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Feasibility of Sand Lobsters Rearing in Floating Net Cages with Different Depths, Number of Shelters, and Stocking Densities

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ABSTRACT

Lobster cultivation can enhance productivity by adjusting the environment to match its natural habitat, such as depth, shelter to protect against cannibalism, and stocking density. This study aimed to analyze the production performance and feasibility of sand lobsters reared in floating net cages at varying depths, shelter numbers, and stocking densities. The research was conducted on Kelapa Dua Island, Seribu Islands, DKI Jakarta, and included three experiments using a completely randomized design (CRD) with three treatments and three replications for each treatment. The first experiment evaluated depths of 1, 2, and 3m. The second experiment tested shelter configurations with no shelters (0:8), a shelter-to-lobster ratio of 1:2 (4 shelter units/m²), and a ratio of 1:1 (8 shelter units/m²). The third experiment focused on stocking densities of 8, 12, and 16 lobsters/m². The results showed that depth significantly influences the production performance of sand lobster cultivation. A depth of 2 meters produced the best survival rates and commercial benefits, making it the most effective depth for floating net cage lobster farming. However, all depth treatments were financially unfeasible. The highest survival rate of 100% was achieved when using polyvinyl chloride (PVC) pipe shelters at a density of 4 units/m² (shelter-to-lobster ratio of 1:2). Although shelters improved survival rates, they did not significantly affect the lobster's weight gain rate, length gain rate, or feed conversion ratio. Nonetheless, shelters provided greater commercial benefits compared to other treatments, making them an attractive option for investment. Increasing stocking density to 16 lobsters/m² remained economically feasible despite a 20% decline in production, highlighting its potential to enhance investment sustainability.

INTRODUCTION

Lobster is one of the commodities that has a high economic value worldwide and is a superior commodity. Vietnam is a country where lobster farming has been commercially successful. The lobster industry in Vietnam depends on a natural supply of lobster seeds, specifically the puerulus stage, which are sourced from South Vietnam and

Indonesia. This success has sparked significant interest in Indonesia, as the lobster seed fishery there has flourished, with catches being 10 to 20 times greater than those in Vietnam **(Petersen *et al*., 2012)**. Based on the Minister of Maritime Affairs and Fisheries Regulation No. 17 of 2021, input for lobster cultivation production is only permitted to use clear seeds captured and cultivated in the same location as the fishing location up to a 5g/ individual lobster size. After reaching this size, lobsters can be distributed to other areas for nursery and rearing activities. There are two segments for lobster rearing activities, namely rearing I with a weight of 30-150g/ individual and rearing II with a minimum weight of 150g/ individual. After enlargement, lobsters can be sold if they have reached a minimum size of 150g for sand lobsters (*Panulirus homarus*) and 200g for pearl types (*Panulirus ornatus*).

Lobsters inhabit certain depths based on the species and age of the lobster **(Wandira *et al*., 2020)**. According to **Pranata *et al.* (2017)**, lobsters in Akudiomi Village, Nabire, were predominantly found at depths of 3-4 meters, with a total of 182 individuals observed during the research period. Based on **Wandira *et al*. (2020)**, lobster seeds (*Panulirus* spp.) are often found at a depth of 3m with water conditions that have a moderate level of brightness, a moderate level of turbidity, and can still be influenced by currents. The research of **Sartimbul *et al*. (2017)** explained that the deeper the water, the lower the temperature, light intensity, waves, and turbidity, while the current and pressure are higher. One type of lobster for rearing is the sand lobster, found in seawaters where there are lots of rocks or coral with water depths of 1–5 m **(Sukamto *et al*., 2017)**. According to the research results of **Liu *et al*. (2019)**, cultivation using sinking net cages can help aquaculture biota avoid problems in surface waters due to fluctuating temperature and salinity which affects growth and survival. In lobster rearing activities, adjusting the cultivation habitat to suit the natural habitat will maximize cultivation results.

Lobster rearing activities in Indonesia still face various obstacles, including lack of feed availability, difficulty in obtaining lobster seeds, diseases in lobsters, high feed conversion ratios, and relatively long rearing times **(Erlania *et al*., 2016)**. Another obstacle experienced in lobster cultivation is the high mortality rate in lobsters. According to **Supriyono *et al*. (2020)**, lobster cultivation using cages in Lombok Regency still has a low survival rate of around 30 - 40%. One of the causes of the low survival rate and productivity of lobsters is environmental factors that can cause stress for lobsters. Unsupportive environmental factors such as overcrowding, unsuitability of containers, and brightness for the nocturnal nature of lobsters, as well as the absence of shelter can cause stress so that growth and physiological conditions are disrupted. Based on research by **Supriyono *et al*. (2020)**, the main cause of death is cannibalism, especially during molting as part of the growth process. These constraints are the reason for developing sand lobster cultivation technology to minimize production losses.

Efforts to reduce cannibalism are by adding shelters to cultivation containers **(Setyono, 2006)**. The addition of shelter refers to the behavior of lobsters in their natural habitat which tend to hide in coral crevices or coral reef areas **(Pratiwi, 2018)**. Lobsters tend to hide in shelters to protect themselves from attacks by other lobsters, thereby reducing cannibalism activities in cultivation containers. Based on research by **Supriyono *et al*. (2020)**, PVC shelters are the best shelters because they can reduce the stress level of sand lobster seeds. The use of PVC shelters with a shelter-to-lobster ratio of 1:3 provides the best survival rate of 56.25% in the lobster rearing phase with an average weight of 41.13g in the indoor cultivation system **(Aji, 2016)**. Adding shelters is one alternative that can be done to increase lobster productivity.

Lobster productivity can also be influenced by stocking density. High stocking densities have the potential to result in deaths caused by a deteriorating environment and cannibalism. According to **Johnston *et al*. (2006)**, stocking density has a significant effect on lobster survival, with the application of a higher stocking density causing lower lobster survival. According to **Mustafa (2013)**, the stocking density in Vietnam for caught seeds is 50–60 individuals/m^2, after 60 days the stocking density is reduced to 15–20 individuals/m^2. The stocking density of lobsters gradually decreases with the length of time they are kept. The application of stocking density in the enlargement phase or initial size of lobsters >50g is 5–8 individuals/m^2. The majority of lobster stocking densities for rearing in Indonesia, specifically in the Lombok region, are 5 individuals/m^2, lower than in Vietnam **(Susanti *et al*., 2017)**. There has been no research regarding business feasibility for stocking density treatment, cultivation depth, and use of PVC pipe shelters in outdoor sand lobster rearing activities in marine cages, therefore this research was conducted. This study aimed to describe the optimal treatment that can improve production performance and profits from lobster rearing.

MATERIALS AND METHODS

1. Time and place of research

The research was carried out from November 2020 to April 2021 covering preparation and installation, lobster procurement, acclimatization, maintenance, data collection, and harvesting. The research was carried out in floating net cages in the waters of Kelapa Dua Island, Seribu Islands Administrative Regency, DKI Jakarta. Ammonia water quality measurements were carried out at the Aquaculture Environmental Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University.

2. Experimental design

This research was carried out in three experiments using a completely randomized design (CRD) with three treatments and three replications for each treatment. The first experiment was for depths of 1, 2, and 3m. Treatment selection was based on the statement of **Wandira *et al*. (2020)**, who explained that the sand lobster habitat is at a depth of 1 - 5m, sand lobsters are often found at a depth of 3m and it is easy to observe during the research. The second experiment was for shelters providing 0 shelters (no shelter) with a shelter-to-lobster ratio of 0:8, 1:2 or 4 shelter units/m^2, and 1:1 or 8 shelter units/m^2. Next, the third experiment was for treatments with lobster stocking densities of 8, 12, and 16 individuals/m^2. The lowest stocking density applied in the first and second experiments, namely 8 individuals/m^2, refers to the majority of lobster stocking densities applied in previous research and Vietnam. The stocking density used is expressed per unit area because lobsters have the characteristic of being at the bottom of the rearing container.

3. Research procedure

3.1. Floating net cages preparation

The floating net cages used in each experiment were constructed from high-density polyethylene (HDPE) and equipped with nine nylon net bags, each measuring 1 × 1 × 1 m with a mesh size of 1 mm. An outer net bag measuring 3 × 3 × 3m with a 5mm mesh was also included to protect the lobsters from predators. Additionally, the cages were fitted with a cover made of paranet to reduce the intensity of light entering the lobster rearing area.

In the first experiment, each cage was wrapped with waring material featuring a 5mm mesh, which was covered with netting having a 0.5-inch mesh size at the top of the cage. The cage was also equipped with a 0.5-inch rope tied to the bottom of the floating net cages (Fig. 1).

In the second experiment, the shelters used were pieces of PVC pipe, 20cm long and 3.5 inches (8.89cm) in diameter. These shelters were secured to the bottom of the net using rope in a structured manner. For the no-shelter treatment, the shelter-to-lobster ratio was 0:8. In the 4 shelter units/m^2 treatment, the distance between shelters was 30cm, and the distance between the shelters and the net wall was about 22cm. In the 8 shelter units/m^2 treatment, the distance between shelters was 10 cm, and the distance between shelters and walls was around 30 cm. Fig. (2) shows the 4 shelter units/m^2 and 8 shelter units/m^2 treatments. A total of 36 shelters were used.

The third experiment tested different lobster stocking densities in floating net cages.

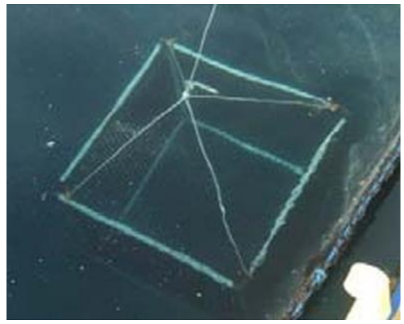

Fig. 1. Lowering the cage with a 0.5-inch rope tied to it hangs at the bottom of the cage

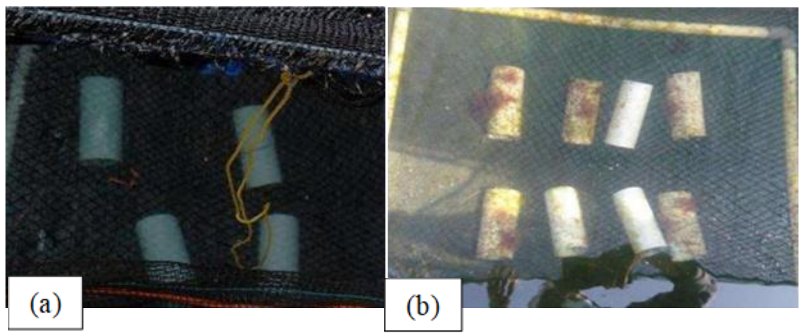

Fig. 2. The shelter arrangement. **a:** 4 units shelter/m^2 with a distance between shelters of 30cm and the distance between the shelter to the net wall is around 22cm, **b:** 8 units shelter/m^2 with a distance between shelters of 10cm and the distance between the shelter to the wall is around 30cm

3.2. Lobster stocking

Sand lobsters weighing 50-70g came from collectors in Ujung Genteng, Sukabumi Regency, obtained from natural catches on the southern coast of West Java. The lobster was then stunned using cold water at 20°C in a fiber bath so that the lobster remains calm during the transportation process. The stunned lobsters were then placed in a tub filled with sawdust and fine sand so that the temperature and humidity were maintained, before being arranged in a transportation container, namely cardboard or styrofoam. The transportation container uses cardboard with each corner filled with ice cubes to maintain temperature. Lobster packing was done in stacks with layers of newspaper. The filled cardboard box was then closed and sealed to keep the lobster from escaping. Lobster transportation took 12 hours from Ujung Genteng to the research location on Kelapa Dua Island. After arriving at the research location, the lobsters were removed and cleaned of adhering sand, then spread out in cultivation containers to be acclimatized in a 3 × 3m net for 14 days. Feeding during acclimatization was conducted 2 times a day using commercial feed. Before being tested, the lobsters were sorted based on their weight. After that, the lobsters were transferred to a rearing net measuring 1 × 1× 1m. Spreading was done in the morning or evening. The sand lobsters used in the first and second experiments were 72 each unit with a stocking density of 8 individuals/m^2. There were 108 sand lobsters used in the third experiment, each by stocking density treatments of 8, 12, and 16 individuals/m^2. The average initial weight of the sand lobster used in the first experiment was 80.14 ± 0.33g, in the second experiment it was 92.45 ± 0.40g, and in the third experiment, it was 75.10 ± 7.80g.

Lobsters were fed commercial sinking pellets with a diameter of 8–12mm with a protein content of 42%, fat of 10%, fiber of 3%, ash content of 10%, and water content of 10%. Feed was given every morning and evening, namely at 08.00 and 16.00 WIB, at 5% of the total biomass of each container **(Vijayakumaran *et al*., 2009)**. According to **Syafrizal (2017)**, feeding twice a day provides the best final weight for lobsters. In the first experiment, feeding was carried out by inserting submerged commercial pellets into a device in the form of a 1-inch diameter paralon with a length of 350cm which was attached to the cage. The food given through the paralon takes about 3 minutes to sink until the food enters the cage. In the second and third experiments, food was given by dropping it from the surface of the water directly above the lobster's head, then the food was grabbed using the antennae are likely to be the first pair of pereiopods, and directed to the lobster's mouth using walking legs

3.3. Water quality management

Water quality in floating net cages was managed by cleaning algae and barnacles attached to the walls of the maintenance net, as well as removing rubbish stuck around the outer net bag using a scoop. Lobsters were collected in baskets during the net cleaning process. Once the net was clean, the lobster was put back into the net. Lobster cages were cleaned every 10 days.

3.4. Measurement of production performance and water quality

Lobster weight measurements were carried out every 10 days until the end of rearing. Measurement of production performance parameters was carried out with the entire lobster population in the floating net cages. Weight measurements were carried out using digital scales with an accuracy of 0.01g. Water quality parameters that were observed directly (*in situ*) every day include temperature with a thermometer, salinity with a refractometer, dissolved oxygen (DO) with a DO meter, and pH with a pH meter. Meanwhile, ammonia measurements with a spectrophotometer were carried out *ex-situ* at the Environmental Laboratory of the Aquaculture Department, FPIK IPB. Ammonia sampling was carried out on days 0, 10, 20, 30, 40. Ammonia was measured using the method of **APHA (1990)**.

4. Test parameters

4.1. Production performance

The parameters tested during the research consisted of survival rate, specific growth rate, absolute growth rate, feed conversion ratio, productivity, and lobster behavior. The survival rate is the result of a comparison between the number of live lobsters at the end of rearing and the number of lobsters stocked at the beginning of rearing. The formula used to measure survival rates (SR) **(Solanki *et al*., 2012)** was:

$$\text{Survival rate (\%)} = \frac{\text{Number of live lobsters at the end of rearing}}{\text{Number of live lobsters at the start of rearing}} \times 100$$

The specific growth rate (SGR) measured was the difference in lobster weight at the end of rearing and the beginning of rearing in relation to the rearing time. SGR aims to determine the daily growth rate of lobsters expressed in % per day. SGR was calculated using the following formula **(Solanki *et al*., 2012)**:

$$\text{Specific growth rate (\%/day)} = \frac{\text{Ln Average weight of lobster at the end of rearing (g)} - \text{Ln Average weight of lobster at the start of rearing (g)}}{\text{Period of rearing (day)}} \times 100$$

The absolute growth rate (AGR) measured was the difference in lobster weight at the end of rearing and the beginning of rearing in relation to the length of rearing time to determine changes per day. The absolute growth rate was calculated using the following formula **(Goddard, 1996)**:

$$\text{Absolute growth rate (g/day)} = \frac{\text{Average weight of lobster at the end of rearing (g)} - \text{Average weight of lobster at the start of rearing (g)}}{\text{Period of rearing (day)}}$$

The feed conversion ratio (FCR) is the amount of feed needed to produce 1kg of lobster weight. Feed conversion was calculated using the following formula **(Goddard, 1996)**:

$$\text{Feed conversion ratio} = \frac{\text{Amount of feed given during rearing (g)}}{(\text{Lobster biomass at the end of rearing (g)} - \text{Lobster biomass dies during rearing (g)}) - \text{Lobster biomass at the start of rearing (g)}}$$

Productivity in cultivation activities was calculated using the following formula **(Haris & Anwar, 2017)**:

$$\text{Productivity (kg/m}^2\text{)} = \frac{\text{Biomass at the end of rearing (kg)}}{\text{Size of rearing media (m}^2\text{)}}$$

Lobster behavior observed included response to food, lobster activity in the morning at 08.00 and in the afternoon at 16.00, molting, and cannibalism. Lobster behavior was observed directly by diving and using an underwater camera capable of operations at a depth of 10m. Cameras were installed during the feeding process to determine the lobster's eating patterns and activity in the morning and evening.

The physicochemical water test parameters are salinity, temperature, pH, dissolved oxygen (DO), and ammonia. Table (1) shows measurements of the physicochemical quality of waters measured at floating net cages from November 2020 to April 2021.

Table 1. Physico-chemical quality of waters in floating net cages waters of Kelapa Dua Island, Seribu Islands Administrative Regency, DKI Jakarta from November 2020 to April 2021

Parameter	Unit	Measuring instrument	Brand model
Temperature	°C	Thermometer	HANNA Instruments HI98107-pHep™
Dissolved oxygen	mg/L	DO-meter	Lutron DO-5510™
pH	-	pH-meter	HANNA Instruments HI98107-pHep™
Salinity	g/L	Refractometer	Otc 5025 Diesel Exhaust Fluid (Def) ™
Ammonia	mg/L	Spectrophotometer	Spectrophotometer OPTIMA SP-300™

4.2. Business feasibility analysis

Business analysis evaluates the profits generated from a business activity over the course of one year. The parameters used in this analysis include investment costs, fixed costs, variable costs, total costs, and revenue.

Investment costs refer to the capital spent to start the business, covering the procurement of equipment, production processes, and facilities over a period longer than one year. Fixed costs are incurred regardless of production activity, while variable costs fluctuate based on production levels. Total costs represent the sum of fixed and variable costs. The total costs for one year of production are the combined fixed and variable costs.

Revenue is the amount of money earned from product sales. Annual revenue is calculated based on six production cycles, while revenue per cycle is determined by multiplying the amount of product produced by the selling price per kilogram.

The business analysis is based on the conditions after development, in accordance with SNI 8116:2015 standards for sand lobster production in floating net cages. The assumptions for lobster production used in the analysis are derived from the research findings. The analysis includes profit analysis, break-even point calculation, cost of production, revenue-cost ratio, and payback period.

Profit is used to determine the input and output components of business activities and the profits obtained. Systematically, business income can be written into the following equation:

$$\text{Profit (IDR)} = \text{Total revenue (IDR)} - \text{Total cost (IDR)}$$

Break-even point unit analysis is a technique for studying the relationship between fixed costs, variable costs, and profits so that the break-even value of the sand lobster rearing business can be determined.

$$\text{Break-even point unit (kg)} = \frac{\text{Fix cost (IDR)}}{\text{Selling price (IDR)} - \frac{\text{Variable cost (IDR)}}{\text{Production quantity (kg)}}}$$

Cost of production is a comparison between total production costs and total production.

$$\text{Cost of production (IDR)} = \frac{\text{Total cost (IDR)}}{\text{Total production (IDR)}}$$

The revenue-cost ratio aims to determine the value of the benefits from the results of business activities during a certain period. This value can determine whether the business is profitable or not. The R/C ratio equation is written as follows **(Soekartawi, 1995)**:

$$\text{Revenue/cost ratio} = \frac{\text{Total revenue (IDR)}}{\text{Total cost (IDR)}}$$

The profit criteria for a business are stated as follows: The business will be profitable if the revenue/cost ratio is > 1, the business will be at the break-even point if the revenue/cost ratio = 1, the business will experience a loss if the revenue/cost ratio < 1. The payback period (PP) is a calculation used to determine the investment return period. The payback period is a period used to find out how long the business capital spent can be returned. According to **Nurmalina *et al.* (2014)**, the payback period is mathematically calculated as follows:

$$\text{Payback period (year)} = \frac{\text{The amount of investment costs (IDR)}}{\text{Net benefits received each year (IDR/year)}}$$

Cumulative cash flows were obtained from cash inflows minus cash outflows during a certain period. A positive value indicates that the inflow exceeds the outflow. In net present value analysis, the time value of money for cash inflows and outflows over the life of a business investment. This was done to evaluate the benefits and costs of business at one point in time **(Zamroni *et al*., 2021)**. Net present value was derived from the present value of future cash flows discounted at the appropriate cost of capital minus the initial amount invested. The economic feasibility indicator will show a positive net present value value, namely the present value of the net cash inflow that will be received over the life of the business more than the initial investment amount. Net present value investment criteria: If net present value > 0, then the business plan is feasible to implement. If net present value < 0, then the business plan is not feasible to implement.

$$\text{Net present value} = \sum_{t=0}^{t=\text{Length of project period (year)}} (\text{Benefits in year t (IDR)} - \text{Cost in year t (IDR)}) \times \left(\frac{1}{(1 + \text{Applicable interest rate (\%)})^t}\right)$$

$$\text{Net present value} = \sum_{t=0}^{t=\text{Length of project period (year)}} (\text{Net benefit}) \times \text{Discount factor (\%)}$$

Net B/C ratio is defined as the ratio of the total present value of benefits to total costs obtained by the following formula:

$$\text{Net benefit/cost} = \frac{\sum_{t=0}^{t=n} \text{Positive net present value}}{\sum_{t=0}^{t=n} \text{Negative net present value}}$$

The investment criteria for net B/C are: If net B/C > 1, then the business is feasible to carry out. If net B/C <1, it shows that the business is not feasible to carry out. Internal rate of return is the rate used to evaluate the feasibility of an investment at the rate of return on business costs.

$$\text{Internal rate of return} = \{\text{The interest rate that produces a positive NPV is closest to 0} + \frac{(\text{Positive net present value})}{(\text{Positive net present value}) - (\text{Negative net present value})} \times (\text{The interest rate that produces a negative NPV is closest to 0} - \text{The interest rate that produces a positive NPV is closest to 0}\ )\}$$

Internal rate of return criteria are as follows: If the internal rate of return > the applicable interest rate then the business plan is feasible to implement. If the internal rate of return < the applicable interest rate then the business plan is not feasible to implement. Return on investment is the percentage of investment returns in the form of profits obtained from the capital used.

$$\text{Return on investment (\%)} = \frac{\text{Net income/year}}{\text{Total investment}} \times 100$$

The profitability index is the percentage of assets from the current value of net receipts to the investment value issued during the investment period.

$$\text{Profitability index} = \frac{\text{Cash flows (IDR)}}{\text{Initial investment value (IDR)}}$$

4.3. Sensitivity analysis

Sensitivity analysis identifies whether increases or decreases in production are likely to impact the economy. After the identification of the main production costs (survival rate and lobster biomass), these cost factors were included in a sensitivity analysis. Production fluctuations were 20% by comparing the financial performance of production businesses in different depths, number of shelters, and stocking densities.

4.4. Data analysis

Data on production performance parameters, including survival rate, specific and absolute growth rates, feed conversion ratio, and productivity, were analyzed using analysis of variance (ANOVA) at a 95% confidence level. If significant effects were found, the Duncan test was performed to determine differences between treatments, also at a 95% confidence level. Data that were not homogeneous were analyzed using the Kruskal-Wallis test, and if significant effects were detected, the Mann-Whitney test was applied at a 95% confidence level. Water quality data, including dissolved oxygen, temperature, salinity, pH, and ammonia, were analyzed descriptively using tables and figures. Data analysis was conducted using Microsoft Office 365 and SPSS 25.0 software.

RESULTS

The results of the analysis of the production performance of different depth, number of shelters, and stocking densities in floating net cages including survival rate (TKH), specific (LPS) and absolute weight growth rate (LPM), feed conversion ratio (RKP), and lobster productivity are seen in Table (2). The production performance of sand lobster rearing was carried out in each experiment during 40 days of rearing.

Table 2. Performance of rearing sand lobster (*P. homarus*) production in floating net cages with different depths, number of shelters, and stocking densities

Parameter	Depth (m)		
	1	2	3
SR (%)	75.00±10.21[a]	100.00±0.00[a]	87.50±17.68[a]
SGR (%/day)	0.29±0.01[c]	0.41±0.02[b]	0.49±0.02[a]
AGR (g/day)	0.25±0.01[c]	0.36±0.01[b]	0.43±0.01[a]
FCR	17.60±8.73[a]	15.84±0.54[a]	12.58±0.24[a]
Productivity (kg/m^2)	0.584±0.045[a]	0.731±0.003[a]	0.652±0.134[a]
Parameter	Number of shelters (unit/m^2)		
	0	4	8
SR (%)	75.00±10.21[b]	100.00±0.00[a]	95.83±5.89[a]
SGR (%/day)	0.55±0.04[a]	0.41±0.06[b]	0.42±0.04[b]

AGR (g/day)	0.46±0.03^{a}	0.42±0.06^{a}	0.45±0.05^{a}
FCR	8.16±4.17^{a}	16.99±1.95^{b}	16.83±1.73^{b}
Productivity (kg/m^2)	0.647±0.039^{b}	0.865±0.016^{a}	0.848±0.065^{a}
Parameter	**Stocking density (individual/m^2)**		
	8	**12**	**16**
SR (%)	70.83±5.89^{a}	77.78±14.16^{a}	79.17±5.89^{a}
SGR (%/day)	0.32±0.14^{a}	0.40±0.02^{a}	0.34±0.05^{a}
AGR (g/day)	0.26±0.11^{a}	0.31±0.03^{a}	0.28±0.04^{a}
FCR	7.27±2.37^{a}	12.11±7.64^{a}	10.88±2.89^{a}
Productivity (kg/m^2)	0.630±0.036^{c}	0.909±0.109^{b}	1.215±0.077^{a}

SR: Survival rate, **SGR**: Specific growth rate, **AGR**: Absolute growth rate, and **FCR**: Feed conversion ratio.

In different-depth experiments, the highest survival rate and productivity in the 2m treatment ($P > 0.05$) was not significantly different from those in the 1 and 3m treatments. Lobsters in the 3m treatment had feed conversion ratios and specific and absolute weight growth rates that were better and significantly different ($P < 0.05$) compared to lobsters in the 1 and 2m treatments. In experiments with different numbers of shelters, the use of 4 units/m^2 shelters in rearing containers resulted in the highest survival and productivity rates. The 4 units/m^2 treatment was significantly different from the treatment without shelter but not significantly different from the 8 units/m^2 treatment. The growth rate and feed conversion ratio did not show significant differences between treatments. In different stocking density treatments, the results of analysis of variance showed that productivity had significantly different results ($P < 0.05$). The 16-lobster/m^2 treatment had significantly different productivity results from the 8-lobster/m^2 treatment but not the 12-lobster/m^2 treatment. The parameters of survival rate, specific and absolute weight growth rate, and feed conversion ratio showed results that were not significantly different ($P > 0.05$) between each treatment.

The behavior of lobsters in different depths, number of shelters, and stocking densities in the marine cages for each trial during the 40-day rearing period is shown in Table (3). Observations of lobster behavior were carried out using tools in the form of underwater cameras. In different depth experiments, the behavior of sand lobsters at a depth of 1m tended to be passive, where the lobsters liked to stay in the corner of the net. Cannibalistic behavior was discovered when observing lobsters at a depth of 1m. Lobsters were seen cannibalizing other lobsters, and post-molting lobster carapaces were also found with the carapace empty. The behavior of sand lobsters at a depth of 2m tends to be active, where the lobsters appear to be actively moving and not standing still. The lobster's response is active when it is given food, it can be seen that the lobster is chasing the food it is given. Observing the behavior of lobsters in the morning of the 6th day, some lobsters had molted. Lobsters about to molt are seen moving away from other lobsters. The behavior of sand lobsters at a depth of 3m tends to be active, where the lobsters appear to be actively moving and not standing still. The lobster's response is active when given food, it can be seen that the lobster is chasing the food given. In the experiment with different numbers of shelters, the activity of lobsters in the rearing containers corresponded to the activity of lobsters in their natural habitat where they were seen hiding in shelters. In different stocking density treatments, the behavior of lobsters during rearing in each treatment was relatively the same. Lobsters will tend to gather and interact to fight for food. Cannibalism in lobsters that occurs is evidenced by incomplete body parts of the lobster, such as the abdominal muscle.

Table 3. Behavior of sand lobsters (*P. homarus*) in floating net cages in different depth, number of shelters, and stocking density in each experiment during 40-day rearing

The behavior of sand lobsters (*P. homarus*) in KJA at treatment depths of 1, 2, and 3m	
The behavior of lobsters at a depth of 1m after being fed has a less active response, tending to group and stay in the corner of the net from morning to afternoon. This observation was carried out on the 3rd day of maintenance at 09.00.	
The cannibalistic behavior of sand lobsters at a depth of 1m shows that sand lobsters are preying on other sand lobsters. This observation was carried out in the afternoon on the 15th day of maintenance at 09.00.	
Lobster behavior at a depth of 1 m. The sand lobster's carapace had just changed its shell or molted, and an empty carapace was found. This observation was carried out on the morning of the 6th day of maintenance at 15.00.	

The behavior of lobsters at a depth of2 m looks active, not in groups, and not staying in the corner of the net. Observations were made in the afternoon before feeding on the 18th day of maintenance at 16.00.

Lobster behavior at a depth of 2m after feeding. Observations were made in the afternoon on the 30th day of rearing, the lobster's behavior looked active when they were fed at 15.00.

Observation of lobster behavior in the morning on the 6th day of rearing at 15.00. Before feeding. The condition of the sand lobster at a depth of 2m after experiencing molting, the lobster looks active in the rearing container.

Lobster behavior at a depth of 3m before feeding. Observations were made in the morning on the 21st day of maintenance at 09.00. Lobsters tend to be active, you can see sand lobsters climbing to the side of the net.

Lobster behavior at a depth of 3m after feeding. Observations were made in the afternoon on the 27th day of rearing at 16.00, and lobsters were seen actively chasing food.

The behavior of sand lobsters (*P. homarus*) in KJA in the shelter number treatments of 0, 4, and 8 units/m^2

Lobsters actively respond to food in the morning, afternoon and evening.	
Lobsters are more often active at the bottom of the net in the morning, afternoon, and evening and tend to be passive during the day.	
The behavior of sand lobsters (*P. homarus*) in KJA at stocking density treatments of 8, 12, and 16 individuals/m^2	
Sand lobsters with a stocking density of 8 individuals/m^2 tend to group and stay in one corner of the rice net in the morning	
Sand lobsters with a stocking density of 16 individuals/m^2 interact with each other in the afternoon and sometimes even look like they are fighting for feed.	

Sand lobsters with a stocking density of 16 individuals/m^2 died allegedly due to cannibalism, as seen from their incomplete bodies.

Water quality parameters that were directly observed include temperature, salinity, dissolved oxygen (DO), and pH. Meanwhile, ammonia measurements were carried out in the Environmental Laboratory, Department of Aquaculture, FPIK IPB. The results of water quality observations are displayed in Table (4) showing the maximum and minimum values for the physico-chemical quality of waters.

Table 4. Water quality of sand lobster (*P. homarus*) in different depths, number of shelters, and stocking density in KJA for each trial during 40-day rearing

Parameter	Depth (m)		
	1	2	3
Temperature (°C)	28.2-28.7	28.2-28.6	27.8-28.4
Salinity (g/L)	30-34	32-34	32-34
DO (mg/L)	3.6-5.8	3.1-6.0	3.1-6.0
pH	8.2-8.5	8.2-8.5	8.2-8.5
Amonia (mg/L)	0.080-0.146	0.048-0.118	0.056-0.122
Parameter	**Number of shelters (unit/m^2)**		
	0	**4**	**8**
Temperature (°C)	27.8-29.2	27.8-29.2	27.8-29.2
Salinity (g/L)	29-36	29-36	29-36
DO (mg/L)	3.5-6.6	3.7-6.5	3.7-6.4
pH	8.1-8.5	8.1-8.6	8.1-8.6
Amonia (mg/L)	0.010-0.150	0.080-0.120	0.050-0.170
Parameter	**Stocking density (individual/m^2)**		
	8	**12**	**16**
Temperature (°C)	28.2-29.1	28.2-29.1	28.2-29.1

Salinity (g/L)	30-34	30-34	30-34
DO (mg/L)	3,1-6,0	3,1-6,0	3,1-6,0
pH	8.2-8.4	8.2-8.4	8.2-8.4
Amonia (mg/L)	0.002-0.006	0.002-0.006	0.002-0.006

Profitability analysis consists of investment costs, fixed costs, variable costs, total costs, production, total income, profits, break-even point unit, cost of production, revenue/cost ratio, and payback period (Table 5). Financial feasibility analysis consists of cumulative cash flow, net present value, net benefit/cost ratio, internal rate of return, return on investment, and profitability index (Table 6). Financial feasibility analysis in this research uses assumptions for business for 5 years.

Table 5. Analysis of the profitability of rearing sand lobsters (*P. homarus*) in KJA with different depths, number of shelters, and stocking densities

Parameter	**Depth (m)**		
	1	**2**	**3**
Investment cost (IDR)	274,114,000	274,120,000	274,126,000
Fixed cost (IDR)	45,399,600	45,400,800	45,402,000
Variable cost (IDR)	108,479,119	111,115,571	109,106,983
Total cost (IDR)	153,878,719	156,516,371	154,508,983
Total revenue (IDR)	153,508,993	214,966,057	191,986,910
Profit (IDR)	-369,726	58,449,686	37,477,927
Break-even point unit	472	287	321
Cost of goods sold (IDR)	328,790	238,816	263,971
Revenue/cost rasio	0.99	1.37	1.24
Payback period (year)	-	4.69	7.31
Parameter	**Number of shelters (unit/m²)**		
	0	**4**	**8**
Investment cost (IDR)	274,114,000	277,623,000	281,132,000
Fixed cost (IDR)	45,399,600	45,700,500	46,051,400
Variable cost (IDR)	108,335,815	115,524,553	115,680,892
Total cost (IDR)	153,735,415	161,225,053	161,732,292
Total revenue (IDR)	157,152,200	256,065,454	251,501,268
Profit (IDR)	3,416,785	94,840,401	89,768,976
Break-even point unit	446	254	260
Cost of goods sold (IDR)	320,869	206.517	210,926
Revenue/cost rasio	1.02	1.59	1.56
Payback period (year)	80.23	2.93	3.13
Parameter	**Stocking density (individual/m²)**		
	8	**12**	**16**
Investment cost (IDR)	274,114,000	274,114,000	274,114,000

Fixed cost (IDR)	45,399,600	45,399,600	45,399,600
Variable cost (IDR)	108,357,292	160,501,443	214,529,476
Total cost (IDR)	153,756,892	205,901,043	259,929,076
Total revenue (IDR)	140,268,964	225,273,969	313,051,807
Profit (IDR)	-13,487,929	19,372,925	53,122,731
Break-even point unit	608	481	440
Cost of goods sold (IDR)	359,540	299,793	272,341
Revenue/cost rasio	0.91	1.09	1.20
Payback period (year)	-	14.15	5.16

Table 6. Analysis of financial feasibility of rearing sand lobsters (*P. homarus*) in KJA with different depths, number of shelters and stocking densities

Parameter	**Depth (m)**		
	1	**2**	**3**
Cumulative cash flow (IDR)	-292,476,629	14,796,690	-100,111,046
Net present value (IDR)	-286,202,477	-53,241,578	-140,360,351
Net benefit/cost ratio	0,00	0.81	0.49
Internal rate of return (%)	-	1.84	-14.10
Return on investment (%)	-0.13	21.32	13.67
Profitability index	-1.07	0.05	-0.37
Parameter	**Number of shelters (unit/m²)**		
	0	**4**	**8**
Cumulative cash flow (IDR)	-273,544,075	217,513,197	191,183,269
Net present value (IDR)	-271,848,622	99,601,434	78,790,580
Net benefit/cost ratio	0.03	1.36	1.28
Internal rate of return (%)	-	23.48	20.66
Return on investment (%)	1.25	34.16	31.93
Profitability index	-1.00	0.78	0.68
Parameter	**Stocking density (individual/m²)**		
	8	**12**	**16**
Cumulative cash flow (IDR)	-358,067,643	66,957,381	505,846,571
Net present value (IDR)	-335,930,787	-13,694,939	319,052,128
Net benefit/cost ratio	0.00	0.95	2.16
Internal rate of return (%)	-	7.97	49.95
Return on investment (%)	-4.92	7.07	19.38
Profitability index	-1.31	0.24	1.85

Changes in lobster production performance are the most important factor in total production. The most important factor in lobster cultivation is biomass. This will affect the number of lobsters sold, which will then affect the value of the profits obtained. The amount of production is influenced by lobster biomass. Changes in the total final biomass sold need to be considered. The results of the sensitivity analysis of lobster-rearing businesses are presented in Table (7).

Table 7. Sensitivity analysis of 20% production fluctuations in sand lobster (*P. homarus*) rearing efforts in KJA with different depths, number of shelters, and stocking densities

Parameter	Production +20%			Production -20%		
	NPV (IDR)	Net B/C	IRR (%)	NPV (IDR)	Net B/C	IRR (%)
Depth 1 m	-169,818,505	0.38	-20.90	-402,586,449	0.00	-
Depth 2 m	109,736,519	1.40	24.95	-216,219,675	0.21	-35.47
Depth 3 m	5,195,936	1.02	10.76	-285,916,638	0.00	-
0 Unit shelter/m²	-152,702,526	0.44	-16.81	-390,994,718	0,00	-
4 Unit shelter/m²	293,739,341	2.06	46.64	-94,536,473	0,66	-4.96
8 Unit shelter/m²	269,468,116	1.96	43.50	-111,886,957	0,60	-7.84
8 Individuals/m²	-229,584,840	0.16	-41.95	-442,276,733	0.00	-
12 Individuals/m²	157,098,177	1.57	30.91	-184,488,055	0.33	-24.79
16 Individuals/m²	556,394,657	3.03	75.73	81,709,599	1.30	21.31

NPV: Net present value, **Net B/C**: Net benefit/cost, and **IRR**: Internal rate of return

DISCUSSION

Depth did not have a significant effect ($P > 0.05$) on survival rate, feed conversion ratio, and productivity, but had a significant effect ($P < 0.05$) on specific and absolute weight growth rates. The number of shelters has a real influence on survival rates, specific weight growth rates, and productivity. However, it has no real effect on the absolute weight growth rate. Different stocking densities had a significant influence on productivity, but had no significant influence on survival rates, specific and absolute weight growth rates, and feed conversion ratios. Based on research by **Prasiska (2020)**, the application of high stocking densities to lobsters in controlled tanks, namely 15 individuals/m^2, 25 individuals/m^{2,} and 35 individuals/m^2, also did not show significantly different results. This is due to lobster's effectiveness in consuming food as well as the lobster's opportunity to get oxygen and space to move **(Cokrowati *et al*., 2012)**. According to **Syafrizal *et al*. (2018)**, the survival rate of lobsters is influenced by the molting phase. Lobsters are in a weak state, so they are very susceptible to cannibalism which affects survival rates. The low survival rate of lobsters in the 1m depth treatment was 75.00 ± 10.21% because they were too close to the surface of the water. According to **Liu *et al*. (2019)**, the temperature and salinity at the surface of the waters fluctuate, and this situation will cause stress to cultivated biota. Stress can cause lobsters to experience molting, and the possibility of cannibalism is very high **(Bianchini & Ragonese, 2007)**.

High levels of cannibalism can be reduced by adding PVC pipe shelters to the rearing container. Shelters made from PVC pipes are effective because they can reduce the level of cannibalism in lobsters. This is by the statement of **Supriyono *et al*. (2020)** that shelters made from PVC pipes provide a stress response that tends to be stable in lobsters because they have a rough surface and there are two open holes on the sides of the shelter. Apart from that, **Segal and Roe (1975)** stated that the shape of the shelter in the form of an elongated pipe would be preferred as a hiding place so that it could not be observed by other shrimp. The light-tight PVC structure can also block light from entering the shelter so that conditions are darker. The survival rate in this study was considered high in the treatment of 4 shelter units/m^2 with a value of 100% because there was little to no contact between lobsters. After all, the addition of shelters was determined by the density of lobster stockings as well as the container area. This is different from lobster cultivation in Vietnam which uses production input in the form of clear lobster seeds (BBL) which germinate first until the lobster reaches consumption size so that the survival rate tends to be consistent at around 90%. When compared with the lobster cultivation business in Indonesia, it is around 50-90% **(Susanti *et al*., 2017)**. Apart from cannibalism, the low survival rate is also due to the production inputs used on average using juvenile lobsters in the first rearing phase measuring 30-150g/ individual. Juvenile lobsters that are used to living in nature are forced to live in cultivation containers, making it more difficult for them to adapt to a size that is ready for harvest. The addition of artificial shelters to lobster cultivation containers is a reflection of the natural state of lobsters which like to hide in coral rocks.

Lobsters are nocturnal animals that are active in low light conditions or at night, as evidenced by the 3m depth treatment, lobsters have a higher growth rate compared to other treatments. According to **Bahrawi (2015)**, lobsters are active at night (nocturnal) and this is when they perform molting (change of carapace). This is to the statement by **Bianchini and Ragonese (2007)**, that growth in length and body weight in crustaceans occurs periodically after molting. Molting in lobsters occurs when the body tissue of the animal has filled the carapace, so the lobster needs a new carapace to accommodate the growth in weight and length. Treatment without additional shelter shows that the nature of lobsters is that they often cluster in the corners of the net, causing competition for food between lobsters so that competition often occurs which causes lobster growth to be uneven for each individual. Treatment with the addition of 4 units/m^2 of shelter can reduce competition for food between individual lobsters because lobsters tend to spread out either in the corners of the net or hide in the shelter. In the treatment with 8 shelter units/m^2, the limited space for lobsters to move makes it difficult for them to access food. When food is provided, lobsters inside the shelters struggle to move out and reach the food, leading to poor food utilization. Additionally, food can become trapped between the shelters, further hindering the lobsters' access. According to **Supriyono *et al.* (2020)**, adding PVC pipe shelters in cultivation containers can reduce stress levels in lobsters, allowing energy to be directed toward growth until they are ready for harvest. Several factors, such as competition for space, oxygen, and food, influence lobster growth.

An increase in stocking density of 8, 12, and 16 individuals/m^2 does not cause competition for space, oxygen, and food for lobsters. Stocking density that is too high can cause stress due to high competition between lobsters in the food fight. This is confirmed by **Cokrowati *et al*. (2012)**, who stated that post-peulurus stage lobsters reared in controlled tanks at a stocking density of 20 individuals/m^2 had the highest specific growth rate, namely 2.154% compared to stocking densities of 40, 60, and 80 individuals/m^2. The implementation of stocking density in this research has not yet reached the maximum carrying capacity. Carrying capacity is closely related to stocking density, survival, and growth. The research results of **Solanki *et al*. (2012)** showed that increasing stocking density can reduce survival rates and growth rates. Therefore, the lobster stocking density in this study has not exceeded the maximum carrying capacity limit based on the same weight and length increase values in all treatments.

The lowest feed conversion ratio in different depth experiments was in the 3m depth treatment with a value of 12.58 ± 0.24. The large value of the feed conversion ratio is due to the behavior of the lobster which grasps the feed with its front walking legs so that it takes a long time to finish the feed in the form of pellets. The feed conversion ratio shows the efficiency of the lobster in digesting the feed given during rearing. The feed conversion ratio will be better if the value is smaller, which means that lobsters need less feed to produce 1kg of body weight **(Riani *et al*., 2012)**. The feed conversion ratio value from this research is relatively greater than the research by **Supriyono *et al*. (2020)** related to the use of PVC shelters with the provision of trash feed resulting in a feed conversion ratio of 8.53 ± 0.16. In addition, the use of PVC shelters with different ratios produces a feed conversion ratio of 5-9 with the provision of trash feed. Differences in feed conversion ratio values are closely related to the type of feed given. The types of feed that can be used are trash fish, shellfish, and crustaceans. Increasing stocking density with restricted feeding methods will increase the amount of feed needed. The feed conversion ratio still tends to be high or the feed efficiency value is low **(Supriyono *et al*., 2020)** which can be caused by the stability of the feed in water. The pellet feed used is easily destroyed when in water and carried away by sea currents. Meanwhile, the lobster's behavior when eating is to grasp the food with its front legs and then bite the food little by little so that it takes quite a long time to finish the food.

Another assessment that can determine the success of lobster cultivation is productivity. Productivity is the lobster biomass production at the end of maintenance per container area. Depth does not affect the productivity of each treatment because it uses the same stocking density. **Priyambodo and Luxianto (2020)**, in their study, statesd that high stocking density affects producing higher productivity. The increase in stocking density is directly proportional to the resulting productivity value or is linear. A stocking density of 16 individuals/m^2 has the highest level of productivity. This happens because it can increase the number of lobsters stocked per unit area so that greater biomass is produced per unit area.

The behavior of lobsters in different depth experiments showed normal activity by their nocturnal nature, with high activity at night or in low light conditions such as the 2 and 3m depth treatments. Lobster behavior is relatively calmer in the morning and afternoon, lobsters like to gather together, are active when fed in the afternoon, and lobsters also molt **(Supriyono *et al*., 2017)**. The observed behavior of lobsters tends to be in groups and interacting with each other. According to **Vijayakumaran *et al*. (2010)**, lobsters that are kept communally or at high densities have higher interactions with each other which are thought to play a role in encouraging growth and molting. The results of behavioral observations also found lobsters that were solitary or separated themselves. This is thought to be because the lobster is preparing itself for molting. Lobsters don't move much to save energy for molting and separate themselves to avoid cannibalism when lobsters molt. Molting will increase the lobster's body volume which will have the effect of increasing the weight and length of the lobster itself **(Frisch & Hobbs, 2011)**. During the observation, sand lobsters were found hanging on the side of the net. This behavior is similar to the observations of **Subhan *et al*. (2018)** in their research, the behavior of lobsters like to hang on the side of the net, lobsters can move quickly using their bodies and swimming legs, especially when they are fed. Based on behavioral observations in response to food, lobsters are more active in taking the food given in the morning and evening. When fed, the lobster's antennae will touch and direct the food to its mouth and then clamp the food with its walking legs. The function of the lobster's antennae is to detect food, detect other lobsters, and detect foreign objects that would threaten the lobster **(Prasiska *et al*., 2020)**.

Lobsters inside the shelter are more passive in responding to food than lobsters outside the shelter. Lobsters also sometimes take food and eat it in the shelter. The food given will be eaten by the lobsters or destroyed because it has been in the water for too long and will undergo a degradation process. Lobsters will eat little by little over a long period. Feed utilization depends on the lobster's appetite, which is different for each individual. This shows that diet and appetite will influence lobster growth. At night, lobsters do not hide in shelters and move very actively at the bottom of the net. According to **Prasiska *et al*. (2020)**, lobsters feel threatened when exposed to light so they move erratically and immediately enter the shelter to hide. Lobsters in maintenance nets without additional shelters tend to cluster in the corners of the net and stay under net weights made from a series of rectangular PVC pipes. Some of the lobsters in the maintenance nets added to the shelter are hiding inside the shelter and the rest are outside the shelter. During maintenance, lobsters carrying eggs were also found. This is confirmed by the statement of **Kintani *et al*. (2020)** regarding that female lobsters with a carapace size of more than 49.5mm have reached sexual maturity and are capable of reproduction. Lobsters carrying eggs were found on the 30th day of rearing, indicating that a spawning process had occurred in the rearing net. Fertilized lobster eggs will come out and will attach to the plumose setae on the swimming legs **(Junaidi *et al*., 2010)**. The energy obtained from feed is used for egg development, not for meat growth, so the growth rate in the 8 shelter units/m^2 treatment is slow and the increase in the average weight of lobsters is only slightly in the 8 shelter units/m^2 treatment compared to other treatments.

Environmental conditions are one of the success factors in lobster cultivation activities. Water quality parameters observed during this research include temperature, salinity, DO, pH, and ammonia. Water temperature will affect lobster metabolism and lobster behavior in response to food. Temperature is also an external factor that can influence molting in crustaceans including lobsters. Sea water temperature during the research period ranged between 27.8-29.20°C, this value is the optimal value for lobster cultivation. According to **Phillips and Kittaka (2002)**, the optimal temperature for lobster cultivation ranges from 25-30°C. Salinity greatly influences the osmoregulation process of lobsters. Salinity that is too low will disrupt the osmoregulation process in lobsters, while salinity that is higher than the optimal value will reduce the frequency of molting because the carapace tends to be hard and lobsters need more energy for the shell replacement process and environmental adaptation **(Haliman & Adijaya, 2005)**. Salinity during this study ranged from 30–40g/ L. This value is still good for lobster maintenance **(Verghese *et al*., 2007)**. Sand lobsters are lobsters that can tolerate water salinity values as much as 20% below sea water salinity values for several days, therefore sand lobsters are included in the *poikilosmotic palinurids*. The dissolved oxygen (DO) content in the waters in the research location during maintenance ranged from 3.1-6.6mg/ L. According to **Phillips and Kittaka (2020)**, the optimal DO value for lobster cultivation is 2.7-5.4mg/ L. According to **Vijayakumaran *et al*. (2009)**, the optimal level of dissolved oxygen for lobster cultivation is >3.5mg/ L. Overall, the dissolved oxygen content during the rearing period still supports lobster cultivation. The pH conditions in the waters during the maintenance period tend to be stable, ranging between 8.1–8.6. A good pH value for lobster is 8–8.5 **(Wickins & Lee, 2002)**. The pH value of the waters of Kelapa Dua Island tends to be stable with insignificant changes every day. Ammonia levels measured during the study ranged from 0.01 to 0.17mg/ L. According to **Wickins and Lee (2002)**, the optimal value for lobster cultivation is <1mg/ L. Increasing amounts of ammonia in the cultivation environment can affect growth and moulting **(Verghese *et al*., 2007)**. Overall, it can be concluded that the experimental depth, number of shelters, and lobster stocking density did not affect the quality of the water during rearing. Overall, the water quality parameters observed during the maintenance period in the waters of Kelapa Dua Island, Seribu Islands are still at the optimal level for lobster cultivation.

The calculation results of the profitability analysis of the sand lobster rearing business carried out in 6 production cycles at different experimental treatment depths of 2m had an R/C ratio of 1.37; payback period of 4.69 years; BEP unit of 287kg; and cost of goods sold of IDR 238,816. The values in the 2m treatment are better than other treatments. In the experiment with different numbers of shelters, better values were obtained in the treatment of 4 shelter units/m^2 with an R/C ratio of 1.59; payback period of 2.93 years; BEP unit of 254kg; and cost of goods sold of IDR 206,517. In different stocking density experiments, better values were obtained in the 16 individuals/m^2 treatment with an R/C ratio of 1.20; a payback period of 5.16 years; BEP unit of 440kg; and a cost of goods sold of IDR 272,341. Efforts showed losses in the treatment depth of 1m, and stocking density of 8 individuals/m^2. The effort was also not feasible in the treatment depth of 3m, the number of shelters was 0 units/m^2, and all treatments in the experimental stocking density were different. This happens because the payback period value obtained exceeds the life of the project, which is 5 years. According to a study from the Department of Investment and One-Stop Integrated Services of East Kalimantan province (2021), it was explained that the lobster rearing business in KJA measuring 3m^3 has an R/C ratio of 1.42; PP for 1.14 years. In research conducted by **Nasrudin (2017)**, an analysis of the feasibility of raising lobsters using the KJA system in Teluk Jor, East Lombok Regency had a profit of IDR 29,835,000 with an R/C ratio of 1.14.

Business feasibility analysis is a process to determine how much profit can be obtained from a business so that it is worth continuing. The cumulative cash flow metric describes all net cash flows during a certain period **(Zamroni *et al*., 2021)**. A positive value means that cash inflow is greater than cash outflow in the period after the cash flows are calculated against each other. NPV analysis applies the time value of money to cash inflows and outflows over the life of an investment project so that management can assess the profits and losses of a project at one point in time. This shows that money received today (present value) is more valuable than money earned in the future. A positive measure of economic viability, positive NPV, indicates that the present value of the expected net cash inflows over the life of the project exceeds the amount of the initial investment **(Gardner *et al*., 2015)**. The business feasibility analysis obtained in this research showed a positive NPV value in the treatment of the number of shelters being 4 units/m^2, 8 units/m^2, and an increase in stocking density of 16 units/m^2. Investment will occur if the benefit-cost ratio is more than one. Meanwhile, a break-even situation will occur if the benefit-cost ratio is equal to one. The discount rate, known as the IRR, reduces the present value of net cash inflows to zero. As a result, a project is approved if its IRR is greater than or equal to the required rate of return. A performance metric known as Return on investment (ROI) is used to assess the effectiveness or profitability of investments to compare the effectiveness of several different investments **(Zamroni *et al*., 2021)**. A better investment is shown in the treatment of the number of shelters 4/m^2 with the highest ROI value. The business feasibility analysis obtained in this research shows that it is not feasible to invest in different depth experiments, treatment with several shelters of 0 individual/m^2, and stocking densities of 8 individual/m^2 and 12 individual/m^2. Based on research by **Divu *et al*. (2024)**, the internal rate of return (IRR) is

33% and the net present value is IDR 17,780,648, which shows profitability. Financial standards and profitability levels serve as indicators of the potential and sustainability of business ventures. When considering the feasibility of an activity from a business perspective, investment criteria and environmental support are some of the factors that production considers **(Zamroni *et al*., 2021)**.

Production in the lobster business is greatly influenced by the survival rate and biomass of the lobsters to be sold. Production is a critical variable in the sensitivity analysis results which shows the most significant influence **(Petersen *et al*., 2012)**. Increasing production by up to 20% which is in line with increasing survival rate and biomass makes a positive contribution to NPV, net B/C, and IRR in production. However, not in the 1m depth treatment, the number of shelters was 0 units/m^2, and the stocking density was 8 units/m^2. This shows that the treatment given is not economically feasible. In terms of investment considerations, the treatment of increasing the stocking density of 16 individuals/m^2 is a better choice than other treatments. An increase in stocking density of 16 individuals/m^2 still shows economic feasibility despite a 20% decline in production. A 20% reduction in production makes all treatments other than a stocking density of 16 individuals/m^2 economically unfeasible. Evaluation of management to increase survival rates and biomass in lobster production is very necessary to obtain more significant economic benefits. The fundamental requirement for implementing lobster cultivation is the ability of the environment to support it financially and ecologically **(Barnett *et al*., 2018)**.

CONCLUSION

Different depths affect production performance and the performance of sand lobster rearing businesses. A depth of 2m produces the best business performance in lobster rearing in KJA because it produces lobsters with the highest survival rate and better business benefits. However, all the different depth treatments are not economically feasible to invest in. Providing PVC pipe shelter with a quantity of 4 units/m^2 or a ratio of shelter to lobster of 1:2 provides the highest survival rate of 100%. Providing shelter can increase survival but does not affect the weight growth rate, length growth rate, and feed conversion ratio of lobsters. The use of shelters can increase business benefits at a higher rate than other treatments. This increases the chances of selecting business investment by using shelters where the ratio of shelter to lobster is 1:2. It is very necessary to increase production to increase investment feasibility. An increase in stocking density of 16 individuals/m^2 still shows economic feasibility despite a 20% decline in production.

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