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Traditional Fish Farming Based on Indigenous Knowledge in Homestead Pond Can Uplift Socioeconomic Status of Coastal Rural People and Sustainability

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Abstract: In a time of environmental degradation and increasing demand for safe food production, traditional fish farming is gaining global attention. Utilizing indigenous agricultural methods founded on traditional knowledge contributes to sustainability by safeguarding the ecosystem and preserving biodiversity. However, it is still less studied whether traditional farming systems based on indigenous knowledge currently in place are improving the socioeconomic conditions of farmers. Hence, this study was conducted with the following objectives: (i) to reveal the present status of traditional fish farming systems, (ii) to define the socioeconomic profile of the farmers, (iii) to identify the problems associated with traditional fish farming, and (iv) to show the inter-relationship between fish farming and socioeconomic development. For achieving these objectives, data were collected from 100 small-scale fish farmers from a rural coastal area of Bangladesh through a well-structured questionnaire, focus group discussion, and cross-check interviews. Our findings showed that most of the homestead ponds were small-sized (44%) and shallow (61%) where a polyculture system was prevalent (91%). The majority of the ponds (77%) were found to be perennial, 60% of which had single ownership. Socioeconomic data revealed that the highest number of farmers (42%) earned 1000.00 to 1500.00 USD annually, and 62% of the respondents took fish farming as their secondary occupation. Among the farmers, 62% had primary education, whereas 7% had no education, and only 26% of the farmers had official training in fish farming, indicating that culture management was mainly based on indigenous knowledge. A total of 55% of the farmers had 5 to 10 family members, and 80% of them lived in joint families. Furthermore, 40% of the farmers owned tin shed houses, whereas the maximum (60%) utilized *katcha* toilets. However, almost half of the farmers (57%) utilized their own funds for fish farming, and the majority (90%) had access to their own tube well. The study found that the biggest obstacles to fish farming were pressure from large families, a lack of education and training, a lack of quality seed and feed, outbreaks of fish diseases, an inadequate supply of water during the dry season, and a lack of adequate funding. However, Pearson correlation showed that there was a significant positive association between age and experience ($r = 0.908$, $p < 0.01$) and age and income ($r = 0.326$, $p < 0.01$). Multiple regression analyses also demonstrated that age and experience in fish farming played a significant role in increased annual income. In conclusion, 94% of the respondents claimed that fish farming had improved their socioeconomic situation. Homestead pond fish farming through indigenous knowledge increased household fish consumption with a source of protein and micronutrients, improved dietary diversity, and generated extra household income, which inferred their better sustenance.

Keywords: sustainable fish farming; homestead ponds; socioeconomic status; inter-relationship; constraints

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1. Introduction

One of the biggest challenges of this century is ensuring safe food and food security because of the high population growth rate. To meet this problem, agricultural scientists are continually making efforts to develop new technology and cultural practices, for instance, intensive fish culture systems through gene manipulation, etc. Although fish yields have been boosted by many folds with this updated modern intensive culture technology, there has been a significant environmental cost [1]. It has compromised the ecological integrity of aquatic habitats through the extensive use of agrochemicals, resources, and equipment. Additionally, it has posed a danger to long-standing conventional aquaculture methods, one of the main industries providing a livelihood to the highest number of coastal rural residents. As a result, traditional fish farming practices are receiving more attention globally in the context of sustainable food production.

The fisheries sector has a lot of potential for the socioeconomic growth of Bangladesh as one of the most productive and dynamic industries. The sector makes a sizeable contribution to the consumption of animal protein (60%) and the GDP (3.52%) of the country [2]. The coastal aquaculture sector in Bangladesh is growing fastest, similar to other tropical or subtropical countries, as it is blessed with suitable sites, cultivable species, and favorable climatic conditions, and it is essential for providing nutrition, creating jobs, reducing poverty, and earning foreign currencies [3] or, to put it another way, for socioeconomic progress [4]. The aquaculture industry in Bangladesh is built on pond culture, which accounted for more than 80% of all reported output in 2014–15 and more than 55% of the area under cultivation [5]. Examples of pond aquaculture include small-scale homestead ponds and industrial aquaculture. More than half of all documented aquaculture production comes from the latter [6], despite nearly all homes in coastal areas of Bangladesh having a small homestead pond. These ponds are found close to houses and are frequently used for extensive aquaculture operations based on farmers' own knowledge or indigenous information. However, it has been reported this cultural practice decreases malnutrition and offers opportunities for income [7,8], as well as giving women a great chance to engage in the fish culture system [9]. There are over 4 million small-scale homestead ponds in Bangladesh that occupy an area of 266,259 ha [10]. These homestead ponds have the potential to provide 3 to 15% of household income and 25 to 50% of all fish consumption [10].

Small-scale fish farmers, one of the poorest groups in our society, lack many contemporary conveniences in daily living [4]. The main barriers to raising fish output in Bangladesh are multiple pond ownership, a lack of technical expertise, and a lack of credit [5]. In addition, one of the significant obstacles to the successful implementation of any development program (e.g., fisheries) is a lack of adequate and accurate information on the socioeconomic state of the target population (e.g., fish farmers) in society. The successful implementation of a developmental program is hampered by a lack of reliable information and socioeconomic statistics [7].

The majority of the central coastal region of Bangladesh is divided into two districts, namely, Noakhali and Lakshmipur. Numerous ponds, canals, floodplains, and the area's proximity to the Meghna River estuary all contribute to the significance of these two districts to the nation's total aquaculture and capture fisheries. In summary, the research that has been conducted so far indicates that homestead pond aquaculture in developing countries may be significant for two reasons. First of all, it regularly and conveniently makes fish available to households. Second, it provides the chance to sell extra fish to the market, which could increase household income. However, it remains unclear from the literature to what extent homestead traditional fish farming built on indigenous knowledge can contribute to better socioeconomic conditions and livelihoods. Hence, the main objectives of this study are to uncover the current status of homestead pond fish farming based on indigenous cultural practices, the socioeconomic status of the farmers, and the challenges associated with fish farming on the central coast of Bangladesh. The evaluation of farmers and farming conditions provides information as to whether and how homestead fish ponds contribute to better socioeconomic status in coastal areas. The findings will be helpful for

prospective and practicing homestead fish farmers, decision makers, researchers, extension representatives, and the general public. It will reveal fish farmer efficiency in terms of business choice, resource usage effectiveness, and production pattern decisions.

2. Materials and Methods

2.1. Study Area

The study was carried out in the coastal areas of Noakhali and Lakshmipur districts in Bangladesh from November 2018 to April 2019. Noakhali is situated between 22°07′ and 23°08′ N latitudes and 90°53′ and 91°27′ E longitudes, while Lakshmipur is between 22°30′ and 23°10′ N latitudes and 90°38′ and 90°01′ E longitudes. There are approximately 414 ha and 13,110 ha of ponds present in the Ramgati Upazila of the Lakshmipur district and Noakhali district, respectively, of which most of the ponds are suitable for fish farming [2]. These homestead ponds have the potential to provide 3 to 15% of household income and 25 to 50% of all fish consumption [10,11]. Homestead ponds have frequently been decried as inefficient by the Department of Fisheries (DoF), the organization in charge of providing guidance to fish farmers, due to the traditional methods of production and the ponds' subpar yield [12]. However, data were gathered from 100 randomly chosen homestead pond fish farmers from 5 coastal upazila, e.g., Noakhali Sadar, Subarnachar, Kobirhat, Companiganj under the Noakhali district, and Ramgati Upazila under the Lakshmipur district (Figure 1).

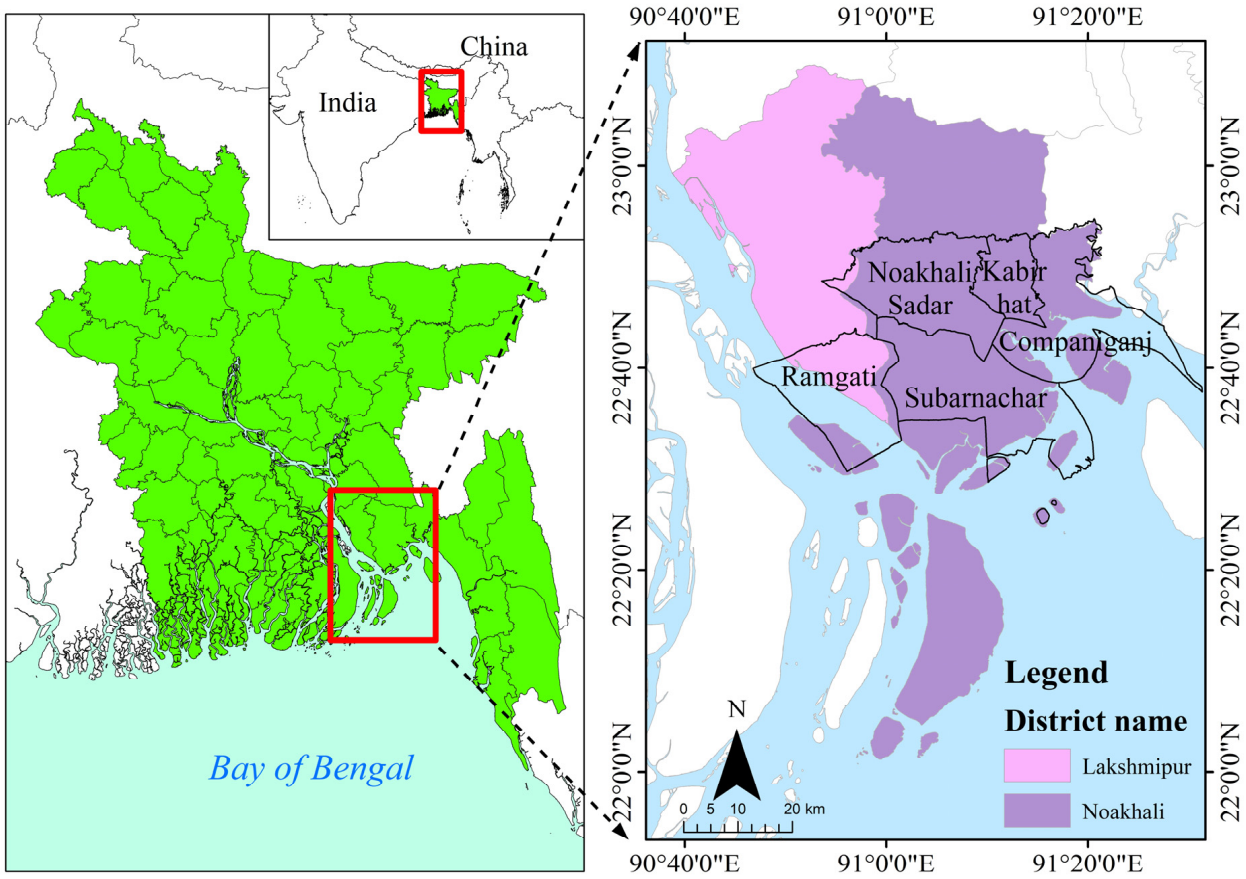

Figure 1. Location of the study sites on the central coast of Bangladesh.

2.2. Data Collection Method

To collect primary data on fish farming status and socioeconomic conditions of the homestead pond fish farmers, a set of questionnaires was designed, including both open and forced forms of questions and pretested with a few pond fish farmers [13]. Then, the questionnaire was modified, enhanced, and reorganized in light of the results from the pilot study. The final questionnaire was organized to collect descriptive data on the status of fish farming and the socio-demographics of fish farmers (income, age, religion, education, family size, etc.). Likert scale with values of 4, 3, 2, and 1 was established to measure constraints experienced by farmers in the studied area. In this method, the fish farmers were questioned to assess their constraint as very critical, critical, to some extent critical, and not critical. A variable mean score of 2.5 was utilized to assess whether the component in question was critical or not. Variables with a mean score of 2.5 and above were recognized as critical, whereas variables with less than 2.5 were not [14]. In this way, the pond fish farmers were asked to rate how "not critical, to some extent, critical, and very critical" their constraint was.

The central library of Noakhali Science and Technology University and other government and non-government institutions, including the District Fisheries Office and other relevant published articles, were used to compile secondary data on farming and socioeconomic situation.

2.3. Processing and Analysis of Data

The mean, percentage, chi-squared test, and simple linear regression were calculated using MS Excel (MS 365) and SPSS software (version 25.5). ArcGIS (version 10.7) was used to generate the research area map. The statistical cut-off was set at $p < 0.01$ or $p < 0.05$. To better understand the current state of fish farming and the socioeconomic circumstances of homestead pond fish farmers, the final results were presented in textual, tabular, and graphical formats.

3. Results and Discussion

3.1. Farming Status

3.1.1. Pond Size and Depth

All management techniques used in pond fish farming must take pond size and depth into account. These aspects were taken into account while developing management strategies in this study. Based on the varying sizes of ponds in the investigated area, three categories were recorded: small ponds (<200 m^2), medium ponds (200–325 m^2), and large ponds (>325 m^2) (40.46 m^2 = 1 decimal) [9]. Only 16% of the cultivated ponds were fairly large (>325 m^2), with the rest of them (44%) being smaller (<200 m^2) (Table 1). Our findings were almost aligned with Das et al. [7], who also reported that most of the cultured ponds (60%) were small (1–4 decimals). However, it was observed that fish farmers can easily manage small ponds during both cultivation and harvest.

Furthermore, 61% of the ponds had a depth of 1–2 m or less, which is ideal for fish farming in the research location (Table 1). The present data align with a previous study that reported 53.64% of ponds had a depth ranging from 1 to 2 m [7]. This range of pond depth really made all the management tasks, such as cultivation and harvesting, simple. While a similar study in the Patuakhali district revealed an average pond depth of higher than this study [14]. In general, the average depth of ponds in Bangladesh is between 2 and 5 m [15], which corresponds well with the present study. Kubra et al. [16] noted that the effectiveness of fish culture relies on the dimensions and depth of the ponds.

Table 1. Fish farming status of homestead ponds on the central coast of Noakhali.

Variables	Frequency	Percentage (%)
Pond size (m^2)		
Small (<200)	44	44
Medium (200–325)	40	40
Large (>325)	16	16
Pond depth (m)		
Low (1–2)	61	61
High (>2)	29	29
Pond ownership		
Single ownership	60	60
Multiple ownership	40	40
Pond type		
Seasonal	77	77
Perennial	23	23
Culture type		
Monoculture	9	9
Polyculture	91	91
Harvesting frequency		
Total harvest	22	22
Partial harvest	78	78
Purpose of fish production		
Personal	36	36
Sell	50	50
Both	14	14

3.1.2. Pond Ownership

Pond ownership is an indispensable factor in making simple decisions regarding fish farming. A pond having multiple ownership is very troublesome in comparison with single ownership [17]. It was observed that the highest number of ponds (60%) was owned by single owners, followed by joint or multiple owners (40%) in the study area (Table 1). A comparable study was carried out in Gazipur Sadar Upazila, where a significant proportion of farmers (74.56%) engaged in fish farming in their own ponds, while 20% of the ponds had multiple owners [7], which closely resembles the findings of the current study.

3.1.3. Pond Type

In the study area, it was observed that ponds were seasonal in 77% of the cases and perennial in 23% of the cases. (Table 1). The present results align closely with the findings of Das et al. [7], who reported that 20.71% of the ponds were permanent, and 79.09% were seasonal. Since perennial ponds lose water during the dry season and become useless for raising fish, some farmers fill their ponds with water to keep the water level up. The dry season makes seasonal ponds unsuitable for fish farming as well. The sandy soil properties play a crucial role in influencing the effects of the dry season on these seasonal ponds. These findings agree with the observations made in a study by Rana et al. [18].

3.1.4. Culture Type

The fish harvesting peak occurred mainly during December and January, while fish fry were stocked between April and June, as they became available. The predominant practice among farmers in the study area (91%) involved using polyculture (Table 1). Rana et al. [18] reported almost similar results in the Gopalgonj Upazila of Sylhet district, where 99% of the farmers practiced polyculture in their ponds. In polyculture, each species stocked has its own niche that reduces competition with other species; additionally, this notion is widespread among farmers. In contrast to monoculture, polyculture makes better use of the limited area and food resources [19]. In this system, farmers cultured mainly Indian major carps viz., Catla (*Geblion Catla*), Rohu (*Labeo rohita*), Mrigal (*Cirrhinus cirrhosus*), Tilapia (*Oreochromis mossambicus*), and Sarputi (*Puntius sarana*), as well as Pangas

(*Pangasianodon hypophthalmus*) in the sampled ponds. Fish farmers did not follow any scientific combination of the species. A related study revealed that the peak period of carp polyculture was from April to June [18]. However, Alom et al. [20] suggested that the best season of carp farming was from March to December and in polyculture.

3.1.5. Harvesting Frequency

Fish are harvested from ponds throughout the year, but this study has revealed that the busiest months are December and January, as the fish reach marketable sizes and command the highest market prices during this period. In this study, it was found that 78% of the fish supplied had been partially harvested in December and January (Table 1). All farmers used to partially harvest fish from their cultivated ponds, according to Zafar et al. [21]. In Gopalgonj Upazila, the peak fishing period was from December to January, during which 70% of the fish were caught; the remaining 30% were caught at a different time of year [18].

3.1.6. Purpose of Fish Production

Out of 100 fish farmers, half of them (50%) utilized the fish they produced for sales, 36% used the fish just for personal consumption to meet their nutritional needs, and the other 14 % used it for both sales and consumption (Table 1). According to research by Zafar et al. [21] on the state of aquaculture practices in a few chosen locations of the Dinajpur district, 92.5% of fish farmers exclusively raise fish for their own consumption, while the remaining farmers (7.5%) raise fish for both their own consumption and for sale. This variability is possibly due to financial conditions and family needs. However, the chi-squared test showed no significant association for categorical variables for pond type with harvesting frequency ($p < 0.05$) and the purpose of fish production ($p < 0.05$), as well as harvesting frequency with fish use ($p < 0.05$).

3.2. Socioeconomic Profile

3.2.1. Human Capital

Age Distribution

It is crucial to understand the age distribution of fish farmers in order to account for the prospective human resources. The three age groups of young (15–35), middle-aged (36–50), and elderly (51–70) were taken into consideration when examining the age distribution (Figure 2). It was discovered that the age range of 15 to 35 years had the highest proportion (67%) and the age range of 51 to 70 years had the lowest percentage (15%) among all fish farmers. This shows that there were a lot of employable people. In the district of Patuakhali, the majority of farmers (43.33%) were between the ages of 31 and 40 [20]. The age structure of rural communities in the Mymensingh district ranged from 25 to 65 years, as reported by Kabir et al. [22], which agrees more or less with the present study.

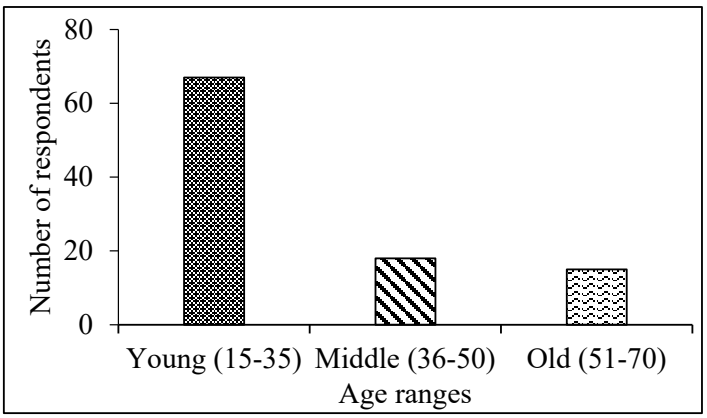

Figure 2. Age distribution of homestead fish farmers in the study area.

Religious Status

Religion plays an important role in the cultural and social life of people in a particular area, which acts as a constraint or modifies the social patterns of people. In the present study, it appeared that most of the pond fish farmers were Muslim (79%) and the smallest portion (21%) were Hindu (Table 2). Alom et al. [20] stated that the majority (90%) and minorities (10%) of fish farmers were Muslims and Hindus, respectively, which is more or less similar to the present findings.

Table 2. Demographic profile of homestead pond fish farmers in the central coastal area.

Variables	Frequency	Percentage (%)
Human capital		
Religion		
Muslim	79	79
Hindu	21	21
Household size		
Small (<4)	17	17
Medium (5–6)	28	28
Large (>7)	55	55
Family type		
Joint	80	80
Nuclear	20	20
Education		
Illiterate	7	7
Primary	62	62
Secondary	23	23
Higher secondary	4	4
Graduate/ bachelor	4	4
Financial capital		
Sources of credit		
Self	56	56
Bank	14	14
NGOs	30	30
Primary occupation		
Fish culture	16	16
Agriculture	28	28
Business	22	22
Day labor	22	22
Poultry raising	5	5
Others	7	7
Secondary occupation		
Fish culture	62	62
Agriculture	12	12
Business	11	11
Day labor	5	5
Poultry raising	8	8
Others	2	2
Physical capital		
Land area (m^2)		
Small (<850)	73	73
Medium (850–2025)	23	23
Large (>2025)	4	4

Table 2. *Cont.*

Variables	Frequency	Percentage (%)
Health facilities		
Village	39	39
Upazila	31	31
MBBS	10	10
Kobiraj	20	20
Drinking water sources		
Own	50	50
Neighbor	42	42
Pond and tube well	8	8
Sanitary facilities		
Kacha	60	60
Semi-pacca	23	23
Pacca	17	17
Electricity facilities		
Yes	72	72
No	28	28
Length of time involved in fish farming (years)		
1–5	8	8
6–10	31	31
11–15	15	15
>16	46	46
Training and experience on fish farming		
Self	68	68
Friends	6	6
Upazila	12	12
NGOs	14	14
Livelihood outcome		
Positive outcome	94	94
Negative outcome	6	6

Household (Family) Size and Types

Household size was defined as the number of people who were either employed or unemployed but belonged to the same family. In this study, household size and types were studied because homestead pond fish farming methods demand a significant human effort from stocking and routine management to harvesting. The families of fish farmers were divided into three groups based on the number of household members they had: small (<4), middle (5–6), and large (>7). In the present research area, 17% of fish farmers had less than four members, while 28% had 5–6, and 55% had more than seven family members (Table 2). A previous study showed that most of the farmers' families (62.5%) had less than seven members in the Patuakhali district [14]. It was recorded that the highest number of fish farmers (75%) had 5–6 family members whereas only 15% had 2–4 and 10% had 7 or more family members in Hobiganj district [9]. The result is more or less similar to the findings of the present study. Household size has a great impact on the income and expenditure of the family.

Among the pond fish farmers, households or families were classified into two types: the nuclear family and the joint family. In the study area, 80% of pond fish farmers lived in joint families and 20% in nuclear families. The above results are corroborated by the findings of Hossen et al. [23], who stated that the attitude of the farmers to live in joint families and nuclear families was about 80% and 20%, respectively, in Kirtankhola River. Both studies showed that the joint family was predominant. The findings of the present study implied that the pond fish farmers of the surveyed area were assenting to live in a joint family owing to the economic condition as a result in the study area the percentage of the nuclear family is lessening gradually. On the other hand, a joint family simplifies

fish farming activities through contributions from other members of their family in fish farming activities when compared to a nuclear family.

Education

The current study categorized pond fish producers into five educational background groups. Based on the findings, 62% had completed their primary education, 23% had completed their secondary education, 4% had graduate degrees, and 7% of the homestead pond fish farmers were found to be illiterate. However, the average literacy rate (93%) in the study region was higher than Bangladesh's overall average literacy rate (65.5%) [24], and the majority of pond fish farmers (62%) had completed primary school. In a previous study, Das et al. [7] revealed the present status, problems, and prospects of fish farming at Gazipur Sadar Upazila in Bangladesh, where 21% of farmers had primary education, while 56% received secondary education, 10% received higher secondary education, and just 9% received higher education, as well as the rest of them were illiterate. These results are more or less similar to the present findings due to the consciousness about education and socioeconomic status of parents influencing the children's education level. The education level of farmers greatly affects the utilization of ponds as well as their fish production [16]. During the survey, older pond fish farmers reported that a few educational institutions in their childhood and extreme poverty forced them to enter into the fish farming profession at an early age of life.

3.2.2. Natural Capital

The term "natural capital of people", in the context of fish farming, refers to the environmental assets that farmers and related communities need to sustain production, such as pond area, open water, land, soil type, fish seed, snails, and tubifex for larvae. The production of fish requires the use of vast areas of land, water, and natural resources. The accelerating loss of natural capital, which is a result of high population growth, has an effect on their income. A fantastic opportunity for managing the community's fisheries and fish farmers' sustainable livelihoods by harnessing natural resources is provided by the study area's close proximity to beels, canals, and floodplains. In the study area, almost every house had a small pond.

3.2.3. Financial Capital

Sources of Credit

In the current study region, 30% of fish farmers received loans from NGOs due to their poor income, as opposed to 14% of fish farmers who received loans from banks. A total of 56% of farmers in the current research area invested their own money in fish farming (Table 2). Only 27% of farmers in the Hobiganj district received bank loans for fish cultivation, whereas the bulk of fish farmers (65%) funded their businesses with their own money [9]. The study region showed that small farmers were in unfavorable circumstances for pond fish farming because they lacked financial support from institutional finance.

Primary and Secondary Occupations

The majority of farmers in the studied areas hunted for additional jobs to maintain their families. Primary and secondary occupations can be separated into the two groups below based on their relative importance (Table 2). It was highlighted that most farmers did not depend primarily on fish farming for their livelihood. Our survey found that 28% of fish farmers said that farming was their major occupation, followed by small-scale business ownership and shop-keeping (22%). Only 16% of pond fish farmers identified fish farming as their primary occupation. It was claimed that a primary occupation alone was insufficient to offer a suitable means of subsistence. Furthermore, in order to protect their year-round livelihood, 62% of pond fish farmers claimed that their secondary occupation was fish farming, while 12%, 11%, 5%, and 8% were employed in agriculture, business, day labor, and poultry farming. In the Sylhet area, Rana et al. [18] noticed that 44% of pond fish

farmers considered fish farming as their main occupation, and 24%, 30%, and 2% of the farmers were related to agriculture, business, and other activities as secondary occupations.

Annual Income

According to their annual household income, pond fish farmers were categorized into five categories in the study area (Figure 3). The first category included pond fish farmers having annual incomes of up to 500 USD. The second, third, fourth, and fifth categories had an annual income of 500.01–1000.00 USD; 1000.01–1500.00 USD; 1500.01–2000.00 USD; and >2000.01 USD, respectively (1 USD is equivalent to 84 BDT), whereas the median income was 1439.29 USD. It was found that the 1000.01–1500.00 USD categories had the highest number (42%) of farmers, which was lower than the national average annual income (2284 USD) [25]. On the other hand, annual income categories for up to 500 USD had the lowest number (5%). In comparison with the findings of Rana et al. [18], the income level of fish farmers in the study area was relatively higher than the fish farmers in Gopalganj Upazila under Sylhet district. They found the highest percentage (51%) of fish farmers earned BDT 50,000 to 70,000 per year, which was lower than the present findings. However, the lower annual income in Noakhali district indicates that this district is undeveloped and needs more social and commercial support to educate farmers on better fish farming methods and improve health care facilities.

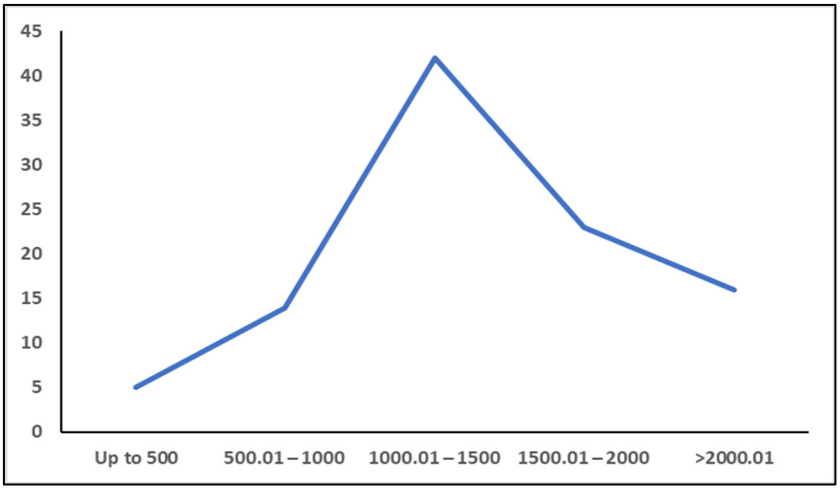

Figure 3. Annual household income of homestead fish farmers in the study area.

3.2.4. Physical Capital

Housing Condition

The housing condition reflects the social standing of its inhabitants. During the study, an effort was made to assess the condition of the fish farmers' residences in order to ascertain their economic situation. Our study area was not as developed as the main town of the Noakhali district, so the majority (44%) of pond fish farmers' homes were made of tin sheds, compared to 33% *kacha* homes (made of bamboo, wood, straw, and mud), 17% made of half-cemented buildings, and 6% made of cemented buildings (Figure 4), which is somewhat in agreement with the findings of Rana et al. [18].

Land Properties

According to their various sizes, the sample ponds in the survey region were divided into three categories: small land (<850 m^2), medium land (850–2025 m^2), and large land (>2025 m^2). According to the current survey, 23% of pond fish farmers had medium land (850–2025 m^2), 73% of pond fish farmers had small land (<850 m^2), and 4% had large land (>2025 m^2) regions (Table 2). According to Rahman et al. [14], the highest number (57.5%) of pond fish farmers owned medium land area (850–2025 m^2), of which the findings are

inconsistent with our study indicating that land ownership patterns varied from place to place.

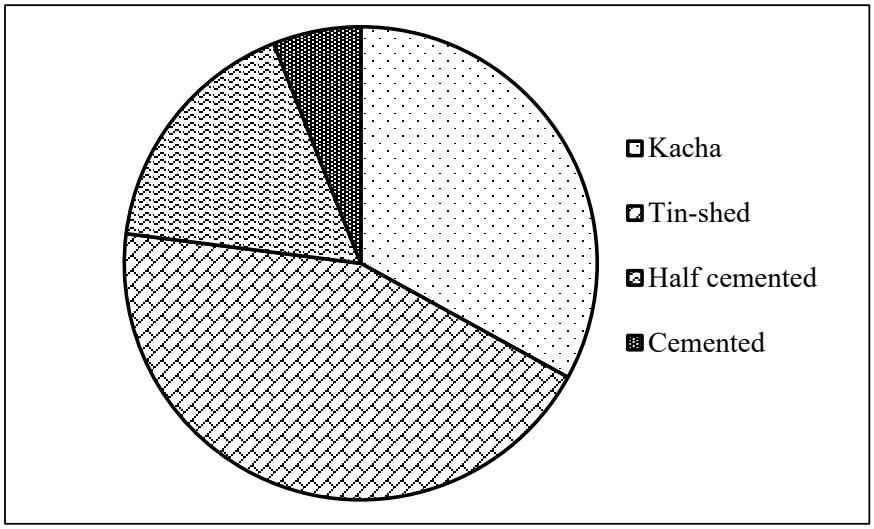

Figure 4. Housing condition of homestead fish farmers in the coastal area of Bangladesh.

Health Facilities

Poor health facilities were present among pond fish farmers, and it was found that 39% of them relied mostly on village doctors, compared to 20% who relied on kobiraj and 31% of whom went to the government Upazila hospital and 10% to MBBS (Table 2). Hossen et al. [23] found that 44% of the fish farmers received health services from village doctors, and 29% from kobiraj, which corresponds well with the present study.

Drinking Water Sources

The ability to access clean, safe drinking water is one of society's most prized possessions. Out of 100 pond fish farmers, 50% had their own tube wells, and 42% obtained drinking water from neighbors' tube wells, which was significantly less than the national utilization of rural tube wells (94.94%) [26]. Only 8% of people in this research area drank water from their backyard pond (Table 2). A prior study focused on the drinking water infrastructure of fish farmers and showed a lower ownership rate (15%) of tube wells, indicating inadequate access to clean, safe drinking water for fish farmers [23]. However, more economic support from the government and NGOs is crucial for the studied area to ensure adequate drinking water sources.

Sanitary Facilities

During the survey, attempts were made to explore their sanitary facilities, and three types of toilets were found to be used by the fish farmers: (1) kacha toilets (made of bamboo, wood, and straw), which provide low sanitation facilities; (2) semi-pacca toilets (made of wood and cemented ring), which provide moderate sanitation facilities; and (3) pacca toilets (made of brick and steel), which provide good sanitation facilities. The majority (60%) of pond fish farmers used kacha toilets, whereas only 17% of pond fish farmers had pacca toilets (Table 2). In comparison, another study reported that the highest proportion (60%) of pond fish farmers had pacca sanitary facilities [18], which is dissimilar to the present outcomes. Although, BBS [24] reported that about 53.27%, 42.98%, and 3.75% of rural people used pacca, kacha, and other toilets, respectively, which is not consistent with the present findings. This indicates that the sanitation facilities are not adequate in the studied area, which may cause serious health issues.

Electricity Facilities

In the study area, after conducting 100 interviews, it was revealed that the majority of pond fish farmers (72%) had electricity available at their homes, as indicated in Table 2. These results align with the findings reported by Hossen et al. [23]. Furthermore, the farmers of the studied area used more electricity than the typical rate for rural areas (68.85%) reported by BBS [26]. However, the consumption of electricity by the majority of the farmers is an upturn in the socioeconomic status of the pond fish farmers in our surveyed area.

Length of Time Involved in Fish Farming

According to the current study, 8% of fish farmers were new to the industry, having only been involved in fish culture for a short period of time (1 to 6 years). This may have been brought on by the growing benefits of fish farming over other occupations. Additionally, the majority of them were motivated by other farmers who discovered that fish culture was successful and raw materials were readily available. The most experienced fish farmers, who had been raising fish for over 16 years, accounted for 46% of the total respondents (Table 2). Moreover, these types of farmers were more abundant in our study than in a prior report [3]. Islam [3] observed that 53.33% of fish farmers came to aquaculture within 5 years. On the contrary, 20%, 20%, 3.33%, and 3.33% of farmers came to the aquaculture business within 6–10 years, 11–15 years, 16–20 years, and more than 20 years, which is more or less similar to the present study.

Training and Experience in Fish Farming

Only 14 out of 100 pond fish farmers attended training programs that they required for improved fish farming techniques from the Upazila Fisheries Office, with assistance from the Department of Fisheries of Bangladesh (DoF). The training was delivered by the Senior Upazila Fisheries Officer (SUFO) and Fisheries Officer. The remaining 68 fish farmers learned about fish farming through self-study, 6% from friends, and 12% from NGOs (Table 2). Rahman et al. [14] and Islam et al. [3] revealed that 22.5% and 100% of fish farmers received training from Upazila Fisheries Office under Patuakhali and Meherpur districts, respectively. There appears strong variability among the districts of Bangladesh in the training provided by the DoF and other organizations.

Livelihood Outcome

The fact that the majority of farmers (94%) reported an increase in income from fish farming implies that the study area's fish farming and related activities had a positive influence on livelihoods. Only 6% of the farmers had not improved their socioeconomic standing (Table 2) because of their lack of experience in fish farming, the high price of fish feed, poor marketing infrastructure, and a lack of investment. Farmers reported that extension services, training on fish farming, institutional and organizational support, and marketing would be helpful for notable livelihood outcomes. In Gopalganj Upazila, which is part of the Sylhet district, it was discovered that 90% of fish producers could enhance their standard of living through fish farming [18]. An earlier study in this region found that 92% of farmers in Subarnachar Upazila in the Noakhali district had improved their socioeconomic circumstances as a result of fish farming [27], which is consistent with the current study.

3.3. Chi-Squared Test between Fish Farming and the Demographic Variables

The interrelationship between fish farming and the demographic profiles of pond fish farmers of the central coastal region is presented in Table 3. In the current research, primary occupation had a statistically significant association with electric facilities and constraints at a $p < 0.01$ significance level. On the other hand, a statistically significant association between primary occupation and sanitation condition was observed at a $p < 0.05$ level of significance. Furthermore, education showed a statistically significant association

with sanitation facilities and drinking water sources at a $p < 0.01$ level of significance. On the other hand, primary occupation, house type, sanitary condition, credit source, and constraints showed a statistically significant relationship with education at a $p < 0.05$ significance level. The association between family type and pond ownership was found to be statistically significant at a $p < 0.01$ level of significance. Moreover, house type showed a statistically significant association with the culture method and livelihood outcome at a $p < 0.05$ level of significance. Land ownership patterns, health facilities, and constraints showed a statistically significant relationship with the use of fish at a $p < 0.01$ significance level. A statistically significant association between health facilities and constraints was observed at a $p < 0.01$ level of significance. A statistically significant association between sanitation condition and drinking water sources was observed at a $p < 0.01$ level of significance. Sanitation condition was statistically and significantly related to health facilities, the type of pond, harvesting frequency, culture method, and constraints at a $p < 0.05$ significance level. In this study, drinking water sources were statistically and significantly related to constraints on fish farming at a $p < 0.01$ level of significance but with health facilities, electric facilities, and livelihood outcomes at a $p < 0.05$ level of significance. Statistically significant associations between harvesting frequency and constraints as well as harvesting frequency and the use of fish were observed at $p < 0.01$ and $p < 0.05$ levels of significance, respectively. Experience in fish farming showed a significant relationship with the culture method at a $p < 0.01$ level of significance but with the type of pond, harvesting frequency, and the use of fish at a $p < 0.05$ level of significance. The type of pond showed a statistically significant relationship with harvesting frequency and constraints at a $p < 0.01$ level of significance but with the use of fish at a $p < 0.05$ level of significance. In this study, credit source showed a statistically significant association with education, electricity facilities, and the use of fish at a $p < 0.01$ level of significance but with health facilities at a $p < 0.05$ level of significance.

Table 3. Chi-squared test (non-parametric data) among the fish farming and demographic variables.

Variables	Chi-Squared Value	*p*-Value
Primary occupation and sanitary condition	11.696	0.03
Primary occupation and electric facilities	16.91	0.00
Primary occupation and constraints	75.570	0.00
Education and primary occupation	72.11	0.00
Education and house type	41.67	0.03
Education and sanitation facilities	37.46	0.00
Education and sanitation condition	18.41	0.02
Education and drinking water sources	46.06	0.00
Education and sources of credit	38.87	0.00
Education and constraints	137.71	0.00
Family type and pond ownership	6.51	0.01
House type and culture method	8.49	0.03
House type and livelihood outcome	9.60	0.02
Electricity facilities and sources of credit	15.40	0.00
Land ownership pattern and use of fish	109.14	0.00
Sanitation condition and drinking water sources	9.612	0.00
Sanitation condition and health facilities	11.35	0.01
Sanitation condition and type of pond	5.38	0.02
Sanitation condition and harvesting frequency	4.78	0.02
Sanitation condition and culture method	4.87	0.02
Sanitation condition and constraints	16.97	0.01
Drinking water sources and health facilities	15.914	0.01
Drinking water sources and electric facilities	7.172	0.02
Drinking water sources and livelihood outcome	6.38	0.04
Drinking water sources and constraints	67.54	0.00

Table 3. *Cont.*

Variables	Chi-Squared Value	*p*-Value
Health facilities and land ownership pattern	146.59	0.00
Health facilities and use of fish	23.61	0.00
Health facilities and sources of credit	15.311	0.01
Health facilities and constraints	75.39	0.00
Land ownership pattern and use of fish	109.14	0.00
Experiences on fish farming and type of pond	8.386	0.03
Experiences on fish farming and harvesting frequency	8.96	0.03
Experiences on fish farming and use of fish	13.22	0.04
Experiences on fish farming and culture method	10.14	0.01
Type of pond and harvesting frequency	**94.43**	**0.00**
Type of pond and use of fish	6.905	0.03
Type of pond and constraints	24.54	0.00
Harvesting frequency and use of fish	6.84	0.03
Harvesting frequency and constraints	25.04	0.00
Use of fish and sources of credit	**48.99**	**0.00**
Use of fish and constraints	29.68	0.00

Simple linear regression was explored to explain the effect of age on experience (Table 4). With an increase in the age of fish farmers each year, the farmer gained 0.781 years of experience in fish farming. This demonstrates that experience is a prerequisite for successful fish farming and proper management. This study revealed the higher the experience of fish farmers in fish farming, the greater the annual income (Figure 5). From this study, we can conclude that both age and experience were significant factors affecting the annual income of pond fish farmers.

Table 4. Simple linear regression among demographic characteristics of pond fish farmers.

	Unstandardized Coefficients		Standardized Coefficients	T	Significance	R	R^2	Adjusted R^2
	B	SE	Beta					
Age	0.78	0.04	0.91	21.47	0.00	0.91	0.83	0.82
Experience	13.61	3.71	0.35	3.67	0.00	0.35	0.12	0.11

Dependent variable: Experience (Yrs); annual income (USD); B—regression coefficient (parameter estimate), SE—standard error; beta—beta coefficient of estimated regression.

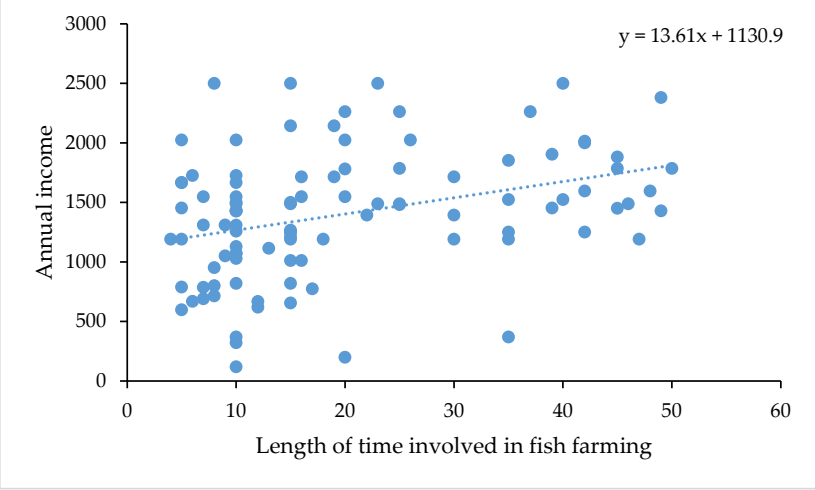

Figure 5. Scatter diagram between annual income and the length of time involved in fish farming of fish farmers.

3.4. Socioeconomic Constraints of the Pond Fish Farmers

A great number of constraints were identified by fish farmers during pond farming and marketing their goods in the local market. Hence, the Likert scale technique was used to analyze the socioeconomic constraints of pond fish farmers in the study area (Table 5). The present findings stated that household pressure for large family sizes, a lack of education due to poverty, insufficient and overflow of water during the dry season, and river erosion were very critical in the studied area. Similarly, a lack of education due to poverty and river erosion were critical constraints for the fishing community in Kirtankhula River, Southern Bangladesh [23], which agrees well with the present study. In contrast, a lack of fishing gear, a lack of credit and training facilities, unbalanced eating due to poverty, fish diseases, and poor housing conditions were not critical in the surveyed area. Though vast pond areas were present in the survey area, the fish farmers had limited resources to purchase nets and good-quality fingerlings, as well as limited access to obtain credit from different sources. Similarly, they were neglected in all respects in society. Moreover, illiteracy problems were prevalent among them, and most of them lived from hand to mouth. Owing to their extreme poverty, their children dropped out of school at an early age. Consequently, they remain illiterate, generation after generation, as well as incapable of playing a role in the prosperity of themselves and their society.

Table 5. Constraints faced by the pond fish farmers in the central coastal region.

	To Sum						
Constraints	**Very Critical**	**Critical**	**Extent Critical**	**Not Critical**	**Scores**	**Points**	**Remarks**
Lack of fishing gear	18	22	36	24	234	2.34	Not critical
Household pressure for large size family	55	8	5	32	286	2.86	Critical
Lack of credit facilities	33	8	15	44	230	2.30	Not critical
Lack of training facilities	20	12	23	45	207	2.07	Not critical
Lack of education due to poverty	56	19	9	16	315	3.15	Critical
Unbalanced eating due to poverty	15	10	28	47	193	1.93	Not critical
Fish diseases	9	10	12	69	159	1.59	Not critical
Insufficient water during the dry season	40	22	7	31	271	2.71	Critical
Overflow of water during the rainy season	47	14	9	30	278	2.78	Critical
Poor housing condition	7	9	14	70	153	1.53	Not critical
River erosion	60	19	0	21	318	3.18	Critical

4. Conclusions

The study was conducted on the central coast of Bangladesh to understand the present status of fish farming in homestead ponds, socioeconomic conditions, and find out the inter-relationships among farming status and socioeconomic attributes. The results concluded that homestead ponds were very small-sized, have single ownership, and were perennial. Polyculture systems of fish were practiced mainly for individual or family-level consumption. Most of the farmers had a low level of literacy, staying in tin-shed homes with poor sanitation conditions. They did not have access to good doctors, quality education, or even training in fish culture. Sometimes, they borrowed credit for fish culture. A lack of funding and proper training had impacts on fish farming. From the current study, it can be stated that homestead fish farmers did not follow any modern pond farming method because most of them were underprivileged in terms of many basic needs, such as education, credit sources, sanitation, good-quality seeds, training facilities, etc., as well as impeded by many constraints. After evaluating the findings, it becomes evident that

improved homestead pond fish farming is crucial for the implementation of agricultural, nutritional, and health policies in rural Bangladeshi households, as demonstrated by the following: (1) the income ensures food, calories, and protein by ensuring dietary diversity in the family; (2) the income is a complementary and significant contribution to other sources of income; (3) fish sales revenue demonstrates the high socioeconomic status of farm households; (4) the improved income can help turn subsistence farms into commercial ones; (5) the younger generation will be inspired to start their own successful businesses by engaging in fish farming activities; and (6) the reliable revenue supports the livelihoods of young rural farmers. Fish culture in homestead ponds using indigenous knowledge is a holistic approach that promotes sustainability by reducing environmental impacts, conserving biodiversity, ensuring food security, and increasing community resilience. This is because indigenous knowledge often involves low-impact or organic farming practices, which can significantly reduce the environmental impacts of fish culture in homestead ponds. In addition, communities can reduce their dependence on external sources and maintain a consistent food source even during times of scarcity by ensuring a steady supply of nutritious fish.

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