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Original Article

Ecological impacts on the distribution of Ganges River dolphin (*Platanista gangetica*) in the lower Gangetic plains and its conservation challenges

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Abstract
Despite threatened status, the Ganges River dolphin (*Platanista gangetica*) received insufficient attention in many habitats including the lower Ganges. In this study, through standardised monitoring programmes, we recorded the population and distribution of the species from a 100-km long stretch of the lower Ganges between January and December 2023. Important ecological parameters (e.g. fish abundance and water quality parameters) were also monitored to understand their effects on dolphin population in the river. Number of Ganges River dolphin varied over time (ANOVA: $F_{11,88}$ = 10.9, p < 0.001) and space ($F_{8,88}$ = 24.1, p < 0.001). Maximum number of dolphin was sighted in the month of August; whereas, the minimum was in February. Population of Ganges River dolphin was affected positively by fish abundance (LMM: F = 19.7, p < 0.001) and water transparency (F = 4.4, p = 0.042) and negatively by total dissolved solids (TDS; LMM: F = 13.5, p = 0.001). A range of challenges related to fishermen's knowledge and attitude towards the Ganges River dolphin were identified. These include lack of awareness, high market demand and price for the species and negative attitude towards the species. Illegally harvested Vulnerable dolphins were sold only to produce dolphin oil to catch another Endangered fish species *Clupisoma garua*. The results of this study have conservation management applications and implications.

Keywords: aquatic mammal; conservation; Ganges River dolphin; Padma River; threatened species

1 | INTRODUCTION

Despite the remarkable significance of freshwater habitats for global biodiversity (e.g. supporting ~10% of all known species, including 33% of vertebrates; Strayer and Dudgeon 2010), their existence is at stake, and they are losing biodiversity at a faster rate than other ecosystems (Dudgeon *et al.* 2006; Arthington *et al.* 2016). Among different freshwater habitats, rivers are the most affected ecosystems due to their sensitivity to various stressors originating from natural variability and anthropogenic activities (Suski and Cooke 2007; Vörösmarty *et al.* 2010).

Endangered species are the top-ranked species on the conservation priorities and therefore, studies dealing with endangered species are important for the global biodiversity as well as its sustainability. However, understanding the key issues of an endangered such as evolutionary potential is often ignored (Sinha *et al.* 2010). The Ganges River dolphin (*Platanista gangetica*) is one of the most threatened freshwater dolphins and a charismatic species in the world (Paudel and Koprowski 2020); the species is native to lowland rivers and tributaries of Bangladesh, Nepal and India (Shostell and Ruiz-García 2010; Kelkar *et al.* 2022). The Ganges River dolphin is important because it is a reliable indicator of the health of the entire

river ecosystem.

Unfortunately, several anthropogenic and natural factors have been affectingly the future of this species (Smith 1993; Kelkar *et al.* 2022). Its population has reduced from 4000 – 5000 in the early 1980s to 3500 in 2014 (Sinha and Kannan 2014). Segregation of population into small sub-populations, primarily due to large structures like dams and dikes is sometimes considered the greatest threat to the Ganges River dolphin (Smith 1993; Kelkar *et al.* 2022). Globally, Ganges River dolphin is an Endangered species (Kelkar *et al.* 2022) but in Bangladesh, it is a Vulnerable species (IUCN Bangladesh 2015). Despite considerable attentions on Ganges River dolphin in India (e.g. Sinha and Kannan 2014; Choudhury *et al.* 2019; Sonkar and Gaurav 2020; Kelkar and Dey 2024) and Nepal (e.g. Paudel *et al.* 2015; Paudel and Koprowski 2020), the dolphin habitats in Bangladesh including the lower Ganges received insufficient attentions and there is lack of up to date robust information on the population and distribution of the species. However, a range of studies identified presence of Ganges River dolphin in Buriganga River (Alam and Sarker 2012; Alam *et al.* 2015), rivers of Pabna district (Rashid *et al.* 2015), Halda River (Kibria *et al.* 2023) and Kaptai Lake and adjacent rivers (Smith *et al.* 2001) but no habitat quality information is available in most of the cases.

Occurrence of any animal including the dolphin in a habitat is affected by different ecological factors (Reeves and Leatherwood 1994; Parvez *et al.* 2023a) but none of available studies in Bangladesh examined any such relationships. To conserve the threatened population of Ganges River dolphin, robust population estimating and better information of habitat characteristics are essential (Paudel *et al.* 2015). In this study, we recorded population and distribution of Ganges River dolphin from nine sampling sites spanning over a 100-km stretch of the river through standardised monitoring programme. We also recorded ecological data to define underlying mechanisms of its presence and distribution in the river which would be helpful for the sustainable conservation measures for the Ganges River dolphin.

2 | METHODOLOGY

2.1 Study area

This study was conducted in the Ganges River in Bangladesh. Nine spots (S1 – S9, spanning over 100-km long river stretch was selected for the purpose of data collection (Table 1; Figure 1). Data were collected for a period of 12 months, from January to December 2023.

2.2 Monitoring of Ganges River dolphin

For cetaceans, capture-recapture analysis of photo-identified individuals is commonly used to estimate the abundance (Hammond 2009). This is not applicable for the Ganges due to high turbidity (Sinha and Kannan 2014). Unfortunately, there is no robust method for the dolphin population estimation and therefore, direct counts in discrete sections of rivers are widely conducted (Smith and Reeves 2000). Therefore, we employed direct count method in this study. A preliminary survey was carried out in December 2022 in which professional fishermen were interviewed (n = 20) to identify optimum time in a day for dolphin observation. Based on their interviews, dawn was identified as the peak dolphin sighting time in the river. In the third week of December, we spent three days at the Premtali, Godagari and Fultala location of this study to ensure the accuracy of the information provided by the fishermen. The results from the 3-day long survey also confirmed that the dawn is the most appropriate time for recording maximum number of dolphin in the river. Therefore, we conducted the monitoring surveys between two hours before and half an hour after the sunset, usually 16.30 to 19.00 hours.

FIGURE 1 Map of Bangladesh showing the locations of the study sites in the lower Ganges River. See Table 1 for details of the sampling sites.

TABLE 1 Location and geographical position of the study sites in the lower Ganges.

Site	Location	Geographical coordinates
S1	Godagari	24°29′56.4″N 88°18′17.1″E
S2	Premtali	24°23′35.9″N 88°23′24.0″E
S3	Keshobpur	24°22′09.1″N 88°33′23.6″E
S4	Fultala	24°21′23.8″N 88°37′55.2″E
S5	Shyampur	24°20′53.2″N 88°39′30.1″E
S6	Yousufpur	24°19′34.0″N 88°42′17.1″E
S7	Charghat	24°16′47.9″N 88°44′16.2″E
S8	Alaipur I badh	24°10′05.7″N 88°48′33.7″E
S9	Hardinge Bridge / Pakshi	24°04′13.6″N 89°02′05.6″E

At each sampling site, three observers were employed to record the number of dolphin through visual surveys (Figure 2). Two observers searched for dolphins

forward of the boat whereas another observer, searched towards the rear (Smith *et al.* 2001). The eye height of observers above the waterline was 2 – 2.5 m. The sighting time was also recorded. In each month, a 4-day monitoring programme, usually in the first week, at the scheduled time was conducted. A 5-km long stretch of the river at each sampling site (= 45 km in total across nine sites) was monitored using the mechanised boats. Similar boat speed (i.e. 8 km hour^{-1}) was maintained across all study sites. A total of six surveys (i.e. runs) along with 5-km stretch of the river were made on each sampling day. Double counts were avoided by maintaining close communication among observers (Smith *et al.* 2001).

FIGURE 2 Ganges River dolphin surfacing (*Platanista gangetica*) in the lower Ganges.

2.3 Determination of ecological factors

As Ganges River dolphin extensively feed on fishes (Smith *et al.* 2001), we determined the fish abundance at every sampling site. For this purpose, we employed, with the help of professional fishermen, two seine nets (mesh 7 × 7 mm, 30 × 2.5 m; following Parvez *et al.* 2023a), at each sampling sites. Fish sampling was done early in the morning (06.00 – 09.00 hours) on the following day of the Ganges River dolphin monitoring study. Number of total fish individuals caught was recorded.

Several water quality parameters were recorded at each sampling site between 14.00 and 16.00 hours on every dolphin monitoring day. Water transparency was determined by a Secchi disc whereas DO was measured by a digital DO meter (model DO-5510, Lutron electronic) following standard procedures (see Parvez *et al.* (2023b) for details).

2.4 Identification of conservation challenges

A range of threats have been identified for the Ganges River dolphin including dams, large embankments, dredging, accidental and intentional catch, and water pollution (Smith *et al.* 1998). In the study area, accidental and intentional catch by the fishermen was the prime concern for the conservation of the species and therefore, we interviewed 180 professional fishermen (20 at each sampling site, see Table 1 for details) with a standard questionnaire, developed to assess the attitude and knowledge of fishermen regarding Ganges River dolphin. In addition, we also visited the survey stretch of the river to identify any actual or potential threats (e.g. water pollution and barriers) to Ganges River dolphin.

2.5 Data analysis

For every sampling day, among the six surveys along the 5-km stretch of the river at each sampling site, only the survey with the maximum dolphin count was considered. Mean daily dolphin count data were calculated from 4-day monitoring programme in each month and used for the final analysis. To determine the variation in number of dolphin sighted at different sampling sites (S1 – S9) and months, one-way ANOVA was employed. To identify the ecological factors affecting the number of dolphin sighted, we used linear mixed-effects modelling (LMM), employing 'lme4' (Bates *et al.* 2015) and 'lmerTest' (Kuznetsova *et al.* 2016) packages in R (R Core Team 2022). During modelling, dolphin count data were used as the fixed effect and ecological data (i.e. fish abundance, DO, TDS, pH and water transparency) were considered random effects in the model.

To determine the relationships between dolphin count and ecological factors, data were subjected to possible regression models. Diagnostic outputs and validation plots (residuals vs. fitted, Q-Q residuals and residuals vs. Leverage) were examined and simple linear regression model with best fit (i.e. no deviation from the linearity of the observations) were selected for the final analysis (Parvez *et al.* 2023a). Data collected through interviews of the fishermen were subjected to simple descriptive analysis. Data were analysed in R (R Core Team 2022). Before analysis, data were checked for normality assumptions and were transformed on a log-scale to meet the assumptions for the analysis concerned (McDonald 2014).

3 | RESULTS

3.1 Variation in dolphin sighting

Number of Ganges river dolphin sighted in the river varied across month (ANOVA: $F_{11,88}$ = 10.9, p < 0.001) and locations ($F_{8,88}$ = 24.1, p < 0.001). The highest number of dolphin was sighted in the month of August; whereas, the minimum number of dolphin was sighted in February (Figure 3 – 4). The maximum mean dolphin sighting was recorded at location S2 (Premtali; mean ± SD: 14.5 ± 2.0, range: 10 – 17, 2.9 individual km^{-1}; Table 2). At location S4 (Fultala), the minimum number of dolphin was sighted (2.3 ± 3.6, 0.47 individual km^{-1}; Table 2).

3.2 Ecological factors affecting dolphin distribution

Presence of Ganges River dolphin was affected positively by fish abundance (LMM: F = 19.7, p < 0.001) and negatively by and water transparency (F = 4.4, p = 0.042) and TDS (F = 13.5, p = 0.001) (Table 3; Figure 5). The mean (± SD) fish abundance was 1296 ± 627 (range: 294 – 2674) whereas the mean water transparency and TDS were 23.5 ± 3.7 cm and 145.3 ± 12.3 mg L^{-1} respectively.

TABLE 2 Occurrence of Ganges River dolphin at different study sites (S1 – S9) in the lower Ganges.

Sampling sites	Dolphin count (*n*)		
	Mean ± SD	Range	No. km^{-1} (mean)
S1	9.8 ± 3.1	4 – 14	1.97
S2	14.5 ± 2.0	10 – 17	2.90
S3	3.9 ± 4.0	0 – 12	0.78
S4	2.3 ± 3.6	0 – 9	0.47
S5	2.5 ± 3.5	0 – 10	0.50
S6	7.5 ± 2.3	4 – 12	1.50
S7	4.9 ± 4.3	0 – 12	0.98
S8	6.3 ± 3.7	0 – 14	1.27
S9	8.9 ± 3.3	4 – 16	1.78
Overall	6.8 ± 4.9	0 – 17	1.35

3.3 Challenges in Ganges River dolphin conservation

None of the respondent fishermen was aware that the Ganges River dolphin is a threatened species in the country but they were aware that the species is illegal to harvest (Table 4). Unfortunately, all the respondents believed that Ganges River dolphin can negatively affect their fish catch by consuming fishes from their fishing nets and therefore, if caught, they did not want to release them (Table 4). Unfortunately, apart from accidental by-catch in gillnet only, a group of people were involved in catching Ganges River dolphin intentionally and 80% of the respondent fishermen were aware of this activity (Table 4). These people use a special fishing device with multiple large fishing hooks, locally known as "hajari borshi".

There were buyers for the harvested dolphin individuals. The fishermen also believed that the market price of a dolphin is lucrative and therefore, it is possible to make more profit by selling a dolphin than fishes (Table 4). Interviews of the fishermen confirmed that the dolphin being sold was only used for producing dolphin oil to be used for fishing of a catfish species, *Clupisoma garua*. Survey of the study stretch revealed no obvious dams or barriers and sources of water pollution. Eighteen drain outlets near Rajshahi City Corporation area were recorded of which municipal water was discharging through thirteen outlets. However, no visible dolphin or fish mortality was recorded.

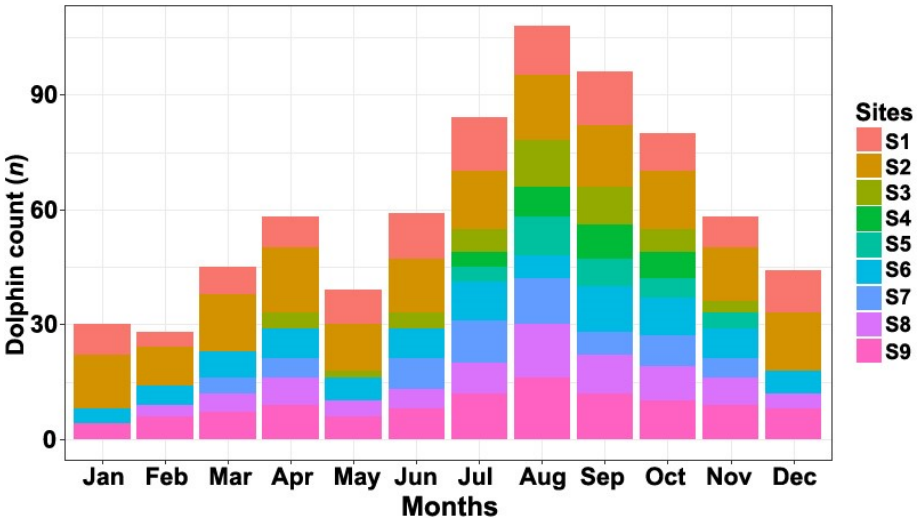

FIGURE 3 Total number of Ganges River dolphin sighted at nine sampling sites (S1 – S9; see Table 1 for details) during January – December 2023.

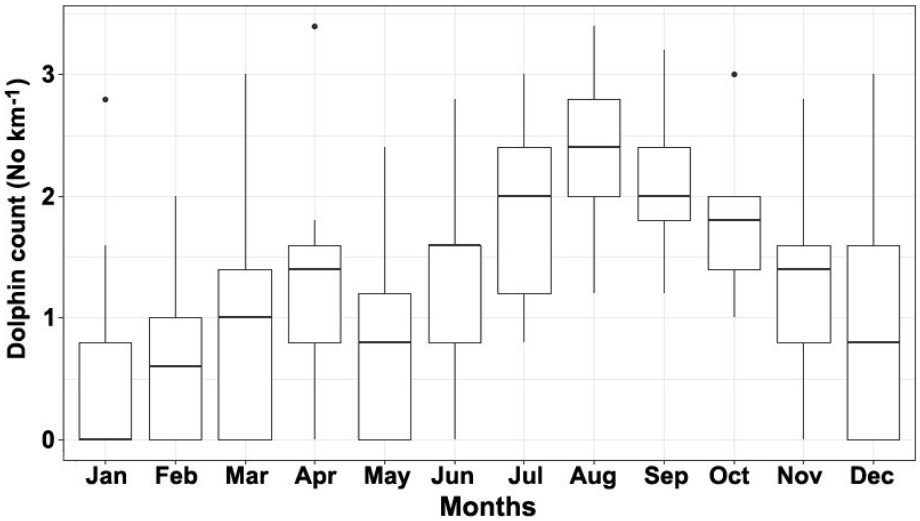

FIGURE 4 Monthly variation in the number of Ganges River dolphin sighted (No. km^{-1}) during January – December 2023. Midline within the box is the median; upper and lower limits of the box represent the third and first quartile (75th and 25th percentile) respectively.

TABLE 3 Factors affecting distribution of Ganges River dolphin in the lower Ganges, determined through linear mixed-effects modelling.

Factors	Estimate	*F*-values	*p*-values
Fish abundance	0.61	19.7	**<0.001**
DO	1.0	1.9	0.171
BOD	–1.9	1.1	0.294
pH	–4.3	1.3	0.253
TDS	–4.8	13.5	**0.001**
Water transparency	–1.2	4.4	**0.042**

Boldface *p*-values indicate statistically significant values. DO, dissolved oxygen; BOD, biochemical oxygen demand; TDS, total dissolved solids.

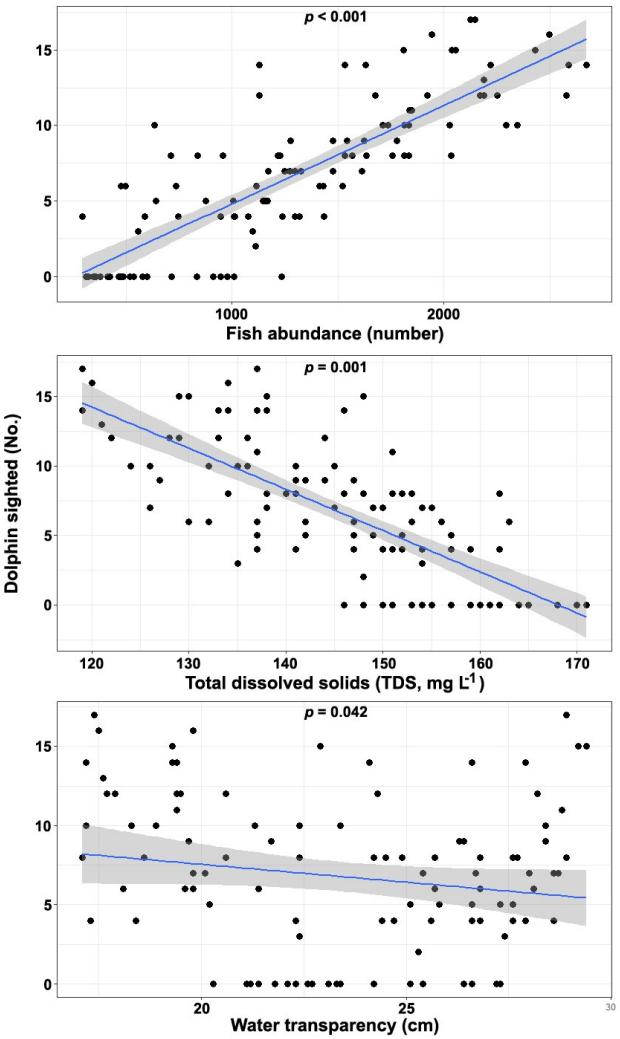

FIGURE 5 Relationships between numbers of Ganges River dolphin sighted and fish abundance (top), TDS (middle) and water transparency (below).

4 | DISCUSSION

This study provides comprehensive population and distribution data in the lower Ganges (Padma in Bangladesh) and identifies the ecological factors affecting the population and distribution of the Ganged River dolphin. The study also highlights the knowledge and perceptions of fishermen regarding the conservation of the Ganges River dolphin.

TABLE 4 Knowledge and perceptions of fishermen regarding the Ganges River dolphin conservation.

Issues	Fishermen (%)
Aware of its threatened status	0
Harvesting of dolphin is illegal	100
It can reduce the efficiency of fish catch	100
Will release dolphin if caught	0
Making profit is easier by selling dolphin	100
Aware of people catching dolphin intentionally	80
There are buyers / markets for dolphin	100

4.1 Population and ecology

In the dry months, usually from November to March, the water level in the river reaches its lowest point, negatively affecting the survival of fish due to increased fishing efforts by fishermen (Parvez *et al.* 2023a). As Ganges River dolphin primarily feed on fish (Smith *et al.* 2001), it is possible that they move to the deeper parts of the river where food is more abundant. This was confirmed by the relationship between the number of dolphins and fish abundance in this study. The highest dolphin population was recorded from July to September; these months are characterised by heavy rain in recent decades in Bangladesh. In a study by Rahman *et al.* (2012), respondent fishermen confirmed the highest occurrence of Ganges River dolphin during the rainy season in the lower Ganges which agrees with the results of this study. Similar findings were also reported from a highly polluted river of Bangladesh, Turag (Baki *et al.* 2017).

A range of dolphin population densities have been summarised, based on the studies conducted between 1995 and 2022, by Kibria *et al.* (2023) and comparing to their findings (dolphin density: 0.23 – 3.4 individual km^{-1}), and, therefore, the dolphin density recorded in our study may represent a moderate dolphin density. However, little information of Ganges River dolphin is available from the study river. Aziz *et al.* (2023), based on the data collected from three sampling sites (Godagari, Rajshahi T-band, Bakarali and Nazirgonj) of the study river (= lower Ganges / Padma), recorded a mean dolphin density of 0.19 individuals km^{-1}. However, one sampling site (i.e. Godagari) was common between studies and we recorded a higher dolphin density (1.97 individuals km^{-1}) than Aziz *et al.* (2023) who recorded a density of 0.48 individuals km^{-1}. The differences in results between studies may be due to differences sampling locations and / or dolphin monitoring methods. A total of nine sites were considered in our study whereas Aziz *et al.* (2023) collected data from four sampling sites. A single pass method was considered by Aziz *et al.* (2023) whereas we used a 5-pass

sampling method.

No studies in Bangladesh determined a concrete relationship, on the basis of statistical data, between ecological factors and dolphin abundance in a habitat. Therefore, it is not possible compare our findings to previous studies. However, in Nepal, the persistence of Ganges River dolphin was studied and six potential trap mechanisms were identified including habitat modification, direct fisheries-dolphin interaction and trapped subpopulation that can affect the dolphin populations discretely or in combination (Paudel and Koprowski 2020).

The dolphin population was positively related to the abundance of fish, which is expected because they rely primarily on fish for their food (Smith *et al.* 2001). Dolphin abundance was negatively related to water transparency. It may be assumed that transparent water contains less natural food for fish, and therefore, fish abundance will be lower in areas with high water transparency, which will negatively affect the abundance of the dolphin population. Similarly, a negative relationship was also recorded with TDS. Currently, it is not evident why dolphin abundance was lower in places with higher TDS when it is known to affect fish species positively (Sarkar *et al.* 2020). However, as changes in TDS concentrations in natural waters may be due to industrial effluent, changes to the water balance and salt-water intrusion (Weber-Scannell and Duffy 2007). Although major industries are absent in the study stretch of the lower Ganges, it receives municipal wastewater through several drains in the stretch located within the Rajshahi City Corporation area of Rajshahi district (Parvez *et al.* 2023a). The study area is located far from the coastal regions of Bangladesh, and therefore, there is no possibility of salt-water intrusion. However, further research is recommended to identify the underlying mechanisms behind the relationship between TDS concentration and the dolphin population observed in this study.

4.2 Conservation challenges

Water pollution and dams have been identified as major causes of the decline in dolphin populations in Bangladesh (Smith *et al.* 1998). Nonetheless, the lower Ganges (Padma) is not a polluted river (Khan *et al.* 2022), and dams or major obstacles are also absent. Therefore, accidental or intentional catch by fishermen might be considered the prime threat to the conservation of the species. Accidental by-catch of the Ganges River dolphin is common in most habitats in India, Nepal, and Bangladesh. (Paudel *et al.* 2015). Unfortunately, there is a lack of by-catch data for this dolphin species (Paudel and Koprowski 2020), and therefore, the actual impacts of accidental by-catch on the dolphin population remain unknown. The intentional catching of dolphins in the study area might pose a real threat to the conservation of the Ganges River dolphin. Fishermen remain reluctant and try to hide information on dolphin catches as they know that killing dolphins is illegal. This scenario is also reported from India (Kelkar and Dey 2024). High market demand and prices for the Ganges River dolphin present another challenge to the conservation of the species. Unfortunately, this issue has received insufficient attention so far. Being a threatened species, it is expected that the Ganges River dolphin would receive the highest level of conservation priority in Bangladesh. However, none of the fishermen were aware of its threatened status. This scenario is common in Bangladesh, where fishermen and other stakeholders involved in threatened fish value chains are not aware of their threatened status (Galib *et al.* 2023).

Interestingly, sold dolphins were only used to produce dolphin oil to be for a catfish, *C. garua* fishing. This has been described earlier in the Jamuna and Kushiyara rivers of Bangladesh (Smith *et al.* 1998) and India (Kelkar and Dey 2024). It should be noted that *C. garua* itself is an Endangered fish species in Bangladesh (IUCN Bangladesh 2015). Therefore, this process is negatively affecting populations of two threatened aquatic species (i.e. the Ganges River dolphin and *C. garua*). Recently, a visual detection method has been described by Kelkar and Dey (2024) to identify dolphin oil-baited *C. garua*. The method may be considered to monitor illegal dolphin hunting. However, the continuous loss of two threatened aquatic species from a habitat should be treated seriously, and sustainable management efforts should be introduced as a priority.

Although the lower Ganges in Bangladesh has no major barriers to the longitudinal movement of aquatic species, including the Ganges River dolphin, its tributaries are not always free-flowing. For example, the Baral, one of the major tributaries of the lower Ganges, is severely affected by the presence of in-stream barriers such as bamboo fences, earthen and sand barriers and lift nets (Galib *et al.* 2018). Most of these barriers are built by local residents without any approval from the government. Apart from the main river, these smaller rivers and other channels (e.g. irrigation canals) may also be used by the dolphin and pose a risk of entrapment (Singh *et al.* 2023). Improving the dolphin population by expanding its geographical distribution through these tributaries could help save this species from extinction threats. Therefore, attention should also be paid to these habitats to ensure they are safe for the Ganges River dolphin.

5 | CONCLUSIONS

The Ganges River dolphin population in the lower Ganges received insufficient attention and the results of this study will contribute to bridge this gap. The lower Ganges is not a polluted river and not highly impacted by the habitat fragmentation or land use changes– three major causes of declination of this species. The key threat in the habitat is the intentional and unintentional catch. Further

studies are suggested on the accidental and intentional catching of Ganges River dolphin to better understand the impacts and to develop an effective conservation policy.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTION

MTK and SMG designed the study. SMG and SN supervised the study. MTK collected and analysed the data and prepared the draft manuscript. SMG participated in the data analysis and critically reviewed the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on a reasonable request from the author.

REFERENCES

Alam SMI, Hossain MM, Baki MA, Bhouiyan NA (2015) Status of Ganges dolphin, *Platanista gangetica gangetica* (Roxburgh, 1801) in the river Buriganga, Dhaka. Bangladesh Journal of Zoology 43(1): 109–120.

Alam SMI, Sarker NJ (2012) Status and distribution of the Gangetic dolphin, *Platanista gangetica gangetica* (Roxburgh, 1801) in river Buriganga during 2003-2004 and its conservation. Bangladesh Journal of Zoology 40(1): 21–31.

Arthington AH, Dulvy NK, Gladstone W, Winfield IJ (2016) Fish conservation in freshwater and marine realms: status, threats and management. Aquatic Conservations: Marine and Freshwater Ecosystems 26: 838–857.

Aziz MA, Khan MMH, Ahsan MM, Chowdhury MRK, Faisal AM (2023) Identification of key habitats and conservation threats of the Ganges river dolphin (*Platanista gangetica*) of Bangladesh. Bangladesh Journal of Zoology 51(3): 253–266.

Baki MA, Bhouiyan NA, Islam MS, Alam SMI, Shil S, Hossain MM (2017) Present status of Ganges River dolphins Platanista gangetica gangetica (Roxburgh, 1801) in the Turag River, Dhaka, Bangladesh. International Journal of Zoology 2017: 1–7.

Bates D, Mächler M, Bolker B, Walker S (2015) Fitting Linear Mixed-Effects Models using lme4. Journal of Statistical Software 67(1): 1–48.

Choudhury NB, Mazumder MK, Chakravarty H, Choudhury AS, Boro F, Choudhury IB (2019) The endangered Ganges river dolphin heads towards local extinction in the Barak river system of Assam, India: a plea for conservation. Mammalian Biology 95: 102–111.

Dudgeon D, Arthington AH, Gessner MO, Kawabata Z-II, Knowler DJ, ... Sullivan CA (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews 81: 163.

Galib SM, Lucas MC, Chaki N, Fahad FH, Mohsin ABM (2018) Is current floodplain management a cause for concern for fish and bird conservation in Bangladesh's largest wetland? Aquatic Conservation: Marine and Freshwater Ecosystems 28(1): 98–114.

Galib SM, Naher S, Arnob SS, Khatun MT, Reza MS, ... Lucas MC (2023) Stakeholders' knowledge of threatened freshwater fishes and their involvement in fishery value chains in order to assist conservation in developing countries. Frontiers in Freshwater Science 1: 1239605.

Hammond PS (2009) Mark-recapture (pp. 705–709). In: Perrin WF, Wursig B, Thewissen JGM (Eds) Encyclopedia of marine mammals, 2nd edition. Academic Press, San Diego, CA.

IUCN Bangladesh (2015) Red list of Bangladesh: a brief on assessment result 2015. International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, Bangladesh.

Kelkar N, Dey S (2024) A new method to detect illegal oil use and estimate mortality rates of endangered Ganges river dolphins based on *Clupisoma* fish catches. Journal of Cetacean Research and Management 25: 49–69.

Kelkar N, Krishnaswamy J, Choudhary S, Sutaria D (2010) Coexistence of fisheries with river dolphin conservation. Conservation Biology 24: 1130–1140.

Kelkar N, Smith BD, Alom MZ, Dey S, Paudel S, Braulik GT (2022) *Platanista gangetica*. The IUCN Red List of Threatened Species 2022: e.T41756A50383346.

Khan MAG, Galib SM, Hasnath M, Mia MR, Kibria R (2022) Exotic fish and decreasing habitats vis-à-vis conservation of freshwater fish biodiversity of Bangladesh. Journal of Fisheries 10(1): 101301.

Kibria MM, Siam MAH, Owaresat JK, Khan AR, Asek AA, Nahian SMA (2023) Current status of Ganges river dolphin (*Platanista gangetica*) in Halda River, Chittagong, Bangladesh. Asian Journal of Conservation Biology 12(1): 27–34.

Kuznetsova A, Brockhoff PB, Christensen RHB (2016) lmerTest: tests in Linear Mixed Effects Models. R Package version 2.0-33. URL https://cran.r520project.org/package=lmerTest

McDonald JH (2014) Handbook of biological statistics, 3rd edition. Sparky House Publishing, Maryland.

Parvez MT, Lucas MC, Hossain MI, Chaki N, Mohsin ABM, ... Galib SM (2023b) Invasive vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) has an impact on highly valued native fish species. Biological Invasions 25: 1795–1809.

Parvez MT, Mohsin ABM, Arnob SS, Lucas MC, Chaki N, ... Galib SM (2023a) Fish diversity decline in the lower Gangetic plains: a victim of multiple stressors. Biodiversity and Conservation 32: 341–362.

Paudel S, Koprowski JL (2020) Factors affecting the persistence of endangered Ganges River dolphins (*Platanista gangetica gangetica*). Ecology and Evolution 10: 3138–3148.

Paudel S, Pal P, Cove M, Jnawali S, Abel G, ... Ranabhat R (2015) The Endangered Ganges River dolphin *Platanista gangetica gangetica* in Nepal: abundance, habitat and conservation threats. Endangered Species Research 29: 59–68.

R Core Team (2022) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.r-project.org/

Rahman MS, Sarker SU, Jaman MF (2012) Ecological status of the herpeto-mammalian fauna of the Padma River and its adjacent areas, Rajshahi and their conservation issues. Bangladesh Journal of Zoology 40(1): 135–145.

Rashid SMA, Akonda AW, Ahmed B (2015) Ganges river dolphin (*Platanista gangetica gangetica*) in the Padma, Jamuna and Hurasagar-Baral rivers of Pabna district, Bangladesh. International Journal of Current Science 14: 107–124.

Reeves RR, Leatherwood S (1994) Dolphins, porpoises, and whales: 1994–1998. Action plan for the conservation of cetaceans. IUCN Species Survival Commission. IUCN, Gland, Switzerland. 92 pp.

Sarkar UK, Bakshi S, Lianthuamluaia L, Mishal P, Das Ghosh B, Saha S, Karnatak G (2020) Understanding enviro-climatological impact on fish biodiversity of the tropical floodplain wetlands for their sustainable management. Sustainable Water Resources Management 6: 96.

Shostell JM, Ruiz-García MR (2010) An introduction to river dolphin species (pp. 1 − 28). In: Ruiz-García M, Shostell JM (Eds) Biology, evolution and conservation of river dolphins within South America and Asia. NOVA Science Publishers Inc., New York.

Singh S, Singh A, Dutta S, Srivastava S (2023) Rescuing Ganges river dolphins (*Platanista gangetica*) from irrigation canals in Uttar Pradesh, North India, 2013-2020. Journal of Cetacean Research and Management 24: 175–188.

Sinha RK, Kannan K (2014) Ganges River dolphin: an overview of biology, ecology, and conservation status in India. AMBIO 43: 1029–1046

Sinha RK, Verma SK, Singh L (2010) Population status and conservation of the Ganges River dolphin (*Platanista gangetica gangetica*) in the Indian subcontinent (pp. 419 – 444). In: Ruiz-García M, Shostell JM (Eds) Biology, evolution and conservation of river dolphins within South America and Asia. Nova Science Publishers Inc., New York.

Smith BD, Ahmed B, Ali ME, Braulik G (2001) Status of the Ganges river dolphin or shushuk *Platanista gangetica* in Kaptai Lake and the southern rivers of Bangladesh. Oryx 35(1): 61–72.

Smith BD, Haque AKMA, Hossain MS, Khan A (1998) River dolphins in Bangladesh conservation and the effects of water development. Environmental Management 22(3): 323–335.

Smith BD, Reeves RR (2000) Report of the second meeting of the Asian River Dolphin Committee, Rajendrapur, Bangladesh, 22–24 February 1997 (pp. 1–14). In: Reeves RR, Smith BD, Kasuya T (Eds) Biology and conservation of freshwater cetaceans in Asia. Occasional Paper of the IUCN Species Survival Commission, Volume 23. IUCN, Gland, Switzerland.

Sonkar GK, Gaurav K (2020) Assessing the impact of large barrages on habitat of the Ganga River dolphin. River Research and Applications 36(9): 1916–1931.

Strayer DL, Dudgeon D (2010) Freshwater biodiversity conservation: Recent progress and future challenges. Journal of the North American Benthological Society 29(1): 344–358.

Suski CD, Cooke SJ (2007) Conservation of aquatic resources through the use of freshwater protected areas: opportunities and challenges. Biodiversity and Conservation 16(7): 2015–2029.

Vörösmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, ... Davies PM (2010) Global threats to human water security and river biodiversity. Nature 467: 555–561.

Weber-Scannell PK, Duffy LK (2007) Effects of total dissolved solids on aquatic organisms: a review of literature and recommendation for salmonid species. American Journal of Environmental Sciences 3(1): 1–6.

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