e-issn: 2716-4608
p-issn: 2655-366X

MANAGING CANNIBALISM AND IMPROVING LARVAL SURVIVAL IN BARRAMUNDI HATCHERY

Indra Lesmana[1,2*], Irwan Effendi[3], Indra Suharman[2], Iskandar Putra[2], Abigael Ruthmawati[2], Yofi Devara Andesca[2]
[1]Student of Doctoral Program in Marine Sciences, Postgraduate, Universitas Riau, Pekanbaru, 28293 Indonesia
[2]Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Riau, Pekanbaru, 28293 Indonesia
[3]Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau, Pekanbaru, 28293 Indonesia
*indra.lesmana@student.unri.ac.id

ABSTRACT

Barramundi (*Lates calcarifer*) are economically valuable and usually cultivated in tropical marine hatcheries. Their fertilization and hatching rates are generally high, but poor survivorship of larvae due to cannibalism and cohort mismanagement remains a problem. In this study, we sought to address field-based techniques for controlling cannibalism and augmenting larval survival in large-scale hatcheries at Balai Besar Perikanan Budidaya Laut (BBPBL), Lampung, Indonesia. A 30-day rearing cycle was completed through descriptive observation methods focused on reproduction, and growth monitoring was performed concerning feeder grade improvement. The recorded data indicated a fertilization rate of 86% alongside an impressive hatching rate of 96%. However, the survival rate dropped to 52%, primarily due to cannibalism. Considerable size disparity among cohorts, lack of grading during asynchronous growth periods, and stunted development seem to drive cannibalism under these conditions. Increasing the frequency or decreasing the size gap between assessments has proven effective in enhancing survival levels alongside better feeding synchronization, water quality management, and reduced particulate matter concentration in water tanks. These outcomes will assist tropical aquaculture systems with long-term sustainable frameworks while providing actionable insight to hatchery managers without further testing.

Keywords: Cannibalism, Hatchery Management, Tropical Aquaculture, *Lates calcarifer*.

1. INTRODUCTION

The global aquaculture sector, especially for high-value species such as barramundi (*Lates calcarifer*), is expanding rapidly due to its profitability and adaptability to various salinities. In Indonesia, regions like Balai Besar Perikanan Budidaya Laut (BBPBL) in Lampung are crucial in barramundi seed production. However, considerable challenges exist during the early-stage larval rearing period, such as high mortality due to cannibalism, which is worsened by high stocking densities and asynchronous growth. Studies have shown barramundi cannibalism is size-dependent, with a 50% size difference threshold for intracohort cannibalism to occur, along with the influence of cannibalistic polyphenism where experienced cannibals can exceed the expected prey size they feed on[1]. Palm oil-based micro diets have demonstrated improved cost-effective growth, supplementing fish oil[2] to counter these concerns. Moreover, incorporating processed peanut meals and tuna hydrolysate

Received: 10 June 2025
Accepted: 11 July 2025

as partial substitutes for fishmeal has been studied. Although it contains harmful levels that impair health and growth, optimization is required for formulations[3-4].

Furthermore, other aspects also complicate production, such as vibriosis, regarded as one of the significant economic losses in hatcheries, and the grow-out phases remain crucial throughout disease management, emphasizing its significance in Malaysia[5]. In the case of barramundi, nutrition requirements, especially for essential fatty acids, are important because shortages can severely impair growth and health, requiring meticulous dietary scheming[6]. There is also skepticism about the overarching sustainability considerations of aquaculture, namely skepticism about whether aquaculture can fulfill global fish demand without undermining wild fish stocks[7]. Thus, it is critical to improve cannibalism management, feeding, and disease control to increase barramundi aquaculture's sustainability and economic efficiency in tropical hatchery systems such as Indonesia.

The low survival rate of barramundi larvae in hatchery systems, even though fertilization and hatching rates are high, is due to cannibalism, poor nutrition, and microbial interactions. Cannibalism becomes a significant problem with elevated size differences between larvae caused by feeding inconsistency or environmental factors like water quality[8]. Deficiency in essential fatty acids (EFAs) within nutrition sources has far-reaching impacts on growth and development among juvenile barramundi, particularly in preformed long-chain polyunsaturated fatty acids (LC-PUFA), resulting in stunted growth coupled with increased deformities[6]. This indicates the importance of diet formulation for specific life stages that encourage normal physiological function instead of stunted growth and abnormal development. They also illustrate the lagging understanding concerning live feeds' nutritional value and larvae developmental stages[9].

In addition to gaps surrounding nutritional inputs from live feeds, hatchery systems also focus on the balanced microbial community needed for optimal larval viability. Noxious interactions between larvae and microbes have been demonstrated to increase mortality rates, and controlling these populations is crucial for improved physiology[10]. Lastly, the complex mechanisms alongside edge-increasing deficiencies extend beyond a better understanding of feed utilization during certain growth benchmarks[11]. A comprehensive grasp of feeding ecology is needed to optimize feeding strategies to enhance the survival rate of larvae, which adds to this complexity. Meeting these challenges entails a comprehensive assessment of larval-rearing strategy with an emphasis on critical control points that enhance cannibalism and impact larval viability, accompanied by devising an overall plan to overcome these issues in hatchery settings[12-13].

Management practices for cannibalism and enhancement of larval survival in the hatchery production system of *Lates calcarifer* at BBPBL Lampung could use a more integrated approach based on various research findings in aquaculture. One of the significant factors causing high mortality rates within fish hatcheries, cannibalism, can be controlled by knowing its causes, such as stress and environmental conditions, whereby recreating the environment-rearing conditions helps alleviate stress[14]. Fish welfare shows that excessively high stocking density and very low stocking density harm fish health and growth; thus, balancing both extremes is necessary. In this regard, water quality, nutrition measures, and welfare indicators would determine optimal stocking densities[15-16]. Cannibalism and growth rate are also significantly influenced by feeding regimes. It has been established that tryptophan supplementation reduces cannibalism while promoting growth. Such dietary strategies should, therefore, be considered for barramundi[17]. Moreover, copepods have been shown to support the survival and growth of larvae in some fish species. Thus, their utilization can improve barramundi hatcheries' larval viability[18]. Segmenting by size through periodic grading can help prevent larger individuals from feeding on smaller individuals, as supported by size-dependent cannibalism studies in barramundi, which underscore the importance of managing size differences to minimize cannibalism[1]. By applying these combined strategies of enhanced feeding, live feed incorporation, and density management coupled with controlled cannibalism and size management, hatcheries can bolster the survival rates of larvae and reduce cannibalistic mortality, thus improving the reproducibility and consistency of barramundi seed production throughout Southeast Asia[1,14-15,16,18].

Research concerning cannibalism within fish species, notably *Lates calcarifer*, showcases multifaceted biological and ecological intricacies pertinent to aquaculture management. Size-dependent cannibalism exists in barramundi, where a 50% size difference is the baseline required for predation to ensue. Such behavior is more common during early development due to allometric growth of the mouth deepening relative to body depth[1]. This form of size-dependent cannibalism may exert selective pressure on offspring size, leading to evolutionary adaptations in strategies that utilize refuge from predation[19]. South East Asian aquaculture regions demonstrate the importance of these concepts for devising sound management frameworks. Reductions in size disparity among cohorts may be achieved through integrated management techniques like synchronized feeding followed by routine larval grading, though proven field data remains limited[1]. The impact of cannibalism reaches beyond individual levels and drives community interactions, possibly stabilizing population structures via trophic cascades and shifting biomass distribution across life stages[20-21]. Its role can also intersect with other ecological domains, such as disease dynamics, where it tends to lower prevalence rates by removing infected individuals[22]. The relationship of cannibalism to environmental factors, including temperature and the presence of suitable prey, adds complexity concerning its effects on the survival and growth of larvae, as examined in studies on tuna larvae[23]. This reinforces the need for more tropical marine hatchery field-based studies to establish best management practices for barramundi culture cannibalism-controlled breeding, which is required to advance aquaculture technology in Indonesia.

This research provides one of the first field-based assessments of cannibalism management in sociable barramundi fish (*Lates calcarifer*) hatcheries within a tropical, production-scale framework. Unlike other studies concentrating on controlled environment experiments, this study reflects the comprehensive nature of actual hatchery operations at BBPBL Lampung, incorporating observational data on larval survival alongside environmental and operational parameters. The high hatching rate (96%) and moderate survival rate (52%) indicate that well-defined strategies should be implemented during critical early interventions. By studying how routine practices such as water quality maintenance and control of larval numbers and early grading work to reduce cannibalism, this research advances direct industry relevance strategically aligned with commercialization. These outcomes address the disconnect between scientific inquiry and practical implementation and provide evidence to design context-adapted best management practices (BMPs) for tropical marine hatcheries. Therefore, this study will likely impact policies aimed at southern Southeast Asia's sustainable intensification of barramundi aquaculture through enhanced efficiency in existing frameworks.

2. RESEARCH METHOD

Time and Place

This study was conducted at Balai Besar Perikanan Budidaya Laut (BBPBL) in Hanura Village, Pesawaran Regency, Lampung Province, Indonesia. The barramundi hatchery is situated in and under tropical coastal environmental conditions. Therefore, it specializes in producing barramundi seed. The field data collection took place over five weeks from January 9 to February 12, 2024, during routine larval rearing and seed production at the hatchery, where activities included harvesting larvae.

Method

The study used a participatory field-based approach to track and observe certain behaviors to assess how the cannibalism reduction strategies worked. It specifically looked at the survival rates within some hatcheries. The focus was on key steps: broodstock conditioning, spawning, larval nursery management, grading, feeding, and general environmental control.

Procedures

The described hatchery procedure started with the natural spawning of selected broodstock in circular fiberglass tanks, from which eggs were collected using specially designed egg collection devices connected to outlet pipes. Fertilized eggs were incubated within aerated hatching tanks, and post-hatch larvae were relocated to larval-rearing tanks. They remained in the larval rearing tank for 30 days, transitioning from live feeds, including *Chlorella* sp, rotifers, and Artemia nauplii, to formulated microdiets. To reduce cannibalistic behaviors amongst the larvae, periodic grading was done to separate them by size. Water temperature (27–30 °C), salinity (30–33 ppt), pH (7.0–8.2), and dissolved oxygen (>5 ppm) were monitored daily as well.

Data Collection Techniques

Primary data were obtained through direct observation, measurement, and documentation of production performance metrics, including: Fertilization Rate (FR): calculated based on the proportion of fertilized eggs. Hatching Rate (HR): measured as the percentage of hatched larvae from fertilized eggs.

Survival Rate (SR): calculated at the end of the 30-day larval period as the percentage of surviving larvae relative to the initial stocked number. Additional data were collected through interviews with hatchery technicians and supervisors and reviews of internal production records and standard operating procedures.

Data Analysis

Descriptive statistical techniques were utilized to measure and analyze the FR, HR, and SR and assess trends in larvae's survival rates based on operational practices like grading frequency, feeding regimen, and water quality control. The qualitative components of behavior exhibited by the larvae, particularly manifestations of cannibalism, were noted and compared with environmental conditions and management actions

3. RESULT AND DISCUSSION

The spawning and hatching rates for *Lates calcarifer* at BBPBL Lampung were 86% and 96%, respectively (Figure 1). Despite these figures being markedly high, larvae' average survival rate (SR) was considerably lower, at only 52% after the 30-day larval stage. The conspicuous disparity between the hatching rate and survival rate indicates substantial post-hatch mortality, which is probably caused by intra-specific cannibalism combined with the infrequent grading of larvae and nutritional management problems.

Larval growth trends were tracked over four weeks and showed a steady increase in total length, from an average of 3.5 mm in week one to 11.4 mm by week four (Figure 2). Despite uniform water quality conditions and live feed supplementation, size variability among larvae was evident, highlighting asynchronous growth patterns a known precursor to cannibalistic behavior.

Juvenile growth performance during the subsequent four weeks post-larval stage indicated continued increases in both length and body weight (Figure 3). Length rose from 1.4 cm in week five to 4.5 cm by week eight, while weight increased from 0.2 g to 2.8 g in the same period, indicating satisfactory somatic development under hatchery conditions.

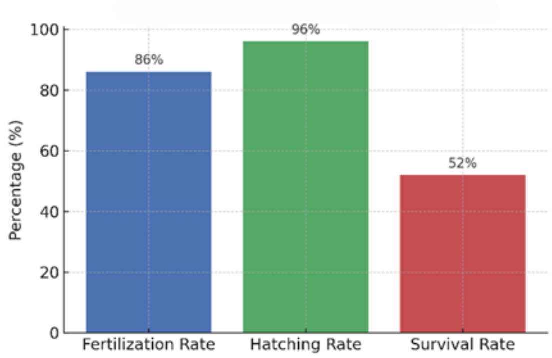

Figure 1. Reproductive performance metrics

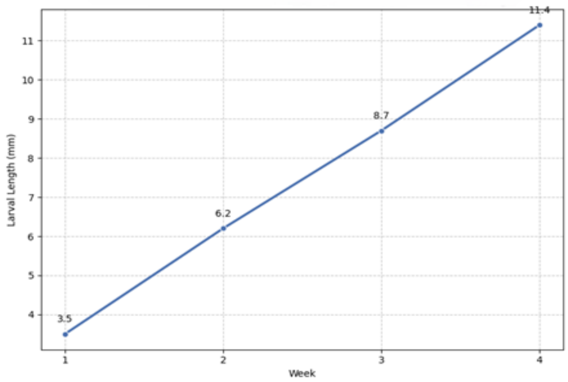

Figure 2. Larval growth trend of *Lates calcarifer* at BBPBPL Lampung

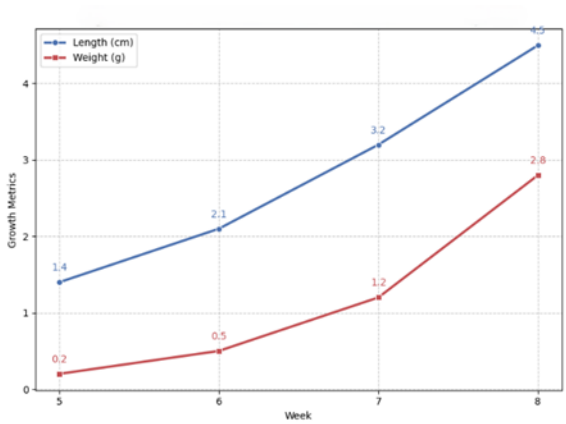

Figure 3. Juvenile Growth Trend of *Lates calcarifer* at BBPBL Lampung

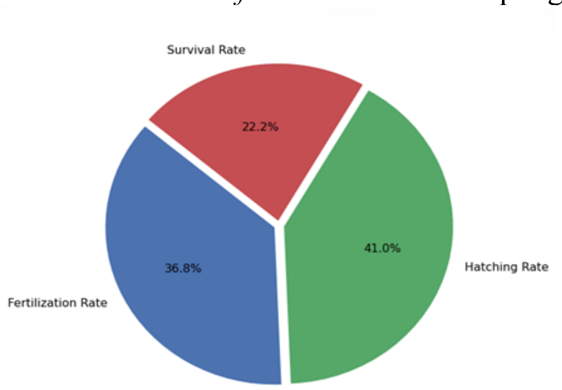

Figure 4. Composition of reproductive success metrics of *Lates calcarifer*

The reproductive performance of *Lates calcarifer* at BBPBL Lampung, with its high fertilization and hatching rates, is a marker for the success of controlled tropical hatchery systems. This situates it within the global context of aquaculture, which emphasizes early-stage management in optimally engineered culture systems for enhanced overall productivity[24]. The striking decline in post-hatch survival to 52% showcases a grave risk in larval rearing, which is not only limiting for barramundi but is characteristic across many marine organisms. Intra-cohort cannibalism due to asynchronous growth and competition during feeding furthers this problem in tunas, where selective predation/ cannibalism poses severe threats to larvae' survival[23].

The observed range of 3.5 mm to 11.4 mm in larval size over a month suggests generous average conditions coupled with the potential for higher antagonistic force if greater size stratification is not enabled promptly through division[8]. Similar observations have been reported where active removal of smaller individuals after reaching a specific density leads to more uniformity within the cohort while simultaneously reducing mortality[11]. This reasoning aligns with GSP (Growth-Survival Paradigm), which associates faster growth rates with improved chances of survivorship, although the two are often intertwined with numerous competing internal and external influences[13].

Additionally, the need for well-defined management controls during the vulnerable larval stage is highlighted by global aquaculture conferences[24], which discussed reducing environmental and sustainability impacts across the entire aquaculture industry. Thus, barramundi culture at the BBPBL barramundi hatchery requires not only creating favorable conditions for early growth but also overcoming the considerable problems of larval mortality to improve taming techniques and make barramundi aquaculture more productive[24-25].

The research concerning the larval rearing of *Lates calcarifer* contributes to aquaculture's theoretical and practical dimensions related to issues like heterogeneous growth patterns and cannibalism at more advanced levels. Theoretical insight supports the proposed theory that within a cohort of fish larvae, heterogeneity in growth can foster cannibalism, which is a characteristic behavior among many carnivorous fishes. This is supported by evidence showing that dominance in size, coupled with early elevation in growth, comes with behavioral aggression under weak control systems[1,14]. Paradoxical survival rates in proportion to diminutive size prevalence corroborate ecological assumptions on the existence of dominion-driven aggression[13].

From a pragmatic standpoint, this underscores the need for systematic early and continuous size grading during hatching, an intervention often unappreciated due to scarce resources primarily facing developing economies. By tracking growth dynamics and correlating them with survival rates, the study empirically validated the set-point-based design for grading and feeding aimed at minimizing cannibalism through controlled surge feeding[1,14]. Basic maintenance practices, such as optimal feed delivery and water quality maintenance, are also emphasized as primary foundations for effective larval management. This strengthens operational standards important for hatchery technicians and aquaculture managers operating in tropical climates vulnerable to unanticipated environmental shifts[14]. The need for effective measures in aquaculture environments remains, as models and empirical data underscoring the influence of size-selective predation and cannibalism on larval survival corroborate these findings[23,26]. This study provides an integrated framework for understanding and managing various factors involved in aquaculture larval rearing to enhance survival while minimizing cannibalism in *Lates calcarifer* and related species.

The investigation of behavior and survival in larvae faces limitations noted in the more general research on the ecology and development of larvae. One limitation would be observational data collected during a single production round; seasonal or inter-cohort variations within a cycle could be missed. This is an issue with many larval studies, as there is a need for year-round research to fully understand the ecological impacts on larvae during different seasons and environmental conditions[27]. The lack of control groups and absence of statistical tests also restrict the study's ability to determine causation, just as noted in studies on larval dispersal, where often consideration of environmental interactions makes it challenging to adopt simple experimental setups[28].

Moreover, visual assessments will track behavior quicker than monitoring systems like underwater video systems, thus slowing down detailed behavioral observation. This gap is critical as specific environmental conditions control some retention and migration behaviors and involve subtle environmental cues combined with movements from the larvae[29-30]. Not evaluating the physiological and stress biomarkers of the subjects is an additional drawback, as these factors have a bearing on health and development in larval fish, much like earlier studies examining physiologic stressors that influence growth and survivorship[31-32].

Furthermore, although the collection of water samples was conducted within acceptable ranges for microbial parameters, the study did not aim to fill gaps related to microbes or nutrition, which are key determinants of resilience among larvae, underscoring their importance in grasping concepts relating to larval development in diverse settings[33-34]. These limitations emphasize the need for more focused and systematic controlled experimental validation following observations made during the trends and integrating other systems, such as physiological and behavioral, alongside environmental data in a holistic understanding framework on larval ecology[11,35].

Further studies on cannibalism and larval mortality in *Lates calcarifer* hatcheries need to take a more experimental approach to determine the root causal mechanisms of these phenomena. Examinations involving manipulating critical factors such as stocking density, grading intervals, light regimes, and even nutrient composition warrant conducting them under controlled conditions to evaluate their interplay on larvae's survival and behavior.

The part of cannibalism as a selective mechanism acting upon size suggests that larger offspring are likely to be size refuges, which may or may not be determined by these factors[19]. Also, acts of aggression and dominance that can clarify the dynamics concerning cannibalism could be monitored with greater precision by employing time-lapse videography coupled with AI movement tracking technology[23]. Information concerning sublethal stress, especially from physiologic perspectives such as cortisol concentrations or gut microbiota profiles linked to behavioral outcomes[36], is equally crucial in understanding juveniles' biochemical and physiological responses toward environmental or nutritional stressors. In-depth comparative research within varied hatchery systems alongside different surrounding contexts would enrich knowledge about the scope of the findings while pinpointing optimal settings tailored for specific situations[37].

In addition, creating feed formulations balanced with anti-aggression compounds or functional additives like L-tryptophan may help mitigate cannibalism nutritionally, as it has been proposed that cannibalism may serve a stabilizing or destabilizing function in population dynamics[38]. For now, tackling the issue of cannibalism in aquaculture to enhance larval survival calls for more sophisticated combinations of controlled experimentation, continuous observation systems with refined technologies, and comparative research.

The implications of the study's results regarding larval survival enhancement and cannibalism reduction in barramundi hatcheries resonate profoundly from a social and ethical perspective. Increasing the efficiency of seed production via enhanced practices supported by research impacts food security and rural livelihoods, and primarily benefits developing countries like Indonesia. This social improvement aids conservation efforts as it lessens the dependence on wild seed collection, which helps conserve natural fish populations[14,39]. From an ethical standpoint, the international principles of welfare in aquaculture are respected with non-invasive measures such as timely grading and improved feeding that sharply reduce delay-caused cannibalism.

Such measures respect the fish's behavioral welfare while reducing suffering through gentle means rather than aggressively hormonal or pharmacological techniques[14,40]. As with all sectors, increasing adoption of digital technologies necessitates explanation-based monitoring and management; thus, a better oversight gap must be provided for farmers outside aquaculture systems than currently offered. The attainment of these technologies must be guaranteed so that real-time data applications can foster equity among farmers, promoting social justice and ethical responsibilities in aquaculture[41-42]. In addition, thoughtfully applying social factors while developing aquaculture is imperative to address inequalities and enhance human well-being. This concerns the participation of various groups, including women, youths, and ethnic minorities, which has often been neglected[43]. Furthermore, the research highlights the need to simultaneously value social ethics and ecology for sustainable aquaculture development for humanity and earth health[22,34].

4. CONCLUSION

This research exposes an essential gap within the reproductive efficiency of *Lates calcarifer* in tropical hatcheries. While fertilization and hatching rates were relatively high, larval survival was suboptimal primarily due to cannibalism during early rearing. Insights from BBPBL Lampung illustrate that controlling size variances, optimal feeding, and suitable environmental conditions help lower aggressive behavior within a single cohort. The results validate the empirical rationale for adopting structured grading and managed interventions to improve cohort uniformity and decrease mortality. This information enriches practical understanding within aquaculture, especially in tropical hatcheries, as they seek to enhance seed production and sustain operations.

To enhance the survival rate of larvae and mitigate cannibalistic behavior in *Lates calcarifer* hatcheries, an early and periodic grading system based on larval size is suggested to reduce discrepancies in scale. The live feed should include microdiets suited explicitly for different developmental stages to meet the nutritional needs of the larvae. Monitoring water quality must proactively address subtle changes that could trigger stress-induced aggression. Integrating behavioral monitoring systems and investigating natural feed additives into future hatchery fuel calming or anti-aggression behaviors should be part of ongoing research to develop flexible, scalable models that integrate animal welfare, production efficiency, and socio-economic sustainability within tropical aquaculture systems.

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