

# CROCODILE

# SPECIALIST

# GROUP

# NEWSLETTER

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VOLUME 36 Number 4  
OCTOBER 2017 - DECEMBER 2017

IUCN - Species Survival Commission

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Printed by: Uniprint NT

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**COVER PHOTOGRAPH:** West Nile crocodile (*Crocodylus suchus*) in Awash National Park, Ethiopia (see pages 24-27).  
Photograph: Ludwig Siege.

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**EDITORIAL POLICY:** All news on crocodylian conservation, research, management, captive propagation, trade, laws and regulations is welcome. Photographs and other graphic materials are particularly welcome. Information is usually published, as submitted, over the author's name and mailing address. The editors also extract material from correspondence or other sources and these items are attributed to the source. If inaccuracies do appear, please call them to the attention of the editors so that corrections can be published in later issues. The opinions expressed herein are those of the individuals identified and are not the opinions of CSG, the SSC or the IUCN unless so indicated.

Khandal, D., Sahu, Y.K., Dhakad, M., Shukla, A., Katdare, S. & Lang, J.W. 2017. Gharial and Mugger in Upstream Tributaries of the Chambal River, North India. Crocodile Specialist Group Newsletter 36(4): 11-16.

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## South Asia and Iran

### India

**GHARIAL AND MUGGER IN UPSTREAM TRIBUTARIES OF THE CHAMBAL RIVER, NORTH INDIA.** The Gharial *Gavialis gangeticus*, endemic to the Indian subcontinent, has been classified as Critically Endangered by IUCN on the basis of a precipitous decline in distribution and abundance, as well as only a remnant global population (IUCN 2007). The National Chambal Sanctuary (NCS) in India holds the largest population of Gharial, estimated at >80% of the remaining world's wild Gharial, with much smaller populations in Katarniaghat Wildlife Sanctuary on the Girwa River, in Chitwan National Park (Nepal) on the Narayani River and on the contiguous Gandak River in India, and in Corbett National Park on the Ramganga River. Nesting has been documented in all of these remaining populations, including those in reservoirs (Katarniaghat and Corbett), but >90% of annual nesting recorded globally occurs in the NCS population (Lang 2016). After an initial and slow recovery in the late 1970s-early 1990s, the NCS population has undergone two sharp declines, one in the decade prior to 2005, and the other in 2007-2008 (Sharma and Basu 2004; IUCN 2007; Stevenson 2015), followed presently by evidence of a robust recovery of the only open-river, self-sustaining Gharial population still extant.

The Chambal River is the last remaining unpolluted tributary river in the greater Ganges drainage system, relative to all others (Hussain *et al.* 2011). However, the extent of Gharial distribution and abundance in the upstream tributaries (Parvati, Banas and Kali Sindh) has remained undocumented. The objective of this study was to document Gharial in these upstream Chambal tributaries, prompted in part by anecdotal reports and previous rescue efforts in the Banas River where seasonal flow has been disrupted. The surveys were carried out in 2015-2017, with each survey focused on a specific objective.

### Study Area

The Chambal is a clear and fast-flowing river that originates from the Vindhya hill range, in central India, lying between 24°55' and 26°50' N, 75°34' and 79°18' E. It flows northeast and joins the Yamuna River to form part of greater Gangetic drainage system. It averages 400 m in width, and 1-26 m

in depth (Hussain and Choudhury 1990). A 618-km stretch of the Chambal River, between Jawahar Sagar Dam and Panchhnada, which is protected under NCS, receives water from the mainstream and additionally from three major tributaries, the Parvati, Kali Sindh and Banas Rivers (Hussain 1999), where the main study area lies. The area is within the semi-arid zone of northwestern India at the border of Madhya Pradesh and Rajasthan.

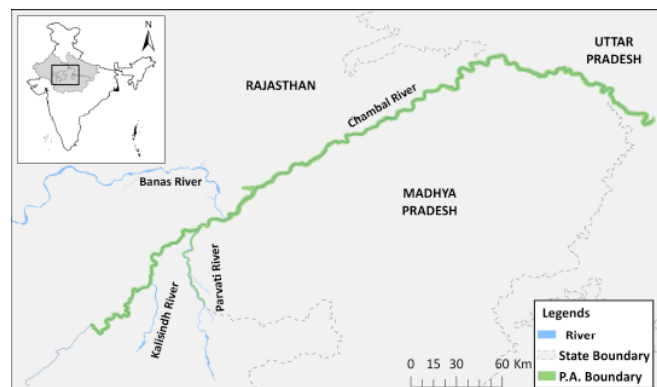


Figure 1. The Banas, Kalisindh, and Parvati Rivers flow into the Chambal River in its upstream (lower left on this map); river flow is from lower left to upper right. The NCS includes 618 km between Jawahar Sagar Dam and Panchhnada (on Yamuna, 10 km downstream from Chambal confluence). On the Parvati River, ~60 km upstream from Chambal confluence is protected; the other two rivers are outside the NCS.

- a. The Parvati River (~159 km in length) originates in the northern slopes of the Vindhyan hills in Madhya Pradesh and enters Rajasthan near Chatarpura village in Baran District, where it forms the boundary between Madhya Pradesh and Rajasthan for about 18 km, then flows for about 83 km in Rajasthan before again forming the boundary between Madhya Pradesh and Rajasthan for a length of about 58 km up to Pali village in Kota District, where it joins the Chambal at  $25^{\circ} 54' N, 76^{\circ} 33' E$  (Sharma 1979). It is a continuous flowing river having a unique ravine ecosystem consisting of sand banks, rocks and boulders spread along the banks in entire survey stretch. It is heavily interspersed by marsh beds forming a diversified habitat for variety of flora (Singh and Shrivastava 2007; Chorghe *et al.* 2011).
- b. The Kali Sindh River (~145 km) originates from Bagli (District Dewas) in Madhya Pradesh and is fed by the Ahu, Niwaj and Parwan Rivers. The river enters in Rajasthan in Binda village and flows down further to the north through Baran and Jhalawar Districts. The river then joins the Chambal River at  $25^{\circ} 32' N, 76^{\circ} 16' E$  to the downstream of Kota District in Rajasthan. The total distance covered by the Kali Sindh River in Rajasthan is 145 km (Sharma 1979). The banks of the Kali Sindh River are primarily dry pebbles, coarse gravel and rocks; consequently, the banks are hard, rocky and barren. Small interspersed sandy portions are usually invaded by thin bushy growth of inferior species and regeneration is negligible.

- c. The Banas River (~512 km) originates in the Khamnor Hills of the Aravalli Range, about 5 km from Kumbhalgarh in Rajsamand District. It flows northeast through the Mewar region of Rajasthan, and meets the Chambal at  $25^{\circ} 54' N 76^{\circ} 16' E$ , near the village of Rameshwar in Sawai Madhopur District (Sharma 1979). The Banas River has dried out since the Bisalpur Dam was completed in 1999. It flows only when surplus water is released from the dam and during the lean period it is reduced to a few deep pools with little or no flow between them.

The Chambal valley of Parvati and Banas confluences is ravine thorn forest and eroded riverbanks and adjacent ravine lands have sparse ground cover (Champion and Seth 1968). Climatically the region lies within semi-arid and sub-humid region of India. Moderate rainfall, high temperatures, dry summers and cold winters are the main features of climate. The landscape either is flattened for agriculture purpose or is invaded by thickets of *Prosopis juliflora* (Sharma 1979).

### Methodology

The 2015 survey was conducted on all three tributaries, to assess the potential of each tributary for the presence of either Gharial and/or Muggar. In winter (December-February), animals were detected basking, and in summer (June) nests and/or hatchlings were evident. Survey routes were plotted on digital maps of each river. The Parvati and Kali Sindh Rivers were surveyed on foot, and targeted surveys were conducted for the Banas River in the remaining pools. Individuals at the Chambal confluences were excluded, since these areas are included in annual surveys on the main Chambal channel (see Discussion). The downstream stretches of each tributary (Parvati 67 km, Kali Sindh 24 km, Banas 53 km) were surveyed.

Visual observations were aided by Olympus 10 × 50 field binoculars. Garmin eTrex units were used to record GPS coordinates for each sighting. The sex of observed Gharial was also recorded in the survey, classifying them as 'males' based on a clear protuberance at the tip of the snout, females/sub-adults for large individuals lacking such a protuberance, and juveniles for smaller size classes. The intensity of human activities along the river banks was recorded as well throughout, notably net fishing, water extraction and sand mining.

### Results

In brief, Gharial and Muggar were present only in the main channel of the Parvati River at any appreciable distance upstream from the confluences of all three rivers. In addition, breeding adults, nests and hatchlings were observed upstream in the Parvati, but nothing comparable was found in the other rivers. The Banas River has records of seasonally isolated individuals; the Kali Sindh River lacked Gharial and had Muggar only a short distance upstream from its confluence with the Chambal. Consequently, the Kali Sindh was excluded after the initial survey, and the Banas was monitored through rescue operations and local reports.

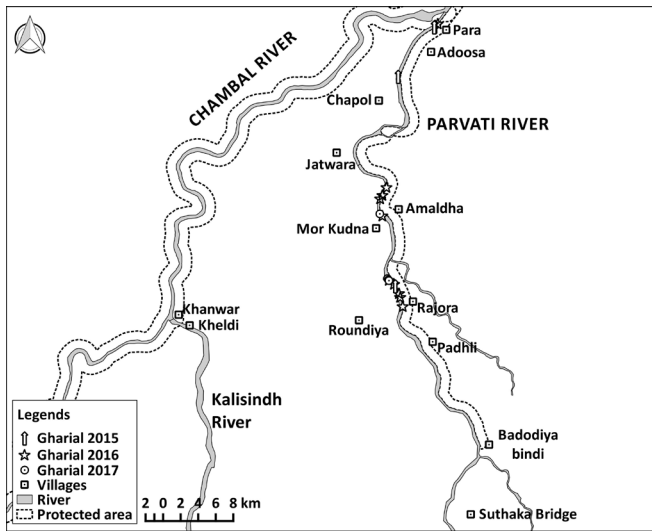


Figure 2. Locations of Gharials encountered on the Parvati River during surveys in 2015, 2016, and 2017. Gharials were observed (Table 1) from the Chambal confluence up to 41 km upstream, but not in the most upstream 26 km section of the 67 km survey upstream. The surveyed Parvati River segment is shown within the dashed lines; Gharial were found up to Roundiya, within the upstream boundary of the NCS at ~60 km.

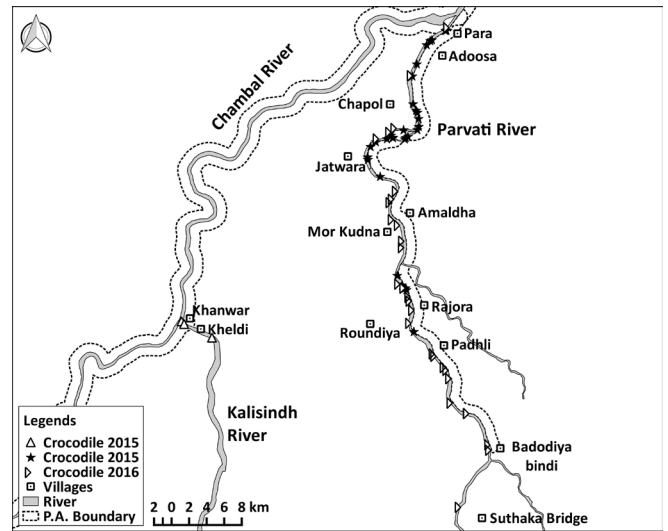


Figure 3. Locations of Muggers encountered in the Parvati and Kalisindh Rivers during surveys in 2015 and 2016. Muggers occurred near the confluence of the Kalisindh River (triangles, 2015), but not upstream. In the Parvati River, Muggers were found at localities along the entire 67 km survey (stars in 2015; right triangle in 2016), from the Chambal confluence upstream. The NCS boundary is at ~60 km, at Badodiya bindi (Table 1).

In the initial 2015 survey along the Parvati River, 14 Gharial were encountered between Pada Ghat and Koth. On the Banas, only one Gharial was observed near Banas bridge, 14 km from the Chambal confluence; and no Gharial were found on the Kali Sindh River. In 2016, 5 Gharials were reported in the Banas River near Aamlideh - 1 was rescued and 4 were noticed alongside by the the Rajasthan Forest Department.

Based on these findings, we focused primarily on the Parvati

River in subsequent surveys. In 2016, 29 Gharial (1 male and 28 females/sub-adults) were observed from Pada Ghat to Rondi (~40 km). The presence of a male Gharial at Jind Baba along the Parvati River (~ 38 km upstream; within the NCS) prompted us to investigate signs of nesting. In June 2017 another survey was conducted at Jind Baba and Mor Kudna area (~30 km upstream), in which 1 male and 3 females/sub-adults along with 203 hatchlings were spotted at Jind Baba (Fig. 4); in addition, 2 females/sub-adults along with

Table 1. Gharial and Muger encounters, as well as disturbance, on a 67-km stretch of the the Parvati River, 2015-2017. The boundaries of the National Chambal Sanctuary on this river are from ~60 km upstream to the Chambal confluence above localities FK and RG. Hatchlings were detected in 2017 at upstream localities MK (30 km) and JB (38 km) at nest sites. PG= Pada ghat; GD= Gudla; CG= Chapol ghata; GR= Gauri; AD= Amaldha ghata; FG= Fara ghata; MK= Mor kudna; JB= Jind baba; KH= Koth area; FK= Fusod killa; RG= Rajora ghata; RD= Rondi; PJ= Padli joja ka Jind Baba; SB= Suthaka Bridge.

Locations	PG	GD	CG	GR	AD	FG	MK	JB	KH	FK	RG	RD	PJ	SB	Totals
Distance (km)	1	1	8	26	27	28	30	38	38	40	40	41	45	67	67
<b>Gharial counts</b>															
February 2015	3	3	2	0	0	0	0	0	6	0	0	0	0	0	14
February 2016	2	0	0	3	7	2	3	5	1	3	1	2	0	0	29
June 2017					0		44	207							251
<b>Muger counts</b>															
February 2015	2	1	5	9	2	1	13	17	5	1	8	5	11	3	83
February 2016	2	0	4	7	5	2	1	12	2	3	4	3	13	8	66
<b>Disturbance</b>															
Net fishing	12	10	13	10	0	0	1	0	0	0	0	5	7	13	71
Sand mining	0	0	0	0	0	0	0	2	0	0	0	3	0	1	6
Water pumps	3	15	19	9	13	3	16	13	0	2	3	7	27	34	164

42 hatchlings were sighted at the Mor Kudna area. Based on an average clutch size of 35-45 eggs/nest, these observations indicate the presence of 4-6 nests at Jind Baba, and possibly an additional 1-2 nests at Mor Kudna. The upstream boundary of the NCS on the Parvati is at ~60 km, so the nesting areas lie within the NCS. Gharial distribution and abundance on the Parvati River are shown on Figure 2 and in Table 1.

Mugger distribution and abundance was noted during the Parvati surveys, and is shown in Table 1 and Figure 3. In comparison with Gharial, Mugger numbers were higher, 83 in 2015 and 66 in 2016, than those of Gharial, and the species was distributed throughout the survey section. Concentrations were highest in the midstream area in both years, where Gharial were also most evident in both years. Size class information for Mugger was not recorded, but incidental observations suggest that small sub-adults and juveniles (<2 m total length) were the most frequently encountered Muggers.

Human activities along the Parvati River were noted (Table 1). These consisted of net fishing, sand mining and water extraction. Fishing and agriculture activities were concentrated near the Chambal-Parvati confluence, diminished in the midstream survey section, then resumed in intensity upstream. In marked contrast to the main Chambal channel, sand mining was infrequent throughout the survey area; sand mining along the Chambal channel has intensified significantly in recent years, and poses a major threat to main stream nesting banks. Clearly, water extraction is the main resource removal activity on the Parvati at present, and occurred throughout the river course surveyed, even near the two sites where nesting occurred in 2017. As is evident in Table 1, Gharial presence during breeding and nesting in 2017 coincided in general with the absence of fishing activity, where sand mining was not detected, and where water extraction varied by site.

## Discussion

The Parvati River lies within the NCS where it reaches its confluence with the Chambal River, and a ~60 km stretch from the confluence upstream is protected. Previously, no records of Gharial using this stretch were available. The present study firmly establishes that this protected stretch of the Parvati River is an important additional segment of Gharial habitat within the NCS, because Gharial utilize this section for breeding, nesting, and hatchling habitats. Human activities are common along this stretch of river, particularly net fishing and water extraction, and pose potential threats to Gharial along the protected Parvati River section, as well as the continuing threats of these activities in the mainstream Chambal. Throughout its entire length inhabited by Gharial, from above Pali to the Yamuna confluence, and the adjacent protected areas upstream and downstream from that point on the Yamuna, these threats are combined in recent years with industrial level sand mining, particularly on the Madhya Pradesh and Rajasthan riversides, upstream.

During seasonally low water periods, the Parvati and the Kali Sindh Rivers are the primary sources of water for the

mainstream Chambal. Three large storage dams (Gandhi Sagar, Jawahar Sagar, and Rana Pratap Sagar) and the Kota Barrage have severely limited water discharge into the mainstream Chambal, with zero water discharge at times during the lean season (Hussain *et al.* 2011). Thus, in addition to its role as a major source of water for the Chambal, the Parvati River lower stretches provide suitable additional river habitats for Gharial.

In contrast, the other two rivers surveyed do not appear to be suitable Gharial habitat. On the Banas River, the Bisalpur Dam completed in 1999 has reduced the river to a few disjointed deep pools, and the river only flows during the monsoon when the dam gates are open. Occasionally, Gharial move upriver during this time, only to be stranded once water levels recede (Taigor 2014). On the Kali Sindh River, the riversides are predominantly rocky, with few sandy areas. Lying outside the NCS boundary, the river has many anthropogenic disturbances in addition to the suboptimal riverside habitat, and consequently harbors few Gharial beyond its confluence with the Chambal. An outlying record exists for the Kuno Wildlife Sanctuary in Madhya Pradesh for a single animal at a distance of 45 km from the confluence of the Kuno River in 2010 (S. Taigor, pers. comm.).



Figure 4. View of Paravati River at the Jind Baba locality (JB on Table 1), looking upstream from the west bank, in June 2017. The open sandy area (center of image) was the nest site where more than 200 hatchlings were detected on the shoreline below. Based on this count, there were likely 4-6 nests at Jind Baba.

Gharials prefer clean, fast flowing rivers with ample sand deposits, especially around sections with deep water (Hussain 2009, 1999; Katdare *et al.* 2011; Stevenson 2015). Recent studies have shown that Gharials undergo seasonal long distance travels, from feeding areas near major confluences during the monsoon, to their basking, breeding, and nesting areas upstream during the post monsoon, winter, and pre monsoon periods (Lang and Whitaker 2010). Female Gharials prefer to nest in colonies on particular sandy stretches that provide high sand banks adjacent to deep water (Lang and Kumar 2013, 2016).

Although preferred areas tend to be consistent over decades,

the exact location of colonial sites, and the numbers of nests per site vary annually, depending on the local river topography produced during the previous monsoon. Traditional river activities by people tend not to deter Gharial from using nearby river habitats, but Gharial generally avoid areas subject to frequent disturbances, especially those where sand mining and net fishing are concentrated. Lateral connectivity in the river is essential because it allows Gharial to seasonally adjust their basking, breeding, and nesting activities to areas where disturbances are minimal (Lang and Kumar 2013, 2016).

Not only does our study highlight the importance of the upstream segments of the NCS, as suitable Gharial habitats and important water sources, but the Gharial counts of breeding adults and nests from the Parvati surveys add to the emerging picture of how many Gharial actually live in the Chambal River, largely within the confines of the NCS. In 2017, independent surveys by the Madhya Pradesh Forest Department and the Gharial Ecology Project, using different methodologies (boat counts vs. stationary counts, respectively), estimated that the mainstream Chambal River, from Pali upstream in Rajasthan to the Yamuna confluence (a river length distance of 415 km), contains a Gharial population >1250 individuals, with conservative counts of 617-761 mature adults (ie 65-121 males and 491-696 females; MPFD 2017; GEP 2017).

In addition, above Pali to the Kota Barrage on the mainstream Chambal, 11 adults were tallied in the top 143 km of the NCS (H. Meena, pers. comm. 2017) We estimate an additional 10-15 mature adults inhabit the stretches of the Parvati and Banas in the areas surveyed in this study. Thus, the total population in the Chambal likely exceeds 1300 non-hatchling Gharial of all sizes, adding an additional 20+ mature adults to those already counted in the Chambal mainstream.

Importantly, our observations in the Parvati add 4-6 nests to the estimated nest tally in 2017 on the Chambal, based on combined surveys on the upstream (WII 2017) and downstream (GEP 2017) main channel of the Chambal. The nesting observed in 2017 was 411 nests along the 415 km stretch of Chambal from Pali (upstream) to Kasaua (downstream) plus 4-6 nests on the Parvati, resulting in a total of ~415+ nests overall, all of these lying within the NCS boundaries.

The fact that Mugger occurred in the lower Parvati that was surveyed may be indicative of the levels of disturbance noted. Some authors have speculated that there has been a gradual increase in Mugger numbers in the NCS, and have suggested that an apparent correlated trend for a decrease in Gharial abundance may be causative (Sharma and Singh 2015). Mugger-Gharial interactions are poorly understood presently and desire further study.

The NCS has well documented issues regarding habitat degradation, in the form of sand mining, fishing, stone mining, river side agriculture, and water extraction projects (Nair 2017). Despite being administrated by three states,

illegal sand mining, fishing and agriculture have shown few signs of subsiding, and sand mining especially has intensified in recent years to an industrial scale, with tractors and trolleys plying 24/7 almost year-round, during all but the 2-3 monsoon months when the river is in full flood. Backhoes are now common on riverbanks (Lang and Kumar 2016).

Recent considerations of river interlinking, particularly on the Parvati and Kali Sindh, need to take into account the devastating effects such projects would have on Gharial specifically, and on the water flow regimes upon which the Chambal fauna and flora depend. All of these anthropogenic activities threaten the entire ecosystem of the NCS, particularly the lateral connectivity of the river at present and the relatively unpolluted quality of the Chambal water.

#### Acknowledgements

The survey team thanks the Village Wildlife Volunteers team, Hanuman Gurjar and Chotu, Rajasthan Forest Department and Tiger Watch (NGO) for their assistance. The authors thank the Madhya Pradesh, Rajasthan, and Uttar Pradesh Forest Departments for permissions and logistic support for all of the recent surveys mentioned in this report.

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