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Determinants influencing fishermen's willingness-to-participate and willingness-to-pay for conservation of small indigenous fishes: a model-based insight from Indian Sundarbans

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Small indigenous fishes (SIF) play a crucial role in supporting the livelihoods and nutritional security of the rural population in Southern Asia. However, their abundance and diversity are under threat due to overexploitation and profitable extensive aquaculture, resulting in a sharp decline, particularly in India. Unfortunately, conservation strategies for SIF have received little attention from researchers, making it imperative to understand stakeholders' decision-making processes to develop effective conservation strategies. This article aims to quantitatively identify the factors that influence fishermen's intention to participate in and pay for SIF conservation efforts. The study utilizes questionnaire-based survey data from 100 households engaged in local fisheries in the rural Indian Sundarbans. To gain critical insight into fishermen's decision processes, a bivariate logistic Generalized Additive Model is employed, focusing on willingness-to-participate and willingness-to-pay for SIF conservation. The study's results indicate that several factors significantly influence fishermen's willingness-to-participate in conservation efforts. These include Literacy, Conservation awareness, and Occupation. On the other hand, Conservation awareness and Household income are identified as significant determinants of fishermen's willingness-to-pay for SIF conservation initiatives. One intriguing finding of the research is the identification of a nonlinear response-age curve for both willingness-to-participate and willingness-to-pay, as well as their interaction. Notably, the 45-50 years old age group emerged as the most likely implementers of small indigenous fish conservation strategies, suggesting that targeting this age group in conservation programs could yield positive outcomes. The study underscores the importance of various conservation strategies to bolster SIF preservation in the region. Recommendations include increasing and extending conservation awareness programs, specifically targeting suitable age-group individuals with appropriate education, household income, and occupation. These strategies are vital for formulating effective conservation guidelines that align with the specific needs and characteristics of the region. In conclusion, this research sheds light on the factors influencing fishermen's participation and willingness to financially support the conservation of small indigenous fish in the rural Indian Sundarbans. The findings contribute valuable insights for policymakers, conservationists, and stakeholders, emphasizing the urgency of sustainable measures to safeguard SIF populations and ensure the continued livelihoods and nutritional security of the local communities.

KEYWORDS

small indigenous fishes, conservation, Sundarbans, India, PRA, VGAM, logistic regression

1. Introduction

Small Indigenous Fishes (SIF) are native fishes, which grow to a maximum attainable size of 25–30 cm at mature or adult stage in their life cycle (Felts et al., 1996). They are mostly available in fresh and brackish waterbodies, such as wetlands, river, creek, backwater, rice field, pond, tank etc. (Saha et al., 2018), and captured by artisanal fishing using traditional knowledge and tools for subsistence, especially prevalent in the low-income group countries. Perhaps, they are the most ignored fish species, as because SIF's commercial fisheries do not exist. Consequently, their fisheries encompass rural sectors, albeit they are available in both rural and urban markets through local marketing channel. They are rich in micronutrients, including calcium, iron, and Vitamin A, and thereby can be a supplement to fight against malnourishment (Thilsted and Wahab, 2014; Bogard et al., 2015). SIFs are also an important animal-source food that can help to improve food and nutritional security (Fiedler et al., 2016; Thilsted et al., 2016). Thus, SIF's not only support livelihood but also provide nutritional security to the rural people, especially to South and Southeast Asia (Saha et al., 2009; Islam et al., 2018; Fabinyi et al., 2022). Despite such importance researchers worldwide, particularly in the said region, paid little or no attention.

Indian Sundarbans is a part of the world's largest delta shared by two countries, India, and Bangladesh. It comprises 102 islands: 54 are rich in inland water bodies—including, fresh and brackish water ponds, wetlands, creeks, canals, and rivers; the rest contains dense mangrove forests. The region is recognized as the biodiversity hotspot, harboring a wide diversity of flora and fauna—including fish species. As many as 267 fish species (Mandal et al., 2013) have been reported from the Indian Sundarbans, including a wide variety of SIF. About 23% of SIFs recorded from Indian inland waters are important as food and/or ornamental fishes (Sarkar and Lakra, 2010), and they provide livelihood and nutritional security to the rural people of India, including Sundarbans. But the SIF stocks drastically reduced, notably in Sundarbans (Sinha et al., 2014). Over-exploitation, extreme climatic events have adversely affected the delicate natural balance of the Sundarbans (Raha et al., 2014); it has perceptibly caused the decline in SIF stocks and consequently affected the livelihoods, and food and nutritional security of poor fishermen (Sinha et al., 2014; Roy et al., 2020). Recently, SIF's prices shoot up due to low availability, and they become unaffordable for poor people. The market price of *Amblypharyngodon mola* (Hamilton), for instance, has doubled between 2005 and 2009 (Milstein et al., 2009). Of late, fishermen shifted to extensive profitable aquaculture of fast-growing exotic fishes, unknowingly destroying the aquatic environment suitable for SIF. This has exacerbated the problems associated with SIF conservation efforts. Despite their value for household nutrition, SIFs are perhaps the most ignored component for priority setting in overall fish biodiversity conservation.

Natural resource conservation focuses on the ecology and biology of fish and other aquatic organisms. But it often ignores fish diversity, especially of freshwater, perhaps due to the lack of robust information facilitating decision-making (Revenga and Kura, 2003). The connectivity of humans with the physical and biological environment plays a significant role in conservation, but interrelationships between the consumers and their resources are rarely accounted for in conservation strategies and planning (Rayfield et al., 2009), yet it is the main factor hindering biodiversity conservation. A review on conservation planning research revealed that only 2% of articles considered dynamic threats and biotic interaction (Pressey et al., 2007), whereas human influence and natural processes that maintain species diversity were often ignored (Klein et al., 2009). The concept of "community conservation" or "participatory management" has evolved from past experiences of exclusionary conservation, which leads to vulnerabilities in local communities (Brosius et al., 1998). In general, conservation needs trade-offs between biodiversity and livelihoods. To this end, "sanctuaries" or "protected areas" are demarcated for conservation. But, the idea of protected areas does not work well in poor tropical countries (Oberosler et al., 2020). The likelihood of such failure might be due to the lack of critical scientific research and ignoring stakeholders' attitudes toward conservation. People's participation and positive attitude are essential to achieve conservation goals (Richards, 1996). Several studies have been carried out by designating human attitude as the key element for conservation in different aspects, such as terrestrial wildlife conservation and management (Zinn et al., 1998; Ojea and Loureiro, 2007; Knight, 2008), terrestrial invasive species management (Sharp et al., 2011), endangered species recovery (Clark and Wallace, 1998), biodiversity conservation in general (Martín-López et al., 2007), and improving biodiversity in water ecosystem. However, inland fisheries have received little attention in this context, and SIF has not received any attention, to be specific.

Although fishermen's willingness-to-participate (hereinafter referred as PAR) and willingness-to-pay (hereinafter referred as WTP) decide the long-term success of SIF's conservation program, several factors influence their intention. Identification of these determinants and interaction pattern with PAR and WTP are essential to leverage them to increase the success probabilities of conservation policies. In the light of above observations, the present study set the objectives (a) to examine the socio-demographic factors affecting fishermen's PAR and WTP in SIF; and (b) to quantify the relationship pattern between influencing factor, and PAR and WTP for better implementation of conservation policies. The present investigation has novelty in two aspects. First, a plentiful literature exists that analyzed PAR and WTP in other fields However, the similar studies are not available in fisheries, especially in SIF's conservation, to the best of our knowledge. Thus, application of PAR and WTP framework in SIFs conservation is a novelty in this article. Secondly, participants' responses to PAR and WTP are conceivably correlated that has seldomly accounted for modeling of PAR and WTP; they are modeled separately, instead. The present article, however, proposes a novel application of bivariate logistic Generalized Additive Model to unravel the relationship between influencing factor and PAR and WTP. The bivariate GAM is particularly chosen, as it can effectively characterize the response-factor relationship patterns of either linear or nonlinear, thereby broadening the scope. Most importantly, this model can decouple the non-linear relationship between two potentially dependent responses—i.e., PAR and WTP.

This paper furnishes the results of empirical research which helps to understand the socio-personal dimensions that influence the behavior of local people in deciding their participation in a conservation program. The findings will facilitate formulation of strategies for SIF's conservation and improve the livelihoods and nutritional security of people dependent on inland fisheries associated with SIFs.

2. Materials and methods

2.1. Study area

The study area is a part of the Sundarbans, a world heritage Ramsar site covering 426,200 ha in India (IUCN, UNEP-WCMC, 2010). It belongs to the network of tidal rivers, creeks and channels in the coastal-saline zone of the southernmost part of West Bengal, India (Figure 1). An exploratory survey revealed that the food patterns of Sundarbans people were like that of rural Bengal (Roy et al., 2016). People depend on fishes, especially SIF, collected mostly from natural water bodies. In the study region, many SIF species are treated as trash fish in aquaculture or rather food fish of the poor. Here, knowledge about SIF is scant, and it is limited to species with relatively higher economic potential. Considering the nutritional and therapeutic value of SIFs, conservation efforts targeting SIF was instigated in a community pond in the village of Madanganj in lower Sundarban by maintaining the natural environment necessary for their breeding and proliferation, and subsequent transfer of larvae/ juveniles in other inland water bodies of the area (CIFRI, 2014). After successfully implementing and establishing SIFs in the area, people became aware of the importance of SIF conservation. The sampling units belonged to the villages within the 5 km radius of the conservation site in Indian Sundarbans, South 24 Parganas, West Bengal, India (see Figure 1).

2.2. Survey design

2.2.1. Selection of the respondents

One hundred households were selected based on the "Wealth Ranking" tool of Participatory Rural Appraisal (PRA) (Adams et al., 1997) from 1,300 households. Wealth ranking refers to placing people on the different social ladder steps according to their criteria. To do the wealth ranking, brain storming was done to list wealth indicators, based on which categorization of the households was performed. Here, the objective for wealth ranking was to identify the wealth status of the villagers for assessing their willingness to participate in the SIF conservation, avoiding wealth-induced sampling bias.

2.2.2. Data collection

A questionnaire-based survey was conducted during April–September, 2017. Before collection of data, the selected resource person was made aware about a "hypothetical SIF conservation program." Briefly "the hypothetical SIF conservation program" included (i) maintaining the natural environment of the water body (restoration/ maintenance of connectivity with river/canal, keeping submerged vegetation, maintenance of pond dike to avoid possible mortality from pollution by run-off pesticides/other anthropogenic loading, retention of minimum water level especially during lean period to avoid complete elimination of SIF from a waterbody) necessary for their breeding and proliferation, (ii) transfer of larvae/juveniles/brooders (potential spawners) in other inland water bodies of the area for possible establishment in new areas, (iii) harvesting after allowing the SIF for breeding (based on their breeding cycle) through observation of closed season, and (iv) not using any highly destructive fishing gear for fish harvesting (like drag net of zero mesh, electrofishing, application of piscicides, etc.). After this awareness, the questionnaire schedule was presented before actual data collection. The questionnaire was consisted of two main parts: general information on the households and people's PAR and WTP in the SIF conservation program. The interview method was used to record responses to specific questions. Regarding PAR and WTP, the respondents ($N = 100$) were presented with a hypothetical conservation program for SIFs, after discussing the importance of the conservation of SIFs. The conservation program described was the same, but on a larger scale as compared to the

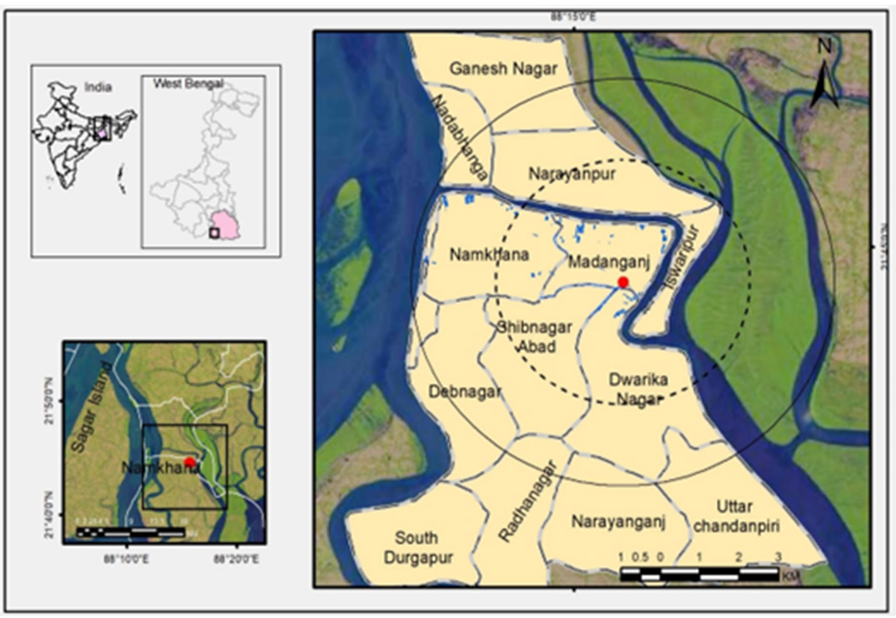

FIGURE 1
Location of the conservation site and sampling area.

demonstration site, with the components: promoting breeding habitat; auto-stocking in the natural environment; secured enclosure and stocking of larvae and juveniles in other available water bodies for their self-establishment. Then close-ended questions were asked to elicit responses on the PAR in SIF conservation programs. Binary answers were recorded for the PAR, ignoring the extent or intensity of participation that are usually recorded using scoring method—e.g., Likert scaling; we ignored scoring method and preferred the binary response to multiple choice responses due to some advantages: ease of eliciting response, time-saving, easy to communicate with illiterate people, and ease of data interpretation in terms of simple odds ratio for a relatively low sample size. The WTP concept, i.e., to pay something to prevent loss (Wossink and van Wenum, 2003) was used to account for contingent participation. In addition, other socio-economic and attitude related data were also collected. The description of the dependent and independent variables is given in Table 1.

2.2.3. Modeling PAR and WTP

All the data collected were tabulated and summarized using descriptive statistics. Contingent participation was analyzed through empirical model. The data analyzed in the present study was multivariate in nature. There were two main response variables, *viz*. PAR and WTP to assess the perceived potential for launching a conservation program on SIFs. Further, it was hypothesized that those responses were affected by explanatory variables, including age, gender, socio-economic and management-related factors. Since both the responses were of binary type (no = 0 and yes = 1), classical multivariate regression analysis was not possible. Moreover, it was likely that these two binary responses were dependent, as the responses were recorded from the same individual. Here, $Y = (Y_1, Y_2)^T$, where Y_1 takes the value 1 if the individual is "willing to participate" and 0 otherwise, and Y_2 takes the value 1 if the individual is "willing-to-pay" and 0 otherwise. Let $p_{rs} = P(Y_1 = r, Y_2 = s), r, s = 0,1$ be the joint probability, and $p_j = P(Y_j = 1), j = 1, 2$ be the marginal probabilities. The effects of explanatory variables on the responses were quantified by applying a bivariate logistic model (McCullagh and Nelder, 1989; Palmgren, 1989). Essentially, the bivariate logistic model is specified by the marginal probabilities and the odds ratio as a function of explanatory variables, say x. The odds ratio, $\psi = (p_{00}p_{11})/(p_{01}p_{10})$, is used to describe the association between the two responses. The bivariate logistic model is written as,

$$logit(p_1) = \eta_1 = \beta_{10} + \beta_{11}X_1 + \ldots + \beta_{1p}X_p$$

$$logit(p_2) = \eta_2 = \beta_{20} + \beta_{21}X_1 + \ldots + \beta_{2p}X_p$$

$$logit(\psi) = \eta_3 = \beta_{20} + \beta_{21}X_1 + \ldots + \beta_{2p}X_p$$

in which logits' are linear functions of $x = (X_1, X_2, \ldots, X_p)'$. The positive and negative value of η_3 indicates positive and negative association between the two responses, respectively. The zero value of the same implies no association between the two responses. However, it is unlikely that the true functions are linear, particularly in real life survey data as in the present study. So, it is worthwhile to incorporate a nonlinear functional form in the model mentioned above. As with Generalized Additive Models (GAM) (Hastie and Tibshirani, 1990), the said model can easily be extended to a Vector Generalized Additive Model (VGAM) (Yee and Wild, 1996), as:

$$\eta_j(x) = \beta_{(j)1} + \sum_{k=2}^{p} f_{(j)k}(x), \quad j = 1,2,3$$

which is a sum of smooth functions of individual explanatory variables. Thus, VGAMs are a visual data-driven method that is well suited for exploring data, and they retain the simplicity of data interpretation.

Six variables, namely *Family Size*, *Time spent on fishery activities*, *Fishery resources for household consumption*, *Bid value*, *Income from fisheries* and *Regulation in fishing* were excluded for model building. *Time spent on fisheries activities* and *Fishery resources for household consumption* were excluded, since they did not directly influence PAR

TABLE 1 Variables and description.

Variable name	Description
Dependent variable	
Willingness to pay (WTP)	The maximum price a beneficiary is willing to pay for a product or service (Ekka and Pandit, 2012) Willingness to pay in rupees to conserve SIFs; 1 for positive response and 0 for non-response/negative response
Willingness to participate (PAR)	Willingness to participate physically (Jennewein and Jones, 2016) in SIF conservation efforts; 1 for positive response and 0 for negative response
Independent variables quantitative variables	
Age	Age of head of the family, which was measured as the chronological age completed at the time of interview (Ekka and Pandit, 2012; Roy et al., 2018)
HH income	Household income in Rs. per year (Ekka and Pandit, 2012; Roy et al., 2018)
Family size	Number of members in family (Ekka and Pandit, 2012)
Time spent	Time spent in a month in hours to collect fishes from natural resources (Ekka and Pandit, 2012)
Bid	Bid value in rupees the respondents willing to pay (Ekka and Pandit, 2012)
Binary and categorical variables	
Occupation	Regular work or profession Agriculture-1; Fishermen-2; Other-3
Gender	Male −1 Female-0 (Gender) (Ekka and Pandit, 2012)
Education	Illiterate-0, Literate-1 (Ekka and Pandit, 2012)
INC FIS	Income from fisheries (Fishery) Yes 1 No 0
Fish consumption	Utilize fisheries resource for consumption Yes 1 No 0
Regulation	Regulations like fishing ban period, destructive fishing methods may be applicable to fisheries resources Yes 1 No 0
Conservation	Positive attitude toward biodiversity conservation Yes 1 No 0

or WTP. *Family size* is an important variable linked to the respondent's living standard but does not have a significant role in PAR or WTP in the conservation program. *Bid value* was discarded due to incomplete data. Further, *Income from fishery* was discarded as it was confounded as a part of *Household income*. A positive attitude toward regulation on fish-catching practices may also lead to a positive attitude toward conservation. Thus, *Regulation on fishing* and *Conservation awareness* were confounded factors. Hence, only *Conservation awareness* was selected: it was more relevant to environmental attitude than others. Six out of twelve variables were finally retained: *Age*, *Conservation awareness*, *Gender*, *Literacy*, *Fishery*, and *Household income*. It was highly improbable that the Age-response pattern would monotonically increase or decrease, thus, it was justifiable to incorporate an unknown Age-response curve that enabled unraveling the relationship between responses and age, which consequently enhanced the data interpretation capability. Thus, the final empirical VGAM model in terms of selected variables and assumed "Age-response" relationship is:

$$\eta_1 = \beta_{10} + f(Age) + \beta_{11} \times Conservation + \beta_{12} \times Gender + \beta_{13} \times \text{Literacy}\beta_{14} \times Fishery + \beta_{15} \times HouseholdIncom,$$
$$\eta_2 = \beta_{20} + f(Age) + \beta_{21} \times Conservation + \beta_{22} \times Gender + \beta_{23} \times \text{Literacy}\beta_{24} \times Fishery + \beta_{25} \times HouseholdIncom,$$
$$\eta_3 = f(Age),$$

where $\beta = (\beta_{10},\ldots,\beta_{15}, \beta_{20},\ldots, \beta_{25})$ is the regression coefficient corresponding to explanatory variables and $f(.)$ is a function of unknown form. For simplicity, the log-odds ratio is assumed as the function of age only. The detailed mathematical formulation and estimation methods of VGAM are rather complex and readers may consult (Yee and Wild, 1996); the model parameters were estimated using "*vgam*" package (Yee, 2010) under the R software (R Core Team, 2017) environment.

3. Results

Respondents' age ranged from 21 to 72 years, with an average age of 49 (Table 2). More than 87% of the respondents were above 35 years of age. Almost 79% of the families were headed by the male members, and the average family size was 4. About 24% of the respondents (heads of the household) were illiterate. But 4% of the respondents had education up to graduate level. Most of the respondents (33%) have primary level education followed by secondary level (32%) and higher secondary level (7%). About 22% of the households were solely dependent on fisheries for their livelihood. Around 63% of the respondents' main occupation was agriculture or farming. The average yearly household income of the respondents was \$ 708 (INR 52630/−). About 49% of the respondents were dependent on various fishery resources like water channels, canals, creeks, rivers and paddy fields for harvesting/catching fish in a traditional way for consumption. The respondents also spent an average time of 3.5 h each day collecting small fishes. About 80% of the respondents had a positive attitude toward regulations, e.g., introducing fishing ban period, use of non-destructive fishing gears, which might be applicable to fishery resource conservation. Some 78% of respondents had positive attitudes toward conservation of SIF. This might be due to the rapid turn down of locally available SIFs in the study area, which might directly affect the respondent's household consumption and income. The respondents agreed to spend an average amount of \$ 6.59 (INR 490/−) per household/per year (Total \$659/− per year), which is equivalent to one man-day per year for conservation of SIFs.

TABLE 2 Socio-economic profile of the respondents.

Socio-economic parameters	Profile
Average age	49 years
Male	79%
Female	21%
Educational status	Illiterate:24%
	Graduate: 4%
	Higher secondary: 7%
	Secondary: 32%
	Primary: 33%
Occupation	Agriculture: 63%
	Fishery: 21%
	Others: 16%
Average annual household income	Rs. 52,630/−
Catches fishes for consumption purpose	49%
Average time spent for catching fish in a day	3.5 h
Positive attitude toward regulation	80%
Positive attitude toward conservation	78%
Bid value	INR 490/−

3.1. Factors influencing participant's PAR and WTP

Analyses set off for the best predictive model of PAR and WTP, and two sets of parameters were estimated corresponding to two model fittings. Vector Generalized Linear Model (VGLM) estimated the first set, while Vector Generalized Additive Model (VGAM)—with a non-linear "Age-response" curve estimated the second set. Out of six explanatory variables, "Gender" was further discarded from both the models due to Hauck-Donner effect (Hauck and Donner, 1977) encountered during model-fitting process; and final results are depicted in Tables 3, 4. The residual deviance of the VGAM (=130.436) was lower than that of VGLM (=146.265), and the log-likelihood value of VGAM (= −65.218) was also higher than that of VGLM (= −73.133). Thus, VGAM performed better than VGLM, based on the model performance criteria of residual deviance and log-likelihood value. Age has noticeably no significant linear effect in the VGLM (Table 3). Thus, improvement in the values of model selection criteria owed incorporating nonlinear effect of age. So, it was worthy to incorporate a non-linear effect of age on "WTP" and "PAR." Thus, the VGAM was selected for further model-based data interpretation.

Conservation awareness, *Literacy* and *Occupation* significantly influenced the participants' willingness to participate (Table 3). *Conservation awareness* positively affected the PAR and WTP (Table 4). The predictive odd of PAR was just above 14 times

TABLE 3 Test of significance of the factors influencing participants' "willingness to participate" and "willingness to pay," using Vector Generalized Linear Model.

Factors	Willingness to participate $logit(p_1) = \eta_1$			Willingness to pay $logit(p_2) = \eta_2$		
	Estimate	SE	p	Estimate	SE	p
Intercept	−2.311	0.996	0.020*	−1.905	0.887	0.032*
Age	0.458	0.454	0.312	−0.208	0.338	0.537
Conservation	2.805	0.728	<0.010*	2.488	0.719	<0.01*
Literacy	2.259	0.831	<0.010*	0.489	0.672	0.467
Occupation	−0.996	0.771	0.167	−0.859	0.622	0.185
Household income	0.892	0.691	0.196	1.001	0.574	0.090
	Odds ratio = 54.104		Residual deviance = 146.265 Log-likelihood = −73.133 Degrees of freedom = 281			

*Significant.

TABLE 4 Test of significance of the factors influencing the participants' "willingness to participate" and "willingness to pay," using VGAM model.

Factors Linear effect	Willingness to participate $logit(p_1) = \eta_1$			Willingness to pay $logit(p_2) = \eta_2$		
	Estimate	SE	p	Estimate	SE	p
Intercept	−0.769	0.974	0.430	−1.555	0.933	0.095
Conservation	2.644	0.717	<0.010*	2.547	0.701	<0.01*
Literacy	1.718	0.794	0.030*	0.443	0.688	0.519
Occupation	−1.423	0.735	0.043*	−0.853	0.593	0.152
Household income	1.167	0.733	0.111	1.063	0.478	0.013*
Non-linear effect		df[a]	p			
f(age): η_1		2.8	0.041			
f(age): η_2		2.7	0.045			
f(age): η_3		2.7	0.834			
			Residual deviance = 130.436 Log-likelihood = −65.218 Degrees of freedom = 279			

*Statistically significant. [a]df, degrees of freedom.

($e^{2.644} = 14.06$) more in favor of conservation than against the conservation. Equivalent interpretation in terms of predictive probability was that there was 55% (*Prob* (*PAR* = *1*|*Conservation* = *1*) – *Prob* (*PAR* = *1*|*Conservation* = *0*) more chance of willingness to participate among respondents in favor of conservation. Similarly, the odd of PAR was approximately 6 times ($e^{1.718} = 5.578$) more among literate respondents. Equivalent probabilistic interpretation was that chance of willingness to participate was approximately 40% more among literate participants. The odd of PAR was 4 times less ($e^{1.432} = 4.157$) among respondents with *Fishery as occupation* than those with other occupations. Alternatively, the chance of PAR was approximately 22% less among participants having fishing as their occupation. It is evident (Table 4) that the relationship between probability of PAR and age is non-linear ($p < 0.05$, df = 2.8). The probability of *Willingness to participate* increased initially with increase in age but plateaued at the age of 45 (Figure 2). Thereafter a decreasing trend of probability of PAR against age was reflected after 60 years of age. So, participants aged between 45 and 60 years were more willing to participate than participants belonging in the rest of the age groups.

Conservation awareness and *household income* had significant positive influence on the participant's WTP (Table 4). In contrast to PAR, *literacy* and *fishery as occupation* did not have any significant effect on participant's WTP (Table 4). The predictive odd ratio of WTP was approximately 13 times ($e^{2.547} = 12.77$) more among participants in favor of conservation. Probabilistically, the chance of WTP was 54% more among the participants in favor of conservation. The odd of WTP was nearly 3 times ($e^{1.063} = 2.895$) more among participants with household income more than $740 (INR 55,000/−) (number of households = 35%). Alternative probabilistic interpretation was that the chance of willing to pay was nearly 20% more among participants having household income more than $740 (INR 55,500/−). Probability of WTP increased with the ages up to approximately 32 years (Figure 3). Thereafter, it continued to be approximately constant but a sharp decrease was observed after the age of 50. Thus, probability of WTP was relatively higher among the respondents aged between 32 and 50 years.

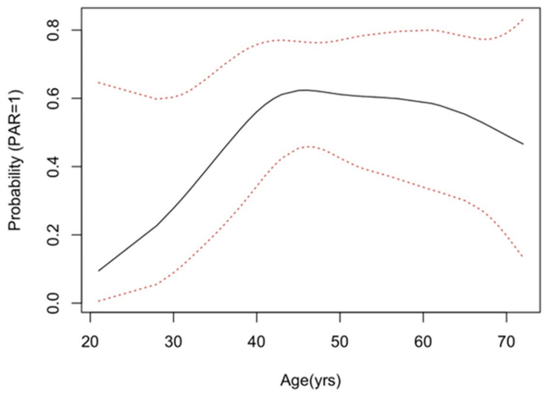

FIGURE 2
Probability of "willingness to participate" (PAR) against age. Solid line denotes the predictive probability and dotted red lines denotes ±1.95 × SE.

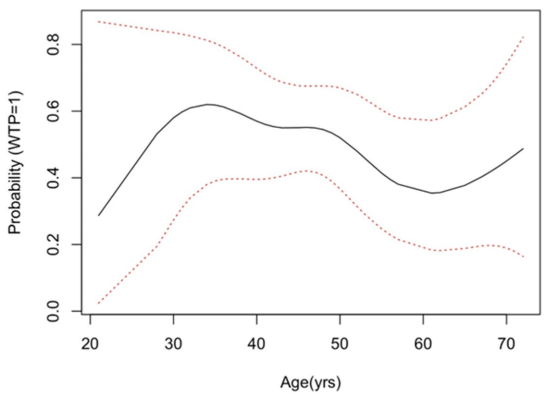

FIGURE 3
Functional form of probability of "willingness to pay" (WTP) and age. Solid line denotes the predictive probability and dotted red lines denote 95% confidence interval.

The observed overall log-odd ratio of PAR against WTP was 3.73, which indicated high positive association between PAR and WTP. However, the same was not constant but varied with age (Figure 4). Although non-linear functional form is not statistically significant (Table 4), a linear decreasing trend of log-odd against age was observed. It is noteworthy that the association between PAR and WTP changes from positive to negative after the age of 55 years.

4. Discussion

The present study demonstrated a model-based approach to assess the impact of socio-economic and environmental attitudinal factors (e.g., awareness about SIF conservation) on willingness-to-participate (PAR) and willingness-to-pay (WTP) toward conservation of SIFs. For this purpose, a bivariate logistic GAM model with non-linear logit function was applied. Though the bivariate probit model would provide similar results, the bivariate logistic model was preferred due to its simplicity and ease of results interpretation, especially the interaction between PAR and WTP. Further, bivariate logit model provides a better model fit (Chen and Tsurumi, 2010), as it uses response data directly rather than latent variable that is used under probit regression. We have established that GAM model outperformed frequently used GLM, which is a new contribution for PAR and WTP analysis. Estimation of association between PAR and WTP as a nonlinear function of age reveals that overall positive association decreases with the increase of age and jumps to negative after the age of 55 years.

SIF fisheries are a part of natural resources, aquatic resource to be precise, on which little information is available on conservation status. A socio-ecological system's conservation strategies must account for two key components: ecological and socio-economic (Bryan et al., 2011). In the absence of any formal ecological research results that may support formulating a conservation strategy, the present study has immense importance on SIF fisheries. The results of this study emanated from a bottom-up approach, which, according to Mehta and Heinen (2001), has multiple benefits such as income generation and conservation of ecological resources. In fact, the feelings and perceptions of stakeholders at the grassroots level are important for the planners and policy makers as the principles of sustainability and equity percolate downstream. The results provide enough evidence toward conservation strategies for SIF fisheries and thereby, a direction toward livelihood improvement.

Literacy, *conservation awareness* and *occupation* have significant influence on PAR, and *conservation awareness* and *household income* have significant impact on WTP. As expected, the "household income" and literacy positively affect PAR and WTP, albeit not statistically significant. This statistical output could be due to the bias in the respondents' perception. So, the results for those effects can be treated as indicative explanatory variables rather than good predictors; the same has been reflected in the observed data (Table 5).

Literacy had a significant positive impact on respondent's PAR. This finding is similar to Zhu et al. (2016) who established education as an important factor in farmers' decision to participate in a wetland restoration program. Thus, *Literacy* can be an imperative for policy-making for SIF conservation. Strikingly, occupation negatively affected respondents' PAR; with respondents with fishing as an occupation less likely (22%) to participate in SIF conservation program than those with other occupation. Besides occupation seems to have a negative effect on WTP-though statistically non-significant. Because, the fishermen had an assumption that the conservation programs may affect their livelihoods. The respondents (63%) reported agriculture as the main occupation with fisheries as part time occupation, thus they have alternative livelihoods. Respondents solely reliant upon fisheries (22%) may be apprehensive toward conservation program, because participation in the conservation program is directly linked to their income. Fisher might be afraid of unforeseen loss of income that other sources cannot meet.

Conservation awareness has a significant positive effect (55% more probable in aware than unaware respondents) on WTP. As discussed earlier, the respondents were already aware of conservation of SIFs, resulting in their affirmative consequences. Hence, they have a positive attitude toward conservation that leads to a positive and significant effect on PAR. Conservation awareness also has a similar (54% probable than those unaware of conservation) significant positive effect on WTP. The sharp decline in the population of SIFs noticed by the respondents in the study area and the conservation initiative by

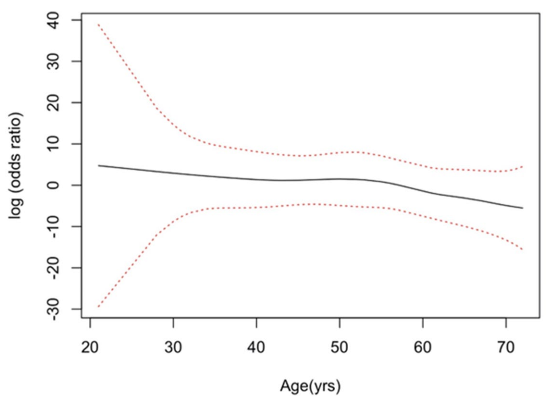

FIGURE 4
Functional form of log (odds ratio) and age. Solid line denotes the predictive probability and dotted red lines denote 95% confidence interval.

TABLE 5 Distribution of respondents according to PAR, WTP with respect to occupation and household income.

		PAR		WTP	
		No	Yes	No	Yes
Occupation	Others	11	52	23	40
	Fishery	12	25	14	22
Household income	<55,000	19	44	29	34
	>55,000	4	31	7	28

research agency have disseminated awareness among the populace about the importance of SIF regarding livelihood and nutritional security. This has resulted in a significant positive effect on respondent's PAR as well as WTP. This is arguably the most important factor related to environmental attitude that influences both PAR and WTP, and it can be one of the most significant variables for conservation strategies.

The results indicate that *household income* has a significant positive effect on WTP of the respondents. Petrolia and Kim (2011) and Ghosh and Mondal (2013) found similar results but Zhang et al. (2011), Kong et al. (2014), and Zhu et al. (2016) found different effects. *Household income* increases the financial ability to pay, thus becomes a facilitating factor for the respondents to respond in favor of WTP.

Several studies have shown that age has a linear effect, and younger members are more willing to participate and pay for any conservation program (Bonnieux et al., 1998; Vanslembrouck et al., 2002). This study found a nonlinear *response-age* (PAR and WTP are responses) curve using VGAM, which highlights effects of age group on PAR and WTP toward SIF conservation. The 45–50-year-old and the 32–50-year-old age groups were more likely respondents (more than 55% probability) for PAR and WTP, respectively, than the rest. The 32–60-year-old age group has seen decadal changes in availability and sharp decline in abundance of SIFs in the natural water resources of the study area, which might have impelled them to participate in conservation program of SIFs. The young age group (less than 30 years) is less likely WTP for any conservation program because they do not foresee the SIFs fishery as a profitable venture. It is conceivable that older people, in general, do not change their attitude toward new endeavors. They have possibly failed to perceive the long-term sustainable benefit of SIFs conservation, probably they have experienced negative result out of similar programs earlier, thus they are unwilling to pay, although a proportion of them are willing-to-participate. Similar negative effect of age on WTP to aquaculture insurance has been reported (Zheng et al., 2018), and on PAR toward ecosystem conservation (Xu et al., 2022), strengthening our findings. In addition, the results have provided an interaction pattern between WTP and PAR, which indicates decreasing interaction against age and changes from positive to negative after the respondents reach an age of 55 years; "*old age*" itself is the reason for explanation, as young people are more risk-seeking before taking any decisions, but older people avoid risk to participate with payment. By taking the intersection of the three age groups, the most conservative estimate of the most likely age group to launch SIF conservation programs is 44–50 years. The finding will be helpful in implementation of policy decision in this regard.

5. Conclusion

Understanding stakeholder decision processes plays a crucial role for designing and implementing conservation strategies, especially for SIF fisheries, where little or no information is available. The present study provides critical insights into respondent's decision on participation and payment toward SIF conservation programs, based on a survey among people involved in SIF fisheries in the Sundarbans. The current study possesses certain limitations, including a small sample size, restricted spatial coverage, and reliance on contingent valuation. Nonetheless, the proposed model-based approach exhibits a high degree of generality, making it readily applicable for replication with a larger sample size and broader spatial scale. This potential future research area can address the aforementioned limitations. Despite the somewhat outdated data, the study presented a convenient framework that yields results with policy implications. The study has suggested "*Literacy*," "*Conservation awareness*," "*Occupation*," and "*Household income*" as significant factors that influence respondents' decision; these factors can be essential components of a matrix for policymaking on SIFs conservation. "Conservation awareness" has been the most important determinant to participate or pay in the SIF conservation; thereby it can get the highest point of leverage for matrix construction on policy-making. The government may extend "conservation awareness" programs to increase participation in SIF conservation program. However, increasing "Conservation awareness" alone may not increase participation, especially payment for conservation, as enacting conservation strategies may be directly affected by loss of income. Therefore, government should provide financial incentives to prospective income-losers during conservation programs. The study has indicated that both the probabilities of PAR and WTP in the 45–50-year-old age group are relatively higher than the rest of the age groups. This age group can be targeted as prospective implementers of conservation program on SIF.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the (patients/participants OR patients/participants legal guardian/next of kin) was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

AR: conceptualization, methodology, formal analysis, investigation, data curation, writing-original draft, review, and editing. MN: methodology, formal analysis, and validation. AS: investigation. RM: methodology and formal analysis. SS: GIS mapping. AE: writing—review and editing. BD: project administration, review, and editing. All authors contributed to the article and approved the submitted version.

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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.

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