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Research paper

Pond Water depth influence upon growth performances, feed utilization and Survival of Population traits of *Clarias batrachus* (Linnaeus, 1758)

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ABSTRACT

The current research explored how varying water depths impact the growth, feed efficiency, and survival of *Clarias batrachus* (Linnaeus, 1758) larvae in earthen ponds located in Siwan district, Bihar. Three water-depth levels were tested: T1 (12 cm), T2 (16 cm), and T3 (20 cm) across two experimental ponds. The study assessed growth metrics such as length increase, weight increase, percentage weight increase, specific growth rate (SGR), feed conversion ratio (FCR), feed efficiency ratio (FER), protein efficiency ratio (PER), condition factor (K), and survival rate. Findings indicated that water depth had a significant impact on larval growth and survival. In the first pond, T1 resulted in the greatest length increase (19.80 mm), weight increase (101.12 mg), percentage weight increase (315.60%), SGR (4.74), PER (8.04), and survival rate (60.00%). Similarly, in the second pond, T1 achieved the highest length increase (26.40 mm), weight increase (134.64 mg), percentage weight increase (423.65%), SGR (6.32), PER (10.72), and survival rate (81.24%). Although initial data suggested a slightly higher average length at a 16 cm depth, overall growth and survival were better at a 12 cm depth. Positive correlations were observed in length–weight relationships across all treatments, and Fulton's condition factor rose with larval growth and feeding activity. Statistical analysis showed significant differences ($p<0.05$) among treatments in terms of weight gain, feed utilization metrics, growth parameters, and survival. The results suggest that shallower water depth improves feeding efficiency, growth, and survival of *C. batrachus* larvae in pond culture. Thus, maintaining a water depth of around 12 cm during larval rearing is advised to enhance seed production and nursery management for this economically valuable catfish species.

1. Introduction

Aquaculture ranks among the most rapidly expanding sectors in global food production, significantly contributing to food security, nutritional sustainability, and the creation of livelihoods. Freshwater catfishes are a major component of inland aquaculture output due to their strong market demand, fast growth rates, resilience to diseases, and adaptability to various environmental conditions. This fish is a key indigenous species with economic importance, prevalent across South and Southeast Asia (FAO, 2024). This species is highly prized for its excellent flavor, high protein content, medicinal benefits, and resilience to challenging environmental conditions, making it an ideal choice for intensive aquaculture systems (Rahman et al., 2021).

The rising demand for high-quality fish seed has underscored the need to refine larval rearing methods in catfish aquaculture. Larval stages are particularly vulnerable to environmental changes, and their growth and survival are crucial for the success of subsequent nursery and grow-out phases (Ahmed et al., 2022). Among the various environmental factors

affecting larval performance, water depth is a critical yet often neglected parameter. It directly influences swimming behavior, feeding efficiency, the distribution of dissolved oxygen, waste buildup, predator evasion, and the energy expenditure of fish larvae (Boyd & Tucker, 2023). Proper water depth enhances food capture efficiency and minimizes unnecessary energy loss, thereby promoting growth and survival.

In aquaculture ponds, water depth affects several physicochemical properties, including temperature stratification, light penetration, dissolved oxygen levels, and primary productivity (Kumar et al., 2021). Shallow water conditions often improve feed accessibility and increase the likelihood of larvae encountering prey, while excessive depth may lead to increased swimming activity and metabolic costs, resulting in diminished growth performance (Islam et al., 2022). Additionally, water depth can significantly impact larval distribution patterns, stress responses, and feeding behavior, collectively affecting survival rates (Mishra et al., 2023).

The larval stage of C. batrachus is marked by rapid growth and high nutritional needs. Successful larval rearing hinges on maintaining environmental conditions that optimize feed utilization and minimize mortality. Previous research has shown that managing water levels is crucial in the nursery rearing of catfish and other freshwater species, as it enhances feed conversion efficiency and growth performance (Sarkar et al., 2020; Das et al., 2021). Lower water depths are often linked to improved feeding opportunities and better utilization of natural productivity, leading to increased weight gain and survival (Pradhan et al., 2022).

In fish culture, growth performance is typically assessed through parameters like length gain, weight gain, specific growth rate (SGR), feed conversion ratio (FCR), feed efficiency ratio (FER), protein efficiency ratio (PER), and condition factor (K). These metrics offer dependable insights into the physiological state, nutritional status, and culture efficiency of fish populations (Nguyen et al., 2021). To evaluate fish health, robustness, and environmental adaptation, length–weight relationships and Fulton's condition factor are frequently utilized (Froese et al., 2023). Generally, a positive correlation between length and weight suggests favorable growth conditions and sufficient nutritional resources.

In larval aquaculture, the survival rate is a vital parameter, as larval mortality often leads to significant economic losses. The environmental factors such as environmental stress, inadequate feeding, and poor pond management can greatly diminish survival rates during early development stages (Jha et al., 2022). Water depth plays a role in larval aggregation, prey access, oxygen levels, and predator-prey dynamics, thus affecting survival outcomes (Verma et al., 2024). Therefore, identifying the optimal water depth is crucial for maximizing seed production and ensuring sustainable aquaculture practices.

Numerous studies have explored the impact of stocking density, feeding strategies, dietary supplements, and water quality management on the growth of C. batrachus larvae. However, there is limited information on the specific effects of water depth in pond culture settings, especially in eastern India (Kumar et al., 2022; Singh et al., 2023). Bihar, a leading state in freshwater aquaculture production in India, is witnessing rapid growth in catfish farming. Thus, a scientific assessment of water depth requirements under local climatic and pond conditions is essential to enhance larval production efficiency and profitability.

Given the significance of water-depth management in larval culture, this study was conducted to examine the effects of varying water depths on growth performance, feed utilization efficiency, condition factor, length–weight relationship, and survival of Clarias batrachus larvae in earthen ponds in Siwan district, Bihar. The study's findings are anticipated to aid in developing improved nursery-rearing protocols and offer practical recommendations for boosting magur seed production in pond-based aquaculture systems.

2. Materials and Methods

The current study took place in two earthen nursery ponds situated in Siwan district, Bihar, India. This research was performed during the larval rearing season with controlled pond management practices. Freshwater from a nearby irrigation source was used to fill both ponds, which were kept under consistent environmental conditions throughout the study.

2.1 Experimental Design

The purpose of the experiment was to assess how varying water depths affect the growth and survival of Clarias batrachus larvae. Three distinct water-depth treatments were implemented in each pond: T1 with 12 cm, T2 with 16 cm, and T3 with 20 cm of water depth. Each treatment was isolated within the experimental ponds. Prior to stocking, the ponds underwent drying, liming, and fertilization. Water levels were regularly monitored and adjusted as needed throughout the experiment.

2.2 Experimental Fish and Stocking

Uniform-sized and aged Clarias batrachus larvae, produced in a hatchery, were sourced from a local fish hatchery. Before being introduced to the ponds, the larvae were acclimated to the pond environment for 24 hours. To reduce bias from size differences and

competition, the larvae were evenly distributed across the experimental treatments at a consistent stocking density.

2.3 Feeding and Pond Management

The larvae were provided with a formulated diet comprising fish meal, oil cake, rice bran, and a vitamin-mineral mix. Feeding occurred twice daily, in the morning (08:00–09:00 h) and evening (16:00–17:00 h). Feed amounts were periodically adjusted based on larval growth and biomass.

To ensure optimal water quality, continuous aeration and regular water exchange were implemented. Any deceased larvae were promptly removed, and pond cleanliness was maintained throughout the study.

2.4 Water Quality Monitoring

Parameters such as temperature, pH, dissolved oxygen (DO), transparency, and alkalinity were regularly checked using standard methods outlined by the American Public Health Association (APHA, 2017). All parameters measured stayed within the recommended range for catfish larval culture.

2.5 Growth Measurement

At set intervals, representative samples of larvae from each treatment were collected using a fine-meshed hand net. Their total length (mm) was measured with a digital vernier caliper, and body weight (mg) was recorded using an electronic balance.
The following parameters related to growth and feed utilization were calculated:

Length Gain (mm) = Final Length − Initial Length
Weight Gain (mg) = Final Weight − Initial Weight
Percent Weight Gain = Final Weight - Initial Weight\Initial \times 100]
Feed Efficiency Ratio (FCR)=Weight of given feed (gm)/Weight gain of fish (gm)
Feed Efficiency Ratio (FER)=Output/Feed input
Protein efficiency Ratio (PER)=Weight gain (gm)/Consumed Protein (gm)
Specific Growth Rate (SGR) = ln W_2-ln W_1/t×100; where: (W_1) = Initial weight; (W_2) = Final weight and (t) = Culture period

2.6 Length–Weight Relationship

The relationship between length and weight was established using the formula: [W = aL^{b}], where (W) represents body weight in milligrams, (L) denotes total length in millimeters, (a) is the intercept, and (b) is the regression coefficient. For regression analysis, the equation was transformed logarithmically: [\log W = \log a + b \log L]. Each treatment's correlation coefficient (r) and determination coefficient (r^2) were computed.

2.7 Condition Factor (K)

To evaluate the larvae's well-being and robustness, the Fulton's condition factor (K) was calculated using the formula: [K = \frac{W \times 100}{L^{3}}], where (W) is the body weight and (L) is the total length. Higher K values suggest a better physiological state and growth condition of the fish.

2.8 Survival Rate

At the conclusion of the experimental period, the survival rate was determined using the equation: [\text{Survival Rate (%)}=\frac{\text{Number of larvae harvested}}{\text{Number of larvae stocked}}\times 100].

2.9 Statistical Analysis

The experimental results were presented as mean ± standard error (SE). To identify significant differences among treatments, a one-way Analysis of Variance (ANOVA) was employed. When significant differences were found, Duncan's Multiple Range Test (DMRT) was used to compare treatment means. A p-value of less than 0.05 was considered statistically significant. Correlation and regression analyses were conducted to assess length–weight relationships. Statistical analyses were performed using SPSS version 25.0 and Microsoft Excel 2021.

3. Results and Observations

3.1 Water depth and catfish culture

The optimum water quality ensures maximum survival and growth of the fish larvae. The water quality of different treatments was within the permissible range as observed due to regular water exchange and provision of continuous aeration. The growth data of *Clarias batrachus* larvae of the ponds are depicted in Fig. 1-2.

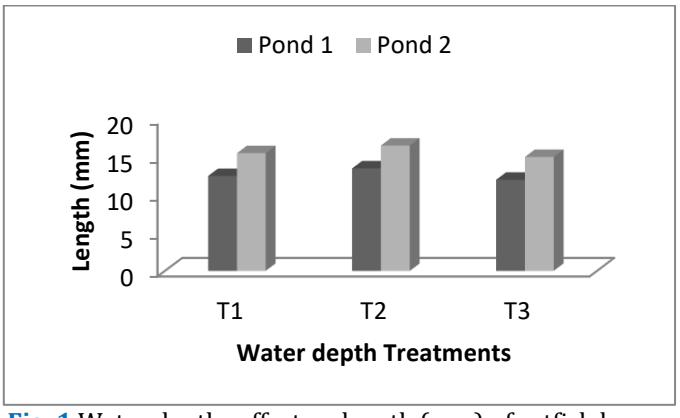


Fig. 1 Water depths effect on length (mm) of catfish larvae in ponds

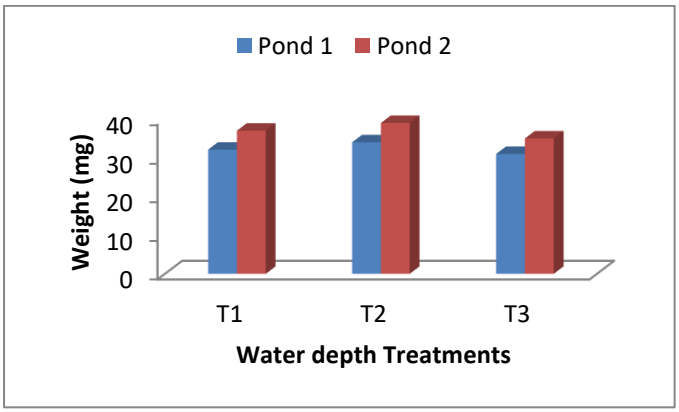


Fig. 2 Water depths effect on length (mm) of catfish larvae in ponds

The highest length (13.5 mm) was recorded in T2 which was followed by T1 and T3 with respective length 12.5 and 12 mm, whereas the highest weight (39 mg) was in T3 followed by T1 and T2 with respective weight 37 mg and 35 mg during the study period. It is obvious from the results (Fig. 1 and Fig. 2; Table 1 and Table 2) that the water depth affected the growth of larvae.

Table 1 Length-weight measurement of C. batrachus larvae in different water depths of pond 1 in Siwan district

Treatments	Water depth	Length (mm)			Weight (mg)		
		Min	Max	Mean	Min	Max	Mean
T1	12 cm	12	13	12.5	32	32.2	32.1
T2	16 cm	13	14	13.5	32	36	34
T3	20 cm	11	13	12	30	32	31

Table 2 Length-weight measurement of C. batrachus larvae in different water depths of pond 2 in Siwan district

Treatments	Water depth	Length (mm)			Weight (mg)		
		Min	Max	Mean	Min	Max	Mean
T1	12 cm	15	16	15.5	36	38	37
T2	16 cm	16	17	16.5	38	40	39
T3	20 cm	14	16	15.0	34	36	35

The statistical analysis (ANOVA) for length again showed that the length and different depth treatment was non-significant between treatments. However, the weight gain was significant between T3 and both T1 and T2. The survival rate was higher in T1 and lower in T3 to ponds water under the study period. No significant difference (p>0.05) with regards to a survival rate of the pond 1, while the highest survival rate was observed in T1 (81.24%) followed by T2 (70.18%) and T3 (52.46%) in this study.

The length and weight were positively correlated in the treatments. The data on the coefficient of correlation (r) along with regression (r2) equation for total length and total weight are presented (Table 3 and Table 4). The value of a coefficient of correlation (r) was less in pond 1 with varied treatments as 0.282792 (T1), 0.444977 (T2) and 0.413837 (T3), whereas high in pond 2 as 0.377056 (T1), 0.599700 (T2) and 0.55178 (T3) in the study period.

Table 3 Length-weight relationship of C. batrachus larvae in different water depths of pond 1 in Siwan district

Treatments	a	b	r	r^2	K-value
T1	27.84976	0.055356	0.282792	0.56558	19.89782
T2	0.83152	1.421583	0.449776	0.89955	21.11943
T3	18.3712	0.291264	0.413837	0.82764	23.60407

Table 4 Length-weight relationship of C. batrachus larvae in different water depths of pond 2 in Siwan district

Treatments	a	b	r	r^2	K-value
T1	37.1334	0.073808	0.377056	0.75408	26.5304
T2	1.10868	1.907284	0.599700	1.19940	28.1592
T3	24.4948	0.388352	0.551780	1.10352	31.4720

The Fulton's conditioning factor (K) or Ponderal Index was also calculated. This expresses the degree of well-being, robustness, fatness in numerical terms. From this study, the value of K were less in pond 1 as K=19.89782 (T1), K=21.11943 (T2) and K = 23.60407 (T3), whereas high in pond 2 as K=26.5304 (T1), K=28.1592 (T2) and K = 31.47208 (T3) in the study which were found positively correlated. These values also indicated the increased fat deposition in the body due to adaptability and high feeding activity of fish (Table 3 and Table 4).

The highest length (19.80mm) was recorded in T1 which was followed by T3 and T2 with respective length 19.60 and 18.95 mm in pond 1, whereas pond 2 exhibited maximum length with T1=26.40mm, T2=25.24mm and T3=26.13mm in this study (Table 5 and Table 6). It would be found highest body weight gain was in T1 followed by T2 and T3 with respective weight in both ponds of Siwan district which confirms that the water depth affected the growth of larvae. The statistical analysis (ANOVA) for length gain showed that the length and different depth treatment was significantly different (p<0.05) between treatments. The highest Percent weight gain was in T1 followed by T2 and T3 with in both culture ponds confirms that the water depth affected the growth of larvae. The statistical analysis (ANOVA) for percent weight gain was significant between T3 and T1.

Further, the growth gain was again non-significant between T2 between T1 and T3.

The food conversion ratio of *C. batrachus* larvae showed low FCR values in T1 followed by T3 and T2 in the culture ponds. A low FCR indicates better conversion of food into flesh. The better FCR was recorded in T1 indicating better utilization of consumed food as compared to other treatments. The mean FCR value was significantly different (p<0.05) between treatments (Table 5 and Table 6). The mean values of FER values were significantly different (p<0.05) between T1 and T3. The highest FER was recorded in treatment T1 followed by T3 and T2 (0.85±0.028) indicated greater feed intake, the greater the growth response and food consumption is the growth limiting factor in the study ponds (Table 5 and Table 6).

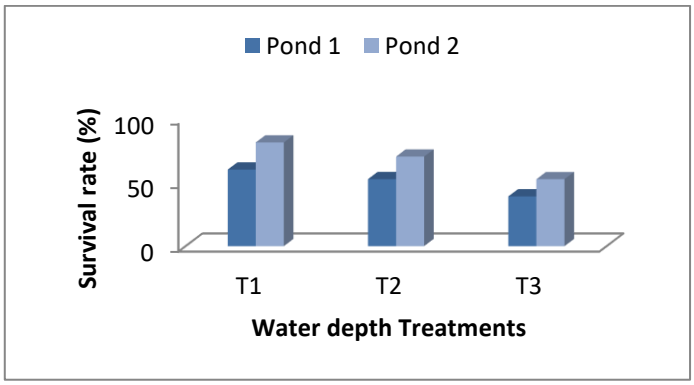


Fig. 3 Water depths effect on survival (%) of catfish larvae in ponds

The specific growth rate (SGR) of experimental fish larvae was highest in T1 followed by T2 and T3 for both ponds were significant at 5 % level (p<0.05) between T1 and T3. The PER values were significantly different (p<0.05) between T3 with both T1 and T2. The increase in PER was high in treatments T1 followed by treatment T3 and T2 in this study (Fig. 3).

Table 5 Effect of varied water depths on growth performance of catfish larvae of pond 1 in Siwan district

Treatments	Length (mm)	Weight gain	% wt gain	FCR	FER	SGR	PER	Survival rate
T1	19.80	101.12	315.60	1.01	0.98	4.74	8.04	60.00
T2	18.95	97.12	294.30	1.17	0.85	4.57	6.98	52.50
T3	19.60	90.53	245.40	1.16	0.86	4.12	7.07	39.00

Table 6 Effect of varied water depths on growth performance of catfish larvae of pond 2 in Siwan district

Treatments	Length (mm)	Weight gain	% wt gain	FCR	FER	SGR	PER	Survival rate
T1	26.40	134.64	423.65	1.34	1.32	6.32	10.72	81.24
T2	25.24	130.56	396.41	1.56	1.12	6.08	9.28	70.18
T3	26.12	121.32	329.15	1.52	1.41	5.48	9.42	52.46

Furthermore, the survival rate of larvae was calculated at the end of the experiment and statistically analyzed result showed highly significant difference between the treatments. The highest survival was found in T1followed by T2 and T3 in both ponds during the study period. It is obvious that the water depth affected the survival rate of magur larvae rearing (Fig. 3; Table 5 and Table 6).

4. Discussion

Larval fish exhibit a high sensitivity to environmental conditions due to their fast metabolic rates and limited physiological ability to handle environmental stressors. Water depth influences various ecological factors such as light penetration, temperature distribution, dissolved oxygen levels, feed availability, and swimming patterns. In this study, larvae raised at a water depth of 12 cm showed the best growth performance, measured by length increase, weight increase, percentage weight gain, and specific growth rate. The rearing of larvae is a crucial phase in the fish production cycle (Alves et al., 2006). The physicochemical water quality parameters in the different treatment tubs were within the optimal range found in the culture ponds of Siwan district.

This study demonstrated that the growth performance of Clarias batrachus larvae is significantly affected by water depth, which has a strong impact on their growth and survival. The best growth performance was observed in treatments with shallow water depth. The greatest length was recorded in T2, followed by T1 and T3 in both ponds. The growth performance of Clarias magur larvae is also significantly influenced by water depth, affecting their growth and survival (Behera, 2013). The highest weight was observed in T3, followed by T1 and T2, in both ponds during the study period.

The growth performance results differ from the findings of Magaya et al. (1995), where Clarias magur showed optimal growth at a water depth of 6 cm. The highest percentage weight gain was noted in T1, followed by T2 and T3 in both experimental ponds. Similarly, improved growth was also observed in *Clarias batrachus* (Giri et al., 2002) and *Pleteobagrus fulvidraco* (Wang et al., 2005). A strong connection was found between the quality of larvae in the early

rearing stages and their survival and growth in later stages (Cahu et al., 2001).

Low FCR and high FER were recorded in *Clarias batrachus* fed with zooplankton at low water depth, followed by higher water depths, with no significant difference in FCR and FER values between the water depths except for T1. This suggests that feed conversion efficiency was not affected by water depth. It may indicate that catfish larvae at low water depth might utilize resources more effectively than at higher water depths. PER are the primary indices used for assessing food and protein utilization in aquaculture. An increase in dietary protein significantly ($p<0.05$) enhances FCR, FER, and PER in the experimental fish. It has been noted that food and protein utilization decreases beyond the maximum level of dietary protein, and the requirements for maximum growth are always higher than those for the least cost (optimal) production (Hossain et al., 2012).

In the treatments, a positive correlation was observed between length and weight. Mosaad (1990) and Ibrahim et al. (2013) also noted allometric growth for Clarias magur in water depths of 10 cm, with a 'b' value of 0.291264. The correlation coefficient (r) and the regression equation (r^2) for total length and weight indicated a similar relationship between body length and weight across different treatments in this study.

The studies revealed that the 'r' value peaked in T1, where the water depth was shallow. Fulton's condition factor (K) is an indicator of fish health or well-being. Fish with a condition factor exceeding 1 are considered healthy (Nash et al., 2006; Singh and Serajuddin, 2017). In this study, the 'K' value for all C. magur treatments was above 1, signifying good fish health.

5. Conclusion

From an aquaculture standpoint, the current study's findings hold significant relevance for the management of Clarias batrachus hatcheries and nurseries. Adjusting water depth offers a straightforward, cost-effective management approach that can greatly improve larval outcomes. Unlike costly technological solutions, managing water depth can be easily adopted by farmers without major financial investment. This study provides crucial insights into the impact of water depth on magur larviculture in earthen ponds. Nonetheless, further research is needed to explore how water depth interacts with other environmental factors like stocking density, feeding frequency, photoperiod, dissolved oxygen, and water exchange rates. Long-term studies using larger culture systems and varying seasons would further refine management strategies and enhance the sustainability of catfish seed production. Overall, the findings clearly show that water depth significantly influences larval growth, feed efficiency, physiological health, and survival in Clarias batrachus. The superior results at a 12 cm depth suggest that shallow water conditions are ideal for larval development and nursery rearing. Implementing suitable water-depth management practices can thus significantly boost the productivity and profitability of magur aquaculture in Bihar and other freshwater aquaculture areas.

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