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BANGLADESH JOURNAL OF FISHERIES RESEARCH

ORIGINAL ARTICLE OPEN ACCESS

Growth Performance and Production Economics of Freshwater Mud Eel (*Monopterus cuchia*) in the Chattogram Hill Tract Districts, Bangladesh

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Received: 01 January 2026 | **Revised:** 15 May 2026 | **Accepted:** 20 May 2026 | **Published:** 19 June 2026

ABSTRACT

The study was conducted to estimate the growth and production economics of freshwater mud eel (*Monopterus cuchia*) culture in three districts e.g. Rangamati (S_1), Khagrachhari (S_2), and Bandarban (S_3) of the Chattogram hilltract, Bangladesh, over a 6-month period (March to September 2022). Juvenile eels (initial weight: 50–60 g; length: 25–34 cm) were stocked at 10 individuals/m² and fed a diet of small indigenous species (1.5% of body weight every three days) and live vermi worm (1.5% of body weight daily). The highest weight gain was recorded in S_3 (130.85±6.36 g, $p < 0.05$), which also exhibited superior survival (73.26±1.5%), specific growth rate (0.70±0.02% day^{-1}), and net production (4,724.27±53.54 kg/acre/6 months) compared to S_1 and S_2. The Cobb–Douglas production function revealed that the cost of seed and live fish had significant negative effects on gross return ($p < 0.01$ and $p < 0.05$), with elasticities of -0.03 and -0.30 respectively. The findings indicate that although growth performance of *M. cuchia* is favorable, profitability is strongly constrained by input costs, particularly seed and feed. Improving the availability of quality seed at affordable prices is therefore essential for the sustainable expansion of cuchia culture in this region.

Keywords: *Monopterus cuchia*, Cuchia, Chattogram Hill Tract (CHT), Cobb-Douglas

1 | Introduction

The mud eel has become an important export species in Bangladesh (Zaher & Mazid, 1995). In the fiscal year 2021-22, Bangladesh earned $10.6 million from the export of 2872 MT of mud eel, supporting over 8,500 fishers, traders, transporters, and exporters (DoF, 2023). The fish has high demand in export markets, with countries like China, Japan, Hong Kong, Taiwan, Thailand, Singapore, and the United States being key importers. This species has high market value due to its nutritional quality, offering a rich source of protein, calcium, unsaturated fatty acids (EPA and DHA), and vitamins A and E. The average protein content of eel flesh is 14g/100g and the caloric value of eel flesh is as high as 303 Kcal/100g compared to 110 Kcal/100g in other average fishes (Nasar, 1997). The freshwater mud eel (*Monopterus cuchia*) is a species of eel in the family of Synbranchidae, order Synbranchiformes,

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Bangladesh Journal of Fisheries Research, 2026; 23-25 (2): 21-28; https://doi.org/10.XXXXX/XXXX.XXXXXX

which Locally known as "cuchia" or "cuche," (Hamilton, 1822). The mud eel has a snake-like body with distinct scales arranged longitudinally. It lacks pectoral and pelvic fins, while its dorsal and anal fins are fused with the caudal fin. It has reduced gills, with a pair of large supra-branchial pouches (respiratory organs) on either side of its head. Therefore, they can breathe in air for a long time (Talwar & Jhingran, 1991). This species inhabits freshwater and saltwater environments such as mud holes, shallow beels, paddy fields, and canals. This species is native to tropical and subtropical regions of Asia, and widely distributed across Bangladesh, Pakistan, Nepal, northern and northeastern India, and Myanmar.

Traditionally, it has been used in folk medicine to treat ailments such as weakness, anemia, asthma, hemorrhoids, piles, and diabetes. Despite its nutritional and medicinal value, mud eel consumption in Bangladesh is limited, as many Bangladeshis are averse to its snake-like appearance. Ethnic and non-Muslim people are the primary consumers of Mud eel in Bangladesh. According to the census of 2022, the total population of the tribal people is 16,50,159, of which about 60% lived in the Chattogram hill tract (CHT) area (BBS, 2023). The region comprises approximately thirteen tribal groups with diverse socio-cultural subgroups. Therefore, mud eel cultivation and research expansion in the Chattogram Hill Tract (CHT) districts has received considerable attention. Researchers have explored various aspects of mud eel culture, including the role of shelters (Narejo *et al.,* 2003), the effects of temperature on growth and survival (M. M. Rahman et al., 2005), co-management practices (TARA, 2010), larval rearing (Khanh & Ngan, 2010), and the impact of different feeds in CHT (Lima *et al.,* 2023; Rahman *et al.,* 2022). Most of these studies have been focused on adaptation of different feed and habitat. Therefore, the present study was designed to assess the culture technique and economic constraints for the adoption of the technology.

2 | Materials and Methods

2.1 Experimental site

The experiment was conducted for a period of six months, from March to September 2022, in three hill districts in CHT (Chattogram Hill tracts) division: Rangamati (S1), Khagrachhari (S2) and Bandarban (S3) (Fig. 1). Each pond had two replications; all experimental sites were selected with the assistance of the officials of Department of Fisheries.

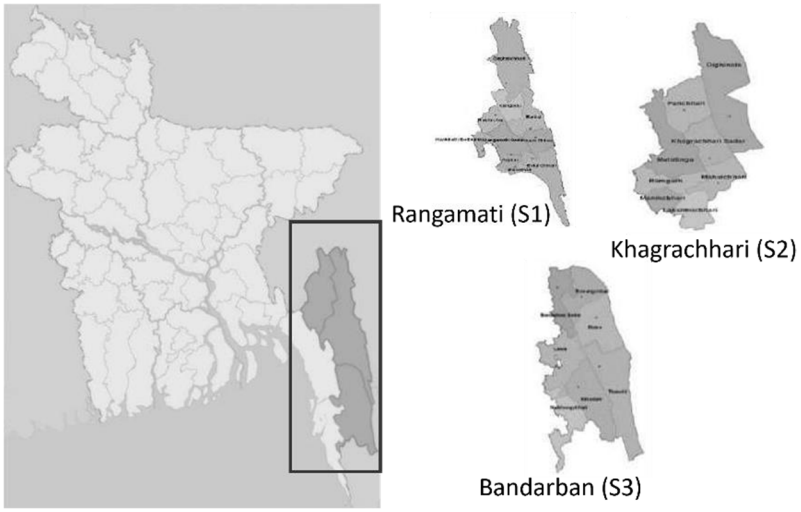


Fig. 1. Experimental sites of cuchia culture in CHT districts.

2.2 Pond preparation

The experimental ponds were about 30 ft long, 15 ft width, and 3.5 ft depth, around 40 m^2 size. The pond floor was prepared using a multi-layered lining system to prevent seepage and burrowing. The base was first covered with a layer of polythene, followed by a 0.5 cm mesh-size knotless nylon net, and sealed with a final tarpaulin lining. Each layer was securely anchored and integrated with the dikes to ensure structural integrity. After that, the ponds were filled with 0.3 m of soil where composition was 70% clay soil and 30% loamy soil. Initially, the ponds were treated with quick lime at the rate of 2kg per decimal. After 15 days, ponds were filled up with 0.6-0.8m water and then dolomite at the rate of 15 ppm to strengthen the water's buffer capacity. After three days, the pond water was fertilized with urea, triple super phosphate (TSP) and muriate of potash (MoP) at the rate of 2.5 ppm, 3.0 ppm and 1.0 ppm respectively to accelerate primary productivity. Water hyacinth and PVC pipe were used as shelter for cuchia. Fencing with a 0.2 cm nylon net was done to protect the pond.

2.3 Fingerlings collection and stocking

The Cuchia fingerlings were collected from natural habitats of the Netrokona and Mymensingh district with an average weight of 50-60 g. Fingerlings were carefully transported to experimental ponds by using drums with water. Just before release, fingerlings were dipped in a 5% potassium permanganate solution for a few seconds to remove surface pathogens and stocked at the stocking density of 10 nos/m^2 in each pond.

2.4 Feeding

Based on Cuchia's feeding preference, feed was designed with fish as available small indigenous species at 1.5% of body weight every three days and live Vermi worm at 1.5% of body weight every day. As they are nocturnal feeders, feed was given two times a day (after sunset and sunrise). Feed was provided at the same location of the ponds in feeding tray. Feeding was done up to their satiation level.

2.5 Water quality parameters

Water quality parameters such as DO, water temperature, TDS, pH, alkalinity, hardness and ammonia were recorded monthly. In situ, water temperature, TDS, dissolved oxygen (DO) and pH were measured using a HANNA series portable multiparameter (HI 98194). Hardness and alkalinity were determined by titrimetric method following APHA (2023). Ammonia was measured by using ammonia kit (HACH FF-2).

2.6 Fish growth analysis

Fish sampling was carried out by collecting PVC pipe shelters or collected from water hyacinth by using triangular shaped small mesh peeling net. Around 10% of fish in each treatment were sampled at one-month intervals to determine length (measuring scale: ±1.0 mm) and weight (TANITA digital scale, model KD-160, Japan). At the final harvest, ponds were drained out, and fish were weighed and measured to determine growth parameters. The following formulas were used to assess the experimental fishes' growth response, yield, and survival rate (Brown, 1957).

a) Weight gain (WG) = Final fish weight (g) - Initial fish weight (g)
b) Weight gain (%) = (Final weight - initial weight) × 100/ initial weight
c) Average daily weight gain (ADWG) = (Final weight - initial weight)/ culture days
d) Specific growth rate (SGR) = 100 × (ln final weight - ln initial weight)/culture days
e) Survival rate (SR%) = 100 × (number of fish survived/number of fish stocked)
f) Net production = Harvested biomass (g) - stocked biomass (g)

The net production data were initially recorded based on the actual pond area (40 m^2) and subsequently extrapolated to a standard per-acre basis to facilitate comparison with existing literature. The conversion was calculated using the formula:

g) Net production = (Net production per pond/Pond area in m^2) × 4046.86

Feed Conversion Ratio (FCR) was calculated on an 'as-fed' basis. The moisture content of the primary feed ingredients—Small Indigenous Species (SIS) and supplemental feeds— was estimated at approximately 75–80% based on established literature for regional freshwater species (Islam *et al.*, 2020).

h) Feed conversion ratio (FCR) = Feed applied (as fed)/ Live weight gain

2.7 Statistical analysis

The mean values of water quality parameters and growth parameters were subjected to one-way ANOVA (Analysis of variance), and DMRT (Duncan's Multiple Range Test) was done by using the SPSS (Statistical Package for Social Science) version 25.0 (Duncan, 1955). To determine the contribution of the most important variables in the production process of cuchia farming, the Cobb-Douglas production function was applied. A p-value ≤ 0.05 was considered statistically significant for this study.

Mathematically, the Cobb-Douglas production function can be written as follows: $Y = \alpha \times_1^{b1} \times_2^{b2} \times_3^{b3} \times_4 e^{\in i} \cdots\cdots (1)$

After taking log on both sides, we get

$$\ln y = \ln \alpha + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + \in_I \quad (2)$$

where, Y = Gross income from cuchia (Tk/pond); X_1 = Cost of seed (Tk./pond); X_2 = Cost of live fish (SIS) (Tk / pond); X_3 = Cost of vermi worm (Tk / pond); X_4 = Cost of fertilizer (Tk / pond); a = Intercept; $b_1 \ldots b_4$= Coefficient of the respective variable; ei= Error Term; i= 1, 24.

3 | Results and discussion

Water quality parameters (mean ± SE) are summarized in Table 1. The air temperature, water temperature, DO, pH, TDS, alkalinity, ammonia and hardness did not change significantly among the treatments ($p > 0.05$).

Table 1: Mean value (± SE) of water quality parameters of different treatments

Water quality parameters	S_1	S_2	S_3
Water temp. (ºC)	26.4 ± 1.09[a]	27.4 ± 0.9[a]	27.0 ± 1.02[a]
DO (mg/l)	6.25±0.6 [a]	7.23±0.7 [a]	6.58±0.9 [a]
pH	6.85±0.83 [a]	7.23± 0.65 [a]	6.75±0.45 [a]
TDS (mg/l)	30.7±2.85 [a]	45.8±5.64 [a]	30.5±3.74 [a]
Alkalinity (mg/l)	72 ± 4.65 [a]	88.23±5.23 [a]	53±4.56 [a]
Ammonia (mg/l)	0.13±0.04 [a]	0.1±0.02 [a]	0.1±0.03 [a]
Hardness (mg/l)	47±3.54 [a]	54±4.50 [a]	63±3.23 [a]

Mean values with same superscripts in the same row do not differ significantly ($p > 0.05$).

Water quality parameters were within the suitable ranges for mud eel production throughout the experimental period (Table 1). Water temperature ranged from 26.4 ℃ to 27 ℃ in all ponds. Boyd (1990) reported that the water temperature from 26.06 to 31.97 ℃ is suitable for tropical fish culture. Oxygen is the most crucial stress factor, and oxygen levels should be above 5 mg/L for optimal growth of warm water fish species (Boyd, 1982). The results revealed that dissolved oxygen and pH concentrations were 6.25-7.23 mg/L and 6.75-7.23, respectively. According to Boyd (1990), Alkalinity above 20 ppm or above indicates productive pond. Ammonia toxicity is a major concern for fish health and mortality. Ammonia concentration less than 0.1 ppm is recommended for fish culture (Parvathy *et al.*, 2023). Studies on Cuchia culture in different areas also found more or less similar results for

water quality (Lima *et al.*, 2023; Rahman *et al.*, 2022; Rahman *et al.*, 2005; Tara, 2010).

Table 2: Production performance of *Monopterus cuchia* in different treatments

Growth parameters	S_1	S_2	S_3
Initial length (cm)	32.34±3.01[a]	33.99±2.71[a]	34.04±2.7[a]
Final length (cm)	54.34±4.7 [a]	57.75±5.3 [b]	59.7±5.1 [a]
Initial weight (g)	50.66±5.38 [a]	51.19±4.19 [a]	51.5±4.26 [a]
Final weight (g)	169.23±6.12 [a]	173.47±7.56 [a]	182.35±6.78 [b]
Weight gain (g)	118.57±2.14 [a]	122.28±1.84 [ab]	130.85±6.36 [b]
Weight gain (%)	234.05±2.3 [a]	238.87±1.64 [a]	254.08±2.5 [b]
Average daily weight gain (g/day)	0.66±0.01 [a]	0.68±0.02 [ab]	0.73±0.01 [b]
Specific growth rate (%)	0.67±0.02 [a]	0.68±0.03 [ab]	0.70±0.02 [b]
Feed conversion ratio (FCR)	2.84±0.1 [a]	2.42±0.22 [b]	2.55±0.5 [b]
Survival rate (%)	71.4±3.12 [a]	70.34±0.72 [a]	73.26±1.5 [a]
Net production (kg/acre/6 month)	4037.27±40.34 [a]	4421.14 ±45.32 [ab]	4724.27±53.54[b]

Mean values with different superscripts in the same row differ significantly ($p < 0.05$).

After 180 days of culture period, growth performances and production of mud eel with different feed were summarized in Table 2. All growth parameters regarding final length, weight gain, average daily gain, feed conversion ratio (FCR), and specific growth rate (SGR) showed significant differences in different locations.

In the present study, growth in terms of final length, final weight, weight gain (g), and specific growth rate of mud eel was higher in S_3 (Bandarban) compared to S_2 (Khagrachhari) and S_1 (Rangamati) (Table 2). Moreover, a higher increasing trend of weight gain was observed in S_3 compared to S_1 and S_2 during the culture period (Fig. 2). Rahman *et al.* (2005) reported that the average weight of *M. Cuchia* in the pond ranged between 119-133 g after 90 days of the culture period. Chowdhury *et al.*, (2019) recorded 157-164 g final weight with supplementary feed, which coincides with our study. The growth of Cuchia to a greater extent depended on the quality and quantity of food available (Chakraborty *et al.*, 2010). The mean values of FCR were significantly different ($p < 0.05$) among the treatments. The highest FCR value (2.84) was observed in S_1 compared to S_2 and S_3. The FCR values reported in this study are based on as-fed weights, and adjusted for an estimated 20% dry-matter content typical of the live feed used. The feed efficiency aligns with previous findings for *Monopterus cuchia* in semi-intensive systems (Narejo *et al.*, 2003; Rana *et al.*, 2022).

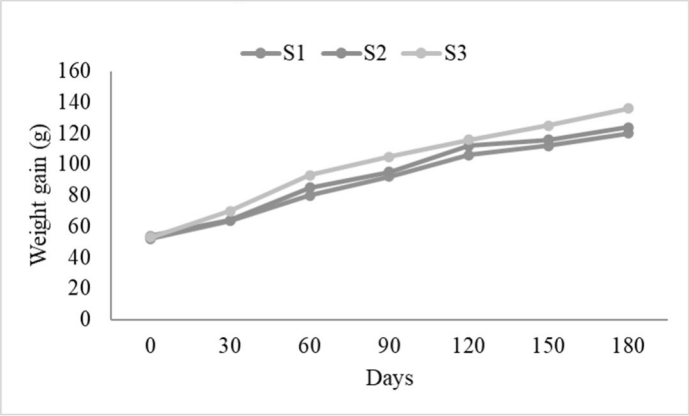


Fig. 2. Mean weight gain in different sites during the culture period.

The survival rate of Cuchia in the present experiment was found to be 73.26±1.5%, 71.4±3.12%, and 70.34±0.72% in S_3, S_2, and S_1 respectively, with no significant differences among the treatments ($p > 0.05$). In this experiment, the Cuchia survival rate was very similar to that of Khan *et al.* (2021) and Miah *et al.* (2015) found higher survival rate in clay ditches. The moderate survival rate was primarily attributed to containment challenges, as the species' burrowing instinct and overland migratory capability facilitated escapes during monsoon-driven flash floods. Despite the multi-layered pond lining, suggesting that conventional containment strategies are frequently compromised under hilly environmental conditions.

Table 3: Estimated values of the coefficients of Cobb-Douglas production function.

Independent variables	Coefficient	Standard error	t value	p value
Intercept	7.23	2.391	2.56	<0.05
Cost of seed (X_1)	-0.33	0.023	4.56	<0.01
Cost of Live fish (X_2)	-0.20	0.014	3.45	<0.05
Cost of vermi worm (X_3)	0.24	0.013	0.75	0.29
Cost of fertilizer (X_4)	0.32	0.042	0.64	0.34
R^2	0.75			
Adjusted R^2	0.67			
F-value	20.32			

n = 6; df = 1. Variance Inflation Factors (VIF) were calculated (< 2.5) to ensure the absence of multicollinearity.

3.1 Economic factors influencing Cuchia Farming Productivity

The Cobb-Douglas production function analysis (R^2=0.75; F=20.32) indicates that input costs significantly influence gross returns (Table 3). The costs of seed (X1) and live fish (SIS) (X2) were negatively related to returns and statistically significant at $p < 0.01$ and $p < 0.05$, respectively. These negative coefficients (-0.33 and -0.20) suggest that for every 1% increase in expenditure on these inputs, gross returns decrease by 0.33% and 0.20%. In contrast, Vermi worm (X3) and fertilizer (X4) costs showed positive but non-significant relationships ($p > 0.05$). Rana *et al.* (2022) also recorded almost similar results for Cuchia culture in plain land (Bogura district), Bangladesh.

The significant negative impact of seed and feed costs highlights an economic "cost-trap" driven by local resource scarcity. Because high-quality seed is unavailable in the studied hilly region, procure it from distant division (Mymensingh), incurring prohibitive transportation costs that outweigh yield gains. Furthermore, the availability of live fish (SIS) is seasonally constrained during the dry season. These factors indicate that the culture was operated in a stage of diminishing returns, where high logistical and environmental costs fundamentally suppress the profitability of Cuchia farming in this hilly area.

5 | Conclusion

The freshwater mud eel (*Monopterus cuchia)* commands high market demand within the local markets of the CHT districts. Consequently, local communities are highly interested regarding the potential for Cuchia culture farming. The study showed that growth and survival rates were within acceptable ranges, and regression analysis revealed that higher costs of seed and live feed (SIS) significantly reduce profitability. In particular, the scarcity of locally available quality seed remains the primary bottleneck to adoption. Therefore, developing reliable seed supply systems, along with cost-effective feeding strategies, is essential to enhance productivity

and support the sustainable expansion of Cuchia culture in the hilly areas.

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