

## Population status, distribution and threats of the critically endangered Gharial (*Gavialis gangeticus*) in Narayani River of Chitwan National Park, Nepal

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### Abstract

The Gharial (*Gavialis gangeticus*), also known as the gavial or fish-eating crocodile, is a member of the family Gavialidae, is the most threatened of the two species of crocodylians found in Nepal. However, sufficient information on its habitat characteristics influencing population status, distribution, and threats to its existence are lacking. We studied the gharial population in the Narayani River that was carried out in the winter season during December 2019 to April of 2020. During our surveys, a total of 117 gharials were recorded, including an adult male, 56 adult females, 19 sub-adults, 32 immature and nine were unidentified. The gharial census recorded 57 gharials in Sikrauli-Amaltari (Chitwan branch) river section followed by 14 in Sikrauli-Amaltari (Nawalparasi branch), 16 in Amaltari-Baguwan and 30 in the Baguwan-Tribeni River sections. Of 117 individuals, the number of gharials sighted under the direct observation category was 112. The majority of respondents (129 of 140) during our questionnaire, considered gharial as an important species and displayed a favorable attitude towards gharial conservation. This study concludes that the population of gharial in the Narayani River has increased, as the present population is larger than recorded during previous surveys. Finally, regular surveys and monitoring of gharial in the area are recommended to investigate the status of gharial, the prevalence of any threats and disturbance along the habitat of this important species.

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**Key words:** Climate change, conservation, disturbance, habitats, threats

### Introduction

The Gharial (*Gavialis gangeticus*), also known as the gavial or fish-eating crocodile of the family Gavialidae. It is critically endangered, and one of two species of crocodylians found in Nepal. Despite its wide distribution and previous abundance, the Gharial is among the most poorly known of the 23 crocodylian species in the world (Whitaker and Basu, 1983), and the only survivor of its family (Maskey and Percival, 1994). Molecular studies have transferred

the Malayan Gharial (*Tomistoma schlegelii*), the False Gharial to the family Gavialidae (Lee and Yates, 2018). It is recognized as thermoregulatory species (Neupane et al., 2020) becoming alarmingly close to the extinction, with about 96%–98% population decline from 1946–2006. Thus, it was shifted from ‘Endangered’ to ‘Critically Endangered’ in the IUCN Red List (2007), and is listed under Appendix I of CITES (Singh and Rao, 2017).

In the wild, survival rate of hatchlings is <1% (Murthy and Menon, 1977; Singh, 1978; Roy et al.,

1982) and only 24% of gharials survive in their natural habitat after release (Maskey, 1989). The name “Gharial” has been derived from Ghara, also known as earthenware pot, common in India and Nepal (Smith, 1931) and Ghati in Bangladesh (IUCN Bangladesh, 2016). Ghara is the large, cartilaginous protuberance on the end of the snout of the adult male. The Ghara is the sole external visual organ that helps to identify the sex in the adult (Isles, 2009). Gharial is characterized by its long and slender snout with sharp teeth which consists of interlocking set of 27–29 teeth on each side of the upper jaw and 25–26 teeth in the lower jaw (Shah and Tiwari, 2004). The average size of adult Gharials is 3.5 to 4.5 m (11 to 15 ft.) though males reach up to 6 m, with an average weight of around 160 kilos (Stevenson and Whitaker, 2010; Saikia, 2013). The longest recorded length is 6.25 m, and the largest recorded weight is 977 kilos (IUCN Bangladesh, 2016). The gharial is sexually dimorphic and reaches sexual maturity in 13 years for the male and 16 years for females, when they are nearly 3 m in length (Maskey and Mishra, 1981). Gharial mostly reside in large-bodied, deep and fast-flowing rivers in the plains (Shah and Tiwari, 2004) and beaches, next to clean and deep water, are the favored habitat of gharials (Maskey et al., 1995).

It is predominantly a fish eater, but occasionally eats turtles, birds and small mammals and is said to feed on corpses (Saikia, 2013). The long snout of the gharial is in keeping with the animal’s feeding habits. Gharial stomachs contain stones as do those of other crocodiles (Saikia, 2013). Saikia (2013) has reported that a 5 m long specimen had 4.5 kilos of stones in its

stomach. Gharials once inhabited the range that extended throughout the Indo-Gangetic plains, west to the Indus River in Pakistan, north and northeast to Nepal and Bhutan, east to Myanmar, and south to Orissa in India (Neill, 1971) is supposed to be virtually extinct in Pakistan (Whitaker and Basu, 1983), Bangladesh (Whitaker and Rajamani, 1976) and Bhutan (Singh, 1991). Until the early 1960s Gharials were found in all the major river systems of Nepal; Mahakali, Karnali, Babai, Kali Gandaki, Narayani and Koshi River. However, a recent survey revealed that Gharial was extinct from the Koshi River (Saikia, 2013). Widely distributed, a population of 5,000–10,000 (Whitaker et al., 1974) declined to 186 adults in 2006 where there were 436 adults in 1997 (IUCN, 2007). Hunting for skins and trophies, egg collection for consumption, killing for indigenous medicine and killing by fisherman are the causes attributed to decline of Gharial population (Biswas, 1970; Whitaker, 1975). While hunting is not considered to be the only significant threat, the disturbances in habitat, riparian agriculture, grazing, etc., have combined to the restriction of the Gharial’s range (IUCN, 2007). A conservation action plan for Nepal (2018–2022) has been prepared for the effective conservation of this species (DNPWC, 2018). In Nepal, habitat loss, construction works in and around the river systems, fishing, etc. have attributed the most in the decline of the population. The new Bheri-Babai diversion multipurpose project, which is expected to complete in 2023, is supposed to add some more challenges in its conservation in the Babai River system.



**Figure 1:** A female Gharial observed in the Narayani River, Nepal (© Sujan Bohara).

The declining situation of Gharial led to the first meeting of Gharial Specialists at Bronx Zoo, New York in 1971 (Das, 1981). Enlisting the animal as protected species in legislation and starting captive breeding in India and Nepal brought back the species from the brink of extinction. With the aim of rehabilitating the wild population, the captive breeding programme started in Nepal in 1978 which includes; egg collection, captive rearing and release of young in rivers within protected areas. At present, there are two breeding centers in Nepal. From 1981 to 2017, a total of 1,246 Gharials have been released in different river systems of Nepal (DNPWC, 2018). In the Narayani River, since 1981, 399 Gharials have been released (DNPWC, 2018). The Gharial monitoring 2016 reported 84 individuals in the Narayani River (DNPWC, 2016). And the latest update of gharial population was 101 individuals as reported by Poudyal et al. (2018). The drastic decline in the population over the last 60 years between 1946 and 2006 (three generations for Gharials) can be attributed to a variety of causes including over-hunting for skins and trophies, egg collection for consumption, killing for indigenous medicine and killing by fisherman across its range in the world (Biswas, 1970; Whitaker, 1975). In Nepal, habitat fragmentation and loss, construction works in and around the river systems, fishing, etc., have attributed the most in decline of the population. The decline from an estimated 436 adult Gharials in 1997 to 186 in 2006 represents a 58% drop across its range in Nepal (IUCN, 2007).

The Narayani River of the Chitwan National Park (CNP) is an important habitat for Gharial in Nepal and supports a sizeable population of Gharial, one of the indicators of healthy freshwater ecosystem. Recognized as a suitable habitat for a Gharial population, a large number of Gharials have been reintroduced since 1981. Gharial, being the top predator, has a pivotal role as a keystone species of running freshwater ecosystem and thus has higher importance in maintaining the health of aquatic biodiversity (Rashid, 2003; Behera et al., 2014). In order to continue this healthy ecosystem, stabilization of Gharial population is essential. Several studies have been conducted that focused on the status and distribution of gharial in the rivers of Nepal (Khadka et al., 2008; Bhatta, 2009; Poudyal et al., 2018). However, limited information on their habitat characteristics exists in literature. Thus, this study intended to fulfill the knowledge gap on the status, distribution and threat to Gharial in the study area in order to provide better decision-making information for the management authorities and will aid in future conservation planning efforts for Gharial and other threatened species. This study will try to identify the factors that are responsible for decreasing rate of population growth of Gharial and also update its status and distribution along the Narayani River.

This study mainly aimed to analyze and focus the long-term gharial conservation efforts on their habitats. This study reveals the perception of local people towards the conservation of Gharial and identifies threats in their views. In addition, this study provides current information on the present status and distribution as well as threats to gharial on their habitats, which will sensitize responsible stakeholders for minimizing prevalent threats in the study area.

## Material and Methods

### Study area

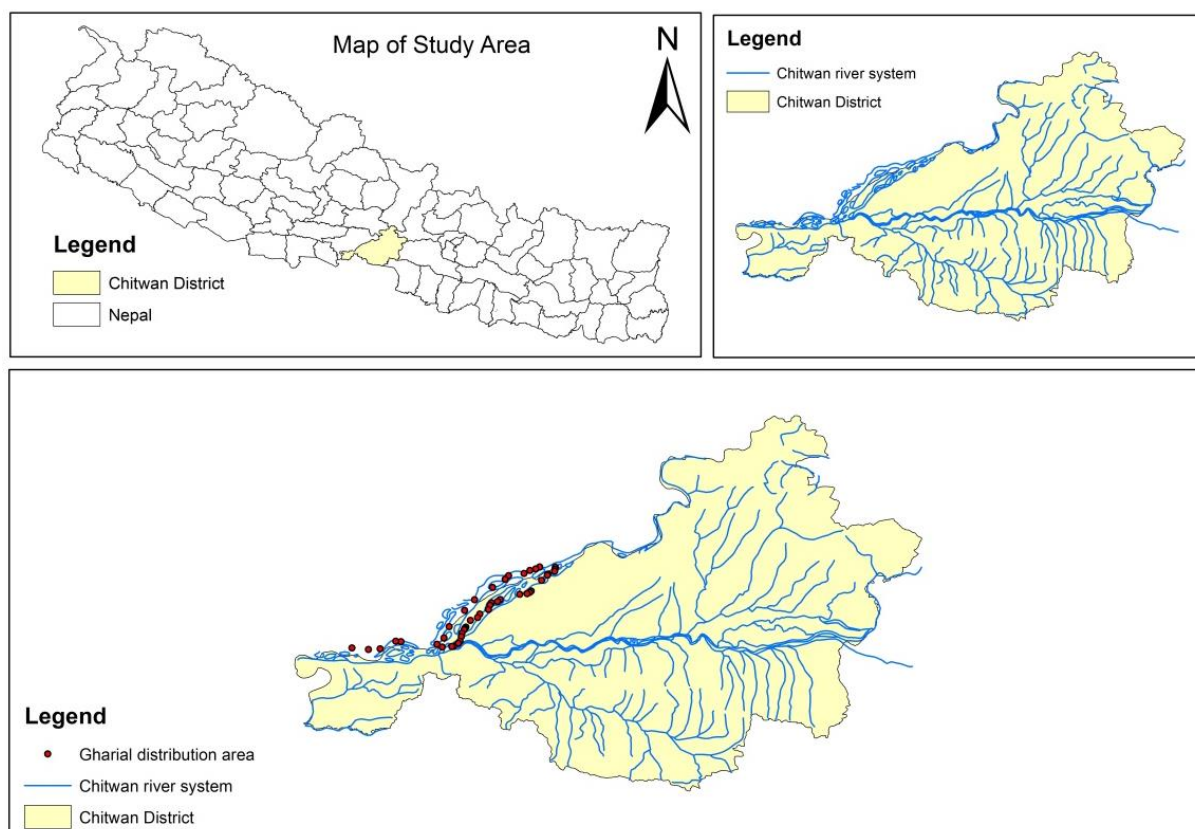
All the potential sites in and around the Narayani River system in the Chitwan National Park that harbored Gharial in the past and present was considered as study area for this purpose. CNP is located in central Nepal lowlands, between 27°30'N and 84°20'E, Nepal (Fig. 2). The Park includes the alluvial flood plain of the Narayani and Rapti Rivers system. The river eventually flows through the CNP, so the conservation of wetland biodiversity of this river depends upon the overall conservation success of respective PAs. Besides, this it also depends upon local people residing in proximity to the Park. Thus, the survival of Gharial in this river system is directly related to the physiographic characteristics of the site, condition of the parameters and attitude of local people towards its conservation.

The Narayani River crosses about 58 km through CNP. Gharials are also found above the Sikrauli, i.e., Devghat to Sikrauli section outside the National Park. For this study, a 84.48 km section of this river inside National Park was surveyed. Each river section is unique from each other in different perspective. Hence, these river sections selected for the study are described as:

**Sikrauli-Amaltari section (North- 25.9 km and South- 26.3 km):** This river section is longest river section and is also branched into number of tributaries, i.e., 3 to 4 tributaries but only two major tributaries were selected for study. There are people living in both sides (Chitwan and Nawalparasi) of river in the buffer zone of Chitwan National Park. Consequently, the human pressure may be more intense in this river section.

**Amaltari-Baguwan section (15.72 km):** This river section branches into 2 to 3 tributaries, but only the major tributaries were selected for study. There are numerous people living in the Nawalparasi side of this river, but there are no human inhabitants on the Chitwan side, as it is occupied by the core area of Chitwan National Park.

**Baguwan-Tribeni section (16.56 km):** This section of river is not branched into tributaries. There is the core area of Chitwan National Park in both side of river. The water level is high (deep) in this section.



**Figure 2:** Map of the study area.

## Data collection

### Primary data collection

#### Reconnaissance survey

A preliminary survey was conducted to understand the field and for primary data collection. It was done by interviewing local leaders, National Trust for Nature Conservation (NTNC) staffs, park staffs and direct observation. Key informants or respondents were accessed using snowballing technique. On one hand, it helped to avoid bias in selection of respondents and on other, knowledgeable persons were featured also as respondents. Almost all the study area was visited to obtain the preliminary data. The preliminary data were collected and used to construct the research framework for further study. A total of 25 key informants were consulted during the reconnaissance survey to collect the information about study area and that information was used for further study. The key informants selected were well-informed people of that area and some of them were involved in the nature conservation.

#### Population survey

For estimating the current population of Gharial, the whole river was divided into four sections as Sikrauli-Amaltari (North) (25.9 km), Sikrauli-Amaltari (South) (26.3 km), Amaltari-Baguwan (15.72 km) and Baguwan-Triveni (16.56 km) in the Chitwan National Park. The counting was carried out in the winter season during December 2019 to April of 2020. Opportunistic survey method as suggested by Maskey (1994) was adopted for census based on direct observation. Active opportunistic

search was conducted during the mid-day between 10:00 am to 4:00 pm in sunny days during winter with the help of Chitwan National Park, Amaltari post.

The accuracy of the census result was largely dependent on the basking habit of the Gharial with an assumption that almost all Gharials come out of water for basking and the minimum will be sighted and this also helps to avoid double counting as one basking site was observed only once. Hence, the number of sightings under direct observation was considered as minimum population and the sightings that will confirm its presence through justifiable indirect evidence was summed up to define the total population.

For indirect evidence of Gharial presence in the study area the 'U' shaped marking was observed and checked. Generally Gharials leave a trace of 'U' shaped marking on the sand along the riverbanks (Whitaker and Basu, 1982) and to confirm that the marks represent the presence of an individual in the site, Gharial monitoring staffs and other local peoples were enquired. Fresh signs of Gharials on the sandbanks farther than 500 m away from observed animals was counted as different individual but the sign with in <500 m, was considered as same individual. Rafting boat was used to conduct survey along the river. In addition to this, survey on foot was also conducted. Number, stage of maturity, sex and GPS location was recorded along with the habitat type. Observation was made using Bushnell binocular with magnification 7x and lens of 35 mm diameter along the downstream of the river. Maturity differentiation and sex

identification was done as per the standard procedure mentioned by Whitaker and Basu (1982) as follows:

Total length (TL) <2.20 m: Immature

2.20 m <TL<2.90 m: Sub-adult

TL> 2.80 without 'Ghara': Mostly adult female or possibly male sub-adult

TL> 2.80 with 'Ghara': Male adult

### Threats identification

Types and level of threats were observed along the river sections. Different parameters such as presence of people, number of people, fishing activities, sand mining and loading activities, construction activities, etc. were scored as threats. All the data collected from direct observation, key informant interviews and household surveys were analyzed statistically for threat identification. Threat identification was done on the basis of different threat parameters such as human interference, natural predators, habitat destruction, pollution, fishing status, etc.

The area which was frequently affected due to the different types of threats was represented as the most threat prone area. After analyzing all the threats, the most threat prone area were marked on map with the help of Arc GIS and Google earth pro software. The ranking of threats was done on the basis of people's perception. For this, total of 140 household surveys were done and responses of respondents were collected. The threat which was claimed by highest respondents was assumed as most severe threat and ranked as 1<sup>st</sup> and the threat which was claimed by less number of respondents was assumed as less severe and ranked as 5<sup>th</sup>. Similarly, other threats were ranked as 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> on the basis of number of respondents.

### Key informant interview

Key informant interview was conducted to understand the population status, current threats and perception of people towards the gharial conservation. Snowball technique was used to find the right informant. All those who were related to the gharial conservation were included in the interview.

### Household survey

To understand the people's perception towards the Gharial conservation and reason behind the decline of its population, total of 140 household surveys was carried out. The household was selected on the basis of information collected from the reconnaissance survey and the method used was random sampling. The data of households living within the 500 m away from river was not available. So, the local communities like Bote, Musahar, Tharus, fishermen and settlements that fall within 500 m away from the river bank was randomly interviewed. For this purpose, the household was covered randomly from all the villages living within 500 m away from river and altogether 140 households were taken for survey. Considering, the high illiteracy rate in rural Nepal, questionnaire

survey was carried out orally using the local language avoiding the jargons. For this interview purpose only adults (>18 years) were approached. The households were selected randomly in their settlements based on information that was obtained during reconnaissance survey.

### Secondary data collection

The population of the released Gharials was assessed through secondary data along with some questionnaire survey with the NTNC and park staffs. Secondary data was obtained from literature review of different research papers, studies published in journals, relevant websites, reports published by DNPWC, NTNC, and other organizations related to the status of released Gharials in this river system.

### Data analysis

Both qualitative and quantitative methods were used to analyze the data, major points raised from the interview and group discussion related to the research problems were recorded and analyzed as per the nature of the information with context to its representation. The information was digested in the form of digital codes using Microsoft Excel. For further analysis, Arc GIS 10.3 and Google earth pro was used to create distribution maps of animal in the Narayani River and also indicating the threat prone areas.

## Results

### Population status of gharial in the Narayani River

The total estimated population of gharial in the Narayani River was 117. Among them 112 were directly sighted and 5 were added based on the indirect signs of gharial presence. Out of 112 directly sighted gharials in the Narayani River, the number of males sighted was 1, 56 females, 19 sub-adult, 32 immature and 4 were unidentified were sighted (Table 1).

Similarly, total of 32 indirect signs (U- shaped marking) were observed. Among them, 19 signs were located within 500 m distance from directly sighted gharial and/or another sign and 13 were observed more than 500 m away from directly sighted gharial and/or another sign. Finally, the estimated population of gharial was 5 from the indirect sign of gharial presence (Appendix 1). As comparing this present data with the past data, the number of gharial in the Narayani River has seemingly increased. The numbers of gharial in 2018 were 101 and now this number stands at an estimated 117. While comparing previous data from 1987 to 2020, the population of the gharial in Narayani River is apparently increasing gradually.

### Distribution of gharial in the Narayani River

Gharials were found all over the area of Narayani River inside the Chitwan National Park. The highest numbers of gharial sightings were in the Sikrauli- Amaltari (Chitwan side) river section. The river section wise estimated population of gharial including the population from indirect sign is given as follows (Table 2). The distribution map of the gharial sighted under direct observation in the Narayani River is given as follows (Fig. 3).

When population survey was being conducted in the Baguwan-Triveni River section, group of 14 gharials was found about 900 m away from the Velauji area. One male gharial was also recorded in that group. This male was the biggest one among the sighted individuals with an estimated length of more than 5 m (Fig. 4).

Total of 32 indirect sign (U- shaped markings) were recorded in the 13 sites. Out of which, indirect sign of only 5 sites were more than 500 m away from the direct sighted and/or another sign and 8 sites were less than 500 m away from the direct sighted and/or another sign. The location of the indirect sign of gharial presence can be shown in following Figure 5.

**Table 1:** Details of directly sighted gharials in the Narayani River.

River section	Adult		Total Adult	Sub-Adult	Immature	Unidentified	Total no. of gharial sighted
	Male	Female					
Sikrauli-Amaltari (Chitwan side)	0	26	26	8	18	4	112
Sikrauli-Amaltari (Nawalparasi side)	0	8	8	3	3	0	
Amaltari-Baguwan	0	5	5	5	6	0	
Baguwan-Triveni	1	17	18	3	5	0	
<b>Total</b>	<b>1</b>	<b>56</b>	<b>57</b>	<b>19</b>	<b>32</b>	<b>4</b>	

**Table 2:** River section wise estimated population of gharial.

S. N.	River section	Length (km)	Number of gharial
1	Sikrauli-Amaltari (Chitwan-North side)	25.9	57
2	Sikrauli-Amaltari (Nawalparasi-South side)	26.3	14
3	Amaltari-Baguwan	15.72	16
4	Baguwan-Triveni	16.56	30
	<b>Total</b>	<b>84.48</b>	<b>117</b>



**Figure 3:** Distribution map of the gharial sighted under direct observation in the Narayani River.



**Figure 4:** Location of male gharial in the Narayani River (© Sujan Bohara).



**Figure 5:** GPS location of indirect sign (U-shaped marking) of gharial presence in the Narayani River.

### Threats to gharial in the Narayani River

Despite all the conservation actions, gharial population in Nepal is staying at a critically low level. Narayani River is one of the major habitats for the gharial in Nepal. The major threats to the gharials that were identified during direct field observation, key informant interview and household survey are as follows:

#### i. Human disturbance and industrial pollution

Human disturbance and industrial pollution is also responsible for habitat destruction. Narayani River is the one of major place for the recreation to the visitors. Every day large number of people use Narayani River for recreation (Rajbanshi, 2002). Due to the human interference, the habitat of gharial gets affected. The water pollution is also one of the major factors for habitat destruction of gharial. According to the prevailing local custom, the dead body of human needs to be burned. During field survey, three sites were found named Amaltari ghat, Sasana ghat and Burmasthan ghat where the dead bodies of

humans are burned and unfortunately waste are left off on river banks (Fig. 6). The non-biodegradable waste such as plastic and its products mixes with the river water and gets polluted resulting in the habitat destruction.

#### ii. Fishing

Fishing in the Narayani River is more common in the nearby villagers. “Bote” and “Musahar” community groups have got the legal right for fishing in the Narayani River and Chitwan National Park has provided fishing license to them. Besides this, other wetland dependent communities are also intensively fishing in the river on both banks resulting in scarcity of fish; a major prey base of gharials. The fisher men use large fishing net (gill net), locally called Tiyari Jaal, which threatens the gharial population due to risk of the gharials getting entrapped in such nets. Besides these, some people stay in the river bank for several days for fishing. Due to their stay in river bank, the sand banks are heavily disturbed resulting in habitat destruction (Fig. 7).

### iii. Flooding

According to key informants and respondents of household survey, more polluted water flows in the Narayani River during the monsoon because of flooding. Gharials had been sighted reaching to the agricultural field during the flooding period. Besides these, many waste materials get deposited in the river bank of Narayani River after the monsoon season resulting in habitat degradation. Thus, the flooding is also harmful to the gharials and is also one of their major threats although flooding may be essential for some aquatic animals.

### iv. Construction of Dam

The large dam called Gandak Barrage, with 36 gates constructed in the Triveni, border of Nepal and India, allow only 2 or 3 gates to flow out (Fig. 8). As a consequence, the flow of water is almost stopped in the Nepal side. This may lead to negative consequences to the survival of Gharials, which prefer fast-flowing deep water (Rajbhandari and Acharya, 2015). Besides this, the dam acts as a barrier to

the movement of spawning fishes and gharials. Once flushed by the monsoon floods, the Gharial cannot come back into Nepal through this dam (Rajbhandari and Acharya, 2015). During the monsoon season, large numbers of Gharials reach India due to large stream channel. Thus, once Gharials reach downstream, it is impossible for them to return to their original habitat of upstream through the dam, decreasing the Nepalese gharial population (Rajbhandari and Acharya, 2015). The same is a transboundary problem affecting the aquatic life of the Narayani River.

### Representation of most threat prone area on map

Based on direct observations, key informant interview and household survey, different sites were recorded as threat-prone areas to the Gharial along the river. The sites which were frequently disturbed due to the human activities, such as fishing, recreational, cremation - burning of dead bodies of human, pollution, etc, were recorded as threat prone areas (Fig. 9). This activities were seen in Sikrauli to Amaltari and Amaltari to Baguwan river sections.



**Figure 6:** Human disturbance and pollution in the Narayani River.

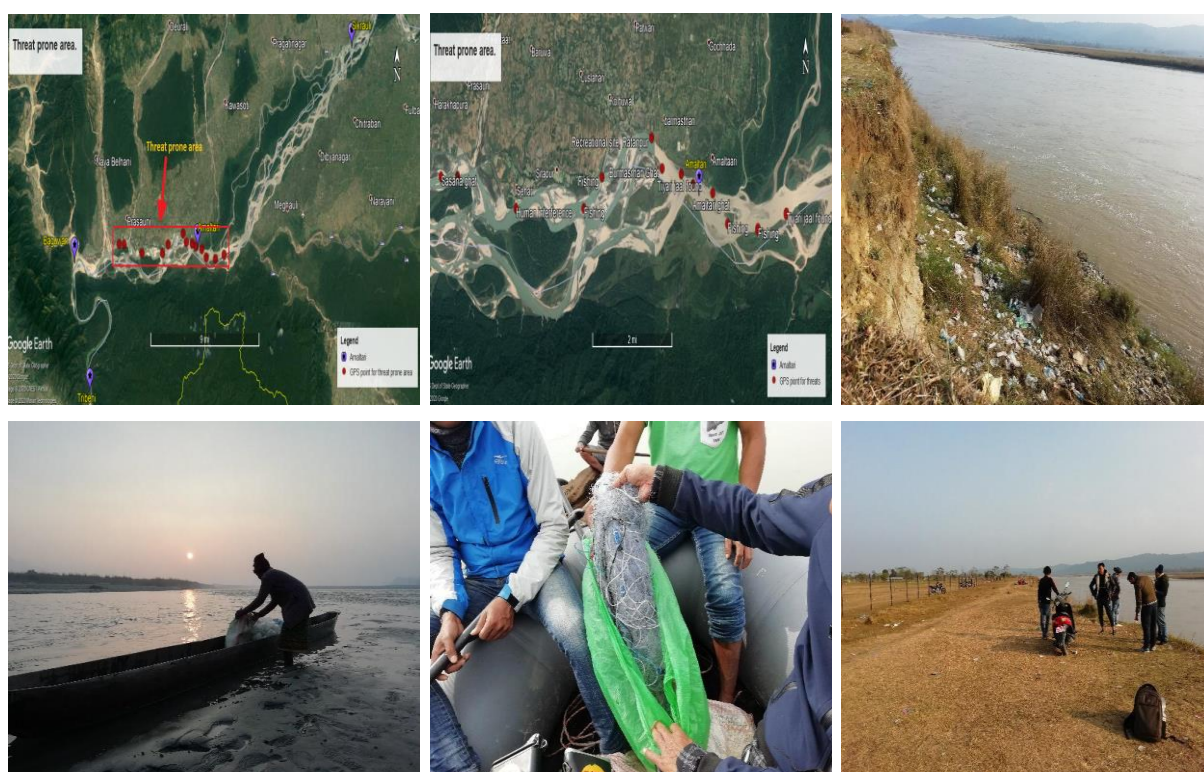


**Figure 7:** People staying in river bank (left) and Tiyari jaal (right).





**Figure 8:** Gandak Barrage showing the water depth difference in Nepal (left) and India (right) side



**Figure 9:** Some photographs of most threat prone area.

### People’s perception

To understand people’s perception towards Gharial conservation, a survey of 140 household was carried out. For this purpose, local communities such as the Bote, Musahar, Tharu, fishermen and settlements that fall within 500 m away from the river bank were interviewed. The GPS location of villages where respondents were interviewed are shown in Figure 10.

### Demographic characteristics of respondents

#### i. Age class of respondents

Age class of respondents was categorized into four classes. The age classes 20–30, 31–40, 41–50 and

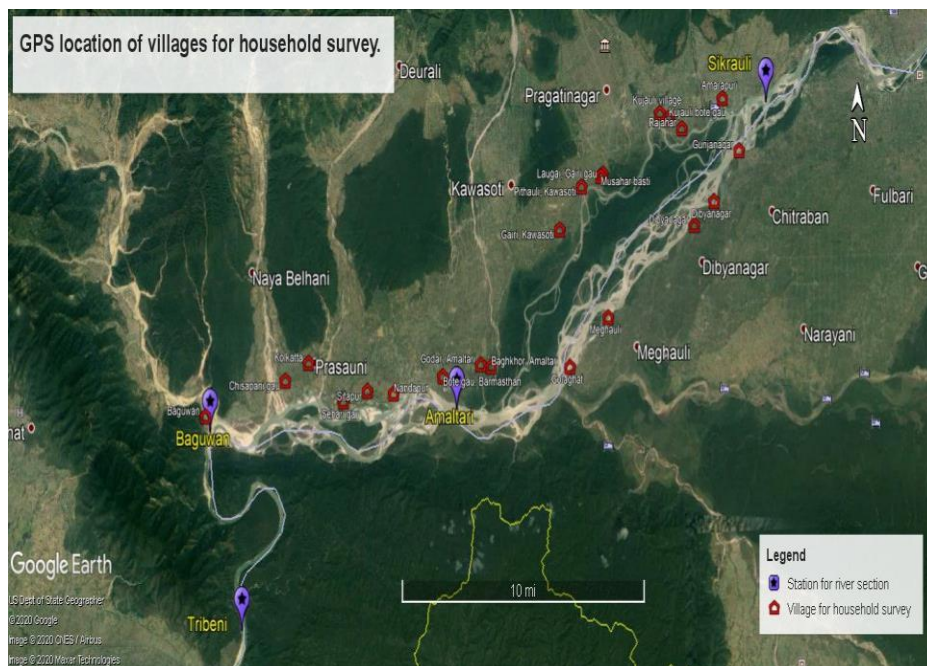
above 50 consist of 31, 51, 42 and 16 respondents respectively. The percentage of respondents in each age class is shown in Figure 11:

#### ii. Sex of respondents

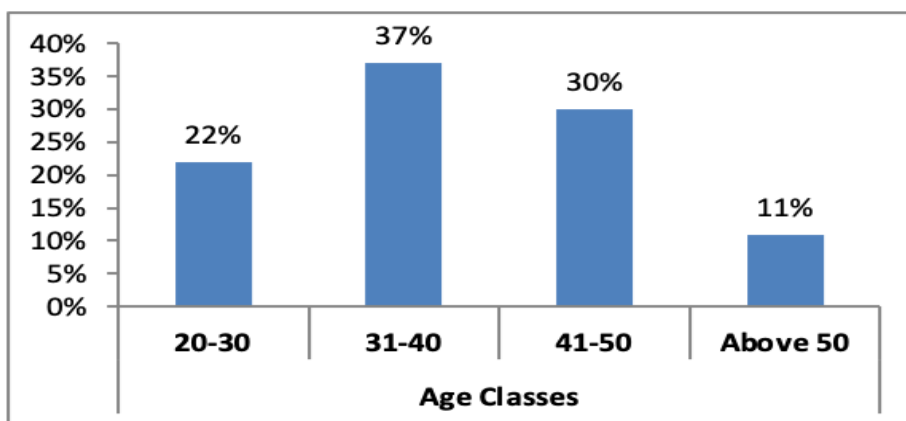
Out of 140 respondents, 127 respondents were males and 13 respondents were females. The age group ranged from 20–60 years.

#### iii. Ethnic groups of respondents

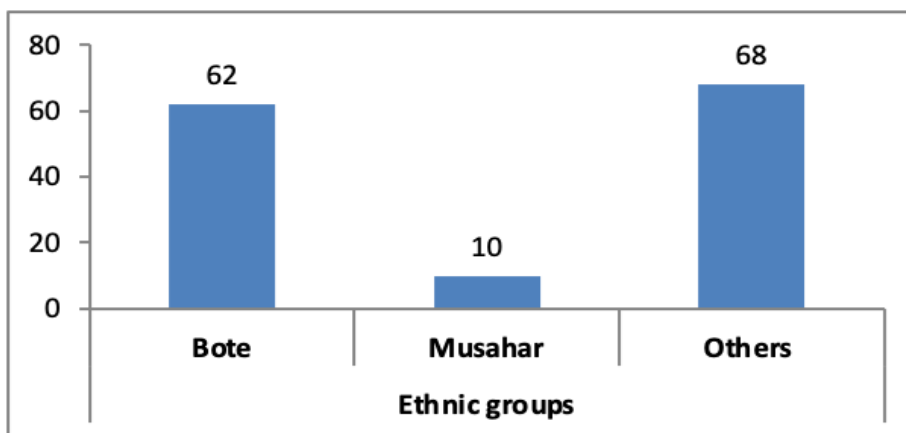
Out of 140 households, 62 (44%) were Bote, 10 (7%) were Musahar and the remaining 68 (49%) households were from other communities, such as Chhetri, Dalit and Janajati. The graphical representation of ethnic groups is shown in Figure 12.



**Figure 10:** GPS location of villages for household survey.



**Figure 11:** Age class of respondents.



**Figure 12:** Ethnic group of respondents.

**iv. Education level of respondents**

The education level of respondents was categorized into four groups: illiterate, primary, secondary and college degree groups (Fig. 13). Illiterate group included those who cannot read and write, primary group includes those having education up to grade eight, secondary level group includes those having education up to grade twelve and college degree group includes those people having higher degrees after grade twelve. Among the respondents, about 45 percent of the respondents were illiterate, 24% had primary school education and 22% had secondary school

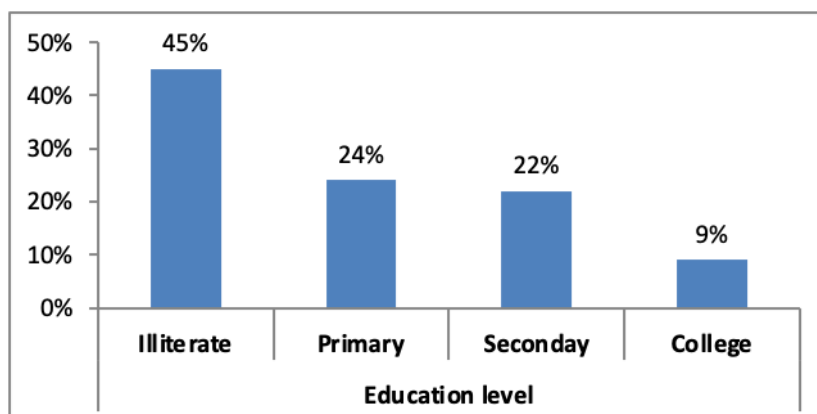
education (Table 3). There were few respondents who pursued higher education (9%).

**Fishing activities in river**

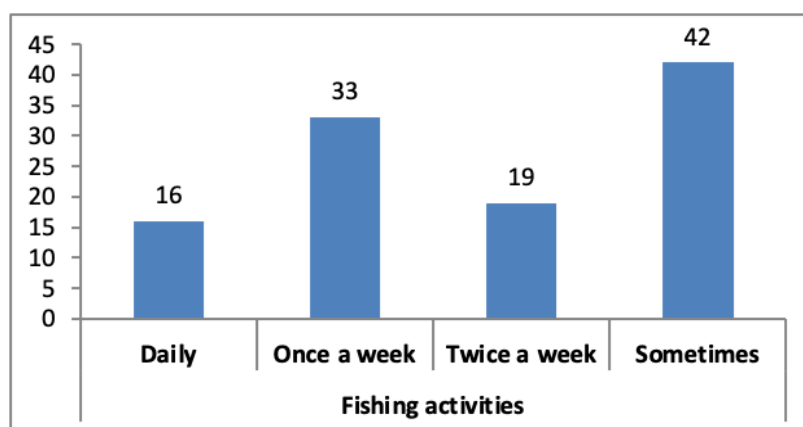
Of the total respondents interviewed, 113 engage in fishing. Among them, 42 respondents hold fishing licenses. Among them, 16, 33, 19 and 42 respondents used to go for fishing daily, once a week, twice a week and occasionally, respectively. The graphical representation of the frequency of fishing by the respondents can be seen as follows (Fig. 14). Of the 113 respondents who used to go fishing, 48%, 34% and 18% respondent's purposes for fishing were food and sell, food and recreational, respectively.

**Table 3:** Gender wise data of total respondents for each group.

S.N.	Education level	Gender of respondents		Total number of respondents	Percentage (%)
		Male	Female		
1	Illiterate	57	6	63	45
2	Primary	28	6	34	24
3	Secondary	30	1	31	22
4	College	12	0	12	9
Total		127	13	140	100



**Figure 13:** Education level of respondents.



**Figure 14:** Frequency of fishing.

### Status of gharial

Of the total respondents interviewed, 136 respondents have seen Gharials in the Narayani River and only four respondents have not. During the household survey, questions were asked regarding the status of gharials in Narayani River. “What is the present status of gharial comparing to the past in the Narayani River”? For this, different respondents gave different opinions. Out of the 140 respondents, 62 (49%) respondent’s opinion was “increasing”, 42 (30%) respondent’s opinion was “decreasing” and 30 (21%) respondent’s opinion was “don’t know”. According to the questionnaire survey, majority (49%) of the respondent’s opinion was “increasing”. So, this is also the evidence of an apparent increase in population of the Gharials in the Narayani River. Of course, this preliminary statement must be further tested using scientific monitoring over longer duration, to confirm the same.

### Status of the river

During the questionnaire survey, out of total respondents, 10 respondents (7%) claimed that the status of river is improved, 122 respondents (87%) claimed that the status of river is degraded and eight respondents (6%) had no idea about status of the Narayani River at present.

### People’s perception towards threats to gharial

During the period of household survey, respondents were asked about the current threats to the Gharial in the Narayani River. Out of 140 respondents, 29, 52,

19, 13 and 17 respondent’s opinion were human interference, habitat destruction, flood, overfishing, and entrapment in fishing net. Among the total respondents, 10 respondents replied that they had no idea. The graphical representation of respondent’s opinion is in Figure 15.

### Ranking of threats on the basis of people’s perception

We ranked the threats on the basis of people’s perception. For this, a total of 140 household surveys were done and responses of respondents were collected. The threat “habitat destruction” was claimed as the highest and was surmised as the most severe threat that ranked as 1<sup>st</sup>. The threat “overfishing” was claimed by a lesser number of respondents and was assumed as less severe and ranked as 5<sup>th</sup>. Similarly, other threats were ranked as 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> on the basis of number of respondents (Table 4).

### People’s perception towards gharial conservation

During the household survey, the questions related to Gharial conservation in the Narayani River were asked to the respondents. Out of total (140) respondents, majority of respondents (129) replied that yes, gharial conservation is necessary. Among the total respondents, majority of people (105) claimed that they know the strategy of National Park for the gharial conservation and 35 respondents had no idea about National Park’s strategy. Also, majority of respondents (103) claimed that the strategy of the Park for Gharial conservation is helpful and 37 respondents had no idea whether the strategy of Park is helpful or not.

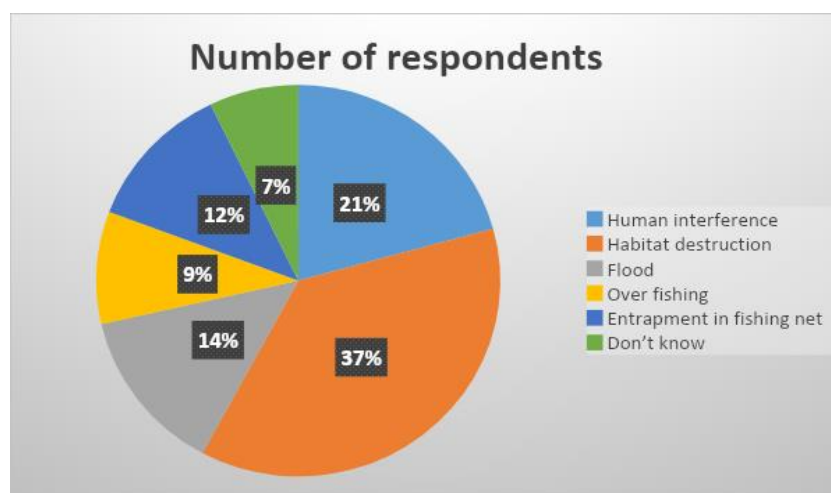


Figure 15: Respondent’s opinion towards threats of gharial.

Table 4: Ranking of threats on the basis of people’s perception.

Threats	Rank	No. of respondents	Percentage of respondents (%)
Habitat destruction	1 <sup>st</sup>	52	37%
Human interference	2 <sup>nd</sup>	29	21%
Flood	3 <sup>rd</sup>	19	14%
Entrapment in fishing net	4 <sup>th</sup>	17	12%
Overfishing	5 <sup>th</sup>	13	9%
Don’t know	6 <sup>th</sup>	10	7%
<b>Total</b>		<b>140</b>	<b>100%</b>

## Discussion

### Status and distribution of gharial

The effectiveness of the crocodile restocking programme is determined either by regular monitoring of the population or by monitoring nesting efforts. In this study, the entire population of gharial crocodile was monitored. The estimated population size of Gharial was 117 which is greater than the latest data provided by Poudyal et al. (2018), the density and number of Gharial population was 1.4/km and 101, respectively as the total length of study area was about 84 km. When comparing the present data from this study with the past data, the number of Gharials in the Narayani River has seemingly increased. While comparing the previous data from 1987 to 2020, the population of the gharials in the Narayani River was apparently increasing gradually. This increased population is due to the regular release of gharials from the Gharial Conservation Breeding Center (GCBC) which is ex-situ conservation of gharials in Nepal. The comparison of different population estimates from regular surveys of gharials in the Narayani River by different researchers in different years during the period from 1987 to 2020 is shown in Figure 16.

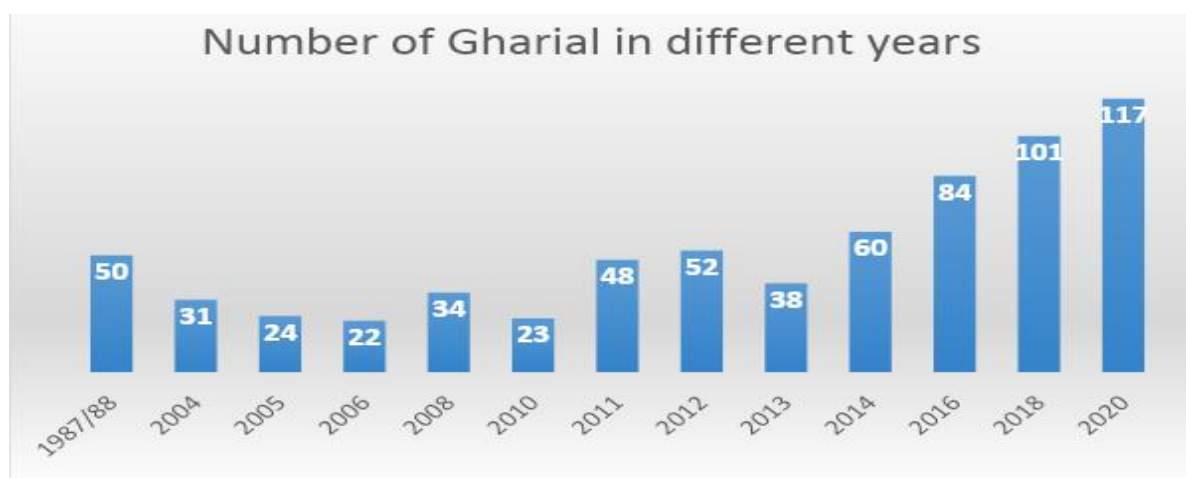
The male population was relatively low, compared with that of females. Only one male individual was observed during the population survey. Rajbhandari and Acharya (2015; 2016) survey data and Poudyal et al. (2018) also reported only one male Gharial in the Narayani River. So, the sex ratio of the Gharial in Narayani River was found to be very low. Bhatta (2009) also reported that the low male and female sex ratio was one of the major factors for declining gharial population in Nepal. Gharial population trend in Nepal is difficult to predict because of periodic releases and irregular monitoring and recording systems (Thapaliya et al., 2009). Moreover, censuses carried out in the past had adopted different

techniques of population estimation. Lack of uniform monitoring or census techniques rendered the census in past results incompatible for comparison. However, the information of Gharial population in the past years (Fig. 18) has been presented for general comparison with the present census result.

The distribution of species was dense along Sikrauli-Amaltari section (Chitwan side) followed by Baguwan-Tribeni section. These sections consist of sand banks suitable for basking and nesting, and are made up of deep water with fewer disturbances. Poudyal et al. (2018) also claim that the distribution of species was dense along Sikrauli- Amaltari section.

### Conservation threats

The river section from Amaltari to Baguwan was seen as a most threat prone area due to human interference, fishing activities, pollution, etc. The population represents both wild and reintroduced gharials and therefore we assume that this number is stable. The presence of only one breeding male for years could be disastrous to the continued existence of this critically endangered species. The Gharial breeding conservation center must adopt effective conservation measures such as ban of fishing activities in nesting sites and other key gharial bearing areas, strict patrolling and monitoring in each block of the river to discourage illicit human activities (use of gill nets, stealing of eggs, human movements, poisoning, etc.). There has been very little effort in investigating the populations, habitats, ecology, breeding ecology, dispersal, home range of reintroduced gharials in the Narayani River. Therefore, the Gharial Conservation and Breeding Center should initiate radio-tracking of breeding male and females to monitor their dispersal and behavioral activities. Such information could be extremely beneficial in designing the conservation strategy to ensure the long-term conservation of the Gharials.



**Figure 16:** Number of Gharials in different years in the Narayani River.

Poaching of Gharials for their skin, male Gharials for their ghara and Gharial eggs for food or medicinal purpose are apparently not reported (Thapaliya et al., 2009). This study also did not report such records. Therefore, it is fortunate enough for gharial, that when most of the wild creatures are becoming victims of humans, gharial is somewhat better. However, disturbance through human activity, overfishing, use of Mahajal and gill nets, construction of dams for their ultimate use, habitat modification due to over-exploitation of land and vegetation all contribute to the declining Gharial population in all Gharial habitats in Nepal and elsewhere too. Rajbhandari and Acharya (2015) also reported that Gharials were threatened by industrial pollution, construction of dam and overfishing in the Narayani River of the Chitwan National Park, Nepal. Similarly, the study conducted by Saikia et al. (2010) in the Brahmaputra and Barak Valley of Assam, India also reported that gharial faces many threats due to flooding and dam construction in rivers, habitat destruction and decline in food quality and quantity. Similarly, a population survey by Thapaliya et al. (2009) carried out in the river systems of Nepal indicated the presence of 70 gharials. The study showed decreasing trend of gharial population due to high human disturbances. The study identified a need to carry out scientific study-based conservation measures such as restocking and habitat improvement.

#### **i. Weak adaptability of released gharials in natural habitat**

Gharial conservation breeding center (GCBC), Kasara has the most important role for conserving the Gharials in Nepal. Due to the contribution of this breeding center, we are able to maintain the Gharial population in the natural habitats of Nepal. Despite all efforts, the adaptability of released Gharials is less than that of naturally grown gharials. The lifestyle of the gharial in breeding center is far different from the gharials in natural habitat. For providing live fishes for feeding to the baby gharials, GCBC, Kasara is managing a live fish farm in an area of 0.15 ha near the gharial ponds (Khadka et al., 2013). In the breeding center gharials are fed and therefore they don't need to search or forage for prey but in natural habitat, gharials need to search and catch the prey for feeding that needs more effort and survival kill to the Gharial. Also the prey species (fishes) in the natural habitat are hard to catch and feed than in breeding center. In addition, after one week of hatching of egg, hatchlings are shifted to separate hatchling nursery ponds (Khadka, 2010). According to key informants, the hunting skills are generally transferred to the offspring by the parents in the natural habitat but in the breeding center, the captive-raised gharials have less hunting skills than that of Gharials in natural habitat due to separation of hatchlings from their parents (Luxmoore, 1992). Similarly, in the breeding center, there are number of small gharial ponds with non-flowing water. Due to which, after releasing, gharial should face the current of flowing water in the river that makes them to face more struggle in natural habitats.

#### **ii. Very low male female sex ratio**

During the population survey, a single male Gharial was recorded. The Gharial census in 2016 also recorded a male gharial in the Narayani River (Acharya et al., 2017). The male female ratio of gharial in the Narayani River is thus low, and offsprings from natural breeding is also expected to be low. It is therefore not illogical to assume that the natural population of the Gharial is on the brink of extinction in the Narayani River. At present, a majority of individuals comprising the areas's Gharial population is maintained by the captive-born, hand reared, released hatchlings. If the gharial conservation breeding center is closed, there will be the great chance of gharial becoming extinct in the Narayani River.

#### **iii. Collection of Gharial eggs**

Gharial eggs were collected from the Narayani River by the GCBC, Kasara for the breeding purpose. One of the key informants, Hom Bdr. Musahar, was appointed by GCBC, Kasara, for gharial monitoring also said that almost every year in a month of April, Gharial eggs were collected for breeding as the crocodiles normally start laying eggs in April. And according to him, if the eggs are lost from the natural nesting site of gharial, then they feel insecure in that site and get compelled to migrate to another site of the Narayani River. Thus, almost every year, this activity of egg collection makes the Gharial to migrate to a new habitat every year. This activity of egg collection also makes the species insecure to stay in its natural habitats.

#### **Gharial conservation in perspective of local people**

A majority of respondents (129 out of 140) considered Gharial an important species and had a favorable attitude towards its conservation. People were aware of declining gharial population and their habitat destruction. However, their awareness has not been used in action which is reflected by continued disturbance through fishing and other activities affecting Gharial in the river. Majority of people were aware of the park's activity plans to conserve the species and they agreed with their activity for conserving the Gharials. They even reported the park is successful in conserving the gharials, at least for now. However, Bhatta (2009) reported that the Park had failed to conserve Gharial in the case of the Rapti River of Chitwan National Park because the population in the Rapti River had not been improved as the population was similar to that of 2005.

#### **Comparison between upstream and downstream Gharial populations**

More number of gharials were found in the upstream side of river, i.e., Sikrauli-Amaltari (Chitwan side) section. In this section, 57 Gharials were recorded with a density of 2.20 individuals per km river length. The density of Gharial population in different river sections is shown in Table 5.

**Table 5:** Density of gharial population in different river sections

S.N	River Section	No. of gharial (N)	Length of river (km) (L)	Density of gharial (N/L)
1	Sikrauli-Amaltari (Chitwan side)	57	25.9	2.2
2	Sikrauli-Amaltari (Nawalparasi side)	14	26.3	0.53
3	Amaltari-Baguwan	16	15.72	1.01
4	Baguwan-Triveni	30	16.56	1.81

During the field survey, it was found that more mature Gharials were recorded in upstream side of river, i.e., Sikrauli-Amaltari (Chitwan side) section. In this section, 26 adult female Gharials were recorded. People were also more aware of Gharial conservation in upstream side as compared to downstream because at the latter, i.e., the Amaltari-Baguwan sections, different human activities, such as fishing, polluting and recreational activities were recorded, adding to the human pressure in this part of the river system. Thus, the area which is located in this section was identified as the most threat prone area. There are more chances of flooding in the downstream side due to the Gandak barrage in the border of Nepal and India. Due to this barrage, Gharial that had once crossed to India side cannot return back to its original habitat resulting in the decrease of Nepalese Gharial population. As compared, the river in upstream side is more branched than in downstream side with higher current of running water and there is also more amount of sand beaches in upstream side which is suitable habitat for basking of Gharial. Thus, the density of the Gharial population was found higher in upstream side, i.e., Sikrauli-Amaltari (Chitwan side) section. The distribution of Gharial was more regular in upstream side as compared to the downstream side. The only one male Gharial was found in the downstream side, i.e., Baguwan-Triveni River section. Hence, there may be crisis of male Gharial in the upstream side.

## Conclusion

The population of Gharial in the Narayani River has apparently improved as the present population is greater than that from previous census. The sex ratio of males is low which is a critical factor for declining population and potential crash. Gharial sightings were regular in all sections of river but more sightings were in Sikrauli to Amaltari (Chitwan side) section followed by Baguwan to Tribeni section. This shows that Sikrauli to Amaltari (Chitwan side) and Baguwan to Tribeni sections are more suitable site for Gharial release and rearing. The most frequently used habitat was sand bank and mud bank. Due to the presence of different human interference and illegal fishing in Amaltari to Baguwan, this river section is placed in most threat prone area as Gharial habitats. After listing the Gharial in protected species by

Department of National Park and Wildlife Conservation (DNPWC), some rules were enforced to protect the species like restriction in use of nylon gill net, sand mining and stone mining, and controlled fishing. But the study showed uncontrolled fishing using gill net (Tiyari jaal) in the river. This indicates possibility of decline of gharial in coming days in the area. Majority of respondents had a favorable attitude towards Gharial conservation and they were aware of declining gharial population and their habitat destruction. A breeding and restocking program by the Park is in effect for several years; however, the study shows that there is high risk of ecological disaster of gharial. From the study, it is found that there is habitat degradation with human disturbance. Therefore, proper attention from the concerned park authorities and buffer zone institutions, tourism entrepreneurs, and fishing communities is required who are responsible for maintaining and enhancing healthy Gharial populations through habitat protection and increased prey population or associated fish species in the near future. Finally, it is recommended that awareness programs on Gharial conservation and regular monitoring of wild and reintroduced gharials needs to be carried out to evaluate its population status, habitat requirements and effects of existing conservation practices to gharials and assess the impacts of overfishing to the survival of gharials in the Narayani River. Similarly, Chitwan authorities must be aware to release an adult male from zoo or other areas, after a brief acclimatization period in semi natural condition, in upstream side of this river as there may be the crisis of male gharial in the upstream side of Narayani River in the near future.

## Data availability

GPS points and maps are available with the authors and will be made available upon requests from bonafide conservationists with an interest for Gharial conservation in the Narayani River.

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### Conflicts of interest

All the authors declare that there are no conflicting issues related to this research article.

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#### Appendix 1: Details of indirect sign of gharial presence.

River section	No. of U- shaped marking (<500 m)	No. of U- shaped marking (>500 m)	Assumed no. of gharial
Sikrauli-Amaltari (Chitwan side)	1	-	-
	5	-	-
	4	-	-
	4	-	-
	-	5	1
Sikrauli-Amaltari (Nawalparasi side)	-	-	-
Amaltari-Baguwan	1	-	-
	2	-	-
	1	-	-
Baguwan-Triveni	-	2	1
	-	1	1
	1	-	-
	-	3	1
	-	2	1
<b>Total</b>	<b>19</b>	<b>13</b>	<b>5</b>