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Assessment of waterfowl diversity of Sardar Sarovar reservoir with special reference to the summer season

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Abstract
A study aimed to maintain a record of waterbird species, repair and sustain the wetland's condition, and recognize the site as a globally significant habitat for waterbird conservation. This study explored the freshwater bird fauna of the Sardar Sarovar Reservoir in Barwani, West Nimar, Madhya Pradesh, India. From March 2023 to June 2023, the research identified 29 species distributed across 8 orders, 24 genera, and 14 families. The dominant family was Ardeidae, followed by Charadriidae and Rallidae. Pelecaniformes was the most prominent order, with 9 species. The study classified birds into five dietary guilds, with carnivores being the most dominant. Among the 29 species, 12 were residents, 13 were residents with local migration, and the remaining three were designated as winter visitors. The study found that 28 identified species were of least concern, while one was near threatened. The largest number of individuals was observed in the H2 habitat (347 individuals), while the lowest number was recorded in the H3 habitat (159 individuals). In conclusion, effective management is needed to enhance the status of the resident species and attract additional migratory and vagrant species in the future.

Keywords: Avifauna Diversity, Conservation status, Habitat, Migratory, Reservoir, Waterbirds, Wetlands.

Introduction

For more than a century, pioneering naturalists have shaped the development of waterbird conservation globally, contributing to creating organizations like the IUCN. Wetland birds are excellent biological indicators of the human environment, providing early warnings of harmful changes and reflecting the health of natural ecosystems (Patel and Dharaiya, 2016) [16]. The bird population has been dwindling continuously over the last few decades, with more than a hundred species either endemic or endangered (Kanaujia *et al*., 2013) [11]. Lakes are popular destinations for both native and migratory birds due to their vast water bodies that provide food and shelter. Wetlands are crucial to the environment because of their high productivity, nutritional value, and support for bird species. At least 20% of the threatened bird species in Asia rely on wetlands, including many migratory and resident species (Gibbs, 1993 [7]; Paracuellos, 2006) [15]. Wetlands are sometimes called "biological supermarkets" because of their extensive food chains and great biodiversity, providing unique habitats for various plants and wildlife. They serve as important feeding, roosting, nesting, and breeding areas for aquatic birds (Veeramani *et al*., 2018) [24]. However, more than half of the world's wetlands have disappeared in the last 100 years due to harmful human activities, and the remaining wetlands have also been damaged. Wetlands are vital habitats for water birds, but their degradation and loss pose significant threats to the survival of these birds (Fujioka *et al*., 2001) [6]. Madhya Pradesh is one of India's most biodiverse states. Compared to other states, the species richness in M.P.'s forests and water bodies is significantly higher. The region's primary causes of biodiversity loss are rapid industrialization, agriculture, urbanization, and large-scale development projects, which lead to habitat destruction, pollution, and overuse of natural resources (Pandey, 2020) [17]. Although various ornithologists have reported many species from different areas of Madhya Pradesh, there is no previous literature on these parameters for the West Nimar region of the Barwani District. Wetlands play a crucial role in the population dynamics of numerous avian species (Trivedi, 2018) [23]. During the summer in Barwani, birds face challenging conditions due to the extreme heat and dry environment. The intense heat, with temperatures often exceeding 45°C, puts significant stress on birds. They struggle to regulate their body temperature and can suffer from heat exhaustion or dehydration. The primary goal of this study is to determine whether the Sardar Sarovar reservoir is a suitable habitat for water birds in summer and how many species of water birds it can provide a favorable habitat for."

The Sardar Sarovar Reservoir in West Nimar has long been known to support a rich diversity of water birds. However, a comprehensive study of the bird diversity in the entire area of the Sardar Sarovar Reservoir is currently lacking. This is crucial given the rising population pressure and human activities harming the reservoir ecosystem. Therefore, the present study has been carried out to identify and document the various species of water birds visiting and residing in the reservoir. This work aims to provide baseline data for the area's future management and conservation of avian fauna.

Material and Methods

Study area: Barwani district, situated in the southwestern region of Central India, is a municipal town in Madhya Pradesh, India. It covers an area of 5,422 square kilometers, with an average elevation of 178 meters. The Holy River Narmada bounds the region. The climate is tropical to sub-tropical, with an average yearly temperature of 27 °C, reaching its peak in April and May at 48 °C. Barwani receives an average annual rainfall of 742.8 mm (Solanki *et al*., 2016) [20]. The sites are quite far apart, with the minimum distance being 4.6 km and the maximum distance being approximately 22–25 km, Because of the large

distances between each site, it was not possible to count water birds in both wetlands on the same day. The local population mainly uses the water body for irrigation, fishing, and drinking.

Four sampling sites were chosen from the Sardar Sarovar Reservoir in the West Nimar area of the Barwani District. They are the following:

Station code No.	Sardar Sarovar Reservoir Sampling Stations (Habitat)	Geographic Coordinates	
		Latitude (m)	Longitude (m)
H1	Kasrawad	22° 4'50.81"N	74°55'55.72"E
H2	Rajghat	22° 4'50.63"N	74°55'55.82"E
H3	Pichhodi	22° 3'24.38"N	74°51'4.61"E
H4	Bhawati	22° 4'13.12"N	74°45'55.45"E

(Geographic Coordinates of Sardar Sarovar Reservoir Sampling Station)

Data collection: The study was conducted between March 2023 and June 2023 using the direct counting method (Colin *et al*., 1993), as the study area was open. Birds were counted through foot surveys that involved walking along selected routes at the reservoir's edge and its environs. A total of 32 surveys were conducted during the research period, with eight surveys per month. Observations were made twice a week at each site, in the mornings between 6:00 AM and 8:00 AM, depending on the light conditions, and in the evenings between 4:00 PM and 6:00 PM, when bird activity was most prominent. The birds were observed using Olympus binoculars at 10x50 magnification. In cases of uncertain identification, photographs were taken with a Canon PowerShot SX70 HS (65x optical zoom, 21–1365 mm, 35 mm equivalent to 130x zoom Plus). The proper identification of birds was performed using standard colored field guides (Ali and Ripley, 2001 [1]; Grimmett *et al*., 2011) [8]. Information from the local community and on-site observations was recorded during each visit and compiled at the end of the study.

Analysis of the data: The mean and standard deviation were computed using Microsoft Excel. Biodiversity indices were assessed using Past Software (Hammer *et al*., 2001) [9]. Various metrics, including the Simpson Diversity Index dominance (D), Simpson Index of Diversity (1-D) (Simpson, 1949) [22], Shannon-Wiener Diversity Index (H) (Shannon and Weaver, 1949) [21], Pielou Evenness (J) and Margalef (d), were used to determine the structure of the waterbird community. The IUCN (2022-2) status was also used to compare the local and global status of the species. Birds were categorized into various feeding guilds according to their feeding habits, following Ali (2002) [2]. A checklist was created according to Manakadan and Pittie (2001) [14]. The residential status of species was classified as resident (R), found in all suitable habitats throughout the study period; migrant (M), found only during a specific season; and local migrant (LM), resident stragglers from the hills. The abundance status of birds was categorized into three categories: common (Com), seen on most visits; uncommon (Un-Com), seen on a few visits; and rare (Ra), seen once or twice (Palei *et al*., 2014) [18]. The average relative abundance was categorized as adopted by Bisht *et al*. (2004) [4]: UC = uncommon, with a relative abundance of less than 0.01; C = common, with a relative abundance of 0.01 and above but less than 0.05; and AB = very common, with a relative abundance of 0.05 and above.

$$Relative\ abundance = \frac{No\ of\ individuals\ of\ a\ species}{Total\ no\ of\ individuals\ of\ all\ species}$$

The findings were analyzed using one-way and two-way ANOVA, followed by Tukey´s test. (Mishra and Kumar, 2016) [13].

Results

Distribution of Species among the Study Sites: The distribution of bird species varied across all surveyed sites. This study reports on the status of freshwater avian fauna in different habitats of the Sardar Sarovar Reservoir (SSR) (Kasrawad H1, Rajghat H2, Pichhodi H3, and Bhawati H4) in Barwani, Madhya Pradesh, India. The study was conducted from March 2023 to June 2023, during the summer season. The study identified 29 species (928 individuals) across 24 genera belonging to 11 families and eight orders (Fig 4, Table 5). A checklist of recorded waterbird species, their abundance, relative abundance, feeding habitat, residential status, WPA status, and IUCN status, is provided in Table 1.

Residential and migratory status: The analysis of data on residential status revealed that out of 29 species, 12 were residents (R), followed by eight that were residential with local migration (R/LM), whereas the remaining nine were identified as winter visitors (WV), as shown in Table 1.

Relative Abundance: During the summer season, the abundance status of bird fauna in the four habitats indicated that seven species were abundant, nine were common, and 13 were uncommon (Table 1).

Feeding guild: The classification of observed species among feeding guilds revealed that the reservoirs supported water birds belonging to five dietary guilds. Carnivores were the dominant species, with eight individuals each, followed by insectivores (7), omnivores (6), fish eaters (6), and herbivores (1) (Table 1).

Species Diversity, Evenness, and Dominance Index: Diversity indices are reported in Table 2 and represented in Fig 4d. Simpson's Index of Diversity (1-D) was the highest in the Rajghat (H2) habitat (0.9315) and lowest in the Pichhodi (H3) habitat (0.8875). Similarly, the Shannon Diversity Index was the highest in the Rajghat (H2) habitat (3.21) and lowest in the Pichhodi (H3) habitat (2.82). The highest Margalef Species Richness (d) was recorded in the H2 habitat (d = 4.787), while the lowest was recorded in the H3 habitat (d = 2.17). In contrast, evenness was highest at the H3 site (0.9209) and lowest at the H2 site (0.8781). The means and standard deviations of the individuals of each species are listed in Table 1. One-way ANOVA revealed a significant value ($p > 0.05$) for months and species. Similarly, species and site also showed significant values ($p > 0.05$), according to the results of the two-way ANOVA. Details of the analysis are listed in Table 3 & Fig (4a.4b). Tukey's test compares the mean values of the two groups, A

(month) and B (site), as listed in Table 4 & Fig 4c. The IUCN data indicated that, in the present study, only one species was near threatened, while the remaining 28 species were of least concern. The WPA data showed that only one species fell under Schedule I, whereas the remaining 28 belonged to Schedule IV (Table 1).

Discussion

In Indian wetlands, 318 bird species have been recorded, of which 193 are fully dependent on wetlands (Bhandarkar and Paliwal, 2014) [3]. Water birds are considered excellent bioindicators and useful models for studying various environmental problems in wetlands (Mishra and Kumar 2016) [13]. Nearly 250 bird species are highly dependent on freshwater habitats, with approximately 62% belonging to the Anatidae family, which includes ducks, swans, and geese. Wading birds such as herons, plovers, and sandpipers are also associated with freshwater bodies (Keshre, 2019) [12]. Keshre (2019) [12] reported 29 bird species from the Tapti River in Burhanpur District (M.P.) belonging to seven different orders, with six species dominating the order Ciconiiformes. The maximum bird species were observed during spring, early monsoon, and late winter, while fewer species were seen during late summer, the rainy season, and early winter. During the present investigation, a total of 29 bird species were recorded in the different habitats of the Sardar Sarovar Reservoir (SSR) in Barwani, Madhya Pradesh, India. The order Pelecaniformes was the most dominant in the study area, with nine species (312 individuals), followed by Charadriiformes with five species (204 individuals). Other orders recorded include Gruiformes (127 individuals), Coraciiformes (70 individuals), Passeriformes (121 individuals), Suliformes (75 individuals), Anseriformes (14 individuals), and Ciconiiformes (5 individuals), comprising four, three, three, two, two, and one bird species, respectively. The most dominant family was Ardeidae, with six species (293 individuals), followed by Charadriidae (132 individuals) with three species, Rallidae (127 individuals) with four species, and Motacillidae (121 individuals) with three species. Other families recorded include Phalacrocoracidae (75 individuals), Alcedinidae (70 individuals), Recurvirostridae (69 individuals), Threskiornithidae (19 individuals), Anatidae (14 individuals), Ciconiidae (5 individuals), and Scolopacidae (3 individuals). Bhandarkar and Paliwal (2014) [3] also reported 52 bird species in the Shrungarbandh Lake District of Gondia, Maharashtra, India. The present study found that the highest number of birds was recorded in March, while the lowest number was recorded in May, due to the departure of winter visitors and the local migration of resident birds during the summer.

Wetland ecosystems are unique because of their migratory water birds, which link nations and continents and serve as excellent environmental indicators (Ramakrishnan *et al*., 2022) [19]. Throughout the study period, the number of birds varied monthly. Among the 29 species recorded, 12 were residents, eight were residents with local migration, and nine were winter visitors (Table 1). Similarly, Ramakrishnan *et al*. (2022) [19] reported 67 resident species and 20 winter migrants. The observed species were classified into five dietary guilds: carnivores (8), insectivores (7), omnivores (6), piscivores (6), and herbivores (1). The IUCN data showed that only one species was near threatened, whereas the rest were of the least concern. The near-threatened species is the Black-headed Ibis or Oriental White Ibis, a winter migratory water bird. The WPA data showed that one species falls under Schedule I, whereas the remaining species belong to Schedule IV. Biodiversity indicators depend on the population and number of species. The Simpson diversity index was highest at the H2 site (0.9315) and lowest in the H3 habitat (0.8875). The Shannon-Wiener Diversity index was highest in the H2 habitat (2.957) and lowest in the H3 habitat (2.288). The Margalef species richness was the highest in the H2 habitat (4.787) and the lowest in the H3 habitat (2.17). Evenness was highest in the H3 habitat (0.8215) and lowest in the H2 habitat (0.6632) (Table 3). The highest abundance of waterbird species was observed in the SSR H2 habitat (29 species), whereas the lowest number of species was found in the SSR H3 habitat (12 species). The highest individual number (146) of species was observed in the H2 habitat in March 2023 and the lowest individual number (21) was found in the H3 habitat in May 2023. Throughout the study period, SSR supported a consistent diversity of water birds, which can be attributed to the wide range of food options and neighboring farm areas that provide foraging grounds. The abundance of fish fauna in the reservoir may explain the dominance of carnivorous guilds. The low number of water birds in May may be due to high temperatures, low water levels, and agriculture-based activities in non-submerged areas. Because of geographical and environmental factors, bird populations may fluctuate as habitats change. In the present study, a sudden rise in water levels in June and a rapid increase in temperature in May led to a decline in species richness. The H2 habitat (Rajghat) was particularly ideal for bird species in March because of its moderate water volume, favorable temperatures, and food availability. The lowest number of migratory bird species was reported in March owing to the departure of winter visitors; May had the lowest number of birds in all habitats. During this period, water levels decreased, habitat coverage changed, and high temperatures made certain areas less suitable for birds. Factors such as the departure of winter visitors, local bird migration, habitat drying, and the onset of heavy rains during the monsoon season contributed to the low number of bird species in the summer. Bengani *et al*., (2007) discovered a similar pattern in Chimdilake, Nepal, and an overall analysis of the birds sighted over four months showed that the Indian pond heron was sighted most frequently (112), followed by the red-wattled lapwing (111), the little egret (110), and the white-breasted water heron (108). Other moderately sighted birds included white wagtails (85), little cormorants (73), black-winged stilts (69), and cattle egrets (44) Figs 1 & 2.

Table 1: Checklist of birds recorded in the Sardar Sarovar Reservoir with their residential, feeding guild, relative abundance, and conservation status.

Order	Family	scientific Name	Common Name or English Name	Authority	IUCN	WLPA Schedule	Feeding Guild	Residential Status	Census Mar-June	Mean±Sd	Relative Abundance	Abundance
1. Pelecaniformes	1. Ardeidae	Ardeola grayii	Indian Pond Heron	(Sykes, 1832)	LC	Sch-IV	CA	R	112	28±5.48	0.121	A
		Bubulcus ibis	Cattle Egret	(Linnaeus, 1758)	LC	Sch-IV	CA	R	44	11±2.16	0.047	C
		Egretta garzetta	Little Egret	(Linnaeus, 1766)	LC	Sch-IV	CA	R	110	27.5±6.19	0.119	A
		Ardea intermedia	Intermediate or Median Egret	(Wagler, 1829)	LC	Sch-IV	CA	R/LM	22	5.5±3.70	0.024	C
		Ardea alba	Great or Large Egret	(Linnaeus, 1758)	LC	Sch-IV	CA	WM	3	0.8±1.50	0.003	Un
		Nycticorax nycticorax	Black-crowned Night-Heron	(Linnaeus, 1758)	LC	Sch. IV	CA	R	2	0.5±1.00	0.002	Un
	2. Threskiornithidae	Pseudibis papillosa	Red Naped Ibis	(Temminck,1824)	LC	Sch-IV	OM	R/LM	13	3.3±2.87	0.014	C
		Threskiornis melanocephalus	Black-headed Ibis	(Latham, 1790)	NT	Sch-IV	CA	WM	5	1.3±2.50	0.005	Un
		Platalea leucorodia	Eurasian Spoonbill	(Linnaeus, 1758)	LC	Sch-I	PI	R/LM	1	0.3±0.50	0.001	Un
2.Suliformes	3.Phalacrocoracidae	Phalacrocorax fuscicollis	Indian Cormorant or Indian Shag	(Stephens, 1826)	LC	Sch. IV	PI	R/LM	2	0.5±1.00	0.002	Un
		Phalacrocorax niger	Little Cormorant	(Vieillot, 1817)	LC	Sch-IV	PI	R/LM	73	18.3±9.00	0.079	A
3.Passeriformes	4. Motacillidae	Motacillamaderaspatensis	White Browed Wagtail	(Gmelin, JF,1789)	LC	Sch-IV	IN	R	10	2.5±5.0	0.011	C
		Motacilla alba	White Wagtail (Black-backed)	(Linnaeus, 1758)	LC	Sch. IV	IN	R/LM	85	21.3±2.06	0.092	A
		Motacilla flava	Western yellow wagtail	(Linnaeus, 1758)	LC	Sch. IV	IN	R/LM	26	6.5±1.19	0.028	C
4 Gruiformes	5. Rallidae	Gallinula chloropus	Common Moorhen	(Linnaeus, 1758)	LC	Sch. IV	OM	R/LM	5	1.3±2.50	0.005	Un
		Porphyrio martinica	Purple Moorhen or swamphen	(Linnaeus, 1758)	LC	Sch. IV	OM	R	9	2.3±4.50	0.010	Un
		Amaurornis phoenicurus	White-breasted Waterhen	(Pennant, 1769)	LC	Sch. IV	OM	R	108	2.70±6.73	0.116	A
		Fulica atra	Eurasian or Common Coot	(Linnaeus, 1758)	LC	Sch. IV	OM	WM	5	1.3±1.50	0.005	Un
5.Coraciiformes	6. Alcedinidae	Alcedo atthis	Common Kingfisher	(Linnaeus, 1758)	LC	Sch. IV	PI	R	22	5.5±4.36	0.024	C
		Ceryle rudis	Pied Kingfisher	(Linnaeus, 1758)	LC	Sch. IV	PI	R	27	6.8±2.87	0.029	C
		Halcyon smyrnensis	White-throated Kingfisher	(Linnaeus, 1758)	LC	Sch. IV	PI	R	21	5.3±3.20	0.023	C
6. Ciconiiformes	7. Ciconiidae	Anastomus ascitans	Asian Open Bill Stork	(Boddaert, 1783)	LC	Sch. IV	CA	WM	5	1.3±2.50	0.005	Un
7.Charadriiformes	8. Scolopacidae	Tringa glareola	Wood Sandpiper	(Linnaeus, 1758)	LC	Sch-IV	IN	WM	3	0.8±1.50	0.003	Un
	9. Charadriidae	Vanellus indicus	Red-wattled Lapwing	(Boddaert, 1783)	LC	Sch-IV	OM	R	111	27.8±14.55	0.120	A
		Charadrius dubius	Little Ringed Plover	(Scopoli, 1786)	LC	Sch-IV	IN	WM	3	0.8±1.50	0.003	Un
		Vanellus malabaricus	Yellow-wattled Lapwing	(Boddaert, 1783)	LC	Sch-IV	IN	WM	18	4.5±1.91	0.019	C
	10.Recurvirostridae	Himantopus himantopus	Black- Winged Stilt	(Linnaeus, 1758)	LC	Sch-IV	IN	R	69	1.73±1.71	0.074	A
8.Anseriformes	11. Anatidae	Anas poecilorhyncha	Indian spot-billed duck	(Forster, 1781)	LC	Sch-IV	HR	WM	6	1.5±3.00	0.006	Un
		Dendrocygna javanica	Lesser Whistling-Duck	(Horsfield, 1821)	LC	Sch. IV	OM	WM	8	2.0±2.83	0.009	Un

Status: R- Resident, WM- Winter Migrant, R/LM- Resident with local movement; IUCN status: LC- Least Concern, NT- Near Threatened; WPA status: Sch-IV-schedules list IV, sch- I -schedules I list
Feeding guild: HR – Herbivore, PI- Piscivore, OM- omnivore, IN- Insectivore, CA- Carnivore; A- Abundance, Com- Common, and Un- Uncommon

Table 2: Biodiversity indices of waterbirds in Sardar Sarovar Reservoir.

Biodiversity indices	Rajghat	Kasrawad	Pichhodi	Bhawati
Species Richness	29	15	12	17
Individuals	347	208	159	214
Dominance_(D)	0.06846	0.09967	0.1125	0.09245
Simpson(1-D)	0.9315	0.9003	0.8875	0.9075
Shannon (H')	2.957	2.466	2.288	2.551
Evenness (e^H/S)	0.6632	0.785	0.8215	0.7541
Margalef (d)	4.787	2.623	2.17	2.982
Equitability (J')	0.8781	0.9106	0.9209	0.9004

Table 3: Statistical description of parameters obtained by non-parametric test One-way & two-way ANOVA between the different groups.

Groups	Df	Sum of sq	Mean Sq	F-value	p-value
One-way ANOVA					
Months	3	411.6	137.21	17.62	> 0.001 ***
Sites	3	10	3.324	0.362	NS
Species	28	1617	57.74	14.63	>0.001***
Two-way ANOVA					
Month vs Site	9	8.2	0.91	0.113	NS
Month vs Species	84	159.9	1.90	0.718	NS
Species vs Site	41	230.2	5.61	1.767	>0.01**

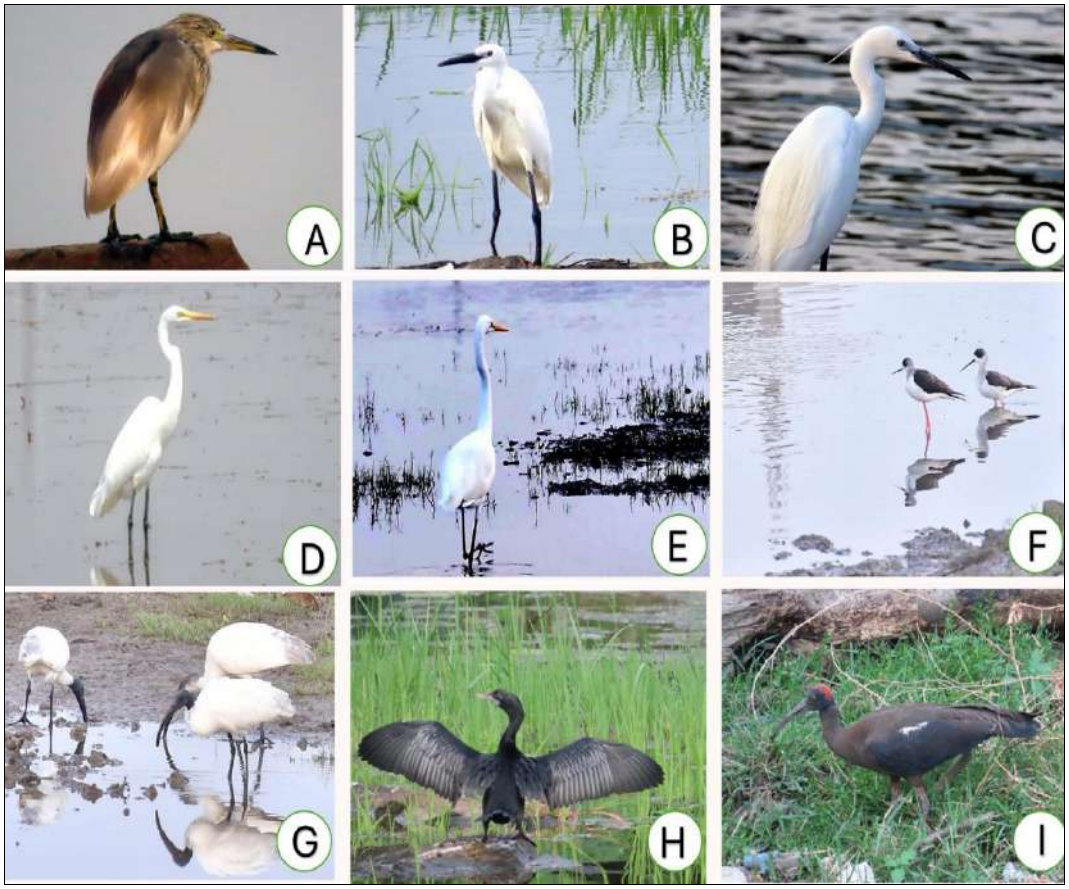
Table 4: Tukey´s Multiple Comparison Test among all groups. Tukey´s Multiple Comparison Test among all groups. Group A* Month, Group B*-Sites, Value * is significantly less than 0.05, **less than 0.01 and *** less than 0.001. Significant Code (p<0.05): 0 '***' 0.001 '**' 0.01 '*' 0.05, NS 'Not Significant.

Tukey's Multiple Comparison Test	Mean Diff.	Lower value	Upper value	Significant (p<0.05)	Summary
Group A *Month					
June-April	-0.3150685	-1.508753	0.8786156	0.9038711	NS
March-April	1.9589041	3.1525882	0.0001756	0.0001756	***
May-April	-1.3150685	-2.508753	-0.1213844	0.0243210	**
March-June	2.2739726	1.080289	3.4676567	0.0000086	***
May-June	-1.0000000	-2.193684	0.1936841	0.1356384	NS
May-March	-3.2739726	-4.467657	-2.0802885	0.0000000	***
Group B * Site					
Kasrawad-Bhawati	0.3196078	-1.067405	1.7066207	0.9333966	NS
Pichhodi-Bhawati	0.1654412	-1.310807	1.6416898	0.9915266	NS
Rajghat-Bhawati	-0.1556795	-1.351679	1.0403202	0.9868680	NS
Pichhodi-Kasrawad	-0.1541667	-1.670593	1.3622594	0.9936388	NS
Rajghat-Kasrawad	-0.4752874	-1.720540	0.7699648	0.7573799	NS
Rajghat-Pichhodi	-0.3211207	-1.665055	1.0228132	0.9264635	NS

Table 5: Family-wise Number of Individuals, Genera, and Species of Water Birds of Reservoir Sampling Stations from March 2023 to June 2023.

S. N	Family	Individual	Genera	Species
1	Ardeidae	293	5	6
2	Threskiornithidae	19	3	3
3	Phalacrocoracidae	75	1	2
4	Motacillidae	121	1	3
5	Rallidae	127	4	4
6	Alcedinidae	70	3	3
7	Ciconiidae	5	1	1
8	Scolopacidae	3	1	1
9	Charadriidae	132	2	3
10	Recurvirostridae	69	1	1
11	Anatidae	14	2	2
Total	11	928	24	29

Figures 1



Figures 2

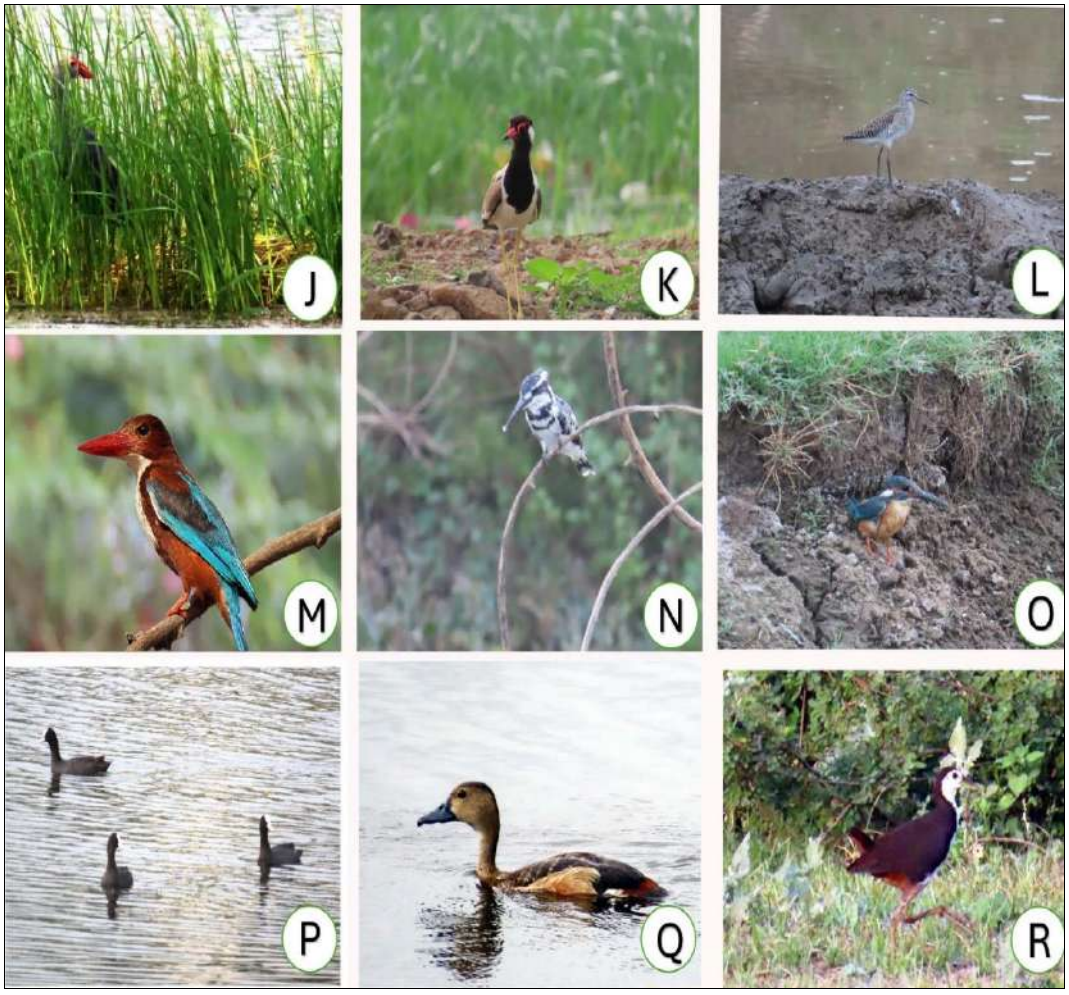


Figure 3

Figure 4a

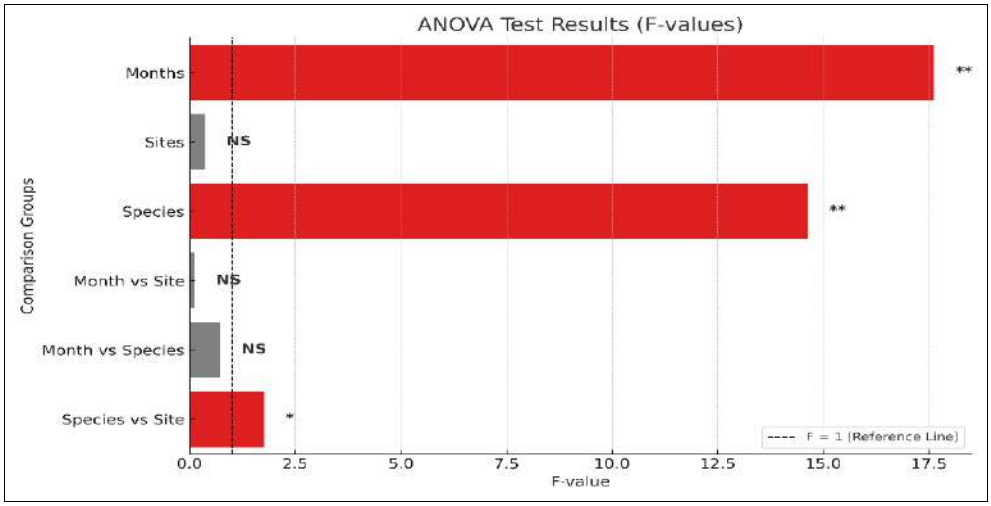


Figure 4b

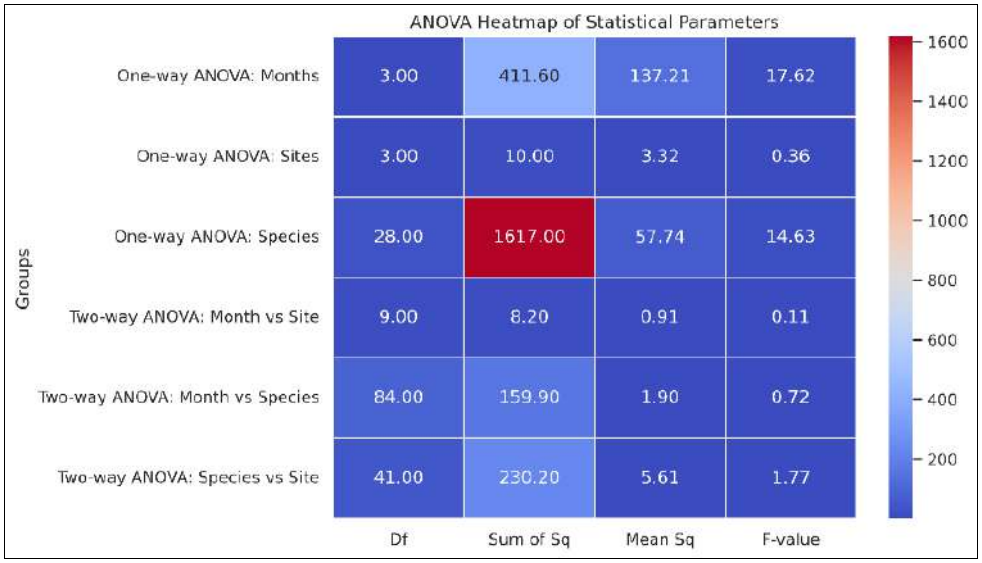


Figure 4c

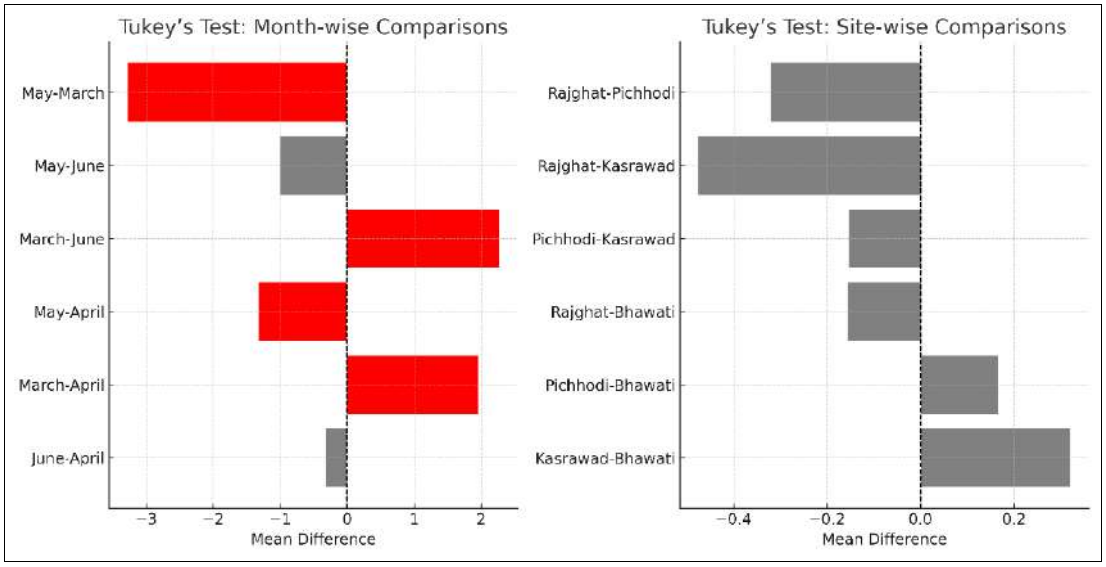


Figure 4d

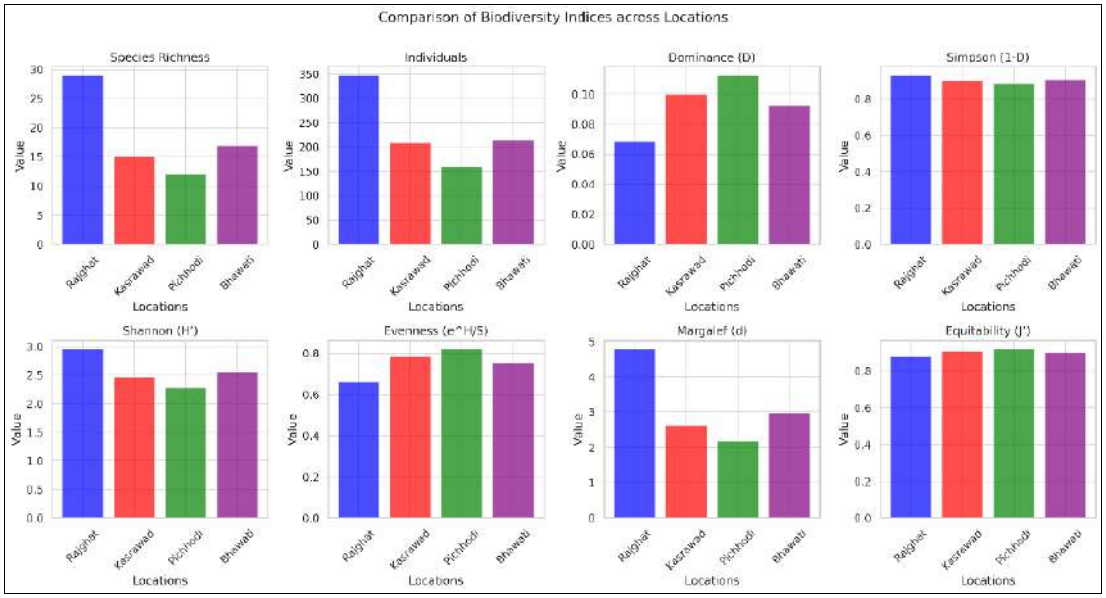


Figure 4e

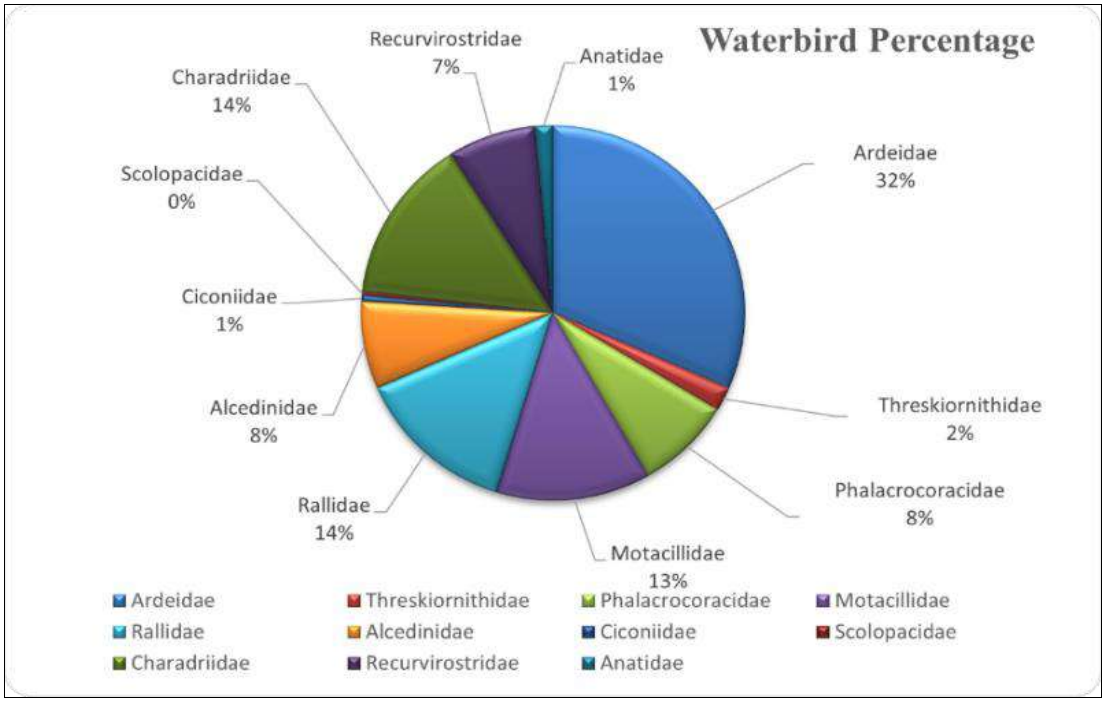


Figure legend

Figure 1

A. Indian Pond Heron, B. Cattle Egret, C. Little Egret, D. Intermediate Egret, E. Great Egret, F. Black-Winged Stilt, G. Black-headed Ibis, H. Little Cormorant, I. Red-napped Ibis

Figure 2.

J. Purple Moorhen, K. Red-wattled Lapwing, L. Wood Sandpiper, M. White-throated Kingfisher, N. Pied Kingfisher, O. Common Kingfisher, P. Common Coot, Q. Lesser Whistling-Duck, R. White-breasted Waterhen

Figure 3.

S. Western yellow wagtail, T. Asian Openbill Stork, U. Eurasian Spoonbill, V. White Wagtail (Black-backed), W. White Browed Wagtail, X. Common Moorhen, Y. Indian spot-billed duck, Z. Yellow-wattled Lapwing, a. Little Ringed Plover.

Figure 4.

4 (a) The bar plot visually represents the F-values from the ANOVA test for different groups and interactions. The highest F-values are observed for Months and Species, indicating strong temporal and species-related effects. Sites show no significant differences, while the interaction between Species and Sites is moderately substantial. The dashed vertical line at F = 1 marks the threshold for potential significance. Significance levels are indicated as *** ($p < 0.001$), ** ($p < 0.01$), * ($p < 0.05$), and NS (not significant). 4 (b) ANOVA heatmap visualizing statistical parameters. The heatmap visually represents the statistical parameters obtained from the One-Way and Two-Way ANOVA tests. Each row corresponds to a different ANOVA comparison, while the columns represent key statistical measures (Degrees of Freedom (Df), Sum of Squares, Mean Square, and F-value). The color intensity indicates the magnitude of these values, with darker shades representing higher values. 4 (c) The bar plot for Tukey's Multiple Comparison Test results: Left plot (Months Comparison): Red bars indicate significant differences ($p < 0.05$), while gray bars represent non-significant differences. Right plot (Sites Comparison): All comparisons are non-significant (gray bars), meaning no strong differences were observed between sites. Fig: 4 (d) Comparison of biodiversity indices across four locations (Rajghat, Kasrawad, Pichhodi, Bhawati), illustrating species richness, diversity, dominance, and evenness. The chart consists of eight bar plots, each representing a different biodiversity metric. The metrics displayed are: Species Richness - Rajghat has the highest species count, while Pichhodi has the lowest. Individuals - The number of individuals recorded is highest in Rajghat and lowest in Pichhodi. Dominance (D) - Higher values indicate dominance by a few species; Pichhodi has the highest dominance. Simpson Index (1-D) - Measures diversity; all locations show high values, with Rajghat leading slightly. Shannon Index (H') - Rajghat has the highest diversity, while Pichhodi has the lowest. Evenness (e^H/S) - Pichhodi has the highest evenness, meaning species are more equally distributed. Margalef Index (d) - Rajghat shows the highest species richness index. Equitability (J') - Similar across locations, indicating a relatively even distribution of species. 4. (e) Family-wise percentage composition of waterbirds. The Pie chart illustrates the percentage distribution of different waterbird families, with Ardeidae being the most prevalent (32%) and Scolopacidae being the least (0%).

Conclusion

This study investigated the biodiversity of water birds in the Sardar Sarovar Reservoir in Barwani District, West Nimar, emphasizing the importance of these sites for conservation. Reservoirs and the surrounding wetlands attract numerous migratory birds and offer favorable habitats. The collected data helped to understand bird populations, migration patterns, and distributions. This study highlighted the ecological value of reservoirs as feeding grounds for migratory and resident bird species. This study, conducted from March 2023 to June 2023, identified 29 species across eight orders, 24 genera, and 14 families. The dominant family was Ardeidae, followed by Charadriidae and Rallidae. Pelecaniformes was the most prominent order, with nine species. Birds were classified into five dietary guilds, with carnivores being the most dominant. Among the 29 species, 12 were residents, 13 were residents of local migration, and three were designated as winter visitors. The study found that 28 identified species were of least concern, while one was near threatened. The highest number of individuals was observed in the H2 habitat (347) and the lowest in the H3 habitat (159). Data analysis using one- and two-way ANOVA revealed significant H2 and H3 habitat results.

Tukey's Multiple Comparison Test was conducted to evaluate statistical differences among groups in Group A (Months) and Group B (Sites). The reason for highly significant differences in month-wise comparisons but no significant differences in site-wise comparisons could be due to several factors: Temporal Variability (Month-wise Differences) The significant differences among months indicate that the measured variable (e.g., water quality, crop yield, temperature, etc.) varies significantly over time. Possible reasons for strong monthly differences: Seasonal changes (e.g., rainfall, temperature fluctuations). Environmental conditions affect the variable being measured. Agricultural or industrial activities that vary by season. Biological cycles, such as plant growth or aquatic ecosystem dynamics. Spatial Uniformity (Site-wise Similarities) The lack of significant differences between sites suggests that the measured variable does not change much across different locations. Possible reasons for no significant site-wise variation: Similar environmental conditions across sites (e.g., same river system, same soil type).

The habitats used by birds are crucial for their survival, and any loss or degradation can negatively affect their populations. The study concluded that the abundance of bird species depends on food availability and habitat suitability. Improving habitat coverage and implementing appropriate management programs can increase the number of resident bird species and attract more migratory and vagrant species. This study was brief, and more intensive research is needed to identify and record additional bird species. This research aims to provide information on the biodiversity of waterbirds, recognizing the site as a globally important habitat for bird conservation. Ongoing research is expected to increase the number of documented bird species.

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Conflict of interest
The authors have no competing interests to declare.

Abbreviations: SSR- Sardar Sarovar Reservoir, H- Habitat, WPA- Wildlife Protection Act, IUCN- International Union for Conservation of Nature.

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