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Case Study: Growth Performance and Business Analysis of Brown-Marbled Grouper (*Epinephelus fuscoguttatus*) in Nursery and Grow-Out Cultivation

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ABSTRACT

Grouper fish, particularly the brown-marbled grouper (*Epinephelus fuscoguttatus*), are among the most economically significant marine species widely farmed and exported. This study aimed to analyze the growth performance and business analysis of the production of brown-marbled grouper, both in nursery and grow-out segments. The research was conducted using a case study method at a governmental production and research center located in Lampung Province, Indonesia. Primary data were collected through field observations, while secondary data were obtained from interviews with farm personnel. The study revealed that the nursery phase faced significant challenges, with larval survival rates as low as 4.2%. In contrast, survival rates improved considerably in larger fish, demonstrating better resilience as they grow (reaching 92-93%). From a business perspective, the grow-out activity was found to be more profitable due to lower investment costs. However, it requires a longer period to raise the fish to market size. Both nursery and grow-out operations proved to be profitable, with respective R/C ratios of 1.6-2.0. Overall, while grouper farming is economically viable, it requires careful management to overcome the high mortality in the early life stages and to optimize the investment cost-effectiveness of the nursery phase.

INTRODUCTION

Grouper fish are one of the economically significant marine species that are widely farmed and exported (Huang *et al*., 2022; Pan *et al*., 2022). The market demand for this commodity is stable and tends to increase annually. The brown-marbled grouper (*Epinephelus fuscoguttatus*), in particular, has gained commercial importance due to its fast growth and high market value, making it the most preferred species for cultivation among groupers (Sutarmat, 2013). This species is increasingly farmed both for seed production and grow-out phases. The high demand for live grouper from countries such as Singapore, Japan, Hong Kong, Taiwan, Malaysia, and the United States has driven production increases in many grouper-producing nations, especially Indonesia.

However, one of the main challenges in grouper farming in Indonesia is the high mortality rate, particularly among the fry, which can reach up to 100% (Lieke *et al*., 2021;

Vadstein *et al*., 2013). The continuously rising market demand and the high economic value of grouper have led to intensified fishing, which poses a significant threat to grouper resources, making them vulnerable to extinction (Cheung *et al*. 2013). Producing grouper fish in a controlled condition through aquaculture becomes a promising future, studies have been conducted to establish a good culture protocol (Amatul-Samahah *et al*., 2022; Huang *et al*., 2024; Pang *et al*., 2024; Wang *et al*., 2017; Zhang *et al*., 2021). However, grouper culture business does not come without bottlenecks challenges, both in the nursery and grow-out segments.

In general, grouper farming requires substantial investment and maintenance of infrastructure. The nursery activity of grouper fish requires proper marine-water-based hatchery, while the grow-out needs floating net cages in open waters. As carnivorous fish, groupers also require high-protein feed, leading to higher feeding costs compared to omnivorous or herbivorous freshwater fish like tilapia, gourami, and carp. In nursery activity, challenges include mastering the technology for spawning and ensuring the survival of larvae. The latest could reach up to 0%. For grow-out operations, the obstacles lie in the high costs and long duration needed to raise fish to market size.

Sustainable grouper production depends on healthy profitability and the robust growth of the farmed fish. Field observations of nursery farms are essential to understand the current state and development of grouper aquaculture in the community. This study aims to observe the growth and business aspects in an actively-producing farm in Sumatra Island, Indonesia. By examining these aspects, the research seeks to provide a comprehensive overview of the technical and economic factors influencing the success of grouper culture, offering insights into both the challenges and opportunities in this sector.

METHODS

Time and Place

The experiment was conducted from January to April 2020 at an production and research center in Lampung Province.

Research Design

The experiment is a case study at one of the fisheries centers actively producing brown-marbled grouper (*Epinephelus fuscoguttatus*), using several approaches:

a. Direct observation (primary data).
b. Collection of secondary data through interviews.
c. Data processing based on the obtained primary and secondary data.

Fish production involves two main activities: nursery (breeding, egg hatching, larva and fry rearing) and grow-out culture.

Nursery

<u>Broodstock Breeding</u>

The broodstock were kept in floating net cages made of high density polyethylene (HDPE) with nets measuring 4 m x 4 m x 4 m, made from polyethylene (PE) with a mesh size of 2 inches and a line size of D18. The ratio of male to female broodstock is 1:2. The brown-marbled grouper broodstock was originally from waters around Ambon. Selection of broodstock was based on criteria such as intact body parts, good health, response to feed, and active movement. They were fed fresh fish (kuniran, *Upeneus moluccensis*) to satiation. Additionally, the broodstock were supplemented with vitamin E at a dose of 10 mg/kg body weight, twice a week to accelerate gonad maturation and improve egg quality. Vitamin E capsules were inserted into the mouth of the kuniran fish. Water management in the floating net cages (KJA) involved changing the nets every 2 weeks.

Egg Hatching

Egg harvesting was done in the morning at 08:00 AM. Floating eggs were collected using a scoop net with a density of 100 µm and placed in a 60 L bucket filled with 30 L of water. Egg counting was performed by sampling at three different points in the bucket using a 20 mL measuring cup. The water with eggs was poured onto a sample board, and the total number of eggs is counted. Eggs were hatched in fiberglass tanks measuring 1.5 m x 0.7 m x 0.5 m, with a density of 1,500 eggs/L. Before hatching, the eggs were sterilized with iodine at a concentration of 2 ppb for 5 minutes to prevent bacterial and fungal infections. The eggs were then hatched using an aeration and water flow system at a rate of 6 L/min. The eggs hatch 16–18 hours after fertilization. Unhatched eggs and debris were siphoned off and discarded.

Larval Rearing

After hatching, larvae are counted using the sampling method and transferred to concrete tanks measuring 5 m x 2 m x 1 m in the morning. The rearing tanks were treated with El Baju at a dose of 1 ppm to prevent disease, and liquid vitamin E 100 IU as a supplement for the larvae. Newly hatched larvae (D1) had endogenous feeding or yolk reserves that last for about 3 days. Subsequent feeding started with *Nannochloropsis oculata* and *Rotifer* sp. from day-2 (D2) to D20. Then, *Artemia nauplii* were given, followed by artificial feed until the larvae reached 35–40 days old. Feeding frequency was twice daily at 08:00 AM and 03:00 PM. Water exchange was done twice daily at 08:00 AM and 01:00 PM. Larval development was regularly monitored.

Fry Rearing

Each production unit contained 2-3 rearing tanks, with one tank for initial fry stocking and two tanks for larger fry. Fry stocking was done in 525 L fiberglass tanks with a density of 431–1,000 fry/tank. Fry are fed to satiation with feed sizes increasing as they grow, starting from 476–630 µm for fry aged D41-D45 to 1.3-1.7 µm for fry aged D55-D60. Feeding occurs four times a day at 06:00–09:00 AM, 10:00–11:00 AM, 01:30–03:00 PM, and 05:00–06:00 PM. Regular sorting and grading were performed every 3–5 days to categorize fish by quality: quality A for fish with no physical abnormalities and quality B for those with eye, mouth, fin, gill, or body deformities. Sick fish were not graded but quarantined for inspection and treatment. Siphoning to remove uneaten feed and fish waste was done three times a day at 06:00 AM, 11:00 AM, and 03:30 PM. Fry that reach 5-6 cm could be harvested after being starved for 10-12 hours to prepare them for transport.

Grow-out

The grow-out phase for brown-marbled grouper was carried out in floating net cages (KJA) with a density of 150–200 fish per 4 m x 4 m x 4 m net compartment. Nets were replaced every 2 weeks to avoid biofouling and clogging from debris. The stocked fry (10-12 cm in length) were sourced from the hatchery at the facility. The fish were fed slow-sinking feed at a feeding rate of 1-4%, decreasing as the fish grow. The feed size increased every 2 months, starting from 0.9-1.1 mm up to 7.5-8.1 mm, and continued to increase until harvest. Feeding occurred once daily between 08:00–11:00 AM. For fish weighing 200-500 g, fresh fish was provided in a ratio of 1:5.6 with artificial feed. The artificial feed contained 48% protein, while the fresh feed contains 19% (wet weight). At this size, artificial feed was given at 08:00 AM, and fresh feed is given at 10:00 AM.

Evaluating Parameters

Parameters observed include growth performance metrics such as fertilization rate, egg hatching rate, survival rates (for larvae, juveniles, and adult fish), length and weight growth, and growth rate. Water quality parameters encompass temperature, salinity, pH, dissolved oxygen (DO), ammonia, nitrite, and clarity. Business aspects parameters include core components such as costs (investment, fixed, and variable), sales, and pricing.

RESULTS

Development and Growth of Brown-Marbled Grouper

The development of brown-marbled grouper larvae can be seen in Table 1. Brown-marbled grouper eggs hatched within 20-25 hours after spawning. Newly hatched brown-marbled grouper larvae were transparent white and planktonic, floating near the water surface with their yolk sac still intact. By D3, the larval yolk reserves were fully absorbed, and their mouth and visual systems began functioning, allowing them to feed externally. Around D35-40, the larvae undergo body color changes (pigmentation) similar to adult fish, transitioning into the juvenile phase. Growth performance from eggs to adult fish could be observed in Table 2. Larval survival rates only reach 4.2%, while survival rates for juveniles were 92% and for adult fish are 87%. Table 3 indicates that Grade A seed quality (without physical deformities) at sizes 3-4 cm and 4-5 cm reached 97-98%, whereas Grade B seed quality (with physical deformities or abnormalities) ranged from 1-3%. The length and weight growth of brown-marbled grouper during the grow-out phase is shown in Figure 1. Weight gain is higher compared to length increase in brown-marbled grouper.

Table 1. Development of Brown-Marbled Grouper Larvae

Age of culture (day-)	Description
D0	The larvae have just hatched and contain a yolk sac as a food reserve
D1	The larvae exhibit planktonic behavior, drifting with the water currents. They still possess the yolk sac for nourishment and remain white and transparent
D2	The larvae continue to drift and have started developing their vision system. They still have the yolk sac but can start detecting their surroundings
D3	The larvae’s vision system is marked by two black spots indicating the formation of eyes. The digestive organs are also starting to develop.
D6	The dorsal and pelvic fin spines appear as small protrusions
D9	Both the dorsal and pelvic fin spines are now clearly visible.
D11	The dorsal and pelvic fin spines extend further.
D15	The spines are now more pronounced.
D16-25	This marks a significant phase in the spine development.
D26-35	The dorsal and pectoral fin spines transform into hardened fins. Black spots begin to appear on the tail, and the larval body elongates, transitioning into the fry stage.

Table 2. Growth Performance from Eggs to Adult Brown-Marbled Grouper

Parameter	Unit	Mean	sd
Nursery			

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Parameter	Unit	Mean		sd
Fertilization rate	%	68	±	20
Hatching rate	%	87	±	3
Larvae survival	%	4.2	±	0.3
Fry survival	%	92		
Fry absolute-length gain	cm	3.6		
Fry absolute-length gain	g	1.6		
Fry length growth rate	cm/day	0.18		
Fry weight growth rate	cm/day	1.03		
Grow-out				
Fish survival 30-200 g	%	93	±	1
Fish survival 200-500 g	%	92	±	1

sd = standard deviation

Table 3. Quality of Brown-Marbled Grouper Fry

Size (cm)	Number (ind)	Quality A (%)	Quality B (%)
3–4	16,115	99	1
4–5	21,408	97	3
Total	**37,523**		

sd = standard deviation

Water Quality

The average water quality parameters, including temperature, salinity, pH, and DO, for the hatchery and grow-out activities of brown-marbled grouper are presented in Table 4. Additionally, the concentrations of ammonia and nitrite, along with water brightness, are provided in Table 5. The temperature and salinity exhibited narrow variations between the different phases of rearing, while the pH and DO values show a wider range of variation. In the grow-out phase, the concentration ranges of ammonia and water clarity were broader compared to the nitrite concentration.

Table 4. Temperature, Salinity, pH, and Dissolved Oxygen (DO) During the Breeding and Rearing of Brown-Marbled Grouper

Parameter	Unit	Nursery				Grow-out
		Broodstock	Egg	Larvae	Fry	
Temperature	^{0}C	29	29	29	29	30
Salinity	ppt	33	33	33	32	32
pH		7.8	7.6	7.6	7.6	8.0
DO	mg/L	5.26	5.8	5.3	5.7	5.7

DO = dissolved oxygen

Table 5. Concentration of Ammonia and Nitrite, and Water Brightness During the Breeding and Rearing of Brown-Marbled Grouper

Parameter	Unit	Concentration		
		mean		sd
Ammonia	mg/L	0.4	±	0.18
Nitrite	mg/L	0.0	±	0.01

Parameter	Unit	Concentration		
		mean		sd
Brightness	m	3.8	±	1.26

sd = standard deviation

Business Analysis

The annual business analysis for brown-marbled grouper hatchery and grow-out activity is presented in Table 6. Based on the analysis results, the investment required for hatchery activities was four times greater than that needed for grow-out operations. However, the revenue and profits generated from the grow-out activities were 1.4 to 1.8 times higher than those from the hatchery activities. Consequently, the payback period (PP) for the grow-out production was eight times faster compared to the hatchery operations. The cost of goods sold (COGS) for market-size fish (500 g), as the final product of the grow-out activities, was 25 times higher than the price of fry produced from the hatchery operations.

Table 6. Annual Business Analysis of Brown-Marbled Grouper Hatchery and Grow-Out Cultivation

Component	Unit	Nursery	Grow-out
Investment cost	IDR	1,229,335,000	296,005,000
Fixed cost	IDR	306,702,029	89,035,650
Variable cost	IDR	199,725,359	488,268,000
Total cost	IDR	506,427,388	577,303,650
Income	IDR	807,791,400	1,127,520,000
Profit	IDR	301,364,013	550,216,350
Cost of goods sold (COGS)	IDR/ind	2,445	61,441
Revenue/cost (R/C) ratio		1.6	2.0
Break event point (BEP, unit)	ind	77,677	1,804
Break event point (BEP, income)	IDR	306,702,029	1,531,796,129
Payback period	year	4.1	0.54

DISCUSSION

Developmental Phases and Early Challenges

Our observations indicate that the developmental trajectory of the brown-marbled grouper (*Epinephelus fuscoguttatus*) from hatching to the fry stage is crucially defined between days 26 and 35 of larval culture. During this period, the fish undergo significant transformations. Initially, the primary functions to develop are vision and digestion, as evidenced by the formation of two black spots which become eyes and the development of the digestive organs, like also observed in yellow rasbora fish (Retnoaji *et al*., 2023). The depletion of the yolk sac within the first few days introduces the necessity for the larvae to commence external feeding, primarily the natural food (Peng *et al*., 2023). This transition is vital as it coincides with the development of skeletal structures and motoric functions, notably the formation of fins.

The energy dynamics during this early developmental phase are pivotal. Most energy produced by the fish is directed towards the development of critical organ systems rather than growth in weight or length (Morales *et al*., 2024; Taslima *et al*., 2022). This phase is identified as critical in the context of this study, highlighted by a markedly low survival rate of larvae at just 4.2% (Table 2), which was is commonly found in early life stage of fish (Vadstein *et al*., 2013). This low survival rate could be attributed to several factors, including the larvae's inability to fully develop essential survival functions, their challenges in adapting to the environmental conditions, pathogens, difficulties in digesting the provided external feed, and the stresses associated with handling during culture activities (Baker & Shartau, 2024; Lieke *et al*., 2021; Rodgers & Isaza, 2024).

Interestingly, among the surviving larvae, a high percentage (97-99%) progressed to the fry stage with complete physical development (Quality A, Table 3). This observation suggests that the majority of larvae that succumbed during the critical early stages had experienced imperfect development. As the fry mature, they exhibit increased robustness and resilience, indicating a positive trajectory in their survival and growth potential as they progress beyond the most vulnerable early larval stages.

Growth Dynamics and Market Relevance

The transition from larvae to fry marks a critical juncture in the growth performance of brown-marbled grouper. The most significant mortality occurs during the early larval stage, emphasizing the importance of management practices that support the rapid development of essential functions such as feeding and vision. By the time the fish reach the fry stage, most survivors display healthy development, with a high proportion classified as Quality A fry. This sharp increase in survival rates from the larval to fry stage indicates that the early larval period is the most vulnerable (Vadstein *et al*., 2013). Effective management during this stage, including optimal feeding strategies and careful handling, is crucial to enhancing overall survival rates.

In the grow-out phase, the fish show a pronounced increase in weight relative to length, indicating a focus on body mass accumulation as they approach market size. This trend aligns with market preferences, where the sale value of fish is often directly correlated with weight. Hence, the grow-out phase not only prepares the fish for market demands but also reflects a shift in the physiological priorities of the fish towards maximizing body mass.

Business Viability and Strategic Considerations

From a business perspective, the analysis of the nursery and grow-out phases reveals distinct challenges and opportunities (Bentzon-Tilia *et al*., 2016; Naylor *et al*., 2021). The nursery phase, characterized by its significant challenges, particularly the low larval survival rate, underscores the need for improved practices and technologies to enhance survival during this vulnerable stage (Bobe, 2015). Despite these challenges, the nursery phase is essential for producing the initial stock required for grow-out operations. In contrast, the grow-out phase, while requiring a longer period to bring the fish to market size, demonstrates better economic viability due to lower relative investment costs and higher survival rates (reaching 92-93%). Both the nursery and grow-out operations are profitable (R/C ratios of 1.6-2.0), but the strategic focus must be on mitigating the high mortality rates in the early life stages and optimizing the cost-effectiveness of the nursery phase. These findings underscore the importance of tailored management strategies for each phase to maximize overall production efficiency and economic returns in grouper farming.

CONCLUSION

Improving larval survival rates through effective management and technological interventions is essential for enhancing the viability of grouper farming. Additionally, the economic analysis reveals that while both nursery and grow-out operations are profitable, careful attention must be paid to the unique demands and challenges of each phase to ensure long-term sustainability and profitability in grouper aquaculture.

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