Status of the Critically Endangered gharial *Gavialis gangeticus* in the upper Ghaghara River, India, and its conservation in the Girwa–Ghaghara Rivers

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Abstract The gharial *Gavialis gangeticus* is a Critically Endangered crocodilian endemic to the Indian subcontinent. Habitat modification by river damming and water extraction has caused a severe decline in its population. The status of the gharial is known within protected areas, but there have been few surveys for this species in unprotected areas. In Katerniaghat Wildlife Sanctuary, a breeding gharial population in Girijapuri Barrage Reservoir has low recruitment, and it has been hypothesized that yearlings disperse downstream into the unprotected Ghaghara River when the barrage gates are opened. We surveyed a 100-km stretch of the Ghaghara River from the Girijapuri Barrage to Chahlari Ghat, observing a total of 84 gharials, including a high proportion of juveniles. A survey in 2021 from Chahlari Ghat to Ayodhya observed 174 gharials, giving a combined total of 258 gharials in a 219-km stretch of the Ghaghara River for the two surveys. Together, these findings confirm the presence of a significant population of gharials in the Ghaghara River. We recommend the adoption of an integrated approach, involving government agencies and local communities along the river, to conserve the protected Girwa–Kaudiyala Rivers and the unprotected Ghaghara River for gharial conservation and recovery. Such a programme will need to tackle the threats facing the gharial and establish baseline data and long-term monitoring protocols for freshwater species conservation in this river system.

Keywords Freshwater crocodile, *Gavialis gangeticus*, Ghaghara, gharial, Girwa, reservoir, river connectivity, India

The gharial *Gavialis gangeticus* is a freshwater crocodilian endemic to the Indian subcontinent (Whitaker & Basu, 1983). Damming, water extraction and diversion of water have modified the river systems of the region and fragmented and isolated gharial populations. In 1975, Project Crocodile was successful in increasing the number of gharials, but loss of habitat continued because of the long-term effects of damming and reduced water flow (Singh, 1999; Vashistha et al., 2021b). Consequently, the gharial has been categorized as Critically Endangered in the two most recent IUCN Red List assessments (Choudhury et al., 2007; Lang et al., 2019).

The construction of the Girijapuri irrigation barrage on the Girwa–Kaudiyala Rivers in 1976 isolated a population of gharials within Katerniaghat Wildlife Sanctuary. A breeding population (72 individuals and 36 nests in February 2020; Vashistha et al., 2021b) remained in the barrage reservoir, but gharials disappeared from the upstream Karnali and downstream Ghaghara Rivers (Thapaliya et al., 2009; Lang et al., 2019; Bashyal et al., 2021; Vashistha et al., 2021b). The gharial population in the Girwa River has been regularly monitored by the Katerniaghat Wildlife Division, Bahraich, but monitoring in the Ghaghara River has been intermittent as it does not lie within a protected area. Juvenile recruitment in the Girwa River, despite lying within a protected area, is low and it has been hypothesized that hatchlings are flushed into the Ghaghara River when the barrage gate is opened during monsoon floods (Vashistha et al., 2021b). To investigate this, we surveyed the upper stretch of the Ghaghara River, from the Girijapuri Barrage in Katerniaghat Wildlife Sanctuary downstream to Chahlari Ghat (Fig. 1). We also compiled data from previous surveys of the gharial in the Ghaghara River.

The Ghaghara River is the largest tributary of the Ganga River (c. 21% of the total volume; Central Water Commission, 2020). Water flow in Ghaghara is regulated by two irrigation barrages: the Girijapuri Barrage on the Girwa River and the Sharda Nagar Barrage on the Sharda River. Both barrage gates are opened three times per year, resulting in a large quantity of sediment transport and braiding (formation of a network of multiple branches within a river channel) in the Ghaghara River. We surveyed a 100-km river stretch of the Ghaghara River from the Girijapuri Barrage to Chahlari Ghat on 26 and 27 February 2023 (Fig. 1), using a wooden ferry boat equipped with an outboard engine. We conducted the survey between 9.00 and 17.00, surveying c. 50 km per day, beginning at the Girijapuri Barrage and moving downstream at a speed of 8 km/h. We recorded any gharials observed and determined their size class based on their estimated total length (tip of snout to end of tail), assigning each individual to one of four

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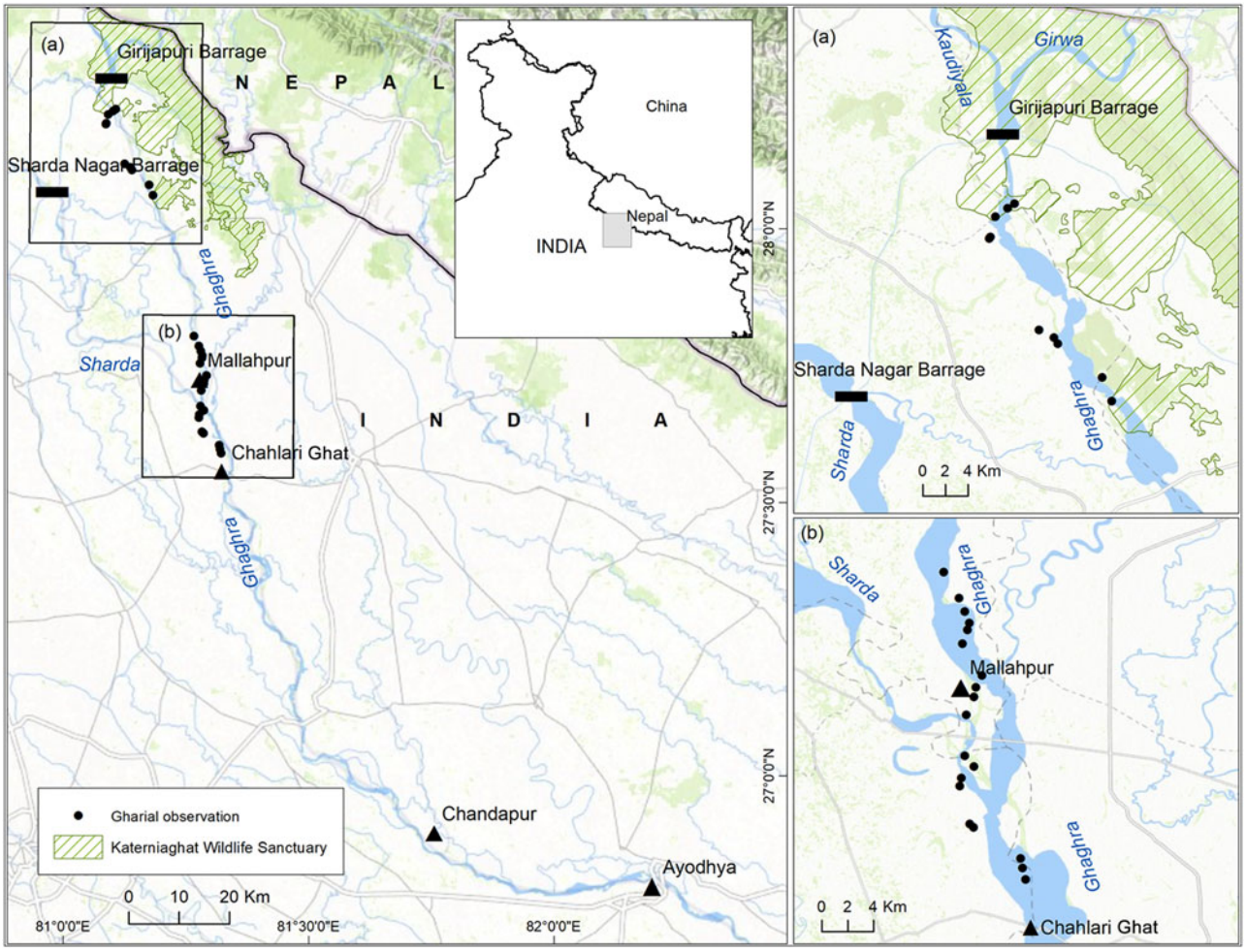

FIG. 1 Locations where we sighted the gharial *Gavialis gangeticus* during our survey of a 100-km stretch of the Ghaghara River, India, from Girijapuri Barrage to Chahlari Ghat. Singh et al. (2021) surveyed the gharial from Chahlari Ghat to Ayodhya. The Girijapuri and Sharda Nagar barrages regulate water flow into the Ghaghara River.

life stage categories: yearling (length < 1 m), juvenile (1–2 m), subadult (2–3 m) and adult (> 3 m). We also searched for crocodile spoor marks on the riverbanks. It was not possible to conduct a replicate survey moving upstream from Chahlari to Girijapuri because of low water levels and navigational issues.

We observed a total of 84 gharials at 29 locations (a density of 0.84/km; Table 1). Of the juveniles, 16 were hatchlings from the 2022 breeding season (i.e. < 1-year old). We did not record any male gharials (which are recognizable by the presence of the so-called ghara, a nasal protuberance). The population structure was skewed towards small-sized gharials (< 2 m in length; Fig. 2). Three of the adult females had bulging abdomens, a possible sign of pregnancy (Plate 1). We did not find any spoor. Although 40 gharials were tagged and released in the Ghaghara River in 2020 by the Uttar Pradesh Forest Department, of which eight were sighted by Singh et al. (2021), we did not observe any tagged individuals.

The most recent population estimate of gharials over a 219-km stretch of the Ghaghara River, from Girijapuri Barrage to Chahlari Ghat (our survey) and from Chahlari Ghat to Ayodhya (Singh et al., 2021), combined, is 258 (Table 1). This is nearly four times higher than the estimate of 72 gharials in the Girwa River upstream, in Katerniaghat Wildlife Sanctuary (Fig. 2; Vashistha et al., 2021b). Our population estimate and that of Singh et al. (2021) appear to confirm the hypothesis that there is dispersal of gharials from the Girwa River into the Ghaghara River when the barrage is opened (Basu & Singh, 2009; Vashistha et al., 2021b) and suggests that gharials are being recruited into the Ghaghara River population. There is as yet no conclusive evidence that gharials are breeding in the Ghaghara River although our observation of adult females with bulging abdomens suggests this. Eight male gharials have been reported from the river stretch between Chahlari Ghat and Ayodhya (Singh et al., 2021). As female gharials are known to move several kilometres between seasons (Lang & Whitaker, 2010), it is therefore possible that the gharial population in the Ghaghara River is breeding.

TABLE 1 Population estimates of the gharial *Gavialis gangeticus* in the Ghaghara River (Fig. 1) during 2001–2023. Individuals were assigned to life stage categories based on their estimated total length (tip of snout to end of tail), which is given in parentheses for each class. Males (of varying sizes) with a visible ghara (nasal protuberance) are also reported separately. Breeding or nesting were not recorded in any of the surveys.

Survey year	Adult (> 3 m)	Subadult (2–3 m)	Juvenile (1–2 m)	Yearling (< 1 m)	Total	Male	Number/ 10 km	River stretch (length in km)	Reference
2001	0	0	1	0	1	0	0.02	Ghaghara (600)	Basu & Singh (2009)
2009	4	12	0	0	16	0	1.78	Mallahpur–Ghaghara Ghat (90)	Basu & Singh (2009)
2013	3	40[1]		0	43	0	3.98	Chalari Ghat–Chandapur (108)	India Turtle Conservation Program & Gharial Conservation Alliance (2013)
2014	4	35[1]		19	58	2	7.25	Not available[2]	Lang et al. (2019)
2021	47	54	71	2	174	8	14.62	Chahlari Ghat–Ayodhya (119)	Singh et al. (2021)
2023	8	22	38	16	84	0	8.40	Girijapuri Barrage–Chahlari Ghat (100)	This study

[1]Subadults and juveniles combined.
[2]Data on river stretch and length were not made available by the surveyor in their personal communication to the IUCN Red List assessors.

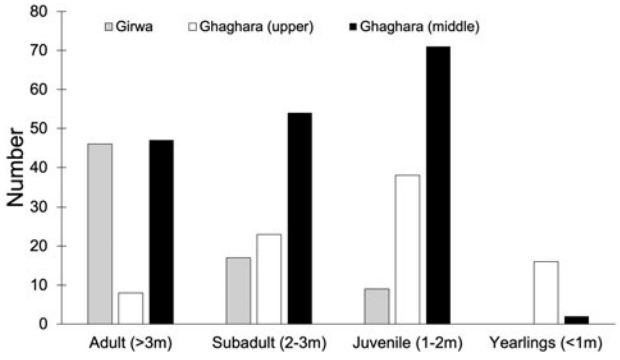

FIG. 2 Population structure of the gharial in the Girwa and Ghaghara Rivers (Fig. 1). Gharial population data for the Girwa River are from Vashistha et al. (2021b) and for the middle Ghaghara River (Chahlari Ghat to Ayodhya) from Singh et al. (2021).

PLATE 1 A basking female gharial *Gavialis gangeticus* on the Ghaghara River bank, with a bulging abdomen suggesting she could be pregnant.

The Ghaghara River contains long stretches of undisturbed, free-flowing water (Basu & Singh, 2009). Although the river discharge volumes are regulated by the two upstream barrages, the surveyed stretches are free-flowing, with abundant sand available on both riverbanks. The Ghaghara River is a sink for aquatic animals dispersing from the upstream Girwa–Kaudiyala Rivers and contains significant populations of gharials, the Endangered Ganges river dolphin *Platanista gangetica*, turtles (*Lissemys punctata*, *Nilssonia gangetica* and *Pangshura tentoria*) and avifauna (Basu & Singh, 2009; Behera et al., 2014; Singh et al., 2021). Gharial nesting habitat in the upstream Girwa River is degraded because of vegetational succession after a channel shift that occurred in 2010 (Vashistha et al., 2021b), but this habitat is being conserved by the construction of artificial sandbanks (Vashistha et al., 2021a). The gharial population in the Ghaghara River is threatened by flow regulation by the two barrages, agricultural use of the riverbanks and small-scale fishing by local communities.

There is currently no consistent monitoring of the gharial in the Ghaghara River. We recommend the adoption of an integrated approach, involving government agencies (forest, revenue and irrigation departments) and local communities along the river (the fishing community and local village groups), to conserve the protected Girwa–Kaudiyala Rivers and the unprotected Ghaghara River for gharial

conservation and recovery. Such a programme will need to tackle the threats facing the gharial and establish baseline data and long-term monitoring protocols for freshwater species conservation in this river system (Sayer et al., 2013).

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Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards. The survey was conducted under research permit Letter no: 896/23-2-12 (G) Lucknow, dated 19 September 2022, issued by the Principal Chief Conservator of Forest and Chief Wildlife Warden, Environment, Forest and Climate Change Department, Government of Uttar Pradesh.

Data availability All data generated during the study are presented in the paper. The locations of gharial observations can be requested from the corresponding author.

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