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GROWTH AND PRODUCTION PERFORMANCE OF SAND LOBSTER (*Panulirus homarus*) CULTURED IN FLOATING NET CAGES

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ABSTRACT

Sand lobster (*Panulirus homarus*) is a high-value marine commodity with promising potential for mariculture development in Indonesia. This study described the grow-out technique for *P. homarus* in floating net cages at BPBL Batam. It evaluated its production performance in terms of growth, feed utilization, survival, and water quality. A field-based observational study was conducted for 74 days using juveniles with an initial mean body weight of 5.14 g and an initial mean total length of 5.44 cm. Lobsters were reared in six submerged M-sized cages (0.7 m² per unit) at a stocking density of 50 individuals per cage and were fed chopped trash fish once daily at 20% of biomass. Mean body weight and total length increased to 20.94 g and 8.47 cm, respectively, with absolute weight gain of 15.80 g, absolute length gain of 3.03 cm, and a specific growth rate of 1.89% day^{-1}. However, the feed conversion ratio was high (30.00), and the survival rate was low (40.33%). Water-quality variables remained within acceptable ranges for lobster culture. These findings indicate that the system supported lobster growth, but feed-use efficiency and survival still require improvement through better feeding and husbandry management.

Keywords: Feed conversion efficiency; Floating net cages, *Panulirus Homarus*, Water quality

1. INTRODUCTION

Aquaculture has emerged as an important cornerstone of the world's aquatic food output. The recent assessment by the FAO has revealed that for the first time ever in 2022, the output from the aquaculture sector of aquatic animals outpaced capture fisheries. High-value marine crustaceans have continued to stand out in this regard since they offer both market value and a ready export market[1,2]. One of the important species that is considered commercially viable for culture in tropical areas is the sand lobster *Panulirus homarus*, owing to its commercial value, wide acceptability, and biological adaptability for on-growing in coastal cages. Indonesia has the advantage of having such a natural resource available in abundance, which can be used as an asset in starting a lobster farming business through capture and on-growing techniques[2,3].

However, even with all its potentials, the cultivation of lobsters in Indonesia has been hindered by several biological, technological, and management barriers. Previous studies have found that the use of inadequate feeds and insufficient capabilities for husbandry were the main limiting factors in the lobster farming industry in Indonesia. Simultaneously, further reviews have pointed out the heavy reliance of the industry on wild seed stocks as well as the problems arising from the harvesting of puerulus and its uses. Lastly, recent studies conducted on spiny lobsters using floating-net cages in Indonesia have found that the threat of diseases is still a real issue in the grow-out process[4].

Grow-out is particularly important in lobster aquaculture as it is at this stage where biomass increase, growth, feed utilization, and survival become the key factors

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determining the viability of the culture process. In group lobster culture, this stage is influenced not only by the availability and nutritional content of feed but also by molting susceptibility, social behavior, shelter provision, and stress tolerance. As such, recent investigations into the culture of *P. homarus* have made increasing use of production variables like absolute growth, specific growth rate, feed utilization, and survival as the principal determinants of system viability under various feeding and management practices[5-7].

Despite recent breakthroughs that have greatly enhanced knowledge on *P. homarus* aquaculture from a technical perspective, the information is scattered within several management domains. Depth manipulation in submerged net cages has been shown to affect production performance in nursery systems. Shelter type has been demonstrated to alter stress response, growth, and survival. Feeding-rate trials have indicated that ration size influences culture efficiency, and formulated-diet studies have shown that fresh natural feeds can be replaced or improved upon by more standardized feeds. In addition, health-status evaluations in submerged net cages have indicated that depth-related environmental stabilization can support acceptable physiological condition in cultured lobsters[5,6,8-10].

Although those studies provide an important state of the art for lobster aquaculture, they are largely factor-specific and predominantly experimental, focusing separately on depth, shelter, feed formulation, feeding rate, or physiological status. As a result, there is still limited field-based information on how day-to-day grow-out practices, cage configuration, feeding management, growth response, survival outcomes, and water-quality profiles are integrated under routine operational conditions in Indonesian mariculture facilities. Such integrated descriptions remain important because they provide the practical bridge between experimental optimization and real-world production systems[2,8-10].

Under this scenario, BPBL Batam is considered to be an appropriate institution where observations about the grow-out of sand lobsters may be made using the net-cage system of lobster farming. In particular, BPBL Batam uses cage lobster farming in marine waters. This institution can be used to observe the entire process of growing out lobsters in cages. A recent study conducted at the same facility on silver pompano nursery management also demonstrated that BPBL Batam provides a relevant operational setting for evaluating growth performance, survival, and water-quality conditions under practical aquaculture management[11].

Hence, this research is aimed at providing the grow-out method of *P. homarus* grown in floating net cages in BPBL Batam, as well as determining their productivity in the 74-day grow-out period. The study specifically assessed absolute weight gain, absolute length gain, specific growth rate, feed conversion ratio, survival rate, and water-quality conditions as the main indicators of operational culture performance.

The findings are expected to contribute both practically and scientifically to improving lobster grow-out management in Indonesia. From a practical perspective, an integrated description of the BPBL Batam system could help refine cage operations, shelter use, feeding strategies, and routine environmental monitoring. From a broader aquaculture perspective, such operational evidence is relevant to ongoing efforts to strengthen Indonesian lobster farming as a more efficient and sustainable mariculture sector based on robust production data rather than on technical assumptions alone[2-3,9].

2. RESEARCH METHOD

Time and Place

This field-based observational study was conducted at the Brackishwater Aquaculture Fisheries Center of Batam (Balai Perikanan Budidaya Laut, BPBL Batam), located on Jalan Raya Trans

Barelang, Setokok Island, Bulang District, Batam City, Riau Islands, Indonesia. The practical culture observation was conducted from August to December 2025, whereas the grow-out cycle used for production-performance assessment lasted 74 days, from September 10 to November 22 2025. The grow-out activity was performed in floating net-cage facilities installed in coastal marine waters at the BPBL Batam mariculture

Procedures

Experimental Animals, Culture Units, and Main Materials

The cultured animal was a sand lobster obtained from the BPBL Batam nursery unit after a nursery phase of approximately 45–60 days. Juveniles with an initial mean body weight of 5.14 g and an initial mean total length of 5.44 cm were transferred to the second grow-out segment. Grow-out was conducted in M-sized cylindrical cages with a culture area of approximately 0.7 m^2. The cages were fixed in the floating cage culture system and were kept submerged under water at a depth of around 3 m to create constant environmental conditions. Each cage contained 50 lobster each making 300 lobsters per six cages in all. The shelters were constructed using PVC pipes with weighted netting and were provided within each cage as refuges during molting.

Cage Preparation and Stocking Procedure

Before stocking, all grow-out cages were cleaned thoroughly to remove adhering biofouling organisms, particularly barnacles and deposited mud, in order to maintain effective water exchange through the cage mesh. Cages with heavy fouling were first lifted and sun-dried to facilitate the removal of attached organisms, and the inner surface of the cage netting was brushed manually to eliminate accumulated sediments. After cleaning, shelters were installed inside each cage. The prepared cages were then fixed securely to the floating cage structure to ensure stability and ease of monitoring. Stocking was conducted in the morning to minimize thermal and handling stress. Juvenile lobsters were visually selected based on active movement, normal external appearance, bright body coloration, and intact appendages. Prior to release, lobsters were acclimated for 2–5 min to the environmental conditions in the grow-out cages. After acclimation, juveniles were stocked at a density of 50 individuals per cage.

Feeding Management and Routine Husbandry

Lobsters were fed fresh trash fish as the principal wet feed throughout the grow-out period. The feed consisted mainly of small marine fish and was stored in a cold room to preserve freshness and nutritional quality. Before feeding, the fish were thawed and cut into small pieces to facilitate the lobsters' grasping and consumption. The feed ration was adjusted to 20% of lobster biomass and offered once daily in the morning at approximately 10:30 a.m.

Routine husbandry included daily cage inspection and removal of uneaten feed and shell remains before the next feeding. Cage cleaning was performed using a scoop net to prevent the accumulation of decomposing organic matter that could deteriorate water quality and increase the risk of disease. This routine was also intended to reduce the attraction of wild fish to the cages and prevent cage damage from external predators attempting to access leftover feed.

Growth Sampling and Production Performance Assessment

Growth monitoring was conducted every two weeks throughout the 74-day culture period. At each sampling event, 10% of the lobster population in each cage was sampled, corresponding to five individuals from a cage containing 50 lobsters. Sampling was conducted before feeding to reduce stress and avoid bias from recent gut filling. Each sampled lobster was weighed using an analytical balance and measured for total length using a vernier caliper.

Production performance was evaluated using absolute weight gain, absolute length gain, specific growth rate, feed conversion ratio, and survival rate. Absolute weight gain was calculated as the difference between the final and initial mean body weights. Absolute length gain was calculated as the difference between the final mean total length and the initial mean total length. The specific growth rate was calculated as the natural logarithm of body weight over the rearing period. Feed conversion ratio was calculated as the total feed provided divided by biomass gain during the culture period. Survival rate was calculated as the percentage of lobsters remaining alive at the end of the grow-out period relative to the initial stocking number.

Table 1. Growth and production variables used in the grow-out evaluation

Variable	Equation	Description
Absolute weight gain (Wm)	$Wm = Wt - Wo$	Difference between final mean body weight (Wt) and initial mean body weight (Wo)
Absolute length gain (Lm)	$Lm = Lt - Lo$	Difference between final mean total length (Lt) and initial mean total length (Lo)
Specific growth rate (SGR)	$SGR = [(\ln Wt - \ln Wo) / t] \times 100$	Daily percentage increase in body weight over culture time (t, days)
Feed conversion ratio (FCR)	$FCR = F / \text{biomass gain}$	Ratio between the total feed given (F) and the biomass increase during culture
Survival rate (SR)	$SR = (Nt / No) \times 100$	Percentage of surviving lobsters at the end of culture (Nt) relative to the initial number stocked (No)

Water Quality Monitoring

Water-quality monitoring was conducted weekly during the grow-out period to ensure that the rearing environment remained suitable for sand lobster culture. The measured parameters included temperature, salinity, dissolved oxygen, pH, ammonia, nitrite, and turbidity. In situ measurements of temperature, salinity, and dissolved oxygen were performed directly at the floating cage site, whereas ammonia, nitrite, turbidity, and pH were analyzed in the BPBL Batam Water Quality Laboratory using water samples collected from the culture site. Water-quality monitoring was used as a routine management tool to detect environmental fluctuations that could induce stress and negatively affect lobster growth and survival.

Data Collection and Data Analysis

The study used a direct field-observation approach combined with active participation in daily grow-out operations at BPBL Batam. Primary data were obtained through direct observation of technical activities, biometric measurements of lobster growth, feed management, and water-quality monitoring. Supporting information regarding operational procedures was obtained through interviews with technical personnel and hatchery staff and through review of institutional records relevant to lobster grow-out management.

All data were tabulated and analyzed descriptively. Mean values of body weight and total length from each sampling event were used to calculate growth and production indices. The results were then presented in narrative and tabular form to describe the grow-out technique and production performance of *P. homarus* under floating net-cage culture conditions. Because this study was observational and conducted under routine hatchery operational management, the data were analyzed descriptively without inferential statistical testing

3. RESULT AND DISCUSSION

Grow-out Configuration of *P. homarus* in floating net cages

The grow-out of sand lobster, *P. homarus*, at BPBL Batam was conducted in M-sized cylindrical cages installed within a floating net-cage system. Each cage had an effective culture area of approximately 0.7 m² and was submerged at a depth of about 3 m. Juvenile lobsters with an initial mean body weight of approximately 5 g were transferred from the nursery phase to the second grow-out segment and stocked at a density of 50 individuals per cage, for a total of 300 lobsters distributed across six cages. The cages were cleaned before use to remove biofouling organisms and deposited sediments. Shelters made of PVC and weighted netting were placed inside the cages to provide refuge during moulting. During the grow-out period, lobsters were fed chopped trash fish once daily at a feeding rate of 20% of biomass.

A possible reason behind such an encouraging growth reaction may be the overall applicability of the grow-out setup used in this experiment, especially because of its use of submersed cages, moderately-stocked units, and incorporation of artificial shelters. Indonesian lobster farming has traditionally evolved through the practice of growing captured pueruli in cage systems, and there have been efforts to promote the use of submersed cages because of their ability to shield farmed lobsters from adverse surface conditions[2]. More recent work has also shown that submerged net cages can enhance nursery and grow-out performance, especially when depth is managed appropriately, and cages are positioned in areas with improved environmental stability and reduced animal behavior[8,10]. Similarly, it is clear that stocking density affects survival and growth rates in *P. homarus* when cultured in cages, showing that the cage structure and biomass stocking levels cannot be considered just as procedural issues but are key biological parameters[12]. In that context, the positive weight and length increments recorded at BPBL Batam are consistent with the broader view that cage-based grow-out is technically feasible for *P. homarus*, provided the physical culture environment remains sufficiently stable.

Temporal Growth Performance during the 74-Day Grow-Out Period

Mean body weight and total length increased progressively throughout the 74-day culture period. Mean body weight increased from 5.14 g at stocking to 20.94 g at the end of the grow-out cycle, while mean total length increased from 5.44 cm to 8.47 cm. The growth pattern showed a continuous increase across all sampling points, with the most marked increment in body weight observed between October 21 and November 8, 2025. A similar increasing trend was also observed for total length, although the increment decreased during the final sampling interval.

Table 2. Temporal changes in mean body weight and mean total length of *Panulirus homarus* during the 74-day grow-out period

Sampling date	Culture day	Mean body weight (g)	Mean total length (cm)
September 10 2025	0	5.14	5.44
October 6 2025	26	8.92	6.30
October 21 2025	41	12.74	7.06
November 8 2025	59	18.94	8.32
November 22 2025	74	20.94	8.47

The present field observation showed that the grow-out of *P. homarus* in submerged M-sized cages at BPBL Batam supported a clear increase in body weight and total length over a 74-day culture period. This growth pattern indicates that juveniles entering the second grow-out segment at around 5 g were already capable of adapting to the cage environment and utilizing the available feed for somatic growth. This is important because the transition from nursery to grow-out is one of the most sensitive phases in lobster culture, particularly for a species that relies heavily on successful molting for size increment. Studies on *P. homarus* have consistently shown that growth performance is highly responsive to rearing conditions, shelter availability, and feed characteristics[6,9]. For example, formulated-feed trials in juvenile *P. homarus* demonstrated that growth can improve markedly when diet quality and physical feed properties are better matched to lobster feeding behavior. In contrast, shelter-based nursery trials showed that lower stress and better protection during molting are associated with better production performance.

Therefore, the positive growth trend observed in the BPBL Batam system most likely reflects the combined effects of acceptable environmental conditions, a culture unit that still permitted normal molting-related growth, and a husbandry routine sufficient to maintain feed intake over the observation period.

Harvest performance and production indicators

At harvest, the grow-out system produced an absolute weight gain of 15.80 g and an absolute length gain of 3.03 cm. The specific growth rate reached 1.89% day^{-1}. Feed conversion ratio was 30.00, indicating that approximately 30 g of feed were required to produce 1 g of biomass gain under the observed grow-out conditions. From the initial stocking of 300 lobsters, 121 individuals remained alive at the end of the culture period, resulting in a survival rate of 40.33%.

Table 3. Final production performance of *P.s homarus* after 74 days of grow-out

Parameter	**Value**
Body weight (mean initial, g)	5.14
Body weight (mean final, g)	20.94
Weight gain (absolute, g)	15.80
Length (mean initial, cm)	5.44
Length (mean final, cm)	8.47
Length gain (absolute, cm)	3.03
Growth rate (specific, % day^{-1})	1.89
Food conversion ratio	30.00
Stocking density (initial, ind.)	300
Survival density (final, ind.)	121
Survival rate (%)	40.33

Overall, the floating net-cage grow-out of *P. homarus* at BPBL Batam was characterized by a progressive increase in body weight and total length over 74 days of culture. The system produced a final mean body weight of 20.94 g, a specific growth rate of 1.89% day^{-1}, and a survival rate of 40.33%. However, these positive growth responses were accompanied by a high feed conversion ratio and relatively low survival, indicating that the system was biologically functional but not yet fully optimized for production efficiency. In practical terms, the present findings suggest that growth can still be achieved under floating net-cage conditions even when production losses remain substantial, and this dual pattern should become the central lens for interpreting the culture performance observed in this study.

Despite that positive growth pattern, the feed conversion ratio of 30.00 indicates very low feed-use efficiency and should be considered a principal constraint of the observed grow-out system. Such a high FCR implies that a large quantity of feed was required to generate a relatively modest biomass increase, which is economically disadvantageous and environmentally inefficient. This issue is particularly relevant in systems relying on trash fish, because field-based hatchery observations in Indonesia have shown that feeding performance is highly dependent on ration management, feeding schedule, and the consistency of fresh feed handling under routine operational conditions[13]. This finding is highly consistent with the broader criticism of trash-fish-based lobster culture, where natural feed inputs are often in variable quality, prone to waste, and poorly converted into retained biomass compared with more controlled feed formulations[2,9].

Recent feed studies on *P. homarus* have shown that juvenile lobsters can achieve better growth and, in some cases, better survival when supplied with properly formulated moist feeds rather than relying solely on fresh fish or traditional natural feeds[9,14]. In addition, the nursery study by Budiardi et al.[8] used a lower daily ration delivered twice a day and still achieved improved production performance at favorable cage depths, implying that feeding schedule and feed management can strongly affect culture efficiency. Thus, the high FCR observed in the present study likely reflects a combination of feed wastage, variable intake efficiency, and the intrinsic limitations of using chopped trash fish as the sole grow-out diet in an open-water cage environment.

Survival represented yet another critical weakness of the cycle studied. The overall survival rate of 40.33% was far below the numbers achieved in laboratory settings through nursery or cage cultures of *P. homarus*, which usually exceed 70% in cases of enhanced shelter provision, improved stocking density, or modified feeding practices[6,12,15]. The relationship between cannibalism and mortality rates of spiny lobsters has been found to be rather strong, particularly in connection with moulting period, when newly moulted animals are extremely soft and weak, thus becoming easy prey for their conspecifics. It has also been demonstrated that mortality rates decrease significantly if proper shelters are provided, since shelters limit interactions among spiny lobsters and protect the creatures during ecdysis[6,15].

Nevertheless, even with shelters in place, the survival may still be inadequate if other risk factors are still present. This interpretation is supported by Lesmana et al.[16], who reported that cannibalism, size disparity, and insufficient grading management were major contributors to survival loss in barramundi hatchery systems. These risk factors may include such parameters as size variability, aggressive behavior, improper density, or nutritional competition[12]. Therefore, the relatively low survival in the present study suggests that the protective value of the installed shelters was insufficient to offset mortality associated with moulting vulnerability and culture-related stress.

Apart from non-pathological factors, the disease remains another probable reason for the poor survival noted in the current investigation. In comparison with high-control indoor rearing systems, floating net cages make lobsters vulnerable to more environmental conditions and biological interactions, which means that the issue of biosecurity is important here. According to research, infections caused by *Vibrio* spp. and milky hemolymph disease of spiny lobster can be found within caged lobster population, resulting in significant mortality if proper health conditions are not maintained[4]. Moreover, environmental stress is known to influence the immune condition of *P. homarus*; experimental work has demonstrated that salinity, dissolved oxygen, pH, and ammonia can alter immune-related hemolymph responses, indicating that survival is shaped not only by overt disease but also by sublethal environmental stress that weakens physiological resilience[17]. Hence, in order to discuss low SR identified in the current investigation, the multifactor approach should be considered, with the interaction between cannibalism, handling stress, and the issues related to health probably being the main reasons.

Water-Quality Conditions during Lobster Grow-Out

The measured water-quality profile during the grow-out period remained within the operational ranges used for lobster culture at BPBL Batam. Dissolved oxygen was 6.7 mg L^{-1}, temperature was 29.8°C, salinity was 30 ppt, pH was 8.00, ammonia was 0.03 mg L^{-1}, nitrite was <0.005 mg L^{-1}, and turbidity was 2.29 NTU. Overall, these values indicate that the rearing environment remained physically and chemically suitable during the observation period.

Table 4. Water-quality variables recorded during the grow-out of *P. homarus*

Parameter	Observed value	Unit	Culture status
Temperature	29.8	°C	Within an acceptable range
Salinity	30	ppt	Within an acceptable range
Dissolved oxygen	6.7	mg L^{-1}	Within an acceptable range
pH	8.00	–	Within an acceptable range
Ammonia	0.03	mg L^{-1}	Within an acceptable range
Nitrite	<0.005	mg L^{-1}	Within an acceptable range
Turbidity	2.29	NTU	Within an acceptable range

Based on the water quality obtained from this experiment, the conditions in which the lobsters were raised were apparently appropriate for *P. homarus* and hence would not be the major determinant in the failure of the lobsters to grow well. This is because parameters such as dissolved oxygen, temperature, salinity, pH, ammonia, nitrite, and turbidity fell under values favorable for raising lobsters. Comparable work in recirculating culture systems has shown that lobster growth can be maintained under dissolved oxygen of 4.6–6.3 mg L^{-1}, salinity of 33.4–37.4 ppt, pH of 6–7.9, and low ammonia concentrations, reinforcing the view that stable water chemistry supports normal growth performance[18].

Similarly, health-status studies in submerged cage systems found no visible tissue damage or immune impairment attributable to depth treatment when environmental conditions remained within acceptable limits[10]. However, water quality should not be overinterpreted as a sufficient explanation for production success. In lobster aquaculture, acceptable water quality establishes baseline conditions for culture, but feed efficiency, survival, and productivity are also heavily influence by nutrition, social interaction, stress exposure, and disease management[2,17]. Thus, the current water-quality results indicate that the system was environmentally supportive. At the same time, the remaining performance gap was more likely driven by management and biological interactions than by gross physicochemical failure.

Overall Implications for Lobster Grow-Out Management

This growth observed in the present experiment also suggests that lobsters in the second phase of grow-out, which started off with an average weight of 5 g, were able to adapt to the cage environment and use feed for body growth. This is significant since the nursery-to-grow-out transfer process is considered one of the most critical stages in the cultivation of lobsters, especially one that depends highly on successful molting for its growth increase. Numerous research findings regarding *P. homarus* suggest that growth efficiency depends greatly on the rearing conditions and feed properties[6,9]. For instance, juvenile *P. homarus* formulated-feed trials revealed that growth can be significantly enhanced by ensuring that diet quality and feed characteristics are more aligned with lobsters' feeding habits.

On the other hand, nursery trials based on shelters indicated that reduced stress and protection during moulting led to improved performance. Therefore, the positive growth trend observed in the BPBL Batam system most likely reflects the combined effects of acceptable environmental conditions, a culture unit that still permitted normal molting-related growth, and a husbandry routine sufficient to maintain feed intake over the observation period.

Taken together, the present study indicates that floating net-cage grow-out of *P. homarus* at BPBL Batam is technically feasible and capable of producing measurable growth under field conditions, but it still requires substantial refinement before it can be considered production-efficient. The most urgent areas for improvement are feed management and mortality control. From a practical standpoint, the use of trash fish should be reassessed through more precise feeding schedules, reduced wastage, and gradual replacement with better-standardized moist or formulated feeds, as these have shown promise in improving juvenile performance in previous studies[9,14].

At the same time, shelter configuration, stocking density, and health surveillance need to be optimized to reduce cannibalism and undetected disease losses in cage-based systems[4,6,12]. Because the present work was observational and did not include controlled treatment comparisons, future studies should test these factors experimentally to quantify the relative contributions of cage depth, feed type, feeding frequency, shelter density, and stocking density to FCR and SR more rigorously. In this way, the grow-out model observed in BPBL Batam can transition from operationally workable to biologically and economically optimized for sand lobster aquaculture.

4. CONCLUSION

The grow-out of sand lobster, *Panulirus homarus*, in submerged M-sized cages within the floating net-cage system at BPBL Batam was able to support positive growth over a 74-day culture period, as indicated by an absolute weight gain of 15.80 g, an absolute length gain of 3.03 cm, and a specific growth rate of 1.89% day^{-1}. The observed water-quality conditions remained within acceptable ranges for lobster culture, suggesting that the rearing environment was generally suitable for supporting growth. However, the high feed conversion ratio (30.00) and relatively low survival rate (40.33%) indicate that the grow-out system was not yet fully efficient from a production perspective. These findings suggest that while the existing cage-based culture practice is technically feasible for *P. homarus* grow-out, further improvements are required in feeding management, shelter optimization, and mortality control to enhance production efficiency. Future studies should evaluate feeding frequency, feed type, shelter configuration, and stocking density under controlled experimental conditions to develop a more efficient and sustainable grow-out strategy for sand lobster culture in Indonesia.

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