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Original Research Article

Poverty Alleviation through Aquaculture: An Inquiry into Some Selected Areas of Rural Bangladesh

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Abstract

An investigation was made to assessing the contribution of aquaculture on poverty alleviation in rural Bangladesh. A total of one hundred five (105) farmers comprising of seventy five (75) from fish farming households and thirty (30) from non-fish farming households were selected as sample. The farmers were selected using stratified random sampling techniques. The data were collected from the study areas through questionnaires survey, focus group discussion (FGD) and cross-check interviews. Results of the study indicated that current fish production increased on an average 4300 Kg/ha/year as compared to before records (1252 Kg/ha/year).Aquaculture contributed 29.67 percent on total annual income after participation in aquaculture. Estimated Benefit-Cost-Ration (BCR) was 3.10. A pronounced changing state on the quality and quantity of livelihoods capitals such as human capital, social capital, natural capital, physical capital and financial capital were observed comparing with the before situation. Fish consumption pattern analysis result showed that in before fish consumption quantity was on an average 33.66 gram/capita/day and that quantity rose to on an average of 63 gram /capita/day after participation in aquaculture. The estimated Head Count Poverty rate was found to be 16 percent in fish farming households as compared to 26 percent of the non-fish farming household which indicated that non-fish farming households were likely more poor than fish farming households. Regarding aquaculture production, income generation, livelihood assets acquisition and food fish security it was concluded from the present study that aquaculture surely have had a significant contribution to poverty alleviation in the rural Bangladesh.

Keywords: Aquaculture, Poverty, Production, Rural, livelihoods, Bangladesh.

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INTRODUCTION

Poverty and hunger are the most vital enemies of human civilization and reducing these are the top most agenda throughout the world for achieving Sustainable Development Goals for sustainable existence of the present and future generation [1, 2]. Of the different global food production systems, aquaculture is widely perceived as an important food production weapon in the global fight against malnutrition and poverty particularly within developing countries [3]. Poverty related to malnutrition and hunger can be eradicated by aquaculture and aquaculture production in Bangladesh has got a considerable momentum in terms of production, nutritional supplement and livelihood improvement of a wide range of people [4, 5]. Poverty reduction through aquaculture in the recent years has emphasized particularly both by the government and the international development partners as no sector in Bangladesh illustrates the development potential more clearly than aquaculture for socio-economic emancipation and poverty reduction of the rural peoples [6]. In order to enable millions of poor people to improve their livelihoods, the millennium development goals (MDG) had been adopted by 192 member states of the United Nations [7]. Out of eight MDGs, the first one was to 'eradicate extreme poverty and hunger' which has been demonstrated as very strongly linked with agriculture. Moreover, the seven other MDGs (modified in SDG) demonstrated are also linked directly and indirectly with aquaculture [8]. In comparison to the agrarian history, aquaculture has been regarded as an infant [9]. But aquaculture as a sector is the most diverse of all animal food production sectors due to the great variety of "cultivable species" and a wide range of "aquatic environments" (e.g. fresh, marine, brackish, cold, temperate and warm water) [10].

Bangladesh is blessed with huge inland water resources with a wide range of variations in nature. There is a little prospect for obtaining increased yields of fish from open water capture fisheries due to man-made hazards and ecological degradation. Now only the culture fisheries especially pond aquaculture seems to be a dependable means of achieving increased yield of fish in order to meet up the ever increasing demand of the protein enriched food fish in the country [2, 4]. The wider popularity of pond aquaculture as compared to others may be due to its greater applicability, high productivity, profitability and greater socio-economic opportunities for livelihoods development that linked to poverty reduction [4, 11].

According to the Millennium Development Goals progress report [1] in Bangladesh where stated that, Bangladesh has made commendable progress in respect of eradication of poverty and hunger through adopting diversified production activities in agriculture sector emphasizing aquaculture resulting poverty reduction [12]. Direct poverty impacts are those which affect the welfare of households who adopt aquaculture; for example, through benefits such as increased regular income or fish consumption. The poverty impact of these benefits depends on the socio-economic status of adopting households and will only be significant if the poor adopt aquaculture. Indirect poverty impacts affect the welfare of the poor through aquaculture adoption by both poor and non-poor farmers through a variety of potential impact pathways. For example, aquaculture development increases fish supplies, potentially increasing the availability and lowering the price of fish in local and urban markets. This may benefit poor consumers if production is not exported and if the poor consume the species produced by aquaculture. However the price reduction may not necessarily help poor producers. Aquaculture development can also increase employment of the poor on fish farms and can potentially increase the marginal productivity of labor leading to higher rural wage rates. Other potential indirect impacts wage and income effects on other sectors which could benefit the poor through production, consumption and other economic growth linkages.

Aquaculture production also contribute to stimulate growth in other sectors producing an economic multiplier effect which could have positive impacts for a range of poor people including landless farm workers, net labor-selling small holders, the rural non-agricultural and urban poor. The extent to which aquaculture will realize its potential to contribute to rural development and poverty reduction is likely to be context specific and dependent on a number of factors, including the level of engagement by the poor, the scale of adoption, the relative importance of livelihood and production effects compared to consumption effects benefiting poor consumers, and the significance of indirect effects such as economic growth linkages arising from different aquaculture production systems.

Considering the enormous importance of aquaculture to poverty reduction the present study was undertaken to investigate the following specific objectives:

- To determine the current fish production and income status from aquaculture that impacted on poverty.
- To assess the livelihood capitals that gained through aquaculture as direct and indirect poverty reduction index.

METHODOLOGY

Selection of the study areas

Selection of the study area for assessing the contribution of aquaculture for poverty reduction of the pond fish farmers is an important step. Three sub-districts of Mymensingh district namely Gaffargoan, Trishal and Valuka from rural Bangladesh were selected as study areas (Figure 1).

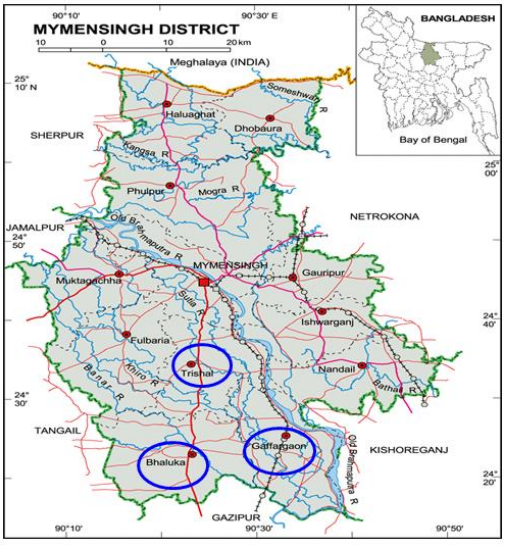

Fig-1: Showing the study areas

Sample Size Selection

In this study the sample size of the respondents were altogether 105 of which 25 fish farming households and 10 non-fish farming households from each sub district as to comparing the income and poverty situation (Table 1).

Table 1: Target area and sample size of the households:

Study areas		Farmers types	
		Fish farming households	Non-fish farming households
District	Sub district		
Mymensingh	Valuka	25	10
	Trishal	25	10
	Gaffargaon	25	10
Total =		75	30

Preparation of the interview schedule: Before preparing the final interview schedule, a preliminary schedule was developed in conformity with the objectives of the study.

Data collection methods: After preparing the final schedule, primary data was collected from the selected fish farmers. Before interview each respondent was given a brief description about the nature and purposes of the study. At the time of interview the farmers were asked questions systematically and explained whenever it was felt necessary. Farmers were requested to provide correct information as far as possible. The following methods were followed for data collection:

Questionnaires interviews

A total of 105 farmers were interviewed with a structured questionnaire at their houses or farm sites. The interview was conducted focusing on present fish production status, productivity, farming constraints, production cost and returns, gender issues, credit issues, livelihood assets of the respondents, vulnerability concerns and livelihood outcomes and sustainability issues.

Participatory Rural Appraisal (PRA)

PRA is a group of methods to collect information in a participatory fashion from rural communities [13]. For this study the PRA tool- Focus Group Discussion (FGD) were conducted with fish farmers and non-fish farming groups. A total of 10 FGD sessions were conducted where each group consisted of 7 to 10 persons (total 105) and duration were approximately two hours.

Cross-check interviews with key informants: A key informant is someone with special knowledge on a particular topic. Key informants are expected to be able of answering questions about knowledge and behavior of others and about the operations of the broader systems. Cross-check interviews were conducted with District and Sub district Fisheries Officers, researchers, relevant Non-government Organization (NGO) workers and social elite persons. A total of 20 key informants were interviewed.

Data processing and analysis

After collecting the data all the collected data were summarized and scrutinized carefully before the actual tabulation. The collected data were tabulated into computer database system using Microsoft Excel software for tabulation and graphical representations of the findings. Statistical method such as SPSS (Statistical Package for Social Science) was also used to analyze the data.

RESULTS

Poverty reduction through aquaculture is a multi-disciplinary concept that depends on aquaculture knowledge, desirable production, income, food security and livelihoods capitals. In respect of that aims and objects the finding of the present study are presented below:

Assessment of farmer's knowledge gained from technical training on aquaculture

The observed training scores of the farmers ranged from 3 to 37 with a mean of 7.74 and standard deviation of 7.42. On the basis of training received scores, the fish farmers were classified into three categories and shown in Table 2.

Table-2: Distribution of farmers according to their training received on aquaculture

Categories	Farmers (N= 75)		Mean ± SD
	Number	Percent	
Short training (up to 7 days)	30	39.6	7.74 ± 7.42
Medium training (8-15 days)	40	52.8	
Long training (> 15)	5	7.6	
Total =	75	100	

Data presented in the Table 2 indicates that majority of fish farmers (52.8%) of the study areas received medium training, 39.6% received short training and only 7.6% received long training. Maximum (92.4%) of the fish farmers of this study areas were short to medium training receiver. The knowledge level of the farmers was assessed depending on the criteria such as, understanding, listening, remembering, analyzing etc. The computed knowledge score of the fish farmers ranged from 29 to 60 with a mean of 46.94 and standard deviation of 6.57. The fish farmers were distributed according to their knowledge level into three categories and shown in Table 3.

Table-3: Distribution of farmers according to their knowledge level after participation in aquaculture

Categories	Farmers (N= 75)		Mean±SD (knowledge score)
	Number	Percent	
Poor knowledge (up to 40)	11	15.1	46.94 ± 6.57
Medium knowledge (41-50)	40	53.3	
High knowledge (> 50)	24	31.6	
Total =	75	100	

Data presented in Table 3 reveals that majority (53.3%) of the fish farmers had medium knowledge compared to 31.6% having high knowledge and 15.1 percent belonged to poor knowledge category. According to farmers' views and secondary information, intensive technical training was offered through different donor funded project to the fish farmers with tri-partite collaboration (Donor-DoF-NGOs). As a result maximum (84.9 percent) of the fish farmers in these study areas were in medium to high aquaculture knowledge categories.

Assessment of aquaculture resources in the study areas up to 2018

It is very rational to assess the aquaculture resources that are ponds characteristics in the study areas before going to determine present pond production status. This assessment will help to predict on present production status. The assessment results of aquaculture resources are shown in Table 4. It is evident from Table 4 that 12% of seasonal pond and 14% of perennial pond increased after participation in aquaculture by the fish farmers.

Table-4: The changing characteristic pattern of ponds before and after participation in aquaculture in the study areas

Assessed farmers	District	Sub districts	Seasonal Pond (%)			Perennial pond (%)		
			Before (%)	After (%)	Change (%)	Before (%)	After (%)	Change (%)
	Mymensingh	Bhaluka	38	62	24	45	55	10
		Trishal	47	53	6.0	48	58	10
		Gaffargaon	49	51	2.0	46	54	6
Study areas average			44	56	12.0	43	57	14.0

Assessment of current fish production status in the study areas up to 2018

The first objective of the present study was to determine the current fish production status in the study areas after participation in aquaculture. The results of the current fish production status are presented in the Table 4 as farmers' type and well beings.

Table-5: Results of current fish production in the study areas (up to 2018)

Assessed farmers	District	Upazila	Average fish production Kg/decimal/year							
			Before participation in aquaculture				After participation in aquaculture			
			Land less	Marginal	Better off	All average	Land less	Margi nal	Better off	All average
Pond fish	Mymensingh	Bhaluka	2.75	4.25	7.09	4.70	14.56	17.46	24.32	18.78
		Trishal	2.58	4.03	5.33	3.98	13.15	14.96	23.47	17.19
		Gaffargaon	2.08	4.25	5.98	4.10	12.91	14.28	21.61	16.27
Study areas average			2.47	4.18	6.13	4.19	12.27	14.61	23.13	16.67

Data furnished in the Table 5 shows that before participation in aquaculture average fish production was 4.19 kg/decimal/year in the study areas. But after participation in aquaculture the average fish production stood at 16.67 kg/decimal/year. A highly positive and significant ($p<0.05$) production increment result was obtained through statistical t-test.

Determination and comparison of average yield cost, return and benefit cost ration from the study areas

Fish culture is more profitable business. The philosophy of the business is to achieve more benefit from less investment. An economic comparison on aquaculture in the study areas is shown in the Table 6.

Table-6: Comparison of per hectare average yield cost and return of fish pond under the study areas (tk. /ha)

Assessed farmers	District	Upazila	Yield (kg/ha/yr)	Gross income (tk./ha/yr)	Total variable cost	Total cost (tk./ha/yr)	Gross margin	Net return	BCR
1			2	3	4	5	6 = 3-4	7 = 3-5	8 = 3/5
Fish farmers	Mymensingh	Bhaluka	4637	438573	121003	135958	317570	302615	3.23
		Trishal	4246	408487	119445	138886	289042	269601	2.94
		Gaffargaon	4019	377112	102575	120676	274537	256436	3.12
Study areas average			4301	408057	114341	131840	293716	276217	3.10

Data presented in the Table 6 reveals that average yield 4301kg/ha/year, gross income 408057tk./ha/year, total variable cost 114341tk./ha/year, total cost 131840tk./ha/year, gross margin Tk.293716/ha/year, net return 276217tk./ha/year and benefit cost ratio 3.10 were achieved by the fish farmers. Total cost of per hectare production was 32 percent. A highly significant positive ($p < 0.05$) result was obtained from the statistical t-test. This trend in income generation would surely impact on poverty reduction in the study areas.

Livelihood capitals of the fish farmers

Development of human capital is one of the pre-requirements for successful achievement of other types of assets. It represents the skill, knowledge, ability of farmers and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives. Most of the respondents reported that quality of the components of human capital has increased over the periods through gaining education, knowledge, better training, development of skill, improving health condition and more access to information for human development Table 7).

Table-7: Livelihoods capitals changing pattern of the fish after participation in aquaculture. % of farmers reported

Livelihoods capitals	Capital types	After participation (%)	Before participation (%)	Changed (%)
Human capital	Good health, Knowledge, skills, attitude	121	12	109
Social capital	Access to information, social groupings, neighboring knowledge sharing	150	5	145
Natural capital	Open water fishing, use of open water, illegal fishing	24	116	(- 92)
Physical capital	Housing, latrine, drinking pure water, furniture, modern amenities, pond resources, trees etc	130	42	88
Financial capital	Liquid assets, ornament, jewellary and savings	192	15	177

A tremendous changed was observed in aquaculture knowledge after participation in aquaculture through statistical t-test. Involvement of people in formal grouping, connection with network, relationship of trust, reciprocity and exchanges etc. are considered as main components of social capital. Increased fish production and economic activities ensure better aquaculture participation of fish farmers in different social asset building process. Fresh water aquaculture did not affect the nature and environment in fish farming areas. However uses of land open water and public open water fishing were addressed to determine changing natural capital context. Intensive land use, bring low lying areas under rice cultivation and some man-made barriers were found responsible to decrease open water resources (Table 7). The changing nature of physical asset in the livelihoods of fish farmers in different locations. Number of tin roof house increased and straw roof house decreased. This simultaneous trend indicates improved housing condition for all types of fish farmers. The condition of other major components of housing as well as safe livelihood such as drinking water and sanitary toilet has also developed after participation in aquaculture. In before period there was a few families used tube well or sanitary latrine in study areas. Now many of fish farmers use modern amenities. Uses of radio, television, watch, electricity etc. have increased tremendously for all kinds of fish farmers after participation in aquaculture. Uses of mechanized and semi-mechanized transportation such as bicycle, rickshaw, van, tempo, bus etc. have also increased. Quality and quantity of household furniture such as chair, table, cot and mattress have increased considerably. In household

areas number of trees and ponds also increased. For all the fish farmers under the study areas there was significant ($p<0.05$) changed in increasing the financial capital. Cash in hand, savings and possessing liquid assets increased considerably for fish farmers under different study areas.

Livelihood strategies and outcomes

Annual income and contribution of aquaculture

Level of income and source of income are the key socio-economic characteristics for determining the socio-economic status of the sampled farmers using before and after methods. The annual income from aquaculture have been considered as an important indicator for this present study assessing what changed aquaculture made after participation that resulting poverty alleviation and presented the results in the Table 8.

Table-8: Comparison of annual aquaculture income of sample farm households before and after participation in aquaculture % of contribution on total annual income

Assessed farmers	District	Upazila	Before		After		Net Increment in total annual income	
			Tk.	%	Tk.	%	Tk.	%
	Mymensingh	Bhaluka	6494	6.03	53429	36	46935	29.07
		Trishal	4060	4.81	41071	29	37011	24.19
		Gaffargaon	2432	3.26	24719	21	22296	17.74
Study area average			4329	5.19	39740	29	35414	23.81

Before participation in aquaculture, the averaged contribution of aquaculture was 5.19% over total annual income but after participation that contribution rose to 29% over total annual income (Table 8). It was also evident from Table 8 that contribution rate of aquaculture has increased 23.81% comparing with before situation over total annual income. This impressive increment rate of aquaculture income contributing poverty reduction of the participating fish farmers in the study areas.

Food security

Adequate and sustained food fish consumption was considered as the main determinant of household food security related poverty.

Fish consumption

Fish consumption status of the sampled households before and after situation has presented in the Table 8. Before participation fish consumption quantity was 33.66 gm/capita/day. After participation this quantity averagely has stood at 63 gm/capita/day and net increment of fish consumption was increased by 19 gm/capita/day with increment rate of 47% (Table 9).

Table-9: Changes in fish consumption pattern of households members before and after participation in aquaculture

Assessed farmers	District	Upazila	Before participation		After participation		Increment of consumed pattern	
			Weekly consumed pattern (% consumed)	Per capita /day (gm)	Weekly consumed pattern (% consumed)	Per capita /day (gm)	Per capita /day (gm)	% of increment
	Mymen	Bhaluka	100	34	100	64	30	88
		Trishal	100	35	100	63	28	80
		Gaffargaon	100	32	100	62	30	94
Study area average			100	33.66	100	63	29.33	87

Determination of Head Count Poverty by defining the poor

To test the hypothesis that fish farming has positive direct impacts on the livelihoods of poor households, identification of poor households is necessary. This was done below by analyzing community wealth ranking exercise results estimating headcount poverty rates of the fish and non-fish farming households surveyed, and analyzing respondents' own subjective perception of their household poverty level.

Table-10: Wealth ranking results: households in three wealth categories

Households from three upazilas	More Wealthy	Medium Wealth	Less wealthy	Total
Total households (Nos.)	21	38	16	75
% of households in each category	27	51	22	100

Of all 75 households, 22 percent were classified as less wealthy and 51 percent as medium and 27 percent fall in of wealthier category (Table 10). A much higher percentage of medium and wealthier households are involved in aquaculture compared to the less well-off groups. Overall the results suggested that while less wealthy (or poor) households are able to adopt fish farming, fish farmers are more likely to be wealthier that indicated the poverty reduction.

Determination of Head Count Poverty Rate

Surveyed households are classified here as 'poor' if their per capita income is below the poverty line and 'non-poor if their per capita income is above the poverty line. Income data were collected in the household survey. Table 10 shows the percentage of poor and non-poor surveyed fish and non-fish farming households.

Table-11: Poor and non-poor surveyed households by fish farming status

Poverty status	Fishfarmer households %	Non fish farmer households %	Total households %
Poor households	16	26	21
Non-poor households	84	74	77
Total households (Nos.)	75	30	105

16 percent of surveyed fish farming households were determined as poor (similar to the 22% less wealthy households from the wealth ranking results above). The international poverty line of US$1.25 a day at 2005 Purchasing Power Parity (PPP) set by the World Bank was used. Percentage of poor fish farmer households is lower than poor non-fish farmer households (p = .11) (Chi square test results). Respondents were also asked about their own subjective perception of their poverty level. Table 11 shows that overall 21 percent categorized their households as very poor or poor. An association was found between poverty status and household's own perception of poverty (p = .1) suggesting that subjective and objective indicators of poverty are related. There is a significant association between fish farming status and households' own perception of poverty (p = .04) indicating non-fish farmers are more likely to assess themselves as being either very poor or poor than fish farmer.

DISCUSSION

For validating the present results of the findings, discussion in respect of present knowledge is virtually important. The finding of the present study in relation to reviewed literature is discussed below:

Training brings desirable changes in knowledge, skills and positive attitudes of fish farmers and makes them capable to do any production oriented activities [14]. The present findings reveals that 84.9% of the fish farmers had medium to high knowledge on aquaculture and 92.4% were short to medium categories aquaculture training receivers after participation in aquaculture in the study areas. These findings are in agreement with the finding of Winrock International [15], RMC [16] and khaleque *et al*. [17] who stated in their impact study report on DANIDA funded aquaculture project that the 91.6% of farmers had short to medium training and maximum (83.5 percent) fish farmers fall into medium to high knowledge categories in Mymensingh district of Bangladesh. Improved culture and management practices through scientific knowledge only can give the guarantees of increased fish production. More input and knowledge based management ensure more production, the modern philosophy of aquaculture business has been recognized by different researchers in modern trends in aquaculture [18].

Aquaculture, mainly the pond aquaculture is the dependable source of animal protein supply for the ever increasing population in the country and it's heavily depends on improved culture and management systems [19]. A tremendous changed in culture fisheries production has occurred during the last few decades [20]. The production of fish was estimated to be 35.48 Lakh Mt (3435 Kg/ha/year) during the fiscal year 2013-14 as against a production of only 0.95 million Mt (807 Kg/ha/year) in 1991-92 which means that production has increased about 254% till the present time. The yearly growth rate of production during this period varied from 5-8%. In this present study, the calculated production in 2015 was 4301 Kg/ha/year with net production increment 11.38 Kg/decimal/year and increment rate of 276% as compared with the production 1020 Kg/ha/year before aquaculture. The production of fish in the study areas are higher than that of national fish production (3435 Kg/hectare/year) [4]. In Table 6, returns from aqua farming especially pond aquaculture have been measured in terms of per hectare yield, gross income and net return. It was seen from the Table4.6 that, fish farmers of the present study areas earned higher financial returns. The present finding well agree with the findings of Islam *et al.* [21] and Mondal *et al.* [22] who conducted a study on the impact of aquaculture extension project on improving production and income of fish farmers in Bangladesh using before and after implementation methods. They stated in their impact study that Mymensingh Aquaculture Extension project farmers ranked top with respect to fish production (4742 Kg, total cost Tk. 117387, net return Tk.129142 per hectare per year respectively with BCR of 2.12). Farjana [23] showed in her study average total cost of fish production 1,12,265, while gross income and net return were Tk. 1,46578 and 1,83,069 per ha per year respectively.

Rabbani [24] stated that increased returned may be achieved by carp poly culture using locally available feed ingredients. Ahmed [25] stated that carpculture is a profitable business and seventy one percent farmers have improved their economic condition through carp polyculture in Mymensingh and Kishoregong districts of Bangladesh. Biswas [26] stated that carp polyculture farmers in Mymensingh district earned net return Tk. 2,10,360 per ha per year following re-stock-harvest method. Rahman [16] observed that the highest per hectare profit amounted to Tk. 1,37,450 earned by the farmers under NGO management and concluded that scientific use of inputs, normal depth of water, easy cash flow of capital, smooth extension services will definitely increase the production of fish. From the above discussion it is concluded that the fish farmers of the surveyed areas enjoyed a handsome amount of aquaculture return per annum using their technical knowledge that gained from technical training.

A livelihood comprises the capabilities, assets and activities needed for a means of living [27, 28]. A livelihood is sustained when it can cope with and recover stresses and shocks, and maintain or enhance its capabilities and assets, both now and in the future, while undermining the natural resource base [29]. The SLA is prominent in recent development programmers that aimed to reduce poverty and vulnerability in communities engaged in small-scale aquaculture and fisheries [30, 31]. It is increasingly being used by many development agencies and NGOs to achieve a better understanding of natural resource management systems [32]. The livelihood approach seeks to improve rural development policy and practice by recognizing the seasonal and cylindrical complexities of livelihood strategies [33, 34]. At present with the increased use of livelihood approaches in development, considerable attention has been given to developing methods for monitoring changes in all aspects of people's lives which considered not only financial improvement but also socio-economic impact on livelihoods and social well-being of the target group of people [35]. In this regards, following socio-economic indicators and livelihood strategies were considered to address the objective of the present study.

The sustainable livelihood framework includes the asset pentagon which is composed of five types of capital [36] namely human capital, social capital, natural capital, physical capital and financial capital. A sustainable livelihood is the outcome of the development and interrelationship between these capitals.

Development of human capital is one of the pre-requirements for successful attainment of other types of assets. It represents the skills, knowledge, ability of farmers and good health that together enable people to pursue different livelihood strategies and achieve the livelihood objectives [36]. The human capital of the assessed farmers are shown in Table 7. It is evident from Table 7 that most of the respondent reported that quality of the components of human capital has increased over the periods through gaining education and knowledge, better training and development of skills, improving health condition and more access to information for human development. In before aquaculture, only 12% respondents reported good education and this percentage rose to 121 and increased 109% after participation (Table 7). Through fisheries training, skill and knowledge was developed in the form of infinity of the fish farmers i.e. 100% knowledge was gained on aquaculture by the farmers through different training programs. This knowledge gained results obviously indicate the miracle human capital development after participation in aquaculture (Table 7). Human capital including skills, acquisition of skills to narrow knowledge gaps and access to source of information are important for small-scale aquaculture development [37]. Development in human assets has been identified as one of the most important factors for reduction of poverty [38]. Generally education encourages the development of the human mind and it increases the power of observation, analysis, integration, understanding, decision making and adjustment to new situations of an individual as well as their family members [39]. Making decisions regarding carrying out of agricultural technologies has shown mixed, positive and no relationship with the education level of farmers [40]. In Vietnam a lower level of education did not hamper the farmers who carried out rice-fish and pond aquaculture [41]. Exchange information among neighboring farmers may be a means of easier knowledge development process [42]. This suggests that accumulation of such knowledge or human capital can occur in farming communities which could be disseminated to other farmers without further formal institutional support. The finding of the present study is similar with the findings of Islam *et al*. [40] and Dixon [55] who reported that human capital development is the prerequisite obligatory factor for achieving higher income from aquaculture that positively impact on poverty reduction.

Involvement of people in formal groupings, attachment with networks and connectedness, relationship of trust, reciprocity and exchanges etc., are considered as main components of social capital [43]. Fish production and increased economic activities ensure better aqua cultural participation of fish farmers in different social asset building process.. From the study it was found from the opinion of farmers that the grouping system training and micro credit provision was the main reason of social network bonding in the study areas. Development requires the mobilization of existing social capital as well as the creation of new linkages as success in communities depends on existing social bonds which encourage individuals to pursue a greater diversity of activities [44, 45]. Growth of social capital can result from group activities in a wider range

of natural resource management sectors, including watershed management, irrigation, micro-finance, forest management, and integrated pest management and farmer experimentation [46]. According to Mondal [47] social capital development involving women were also reported to mitigate domestic violence, early marriage, polygamy, dowry problems etc after participation in aquaculture in Mymensingh district of Bangladesh. Poverty reduction not only dependent on income but also depend on integrated social strata development such as reduction of social violence and up gradation of social justice. This is only can be done through embedding social networks.

Table 7 shows the changing state of physical asset in the livelihood of fish farmers in different locations of the study areas. Number of tin roof house increased and straw roof house decreased. This simultaneous trend indicates improving housing condition for all types of fish farmers. The condition of other major components of housing as well as safe livelihood such as, drinking water and sanitary toilet 100% has also developed after participation in aquaculture. In before period, there was few families used tube well or sanitary latrine in study areas. Now many of fish farmers use modern amenities. Uses of radio, television, watch and electricity have increased tremendously for all kinds of fish farmers.. Quality and quantity of household furniture such as chair, table, cot and mattress increased considerably. In household areas, number of trees and ponds also increased. These finding are similar to the National Statistics, where it has been reported that 76% of living room roofs were made of tin in rural areas, majority of living rooms fences were made of tin and about 50% was made of semi concrete [48]. Recent studies by CARE Bangladesh [11] show that during the last two decades, a notable improvement has occurred in the area of housing, safe drinking water and sanitation in Bangladesh .The finding of the present study more or less similar with CARE Bangladesh. A similar finding was reported by Mondal [22] and Hoods *et.al.* [54] who stated in their impact study that physical capital like housing, sanitation, modern amenities, pond and trees has notably increased after participation in aquaculture. As a result the farmers are now leading better livelihood than before condition. Khaleque *et al*. [17] reported that MAEP project farmers made a change of 75% housing, 94% sanitation which proved positive change of livelihood than prior to Aquaculture.

The poverty reduction through aquaculture in the present study addressed the key indicators such as aquaculture income and food security that is consumption pattern of food fish in household family level. It was found from the table 8 that aquaculture contributed on an average 29 percent over total annual income. According to Bouis [49] that aquaculture can be the good source of income and in Bangladesh aquaculture contributed 5 to 10 percent of aquaculture income over the total annual income in case of small farmers. In Mymensigh region of Bangladesh aquaculture contributed on an average 30 percent over total annual income [47, 21). The present finding on income bears a similarity with the findings of the above mentioned authors.

Adequate and sustained food consumption was considered as the main indicator of household food security and malnutrition poverty reduction. Food consumption and food purchasing capacity of the fish farmers were critically depends on their income. Most of the fish farmers of the study areas have increased the consumption of fish from 33.60 to 63 grams per day after participation in aquaculture is relatively higher compared to national average 60 gram/day [4]. The present study more similar with the finding of Karim [50] who reported that high income households consumed more (90.93 kg/household/year than low income households (64.88 kg/household/year in the Mymensingh region of Bangladesh. For low income people particularly dependent on fish in their diets thus reduction in supply may have serious consequences in terms of both economics and nutrition [51]. Rural aquaculture offers a tremendous direct opportunity on income generation, employment creation and potein enriched food security for the mass population of Bangladesh [52]. Livelihoods capitals increment through aquaculture pave the way of poverty reduction [36]. It was observed from the present study that aquaculture generated income in a more stable way that is opening a new horizon for escaping of poverty line. This study is well agreement with the finding of Karim [50], Belton *et al*. [6] and Mondal *et al*.[47] who stated in their research that fish farmers in the greater Mymensigh region enhancing their socio-economic condition achieving livelihoods capital and income that is helping them eradicating poverty. The estimated head count poverty rate among the fish farmers household in the study area was 16% comparing with 26% of the non-fish farmers (Table 11) This poverty rate was lower than the head count poverty rate of Bangladesh up to 2015 that is the present poverty rate is 24.8% percent in Bangladesh [12]. The present study also showed that fish consumption in the study area had increased after participation in aquaculture than before condition that is assisting malnutrition related poverty eradication. This impressive finding is in accord with the finding of [53] who stated that aquaculture is an important fighter against poverty and hunger and aquaculture has the ability to alleviate poverty.

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