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PRODUCTION PERFORMANCE OF SPINY LOBSTER (*Panulirus homarus*) NURSERY IN SUBMERGED NET CAGES WITH DIFFERENT DEPTHS

KINERJA PRODUKSI PENDEDERAN LOBSTER PASIR (*Panulirus homarus*) PADA KARAMBA JARING TENGGELAM DENGAN KEDALAMAN BERBEDA

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ABSTRACT

The primary challenge in rearing spiny lobsters (*Panulirus homarus*) is the low growth and survival rates, which directly hinder the optimization of production performance. Lobster seeds can be reared in submerged net cages to improve production performance. This study aims to analyze the effect of depth on the production performance of lobster nurseries in submerged net cages. The study was conducted at the Sea Farming Center, Center for Coastal and Marine Resources Studies (PKSPL), IPB University, in the waters of Karang Lebar, Semak Daun Island, Seribu Islands, Jakarta. This study used a completely randomized design with three replications and cage placement treatments at depths of 4 and 6 m. Natural spiny lobster seeds weighing 1.0 ± 0.04 g were cultivated at a density of 50 individuals per cage. A total of 10% of biomass was given to lobsters twice a day in the form of 70% green mussels and 30% trash fish. The study's results showed improved production performance, as indicated by a higher survival rate, absolute growth rate, specific growth rate, feed conversion ratio, and lobster nursery productivity, at a depth of 6 m.

Keywords: depth, lobster behavior, production performance, spiny lobster, submersible net cage

ABSTRAK

Tantangan utama dalam pemeliharaan lobster pasir (*Panulirus homarus*) adalah rendahnya laju pertumbuhan dan tingkat kelangsungan hidup, yang secara langsung menghambat optimalisasi kinerja produksi. Benih lobster dapat dipelihara di karamba jaring tenggelam untuk meningkatkan kinerja produksi. Penelitian ini bertujuan untuk menganalisis pengaruh kedalaman terhadap kinerja produksi pendederan lobster pasir di karamba jaring tenggelam. Penelitian dilakukan di Sea Farming Center, Pusat Kajian Sumberdaya Pesisir dan Kelautan (PKSPL) IPB, di perairan Karang Lebar, Pulau Semak Daun, Kepulauan Seribu, DKI Jakarta. Penelitian ini menggunakan rancangan acak lengkap dengan tiga kali ulangan dan perlakuan penempatan karamba pada kedalaman 4 dan 6 m. Benih lobster pasir alami dengan berat 1,0 ± 0,04 g dibudidayakan dengan kepadatan 50 ekor per karamba. Sebanyak 10% biomassa diberikan kepada lobster dua kali sehari berupa 70% kerang hijau dan 30% ikan rucah. Hasil penelitian menunjukkan hasil kinerja produksi berupa tingkat kelangsungan hidup, laju pertumbuhan mutlak, laju pertumbuhan spesifik, rasio konversi pakan, dan produktivitas pendederan lobster yang lebih baik pada kedalaman 6 m.

Kata kunci: karamba jaring tenggelam, kedalaman, kinerja produksi, lobster pasir, tingkah laku lobster

INTRODUCTION

The spiny lobster (*Panulirus homarus*) is one of the lobster species commonly found in Indonesian waters, particularly in the Indian Ocean (Kembaren *et al*. 2015). Lobster is an export commodity that is widely hunted by fishermen because of its superior quality and high economic value (Djayanti *et al*. 2021; Ridwanudin *et al*. 2018). The export value of the lobster was IDR 48,541,665,488 (in 2019) and increased to IDR 480,862,269,729 (in 2020) (KKP 2021). Indonesia has the opportunity to dominate the world lobster export market due to its potential resources, especially to export to the destination countries, i.e. were Hong Kong, Taiwan, China, Singapore, Thailand, Malaysia, Vietnam, South Korea, and Japan (KKP 2020). The price of lobster seeds has become more expensive due to increasing market demand, especially to fulfill aquaculture needs in lobster development areas. The price of 2-3 cm lobsters increased from IDR 1,500-2,500 per individual to IDR 17,000-20,000 per individual (Junaidi *et al*. 2021; Erlania *et al*. 2016).

The main source of lobster production worldwide, especially in Indonesia, still comes from nature, both for mariculture seeds and for consumption. It is feared that the high price and demand for lobster seeds will endanger the sustainability of natural resources (Furqan *et al*. 2017). The management of lobsters, crabs, and swimming crabs is regulated in the Regulation of the Minister of Marine Affairs and Fisheries Number 17 of 2021, which states that lobster cultivation efforts are divided into four segments, namely 2 nursery segments and 2 enlargement segments. A lobster nursery is carried out to produce lobsters that can adapt to environmental changes (Syda-Rao *et al*. 2010; Adiyana *et al*. 2015). Production performance in the nursery segment is limited due to low growth rates and high mortality rates (Pratiwi *et al*. 2016). Sinking net cages used for lobster seed cultivation can help avoid problems with temperature fluctuations, contaminated materials, and biofouling (Liu *et al*. 2019). Lobster cultivation is generally carried out in submerged net cages, which provides the advantage of being able to adapt to their natural habitat (Prariska *et al*. 2020).

The natural habitat of lobsters in coastal waters with many coral reefs that protect from waves, provide hiding places from predators, and provide feeding areas is the habitat of lobsters (Setyanto *et al*. 2018). In addition, sandy sediments with small particles and high organic content are usually found on the seabed where lobsters are located (Mustafa 2013; Setyanto and Halimah 2019). The depth at which lobsters live varies depending on the species and age. Lobster seeds (*Panulirus* spp.) can be found at depths of up to 3 m in waters with moderate clarity, moderate turbidity, and the influence of currents (Wandira *et al*. 2020). The sustainability of lobster seed cultivation is highly dependent on suitable water conditions (Yudha *et al*. 2018). Based on this, it is very important to place lobsters in submerged net cages at the right depth so that production performance can be maximized. This study aims to analyze the effect of depths of 4 and 6 m on the production performance of spiny lobster nurseries raised in submerged net cages.

METHODS

This research was conducted from March to April 2022 with a rearing interval of 40 days. This research was conducted at the Sea Farming Center, Center for Coastal and Marine Resources Studies (PKSPL), IPB University, in the waters of Karang Lebar, Semak Daun Island, Seribu Islands, DKI Jakarta. This study used a Completely Randomized Design (CRD) consisting of two treatments with three replications each. The treatments applied were nursery at two different depths, namely 4 m and 6 m. Research on the dynamics of temperature, salinity, and seawater density shows that oceanographic conditions and water quality in the area support the cultivation of crustaceans, including lobsters. In addition, compared to other seas, the abundance of phytoplankton indicates the water trophic status that occurs in the area (Effendi *et al*. 2016). These waters have a lot of life feed, waves that are not too big, winds that are not too strong, and water depths of up to 7 m, which are ideal for lobster seed habitat (Mustafa 2013).

Implementation of research

Preparation of containers and rearing of test lobsters

The experimental container used was a cylindrical sinking net cage with a diameter of 0.8 m and a height of 1 m. The sinking net cage material used was Prime Grade High-Density Polyethylene (HDPE) PE 100. The surface area of the container used was 0.5 m^2. On the upper side, a rope was designed to make a grate to ensure that no lobsters escaped from the cage. The sinking net cage has an inner and outer net, each with a mesh size of 4 mm. The outer net keeps predators away and prevents wild animals from biting the lobster's legs, and the inner net is for the lobster cultivation container. The process of sinking the cage begins with selecting a location that is far from coral reefs, river estuaries, and shipping lanes and is free from pollution. The installation of buoys on the cage and weights according to the depths of 4 m and 6 m. The slow lowering of the cage was carried out with the help of a strong rope.

Lobster seed distribution

The lobsters used in this research were spiny lobsters (*P. homarus*) with a stocking density of 300 individuals/m^3 and an average weight of 1.00±0.45 g. Lobster seed rearing was carried out in submerged net cages with a predetermined depth according to the treatment used.

Research data collection

Lobster sampling was done directly by diving. Lobster length and weight measurements were carried out every ten days until the rearing was completed. Lobster weight and length measurements were carried out on each lobster by census. A ruler with an accuracy of 1 mm was used to measure the total length of the lobster, and a digital scale with an accuracy of 0.01 g was used to measure the weight of the lobster.

Water quality management and measurement

The floating net cages were cleaned of leftover feed and other accumulated dirt before feeding. Temperature, pH, salinity, and dissolved oxygen (DO) were measured directly in the submerged net cages every five days as indicators of water quality. Ammonia parameters were measured ex-situ every 10 days using the APHA method (1990) at the Aquaculture Environment Laboratory, Department of Aquaculture, IPB University. Water quality parameters measured during the study are listed in Table 1.

Test parameters

Observation parameters during the study were used to calculate test parameters, which consisted of production performance parameters, lobster behavior, and water quality. Production performance parameters included survival rate, specific growth rate, absolute growth rate, feed conversion ratio, and productivity.

Survival rate

The survival rate is a comparison of the number of lobsters that are alive at the end of rearing and the beginning of rearing. The survival rate is calculated using the following formula (Effendi 2002):

$$SR(\%) = \frac{Nt}{N0} \times 100$$

Description:
SR = Survival rate (%)
Nt = Number of live lobsters at the end of rearing (individual)
No = Number of lobsters at the beginning of rearing (individual)

Table 1. The physicochemical quality of the waters of the spiny lobster (*Panulirus homarus*) nursery in submerged net cages measured during 40 days of rearing.

Parameters	Tools	Times
Temperature (°C)	Thermometer	08.00; 16.00
pH	pH meter	08.00; 16.00
Dissolved oxygen (mg/L)	DO meter	08.00; 16.00
Salinity (g/L)	Refractometer	08.00; 16.00
Total ammonia nitrogen (TAN) (mg/L)	Spectrophotometer	Day 0, 10, 20, 30, 40

Specific growth rate (SGR)

Specific growth rate (SGR) is the logarithmic percentage of lobster length and weight growth each day. The formula for calculating this growth rate (Effendi 2002) is:

$$SGR\ L\ (\%) = \frac{(LnLt - LnL0)}{t} \times 100$$

Description:
SGR = Specific growth rate (%)
Lt = Average length at the end of rearing (g)
Lo = Average length at the beginning of rearing (g)
t = Rearing period (day)

$$SGR\ W\ (\%) = \frac{(LnWt - LnW0)}{t} \times 100$$

Description:
SGR = Specific growth rate (%)
Wt = Average weight at the end of rearing (g)
Wo = Average weight at the beginning of rearing (g)
t = Rearing period (day)

Absolute growth rate (AGR)

Absolute growth rate (AGR) is the growth of lobster length and weight from the beginning of rearing to the end of rearing per day. The absolute weight growth formula (Goddard 1996) is:

$$AGR\ L\ (g/day) = \frac{Lt - L0}{t} \times 100$$

Description:
AGR = Absolute growth rate (g/day)
Lt = Average length at the end of rearing (g)
Lo = Average length at the beginning of rearing (g)
t = Rearing period (day)

$$AGR\ W\ (g/day) = \frac{Wt - W0}{t} \times 100$$

Description:
AGR = Absolute growth rate (g/day)
Wt = Average weight at the end of rearing (g)
Wo = Average weight at the beginning of rearing (g)
t = Rearing period (day)

Productivity

Productivity in cultivation activities is calculated using the formula:

$$P = \frac{Bt}{L}$$

Description:
P = Productivity
Bt = Biomass at the end of rearing (kg)
L = Area of container used (m^3)

Feed conversion ratio

The feed conversion ratio (FCR) is the ratio of the amount of feed (kg) needed to produce 1 kg of lobster. The feed conversion ratio is calculated using Goddard's formula (1996):

$$FCR = \frac{F}{(Bt + Bm) - B0}$$

Description:
FCR = Feed conversion ratio
F = Amount of feed given (kg)
Bt = Biomass at the end of rearing (kg)
Bm = Biomass of dead lobsters (kg)
B0 = Biomass at the beginning of rearing (kg)

Lobster behavior

The observed lobster behaviors include response to feed, lobster activity in the morning and evening, and molting. Lobster behavior was observed directly using an underwater camera that can survive at a depth of 10 m. The camera was installed during the feeding process to determine the eating patterns and activity of lobsters in the morning at 07.00 WIB and in the afternoon at 16.00 WIB.

Water quality

Water quality parameters, including temperature, pH, salinity, dissolved oxygen (DO), ammonia, nitrite, and nitrate, were measured as the basis for physiological studies of lobsters during rearing. Ammonia concentration was calculated from the results of total ammonia nitrogen (TAN) measurements.

Data analysis

The parameters of the production performance test in the form of survival rate, absolute growth rate and weight, specific growth rate and weight, feed conversion ratio, and productivity were analyzed as a database for discussion. Production performance parameters were analyzed using an independent sample t-test with a 95% confidence interval. Lobster behavior and water quality parameters were analyzed descriptively through the presentation of tables or images. Data analysis was carried out using Microsoft Excel 2016 and SPSS version 26.0 software.

RESULTS AND DISCUSSION

The growth of lobster length is shown in Figure 1. The length of lobster seeds was 3.0±0.5 cm (4 m depth) and 3.0±0.5 cm (6 m depth) at the beginning of rearing. After rearing, the length of lobsters at 4 m and 6 m depths was 3.8±0.6 cm and 3.9±0.7 cm, respectively. The growth of lobster weight is shown in Figure 2. At the beginning of stocking, the weight of lobsters in the 4 m and 6 m treatments was 1.00±0.46 g and 1.00±0.43 g, respectively. At the end of the rearing period, the weight of lobsters in the 4 m and 6 m treatments was 1.84±1.04 g and 2.10±1.16 g, respectively.

The results of production performance at a depth of 6 m showed higher survival rates, absolute growth rates, specific growth rates, feed conversion ratios, and productivity compared to a depth of 4 m (Table 2). Although there was a numerical trend toward higher production performance at a depth of 6 m, statistical analysis showed that this difference was not significant ($p>0.05$). This indicates that within the depth range tested, there was no strong evidence of an effect of depth on nursery performance.

Cannibalism, the process of eating meat from the same species, causes a decrease in survival rates. When lobsters change their skin (molting), the lobster survival rate (SR) will decrease. This is because lobsters will attack weaker ones due to molting, which can lead to cannibalism. Lobster seed habitats are often found at depths of 5 to 7 m below the surface. An unsuitable environment can cause lobsters to molt, thus affecting the possibility of cannibalism (Mustafa 2013).

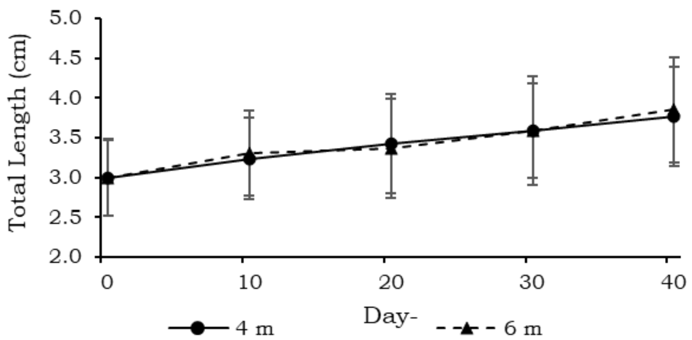

Figure 1. Total length growth of spiny lobster (*P. homarus*) seeds in submerged net cages with depths of 4 m and 6 m during 40 days of rearing.

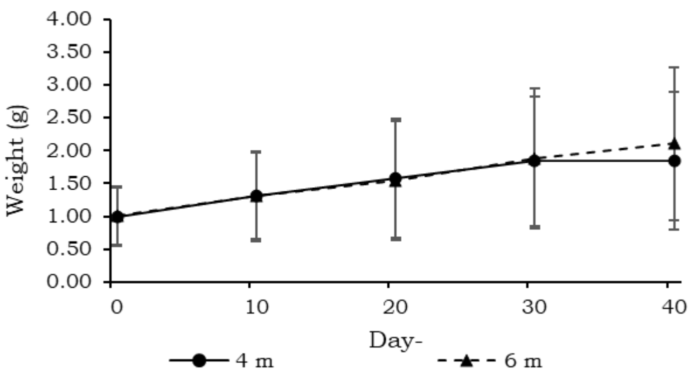

Figure 2. Growth in weight of spiny lobster (*P. homarus*) seeds in submerged net cages with depths of 4 m and 6 m during 40 days of rearing.

Table 2. Production performance of spiny lobster (*P. homarus*) nursery in submerged net cages at depths of 4 m and 6 m for 40 days of rearing.

Parameters	Depth	
	4 m	6 m
Survival rate (%)	72.7±10.07^{a}	80.0±7.2^{a}
Absolute weight growth rate (g/day)	0.57±0.008^{a}	0.84±0.004^{a}
Absolute length growth rate (cm/day)	0.019±0.128^{a}	0.021±0.077^{a}
Specific weight growth rate (%/day)	1.75±0.333^{a}	1.85±0.233^{a}
Specific length growth rate (%/day)	0.572±0.333^{a}	0.627±0.233^{a}
Feed conversion ratio	0.93±0.162^{a}	0.81±0.032^{a}
Productivity (kg/m^3)	0.0007±3×10^{-5a}	0.0008±8×10^{-5a}

*Numbers in the same row followed by the same letter indicate that the results are not significantly different at the 10% test level (t-test).

Many variables affect the growth of spiny lobster (*P. homarus*) seeds, including genetic characteristics carried by lobsters and the influence of external factors such as the environment in which they live. One thing that has a significant impact on lobster growth is molting because the molting process is necessary for lobster growth (Cokrowati *et al.* 2012). The body weight has filled the carapace to the full, so that new carapace growth is needed to support the weight after molting. In addition, there is a high growth curve during the lag period. During this phase, the energy network obtained by lobsters when diving begins to replace water with the body (Bianchini and Ragonese 2007).

The stocking density of lobsters of 300/m^3 in each treatment caused the environmental carrying capacity in the cage to be less than optimal (maximum carrying capacity) by producing productivity between treatments at a depth of 4 m and 6 m of 0.0007 kg/m^3 and 0.0008 kg/m^3. A numerical tendency toward improved production performance was seen at a depth of 6 m; however, statistical analysis revealed that this difference was not significant ($p>0.1$). This shows that there was no substantial evidence of a depth-related impact on nursery performance within the depth range examined. The results of crustacean cultivation, such as vaname shrimp with high stocking density treatment, will show higher productivity values (Priyambodo and Luxianto 2020). The feed conversion ratio will decrease along with more effective feed utilization for growth. It is important to understand the level of feed digestibility and the rate of gastric emptying when feeding cultivated commodities to maximize feed provision. The nocturnal nature of lobsters means that light intensity can also affect the feed conversion ratio. Lobsters are more active at night or in low light, especially when searching for food, due to their natural tendencies (Bahrawi *et al.* 2015).

The behavioral parameters of lobster seeds during rearing were observed using an underwater camera that could survive at a depth of 10 m (Figure 3). The behavior of spiny lobsters (*P. homarus*) in each treatment during rearing was relatively the same, namely, tending to gather and interact when fighting for food. Lobsters were seen socializing and behaving normally. Based on research conducted by Wahbi *et al.* (2023), the behavior of lobsters in nature actively moves to shallow waters and fertile locations to find food and shelter. Each lobster species has a certain depth where it lives, and the movement of waves and wind can cause lobsters to move closer to or away from the coast. Lobsters hide among seagrass and algae to avoid predators and currents. Lobsters actively forage in the afternoon compared to the morning. This data can be seen from the activity of lobsters, where they take food in the morning and take food in the afternoon. Lobsters that are molting will move away from their group and are not actively moving. The distinctive aroma emitted by lobsters when molting will encourage other lobsters in the same container to commit cannibalism (Ningtias *et al.* 2019).

Results of water quality observations during the rearing are shown in Table 3. The values of all parameters were not significantly different between treatments and were still within the optimal tolerance range. The optimal salinity value ranged from 34 to 36 g/L, the temperature ranged from 27 to 32°C, the pH ranged from 8.0 to 8.5, dissolved oxygen was >5 mg/L, and total ammonia nitrogen (TAN) ranged from <0.1 mg/L. The waters at the research location showed salinity ranging from 30 to 35 g/L, which tended to be lower than the optimal value. Water quality is an aspect that must be monitored periodically because of its role in increasing the survival rate and growth of lobsters.

The survival rate and growth of lobsters can be affected by osmotic pressure. Osmotic pressure increases with salinity levels. Living in unregulated waters, cultivated biota must be able to use energy from their food to change osmotic pressure (Cokrowati *et al.* 2012). A salinity of 30–40 g/L is the ideal value for lobsters. Thus, the salinity of the waters at the research location is still ideal and good for the growth and survival rate of lobsters (Wickins and Lee 2002).

The morning and afternoon water temperatures recorded during the study varied between 28.1 and 30.2°C. Based on the recommended temperature range of 26–32°C for marine cultivation, this range is ideal for lobster cultivation (Junaidi *et al.* 2018). Rapid temperature fluctuations make it difficult for lobsters to molt, which will inhibit growth (Setyono 2006). The pH value in the waters at the research location ranged from 8.2 to 8.5. The pH value of waters that are good for lobsters ranges from 8.0 to 8.5 (SNI 8116:2015). Waters with low pH are not effective for cultivation because they can cause decreased appetite (Giri *et al.* 2020).

Dissolved oxygen is needed in the rearing of spiny lobsters in the respiration process for growth and survival. Weight, temperature, and salinity affect the dissolved oxygen requirements of lobsters. The range of dissolved oxygen levels during rearing is 6.4-7.7 mg/L, which is still within the optimal value of more than 5 mg/L (Giri *et al.* 2020; Rathinam *et al.* 2014). TAN during lobster seed rearing varies between 0.11 and 1.25 mg/L.

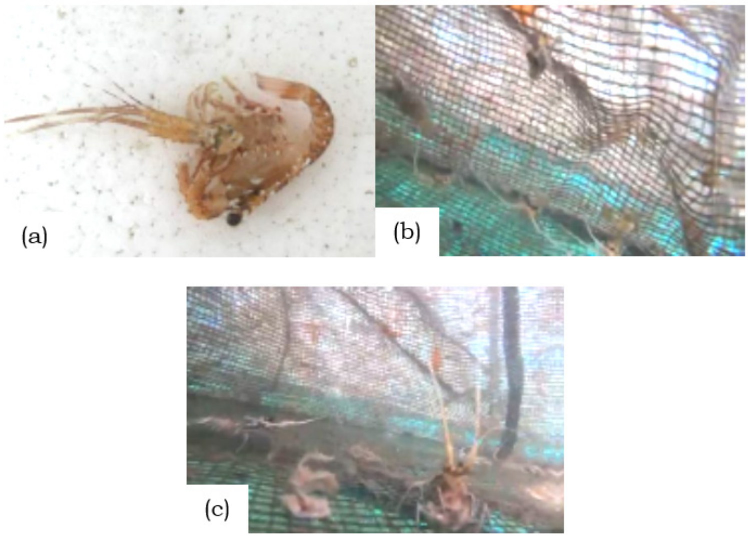

Figure 3. Behavior of lobster seeds (*P. homarus*): (a) spiny lobsters during molting, (b) spiny lobsters clustering and interacting with each other when fed, and (c) lobsters competing for food.

Table 3. Physicochemical quality of lobster seed water (*P. homarus*) in a submersible cage during rearing.

Parameters	Depth		Indonesian National Standard (SNI) 8116:2015
	4 m	6 m	
Salinity (g/L)	30–35	31–35	34–36
Temperature (°C)	28.1–30.1	28.1–30.2	27–32
pH	8.2–8.4	8.2–8.5	8.0–8.5
Dissolved oxygen (mg/L)	6.4–7.6	6.4–7.7	>5
Total ammonia nitrogen (TAN) (mg/L)	0.11–1.25	0.11–1.25	<0.1

Lobster growth and molting can be affected by increased ammonia in the cultivation environment. Ammonia is a result of nitrogen metabolism, especially from leftover feed and lobster excretion. In the postmolt phase, high ammonia interferes with calcium uptake and chitin formation so that new skin does not harden perfectly, making lobsters more susceptible to disease and cannibalism. In high concentrations, ammonia is very toxic to aquatic organisms (Verghese *et al.* 2007). Ideal total ammonia nitrogen (TAN) is less than 0.1 mg/L based on SNI 8116:2015. Ammonia levels exceeding the optimal threshold may have been a stress factor affecting lobster performance in all treatment groups, and potentially masking subtle differences that may have been caused by depth.

CONCLUSION

This study provides an important contribution to the development of spiny lobster cultivation techniques, especially in terms of selecting the depth of the submerged net cages. Production performance parameters such as survival rate, absolute growth rate, specific growth rate, feed conversion ratio, and productivity showed better values at a depth of 6 m. Other factors such as water quality, feed, and cultivation management must still be considered to achieve optimal production results.

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