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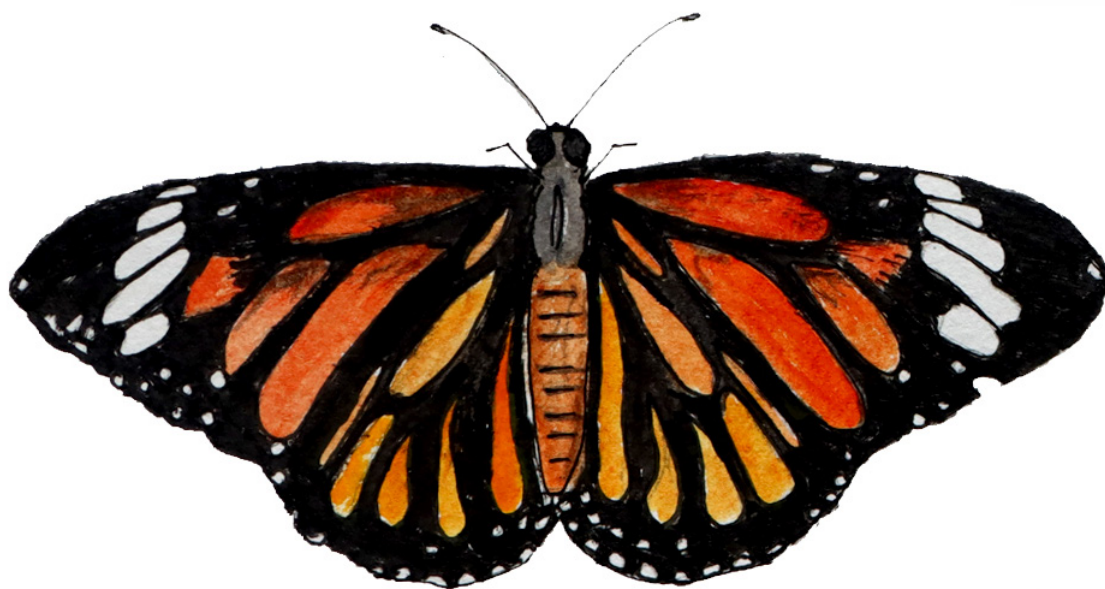
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Cover: Watercolour illustrations—Striped Tiger *Danaus genutia*, Common Silverline *Cigaritis vulcanus*, Tamil Lacewing *Cethosia mahratta*. © Mayur Nandikar.



Seasonal changes in waterbird assemblages in Chambal River at Mukundra Hills National Park, Rajasthan, India

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Abstract: The seasonal pattern of species diversity and abundance of waterbirds of the Chambal River in the extent of Mukundra Hills National Park, Rajasthan, India was evaluated. The pre-monsoon (March–April 2021) and post-monsoon surveys (August–September 2021) were carried out using the direct count method with the help of a motorboat to monitor the population status of waterbirds. A total of 44 species of waterbirds belonging to 15 families and nine orders were identified, including 11 winter migratory species. Forty species of birds were recorded during pre-monsoon and 27 species during post-monsoon seasons. The species richness and relative abundance varied significantly between observed seasons ($\chi^2 = 532.77$, $df = 43$, $p < 0.05$). Breeding activities of three species were recorded, namely, Grey Heron, Black-crowned Night Heron, and the 'Near Threatened' Woolly-necked Stork. The present study reveals the status of waterbirds in the protected area of Mukundra Hills National Park.

Keywords: Avifauna, Central Asian Flyway, Heronry, migratory birds, pre and post-monsoon, seasonal patterns, species richness.

Abbreviations: IUCN—International Union for Conservation of Nature | CAF—Central Asian Flyway.

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INTRODUCTION

The biodiversity assessment is a crucial component of conservation and is most often used to evaluate the importance of indigenous biodiversity values at one site compared with others (Usher 1986). The diversity of significant megafauna in a particular habitat is also widely used for assessing a riverine ecosystem. It includes major vertebrates like fishes, reptiles, waterbirds, and aquatic mammals. Freshwater fishes and waterbirds are by far the best-studied groups of freshwater habitats; sometimes, they are used as an indicator of ecosystem health (Revenga et al. 2005). Wetland ecosystems are generally considered to be one of the most productive as well as fragile ecosystems. The waterbirds are considered significant biological indicators of the health of these ecosystems. Globally, 871 species of waterbirds have been identified so far (Gopi & Hussain 2014).

Wetland biodiversity strongly depends on the quality, quantity, and local water cycle (van der Valk 2006). The hydroperiod may substantially impact species sorting and assemblage; thus, local variation in the hydrological pattern may constitute an important predictor of species composition (Urban 2004; Brönmark & Hansson 2005). The abundance and diversity of wetland birds show a strong relationship with seasons, the maximum turnover of bird density, diversity, and species richness observed in migratory seasons (Nagarajan & Thiyagesan 1996; Khan 2010; Pandiyan et al. 2010).

India covers a wide range of wetland habitats known to support the occurrence of over 240 species of waterbirds, except for 33 vagrant waterbirds (Gopi & Hussain 2014). Of the 243 species, 114 are migratory, and among them, two are summer visitors, four are local visitors, and 108 are winter visitors. Forty-four species of waterbirds are threatened as per the IUCN Red List 2014 (Gopi & Hussain 2014). Regarding Indian states, around 485 species of birds have been reported in Rajasthan (eBird 2021). Some of the studies on waterbirds in different parts of India are Kumar et al. (2007), Khan (2010), Mazumdar (2019), and Kar & Debata (2019). However, the information on seasonal variation in waterbird assemblage in riverine habitats is inadequate from wetlands of semi-arid regions. Systematic studies on the diversity and abundance of the waterbirds of the Chambal River in Mukundra Hills National Park are lacking. In order to evaluate one of the important rivers in a semi-arid region, the present study was undertaken to assess the seasonal status of waterbird assemblages in the Chambal River between Kota Barrage and Jawahar Sagar Dam, Rajasthan, India.

Study Area

The study area encompassed a total stretch of 30 km of the Chambal River upstream from Kota Barrage to Jawahar Sagar Dam, a part of Mukundra Hills National Park (25.176–25.037 °N and 75.825–75.678 °E; Figure 1). The most extended and only perennial river of Rajasthan state, the Chambal River originates from the southern slopes of Madhya Pradesh and flows through Rajasthan in the northeast direction covering a total distance of 960 km before joining to Yamuna River in Uttar Pradesh. Nearly 24% of the river course falls within Rajasthan and sprays over seven districts, mainly over southeastern districts embracing Kota, Baran, Jhalawar, and Bundi, called the 'Hadoti region'. The study site of Mukundra Hills National Park is an evenly topped and virtually parallel hill with a narrow central elevation. It has a subtropical climate with a wide array of temperatures (7–43°C) and rainfall (4–225 mm) throughout the year (IMD 2021). The vegetation consists of a ravine thorn forest, a subtype of the northern tropical forests (Champion & Seth 1968). The gorges of Chambal River, with an average width of 220 m and an elevation of about 850 m, are life ground to various bird species, including waterbirds, vultures, and other raptors.

MATERIALS AND METHODS

The study was carried out during the months of March–April and August–September 2021, largely classified into pre-monsoon and post-monsoon seasons, respectively. To understand the spatial status of waterbird assemblages, the total study stretch was divided into five equal segments of 5 km in length (Figure 1). Each segment was surveyed twice in a season and waterbird counts were made by direct count method with the help of a slow-moving motorboat (with an average speed of 5 kmph) (Weller 1999). During the survey, we observed birds on either side of the river banks/ riparian strips using binoculars (Hawke Nature Trek 8 × 42 mm & Nikon 8 × 40). To maximize the detection, surveys were conducted during the hours of peak activity of birds, i.e., 0630–1030 h and 1500–1730 h. Waterbirds were identified upto species level using standard field guides (Ali & Ripley 1987; Grimmett et al. 2016).

The residential/ migratory status of waterbirds was extracted from available literature (Ali & Ripley 1987; Grimmett et al. 2016). The checklist of Indian birds to obtain common and scientific names of waterbirds was followed (Praveen et al. 2021). We assigned the global conservation status of recorded waterbirds based

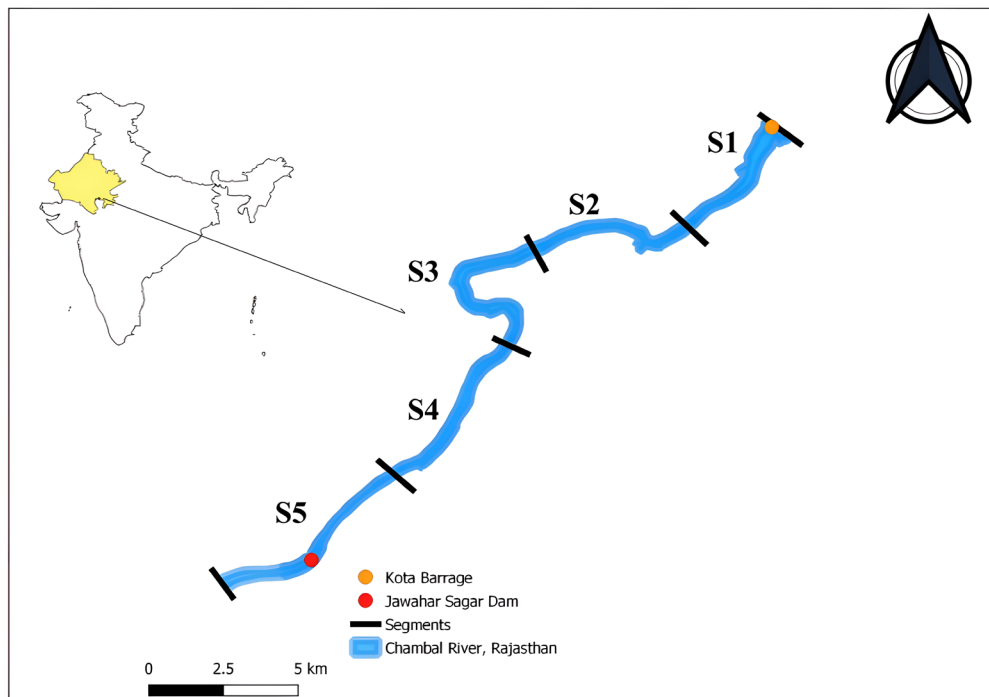


Figure 1. Study area of Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan (S1 to S5-denotes the sampling segments one to five).

on the IUCN Red List assessments (IUCN 2021). The Shannon diversity index (H), dominance index (D), and evenness index were calculated to evaluate the diversity trend between studied seasons. We also performed a chi-square test (χ^2) to evaluate species richness and abundance variances between the seasons. Based on the abundance of different species, a hierarchical clustering using a single linkage algorithm and Bray–Curtis similarity index was prepared to find the rescaled (dis)similarity in species richness between studied river segments. All statistical analyses were done using the software PAST version 4.03 (Hammer et al. 2001). Relative species abundance (RA) of families was calculated using the following formula as per Torre-Cuadros et al. (2007).

$$RA = N_i / N_t \times 100$$

N_i is the number of species in a family and N_t is the total number of species.

RESULTS

The present study recorded a total of 44 species of waterbirds belonging to 15 families and nine orders. The checklist of waterbirds recorded in the study area is presented in Table 1. Among the species, the order Pelecaniformes was well noticed and represented by two families and 14 species (Table 1). Similarly, the

family Ardeidae belonging to the Pelicaniformes order was the most dominating family, with a maximum of twelve species. In each, only one species represented families like Anhingidae, Ciconidae, Podicipedidae, and Recurvirostridae.

The highest overall species richness was observed during the pre-monsoon season ($S = 44$), with a high number at river segment one (32 species). At the same time, low species richness was observed during the post-monsoon season, where only 27 species were recorded (Table 2). The species richness of waterbirds varied considerably between the seasons. Orders Pelecaniformes and Charadriiformes were encountered more in pre-monsoon with 12 and 10 species, respectively. The post-monsoon also shows the same trend with nine species in Pelecaniformes and six species in Charadriiformes (Figure 3). The total number of individuals of waterbirds observed in pre-monsoon (Number of Individuals $N = 1233$) was much higher than the post-monsoon ($N = 336$) ($\chi^2 = 532.77$, $df = 43$, $p < 0.05$). The Shannon index was highest in segment one during post-monsoon ($H = 2.44$) and least in segment five ($H = 1.62$). The segment-wise information on waterbird assemblages covering pre-monsoon and post-monsoon seasons is given in Table 2.

In the pre-monsoon, segment-wise waterbird abundance ranged from 61 to 594 individuals (Table 2),

Table 1. Checklist of waterbirds recorded in Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Common name	Zoological name	IUCN Red List status	Residential status	Feeding guild	Relative abundance (%)		
					Pre-monsoon	Post-monsoon	Overall
Order: Coraciiformes							
Family: Alcedinidae							
Common Kingfisher	<i>Alcedo atthis</i> (Linnaeus, 1758)	LC	R	CA	1.54	-	1.21
Pied Kingfisher	<i>Ceryle rudis</i> (Linnaeus, 1758)	LC	R	CA	0.16	-	0.13
Stork-billed Kingfisher	<i>Pelargopsis capensis</i> (Linnaeus, 1766)	LC	R	CA	0.08	0.6	0.19
White-throated Kingfisher	<i>Halcyon smyrnensis</i> (Linnaeus, 1758)	LC	R	CA	4.06	19.05	7.27
Order: Anseriformes							
Family: Anatidae							
Garganey	<i>Spatula querquedula</i> (Linnaeus, 1758)	LC	WM	OM	0.32	5.06	1.34
Lesser Whistling Duck	<i>Dendrocygna javanica</i> (Horsfield, 1821)	LC	R	HE	-	1.49	0.32
Ruddy Shelduck	<i>Tadorna ferruginea</i> (Pallas, 1764)	LC	WM	OM	0.16	-	0.13
Indian Spot-billed Duck	<i>Anas poecilorhyncha</i> (Forster, 1781)	LC	R	HE	0.16	-	0.13
Tufted Duck	<i>Aythya fuligula</i> (Linnaeus, 1758)	LC	WM	OM	0.08	-	0.06
Order: Suliformes							
Family: Anhingidae							
Oriental Darter	<i>Anhinga melanogaster</i> (Pennant, 1769)	NT	R	PI	0.32	0.3	0.32
Family: Phalacrocoracidae							
Great Cormorant	<i>Phalacrocorax carbo</i> (Linnaeus, 1758)	LC	R	PI	0.65	-	0.51
Indian Cormorant	<i>Phalacrocorax fuscicollis</i> (Stephens, 1826)	LC	R	PI	22.3	0.89	17.72
Little Cormorant	<i>Microcarbo niger</i> (Vieillot, 1817)	LC	R	PI	23.28	6.85	19.76
Order: Pelecaniformes							
Family: Ardeidae							
Intermediate Egret	<i>Ardea intermedia</i> (Wagler, 1829)	LC	R	CA	0.08	-	0.06
Indian Pond Heron	<i>Ardeola grayii</i> (Sykes, 1832)	LC	R	CA	2.51	3.27	2.68
Black-crowned Night Heron	<i>Nycticorax nycticorax</i> (Linnaeus, 1758)	LC	R	CA	1.3	3.27	1.72
Cattle Egret	<i>Bubulcus ibis</i> (Linnaeus, 1758)	LC	R	CA	3	0.3	2.42
Great Egret	<i>Ardea alba</i> (Linnaeus, 1758)	LC	R	CA	1.05	0.6	0.96
Grey Heron	<i>Ardea cinerea</i> (Linnaeus, 1758)	LC	R	CA	8.19	11.9	8.99
Little Egret	<i>Egretta garzetta</i> (Linnaeus, 1766)	LC	R	CA	1.22	-	0.96
Purple Heron	<i>Ardea purpurea</i> (Linnaeus, 1766)	LC	R	CA	1.62	2.38	1.78
Striated Heron	<i>Butorides striata</i> (Linnaeus, 1758)	LC	R	CA	0.32	-	0.25
Black Bittern	<i>Ixobrychus flavicollis</i> (Latham, 1790)	LC	R	CA	-	0.3	0.06
Cinnamon Bittern	<i>Ixobrychus cinnamomeus</i> (J.F. Gmelin, 1789)	LC	R	CA	-	0.3	0.06
Yellow Bittern	<i>Ixobrychus sinensis</i> (Gmelin, 1789)	LC	R	CA	0.16	0.3	0.19
Family: Threskiornithidae							
Black-headed Ibis	<i>Threskiornis melanocephalus</i> (Latham, 1790)	NT	R	CA	0.65	-	0.51
Red-naped Ibis	<i>Pseudibis papillosa</i> (Temminck, 1824)	LC	R	CA	0.08	-	0.06
Order: Charadriiformes							
Family: Charadriidae							
Red-wattled Lapwing	<i>Vanellus indicus</i> (Boddaert, 1783)	LC	R	IN	12.08	3.87	10.33

Common name	Zoological name	IUCN Red List status	Residential status	Feeding guild	Relative abundance (%)		
					Pre-monsoon	Post-monsoon	Overall
Family: Jacanidae							
Bronze-winged Jacana	<i>Metopidius indicus</i> (Latham, 1790)	LC	R	HE	1.05	0.6	0.96
Family: Laridae							
River Tern	<i>Sterna aurantia</i> (Gray, 1831)	NT	R	PI	3.57	19.94	7.07
Whiskered Tern	<i>Chlidonias hybrida</i> (Pallas, 1811)	LC	R	CA	0.89	1.79	1.08
Lesser Black-backed Gull	<i>Larus fuscus</i> (Linnaeus, 1758)	LC	WM	CA	0.32	-	0.25
Pallas's Gull	<i>Ichthyaetus ichthyaeus</i> (Pallas, 1773)	LC	WM	PI	0.16	-	0.13
Family: Scolopacidae							
Common Sandpiper	<i>Actitis hypoleucos</i> (Linnaeus, 1758)	LC	WM	IN	0.08	2.68	0.64
Green Sandpiper	<i>Tringa ochropus</i> (Linnaeus, 1758)	LC	WM	IN	0.32	-	0.25
Wood Sandpiper	<i>Tringa glareola</i> (Linnaeus, 1758)	LC	WM	IN	0.32	-	0.25
Famil: Recurvirostridae							
Black-winged Stilt	<i>Himantopus himantopus</i> (Linnaeus, 1758)	LC	WM	CA	2.27	0.3	1.85
Order: Gruiformes							
Family: Rallidae							
Common Moorhen	<i>Gallinula chloropus</i> (Linnaeus, 1758)	LC	R	OM	0.24	-	0.19
White-breasted Waterhen	<i>Amaurornis phoenicurus</i> (Pennant, 1769)	LC	R	OM	3.81	3.87	3.82
Baillon's Crake	<i>Zapornia pusilla</i> (Pallas, 1776)	LC	WM	IN	0.16	-	0.13
Order: Passeriformes							
Family: Motacillidae							
Grey Wagtail	<i>Motacilla cinerea</i> (Tunstall, 1771)	LC	WM	IN	-	0.3	0.06
White-browed Wagtail	<i>Motacilla maderaspatensis</i> (Gmelin, 1789)	LC	R	IN	1.05	2.98	1.47
Order: Ciconiiformes							
Family: Ciconiidae							
Woolly-necked Stork	<i>Ciconia episcopus</i> (Boddaert, 1783)	VU	R	CA	0.24	6.55	1.59
Order: Podicipediformes							
Family: Podicipedidae							
Little Grebe	<i>Tachybaptus ruficollis</i> (Pallas, 1764)	LC	R	IN	0.08	0.3	0.13

NT—Near Threatened | VU—Vulnerable | LC—Least Concern | R—Resident | WM—Winter Migrant | CA—Carnivore | IN—Insectivore | OM—Omnivore | PI—Piscivore | HE—Herbivore.

with an average of $246.6 \leq 1.60$ ($\leq z$ value). In the case of post-monsoon, waterbird abundance was reduced to 336 individuals with an average of $67.2 \leq 1.69$ ($\leq z$ value). Similarly, the bird species composition also varied between the seasons. Darters and Cormorants were most abundant during pre-monsoon and constituted about 50% of the total pre-monsoon population (Figure 2). Next, egrets, herons, and bitterns populations dominated in the waterbird assemblage; they occupied 22.87% of the population ($N = 188$). In the post-monsoon season, Egrets, Herons, Kingfishers, Terns and Gulls were almost equal in abundance (Figure 2). Little Cormorant

Microcarbo niger and Indian Cormorant *Phalacrocorax fuscicollis* were dominant in overall abundance with 19.76% and 17.72%, respectively. Among the 44 species observed, 33 were residents, and 11 were winter migrants (Table 1). Most of the winter migrants belong to the order Charadriiformes, including species such as the Common Sandpiper *Actitis hypoleucos*, Green Sandpiper *Tringa ochropus*, Wood Sandpiper *Tringa glareola*, and Pallas's Gull *Ichthyaetus ichthyaeus*. Four out of the 44 species recorded in the study area are globally threatened (Table 1). Among these, three species are listed as Near-threatened (NT) and one

Table 2. Season wise diversity of waterbirds recorded in Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Segment	Season	Species richness (D)	Abundance (N)	Shannon index (H)	Dominance (D)	Evenness (J)
S1	Pre-monsoon	32	594	2.15	0.24	0.26
	Post-monsoon	19	100	2.44	0.12	0.60
S2	Pre-monsoon	16	237	2.02	0.20	0.47
	Post-monsoon	14	62	2.23	0.13	0.72
S3	Pre-monsoon	13	156	1.84	0.23	0.48
	Post-monsoon	11	56	1.96	0.18	0.64
S4	Pre-monsoon	11	185	1.85	0.18	0.58
	Post-monsoon	12	71	1.96	0.18	0.59
S5	Pre-monsoon	15	61	2.15	0.18	0.57
	Post-monsoon	9	46	1.62	0.28	0.56
Overall	Pre-monsoon	40	1233	2.52	0.13	0.31
	Post-monsoon	27	336	2.56	0.11	0.49

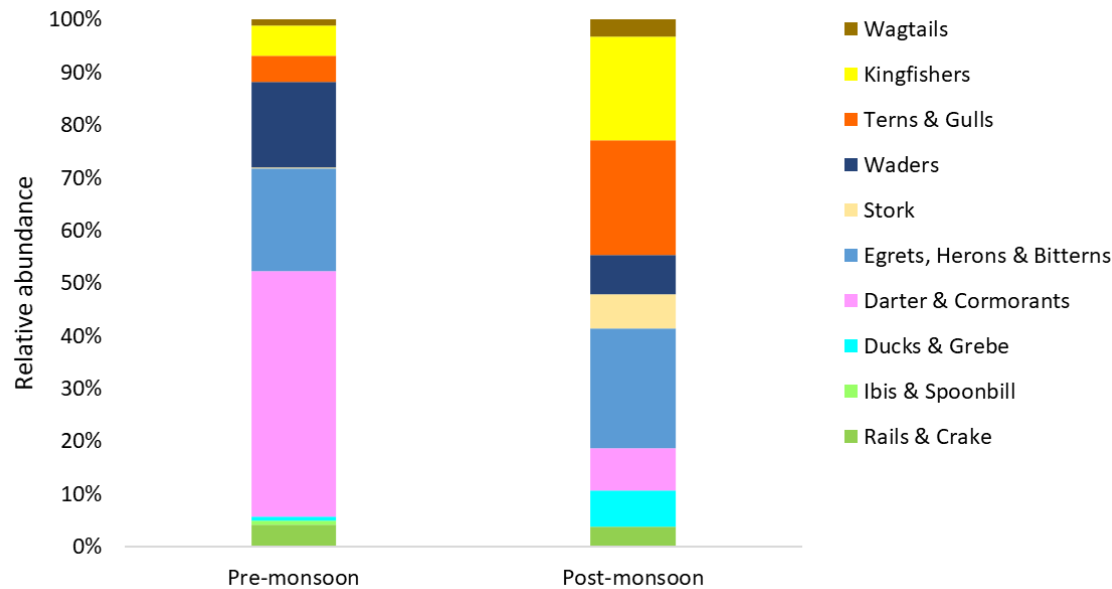


Figure 2. Seasonal variation in the composition of waterbirds in Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

species as Vulnerable (VU) according to the IUCN Red List assessments (IUCN 2021).

The dendrogram analysis results showed differences in species composition between segments (Figure 4). The dendrogram produced three distinct clusters: one containing segment one, another containing segment five, and a third combining segments two, three, and four. There was a distinct variation in species composition between clusters one and two, indicating that segments two, three, and four had different species compositions. High dissimilarities in species assemblages between segments one and five led to their segregation into

separate clusters. Segments three and four, showing the highest similarity in species composition, were grouped together in a single cluster (Figure 4).

DISCUSSION

It is a well-known fact that the Chambal River serves as one of the best over-wintering sites for migratory birds (Nair & Krishna 2013). Our surveys revealed that the Chambal River gorge provides a potential nesting site for three important waterbirds, including the

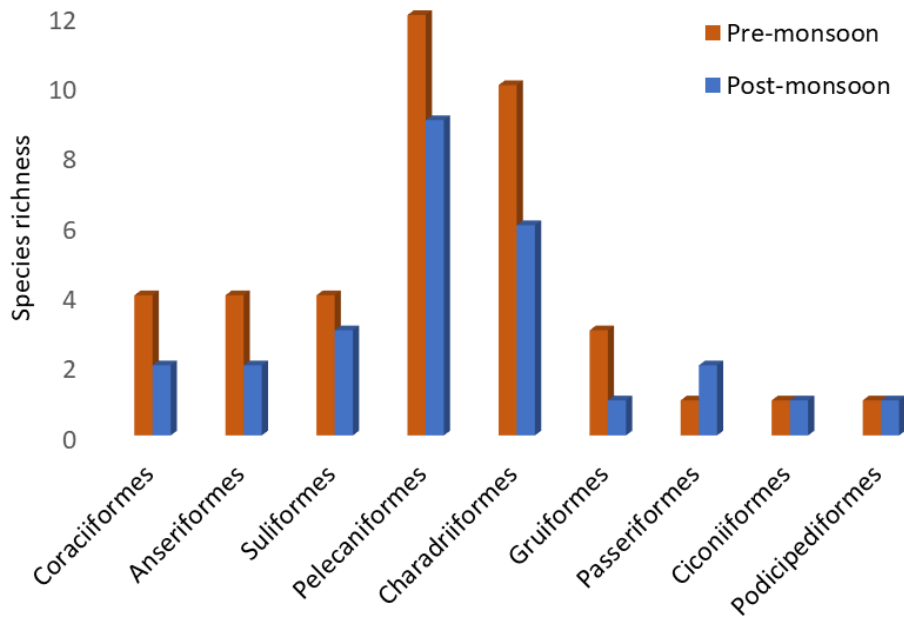


Figure 3. Occurrence of order-wise species richness of waterbirds in the study area.

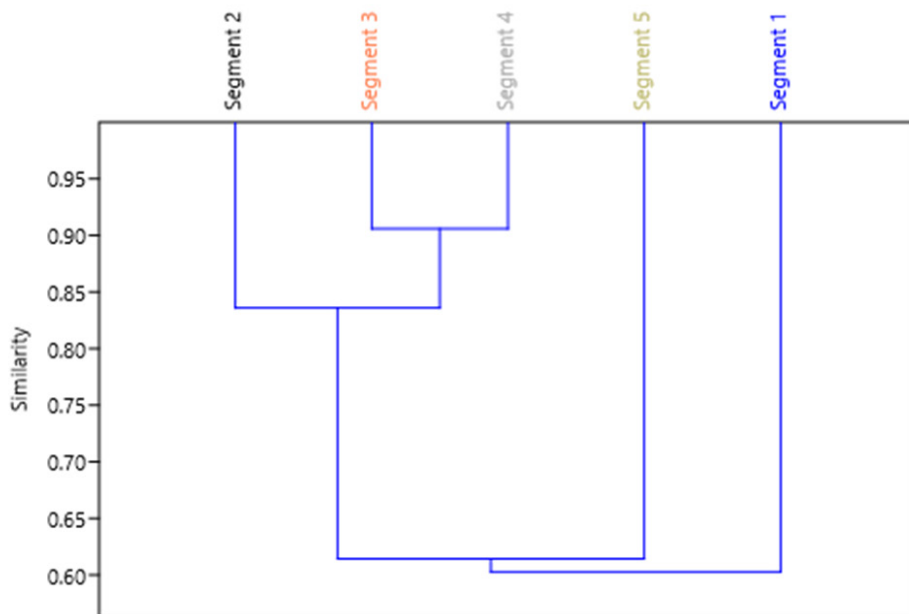


Figure 4: Dendrogram showing dissimilarity in waterbird species richness and composition between studied river segments in the Chambal River between Kota barrage and Jawagar Sagar Dam, Rajasthan.

threatened Woolly-necked Stork *Ciconia episcopus*. Grey Heron *Ardea cinerea* and Black-crowned Night Heron *Nycticorax nycticorax* are the other two species observed with the nests.

It was observed that resident species dominate the bird community, similar to that of earlier studies reported from different parts of India (Verma 2008;

Nair & Krishna 2013; Kar & Debata 2019). In the present study, 33 resident waterbirds, constituting about 75% of the total recorded species from the study area were recorded. The remaining 25% were winter migrants. Generally, food availability, water levels, and habitat diversity are the essential factors determining the abundance and distribution of waterbirds (Saygili et



Image 1. Purple Heron. © Arun George.



Image 2. Baillon's Crake. © Arun George.



Image 3. Black-winged Stilt. © Arun George.



Image 4. River Tern. © Arun George.

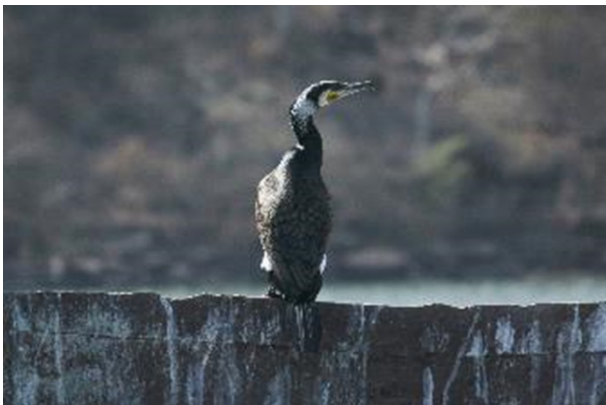


Image 5. Great Cormorant. © Arun George.



Image 6. Common Moorhen. © Arun George.

al. 2011). Earlier studies have found that the Chambal River inhabits highly diverse fish fauna (Sivakumar & Choudhury 2008; Meshram 2010; Nair & Krishna 2013), which may be one of the reasons for the congregation of residents as well as wintering waterbirds.

The species richness, diversity, and abundance of waterbirds in the study area varied seasonally, and it

may be due to the movement pattern of long-distance migrants during winter and local migrants during summer. The Central Asian Flyway (CAF) is one of nine global waterbird flyways, where India serves as a destination for nearly 71% of the CAF's migratory waterbirds (Kumar 2019). Maintaining the health of Indian wetlands is thus critical for the survival of waterbird populations along



Image 7. Bronze-winged Jacana. © Arun George.



Image 8. Grey Heron. © Arun George.



Image 9. Great Egret. © Arun George.



Image 10. Indian Cormorant. © Arun George.



Image 11. White-browed Wagtail. © Arun George.



Image 12. Little Egret. © Arun George.

the Flyway. In India, the arrival of waterbirds occurs in October, and departure takes place in March (Kar & Debata 2019). Thus, the high species richness and abundance of the waterbirds encountered during pre-monsoon account for migrant waterbirds in the study area. Though the survey season was at the temporal end

of winter, few winter migratory species were observed during the surveys. Most wetlands usually dry during high temperatures, and resident waterbirds typically move to appropriate permanent water habitats (Balachandran et al. 2009). This might be the reason for the increase in the abundance of darters and cormorants in pre-monsoon.



Image 13. Lesser Whistling Duck. © Arun George.



Image 14. White-throated Kingfisher. © Arun George.



Image 15. Cinnamon Bittern. © Arun George.



Image 16. Red-wattled Lapwing. © Arun George.



Image 17. Black-crowned Night Heron. © Arun George.



Image 18. Indian Pond Heron. © Arun George.

The increase in local abundance of some resident birds, which possibly have migrated from nearby dried-up wetlands, was observed by Kar & Debata (2019). During the post-season, resident waterbirds are much more widely distributed due to the availability of wetland habitats and food resources (Kar & Debata 2019). Thus,

this might be the reason for the lowest species richness encountered in the study area in post-monsoon.

About 65.58% of the total waterbird species in the present study, as reported in earlier studies were recorded. Previous long-term studies by Verma (2008) reported 61 species, from the entire Rajasthan state. Vyas



Image 19. Common Sandpiper. © Arun George.



Image 20. Red-naped Ibis. © Arun George.



Image 21. Little Cormorant. © Arun George.



Image 22. Striated Heron. © Arun George.



Image 23. Woolly-necked Stork. © Arun George.



Image 24. Black Bittern. © Arun George.

(2006) studied the heronries of the Kota district alone and recorded 829 nests. Cattle Egrets and Cormorants were the most abundant species in his heronry study. Apart from these, we also witnessed the breeding activities of Grey Heron *Ardea cinerea*, Black-crowned Night Heron *Nycticorax nycticorax*, and Woolly-necked Stork *Ciconia*

episcopus in the study area. A total of 36 nests of Herons and five nests of Storks were observed in the Chambal River at Mukundra Hills National Park. Compared to an earlier study by Vyas (2006), the breeding activities of the Woolly-necked Stork, Grey Heron, and Night Heron are new additions to the heronries information

of the Kota district, Rajasthan. A recent study by Koli et al. (2019) observed the nesting association of Black-headed Ibis with some other waterbirds, whereas it was observed that the nesting activity of Herons and Stork was independent of each other.

From the study, it can be inferred that the Chambal River stretch flowing through the Mukundra Hills National Park is a potential congregation site for resident waterbirds in pre-monsoon. Moreover, the area supported the breeding of some resident waterbirds, including the 'Near Threatened' Woolly-necked Stork *Ciconia episcopus*. In the present study, we also recorded some of the migratory waterbirds. Though the study area falls under the well-protected stretch of the Chambal River, some levels of human disturbance were observed in the study area, such as illegal fishing and noise pollution from residents, which may potentially disturb the residing and migrant waterbirds. In addition, abandoned fishing nets and lines threaten the Chambal River bird community, specifically diving waterbirds. Thus, sensitizing the local community towards conserving waterbirds and their habitat is essential for the long-term conservation of waterbirds in the Chambal River.

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