



Assessment of Avifaunal Status, Diversity, and Conservation Implications in and around the Wetlands of Dharwad, Karnataka, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study shows an overall avifaunal diversity and status of selected wetlands in Dharwad district and conveys the presence/absence of bird species on habitat changes caused due to varying water levels (exposure/submergence of mudflats) and destruction of riparian vegetation such as the reed species. These wetlands have attracted bird species from local to migratory to forage, roost and breed in the area. The avifaunal diversity was found to fairly vary across the different wetlands. The data portrayed here are from the surveys during wintering months of 2017-18 and 2021-22. Line transects, point count and total count methods were used for surveying. Diversity indices (Beta, Shannon, Simpson, Evenness) and similarity matrices (Bray-Curtis cluster) were calculated using

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Past 4 package. The Pearson correlation, beta diversity and Bray-Curtis's clustering were used to compare the wetlands for the similarity/dissimilarities in species composition. Overall, Shannon and Simpson diversity of the wetlands were $H'=4.67$ & $D= 0.98$ with total of 177 species, which portrays high degree of diversity. There were around 46 species of migrant birds and 133 resident species. The work also reports a few rare and coastal birds. The study suggests the management plans for the conservation of avifauna in and around the wetlands to prevent human disturbances and also considering the importance of faunal habitats before adopting lake developmental plans.

Keywords: Urban avifauna; wetland; biodiversity.

1. INTRODUCTION

Total wetland area in India is estimated to be 15.98 Mha, which is around 4.86 percent of the total geographic area of the country [1]. Wetlands are widely recognized as dynamic ecosystems with diverse attributes, including distinctive avifauna. It has been estimated that about 35% of global wetlands have been lost since 1970 [2]. The world's freshwater wetland is rich in species composition and serves as a habitat for about 40% of bird species and 12% of all animal species [3]. The microhabitats of a wetland provide rich and quality shelter and food for the avifauna populations throughout the year [4-6]. In addition, wetlands also provide essential ecological and economic services, including food and water source for domestic animals, climate change regulation, fish supply, recreational values, and medicinal plants [7,8]. Wetlands in urban settings fulfil additional environmental and social needs, which include storm-water retention of runoff from impervious surfaces, as well as removing pollutants and waste from water. The economic benefits include potentially reducing infrastructure costs, due to their ability to act as storm-water retention areas [9].

Wetland birds in particular are sensitive indicators of wetland conditions [9]. In urban areas the ecosystem of wetlands is the life support system, ensuring the effective functioning of the water cycle as they help recharge groundwater aquifers, cleanse polluted waters and act as sponges to mitigate floods [10]. In arid and semi-arid mid-latitudes, migratory shorebirds, waterfowl, and wading birds, rely on a limited number of important wetland areas (i.e., wetland habitat network) to connect continental movements supporting annual life-cycle events. Today, water development associated with many of these sites acts as drivers of urban development and irrigated agriculture supporting metropolitan centers and agricultural economies that account for 40% of global food production [11].

Wetland areas situated in dry and sub-humid places play an important role in supporting migratory bird species [12]. The degradation of wetlands can have significant conservation implications extending beyond the local scale when degradation affects migratory birds, which rely on wetlands for suitable habitat during the migration [13].

The presence or absence of birds may indicate the ecological conditions of wetland habitats and form an essential link between the food web and the nutrient cycle [14]. Avifauna is a highly diverse, conspicuous, and significant component of freshwater wetland ecosystems [15,16,17]. Moreover, birds may respond quickly to any change in habitat structure and climatic conditions [18-21]. The number of species and their relative abundance of birds depend upon wetland characteristics such as size, water level, quality of water, availability and distribution of food resources, and presence of suitable roosting and nursery sites [22].

Due to rapid urbanization, the birds' natural habitats have been lost, fragmented or modified with non-native vegetation to a larger extent, which affects community structure or distribution and other behavioural aspects [23-25].

In Karnataka, inland wetlands dominate, which account for 93.44% of the total wetland area [26]. Dharwad district (13507.14 km²) has a total wetland of 36 with area extent of about 44.0 km² [27].

The present study was undertaken to describe the avian species diversity, resident status and threat concerns wetlands of Dharwad district, Karnataka, India.

2. MATERIALS AND METHODS

Dharwad town and district of North Karnataka (15.417°N, 75.35°E; 727 m alt.) (Fig. 1), spans an area of 200 km² and has 45 villages in five

talukas. Human population is just over 1.6 million, 1.2 million of them in the Hubli–Dharwad twin city area. Rainfall is about 90 cm per annum, most falling in July and ranging from June end to early September, with 27°C–36°C average temperature. West of the city is an undulating foothill of Western Ghats tract (400–800 m) with red to greyish-brown soil, and to the east the Deccan plain with red loams to black cotton soil. Flora is disturbed deciduous forest, reduced to low scrub, interspersed with cultivation. The tropical dry deciduous forest begins some 20km west of Dharwad. The surveys were conducted in Chinnadakere Pond, Neersagar reservoir, Devaragudihal lake, Navaloor lake, Kelgeri Lake, Toppalgatti lake, Adavisomapur lake, Magadi Bird conservation reserve and Bachanaki Reservoir. These are utilized for irrigation purposes, domestic use and few for recreational purposes as a part of city parks. The riparian zones and surrounding terrestrial vegetation around wetlands are used by resident and migratory birds for roosting, feeding and nesting.

2.1 Bird survey

The methodologies used for bird counts were both point & line transect methods. Line

transects of 50mtr each and the distance between each line transect & point was about 200mtrs and for point count 50mtr radius around each point and the perpendicular distance of 50mtrs from each line transect was observed by walking at a constant pace for both visual and auditory sightings. Total count was used for birds in open waters [28] and were counted at 2-3 scanning points selected based on pilot surveys. To count the large flocks, the flock size was broken into units of 20 individuals [29]. The survey was conducted mostly during dawn and dusk hours. Avifauna was identified by sight and call, and individual counts were recorded. Equipment used for photography & observation was Nikon DSLR (D5200) with a 300mm Nikkor telephoto lens and Olympus Binocular 10x50.

Grimmett et al. [30], was used as a field guide for identification and for the information on distribution, resident status & occurrence status [25,30] were referred. IUCN [31], was used for the information on conservation status. The avifaunal data here were from the surveys of wintering months during 2017-18 and 2021-22. The individual encounters and habitat features, were noted. The human activities in and around the site were also observed for further interpretation.

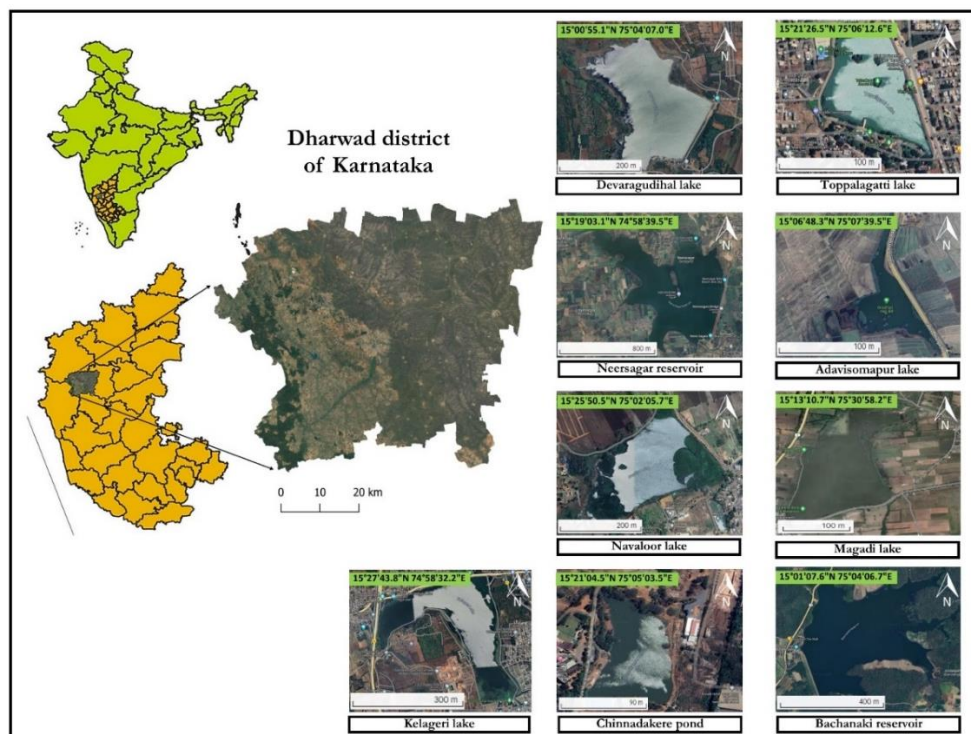


Fig. 1. Map of study area showing the 9 selected wetlands of Dharwad district, Karnataka State, India

2.2 Data Analysis

Relative abundance of all bird species was calculated by the expression,

$$\text{Relative abundance} = \frac{\text{No. of individuals of the species}}{\text{Total no. of individuals of all species}} \times 100$$

It is a measure of how common or rare a species is in relation to other species in a community.

The diversity and evenness were calculated by using the diversity indices, such as the Shannon-Wiener diversity index (which is a measure portraying diversity of a community by considering both species richness and evenness), Simpson diversity index (a measure of biodiversity which takes into account the number of species and how evenly individuals are distributed among them), Evenness (which is a measure of how similar the abundance of each species is in a given environment), beta diversity (measure of how species composition changes as one moves between different ecosystems, habitats, or communities) [28] and Bray-Curtis Cluster analysis (a method of classification that uses a distance measure to group objects based on their similarity) [32] using PAST 4 statistical software.

3. RESULTS AND DISCUSSION

A total of 177 species of birds were recorded across all field sites from both winter counts. The Shannon and Simpson diversity index was $H' = 1.97$ and $1-D = 0.4987$. The diversity indices without the Bar-headed geese would be $H' = 4.66$ and $1-D = 0.9865$ as Magadi bird conservation reserve receives over 3000-5000 individuals every winter which affects the diversity indices drastically (Table 1).

There were around 126 species of resident avifauna with Shannon index of $H' = 4.338$ which indicates high species richness and Simpson index $1-D = 0.9817$ indicating high degree of heterogeneity. The species richness of both local and winter migrants is = 51. During the present study, we reported the occurrence of Great bittern (*Botaurus stellaris*) an elusive rare species, which is the first record from across dryland Karnataka.

Considering how often the species were observed in the area during the survey period, the frequency of occurrence of resident birds showed 14 species belonging to very common category, 68 to common category, 72 uncommon and 23 to rare category. Among winter migrants, 16 were under common category, 26 uncommon and 8 species were Rare in occurrence.

The data for the conservation status was referred from the IUCN Red list. From the total of 177 species, 168 species belong to the Least concern category (94.9%) among which 74 species show stable population trend, 42 species are under decreasing population trend and 26 species under increasing population trend. The remaining 26 species have no proper documentation on their population patterns. There were 6 species (3.39%) under the Near threatened category with decreasing population trend (Woolly-necked Stork (*Ciconia episcopus*), Painted Stork (*Mycteria leucocephala*), Black-headed Ibis (*Threskiornis melanocephalus*), Oriental Darter (*Anhinga melanogaster*), Black-tailed Godwit (*Limosa limosa*) and Malabar Pied-Hornbill (*Anthracoceros coronatus*)). 3 species (1.7%) under Vulnerable category with decreasing population trend (Lesser Adjutant (*Leptoptilos javanicus*), Common Pochard (*Aythya ferina*) and River Tern (*Sterna aurantia*)).

Table 1. The total diversity of Avifauna in selected wetlands of Dharwad district with their frequency, conservation status and relative abundance

Sl No	Common Name	Scientific Name	Count	Occurrence frequency	Conservati on status	Relative abundance
1	Bar-headed Goose	<i>Anser indicus</i>	5000	C	LC	70.54
2	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	99	C	LC	1.4
3	Rock Pigeon	<i>Columba livia</i>	60	VC	LC	0.85
4	River Tern	<i>Sterna aurantia</i>	57	C	VU	0.8
5	Painted Stork	<i>Mycteria leucocephala</i>	51	C	NT	0.72
6	Small Pratincole	<i>Glareola lactea</i>	50	UC	LC	0.71
7	Red-vented Bulbul	<i>Pycnonotus cafer</i>	46	VC	LC	0.65
8	Black-winged Stilt	<i>Himantopus himantopus</i>	45	VC	LC	0.63
9	Red-wattled Lapwing	<i>Vanellus indicus</i>	45	VC	LC	0.63

SI No	Common Name	Scientific Name	Count	Occurrence frequency	Conservation status	Relative abundance
10	Eurasian Coot	<i>Fulica atra</i>	42	VC	LC	0.59
11	Eastern Cattle Egret	<i>Bubulcus coromandus</i>	41	VC	LC	0.58
12	Little Cormorant	<i>Microcarbo niger</i>	40	C	LC	0.56
13	Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	39	UC	LC	0.55
14	Red-rumped Swallow	<i>Cecropis daurica</i>	37	C	LC	0.52
15	Indian Pond-Heron	<i>Ardeola grayii</i>	35	VC	LC	0.49
16	Barn Swallow	<i>Hirundo rustica</i>	34	UC	LC	0.48
17	Little Egret	<i>Egretta garzetta</i>	34	VC	LC	0.48
18	Asian Green Bee-eater	<i>Merops orientalis</i>	28	C	LC	0.4
19	Baya Weaver	<i>Ploceus philippinus</i>	28	UC	LC	0.4
20	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	28	C	NT	0.4
21	Brahminy Starling	<i>Sturnia pagodarum</i>	28	UC	LC	0.4
22	Little Grebe	<i>Tachybaptus ruficollis</i>	28	C	LC	0.4
23	Wire-tailed Swallow	<i>Hirundo smithii</i>	28	C	LC	0.4
24	Lesser Whistling-Duck	<i>Dendrocygna javanica</i>	27	C	LC	0.38
25	Common Myna	<i>Acridotheres tristis</i>	25	VC	LC	0.35
26	Northern Pintail	<i>Anas acuta</i>	25	UC	LC	0.35
27	Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>	25	VC	LC	0.35
28	Rose-ringed Parakeet	<i>Psittacula krameri</i>	25	C	LC	0.35
29	Gray Heron	<i>Ardea cinerea</i>	24	C	LC	0.34
30	House Crow	<i>Corvus splendens</i>	24	C	LC	0.34
31	White-browed Bulbul	<i>Pycnonotus luteolus</i>	24	C	LC	0.34
32	Ashy Prinia	<i>Prinia socialis</i>	23	VC	LC	0.32
33	Common Sandpiper	<i>Actitis hypoleucos</i>	23	C	LC	0.32
34	Garganey	<i>Spatula querquedula</i>	23	UC	LC	0.32
35	Eurasian Spoonbill	<i>Platalea leucorodia</i>	22	UC	LC	0.31
36	Black-headed Bunting	<i>Emberiza melanocephala</i>	20	UC	LC	0.28
37	Gray-headed Swamphen	<i>Porphyrio poliocephalus</i>	20	C	LC	0.28
38	Wood Sandpiper	<i>Tringa glareola</i>	20	UC	LC	0.28
39	Black Kite	<i>Milvus migrans</i>	19	C	LC	0.27
40	Medium Egret	<i>Ardea intermedia</i>	19	C	LC	0.27
41	Dusky Crag-Martin	<i>Ptyonoprogne concolor</i>	18	C	LC	0.25
42	Purple Heron	<i>Ardea purpurea</i>	17	C	LC	0.24
43	Cotton Pygmy-Goose	<i>Nettapus coromandelianus</i>	15	UC	LC	0.21
44	Glossy Ibis	<i>Plegadis falcinellus</i>	15	UC	LC	0.21
45	Northern Shoveler	<i>Spatula clypeata</i>	15	UC	LC	0.21
46	Yellow-wattled Lapwing	<i>Vanellus malabaricus</i>	15	UC	LC	0.21
47	Asian Openbill	<i>Anastomus oscitans</i>	14	C	LC	0.2
48	Blyth's Reed Warbler	<i>Acrocephalus dumetorum</i>	14	C	LC	0.2
49	Brahminy Kite	<i>Haliastur indus</i>	14	C	LC	0.2
50	Common Tailorbird	<i>Orthotomus sutorius</i>	14	C	LC	0.2
51	Bronze-winged Jacana	<i>Metopidius indicus</i>	13	C	LC	0.18
52	Indian Silverbill	<i>Euodice malabarica</i>	13	C	LC	0.18
53	Purple-rumped Sunbird	<i>Leptocoma zeylonica</i>	13	C	LC	0.18
54	Indian Robin	<i>Copsychus fulicatus</i>	12	C	LC	0.17
55	Jungle Myna	<i>Acridotheres fuscus</i>	12	C	LC	0.17
56	Large Gray Babbler	<i>Argya malcolmi</i>	12	C	LC	0.17
57	White-breasted	<i>Amauornis</i>	12	C	LC	0.17

SI No	Common Name	Scientific Name	Count	Occurrence frequency	Conservation status	Relative abundance
58	Waterhen Laughing Dove	<i>phoenicurus</i> <i>Spilopelia</i> <i>senegalensis</i>	11	VC	LC	0.16
59	Little Swift	<i>Apus affinis</i>	11	C	LC	0.16
60	Scaly-breasted Munia	<i>Lonchura punctulata</i>	11	C	LC	0.16
61	Blue-tailed Bee-eater	<i>Merops philippinus</i>	10	Ra	LC	0.14
62	Common Pochard	<i>Aythya ferina</i>	10	Ra	VU	0.14
63	Pale-billed Flowerpecker	<i>Dicaeum</i> <i>erythrorhynchos</i>	10	UC	LC	0.14
64	Pied Kingfisher	<i>Ceryle rudis</i>	10	C	LC	0.14
65	Plain Prinia	<i>Prinia inornata</i>	10	UC	LC	0.14
66	Thick-billed Flowerpecker	<i>Dicaeum agile</i>	10	UC	LC	0.14
67	Asian Koel	<i>Eudynamis</i> <i>scolopaceus</i>	9	C	LC	0.13
68	Asian Woolly-necked Stork	<i>Ciconia episcopus</i>	9	C	NT	0.13
69	Black Drongo	<i>Dicurus macrocercus</i>	9	VC	LC	0.13
70	Long-tailed Shrike	<i>Lanius schach</i>	9	C	LC	0.13
71	Red-naped Ibis	<i>Pseudibis papillosa</i>	9	C	LC	0.13
72	Ruddy Shelduck	<i>Tadorna ferruginea</i>	9	UC	LC	0.13
73	Small Minivet	<i>Pericrocotus</i> <i>cinnamomeus</i>	9	C	LC	0.13
74	Spotted Dove	<i>Spilopelia chinensis</i>	9	C	LC	0.13
75	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	9	VC	LC	0.13
76	Clamorous Reed Warbler	<i>Acrocephalus</i> <i>stentoreus</i>	8	C	LC	0.11
77	Common Greenshank	<i>Tringa nebularia</i>	8	UC	LC	0.11
78	Great Egret	<i>Ardea alba</i>	8	UC	LC	0.11
79	Greater Coucal	<i>Centropus sinensis</i>	8	C	LC	0.11
80	Indian Peafowl	<i>Pavo cristatus</i>	8	C	LC	0.11
81	Kentish Plover	<i>Anarhynchus</i> <i>alexandrinus</i>	8	UC	LC	0.11
82	Oriental Darter	<i>Anhinga melanogaster</i>	8	C	NT	0.11
83	Tree Pipit	<i>Anthus trivialis</i>	8	Ra	LC	0.11
84	Cinereous Tit	<i>Parus cinereus</i>	7	C	LC	0.1
85	Common Iora	<i>Aegithina tiphia</i>	7	C	LC	0.1
86	Eurasian Hoopoe	<i>Upupa epops</i>	7	C	LC	0.1
87	Marsh Sandpiper	<i>Tringa stagnatilis</i>	7	UC	LC	0.1
88	Nilgiri Flowerpecker	<i>Dicaeum concolor</i>	7	UC	LC	0.1
89	Paddyfield Pipit	<i>Anthus rufulus</i>	7	C	LC	0.1
90	Yellow-eyed Babbler	<i>Chrysomma sinense</i>	7	C	LC	0.1
91	Eurasian Collared- Dove	<i>Streptopelia decaocto</i>	6	C	LC	0.08
92	Little Ringed Plover	<i>Charadrius dubius</i>	6	UC	LC	0.08
93	Oriental Magpie- Robin	<i>Copsychus saularis</i>	6	C	LC	0.08
94	Red Avadavat	<i>Amandava amandava</i>	6	UC	LC	0.08
95	Indian Swiftlet	<i>Aerodramus unicolor</i>	5	UC	LC	0.07
96	Jungle Babbler	<i>Argya striata</i>	5	UC	LC	0.07
97	Large-billed Crow	<i>Corvus macrorhynchos</i>	5	C	LC	0.07
98	Little Stint	<i>Calidris minuta</i>	5	UC	LC	0.07
99	Purple Sunbird	<i>Cinnyris asiaticus</i>	5	C	LC	0.07
100	Spot-breasted Fantail	<i>Rhipidura albogularis</i>	5	UC	LC	0.07
101	Yellow-footed Green- Pigeon	<i>Treron phoenicopterus</i>	5	UC	LC	0.07
102	Yellow-throated Sparrow	<i>Gymnoris xanthocollis</i>	5	UC	LC	0.07
103	Zitting Cisticola	<i>Cisticola juncidis</i>	5	UC	LC	0.07

SI No	Common Name	Scientific Name	Count	Occurrence frequency	Conservation status	Relative abundance
104	Caspian Tern	<i>Hydroprogne caspia</i>	4	Ra	LC	0.06
105	Common Kingfisher	<i>Alcedo atthis</i>	4	C	LC	0.06
106	Eurasian Moorhen	<i>Gallinula chloropus</i>	4	UC	LC	0.06
107	Eurasian Wigeon	<i>Mareca penelope</i>	4	Ra	LC	0.06
108	Gray Wagtail	<i>Motacilla cinerea</i>	4	C	LC	0.06
109	Gray-bellied Cuckoo	<i>Cacomantis passerinus</i>	4	UC	LC	0.06
110	Malabar Lark	<i>Galerida malabarica</i>	4	UC	LC	0.06
111	Malabar Pied-Hornbill	<i>Anthracoceros coronatus</i>	4	UC	NT	0.06
112	Olive-backed Pipit	<i>Anthus hodgsoni</i>	4	UC	LC	0.06
113	Pheasant-tailed Jacana	<i>Hydrophasianus chirurgus</i>	4	UC	LC	0.06
114	Pied Bushchat	<i>Saxicola caprata</i>	4	C	LC	0.06
115	Temminck's Stint	<i>Calidris temminckii</i>	4	UC	LC	0.06
116	Vernal Hanging-Parrot	<i>Loriculus vernalis</i>	4	Ra	LC	0.06
117	Whiskered Tern	<i>Chlidonias hybrida</i>	4	C	LC	0.06
118	Yellow-billed Babbler	<i>Argya affinis</i>	4	C	LC	0.06
119	Ashy Drongo	<i>Dicrurus leucophaeus</i>	3	C	LC	0.04
120	Common Babbler	<i>Argya caudata</i>	3	Ra	LC	0.04
121	Gray-breasted Prinia	<i>Prinia hodgsonii</i>	3	UC	LC	0.04
122	House Sparrow	<i>Passer domesticus</i>	3	C	LC	0.04
123	Indian Bushlark	<i>Mirafra erythroptera</i>	3	UC	LC	0.04
124	Indian Gray Hornbill	<i>Ocyrceros birostris</i>	3	C	LC	0.04
125	Indian Paradise-Flycatcher	<i>Terpsiphone paradisi</i>	3	UC	LC	0.04
126	Oriental Honey-buzzard	<i>Pernis ptilorhynchus</i>	3	UC	LC	0.04
127	Siberian Stonechat	<i>Saxicola maurus</i>	3	C	LC	0.04
128	Shikra	<i>Accipiter badius</i>	3	UC	LC	0.04
129	White-browed Wagtail	<i>Motacilla maderaspatensis</i>	3	C	LC	0.04
130	Brown-headed Seagull	<i>Chroicocephalus brunnicephalus</i>	2	UC	LC	0.03
131	Ashy Woodswallow	<i>Artamus fuscus</i>	2	Ra	LC	0.03
132	Asian Palm Swift	<i>Cypsiurus balasiensis</i>	2	UC	LC	0.03
133	Black-crowned Night Heron	<i>Nycticorax nycticorax</i>	2	UC	LC	0.03
134	Blue-faced Malkoha	<i>Phaenicophaeus viridirostris</i>	2	UC	LC	0.03
135	Bluethroat	<i>Luscinia svecica</i>	2	Ra	LC	0.03
136	Chestnut-tailed Starling	<i>Sturnia malabarica</i>	2	UC	LC	0.03
137	Common Hawk-Cuckoo	<i>Hierococcyx varius</i>	2	UC	LC	0.03
138	Common Woodshrike	<i>Tephrodornis pondicerianus</i>	2	UC	LC	0.03
139	Coppersmith Barbet	<i>Psilopogon haemacephalus</i>	2	C	LC	0.03
140	Crimson-backed Sunbird	<i>Leptocoma minima</i>	2	UC	LC	0.03
141	Golden-fronted Leafbird	<i>Chloropsis aurifrons</i>	2	UC	LC	0.03
142	Gray Francolin	<i>Ortygornis pondicerianus</i>	2	C	LC	0.03
143	Green Sandpiper	<i>Tringa ochropus</i>	2	UC	LC	0.03
144	Green/Greenish Warbler	<i>Phylloscopus nitidus/trochiloides</i>	2	UC	LC	0.03
145	Green-winged Teal	<i>Anas crecca</i>	2	Ra	LC	0.03
146	Jungle Prinia	<i>Prinia sylvatica</i>	2	UC	LC	0.03

SI No	Common Name	Scientific Name	Count	Occurrence frequency	Conservation status	Relative abundance
147	Lesser Adjutant	<i>Leptoptilos javanicus</i>	2	UC	VU	0.03
148	Painted Francolin	<i>Francolinus pictus</i>	2	UC	LC	0.03
149	Pied Cuckoo	<i>Clamator jacobinus</i>	2	UC	LC	0.03
150	Plum-headed Parakeet	<i>Psittacula cyanocephala</i>	2	UC	LC	0.03
151	Stork-billed Kingfisher	<i>Pelargopsis capensis</i>	2	Ra	LC	0.03
152	Western Marsh Harrier	<i>Circus aeruginosus</i>	2	C	LC	0.03
153	Yellow Bittern	<i>Ixobrychus sinensis</i>	2	Ra	LC	0.03
154	Asian Emerald Dove	<i>Chalcophaps indica</i>	1	Ra	LC	0.01
155	Black-hooded Oriole	<i>Oriolus xanthornus</i>	1	Ra	LC	0.01
156	Black-tailed Godwit	<i>Limosa limosa</i>	1	Ra	NT	0.01
157	Black-winged Kite	<i>Elanus caeruleus</i>	1	C	LC	0.01
158	Booted Warbler	<i>Iduna caligata</i>	1	UC	LC	0.01
159	Brown-backed Needletail	<i>Hirundapus giganteus</i>	1	Ra	LC	0.01
160	Common Cuckoo	<i>Cuculus canorus</i>	1	UC	LC	0.01
161	Crested Serpent-Eagle	<i>Spilornis cheela</i>	1	UC	LC	0.01
162	Graylag Goose	<i>Anser anser</i>	1	Ra	LC	0.01
163	Great Gray Shrike	<i>Lanius excubitor</i>	1	Ra	LC	0.01
164	Indian Nightjar	<i>Caprimulgus asiaticus</i>	1	UC	LC	0.01
165	Indian Pitta	<i>Pitta brachyura</i>	1	Ra	LC	0.01
166	Knob-billed Duck	<i>Sarkidiornis melanotos</i>	1	Ra	LC	0.01
167	Lesser Whitethroat	<i>Curruca curruca</i>	1	C	LC	0.01
168	Montagu's Harrier	<i>Circus pygargus</i>	1	C	LC	0.01
169	Oriental Skylark	<i>Alauda gulgula</i>	1	UC	LC	0.01
170	Paddyfield Warbler	<i>Acrocephalus agricola</i>	1	UC	LC	0.01
171	Rain Quail	<i>Coturnix coromandelica</i>	1	UC	LC	0.01
172	Red-necked Falcon	<i>Falco chicquera</i>	1	Ra	LC	0.01
173	Rufous Woodpecker	<i>Micropternus brachyurus</i>	1	UC	LC	0.01
174	Striated Heron	<i>Butorides striata</i>	1	UC	LC	0.01
175	Tickell's Blue Flycatcher	<i>Cyornis tickelliae</i>	1	UC	LC	0.01
176	Western Yellow Wagtail	<i>Motacilla flava</i>	1	C	LC	0.01
177	White Stork	<i>Ciconia ciconia</i>	1	Ra	LC	0.01

Table 2. The biodiversity indices of all the waterbodies under study

Waterbodies	Taxa_S	Individuals	Simpson_1-D	Shannon_H	Evenness_e^H/S
Adavisomapur Lake	75	500	0.9651	3.866	0.6364
Bachanaki Reservoir	29	214	0.8049	2.484	0.4136
Chinnadakere Pond	56	177	0.9789	3.96	0.9364
Devaragudihal Lake	101	598	0.9775	4.232	0.6814
Kelgeri Lake	53	200	0.9674	3.724	0.7819
Magadi Bird Sanctuary	59	5365	0.1313	0.4988	0.02791
Navaloor Lake	82	429	0.9764	4.099	0.7352
Neersagar	46	130	0.9795	3.863	1.034
Tolanakere	62	327	0.962	3.713	0.6607

3.1 Comparative Diversity within and between the Waterbodies

The data analysis suggests that the high degree of diversity and evenness was found to be in Neersagar due to even distribution of bird

population and the lowest was in Magadi bird sanctuary due enormous accumulation of Bar headed goose (*Anser indicus*) during the months of November to February leading high dominance and low evenness in the community (Table 2).

The mean standard deviation suggests that the Magadi bird sanctuary (28.84409 ± 366.5047) has very high-density variation between species in the community due to the large occurrence of migrant Bar headed goose (*Anser indicus*) during winters whereas, Neersagar (0.6989247 ± 1.439106) and Chinnadakere (0.9516129 ± 1.895321) waterbodies have least density variations between the species in the community.

3.2 Beta Diversity

Beta diversity explains change in species composition and abundance across the study sites and change in number of species between the sites [33,34]. Also describing the species turnover [35]. The present data (Fig. 2) shows that Bachanaki Reservoir and Chinnadakere Pond has the value of 0.93 with Highest Dissimilarity (Values near 1.0), indicates that these wetlands are highly dissimilar in terms of species composition. Neersagar and Kelgeri Lake with a value of 0.35 have Lowest Dissimilarity (Values near 0.0), these wetlands are quite similar in species composition. This states that higher the pairwise values, more dissimilar two sites are [36].

Wetlands like Bachanaki Reservoir tend to be quite distinct from others, with high dissimilarity values, indicating different species compositions. On the other hand, wetlands like A Davisomapur Lake, Kelgeri Lake, and Devaragudihal Lake

show relatively lower dissimilarity values, meaning they share more species and have similar ecological conditions. Wetlands with moderate to high dissimilarity (like Chinnadakere Pond and Bachanaki Reservoir) may require targeted conservation efforts to protect their unique species compositions.

3.3 Clustering of Sites

The Bray-Curtis similarity measure ranges from 0 (completely dissimilar) to 1 (completely similar) [37]. The Clustering was based on how soon the lines meet each other. The clusters described closeness between different sites.

Neersagar and Kelgeri Lake are clustered closely, indicating a relatively high similarity in their bird species compositions, which aligns with the earlier observation from the Whittaker beta diversity (Fig. 2). A Davisomapur Lake is most similar to the first cluster of Kelgeri Lake and Neersagar, suggesting that the three wetlands have relatively similar bird communities. Navaloor Lake and Tolanakere are clustered together, indicating they share similar bird species and abundance. Chinnadakere Pond and Devaragudihal Lake form another cluster, indicating their similarity. Whereas, Magadi Bird Sanctuary and Bachanaki Reservoir appear to be outliers, showing higher dissimilarity to all other wetlands and to each other.

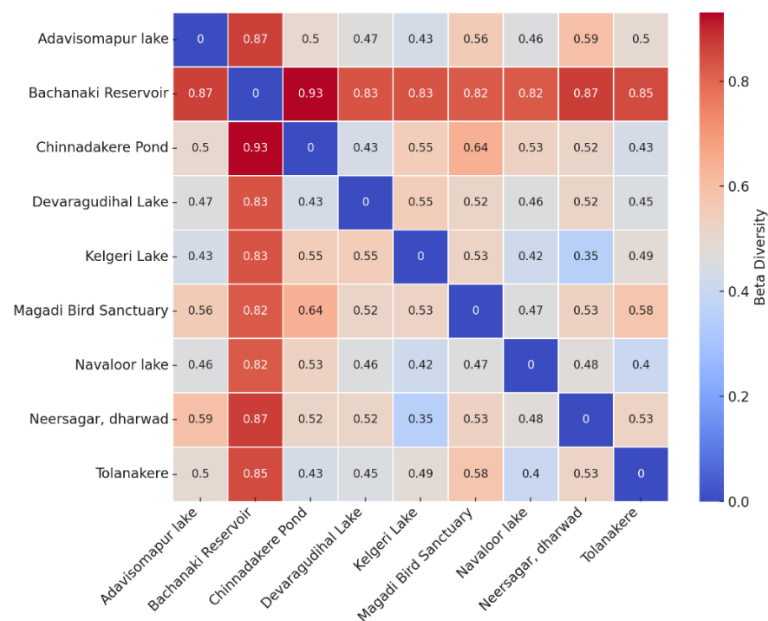


Fig. 2. Whittaker beta diversity pairwise comparison heatmap

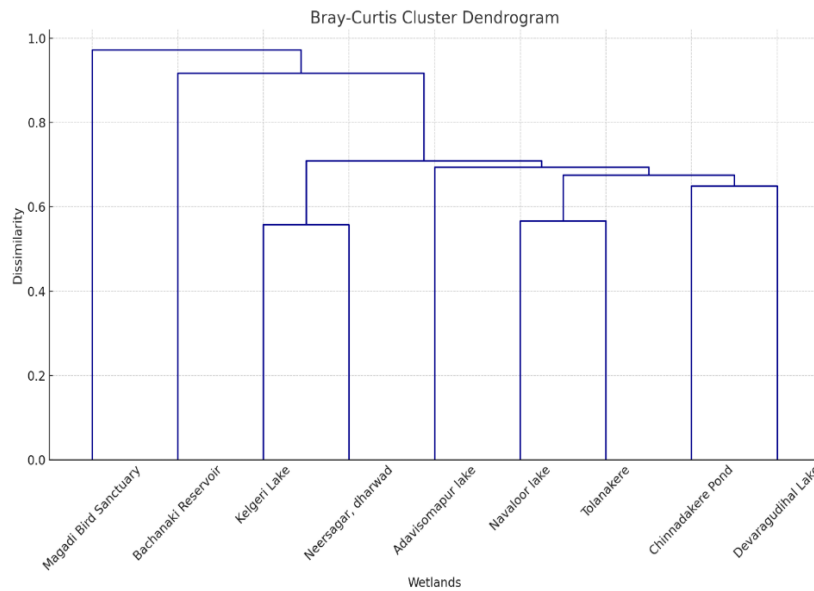


Fig. 3. Bray- curtis cluster dendrogram

The y-axis shows the Bray-Curtis dissimilarity, with 0 representing no dissimilarity (completely similar) and 1 representing maximum dissimilarity. The closer the merging happens to the x-axis, the more similar the wetlands are.

The height at which the clusters are joined indicates the degree of dissimilarity between them. Wetlands that join together at a lower level of the y-axis are more similar in bird species composition than those that join at higher levels. (Fig. 3).

3.4 Other Observations

During the survey period, there were presence and absence of certain bird species. Due to raise in water levels in the wetlands post floods in 2018 and directing sewage canals from surrounding catchment areas through flood canals of the lakes, birds such as Little Tern (*Sternula albifrons*), more abundance of Whiskered Tern (*Chlidonias hybrida*) and Plovers like Little ringed Plover (*Charadrius dubius*) and Kentish Plover (*Charadrius alexandrinus*) (Fig. 4), were never sighted as the mud flats were lost. Gaudet [38], mentions that lake water level fluctuates considerably from year to year, creating temporary mud flats, which are crucial for wading birds.

Shallow water bodies with variations in depth might be the factor for aggregation of birds

compared to deeper tanks, and support more species and greater densities [39,40]. Similarly, in our wetlands with shallow water banks harboured floating, submergent and emergent plants. It provides suitable site for the wetland birds with respect to their roosting, feeding and nesting needs. Vegetation like *Nymphae* sp., *Nymphoides indica* were used especially by *Jacanas*, Submerged vegetation like, *Hydrilla* sp., *Chara* sp., *Vallisneria* sp., *Ceratophyllum* spp. were preferred by Eurasian Coot, Grey headed Swamphen, Cotton Teal, Indian Spot-billed Duck and Migratory ducks (Fig. 5). the high vegetation cover forms a suitable habitat for breeding birds and also for overall species richness [41].

The decline of the water levels aided growth of *Eleocharis* sp. *Typha* sp. and *Cyperus* sp. at the riparian zone along with submerged vegetation, which resulted in the assemblage of elusive birds like Crakes, Snipes and Bitterns. The species such as Ballion's Crake, Common/Pintail/Painted Snipes and Cinnamon/Yellow bittern were sighted during the survey period when the growth of Reed species was abundant (Fig. 6). Apart from the raise in the water level, anthropological disturbances such as clearing of the reed patches (*Typha* sp. and *Cyperus* sp.) for livestock fodder, destroyed the roosting and breeding grounds of both migrant and resident species.

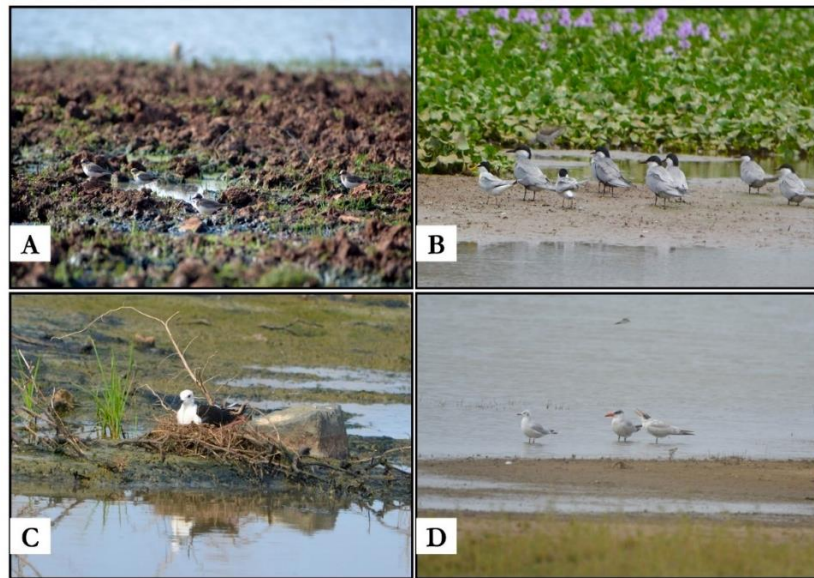


Fig. 4. Some mudflats depended avifauna from the study wetlands: (A) Kentish plovers; (B) Little tern (left corner) & Whiskered terns; (C) Black winged Stilt; (D) Brown headed gull (left) & Caspian Terns

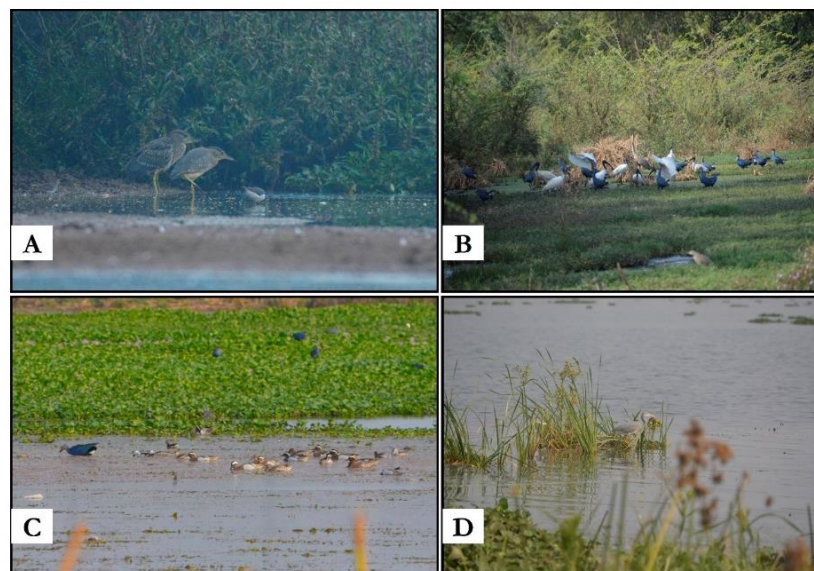


Fig. 5. Some marsh and aquatic vegetation depended avifauna from the study wetlands: (A) Black crowned night Heron; (B) Black headed Ibis & Purple Moorhen; (C) Garganey flock & Gray headed swamphen; (D) Western reef Heron

The vegetation diversity and richness of the wetland directly affect species diversity and richness of birds because it provides heterogeneous and suitable sites for foraging, nesting, and roosting [42,43,44].

There are several species in our study sites which portray significant information about the state of wetlands such as the Black-winged Stilt

which is considered to be the indicator of polluted water body was found in high numbers in Navaloor lake, and this lake has the highest inflow of sewage. And contrast to it Lesser Adjutant is considered to be the indicator of less or undisturbed waterbody especially in terms of pollution and this species was only sighted in Adavisomapur lake and Magadi bird sanctuary which are least disturbed by human influence.

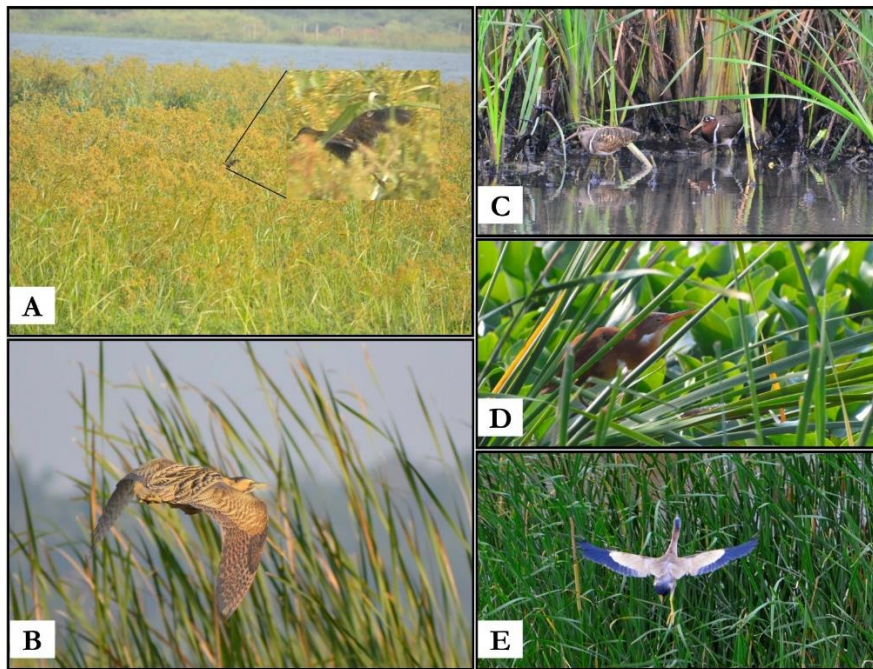


Fig. 6. Some shoreline vegetation depended avifauna from the study sites: (A) Ballion's Crake; (B) Great Bittern; (C) Painted Snipes; (D) Cinnamon Bittern; (E) Yellow Bittern

Several species such as Little Grebe (*Tachybaptus ruficollis*), Indian Spot-billed Duck (*Anas poecilorhyncha*), Black-headed Ibis (*Threskiornis melanocephalus*) being sensitive towards pollution levels and both of these species are in decent populations in all our wetlands but in reduced numbers in some wetlands indicating anthropologic influence in those sites. Bronze-winged Jacana (*Metopidius indicus*) and Pheasant-tailed Jacana (*Hydrophasianus chirurgus*) are only present in marshy wetlands with dense floating vegetation diversity, hence Advaisomapur lake, Bachanaki Reservoir, Chinnadakere Pond and Devaragudihal Lake lack these species due less or no floating vegetation. Species such as Asian Openbill Stork (*Anastomus oscitans*) and Painted Stork (*Mycteria leucocephala*) are large waders which feeds on mollusks, snails, and small aquatic animals, abundant fishes indicating healthy freshwater wetlands and also these species are usually present in wetlands with least human presence and accordingly only 4-5 wetlands out of the 9 wetlands under study constitutes these species.

Study by Chen et al. [45], suggests that the critical land use types such as medium grassland, tidal flat, and pond landscapes which will sustain diverse resources are important for

protecting and maintaining good bird species diversity in and around urban ecosystems. Hence wetland restoration projects should keep these pointers as the basis of design [46,47].

4. CONCLUSIONS

The study on avifaunal diversity in the selected wetlands in and around Dharwad district suggests that they support a good number of resident and migratory birds including generalist coastal and some rare species of birds. Among the sites Devaragudihal Lake had maximum species richness and Neersagar with most evenly distributed population, this may be due to the landscape heterogeneity with good amount of shallow water areas providing growth of hydrophytes, exposed mud flats and also might be due surrounding agroecosystems and woody landscapes. All of the wetlands surveyed are prone to anthropocentric activities at different frequencies and intensities like; release of domestic wastes, discharge of non-biodegradable wastes, washing clothes and vehicles, extensive fishing, pumping of waters during the dry seasons and destruction of riparian zones/vegetation for fodder and unscientific lake developments for recreational purposes, causing irregularity, reduction and even resulting in complete absence of some

migratory species and few of the sensitive resident species. If this continues the biodiversity in the region decreases leading to ecosystem imbalances, leading to water quality deterioration, proliferation of invasive species as the balanced biodiversity will also be curbing the spread of invasive species. Proper attention is needed from the public as well as the local governing bodies towards the protection and conservation of these habitats, which can be promising sites for rich resident, migratory avifauna and related terrestrial aquatic fauna.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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