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Research Article

Reproductive Performance, Larval Rearing, and Economic Feasibility of Royal Whiptail Catfish *Sturisoma panamense* Under Captive Culture Conditions

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Abstract

The royal whiptail catfish Sturisoma panamense is a high-value ornamental freshwater species with increasing market demand but limited standardized aquaculture protocols. This study aimed to evaluate breeding performance, larval and juvenile rearing management, and business feasibility of *S. panamense*cultured at Tetra Aquaria Farm, Sukabumi, West Java, over a 45-day period. Broodstock (1.5 years old) were maintained in glass aquaria (100 × 50 × 40 cm) at a male-to-female ratio of 1:2 and fed frozen bloodworms twice daily. Spawning occurred naturally without hormonal induction, with males exhibiting parental care. A total of 1,481 eggs were produced from five breeding pairs across spawning events, with an average fecundity of 296 eggs per spawning. The mean fertilization rate and hatching rate were 96.6% and 94.8%, respectively, exceeding previously reported values. Larvae were reared in plastic trays at a density of 25 individuals per container and fed a spirulina-enriched paste diet. The average survival rate during the 14-day larval phase reached 90.4%. Juveniles were subsequently reared in styrofoam boxes until reaching a market size of 4–5 cm, fed chopped *Tubifex* sp., and maintained under optimal temperature conditions (23–26°C). White spot disease Ichthyophthirius multifiliis was controlled through preventive salt application and routine sanitation. Economic analysis indicated total annual revenue of IDR 43,520,000 with a profit of IDR 6,412,620, an R/C ratio of 1.17, a break-even point of 4,585 units, and a payback period of 1.7 years. These results demonstrate that standardized breeding and rearing management can enhance reproductive success and confirm the technical and economic feasibility of royal whiptail catfish hatchery operations.

Keywords: *Sturisoma panamense*, ornamental fish, breeding management, fertilization rate, business feasibility.

I. INTRODUCTION

The royal whiptail catfish *Sturisoma panamense* is a freshwater ornamental fish species native to the Latin American region (Covain *et al.,* 2016; Firdausi *et al.,* 2025). This species naturally inhabits rivers with moderate to strong currents, particularly in the Amazon basin as well as rivers in Ecuador and Panama (Reis, 2003). In aquarium conditions, *S. panamense* generally regardedas a herbivorous species and is commonly utilized as an algae grazer, functioning as a "cleaner fish." Behaviorally, this species is non-aggressive, exhibits a calm disposition, and predominantly occupies the bottom layer of the water column (Londoño &

Britto, 2023).

Morphologically, the royal whiptail catfish is characterized by an elongated body with a dark brown coloration and a slender, forked caudal fin, which constitutes a distinctive feature and enhances its ornamental value (Eigenmann *et al.,* 1889). This unique body shape contributes significantly to its aesthetic appeal and relatively high economic value compared to other freshwater ornamental fish species (Figure 1).

In terms of reproduction, *S. panamense* typically produces 50–150 eggs per spawning event, although fecundity may vary depending on broodstock size, age, nutritional status, and environmental conditions. Eggs are usually deposited on smooth substrates such as aquarium walls, and males exhibit parental care by guarding and aerating the eggs until hatching, which contributes to high egg survival and hatching success (Jain, 2025; Akbar, 2021). Despite its potential for aquaculture, Wise *et al.* (2021) state that the royal whiptail catfish remains susceptible to health disturbances, particularly white spot disease caused by Ichthyophthirius multifiliis. This susceptibility is mainly associated with poor water quality, suboptimal environmental conditions (such as temperature fluctuations and low dissolved oxygen), high stocking density, and stress from handling or inadequate nutrition, all of which can reduce immune function and increase infection risk. This parasite infects the epidermal layer of the fish and may induce stress, reduced immunity, and mortality, especially during the larval and juvenile stages (Farmer *et al.,* 2013; Wang *et al.,* 2019). These conditions indicate that fish health management represents a critical factor in successful breeding and larval rearing (Prajapat, 2025).

In recent years, royal whiptail catfish has emerged as one of the ornamental fish commodities with high demand in both domestic and international markets (Firdausi *et al.,* 2025). The increasing market interest is primarily driven by its unique morphology and limited availability due to the small number of producers capable of maintaining consistent and sustainable breeding operations (Mauladina, 2024). In the Sukabumi region, market demand for royal whiptail catfish has been reported to reach approximately 800–1,000 individuals per month, with a selling price of around IDR 8,000 per individual for fish measuring 4–5 cm in total length (interpersonal communication, Dermawan 2024). However, this high demand has not

Figure 1. The royal whiptail catfish *Sturisoma panamense* morphology (research documentation)

yet been matched by stable and standardized production capacity.

To date, scientific studies addressing the technical aspects of royal whiptail catfish aquaculture particularly breeding techniques, broodstock management, larval rearing, and disease control remain very limited. Most available literature primarily focuses on taxonomy, distribution, and general morphological characteristics of Loricariidae species (Reis, 2003; Covain *et al.,* 2016), while detailed documentation of domestication and controlled breeding of royal whiptail catfish is still scarce. Similar limitations have been reported for several non-mainstream ornamental fish species, in which insufficient technical data on breeding represents a major constraint to commercial aquaculture development (Jain *et al.,* 2025; Peh & Azra, 2025).

The absence of standardized breeding and rearing protocols for royal whiptail catfish has led producers to rely largely on trial-and-error approaches or wild capture, which may hinder production efficiency and threaten the sustainability of ornamental fish resources (Maia *et al.,* 2025; Peh & Azra, 2025). Therefore, systematic studies focusing on the breeding of royal whiptail catfish including spawning techniques, egg incubation, larval rearing, water quality management, and disease prevention are urgently needed. The results of such studies are expected to provide a scientific foundation for the development of effective and sustainable aquaculture technologies for *S. panamense*and to support the expansion of high-value ornamental fish production at the national level.

II. MATERIALS AND METHODS

2.1. Preparation of Grow Out Site

The study was conducted at Tetra Aquaria Farm, Sukabumi, West Java, Indonesia, for 45 days, from 18 February to 29 March 2025. The location map is

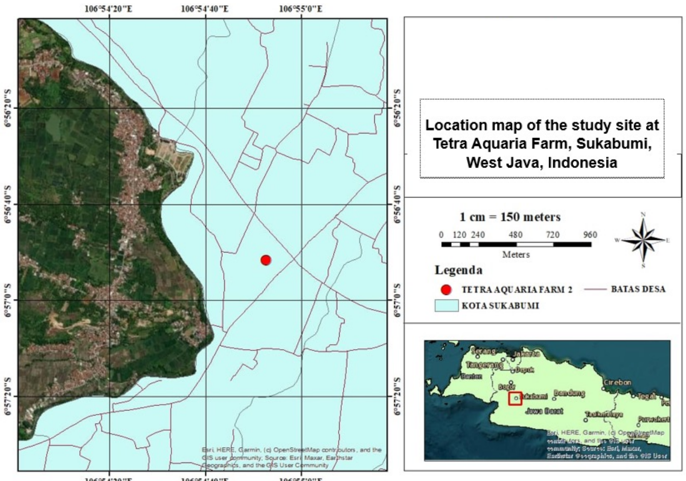

Figure 2. Location map of the study site at Tetra Aquaria Farm, Sukabumi, West Java

presented in Figure 2.

2.2 Broodstock Rearing

Broodstock rearing of the royal whiptail catfish was conducted in four glass aquaria, each measuring 100 × 50 × 40 cm. Prior to use, aquaria were prepared by draining any residual water, scrubbing the inner surfaces to remove debris, rinsing thoroughly with clean water, and allowing the tanks to air-dry for approximately 24 h, following established aquarium cleaning protocols used in controlled aquatic research and production systems (Figure 3a) (Pandang *et al.,* 2025). The aquaria were then filled with clean freshwater to approximately 80% of their total volume, corresponding to a water depth of about 30 cm (±150 L), following standard procedures for freshwater ornamental fish husbandry (Datta *et al.,* 2013; Akbar, 2021) (Figure 3b).

Each aquarium was equipped with one water pump and a box filter to provide water circulation and filtration. In addition, two glass partitions were installed in each aquarium and used as egg-attachment substrates. The use of smooth substrates is essential to support successful spawning and egg adhesion in substrate-spawning fish species (Evans & Meisner, 2019; Nair *et al.,* 2020).

The broodstock used in this study originated from Bandung, West Java, Indonesia and were selected based on good health and active behavior. The broodstock consisted of males measuring >12 cm and females measuring 10–12 cm. Healthy broodstock were characterized by active swimming behavior, normal body morphology, intact fins, no visible lesions or disease symptoms, and good responsiveness to feed. A total of nine broodfish were stocked in each aquarium, consisting of three males and six females, resulting in a male-to-female ratio of 1:2. This ratio was applied to improve spawning efficiency and fertilization success, as a higher proportion of females relative to males can increase egg production while still ensuring adequate sperm availability for successful fertilization, as commonly recommended in broodstock management practices (Effendie, 2002; Bagenal, 1978; Bromage & Roberts, 1995). The stocking density applied was three fish per 50 L of water, which falls within the recommended range for medium-sized ornamental fish to minimize stress and promote reproductive activity.

The broodstock were fed frozen bloodworms cut into small cubes (Patekar *et al.,* 2025). Feeding was conducted ad libitum twice daily, at 08:30 and 16:00 local time. The provision of high-quality, protein-rich feed plays an important role in supporting gonadal development and enhancing spawning success in ornamental fish broodstock (Hendriana *et al.,* 2022; Iskandar *et al.,* 2022;).

Water quality management was performed through bottom siphoning prior to feeding to remove fecal matter and uneaten feed, followed by the addition of fresh water. Water quality monitoring was carried out twice daily, in the morning at 07:30 and at midday at 13:00. The water quality parameter measured in this study was temperature, which was recorded using a digital thermometer, as temperature is a key environmental factor influencing fish metabolism, health, and reproductive performance (Van, 1997; Kumar *et al.,* 2023).

2.3 Larval Rearing

The maintenance tanks consisted of nine fiber tanks measuring 1.5 m in diameter and 0.3 m in height. The entire interior of the fiber tanks was cleaned using a sponge and then dried for one day. The fiber tanks were filled with clean water to a height of 25 cm, or a total volume of 112.5 L. The water was allowed to settle for 24 hours before being used for the test research. The aeration installation in each fiber tank consisted of an air stone and an aeration hose.

Larval rearing was conducted using plastic trays measuring 45 cm × 35 cm × 15 cm. Each tray was filled with freshwater to a depth of 10 cm (approximately 80% of the effective volume). Prior to use, the trays were sanitized to prevent disease transmission by washing with clean water and soap, scrubbing with a sponge, thoroughly rinsing, and air-drying (Husnan, 2024).

Larvae were stocked at a density of 25 individuals per tray. Stocking was carried out carefully by transferring the larvae using a ladle, followed by brief acclimatization before gradual release into the rearing container. The larvae were fed a commercial diet (Fengli 0) prepared in paste form at 50 g per feeding batch, supplemented with 6% spirulina powder (based on total feed weight) and 0.5 g binder (Firdausi *et al.,* 2025). Fengli 0 contains approximately 45–50% crude protein, which is suitable for larval fish stages due to their high protein requirements to support rapid growth, tissue formation, and physiological development (Tacon, 1990; NRC, 2011). Feed was administered at two designated points within each tray twice daily, at 08:30 and 16:00 local time. Siphoning was performed prior to feeding to remove waste and maintain water quality. Water temperature was monitored daily at 07:30 and 13:00.

To maintain fish health and reduce the risk of white spot disease and abdominal swelling, 5 g of coarse salt was added to each 80-L rearing tank as a preventive treatment. In cases where disease symptoms appeared, the dosage was increased to 10 g per 80 L of water as a curative measure (interpersonal communication, Dermawan 2024). Additionally, the rearing trays were replaced once per week to prevent the accumulation of mucus and pathogens on the container walls.

Harvesting at the first nursery stage was conducted when the larvae reached two weeks of age or attained an average total length of 1.5–2 cm. Juveniles were collected using a hand net and ladle, then transferred to styrofoam boxes for the second nursery phase.

2.4 Juvenile Rearing

The Nile tilapia (*O. niloticus*) fry used were 5–6 cm in size. They were sourced from the Cibalagung Fisheries Research Institute in Bogor, West Java. The fry were healthy, free of defects, and active. The fry were first acclimatized for 30 minutes. The fry were first acclimatized seven days prior to the experiment.

Juveniles were reared in styrofoam tanks measuring 75 cm × 42 cm × 32 cm, each containing 80 L of water. Prior to use, the containers were cleaned with a sponge, coated with paint to prevent leakage, and air-dried for 24–36 hours.

The stocking density applied was one fish per liter of water, which was considered optimal to support juvenile growth. The juveniles were fed chopped Tubifex worms that had been previously cleaned using a plankton net. Feeding was provided ad libitum twice daily at 08:30 and 16:00 local time. During the rearing period, each culture tank received 5 g of coarse salt in 80 L of water as a prophylactic treatment to support fish health and reduce susceptibility to ectoparasitic and fungal diseases.

Comprehensive sampling was performed to measure total length. Juveniles that reached market size (4–5 cm) were separated for sale, while smaller individuals were reared further. Marketable fish were selected not only based on size, but also on external quality characteristics, including bright and uniform body coloration, normal body shape, active swimming behavior, intact fins, and the absence of physical deformities or disease symptoms. These characteristics are important because the commercial value of ornamental fish is strongly influenced by visual appearance, particularly body coloration, pattern, and morphology, which affect consumer preference and market price (Lau *et al.,* 2023). Fast-growing individuals with superior morphological characteristics were retained as prospective broodstock. Harvesting was conducted using a hand net, followed by size grading to ensure uniformity.

2.6 Juvenile Transportation

Transportation preparation involved the use of plastic bags measuring 60 cm × 40 cm, rubber bands, oxygen, and appropriate cardboard boxes. Each package consisted of double-layered plastic bags secured with two rubber bands on each side. The plastic bags were inverted to eliminate dead corners prior to stocking.

Juveniles were harvested in the morning using a hand net and sorted to ensure uniform size according to consumer demand, with 50 individuals per package. The air was first expelled from the plastic bag, after which water and oxygen were added at a ratio of 1:2 (water:oxygen) (Bakrie & Olgani, 2020). The sealed bags were placed horizontally inside cardboard boxes, which were tightly secured with adhesive tape and labeled with the destination address. Transportation was carried out by bus for long-distance shipments and by motorcycle for short-distance deliveries.

2.7 Business Analysis

The business feasibility analysis was calculated based on annual investment costs, fixed costs, and variable costs (Hendra *et al.,* 2021). Total revenue was obtained by multiplying annual production volume by

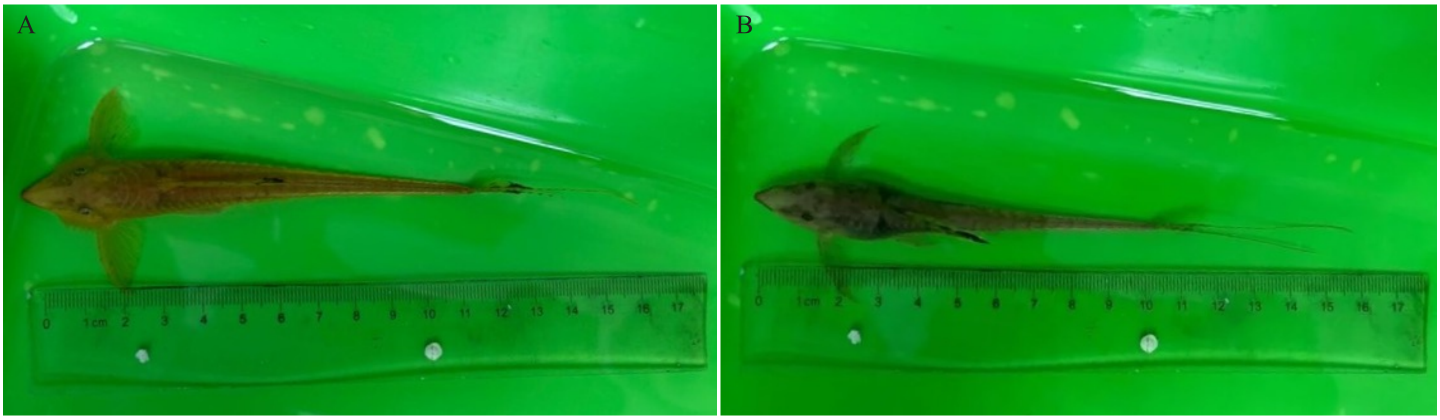

Figure 3. Royal whiptail catfish broodstock: (A) male; (B) female

the selling price per juvenile. Profit was determined as the difference between total revenue and total production costs.

The unit production cost (cost of goods manufactured) was calculated by dividing total costs by total production output (Shephard, 2015). The R/C ratio was determined by comparing total revenue to total costs. The payback period was estimated by dividing the total investment cost by annual profit to determine the time required for capital recovery.

The Break Even Point (BEP) was calculated using the following formulas by Roach & Milhollin (2020) :

- BEP (units) = Fixed Costs / (Selling Price per Unit − Variable Cost per Unit)
- BEP (IDR) = Fixed Costs / (1 − (Variable Costs / Total Revenue))

These formulas were used to determine the minimum production volume (in units) and minimum revenue (in IDR) required to cover total production costs.

2.8 Data analysis

In this study, the working method employed combined data obtained through direct on-site observations with active participation in all stages of the activities. Iskandar *et al.,* (2022) stated that this approach aims to obtain comprehensive information covering all technical aspects of aquaculture operations, from production processes to distribution and marketing.

Secondary data were collected from various documents and subsequently processed to support the study analysis through relevant stakeholders (Goel, 2023). This study employed a non-experimental approach (Putra *et al.,* 2025), involving the observation of a single culture system implemented under routine and continuous husbandry practices. The observational unit consisted of a breeding pair of fish, with five breeding pairs serving as biological replicates (n = 5). The secondary data collected in this study included fish fecundity, fertilization rate (FR), egg hatching rate (HR), and survival rate (SR) of the cultured fish. The fertilization rate (FR), hatching rate (HR), and survival rate (SR) were calculated using the following formulas:

- Fecundity was determined by direct counting of all eggs produced during each spawning event and expressed as the total number of eggs per spawning
- FR (%)= (Number of fertilized eggs)/(Number of eggs sampled) x100% (Prama *et al.,* 2014)
- HR (%)= (Number of hatched eggs)/(Total number of eggs) x100% (Effendie, 2002)
- SR (%)= Nt/No x100% (Effendie, 2002)

note:
Wo = Body weight of the female before spawning
Wt = Body weight of the female after spawning
No = Number of fish at the beginning of the rearing period (individuals)
Nt = Number of fish at time t (individuals)

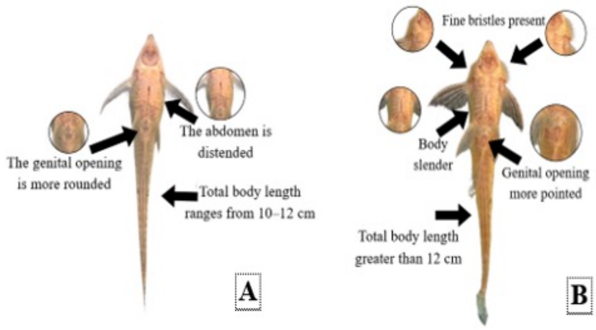

Figure 4. Identification of sexual dimorphism characteristics between male and female royal whiptail catfish broodstock (A) male; (B) female

Table 1. External morphological characteristics and secondary sexual traits of royal whiptail catfish broodstock

No	Criteria	Male	Female
1	Age	> 1 year	> 1 year
2	Size	Larger (>12 cm)	Smaller (10–12 cm)
3	Body shape	Slender body	Distended abdomen
4	Head	Presence of fine barbels	No fine barbels
5	Genital opening	More pointed	More rounded

III. RESULT AND DISCUSSION

3.1 Broodstock Rearing and Spawning

Broodstock of the royal whiptail catfish used in this study were approximately 1.5 years old and maintained under controlled conditions. Water quality was maintained at 25–27°C, pH 6.5–7.5, and dissolved oxygen levels above 5 mg L^{-1} through regular water exchange and continuous aeration to support optimal growth and reproductive performance (Aquadiction, 2026). During the rearing period, broodfish were fed frozen bloodworms containing 56% protein, 2.80% lipid, and 15.4% carbohydrate (Tevapawat & Tungpairojwong, 2024). The nutritional composition and freshness of frozen bloodworms have been reported to remain stable, thereby supporting optimal feed quality (Hendriana *et al.,* 2022; Martadinata *et al.,* 2024). Adequate dietary protein is essential for vitellogenesis and gonadal maturation, as sufficient protein availability accelerates gonad development and enhances egg production potential (Mauladina, 2024).

The morphological differences between male and female broodstock are presented in Figure 3. Sex identification of broodfish was conducted based on external morphological characteristics and secondary sexual traits observed visually, as presented in the Figure 4 and described in Table 1.

Broodfish reaching gonadal maturity were generally older than one year. Broodstock were fed a commercial pellet diet containing approximately 40–45% crude protein twice daily to apparent satiation. The protein-rich diet was provided to support gonadal development and reproductive maturation (Mauladina, 2024; Zufar *et al.,* 2025).

Water quality management focused on daily temperature monitoring. Morning temperatures ranged from 23.0–24.6°C, while midday temperatures ranged from 24.8–26.1°C. These values fall within the optimal tolerance range for tropical ornamental fish (24–29°C) (Yanar *et al.,* 2019; Iskandar *et al.,* 2025), indicating that thermal conditions were suitable for reproductive activity.

Natural spawning occurred without the uses of hormonal induction. Courtship behavior was initiated by the male wagging its caudal fin toward the female and engaging in chasing behavior. Females selected smooth substrates such as glass partitions or aquarium walls for oviposition. Following egg deposition, males guarded and incubated the eggs until hatching (Michael, 2025).

3.2 Egg Incubation and Hatching

Egg incubation occurred in the same spawning aquarium due to the species paternal care behavior. Eggs measured approximately 0.2 cm in diameter and were initially milky white. During incubation, progressive color changes were observed: milky white on day 1, turning yellowish white, and gradually darkening between days 4–6 prior to hatching, indicating normal embryonic development. Hatching occurred between days 7–8 post-spawning. Data on fecundity, fertilization rate (FR), and hatching rate (HR) are presented in Table 2.

Table 2. Total eggs, fertilization rate (FR), and hatching rate (HR) of royal whiptail catfish

Date	Total eggs	Fertilized eggs	Unfertil-ized eggs	FR (%)	HR (%)
24/02/2025	384	372	12	96	93
07/03/2025	294	287	7	97	97
11/03/2025	307	299	8	97	95
17/03/2025	261	256	5	98	94
25/03/2025	235	225	10	95	95
Average	296	287	8	96.6	94.8

Table 3. Larval survival rate (SR)

Tank	Initial number (ind.)	Final number (ind.)	SR (%)
1	345	317	92
2	278	250	90
3	284	255	90
4	240	216	90
5	213	191	90

Table 4. Economic analysis of royal whiptail catfish hatchery operations

Component	Amount (IDR)
Investment cost	11,388,000
Fixed cost/year	34,431,380
Variable cost/year	2,676,000
Total cost/year	37,107,380
Revenue/year	43,520,000
Profit/year	6,412,620
Production cost/unit	6,821
BEP (units)	4,585
BEP (IDR)	36,668,136
R/C ratio	1.17
Payback period (years)	1.7

A total of 1,481 eggs were produced across spawning events, with an average fecundity of 296 eggs per spawning. The mean fertilization rate was 96.6%, and the mean hatching rate was 94.8%. These values exceeded previously reported averages FR 71% and HR 78% (Akbar, 2021), indicating improved reproductive performance under the present management conditions.

3.3 Larval and Juvenile Rearing

Larvae were reared for 14 days until reaching the early juvenile stage. Daily siphoning was conducted to remove uneaten feed and organic waste, thereby preventing mucus accumulation and water quality deterioration. Feeding commenced at 2–3 days post-hatch using a formulated paste feed enriched with spirulina and was administered twice daily until day 10.

Water temperature during larval rearing ranged from 23.2–24.8°C in the morning and 24.9–26.1°C at midday, remaining within the optimal range for tropical ornamental fish larvae (Iskandar *et al.,* 2021). Within this range, temperature supports metabolic activity, nutrient assimilation, and physiological development, which are essential for larval growth and survival (Thomas *et al.,* 2022; Prakoso *et al.,* 2021).

The most common disease observed during the rearing period was white spot disease caused by Ichthyophthirius multifiliis, a ciliated protozoan that infects the epidermal tissue and is characterized by the appearance of visible white nodules on the fish body (Farmer *et al.,* 2013). Parasitic infections such as]*I. multifiliis* remain one of the major constraints in hatchery operations because they can reduce survival, impair fish health, and increase production costs. Similar impacts of ectoparasitic infestations on hatchery performance have been reported in red tilapia hatcheries, highlighting the importance of implementing effective preventive health management strategies to maintain production efficiency and fish welfare (Ramadhani *et al.,* 2024).Preventive measures included routine sterilization and drying of equipment. In cases of infection, 5 g of coarse salt was applied at one-day intervals. Survival rate data are presented in Table 3.

The average survival rate was 90.4%, indicating effective larval management. High survival was attributed to appropriate feeding, stable environmental conditions, and consistent disease prevention practices (Waybright, 2009). Juveniles were subsequently reared in styrofoam boxes for 2–3 weeks until reaching a harvest size of 4–5 cm. Feed consisted of chopped *Tubifex* sp., adjusted to mouth size to optimize feed efficiency. Tubifex contains approximately 57% protein and 13% lipid, supporting optimal growth (Santoso *et al.,* 2022). Water temperatures ranged from 23.7–24.9°C (morning) and 25.0–26.1°C (midday), remaining within suitable limits.

3.1 Business Feasibility Analysis

The economic analysis of royal whiptail catfish hatchery operations at Tetra Aquaria is presented in Table 4. The R/C ratio of 1.17 indicates that revenue exceeded total costs, confirming the economic feasibility of royal whiptail catfish hatchery operations. The positive profit margin and relatively short payback period (1.7 years) further demonstrate the financial viability of this aquaculture business.

V. CONCLUSION

The captive breeding of the royal whiptail catfish *Sturisoma panamense* demonstrated favorable reproductive performance and economic feasibility under controlled culture conditions. A total of 1,481 eggs were produced from five spawning events, with an average fecundity of 296 eggs per spawning. The mean fertilization rate (FR) and hatching rate (HR) were 96.6% and 94.8%, respectively, while larval rearing achieved an average survival rate (SR) of 90.4%. Furthermore, the hatchery operation generated an annual profit of IDR 6,412,620, with an R/C ratio of 1.17, a break-even point of 4,585 fish, and a payback period of 1.7 years. These findings indicate that the application of appropriate broodstock management, larval rearing practices, and disease prevention measures can support both high production performance and the economic sustainability of *S. panamense* hatchery operations.

CONFLICT OF INTEREST

We certify that there are no conflicts of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

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