motacillidae with 07 species (5%), Charadriidae and Hirundinidae with 06 species (4%) each, Anatidae, Accipitridae and Alaudidae with 05 species (3%) each, Threskiornithidae, Sturnidae and Muscicapidae with 04 species (2.7%), Columbidae, Cuculidae, Rallidae, Phalacrocoracidae, Laniidae, Corvidae, Cisticolidae and Leiothrichidae with 03 species (2.05%), Phasianidae, Phoeni copteridae, Podicipedidae, Burhinidae, Recurvirostridae, Ciconiidae, Pelecanidae, Alcedinidae, Meropidae and Pycnonotidae with 02 species (1.37%) each; whereas 20 families Apodidae, Grui dae, Haematopodidae, Anhingidae, Strigidae, Upupidae, Coraciidae, Megalaimidae, Picidae, Falconidae, Psittaculidae, Oriolidae, Dicruridae, Acrocephalidae, Phylloscopidae, Zosteropidae, Nectariniidae, Ploceidae, Estrildidae and Passeridae with only one species for each. The population of the family Sturnidae (9.4%, individual n=1683) stands first; thereafter Rallidae (7%, n=1278) and Columbidae (6.5%, n=1169) have shown higher population; the family Haematopodidae with species Eurasian Oystercatcher, Strigidae (i.e. Oriental Scops Owl), Picidae (i.e. Yellow-fronted Woodpecker) and in Falconidae Common Kestrel (0.01%, n = 1) has been sighted only single time during the study period (Table 1 & 2).

Table 1 Checklist of Avifaunal diversity of Khijadiya bird sanctuary, Jamnagar, Gujarat. (Sampling Units N=56)

Sr. No.	Scientific Name /Common Name	M	Fr %	AS	SG	IUCN	WPA	FG
	Order: Anseriformes (i) Family: Anatidae							
1	*Dendrocygna javanica* / Lesser Whistling Duck	1.75	9	VR	R	LC	Sch II	O
2	*Sarkidiornis melanotos* / Knob-billed Duck App-II	3.57	23	R	R	LC	Sch II	O
3	*Spatula querquedula* / Garganey	0.07	2	VR	W	LC	Sch II	H
4	*Spatula clypeata* / Northern Shoveler	8.25	23	R	W	LC	Sch II	O
5	*Anas poecilorhyncha* / Indian Spot-billed Duck	12.61	30	R	R	LC	Sch II	O
	Order: Galliformes (i) Family: Phasianidae							
6	*Pavo cristatus* / Indian Peafowl App-III	0.14	4	VR	R	LC	Sch I	O
7	*Ortygornis pondicerianus* / Grey Francolin	7.29	38	R	R	LC	Sch II	O
	Order: Phoenicopteriformes (i) Family: Phoenicopteridae							
8	*Phoenicopterus roseus* / Greater Flamingo App-II	38.50	54	OC	R	LC	Sch II	O
9	*Phoeniconaias minor* / Lesser Flamingo App-II	0.14	5	VR	R	NT	Sch II	O
	Order: Podicipediformes (i) Family: Podicipedidae							
10	*Tachybaptus ruficollis* / Little Grebe	1.96	18	VR	R	LC	Sch II	C
11	*Podiceps cristatus* / Great Crested Grebe	3.11	27	R	R	LC	Sch II	C
	Order: Columbiformes (i) Family: Columbidae							

12	*Columba livia* / Rock Pigeon	8.79	48	OC	R	LC	Sch IV	G
13	*Streptopelia decaocto* / Eurasian Collared Dove	14.64	57	OC	R	LC	Sch II	G
14	*Spilopelia senegalensis* / Laughing Dove	18.32	86	VC	R	LC	Sch II	G
	Order: Cuculiformes (i) Family: Cuculidae							
15	*Centropus sinensis* / Greater Coucal	0.82	20	VR	R	LC	Sch II	O
16	*Clamator jacobinus* / Pied Cuckoo	0.25	7	VR	MB	LC	Sch II	O
17	*Eudynamys scolopaceus* / Asian Koel	0.79	16	VR	R	LC	Sch II	O
	Order: Caprimulgiformes (i) Family: Apodidae							
18	*Apus affinis* / Little Swift	3.93	21	R	R	LC	Sch II	I
	Order: Gruiformes (i) Family: Rallidae							
19	*Fulica atra* / Common Coot	45.14	32	R	R, W	LC	Sch II	O
20	*Porphyrio poliocephalus* / Grey-headed Swamphen	0.29	11	VR	R	LC	Sch II	O
21	*Amaurornis phoenicurus* / White-breasted Waterhen	0.21	9	VR	R	LC	Sch II	O
	(ii) Family: Gruidae							
22	*Grus virgo* / Demoiselle Crane App-II	20.25	20	VR	W	LC	Sch I	O
	Order: Charadriiformes (i) Family: Burhinidae							
23	*Burhinus indicus* / Indian Thick-knee	2.36	14	VR	R	LC	Sch II	O
24	*Esacus recurvirostris* / Great Thick-knee	0.75	18	VR	R	NT	Sch II	C
	(ii) Family: Recurvirostridae							
25	*Himantopus himantopus* / Black-winged Stilt	13.29	64	C	R	LC	Sch II	O
26	*Recurvirostra avosetta* / Pied Avocet	11.14	50	OC	W, R	LC	Sch II	C
	(iii) Family: Haematopodidae							
27	*Haematopus ostralegus* / Eurasian Oystercatcher	0.04	2	VR	W	NT	Sch II	C
	(iv) Family: Charadriidae							
28	*Pluvialis squatarola* / Grey Plover	0.14	2	VR	W	LC	Sch II	O
29	*Vanellus indicus* / Red-wattled Lapwing	9.96	82	VC	R	LC	Sch II	O
30	*Anarhynchus atrifrons*/ Tibetan Sand Plover	0.50	13	VR	W	LC	Sch II	C
31	*Anarhynchus leschenaultia* / Greater Sand Plover	0.14	2	VR	W	LC	Sch II	C
32	*Anarhynchus alexandrinus* / Kentish Plover	1.36	7	VR	R	LC	Sch II	I/O
33	*Charadrius dubius* / Little Ringed Plover	0.68	11	VR	R	LC	Sch II	O
	(v) Family: Scolopacidae							
34	*Numenius arquata* / Eurasian Curlew	0.29	9	VR	W	NT	Sch II	O
35	*Limosa limosa* / Black-tailed Godwit	10.32	52	OC	W	NT	Sch II	O
36	*Calidris canutus* / Red Knot	0.07	4	VR	V	NT	Sch II	I/O
37	*Calidris pugnax* / Ruff	6.39	34	R	W	LC	Sch II	H
38	*Calidris ferruginea* / Curlew Sandpiper	0.89	14	VR	W	NT	Sch II	C
39	*Calidris temminckii* / Temminck's Stint	2.75	4	VR	W	LC	Sch II	C
40	*Calidris alba* / Sanderling	2.14	21	R	W	LC	Sch II	I/O

41	*Calidris alpina* / Dunlin	0.07	2	VR	W	LC	Sch II	O
42	*Calidris minuta* / Little Stint	3.86	25	R	W	LC	Sch II	C
43	*Gallinago gallinago* / Common Snipe	0.07	4	VR	W	LC	Sch II	C
44	*Xenus cinereus* / Terek Sandpiper	171	2	VR	W	LC	Sch II	O
45	*Actitis hypoleucos* / Common Sandpiper	1.43	13	VR	W	LC	Sch II	C
46	*Tringa ochropus* / Green Sandpiper	0.25	5	VR	W	LC	Sch II	C
47	*Tringa nebularia* / Common Greenshank	0.21	7	VR	W	LC	Sch I	C
48	*Tringa totanus* / Common Redshank	3.61	34	R	W	LC	Sch II	C
49	*Tringa glareola* / Wood Sandpiper	0.07	2	VR	W	LC	Sch II	C
50	*Tringa stagnatilis* / Marsh Sandpiper	4.79	41	OC	W	LC	Sch II	C
	(vi) Family: Laridae							
51	*Chroicocephalus genei* / Slender-billed Gull	1.46	13	VR	R, W	LC	Sch II	P/C
52	*Chroicocephalus brunnicephalus* / Brown-headed Gull	0.14	2	VR	W	LC	Sch II	C
53	*Larus cachinnans* / Caspian Gull	0.18	2	VR	W	LC	Sch II	C
54	*Sternula albifrons* / Little Tern	0.04	2	VR	R	LC	Sch II	P/C
55	*Gelochelidon nilotica* / Gull-billed Tern	0.07	2	VR	W	LC	Sch I	I/C
56	*Hydroprogne caspia* / Caspian Tern	0.21	2	VR	R, W	LC	Sch II	P/C
57	*Chlidonias hybrida* / Whiskered Tern	0.54	14	VR	W	LC	Sch II	I/C
58	*Sterna aurantia* / River Tern	1.57	23	R	R	VU	Sch I	C
59	*Sterna hirundo* / Common Tern	0.43	11	VR	W	LC	Sch II	P/C
	Order: Ciconiiformes (i) Family: Ciconiidae							
60	*Ephippiorhynchus asiaticus* / Black-necked Stork	0.32	11	VR	R	NT	Sch II	C
61	*Mycteria leucocephala* / Painted Stork	17.96	63	C	R	LC	Sch II	C
	Order: Suliformes (i) Family: Anhingidae							
62	*Anhinga melanogaster* / Oriental Darter	2.25	38	R	R	NT	Sch II	C
	(ii) Family: Phalacrocoracidae							
63	*Microcarbo niger* / Little Cormorant	7.14	43	OC	R	LC	Sch II	C
64	*Phalacrocorax carbo* / Great Cormorant	6.93	43	OC	R	LC	Sch II	C
65	*Phalacrocorax fuscicollis* / Indian Cormorant	10.07	48	OC	R	LC	Sch II	C
	Order: Pelecaniformes (i) Family: Pelecanidae							
66	*Pelecanus onocrotalus* / Great White Pelican	0.54	2	VR	W	LC	Sch II	C
67	*Pelecanus crispus* / Dalmatian Pelican App-I	9.93	32	R	W	NT	Sch II	P
	(ii) Family: Ardeidae							
68	*Ardea cinerea* / Grey Heron	7.36	45	OC	R	LC	Sch II	C
69	*Ardea purpurea* / Purple Heron	0.21	7	VR	R	LC	Sch II	C
70	*Ardea alba* / Great Egret	10.00	63	OC	R	LC	Sch II	C
71	*Ardea intermedia* / Intermediate Egret	0.32	7	VR	R	LC	Sch II	C
72	*Egretta garzetta* / Little Egret	4.89	41	OC	R	LC	Sch II	C
73	*Egretta gularis* / Western Reef Egret	7.18	48	OC	R	LC	Sch II	C

74	*Bubulcus ibis* / Western Cattle Egret	0.39	4	VR	R	LC	Sch II	C
75	*Ardeola grayii* / Indian Pond Heron	0.04	2	VR	R	LC	Sch II	C
76	*Butorides striata* / Striated Heron	0.11	5	VR	R	LC	Sch II	P/C
77	*Nycticorax nycticorax* / Black-crowned Night Heron	0.07	4	VR	R	LC	Sch II	C
	(iii) Family: Threskiornithidae							
78	*Plegadis falcinellus* / Glossy Ibis	1.61	30	R	R, W	LC	Sch II	C
79	*Threskiornis melanocephalus* / Black-headed Ibis	8.11	63	C	R	NT	Sch II	C
80	*Pseudibis papillosa* / Red-naped Ibis	3.04	39	R	R	LC	Sch II	C
81	*Platalea leucorodia* / Eurasian Spoonbill App-II	10.43	54	OC	R	LC	Sch I	C
	Order: Accipitriformes (i) Family: Accipitridae							
82	*Elanus caeruleus* / Black-winged Kite App-II	0.61	14	VR	R	LC	Sch II	C
83	*Ictinaetus malaiensis* / Black Eagle App-II	0.14	7	VR	W	LC	Sch I	C
84	*Accipiter badius* / Shikra App-II	0.39	9	VR	R	LC	Sch I	C
85	*Milvus migrans* / Black Kite App-II	0.82	14	VR	R	LC	Sch II	C
86	*Haliastur indus* / Brahminy Kite App-II	0.29	7	VR	R	LC	Sch I	C
	Order: Strigiformes (i) Family: Strigidae							
87	*Otus sunia* / Oriental Scops Owl App-II	0.04	2	VR	R	LC	Sch II	C
	Order: Bucerotiformes (i) Family: Upupidae							
88	*Upupa epops* / Eurasian Hoopoe	0.89	16	VR	R, W	LC	Sch II	O
	Order: Coraciiformes (i) Family: Alcedinidae							
89	*Halcyon smyrnensis* / White-throated Kingfisher	2.18	39	R	R	LC	Sch II	C
90	*Ceryle rudis* / Pied Kingfisher	1.04	23	R	R	LC	Sch II	C
	(ii) Family: Meropidae							
91	*Merops orientalis* / Green Bee-eater	12.54	73	C	R	LC	Sch II	I
92	*Merops persicus* / Blue-cheeked Bee-eater	9.93	9	VR	PM	LC	Sch II	I
	(iii) Family: Coraciidae							
93	*Coracias benghalensis* / Indian Roller	0.14	4	VR	R	LC	Sch II	C
	Order: Piciformes (i) Family: Megalaimidae							
94	*Psilopogon haemacephalus* / Coppersmith Barbet	0.25	5	VR	R	LC	Sch II	F
	(ii) Family: Picidae							
95	*Leiopicus mahrattensis* / Yellow-fronted Woodpecker	0.04	2	VR	R	LC	Sch I	I
	Order: Falconiformes (i) Family: Falconidae							
96	*Falco tinnunculus* / Common Kestrel App-II	0.04	2	VR	W	LC	Sch II	R/C
	Order: Psittaciformes (i) Family: Psittaculidae							
97	*Psittacula krameri* / Rose-ringed Parakeet	2.89	36	R	R	LC	Sch II	F
	Order: Passeriformes (i) Family: Oriolidae							
98	*Oriolus kundoo* / Indian Golden Oriole	0.14	7	VR	R	LC	Sch II	O
	(ii) Family: Dicruridae							
99	*Dicrurus macrocercus* / Black Drongo	14.32	70	C	R	LC	Sch II	I

	(iii) Family: Laniidae							
100	*Lanius schach* / Long-tailed Shrike	0.50	13	VR	R	LC	Sch II	C
101	*Lanius excubitor* / Great Grey Shrike	0.04	2	VR	R	LC	Sch II	C
102	*Lanius vittatus* / Bay-backed Shrike	0.18	7	VR	R	LC	Sch II	C
	(iv) Family: Corvidae							
103	*Dendrocitta vagabunda* / Rufous Treepie	0.07	2	VR	R	LC	Sch II	O
104	*Corvus splendens* / House Crow	7.21	70	C	R	LC	Sch IV	O
105	*Corvus macrorhynchos* / Large-billed Crow	0.04	2	VR	R	LC	Sch II	O
	(v) Family: Alaudidae							
106	*Eremopterix griseus* / Ashy-crowned Sparrow Lark	0.93	14	VR	R	LC	Sch II	I
107	*Alaudala raytal* / Sand Lark	9.82	66	C	R	LC	Sch II	O
108	*Melanocorypha bimaculata* / Bimaculated Lark	0.04	2	VR	W	LC	Sch II	O
109	*Galerida cristata* / Crested Lark App-III	2.68	23	R	R	LC	Sch II	O
110	*Galerida deva* / Sykes's Lark	0.07	4	VR	R	LC	Sch II	O
	(vi) Family: Cisticolidae							
111	*Prinia hodgsonii* / Grey-breasted Prinia	0.11	5	VR	R	LC	Sch II	I
112	*Prinia socialis* / Ashy Prinia	1.61	23	R	R	LC	Sch II	I
113	*Prinia inornata*/ Plain Prinia	0.18	5	VR	R	LC	Sch II	I
	(vii) Family: Acrocephalidae							
114	*Iduna rama* / Sykes's warbler	0.96	16	VR	W	LC	Sch II	I
	(viii) Family: Hirundinidae							
115	*Riparia riparia* / Sand Martin	0.18	4	VR	W	LC	Sch II	I
116	*Riparia chinensis* / Grey -throated Martin	0.14	2	VR	R	LC	Sch II	I
117	*Ptyonoprogne concolor* / Dusky Crag Martin	0.64	5	VR	R	LC	Sch II	I
118	*Hirundo rustica* / Barn Swallow	17.93	48	OC	W	LC	Sch II	I
119	*Hirundo smithii* / Wire-tailed Swallow	16.29	57	OC	R	LC	Sch II	I
120	*Cecropis daurica* / Red-rumped Swallow	1.50	11	VR	R	LC	Sch II	I
	(iv) Family: Pycnonotidae							
121	*Pycnonotus cafer* / Red-vented Bulbul	11.21	63	C	R	LC	Sch II	O
122	*Pycnonotus leucotis* / White-eared Bulbul	16.57	61	C	R	LC	Sch II	O
	(x) Family: Phylloscopidae							
123	*Phylloscopus collybita* / Common Chiffchaff	0.11	2	VR	W	LC	Sch II	I
	(xi) Family: Zosteropidae							
124	*Zosterops palpebrosus* / Indian White-eye	0.89	13	VR	R	LC	Sch II	F
	(xii) Family: Leiothrichidae							
125	*Argya striata* / Jungle Babbler	0.75	9	VR	R	LC	Sch II	O
126	*Argya caudata* / Common Babbler	11.00	55	OC	R	LC	Sch II	O

127	*Argya malcolmi* / Large Grey Babbler	0.14	2	VR	R	LC	Sch II	O
	(xiii) Family: Sturnidae							
128	*Pastor roseus* / Rosy Starling	37.29	82	VC	W	LC	Sch II	O
129	*Sturnia pagodarum* / Brahminy Starling	12.96	39	R	R	LC	Sch II	O
130	*Acridotheres tristis* / Common Myna	9.39	59	OC	R	LC	Sch II	O
131	*Acridotheres ginginianus* / Bank Myna	0.46	9	VR	R	LC	Sch II	O
	(xiv) Family: Muscicapidae							
132	*Copsychus fulicatus* / Indian Robin	8.29	57	OC	R	LC	Sch II	I
133	*Copsychus saularis* / Oriental Magpie Robin	0.71	16	VR	R	LC	Sch II	I
134	*Saxicola maurus*/ Siberian Stonechat	0.07	2	VR	W	LC	Sch II	I
135	*Oenanthe deserti* / Desert Wheatear	0.04	2	VR	W	LC	Sch II	O
	(xv) Family: Nectariniidae							
136	*Cinnyris asiaticus* / Purple Sunbird	4.00	41	OC	R	LC	Sch II	N
	(xvi) Family: Ploceidae							
137	*Ploceus philippinus* / Baya Weaver	2.39	21	R	R	LC	Sch II	I
	(xvii) Family: Estrildidae							
138	*Euodice malabarica* / Indian Silverbill	2.32	20	VR	R	LC	Sch II	G
	(xviii) Family: Passeridae							
139	*Passer domesticus* / House Sparrow	26.50	84	VC	R	LC	Sch II	O
	(xiv) Family: Motacillidae							
140	*Motacilla cinerea* / Grey Wagtail	0.11	2	VR	W	LC	Sch II	I
141	*Motacilla flava* / Western Yellow Wagtail	0.75	9	VR	W	LC	Sch II	I
142	*Motacilla citreola* / Citrine Wagtail	0.07	2	VR	W	LC	Sch II	I
143	*Motacilla maderaspatensis* / White-browed Wagtail	0.04	2	VR	R	LC	Sch II	I
144	*Motacilla alba* / White Wagtail	0.21	5	VR	W	LC	Sch II	I
145	*Anthus trivialis* / Tree Pipit	0.57	11	VR	W	LC	Sch II	O
146	*Anthus rufulus* / Paddyfield Pipit	1.43	23	R	R	LC	Sch II	I

Abbreviations: M – Mean per survey (Total Survey =28), Fr – Frequency (%), AS – Abundance status: VR - Very rare, R - Rare, OC - Occasional, C - Common, VC - Very Common (Frequency base; Total Samplings N=56). | SG - Status in Gujarat: R - Resident / Resident Breeding, MB - Monsoon Breeding Migrant, W - Winter Migrant, PM - Passage Migrant, V – Vagrant**,** R, W **-** Resident & winter migrant, W, R - Winter migrant & resident Ganpule, (2020). | Conservation status: LC – Least Concern, NT – Near Threatened, VU- Vulnerable (IUCN, 2023, accessed on 27 April 2024); Sch – I, Sch –II & Sch –IV (IWPA, 2023 accessed on 28 April 2024); App – I, II & III. | Feeding Guilds (FG): C- Carnivore, F- Frugivore, G – Graminivore, H – Herbivore, I – Insectivore, I/C – Prime insectivore occasional animal matters, I/O – Prime insectivore occasional plant matters, N – Nectarivore, O – Omnivore, P – Piscivore, P/C - Prime piscivore occasional animal matters, R/C - Prime rodents occasional animal matters (IUCN, 2023).

Table 2 Family wise numbers of individuals, genus and species of Birds.

Sr. No	Family	Individuals	Genus	Species
1	Anatidae	735	4	5
2	Phasianidae	208	2	2
3	Phoenicopteridae	1082	2	2
4	Podicipedidae	142	2	2
5	Columbidae	1169	3	3
6	Cuculidae	52	3	3
7	Apodidae	110	1	1
8	Rallidae	1278	3	3
9	Gruidae	567	1	1
10	Burhinidae	87	2	2
11	Recurvirostridae	684	2	2
12	Haematopodidae	1	1	1
13	Charadriidae	358	4	6
14	Scolopacidae	1090	7	17
15	Laridae	130	7	9
16	Ciconiidae	512	2	2
17	Anhingidae	63	1	1
18	Phalacrocoracidae	676	2	3
19	Pelecanidae	293	1	2
20	Ardeidae	856	6	10
21	Threskiornithidae	649	4	4
22	Accipitridae	63	6	5
23	Strigidae	1	1	1
24	Upupidae	25	1	1
25	Alcedinidae	90	2	2
26	Meropidae	629	1	2
27	Coraciidae	4	1	1
28	Megalaimidae	7	1	1
29	Picidae	1	1	1
30	Falconidae	1	1	1
31	Psittaculidae	81	1	1
32	Oriolidae	4	1	1
33	Dicruridae	401	1	1
34	Laniidae	20	1	3
35	Corvidae	205	2	3
36	Alaudidae	379	4	5
37	Cisticolidae	53	1	3
38	Acrocephalidae	27	1	1
39	Hirundinidae	1027	4	6
40	Pycnonotidae	778	1	2
41	Phylloscopidae	3	1	1
42	Zosteropidae	25	1	1
43	Leiothrichidae	333	1	3
44	Sturnidae	1683	3	4

45	Muscicapidae	255	3	4
46	Nectariniidae	112	1	1
47	Ploceidae	67	1	1
48	Estrildidae	65	1	1
49	Passeridae	742	1	1
50	Motacillidae	89	2	7
	Total	17912	106	146

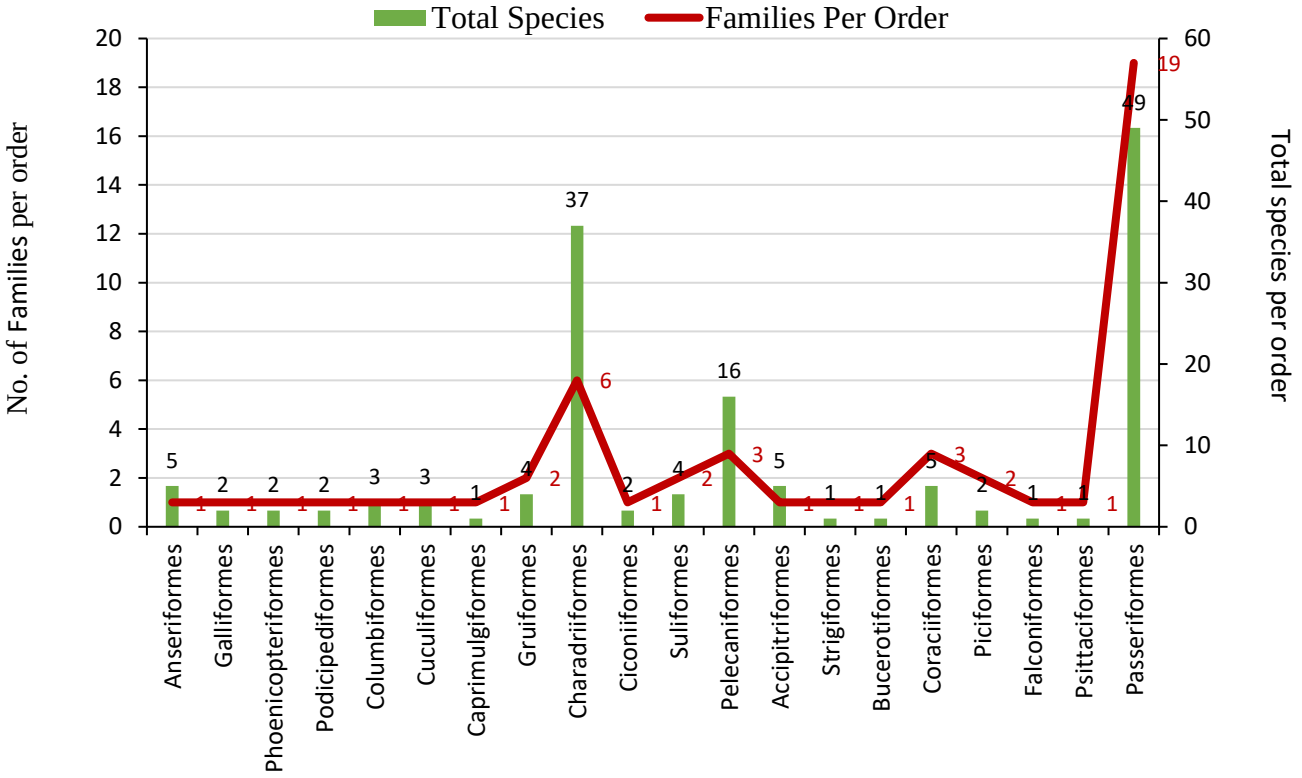

Figure 2 Family and species in order representation of birds from KBS.

Species composition as per residential and abundance status

The analysis of data on the residential status revealed that out of 146 species, 92 species (63%) were resident, 45 (31%) were winter migrants, 05 (3%) were resident and winter migrants, and 1 (1%) monsoon breeding migrant, passage migrants, vagrant, winter migrant and resident respectively. A similar pattern of population status of birds was also observed (Figure 4A, B). Top most populated resident species were Greater Flamingo (M=38.50, n=1078), House Sparrow (M=26.50, n=742) and Laughing Dove (M= 18.32, n=513); as migratory species were Rosy Starling (M=37.29, n=1044), Demoiselle Crane (M= 20.25, n=567) and Barn Swallow (M=17.93, n=502). The occurrence of a significant number of residents facilitated by multi-habitat characteristics of KBS and winter migrant species can be attributed partly to the study area being on the Central Indo-Asian Flyway and serving as a wintering and stopover site for migratory birds that breed in the Palearctic region (Kumar et al., 2016).

The abundance status based on the frequency of sightings indicated that 89 species (61%) were very rare, 24 (16%) rare, 20 occasional, 9 (6%) common and 4 (3%) species were very common, the population status which reflects dissimilar 34% occasional, 23% rare, 17% common, 15% very common, and 11% very rare in the study area (Figure 3A, B). This may be due to the stopover site of the migratory birds at KBS. 4 very common bird species i.e. Rosy Starling, House Sparrow, Laughing Dove, and Red-wattled Lapwing were sighted in every visit (82-86%); 09 common species between 34 to 41 times out of the 56 samplings; among these, the most populated species were Painted Stork (35 times).

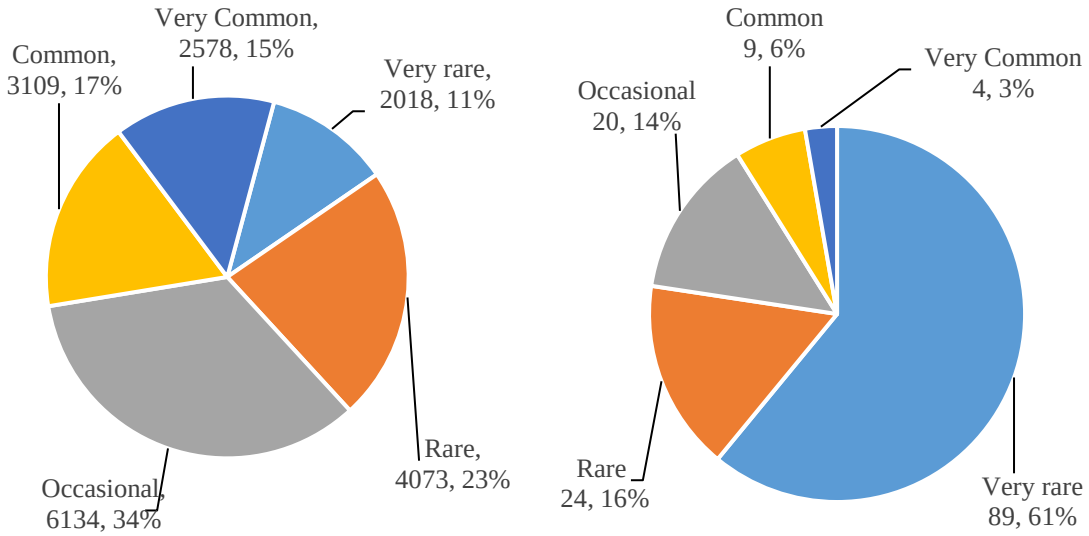

Figure 3 Abundance status (Number & %) of birds at KBS (Frequency base).

20 occasional species dominated with Greater Flamingo sighted 30 times, 24 rare species, and 89 species were very rare; of these rarest 11 species were Eurasian Oystercatcher, Little Tern, Indian Pond Heron, Oriental Scops Owl, Yellow-crowned Woodpecker, Common Kestrel, Great Grey Shrike, Large-billed Crow, White-browed Wagtail, Bimaculated Lark, and Desert Wheatear sighted only once single during the survey (Table 1). The spatiotemporal distribution and abundance of avifauna in any given habitat are determined based on the quality and quantity of food available as the major factor Wiens, (1989), Ma et al., (2010), Jha, (2013); species diversity and productivity driven by changes in environmental conditions (Loreau et al., 2001).

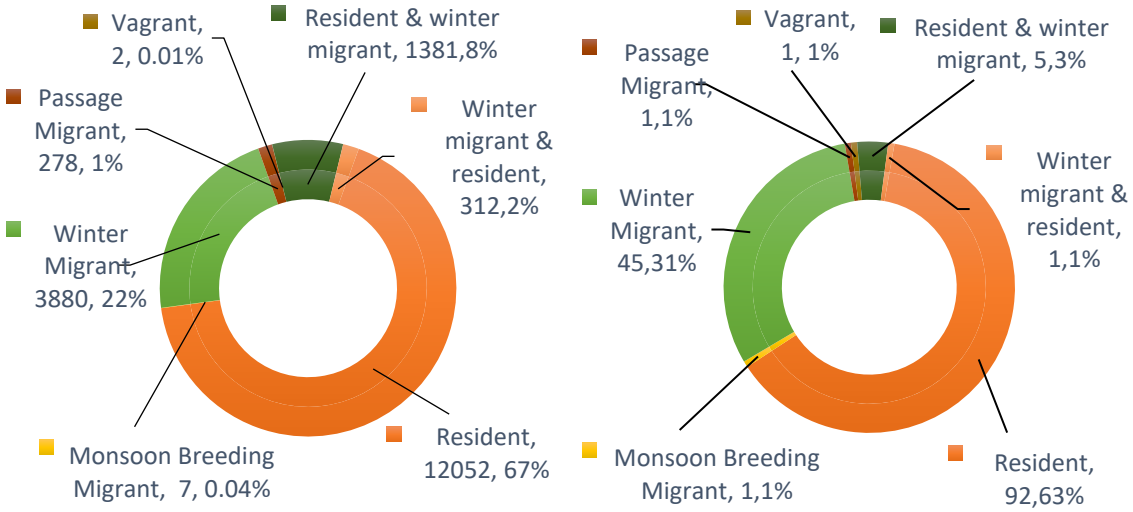

Figure 4 Residential status of birds in Gujarat (%) at KBS.

Avian community as per habitat

Of the recorded 146 bird species, 75 species and 52% population (n=9273) were associated with terrestrial habitat, and 71 species populated with 48% (n = 8639) wetland associated. Rosy Starlings (Mean M=37/survey) and House Sparrow (M = 27) were dominant in terrestrial habitats and Common Coot (M = 45) and Greater Flamingo (M=39) were dominant (Table 1) among water-birds. During the present study, wetland birds such as ducks, garganey, northern shovelers, herons, egrets, common coot, cormorants, grebes, storks, pelicans, flamingos, sand plovers, oystercatchers, curlews, greenshank, redshank, pied avocet, gulls, sandpipers, waterhen, swamphen, terns, dunlin, kingfishers, wagtails, and many other shorebirds which were observed to feed on aquatic organisms (fish, amphibians, invertebrates, etc.) at different water depths available in the wetlands and adjoining agriculture fields and marshy area. Such extensive species diversity of wetland birds relies upon wetland characteristics like size, water depth, quality of water, trophic structure, and presence of suitable roosting and nursery sites and influence the abundance and diversity of birds (Wiens, 1989; Mukherjee et al., 2002; Ma et al., 2010).

Feeding guild structure

An analysis of the feeding guilds of these birds revealed that 36% (52 species - s) were carnivores, 31% (s=45) were omnivores, 18% (s=27) were insectivores, 3.42% (s=5) prime piscivore occasional animal matters, 2.74% (s =4) were graminivore, 2% (s= 3) were frugivore and prime insectivore occasional animal matters, 1% (s=1) were nectarivore, piscivore and prime rodents occasional animal matters .respectively; whereas population of birds were found greater in Omnivore (51%) and Carnivore (22%) (Figure 5A, B). The most populated omnivore species were Common Coot (n=1264), and Greater Flamingo (n=1078), and carnivore species were Painted Stork (n=503) and Pied Avocet (n=312). The occurrence of a significant number of carnivores and omnivore bird communities, which is primarily influenced by the availability of food sources, indicates the abundance of their prey during the study period. The importance of the feeding guilds will guide us in the use of the habitat and niche of the species. Due to their specialized diet and low availability of preferable food resources, the nectarivore, piscivore, and prime rodent groups are traditionally less represented (Wiens, 1989).

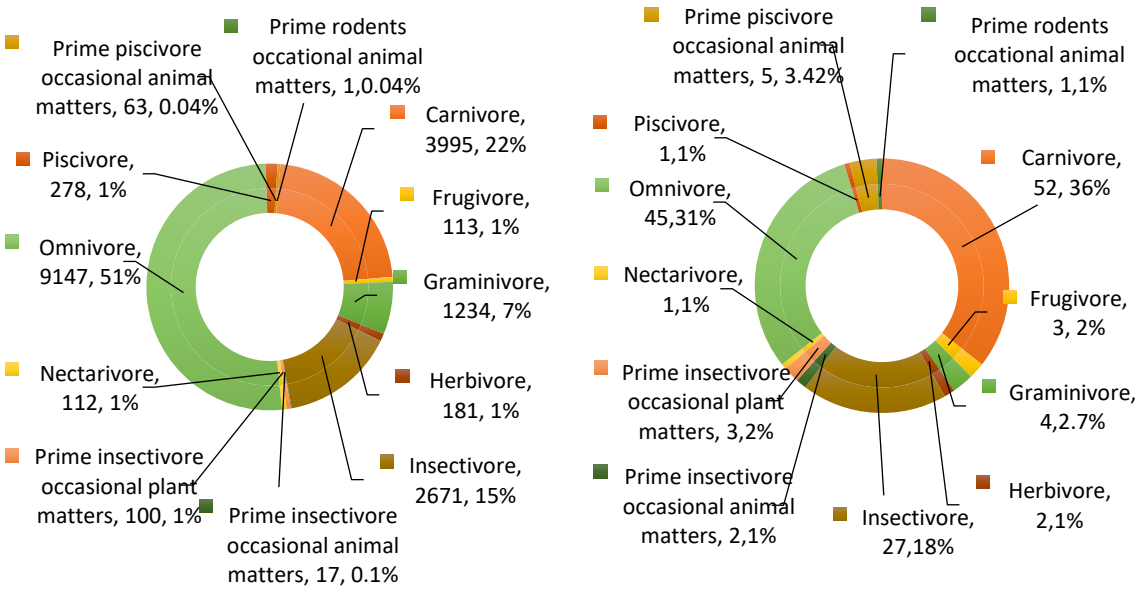

Figure 5 Feeding Guilds and population of birds and species number at KBS (IUCN, 2023).

Among the top less represented group, 07 species were birds of prey; 06 species were diurnal raptors and their population was very small (n=65, 0.4%). 05 species belonging to Accipitridae are sighted, namely, Black-winged Kite (*Elanus caeruleus*), Black Eagle (*Ictinaetus malaiensis*), Black Kite (*Milvus migran*), Brahminy Kite (*Haliastur ind*us) and Shikra (*Accipiter badius*), 01 species Common Kestrel (*Falco tinnunculus*) of Falconidae and 01 nocturnal species Oriental Scops Owl (*Otus sunia*) (Table 1) recorded from the study area. Although owls and raptors can acclimatize according to the environment their populations are suggestive of ecosystem problems or changes

(Movalli et al., 2008). Raptors are considered third or fourth-level consumers and play an important role in the ecosystem and are also known for controlling the rodent and small mammal population.

The nectarivore Purple Sunbird (*Cinnyris asiaticus*) has been sighted 23 times from the area, feeding mainly on nectar and taking insects. 02 species, the Pied Kingfisher (*Ceryle rudis*), and White-throated Kingfisher (*Halcyon smyrnensis*) belonging to Alcedinidae the family are sighted near the water body and are good indicators of freshwater community health. The frugivore feeding of Rose-ringed Parakeet (*Psittacula krameri*) was sighted near the farm areas and is considered a pest to the farmers.

Conservation status of avian fauna

The KBS supports 10 species of birds included in Schedule-Sch I, 134 species included in Sch II, and 02 species in Sch IV of the Wildlife Protection Act IWPA, (2023); One species that are listed in Appendix – App I, 02 in App III and 12 in App II of the Convention on International Trade in Endangered Species of Flora and Fauna. As per the IUCN red list IUCN, (2023), KBS supports 11 NT species, and one species VU, and the remaining 134 species are under LC (Table 1).

Statistical Analysis

Out of 17912 individuals (n) of birds reveal 146 species (s) of all total survey (S=28). The species Density (S/n) was high 5.21 species per survey; the Evenness index (e) is low (e < 0, 0.380). As evenness increases with a decrease in stress (Pielou 1966), this clears study areas has no stress and evenly distributed during the survey. Species richness Margalof's index (d) was high at 14.81; Shannon Weiner Index (H') was also high at 4.016, if the species are evenly distributed then the H' value would be high. So, it concludes that the abundance of avian species at this study site was high; Fisher's alpha diversity (α = 21.74) was also high in study areas during the entire study period.

This may reflect comparatively less stress in their environment and the climatic factor (i.e., Annual rainfall – 1311mm, average temperature 21.46-31.69°C, average humidity ranges 67.32-88.03% by morning, 2019), their physiography may provide suitable habitat and food availability during the study period at KBS. This indicates that multi-habitat characteristics of KBS areas support a wide range of specialist and generalist species of birds. Moreover, the details of individual species, population size, presence or absence, abundance, distributions, status, and ecological requirements of the birds, provide evolutionary history for the management and conservation of the site and taxa (Bruford, 2002).

4. CONCLUSION

During this study period, 146 species of birds representing 106 genera belonging to 50 families and 20 orders; 92 species resident types, 45 winters migratory, 05 resident and winter migrants and 01 monsoon breeding migrant, passage migrants, vagrant, winter migrant and resident for each was observed at KBS. 89 species were very rare, 24 rare, 20 occasional, 9 common and 4 were very common species, according to the frequency of distribution in the study area. Concerning feeding guilds, the largest number of species were recorded from carnivores and omnivores. The current study emphasizes the significance of the multi-habitat characteristics of the KBS as a favorable habitat and stopover site for avifauna in the Indo-Asian Flyway.

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Authors' contribution

VLS designed and carried out the research collected data and was involved in the identification, analysis, and interpretation of data and manuscript writing. VMT suggested the concept of the work, designed the study, and was involved in the identification, analysis of data, and manuscript writing. Both authors read and approved the final manuscript.

Informed consent

Permission granted under Wildlife Protection Act-1972No.WLP/RTC/28/C/35/2019-2020, dated: 24/04/2029, Chief Wildlife Warden, Gujarat State, Gandhinagar for data collection in Khijadiya Bird Sanctuary.

Ethical approval & declaration

In this article, as per the animal regulations in Khijadiya Bird Sanctuary (KBS) - (Ramsar site No. 2464) & Animal Ecology - Conservation Biology Research Laboratory, Department of Biosciences, UGC Centre of Advanced Studies, Saurashtra University, India, the authors observed the Birds' diversity from the Khijadiya Bird Sanctuary, Jamnagar, Gujarat, India. The Animal ethical guidelines are followed in the study for species observation, identification & experimentation.

Conflicts of interests:

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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