

Nesting of the Critically Endangered gharial *Gavialis gangeticus* in Bardia National Park, Nepal

ASHISH BASHYAL^{*1} , NISCHAL SHRESTHA¹ , ROSY THAPA¹, SANDEEP SHRESTHA²
MAKUNDA SANJEL³, LLEWELLYN D. DENSMORE⁴ and BED KHADKA⁵ 

Abstract The gharial *Gavialis gangeticus* is a Critically Endangered crocodylian currently known from only 14 disjunct locations in Nepal and India. The protected stretch of the Babai River in Bardia National Park, Nepal, is home to one of the six subpopulations of gharials that have exhibited recent evidence of reproduction. However, there is limited information available on the gharial population in this region. We conducted surveys during the breeding, nesting and hatching seasons of gharials during 2020–2022 to study the gharial population in the Babai River in Bardia National Park. We located one breeding group of gharials in Soth Khola (2–3 individuals) and one in Dhanuse (5–6 individuals), and we observed pre-mating or mating behaviours in all 3 years. We identified potential nesting areas on sand banks of 19–175 m in length. During nesting seasons we found abundant signs of nesting only in Dhanuse, including entry and exit trails of female gharials to and from the water and trial nests. In 2020 and 2021 we did not find any signs of hatching, probably because of flooding. In 2022 we recorded two gharial nests, producing c. 60 hatchlings, in Dhanuse. Our findings indicate that the gharial population in the Babai River is probably nesting annually. We recommend various conservation actions for this gharial population.

Keywords Babai River, Bardia National Park, *Gavialis gangeticus*, gharial, hatchlings, Nepal, nest, sandbank

The gharial *Gavialis gangeticus* is a Critically Endangered crocodylian that is now extinct throughout most of its historical range and is currently known from only 14 disjunct locations in Nepal and India (Lang et al., 2019). In Nepal, gharials occur in the Narayani and Rapti rivers in Chitwan National Park and in the Babai and Karnali rivers in Bardia National Park (Lang et al., 2019).

Knowledge of the gharial population in Bardia National Park is limited compared to that in Chitwan National Park,

where the population has been relatively well studied (Lang et al., 2019). Preliminary information is available on gharial reproduction in Bardia National Park (Acharya et al., 2017; Bashyal et al., 2019, 2021), where the Babai River is home to one of the six subpopulations of gharials that have exhibited recent evidence of reproduction (Bashyal et al., 2019; Lang et al., 2019). Our goal was to investigate the breeding, nesting and reproduction of the gharial population in the Babai River by conducting multiple surveys during 2020–2022.

The 968 km² Bardia National Park lies in south-west Nepal (Fig. 1). It has a subtropical climate and vegetation, with floodplain vegetation along the riverbanks. The Babai River originates in the Churia Range in the Dang Valley and is a warm-water river system (Yadav, 2002).

We conducted surveys in the Babai River during February 2020–July 2022 during the breeding season (from the second to the last week of February in 2020 and 2021; 10–12 days each season), nesting season (third week of March to the first week of April in 2020, 2021 and 2022; 15–18 days each season) and hatching season (second week of June to the last week of July in 2020, 2021 and 2022; 20–30 days each season) of gharials. The survey team, led by AB and occasionally accompanied by NS and MS, comprised 3–7 people, including field assistants and park rangers.

For the breeding season surveys we divided a 46 km protected stretch of the Babai River into 46 1-km lengths (Fig. 1) and surveyed by walking downstream along riverbanks during 9.00–16.00. We searched both banks for gharials and noted size (by visual observation following the classification scheme described by Lang & Kumar, 2016) and sex (based on absence/presence of ghara and estimated total length) using binoculars. We also collected information on the size, composition and location of any breeding groups (two or more adult gharials of mixed sexes that gather together for mating). We made observations on the pre-mating and mating behaviours exhibited by breeding groups (Lang & Kumar, 2016).

In the nesting season we searched for gharial nests (Lang & Kumar, 2016; Khadka et al., 2020), focusing on locations where groups were present during the breeding season surveys as well as locations containing potential or known nesting areas (which were also identified and mapped during the breeding season). We followed adult female gharials and scanned the riverbanks, noting any signs of nesting activities such as the presence of trial nests (gravid female gharials are known to dig trial nests before digging the nest in which they lay their eggs), body prints and trails to and from the

*Corresponding author, bashyal.ashish@gmail.com

¹Biodiversity Conservancy Nepal, Rupandehi, Nepal

²Department of Environmental Science and Engineering, Kathmandu University, Kavrepalanchok, Nepal

³Bardia National Park, Bardia, Nepal

⁴Department of Biological Sciences, Texas Tech University, Lubbock, Texas, USA

⁵Chitwan National Park, Chitwan, Nepal

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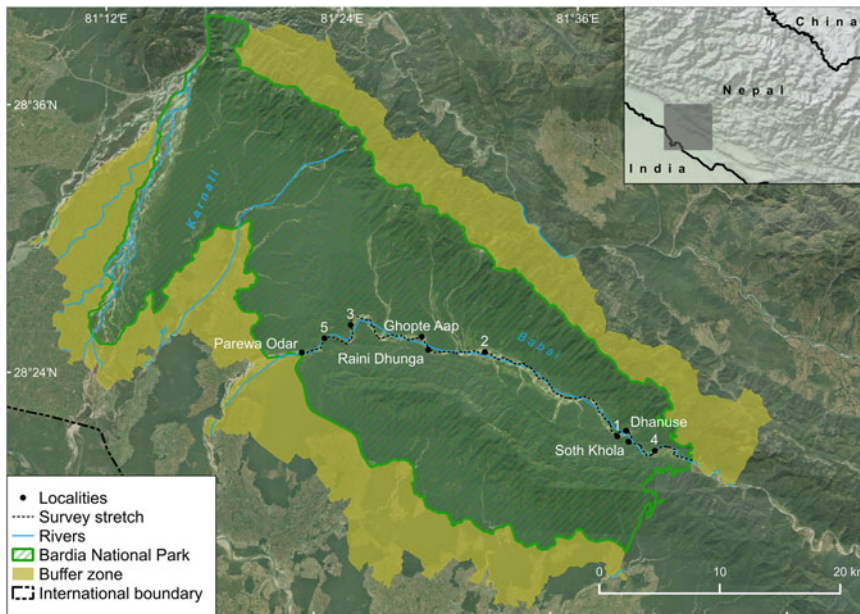


FIG. 1 Bardia National Park, Nepal, showing localities of breeding groups and/or nesting sites of the gharial *Gavialis gangeticus* observed in surveys along the protected stretch of the Babai River during February–July 2020–2022.

water (Plate 1; Khadka et al., 2020). We did not excavate gharial nests as this would render them vulnerable to predation. During the hatching season we surveyed nesting areas where trial nests were found during the nesting season surveys, looking for any signs of successful hatching (nests excavated by gharials, remnant eggshells or live hatchlings).

We located two breeding groups, one each in Soth Khola and Dhanuse, in February 2020, 2021 and 2022 (Table 1, Fig. 1). Both groups comprised one adult male and 2–5 adult females (Table 1). In Raini Dhunga and Parewa Odar we observed two adult females in each location but did not see any males. During all 3 years in Soth Khola

and Dhanuse we observed signs of breeding behaviours such as males and females swimming together, body rubbing and females staying submerged whilst a male swam towards them, accompanied by large splashes in the water. We also heard pop sounds being made by adult males (these sounds are used for communicating with other males and during courtship with females). Such behaviours have also been observed during the gharial breeding season in other parts of their range (Lang & Kumar, 2016).

We identified seven potential nesting areas in 2020, four in 2021 and three in 2022 (Table 2). We were not able to examine some stretches of the river during our surveys

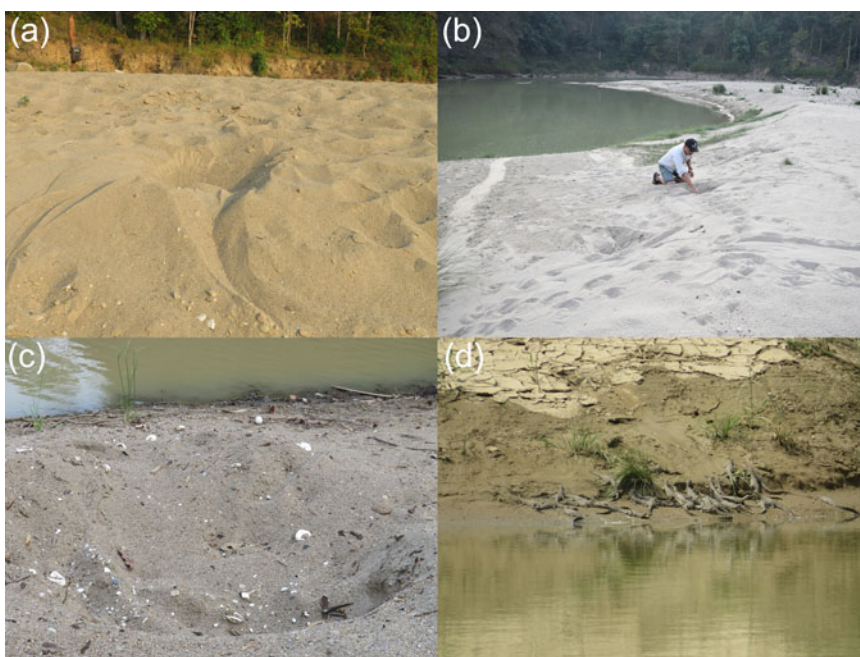


PLATE 1 (a) Gharial *Gavialis gangeticus* trial nest, (b) trails of female gharials to and from the water, (c) nest excavated by a gharial, with remnant eggshells, and (d) gharial hatchlings in the Dhanuse nesting area in the Babai River in Bardia National Park, Nepal, during 2020–2022.

TABLE 1 Size class and sex of breeding groups of gharials *Gavialis gangeticus* observed in the Babai River in Bardia National Park, Nepal (Fig. 1), during surveys in March–April 2020–2022.

Year	Location	Total count	Size class			Sex	
			Adult	Subadult	Juvenile	Male	Female
2020	Dhanuse	5	5	0	0	1	4
	Soth Khola	2	2	0	0	1	1
2021	Dhanuse	6	6	0	0	1	5
	Soth Khola	3	3	0	0	1	2
2022	Dhanuse	6	6	0	0	1	5
	Soth Khola	3	3	0	0	1	2

TABLE 2 Characteristics of potential and observed nesting areas of gharials in the 46 km protected stretch of the Babai River in Bardia National Park (Fig. 1) during March–April 2020–2022.

Nesting/potential nesting area (by year)	Length of sandbank (m)	Aspect of sandbank (°)	Height of sandbank above water \pm SD (m)	Mean slope of sandbank \pm SD (°)
2020				
1	59	182 (S)	1.46 \pm 0.05	14.33 \pm 1.15
2	25	298 (NW)	3.00	2.00
Ghopte Aap	91	310 (NW)	1.69 \pm 0.23	5.33 \pm 0.58
3	95	220 (SW)	0.68 \pm 0.20	4.50 \pm 0.58
Dhanuse (east)	168	180 (S)	1.48 \pm 0.37	13.83 \pm 3.97
Dhanuse (west)	26	60 (NE)	1.20 \pm 0.18	9.50 \pm 0.71
Soth Khola	40	310 (NW)	1.48 \pm 0.16	12.33 \pm 2.08
Mean \pm SD	72.00 \pm 51.02		1.60 \pm 0.78	11.69 \pm 5.99
2021				
4	51	312 (NW)	1.07 \pm 0.15	12.75 \pm 5.68
5	86	218 (SW)	0.69 \pm 0.15	4.50 \pm 0.58
Dhanuse (west)	19	20 (N)	1.09 \pm 0.34	21.00 \pm 5.57
Dhanuse (east)	175	188 (S)	1.76 \pm 0.71	24.00 \pm 6.99
Mean \pm SD	82.50 \pm 67.30		1.12 \pm 0.38	15.90 \pm 8.71
2022				
Soth Khola	14	291 (W)	1.69 \pm 0.06	17.00 \pm 2.00
Dhanuse (east)	48	130 (SE)	1.92 \pm 0.22	14.75 \pm 5.50
Dhanuse (west)	29	34 (NE)	1.12 \pm 0.18	9.00 \pm 2.00
Mean \pm SD	30.30 \pm 17.04		1.58 \pm 0.34	13.58 \pm 4.12
Overall mean \pm SD	66.07 \pm 51.85		1.46 \pm 0.62	13.22 \pm 2.32

because of inaccessibility as a result of thick vegetation or the presence of wildlife. Sand banks in potential nesting areas were 19–175 m in length and $1.46 \pm \text{SD } 0.62$ m above the water, with a mean slope of $13.22 \pm \text{SD } 2.32^\circ$ (Table 2). Sand banks in Soth Khola, Dhanuse (east and west, the opposite banks of the same location) and Ghopte Aap were in the same sites in each of the 3 years, although the length of the sandbanks varied between years. During nesting seasons we found abundant signs of nesting only in Dhanuse, including trails of female gharials to and from the water, and trial nests (Plate 1).

We did not observe any signs of hatching in 2020 or 2021. In both of these years all nesting areas were flooded by the first week of June, submerging the sandbanks. It is likely that the nests flooded before hatching, destroying the eggs. In

2022 we recorded two gharial nests and c. 60 hatchlings in the Dhanuse nesting area (Plate 1d). One nest hatched on 17 June and one on 22 June (Plate 1). Hatchlings from both nests associated together to form a single crèche and were guarded by female gharials. We did not find any signs of gharial reproduction in Soth Khola, Parewa Odar, Raini Dhunga, Ghopte Aap or in five other, unnamed sites.

Regular reproduction and recruitment are critical for the long-term survival of the small population of gharials in the Babai River. However, there was no known evidence of recent gharial reproduction in the protected stretch of the Babai River until 2019, when the first record of gharial reproduction in 37 years was documented (Bashyal et al., 2019). Our 3 years of data indicate that the gharial population in the Babai River is probably nesting annually.

Comparing our results with those of previous studies (Bashyal et al., 2019, 2021), it appears that the number of breeding groups of gharials has decreased from four in 2019 to just two in 2021. The decline in adult males from four in 2019 (Bashyal et al., 2021) to only two in 2021 could have resulted in the observed decline in breeding groups.

We did not observe gharials in our 2020–2022 surveys that would correspond to the size class of the 2019 hatchlings. Khadka (2020) reported survival rates of 0.4–8.2% for gharial hatchlings in Rapti and Narayani rivers and suggested that survival rates were lower in years with extreme monsoon flooding. However, it is also possible that we did not detect smaller gharials because daytime surveys are biased towards observing larger individuals (we surveyed river stretches from a distance of > 50 m, using binoculars, to avoid causing gharials to flee; at this distance hatchlings and yearlings, which are < 70 cm in total length, are difficult to observe).

Based on our results we recommend the following actions for the protected stretch of the Babai River in Bardia National Park: (1) regular monitoring during the breeding, nesting and hatching seasons of gharials; (2) monitoring of recruitment success, including the survival and growth of hatchlings and yearlings; (3) prohibition of recreational fishing and camping at or near nesting sites used by gharials; and (4) creation of thermal profiles of nesting and basking areas of gharials by recording air, water and soil temperatures along the Babai River.

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Conflicts of interest None.

Ethical standards This research was conducted with permission from the Department of National Parks and Wildlife Conservation (Permit: 1232-077/078 Eco) and Bardia National Park (Permit: 1242-077/078), and abided by the *Oryx* guidelines on ethical standards.

Data availability All of the data supporting the findings of this study are available within the article.

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