Communal nesting behavior of Gharial (*Gavials gangeticus*) in Chitwan National Park, Nepal

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Abstract:

The gharial (Gavialis gangeticus), a critically endangered crocodilian species, faces significant conservation challenges due to habitat degradation, human disturbances, and climate change. This study examines the nesting ecology and hatching success of gharials along the Narayani and Rapti Rivers in Nepal, focusing on key nesting parameters such as clutch size, nest elevation, distance from the river, and hatching success rates. Data were collected through systematic field surveys conducted during the nesting season across four nesting sites, where we recorded nest locations, nest depth, clutch size, nest elevation, and distance from the river. Eggs were collected and incubated ex-situ to assess hatching success rates. Our findings reveal that nests in the Narayani River tend to have larger clutch sizes, higher nest elevations, and greater distances from the river compared to those in the Rapti River, a pattern consistent with previous studies. However, hatching success rates were lower in the Narayani River. Additionally, we observed communal nesting behavior, with multiple nests clustered within nesting sites, further supporting previous reports of this phenomenon in gharials. While our study provides valuable insights, further statistical analyses incorporating ecological, environmental, and anthropogenic factors are recommended to better understand the drivers of hatching success and nest site selection. These findings contribute to ongoing conservation efforts and highlight the need for nesting site protection and further detailed research to safeguard the remaining gharial populations.

Keywords: Gharial, Communal Nesting, Clutch, Hatching Success

1. Introduction

Gharial is a keystone species of running freshwater ecosystem; hence it is quite important in biodiversity conservation. The gharial population in Chitwan National Park is estimated to be 198 (DNPWC, 2018). The fragmented population of the endangered gharial crocodile is continuously under high risk by human disturbances. Gharials are under tremendous threats from human disturbances such as overfishing, grazing, dam construction and over-exploitation of natural resources (Rajbhandari & Acharya, 2013). The main threats are from a dam that causes fish depletion and flushes gharials from the protected area, sand mining and grazing that destroy basking and nesting sites, fishing that causes food shortage, drift nets that kill gharial and water pollution. The conservation measures recommended are strict protection of preferred basking and nesting sites and prohibition of fishing in the main settling zones and participatory management by local people.

Communal nesting behavior has been reported in several crocodile species. In regions like the Ayeyarwady Delta, saltwater crocodiles (*Crocodylus* porosus) exhibit communal nesting, which can be advantageous in terms of resource utilization (Than et al., 2021). Communal nesting behavior can influence the choice of nesting sites for female crocodiles seeking to increase the survival potential of their offspring (Campbell et al., 2013). The presence of other nesting females may also provide a protective advantage against predation, a significant risk for vulnerable eggs

(Than et al., 2021). Research indicates that communal nesting can foster a cooperative breeding strategy that enhances hatchling survival rates through increased attendance of nests, as observed in species like the American crocodile (*Crocodylus acutus*). Female crocodiles are known to assist in the hatching process and care for hatchlings, an aspect that can be amplified when multiple nests are nearby (Hénaut & Charruau, 2012). Social interactions among nesting females may lead to improved hatching success rates and reduced predation risk (Hénaut & Charruau, 2012).

Communal nesting behavior has also been reported in the Gharials, where multiple females lay their eggs close together at the same sand deposit. (Rao & Singh, 1993). Nest dispersion is influenced by various factors, including distance to water, substrate depth, elevation from river water levels, distance from previous nests, etc. (Rao & Singh, 1993) A detailed understanding of the nesting habitats of Gharial, which affects the hatching success, is necessary for gharial conservation (Hussain, 2009).

Figure 1: Gharial sighted near the nesting sites during the field survey in the Rapti river of Chitwan National Park.

The primary objective of this research was to identify the locations of communal nesting sites of endangered gharials in Chitwan National Park (CNP) and analyze nest characteristics and patterns in relation to key environmental factors such as elevation above water, distance from water, and sand depth. This study also investigates the ex-situ hatchling success. The research

provides valuable insights that can inform effective conservation strategies for the long-term protection of gharials in Nepal's river basins. Proper management of nesting sites could enhance hatchling survival rates, offering crucial guidance for park managers in ensuring the species' continued survival. Additionally, a conservation awareness program was implemented to educate local communities on gharial ecology and the impacts of human disturbances. By integrating ecological research with community engagement, this initiative aims to strengthen gharial conservation efforts and support a sustainable population in Nepal's river systems.

2. Methods

2.1 Study Area

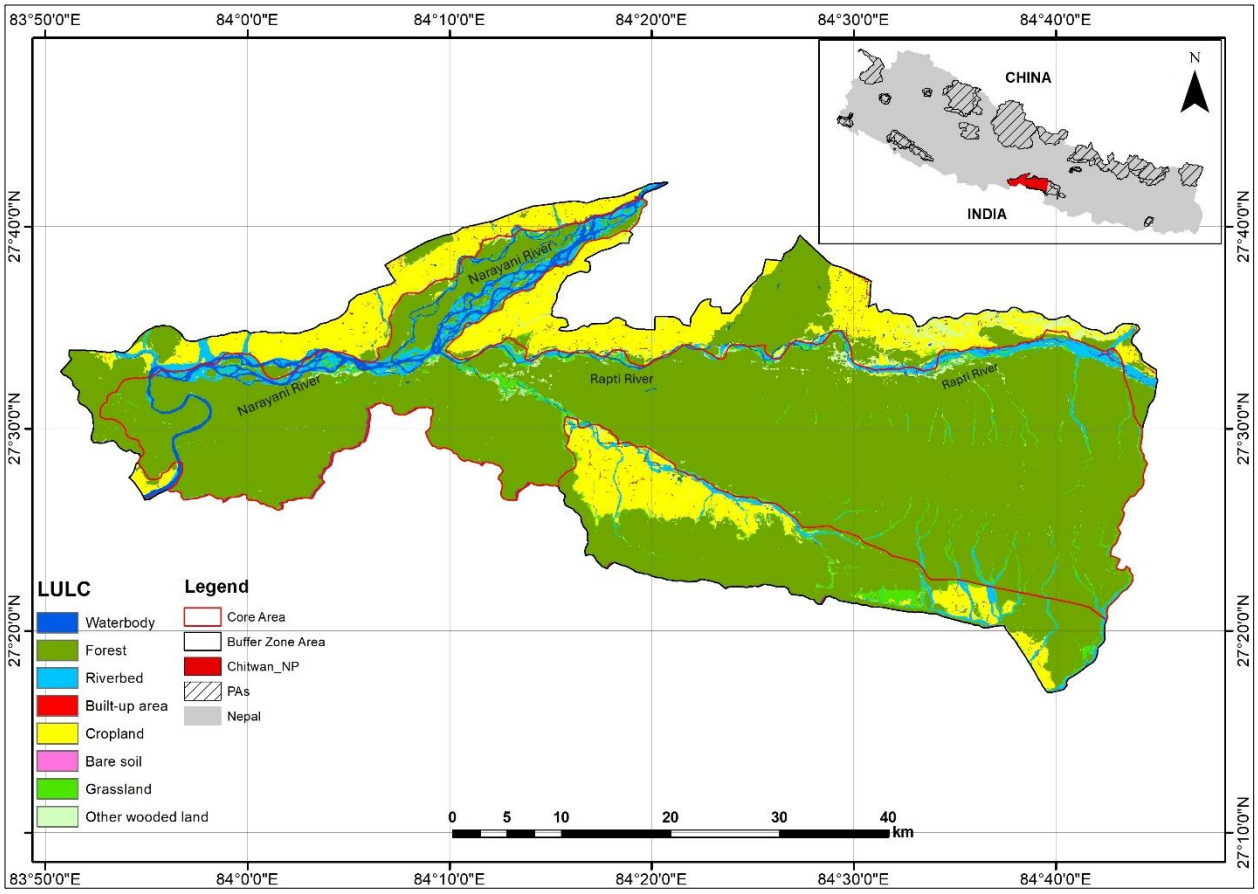

Figure 2: Map showing Chitwan National Park's land use land cover with two major river systems (Narayani and Rapti).

2.2 Data Collection and Analysis:

Data was collected in the Narayani and Rapti rivers within Chitwan National Park (932 km²), located in the Terai plains of south-central Nepal. The study was conducted with permission from the Department of National Parks and Wildlife Conservation and Chitwan National Park. Given the sensitive nature of the methodology, which involves regularly monitoring the site, this research was done in collaboration with the national parks and the Gharial breeding center of Chitwan

National Park. All legal and ethical guidelines were strictly followed throughout the data collection process.

During March–April 2021, field inspections were conducted along the riverbanks to identify nesting sites. These surveys were conducted in the early mornings by trained staff and volunteer boatmen assigned to monitor breeding gharials. Surveyors searched for the distinctive long, inverted U-shaped tracks of nesting females leading away from the water, indicating potential nesting locations. The sand was often loose, moist, and disturbed at the apex of these tracks. In most cases, nesting sites remained consistent with previous years, though occasional new nesting sites were also identified.

Once a nest was located, some nests in areas vulnerable to flooding, human activity, and predation by mongooses were selected for ex-situ hatching at the Gharial Conservation and Breeding Center in Chitwan National Park. After locating and probing a nest, the following data were recorded: date of egg-laying, number of eggs per nest, total nests at each site, nest depth in the sand, number of damaged or cracked eggs, precise location mapped onto a sketch of the nesting bank, distance from water, height above water, distance to the nearest nest, and the chronological order of nest laying during the season.

Figure 3: Probing gharial nests at the Bhelauji site of the Narayani River in Chitwan National Park. The eggs are collected and transported to the Gharial Breeding Center, Kasara, for ex situ hatching and conservation efforts.

The eggs are transferred to the Gharial Conservation and Breeding Center for monitoring until hatching begins. Observations continue until all eggs have hatched, with data recorded on hatching dates, the number of empty eggshells, death after being developed (hereafter referred to as “embryo mortality”), infertile eggs, and successful hatchings. The collected data was analyzed using R, and conduct statistical analysis. Arc GIS was used generate maps

3. Results and Discussion

3.1 Nest Sites and Location

Field surveys and consultations identified major nesting sites of the Gharial in Chitwan National Park along the Rapti and Narayani rivers. Key sites along the Narayani River include Sishwar, Badar Jhula, Golaghat, Khoriya Muhan, Hattisar-Khoriya, Temple Area, Velauji, etc., while the

Rapti River hosts Dudhaura, Hattidundi, Sitamai, Charhara, etc. The present study, conducted in 2021 and 2022, focused on 14 nests across two river systems and four nesting sites: eight nests in the Rapti (Hattidundi with seven nests and Dudhaura with one) and six nests in the Narayani (Velauji with four nests and Sishwar with two) (Figure 4, Figure 5).

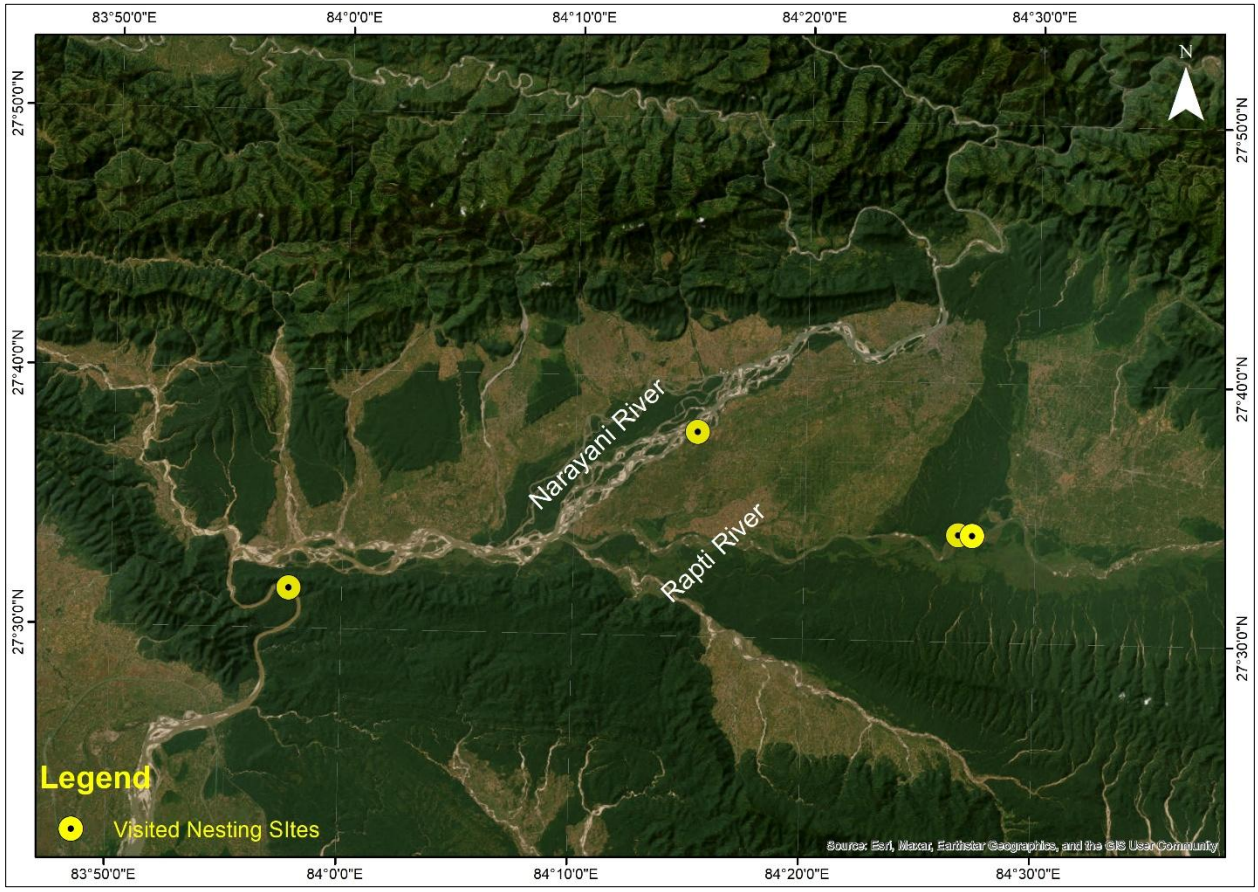

Figure 4: Distribution of visited gharial nests along the Narayani and Rapti rivers in Chitwan National Park in 2021.

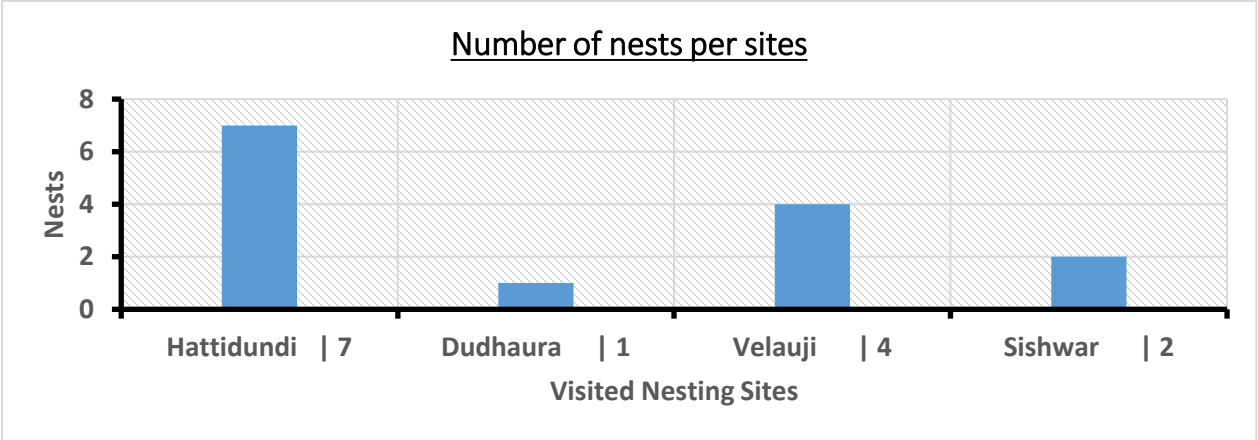

Figure 5: Number of gharial nests recorded at visited nesting sites in Chitwan National Park during

the 2021–2022 survey. The study focused on four nesting sites: Hattidundi (7 nests), Dudhaura (1 nest), Velauji (4 nests), and Sishwar (2 nests).

3.2 Nest site characteristics

The analysis of nest site characteristics for the Narayani and Rapti rivers reveals notable differences in depth, height from water, and distance from water. (Figure 6). On average, the Narayani River has a greater depth (38.3 ± 2.3 cm) compared to the Rapti River (35.8 ± 3.1 cm). Similarly, the height from water is slightly higher in the Narayani (2.5 ± 1.0 m) than in the Rapti (2.4 ± 0.6 m). The distance from water follows a similar trend, with nesting sites along the Narayani being farther from the water (11.3 ± 4.9 m) than those along the Rapti (10.0 ± 1.5 m). These variations suggest potential differences in river dynamics, sediment deposition, or nesting habitat preferences along the two rivers.

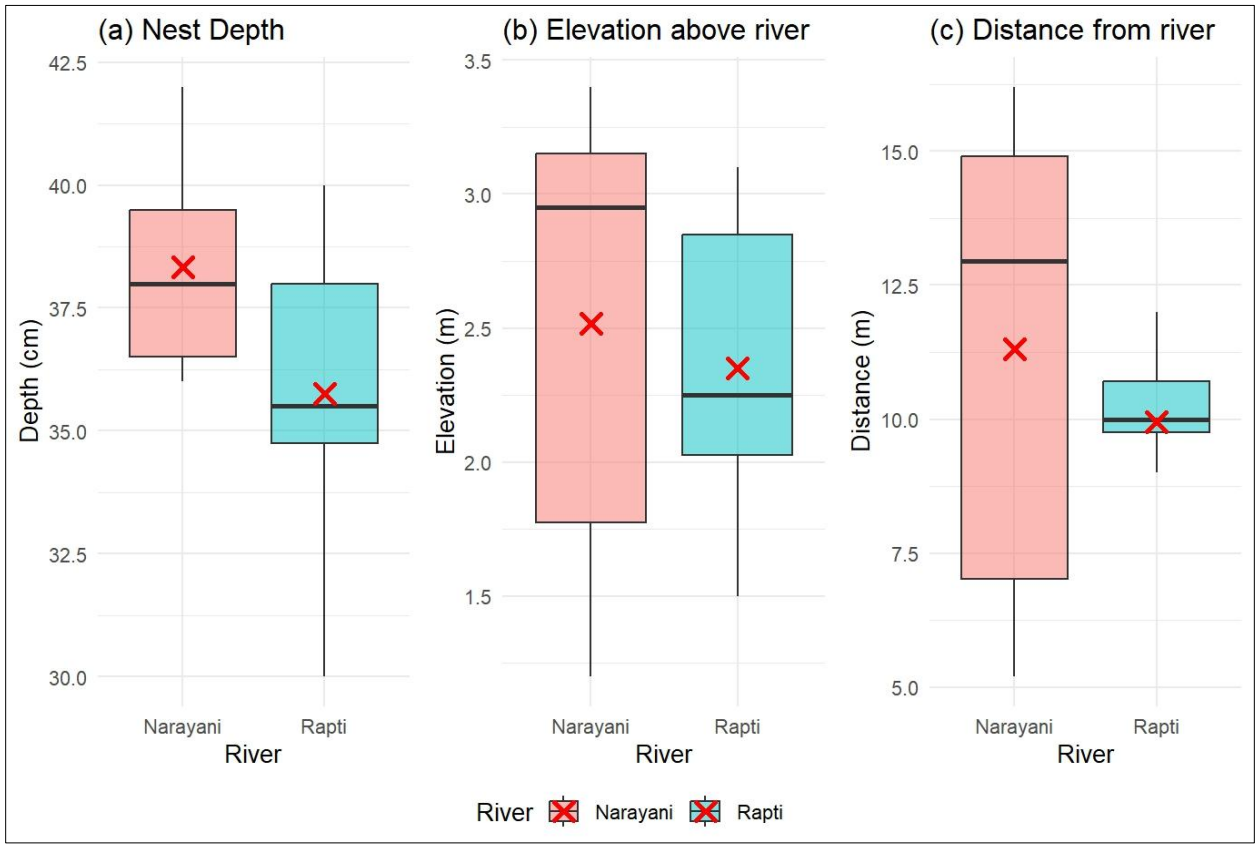

Figure 6: Comparison of Nest Depth, Elevation Above River, and Distance from River for Narayani and Rapti Rivers in Chitwan National Park.

3.1 Clutch Characteristics, Incubation Duration and Hatching Success

The mean clutch size for the Rapti River was 29.75 eggs, with a range of 12 to 39 eggs, while for the Narayani River, the mean clutch size was 35 eggs, with a range of 31 to 45 eggs. In Hattidundi (Rapti River), the egg-laying period ranged from March 19 to April 2, 2021, with hatching occurring between June 17 and June 28, 2021. The mean incubation duration was approximately

89.14 days (±1.64 days). In Dudhaura (Rapti River), egg-laying occurred on April 4, 2021, with hatching on July 20, 2021, and an incubation duration of 74 days. In Velauji (Narayani River), egg-laying spanned from March 19 to April 4, 2021, with hatching between June 17 and June 22, 2021, and a mean incubation duration of 86 days (±2.52 days). In Sishwar (Narayani River), egg-laying occurred from April 06 to April 07, 2021, with hatching between June 26 and June 29, 2021, and a mean incubation duration of 83 days (±2.00 days). Overall, hatching dates were concentrated in late June, with varying incubation durations across locations. Hatching success varied among different sites with the highest in the Hattidundi (Figure 7).

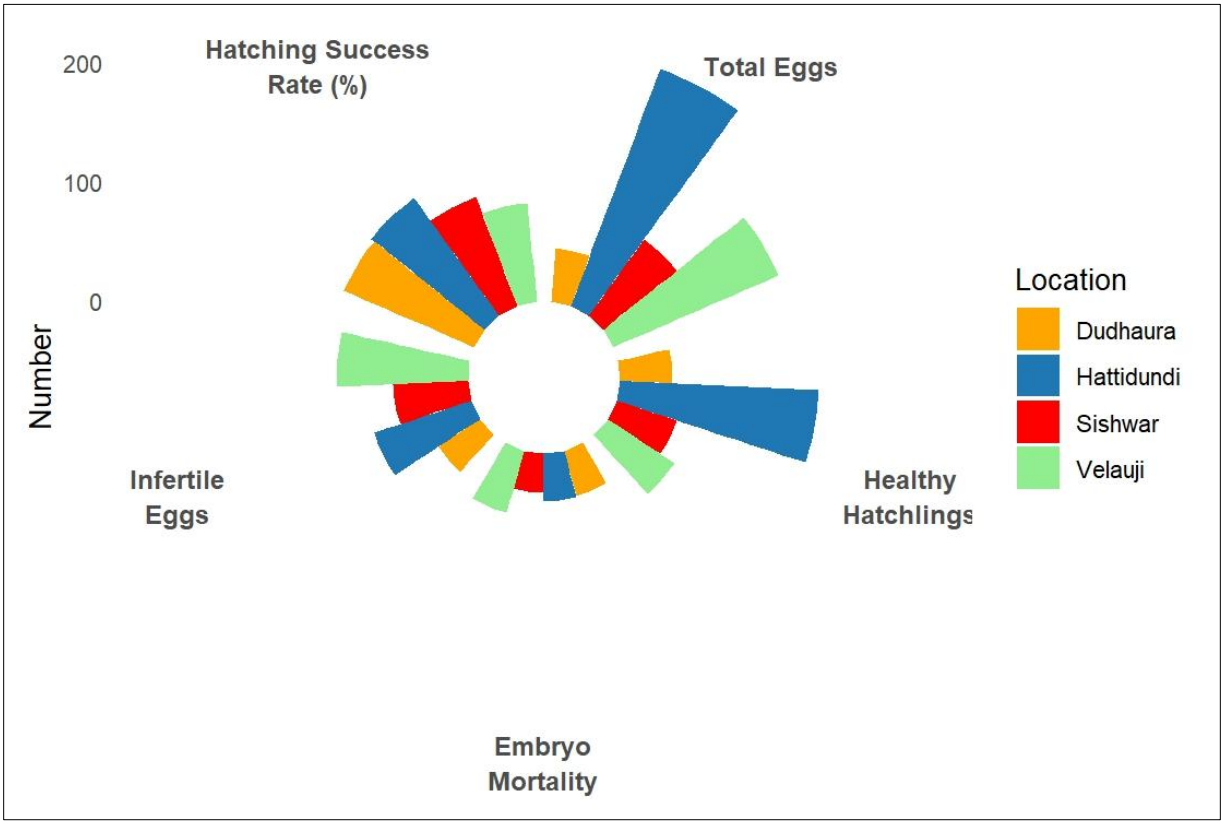

Figure 7: Circular bar chart showing the number of total eggs, healthy hatchlings, embryo mortality, infertile eggs, and hatching success rate (%) across four visited nesting sites (Dudhaura, Hattidundi, Sishwar, and Velauji). Hattidundi exhibits a higher number of total eggs as well as healthy hatchlings, indicating better hatching success. In contrast, Sishwar and Velauji in the Narayani River display a considerable proportion of embryo mortality and infertile eggs, as well as lower hatching success rates.

4. Discussion

Khadka et al. (2020) documented a total of 154 gharial nests over a 17-year study period from 2001 to 2017, with approximately 94 nests recorded in the Narayani River and 57 nests across 17 nesting sites within Chitwan National Park (CNP). Similarly, Maskey (1989) reported 53 nests in the Narayani River between 1977 and 1987. Additionally, Khadka et al. (2020) were the first to identify gharial nests in the Rapti River in 2002. Our study aligns with the findings of Khadka et al.(2020), which reported greater nest-to-river distance, deeper nests, and higher elevation in the

Narayani River compared to the Rapti River. Maskey et al. (1989) suggested that gharials in the Narayani River select nesting sites at higher elevations and farther from the river as a local adaptation to the river's characteristics, particularly near nesting areas. Additionally, we observed several nests clustered within nesting sites, indicating communal nesting behavior among gharials. This behavior has also been documented by Lang et al. (2018).

Our study indicates that nests in the Narayani River tend to have slightly larger clutch sizes compared to those in the Rapti River, a pattern also supported by Khadka et al. (2020). Maskey (1989) reported an oviposition period ranging from March 24 to April 18, while Khadka et al. documented a range from March 22 to April 20 over a 17-year period. In contrast, our study, based on 14 nests, recorded oviposition between March 19 and April 7. Although our sample size is limited, these findings suggest that the oviposition period has shifted earlier by at least a few days in recent years. We observed lower hatching success rates in the Narayani River (Velauji and Sishwar) compared to the Rapti River (Hattidundi and Dudhaura). Interestingly, while the Narayani River had larger clutch sizes, we did not conduct statistical analysis to determine a correlation between clutch size and hatching success due to less sample size. Khosa et al. (2012) found no strong correlation between these variables in Nile crocodiles. We recommend conducting a more detailed analysis incorporating additional factors to better understand these dynamics.

5. Conservation awareness programs

We conducted an awareness program in a local community to explore their perceptions, knowledge, and attitudes toward gharials. During our discussions, we identified fishing and water pollution as significant threats to gharial conservation. As researchers and conservationists, we highlighted the ecological importance of protecting gharials and aimed to foster a more positive attitude toward their conservation.

Figure 8: Conservation awareness program conducted in a village. Funded by IUCN CSG Crocodile Specialist Group.

6. Future recommendations

This research primarily focused on ex-situ hatching success. Future studies should emphasize in-situ hatching by regularly monitoring natural nests. However, careful considerations must be taken during such research. Monitoring should include the number of hatchlings emerging from the eggs, the presence and proximity of attending females, the locations of other females and males, and any behaviors related to parental care. Additionally, a radiotelemetry study is recommended to better understand the movement ecology of gharials, particularly during the reproductive season.

7. Acknowledgement

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References

1. Campbell, H., Dwyer, R., Irwin, T., & Franklin, C. (2013). Home range utilisation and long-range movement of estuarine crocodiles during the breeding and nesting season. Plos One, 8(5), e62127. https://doi.org/10.1371/journal.pone.0062127
2. DNPWC. (2018). Gharial Conservation Action Plan for Nepal (2018-2022). Department of National Parks and Wildlife Conservation and Department of Forests, Kathmandu, Nepal. (https://dnpwc.gov.np/media/publication/Gharial_Conservation_Action_Plan_for_Nepal_2018-2022.pdf)
3. Hénaut, Y. and Charruau, P. (2012). Nest attendance and hatchling care in wild american crocodiles (crocodylus acutus) in quintana roo, mexico. Animal Biology, 62(1), 29-51. https://doi.org/10.1163/157075511x597629
4. Hussain, S. A. (2009). Basking site and water depth selection by gharial (*Gavialis gangeticus*) in the Chambal River, India. *Herpetological Journal, 19*(4), 157–163.
5. Khadka, B., Bashyal, A., Luitel, K. P., & Kandel, R. C. (2020). Nesting ecology of gharials (Gavialis gangeticus): Implications from in situ and ex situ conservation programs in Chitwan National Park, Nepal. Herpetologica, 76(3), 297-303.
6. Khosa, P., Imbayarwo-Chikosi, V. E., & Hamandishe, V. (2012). Comparative analysis of hatching rates and clutch sizes of Nile crocodile (Crocodylus niloticus) eggs collected on-and off-farm in Zimbabwe. Tropical animal health and production, 44, 905-909.
7. Lang, J. W., Jailabdeen, A., & Kumar, P. (2018). Gharial ecology project update. Crocodile Specialist Group Newsletter, 37(4), 15-17.
8. Maskey, T.M. 1989. Movement and survival of captive-reared gharials, Gavialis gangeticus, in the Narayani river, Nepal. Ph.D. dissertation, University of Florida, USA
9. Rajbhandari, R., & Acharya, K. (2013). Threats to gharial conservation. *Journal of Threatened Taxa, 5*(12), 4500–4507.
10. Rao, R. J., & Singh, L. A. K. (1993). Communal nesting by gharial Gavialis gangeticus (Gmelin)(Reptilia: Crocodilia) in National Chambal Sanctuary. Journal of the Bombay Natural History Society, 90(1), 17-22.
11. Than, K., Zaw, Z., & Hughes, A. (2021). Investigating seasonal habitat-use of saltwater crocodiles in the ayeyarwady delta to identify potential conservation areas in myanmar. Aquatic Conservation Marine and Freshwater Ecosystems, 31(9), 2389-2401. https://doi.org/10.1002/aqc.3652