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Reintroduction of the Gharial (Gavialis Gangeticus) at the State Animal Barasingha Sanctuary Uttar Pradesh, India

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ABSTRACT

The gharial (Gavialis gangeticus), a critically endangered species endemic to the Indian subcontinent, has experienced significant declines in numbers and distribution, with existing populations now limited to a few protected areas. This manuscript highlights the importance of reintroducing the gharial in the State Animal Barasingha Sanctuary, Uttar Pradesh, which historically supported populations of this unique crocodilian species. The gharial, characterised by its long, slender snout and distinctive narial excrescence, plays a crucial role as a keystone species in maintaining the structure and function of aquatic ecosystems. The Barasingha Sanctuary covers an area of 2073 km² and encompasses vital riverine habitats that can support gharial reintroduction efforts. It lies within the Upper Gangetic Plains and has been recorded as having a gharial presence in historical documents. This sanctuary serves as a crucial site for conservation initiatives aimed at enhancing gharial populations and ensuring the species' survival in a rapidly changing environment. Effective management and scientifically informed strategies will be essential for the successful reintroduction and long-term conservation of the gharial in this region.

INTRODUCTION

The order Crocodilia is represented in India by three distinct species: the mugger or marsh crocodile (Crocodylus palustris), the saltwater crocodile (Crocodylus porosus), and the gharial (Gavialis gangeticus). The gharial, endemic to the Indian sub-continent, is one of the rarest and most aquatic of all crocodilians. It leaves the water only for basking and building nests on moist sandbanks (Maskey et al. 2006). Gharials are the survivors of the great reptilian age and are considered keystone species that maintain ecosystem structure and function through their activities (Behera et al. 2014). Gharials are both taxonomically and structurally unique. Being the only representative of a once well-represented family, Gavialidae (Maskey and Percival 1994), they can be easily distinguished from other crocodiles by their long, narrow and slender snout, the most attenuated snout among all crocodilians. It is interesting to note that the name “gharial” is derived from the Hindi word “ghara”, meaning pot.

The mature male possesses a ‘ghara’ which is a bulbous knob (narial excrescence) present at the end of their snout (Smith 1939). The ‘ghara’ also renders the gharial as the only visibly sexually dimorphic crocodilian. Currently, the species is locally extinct in the Indus, Irrawaddy, and most rivers and tributaries of the Ganges and Brahmaputra-Meghna River systems. Today, only four sites, i.e., Chambal National Sanctuary, Katerniaghat Wildlife Sanctuary, Corbett National Park (River Ramganga) and River Gandak (Uttar Pradesh and Bihar) hold the breeding populations of gharials in India.

Furthermore, the estimated global gharial population is approximately 650 breeding adults, with 88% confined within the National Chambal Sanctuary inIndia (Lang et al. 2019).The gharial has been accorded the highest level of protection under the Indian Wildlife (Protection) Act, 1972, having been placed on Schedule I. The species is Critically Endangered under the IUCN Red List (2007). Stretches of the Chambal, Girwa-Sharda, and Son rivers have been declared Wildlife Sanctuaries by the Government of Uttar Pradesh under the Wildlife (Protection) Act, 1972, for the conservation of these species. Protected Areas aiming to protect specific species, such as the gharial and its habitat, through scientific management reflect the conservation priority accorded to the species.

Study Area

State Animal Barasingha Sanctuary (State Animal BarasinghaSanctuary) is the largest wildlife sanctuary in the state of Uttar Pradesh, spanning an area of 2073 km² (Hastinapur Management Plan 2002-2012). It was declared a wildlife sanctuary by the Government of Uttar Pradesh on 30th July 1986 (3782/14-3-57-84). The sanctuary covers five districts: Muzaffarnagar, Bijnor, Meerut, Ghaziabad, and Jyotiba Phule Nagar, located between 28°46' and 29°35' N latitude and 77°30' and 78°30' E longitude (Figure 01). The altitude of the area ranges from 130m to 150m above sea

level. According to Rodgers and Panwar (1988), the State Animal BarasinghaSanctuary (Old name Hastinapur Wildlife Sanctuary) falls within the Upper Gangetic plains (7A) Biogeographic Classification and represents the Gangetic grassland biome. The sanctuary is located in the Upper Gangetic Plain, a flat alluvial region formed by the deposition of silt by the River Ganga. This alluvial region comprises khola (high-level lands after Bangar, parallel to the River Ganga), khadar (the low-lying old bed of the regularly shifting River Ganga), and Boodhi Ganga (a tributary of the River Ganga), which is typically a more or less permanent feature of ravines.

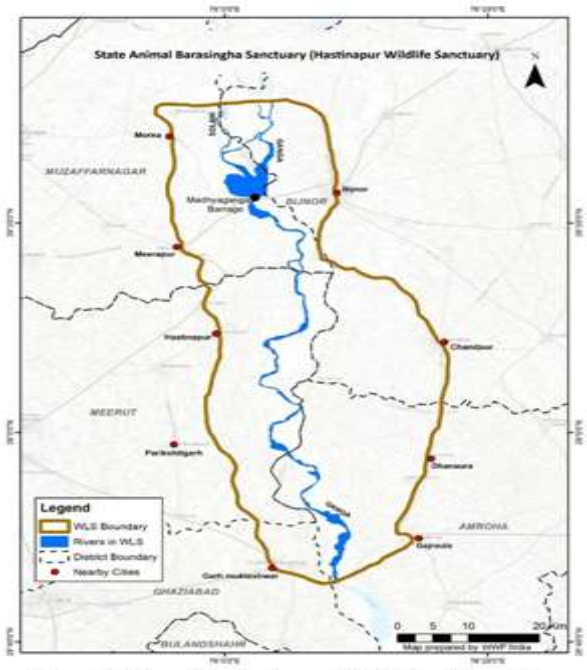

Figure 01: Map of the study area (State Animal Barasingha Sanctuary)

Why State Animal Barsingha Sanctuary (State Animal BarasinghaSanctuary):
State Animal Barahsingha Sanctuary (SABS) is one of the largest wildlife sanctuaries in Uttar Pradesh state, spread over an area of 2073 km2 (Figure 01). It was provisionally notified as a Wildlife Sanctuary by the Government of Uttar Pradesh on 30th July, 1986. The Sanctuary falls between 280 46' and 290 35' N latitude and 770 30' and 780 30'E longitude. The altitude of the area ranges between 130m and 150m above sea level. According to Rodgers and Panwar (1988) SABS falls in the Upper Gangetic plains (7A) biogeographic classification and represents the Gangetic grassland biome. The Ganga flows for about 173 km within the limits of the Sanctuary i.e., from Balawalito Garhmukteshwar and is known to historically support gharial populations as recorded in the District Gazetteer of Bijnor (1908) and Meerut (1965). It was because of the history of the presence of the species and the riverine habitat that the Protected Area was considered suitable to support a gharial population and captive-reared gharials were reintroduced in the SABSthrough a joint decision between the UP-Forest Department and WWF-India.

By the time the River Ganga reaches the State Animal BarasinghaSanctuary, its flows are somewhat altered (especially in lean season) by upstream barrages, due to which a large share of water is diverted for irrigation across districts of Uttar Pradesh. Flows in the Ganga at the SABS are mainly affected by the Bhimgoda Barrage (perennial) and the Madhya Ganga Barrage which is a kharif channel (diverts surplus monsoon season high flows for kharif crops) before it reaches the Narora Barrage (via SABS) further downstream.

Despite these diversions of water in the river, several stretches of the Ganga within the Protected Area can support a population of the Critically Endangered gharial and other associated fauna such as the Ganges River dolphin, freshwater turtles and smooth-coated otter. The river divides the Protected Area into almost two halves, and the area spans between the districts of Bijnor, Meerut, Hapur, Ghaziabad, and J.P Nagar. The villages of Shukartal, Mukhdumpur and Tigri have a high human population density, with villagers somewhat dependent on artisanal fishing and riverbed cultivation as primary sources of livelihood.

Though the most suitable habitat for the gharial, within the SABS, is on the upper half of the Ganga within the PA, a protected riverscape of 173 Km. of mainstream the River Ganga provides the prospects and possibilities of released gharials migrating upstream up to the Madhya Ganga Barrage and downstream to the Narora Barrage, stretching the riverine habitat to a total of 225 km.

METHODOLOGY

1. Suitable Site Selection

Protocols, as outlined by Rao (1998) in the Re-introduction Specialist Group of IUCN's Species Survival Commission, were followed to assess habitat viability for the reintroduction of the species in this area. Intensive monitoring took place in December 2008 along a 173 km stretch of the Ganga River (from Balawali to Garhmukteshwar) within the Sanctuary boundaries (Figure 4), assessing the following parameters.

(a) Physical parameters

a)Shallow water
b)Deep pool
c)Sandy bank/islands
d)River width
e)Shelter (shoreline vegetation/backwater/creeks)
f)Water flow/current

(b) Chemical parameters

a)pH
b)Dissolved oxygen (DO)
c)Lead content (mg. /lit.)
d)Fluoride content (mg. /lit.)

(c) Evidence of disturbance

a)Poaching
b)Fishing
c)Riverbed cultivation
d)Sand-mining
e)Other anthropogenic pressure(s)

Monitoring Method

Seasonal field monitoring was conducted to determine the spatio-temporal distribution of reintroduced juvenile Gharials in the Upper Ganga, covering a 125 km stretch of the River Ganga from Bijnor (29°22'23.56"N, 78° 2'17.97"E) to Brijghat (28°45'44.08"N, 78° 8'34.67"E). The data on direct sightings of the Gharial were recorded while traversing the river in a boat in the midstream (Crump and Scott, 1994). Surveys were conducted from upstream to downstream, covering the study stretch of the river, and distance measurements were guided by GPS. For the winter survey, the time frame was 0900 to 1500. The summer survey was conducted from 0800 to 1200 and 1500 to 1730, while the monsoon survey was conducted from 0700 to 1200 and 1400 to 1730.

For consistency, the monitoring shall be conducted by the motorboat (mercury engine (25H.P) with a constant speed of 7-10 km per hour. The monitoring shall be conducted using an Image stabiliser (10x30 IS) for sighting the Gharial. The Nikon DSLR D780 camera was used for recording photographic evidence. Ocular estimation was used for categorising Gharial size, i.e. juvenile (>120-180 cm total body length); sub-adult (>180-270 cm total body length); adults (>270 cm total body length) (Hussain 1991, Choudhury B.C., 1991). The survey methodology was designed after referring to the methods used by various authors, including Biswas (1970) and Ahmad (1986). Usually, two observers were stationed at the front of the motorboat, each searching for Gharials on either bank. Ecological parameters and human activities that affect the occurrence of the Gharial shall be recorded (Yadav et al., 2013).

Figure 02. Survey stretches (Stretch 01: Balawali to Madhya Ganga Barrage, Stretch 02: Madhya Ganga Barrage to Makhdumpur, Stretch 03: Makhdumpur to Tigri Ghat, Stretch 04: Tigri Ghat to Garhmukteshwar) for identifying suitable habitat for gharial re-introduction in the River Ganga at the State Animal Barasingha

Rationale of Gharial Reintroduction

in captivity and re-stocking of depleted wild populations with captive-reared gharials in the tri-state National Chambal Sanctuary, Katerniaghat and the Corbett Tiger Reserve. However, the continued long-term survival of gharials remains threatened by many factors, which are expected to multiply with increased pressure on limited freshwater resources (GCA 2009).In 2006, WWF-India spearheaded a consortium of conservation organisations to review the status of gharials in the wild and the actions required for their long-term survival. It was unanimously agreed that all suitable gharial habitats should be included in the gharial reintroduction programme. Between December 2007 and March 2008, 111 gharial deaths were recorded across a 40 km long segment of the river, extending from Bareh in the Bhind district, Madhya Pradesh, to Udi (downstream of Sahson) in the Etawah district, Uttar Pradesh, within the National Chambal Sanctuary. While preliminary veterinary findings suggested toxicants as the cause of death, the nature, composition, source and pathway to the affected gharials were not precise. This incident further demonstrated the extreme vulnerability faced by the species, and it was urgent to locate viable alternative habitats to supplement the several other existing habitats where the species historically occurred or current remnant populations existed.

RESULTS

Suitable site selection for Gharial re-introduction

A team of WWF-India and Uttar Pradesh Forest Department officials conducted a field survey to assess the suitability of the Ganga's mainstream within the SABS and locate potential habitats for gharial reintroduction in the river within the SABS limits. The river stretch was divided into 04 sections, i.e., Stretch 01: Balawali to Madhya Ganga Barrage, Stretch 02: Madhya Ganga Barrage to Makhdumpur, Stretch 03: Makhdumpur to Tigri Ghat, and Stretch 04: Tigri Ghat to Garhmukteshwar, based on the discussions with the Uttar Pradesh Forest Department (Figure 02).

Based on the presence or absence of various physical and chemical parameters and disturbances, the Makhdumpur stretch of the River Ganga, within the SABS, was found to be most suitable for the release of gharials, with the highest overall score of 4. (Table 01).

Table 01: Suitability criteria matrix for selection of Gharial release site along River Ganga in the State Animal Barasingha Sanctuary.

Stretch Name	Physical Parameters (Present: 1 ; Absent: -1)					Disturbances (Present: -1 ; Absent: 1)					Total Score
	Shallow water	Deepwater (< 2 m)	Sandy banks/island	(shoreline vegetation /Backwater/	Water flow/current	Poaching	Fishing	Riverbed cultivation	Sand mining	Bathing ghat/crematorium	
Shukaral to Madhya Ganga Barrage stretch, 37Km	1	-1	1	-1	1	1	-1	-1	1	-1	0
Madhya Ganga Barrage – Makhdumpur stretch, 58km	1	-1	1	1	1	1	1	-1	1	-1	4
Makhdumpur to Tigri ghat stretch, 60km	1	-1	1	-1	1	1	-1	-1	1	-1	0
Tigri ghat to Garhmukteshwar stretch, 18km	1	1	1	-1	1	1	-1	-1	1	-1	2

Gharial Reintroduction

Captive-bred gharials are collected from the Kukrail Gharial Breeding Centre, located about 12 km away from Lucknow city (Uttar Pradesh) and established as a gharial breeding centre in 1976.

According to protocols, as outlined by Rao (1998), juveniles of the size class 125cm-150 cm are segregated from the entire stock and kept off exhibit for approximately six months. The released stock is fed live fish to prevent human familiarity, which can make animals more vulnerable when they are released into the wild. These animals are reared in enclosures where their natural flowing water habitat is simulated, allowing them to become accustomed to the flowing water of a river. Physical health examinations (including assessments of tail fat content, the presence of ecto-parasites, and visible injuries) and biometric measurements (body weight, length, and sex) are made and recorded for these animals.Tail scutes are cut in a manner to give each individual being released in the wild an identity number (ID no)

(Figure 03, Bustard and Choudhury 1981). Once the animals are ready, they are placed in specially designed 'wooden boxes' with dimensions of 152 x 46 x 33 cm, featuring internal padding. Every surface inside the box is completely clear of any protruding nails, screws, mesh ends, or other sharp or jagged materials that could harm the animal. The boxes are then loaded onto a vehicle for an overnight journey of approximately 650 km to the State Animal BarasinghaSanctuary ,located in Lucknow, Kukrail.

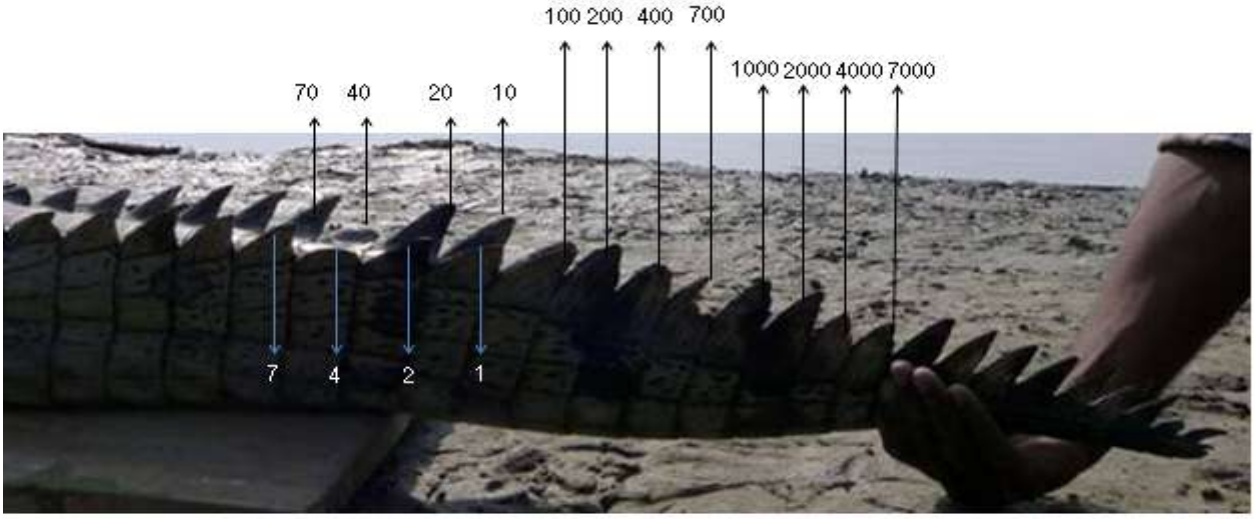

Figure 03. Scute clipping - a formal way of marking an individual gharial at the Kukrail Rehabilitation Centre, Lucknow (Adopted from Bustard and Choudhury 1981).

Dispersal of reintroduced Gharial

Between 2023 and 2024, a release stock of 135 captive-bred juvenile gharials (comprising 111 females and 24 males) was segregated and prepared at the Gharial Rehabilitation Centre in Kukrail, Lucknow. Biometric measurements (total body length, girth, and weight) were performed for these juvenile gharials, followed by a preliminary physical health assessment to examine for any injuries. The stock was then transported in specially designed containers to the State Animal Barasingha Sanctuary in Meerut. The released stock comprised individuals aged from 3 years 10 months, with body lengths ranging between 1.35±1.20 m (total body length) and weighing between 6.36±1.5 kg. The mean total body length and weight for females were 1.35 m ± 0.13 and 6.39 kg ± 0.18,respectively. Similarly, the mean total body length and weight for males were 1.32 m ± 0.33 m and 6.23 kg ± 0.04 kg, respectively (Mean ± SE).

Bi-directional post-release monitoring is conducted for 20 consecutive days, immediately following the release of gharial juveniles into the river. On average, 58.8% of released gharials were recorded during monitoring, up to 10 km upstream and downstream of the release site. It was found that the released gharial juveniles initially preferred to stay near the release site for a few days and then began migrating up and down the river in search of food and new basking sites. It was further observed that more gharial individuals migrated downstream than upstream (Figure 04).

The sudden significant and minor releases of water from the Madhya Ganga Barrage during different months of the year can be attributed to the unprecedented rainfall in the hilly regions, as well as the diversion of water into the canal and the main river, respectively, causing fluctuations in the water levels downstream.

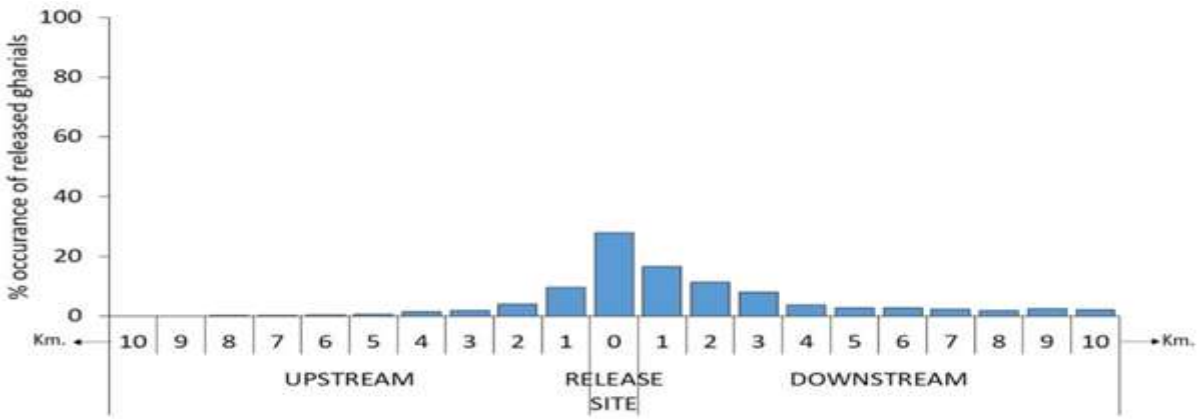

Figure 04. Distribution of released Gharial juveniles in up and downstream of the release site with in first 20 days.

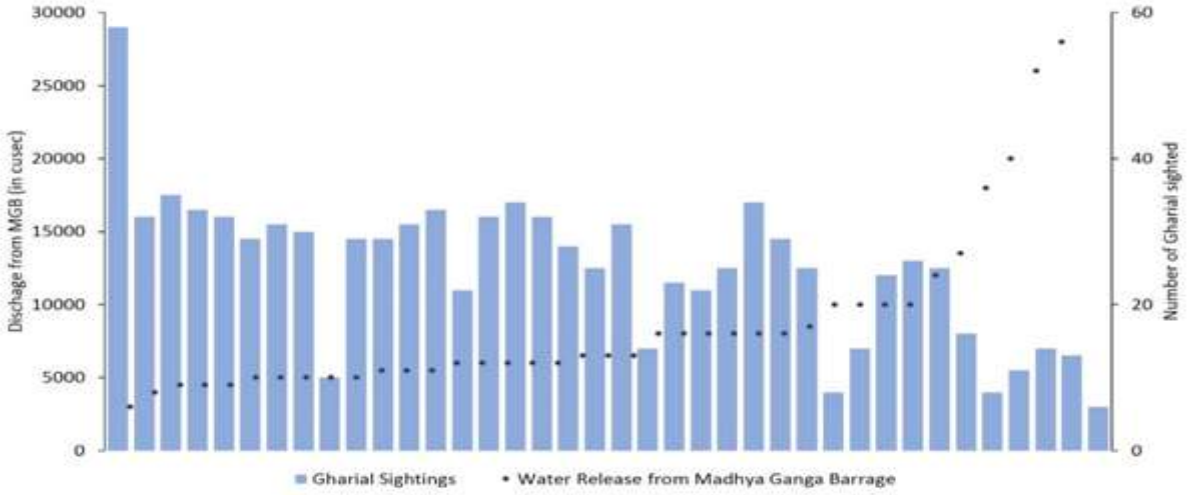

Figure 05. Trend of Gharial sighting with respect to water release form Mid Ganga Barrage.

A Pearson product-moment correlation was run to determine the relationship between the total number of Gharial sightings post-release and the water releases from the Madhya Ganga Barrage. There was a significant negative correlation (r= -0.657, n=38) between sightings and water release (Figure 05) as evidenced bythe low sighting of gharials immediately after the water release from Madhya Ganga Barrage.

DISCUSSION

Based on data from seasonal monitoring during the study period, an average of 54.6% of newly released juvenile gharials were sighted in the study stretch, with the rest dispersed upstream and downstream of the Ganga. This finding is consistent with the results of a similar study conducted in Nepal. Twenty-six adults were also sighted in the study stretch, which were the surviving individuals released during the head-start programme between 2009 and 2020. The population was then left to grow naturally. Given the gharial's low survival rate of less than 1%, population growth has been very slow, which may explain why sub-adults are less abundant compared to juveniles.

Studies on Gharial ecology, primarily based on anecdotal accounts and focusing on dispersal patterns, suggest that during the monsoon, juveniles and subadults tend to disperse over longer distances. At the same time, adults usually stay within their home range. Biswas (1970) noted that Gharials tend to move downstream from the Kosi in Bihar to the Ganges during the monsoon, whereas Rao (1933) reported that Gharials in the Indus River move upstream as water levels rise during the monsoon and downstream when water levels fall in autumn and winter. In the Girwa River at Katerniaghat Wildlife Sanctuary, Uttar Pradesh, adult Gharial have been observed to disperse locally (8-10 km) annually and to orient upstream during floodwaters in the monsoon (Whitaker and Basu 1982).

Reintroduction efforts in the Narayani River within Chitwan National Park are hindered by the Nepal-India dam, which lacks a fish ladder and leads to food depletion (Madhu, 1977). Additionally, the release of monsoon overflow waters washes Gharial out of protected areas (Bustard and Singh, 1983). After 20 days of regular monitoring immediately following release, it was observed that newly released Gharial dispersed both upstream and downstream, with sightings correlating directly to water discharge from Madhya Ganga Barrage, Bijnor. In the State Animal Barasingha Sanctuary, bi-directional post-release monitoring over 20 consecutive days revealed that, on average, 58.8% of released Gharials were recorded within a 10 km radius, both upstream and downstream of the release point. Initially, the Gharial preferred to stay near the release site for a few days before migrating up and down the river in search of food and basking sites. It was further noted that more Gharials migrated downstream than upstream (Yadav et al. 2023). Gharial released in the State Animal Barasingha Sanctuary have been recorded up to 915 km downstreamnear Mirzapur during biodiversity monitoring of the Ganga River.

CONCLUSION

This research also focused on the dispersal patterns of reintroduced gharials. The data revealed that gharials exhibit a range of dispersal behaviours, influenced by factors such as age, sex, and environmental conditions. Younger gharials tended to disperse more widely in search of suitable habitats, while adults displayed more site fidelity, often returning to familiar areas. This variation in dispersal behaviour has important implications for the management of reintroduced populations, as it suggests that different age classes may require tailored conservation strategies. The study also found that the availability of suitable basking and nesting sites significantly influenced dispersal patterns. This finding emphasises the importance of habitat restoration and the creation of protected areas that cater to the specific needs of gharials, thereby facilitating their natural behaviours and promoting population growth.

Acknowledgement
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Ethical Statement
This research was conducted in accordance with the ethical guidelines for scientific research and conservation practices. All necessary permissions and approvals were obtained from the relevant authorities prior to the commencement of fieldwork. The study did not involve any direct experimentation on endangered species; observational methods were employed to minimise disturbance to wildlife and their habitats.

Conflict of Interest
The authors declare no conflicts of interest.

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