Grouper: Jurnal Ilmiah Perikanan
Vol. 17 No. 1 (2026) pp. 246 - 254
pISSN: 2086-8480 | eISSN: 2716-2702
Journal Homepage: https://grouper.unisla.ac.id/index.php/grouper

Optimization of Grouper Nursery Rearing Techniques to Improve Production Yields at CV. Bali Akkua Marine

Jefri Putri Nugraha[1*], Putri Nurhanida Rizky[2]

[1]Agribisnis Perikanan, Politeknik Kelautan dan Perikanan, Sidoarjo, Jawa Timur, Indonesia, 61254
[2]Teknik Budidaya Perikanan, Politeknik Kelautan dan Perikanan, Sidoarjo, Jawa Timur, Indonesia, 61254

*Correspondence Author: jputrinugraha@gmail.com

Submitted: 14 March 2025 | Revised: 01 October 2025 | Accepted: 30 April 2026

Keywords:
aquauclture efficiency; Cantang grouper; economic analysis; nursery rearing

ABSTRACT

The optimization of nursery rearing techniques plays a crucial role in improving the survival rate and growth performance of cantang grouper (Epinephelinae). This study evaluates the effectiveness of a two-stage nursery rearing system at CV. Bali Akkua Marine, Bali, in enhancing production efficiency and economic feasibility. The results showed a consistently high survival rate of 95% across both phases. The reduction in stocking density in the second phase minimized stress and improved fish growth, while optimized water quality management, including filtration and flow-through systems, maintained stable environmental conditions. In addition, tailored feeding strategies incorporating vitamin C, probiotics, and Enrofloxacin 2S improved feed efficiency (FCR 1.3) and fish health. Economic analysis indicated that the system is highly feasible, with an R/C ratio of 3.48 and a break-even point far below actual production levels, demonstrating a high margin of safety. These findings highlight that the integration of optimized technical practices and efficient resource utilization can significantly enhance both production performance and economic sustainability in grouper nursery operations.

INTRODUCTION

The aquaculture industry has witnessed significant growth in recent decades, driven by increasing global demand for seafood (Aquaculture, 2021). Among the various species cultivated, the grouper (family: Serranidae), particularly the Cantang grouper (Epinephelinae), has gained attention due to its high market value, fast growth rates, and excellent meat quality (Henriksson et al., 2019). However, the cultivation of Cantang grouper faces several challenges, particularly in the early stages of life, where the successful seedling (or larvae) development is crucial to ensuring a steady supply of healthy juveniles for grow-out operations (Dwifajri, Tapilatu, Pranata, & Kusuma, 2022; Hidayani et al., 2022).

The ability to culture groupers effectively in controlled systems has become increasingly significant as consumer preferences shift toward seafood as a primary protein source (FAO, 2020). At CV. Bali Akkua Marine, an established aquaculture company in Bali, the optimization of grouper seedling techniques is essential to enhance production efficiency and ensure the sustainability of operations. This process involves refining various aspects of the hatchery and nursery systems, including water quality management, feeding strategies, and environmental conditions, to maximize survival rates and growth performance. In addition to biological performance, production efficiency in aquaculture is closely linked to economic viability, where improved survival rates and feed utilization can significantly reduce production costs and increase profitability.

Despite advancements in aquaculture technologies, significant challenges remain in the hatchery and early-life stages of grouper cultivation, particularly concerning seedling mortality, slow growth rates, and inconsistencies in product quality (Goçalo & Lopes, 2024; Vasbinder & Ainsworth, 2020). Moreover, many studies tend to focus primarily on technical performance, while limited attention is given to how these improvements translate into economic benefits at the farm level. Therefore, integrating technical optimization with economic evaluation is essential to ensure that aquaculture practices are not only biologically effective but also financially feasible.

This study aims to evaluate and optimize the existing techniques for grouper seedling production, focusing on best practices to improve survival rates, growth efficiency, and overall production outcomes at CV. Bali Akkua Marine. In addition, this study incorporates an economic analysis to assess the feasibility and profitability of the optimized nursery rearing system. By examining the technical and environmental factors that impact seedling development, this research seeks to provide practical recommendations for aquaculture practitioners, contributing to enhanced productivity in the Indonesian grouper farming sector. Moreover, the findings aim to support the broader goal of sustainable and efficient aquaculture practices that can meet the growing global demand for high-quality fish products.

METHOD

Location and Time

The research was conducted at CV. Bali Akkua Marine, Gerogak, Buleleng, Bali, Indonesia. The climate conditions are tropical, with an average temperature of 29°C, Type C rainfall (5 to 6 consecutive months of wet season), and humidity levels ranging from 75% to 95%. Data collection for this activity was carried out over a period of 5 months (August to December 2024).

Experimental design

The process of nursery rearing for the cantang grouper begins with tank preparation, selection and stocking of seeds, grading, feed management, water quality management, growth measurement, pest and disease control, harvesting, and packaging. There are four types of grouper maintenance tanks made of concrete, including: 3.3 x 3 x 1 m an indoor tank for grouper nursery; 2.7 x 1.3 x 1 m an outdoor tank for maintenance and nursery of grouper; 1.2 x 1.5 x 1 m a quarantine/isolation tank; and 10 x 3 x 1 m a natural feed (plankton and rotifer) tank. All tanks are equipped with inlet, outlet, and aeration channels. The inlet channel uses 1-inch diameter PVC pipes. The outlet channel uses 4-inch and 2-inch diameter PVC pipes.

The seawater source used in this research activity comes from the northern coast of Bali, approximately 240 meters from the research location. Seawater is collected using an 8-inch diameter PVC pipe that is buried in the sand, angled towards the sea. The end of the pipe is equipped with a suction filter and is directly connected to a 24 HP (Paard Kaard) electric pump with a power of 7.5 HP (Horse Power). The seawater is then stored in a PVC reservoir and allowed to settle for 24 hours. Water from the reservoir will then pass through two stages of filtration. The first filter uses a physical filter (sand filter) measuring 4 x 1.7 x 3.5 m, consisting of layers from bottom to top of river stones, gravel, charcoal packing, coir, mesh, and sand. The second filter is a biological filter measuring 2 x 1.7 x 3.5 m, equipped with bacteria and probiotics to improve water quality. The result from the second filtration will be directly distributed to each maintenance tank.

Concrete tank preparation

The preparation of tanks for cantang grouper seeds is carried out through several stages. Each concrete tank is cleaned using 100 ppm of chorine, followed by rinsing with freshwater. After a drying process of 72 hours under sunlight, the aeration system were installed. The aeration system used in the nursery rearing of cantang grouper comes from a 2 KVA supercharged blower, which distributes air through 1-inch PVC pipes to each aeration hose located in the maintenance tanks. In the tank measuring 3.3 x 3 x 1 m, 9 aeration points are used; in the tank measuring 2.7 x 1.3 x 1 m, 5 aeration points are used; in the tank measuring 1.2 x 1.5 x 1 m, 3 aeration points are used; and in the tank measuring 10 x 3 x 1 m, 18 aeration points are used. Each aeration point is installed at a height of 9 cm from the bottom of the tank, with a spacing of 30 to 40 cm between each aeration point. The filling of water in the maintenance tanks is done by adding filtered water stored in the reservoir, up to ¾ of the tank's volume.

Cantang grouper seed and feeding management

The cantang grouper seeds used are from the Brackish Water Aquaculture Seed Center (BPBAP) in Situbondo, with a size of 2.7 – 3 cm and a weight of approximately 1.5 – 2.5 grams. Visual observations and seed resilience tests are conducted. Visual observations include active movement of the seeds, uniformity in seed size, bright scale color, good response to feed, and the absence of physical defects were analyzez (Ybanez Jr. & Gonzales, 2023). The seeds were stocks in concrete tanks with 1 – 2 seed/liter of water and added with 3 ppm of Mb and antibiotics.

This study conducted in two phases of nursery rearing. The first phase was stock with 2 – 3 cm fry in 3.3 x 3 x 1 m of indoor tank with the stocking density of 20.000. In addition, the second phase was stock with 5 – 6 cm of fry in 2.7 x 1.3 x 1 m an outdoor tank with stocking density of 19.000. Feeding is conducted using the ad satiation method, providing 3 – 5% of the fish's body weight in four feedings time, specifically at 07:00, 11:00, 15:00, and 18:00 WIB. Cantang grouper seeds measuring 2.7 – 3 cm are fed with KAIO pellets of size 0, which are further ground using a blender. KAIO feed contains 51% protein, 8% fat, 3% fiber, 16% ash, 1.5% amino acids, 2.4% lysine, 1.5 – 4% calcium, and 0.5 – 2% phosphorus. For seeds measuring 4 – 6 cm, MEGAMI GR1 pellets are used, and for seeds larger than 7 cm, MEGAM GR2 pellets are used. MEGAMI GR1/2 pellets contain 48% protein, 2% fat, 2% fiber, 10% ash, 2.5% amino acids, 2.4% lysine, 3% calcium, and 1% phosphorus. A total of 1 gram of Vitamin C (Ascorbic acid), 1 gram of Inrofloxacin 2S, and 5 grams of Progol booster are dissolved in 100 mL of freshwater and mixed evenly into 4 kg of feed.

Water quality management

Water quality management during the nursery rearing process is carried out through daily siphoning of the tank's bottom. Siphoning is done carefully to avoid disturbing the settled waste. Waste and the layer of oil covering the surface of the maintenance tank, especially leftover uneaten feed, are removed using a scoop. Additionally, 30 – 50% of the tank's water volume is replaced weekly. Water quality parameters such as temperature, pH, and salinity are measured daily using DO meter TOX-901, Measurements of nitrite and ammonia were carried out before stocking and every 10 days.

Growth parameter

After the experiment, the individual weight and total weight of the cantang grouper were measured to calculate the growth paramters of the cantang grouper, including the equaction;

$$Suvivale\ rate = \frac{No - Na}{No} x\ 100\%$$

$$Weight\ gain\ rate\ (WGR) = \frac{mt - mo}{mo}\ x\ 100\%$$

$$Feed\ convertion\ rate\ (FCR) - \frac{G}{mt - mo}$$

Where: No represent the initial number of fish; Na is the number of fish deaths; mr and mo denote the final and intial fish body masses; t denotes the duration of the experiment, and G represents the total feed amount.

Economic Analysis

An economic analysis was conducted to evaluate the financial feasibility of the nursery rearing system. The analysis was performed using a cost–revenue approach based on production data obtained during the study period. The total production cost consisted of seed cost, feed cost, and operational costs, including labor, electricity, and supporting materials.

Total revenue was calculated based on the number of harvested fish multiplied by the prevailing market price per unit. The following economic indicators were calculated:

$$Total\ Revenue\ (TR) = Number\ of\ harvested\ fish\ X\ selling\ price\ per\ fish$$

$$Total\ Cost\ (TC) = Seed\ cost + Feed\ Cost + Operational\ Cost$$

$$Profit\ (\pi) = TR - TC$$

$$RC\ Ratio = \frac{TR}{TC}$$

To further assess economic feasibility, the break-even point (BEP) was calculated as follows:

$$BEP\ (Production) = \frac{TC}{Selling\ price\ per\ fish}$$

$$BEP\ (Price) = \frac{TC}{Total\ Production}$$

Economic values were estimated based on field data and prevailing market prices in Indonesia.

RESULT AND DISCUSSION

The grouper seedling process involves two stages to ensure optimal growth and enhance the survival rate of the fish Observations indicate that the two-stage seedling method implemented significantly enhances the growth rate of the grouper fish and their survival rate (Table 1). The survival rate (SR) for the grouper fish during both stages of the seedling process is 95%. A high SR is an indicator of success in fish farming and can be achieved through good management practices and optimal environmental conditions (Astari et al., 2024). Table 1 also shows that although the stocking density slightly decreased from Phase I to Phase II, the harvest quantity remained high with a consistent survival rate. The weight and length of the fish significantly increased in Phase II.

Table 1. Comparison Between Two Phases of Grouper Nursery Rearing

Description	Nursery rearing phases	
	I	II
Stocking Density	20.000	19.000
Harvest Quantity	19.000	18.050
SR (%)	95	95
Final weight (gr)	5	35
Final height (cm)	5 – 6	10 - 13
Culture periode (days)	45	40
FCR	1.3	1.3

The decrease in stocking density from Phase I to Phase II can help reduce stress on the fish, contributing to better growth and overall fish health. According to research by (Astari, Budiardi, Ismi, Effendi, & Hadiroseyani, 2023), lower densities can enhance the quality of life for fish and reduce competition for resources. The harvest quantities in Seedling 1 and Seedling 2 indicate an increase in the weight and length of the fish.

The significant increase in final weight from Phase I to Phase II indicates that the applied seedling techniques successfully enhanced fish growth. The addition of boosters such as vitamin C, progol, and Enrofloxacin 2S in this study has proven effective in improving the growth and survival rate (SR) of grouper fish (Table 1). The production of dusky grouper in Brazil, with an average size of 2 to 3 cm, takes approximately 60 to 180 days to grow to sizes of 5 to 10 cm (Ehlers et al., 2025). Vitamin C helps prevent stress in fish, leading to longer survival(Cai et al., 2022). It influences growth, antioxidant status, and serum immune parameters in grouper fish (Ebi et al., 2025).

Progol is an all-purpose, organic, thermo-reactive binder that is stable at room temperatures and therefore will mix well with other feed ingredients. Once the feed mix is exposed to moisture and heat in the conditioner, this feed binder binds other feed ingredients. It enhances pelleting capacity and reduces energy consumption at the feed mills. Morover, Enrofloxacin is an antibiotic used to control bacterial infections in fish. In grouper farming, the use of Enrofloxacin 2S can help reduce the incidence of diseases caused by pathogenic bacteria, thereby improving fish health. By controlling infections, Enrofloxacin can enhance the survival rate of grouper fish. This is particularly important during the seedling phase, where fish are vulnerable to various diseases (Milijasevic, Veskovic-Moracanin, Babic Milijasevic, Petrovic, & Nastasijevic, 2024).

The seedling activities for grouper fish utilize rectangular concrete tanks. Concrete tanks help maintain a more stable water temperature compared to earthen ponds or floating net cages (KJA), which can be affected by weather conditions. According to the (Haini & Sumsanto, 2024), the smooth surfaces of concrete tanks reduce the likelihood of algae and pathogen growth.

Water is a crucial factor in aquaculture activities; therefore, the water used must be suitable for the natural habitat of the fish being cultivated. To maintain water quality during the practice, two methods are employed: the use of a flow-through system, which ensures that the water is continuously renewed and that waste settling at the bottom of the tank is naturally flushed out. The second method is flushing, which is performed to prevent the accumulation of bacteria from leftover feed and fish metabolic waste that settles at the bottom of the tank. Additionally, each concrete tank in this studied was marked with horizontal and diagonal yellow lines on the walls (Figure 1). This facilitates water quality management and reduces the risk of contamination.

Figure 1. The concrete tank for cantang grouper seedling process in CV. Bali Akkua Marine

Table 2 shows the water quality parameters measured during the seedling rearing period of the cantang grouper. The analyzed parameters include temperature, pH, salinity, nitrite, and ammonia, with average values taken from several sampling periods. The average water temperature recorded during the observation period ranged from 29°C to 30°C. This value falls within the standard range set by the Indonesian National Standard (SNI), which is between 28°C and 32°C. Optimal temperature is crucial for the growth and health of fish, as it can affect their metabolism and physiological activities. A stable and appropriate temperature can enhance the growth rate and survival of grouper fish (Das et al., 2021).

Table 2. Water Quality

Paramter	Sampling periode average	Standard (SNI)

	I	II	III	IV	
Temperature (°C)	30	29	29	29	28 - 32
pH	8.14	8	7,96	8	7.5 – 8.5
Salinity (ppt)	32	32	32	32	30 – 32
Nitrit (mg/L)	0.01	0.001	0.001	0.001	< 1
Amonia (mg/)	0	0	0	0	< 0.01

Stable pH and salinity in grouper aquaculture can significantly enhance feed efficiency and fish growth (Wijayanto, Nugroho, Kurohman, & Nursanto, 2023). Fish living in optimal conditions tend to grow faster. Rapid growth is directly related to feed efficiency, where fish can convert feed into body mass more effectively. (Haini & Sumsanto, 2024). In addition to biological performance, an economic analysis was conducted to evaluate the feasibility of the nursery rearing system (Table 3). The total production cost was estimated at IDR 41,425,600, consisting of seed cost, feed cost, and operational expenses. Meanwhile, total revenue reached IDR 144,400,000, resulting in a net profit of IDR 102,974,400 per production cycle.

Table 3. Economic Analysis of Cantang Grouper Nursery Rearing

Parameter	Unit	Value
Initial stocking	fish	20,000
Harvest quantity	fish	18,050
Survival rate	%	95
Final biomass	kg	631.75
Feed conversion ratio (FCR)	-	1.3
Total feed used	kg	821.28
Feed cost	IDR	16,425,600
Seed cost	IDR	20,000,000
Operational cost	IDR	5,000,000
Total cost	IDR	41,425,600
Selling price	IDR/fish	8,000
Total revenue	IDR	144,400,000
Net profit	IDR	102,974,400
R/C ratio	-	3.48
Cost per fish	IDR/fish	2,295
BEP (production)	fish	5,178
BEP (price)	IDR/fish	2,295

Furthermore, the economic performance observed in this study is consistent with previous findings in grouper aquaculture, which emphasize the strong relationship between technical efficiency and financial outcomes. Astari et al. (2024) reported that hatchery-scale grouper production systems can achieve profitable operations when survival rates are maintained above 80% and feed efficiency is optimized. The higher survival rate obtained in this study (95%) indicates a more efficient production system, contributing to increased revenue and reduced financial risk.

The R/C ratio was calculated at 3.48, indicating that the nursery operation is highly profitable, where every IDR 1 invested generates IDR 3.48 in return. The cost per fish was estimated at IDR 2,295, which is significantly lower than the selling price of IDR 8,000 per fish, demonstrating a high profit margin.

The break-even point (BEP) analysis further supports the economic feasibility of the system. The BEP production was calculated at 5,178 fish, which is considerably lower than the actual production of 18,050 fish. Similarly, the BEP price was estimated at IDR 2,295 per fish, far below the market price. This indicates a strong margin of safety and resilience against potential market fluctuations. The high economic performance is closely linked to the technical

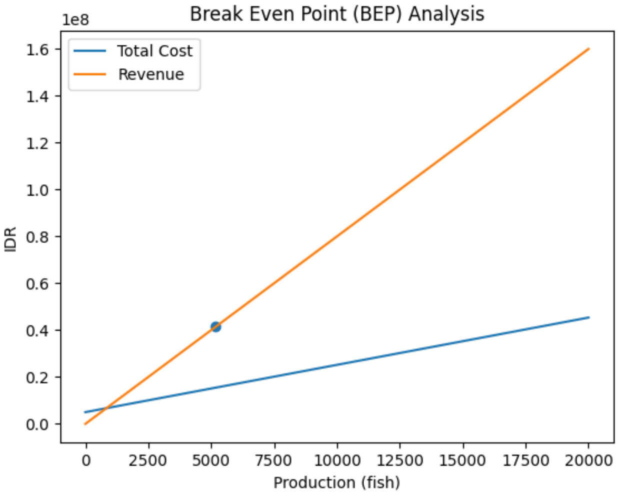

Figure 2. Break Even Point

efficiency achieved in this study. The high survival rate (95%) increases the number of marketable fish, while the low feed conversion ratio (FCR = 1.3) reduces feed costs, which are the largest component of operational expenses in aquaculture. Therefore, the optimization of nursery rearing techniques not only improves biological performance but also significantly enhances economic profitability.

In terms of feed efficiency, the FCR value of 1.3 obtained in this study is relatively low compared to several reported nursery systems, where FCR values typically range from 1.5 to 2.0 depending on feeding strategies and management practices. Lower FCR values directly reduce feed costs, which represent the largest proportion of operational expenses in aquaculture systems. This supports findings by Wijayanto et al. (2023), who highlighted that improved feed utilization significantly enhances profitability in grouper farming.

The R/C ratio of 3.48 obtained in this study is higher than those reported in several small- to medium-scale aquaculture operations, where R/C values generally range between 1.5 and 2.5. This indicates that the optimized two-stage nursery system applied in this study provides a higher economic return and greater operational efficiency. Additionally, the relatively low break-even point further confirms the financial resilience of the system, making it more adaptable to market fluctuations.

These results demonstrate that integrating optimized technical practices with efficient resource utilization not only improves biological performance but also significantly strengthens the economic sustainability of grouper nursery operations. Therefore, the implementation of such optimized systems can be recommended as a viable strategy for enhancing both productivity and profitability in aquaculture enterprises.

CONCLUSION

The optimized two-stage nursery rearing system significantly improved the growth performance and survival rate of cantang grouper, achieving a consistent survival rate of 95%. Efficient feeding strategies and proper water quality management contributed to enhanced fish growth and health. Economically, the system proved highly feasible, with an R/C ratio of 3.48 and a break-even point far below actual production levels. The high survival rate and low FCR (1.3) played a key role in reducing costs and increasing profitability. Overall, the integration of technical optimization and efficient resource use enhances both production performance and economic sustainability in grouper nursery operations.

REFERENCES

Anton-p, D., Trofin, F., Chis, A., Sur, L. M., Streang, V., Mîndru, D. E., … Vulturar, R. (2025). Current

Insights into Nutritional Management of Phenylketonuria : An Update for Children and Adolescents, 1–30.

Aquaculture, E. T. D. E. L. (2021). FAO Yearbook. Fishery and Aquaculture Statistics 2019/FAO annuaire. Statistiques des pêches et de l'aquaculture 2019. https://doi.org/10.4060/cb7874t

Astari, B., Budiardi, T., Ismi, S., Effendi, I., & Hadiroseyani, Y. (2023). Increasing The Stocking Density of Grouper Nurseries for Aquabusiness Efficiency in Recirculating Aquaculture System (RAS) with Bioremediation. *HAYATI Journal of Biosciences*, *30*(2), 198–206. https://doi.org/10.4308/hjb.30.2.198-206

Astari, B., Effendi, I., Budiardi, T., Hadiroseyani, Y., Diatin, I., & Ismi, S. (2024). Financial analysis business of cantang (*Epinephelus fuscoguttatus × E. lanceolatus*) and cantik (E. fuscoguttatus × E. polyphekadion) hybrid groupers in hatcheries. *Aquaculture Reports*, *39*(March), 102364. https://doi.org/10.1016/j.aqrep.2024.102364

Cai, Q., Wu, X., Gatlin, D. M., Zhang, L., Zhai, H., Zhou, Z., … Irm, M. (2022). Dietary vitamin C affects growth, antioxidant status and serum immune parameter of juvenile hybrid grouper (*Epinephelus fuscoguttatus ♀× Epinephelus lanceolatus ♂*) fed low fishmeal diets. *Aquaculture*, *556*, 738285. https://doi.org/https://doi.org/10.1016/j.aquaculture.2022.738285

Das, S. K., Xiang, T. W., Noor, N. M., De, M., Mazumder, S. K., & Goutham-Bharathi, M. P. (2021). Temperature physiology in grouper (Epinephelinae: Serranidae) aquaculture: A brief review. *Aquaculture Reports*, *20*, 100682. https://doi.org/10.1016/j.aqrep.2021.100682

Dwifajri, S., Tapilatu, R. F., Pranata, B., & Kusuma, A. B. (2022). Molecular phylogeny of grouper of Epinephelus genus in Jayapura, Papua, Indonesia inferred from Cytochrome Oxidase I (COI) gene. *Biodiversitas*, *23*(3), 1449–1456. https://doi.org/10.13057/biodiv/d230332

Ebi, I., Shapawi, R., Lim, L. S., Yong, A. S. K., Mazlan, N., Shah, M. D., … Jaziri, A. A. (2025). Effects of dietary vitamins C and E on growth performance, hematological and biochemical parameters, skeletal abnormalities, and disease resistance against *V. harveyi* of hybrid groupers (*Epinephelus fuscoguttatus♀ × Epinephelus lanceolatus♂*). *Aquaculture International*, *33*(2). https://doi.org/10.1007/s10499-025-01832-0

Ehlers, C., Caio, K., Perazza, A., Hallerman, E., Sant, M., Wagner, A., & Hilsdorf, S. (2025). Evaluation of a pilot reintroduction program for dusky grouper (*Epinephelus marginatus*) juveniles in inshore marine areas off the southeast Brazilian coast. *Discover Conservation*. https://doi.org/10.1007/s44353-025-00022-6

Essamlali, I., Nhaila, H., & El Khaili, M. (2024). Advances in machine learning and IoT for water quality monitoring: A comprehensive review. *Heliyon*, *10*(6), e27920. https://doi.org/10.1016/j.heliyon.2024.e27920

FAO. (2020). The State of World Fisheries and Aquaculture 2020. Inform (Vol. 32). *Sustainability in action*. Rome. https://doi.org/10.4060/ca9229en

Glamuzina, B., & Rimmer, M. A. (2022). Grouper Aquaculture World Status and Perspectives. *Biology and Ecology of Groupers*, (March 2022), 166–190. https://doi.org/10.1201/b20814-9

Goçalo, C. G., & Lopes, R. M. (2024). Movement Behavior of the Dusky Grouper *Epinephelus marginatus* (Lowe, 1834) in Early Life Stages. *Journal of Marine Science and Engineering*, *12*(7). https://doi.org/10.3390/jmse12071068

Haini, N., & Sumsanto, M. (2024). Study Of Hybrid Cantang Grouper Breeding Techniques (*Epinephelus Fuscoguttatus X Epinephelus Lanceolatus*) At The Brackish Water Fisheries Cultivation Center Situbondo , East Java, *4*(3), 142–157.

Henriksson, P. J. G., Banks, L. K., Suri, S. K., Pratiwi, T. Y., Fatan, N. A., & Troell, M. (2019). Indonesian aquaculture futures-identifying interventions for reducing environmental impacts. *Environmental Research Letters*, *14*(12). https://doi.org/10.1088/1748-9326/ab4b79

Hidayani, A. A., Malina, A. C., Tasakka, Umar, W., Alam, M. J., Neogi, A. K., & Andriyono, S. (2022). Low Genetic Diversity Study on Leopard Coral Grouper Plectropomus leopardus (Perciformes: Serranidae) from Sulawesi, Indonesia. *Jurnal Ilmiah Perikanan Dan Kelautan*, *14 No 2*(2), 349–359. https://doi.org/10.20473/jipk.v14i2.32815

Ismi, S., Astari, B., & Mastuti, I. (2023). Dynamics of water quality in grouper nurseries with flow through, recirculation and bioremediation systems. *IOP Conference Series: Earth and Environmental Science*, *1273*(1). https://doi.org/10.1088/1755-1315/1273/1/012038

Kandathil Radhakrishnan, D., AkbarAli, I., Schmidt, B. V, John, E. M., Sivanpillai, S., & Thazhakot Vasunambesan, S. (2020). Improvement of nutritional quality of live feed for aquaculture: An overview. *Aquaculture Research*, *51*(1), 1–17. https://doi.org/https://doi.org/10.1111/are.14357

Milijasevic, M., Veskovic-Moracanin, S., Babic Milijasevic, J., Petrovic, J., & Nastasijevic, I. (2024). Antimicrobial Resistance in Aquaculture: Risk Mitigation within the One Health Context. *Foods*, *13*(15). https://doi.org/10.3390/foods13152448

Qu, Y., Yin, Z., Fan, X., Hu, H., Cui, H., Cui, Z., … Li, H. (2024). A comparative analysis of growth and nutritional quality of the hybrid grouper (*Epinephelus fuscoguttatus ♀× Epinephelus lanceolatus ♂*) in a simulated pond system and a recirculating aquaculture system. *Frontiers in Marine Science*, *11*(June), 1–11. https://doi.org/10.3389/fmars.2024.1378735

Ranjan, R., Megarajan, S., Xavier, B., Bhaskaran Pillai, S., Bathina, C., Avadhanula, R. K., … Gopalakrishnan, A. (2022). Enhanced larval survival in orange-spotted grouper (*Epinephelus coioides*) using optimized feeding regime. *Aquaculture Research*, *53*(9), 3430–3440. https://doi.org/https://doi.org/10.1111/are.15850

Vasbinder, K., & Ainsworth, C. (2020). Early life history growth in fish reflects consumption-mortality tradeoffs. *Fisheries Research*, *227*(February), 105538. https://doi.org/10.1016/j.fishres.2020.105538

Vij, S., Lee, Y. S., Purushothaman, K., & Jerry, D. (2024). Challenges in Singapore Aquaculture and Possible Solutions. *Aquaculture Journal*, *4*, 316–323.

Wijayanto, D., Nugroho, R. A., Kurohman, F., & Nursanto, D. B. (2023). The effect of salinity on the growth, survival and profitability of TGGG hybrid grouper culture (♀ *tiger grouper × ♂giant grouper*). *AACL Bioflux*, *16*(1), 3357–3365.

Ybanez Jr., C., & Gonzales, R. (2023). Challenges and Progress of Grouper Aquaculture in Asia: A Review. *Davao Research Journal*, *14*(2), 6–29. https://doi.org/10.59120/drj.v14i2.109