Population status and factors influencing the distribution of Critically Endangered gharial (Gavialis gangeticus) in a regulated unprotected river system in India

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Population status and factors influencing the distribution of Critically Endangered gharial (*Gavialis gangeticus*) in a regulated unprotected river system in India

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A B S T R A C T

Gharial (*Gavialis gangeticus*), the last surviving crocodilian member of the genus Gavialis, is endemic to the Indian subcontinent and is listed as one of the priorities species under the Evolutionary Distinct and Globally Endangered framework. Historically, the gharial used to occur in all major river systems of the Indian Subcontinent, now found in isolated stretches, mostly within the boundaries of Protected Areas. The gharial population decreased by over 80 % between the 1950s and 1960s due to habitat degradation, poaching, and mortality from passive fishing. The gharial population is, however, rebounding due to concerted conservation efforts launched in the mid-1970s. One of the largest gharial populations outside of the Protected Area is in the Gandak River, a transboundary northern tributary of the Ganga. However, the habitat association of gharial in relation to the rising anthropogenic stressors is not well-documented from an ecological standpoint in the Gandak River. The present study assessed the population status and factors influencing the gharial distribution in the Gandak River. Boat-based visual encounter surveys were conducted for data collection, and generalized linear models (GLMs) were employed to evaluate the factors influencing gharial distribution. The encounter rate fluctuated along the surveyed river stretches, peaking in the upstream. We observed a positive association with channel depth while a negative one with channel width, livestock presence, fishing nets, and fishing boats. The observed pattern of encounter rate and negative association with anthropogenic variables indicate spatial avoidance of these factors. Overall, conservation interventions, such as adaptive management strategies to reduce and remove these factors, are required for long-term gharial persistence in the regulated unprotected riverscape.

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1. Introduction

The members of the order Crocodilia are among the largest living reptiles known as crocodylians (Grigg, 2015). The order is represented by 27 recognized species belonging to three families: Alligatoridae, Crocodylidae, and Gavialidae (Smith, 1931; Grigg, 2015). In India, three species of crocodylians are found, the gharial (*Gavialis gangeticus* Gmelin, 1789), the mugger (*Crocodylus palustris* Lesson, 1831), and the saltwater crocodile (*Crocodylus porosus* Schneider, 1801) (Martin, 2007). The gharial has the narrowest distribution and is the most threatened amongst all crocodylians in India. The gharial is endemic to the Indian subcontinent (Grigg, 2015) and the last surviving member of the once-diverse genus, Gavialis (Martin, 2019). It is listed as one of the top priority species under the Evolutionary Distinct and Globally Endangered (EDGE) framework that works to identify and protect the unique species on the earth (Gumbs et al., 2018).

Historically, the gharial was distributed in all major river systems, including the Indus, Ganges, Mahanadi, Brahmaputra-Meghna, and possibly in the Irrawaddy river systems (Neupane et al., 2020), with an occupancy area of 80,000 km^2. Their estimated population ranged from 5000 to 10000 individuals until the 1940s (Whitaker et al., 1974). In the last century, the gharial population dropped by over 80 % due to habitat loss, poaching, and mortalities in passive fishing (Bustard, 1975; Hussain, 1999). By the early 1970s, the gharial had been confined to a few isolated pockets in Ganga and its major tributaries, Mahanadi and Brahmaputra (Singh, 1978). As a result, the species has been listed as Critically Endangered on the IUCN Red List (Lang et al., 2019) and Appendix I of CITES (2023). Following the drastic decline in population and range, the Government of India included all three species of crocodylians in Schedule I of the Indian Wild Life (Protection) Act, 1972 (Hussain, 1999).

Since the middle of the 1970s, conservation efforts were initiated under project crocodile to protect the species and achieve quick recovery of the depleted crocodilian populations. These approaches included 'head-starting' assisted conservation translocation programmes and protecting appropriate natural gharial habitats to rebuild the gharial population in the wild (Bustard, 1975). These efforts have successfully prevented the immediate extinction of the gharial and aided in their recovery (Hussain, 2009; Sharma et al., 2021). The species is now occurring in 14 small and spatially fragmented populations in India, Nepal, and Bangladesh and is possibly extinct in Bhutan, Myanmar, and Pakistan (Lang et al., 2019).

The gharial at present continues to occur within the Protected Areas (PAs) such as National Chambal Sanctuary in Chambal River, Katerniaghat Wildlife Sanctuary in Girwa River, Corbett National Park in Ramganga River, Son Gharial Sanctuary in Son River and

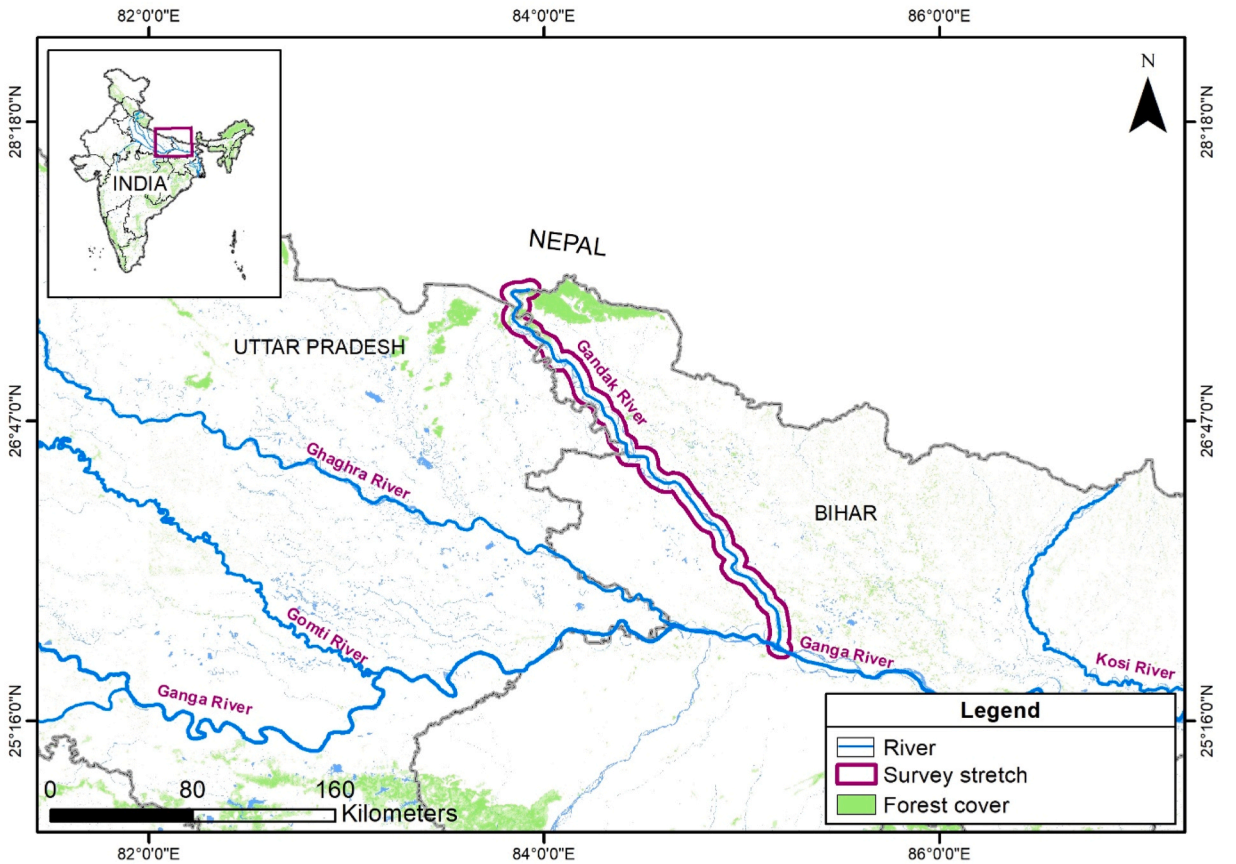

Fig. 1. Gandak River along with mainstem Ganga and other tributaries in India. The survey stretch is marked in cattleya orchid colour.

Satkosia Gorge Wildlife Sanctuary in the Mahanadi River, Hastinapur Wildlife Sanctuary in the Ganga River (Lang et al., 2018; Sharma et al., 2021; Lang et al., 2019. However, populations also exist outside PAs, i.e., in Ghaghara and Gandak rivers (Singh, 1978; Choudhary, 2010).

Population assessment surveys conducted in 2010 by the Wildlife Trust Of India (WTI) team confirmed the presence of 15 gharial individuals of all size classes in the Indian section of the Gandak River (Choudhary, 2010). Similarly, a population assessment survey by the Gharial Conservation Alliance (GCA) team recorded 50 gharials, including two males in the Gandak River (Nair and Katdare, 2014). Recent population surveys have reported 259 gharial individuals, including all size classes, of which 11 % were adults, including five adult males and 24 females (WTI, 2020). Subsequent monitoring surveys have recorded gharial breeding in the Gandak River (Sinha et al., 2020).

The Gandak River, a transboundary tributary of the Ganga River, now holds the second largest gharial population in an unprotected riverscape (Srivastava, 2013; Sinha, 2020). The gharial experiences a range of stressors, owing to the small number of breeding individuals and unprotected nature that threaten their long-term survival. Despite being the second largest population and perhaps the only breeding population outside PAs, prior research is limited only to determining population status (Sinha et al., 2020; Choudhary, 2010), resulting in little information on critical aspects such as habitat use and the impact of anthropogenic stressors in this riverscape.

Hence, this study was conducted to gain insight into the gharial population status and factors that influence gharial distribution. We, thus, aim to address the following questions; (a) What is the current population status and size-class composition of gharial in Gandak River? and (b) What factors influence gharial distribution in the Gandak River?

2. Materials and methods

2.1. Study area

The Gandak River is known as Kali Gandaki and Narayani after its confluence with the Trisuli River in Nepal. It rises at an altitude of approximately 7620 m asl in Tibet, near the Nepal border. While flowing through the Himalayas in Nepal, it forms the Kali Gandaki Gorge, one of the deepest river gorges in the world. The river enters the Indian geographical boundary from Valmikinagar in the West Champaran district of Bihar. Thereafter, it covers a course of more than 300 km south-east, across the upper Gangetic plain in eastern Uttar Pradesh and north-western Bihar to join the main stem, Ganga, near Patna downstream of Hajipur in Vaishali district of Bihar (Kansal et al., 2016). The present study was undertaken approximately 320 km in the stretch from Lav-Kush ghat (N 27°26'10.73" E 83°53'53.70) to the confluence with Ganga River near Patna immediate downstream of Hajipur (E 25°38'18.60" E 85°11'33.55) in Vaishali district, Bihar (Fig. 1).

The climate of the Gandak basin ranges from sub-humid to humid-monsoon type. The annual rainfall ranges from 1000 mm to 1660 mm, with 80–85 % rainfall from July to September. Maximum downpour is received in the plains than at the foothills of the Himalayas and decreases towards the south. The temperature in the Gandak basin shows an upward trend from February onwards till June, with July bringing Monsoon rains and a drop in temperature (Mohindra et al., 1992). Due to the steep slope and loose soil in the upper catchment, the river brings a lot of silt and other deposits to the Indian side, which results in the shifting course of Gandak. The course of Gandak has moved 80 km eastwards over the past 5000 years, and the annual movement continues (Mohindra and Parkash, 1994). The floodplains of Gandak are highly affected by this frequent channel migration or river avulsion, making it vulnerable to frequent floods in Bihar (Jain and Sinha, 2004; Mohindra and Parkash, 1994; Sinha and Friend, 1994).

2.2. Factors influencing habitat use

2.2.1. Field methods

The objective of the study was to understand the encounter rate, population size structure, spatial distribution, and factors influencing the distribution of the gharial in the Gandak River. The entire ~320 km survey stretch was divided into six segments (Table S1) (Fig. 1). We conducted three boat surveys during the post-monsoon (October-February) of 2019, post-monsoon of 2020, and pre-monsoon (March-July) of 2021 to record the gharial presences and habitat variables (Fig. S1). To determine the gharial presence and count boat-based total count method was followed to effectively survey aquatic macrofauna species diversity and abundance (Bayliss, 1987; Hussain, 2009). The survey was counted during daylight between 10:00–16:00 hrs and subject to suitable weather conditions. Gharial presence was mainly determined through direct observations through an inflatable motorboat, moving 8–10 km/hr. Gharial individuals between 0 and 60 cm in length were considered hatchlings, 60–120 cm as yearlings, 120–180 cm as juveniles, 180–270 cm as sub-adults, and 270 cm and above as adults (Hussain, 2009, 1999; Whitaker and Basu, 1982) with the help of Bushnell POWERVIEW 2 10 × 42 Binoculars. The number of individuals and size class were recorded for every gharial encounter, along with habitat variables and GPS (Global Positioning System) coordinates. We selected eleven habitat variables a priori based on literature (Hussain, 2009; Nair, 2010). The variables, viz., channel depth, channel width, temperature and anthropogenic disturbance (livestock, burning ghats, ferry, feral dogs, fishing net, fishing boat, human settlement and religious ghats) were recorded at regular intervals every 5 km (Salafsky et al., 2008). The presence of these variables was recorded from both banks. We construed anthropogenic disturbance as any form of human activity likely to cause degradation, loss, and fragmentation of gharial habitat within 1 km of shoreline (Fig. S1). Channel depth was measured using depth sounder (Hondex PS-7), channel width was measured using a laser range finder (Hawkeye Endurance LRF-1000), and temperature, was measured using a YSI ORP15A - ORP Pen Tester − 1100 to 1100 mV. GPS coordinates were also recorded with a Garmin eTrex® 30x GPS, and for photographs, we used Canon SX60 HS.

2.3. Data analysis

The habitat use by gharial and the influence of anthropogenic stressors on gharial distribution was inferred using post-monsoon data. We used the gharial count observed in each segment as the dependent variable and all the twelve variables described above as explanatory variables, including categorical and continuous data. We used Spearman's rank correlation to test for multi-collinearity among variables. Correlated variables with Spearman's rank correlation coefficient (Spearman's $\rho > 0.7$) were excluded.

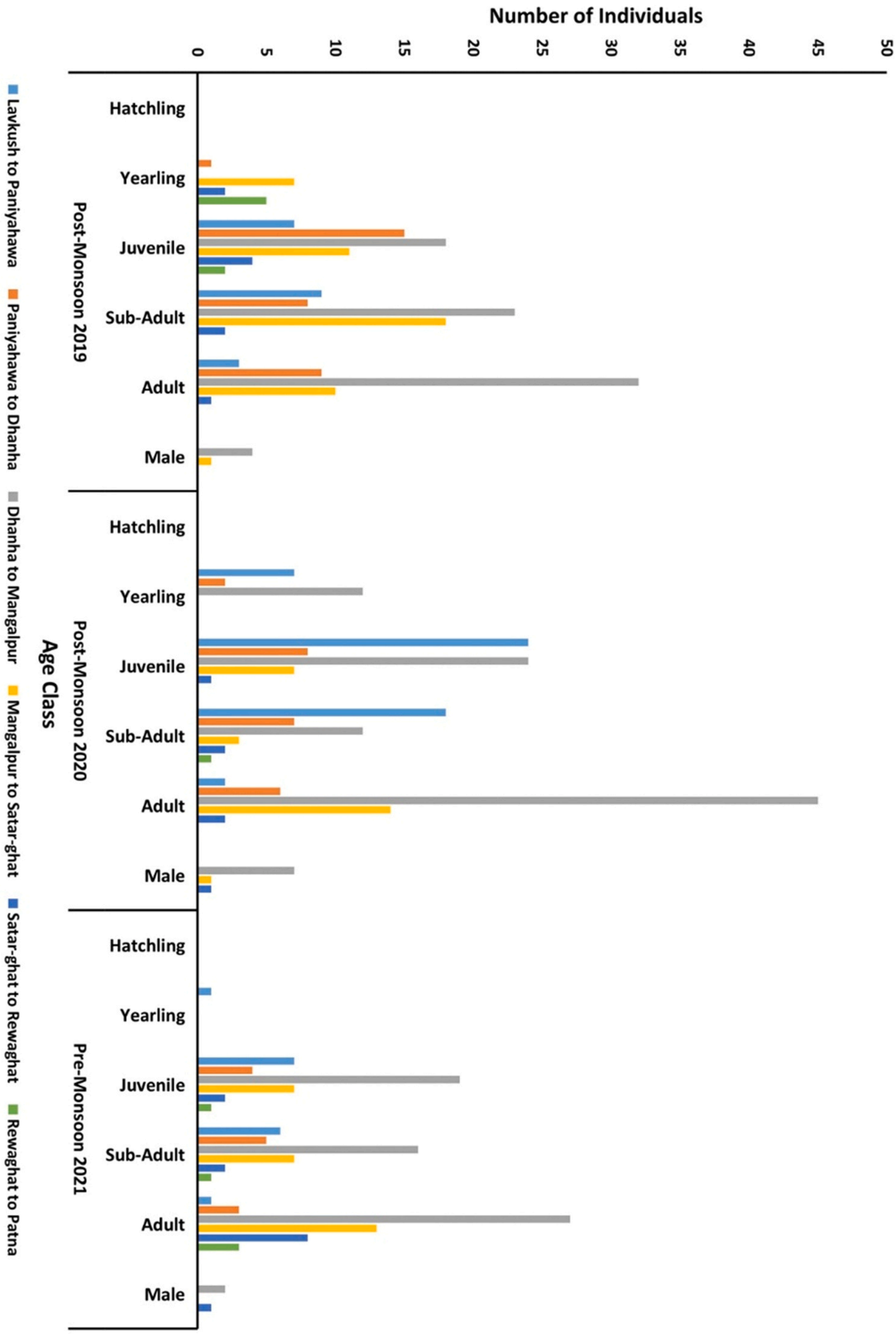

Fig. 2. Age size classes found in post-monsoon of 2019, 2020 and pre-monsoon of 2021. Numbers within all segments.

Continuous variables were z-standardized before the analysis. We tested for the presence of overdispersion in the dataset and selected the negative binomial distribution (i.e., Poisson and negative binomial). We used Akaike's information criterion (AICc) adjusted for the sample size to rank models and considered models with AICc values < 2 to have equivalent support to the top-ranked models (Burnham and Anderson, 2002). We applied model averaging and calculated a model-averaged parameter estimate and conditional standard error for each parameter. We evaluated the factors affecting the habitat use of gharials with the Generalized Linear Model (GLM) using the package MuMIn (Barton and Barton, 2015) in R version 4.1.0 (Team, 2020). The GLM models are more flexible and can use single observation survey data to provide information on species habitat use.

3. Result

A total of 192 in 2019 (post-monsoon), 206 in 2020 (post-monsoon), and 139 in 2021 (pre-monsoon) gharial were detected. Across all the surveys, the proportion of adults was highest, followed by juvenile, sub-adult, yearlings, and hatchlings (Table S1). The number of adult male gharial was five in 2019, three in 2021, and nine in 2020. The total number of adults was 196 (36.70 %), followed by juvenile 161 (30.14 %), sub-adult 140 (26.21 %), and yearlings 37 (6.92 %) of the total sighted gharials across all the years (Fig. 2). In post-monsoon surveys, the proportion of gharials was higher in the upriver segments 1–3 (Gandak Barrage to Mangalpur) while considerably lower in downstream segments (Table S1) (Fig. 3). We sighted fewer gharial individuals of the smaller size classes (juvenile, yearling, and hatchlings) during the surveys (Table 1). The mean encounter rate (Number of individuals sighted per km of the river) of gharial was 0.52 ± 0.43 ($\pm$ SD) in the Gandak River (Table S1). The encounter rate varied throughout the segments, and the highest encounter rate was recorded in segment 3 (Dhanha to Mangalpur) (2019 =1.18, 2020 =1.54, and 2021 = 1.03) (Fig. 3). Whereas the encounter in segment 6 (Rewaghat-Patna /Confluence) was lowest throughout the survey years (Fig. 3). The number of gharials recorded during each survey should be considered the least number of individuals present and directly observed in the river during the respective surveys.

Spearman's rank correlation test indicated that none of the habitat variables was strongly correlated (Spearman's $\rho > 0.7$ for all pairs tested); hence we used all the variables for the analysis. The overdispersion test on the Poisson model revealed that the data was over-dispersed ($P < 0.001$), therefore, we used a negative binomial to obtain the best-fit model. Negative binomial models are suitable for skewed and over-dispersed data with wide-ranging values (Anscombe, 1949; Bowden et al., 1969). We tested a total of 16 ecologically meaningful models, and the top-ranked model (ΔAICc = 0) revealed that the habitat use of gharial is influenced by channel depth, channel width, fishing nets, livestock and fishing boats (Table 2). The top-ranked model yielded an Akaike weight (ωi)

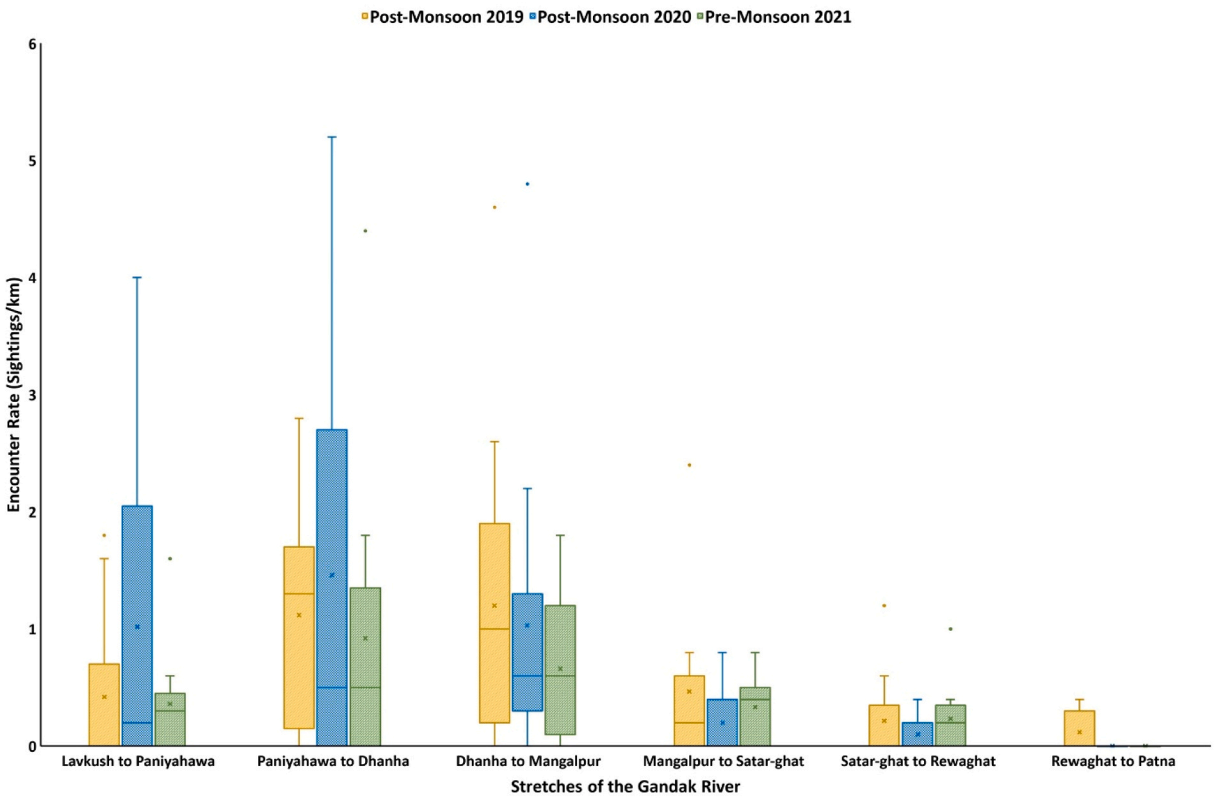

Fig. 3. Box and whiskers plot of encounter rate (Gharial presences/Segment) along the Gandak River. Boxes show median and quartiles. Whiskers show maximum and minimum defined as > 1.5 times the interquartile range, excluding outliers.

Table 1
Summary of sixteen models examining the factors influencing the gharial habitat use, with each model's Akaike information criteria adjusted for small sample sizes (AICc), the difference in AICc from the top-ranked model (ΔAICc), and Akaike weight.

Response variable	Models	Predictor variables	AICc	ΔAICc	Weight
Gharial Presence	1	~Depth + Ch width + Fishing Net + livestock + Fishing Boat	523.85	0.000	0.12
	2	~ Depth + Ch width + Fishing Net + livestock	524.37	0.52	0.09
	3	~ Depth + Ch width + Fishing Net + livestock +Feral dog + Fishing Boat	524.85	1.00	0.072
	4	~ Depth + Ch width + Fishing Net + livestock + Fishing Boat + Feral dog	524.89	1.04	0.07
	5	~ Depth + Ch width + Fishing Net + livestock + Settlement	525.14	1.29	0.06
	6	~ Depth + Ch width + Fishing Net + livestock + Fishing Boat + Religious Ghat + Settlement	525.21	1.36	0.06
	7	~ Depth + Ch width + Fishing Net + livestock + Religious Ghat	525.27	1.42	0.06
	8	~ Depth + Ch width + Fishing Net + livestock + Feral Dogs	525.28	1.42	0.06
	9	~ Depth + Ch width + Fishing Net + Fishing Boat	525.38	1.53	0.06
	10	~ Depth + Ch width + Fishing Net + livestock +Ferry + Fishing Boat	525.48	1.62	0.05
	11	~ Depth + Ch width + Fishing Net + livestock +Ferry	525.50	1.64	0.05
	12	~ Depth + Ch width + Fishing Net + Feral dogs	525.64	1.79	0.05
	13	~ Depth + Ch width + Fishing Net + livestock	525.71	1.86	0.05
	14	~ Depth + Ch width + Fishing Net + Fishing Boats+ Settlement	525.73	1.88	0.05
	15	~ Depth + Ch width + Fishing Net + Feral Dogs + Fishing Boats+ Ferry	525.73	1.88	0.05
	16	~ Depth + Ch width + Fishing Net + Feral Dogs + Ferry	525.74	1.88	0.05

= 0.12, implying a 12 % chance of being the best among the evaluated models. The second-best model with ΔAICc = 0.52 and Akaike weight (ωi) = 0.09 (Table 2). The variable, channel depth β = 0.480 (± 0.1195) in the top-ranked model showed a significantly strong positive association with gharial presences.. In contrast, the negatively associated variables were: channel width β = −0.579 (± 0.1422), fishing nets β = −0.355 (± 0.1941), livestock β = −0.352 (± 0.1969), and fishing boats β = −0.255 (± 0.1785) (Table 2) (Table S3).

4. Discussion

India holds the largest gharial population in the world, and within India, the gharial population is restricted to 14 subpopulation units, most of which lie within the Ganga River Basin (Lang et al., 2019). Of these, only four subpopulations are deemed to be breeding populations with annual confirmed evidence of reproduction (Thapaliya et al., 2009). The Chambal River holds the highest number of breeding individuals (~500), followed by the Girwa (~50), Ramganga (~32) and Gandak River (~21) (Sharma et al., 2021; Vashistha et al., 2022; Lang et al., 2019). While protected areas aid the other three subpopulations, most of the gharial population in Gandak River lies outside the protected area (WTI, 2020; Maskey, 1989). However, only minor portions of the river fall within the jurisdiction of the Valmiki Tiger Reserve on the east bank and the Sohagi Barwa Wildlife Sanctuary on the west bank. Thus, the gharial population in the Gandak River is the only known breeding population outside of a protected area and holds an important place in the global context of gharial conservation. In accordance with the same, continuous monitoring of the population and factors influencing their distribution are crucial for managing gharial in the Gandak River.

In all three survey occasions, the highest proportion of animals (2019 post-monsoon= 67.1 %, 2020 post-monsoon= 84.4 % (S1, S2, S3) and 2021 pre-monsoon = 67.6 %) (S2, S3, S4) has been consistently recorded in the first three segments, i.e., the river stretches between Lavkush ghat and Mangalpur covering approximately 165 km (Fig. S2). The higher number of individuals sighted in the upstream segments could potentially be because of lower disturbances in these stretches (WTI, 2020). These segments are also preferred as nesting sites, hence higher sightings in these segments 1–4 (Lavkush-Satarghat) (WTI, 2020). The lower half of the river sees an increase in human presence and interventions on the river bank, such as embankments which are a measure of preventing river bank erosion, resulting in a more defined course of the river and human habitation closer to the river. Gharial tends to avoid areas with persistent anthropogenic presence and disturbance, which may be why the occurrence of gharial in the lower stretch of the river is relatively lower.

We observed an age-structured gharial population in the Gandak River, where we observed a higher number of adult-size class individuals (PM 2020–33 %, PrM 2021–40 % and PM 2019–32 %), followed by juvenile-size class individuals (PM 2020–31 %, PrM 2020–29 % and PM 2019–30 %) and lowest size class detected was yearlings (PM 2020–10 %, PrM 2020–1 % and PM 2019–8 %).

Table 2
Summary of variables in the top-ranked model (ΔAICc = 0.0) explaining the factors influencing gharial habitat use. (Ch width – Channel Width, livestock - Livestock).

	Estimate (β)	SE	Z-value	P-value
(Intercept)	0.617	0.144	4.284	3.63e-05***
CH.Width	-0.5794	0.1422	-4.075	8.13e-05***
Depth	0.4805	0.1195	4.023	9.89e-05***
Livestock	-0.3528	0.1969	-1.792	0.0756
Fishing.net	-0.3559	0.1941	-1.833	0.0692
Fishing boats	-0.2553	0.1785	-1.431	0.155

Surprisingly, we did not encounter any hatchlings during the surveys. The higher contribution of adult individuals in the gharial population is not rare. A similar pattern of size-class composition is often seen in long-lived reptiles, especially in turtles and crocodylians (Grigg, 2015; Whitaker, 1982). However, no sighting of hatchlings and a lower number of yearlings is possibly due to the high mortality recorded in crocodilian species and likely due to missed sightings of small individuals in highly braided channels. Further, a high sighting of juvenile class (>1.2 m) gharial is likely due to the release of captive-reared gharial individuals. Annual record of nesting and the presence of at least seven adult males and a sizeable juvenile size class indicates that this population is gradually persisting in the Gandak River. The gharial males are counted separately since they contribute towards an important demographic index.

Species' habitat use is often determined by the availability and distribution of resources (Morris, 1987) and may change in response to interaction with several biotic and abiotic factors. In the present study channel or the river, depth is positively correlated with the presence of gharial, which is attributed to their foraging preferences in deep pools. Previous studies on site selection and habitat use of gharial have revealed a preference for a sandy substrate, higher depth (>4 m), river braiding and avoidance of anthropogenic stressors in other river systems (Nair and Katdare, 2013, 2014b; Nair, 2017; Hussain, 2009). Water columns in deep pools harbour higher diversity of fish as they provide greater habitat complexity and resources as compared to water columns in the stretches of the river with lower depth. Hence, greater depth provides more prey to gharial in a localised area and enables them to forage efficiently with low energy investment (Maskey et al., 1995). Moreover, it was observed that pools provide refuge for large fishes during the summer, when the water level decreases, serving as ideal foraging grounds for adult gharials. The deep pools also provide an ideal thermal gradient for the gharial to regulate their body temperature during different seasons (Whitaker, 1982; Hussain, 2009).

Further, we found a negative association of gharials with channel width, which may be a consequence of lack of detection. The gharial presence shows a negative association with fishing nets and fishing boats. Fishing gear poses a direct threat of entanglement to the gharial (Hussain, 1999; Sharma and Basu, 2004). Hence as an adaptive mechanism, they are likely to avoid stretches with high fishing activities. In other rivers, it has also been reported that the death of adult gharial is mostly due to passive fishing, especially in Ken and Son rivers (Nair, 2017). The increased fishing activity could also influence food availability, as fish form a major part of their diet. Thus, overfishing could potentially disrupt the food chain and interfere with ecosystem functioning (Katdare et al., 2011).

The presence of feral dogs and livestock also negatively affects gharial presence. Livestock and feral dog presence are an indirect indicator of high human presence and are reported to pose a threat to wildlife (Costanzi et al., 2021; Reshamwala et al., 2021). Their presence near basking and nesting sites might be perceived as a threat by gharial and are likely to avoid areas with a high presence of livestock and feral dogs. Moreover, the expansion and extensive use of the river banks for agriculture, mining and other associated activities, such as fishing, are known to affect the gharial's habitat, diet, recruitment and ecology. Further, the presence of cremation and religious ghats are negatively associated with gharial presences. We observed that the presence of human settlements near the bank also poses a severe threat to gharial presence. The disturbance also causes gharial to avoid human dominated areas, affecting their physiology by reducing basking time.

During our survey of the Gandak River, we encountered river braiding because of the river's inclination to flood and the barrages sudden discharge of water for irrigation purposes, braiding is a typical occurrence. This braiding may cause the river to split into several separate channels, affecting the accuracy of our gharial population estimates. The braiding of the river has most certainly resulted in an undercount of the gharial population. It can be time-consuming and resource-intensive to survey all of the minor channels generated by river braiding. It may have been difficult to thoroughly cover all of these tiny routes throughout our survey. As a result, some of these channels may have been overlooked inadvertently, resulting in an undercount.

A mixed survey strategy may be required to produce a more reliable and fair count. Methods like Visual Encounter Survey in conjunction with UAV-based surveys or Mark-Recapture techniques could be implemented. These methods would assist in overcoming the limits imposed by river braiding and give a more comprehensive assessment of the Gandak River's gharial population.

5. Conclusions

The gharial population in the Gandak River is the second largest population and among the few breeding populations globally. The river also serves as a sink for gharial dispersing from the Narayani-Rapti River system. Adequate conservation interventions, including habitat protection, reducing the limiting factors, and continuous demographic and genetic monitoring of the population, will benefit residents and dispersed individuals. Conservation action is needed to enhance gharial protection and their successful recruitment into the higher size class to enhance and ensure the long-term survival of gharial in the Gandak River. Considering the magnitude and complexity of stressors that are currently prevailing at Gandak River, a worst-case scenario exists in which the wild gharial population can decline to the level of extirpation if the condition of the river continues to deteriorate.

A logical next step in understanding the ecology of the gharial in the Gandak River would be determining the survivorship and mortality in different size classes. Concurrently, hotspots of low and/or high anthropogenic pressures need to be delineated. The information thus collected can help prepare a conservation roadmap for securing the future of the gharial in unprotected riverscapes such as the Gandak River. Through sustained research efforts and monitoring, protection measures need to be tailored based on the socio-economic scenario of the region as well. The local populace is highly dependent on the river for daily sustenance through fishing, regular use of water and riverbank cultivation. Thus, through workshops and sensitization exercises involving all stakeholders, conservation strategies can be developed that benefit all.

CRediT authorship contribution statement

Ashish Panda: Data curation, Formal analysis, Software, Writing – original draft. **Saurav Gawan:** Data curation, Writing – original draft. **Suyash Katdare**: Data curation, Writing– original draft. **Surya Prasad Sharma**: Data curation, Formal analysis, Writing – original draft. **Ruchi Badola**: Conceptualization, Funding acquisition, Project administration, Supervision, Methodology, Writing – review & editing. Syed **Ainul Hussain**: Conceptualization, Funding acquisition, Project administration, Supervision, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Data availability Data will be made available on request.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2023.e02547.

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