The Effect of water depth on the growth and survival rate of *Panulirus homarus* in floating net cages: implications for sustainable coastal aquaculture and marine conservation

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Abstract. *Panulirus homarus* is a valuable fishery commodity, is in high demand both in Indonesia and internationally. Its cultivation often utilizes floating net cages, where environmental factors, such as water depth, are crucial to the lobster's well-being. This study aimed to analyze the effect of different water depths in floating net cages on the survival rate and growth of *P. homarus*. The research employed an experimental method with a completely randomized design, consisting of three treatments and five replications. The water depth treatments were WD 01 (4 meters), WD 02 (8 meters), and WD 03 (12 meters). Data were analyzed using analysis of variance. After 60 days of cultivation, the results showed that water depth had no significant effect on the survival rate and growth of *P. homarus*. The 8-meter depth yielded the highest results with 67±38.19 % of survival rate, 50.33±8.08 g of weight growth, 0.50±0.20 cm of carapace length growth, 0.17±0.15 cm of carapace width growth, 5.11±0.074 $\%^{-1}$ day of specific growth rate, and 25.00±0.76 % of molting rate. Although water depth did not significantly affect outcomes, the 8-meter depth appeared to be optimal for *P. homarus* in this study.

1 Introduction

Indonesia is one of the largest lobster producing countries in Southeast Asia[1]. According to Erlania et al. [2] Lobster has significant economic value in Indonesian waters. From the genus Panulirus, there are six species of marine lobsters that are widely distributed in Indonesian waters, including *Panulirus Homarus*, *P. longipes, P. penicillatus*, *P. ornatus*, *P. versicolor*, and *P. polyhagus* [3]. Indonesian waters are known for their rich lobster species

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spread across various regions. Lobster cultivation is one of the attractive business opportunities for most people in Indonesia, because cultivation with simple technology can be done with relatively small capital [2]

Lobster cultivation has been growing in Indonesia, both through marine cultivation centers and by fishermen. This is in line with increasing market demand, especially in the international market [4]. The demand for marine lobsters in the global market has increased by around 15% annually, mainly due to increasing demand from the international market, especially from countries such as China. *Panulirus homarus* is one of the fishery commodities that has high economic value in Indonesia and has high demand in the international market [5]. In an effort to increase sand lobster production, cultivation is an important solution. Sand lobster cultivation is carried out using various methods, including the use of floating net cages which are one of the effective cultivation systems. Management of sand lobster cultivation through floating net cages considers various environmental factors, one of which is water depth. The optimal water depth around floating net cages can affect the environmental conditions and welfare of the cultivated sand lobsters. However, until now, understanding of the effect of water depth on the survival rate and growth of sand lobsters in floating net cages is still limited.

Lobsters have a relatively narrow temperature range, between 20-30°C. Deeper water depths can affect water temperature, which can affect lobster growth. Cultivation with submerged cages can avoid problems that occur on the surface of the water temperature, light, waves, predators, and turbidity [6]. Research conducted by [7] stated that lobsters kept at an optimal depth are at a depth of 7 meters, with a survival rate of 96.66%, Average Daily Growth (ADG) average daily weight of 0.34 grams, and Mean Body Weight (MBW) average weight of 10.065 grams resulting in good growth. In lobster cultivation, floating net cages can also affect lobster growth. Floating net cages can affect food availability and water quality, and can affect the water temperature around the cage.

Therefore, in lobster cultivation using floating net cages, environmental factors such as water depth, temperature, and food availability must be considered in order to optimally affect the growth and survival of lobsters. In this study, we want to know more about the effect of water depth in floating net cages on the survival rate and growth of sand lobsters. We also want to know whether there is a significant difference between the growth of lobsters raised in floating net cages with different water depths. Thus, this study can contribute to the development of more effective and efficient lobster cultivation. The purpose of this study was to analyze the effect of water depth in floating net cages on the survival rate and growth of *Panulirus homarus*.

2 Materials and method

2.1 Time and place

This research will be conducted in June to July 2024 located at the UPTD of the Marine and Brackish Water Aquaculture Center (BPBALP) Sungai Nipah, Pesisir Selatan Regency, West Sumatra, Indonesia.

2.2 Materials and tools

The materials used in this study were *Panulirus homarus* as the research objects. The feed of small fish, Lemuru fish *Sardinella lemuru* as the feed for sand lobsters during the study. The research tools were cages made of 3 mm netting and ¾ inch PVC pipes in the form of boxes with sizes of 100 cm, 100 cm, 80 cm. Weights. Nylon rope, PVC pipe (shelter), bucket, boat,

digital scale and ruler. Water quality tools, namely thermometer, pH meter, refractometer and DO meter.

2.3 Research methods

The method used in this study is an experimental method, namely 3 treatments 3 replications with a completely randomized design (CRD). The water depth in the floating net cages is carried out with a difference of every 4 meters. The research treatments tested are as follows:

- WD01 = Water depth 4 meters in floating net cages
- WD02 = Water depth 8 meters in floating net cages
- WD03 = Water depth 12 meters in floating net cages

2.4 Observed variables

1. Survival rate of Lobster can be calculated using the formula: SR = $\frac{Nt}{No} \times 100\%$
2. Growth in weight of an object or organism in a certain time interval, measured by calculating the difference between the initial weight and the final weight. Lobster weight growth is calculated using the formula: Wm= Wt-Wo
3. Growth in Carapace Length, the increase in body length is the difference between the carapace length at the end of the study and the body length at the beginning of the study. The increase in lobster length is calculated using a formula Effendi (2002): Pm = Lt – Lo
4. Growth in Carapace Width, the formula for calculating carapace width growth can be calculated using the formula: L = Lt – Lo
5. Specific Growth Rate, the formula for calculating the specific growth rate (LPS) or Specific Growth Rate (SGR) is SGR = $\frac{(Ln\,Wt - Ln\,Wo)}{t}$
6. Molting frequency is the number of skin changes carried out by lobsters during a rearing period. Moulting frequency can vary based on the type of lobster, rearing conditions, and environmental conditions. The molting rate is calculated using the Modified formula : $TM = \frac{Mt}{Mo}$ x 100%
7. Measuring water quality parameters involves monitoring temperature, dissolved oxygen (DO), pH, and salinity. Every 10 days, the condition of the maintenance media was observed twice, in the morning and evening.

2.5 Data analysis

Data obtained from observations were analyzed using analysis of variance (ANOVA) according to a completely randomized design. To assess differences between treatments, further tests will be carried out using the Duncan New Multiple Range Test (DNMRT).

3 Results and discussion

3.1 Survival rate

Data on the average survival rate (SR) of sand lobster (*Panulirus homarus*) from each treatment can be seen in Table 1. The results of the average survival rate of sand lobsters during the study showed that the highest survival rate was in WD01 with an average value of 75 ± 0.00%. WD02 had the second highest survival rate with a value of 67 ± 38.19%, while treatment C showed the lowest results with an average of 50 ± 43.30%. The results

of the analysis of sand lobster variants showed that the influence of water depth in floating net cages on the survival rate and growth of sand lobsters did not have a significant effect (P>0.05). Observations of cannibalism include the number of dead lobsters observed which are then identified based on damage to the tail, intact with bite marks on the stomach, head and part of the body being eaten or the condition of the lobster being eaten entirely [8]. Low survival rates indicate higher levels of cannibalism. Cannibalism is the ability of lobsters to eat other lobsters. In addition to cannibalism, which is often cited as a cause of low survival rates, environmental factors also played a significant role in this study. During the cultivation period, storms and heavy rainfall led to high waves and strong currents around the floating net cages (KJA). These conditions likely caused stress in the lobsters, further reducing their survival rate. This environmental stress, combined with other factors such as fluctuations in water quality, could explain the difference in survival rates compared to previous studies that reported higher survival rates under more stable conditions.

Table 1. Survival Rate (SR) of sand lobsters during the study.

Treatment	Lobster at the start	Lobster at the end	Average survival rate (%)
WD01	12±0.00	9±0.00	75±0.00
WD02	12±0.00	8±1.53	67±38.19
WD03	12±0.00	6±1.73	50±43.30

Note: The same superscript letter behind the average value indicates that it is not significantly different (P>0.05)

The condition of the lobster after molting is that the shell is still soft, moves weakly and emits a certain aroma that can attract other lobsters [9] stated that providing sufficient quality and quantity of feed as well as good environmental conditions can support the survival of the biota being reared [10]. Lobsters that are growing also often experience molting which triggers cannibalism from other lobsters so that lobsters can die because they are prey or because they are preyed upon. In line with [11] which stated that the cannibalism that occurred in the test biota and the lack of food consumed resulted in the test animals being in a stressed and hungry condition. Cannibalism in lobsters occurs due to lack of food. Shells that are still soft during molting make lobsters easy targets for other lobsters that may be nearby. Cannibalism could be a natural behavior that appears as an attempt by lobsters to survive. This makes the survival rate for lobsters low.

3.2 Growth in weight

Data on the average absolute weight growth of *Panulirus homarus* from each treatment can be seen in table 2. Based on table 2 it can be seen that WD02 with an average absolute weight (50.33 ± 8.08 g) is the best followed by WD01 (39.00 ± 8.54 g) and the lowest is treatment C 35.33 ± 18.18 g). Based on the results of analysis of variance, it shows that the influence of water depth in floating net cages and the growth of sand lobsters does not have a significant effect on the growth of sand lobsters (P>0.05).

Table 2. Absolute weight growth of *Panulirus homarus* during the study.

Treatment	Average initial weight	Average final weight	Average final weight
WD01	129.33±1.15	168.33±7.64	39.00±8.54[a]
WD02	129.67±10.02	180.00±13.23	50.33±8.08[a]
WD03	137.00±7.81	113.00±97.89	35.33±18.18[a]

Note: The same superscript letter behind the average value indicates that it is not significantly different (P>0.05)

Factors that influence the growth of *Panulirus homarus* include the genetic characteristics of the lobster species itself as an internal factor and the environmental conditions in which the lobster lives as an external factor. These two factors influence each other to determine the growth rate of sand lobsters under certain conditions. According to [12], The growth of young to juvenile lobsters is influenced by the fertility of the waters, especially the availability of food and environmental parameters that support lobster growth.

The weight gain of *Panulirus homarus* in each treatment varies. This is related to the influence of water depth in floating net cages on survival and growth rates. The results of the study obtained the highest value at a depth of 8 meters. (Treatment WD02) At a depth of 8 meters, the environment is thought to be more stable with temperatures and salinity that support lobster growth, at a depth of 8 meters more natural food sources are needed for growth. The appropriate depth can reduce stress when feeding lobsters, which has a positive impact on growth. According to [13] who reviewed lobster cultivation locations in Vietnam, that a good depth for lobster cultivation is 3-5 m for fixed net cages and 6-20 meters for floating net cages at the lowest low tide.

3.3 Growth in Carapace Length

Data on the average growth of sand lobster (*Panulirus homarus*) carapace length from each treatment can be seen in Table 3. From the average carapace length growth of sand lobsters after the research, the average for WD02 showed better carapace length growth (0.50 ± 0.20 cm), followed by WD03 (0.33 ± 0.26 cm) and the lowest was WD01 (0.07 ±0.06 cm). Based on the results of analysis of variance, it shows that the difference in water depth in floating net cages on the increase in lobster carapace length has a significant effect on the growth of sand lobster length (P>0.05).

Table 3. Growth of lobster carapace length.

Average Treatment	Average Treatment	Average Treatment	Average Treatment
WD01	6.93±0.15	7.00±0.17	0.07±0.06[a]
WD02	6.73±0.35	7.23±0.32	0.50±0.20[a]
WD03	6.80±0.00	7.13±0.21	0.33±0.26[a]

Note: The same superscript letter behind the average value indicates that it is not significantly different (P>0.05)

Lobsters are organisms known for their long lifespan and slow growth. This is caused by various biological factors that influence the way lobsters grow and develop. The growth in length and width of the carapace occurs more slowly than the increase in weight. lobsters have an influence on their growth characteristics. [10] stated that the increase in carapace length was faster than the increase in body weight of lobsters. Good conditions for growth are increasing length and balanced body weight (isometric). Even according to [12] lobster growth is influenced by habitat, age and food as well as changing environmental oceanographic conditions which can inhibit growth.

3.4 Growth in carapace width

Data on the average growth of *Panulirus homarus* carapace width from each treatment can be seen in Table 4.

Table 4. Growth of sand lobster carapace width during the study

Treatment	Average initial carapace width	Average final carapace width	Average carapace width
WD01	4.30±0.10	4.33±0.12	0.03±0.21[a]
WD02	4.20±0.12	4.37±0.31	0.17±0.15[a]
WD03	4.07±0.17	4.33±0.06	0.27±0.15[a]

Note: The same superscript letter behind the average value indicates that it is not significantly different (P>0.05)

From the average growth in sand lobster carapace width after the research, WD03 showed that the carapace width growth was higher (0.27 ± 0.15 cm), followed by WD02 (0.17 ± 0.15 cm) and the lowest was in WD01 (0.03 ± 0.21 cm). Based on the results of analysis of variance, it shows that the difference in water depth in floating net cages on the increase in lobster carapace width does not have a significant effect on the growth of sand lobster carapace width (P>0.05). The results of this study show that water depth does not affect the growth rate of sand lobster carapace width, slow growth The carapace depends on the size of the lobster being kept. Growth slows down as the lobster increases in age and size. The growth rate of adult lobsters is slow. Lobster growth is faster in the larval phase compared to the adult phase. [10] also stated that the availability of food and the ability of lobsters to utilize or digest food will determine lobster growth.

3.5 Specific growth rate

Data on the average specific growth rate of *Panulirus homarus* from each treatment can be seen inTtable 5. From the average specific growth rate, sand lobsters got the highest value in WD02 (5,110 ± 0.074 g) followed by WD01 (5,044 ± 0.046 g) and the lowest in WD03 (4.899 ± 2,916 g). Based on the results of variance analysis, it shows that the specific growth rate of lobsters does not have a significant effect (P>0.05).

Tabel 5. SGR growth data of sand lobster during research.

Treatment	**Total SGR (g)**
WD01	5.044±0.046[a]
WD02	5.110±0.074[a]
WD03	4.899±2.916[a]

Note: The same superscript letter behind the average value indicates that it is not significantly different (P>0.05)

The results of research conducted for 60 days showed that WD02 and WD01 gave better results in increasing the specific growth rate of sand lobsters, this difference was not significant. Water depth can affect water productivity, light penetration temperature and oxygen levels and density which play an important role in the suitability of lobster life [14]. Phytoplankton usually gather in the euphotic zone, namely the zone with low light intensity. still allows photosynthesis to occur. At shallower depths, water temperatures tend to be warmer and more sunlight penetrates the water, which supports the availability of natural food. This condition can increase the metabolic rate of lobsters, thereby accelerating the specific growth rate of lobsters. On the other hand, at deeper depths, the water temperature tends to be more stable but colder, which can slow down the lobster's metabolism [15].

The abundance of plankton as a natural food ingredient is at a depth of 3 to 5 m from the surface of sea water. At a depth of 4.5 m there are abundant nutrients, oxygen and

light which support the photosynthesis process for phytoplankton [16]. The availability of natural food at deeper depths is limited due to lack of light penetration. So further research is needed to analyze other factors that can significantly influence the specific growth rate of sand lobsters.

According to [11], not all the food consumed by lobsters is used for their growth. Most of the energy from food is used to maintain metabolism, the rest is used for activity, growth and reproduction. Good environmental conditions also support the life and physiology of lobsters and frequent molting of lobsters can increase their specific growth rate. This is in accordance with the statement [17], Metabolism that runs well will affect the efficiency value of feed eaten by lobsters. The tendency for long growth in lobsters is due to a growth pattern that will only grow if they molt [18].

3.6 Molting frequency

Data on the average molting frequency of *Panulirus homarus* from each treatment can be seen in table 6. From the average molting frequency of sand lobsters during the research, it can be concluded that WD01 had a high average molting frequency in WD01 (1.08 ± 0.69 times/head) followed by WD03 (33 ± 0.19 times/head) and that the lowest was in treatment B (0.11 ± 0.11 times/head) but had no significant effect on growth (P> 0.05).

Table 6. Frequency of sand lobster molting during the study.

Treatment	Lobster molting(tail)	Lobster reared(tail)	Average molting frequency (%)
WD01	13±2.08	12±0	1.08±0.69[a]
WD02	3±2.65	12±0	0.25±0.76[a]
WD03	4±1.53	12±0	0.33±0.19[a]

Note: The same superscript letter behind the average value indicates that it is not significantly different (P>0.05)

The higher molting frequency at a depth of 4 meters is caused by factors such as higher water temperatures or erratic changes and the availability of food that stimulates molting. Meanwhile, growth is higher at a depth of 8 meters, environmental conditions are more stable and optimal, temperature and salinity support higher metabolic efficiency and are better for body tissue growth than increasing molting frequency. According to [19] that crustaceans that obtain sufficient nutritional content will experience skin change more quickly because the energy stored in food will be metabolized and used directly for growth and maintenance. Growth characteristics in crustaceans are different from fish. This is due to a skin change event in its life cycle. Moulting is one of the factors that influences lobster growth because to grow lobsters they must undergo a moulting process. Molting plays an important role in the lobster life cycle; this is because the success of molting will determine the growth of the lobster. Weight gain can reach 50% if the lobster is molting [20].

3.7 Water quality

Water quality is an important factor supporting the growth and survival of sand lobsters. Water quality parameter measurements during research include temperature, salinity, pH, DO. The results of water quality measurements during the research are seen in Table 7. The temperature when rearing sand lobsters ranges from 29.6-30.2. The temperature in sea water has a significant influence on the metabolic exchange process of an organism [21]. Lobsters are often found in waters with temperatures ranging between 26-30 ºC or prefer cold water.

During the maintenance carried out, the temperature was still in a good range for the growth and survival of sand lobsters. [22], The optimal temperature for keeping seawater lobsters ranges from 23-30ºC. If temperature fluctuations occur, lobsters will have an impact on inhibiting growth and the molting process [23].

Table 7. *Panulirus homarus* water quality parameters during the study**.**

Parameters	Average	Range	BMKA
Temperature (°C)	30.00	29,6 - 30,2	27-32*
Salinity (ppt)	30.00	30 – 30	28-32*
DO (mg/L)	15.99	15,03 - 16,35	>5*
pH (ppm)	7.30	7,04 - 7,42	8-8.5*

The salinity measurement ranges from 30 – 30 ppt, where this salinity is suitable for cultivating sand lobsters. According to [24], the optimal salinity for rearing sand lobsters is 32-36 ppt. Salinity can affect the survival and behavior of lobsters. Poor water quality can cause lobsters to get sick or die due to stress and loss of appetite. The salinity range of 29-34 ppt is able to support the life of lobster seeds well and is able to directly influence the growth rate, amount of food and survival of lobsters in nature [10]. The salinity conditions during lobster rearing are still suitable for cultivation. The availability of dissolved oxygen in lobster cultivation in Floating net cages was one of the factors supporting growth during the research. The dissolved oxygen in the waters during the study ranged from 15.03 - 16.35 ppm, which is suitable dissolved oxygen for cultivating sand lobsters. According to [25] The dissolved oxygen required for seawater lobsters in floating net cages is >4 ppm. Lobsters cannot molt, so an unstable environment can inhibit lobster growth. During research carried out in cages, the pH of the waters ranged between 7.04 – 7.42, which is a suitable pH for cultivating sand lobster seeds. The optimal pH for marine biota is 7.6-8.7 [22]. Sea lobster cultivation the pH value required for survival is 7.8 - 8.5. The recommended pH values for clawed lobsters and spinny lobsters are 7.8-8.2 and 8.0-8.5 respectively. Overall, the pH value is still suitable for lobster cultivation [18].

4 Conclusion

Based on the results of 60 days of research, it can be concluded that the water depth in floating net cages does not have a significant effect on the survival and growth of sand lobsters. The water depth in floating net cages shows that 8 meters is the value of lobster survival in WD01 (67 ± 38.19%), weight growth in treatment B (50.33 ± 8.08 g), carapace length growth in treatment B (0.50 ± 0.20 cm), carapace width growth in WD03 (0.27 ± 0.15 cm), and molting frequency percentage in WD01 (1.08 ± 0.69 times/head).

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