

RAPID ASSESSMENT REPORT

STATUS OF  
WILDLIFE BETWEEN

KOTA BARRAGE

AND

JAWAHAR SAGAR DAM

RAJASTHAN



भारतीय वन्यजीव संस्थान  
Wildlife Institute of India



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JAWAHAR SAGAR DAM, RAJASTHAN

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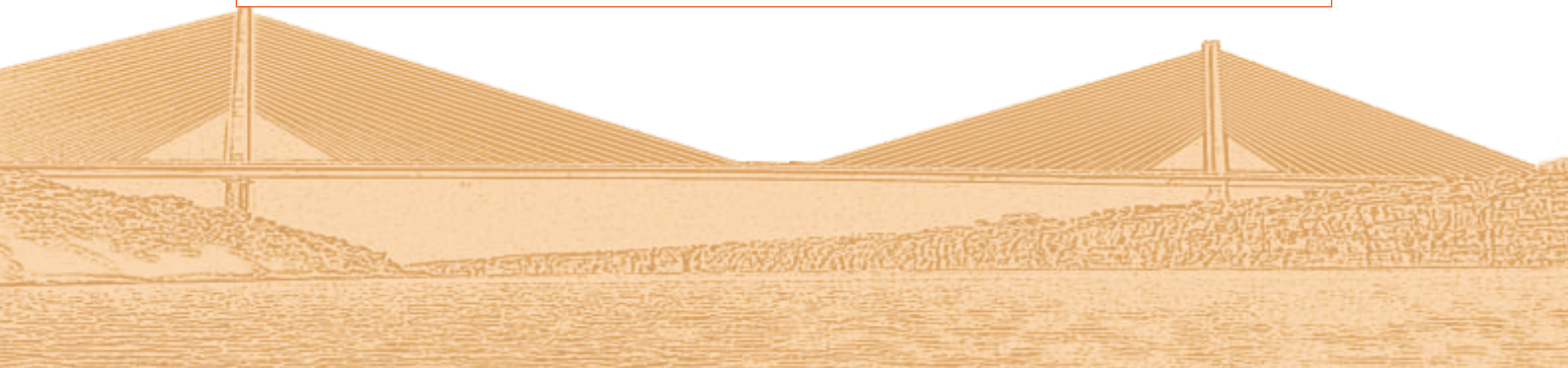
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Rajasthan State Forests Department

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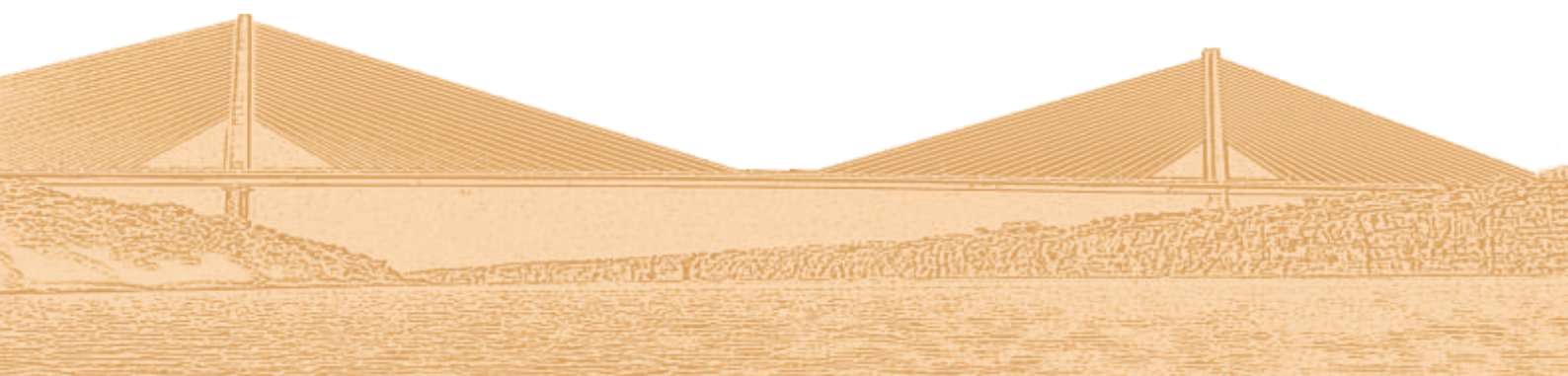
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## SUMMARY

The present study examined the impacts of post-construction phase of the cable-stayed bridge on the aquatic wildlife and river habitat quality of the Chambal River between Kota barrage and Jawahar Sagar dam, Rajasthan. The study was carried out between March and November 2021. The study area was divided into 5 segments (each comprising 5 Km length of river) and the segment 1 starts from the Kota barrage. We recorded good signs/ activities of smooth-coated otters in the study area. This species is listed under "Schedule II" of IWPA 1972 and "Vulnerable" as per the IUCN Red List. A total of 10 sites within five river segments were surveyed for otter signs during pre-monsoon and post-monsoon seasons. Out of which five sites (50%) have shown positive otter signs (fresh spraints, tracks, and direct sightings) during pre-monsoon, whereas in the post-monsoon season the number of otters occupied sites have reduced to four sites (40%). The otter occupancy map indicated, the segment 2 (just above the bridge area) had high level of otter presence.

We recorded good population of bird diversity between Kota barrage and Jawahar Sagar dam. A total of 132 bird species, which includes 45 wetland birds (N=1569), 21 species of raptors (N=928), and 66 species of other terrestrial birds (N=1351) were recorded. These include two Critically Endangered (Indian Vulture and Red-headed Vulture), one Endangered (Egyptian Vulture), one Vulnerable (Woolly-necked Stork) and four Near Threatened species (River Tern, Black-headed Ibis, Oriental Darter and Alexandrian parakeet). During the study period, the raptors, Indian Vulture (*Gyps indicus*) and Egyptian vultures (*Neophron percnopterus*) were very commonly recorded and more number of nests were recorded in the third segment of the study stretch. In addition to vulture nests, we also observed nests of Bonelli's eagle (*Aquila fasciata*) and Dusky eagle-owl (*Bubo coromandus*) in the riverside escarpments. We also recorded nests of three waterbird species, which include Grey Heron (*Ardea cinerea*), Black-crowned night heron (*Nycticorax nycticorax*) and Woolly necked stork (*Ciconia episcopus*). Avian richness was varying with the season maximum number of waterbirds were observed during pre-monsoon (S=40), this same trend was followed by raptors (S=15) and other terrestrial birds (S=57). The bird occupancy map indicated that the segment 1 and segment 2 supported high abundance birds. We also recorded two species of aquatic reptiles, which are Mugger (*Crocodylus palustris*) and Indian roofed turtle (*Pangshura tecta*). Though, the river banks are mostly of rocky and large boulders with limited sand beach, we found quite a few nesting sites of muggers along the river banks. A total of 34 individuals and 23 individuals of muggers were recorded during pre-monsoon and post-monsoon respectively. The study area also supports good population of freshwater fishes.

During the study we recorded 46 species of fishes from the study area. Fishes belonging to the carp family were dominant in species richness ( $S=22$ ). Among the 46 species of fish, three species are listed under threatened categories as per the IUCN Red List. During the study period the important physicochemical parameters of the water was monitored and the values were significantly varied between the river segments ( $p<0.05$ ). The pH was found to be slightly alkaline across the river segments ranged from  $7.08\pm 0.02$  and  $8.55\pm 0.01$ . Like conductivity, total dissolved solids in water (TDS) varied, ranging from 91.54 ppm at the second segment of the river in post-monsoon to 150 ppm at the second segment in pre-monsoon. All water quality parameters were found within the normal range of river water quality.

Based on our findings we conclude that the cable-stayed hanging bridge of Kota does not have any negative impact on the wildlife of the Chambal River. The bridge is on the stable rocky gorge area, around 30 m above the water level across the river Chambal without any supporting billers from the riverbed. Thus, there is no direct contact between the river and bridge structure. Further, the technology used in this structure is marvellous, because it is totally vibration and noise proof. In this study we had some significant observations very close to this cable bridge such as an active nest of Egyptian Vulture (*Neophron percnopterus*) very close to this bridge ( $25^{\circ} 8'23.14''N$ ,  $75^{\circ}47'36.64''E$ ), which is just 80 meters away from the bridge and a nest of Woolly-necked Stork (*Ciconia episcopus*) just 200 meters downstream from the bridge ( $25^{\circ} 8'20.90''N$ ,  $75^{\circ}47'33.11''E$ ). Generally, Woolly-necked Storks are assumed to prefer isolated areas for nesting (Mehta 2020). Previous studies indicated that disturbance is one of the major factors for avoiding nesting habitat by Storks (Bouton *et al.*, 2005). We also observed the permanent roosting sites of the Indian eagle-owl (*Bubo bengalensis*) nearer to this bridge ( $25^{\circ} 8'16.12''N$ ,  $75^{\circ}47'27.02''E$ ). Likewise, we observed number of direct sighting of otters and crocodiles near as well as downstream regions of bridge when compared to other segments of the rivers. Moreover, the water quality parameters examined were within the normal range of river water quality. Thus, the present study revealed that the presence of cable-stayed bridge does not have any negative impact on the aquatic wildlife and quality of habitats in the Chambal River.

# STATUS OF WILDLIFE BETWEEN KOTA BARRAGE AND JAWAHAR SAGAR DAM, RAJASTHAN

## Background

The Mukundra Hills Tiger Reserve in Rajasthan is an evenly topped and virtually parallel hill with narrow central elevations has a subtropical climate with an extensive and warm summer in April, short rainfall in June and severe winter in December. The vegetation consists of the ravine, thorn forest, a subtype of the northern tropical forests (Champion and Seth, 1968). The only perennial river of Rajasthan state, the Chambal River flows through this landscape and supports rich wildlife along the river valley. Two reservoirs lie within the Tiger Reserve, the upper one is Jawahar Sagar Dam with live storage of 99 Mm<sup>3</sup> and the lower one is the Kota barrage located near Kota city (0.8 km away from the city).

This river valley is composed of a ravine dominating structure and both banks of the river are mainly of rocky escarpments composed of bedrocks, large boulders, combined with a very tiny layer of slack soils. The deep picturesque gorges of Chambal River with an average width of 400m with an elevation of about 850m are life ground to various bird species such as water birds, vultures and other raptors. This riverine sector provides irrigational support to the locals and becomes a lifeline to the Kota and other cities of Rajasthan. Besides, the river is also rich in a diversity of aquatic fauna such as turtles, muggers and many varieties of fish. Moreover, the Chambal River also includes critically endangered aquatic species like the Gangetic River dolphin (*Platanista gangetica*) at the lower reaches and smooth coated otter (*Lutrogale perspicillata*). Apart from aquatic mammals, this landscape also supports important conservation of significant wildlife such as Nilgai (*Boselaphus tragocamelus*), Sloth Bear (*Melursus ursinus*), Leopard (*Panthera pardus*) and Hyena (*Hyaena hyaena*) and other mammals.

The Mukundra Hills Tiger Reserve also known for its development, the National Highway 27 (NH27 runs between Gujarat and Assam) cut through the Mukundra Hills Tiger Reserve, near Kota. A cable-stayed hanging bridge was constructed across the Chambal River in 2017 to facilitate the

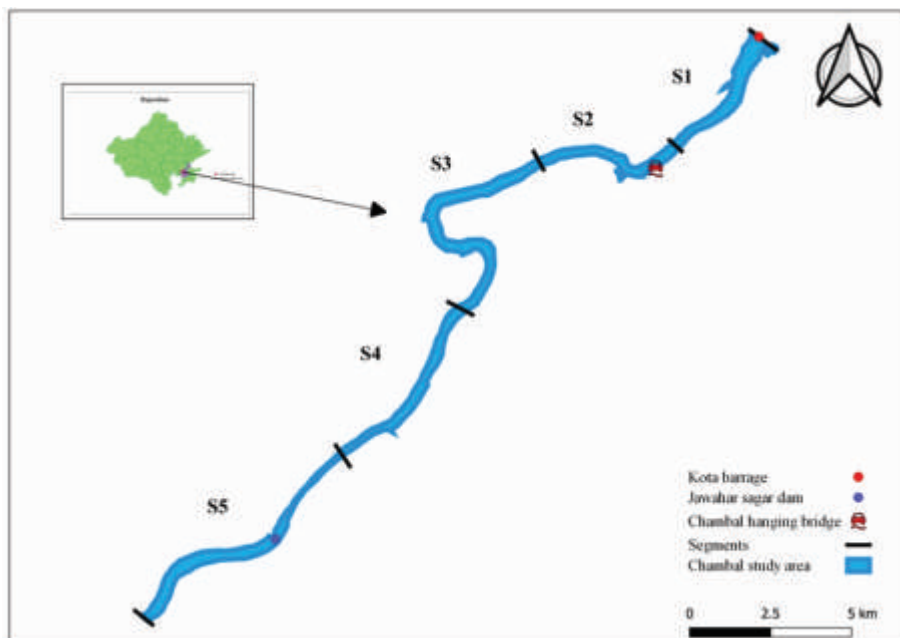
movement of vehicles. During the construction phase of the bridge, some portion of the bridge collapsed and fell into the river. This incident raised great concern among wildlife conservationists since the Chambal River is the home form many aquatic wildlife. In this background a study was assigned to Wildlife Institute of India to assess the status of wildlife between Kota Barrage and Jawahar Sagar Dam, Rajasthan with the following objectives:

## Objectives

1. To assess the status of wildlife between Jawahar Sagar dam and Kota Barrage.
2. To assess the impact of the cable-stayed bridge on the surrounding wildlife habitat and biodiversity
3. Recommend mitigation measures

## Study Area

The present study area covers 30 km of the Chambal River starting from Kota Barrage to Jawahar Sagar dam ( $25^{\circ} 10' N 75^{\circ} 49' E$  and  $25^{\circ} 02' N - 75^{\circ} 40' E$ ). Based on the accessibility of the river, the entire river stretch was divided into five segments (each segment covers 5kms river length) and the rapid survey was carried out in pre-monsoon (March-April 2021) and post-monsoon (September-November 2021) seasons. The study area covering different sampling segments is given in Figure 1.



**Figure 1.** Map showing the study area of Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan (S1 to S5-denotes the sampling segments 1 to 5).

## Materials and Methods

### Otter survey

Since the study area is one of the known otter habitats, a systematic sign survey was carried out along the river banks of every 5 Km stretch. Spraints, pugmarks, tail track, grooming sites and direct encounters are the important signs for determining otter occupancy in a given habitat (Crawford *et al.*, 1979). It is considered a standard and widely used for studying otter distribution and monitoring (Reuther *et al.*, 2000). The bank of each segment is taken as a different site for sign surveys. At each site, a maximum of 2 km length and 10 m width area was searched along the bank, looking for otter spraints and tracks. When the signs were found, the site was marked as a positive site. If no otter signs were found that site was considered negative. Any opportunistic encountering of otters during the study was also recorded and their position was noted by GPS. Every sighting, otter group size, structure, and activity was recorded. The survey usually started from the starting point of the segments. During the survey, environmental variables like river width, water depth and elevation were recorded. In addition, a few specific habitats feature that could affect the detection of signs at each site was also recorded. Human disturbances, potential spraint site and bank type were taken as habitat features. The intensity of human use (number of any sign of fishing at riverbank) was noted under three categories: low (<3 signs/500m), average (3-10 signs/500 m), high (>10 signs/500 m). Potential spraint site was noted under two categories: few (<1 spraint/500 m), many (>1 spraints/500 m). All statistical analyses were carried out by SPSS 26.0 version (2019). Site wise presence and absence data of otters at the study site was analysed in the occupancy framework using the software Presence ver.12 (Hines, 2006).

### Bird survey

During the survey, number of waterbird encountered in each segment were recorded by direct counts (Weller, 1999). The bird count was carried out with the help of a slow-moving motorboat with two observers focussing on both river banks. The survey was conducted in every segment and the total bird count method was adopted for documenting bird abundance. We also counted the raptors and other terrestrial birds using the river banks in each segment. Nesting sites of raptors and resting individuals were recorded in the entire study area. During the survey, the boat speed was maintained up to 5km/hr speed and observed the birds on either side of the river stretch. Birds were counted using binoculars (Hawke Nature Trek 8×42 mm & Nikon 8×40). Species were recorded during their peak activity hours; morning 6.00 to 10.30 am and evening 3.00 to 5.30 pm. At each observation, the following details were recorded: the name of the bird species, number of individuals, feeding guild, sighting distance and their habitat. The activity of water birds was recorded as foraging and feeding, moving, resting, calling, preening, chasing, hiding and breeding (Akhtar *et al.*, 2013). Distance of bird species from the point of observation was recorded using Hawke sport range finder (6×25 mm). Starting and ending points of each segment were noted by GPS (Garmin etrex 20 model). Waterbirds were identified to species level using standard

field guides (Grimmett *et al.*, 2016). Species that were difficult to identify directly during the survey were photographed using Canon digital camera (EOS1200D & 55-250mm lens) and identified later with the help of Ali and Ripley (1987). Feeding guilds were noted using direct observations and also from the available bird database (Ali and Ripley, 1987).

For common names and scientific names, we followed the checklist of Indian Birds (Praveen *et al.*, 2021). We assigned the global conservation status of recorded birds and raptors, based on the IUCN Redlist (IUCN, 2021). In the present study, we measured diversity, richness, abundance (as the total number of individuals), feeding guild and migratory status (Ali and Ripley, 1987) of all the birds and raptors in this sector of the Chambal River. Relative abundance of families was calculated using the following formula as per Torre-Cuadros (2007). Relative abundance (RA) was analyzed using the formula:  $RA = N_i / N_t \times 100$ ; where  $N_i$  is the number of species in a family and  $N_t$  is the total number of species. The data were processed for different diversity analyses using Shannon diversity (H), maximum diversity (H<sub>max</sub>) and Evenness (E):

$$H = \text{Shannon diversity} = \sum [(p_i) \times \ln(p_i)]; H_{\max} = \text{maximum diversity} = \log(S); E = \text{Evenness} = H/H_{\max}$$

Where  $P_i$  is the proportion of each species in the sample, and  $\ln(P_i)$  is the natural logarithm of this proportion. Where H' is the Shannon diversity index and  $H_{\max}$  is the natural log of the total number of species,  $N_{\max}$  is the number of individuals in the most abundant species and N is the total number in the community.

### Crocodile and turtle survey

In all five segments, a systematic search of turtles and crocodiles were carried out. The total count method was adopted for counting crocodiles as per the methods of Behera *et al.* (2014). It is easier to count the number and estimate the size of crocodiles basking on land during the daytime particularly in post-winter and pre-summer seasons (Rodgers, 1991). Since the river terrine is inaccessible through the riverbank, a motorboat survey was employed during good daylight time (8 to 11.30 am) in every segment. The potential basking places were regularly inspected to explore the footprints and body impression signs. Moreover, the nesting sites of crocodiles along the riverbanks also were studied wherever accessibility had seen. Visual observations of muggers, other fauna and human activities in the river or on the banks were aided by Olympus 10 × 50 field binoculars. A Garmin etrex GPS unit was used to record the coordinates of the spot perpendicular to the animal locations at every sighting. The specific locations of two individuals were noted, classifying them by position including 'in water', 'on sandbank/bar/island', 'on rocks' or 'on mud banks. The age class of Mugger was estimated visually as suggested by Rodgers (1991) as hatchling (<50 cm), yearling/juvenile (50 - 120cm), sub-adult (120 - 180cm), Adult (>180cm), eyes only (for very far or difficult to estimate). To confirm the presence, camera traps were utilized and monitored every alternative day. All the data collected were entered on pre prepared data sheets in the field.

## Fish survey

### Fish sampling

At each segment, the fish sampling was performed at three locations covering approximately each 500m length. The sampling was carried out in the early day hours (6-9 am) of the day. Fish sampling was performed using gill nets (Fig. 2) of different mesh sizes ranging from 12mm to 35mm, hand nets, baited hooks and scoop nets also were utilized. The gill nets were kept in the sampling area for 2 hrs for estimating fish catch per unit effort (CPUE). The length and weight of fish samples were measured, and the samples were labelled with site location, date of the sampling. Further, fishes were photographed for correct identification before preserving in a solution of 10% formalin. Some portions of tissue samples, preferably a portion of the fin was dissected and kept in absolute alcohol for further molecular analysis. The fishes were identified to species level with the help of local expertise and taxonomic literature (Jayaram, 2010). Current vailed names of the species were confirmed in the Eschmeyer's catalogue of Fishes (California Academy of Sciences). The current conservation status of fish species was obtained from the latest IUCN redlist data. The Paleontological Statistics software (PAST ver.4.03; Hammer *et al.*, 2001) was used to estimate various biodiversity indices like the most popular and standard - diversity index Shannon index, Evenness, Richness and Dominance.

Species richness is the number of different species present in an area (Deitmers *et al.*, 1999). Shannon index (H) was calculated in order to know the species diversity (Hutcheson, 1970) based on species abundance using the Shannon and Wienered (1949) formula:

$$H = - [\sum Pi * \ln(Pi)]$$

Where H' is the Shannon index,  $P_i$  is the proportion of each species in the sample, and  $\ln(P_i)$  is the natural logarithm of this proportion

- Relative abundance of families was calculated using the following formula as per Torre-Cuadros *et al.* (2007).

$$RA = Ni / Nt \times 100$$

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

- The evenness of fish species compares the similarity of the population size of each species. Evenness Index (E) (Kiros *et al.*, 2018) was calculated using the ratio of observed diversity to maximum diversity using the equation.

$$E = H' / H_{\max}$$

where H' is the Shannon index and  $H_{\max}$  is the natural log of the total number of species.

- Dominance indices are weighted towards the abundance of the commonest or dominant species. The simplest dominance index is the Berger-Parker index (Berger and Parker, 1970). It is calculated using the formula,

$$D = N_{\max} / N$$

Where  $N_{\max}$  is the number of individuals in the most abundant species and  $N$  is the total number in the community.

### **Water quality sampling**

The physio-chemical parameters of water were measured randomly in every segment before starting the fish sampling. The air and water temperature ( ), total dissolved solids (ppm) and electrical conductivity ( $\mu\text{Scm}^{-1}$ ) of water and pH were obtained from the commercially available digital meters for water quality analyses. Water turbidity (NTU) and Salinity (ppt) were also noted using digital meters, whereas the dissolved oxygen content of water was analysed using the standard procedure of Winkler's method. The Pearson's (2-tailed) correlation analysis was carried out to determine the relationship between water quality variables. The single asterisks mark on the data indicates the values are significant at 0.05 and the double asterisks mark indicates the values are significant at 0.01 level. The correlation analyses were performed by using the Statistical Package for Social Sciences (SPSS ver.26) for Windows.

### **River habitat assessment**

The water velocity (cm/S) of the sampling area was quantified using a pigmy water current meter (Model Geopack, UK). The water depth across the river channel was recorded using a digital depth finder (HawkEye DT1H). The mean width was calculated by measuring the width from bank to bank at different locations using a range finder. Likewise, the depth was measured from the surface of the water to the riverbed at every 10m intervals of width perpendicular to the river channel at several locations and the average was taken as the mean depth. Riparian and aquatic vegetation is assessed in terms of percentage cover for various growth forms, vegetation was estimated using a rank (0–4) of five cover classes; absent (0%), sparse (0–10%), moderate (10–40%), dense (40–75%), and very dense (>75%; Lazorchak *et al.*, 1998). Mean rank was then averaged across all sites to obtain a value for each segment. Canonical correspondence analysis (CCA; Ter Braak, 1986) was used to determine the correlation between environmental variables with fish assemblage using PAST software ver. 4.03. Glimpse of field data collection method adopted are given in Figure 2.



*Fish sampling*



*Recording animal signs*



*Morphometric measurement of fish*



*River flow measurement*



*Bird survey with the help of boat*



*Checking camera traps*

**Figure 2.** Glimpse of field data collection in Chambal River, Rajasthan

## Findings

### Otter occupancy

The sole otter species found in the study area was identified as smooth-coated otter (*Lutrogale perspicillata*), confirmed by the shape of rhinarium, coat texture and flat under tails (Hussain and Choudhury, 1997; Menon and Daniel, 2009) (Fig. 3). A total of 10 sites within five river segments were surveyed for otter signs during pre-monsoon and post-monsoon seasons. Out of which five sites (50%) have shown positive signs of otter such as spraints, tracks and direct sightings of otter during pre-monsoon, whereas in the post-monsoon season, the number of otters occupied sites have reduced to four sites (40%). A total of 19 individuals, 21 spraints and 4 otter tracks were recorded during the pre-monsoon survey, but in the post-monsoon survey only 6 individuals and 6 spraints were observed without any track mark from the study sites, this was mainly because of heavy rainfall the availability of food source in elevated regions and less grooming sites due to increased water level. Different types of otter signs encountered across different segments of the Chambal River are given in Figure 4 and the data are given in Table 1. The group size was maximum with 8 individuals (4 adult and 4 sub-adult), sighted in the second segment of the river (S2) during pre-monsoon whereas 6 individuals (2 adults and 4 sub-adult) were spotted in the same segment (S2) in the post-monsoon. The maximum number of spraints were recorded before the monsoon (N=21) while fewer spraints (N=6) were observed during the post-monsoon survey (Fig. 5). These might attribute due to the splash rains the spraints and signs might get washed away. Significance of habitat features by ANOVA results suggested that the number of spraints significantly varied with bank type ( $F=40.5$ ,  $p=0.008$ ) (Table 2). All the spraints were recorded from the rocky surface as most of the potential otter occupancy sites are formed of rocky banks, moreover, the same relationship was observed in the case of the total number of individuals sighted in the present study area ( $F=18.77$ ,  $p=0.023$ ). In the present study, human disturbances were observed mainly as illegal fishing and limited tourism activities, although there is no significant relationship observed between human disturbance and otter distribution ( $F=6.4$ ,  $p>0.05$ ). Based on the intensity of otter signs recorded an occupancy heat map was produced (Fig. 6), which indicates that the high level of otter activities was observed in river segment 2 (S2).

**Table 1 :** Number of otter signs/ direct sighting recorded across the sampling locations.

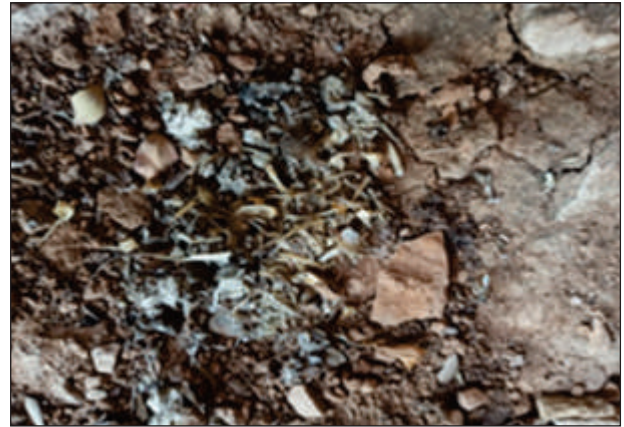
Site	Pre-monsoon			Post-monsoon		
	No. of spraints	No. of tracks	No. of individuals	No. of spraints	No. of tracks	No. of individuals
1	-	-	-	-	-	-
2	6	2	8	1	-	6
3	2	-	4	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	11	-	-	4	-	-
7	-	-	-	-	-	-
8	2	1	7	-	-	-
9	-	-	-	-	-	-
10	-	1	-	1	-	-



**Figure 3.** Smooth-coated otters of Chambal River, Rajasthan.



*Track signs of otter*



*Fresh spraints of otters*

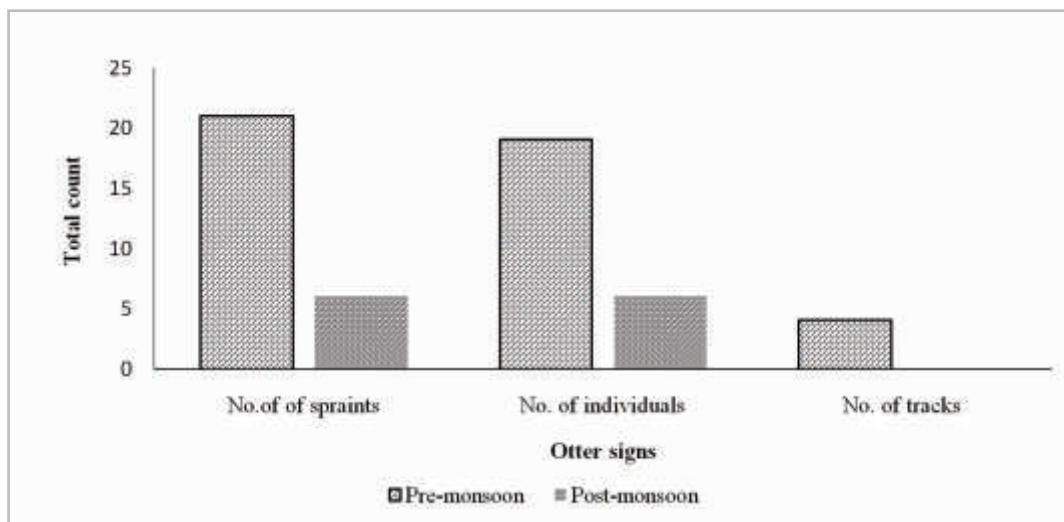


*Direct sighting*

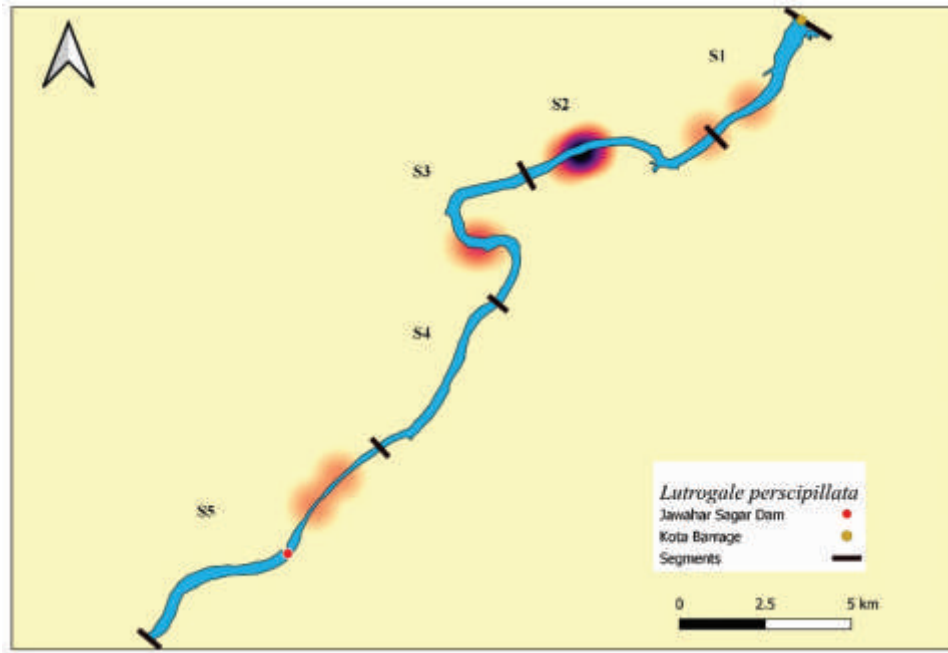


*Old Spraints*

**Figure 4.** Different types of otter signs recorded during the occupancy survey.



**Figure 5.** Seasonal variation of otter signs encountered between Kota barrage and Jawahar Sagar Dam, Rajasthan.



**Figure 6.** Occupancy heat map of *smooth coated otters* between Kota barrage and Jawahar Sagar Dam, Rajasthan.

**Table 2:** Results of ANOVA with average number of otter spraints, tracks and number of individuals as response variables and habitat features as predictor variable.<ns> connotes no significance

Variables	Spraints		Track		Number of individuals	
	F	p	F	p	F	P
<b>Human disturbance intensity</b>	4.15	<ns>	2.4	<ns>	6.4	<ns>
<b>Potential spraint site</b>	69.44	<ns>	13.44	0.035	6.12	<ns>
<b>Bank type</b>	40.5	0.008	0.5	<ns>	18.77	0.023

The correlation results between habitat variables and otter signs revealed that the number of spraints in the positive sites showed a negative relationship with river depth ( $r=-0.52$ ). Whereas the otter sighting was significantly correlating with the depth ( $r=0.60$ ) and elevation ( $r=-0.12$ ) of the river. However, the site elevation showed a negative correlation with the river width and depth (depth;  $r=-0.358$ , width= $-0.382$ ) (Table 3). The probability of finding the otter was less in highly elevated regions of the study area as the number of tracks showed a negative correlation with elevation ( $r=-0.621$ ).

**Table 3 :** Correlation between habitat variables and otter signs encountered in the study area

	Sprints	Tracks	Individuals	Width	Depth	Elevation
Sprints	1	0.243	0.284	-0.52*	-0.258	0.207
Tracks	0.243	1	0.762*	0.183	0.391	-0.621*
Individuals	0.284	0.762	1	0.112	0.6*	-0.12
Width	-0.52	0.183	0.112	1	0.602	-0.382
Depth	-0.258	0.391	0.6	0.602*	1	-0.358
Elevation	0.207	-0.621	-0.123	-0.382	-0.358	1

\*Correlation is significant at the 0.05 level (1-tailed)

## Bird diversity and distribution

### Water bird abundance

In the present investigation, a total of 45 species of waterbirds belonging to 15 families and nine orders were recorded (Table 4). Among the recorded species, the order *Pelecaniformes* was well represented by two families and 14 species. Similarly, *Ardeidae* was the most dominating family with a maximum of twelve species. Families like *Anhingidae*, *Ciconidae*, and *Recurvirostridae* were represented with a low number of species (one species in each). The highest overall species richness was observed in the pre-monsoon ( $S=44$ ), whereas low species richness was recorded in the post-monsoon ( $S=28$ ) season. Darters and Cormorants were most abundant during pre-monsoon. It accounted for about 50% of the total pre-monsoon population (Fig. 7). Likewise; Egrets, herons, and Bitters were the second-highest in pre-monsoon, they accounted for 22.87% of the population ( $N=188$ ). Whereas in the post-monsoon; egrets, herons, kingfishers, terns, and gulls were represented almost equal in abundance (Fig. 7). Little Cormorant (*Microcarbo niger*) and Indian Cormorant (*Phalacrocorax fuscicollis*) were dominant in overall abundance with 19.76% and 17.72% in pre-monsoon and post-monsoon respectively. Among the 45 species observed; 33 species were resident and 12 of them are winter migrants (Table 4). Most of the winter migrants observed are belonging to the order Charadriiformes; i.e., Common Sandpiper (*Actitis hypoleucos*), Green Sandpiper (*Tringa ochropus*), Wood Sandpiper (*Tringa glareola*), Pallas's Gull (*Ichthyaetus ichthyaetus*). Four out of 45 species recorded in the field are globally threatened (Table 4). Among them, three belonged to Near-threatened (NT) and one, Vulnerable (VN). Order Pelecaniformes and Charadriiformes were dominating in pre-monsoon with twelve and ten species, respectively. A similar trend was also noted in the post-monsoon where nine species in Pelecaniformes and six species were in Charadriiformes (Fig. 8). Segment-wise waterbirds recorded during pre-monsoon and post-monsoon are given in Table 5. Segments 1 & 2 had more waterbirds in pre and post-monsoon seasons, however, the birds' richness was varied significantly between the seasons (Table 5). The total number of individuals of waterbirds observed in pre-monsoon ( $N=1233$ ) was much higher than post-monsoon ( $N=336$ ) ( $\chi^2=532.77$ ,  $df=43$ ,  $P<0.05$ ). The Shannon index was highest in S1 during post-monsoon ( $H=2.44$ ) and least in S5 ( $H=1.62$ ).

**Table 4.** List of waterbirds recorded from the study area between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Common name	Scientific name	IUCN status	Residential status	Feeding guild	Relative abundance (%)		
					Pre-monsoon	Post-monsoon	Overall
Order: Coraciiformes							
Family: Alcedinidae							
Common Kingfisher	<i>Alcedo atthis</i>	LC	R	CA	1.54	-	1.21
Pied Kingfisher	<i>Ceryle rudis</i>	LC	R	CA	0.16	-	0.13
Stork-billed Kingfisher	<i>Pelargopsis capensis</i>	LC	R	CA	0.08	0.60	0.19
White-throated Kingfisher	<i>Halcyon smyrnensis</i>	LC	R	CA	4.06	19.05	7.27
Order: Anseriformes							
Family: Anatidae							
Garganey	<i>Spatula querquedula</i>	LC	WM	OM	0.32	5.06	1.34
Lesser Whistling Duck	<i>Dendrocygna javanica</i>	LC	R	HE	-	1.49	0.32
Ruddy Shelduck	<i>Tadorna ferruginea</i>	LC	WM	OM	0.16	-	0.13
Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	LC	R	HE	0.16	-	0.13
Tufted Duck	<i>Aythya fuligula</i>	LC	WM	OM	0.08	-	0.06
Order: Suliformes							
Family: Anhingidae							
Oriental Darter	<i>Anhinga melanogaster</i>	NT	R	PI	0.32	0.30	0.32
Family: Phalacrocoracidae							
Great Cormorant	<i>Phalacrocorax carbo</i>	LC	R	PI	0.65	-	0.51
Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	LC	R	PI	22.30	0.89	17.72
Little Cormorant	<i>Microcarbo niger</i>	LC	R	PI	23.28	6.85	19.76

Order: Pelecaniformes							
Family: Ardeidae							
Intermediate Egret	<i>Ardea intermedia</i>	LC	R	CA	0.08	-	0.06
Indian Pond Heron	<i>Ardeola grayii</i>	LC	R	CA	2.51	3.27	2.68
Black-crowned Night Heron	<i>Nycticorax nycticorax</i>	LC	R	CA	1.30	3.27	1.72
Cattle Egret	<i>Bubulcus ibis</i>	LC	R	CA	3.00	0.30	2.42
Great Egret	<i>Ardea alba</i>	LC	R	CA	1.05	0.60	0.96
Grey Heron	<i>Ardea cinerea</i>	LC	R	CA	8.19	11.90	8.99
Little Egret	<i>Egretta garzetta</i>	LC	R	CA	1.22	-	0.96
Purple Heron	<i>Ardea purpurea</i>	LC	R	CA	1.62	2.38	1.78
Striated Heron	<i>Butorides striata</i>	LC	R	CA	0.32	-	0.25
Black Bittern	<i>Ixobrychus flavicollis</i>	LC	R	CA	-	0.30	0.06
Cinnamon Bittern	<i>Ixobrychus cinnamomeus</i>	LC	R	CA	-	0.30	0.06
Yellow Bittern	<i>Ixobrychus sinensis</i>	LC	R	CA	0.16	0.30	0.19
Family: Threskiornithidae							
Black-headed Ibis	<i>Threskiornis melanocephalus</i>	NT	R	CA	0.65	-	0.51
Red-naped Ibis	<i>Pseudibis papillosa</i>	LC	R	CA	0.08	-	0.06
Order: Charadriiformes							
Family: Charadriidae							
Red-wattled Lapwing	<i>Vanellus indicus</i>	LC	R	IN	12.08	3.87	10.33
Family: Jacanidae							
Bronze-winged Jacana	<i>Metopidius indicus</i>	LC	R	HE	1.05	0.60	0.96
Family: Laridae							
River Tern	<i>Sterna aurantia</i>	NT	R	PI	3.57	19.94	7.07
Whiskered Tern	<i>Chlidonias hybrida</i>	LC	R	CA	0.89	1.79	1.08
Lesser Black-backed Gull	<i>Larus fuscus</i>	LC	WM	CA	0.32	-	0.25
Pallas's Gull	<i>Ichthyaetus ichthyaetus</i>	LC	WM	PI	0.16	-	0.13
Family: Scolopacidae							
Common Sandpiper	<i>Actitis hypoleucos</i>	LC	WM	IN	0.08	2.68	0.64

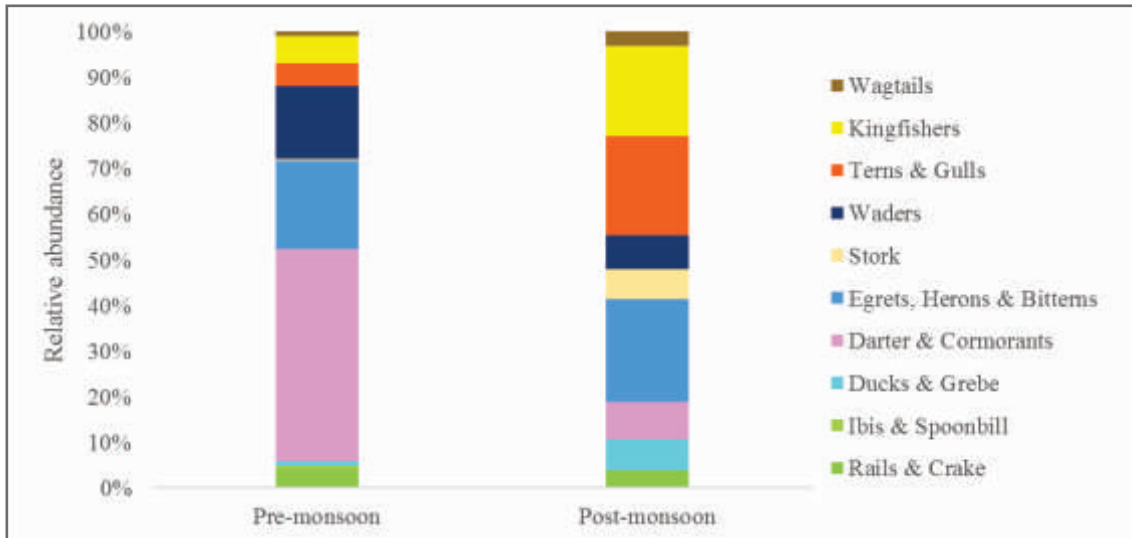
Green Sandpiper	<i>Tringa ochropus</i>	LC	WM	IN	0.32	-	0.25
Wood Sandpiper	<i>Tringa glareola</i>	LC	WM	IN	0.32	-	0.25
Family: Recurvirostridae							
Black-winged Stilt	<i>Himantopus himantopus</i>	LC	WM	CA	2.27	0.30	1.85
Order: Gruiformes							
Family: Rallidae							
Common Moorhen	<i>Gallinula chloropus</i>	LC	R	OM	0.24	-	0.19
White-breasted Waterhen	<i>Amaurornis phoenicurus</i>	LC	R	OM	3.81	3.87	3.82
Baillon's Crane	<i>Zapornia pusilla</i>	LC	WM	IN	0.16	-	0.13
Order: Passeriformes							
Family: Motacillidae							
Grey Wagtail	<i>Motacilla cinerea</i>	LC	WM	IN	-	0.30	0.06
White-browed Wagtail	<i>Motacilla maderaspatensis</i>	LC	R	IN	1.05	2.98	1.47
Order: Ciconiiformes							
Family: Ciconiidae							
Woolly-necked Stork	<i>Ciconia episcopus</i>	VU	R	CA	0.24	6.55	1.59
Order: Podicipediformes							
Family: Podicipedidae							
Little Grebe	<i>Tachybaptus ruficollis</i>	LC	R	IN	0.08	0.30	0.13
Great Crested Grebe	<i>Podiceps cristatus</i>	LC	WM	IN	-	0.3	0.06

\* NT= Near Threatened, VU= Vulnerable, LC= Least Concern, R=Resident, WM=Winter Migrant, CA= Carnivore, IN=insectivore, OM= Omnivore, PI= Piscivore, HE= Herbivore

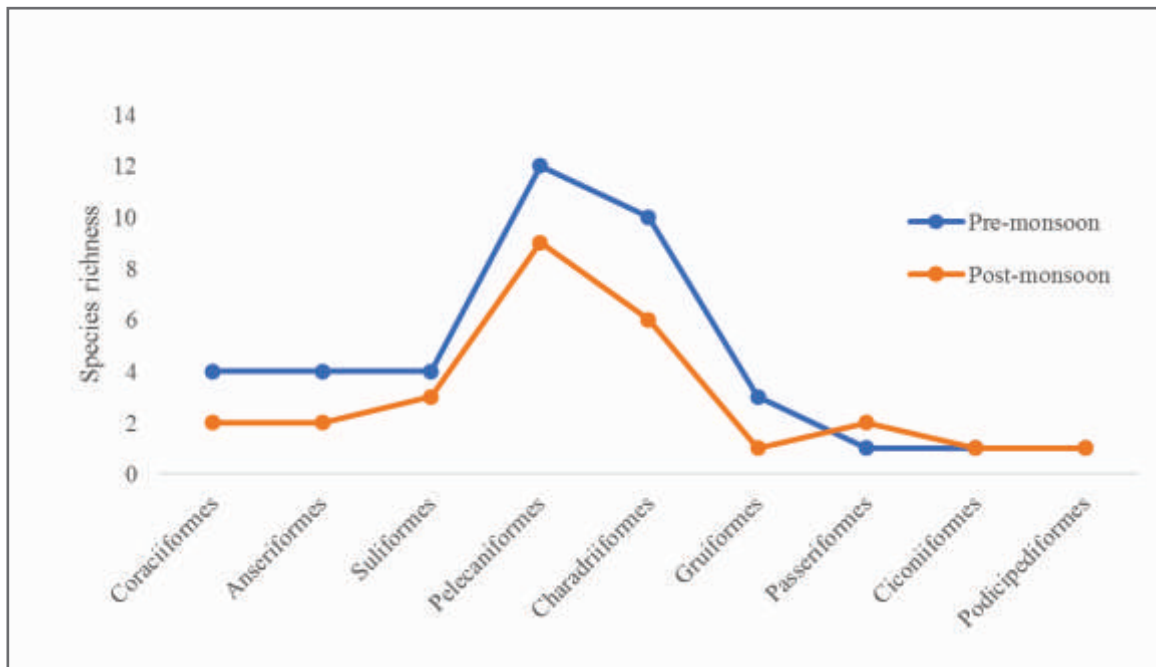
In the pre-monsoon season segment-wise abundance of waterbirds recorded was ranged from 61 to 594 individuals (Table 5) with an average of  $246.6 \pm 204.46$  ( $\pm$  Standard deviation). Whereas in the post-monsoon, the total abundance of waterbirds was reduced to 336 individuals (average number  $67.2 \pm 20.51$ ). The abundance of waterbirds significantly varied with segments during respective seasons (Table 5).

The feeding guild also shows seasonal change, carnivore species were dominating in both seasons (Fig. 9), which includes woolly-necked stork, Ibis, Egrets, Herons, Gulls, and Terns. They depended on the water body for fish, frogs, snakes, and other invertebrates. The second leading

group was Insectivores. Total nine species of waterbirds were listed under insectivores (Table 4). They mainly feed on aquatic insects, especially water mites, odonate larvae, and beetles. Herbivores (2) are the poorly represented group in both seasons (Fig. 7), which included Indian Spot-billed Duck and Bronze-winged Jacana. Leaves, roots, stems, and algae were the major diet of herbivores. Piscivores were the third leading group in the feeding guild for both seasons, it includes mainly Darters and Cormorants (Fig.9).



**Figure 7.** Seasonal variation in the composition of waterbird community recorded in Chambal River between Kota and Jawahar Sagar Dam.



**Figure 8.** Species richness of waterbirds in the study area.

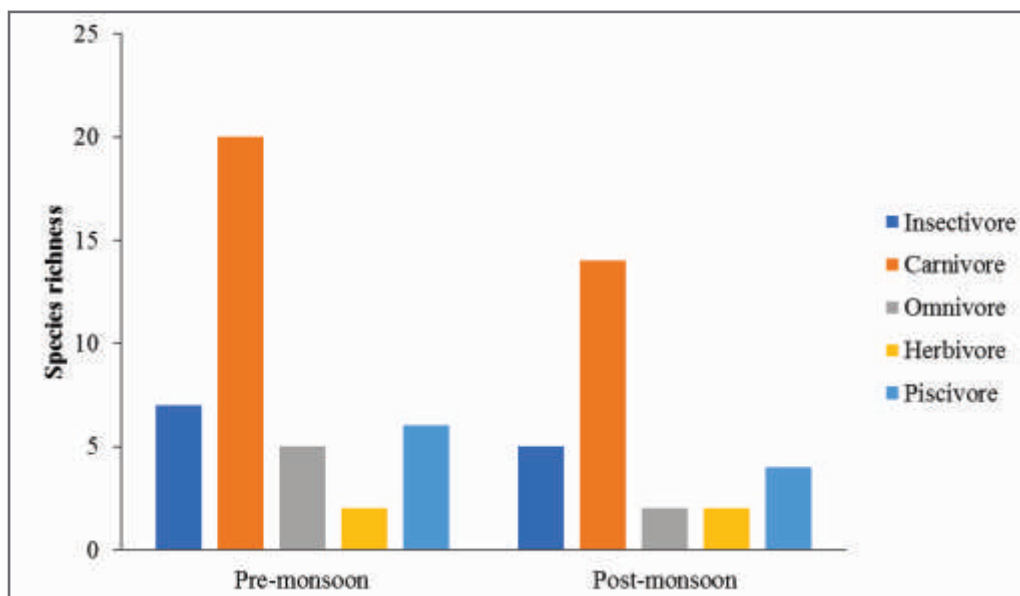
**Table 5.** Season wise diversity indices of waterbirds recorded in Chambal River between Kota and Jawahar Sagar Dam, Rajasthan

Segment	Season	Species Richness (D)	Abundance (N)	Shannon index (H)	Dominance (D)	Evenness (E)
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	0.19	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	28	336	2.56	0.11	0.49

\*Pre-monsoon (March-April); Post-monsoon (September-November)

### **Raptor abundance**

During the study period (covering pre-monsoon and post-monsoon seasons), we recorded 21 species of raptors, including belonging to 3 order and 4 families from Chambal River between Kota barrage and Jawahar Sagar Dam (Table 6). Among the raptors, one winter migrant, the Osprey was recorded from the study area. The member of the family Accipitridae was maximum representation from the study area (14 species), followed by Strigidae family had 4 species, whereas the family Falconidae and Pandionidae represented two and one species respectively.



**Figure 9.** Feeding guilds of waterbirds recorded in different seasons.

**Table 6.** List of raptors recorded from Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Common name	Scientific name	IUCN status	Residential status	Feeding guild
<b>Order: Accipitriformes</b>				
<b>Family: Accipitridae</b>				
<b>Black-winged Kite</b>	<i>Elanus caeruleus</i>	LC	R	CA
<b>Black Kite</b>	<i>Milvus migrans</i>	LC	R	CA
<b>Bonelli's Eagle</b>	<i>Aquila fasciata</i>	LC	R	CA
<b>Griffon Vulture</b>	<i>Gyps fulvus</i>	LC	W	CA
<b>Egyptian Vulture</b>	<i>Neophron percnopterus</i>	EN	R	CA
<b>Indian Vulture</b>	<i>Gyps indicus</i>	CR	R	CA
<b>Red-headed Vulture</b>	<i>Sarcogyps calvus</i>	CR	R	CA
<b>Black Eagle</b>	<i>Ictinaetus malaiensis</i>	LC	R	CA
<b>Booted Eagle</b>	<i>Hieraetus pennatus</i>	LC	W	CA
<b>Changeable Hawk Eagle</b>	<i>Nisaetus cirrhatus</i>	LC	R	CA
<b>Crested Serpent Eagle</b>	<i>Spilornis cheela</i>	LC	R	CA
<b>Eurasian Sparrowhawk</b>	<i>Accipiter nisus</i>	LC	R	CA
<b>Oriental Honey Buzzard</b>	<i>Pernis ptilorhynchus</i>	LC	R	CA
<b>Shikra</b>	<i>Accipiter badius</i>	LC	R	CA
<b>Family: Pandionidae</b>				
<b>Osprey</b>	<i>Pandion haliaetus</i>	LC	W	PI

Order: Falconiformes				
Family: Falconidae				
Common Kestrel	<i>Falco tinnunculus</i>	LC	W	CA
Shaheen falcon	<i>Falco peregrinus peregrinator</i>	LC	R	CA
Order: Strigiformes				
Family: Strigidae				
Brown Fish Owl	<i>Ketupa zeylonensis</i>	LC	R	PI
Dusky Eagle Owl	<i>Bubo coromandus</i>	LC	R	CA
Indian Eagle Owl	<i>Bubo bengalensis</i>	LC	R	CA
Indian Scops Owl	<i>Otus bakkamoena</i>	LC	R	CA

LC=Least Concern, CR=Critically Endangered, EN=Endangered, R= Resident, W= Winter migrant; CA= Carnivore, PI= Piscivore.

**Table 7.** Seasonal variation in raptors assemblages recorded in the Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Diversity indices		Species richness (S)	Total number of individual (N)	Shannon index (H)	Dominance (D)	Evenness (E)
S1	pre-monsoon	9	106	0.76	0.69	0.24
	post-monsoon	3	8	0.90	0.47	0.82
S2	pre-monsoon	8	130	0.86	0.61	0.29
	post-monsoon	6	25	1.56	0.24	0.79
S3	pre-monsoon	6	121	0.97	0.50	0.44
	post-monsoon	5	97	0.78	0.61	0.44
S4	pre-monsoon	8	279	1.18	0.37	0.41
	post-monsoon	6	43	1.16	0.44	0.53
S5	pre-monsoon	6	115	0.68	0.64	0.33
	post-monsoon	2	4	0.69	0.50	1.00
Overall	pre-monsoon	15	751	1.36	0.30	0.26
	post-monsoon	14	177	5.09	2.25	3.58

A total of 751 individuals of raptors were recorded in pre-monsoon, whereas in the post-monsoon and 177 individuals were recorded (Table 7). During the pre-monsoon season, 4 had more individuals (N=279) and the low number of raptors were recorded in segments 1 (N=106). In the case of post-monsoon, more individuals of raptors were recorded in segments 3 (N=97) and the low number of individuals were recorded in segments 5 (N=4). High species richness (S) was observed in segment 1 during pre-monsoon (S=9), low richness was recorded in segment 5 during post-monsoon (S=2) (Table 7). Segment-wise calculated diversity index across different seasons (pre-monsoon & post-monsoon) is given in Table 7. The results of diversity index analysis revealed that segment 2 had a high Shannon index during the post-monsoon season (H=1.56) and a low value was observed in segment 5 during the pre-monsoon season (H=0.67).

Of the 21 species of raptors recorded, 3 species are having globally high conservation significance: two critically endangered species (Indian vulture *Gyps indicus*, Red-headed Vulture *Sarcogyps calvus*) and one endangered (Egyptian vulture *Neophron percnopterus*). The rest of them are listed as near threatened categories. In terms of migratory species, three winter migratory species Osprey (*Pandion haliaetus*) was recorded during the pre-monsoon season. While Griffon vulture (*Gyps fulvus*) and Booted eagle (*Hieraetus pennatus*) were recorded during the post-monsoon season (Table 6). Further, it is noted that all raptors' species recorded from the study area are listed in the scheduled list of the Indian Wildlife Protection Act 1972. This reveals that the Chambal Valley is one of the ecologically important areas for raptor conservation. Most of the scavenging raptors prefer soaring over the open areas, for roosting they preferred riparian forest or barren rocks on hilltop/rocky cliffs for roosting and nesting

### Other terrestrial bird abundance

During the pre-monsoon and post-monsoon study, sixty-six species of terrestrial birds belonging to 32 families and 9 orders were recorded (Table 8). The family Muscicapidae represented the maximum number of species (6 species), next to that family Hirundinidae had a high number of species (5 species). The following 16 families: Apodidae, Bucerotidae, Aegithinidae, *Artamidae*, Acrocephalidae, Estrildidae, Laniidae, Monarchidae, Nectariniidae, Oriolidae, Paridae, Vangidae, Megalaimidae, Pycnonotidae, Rhipiduridae and Picidae were represented by only one species in each (Table 8). Most of the terrestrial birds recorded from the study area are residents, except Greenish wabler (*Phylloscopus trochiloides*) is a winter migrant. Further, it is observed that all 66 species recorded are listed in schedule IV in the Indian Wildlife Protection Act 1972 and most of them are listed as least concern category in IUCN red list. High species richness was recorded in segment 1 (S=31) during pre-monsoon, whereas low species richness was recorded in segment 5 (S=15) during the same period. In the case of the post-monsoon season, the same segment 1 had high species richness (S=21), but segment 3 recorded low species richness (S=8) when compared to other segments (Table 9). These findings indicate that bird distributions across the segments as well as across the seasons. The results of Shannon diversity index say that segment 5 shows highest diversity (H=2.61) during the post-monsoon, whereas the post-monsoon segment 2 has

low diversity ( $H=1.33$ ). In pre-monsoon, dominance index ( $D$ ) was high in segment 4 with value of 0.16 and least in segment 5 ( $D=0.1$ ).

**Table 8.** List of terrestrial birds recorded from Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Common name	Scientific name	IUCN status	Residential status	Feeding guild
<b>Order: Caprimulgiformes</b>				
<b>Family: Apodidae</b>				
Little swift	<i>Apus affinis</i>	LC	R	IN
<b>Order: Bucerotiformes</b>				
<b>Family: Bucerotidae</b>				
Indian Grey Hornbill	<i>Ocyrceros birostris</i>	LC	R	OM
<b>Order: Columbiformes</b>				
<b>Family: Columbidae</b>				
Rock Pigeon	<i>Columba livia</i>	LC	R	HE
Eurasian Collared Dove	<i>Streptopelia decaocto</i>	LC	R	HE
Laughing Dove	<i>Streptopelia senegalensis</i>	LC	R	HE
Spotted Dove	<i>Streptopelia chinensis</i>	LC	R	HE
<b>Order: Coraciiformes</b>				
<b>Family: Meropidae</b>				
Blue-tailed Bee-eater	<i>Merops philippinus</i>	LC	R	IN
Green Bee-eater	<i>Merops orientalis</i>	LC	R	IN
<b>Order: Cuculiformes</b>				
<b>Family: Cuculidae</b>				
Asian Koel	<i>Eudynamys scolopaceus</i>	LC	R	CA
Common Hawk Cuckoo	<i>Hierococcyx varius</i>	LC	R	CA
Greater Coucal	<i>Centropus sinensis</i>	LC	R	CA
<b>Order: Galliformes</b>				
<b>Family: Phasianidae</b>				
Grey Francolin	<i>Francolinus pondicerianus</i>	LC	R	OM
Indian Peafowl	<i>Pavo cristatus</i>	LC	R	OM
Painted Spurfowl	<i>Galloperdix lunulata</i>	LC	R	OM
<b>Order: Passeriformes</b>				
<b>Family: Aegithinidae</b>				
Common lora	<i>Aegithina tiphia</i>	LC	R	IN
<b>Family: Alaudidae</b>				
Ashy-crowned Sparrow Lark	<i>Eremopterix griseus</i>	LC	R	OM
Indian Bushlark	<i>Mirafra erythroptera</i>	LC	R	OM

	<b>Family: Artamidae</b>			
<b>Ashy Woodswallow</b>	<i>Artamus fuscus</i>	LC	R	IN
	<b>Family: Acrocephalidae</b>			
<b>Clamorous Reed Warbler</b>	<i>Acrocephalus stentoreus</i>	LC	R	IN
	<b>Family: Cisticolidae</b>			
<b>Ashy Prinia</b>	<i>Prinia socialis</i>	LC	R	IN
<b>Common Tailorbird</b>	<i>Orthotomus sutorius</i>	LC	R	IN
<b>Grey-breasted Prinia</b>	<i>Prinia hodgsonii</i>	LC	R	IN
<b>Plain Prinia</b>	<i>Prinia inornata</i>	LC	R	IN
	<b>Family: Campephagidae</b>			
<b>Small Minivet</b>	<i>Pericrocotus cinnamomeus</i>	LC	R	IN
<b>white-bellied Minivet</b>	<i>Pericrocotus erythropygius</i>	LC	R	IN
	<b>Family: Corvidae</b>			
<b>House Crow</b>	<i>Corvus splendens</i>	LC	R	OM
<b>Large-billed Crow</b>	<i>Corvus macrorhynchos</i>	LC	R	OM
<b>Rufous Treepie</b>	<i>Dendrocitta vagabunda</i>	LC	R	OM
	<b>Family: Dicuridae</b>			
<b>Ashy Drongo</b>	<i>Dicrurus leucophaeus</i>	LC	R	IN
<b>Black Drongo</b>	<i>Dicrurus macrocercus</i>	LC	R	IN
<b>White-bellied Drongo</b>	<i>Dicrurus caerulescens</i>	LC	R	IN
	<b>Family: Estrildidae</b>			
<b>Red Munia</b>	<i>Amandava amandava</i>	LC	R	OM
	<b>Family: Hirundinidae</b>			
<b>Barn Swallow</b>	<i>Hirundo rustica</i>	LC	R	IN
<b>Dusky Crag Martin</b>	<i>Ptyonoprogne concolor</i>	LC	R	IN
<b>Red-rumped Swallow</b>	<i>Cecropis daurica</i>	LC	R	IN
<b>Streak-throated Swallow</b>	<i>Petrochelidon fluvicola</i>	LC	R	IN
<b>Wire-tailed Swallow</b>	<i>Hirundo smithii</i>	LC	R	IN
	<b>Family: Laniidae</b>			
<b>Long-tailed Shrike</b>	<i>Lanius schach</i>	LC	R	IN
	<b>Family: Leiothrichidae</b>			
<b>Common Babbler</b>	<i>Argya caudata</i>	LC	R	OM
<b>Jungle Babbler</b>	<i>Turdoides striata</i>	LC	R	OM
<b>Large Grey Babbler</b>	<i>Argya malcolmi</i>	LC	R	OM
	<b>Family: Monarchidae</b>			
<b>Indian Paradise-flycatcher</b>	<i>Terpsiphone paradisi</i>	LC	R	IN
	<b>Family: Muscicapidae</b>			
<b>Blue Rock Thrush</b>	<i>Monticola solitarius</i>	LC	R	IN
<b>Brown Rock Chat</b>	<i>Oenanthe fusca</i>	LC	R	IN

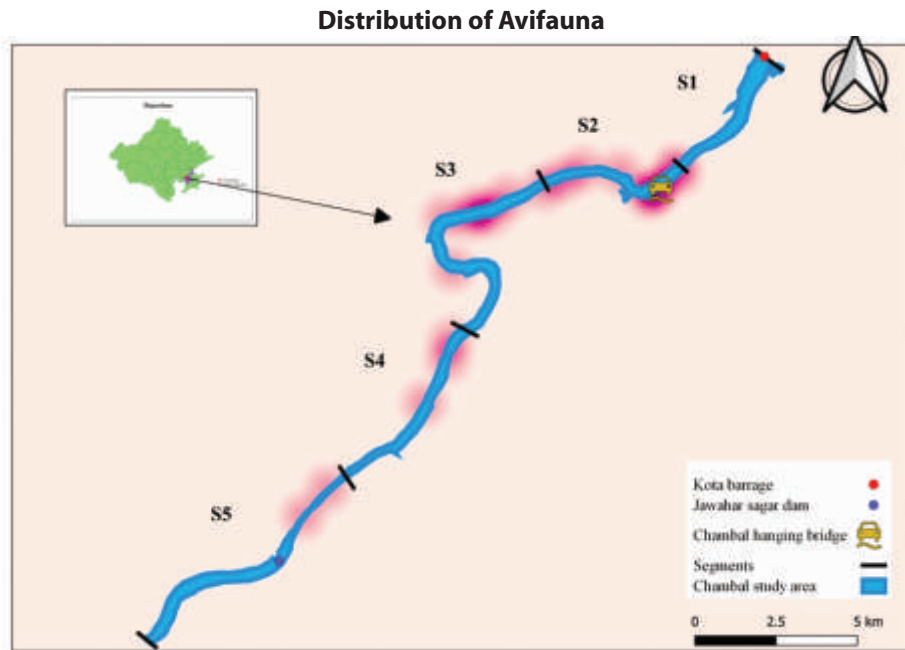
<b>Indian Robin</b>	<i>Copsychus fulicatus</i>	LC	R	IN
<b>Oriental Magpie Robin</b>	<i>Copsychus saularis</i>	LC	R	IN
<b>Siberian Stonechat</b>	<i>Saxicola maurus</i>	LC	R	IN
<b>Tickell's Blue Flycatcher</b>	<i>Cyornis tickelliae</i>	LC	R	IN
<b>Family: Nectariniidae</b>				
<b>Purple Sunbird</b>	<i>Cinnyris asiaticus</i>	LC	R	OM
<b>Family: Oriolidae</b>				
<b>Indian Golden Oriole</b>	<i>Oriolus kundoo</i>	LC	R	OM
<b>Family: Paridae</b>				
<b>Cinereous Tit</b>	<i>Parus cinereus</i>	LC	R	IN
<b>Family: Passeridae</b>				
<b>House Sparrow</b>	<i>Passer domesticus</i>	LC	R	OM
<b>Yellow-throated Sparrow</b>	<i>Gymnoris xanthocollis</i>	LC	R	OM
<b>Family: Phylloscopidae</b>				
<b>Common Chiffchaff</b>	<i>Phylloscopus collybita</i>	LC	R	IN
<b>Greenish Warbler</b>	<i>Phylloscopus trochiloides</i>	LC	W	IN
<b>Family: Pycnonotidae</b>				
<b>Red-vented Bulbul</b>	<i>Pycnonotus cafer</i>	LC	R	OM
<b>Family: Rhipiduridae</b>				
<b>White-browed Fantail</b>	<i>Rhipidura aureola</i>	LC	R	IN
<b>Family: Sturnidae</b>				
<b>Bank Myna</b>	<i>Acridotheres ginginianus</i>	LC	R	OM
<b>Rosy Starling</b>	<i>Pastor roseus</i>	LC	R	OM
<b>Common Myna</b>	<i>Acridotheres tristis</i>	LC	R	OM
<b>Family: Vangidae</b>				
<b>Common Woodshrike</b>	<i>Tephrodornis pondicerianus</i>	LC	R	IN
<b>Order: Piciformes</b>				
<b>Family: Megalaimidae</b>				
<b>Coppersmith Barbet</b>	<i>Psilopogon haemacephalus</i>	LC	R	FG
<b>Family: Picidae</b>				
<b>Black-rumped Flameback</b>	<i>Dinopium benghalense</i>	LC	R	OM
<b>Order: Psittaciformes</b>				
<b>Family: Psittaculidae</b>				
<b>Alexandrian parakeet</b>	<i>Psittacula eupatria</i>	NT	R	FG
<b>Plum-headed Parakeet</b>	<i>Psittacula cyanocephala</i>	LC	R	FG
<b>Rose-ringed Parakeet</b>	<i>Psittacula krameri</i>	LC	R	FG

LC=Least Concern, NT=Near Threatened; W=Winter migrant, R= Resident; IN = Insectivore, HE= Herbivore, CA= Carnivore, OM=Omnivore,FG=Frugivore

**Table 9.** Different diversity indices of terrestrial birds recorded in Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Diversity indices		Species richness (S)	Total number of individual (N)	Shannon index (H)	Dominance (D)	Evenness (E)
<b>Segment 1</b>	Pre-Monsoon	31	315	2.47	0.14	0.38
	Post-Monsoon	21	185	2.07	0.26	0.38
<b>Segment 2</b>	Pre-Monsoon	24	176	2.57	0.11	0.55
	Post-Monsoon	13	176	1.33	0.36	0.29
<b>Segment 3</b>	Pre-Monsoon	17	185	2.20	0.15	0.53
	Post Monsoon	8	66	1.59	0.25	0.61
<b>Segment 4</b>	Pre-Monsoon	17	108	2.26	0.16	0.56
	Post Monsoon	9	44	1.37	0.38	0.44
<b>Segment 5</b>	Pre-Monsoon	15	57	2.45	0.10	0.77
	Post Monsoon	17	39	2.61	0.09	0.80
<b>Overall</b>	Pre-Monsoon	57	841	2.99	0.08	0.35
	Post Monsoon	35	510	2.25	0.20	0.27

Overall, the occupancy of birds (combined waterbirds, raptors and terrestrial birds) between between Kota barrage and Jawahar Sagar Dam indicated that the segment 2 had more birds life with many active nests of Vultures, Woolly-necked stork and Indian eagle-owl. The heat map showing avifauna distribution along the study area is given in Figure 10.



**Figure 10.** Occupancy heat map of avifauna abundance between Kota barrage and Jawahar Sagar Dam, Rajasthan.

### Crocodile and Turtle occupancy

All through our survey across six months, only one turtle species was recorded, which was identified as *Pangshura tecta*, an Indian roofed turtle (n=1) during August at the Segment 2 (S2). Besides, those periodic sightings of muggers *Crocodylus palustris*, basking along the riverbank and swimming on the surface of the water were observed from the study area. During the pre-monsoon season, 34 individual crocodiles were recorded across all river segments and most of the sightings were on the rocks. In the case of the post-monsoon season, the number has been reduced to 23 individuals. This reduction is mainly because of the submergence of basking rocks due to water level rise in river channel during monsoon (Taigor and Rao, 2010). In the pre-monsoon seasons, a high number of individuals were recorded at S5 and S4 (both had n=9: six adults and 3 sub-adults). Followed, by S3 had 6 individuals (including one juvenile). Juvenile individuals were not recorded during the pre-monsoon season. Moreover, the sightings of muggers were limited in all segments. However, S4 had more numbers similar to the pre-monsoon, whereas the number of the sighting was less in S5 (n=5) during post-monsoon. These changes might be due to the fast-flowing waters from the dam openings that the muggers might be moved to the flow refuge areas. After the monsoon, 3 juveniles have recorded in S2 (n=2) and in S5 (n=1), this implied that the study stretches support good habitat for nesting and breeding ground for crocodiles. The water temperature where the *C. palustris* has spotted has taken which shown highest in S5 ( $29.1 \pm 0.6$ ) and the mean depth which was perpendicular to mugger locations were documented, which was lowest at S5 ( $6.7 \pm 0.5$ m) during the pre-monsoon, that could be a reason too many individual sightings as they prefer good rocky surface and warmer

conditions for basking. In the case of post-monsoon, we observed a reduction in mean water temperature of  $1.5\pm 0.4$  when compared to pre-monsoon. This reduction might be due to rainfall and the rapid flow of water. However, the S4 had a maximum temperature ( $27.2\pm 0.9$ ) and the depth was slightly lower ( $11.7\pm 0.6$ m), so it is evident that in both seasons the muggers prefer slightly warmer temperatures and less depth than other segments of the river. Meanwhile, S3 with the maximum depth of the stretch  $16.3\pm 0.4$ m and  $16.9\pm 0.5$ m were recorded with ( $n=6$  &  $n=4$ ) during pre and post-monsoon respectively. Whereas S1 ( $n=7$ ) mostly the sightings occurred on the surface of the water like in S2 ( $n=8$ ) across two seasons. Segment-wise number of crocodiles recorded and their size classes are given in Table 10 and segment-specific habitat characters are presented in Table 11. The comparison between the two seasons is given below in Figure 11.

**Table 10.** Segment wise number of crocodiles recorded in Chambal River between Kota barrage and Jawahar Sagar Dam, Rajasthan.

Segment (S)	Individual count		Size class					
			Pre-Monsoon			Post-monsoon		
	Pre-Monsoon	Post-monsoon	Adult	Sub-adult	Juvenile	Adult	Sub-adult	Juvenile
S1	5	2	4	1	0	1	1	0
S2	5	3	4	1	0	1	0	2
S3	6	4	5	1	0	4	0	0
S4	9	9	6	3	0	5	4	0
S5	9	5	6	3	0	2	2	1
Total	<b>34</b>	<b>23</b>	<b>25</b>	<b>9</b>	<b>0</b>	<b>13</b>	<b>7</b>	<b>3</b>

**Table 11.** Segment-wise habitat parameters perpendicular to the mugger's observed location.

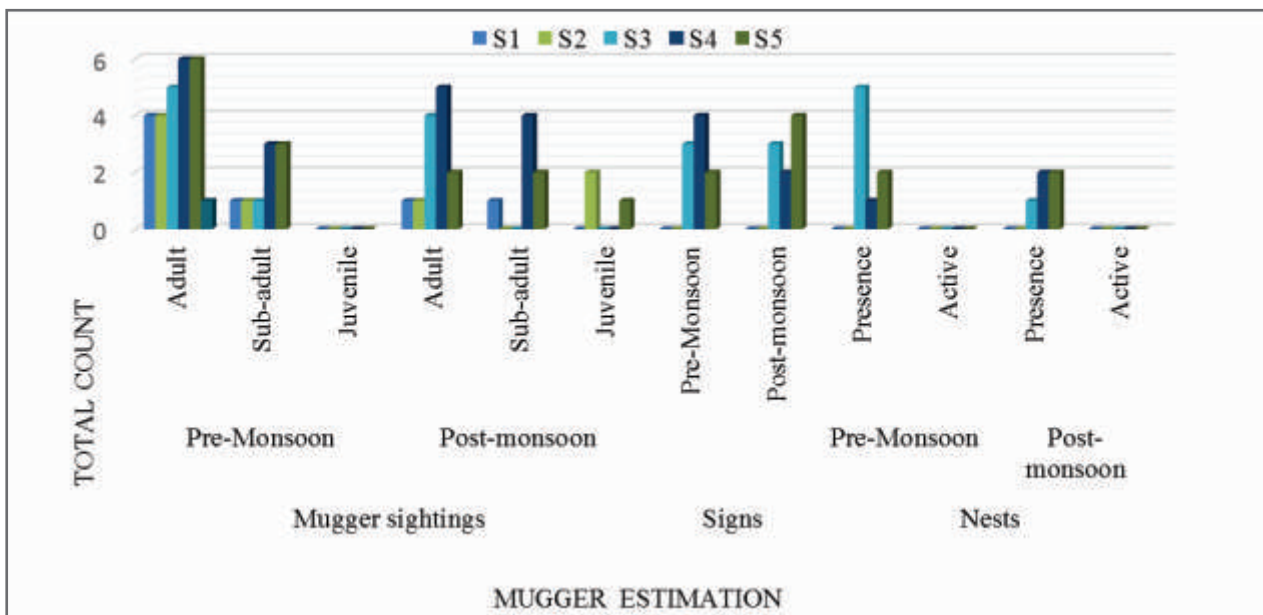
Segment (S)	Habitat parameters			
	Depth (m)		Temperature ( $^{\circ}$ C)	
	Pre-Monsoon	Post-monsoon	Pre-Monsoon	Post-monsoon
S1	$12.9\pm 1.3$	$10.9\pm 0.4$	$27.7\pm 0.7$	$26.8\pm 0.5$
S2	$13.4\pm 0.9$	$14.2\pm 0.8$	$26.6\pm 0.4$	$26.3\pm 0.6$
S3	$16.3\pm 0.4$	$16.9\pm 0.5$	$27.3\pm 1.3$	$26.7\pm 0.3$
S4	$9.6\pm 0.7$	$11.7\pm 0.6$	$27.9\pm 1.7$	$27.2\pm 0.9$
S5	$6.4\pm 0.4$	$7.9\pm 1.2$	$29.1\pm 0.6$	$26.6\pm 0.2$

In the lower segments like S1 and S2, the bank edges are narrow with little resting place offered, the probability of finding nesting locations were limited. Unlike downstream, the middle and upper regions have sandy banks with 8 nesting sites were located, where five nests at S3, two nests at S5 and one nest at S4. All nests were found to be abandoned/ old as none of the muggers

turned to the nests, which were confirmed through camera traps. Apart from the direct count and nest count, 9 crocodile signs (body impression marks and footprints) were recorded along the river banks 3 signs in S3, 4 signs in S4 and 2 signs in S5 during the pre-monsoon survey. On the other hand, during the post-monsoon survey, there were 5 signs (S3=3, S4=2 & S5=4) and 5 nests were observed: one nest at S3 and two nests at S1 and S2. Segment-wise nesting sites and other crocodile signs observed during the study period is given in Table 12.

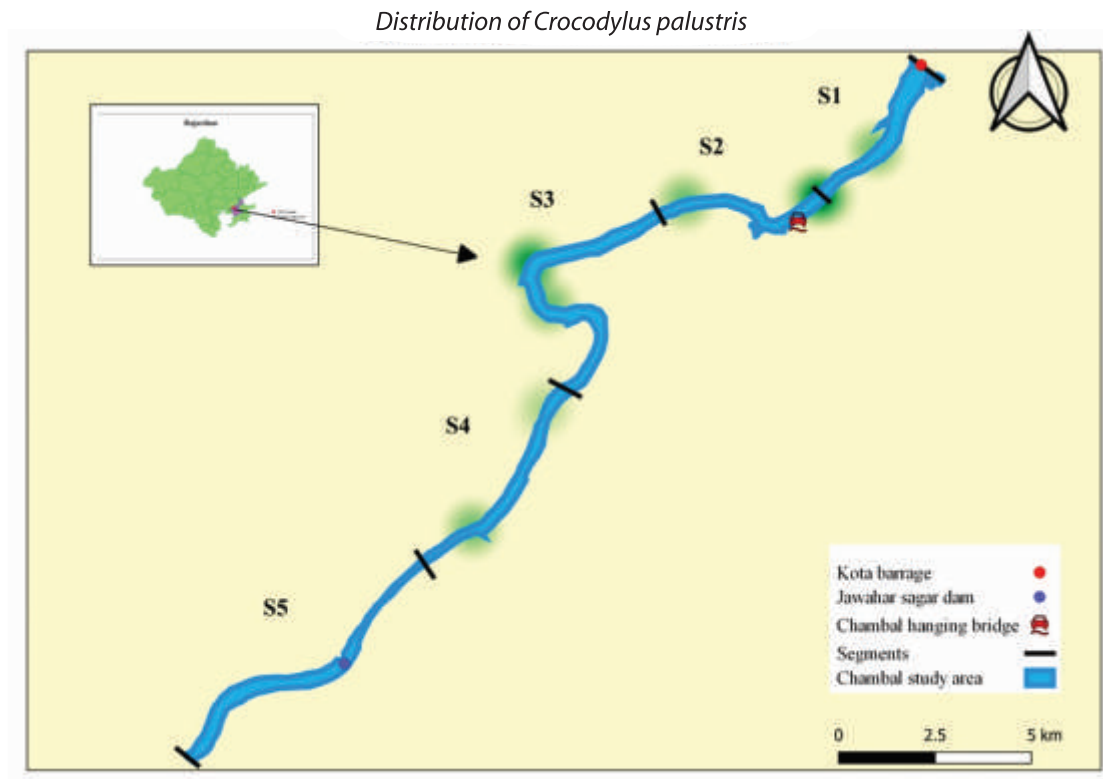
**Table 12.** Nest sites and tracks of Mugger crocodile in the Chambal River across two seasons.

Segment (S)	Signs (Body impressions, tail marks)		Nests			
	Pre-Monsoon	Post-monsoon	Pre-Monsoon		Post-monsoon	
			Presence	Active	Presence	Active
S1	0	0	0	0	0	0
S2	0	0	0	0	0	0
S3	3	3	5	0	1	0
S4	4	2	1	0	2	0
S5	2	4	2	0	2	0
<b>Total</b>	<b>9</b>	<b>9</b>	<b>8</b>	<b>0</b>	<b>5</b>	<b>0</b>



**Figure 11.** Estimation of mugger population across two seasons.

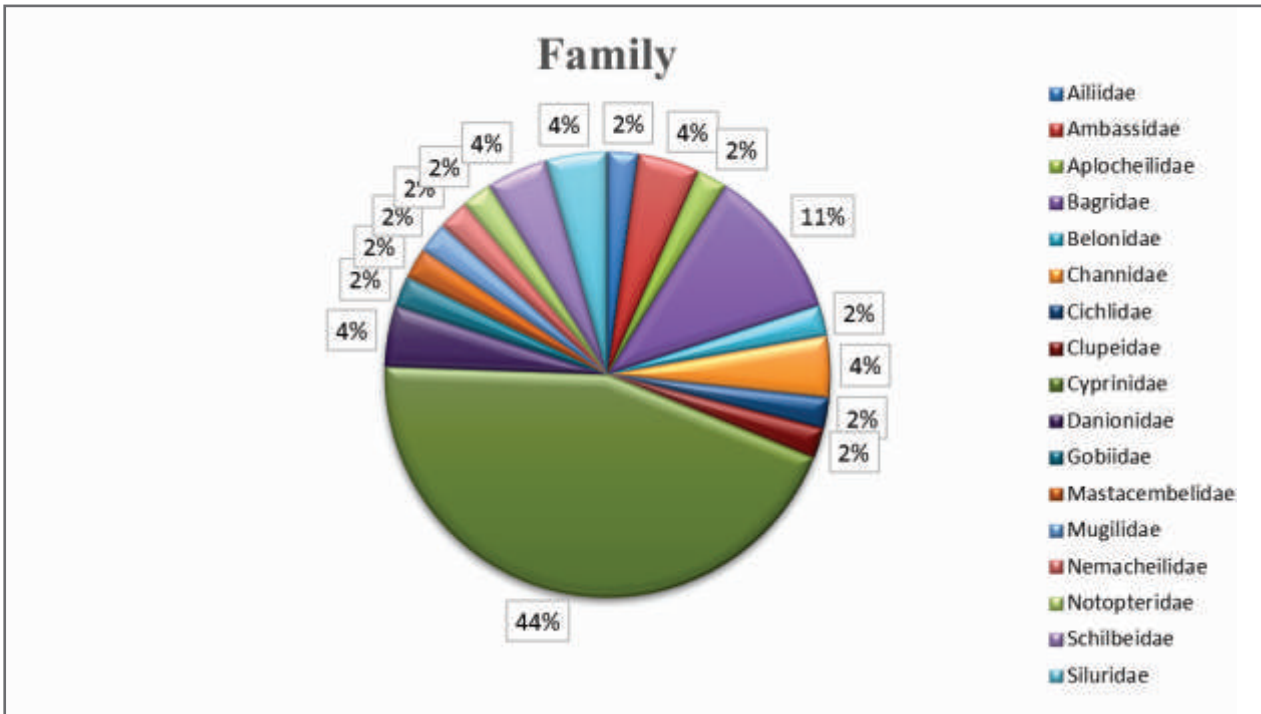
Overall, the distribution patterns of muggers between Kota barrage and Jawahar Sagar Dam indicated that the segment 2 is one of the active sites for mugger activities. The heat map showing muggers distribution along the study area is given in Figure 12.



**Figure 12.** Occupancy heat map of muggers between Kota barrage and Jawahar Sagar Dam, Rajasthan.

### Fish diversity and distribution

A total of 46 species of fishes belonging to 12 orders, 15 families, and 32 genera were recorded between Kota barrage and Jawahar Sagar Dam. Out of which 34 species and 29 species were recorded in Pre-monsoon and Post-monsoon, respectively (Table 13). Fishes belonging to the Cyprinidae family are dominant assemblage members, which accounts 22 species, followed by 5 species from the family *Bagridae* and 2 species in *Ambassidae*, *Channidae*, *Danionidae*, *Schilbeidae*, and *Siluridae* (Table 13). Overall, Family Cyprinidae has shown maximum abundance and contributed about 44%, whereas the least was shown by 10 different families, which constitute 2 % of species composition each in the overall assemblages (Fig.13).



**Figure 13.** Percentage composition of fish species recorded from different families in Chambal River, Rajasthan.

**Table 13.** Segment-wise fish species recorded during pre-monsoon (PM) and post-monsoon (POM).

Sl no	Fish taxa	IUCN status	S1		S2		S3		S4		S5	
			PM	PO M	PM	PO M	PM	PO M	PM	PO M	PM	PO M
<b>Cyprinodontiformes</b>												
Aplocheilidae												
1	<i>Aplocheilus panchax</i> (Hamilton 1822)	LC	4	-	-	-	-	-	-	-	-	-
<b>Anabantiformes</b>												
Channidae												
2	<i>Channa marulius</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
3	<i>Channa punctatus</i> (Bloch, 1793)	LC	1	-	-	-	-	-	-	-	-	-
<b>Cypriniformes</b>												
Cyprinidae												

4	<i>Bangana dero</i> (Hamilton 1822)	LC	-	-	-	-	-	1	-	-	-	-
5	<i>Cirrhinus reba</i> (Hamilton 1822)	LC	-	-	1	-	-	1	-	-	-	-
6	<i>Cirrhinus mrigala</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
7	<i>Garra gotyla</i> (Gray 1830)	LC	-	-	-	-	-	-	-	-	1	-
8	<i>Labeo angra</i> (Hamilton 1822)	LC	13	-	-	2	3	-	3	-	-	-
9	<i>Labeo bata</i> (Hamilton 1822)	LC	-	-	-	-	-	-	-	-	1	-
10	<i>Labeo calbasu</i> (Hamilton 1822)	LC	-	-	-	1	-	-	2	-	1	2
11	<i>Labeo catla</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
12	<i>Labeo gonius</i> (Hamilton 1822)	LC	4	-	6	-	-	2	-	3	-	-
13	<i>Labeo pangusia</i> (Hamilton 1822)	LC	-	-	-	-	-	-	1	-	-	-
14	<i>Labeo rohita</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
15	<i>Labeo sp.*</i> (Hamilton 1822)	-	24	-	4	-	1	-	-	-	-	-
16	<i>Osteobrama cotio</i> (Hamilton 1822)	LC	1	-	-	2	-	-	-	-	-	-
17	<i>Pethia conchoniis</i> (Hamilton 1822)	LC	-	-	-	-	-	-	-	-	1	-
18	<i>Puntius amphibius</i> (Valenciennes 1842)	LC	1	-	-	-	-	-	-	-	-	-
19	<i>Puntius chola</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
20	<i>Puntius sophore</i> (Hamilton 1822)	LC	-	-	-	1	-	-	-	-	-	-
21	<i>Systemus sarana</i> (Hamilton 1822)	LC	18	-	1	-	-	4	2	-	5	-

22	<i>Tariqilabeo latius</i> (Hamilton 1822)	LC	-	-	-	-	-	-	-	-	10	-
23	<i>Tor tor</i> (Hamilton 1822)	DD	-	-	-	-	1	-	2	-	4	1
<b>Cypriniformes</b> Danionidae												
24	<i>Rasbora daniconius</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
25	<i>Salmostoma sp.</i> (Swainson 1839)	-	1	-	20	-	4	-	2	-	5	-
<b>Cypriniformes</b> Nemaceilidae												
26	<i>Paracanthocobitis botia</i> (Hamilton 1822)	LC	-	-	-	-	-	-	-	-	-	3
<b>Siluriformes</b> Ailiidae												
27	<i>Clupisoma garua</i> (Swainson 1838)	LC	-	-	-	-	-	-	1	-	-	-
<b>Siluriformes</b> Schilbeidae												
28	<i>Eutropiichthys vacha</i> (Hamilton 1822)	LC	2	1	6	1	9	2	1	-	-	3
29	<i>Silonia silondia</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
<b>Siluriformes</b> Bagridae												
30	<i>Mystus cavasius</i> (Hamilton 1822)	LC	-	1	-	-	-	-	-	-	-	-
31	<i>Mystus tengra</i> (Hamilton 1822)	LC	-	-	-	-	-	1	-	-	-	-
32	<i>Rita rita</i> (Hamilton 1822)	LC	-	1	-	-	-	-	-	-	-	-
33	<i>Sperata aor</i> (Hamilton 1822)	LC	1	-	1	-	-	1	-	-	-	-

34	<i>Sperata seenghala</i> (Sykes 1839)	LC	-	-	-	-	-	-	-	1	-	5
<b>Siluriformes</b>												
Siluridae												
35	<i>Ompok bimaculatus</i> (Bloch 1974)	NT	-	1	-	-	-	-	-	-	-	3
36	<i>Wallago attu</i> (Bloch & Schneide 1801)	VU	1	-	-	-	-	-	-	-	-	-
<b>Gobiiformes</b>												
Gobiidae												
37	<i>Glossogobius giuris</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-
<b>Clupiformes</b>												
Clupidae												
38	<i>Gudusia chapra</i> (Hamilton 1822)	LC	1	-	-	10	152	25	7	-	3	-
<b>Synbranchiformes</b>												
Mastacembelidae												
39	<i>Mastacembalus armatus</i> (Lacepede 1800)	LC	-	-	-	1	1	-	-	-	-	-
<b>Osteoglossiformes</b>												
Notopteridae												
40	<i>Notopterus Synurus</i> (Lacepede 1800)	LC	-	-	-	1	-	-	2	-	-	-
<b>Perciformes</b>												
Ambassidae												
41	<i>Chanda nama</i> (Hamilton 1822)	LC	-	-	-	1	-	-	-	-	-	-
42	<i>Parambassis ranga</i> (Hamilton 1822)	LC	-	-	1	-	-	-	-	-	-	-
43	<i>Parambassis lala</i> (Hamilton 1822)	NT	2	-	-	-	-	-	-	-	-	-
<b>Cichliformes</b>												
Cichlidae												

<b>44</b>	<i>Oreochromis niloticus</i> (Linnaeus)	LC	3	-	-	-	-	1	-	-	-	-
<b>Beloniformes</b>												
Belonidae												
<b>45</b>	<i>Xenotodon cancila</i> (Hamilton 1822)	LC	-	-	1	11	2	-	1	-	-	-
<b>Mugiliformes</b>												
Mugilidae												
<b>46</b>	<i>Rhinomugil corsula</i> (Hamilton 1822)	LC	1	-	-	-	-	-	-	-	-	-

\*Needed to be confirmed. EN=Endangered, VU=Vulnerable, NT=Near Threatened, LC=Least Concern, CR=Critically endangered, DD=Data deficient, NE=Not Evaluated.

### Patterns of fish distribution

In the present study, during the pre-monsoon fish catch there were 34 species, in which *Gudusia chapra* was the dominant species among the total distribution across five segments, followed by *Labeo sp.*, *Systemus sarana* and *Eutropiichthys vacha* also showed dominance in S1, S2 and S4 respectively. The small-sized fishes, *Parambassis ranga* and *Salmostoma sp.* were reported in the segments two and three (S2 and S3) comprised major contribution to the overall catch. Similarly, the species like *Garra gotyla*, *Clupisoma garua*, *Notopterus synurus*, *Labeo calbasu* and *Tor tor* were reported only in the upper segments (S4 and S5), whereas *Labeo sp.* were mostly restricted to lower stretches (S1 and S2) during the pre-monsoon period. There were 28 fish species were recorded during the post monsoon study, like pre-monsoon *Gudusia chapra* has shown dominant among the total catch among the species at S2 & S3. The species composition at S1 in pre-monsoon has seen a wide range of species such as *Wallago attu*, *Rasbora daniconius*, *Silonia silonida*, *Puntius amphibius*, *Channa marulius* and *Channa punctatus* whereas the post-monsoon catch comprised 12 more species which were added during the post-monsoon study period. The species like *Cirrhinus reba*, *Bengaro dero*, *Mystus cavasius*, *Mystus tengra* and *Rita rita*, were only reported during the post-monsoon survey. However, the species such as *Paracanthocobitis botia*, *Tariqilabeo latius* and *Ompok bimaculatus* were mostly distributed in the upstream segments S4 and S5. The overall species distribution across different segments is given in Table 9.

### Fish diversity

The Shannon diversity was found to be higher in segment S1 (H=2.27) during pre-monsoon, whereas in the post-monsoon segment S2 had high Shannon index (H=2.01). Low diversity was recorded at S3 during pre-monsoon (H=0.56) as well as in the post-monsoon (H=1.52). In the case of species richness, high richness was recorded in downstream segment-1 (S=23) during pre-

monsoon and overall richness is also high in segment S1 (S=27). The overall dominance value was high in segment-3 (D=0.77) and the minimum value was observed in the S2 (D=0.66) and the segment-wise diversity indices covering Pre-monsoon and Post-monsoon are given in Table 14.

**Table 14.** Seasonal changes in fish abundance, species richness and diversity recorded in different segments of the Chambal River during Pre-monsoon and Post-monsoon.

	River segment (S)														
	S1			S2			S3			S4			S5		
	Pre-Monsoon	Post-Monsoon	Overall	Pre-Monsoon	Post-Monsoon	Overall	Pre-Monsoon	Post-Monsoon	Overall	Pre-Monsoon	Post-Monsoon	Overall	Pre-Monsoon	Post-Monsoon	Overall
<b>Richness (S)</b>	23	5	27	8	14	18	8	10	16	9	4	12	7	8	13
<b>Abundance (nos)</b>	81	5	86	24	65	89	173	44	217	19	8	27	16	29	45
<b>Diversity (H)</b>	2.27	1.61	2.43	1.82	2.01	2.31	0.56	1.52	0.90	1.93	1.25	2.29	1.71	1.85	2.36
<b>Evenness (E)</b>	0.42	1.0	0.42	0.77	0.53	0.56	0.22	0.45	0.15	0.76	0.87	0.82	0.79	0.80	0.81
<b>Dominance (D)</b>	0.16	0.20	0.15	0.18	0.17	0.13	0.77	0.35	0.66	0.19	0.31	0.12	0.21	0.19	0.11

### Fish abundance vs Environmental variables

#### Environmental variables

The present study showed very little variation in environmental variables. The sites were showing variations in the physicochemical parameters were significant ( $p < 0.05$ ). The mean values recorded across the study area during Pre-monsoon and Post-monsoon is given in Table 15. Temperature plays a vital role in certain biochemical reactions for aquatic organisms and it is considered as the key environmental parameter for deciding the quality of aquatic habitat. The mean water temperature recorded across all segments was about  $27.7 \pm 0.9$  during pre-monsoon, but it was slightly reduced ( $26.2 \pm 0.5^\circ\text{C}$ ) post the monsoon but the air temperature has a slight variation between the seasons, pre-monsoon ( $28 \pm 0.75$ ) recorded lower than the and post-monsoon ( $30.91 \pm 0.17$ ), but S1 showed little higher than all other segments however, the warmest being recorded with  $31.8 \pm 0.33$  in the segment (S1) during post-monsoon. The hydrogen ion concentration (pH) was found to be slightly alkaline ranged from  $7.08 \pm 0.02$  and  $8.55 \pm 0.01$  units across the sites, which were steady over time with the lowest value recorded at S1 and the highest value recorded at S4. Dissolved oxygen (DO) is considered an indicator of the healthy riverine system and aquatic life by regulating the metabolic activities of the aquatic community. The present study minimum DO value 6.3 mg/l and a maximum of 8.4 mg/l were

recorded in S2 in post-monsoon and in S5 during pre-monsoon respectively. Thus, the river habitat is considered healthy for fish fauna and other aquatic species since the 3 mg/l DO is required for the wellbeing of inhabitant aquatic life forms (Bose *et al.*, 2019). The presence of ionic concentrations such as Ca<sup>2+</sup>, Mg<sup>2+</sup>, NO<sub>3</sub><sup>-</sup> and few other ions contribute to the Electrical Conductivity (EC) of the water. The specific conductivity was varying widely between 183 and 302 µS/cm with a minimum and maximum recorded at S2 during the post-monsoon and pre-monsoon respectively. The open waters mainly comprise a huge amount of mineral salts and inorganic minerals like calcium, phosphates, potassium, bicarbonates, and other dissolved substances. Like conductivity, total dissolved solids in water (TDS) varied along all sites ranging from 91.54 ppm at S2 in post-monsoon to 150 ppm at S2 in pre-monsoon. Overall, the deep river channel was recorded in segment 4 during post-monsoon (S4= depth 45.3±4.5m), and comparatively low depth profile was recorded in the uppermost segment of the study area (S5= depth 6.47±0.25m). In the case of pre-monsoon, because of the high gradient terrain type in the upper portion of the river segment, which holds less volume of the water in the river channel. Throughout the study, the mean velocity of water during pre-monsoon was recorded at S4 (0.2 m/Sec) however the water velocity was found to be almost zero at S1, S2, and S3 whereas S5 had a constant water velocity of 0.5 m/s. In the case of post-monsoon, it was found to be in between 0.17 at S1 and 0.41 m/s at S5. The mean width of the study area was about 240.2 m and the widest river channel was recorded in S4 (324m) whereas the narrow river width was recorded at S5 (110.9m). However, the mean dominant substratum was observed to be boulders and bedrocks along the entire stretch.

**Table 15.** Segment-wise environmental variables (mean±SD) recorded from the study area covering Pre-monsoon and Post-monsoon seasons.

Environmental variables	Segment (S)									
	S (1)		S (2)		S (3)		S (4)		S (5)	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<b>pH</b>	8.07±0.09	7.08±0.02	8.23±0.11	7.42±0.01	8.33±0.01	8.38±0.02	8.36±0.00	8.55±0.01	8.31±0.01	8.14±0.06
<b>Conductivity (µS/cm)</b>	297±1.5	236.9±10.8	302±5.5	183±3.16	281±3.5	236.1±7.38	285±1.0	208±9.74	276±1.0	224.2± 23.2
<b>TDS (ppm)</b>	149±2.5	122.1±4.22	150±2.5	91.5±1.54	141±1.0	117.7±3.68	142±0.5	103.8±4.84	139±0.5	109.4±12.0
<b>DO (mg/l)</b>	6.46±0.16	4.40±0.11	7.64±0.32	4.24±0.08	8.2±0.10	5.31±0.15	8.3±0.10	6.7±0.10	8.35±0.05	6.4±0.10
<b>Water temperature (°C)</b>	27.7±0.7	26.8±0.5	26.6±0.4	26.8±0.5	27.3±1.3	26.7±0.3	27.9±1.7	27.2±0.9	29.1±0.6	26.6±0.2
<b>Air temperature (°C)</b>	27±0.90	33.12±0.24	27.7±0.25	30.2±0.26	28.5± 0.2	28.86±0.40	30.1±0.15	30.77±0.20	31.1±0.9	31.8±0.11
<b>Depth (m)</b>	12.9±0.02	39.74±6.7	13.0±0.03	34.4±5.13	16.3±0.1	27.98±4.03	9.68±0.18	45.30±4.59	6.47±0.25	23.66±2.19
<b>Width (m)</b>	275±1.0	275±1.0	243±1	243±1	243.5±2.5	243.5±2.5	324±8	324±8	113±7	113±7
<b>Velocity (m/Sec)</b>	0	0.21±0.11	0	0.17±0.002	0	0.325±0.02	0.2±0.2	0.41±0.02	0.5	0.39±0.03

### Fish abundance vs Environmental variables

The canonical correspondence analysis (CCA) was implemented to show the relationship between major fish species recorded and environmental variables through the segments. Totally 8 environment variables were used to establish significant contributors to variation in the

ordination. The species recorded across the sites showed a significant correlation with the environmental factors ( $p < 0.001$  along axes one and two; Monte Carlo test with 1,000 permutations). Width, depth, conductivity, TDS, air and water temperature were negatively correlated with the first ordination axis (Table 16). Depth was the only parameter positively correlated with the second ordination axis. The species were scattered in three assemblages corresponding to the significant habitat features Figure 14. The species like *C. garua* were mainly associated to the water temperature and air temperature, and on the other hand *Tor tor*, *E. vacha* and *L. calbasu* were mostly related to the depth of the water. The species *Gudasia chapra*, the most abundant fish species distribution was correlated to high pH and dissolved oxygen.

**Table 16.** Canonical correspondence analysis (CCA) summary statistics for the fish and environment variables in Chambal River.

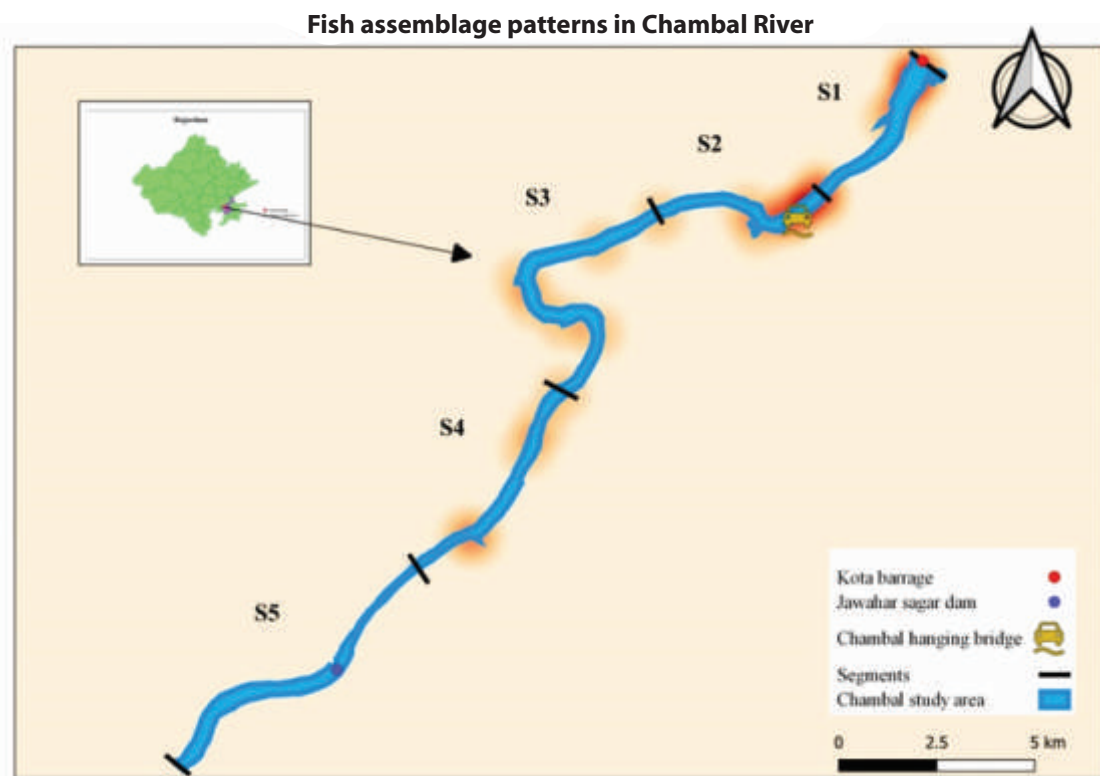
	Axis 1	Axis 2	Axis 3	Axis 4
<b>Eigenvalue</b>	0.55106	0.46048	0.31347	0.07923
<b>pH</b>	0.601467	-0.4154	0.495619	0.457787
<b>Conductivity (<math>\mu\text{S}/\text{cm}</math>)</b>	-0.71764	-0.66032	-0.32328	-0.32639
<b>TDS (ppm)</b>	-0.75956	-0.61557	-0.37488	-0.29005
<b>DO (mg/l)</b>	0.479963	-0.22968	0.762375	0.396376
<b>Water temperature <math>^{\circ}\text{C}</math></b>	-0.88768	-0.17097	0.230609	0.244231
<b>Air temperature <math>^{\circ}\text{C}</math></b>	-0.33344	-0.09427	-0.70616	0.688847
<b>Depth (m)</b>	-0.36341	0.077371	0.862644	0.035823
<b>Velocity (km/h)</b>	0.130486	-0.08734	0.982457	0.074129
<b>Richness S</b>	-0.73748	-0.00617	-0.6419	-0.36274
<b>Abundance</b>	0.304174	-0.52902	-0.53471	-0.35666

### Conservation significant fish species

Out of 46 species recorded, good population of one vulnerable species *Wallago attu* and two near threatened species such as *Parambassis lala* and *Ompok bimaculatus* were recorded from the study area. These species are listed in the regional threatened species list of the National Bureau of Fish Genetic Resources (NBFGR), India & IUCN red data list. Overall, the percentage of contribution of vulnerable species is 2%, data deficient species is 2% and the near threatened constitutes 5% (Fig. 15). Rest of the species (91%) are listed in the least concern category (IUCN, 2021).



Overall, the abundance of fish species recorded between between Kota barrage and Jawahar Sagar Dam indicated that the segment 2 and section 1 inhibit more diverse and abundance fish species (Figure 16) as these segments have more deeper habitats.



**Figure 16.** Occupancy heat map of fish abundance between Kota barrage and Jawahar Sagar Dam, Rajasthan.

## Impacts of Cable-stayed Bridge on Aquatic wildlife

The cable-stayed bridge was constructed by the National Highway Authority of India (NHAI) to make a connection between one end to the other end of National Highway 27; which connects Kota and Chittorgarh, which was considered to exert some ecological disturbances to the Chambal River ecosystem and its biological components. The bridge is situated about 5 km away from the Kota barrage, which falls under the second segment of the present study. The bridge is on the stable rocky gorge area, around 30 m above the water level across the Chambal River without any supporting billers from the riverbed. Thus, there is no direct contact between the river and bridge structure. Further, the technology used in this structure is more ecofriendly, because it is totally vibration and noise proof (Fig. 17).



**Figure 17.** A view of cable-stayed bridge from Chambal River

The present survey indicated that abundance of wildlife such as otter presence, mugger sightings, birds' diversity and abundance were concentrated around Segment 2 (where the bridge passes) and Segment 1 (near Kota barrage) (Fig.19). The present study indicated that Segment 2 and Segment 1 have cavernous habitats which support more abundance for the population of fish. One of the strong reasons for the abundance of wildlife around these regions is mainly due to the habitat that supports food resources for the inhabiting population.

In this study we had some significant observations very close to this cable bridge such as, we have recorded otter populations from the same segment of the river nearer the bridge. One otter den site and a spraint site were observed, which was on the right side of the cable bridge. The habitat of the area was rocky escarpment along with sets of floating vegetation. The left side has an area where otters seemed to be accumulated much as many direct sightings, foraging grounds and a den site were observed at a distance of about 1 km from the bridge, this indicated that the area is undisturbed due to the presence of this bridge or by any anthropogenic activities like higher hertz of horn from the vehicles passing through.

Similarly, nesting sites of birds like Grey heron, Night heron, vultures were also observed even closer within the radius of 700m on either side of the bridge around fourteen grey heron nests were recorded on the arjuna trees nearby to the hanging bridge. The nesting colonies of grey herons under the bridge showed the evidence that there were no such real disturbances owing to the bridge and also a threatened raptor species Egyptian Vulture (*Neophron percnopterus*) active nest was observed on the rocky escarpment (25° 8'23.14"N, 75°47'36.64"E), which was just 80 meters away from the bridge. We also observed the permanent roosting sites of the Indian eagle-owl (*Bubo bengalensis*) nearer to this bridge (25° 8'16.12"N, 75°47'27.02"E). The major vulture colonies were situated around 6 km away from the hanging bridge hence the chance of vulture hit is negligible as per our observation.

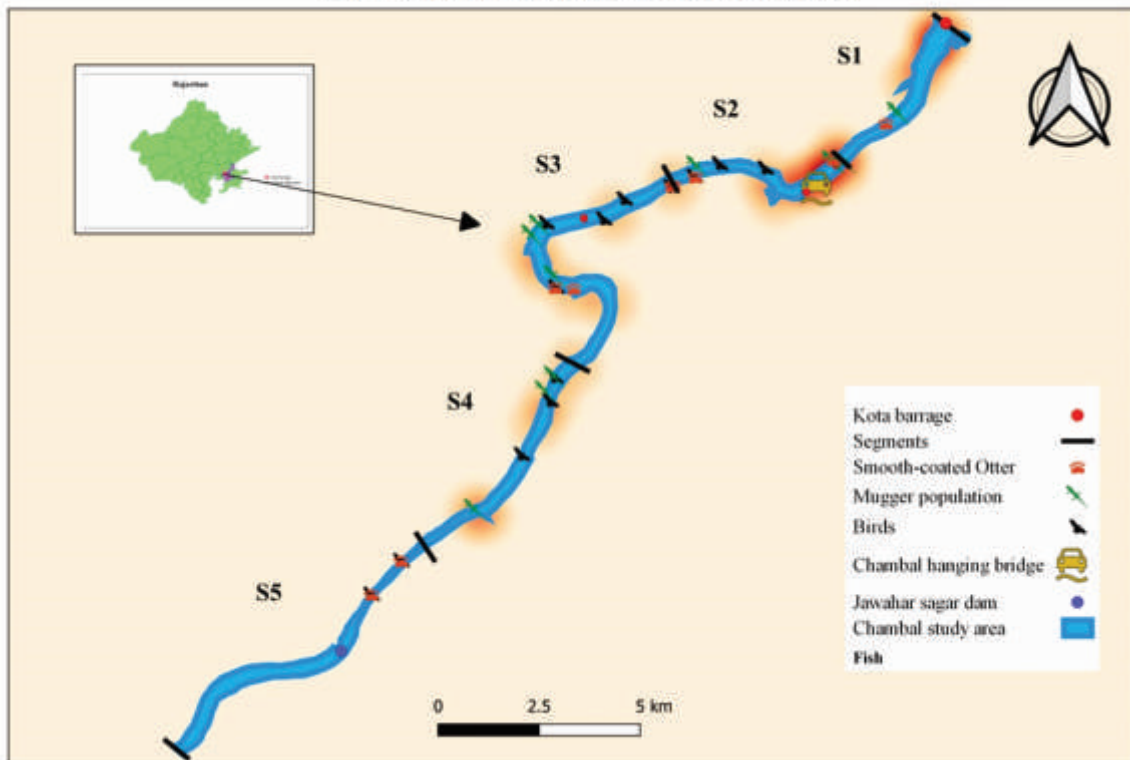
In addition, a vulnerable stork species Woolly-necked Stork (*Ciconia episcopus*) are assumed to prefer isolated areas for nesting (Mehta, 2020) and some previous studies suggests that disturbance could be the major issue for avoiding nesting in Ciconiiformes birds (Bouton et al., 2005) were found to have a breeding site was also observed just 200 meters downstream from the bridge (25° 8'20.90"N, 75°47'33.11"E). Interestingly, hundreds of flocks of species like cormorant and black kite were sighted around the extent of the bridge. Likewise, we observed a number of direct sightings of crocodiles and a good number of fishes were caught near as well as downstream regions of the bridge when compared to other segments of the rivers.

This says that the bridge does not insert any pressure on the nesting activities or on feeding activities of the avifauna in the river, and disturbance due to vehicle movement is found to be negligible. Noise pollution by vehicles is kept minimum because of the well-maintained noise barriers, which had been proposed in the pre-construction study. Moreover, the water quality parameters examined, which were within the optimal range for aquatic life form. Thus, the present study revealed that the presence of cable-stayed bridge does not have any negative impact on the aquatic wildlife and quality of habitat structures in the Chambal River.



**Figure 18.** Wildlife activities near to cable-stayed hanging bridge

## Distribution of wildlife in Chambal River



**Figure 19.** Overall occupancy heat map of otters, birds and muggers between Kota barrage and Jawahar Sagar Dam, Rajasthan.

## Conclusion

In this present scenario, our observations are strongly supporting the fact that there is no adverse impact on wildlife due to this bridge. In particular, the 2 km radius either side of the bridge is enriched with good aquatic and avifauna. Besides that, cable-stayed bridge may channel polluted diesel mixed water from the bridge intruding in the river system and become a reason for pollution. Also, dumping of wastes from the bridge by the locals may put the cleanest river into chaos and may harm the aquatic forms. Moreover, there may be a chance of collision and mortalities of birds when they move in flocks all along the river.

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PLATE I

WATER BIRDS



River Tern (NT)



Woolly-necked Stork (VU)



Purple Heron (LC)



Black-winged Stilt (LC)



Baillon's Crake (LC)



Great Egret (LC)

\*NT=Near Threatened, VU=Vulnerable, LC=Least Concern

PLATE I

WATER BIRDS



Striated Heron (LC)



Great Cormorant (LC)



Lesser Whistling Duck (LC)



White-throated Kingfisher (LC)



Gray Heron (LC)



Black-crowned Night Heron (LC)

\*NT=Near Threatened, VU=Vulnerable, LC=Least Concern

PLATE II

RAPTORS



Indian Vulture (CR)



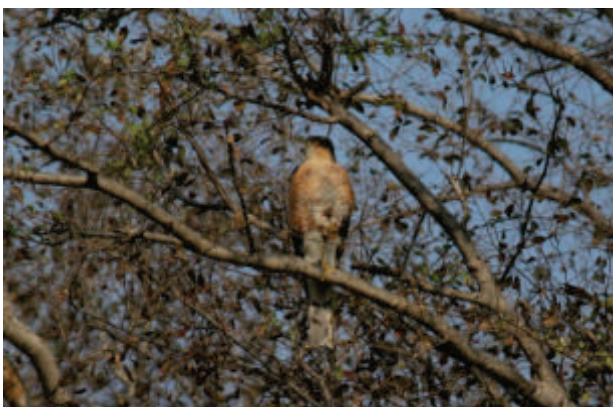
Egyptian Vulture (EN)



Red-headed Vulture (CR)



Oriental Honey Buzzard (LC)



Eurasian Sparrowhawk (LC)



Black Kite (LC)

\*CR=Critically Endangered, EN= Endangered, LC=Least Concern

PLATE II

RAPTORS



Brown Fish Owl (LC)



Osprey (LC)



Shikra (LC)



Indian Eagle Owl (LC)



Bonelli's Eagle (LC)



Dusky Eagle Owl (LC)

\*LC=Least Concern

PLATE III

TERRESTRIAL BIRDS



Alexandrine Parakeet (NT)



House Sparrow (LC)



Common Woodshrike (LC)



Indian Peafowl (LC)



Laughing Dove (LC)



Grey-breasted Prinia (LC)

\*NT=Near Threatened, LC=Least Concern

PLATE III

TERRESTRIAL BIRDS



White-browed Fantail (LC)



Brown Rock Chat (LC)



Coppersmith Barbet (LC)



Tickell's Blue Flycatcher (LC)



Ashy-crowned Sparrow Lark (LC)



Indian Robin (LC)

\*LC=Least Concern

## PLATE IV

# FISHES



*Eutropiichthys vacha* (LC)



*Tor tor* (DD)



*Notopterus synurus* (LC)



*Channa marulius* (LC)



*Gudusia chapra* (LC)



*Cirrhinus reba* (LC)

\* LC-Least Concern, DD- Data Deficient

PLATE IV

FISHES



*Xenetodon cancila* (LC)



*Pethia concohnii* (LC)



*Ompok bimaculatus* (VU)



*Rasbora daniconius* (LC)



*Oreochromis niloticus* (LC)



*Rhinomugil corsula* (LC)

\* LC=Least Concern, VU=Vulnerable

PLATE V

REPTILES  
AND  
AQUATIC MAMMALS



*Crocodylus palustris* (VU)



*Pangshura tecta* (VU)



Habitat of *Pangshura tecta*



Smooth-coated otters (VU)

\*VU=Vulnerable





