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Growth Performance and Economic Analysis of Swamp Eel (*Monopterus cuchia*): An Application of Cobb-Douglas Production Function

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Abstract

This study was designed to highlight the culture techniques and socio-economic conditions of cuchia farmers. The study used primary data collected from Adamdighi upazila in Bogura district of Bangladesh for a period of 120 days from 05 March to 26 June 2016. Three different experimental treatments were used. For socio-demographic factors, two-stage stratified sampling design was used in this study. The target population was Cuchia farmers. So, a total of 90 Cuchia farmers were finally selected for analysis. One way ANOVA with multiple comparison test was applied to identify significant treatments. Cobb-Douglass production function was used to determine the contribution of the most important variables in the production process of Cuchia farming. Analysis showed that, more than 80 percent of Cuchia fish survived with fish fry and snail meat feed. All the mean differences were statistically significant to compare Cuchia meals between two periods of time. For both cases weight and height, the result showed that vermi meals were significantly different from dried fish, while fish fry and dried fish were also significantly different. The estimated result showed that a significant negative association was found between cost of fish fry feed and gross income of Cuchia farming. The cost of seed also showed a negative association. In the contrary, this study found positive and significant association in cost of Dried fish, cost of human labor. It is well known fact that Cuchia contain higher amount of nutritious value which is important for human health. Therefore, policymakers should pay special attention to this sector.

Introduction

Bangladesh is an agricultural country, the weather is considered to be the most suitable for aquaculture and fisheries on the global map, currently not only one of the richest countries of aquatic biodiversity but also one of the world's leading fish producing countries Shamsuzzaman et al (2017)Fisheries is currently the most valuable agricultural activity in Bangladesh which is playing a significant role in the smooth use of aquatic resources, food security, employment and income generation, trade, foreign exchange income sources and above all poverty reduction in the national economy (Sarker et al., 2014). This sector of agriculture plays a vital role in having 3.50% share in national GDP (Dey, 2020) 25.71% in agricultural GDP and 1.23% of the country's export earnings (DoF, 2020).

Bangladesh achieved self-sufficiency in fish production, producing more fish than the country's demand Shamsuzzaman et al (2017). Millions of rural people in the country, directly or indirectly, have earned their livelihood by participating in fish production to processing, and more than 80 million people are employed in this sector every year Bangladesh is currently ranked 1st in hilsa production, 2nd in the rate of increase in freshwater fish production, and 5th in the world of total fish production which has brought unparalleled success in the world arena.

The climate and aquatic environment of Bangladesh are very suitable for living of eel-like fish, especially freshwater mud eel (*Monopoterus cuchia*), so their distribution in the wetlands of the country is extensive. Freshwater mud eel is an air breathing fish locally known as "kuchia" or “Cuicca fish” belongs to the Synbranchiformes order's Synbranchidae family (Rosen and Greemwood, 1976; Jhingran and Tawler, 1991). Cuchia is a fish, rich in delicious nutrients and medicinal values that plays an important role in the socioeconomic development of Bangladesh and is highly demanded in the global market (Miah et al., 2015). Cuchia can survive with low dissolve oxygen and high water temperatures, which is found in large quantities in all water bodies, including canal-beel, haor-baor, paddy fields, and floodplain areas of Bangladesh. Remaining yearly country production of cuchia was found to be 364.57 MT. where highest production comes from Borguna district (Islam, et al, 2020) 43.91 tonnes. Cuchia is an advanced food-quality fish found in other South Asian countries such as India, Pakistan, Nepal besides Bangladesh Chakraborty et al. (2017). Cuchia is high in protein compared to other fish; about 303 kcal of energy are available every 100 grams of cuchia, where 110 kcal of energy are found in other fish such as carp. Cuchia fish play an important role in eliminating anemia, controlling hypertension, and preventing cancer. Although this fish is not of much importance to the people of the country, it is very popular item in the tribal community.

A large amount of foreign currency is acquired every year from the natural water bodies of Bangladesh by exporting a large quantity of cuchia to China, Japan, Hong Kong, Thailand, Malaysia, South Korea and Europe, resulting in the snake-like fish opening by an immense possibility. In recent years, it has been considered one of the export products especially among fisheries products, according to Bangladesh Export Promotion Bureau (EPB) in fy 2017-18, Bangladesh has earned USD 15 million by exporting 70.0175 tons of cuchia to 17 countries including Taiwan, China, Hong Kong (EPB, 2018). Today, cuchia is recorded as not only rare species, but also red-listed species (Khan et al., 2000) due to its lack of cultivation, huge demand in the market, and over-harvesting. In addition, some natural and manmade causes, such as wetland filling, extreme drought, unplanned sluicegate construction, flood control dam construction, convert wetlands into land, excessive pest use in agricultural land are reducing the abundance of this fish day by day.

This situation continues, the nutrient-rich fish is likely to be extinct from the water bodies of Bangladesh. The near future, so some initiatives need to be taken publicly and privately to protect the fish such as the conservation of natural biodiversity through artificial production which has been successfully implemented at the Flood Plains Sub-Centre of Bangladesh Fisheries Research Institute. As a result, there has been a huge opportunity to become self-reliant by cultivating cuchia and activating the wheels of the Bangladeshi economy. However, there is no reliable information on eel culture technology in Bangladesh yet. Therefore, a study was designed to highlight the culture techniques and socioeconomic conditions of cuchia farmers.

Materials and Methods

Experimental Design

The study was conducted in Adamdighi upazila of Bogura district of Bangladesh for a period of 120 days from 05 March to 26 June, 2016. There were three different treatments in this experiment named T-1, T-2 and T-3. T-1 is the treatment where vermi and snail meat were fed, T-2 is the treatment where fish fry and snail meat were fed and T-3 is the treatment where dried fish along with snail meat were fed as cuchia feed.

Ditch Preparation and Management

The ditches were about 15.8 m long, 12.13 m wide in, and 1.22 m depth. The ditches were made of tarpaulin lining the inside of the bamboo wall, with the entire tarpaulin lining on the floor. The bottom of each ditch was filled with 0.3 m of soil where composition was 70% clay soil and 30% loamy soil. Initially, each tank was disinfected with lime, and then water was entered in such a way that it was 0.15 m empty from the top. For 3-4 days after entering the water, various water quality parameters such as PH, DO, Temperature, Transparency, Ammonia, Alkalinity, TDS were regularly measured and some carp fries were released kept under close observation. When the fish fry was alive after 7 days and the water quality parameters were within acceptable range, it was thought that the ditches were suitable for the culture of fresh water mud eel.

Seed Collection and Storage

The cuchia seeds were collected from cuchia collectors with an average length of 25-30 cm and an average weight of 80-100 g. They were carefully transported from the wild to experimental ditch in drums with water and were stored at 1500 per ditch. Just before release, all seeds were dipped in a 5% potassium permanganate solution for a few seconds to ensure removing germs present on the fish surface.

Determination of Water Quality Parameters

It is very important to keep the water quality parameters at an acceptable level for tank/ditch fish culture. During the study periods following water quality parameters were measured.

Dissolved Oxygen (DO)

issolved oxygen of water states the level of free, non-compound oxygen existing in water. It is an important water quality parameter because of its influence on the organisms alive within a body of water. The dissolve oxygen level of water was measured in each 15 days interval by using a DO meter (Hanna-HI-9142, Woonsocket, RI, USA).

Potential of Hydrogen (pH)

pH is considered as the 'pulse of water" which is the most important parameter for fish culture (Munni et al., 2013). Fish cannot survive in waters below pH 4 and above pH 11 for long periods. A pH range of 6.5 to 9 is suitable for fish culture in both an open and the closed system and growth rate of cultured species strongly affected at consistently higher or lower pH levels. pH of each ditch was measured by pH meter (Hanna-HI 98127, Woonsocket, RI, USA) in 15 days interval.

Temperature

Water temperature is an important parameter effecting the feed uptake, growth and survival of all aquatic organisms which is essential to maintained at tolerable range throughout the culture period. Temperature of each experimental ditches were measured using pH meter (Hanna-HI 98127, Woonsocket, RI, USA) where both p and temperature reading were found.

Total Dissolve Solids (TDS)

Total Dissolve Solids of each ditch were measured in 15 days intervals by TDS meter (Hanna-HI-98301, Woonsocket, RI, USA).

Transparency of Water

The transparency of water is the key parameter that indicates the biological productivity or presence of natural food in the water, transparency of the water reduces is due to the presence of particles in the water. The transparency of the ditch water were measured by Secchi disk or a Secchi disc (Angelo Secchi, 1865).

Alkalinity

Alkalinity of water is the measurement of dissolved alkaline substances in water that have the ability to neutralize acid. Alkalinity was measured by alkalinity test kit (Hach-Alkalinity-Test-Kit).

Ammonia

Ammonia, the most important pollutants that cause disease, lower production and growth, or death, can be measured by measuring the total ammonia nitrogen (TAN) presence in water. $NH_3 - N$ (TAN) levels in each ditch were measured in 15 days intervals using an ammonia test kit (Hanna-HI-91700-01, Woonsocket, RI, USA) and ammonia was calculated by using the following formula:

$$TAN = (NH_3 - N) \times \{1 + antilog\left[0.09018 + \left(\frac{2729.92}{273.15 + T}\right)\right] - pH\} \quad (1)$$

here,
TAN = total ammonia nitrogen
NH_3-N= ammonia–nitrogen
T=Water temperature (℃)
pH =Water pH

Feed Management

Cuchia (*M. cuchia*) is a nocturnal animal so, feed was given in the evening once days. It is a carnivorous fish and taken fish seed, frog larvae and different types of aquatic insects as food. Each ditch supplied with sufficient amount of feed considering their body weight and water quality parameters to ensure better growth. The amount of supplied feed was changed in every 30 days interval with the change of their body weight. Feed was supplied approximately 4-7% of their body weight throughout the culture period. The effect of different feeds on growth of the cuchia was observed by providing various types of feed in each ditch during the study period. Treatment 1 supplied with 350 g of vermi and 250 g of snail meat in the first 30 days, 500 g of vermi and 350 gms of snail meat in 2nd 30 days, 750 g of vermi and 450 gms of snail meat in the third 30 days and 1050 g of vermi and 550 gms of snail meat in the last 30 days, respectively. Treatment 2 supplied with 350 g of fish fry and 250 gms of snail meat in 1st 30 days, 500 g of fish fry and 350 gms of snail meat in 2nd 30 days, 750 g of fish fry and 450 gms of snail meat in 3rd 30 days and 1050 g of fish fry and 550 gms of snail meat in the last 30 days, respectively. However, treatment 3 was supplied with 350 g of dry fish and 250 gms of snail meat in the first 30 days, 500 g of dry fish and 350 gms of snail meat in 2nd 30 days, 750 g of dry fish and 450 gms of snail meat in the third 30 days and 1050 g of dry fish and 550 gms of snail meat in last 30 days, respectively.

Growth Performance Analysis

Fish growth varies with seasons, water quality parameters, feed composition and feeding trial, culture techniques, and stocking density. During the study period, freshwater mud eels were sampled at 30 days intervals, to monitor their growth parameters. The growth of the cultured species was documented by measuring the length (cm) and weight (gm) of the samples with the help of a measuring tape and an electric balance (MANSI Digital PIECE Counting Scale, 30 Kg), respectively.

Weight gain (W) of cuchia sample were calculated as:

$$W = W_2 - W_1$$

Where W_1 is initial weight of cuchia and W_2 is final weight of cuchia sample.

Specific growth rate (SGR) the culture species in three different treatments were calculated by using the following formula:

$$SGR\% = \frac{lnW_2 - lnW_1}{T_2 - T_1} \times 100 \text{.................................(2)}$$

Where, $lnW_2 - lnW_1$ is the difference of the logarithm of initial and final weight and $T_2 - T_1$ time of experiment (days).

Survival rate (SR) was calculated by using the following formula:

SR% = (No. of cuchia harvested/No. of cuchia stocked) ×100

Data Source

This study was a cross-sectional study and was carried out in 2021. Data were collected from Cuchia fattening from the two Upazilas in the Bogura district.

Sampling

The survey was based on a two-stage stratified sample of a Cuchia fish producer. At the first stage, we selected two major cuchia farm under Adamdighi upuzila of Bogura district. After identifying the area, we contacted the corresponding district Department of Fisheries (DoF) and Department of Agricultural Extension (DAE) personnel in each upazila and collected a comprehensive list of Cuchia producing farmers. After collecting the farmers' lists, we considered each upazila as a stratum. In the second stage, a random number generator was be considered, and we selected 90 farmers per strata from this Upazila. A total of 90 Cuchia farmers were selected from this selected Upazila.

Statistical Analysis

To determine the contribution of the most important variables in the production process of Cuchia farming, we applied the Cobb-Douglass production function. A p-value ≤0.05 was considered statistically significant for this study.

Mathematically, the Cobb-Douglas production function can be written as follows:

$$Y=\alpha X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7}...X_n^{bn} e^{\epsilon_i} \text{........ (3)}$$

After taking log on both sides, we get

$$lnY= ln\ \alpha + b_1 lnX_1 + b_2 lnX_2 + b_3 lnX_3 + b_4 lnX_4 + b_5 lnX_5 + b_6 lnX_6 + \epsilon_i \text{ ..(4)}$$

where, Y = Gross income from Cuchia (Tk/disk);
X_1= Cost of Vermi (Tk./ditch);
X_2= Cost of fish fry (Tk / ditch);
X_3= Cost of dried fish (Tk / ditch);
X_4= Cost of human labor (Tk / ditch);
X_5= Cost of seed (Tk / ditch)
X_6= Cost of fertilizer & manure (Tk / ditch);
a= Intercept;
$b_1...b_6$= Coefficient of the respective variable;
e_i= Error Term;
i= 1, 2...6.

For data analysis, SPSS (v 25.0) and R-programming (4.0.0) were used.

Results

Figure 1 shows the survival rate (in percentage) of several treatments. Almost 85% (N=13) of Cuchia survived when they ate fish fry, while only 50% of Cuchia survived when they ate dried fish.

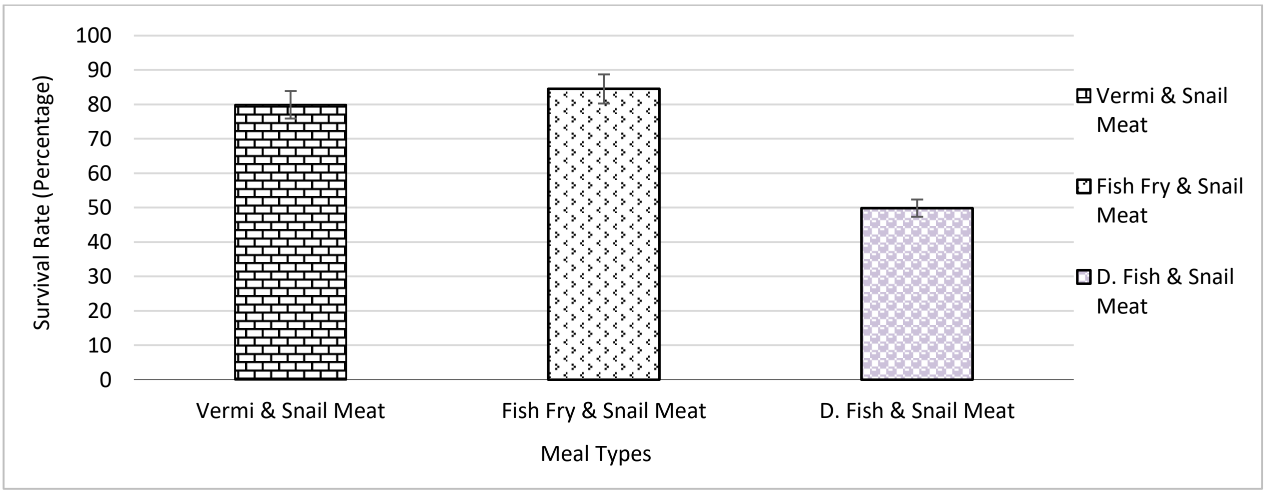

Figure 1. Percentage of survival rate among fish meals (N=13).

Table 1 shows Cuchia fish farming between two times (initial time farming and final time farming). The mean difference was statistically significant (P<0.05). In terms of Vermi meals, the mean ± SD length of the initial time was 27.62±1.81 cm (N=13), whereas for the final time frame (120 days), it was 39.48±2.16 cm (N=13) (Figure 2). In addition to fish fry, the mean weight (gm) of the initial Cuchia was significantly different from the mean weight (gm) of the final Cuchia farming. Details are presented in Table 2. Figure 2 and 3 shows the Comparison of Cuchia growth performances (length and weight) based on three treatments in two-time frame.

Table 2 shows the water quality parameters for three treatments and their comparison between two time frames (initial time frame and final time frame). The mean difference was not statistically significant (P>0.05). In terms of treatment 2, the mean difference was not statistically significant (P>0.05) except for dissolved oxygen (DO). From Table 2, we observed that the mean DO (mgl-1) of the initial time frame of Cuchia fish farming significantly differed from the mean DO (mgl-1) of the final time frame of Cuchia fish farming. The mean difference was not statistically significant (P>0.05) for treatment 3 (Table 2).

In terms of vermi fish, the average weight of Cuchia was 217gm (Table 3). On the contrary, the highest average weight of Cuchia was detected in those who ate fish fry in this analysis. Similarly, the highest average height of Cuchia was identified among those who took vermi, while the shortest length of Cuchia was found among dried fish taken (Table 3). Details are presented in Table 3 and Figure 4.

To identify whether three specific groups (vermi, fish fry, and dried fish) were significantly different from each other or not, we applied one-way analysis of variance. For the weight data in the ANOVA test, it is concluded that there is a statistically significant difference between the mean of the group means (P<0.05). In terms of length measures, the result of one-way ANOVA revealed that the *P*-value was found to be 0.024, which signifies that there is a significant difference between the scores obtained in different groups (Table 4).

LSD and Tukey simultaneous with a 95% error rate of Cuchia growth (weight and length) are presented in Table 5. For weight cases from the Tukey test at 95% CI, we show that vermi meals were significantly different from the dried fish, while fish fry and dried fish were also significantly different. Conversely, it was also observed that the difference between vermi and fish fry mean is not statistically significant. However, in the LSD multiple comparison test, we found similar results as before in the Tukey HSD test. In terms of length cases (cm), the P value indicated that there is a significant difference between vermi and dried fish meal. From the Tukey test, we show that the mean difference between fish fry and

Table 1. Comparison of Cuchia meals between two time periods of farming (N=13)

Food Habits/Treatments	Measures	Initial time (Day 30)	Final time (Day 120)
		Mean±SD	Mean±SD
Vermi	Length (cm)	27.62^{a} ±1.81	39.48^{a} ±2.16
	Weight (gm)	74.84^{b} ±14.07	217.1^{b} ±37.91
Fish Fry	Length (cm)	30.86^{b} ±3.56	39.14^{b} ±2.87
	Weight (gm)	106.65^{b} ±14.96	235.04^{b} ±54.03
Fried Fish	Length (cm)	24.5^{a} ±0.93	35.44^{a} ±1.31
	Weight (gm)	64.86^{b} ±6.17	121^{b} ±16.26

Note: Values for each experiment group in the same row followed by different superscripts are significantly (P<0.05) different.

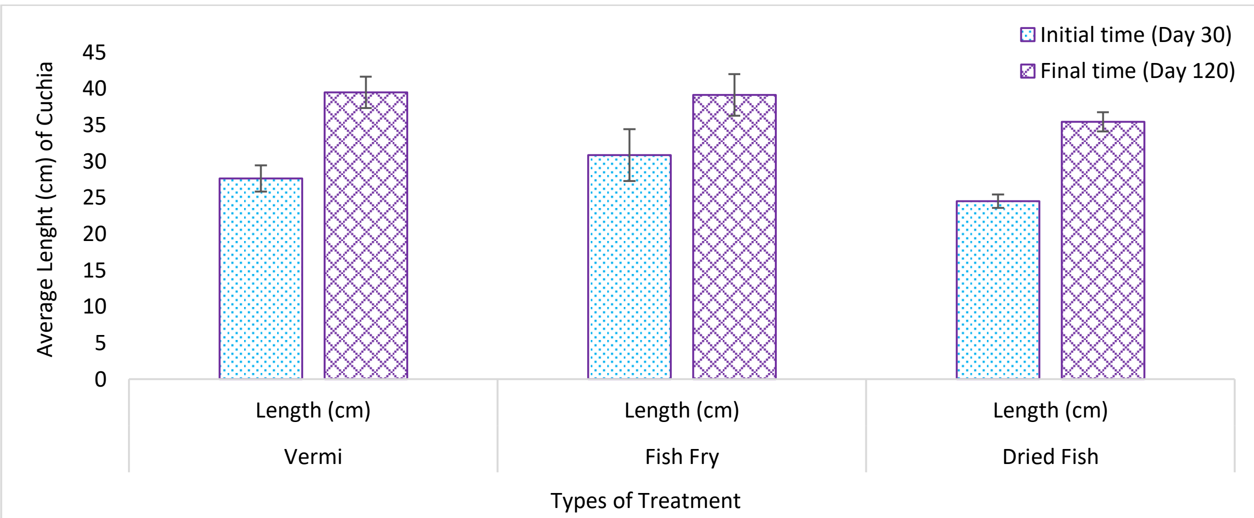

Figure 2. Comparison of Cuchia length (cm) based on three treatments in a two-time frame (N=13).

Table 2. Water Quality Parameters on various Treatments and their comparison between Two-Time Frame

Water quality parameters	Day 30 Mean±SD	Day 120 Mean±SD	p-value
Treatment 1			
PH	7.70 ±0.92	7.77±0.96	0.910
Ammonia (mgl-1)	0.53±0.15	0.59±0.06	0.673
TDS (mgl-1)	344.33±111.01	265.00±11	0.323
DO (mgl-1)	4.73±0.70	4.87±0.38	0.803
Transparency (cm)	28.66 ±0.59	26.43±2.03	0.131
Total Alkalinity (mgl-1)	152.26±7.08	148.95±5.11	0.197
Temperature (o C)	23.93±0.24	21.17±2.49	0.221
Treatment 2			
PH	7.30 ±0.60	7.97±0.95	0.109
Ammonia (mgl-1)	0.53±0.04	0.41±0.07	0.202
TDS (mgl-1)	320.00±73.26	321.00±132.25	0.991
DO (mgl-1)	5.00±0.30	5.67±0.57	0.047
Transparency (cm)	28.95 ±1.50	27.49±0.68	0.176
Total Alkalinity (mgl-1)	161.92±22.29	168.79±16.65	0.764
Temperature (o C)	21.57±1.42	21.70±2.14	0.954
Treatment 3			
PH	7.60±0.82	7.03±0.32	0.467
Ammonia (mgl-1)	0.37±0.26	0.35±0.05	0.935
TDS (mgl-1)	274.00±61.65	226.67±77.69	0.615
DO(mgl-1)	4.57±0.67	5.43±0.81	0.258
Transparency (cm)	29.06±0.53	30.34±3.60	0.575
Total Alkalinity (mgl-1)	157.24±4.99	141.28±16.58	0.186
Temperature (℃)	24.43±0.78	21.53±1.86	0.118

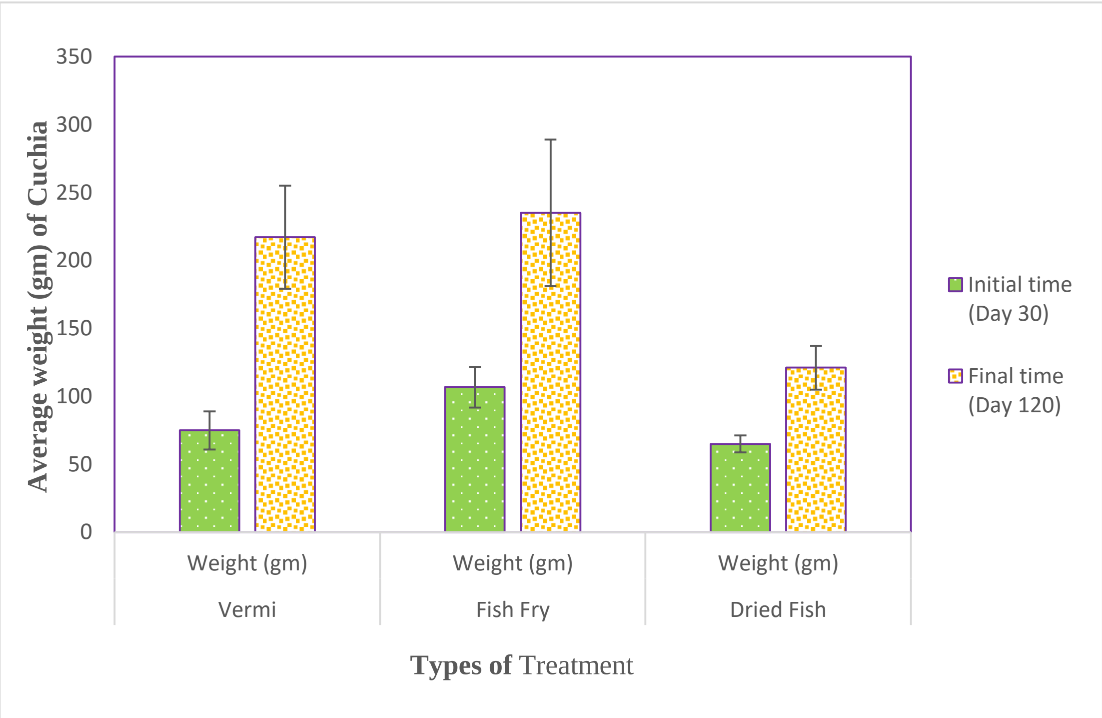

Figure 3. Comparison of Cuchia weight (gm) based on three treatments in a two-time frame.

Table 3. Mean comparison of Vermi, Fish Fry, and Dried Fish.

Meals	Vermi Mean±SD	Fish Fry Mean±SD	Dried Fish Mean±SD	F-value	p-value
Weight (gm)	217.10±37.92	235.04±54.03	121.00±16.26	12.20	0.001
Length (cm)	39.48±2.16	39.14±2.87	35.44±1.31	5.16	0.024

dried fish is also significantly different (p=0.049). Conversely, it was also observed that the difference between vermi and fish fry is not statistically significant. However, the same result was also found in the LSD multiple comparison test (Table 5).

Factors Affecting Cuchia Farming Productivity

The estimated values of the regression coefficient are presented in Table 6. As seen in Table 6, the R-squared is 0.72, showing that about 72% of the variation in return from the Cuchia farm was explained by the explanatory variables considered in this analysis. The F value for Cuchia farming was found to be 24.22 (p < 0.001), which implies that the independent variables included in the analysis were important in explaining the variation in the gross return.

The cost of fish fry, the cost of human labor, and the cost of seed variables significantly influenced the gross return of Cuchia fish farming. The coefficients of cost of human labor were found to be positively associated with gross return with a 5% significance, whereas the coefficients of cost of fish fry and cost of seed were found to be negatively associated with gross return of Cuchia faming with a 5% significance.

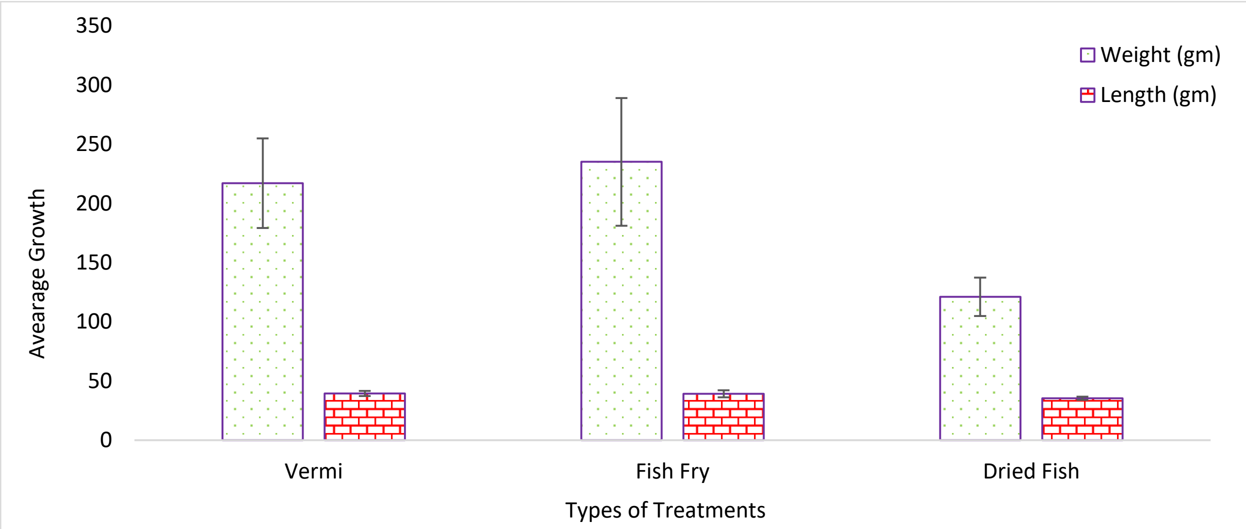

Figure 4. Average growth performance of Cuchia by various treatments.

Table 4. Analysis of variance (ANOVA) table for Cuchia Weight and length data.

Data Types	Source of variation	Degrees of freedom (df)	Sum of squares	Mean square	F	P value
Weight	Between groups	37603.63	2	18801.81		
	Within groups	18487.23	12	1540.60	12.20	0.001
	Total	56090.86	14			
Length	Between groups	50.21	2	25.11		
	Within groups	58.39	12	4.87	5.16	0.024
	Total	108.60	14			

Table 5. Multiple comparisons based on Tukey's and LSD procedure with simultaneous 95% confidence limits.

Types of Growth	Multiple comparison Test	Group comparison	Difference between means	Simultaneous 95% confidence interval	Adjusted P-value
Weight (gm)		Vermi- Fish Fry	-17.94	(-84.17,48.29)	0.755
	Tukey HSD	Vermi- Dried Fish	96.10**	(29.87, 162.33)	0.006
		Fish Fry - Dried Fish	114.04**	(47.81, 180.27)	0.002
		Vermi- Fish Fry	-17.94	(-72.03,36.15)	0.484
	LSD	Vermi- Dried Fish	96.10**	(42.01, 150.19)	0.002
		Fish Fry - Dried Fish	114.04**	(59.95, 168.13)	0.001
Length (cm)		Vermi- Fish Fry	0.34	(-3.38, 4.06)	0.968
	Tukey HSD	Vermi- Dried Fish	4.04*	(0.32, 7.76)	0.033
		Fish Fry - Dried Fish	3.70*	(-0.02,7.42)	0.049
		Vermi- Fish Fry	0.34	(-2.70, 3.38)	0.812
	LSD	Vermi- Dried Fish	4.04*	(1.00, 7.08)	0.013
		Fish Fry - Dried Fish	3.70*	(0.66,6.74)	0.021

Table 6. Estimated values of the coefficients of Cobb-Douglas production function.

Independent variables	Coefficient	Standard Error	t value	*P*-value
Intercept	8.22***	1.179	4.83	<0.001
Cost of Vermi (X_1)	0.10	0.023	2.30	0.290
Cost of Fish Fry (X_2)	-0.28*	0.201	1.71	0.049
Cost of Dried Fish (X_3)	0.13***	0.040	8.24	<0.001
Cost of human labor (X_4)	0.09**	0.029	2.89	0.005
Cost of Seed (X_5)	-0.35***	0.056	6.78	<0.001
Cost of fertilizer & manure (X_6)	-0.05	0.094	0.75	0.245
R^2	0.72			
Adjusted R^2	0.68			
F-value	24.22***			

Discussion

The present study was conducted to observe the growth of *Monopterus cuchia* in man-made ditches. The growth of cuchia to a greater extent depended on the quality and quantity of food available (Chakraborty et al., 2010). According to Rahman et al., 1982, the primary productivity of water body is dependent on physicochemical factors of water, which are governed by environmental factors. The temperature of the present experimental ditches was within the acceptable range for fish culture that agrees the findings of Boyd (1979). An ideal temperature for proper feeding and growth of *M. cuchia* is between 20.0 to 35.0 ˚C and it is further reported that the fish would not eat well below and above this temperature (Usui, 1974; Nasar, 1997). The transparency level that is observed in experimental ditches is similar to the findings of Boyd (1979) and Dewan (1973); where the authors reported 15.0 to 40.0 cm transparency for fish culture as appropriate and further added that the close variation in transparency could be due to depth of water, availability of the plankton population, and rainfall. pH in the water body is a significant factor for successful fish culture. The pH values were in an acceptable range and is well with the findings of Bashak et al. (2021), Chakraborty et al. (2018), Chakraborty et al. (2003), Baird et al. (2017) and Narejo et al. (2003). Usually, successful fish culture depends on the careful management of dissolved oxygen at optimum level. DoF (1996) stated that the range of dissolved oxygen content for the fish culture should be 5.0-8.0 mgL^{-1}. DO values of the experimental ditches were found to vary from 4.73$\pm$0.70 to 4.87$\pm$0.38, 5.00$\pm$0.30 to 5.67$\pm$0.57 and 4.57$\pm$0.67 to 5.43$\pm$0.81 in treatment 1, 2 & 3 respectively which are agreed well with the findings of Chakraborty et al. (2017); Chakraborty et al. (2010); Rahman et al. (2018); Chakraborty et al., (2018); Chowdhury et al., (2019). The Alkalinity of the present study was found to be similar to the findings of Chakraborty et al. (2017) and Rahman et al. (2018). These higher values of total alkalinity might be due to the higher amount of lime used for ditch preparation (Boyd and Lichtkoppler, 1982). Ammonia concentrations were found as 0.59$\pm$0.06 mgL^{-1}, 0.41$\pm$0.07 mgL^{-1} and 0.35$\pm$0.05 mgL^{-1} in treatment 1, 2 & 3 respectively which are slightly higher than the findings of Rahman et al. (2018) and Chowdhury et al. (2019). This might be due to the use of high-protein sources as feed.

The growth of cuchia to a greater extent depended on the quality and quantity of food available (Chakraborty et al., 2010). Final weight of cuchia in the experimental ditches was found as 217.10$\pm$37.92 g, 235.04$\pm$54.03 g and 121.00$\pm$16.26 g in treatment 1, 2 & 3 respectively. That indicates the growth of cuchia in treatment 2 (where experimental cuchia is fed with fish fry) is significantly higher than treatment 1 and 3. This finding is quite similar to the findings of Narejo et al. (2003), where the authors reported better growth of cuchia fed with fish fry over those fed with pelleted diets. The significantly highest survival rate was recorded in treatment 2 (fed with fish fry), which is 84.53% whereas the lowest survival rate was recorded in treatment 1 (fed with vermi), which is 49.87%. The findings of the present study agree well with the findings of Narejo et al. (2003) where the authors reported highest survival rate of cuchia fed with fish fry than the other two treatments.

Conclusions

Monopterus cuchia have great food value, as they are highly nutritious fish and are used as delicate food items in the different parts of the world. Better production of *Monopterus cuchia* could lead to export of larger fishery products in the international markets which will ultimately end with grater earning of foreign currency. Alongside, it can generate better income and employment opportunities for the peoples who are involved directly or indirectly with its marketing channel.

Ethical Statement

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Funding Information

None.

Author Contribution

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Conflict of Interest

The authors declare that they have no competing interests.

References

A. Munni, Z. Fardus, M. Y. Mia and R. Afrin, 2013. Assessment of Pond Water Quality for Fish Culture: A Case Study of Santosh Region in Tangail, Bangladesh. J. Environ. Sci. & Natural Resources, 6(2): 157-162

Baird, R., Eaton, A.D., Rice, E.W., Bridgewater, L., Water Environment Federation, 2017. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, Dc.

Bashak, S.K., Paul, A.K., Hossain, Md.A., Atique, U., Iqbal, S., Uddin, Md.N., Farhaduzzaman, A.M., Rahman, Md.M., Islam, Md.S., 2021. Growth Performance and Culture Economics of Mud Eel Semi-Intensively Cultured under Varying Stocking Densities in Rain-fed Earthen Ponds. Punjab University Journal of Zoology 36. https://doi.org/10.17582/journal.pujz/2021.36.1.101.110

Boyd, C.E., 1979. Water Quality in Warm Water Fish Ponds. Auburn University, Agricultural Experiment Station.

Boyd, C.E., Lichtkoppler, F., 1982. Water Quality Management in Pond Fish Culture. Academic Press, New York.

Chakrabort, B.K., Miah, M.I., Mirza, M.J.A., Habib, M.A.B., 2003. Rearing and Nursing of Local Sarpunti, Puntius sarana, (Hamilton) at Different Stocking Densities. Pakistan Journal of Biological Sciences 6, 797–800. https://doi.org/10.3923/pjbs.2003.797.800

Chakraborty, B., Shahroz, M., Lucky, D., 2018. Effect of Stocking Density on Survival, Growth and Production of Mud Eel, Monoterus Cuchia (Hamilton) under semi-intensive Pond Aquaculture. Journal of Crop and Weed 14.

Chakraborty, B.K., Azad, S., Barman, B.K., Ahmed, M.J., Faruque, A.M.O., 2010. To Investigate the Technical and Comanagement Aspects of Mud Eel (Monopterus cuchia) Culture B Y Ethnic (Adivasi) Communities in the Northern Bangladesh. Journal of Crop and Weed 6, 19-25.

Chakraborty, B.K., Haque, S.M., Sarker, S., Tripura, R., 2017. Growth and Yield Performance of a Sustainable Aquaculture of cuchia, Monopterus Cuchia (Hamilton) under Semi Intensive Aquaculture in Bangladesh. Journal of Crop and Weed 13, 34–41.

Chowdhury, P., Mahmud, Y., Jahan, D.A., 2019. Freshwater Mud Eel (Monopterus cuchia) Culture with Supplementary Feed at on-farm Management. International Journal of Fisheries and Aquatic Studies 7, 7–11.

Dewan, S. 1973. Investigation into the Ecology of Fishes of a Mymensingh Lake. A Ph.D. thesis submitted to the Department of Aquaculture and Management, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. pp. 191-202.

Dey, S., 2020. Relationship Between Rice Production, Fisheries Production and Gross Domestic PRODUCT (GDP) IN Bangladesh: Co Integrating Regression Analysis (1971-2017). International Journal of Economics and Financial Issues 1, 201–216.

DoF, 1996. Fisheries Statistical Yearbook of Bangladesh. Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh.

EPB, 2018. Export performance (Goods) for FY 2017-18. Ministry of Commerce, Dhaka, Bangladesh.

Islam, Md.T., Hossain, Md.F., Rana, Md.M., Sufian, Md.A., Rabbane, Md.G., Mustafa, Md.G., Kabir, Md.A., Habib, K.A., 2020. Marketing Channel of the Freshwater Mud Eels in Northern Region of Bangladesh and Its Pre-Export Processing Activities. Journal of Aquaculture & Fisheries 4, 26.

Jhingram, A.G., Talwar, P.K., 1991. Inland Fishes of India and Adjacent Countries. Oxford & Ibh, New Delhi.

Khan, S.M.M.H., Khan, M.M.H., Ahmed, R., Islam, M.A., Ameen, M.-U., Nishat, A., Iucn--The World Conservation Union. Bangladesh Country Office, 2000. Red List of Threatened Animals of Bangladesh. Iucn Bangladesh, Dhaka.

Miah, M.F., Ali, H., Zannath, E., Shuvra, T.M., Naser, M.N., Ahmed, M.K., 2015. Breeding Biology and Induced Breeding Status of Freshwater Mud Eel, Monopterus Cuchia. International Scholarly and Scientific Research & Innovation 9, 680–684.

Narejo, N.T., S.M. Rahmatullah, M. Mamnur Rashid, 2003. Effect of Different Shelters on Growth, Survival and Production of Freshwater Mud eel, Monopterus Cuchia (Hamilton) Reared in Cemented Cisterns of BAU, Mymensingh, Bangladesh. Pakistan Journal of Biological Sciences 6, 1753–1757. https://doi.org/10.3923/pjbs.2003.1753.1757

Nasar, T., 1997. Backyard Eel Culture. International Institute of Rural Reconstruction, Cavity, Philippines.

Rahman, M.A., Gheyasuddin, H., Rasid, M. H., & Choudhury, M.F.Z. (1982). Proximate composition and native quality of freshwater Zeol fishes of Bangladesh. *Bangladesh J. Fish*, *2*(5), 34-43.

Rahman, M.M., Hossain, M.M.M., Billah, M.M., Abdulla-Al-Asif, Ferdous, J., 2018. Effects on Growth of Freshwater Mud Eel (Monopterus cuchia) in Different Water condition, Feeds and Probiotics. International Journal of Business, Social and Scientific Research 7, 10–17. https://doi.org/10.5281/zenodo.5042642

Rosen, D.E., Greenwood, P.H., 1976. A fourth Neotropical species of synbranchid eel and the phylogeny and systematics of synbranchiform fishes. Bulletin of the American museum of natural history 157.

Sarker, Md.A.A., Arshad, F.M., Alam, Md.F., Mohamed, Z.A., Khan, Md.A., 2014. Economics of Thai Koi (Climbing Perch, Anabas Testudineus) Farming in Pond in Bangladesh. Trends in Agricultural Economics 7, 26–40. https://doi.org/10.3923/tae.2014.26.40

Shamsuzzaman, Md.M., Islam, M.M., Tania, N.J., Abdullah Al-Mamun, Md., Barman, P.P., Xu, X., 2017. Fisheries Resources of Bangladesh: Present Status and Future Direction. Aquaculture and Fisheries 2, 145–156. https://doi.org/10.1016/j.aaf.2017.03.006

Usui, A., 1979. Eel Culture. Fishing News Books, Farnham, Surrey.