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EXISTING FISH CULTURE STRATEGY AND MANAGEMENT PRACTICES: IMPACT ON POTENTIAL PRODUCTION AND PROFITABILITY

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ABSTRACT

The objective of the study was to evaluate the profitability of farm fish production with relation to management practices and disease control. A survey was carried out with a pretested questionnaire in six upazilas of Mymensingh district where 100 sample farms were randomly chosen. Farmers were interviewed for the study to know productivity and diseases throughout the 6-month data collection period. Multiple linear regression model was fitted, and benefit cost ratio was determined for farm fish production. The majority of respondents (42%) were middle-aged between the ages of 30-45 years and 24% had secondary education with 29% graduated/post graduated. Only 37% of the fish farmers were trained. For the removal of aquatic weeds and undesirable species, antibiotics and a variety of chemicals were used. Fertilization was done after fish stock with 200-350 g/decimal of urea and the same dose of TSP. The majority of the farmers buy feed on an installation basis whereas 24% farmers could not use supplemental feeds for high-cost Farmers (82%) check the quality of water on a monthly, weekly and daily basis. Lime, amount of fertilizer, cost of chemicals/medicine and utility cost had a positive impact on the production of fish. Age and experience of farmers also had a positive impact on production, but they were not significant. The overall benefit-cost ratio for farm fish production in this study was 1.37. Mymensingh district has excellent prospects in fish production that may be enhanced by applying comprehensive post-stocking and health management. Fish production is cost-effective enterprises as indicated by the benefit-cost ratio and has great scope for the fishery sub sector for increasing employment prospects.

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I. INTRODUCTION

The fish and fisheries sector play a vital role in the national economy as well as in meeting the demand for animal protein for the increased population of the country. The fisheries sector of Bangladesh is a very important sector in respect to the nutrition of the people and the export earnings of the country. It has the 3rd largest aquatic biodiversity in Asia behind China and India and has about 800 species of fresh, brackish and marine waters (Hossain *et al.*, 2019) and 4th in world aquaculture production. The contribution of the fisheries sector in the national GDP and agricultural GDP are 3.65% and 23.11%, respectively (BER, 2020). It is a densely populated country where it has excellent aquaculture potential because of its vast water resources in the form of pond, beel, lake, canals, small and large rivers and estuaries. To ensure the consumption of the required level of protein and other essential nutrients, more fish production is one of the important strategies in Bangladesh. Considering this fact, carp oriented farming practice and some exotic carp species of fish such as silver carp, grass carp, common carp and thai-sarpunti have been introduced in Bangladesh for their aquaculture potentials and are available in the market (Shamsuzzaman *et al.*, 2017). Use of high yielding and fast growing fish species with proper combinations and stocking densities along with appropriate production technologies may help to boost fish production.

The tendency for higher fish production is to ensure the use of better farm management practices by the fish farmers such as control of predatory animal by rotenone, use of lime, fertilization of pond with urea and TSP, selection of appropriate species, supplementary feeds, preventive measures against outbreak of disease, water quality parameters, partial harvesting and restocking etc. (Sarker and Ali, 2016) are quite suitable for sustainable aquaculture development. Most of these activities are not practiced properly by the fish farmers. It was found that 54% of the farmers used lime in their ponds at the rate of 0.5kg/decimal, 48% of farmers used lime at the rate of 1kg/decimal and 4% at the rate of 2kg/decimal. Due to lack of knowledge on aquaculture management practices, fish farmers never thought that diseases were the major constraints for higher fish production. Thus, from the above discussion it is clear that the fish farmers are not practicing aquaculture management successfully. So, for higher fish production it is necessary to identify the problems that are faced by the fish farmers in aquaculture management.

The success of fish culture depends on its proper management, which is related to understanding the biology of fish and the aquatic environment in which they live. Management of effective healthy fish arises with prevention rather than treatment, which is achieved through quality water management, nutrition and hygiene. Without this foundation it is impossible to prevent outbreaks of opportunistic diseases. With the expansion and diversification of aquaculture practices, disease has become the constraining factors for fish production in Bangladesh. Approximately, 15% of the total freshwater fish production was lost due to fish disease (Faruk *et al.*, 2004) and such loss affects the livelihood of poor people involved in the aquaculture sector. Fish death occurs frequently in wide-ranging of environmental stress resulting from parasitic attack or fungal and protozoan infections (Hossain *et al.*, 2011). Also, with the introduction of new exotic fish species in aquaculture, there is always a risk of pathogen transfer, disease incursion and subsequent outbreaks of disease in the existing aquaculture systems. Although disease diagnosis and control programs have generally tended to focus on more intensive aquaculture systems, it is known that small-scale rural aquaculture systems are also prone to disease. Low physicochemical and microbiological quality of water, poor nutritional condition and stocking density may lead to fish infection and hence preventing fish infections is essential for the long-term expansion of aquaculture (Mishra *et al.*, 2017). Fish disease problems have a negative impact on the livelihood of rural fish farmers and their dependents through loss of production, income and assets.

Economy of Bangladesh considerably depends on the development of the fisheries sector. Overall monetary advancement of the country also varies upon increase of productivity and aquaculture production. Before giving any policy direction towards increasing fish production, it is important to know the socio-economic characteristics of the fish farmers, input used, their production costs, benefit cost ratio and factors influence in fish production, etc. Information on the socio-economic framework of the fish farmers forms a good base for planning and development of the economically backward sector (Ofuoku *et al.*, 2008). Pond fish farming is profitable depends upon its management and some other factors (Khan *et al.*, 2021 and Ragasa *et al.*, 2022).Based on the benefit cost ratio fish production was profitable enterprise (Hossain and Islam, 2014; Uddin and Akhi, 2014, Islam *et al.*, 2017 and Sarker *et al.*, 2022). Furthermore, it is imperative to determine the level of practice of fisheries technology by the fish farmers and their ability to utilize aquaculture management knowledge, which they acquired from extension activities and training.

The findings of the study could help the government to enhance preparation and execution of appropriate strategy measures to improve the livelihood of the rural people and to provide helpful evidence to the researchers. No considerable effort is being undertaken to increase management practices of fish farmers through research and extension delivery to increase fish production. Thus, it was needed to conduct a study regarding the problems of aquaculture practice by the farmers. Hence, the research was undertaken ii) to know the status of farm management practices by the fish farmers, ii) to identify the causes of fish disease and measures taken to disease control, iii) to estimate the profitability of fish production and iv) to determine factors that enhance fish production.

II. METHDOLOGY

2.1 Study Location and Sampling Technique

To attain the objective of the study, six upazilas were purposively chosen since they were highly populated with native and exotic fish farms out of twelve upazilas of Mymensingh district those were the Mymensingh Sadar, Trishal, Muktagacha, Bhaluka, Phulbaria, and Phulpur.0ne hundred farmers were selected from six upazilas using a simple random sampling technique. Among them, 19 respondents were selected from Mymensingh sadar upazila, 23 from Trishal upazila, 15 from Muktagacha upazila, 11 from Bhaluka upazila, 18 from Phulbaria upazila and 14 from Phulpur upazila of Mymensingh district.

2.2 Data Collection and Analysis

An interview schedule was prepared, which includes all study-related information. Direct interviews were used to gather data, and the researchers personally visited the respondents. The respondents were each individually interviewed at their own homes. The researchers made every effort to set up a rapport with the respondents before the interview so that they wouldn't experience any difficulties. The researchers took great care to explain and clarify any questions that the respondents had no trouble. Data was gathered between March and August 2022. The people had been asked to supply accurate information as much as feasible for the study. The phrases and questions were carefully crafted, and they were simplified so that farm owners could understand them. The researchers also gathered information from several pertinent sources, including books, journals, theses, abstracts, reports, and the internet, in order to build the conceptual underpinnings of the study. "Microsoft Excel 2020" and "IBM SPSS Statistics 22" were used to analysisall of the data that had been gathered. The outcomes were presented in a descriptive tabular form.

2.3 Analytical Techniques

Multiple regression

To investigate the impact of farm management and disease control strategies on the fish production by the farmers, multiple regression analysis was used. The multiple linear regression production model that was chosen can be presented in the following way to investigate the relationship between input and output in aquaculture production:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + U_i \quad \text{------ (1)}$$

Where, Yi = Fish Production (Kg), β_0 = Intercept, X_1= Age of fish farm owner (year), X_2= Education of fish farm owner (year of schooling), X_3 = Experience of farming (year), X_4 = Farm size (decimal), X_5= Mud removal cost (Tk.), X_6 = Liming (Kg), X_7= Labor (Man day), X_8 = Fingerling (Kg), X_9 = Fertilizing (Kg), X_{10} = Chemical (Kg), X_{11} = Medicine (Kg /ha), X_{12} = Feed (Kg), X_{13} = Maintenance cost (Tk), U_i = Error term.

Gross return (GR)

The total volume of an enterprise's output was multiplied by the average price during the harvesting season to determine gross return (Dillon and Hardaker, 1993).

To calculate GR, the following equation was used:

Gross return,

$$GR = \sum_{i=1}^{N} Q_{ai} P_{ai} \quad \text{------} \quad (2)$$

Where,

GR = Gross return from i^{th} production (Tk. /unit); Q_{ai} Quantity of the i^{th} output (Kg); P_{ai}= Average price of the i^{th} output (Tk. /unit); and i = 1, 2, 3... N.

Net return or profit

Total costs were subtracted from the gross return to arrive at the net return. The difference between per hectare total return and per hectare total cost (variable cost and fixed cost) of production was used to calculate per hectare net return. The following equation was used to calculate the aquaculture production's net return.

Net return,

$$NR = \sum_{i=1}^{N} Q_{ai} P_{ai} - \left(\sum_{i=1}^{N} X_i W_i + TFC\right) \quad \text{----------} \ (3)$$

Where,

NR = gross Return – (variable cost + fixed cost)

$$TC = \sum_{i=1}^{N} X_i W_i + TFC$$

Where,

TC= Total cost per hectare, NR= profit per hectare and TFC=Total fixed cost

Benefit-cost ratio (BCR)

The predicted advantages and costs are analyzed, together with the alternatives that were foregone. The ratio of gross returns to total costs was calculated as the benefit cost ratio (BCR). If BCR>1 (benefit over cost), the farm has made a solid investment. The benefit per unit of cost was compared using this relative measure. The following formula is used to calculate BCR (undiscounted):

Benefit cost ratio (BCR),

$$BCR = \frac{GR}{TC} \text{ ---------- } (4)$$

III. RESULTS AND DISCUSSION

3.1 Pond Owner's Characteristics

A significant proportion of pond owners (41%) in the studied areas attained secondary level of education and 20% had higher secondary or more education (Table 1) implies that pond owners are well educated which is helpful to understand fish culture management practices. Similar results were obtained by the study of Fatema *et al.* (2018) where 40% fish farmers were of secondary level of education.In the current study's area, 37% pond owners had formal training in pond fish cultivation. It was observed that there were 20% pond owners having farming experience less than 10 years, 60 having experience 10-20 years and 20 having experience more than 20 years in Trisal upazila. These figures of the entire study were 42%, 41% and 17% respectively. Farmers in the study region had a better extent of expertise in pond fish farming as the majority of them had carried on their fathers' businesses. Significant positive association $P(\chi^2>18.31)<0.05]$ between different upazilas and age of farmers indicates that these two categorical variables are dependent on each other. The Chi-square tests indicate that the farmer's education level; level of farming experience and their training on fish farming did not depend on different upazilas significantly.

3.2 Fish Culture Management Practices

Pond preparation

Ponds were prepared extensively as farmers were not introduced with good aquaculture practices. Ponds preparation was executed mainly by applying lime, removing excessive silt from the bottom and entering water. Overall study indicates that 24% ponds were repaired and muds were removed from 26% ponds. About 66% farmers prepared their ponds by pond drying, 75% by pond mud removal, 100% by undesirable species removal, 83% by aquatic weeds removal, 100%

by liming and 17% by fertilization (Rahman *et al.*, 2022). Undesirable species were removed and ponds were repaired in Muktagacha at the highest proportion compared to other upazilas. Similarly, the highest proportion of aquatic weeds was removed and ponds were dried in Phulbaria and muds were removed in Bhaluka upazila (Table 2). Two different techniques were used to remove aquatic weeds. The use of laborers was widespread (62%) among farmers while 38% of respondents used chemicals like Lithion, Lipcod, Paraquet and Rotenone. Ponds were limed usually by ACI Aqua lime (ACI Animal Health Ltd.), Geotox, Pontox Plus, and Geolite Gold.

Table 1: Socio-demographic characteristic of farmers

Characteristics	Percentage of farmers	χ^2-value(d.f.)
Age group of farmers		21.64*(10)
Young (Less than 30 years)	28	
Middle aged (30 - 45 years)	42	
Older aged (46 years and more)	30	
Education level of farmers		17.28(15)
Illiterate	10	
Primary	29	
Secondary	41	
Higher secondary or more	20	
Level of fish farming experience		9.93(10)
Less than 10 years	42	
10 to 20 years	41	
Morethan 20 years	17	
Having training on fish farming		3.46(5)
Yes	37	
No	63	

Chi-square values were calculated from contingency tables between farmer's characteristics and six upazilas

- Indicates significant at 5% level of significance

Table 2: Different activities performed by the farmers for pond preparation

Upazila	Percentages of farmers in different activities				
	Remove undesirable species	Remove aquatic weeds	Repair ponds	Remove mud	Dry pond
Mymensingh Sadar	11	26	16	26	21
Muktagacha	22	13	35	17	13
Trishal	20	13	34	20	13
Bhaluka	09	28	18	36	09
Phulbaria	17	11	17	33	22
Phulpur	21	14	21	30	14

Fish stocking

The highest quantity of seeds (66%)was collected from Government hatchery and BFRI whereas 28% and 6% seeds were collected from local and others hatchery respectively (Table 3). Most of the farmers 'stock five to seven different fish species in their ponds, including Rui (*L. rohita*), Catla (*C. catla*), Mrigal (*C. cirrhosus*), Silver carp (*H. molitrix*), Big head carp (*C. idella*), Carpio (*C. carpio*), Sarpunti (*Barbodes gonionotus*), Bata (*L. bata*). Also, six species of catfisheswere stocked with different stocking density. Farmers typically put fingerlings in breeding ponds after placing fertilized eggs in nursery ponds for carp polyculture, while they stocked fry for catfish culture. Native fish species were stocked by 67%, exotic species by 12% and combination of native and exotic fishes by 21% farmers.

Table 3: Sources of fish seeds and types of stock

	Percentage of pond owners
Sources of fish seeds	
Government hatchery and BFRI	66
Local hatchery	28
Others	06
Types of fish stock	
Native fish	67
Exotic fish	12
Combined	21

Fertilization

Following the release of fry, 10–20 kg/decimal cow dung or manure was used every two months. Sometimes it was used every month for large fishes. Depending on the color of the water, urea (200-350 gm/decimal) and TSP (200-350 gm/decimal) were utilized. Fertilization was done by each of the pond owners after fish stock.

Feeding the fishes

Both types of supplemental feeds (homemade and ready feed) were used. Only 24% farm owners solely used feed ingredients to feed fish that they had themselves prepared, while 76% of farmers utilized both ready feed and feed ingredients. Some of the farmers could not use supplemental feeds for high cost, despite the fact that farmers claim that high-quality commercial feed increases both output and profit. Some farmers experiment at their own risk with various feeds from various suppliers before settling on the best one. For the duration of the culture, fish are fed twice daily based on body weight. In the Mymensingh region, farmers used 26% floating feeds, 53% sinking feeds and 21% a combination of floating and sinking feeds of the culture period. Highest proportion of sinking feeds (64%) was used in Phulpur upazila compared to other upazilas. In the research region, floating feeds are primarily used for tilapia, Vietnam koi, and shing whereas sinking feeds are primarily used for pangus fish and carp fish.

The amount purchased is influenced by factors such as farm size, fish type, stocking density, and feed or feed ingredient costs. They purchase ingredients or feed on a daily basis (for 3–4 days at a time) if the market price is high, or they stock up on fish feed on a monthly basis if the market price is low (for 6 month). If there is a high stocking density and catfish are raised, weekly feed purchases are made. But among farmers, stocking feed on a weekly basis is the most typical technique. The majority of farmers (82%) buy their feed in installments. They buy as much feed as they require from a merchant, and they make their payment by selling fish. Few (18%) farmers make immediate payments for their feed purchases.

Labor and harvesting strategies

In the entire Mymensingh District, 3-4 laborers/hundred decimal area needed for pond preparation before beginning farming, and 2 laborers are necessary for pond preparation following the management of fish farming activities. The performance of the workforce was dependent on proper management practices. There were several types of work, including day labor, seasonal work, permanent work, and work requiring specialized expertise. Partial harvesting was a common farming practice. The final harvest was carried out in the months of November and December. They sustain two or three crop cycles per year. They employed local fisherman and paid them according to the quantity of nets pulled. The pay is based on the size of the pond.

Fish production, transportation and marketing

For carp polyculture exclusively, Mymensingh Sadar (17.63 kg/decimal) had the highest per-unit production among the six upazilas, followed by Trishal (17 kg/decimal), Muktagacha (14.9 kg/decimal), Bhaluka (14.47 kg/decimal), Phulbaria (14.35 kg/decimal), and Phulpur (14.20 kg/decimal), in that order. Average annual output for tiny ponds (less than 0.5 ha) was lower (2.21 MT) in Mymensingh sadar than Muktagacha, despite the fact that it was slightly greater per unit than Trishal (2.33 MT). The average annual production of the small and large ponds in Mymensingh sadar was about higher than that of the other five upazilas.

Since most of the ponds are located in mango orchards and some are flanked by paddy fields, all farmers transport their fish from the pond to the main road using metal containers because those locations are inconvenient for any kind of vehicle, whether it be motorized or not. They transport fish directly from the main road to the market in a half drum on a motorized pick up or a bamboo basket on a vehicle while holding water through plastic. Farmers sold their fish in small village markets in about 20% (20 respondents), arotdar in only 74% (74 respondents), and 6% (6 respondants) other cities respectively. The majority of respondents sold their fish through arotder and had no dealings with faria (buy fish on the behalf of arotder). They all engaged in wholesale fish sales.

Water quality management

Farmers routinely observed dissolved oxygen and transparency, and their accuracy was mostly based on their experiences. They were completely ignorant of concepts like pH, alkalinity, acidity, etc. They advised utilizing lime to reduce an excessive gaseous problem that was primarily caused by ammonia. Commercial medications including Oxymore (SK+F), Gasonix-Y (Growel Formulation Pvt. Ltd.), and GR+ (ADDIC), among others, were utilized to regulate the lack of dissolved oxygen in the water. Nobody assesses the water's temperature. Farmers check the quality of their water on a monthly basis in 27% cases, weekly in 35% cases, daily in 20% cases and no checkup in remaining 18% cases (Table 4).

Table 4: Water quality checkup of fish farming in the study area

Upazila	Monthly	Weekly	Daily	No check Up
Mymensingh Sadar	8	7	3	1
Muktagacha	7	10	4	2
Trishal	5	6	3	1
Bhaluka	2	4	2	3
Phulbaria	3	6	4	5
Phulpur	2	2	4	6

3.3 Fish Disease Management

Common fish diseases

The majority of farmers check on the health of their fish on a weekly or monthly basis. The most common clinical symptoms of sickness included body surface reddening, tail and fin rot, and hemorrhagic lesions, among others (Table 5). The farmers also noted other ailments as red spot, argulosis, and starvation. Degradation of water quality was the primary factor in the disease outbreak. In addition, fish were more susceptible to infections due to overfeeding, poor feed quality, and a lack of necessary feed ingredients. Generally speaking, diseases could affect carps and catfish of any size or age. Prevalence of fish disease varied with cultured species and locations and the most prevalent diseases were pop eye, ventral reddening, tail and fin rot, hemorrhagic lesion, dropsy, gill rot, white spot and epizootic ulcerative syndrome (Faruk *et al.*, 2013). Rasul *et al.* (2017) studied the status of practice of chemicals and antibiotics for fish health management in freshwater aquaculture and observed that the lack of knowledge of farmers about the use of chemicals, appropriate dose and their indiscriminate usage.

Identification of causes of fish disease

Farmers who were surveyed use a cursory examination of fish health and their own accumulated practical expertise to detect or suspect the illness epidemic. Fish farmers frequently examined the physical appearance and behavior of their fishes. However, when farmers received any spotted fish after harvest, they immediately checked its sickness. The environmental conditions of the farm during disease epidemic were recorded for various farm environment parameters (Table 6).

Table 5: Diseases commonly occurred in study area

Name of disease	Clinical sign	Age and size of affected fish
Ulcer disease/ EUS	1. Red wound at the base of dorsal fin, pectoral fin and caudal fin. 2. Fragmentation of caudal fin.	All fishes can be affected at any size and age but they are more susceptible after at the age of 2 month.
Fin and Tail rot	1. Fragmentation of fin. 2. Excess mucus secretion.	All fishes can be affected at any size and age.
Argulosis	1. Restlessness. 2. Argulas in scale pocket. 3. Scrubbing at pond wall.	Fingerling to large fishes can be affected at any size and age.
Malnutrition	1. Disproportional head and body ratio.	At any size and age.

Table 6: Some important parameters of checking diseases

Parameters	Comments
Temperature	67% of the farmers viewed that water temperature was much higher than normal condition and suddenly decreased due to raining.
PH	Farmers suspected about higher pH fluctuation due to sudden raining.
Dissolve oxygen	17% of the farmers think about dissolve oxygen deficiency after raining
Hydrogen sulphide	92% of the farmers surveyed were leaking knowledge about hydrogen sulphide.
Water Depth	76% of the farmers reported that the farm possessed very high depth than the recommended depth.
NH_3, NH_4	59% of the farmers surveyed were leaking knowledge about NH_3, NH_4.

Treatment

For the treatment of ailments, farmers employed salt, potassium permanganate, copper sulphate, vitamin C, etc. (Table 7). Additionally, they treated ulcers with the antibiotic erythromycin. Although they claimed that Timsen is a viremicide, they utilized it to treat fin rot.Farmers also applied various chemicals, high doses of vitamin C, complete water exchange and transport to another pond to cure diseases (Aftabuddin *et al.*, 2016). About 38% of farmers made contact with UFO and they got assistance, which were limited to offering recommendations only.

Table 7: The common treatment of fishes

Name	**Drug**	**Dose**	**Price**
Ulcer disease/ EUS	Copper sulphate	7.57 gm. CuSO4+ 7.75 gm. KMnO4 + 242 gm. salt/decimal (pond treatment)	20 tk./gm.
	Potassium permanganate		40 tk./gm.
	Salt (NaCl)		25 tk./kg.
	Erythromycin (Erythromycin thaiosaianate)	3 gm. erythromycine + 5 gm. vitamin-C /kg feed (Oral treatment)	400 tk./100gm.
	Vitamin-C		1000 tk./500gm.
Tail and fin rot	Timsen	1 gm./decimal	300 tk./50ml.
Argulosis	Fresh magic (Sulphadiagin, Trimetheprim)	3 ml./decimal	1200 tk./1L
	Rip cot (Sypermethrine)	1.82 gm.	500 tk./400ml.
	Salt	250 gm. KmnO4+ 5 kg salt	25 tk./kg
	Potassium permanganate		35 tk./gm.

Remedial measures undertaken to prevent different types of fish diseases

It was found that farmers sometimes used bleaching powder to get rid of the sickness and utilize treatment when it should happen within 40 days of stocking. This was a precaution that would stop the sickness from spreading further. Farmers started an emergency harvest if a disease epidemic arose on the farm after 40 days had passed since stocking. A little proportion of farmers were found to regularly treat diseases using bleaching powder, while other chemicals were used without any set dose restrictions. When the first treatment for bleaching powder was ineffective, a second treatment was administered after 7–10 days and occasionally salt and antibiotics are used. Farmers used to feeding Oxy-tetracycline or teramycine 40-50 mg per kg body weight of fishes for 5-7 days orDoxycycline 20-30 mg per kg body weight of fishes for 5-7 days to control the bacterial diseases. They used lime (CaO) 400-500g or sprinkled salt (NaCl) 5-8 kg or combination of sprinkled lime 0.25 kg and salt 0.25 kg per decimal per five feet depth of pond water to prevent fungal diseases. For white spot parasitic disease prevention, salt or NaCl at 7000-20000 ppm were used. Vitamin supplement, beef liver, yeast and dried milk were used to prevent gill diseases. Smith (2012) stated that an important area of disease prevention and control that is often overlooked in the aquaculture industry is disinfection. The study found that government extension programs and non-governmental organizations (NGOs) provided very little help to fish farmers with regard to disease prevention and health management. During interviews, it was observed that farmers and workers were engaged in cultural activities and unwilling to disease recovery issues in most of the cases. When they faced with severe illness issues, they sought counsel on the best course of action from other farmers, pesticide and feed salespeople, hatchery operators, and themselves.

3.5 Profitability of Fish Production

Cost components of fish farming were divided into two main categories named (a) variable costs and (b) fixed costs. The following variable cost elements like mud removal cost, lime solution cost, labor cost, fingerling cost, fertilization cost, chemical cost, medicine cost, feed cost and maintenance cost were measured. Similarly, the fixed cost elements like land use cost and total cost of production were measured. Gross return, gross margin, net return and undiscounted benefit cost ratio (BCR) were computed to estimate the profitability. Total cost of this study was Tk. 904,630 per hectare per year of which the average fixed cost was Tk. 144,530, which was 16% of the total cost and the total variable cost was Tk. 760,100 (Table 8). Shawon *et al.* (2018) calculated total fixed cost and variable cost to be Tk. 41801 per hectare and Tk. 102795 per hectare, respectively. Total fixed and variable cost to be Tk. 38,908 and Tk. 3,344,966 respectively per hectare for pangas fish production (Sharmin, 2016). Prodhan and Khan (2018) also found into the overall fixed and variable costs were Tk. 58,045 per hectare and Tk. 2,192,313 per hectare, respectively in commercial aquaculture farms in a few different areas of Bangladesh. The total cost and variable cost of fish production per hectare were Tk. 3,33,457.75 and Tk. 297753.86, respectively, i.e. 89.29% of the total cost in Mymensingh (Saha, 2004). Whereas the total and variable cost was Rs. 7,43,798 and Rs. 5,85,724.58 respectively i.e. variable cost was 79% of the total cost in Nepal (Sharma *et al.*, 2018). The production cost of fish was higher compared to most of the previous study, especially, due to the increase of the price of fingerlings, feeds, fixed cost and labor cost.

The larger amount of money spent by fish farmer in the study area was mainly on purchase of fish feeds (42.5%) and labor cost (13.9%). The result of highest feed cost is in agreement with the findings of Okpeke and Akarue (2015) who found out that feed accounted for the highest cost (59.45%) of fish production in Nigeria. Cost of fingerlings was Tk. 78,520 and fertilizers and manure was Tk. 34,220 per hectare and those were about 8.7% and 3.8% respectively of the total cost. Cost of fingerlings and fertilizer were lower and labor cost was higher (Hossain and Islam, 2014) compared to this study. The utility cost for pond management was Tk. 54,295 i.e. 6% of the total cost.Total utility cost was Tk. 21,800 i.e. 3.65% of the total cost (Quddus and Sen, 2020). Gross return, gross margin and net return were found to be Tk. 1,239,400, Tk. 479,300 and Tk. 334,770 respectively per hectare per year. These gross and net returns were approximately double from the study of Quddus and Sen (2020) and Sarwer *et al.* (2016).The gross margin wasTk. 479,300 indicates that it was a good amount of return over variable cost of production. The benefit-cost ratio (BCR) was 1.37 in this study. Benefit cost ratio of pond fish farming was 1.41 in Satkhira (Hossain, 2020) and 1.51 in Tangail (Rahman *et al.*, 2015) and 1.28 in Jamalpur (Quddus and Sen, 2020). For marketable fish culture is reasonable and cost-effective with a cost-benefit ratio of 1.50 (Islam *et al.*, 2017) and 1.39 (Prodhan and Khan, 2015). Therefore, pond fish farming was moreprofitable and potential in Mymensingh district and not much lower than other regions of Bangladesh.

Table 8: Cost and return of farm fish production per hectare per year

Cost Item	Cost (Tk./ha)	Percentage of Total Cost
Cost		
Mud removal	26,550	2.9
Lime solution	18,130	2.0
Labor	125,565	13.9
Fingerling	78,520	8.7
Feed	384,450	42.5
Fertilizer / manure	34,220	3.8
Chemical cost	12,700	1.4
Medicine cost	25,370	2.8
Utility cost	54,295	6.0
Total variable cost (TVC)	760,100	84.0
Fixed cost	144,530	16.0
Total cost (TC)	904,630	100.0
Return		
Gross return (GR)	1,239,400	
Gross Margin (GM) = (GR-TVC)	479,300	
Net Return (NR) = (GR-TC)	334,770	
Benefit Cost Ratio (BCR) = (GR/TC)	1.37	

1 US Dollar = Tk. 86 at the time of data collection

3.6 Multiple Linear Regression Analysis for Fish Production

The multiple regression results explained about 93.7 percent variability of farm fish production (Table 9). Highly significant F values interpret that all the explanatory variables were important for explaining the variation of fish production. Therefore, F values of the individual coefficient of the selected explanatory variables should be expected to become significant, which exposes that the descriptive strength of the model was extremely robust. The positive sign and values of regression coefficients indicate increase and negative sign and values indicate decrease of fish production with increase of the degree of independent variables. From the fitted regression line respectively, it was observed that lime, amount of fertilizer, cost of chemical, cost of medicine and utility cost have positive impact on the production of fish. However, age of farmer and experience of farming have also positive impact on fish production, but they are not significant. Other variables in the model did not have any impact. Coefficients of fertilizer and utility cost were highly significant in this study whereas Amin *et al.* (2001) founds coefficients of fertilizer; fingerlings and feed cost were significant.

Table 9: Estimated coefficient and related statistics of the multiple linear regression function of farm fish production

Variables	Coefficients	Significance	t-values
Age of owner	685.998	0.166	1.398
Education of owner	498.872	0.678	0.417
Experience of farming	959.902	0.178	1.357
Farm size (decimal)	89.517	0.081	1.767
Mud removal cost in pond preparation	-0.008	0.996	0.005
Lime solution cost in pond preparation	3.014	0.004	2.938**
Labor cost in pond preparation	-0.492	0.853	0.186
Total cost of fry	0.013	0.376	0.890
Cost of fertilizer used	56.175	0.000	5.695**
Cost of chemical used	7.548	0.000	10.923**
Cost of medicine used	2.011	0.000	14.337**
Total cost of feed used	-0.010	0.108	1.625
Utility cost	0.553	0.000	9.717**
R^2	0.937		
Adjusted R^2	0.927		
F-value	97.667	0.000	

(* and** indicates significances at 0.05 and 0.01 probability level respectively)

IV. CONCLUSIONS

The required data was collected from a specific area of the country covering a small number of respondents. Thus, the study has a narrow scope to generalize the conclusions. The researchers faced some problems collecting reliable information as they had no written records of their transactions and hesitated to provide data from their memories. Therefore, efforts were made to minimize errors as far as possible. But the farmers studied lacked access to training and 39% were illiterate and primary level of education. Thus, farm families should be motivated to educate their children and Fisheries Department should take initiative to facilitate more training programs on fish farm management in the rural areas. Maintaining a good culture environment through the use of proper management practices will increase production, fish quality and marketability as well as reduce the risk of disease. In resolving disease issues, the researcher's intense motivation in taking part to solve the problems by paying more attention to them and having more deliberations. Appropriate biosecurity guidelines are essential for sustaining healthy fish and limiting the danger of disease transmission. Farmers should be trained about basic health management plans and there should be a support service for easy and proper diagnosis and treatment of fish disease.

Fish production should be increased through promoting the knowledge level of the farmers and improving the production technology. They would be attracted to invest more in fish production in order to ensure easy accessibility of different inputs to the fish farmers. It is evident from the study that fish production is labor intensive which means there has a great scope to fishery sub sector for increasing employment prospects. Evident from the findings of the study is that fish production is cost-effective enterprises as indicated by the benefit-cost ratio and hence fish farming should be encouraged. The results from multiple regression analysis implied that the included variables accounted only for 6.3 percent of the variation in pond fish farming and highly significant F-values indicating that all the included variables were important for expressing the variation in pond fish production. Hence, the inclusion of independent variables was reasonable. Lime, amount of fertilizer, cost of chemical, cost of medicine and utility cost have positive and significant impact on the production of fish means that farmers should give more emphasis to these inputs for higher fish production.

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