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Basking Habitat Preference and Threat Assessment of Reintroduced Gharial in Upper Ganga River, Uttar Pradesh, India

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Abstract: The gharial (*Gavialis gangeticus*), endemic to the Indian sub-continent, is one of the rarest crocodilians. The species is Critically Endangered, with only 650 breeding adults worldwide. Seasonal field monitoring to determine the spatial distribution and habitat use pattern of re-introduced juvenile Gharial in Upper Ganga was conducted from Bijnor Barrage to Brijghat, covering 125 kms of the River Ganga in the present study. The data on direct sightings of the Gharial were recorded while traversing the river in a boat from upstream to downstream. Two observers recorded the Gharial sightings, Habitat parameters and human-caused disturbances at every kilometre plot of the river. The data of used and available plots was compared with Ivlev's Index to know the species preference. The utilization of sandy substrate for basking was found to be higher in proportion to availability. The gharial was also found preferring the flatter banks for basking. This trend was recorded across the study period. The Gharial were found to prefer the basking sites that were far from riverbed cultivation, fishing, crematoriums and bathing ghats; however, the basking was not much affected by ferrying in the river. Gharial's preference for flatter and sandy banks or islands for basking may be owing to the ease with which they can crawl on flatter and sandy banks rather than steeper, muddy, or clayey banks or islands. Another advantage of basking on a sandy substrate is that it contains far more moisture than other substrates, providing a hot (sun) and cool (moisture in the sand) environment, thus reducing the chances of aridness while basking in the sun. Further, the gharial also found avoiding human-caused disturbances by effectively selecting the sites with less or no disturbance.

Keywords: Gharial, Basking habitat, Upper Ganga River, State Animal Barasingha Sanctuary (Hastinapur wildlife sanctuary)

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Introduction

Crocodylians, remnants of the great reptilian age, are crucial 'keystone species' in maintaining ecosystem structure and function (Behera *et al.*, 2014). In India, Crocodylia includes three species: Mugger (*Crocodylus palustris*), Saltwater (*Crocodylus porosus*), and Gharial (*Gavialis gangeticus*). The Gharial, rare and primarily aquatic, leaves water mainly to bask and nest (Maskey *et al.*, 2006). It is unique as the only member of the Gavialidae family (Maskey and Percival, 1994), easily identified by its long, slender snout. The name Gharial comes from 'Ghara,' Hindi for 'pot,' and mature males have a bulbous knob at the end of their snout (Smith, 1939), the sole visible sexual dimorphism among crocodylians. Once abundant, the Gharial was estimated at 5,000-10,000 individuals in the 1940s, covering 20,000 km² from the Indus to the Irrawaddy (Whitaker, 2007). By the mid-1970s, it was nearly extinct due to habitat loss, fishing nets (Whitaker, 1987), poaching (Daniel, 1970, Honegger, 1971, Choudhury and Bustard, 1979, Whitaker and Basu, 1983), and superstitions (Mishra and Maskey, 1981). Gharial listed as Schedule I under the Indian Wildlife (Protection) Act (1972 a, 1974). FAO and UNDP survey revealed all Crocodylian species in India are endangered. In response, the "Indian Crocodile Conservation" project was launched in 1975 with the support of the UNDP and FAO, protecting habitats along the Ganga, Mahanadi, and other rivers. The first successful breeding of Gharials in captivity occurred in 1982 at Nandan Kanan Zoological Park (NKZP). Between 1975 and 1982, sixteen rehabilitation centres and five Gharial sanctuaries were established. Gharial restocking was paused in 1993 due to resource shortages but resumed in 2003 (Sharma and Basu, 2004). The Madhya Pradesh Forest Department released 35 Gharials from December 2005 to February 2006, and the U.P. Forest Department released 112 in January 2006 in the Chambal River. Since 1999, Gharial populations have declined sharply, with a 2006 assessment revealing fewer than 200 breeding individuals in Nepal and India (Andrews,

2006). The species was listed as "Critically Endangered" in the IUCN Red List (2007). In 2008, 110 Gharials mysteriously died in the National Chambal Sanctuary, prompting a re-evaluation of conservation strategies due to pollution and human disturbances. In January 2009, WWF-India collaborated with the Uttar Pradesh Forest Department to revive the Gharial reintroduction programme, releasing Gharials from the Kukrail Rehabilitation Centre into the Ganges, near the Hastinapur Wildlife Sanctuary (recently renamed as State Animal Barasingha Sanctuary). From 2009 to 2024, a total of 973 Gharials were released in the River Ganga. Present study, conducted from January 2023 to January 2025, aims to monitor their success and viability in the Ganges.

Materials and Methods

Study Area

State Animal Barasingha Sanctuary (Hastinapur Wildlife Sanctuary) (Fig. 1) 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. The altitude of the area ranges from 130 m to 150 m above sea level. According to Rodgers and Panwar (1988), the Hastinapur Wildlife Sanctuary (State Animal Barasingha 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

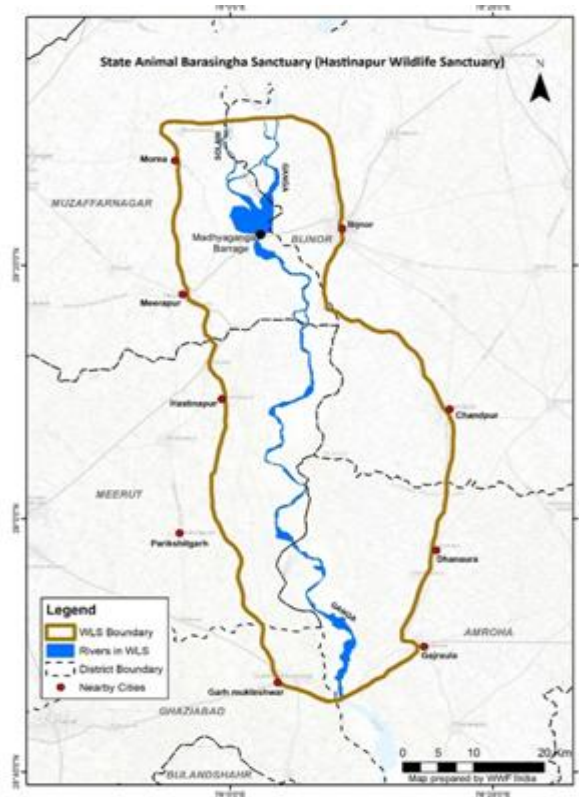


Fig. 1: Study area (State Animal Barasingha Sanctuary).

typically a more or less permanent feature of ravines.

Methodology

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 ($29^{\circ}22'23.56''\text{N}$, $78^{\circ}2'17.97''\text{E}$) to Brijghat ($28^{\circ}45'44.08''\text{N}$, $78^{\circ}8'34.67''\text{E}$). 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 was conducted by the motorboat (mercury engine 25H.P.) with a

constant speed of 7-10 km per hour. The monitoring was 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 ($>120\text{-}180$ cm total body length); sub-adult ($>180\text{-}270$ cm total body length); adults (>270 cm total body length) (Hussain, 1991; Choudhury, 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 was recorded (Yadav and Chauhan, 2013).

Results

Gharial habitat selection is influenced by multiple ecological factors at favored sites. Preference for sandy substrates was higher relative to

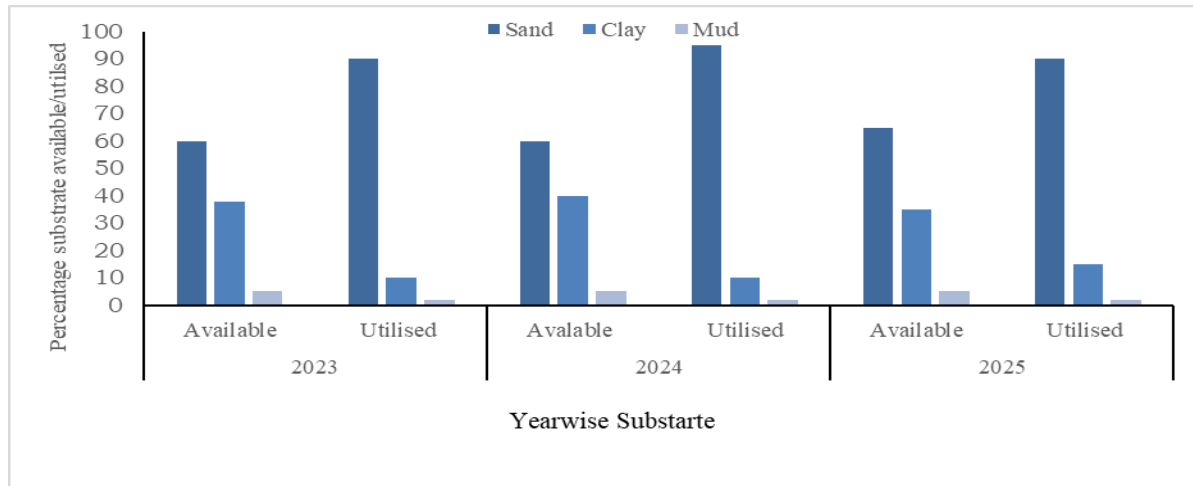


Fig. 2: Sand-substrate preference by Gharial in Hastinapur Wildlife Sanctuary.

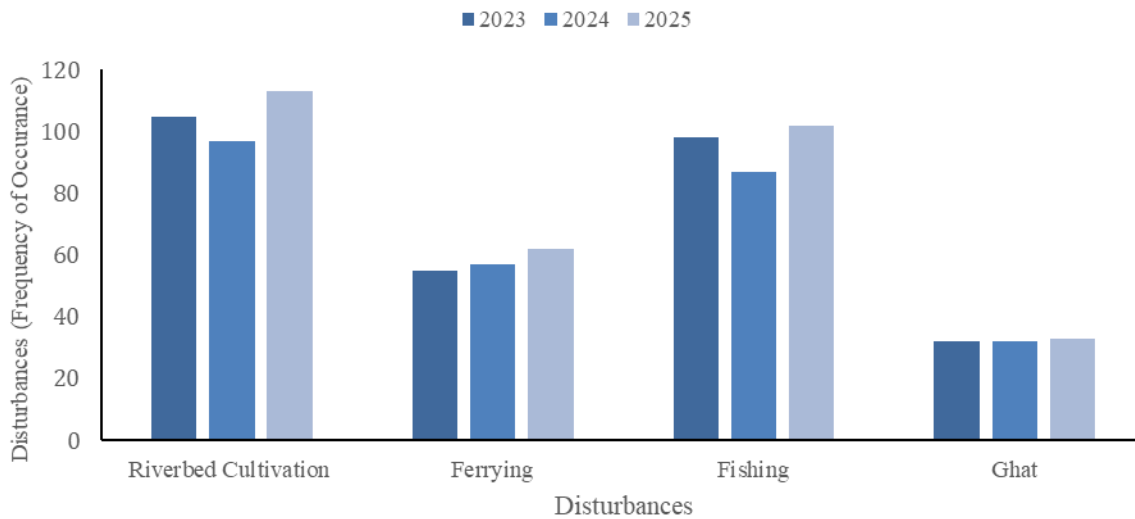


Fig. 3: Disturbance activities recorded across different sampling sites in the State Animal Barasingha Sanctuary, Uttar Pradesh.

availability, a trend consistent across study years (Fig. 2). Gharials prefer sand banks for basking, as it is easier for them to crawl on sand than on mud or clay. Additionally, sandy substrates retain more moisture, creating a warm (sun) and cool (moist) environment, reducing arid conditions while basking. Temperature selection (heat seeking or avoidance) is vital for crocodilians. Studies show they bask in winter and stay in water during summer, helping regulate body temperature with low energy use and optimizing metabolism. Food

availability and the need to escape disturbances also affect depth preferences. Young Gharials feed on small fish, favoring shallow waters for foraging. Juvenile and sub-adult Gharials have a broad depth selection, likely due to their long-distance movements and opportunistic nature, settling where competition is less.

It is paramount to identify the nature of the threats to the species in question, which is crucial for diagnosing the processes endangering the species as accurately and comprehensively as

Table 1: Basking habitat use by the Gharials in the Upper Ganga River

S. No.	Habitat Variable	Available (%)	Used (%)	Ivlev's Index Value	Inference
Substrate type					
1	Sand	70.66	79.12	0.056474	Preference
2	Clay	21.46	16.48	-0.13118	Avoidance
3	Mud	7.88	4.40	-0.28366	Avoidance
Slope					
1	<10 (Flat)	3.29	18.89	0.70319	Preference
2	11-30 (Moderate)	88.82	78.89	-0.05921	Avoidance
3	31-60 (Steep)	7.89	2.22	-0.56043	Avoidance
Disturbance					
1	Riverbed cultivation	52.97	48.91	-0.03982	Avoidance
2	Fishing	21.41	20.65	-0.01804	Avoidance
3	Ferry	8.79	14.13	0.233153	Preference
4	Ghat	9.90	9.78	-0.00601	Avoidance

possible to ensure its long-term survival. Riverbed cultivation (riparian seasonal agriculture), fishing, ferrying and Ghats were recorded as significant disturbance forms to Gharial during the course of the study (Fig. 3).

Riparian seasonal riverbed agriculture (melons, gourds, mustard, and wheat), constitutes the primary form of disturbance to Gharial habitat. This activity encroaches upon basking and nesting sites and may disrupt animal behaviour, potentially forcing local populations to abandon the area. The disturbance and disruption of basking sites diminish habitat quality for the Gharial and may compromise their thermoregulatory behaviour, further affecting feeding, growth, and reproduction. Riverbed agriculture has been recorded to have declined drastically over the study years, attributed to the large-scale erosion of sandbanks caused by flash floods during 2010-2011, which left little space for such riparian cultivation.

The utilisation of sandy substrate for basking was found to be higher in relation to availability. The gharial also preferred the flatter banks for basking. This trend was recorded throughout the study period. The gharial was found to favour basking sites that were distant from riverbed cultivation, fishing, crematoriums, and bathing ghats; however, basking was not significantly affected by ferrying in the river (Table 1).

Discussion

Gharial habitat selection is influenced by various ecological factors. They prefer sandy banks and islands with river segment variations (Hussain *et al.*, 1990). Food availability and hiding cover, dependent on water depth, affect their foraging. Young gharials feed on small fish in shallow water, while larger ones require deeper water for bigger fish. Their weak legs limit navigation in steep areas. Current land usage impacts basking site selection due to disturbances between land and water, hindering thermoregulation. Gharials prefer to bask on sand or sandy silt, which retains moisture, providing a hot and cool environment that reduces desiccation risk and increases basking duration (Hussain, 2009). In the Chambal region, 67% of observed gharials basked on sand (Hussain, 2009). Hatchlings keep distance from sub-adult gharials that may threaten them, similar to reports involving *Crocodylus moreleti* (Hunt, 1977) and *Alligator mississippiensis* (Hunt and Watanabe, 1982). Gharial juveniles rarely mix with Mugger sub-adults or adults unless accompanied by an adult gharial. Gharials under 1.2 m prefer depths of 1-2 m; those over 1.2 m but under 1.8 m prefer 2-3 m, while sub-adult and adult gharials favour depths over 5 m. Gharials smaller than 1.8 m, often released ones, have a broad depth selection as they tend to move long distances (Singh, 1985). Adult gharials prefer deeper water for adequate cover (Hussain, 2009).

The habitat selection study indicates a higher preference for sandy substrate relative to its availability, consistently observed over the years. Gharials prefer sandbanks for basking since it is easier to crawl on sandy rather than muddy or clayey substrates. Basking on sandy areas offers elevated moisture content, providing a warm and calm environment that minimises aridness while basking. Temperature selection is crucial for crocodilians, and basking in winter while staying in water during summer helps regulate body temperature with minimal energy use, supporting optimal metabolism. Food availability and escape tendencies influence depth preferences. Young gharials, feeding on small fish, prefer shallower waters. Juvenile and sub-adult gharials exhibit broad depth selection as they roam considerable distances and occupy less competitive areas.

Conclusion

The Gharials' preference for flatter, sandy banks or islands for basking may stem from the ease with which they can crawl on these surfaces compared to steeper, muddy, or clayey banks or islands. Another advantage of basking on sandy substrates is that they contain significantly more moisture than other substrates, thus providing a hot (sun) and cool (moisture in sand) environment, which reduces the likelihood of arid conditions while basking in the sun. Furthermore, the gharial is also observed to effectively avoid human disturbances by selecting sites with less or no disturbance. These results align with findings from similar studies in Chambal WLS, Katarniaghat WLS, and Nepal (Hussain, 1991).

Ethical Statement

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

Author Contributions

Sanjeev Kumar Yadav was responsible for the experimental design, data collection, and analysis; *Dheer Pal Singh* handled the manuscript writing and conducted the statistical evaluation; *Sushil Kumar Upadhyay* and *Sadguru Prakash* reviewed and revised the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

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