A COMPREHENSIVE EVALUATION OF BIOLOGICAL PERFORMANCE, ECOLOGICAL ROLE, AND ECONOMIC EFFICIENCY OF *ANCISTRUS* IN AQUARIUM SYSTEMS

F.Sh. Abdurasulova[1], Sh.B. Khujabekov[1], A.F. Khikmatullayev[1], S.V. Mamadillayev[1], D.R. Dekhkonova[2]
Student, Tashkent State Agrarian University[1]
Senior Lecturer, PhD (Biological Sciences), Tashkent State Agrarian University[2]
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Abstract. *This study investigates the biological characteristics, reproductive performance, and economic efficiency of culturing* Ancistrus *species under controlled aquarium conditions. The experiments were conducted in laboratory aquaria, where environmental parameters and growth indicators were systematically monitored and analyzed. The results demonstrated that under optimal conditions (water temperature of 24–27 °C and dissolved oxygen levels above 6 mg/L), the growth rate and survival of fish increased substantially. In particular, survival rates reached up to 90–95% under optimal conditions. Reproductive performance showed that the number of eggs ranged from 50 to 120 per spawning, with hatching success rates between 85–90%. Larvae transitioned to independent feeding within 3–5 days, indicating high reproductive potential of the species.*

Additionally, the ecological role of Ancistrus *in aquarium ecosystems was identified. The species contributes to biofilm and organic matter consumption, thereby improving water quality and maintaining ecological balance. Economic efficiency was evaluated based on model calculations. The total production cost was estimated at approximately 2,150,000 UZS, while potential revenue could reach up to 4,800,000 UZS depending on market conditions. Accordingly, net profit may reach around 2,650,000 UZS, with profitability levels up to 123%. These estimates indicate a high economic potential of* Ancistrus *culture under aquarium conditions.*

The findings confirm that culturing Ancistrus *species is both biologically viable and economically efficient, making it a promising direction for ornamental fish farming and small-scale aquaculture development.*

Keywords: *aquarium, aquaculture,* Ancistrus*, biofilm, profitability, biomass dynamics, microalgae, abiotic factors, live feed, survival rate, growth rate.*

INTRODUCTION

In recent decades, aquaculture has emerged as one of the fastest-growing sectors contributing to global food security and the sustainable use of biological resources. Within this framework, ornamental fish farming has gained particular importance due to its economic profitability, ecological relevance, and potential for small-scale entrepreneurship [7; 18]. Identifying species that combine high biological adaptability with strong market demand remains a key priority in the development of sustainable aquaculture systems. In this regard, species of the genus *Ancistrus* (family Loricariidae) represent a promising group of organisms with both scientific and practical significance.

Members of the genus *Ancistrus* are native to the Neotropical region and are widely distributed across freshwater systems of South America, including the Amazon, Orinoco, and

Paraná river basins [14; 10]. These fish occupy a benthic ecological niche and exhibit a high degree of specialization to substrate-associated habitats. Their morphological features—such as a dorsoventrally flattened body, dermal bony plates, and a ventrally positioned suctorial mouth—reflect advanced adaptations to environments characterized by strong water currents and complex substrates [16; 1]. The specialized oral apparatus enables efficient scraping of periphyton, biofilm, and detrital material, thereby defining their trophic ecology [8; 9].

From an ecological perspective, *Ancistrus* species play a significant functional role in aquatic ecosystems. By consuming biofilm and organic matter, they contribute to nutrient cycling, regulate algal biomass, and enhance ecosystem stability [13; 20]. In controlled aquarium environments, these characteristics translate into improved water quality and maintenance of biological balance, positioning *Ancistrus* as effective biological regulators.

Biologically, *Ancistrus* species are characterized by high survival rates, rapid adaptation to controlled conditions, and efficient reproductive strategies. Previous studies have demonstrated that environmental parameters—particularly temperature, dissolved oxygen, and feeding regimes—directly influence growth performance and reproductive success [11; 19]. Under optimal conditions, metabolic activity increases, resulting in enhanced growth rates and survival. Furthermore, their reproductive traits—including relatively high fecundity, male parental care, and rapid larval development—facilitate successful propagation in aquaculture systems [5; 2].

Recent advances in molecular phylogenetics have revealed substantial genetic diversity and evolutionary complexity within the Loricariidae family, highlighting the adaptive potential of *Ancistrus* species across diverse environmental conditions [12; 6]. These findings underscore the importance of integrating ecological, biological, and genetic perspectives in evaluating species performance.

Despite the growing body of literature on morphology, systematics, and ecology, comprehensive studies that integrate both biological performance and economic feasibility of *Ancistrus* culture under controlled aquarium conditions remain limited [18]. In particular, there is a lack of detailed assessments focusing on small-scale recirculating aquaculture systems (RAS), where resource efficiency and economic viability are critical factors.

Economic evaluation is a fundamental component of aquaculture research, as it determines the practical applicability and sustainability of production systems. Small-scale aquarium-based systems require relatively low capital investment but can yield high returns when properly managed [15; 17]. Therefore, understanding the relationship between biological efficiency and economic outcomes is essential for optimizing production strategies.

The aim of this study is to comprehensively evaluate the biological characteristics, reproductive performance, and economic efficiency of *Ancistrus* species cultured under controlled aquarium conditions.

MATERIALS AND METHODS

This study was conducted under controlled laboratory–aquarium conditions to comprehensively evaluate the biological characteristics, ecological role, and economic efficiency of *Ancistrus* species. Experimental systems were established using glass aquaria of varying volumes (30–200 L), and a comparative design was applied, including both optimal and suboptimal (control) conditions.

During the experiment, key physico-chemical parameters of the water were continuously monitored and maintained. Water temperature was kept within the optimal range of 24–27 °C, while additional observations were conducted at 20–22 °C and 28–30 °C for comparative analysis.

Dissolved oxygen levels were maintained at 6.5–7.5 mg/L under optimal conditions, whereas lower levels were recorded in control systems. The pH values were stabilized within the range of 6.5–7.5. A photoperiod of 12 hours light and 12 hours dark was applied. Aeration and filtration systems were used to ensure water quality stability.

Feeding regimes were designed based on the natural trophic behavior of the species. Fish were provided with a combined diet consisting of biofilm, periphyton, and supplemental artificial feed. Natural substrates, including driftwood, gravel, and stones, were introduced to promote biofilm development and support natural feeding behavior. Feeding frequency was adjusted according to the ontogenetic stage of the fish.

Morphometric and biological analyses constituted a key component of the study. Morphometric measurements were carried out using a digital caliper with an accuracy of 0.01 mm, following the point-to-point method described by Boeseman (1968) and Weber (1985) [3; 21]. The measured parameters included standard length, head length, body depth, and fin dimensions.

Biological assessments focused on key indicators reflecting growth performance and physiological activity. Growth rate was determined based on changes in body length and mass, while survival rate was calculated as a percentage. Reproductive parameters included the number of eggs per spawning event and hatching success (%). Additionally, the time required for larvae to transition to independent feeding (in days) was recorded as an indicator of developmental rate.

The ecological role of *Ancistrus* within aquarium systems was evaluated through observations of biofilm coverage on substrates, water transparency, and the rate of organic matter decomposition. Comparative assessments were conducted between systems with and without *Ancistrus* individuals.

Economic efficiency was assessed using a model-based approach derived from experimental biological data and prevailing market conditions. The analysis included total production costs (equipment, feed, energy, and maintenance), potential revenue based on the number of marketable juveniles, net profit estimation, and profitability (calculated as net profit divided by total cost × 100). It should be noted that these economic indicators are based on calculated estimates and may vary depending on production conditions and market fluctuations.

The obtained data were analyzed using comparative and descriptive statistical methods. Mean values and variation ranges were used to interpret biological and economic indicators.

RESULTS AND DISCUSSION

Biological Performance The results of the study demonstrated that the biological efficiency of *Ancistrus* is strongly dependent on environmental factors, particularly water temperature and dissolved oxygen levels. Under optimal conditions (24–27 °C; DO > 6 mg/L), both growth rate and survival reached their highest values.

Experimental observations revealed that under optimal conditions the survival rate reached 92.3 ± 2.1%, whereas under suboptimal conditions this value decreased to 78.6 ± 3.4%. These findings confirm the notable influence of environmental parameters on fish physiological performance.

Analysis of growth dynamics indicated that the most intensive development occurred during the juvenile stage, when metabolic activity is at its peak. Under optimal conditions, the average increase in body length was 0.85 ± 0.06 mm/day, while under suboptimal conditions it decreased to 0.52 ± 0.04 mm/day. Similarly, body mass gain was higher in optimal systems, reflecting the direct effect of oxygen availability and feeding conditions on growth performance (Table 1, Figure 1).

Table 1. Biological Performance of Ancistrus ***under Optimal and Suboptimal Environmental Conditions (Mean ± SE)***

Parameter	Optimal Conditions	Suboptimal Conditions
Temperature (°C)	24–27	20–22 / 28–30
Dissolved Oxygen (mg/L)	6.5–7.5	4.5–5.5
Survival Rate (%)	92.3 ± 2.1	78.6 ± 3.4
Growth Rate (mm/day)	0.85 ± 0.06	0.52 ± 0.04
Weight Gain (g/day)	0.34 ± 0.03	0.21 ± 0.02
Egg Number (units)	80–120	40–70
Hatching Success (%)	88.5 ± 2.7	72.4 ± 3.1
Time to Independent Feeding (days)	3–4	4–6

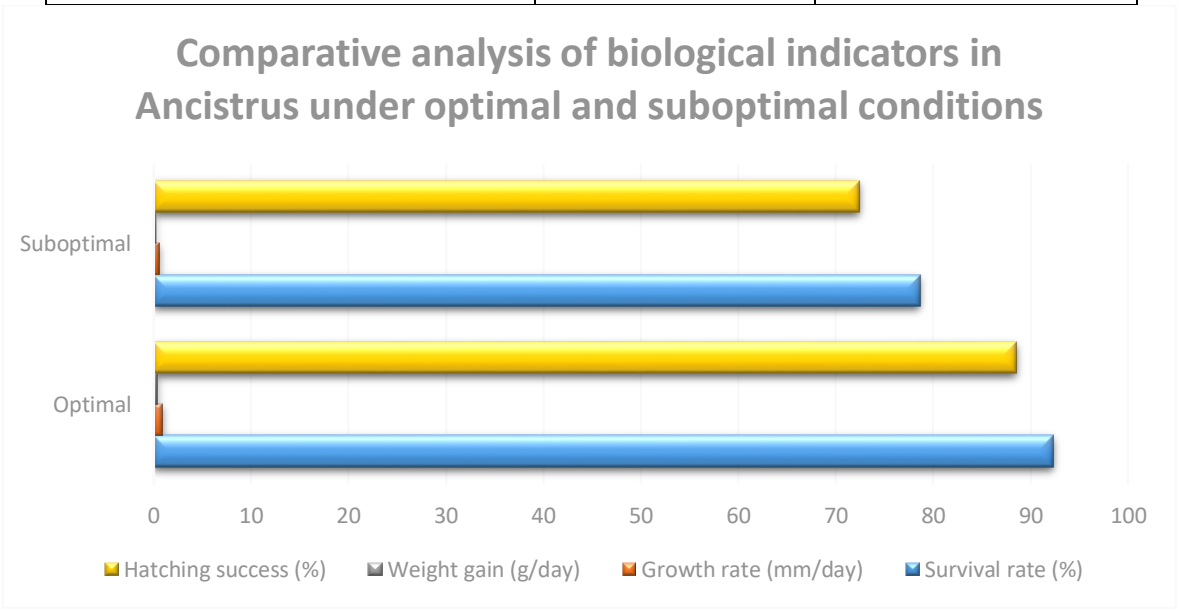


Figure 1. Comparative analysis of biological performance indicators (survival rate, growth rate, weight gain, and hatching success) of **Ancistrus** ***under optimal and suboptimal environmental conditions.***

The results indicate that all biological indicators were higher under optimal conditions compared to suboptimal environments. In particular, survival rate and hatching success showed the greatest differences, confirming the strong influence of temperature and dissolved oxygen on the physiological performance and development of *Ancistrus*. These observations align with earlier studies emphasizing the sensitivity of loricariid catfishes to abiotic factors and underscore the importance of precise environmental control in aquarium-based culture.

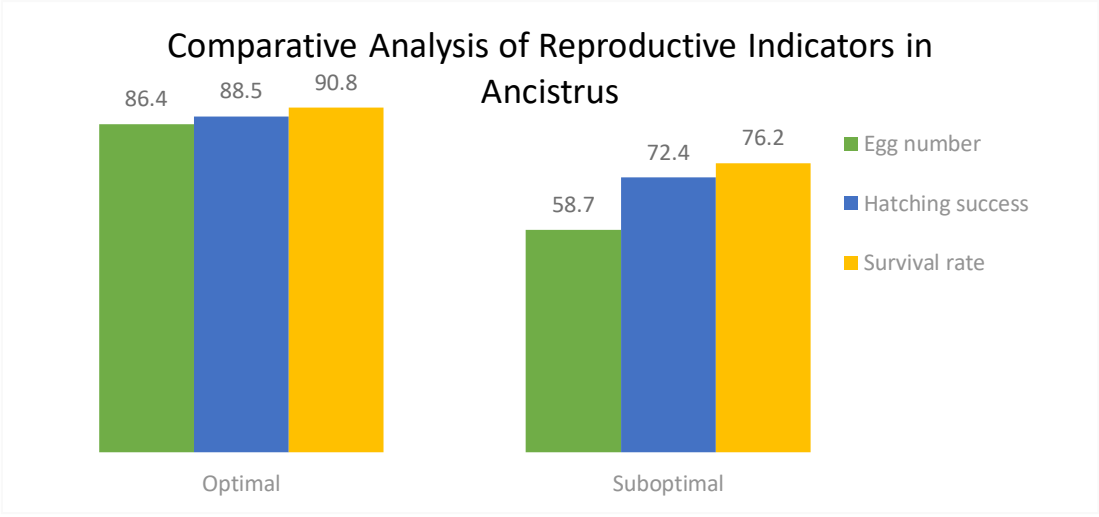
Reproductive Performance The results of the study demonstrated that *Ancistrus* exhibits high reproductive potential under controlled aquarium conditions. Reproductive performance was strongly influenced by environmental stability, particularly temperature, dissolved oxygen levels, and feeding conditions.

Experimental observations showed that the number of eggs per spawning ranged between 50 and 120, with an average value of 86.4 ± 7.2 eggs under optimal conditions. Under suboptimal conditions, this value decreased to 58.7 ± 6.5 eggs, indicating the sensitivity of reproductive activity to environmental stress.

Table 2. Reproductive Performance of Ancistrus ***under Different Environmental Conditions (Mean ± SE)***

Parameter	Optimal Conditions	Suboptimal Conditions
Egg Number (units)	86.4 ± 7.2	58.7 ± 6.5
Hatching Success (%)	88.5 ± 2.7	72.4 ± 3.1
Time to independent feeding (days)	3–4	4–6
Survival rate (%)	90.8 ± 2.3	76.2 ± 3.6

Figure 2. Reproductive performance of* Ancistrus *under optimal and suboptimal environmental conditions.



Reproductive indicators, including egg number, hatching success, and survival rate, were higher under optimal conditions compared to suboptimal environments. Hatching success was higher under optimal conditions, reaching 88.5 ± 2.7%, while in suboptimal systems it declined to 72.4 ± 3.1%. These results highlight the importance of stable water parameters during embryonic development. Larval development analysis revealed that under optimal conditions larvae transitioned to independent feeding within 3–4 days, whereas under suboptimal conditions this period extended to 4–6 days. This reflects the direct influence of environmental factors on metabolic processes. Additionally, male parental behavior, including egg guarding and continuous ventilation, was identified as a key factor enhancing embryo survival and overall reproductive success (Table 2, Figure 2).

Overall, the findings confirm that *Ancistrus* species possess high reproductive efficiency, particularly under optimal environmental conditions, making them suitable for controlled breeding and ornamental aquaculture systems. The results are consistent with prior reports on loricariid reproductive biology and demonstrate the practical value of environmental optimization for commercial propagation.

Ecological Impact The results of the study demonstrated that *Ancistrus* exerts a notable influence on aquarium ecosystem functioning. A comparative experimental analysis between systems containing *Ancistrus* and control systems (without *Ancistrus*) revealed pronounced differences in key ecological parameters (Table 3, Figure 3).

In aquaria where *Ancistrus* were present, a consistent reduction in biofilm and algal layer accumulation on substrate surfaces was observed. This effect can be attributed to the feeding behavior of *Ancistrus*, which actively graze on periphyton and biofilm. As a result, a noticeable

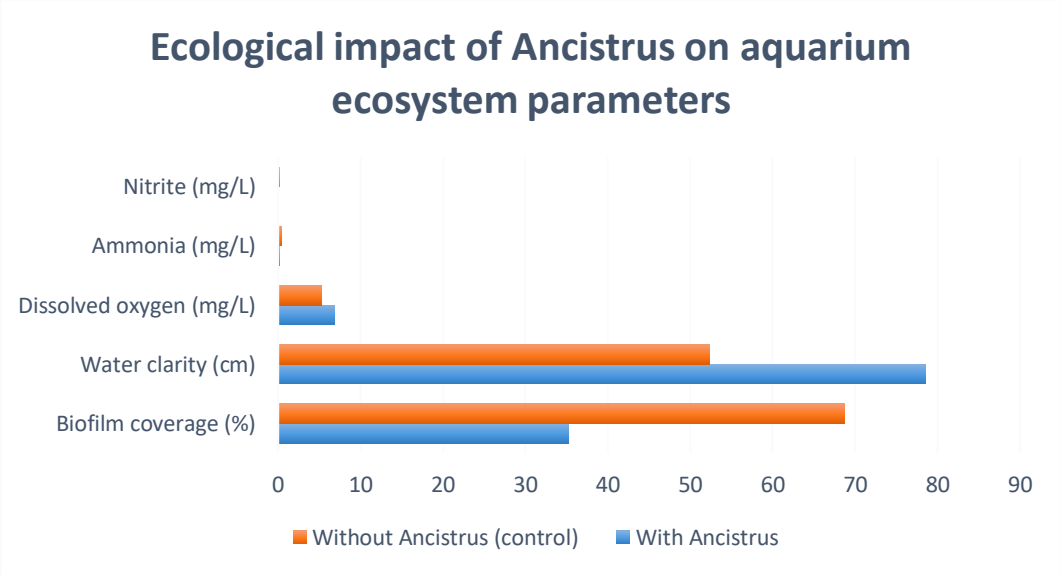
improvement in water clarity and a reduction in organic matter accumulation were recorded. In contrast, control aquaria lacking *Ancistrus* showed a progressive increase in organic residues and algal biomass over time. This led to decreased water transparency and signs of ecological imbalance, including the deterioration of overall water quality.

Furthermore, comparative analysis of physico-chemical parameters indicated that systems containing *Ancistrus* maintained higher levels of dissolved oxygen and lower concentrations of ammonia and nitrite. These findings suggest enhanced biofiltration processes and accelerated decomposition of organic matter in the presence of *Ancistrus*.

Table 3. Ecological Parameters of Aquarium Systems with and without Ancistrus ***(Mean ± SE)***

Parameter	**With Ancistrus**	**Without Ancistrus (control)**
Biofilm coverage (%)	35.2 ± 3.1	68.7 ± 4.5
Water clarity (cm)	78.5 ± 5.2	52.3 ± 4.8
Dissolved oxygen (mg/L)	6.8 ± 0.4	5.2 ± 0.3
Ammonia (mg/L)	0.18 ± 0.02	0.36 ± 0.04
Nitrite (mg/L)	0.09 ± 0.01	0.21 ± 0.02

Figure 3. Ecological impact of* Ancistrus *on aquarium ecosystem parameters.



The presence of *Ancistrus* reduced biofilm accumulation and improved key water quality indicators. Systems containing *Ancistrus* exhibited higher water clarity and dissolved oxygen levels, while concentrations of ammonia and nitrite were notably lower than those in control systems. Overall, the obtained results confirm that *Ancistrus* functions as an effective biological regulator within aquarium ecosystems. By controlling biofilm growth, reducing organic load, and improving water quality, these fish contribute to the stabilization of ecological conditions. Therefore, *Ancistrus* can be considered a valuable biological component for supporting natural biofiltration processes in closed aquatic systems. These outcomes are in agreement with established ecological principles regarding the role of benthic grazers in nutrient cycling and water-quality maintenance.

Economic Interpretation (Profitability Analysis) Profitability is one of the most important economic indicators used to evaluate the efficiency and sustainability of aquaculture

production systems. It reflects the relationship between the net profit obtained and the total production costs incurred, thereby providing an integrated assessment of economic performance.

In the present study, profitability was evaluated based on model-derived calculations that incorporated both biological performance indicators and current market conditions. According to these estimates, total production costs were approximately 2,150,000 UZS, including expenses related to equipment, feed, energy consumption, and system maintenance. At the same time, the potential total revenue, calculated based on the number of marketable juveniles and average market prices, may reach up to 4,800,000 UZS under favorable conditions. Consequently, the estimated net profit may amount to approximately 2,650,000 UZS.

Profitability was calculated using the standard economic formula:

$$\text{Profitability}\,(\%) = \left(\frac{\text{Net profit}}{\text{Total cost}}\right) \times 100$$

Substituting the obtained values into the formula:

$$\left(\frac{2{,}650{,}000}{2{,}150{,}000}\right) \times 100 \approx 123\%$$

This result indicates that profitability may reach approximately 123%, meaning that for every 1 UZS invested in production, a net profit of approximately 1.23 UZS is generated. Such a level of profitability reflects relatively high economic efficiency compared to many conventional aquaculture practices, particularly in small-scale production systems (Table 4).

Table 4. Main Economic Indicators of Ancistrus ***Production (Model-Based Estimation)***

Parameter	**Value (UZS)**
Total production cost	2,150,000
Including: equipment and feed costs	represent the major share
Total revenue	up to 4,800,000
Net profit	around 2,650,000
Profitability (%)	up to 123

The results indicate that under optimal conditions total revenue may substantially exceed production costs, resulting in high profitability. These values are based on model calculations and may vary depending on production scale, management efficiency, and market conditions. Furthermore, the high profitability observed in this study can be attributed to several key factors, including relatively low operational costs, efficient feed utilization, high survival rates, and strong reproductive performance of the cultured species. The ability of *Ancistrus* to utilize natural biofilm as a supplementary food source also contributes to reducing feed expenses, thereby improving overall economic efficiency.

However, it should be emphasized that the presented economic indicators are based on model estimations and may vary depending on production scale, environmental conditions, management practices, and fluctuations in market demand and prices. Therefore, these results should be interpreted as indicative rather than absolute values. Overall, the findings suggest that *Ancistrus* culture under controlled aquarium conditions has considerable economic potential and may serve as a viable option for small-scale aquaculture enterprises and ornamental fish production systems.

CONCLUSION

The results of this study comprehensively demonstrate that *Ancistrus* species exhibit high biological and economic efficiency under controlled aquarium conditions. The findings reveal a

strong interrelationship between environmental factors, reproductive performance, and economic outcomes.

The analysis of biological indicators showed that under optimal conditions (24–27 °C; DO > 6 mg/L), survival rates reached up to 90–95%, while growth rates were substantially enhanced. These findings are consistent with previous studies by Jobling (1994) and Val & Almeida-Val (1998) [11; 19], which emphasize the strong dependence of metabolic activity and growth processes on environmental parameters. Moreover, the results of the present study indicate that stable and controlled aquarium conditions can further optimize growth performance.

Regarding reproductive performance, the obtained results confirm that *Ancistrus* species possess high reproductive potential. The observed fecundity range of 50–120 eggs per spawning event and hatching success rates of 85–90% are comparable to the findings reported by Breder & Rosen (1966) and Balon (1975) [5; 2]. In particular, male parental behavior, including egg guarding and active ventilation, was identified as a key factor enhancing reproductive success, which is characteristic of many members of the Loricariidae family.

Ecological analysis demonstrated that *Ancistrus* plays a significant functional role in aquarium ecosystems. The reduction of biofilm and algal accumulation, along with improved water clarity, is in agreement with ecological principles described by Power (1990) and Vanni (2002) [13; 20]. The present study further confirms these processes experimentally, highlighting the role of *Ancistrus* in biofiltration and organic matter regulation.

Economic evaluation based on model calculations indicates that *Ancistrus* culture can achieve a high level of profitability, reaching up to 123% under optimal conditions. These results are consistent with the findings of Timmons (2002) and Romanov (2010) [17; 15], who reported high efficiency in small-scale aquaculture systems. Additionally, the ability of *Ancistrus* to utilize biofilm as a supplementary food source contributes to reducing feed costs and improving overall economic efficiency.

Overall, the findings suggest that *Ancistrus* species represent a highly promising candidate for ornamental aquaculture due to their high survival rate, rapid growth, efficient reproduction, and ecological benefits. Their role in maintaining ecosystem stability further enhances their value in closed aquatic systems. The results of this study have both theoretical and practical significance, providing a scientific basis for optimizing biological management and improving economic efficiency in small-scale aquaculture systems.

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