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EDITED BY
Paul Kemp,
University of Southampton, United Kingdom

REVIEWED BY
Kevin Hunt,
Mississippi State University, United States
Vasilis Louca,
University of Aberdeen, United Kingdom

*CORRESPONDENCE
Shams M. Galib
✉ thegalib@ru.ac.bd

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Stakeholders' knowledge of threatened freshwater fishes and their involvement in fishery value chains in order to assist conservation in developing countries

Shams M. Galib [1]*, Sheratun Naher[1], Sadman S. Arnob [2], Mst. Tasnima Khatun[1,3], Md. Selim Reza [1,4], Md. Taskin Parvez [1], Jingrui Sun [5,6] and Martyn C. Lucas [7]

[1]Department of Fisheries, University of Rajshahi, Rajshahi, Bangladesh, [2]Department of Soil, Water and Environment, University of Dhaka, Dhaka, Bangladesh, [3]Institute of Environmental Science, University of Rajshahi, Rajshahi, Bangladesh, [4]Palli Karma-Sahayak Foundation, Dhaka, Bangladesh, [5]Yunnan Key Laboratory of International Rivers and Transboundary Eco-Security, Yunnan University, Kunming, China, [6]Institute of International Rivers and Eco-Security, Yunnan University, Kunming, China, [7]Department of Biosciences, University of Durham, Durham, United Kingdom

Introduction: Improved conservation of exploited freshwater biodiversity is an increasing priority globally, but in developing countries there is often little insight of stakeholder attitudes within the value chains through which exploited species are passed, upon which to make informed management decisions.

Methods: We determined knowledge concerning threatened freshwater fishes in Bangladesh by key stakeholder groups (fishermen, faria agents, commission agents, retailers and consumers; $n = 485$ respondents) and their participation level in the threatened fish value chain. We also determined factors affecting local ecological knowledge and participation in the value chain.

Results and discussion: The highest mean number of threatened fish species (4.8 $\pm$ 3.5% of species) was identified by the fishermen group, whereas consumers identified fewest (0.5 $\pm$ 1.1% of species). All respondent groups participated in the threatened fish value chain and their participation varied across respondent groups. 45.3% of the total number of threatened fish species appeared in the value chain. Participation level was highest for commission agents, involved in the trade of 21.5 $\pm$ 4.2% of threatened fish species, and lowest for consumers (7.4 $\pm$ 6.5% of threatened species). For fishermen, the principal component "experience-income-age" and the interaction between education and financial loan factors affected fishers' participation in the threatened fish value chain positively whereas, this was negatively affected by their knowledge level of threatened fishes. This study reveals the poor knowledge of stakeholder groups regarding threatened fishes, but establishes their active participation in the value chain of these species in Bangladesh. With limited resources for conservation of threatened species in many developing countries, it is very risky to implement commonly used *in-situ* conservation methods (e.g., habitat quality improvement) without fuller buy-in from the stakeholders.

Conclusions: We recommend specific protection laws for threatened fishes and awareness building campaigns for stakeholder groups to ensure minimum impact to threatened fish species. As overharvesting is a major cause of threatened fish species decline, such training programmes should be designed for fishers in developing regions. Education programmes on threats to ecosystems and biodiversity should be prioritized in schools and fishing communities. In addition, regular monitoring for protected species at harvesting sites and fishing markets should be ensured.

KEYWORDS

IUCN Redlist, threatened fish, conservation, human impacts, value chain, freshwater fish

1 Introduction

Human impacts on the global environment now pose major threats to ecosystems in the Anthropocene (Seddon et al., 2016). This is particularly the case for freshwater habitats and their biota (Dudgeon et al., 2006; Arthington et al., 2016; Parvez et al., 2023). Freshwater habitats have been degraded for centuries by over-exploitation, pollution, and habitat destruction (Dudgeon et al., 2006). More recent threats, including rapidly expanding hydropower, anthropogenic climate change, biological invasions are exerting further stresses (Reid et al., 2019). To help safeguard biodiversity, the International Union for Conservation of Nature (IUCN) identifies species that are at risk of extinction globally (Rodrigues et al., 2006). Species classified as threatened with extinction under several categories (e.g., critically endangered, endangered and vulnerable) on the IUCN Redlist, demand immediate conservation priority as their existence has been seriously threatened (Master, 1991; Díaz et al., 2019; Martin et al., 2022). Freshwater fish account for approximately one-third of global vertebrates (Fricke et al., 2023), and are among the most endangered taxa in freshwater ecosystems (Arthington et al., 2016). However, conservation actions are often less focused on freshwater species, and a strong geographical bias persists, with the majority of conservation actions and underpinning science conducted in developed countries (e.g., USA, Australia, UK), and much less so in developing countries, including in South East Asia (Di Marco et al., 2017).

Historically, fish conservation and fisheries management have largely relied on detailed biological data (e.g., standardized long-term monitoring data and accurate Catch Per Unit Effort data), but these data are often unavailable in developing countries (Baird et al., 2005; Parvez et al., 2023). To facilitate ecologically sensitive management strategies for conserving and protecting threatened wild fish, an alternative approach is to combine quantitative or qualitative ecological data alongside local stakeholders' knowledge (Bennett, 2016). Studies of the perceptions of fisheries stakeholders can provide important insights into anthropogenic impacts on fish and of the ecological outcomes of conservation actions (Drew, 2005; Bennett, 2016). These perceptions, when generated by experiential observation and adaptive processes, and passed on to others by cultural transmission, are often termed "Local Ecological Knowledge", LEK (Drew, 2005). Recent studies have demonstrated that fisheries stakeholders across different countries showed certain levels of knowledge related to fish ecology, fishing activities and aquatic habitat, i.e. LEK, (de Souza Junior et al., 2020; Ribeiro et al., 2021; Rasekhi et al., 2022) which are important for development of effective conservation strategies. By contrast, there are places, especially in parts of the developing world, and in rapidly growing economies, where some stakeholders are less concerned about the conservation of aquatic fauna, and instead give priority to harvesting it to achieve greater production (Jones et al., 2021; Latini et al., 2021).

Fishery value chains usually consist of multiple groups of stakeholders (Hamilton-Hart and Stringer, 2016; Shalehin et al., 2022). These stakeholder groups may have widespread knowledge of general fish ecology (e.g., Pinto et al., 2013; Braga et al., 2017) but their understanding of threatened species is less clear. A few studies have evaluated the attitudes of a particular stakeholder toward certain fish species or categories of fish species (e.g., Braga et al., 2017; Pinto et al., 2013) but studies considering all stakeholder groups are absent. To ensure an effective conservation policy, all stakeholders' attitudes toward the target species should be known and policies should be applied accordingly. Therefore, analysis of knowledge and participation level of multiple stakeholder groups in the value chain of threatened fish species could reveal important information for the development of effective conservation strategies.

Bangladesh, where this study was carried out, is a subtropical country in South Asia, with rich biodiversity (Parvez et al., 2023), having over 265 freshwater fish species (Rahman, 2005). Wild fish are considered to be one of the major protein sources nationally, to meet the needs of local people. Currently, the fisheries sector contributes 3.57% to the national GDP (DoF, 2022) but our understanding of fisheries stakeholders toward threatened fish species is unclear. A total of 64 freshwater fish species have been classified as threatened to extinction in Bangladesh, due to increased pressure through overexploitation, habitat destruction, flow modification and water pollution (IUCN Bangladesh, 2015). Despite their threatened status, many of these species still appear in the fisheries value chain (Samad et al., 2010), potentially due to a lack of awareness among local stakeholders. Conversely, the presence of threatened fishes in the value chain may be due to a priority on greater harvesting to produce more food, a common approach in developing countries, including Bangladesh, that supresses biodiversity conservation actions (Galib et al., 2018; Jones et al., 2021). Therefore, it is more difficult to ensure the conservation management of fish in the country. Since stakeholders are increasingly involved in decision-making on management issues, and nowadays governments are actively seeking the views of the public before making decisions on future conservation plans (White et al., 2005), there is an urgent need to understand local stakeholders' knowledge of threatened fishes before taking further actions.

In this study, we assessed local stakeholders' knowledge of threatened freshwater fishes in Bangladesh, by using questionnaires in several key fisheries stakeholder groups. Differences in knowledge across stakeholder groups were tested. The occurrence of threatened freshwater fish at fish markets in the country was monitored to determine the level of participation of the stakeholders in the threatened fish value chain. Furthermore, factors affecting knowledge of the threatened fishes and respondents' participation in the threatened fish value chain were assessed using information gathered from each respondent.

2 Materials and methods

2.1 Study area

The study area comprised three major rivers [Padma (= lower Ganges), Jamuna and Atrai] and the largest wetland of the country, the Chalan Beel (Figure 1). Rivers and wetlands are the major sources of inland capture fisheries in the Bangladesh (DoF, 2019; Khan et al., 2022). Eight major fish markets, adjacent to the study aquatic habitats (two for each habitat; Figure 1, Supplementary Table S1), were surveyed on a monthly basis from April to December 2022.

2.2 Study approach

2.2.1 Respondents

Data were collected from fishers, farias (mid-level actor in the distribution channel), commission agents, fish retailers and consumers, the key fisheries stakeholder groups in Bangladesh (Shalehin et al., 2022). Respondents (n = 485; Table 1) were identified at the local fishing sites (fishers and farias) or markets (farias, commission agents, retailers and consumers) randomly. We tried to select similar numbers of respondents for each respondent group and sampling site to avoid any regional biasness on the results. Two 5-km long stretches of each aquatic habitat (=10 km in total) and fish markets were visited weekly (every Friday or Saturday) in March 2022 to make a list of people belonging to different stakeholder groups. During this time, we recorded a total of 324 fishermen, 68 farias, 67 commission agents and 214 retailers who were involved in fish harvesting or selling activities at least 5 days a week. Based on this preliminary information, the respondents for this study were selected randomly and represented 41.7, 76.5, 73.1, and 49.5% of the fishermen, farias, commission agents and retailers respectively. No such data were collected for consumers due to their irregular appearance in the fish markets. We selected fishermen who used seine and gill nets in rivers and seine, gill and lift nets in Chalan Beel for fishing because these are the most commonly used fishing methods in open waters of Bangladesh and capable of harvesting all species, including the threatened ones. These fishing nets were also used by over 90% of the fishermen, recorded during the preliminary survey of this study. Respondents were informed about the study, that their participation was voluntary, and that all data obtained would only be used for research purposes and would be kept confidential and anonymous. Data were collected through questionnaires developed for each group (Form S1; developed based on relevant literature Bitanyi et al., 2012; Shalehin et al., 2022 and personal experience).

2.2.2 Determination of knowledge of threatened fishes

A total of 64 freshwater fish species have been classified as threatened to extinction in Bangladesh under three categories (Vulnerable, 25; Endangered, 30; Critically Endangered, 9; Supplementary Table S2) by IUCN Bangladesh (2015). We asked respondents if they were aware of any of these threatened fish species and if they answered yes, they were asked to name these fish. Appropriate species for each described fish was determined based on the local names mentioned and morphometric description provided by the respondents. The identification was confirmed by showing the respondent color photographs of the fish species. All the fish names mentioned by the respondents were listed and cross-checked to determine if the species is on the list of threatened fishes of Bangladesh (IUCN Bangladesh, 2015).

2.2.3 Participation of respondents in threatened fish value chain

Fishers' landings, and fish being sold by the farias, commission agents and fish retailers were monitored and analyzed on each sampling date to determine number of threatened fish species in the catch (for fishers) or offered for selling (for farias, commission agents and fish retailers). Fish consumption data (= fish purchased) were obtained from the fish consumers to identify threatened fish species in their diet, if any.

2.2.4 Factors affecting knowledge of threatened fishes and respondents' participation in threatened fish value chain

We collected information on each respondent's age, gender, experience, income, education level, relevant training, financial loan and knowledge of laws concerning threatened fishes (e.g., ban on catching and trading) to examine their effects on knowledge level about threatened fish species and the participation of respondent groups in the threatened fish value chain. These factors, considered important in making decisions concerning fishing, fish distribution and purchasing, were selected based on relevant literature (Bitanyi et al., 2012; Shalehin et al., 2022) and personal experience.

2.3 Data analysis

We aimed to determine overall trends in the results and therefore, regional differences were not considered, mostly due to comparatively smaller sample size for respondent groups and also due to precautions taken to avoid regional bias on results described earlier in the subsection concerning respondent selection. To determine the respondent groups' knowledge level of threatened freshwater fish species in Bangladesh, the total number of genuine threatened fish species mentioned by each respondent was compared against the total number of threatened fish species in Bangladesh (i.e. 64; Supplementary Table S2). To determine the level of participation in the threatened fish value chain, the number of threatened freshwater fish species caught (for fishers) or offered for sale (for farias, commission agents and

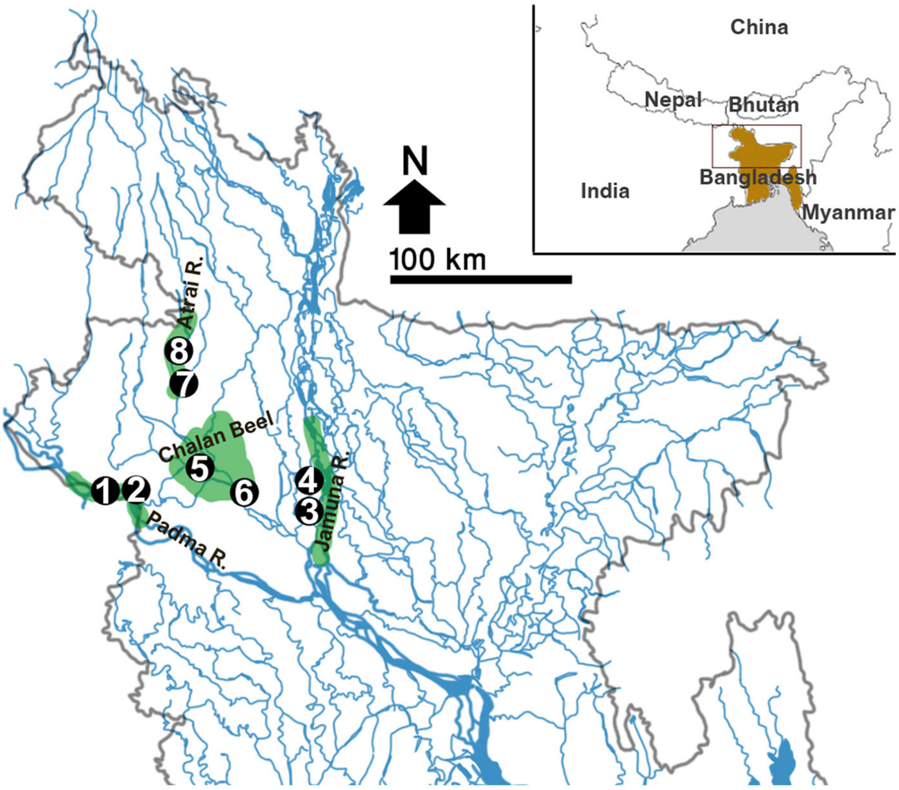

FIGURE 1
Map of the northern Bangladesh showing its location in South Asia (inset) and sampling fishing sites in four aquatic habitats (Padma River, Atrai River, Jamuna River and Chalan Beel) and fish markets (1, Shaheb Bazar; 2, Kathakhali; 3, Borobajar; 4, Bahirgola; 5, Singra; 6, Mahisluti Bajar; 7, Atrai; 8, Bhabanipur Bajar).

TABLE 1 **Numbers of respondents in different groups and their representation relative to the total recorded number in each group for the four study localities in Bangladesh.**

Respondent groups	Number of respondents (% of total number)				Total
	Jamuna	Padma	Chalan Beel	Atrai	
Fishermen	32 (38.1)	31 (32.0)	35 (46.1)	37 (55.2)	135 (41.7)
Farias	12 (80.0)	13 (59.1)	13 (86.7)	14 (87.5)	52 (76.4)
Commission agents	11 (84.6)	13 (81.3)	12 (57.1)	13 (76.5)	49 (73.1)
Retailers	30 (54.5)	33 (47.1)	20 (47.6)	23 (48.9)	106 (49.5)
Consumers	41	38	32	32	143

Proportions are not given for consumers as they occurred irregularly at markets and so could not be enumerated consistently.

fish retailers) or consumed (for consumers) was also compared against the total number of threatened freshwater fish species of Bangladesh.

To determine the factors affecting the knowledge level concerning threatened fishes of the respondents, linear mixed-effect modeling (LMM) was employed using the lme4 and lmerTest packages (Bates et al., 2015; Kuznetsova et al., 2016) of the software R (R Core Team, 2022). Potential factors (i.e. age [in years], experience [in years], education [in schooling years] and training [yes/no]) were considered fixed factors and sampling location was considered a random factor in the model. As several factors (e.g., age, experience and education) may be correlated, principal component analysis (PCA) was employed to define their dimensions for each respondent group (Cote et al., 2010; Parvez et al., 2023). Two PCA factors were identified for further analysis for each respondent group (Supplementary Table S3) based on scree plots and a broken-stick model (Jackson, 1993). Factors with a loading of > 0.60 were considered to contribute to the meaning of a PCA component (Galib et al., 2022).

Linear mixed-effect modeling was also employed to determine the factors affecting participation level of key stakeholder groups in the threatened fish value chain. A full LMM model incorporating those factors considered in the above-mentioned LMM, as

TABLE 2 Mean age, education, experience and daily income of the threatened fish stakeholder groups in Bangladesh.

Group	Mean ± SD			
	Age (years)	Education (years)	Experience (years)	Daily income (BDT)
Fishermen	34.9 ± 11.5^{c}	1.6 ± 2.1^{c}	16.3 ± 10.1^{ab}	640.5 ± 297.2^{e}
Farias	37.6 ± 6.4^{bc}	3.4 ± 2.0^{b}	10.0 ± 5.6^{c}	$1{,}496.9 \pm 547.0^{b}$
Commission agents	45.3 ± 8.0^{a}	2.4 ± 1.9^{bc}	12.8 ± 7.9^{bc}	$2{,}774.5 \pm 428.2^{a}$
Fish retailers	40.1 ± 12.2^{b}	2.6 ± 2.9^{c}	17.5 ± 12.2^{ab}	859.4 ± 392.7^{d}
Fish consumers	44.1 ± 9.3^{a}	10.6 ± 6.3^{a}	17.4 ± 9.1^{a}	$1{,}314.7 \pm 1{,}031.4^{c}$

Since all fishers were male they are referred to as fishermen.
1 USD$ is ~100 BDT; different superscript letters in each column/factor indicate significant differences ($p < 0.05$) across stakeholder groups.

TABLE 3 Knowledge level (listing of threatened freshwater fish species as a percentage of those formally listed) of respondent stakeholder groups and their participation in the threatened fish value chain.

Group	Knowledge level (% of threatened fish species)		Participation level in value chain (% of threatened fish species)	
	Mean ± SD	Range	Mean ± SD	Range
Fishermen	4.8 ± 3.5^{b}	0–18.8	15.2 ± 6.4^{b}	0–26.6
Farias	1.8 ± 2.8^{bc}	0–10.9	12.1 ± 4.9^{c}	0–21.9
Commission agents	1.1 ± 1.6^{a}	0–4.7	21.5 ± 4.2^{a}	10.9–29.7
Fish retailers	1.9 ± 2.1^{c}	0–10.9	9.4 ± 4.2^{d}	0–25
Fish consumers	0.5 ± 1.1^{d}	0–6.3	7.4 ± 6.5^{e}	0–23.4

Different superscript letters in each column/factor indicate significant differences ($p < 0.05$) across stakeholder groups.

well as the knowledge level of respondents about threatened fishes, the financial loan status of respondents (continuous scale; in Bangladesh Taka, BDT), and possible interactions (e.g., income–loan and knowledge–education), was developed (Supplementary Table S4). A reduced model was finalized by dropping non-significant factors from the full model and based on ΔAIC values for final analysis (Supplementary Table S4). However, training on threatened fish species or associated topics (e.g., fisheries laws) was not considered in the final analysis as none of the respondents received any such training or were aware of such laws. Gender of the participants was also not considered because all were male.

To examine the differences in respondents' knowledge levels of threatened fish and respondents' participation in the threatened fish value chain among respondent groups, LMMs were also used. Respondent group was considered a fixed effect and location was considered a random effect. Before analysis, normality of the data were checked and subjected to log transformation to meet the assumptions for the test, if needed (McDonald, 2014).

3 Results

3.1 Basic profile of the respondents

All fishers were male (i.e. fishermen). Mean age (±SD) of the threatened fish stakeholder groups varied from 34.9 ± 11.5 (fishermen) to 45.3 ± 8.0 (commission agents) years (Table 2). Mean education duration ranged from 1.6 ± 2.1 (fishermen) to 10.6 ± 6.3 (consumers) years, experience ranged from 10.0 ± 5.6 (farias) to 17.5 ± 12.2 (retailers) years and daily income ranged from BDT 640.5 ± 297.2 (fishermen) to 2,774.5 ± 428.2 (commission agents), respectively (Table 2).

3.2 Knowledge of threatened fishes

Poor knowledge about threatened fish species (percentage of threatened fish species listed by respondents; 0.5–4.8% of 64 species; Table 3) was recorded for all respondent groups, but the extent of knowledge differed across groups (LMM: $F = 67.3$, $p < 0.001$; Figure 2). The highest mean percentage of threatened fish species (4.8 ± 3.5% of species) was identified by the fishermen group, whereas consumers were the least knowledgeable group (0.5 ± 1.1% of species identified, Figure 2, Table 3). No respondent was able to identify all threatened freshwater fish species in Bangladesh, but one was able to identify 12 (18.8%) species. None of the respondents received any training on threatened fish species or attended relevant awareness building programmes.

3.3 Participation of respondents in threatened fish value chain

All respondent groups participated in the threatened fish value chain and the extent of participation varied across respondent groups (LMM: $F = 57.5$, $p < 0.001$; Figure 3). A total of 29 threatened fish species including three critically endangered, 14 endangered and 12 vulnerable species were recorded to be traded.

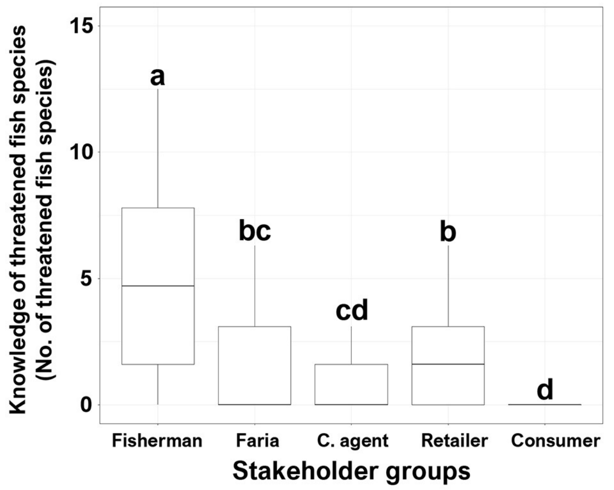

FIGURE 2
Key stakeholders' knowledge of threatened fish species in Bangladesh. Total number of threatened fishes in Bangladesh is 64. Midline within the box is the median; upper and lower limits of the box represent the third and first quartile (75th and 25th percentile) respectively. Categories not sharing the same letter (a–d) differ significantly ($p < 0.05$).

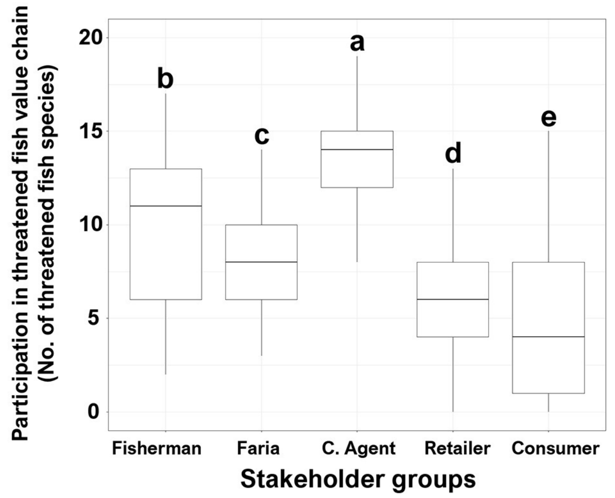

FIGURE 3
Key stakeholders' participation in threatened fish species value chain as number of threatened fish species caught (for fishermen), bought/sold (for faria, commission agents and retailers) and consumed (for consumers). Total number of threatened fishes in Bangladesh is 64. Midline within the box is the median; upper and lower limits of the box represent the third and first quartile (75th and 25th percentile), respectively. Categories not sharing the same letter (a–d) differ significantly ($p < 0.05$).

This represents 45.3, 33.3, 46.7 and 48% of the total number of threatened, critically endangered, endangered and vulnerable fish species of the country, respectively (Supplementary Table S2). All the respondents except one fish retailer (0.9% of the total sample of fish retailers) and 33 consumers (23.1% of the total consumers) participated in some sort of value chain of threatened fish species. In terms of the number of threatened species traded, participation level was highest for commission agents, involved in the trade of 21.5 ± 4.2% of threatened fish species of Bangladesh. This value was the lowest for the consumer group, purchasing on average 7.4 ± 6.5% threatened species (Table 3). None of the respondents were aware of the existence of laws for the protection of threatened fishes in Bangladesh. All participants reported that they had seen no one taking initiatives to protect threatened fishes, nor tried to prevent them from trading or purchase of threatened fishes.

3.4 Factors affecting knowledge of threatened fish species

Knowledge of fishermen with regard to threatened fish species was increased by PC1 (age-fishing experience–income) and PC2 (education) (Table 4). This knowledge was positively affected by PC1 (age–experience–education) for commission agents whereas, for retailers, both PC1 (age–experience) and PC2 (education–income) had a positive effect. However, for consumers, knowledge level was significantly positively affected by interaction of PC1 (age–experience) and PC2 (education–income) (Table 4).

3.5 Factors affecting participation in the threatened fish value chain

For fishermen, PC1 (experience–income–age) and interaction between PC2 (education) and financial loan significantly affected their participation in the threatened fish value chain positively whereas, this was negatively affected by their knowledge level of threatened fish species (LMM, all $p < 0.029$; Table 5). Financial loan negatively impacted the extent of participation in the threatened fish value chain for both farias and commission agents (Table 5). Retailers' participation in the threatened fish value chain was positively affected by their knowledge of threatened fishes ($p = 0.041$, Table 5). Interestingly, consumers' participation in the value chain was negatively affected by PC1 (experience–age), financial loan and interaction between PC1 and knowledge of threatened fishes whereas positively affected by PC2 (education–income) (all $p < 0.016$; Table 5).

4 Discussion

This study revealed the knowledge level of key stakeholder groups about threatened freshwater fish species in Bangladesh and their participation level in the value chain of these fishes. Poor knowledge of threatened fish species and high level of participation of all key stakeholder groups in the value chain of threatened species pose a threat to the conservation of these species because it is almost impossible to ensure success of any conservation strategy with such poor knowledge and without active participation of key stakeholders (Drew, 2005; Bennett, 2016).

TABLE 4 Factors affecting knowledge level concerning threatened fish species for respondent groups.

Groups	Factor	Estimate	*F*-value	*p*-value
Fishermen	PC1 (Age–experience–income)	0.30	16.6	**<0.001**
	PC2 (Education)	0.45	23.5	**<0.001**
Farias	PC1 (Age–experience–income)	0.09	0.2	0.648
	PC2 (Education)	0.15	0.5	0.499
Commission agents	PC1 (Age–experience–education)	0.31	8.2	**0.006**
	PC2 (Income)	0.14	0.4	0.534
Retailers	PC1 (Age–experience)	0.22	12.8	**0.001**
	PC2 (Education–income)	0.28	7.2	**0.001**
	PC1 × PC2	−0.48	2.5	0.118
Consumers	PC1 (Age–experience)	−0.04	1.1	0.297
	PC2 (Education–income)	−0.01	0.1	0.967
	PC1 × PC2	0.32	4.5	**0.037**

Bold values refer to those significant at $p < 0.05$.

TABLE 5 Factors affecting participation of key stakeholder groups in the threatened fish value chain.

Groups	Factor	Estimate	*F*-value	*p*-value
Fishermen	PC1 (Age–experience–income)	0.07	4.9	**0.029**
	PC2 (Education)	0.03	0.5	0.488
	Knowledge of threatened fish	−0.10	7.0	**0.009**
	Financial loan	−0.01	1.6	0.211
	PC2 × Financial loan	0.04	4.9	**0.028**
Farias	PC1 (Age–experience–income)	0.04	0.4	0.529
	PC2 (Education)	0.04	0.2	0.623
	Knowledge of threatened fish	0.08	2.4	0.128
	Financial loan	−0.03	6.5	**0.014**
Commission agents	PC1 (Age–experience–education)	0.05	3.1	0.084
	PC2 (Income)	0.05	0.9	0.340
	Knowledge of threatened fish	−0.05	1.8	0.183
	Financial loan	−0.02	8.5	**0.006**
Retailers	PC1 (Age–experience)	−0.04	0.7	0.404
	PC2 (Education–income)	−0.03	0.2	0.629
	Knowledge of threatened fish	0.14	4.3	**0.041**
	Financial loan	0.01	0.3	0.571
Consumers	PC1 (Age–experience)	−0.38	86.9	**<0.001**
	PC2 (Education–income)	0.18	6.7	**0.010**
	Financial loan	−0.10	97.3	**<0.001**
	PC1 × Knowledge of threatened fish	−0.63	5.9	**0.016**

Bold values refer to those significant at $p < 0.05$.

4.1 Knowledge of threatened fishes and its determinants

The PCA analyses revealed different axes of correlated factors for stakeholder groups. Age and experience were correlated in all cases, with education (for commission agents) and income (for fishermen and farias). This could be expected as it is a common occurrence that an experienced person would be older and a highly experienced person can earn more.

Although all stakeholder groups exhibited poor knowledge concerning the existence and identity of threatened freshwater fish species, knowledge of fishermen, commission agents and fish retailers was positively affected by their age, experience and education and income, while income was positively affected knowledge for fishermen and retailers. Age, experience and education are widely acknowledged to broaden the knowledge of people, including with regard to ecosystem services and biodiversity conservation (Bitanyi et al., 2012). Older and experienced fishermen can provide critical information such as local ecological knowledge about a species that is important for its conservation (Braga et al., 2017). Therefore, it is likely that they would be more able to identify species and speculate their availability in the habitat. Similar explanation may also be true for commission agents and fish retailers. It was not possible to compare our findings with the wider literature for the latter groups due to a lack of previous studies on these.

Formal education at primary and secondary level can broaden conservation knowledge (Børresen et al., 2023) and this may have been the case for stakeholder groups with a low level of education (e.g., fishermen, commission agents and retailers). In the developing world, fishers are among the least educated people in society (Rahman et al., 2020) and in Bangladesh, they are mostly illiterate or do not have any formal education (Kostori, 2012; Islam et al., 2013). This is also true for intermediate groups (e.g., fish retailers) involved in the fish distribution in the country (Halder et al., 2011; Adhikary et al., 2018). However, specifically-designed education programmes can increase the awareness of people and can be an important tool in conservation (Eshun et al., 2022; Børresen et al., 2023). None of the respondents belonging to any of the studied stakeholder groups had training on threatened fishes or attended any other programme (e.g., local ecological knowledge) that could help to build their awareness about nationally threatened fish species. However, knowledge of farias concerning threatened fishes was not explained by the factors considered (i.e. age, experience, education and income). This indicates that there might be some other outstanding factors responsible, which requires further studies to identify influencing factors.

4.2 Participation in threatened fish value chain and its determinants

Nearly half of the nationally threatened freshwater fish species appeared in the fishery value chain within the study area, reflecting the poor situation of threatened fish conservation in Bangladesh (Galib et al., 2018; Parvez et al., 2023). Conservation may be a real challenge in circumstances where it competes with pressing human demands (Buckley, 2015) and this is frequently the case for freshwater fishes (Arthington et al., 2016; Phang et al., 2019). In many developing countries of the world, the local priority is more on consumption than conservation of fish species (Galib et al., 2018; Jones et al., 2021) and this study's findings support that statement. Participation of most of the respondents in the value chain of threatened fish species indicates a lack of community awareness about nationally threatened fish species. These days, people-centered conservation governance or community-centered management are being encouraged (Hoffmann, 2022) and therefore, this issue should be considered carefully in designing such conservation programmes in Bangladesh and other developing countries where capture fisheries play an important role in food provision.

For fishermen, the interaction between age-experience-income and education-financial loan PCA axes positively affected participation in the threatened fish value chain, whereas involvement in the threatened fish value chain was negatively related to threatened fish knowledge. In Bangladesh, threatened fish species are usually traded at a higher price than other fishes (T. Parvez and S. Galib, Pers. obs.) which may act as a motivating reason for fishermen to get involved in value chain of threatened fish species. Fourteen (48.3%) of the 29 threatened fish species in the value chain were siluriforms (catfishes) which are often desirable food fishes in tropical and subtropical freshwater fisheries (Phang et al., 2019). Fishermen in developing countries are one of the poorest groups of people and those with financial loans could be put in a highly vulnerable position in society (Rahman et al., 2020). Therefore, it is possible that they would try to capture threatened fishes for more profit to cope with their social vulnerability. A similar explanation, i.e. capturing more threatened fish makes more profit, may also be applicable for fishermen of the higher age-experience-income category.

Participation in the value chain of threatened fishes was negatively affected by financial loan for farias, commission agents and fish consumers. More investment is needed to trade highly-priced species such as threatened fishes in Bangladesh which may have adversely affected the participation of respondents belonging to two intermediate groups (i.e. farias and commission agents) with financial loans. A similar explanation may be also true for fish consumers, those with financial loans may have bought lower amounts of highly-priced threatened fish species. Detailed analysis of the economic value of threatened fish landings was not possible in this study because small-sized threatened fish species were often landed mixed with other native species and sold collectively. This made it difficult to collect pricing data for a substantial proportion of threatened fish species.

Interestingly, educated consumers with higher incomes buy more threatened fishes from the fish markets which may be expected as they have more buying power and are, therefore, capable of buying highly-priced threatened fishes. This behavior may be due to a lack of awareness about the threatened species and/or ignorance of their threatened status. In Bangladesh, people with lower income prefer to buy fishes of low price in the markets, mostly those produced through aquaculture (Galib et al., 2013). This agrees with our findings, where an inverse relationship was recorded between income and consumption of threatened fishes. Formal education can contribute positively to biodiversity conservation (Braga et al., 2017; Børresen et al., 2023) but no such relationship was determined for any stakeholder groups in our study. This may be due to the comparatively lower level of education among the stakeholder groups examined, except for consumers. It might also be that the nature of primary and secondary education experienced by the stakeholders did not include environmental or conservation topics, or that linkage to local issues such as threatened freshwater fishes is not made clear.

Insufficient or poor implementation of conservation laws and regulation can lead to a faster reduction of threatened species (Campbell et al., 2020) and this is likely to be occurring in Bangladesh. Unfortunately, in Bangladesh, specific fishing laws to protect threatened fish species are lacking and only five threatened fish species are protected by existing partial legislation (ban on harvesting small-sized fish during specific periods, especially during the breeding season—see Supplementary Table S2). Despite having such laws, threatened fishes find their way into the fish markets easily, even during the fishing closed season (Shalehin et al., 2022). Therefore, availability of threatened fish species in fish markets is also common (Samad et al., 2010). Absence of laws prohibiting the taking of most threatened fishes and lack of knowledge regarding existing laws seemed to be a key factor for the trading and distribution of threatened fishes in the country. For our study timescale and locality, no monitoring for threatened fishes, including those protected by existing fishing laws by the regulatory authorities (e.g., Department of Fisheries), was recorded. Unfortunately, lack of sufficient monitoring for the protection of wildlife is very common in biodiversity hotspots in developing regions and that makes biodiversity conservation challenging (Bitanyi et al., 2012). This was also the case in our study, in which no protection activities for the threatened fish species were recorded. Less priority on inland fisheries (compared to marine or terrestrial environments) by the government or local government is often common and is largely overlooked in many countries, both developing and developed ones (Cooke et al., 2016).

5 Conclusions

This study reveals the poor knowledge key stakeholder groups have regarding threatened fish species in Bangladesh, but also their active participation in the value chain of those threatened fishes. With limited conservation resources and funds for the conservation of threatened species (Joseph et al., 2009; McCarthy et al., 2012), it is very risky to implement commonly used *in-situ* conservation methods (e.g., habitat quality improvement) with such little knowledge of the stakeholders. As there is no fish conservation law prohibiting the taking of 'threatened fishes' in Bangladesh, we recommend protection of these species by introducing new laws or modification of existing laws to broaden protection for most or all nationally listed threatened fish species. We also recommend awareness building campaigns for these stakeholder groups to ensure minimum damage to threatened fish species. These programmes should shed light on identification of threatened species and transfer of local ecological knowledge. As harvesting is one of the major causes of threatened species declines (Buckley, 2015), such training programmes should be designed for fishermen on a priority basis as they form the basis of the threatened fish value chain. Education programmes on threats to ecosystems and biodiversity in primary and secondary schools, a proven strategy to build up conservation knowledge of stakeholders, should be prioritized, but also supplemented by workshops within existing fishing communities. In addition, regular monitoring for protected species at the harvesting sites and fishing markets should be ensured.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Faculty of Fisheries, University of Rajshahi. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because there is no such national legislation or the institutional requirements. Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements because commercial fish catch data were analyzed.

Author contributions

SG designed the study, analyzed the data, and led writing of the manuscript. SN, SA, MK, MR, and MP collected data. JS participated in drafting of the manuscript and participated in data analysis. ML participated in data analysis and critically revised the manuscript. All authors gave final approval for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffwsc.2023.1239605/full#supplementary-material

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