***Grouper : Jurnal Ilmiah Perikanan***
Vol. 16 No. 2 (2025) pp. 414-430
pISSN: 2086-8480 | eISSN: 2716-2702
Journal Homepage: https://grouper.unisla.ac.id/index.php/grouper

# Effects of Feed Type on Growth and Food Habits of Green Lobster (*Panulirus homarus*) Using Smart Lobster Culture

**Nury Nurmalasari*[1], Rita Rostika[2], Nora Akbarsyah[1], Irfan Zidni[2]**

[1]Department of Tropical Marine Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Indonesia
[2]Department of Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Indonesia

*Correspondence Author: nury21001@mail.unpad.ac.id

Submitted: 24 July 2025 Revised: 04 September 2025 Accepted: 27 September 2025

**Keywords:**
Food Habits; Growth; Natural Feed; *Panulirus homarus*; Smart Lobster Culture

***ABSTRACT***

This study aimed to evaluate the effects of different types of natural feed on the growth performance and feeding habits of green lobsters (*Panulirus homarus*) using Smart Lobster Culture technology in floating net cages in Pangandaran Regency. The research was conducted over a 60-day cultivation period from February to April 2025. A completely randomized design (CRD) was used with four treatments A: 100% anchovy, B: 80% anchovy, C: 100% rebon, and D: 80% rebon each with four replications. The parameters observed included length and weight growth, survival rate, length percentage per harvest (LPH), efficiency of protein production (EPP), feeding behavior, and water quality. The results showed that the 80% anchovy diet (Treatment B) produced the best outcomes, with an average length increase of 5.08 ± 0.09 cm, a weight gain of 145.13 ± 5.78 g, LPH of 2.09 ± 0.08%, survival rate of ± 98%, EPP of 13.28 ± 0.47%, and a tendency for more active nocturnal feeding behavior with a higher preference for anchovy. Sufficient feed and shelter availability effectively suppressed cannibalism. Water quality parameters remained within optimal ranges: temperature 27.6–29.3 °C, pH 8.1–8.4, salinity 34–36 ppt, and dissolved oxygen (DO) 6.10–8.30 mg/L.

## INTRODUCTION

Lobsters (*Panulirus* sp.) are high-value fishery commodities that are in strong demand in both domestic and international markets (Munandar *et al.,* 2018). Despite this growing demand, lobster production in Indonesia is still predominantly sourced from wild catches (Budiyanto, 2021). According to data from the Ministry of Marine Affairs and Fisheries (KKP, 2022), wild-caught lobster production in 2021 reached only 8,719 tons, valued at over IDR 2.8 trillion—representing a decline of more than 50% compared to the 17,600 tons recorded in 2017. In contrast, lobster aquaculture contributed only approximately 433 tons in 2023, highlighting its minimal role in meeting market demand. To address the increasing demand, aquaculture is essential for mitigating the depletion of wild lobster stocks and habitat degradation (Amira, 2021).

Feed is a key factor influencing the growth performance and overall success of lobster aquaculture. Lobster growth is particularly affected by the adequacy of calcium and phosphorus intake from the diet (Faqih *et al.,* 2022). These two minerals play essential roles in facilitating the molting process and in the hardening of the exoskeleton (Arsono *et al.,* 2010). Mineral deficiencies frequently occur due to the use of low-quality fish as the primary feed source, as the calcium and phosphorus content in fish waste is relatively low—calcium ranges from 12.9 mg/100 g to 49.52 mg/100 g, and phosphorus ranges from 4.20 mg/100 g to 6.78 mg/100 g (Talat *et al.,* 2005). Recent research by Rostika *et al.,* (2024) indicates that natural feed such as anchovies (*Stolephorus* sp.) and rebon (*Acetes* sp.) contains higher levels of calcium and phosphorus, which can better support the molting process and promote optimal lobster growth.

Feed consumption efficiency is another critical factor influencing the success of lobster farming. As nocturnal animals and active hunters, lobsters exhibit a characteristic feeding behavior: they swim toward food sources using their walking legs, grasp the food with their claws, carry it to a secure location, and then consume it (Lubis *et al.,* 2024). Despite its importance, information regarding the feeding habits of farmed green lobsters remains limited. Nonetheless, a comprehensive understanding of these behaviors is essential for developing efficient feeding strategies in aquaculture systems. In line with the advancements of the Fourth Industrial Revolution, technologies such as the Internet of Things (IoT) are increasingly being applied in the fisheries sector, including in the management of lobster aquaculture.

The novelty of this research lies in the implementation of IoT-based monitoring technology through the Smart Lobster Culture system to observe and analyze the feeding habits of green lobsters. Unlike conventional methods that rely solely on manual observation, this technology allows for the real-time collection of data on both feeding behavior and environmental parameters, resulting in more accurate and comprehensive insights. By integrating artificial intelligence (AI) with the use of natural feed, this study introduces a modern and innovative approach to lobster aquaculture, which has not been extensively explored in previous research.

## LITERATURE REVIEW

Green lobsters (*Panulirus homarus*) are a species of spiny lobster commonly found in shallow rocky areas with sandy coral substrates, particularly in the Indian Ocean and Indonesian waters (Milton, 2012). These lobsters are nocturnal organisms that actively forage at night (Kintani *et al.,* 2020). According to Mashai *et al.,* (2011), their natural diet in the wild consists of mollusks, crustaceans, polychaetes, and other benthic organisms rich in calcium and phosphorus—

minerals essential for the formation of a new exoskeleton following molting. A deficiency in calcium and phosphorus not only impedes growth but also increases the risk of exoskeleton hardening failure, leaving lobsters more vulnerable to cannibalism by larger individuals or those that have already completed the molting process (Suprihadi *et al.,* 2023).

Cannibalism is one of the leading causes of mortality in intensive lobster farming, particularly during the molting phase, when lobsters become soft and highly vulnerable to attacks by other individuals (Hakim, 2008). The provision of appropriate natural feed plays a critical role in reducing cannibalistic behavior, as sufficient nutritional intake can minimize aggressive tendencies among lobsters (Purnamaningtyas S Nurfiani, 2017). Anchovies (*Stolephorus* sp.) are known for their high nutritional value, containing approximately 70% protein (dry matter), along with 500 mg of calcium and 500 mg of phosphorus per 100 g—adequately fulfilling the nutritional requirements of lobsters (Gunawan, 2003, as cited in Tob, 2019). In addition, anchovies also provide essential micronutrients such as selenium and iron (Amrillah *et al.,* 2023).

Rebon (*Acetes* sp.) contain essential nutrients that support lobster growth, including 16.2 g of protein, 757 mg of calcium, and 292 mg of phosphorus per 100 g of material (Directorate of Nutrition, Ministry of Health, 1992; Anton *et al.,* 2021). Haetami *et al.,* (2025) demonstrated that feeding lobsters with rebon can improve their survival rate due to the high mineral content, which supports the molting process and consequently reduces the risk of cannibalism associated with exoskeleton hardening failure.

## METHOD

This study was conducted from February to April 2025 in the coastal waters of the East Coast, Pangandaran Regency, West Java. Lobster farming was carried out using M-sized submerged cages installed within floating net cages (KJA). The cage had a diameter of 96 cm and a height of 89 cm. The equipment used in this study included M-sized cages, the Smart Lobster Culture system, buoys, a digital scale (0.1 g resolution), millimeter blocks, a dissolved oxygen (DO) meter, a pH meter, a refractometer, a thermometer, ropes, nets, and containers. The materials used included green lobsters (*Panulirus homarus*) weighing between 50–70 g as test animals, with anchovies (*Stolephorus* sp.) and rebon (*Acetes* sp.) provided as feed for the treatments.

The study employed an experimental method using a completely randomized design (CRD) consisting of four treatments with four replications each. The treatments involved the use of different types and proportions of natural feed, as follows:

P1: 100% anchovy (*Stolephorus* sp.) as natural feed
P2: 80% anchovy (*Stolephorus* sp.) as natural feed

P3: 100% rebon (*Acetes* sp.) as natural feed
P4: 80% rebon (*Acetes* sp.) as natural feed

Prior to use, the cages were cleaned of algae and barnacles, then secured to floats with ropes at a depth of 2 meters. Each cage was equipped with a top cover to prevent lobsters from escaping and was made using HDPE nets with a mesh size of 4 mm. A depth of 2 meters was selected due to its relatively stable temperature, moderate wave conditions, and suitability for lobster growth (Rostika *et al.,* 2022; Mustafa, 2013). Lobsters were stocked in the afternoon to minimize stress from high temperatures (Saragih *et al.,* 2019), with a total of 100 individuals weighing 70–90 grams and a stocking density of 25 lobsters per cage (Rostika *et al.,* 2024). The lobsters underwent a two-day acclimatization period to adapt to the environment before the cages were submerged.

Lobster maintenance was carried out for 60 days, with growth measurements conducted every 10 days, following the method of Syahrizal *et al.,* (2016). The observed parameters included absolute length growth, absolute weight gain, survival rate, and feed efficiency. In addition, water quality parameters—such as temperature, pH, dissolved oxygen (DO), salinity, and turbidity—were measured every 10 days to ensure optimal environmental conditions (Sinaga *et al.,* 2021). Lobsters were fed once daily in the afternoon at a feeding rate of 20% of the total biomass in each cage. The feed used corresponded to the respective treatments, consisting of rebon rebon (*Acetes* sp.) and anchovies (*Stolephorus* sp.), which were administered through a feeding funnel to allow gradual entry of feed into the cages (KKP, 2021).

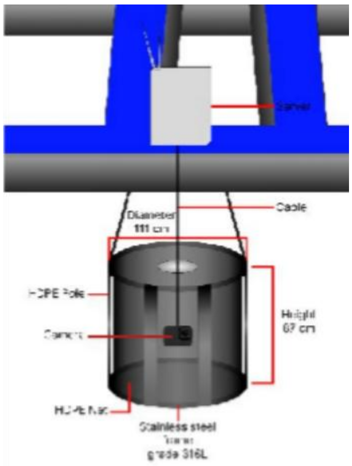



Figure 1. Smart Lobster Culture

Length measurements were performed using a millimeter block with 1 mm precision, while weight measurements were conducted using a digital scale with an accuracy of 0.1 g. Samples were collected from 20% of the lobster population in each cage, following the method described by Rostika *et al.,* (2024). Lobster feeding behavior was observed using the Smart Lobster Culture system (Figure 1), an IoT-based monitoring technology that utilizes waterproof cameras installed in each cage within the floating net pen. These cameras recorded real-time feeding activity for six hours post-feeding.

**Observation Parameters**

**Absolute Length Growth**

According to Effendie (2002), absolute length growth can be calculated using the following formula:

$$G = Pt - P0$$

Information:

G = Absolute length growth (cm)
Pt = Average length of seeds at the end of the study (cm)
P0 = Length Average seeds at the beginning of the study (cm)

**Absolute Weight Growth**

According to Effendie (1997), absolute weight growth can be calculated using the following formula:

$$W = Wt - W0$$

Information:

W = Absolute weight growth rate (g)
Wt = Average weight of seeds at the end of the study (g)
W0 = Average weight of seeds at the beginning of the study (g)

**Survival Rate**

According to Effendie (2002), the survival value can be calculated using the following formula:

$$SR = \frac{Nt}{N0} x\ 100\%$$

Information:

SR = Survival rate (%)
Nt = Number of test fish individuals at the end of rearing (tail)
N0 = Number of test fish individuals at the beginning of rearing (tail)

**Daily Growth Rate (LPH)**

The calculation of the daily growth rate uses the formula put forward by Effendie (1997) as follows:

$$G = \frac{lnWt - lnWo}{t} x\ 100\%$$

Information:

G = Daily growth rate (%)
Wt = Average weight of fish at the end of rearing (tail)

W0 = Average weight of fish at the beginning of rearing (tail)
t = Length of maintenance time (days)

**Feeding Efficiency (EPP)**

The efficiency of feed utilization is calculated through the formula according to Iskandar and Elrifadah (2015) as follows:

$$EPP = \frac{Wt - Wo}{F} x\ 100\%$$

Information:
EPP = Feeding Efficiency (%)
F = Number of feeds given during the study (g)
Wt = Average weight of seeds at the end of the study (g)
W0 = Average weight of seeds at the beginning of the study (g)

**Food Habits**

Food preference refers to the type of feed most favored by lobsters among several options provided. Observations were conducted to determine which feed was consumed more rapidly, based on its type, texture, and size (Makasangil *et al.,* 2017). Feeding activity patterns defined as the periods when lobsters are actively searching for and consuming feed were also observed, particularly to compare behavioral differences between day and night. Understanding these patterns is essential for determining optimal feeding times to support growth and minimize the risk of cannibalism.

**Water Quality**

Water quality management in the floating net cages was carried out by cleaning the enclosures of accumulated feed residues and waste prior to feeding. The water quality parameters measured included temperature, pH, salinity, and dissolved oxygen (DO). The measurement of these parameters referred to the standards outlined in SNI 8116:2015.

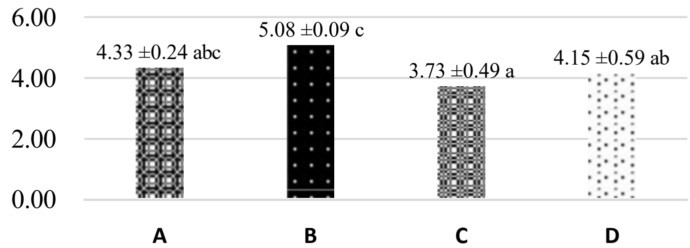
**Data Analysis**

Growth data were analyzed using analysis of variance (ANOVA) with an F-test at a 5% significance level to determine the effect of each treatment. If significant differences were found, Duncan's Multiple Range Test (DMRT) was conducted at a 95% confidence level to compare treatment means. Water quality and feeding habit data were analyzed descriptively based on observational studies, supported by relevant data and literature.

## RESULT AND DISCUSSION

**Absolute Length Growth**

The absolute length growth of lobsters was obtained by measuring the initial and final average lengths of the lobsters over a 60-day period (Rostika *et al.,* 2024). The average absolute length growth rate of green lobsters during the 60-day study period is presented in Figure 2.




Treatment: A (100% anchovies), B (80% anchovies), C (100% rebon), D (80% rebon)

Figure 2. Absolute Length Growth Rate

The results showed that natural anchovy feed particularly at the 80% composition—was more effective in enhancing the growth rate of green lobsters compared to rebon feed. This finding is consistent with the study by Rostika *et al.,* (2024), which reported that feeding green lobsters with 100% anchovy feed resulted in the highest length growth of 6.30 cm. The higher growth performance observed in this study is attributed to the calcium content of anchovies, which meets the nutritional requirements necessary for green lobster development. In addition to feed composition, lobster growth is also influenced by feed quality and quantity, the age of the lobster, and environmental conditions such as water quality (Mulqan *et al.,* 2017).

The amount of feed provided must correspond to the nutritional requirements of the lobsters. If the feed quantity is below the required level, it will only be sufficient to maintain body condition without supporting growth. Conversely, overfeeding can result in uneaten feed accumulating in the rearing environment, leading to decomposition and water quality deterioration (Lampster *et al.,* 2001). Feeding at 100% resulted in lower growth rates compared to 80% feeding due to the higher amount of feed provided. Excessive feed increases metabolic waste and produces higher concentrations of ammonia. In marine aquaculture systems, the maximum permissible concentration of free ammonia is 0.1 ppm (Kordi, 2005). If the ammonia concentration exceeds this threshold, it can negatively affect the survival and health of cultured organisms.

**Absolute Weight Growth**

According to Zhufadillah *et al.,* (2018), absolute weight growth is defined as the difference between the final and initial body weights. Ilhamdi and Harahap (2020) also noted that growth rate reflects the average increase in body size over time. Based on observation results, the average absolute weight growth of green lobsters is presented in Figure 3.

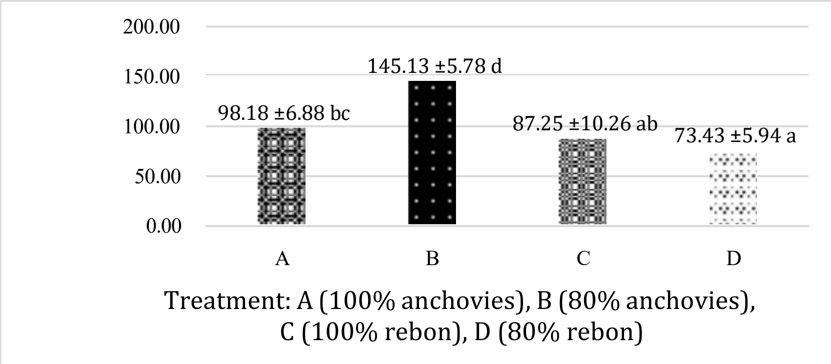



Figure 3. Absolute Weight Growth Rate

The results showed that anchovy feed, both at 80% and 100% concentrations, tended to support greater weight growth in green lobsters compared to rebon feed. This is likely due to the more complete and balanced nutritional content of anchovies. As stated by the Ministry of Health (2005), animal-based protein sources such as fish contain essential amino acids that are crucial for the growth of aquatic organisms. These findings are further supported by the study of Rostika *et al.,* (2024), which reported that feeding green lobsters with 100% anchovy feed resulted in the highest absolute weight gain of 116.63 g. This confirms that anchovies are an efficient and optimal feed source for promoting weight growth performance in green lobsters.

Green lobster cultivation with anchovy feed in this study (treatment B) resulted in an absolute weight growth rate of 145.13 ± 5.78 g, significantly higher than the previous study, which reported a weight growth value of 116.63 grams in green lobster cultivation with 100% anchovy feed. This is because the lobsters utilized the feed more efficiently compared to the previous study. As stated by Makasangkil *et al.,* (2017), marine lobsters require feed with a significant amount of animal protein to meet their nutritional needs.

**Daily Growth Rate**

The daily growth rate (DGR) is the percentage increase in the daily weight of an organism calculated during the study period (Balqis S Isma 2021). This growth is influenced by various factors, including cannibalism, environmental conditions, and the quality of feed given to lobsters (Timumun *et al.,* 2022). Among these factors, feed plays an important role because it is the main source of energy for lobsters. The average daily growth rate of green lobsters during the study can be seen in Figure 4.

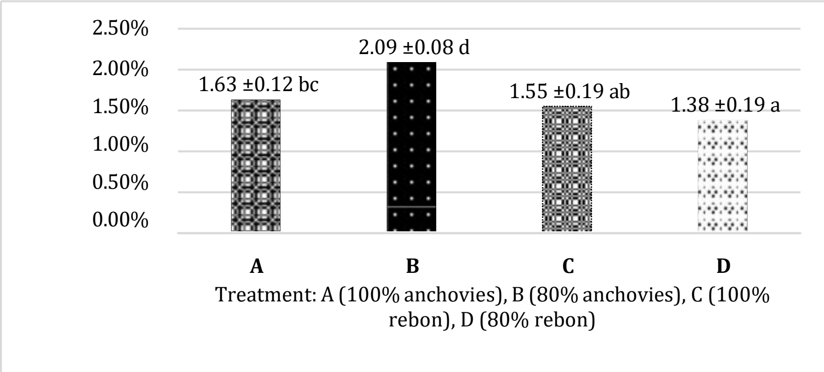



Figure 4. Daily Growth Rate

The daily growth rate in each treatment increased. This increase was due to the influence and effectiveness of feed performance on the body. Treatment B had the best daily growth rate. This was because the timing and frequency of feeding were appropriate and in line with the growth requirements of lobsters. According to Rihardi *et al.,* (2013), in aquaculture activities, the frequency of feed administration is very important to consider because it will affect the amount of feed consumed, feed efficiency, and the potential for environmental pollution. Environmental pollution will affect health and survival. According to Kordi (2010), feeding frequency refers to the number of times feed is provided in a day, which can be once, twice, three times, four times, five times, or more frequently. Lobsters are nocturnal creatures, particularly active during the night, especially when foraging for food. In line with the frequency used in this study, feed is provided once in the afternoon based on the characteristics of lobsters.

Treatment A had the second highest effect after treatment B. This is because both treatments had high nutritional content, especially calcium and phosphorus, but differed in feed composition (Rostika *et al.,* 2024). Anchovies are a source of insoluble calcium that is stable in water (Litaay *et al.,* 2021). Meanwhile, treatments C and D have the lowest values because the feed does not sink, resulting in ineffective feed consumption (Sholichin *et al.,* 2012).

**Survival rate**

Survival rate is the ratio of the number of lobsters that survive from the beginning to the end of the study. A higher percentage indicates that more organisms survive at the end of the cultivation period (Slamet *et al.,* 2023). Figure 5 shows the average survival rate of green lobsters observed during a 60-day cultivation period.

The survival rate obtained can be categorized as good because its value exceeds 70%. According to Widigdo (2013), the survival rate (SR) is considered good if it is above 70%, while the 50%–60% category or even below 50% is considered poor. The high survival rate is likely influenced by various factors, such as the biological characteristics of green lobsters, sufficient feed availability, and supportive water quality, which collectively play a crucial role in maintaining the survival of green lobsters during the cultivation process.

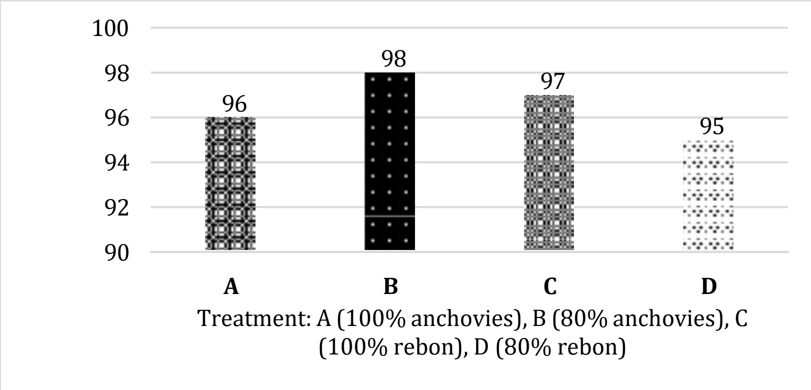



Figure 5. Survival rate

Feeding is also one of the factors that can determine the survival rate of organisms. This is in line with Herlina's (2016) opinion, who states that feeding with sufficient quality and quantity, as well as good environmental conditions, can support the survival of cultivated biota. A similar view is expressed by Rihardi *et al.,* (2013), who state that high survival rates are due to the fact that the amount and timing of feeding, as well as water quality conditions during maintenance, do not act as limiting factors for lobster survival. Feeding with the appropriate amount and frequency will support growth and prevent cannibalism among lobsters.

Lobsters in growth also often experience molting, which triggers cannibalism from other lobsters, causing them to die from being eaten. In line with Nugraha *et al.,* (2019), who stated that cannibalism occurring in test biota and a lack of food consumption resulted in the test animals being in a state of stress and hunger. Stressed lobsters may be triggered to molt, and during this period, their shells become extremely soft and weak for several days. Hungry lobsters will immediately prey on individuals undergoing molting.

**Feed Efficiency**

Feed efficiency values indicate the percentage of feed utilized by lobsters for growth compared to the amount of feed utilized for lobster growth (Anggraini *et al.,* 2018). The higher the feed efficiency value, the greater the utilization of feed provided for growth (Iskandar, 2015). The average feed efficiency of green lobsters during the 60-day study can be seen in Figure 6.

Treatment B in this study showed the highest value of 13.28%. This is consistent with the study by Anggraini *et al.,* (2018), which reported a feed efficiency of 18.99% in green lobsters fed with anchovy feed. This is further supported by the findings of Utama *et al.,* (2023), who obtained the best feed efficiency value of 15.42% with fish feed. This may occur because the feed provided to lobsters aligns with their nutritional needs, particularly calcium and phosphorus, and is consistent with their feeding habits and characteristics, thereby enhancing feed efficiency.

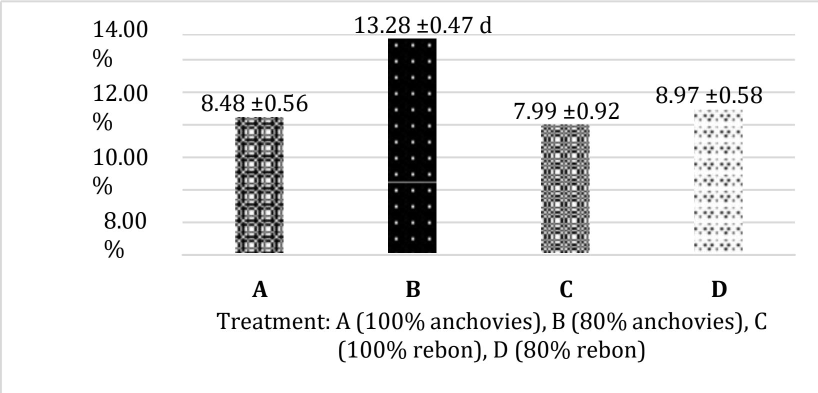



Figure 6. Feed Efficiency

The use of anchovy feed is believed to be optimally utilized by lobsters due to its complete nutritional content, particularly minerals such as calcium and phosphorus, each amounting to 500 mg (DepKes, 2005). These mineral contents are considered capable of meeting the nutritional requirements needed to support the growth of green lobsters. This statement aligns with the opinion of Gallagher *et al.,* (1978), who recommended a calcium-to-phosphorus ratio of 1:1 for the growth of American lobsters.

**Food Habits**

Observations of the food habits of green lobsters (*Panulirus homarus*) conducted using the Smart Lobster Culture system show that these lobsters are opportunistic omnivores. This means that lobsters are able to utilize various types of natural feed available in the cultivation environment (Rostika *et al.,* 2025). This is important to support the growth and survival of lobsters, especially during the juvenile phase when they are prone to stress and cannibalism.

Based on observations obtained from Smart Lobster Culture recordings, lobsters show a preference for several types of natural feed, including mollusks, small fish, small crustaceans, and organic detritus found at the bottom of the water. The two types of natural feed used in this study, anchovies and rebon, were both favored by lobsters, as indicated by the relatively short response time after the feed was provided in the floating net cages.

**Lobster Feeding Behavior**

The feeding behavior of green lobsters is observed to be more dominant at night, indicating the nocturnal nature of lobsters (Lubis *et al.,* 2024). Lobster feeding activity begins with an orientation phase, during which lobsters actively move their antennae to detect the presence of food around them. After that, the lobster enters the approach phase and begins to use its walking legs (pereiopoda) and claws to grab food.

After successfully grasping the food, the lobster will break it down into smaller pieces using its claws and front legs. The pieces of food that are the right size are then carried to the mouth using the maxillipeds (jaw legs), then chewed and swallowed. This behavior shows the complex coordination of the lobster's body movements during the feeding process.

**The Effect of Feed Availability**

Feed availability and shelter have a significant effect on lobster feeding behavior and cannibalism rates. Under conditions where feed is provided in sufficient and even amounts, cannibalism tends to be lower because lobsters do not attack each other to obtain food sources. Conversely, when feed availability is limited or shelter is inadequate, lobsters become more aggressive, triggering cannibalism, which can lead to increased mortality rates in the rearing tank (Sopandi *et al.,* 2023).

**Feeding Activity Patterns**

Based on observations during the study, lobster feeding activity tends to increase during the night, between 6:00 p.m. and 10:00 p.m. This is consistent with the natural behavior of lobsters, which are active in search of food at night to avoid predators and adapt to a darker environment. Meanwhile, during the day, lobsters more often hide in the substrate provided in the cages, showing minimal feeding activity (Lubis *et al.,* 2024).

**Implications for Cultivation Management**

This data on lobster feeding habits provides important information for the design of cultivation management, particularly in relation to feeding times and quantities. It is recommended that feeding be carried out in the afternoon to evening, close to the lobsters' active feeding period, so that feed consumption efficiency can be improved. Additionally, providing adequate shelter within the net pen is essential to ensure lobsters have sufficient hiding space, thereby reducing aggressive interactions that could lead to cannibalism.

To support these observations, video documentation of lobster feeding behavior was recorded using an underwater CCTV system installed on the floating net pen. The video can be accessed via the following link: https://shrturl.app/a7W_7c. This documentation shows in detail the process of lobsters detecting, grabbing, breaking, and consuming the natural food provided.

**Water Quality**

The success of aquaculture is largely determined by the quality of the water medium, as water quality has a significant impact on the growth of aquatic organisms. The water quality parameters observed during aquaculture in floating net cages include temperature, salinity, pH, and dissolved oxygen (DO). In general, the water quality parameters obtained are still within the standard limits for rebon farming (Table 1).

**Table 1. Water Quality Parameters in Floating Net Cages**

| Parameter | Results | Quality Standards (SNI 8116:2015) |
|---|---|---|
| Temperature | 27.6-29.3°C | 27–32 °C |
| pH | 8,1-8,4 | 8,0–8,5 |
| Salinity | 34 – 36 ppt | 34–36 ppt |
| Dissolved oxygen | 6,10 – 8,30 mg/L | ≥ 5 mg/L |

Based on the results of water quality parameter measurements presented in Table 1, all temperature, pH, DO, and salinity values during the maintenance period were within the range specified in the water quality standards according to SNI 8116:2015, indicating that the maintenance medium conditions supported the survival and optimal growth of green lobsters.

## CONCLUSION

This study shows that different natural feeds have a significant effect on the growth of green lobsters in floating net cages. The treatment using 80% anchovy feed resulted in the best growth, with an absolute length of 5.08±0.09 cm, weight of 145.13±5.78 g, LPH of 2.09±0.08%, and EPP of 13.28±0.47%. Lobsters are active feeders at night with a higher preference for anchovies, and adequate feed availability and shelter reduce cannibalism. Water quality remained stable within optimal ranges throughout the study: temperature 27.6–29.3°C, pH 8.1–8.4, salinity 34–36 ppt, and dissolved oxygen (DO) 6.10–8.30 mg/L.

## ACKNOWLEDGEMENT

Thank you to Prof. Dr. Ir. Rita Rostika, MP., and her team for generously providing the facilities and for their continuous help and guidance during the research process, which contributed greatly to the success of this study.

## REFERENCES

Amira, I. (2021). *Sistem Pengawasan Dinas Kelautan dan Perikanan Kabupaten Simeulue terhadap Praktik Perdagangan Benur Lobster dalam Perspektif Al-Hisbah* (Doctoral dissertation, UIN Ar-raniry).

Amrillah, T. A., Sentanu, I. G. E. N., Andriani, Y., S Fadjar, M. (2023). Pengaruh penambahan tepung ikan teri (Stolephorus sp.) terhadap performa pertumbuhan ikan nila (*Oreochromis niloticus*). *Journal of Aquaculture and Fish Health*, 12(1), 25–34.

Anggraini, W., Abidin, Z., S Waspodo, S. (2018). Pengaruh pemberian pakan keong mas terhadap pertumbuhan dan kelangsungan hidup lobster pasir (*Panulirus homarus*). *Jurnal Perikanan Unram*, 8(2), 20–29.

Anton, S., Bukhari, A., Baso, A., Erika, K., S Syarif, I. (2021). Analisis Proksimat, Mineral, dan Vitamin pada Produk Diversifikasi Udang Rebon sebagai Produk Lokal Indonesia: Makanan Tambahan untuk Anak Gizi Buruk. *Jurnal Ilmu Kedokteran Makedonia Akses Terbuka.*

Arsono, A. Y., Rustadi, R., S Triyatmo, B. (2010). Pengaruh Konsentrasi Kapur (CaCO3) Terhadap Pertumbuhan Lobster Air Tawar (*Cherax quadricarinatus*). *Jurnal Perikanan Universitas Gadjah Mada*, 12(1), 28-34.

Balqis, A. F., S Isma, I. R. (2021). Effect of Different Natural Feeds Containing Calcium and Phosphorus on the Growth Rate of Sand Lobster (*Panulirus homarus*) in Floating Net Cages. *Return Publisher*, 1–8.

Budiyanto, B. (2021). Socio-Spatial Approach to Cultivation of Lobster in the Ekas Bay Area, Lombok, West Nusa Tenggara. *Journal of Tropical Fisheries Management*, 5(2), 121-133.

Direktorat Gizi Departemen Kesehatan. (1992). *Kandungan gizi bahan makanan Indonesia*. Jakarta: Departemen Kesehatan Republik Indonesia.

Direktorat Gizi Departemen Kesehatan. (2005). *Tabel komposisi pangan Indonesia (6th ed.).* Jakarta: Kementerian Kesehatan.

Effendie, M. I. (1997). *Biologi Perikanan*. Yayasan Penebar Swadaya.

Effendie, M. I. (2002). *Biologi Perikanan*. Yogyakarta: Yayasan Pustaka Nusatama.

Faqih, A. R., Anitasari, S., S Pratama, A. M. (2022). *Prospek Pembenihan dan Budidaya Lobster Kipas beserta Pengelolaannya pada Berbagai Belahan Dunia*. Media Nusa Creative (MNC Publishing).

Gallagher, M. L., Brown, W. D., Conklin, C. E., S Sifri, M. 1978. Effects of Varying Calcium Phosphorus Ratios in Diets Fed to Juvenile Lobsters (*Homarus americanus*). *Comparative Biochemistry and Physiology Part A: Physiology*., 60(4), 467-471.

Haetami, K., Maulida, Y., Zidni, I., Utama, M. I. C., S Pasaribu, B. (2025). The use of natural feed for the growth of green lobster (*Panulirus homarus*) in submerged cages in Pangandaran Regency. *AACL Bioflux*, 18(2), 785–795.

Hakim, R. (2008). Kanibalisme pada lobster saat molting: Dampaknya terhadap tingkat kelangsungan hidup. *Jurnal Akuakultur Tropika*, 10(3), 88-95.

Herlina, A. (2016). Pengaruh kualitas pakan dan lingkungan terhadap kelangsungan hidup biota budidaya. *Jurnal Akuakultur Indonesia*, 8(2), 123–130.

Ilhamdi, R., S Harahap, K. S. (2020). The effect of different submerged cage depth on the growth of green lobster (*Panulirus homarus*) in Pangandaran District. *International Journal of Science Research*, 2(9), 2995–3003.

Iskandar, R., S Elrifadah. (2015). Pertumbuhan dan Efisiensi Pakan Ikan Nila (*Oreochromis niloticus*) yang diberi Pakan Buatan Berbasis Kiambang. *Jurnal Ziraa'ah*, 40(1), 18–24.

Kementerian Kelautan dan Perikanan (KKP). (2021). *Pedoman Teknis Budidaya Lobster Pasir (Panulirus homarus) di KJA*. Direktorat Jenderal Perikanan Budidaya. Jakarta.

Kementerian Kelautan dan Perikanan (KKP). 2022. *Statistik Kelautan dan Perikanan Tahun 2022*. Pusat Data dan Informasi. Jakarta.

Kintani, M., Ibrahim, T., S Hermawan, H. (2020). Identifikasi morfologi lobster pasir (*Panulirus homarus*) berdasarkan corak abdomen. *Jurnal Biologi Laut*, 18(2), 65-70.

Kordi, K. M. G. H. (2005). *Pengelolaan kualitas air dalam budidaya perairan*. Rineka Cipta.

Lampster, R. K., King, R. P. V., S Bennett, D. B. (2001). Growth, feeding frequency, protein turnover and amino acid metabolism in European lobster (*Homarus gammarus*). *Journal of the Marine Biological Association of the United Kingdom*, 81(4), 647–653.

Litaay, M., Sumual, H., S Wantasen, E. (2021). Ketersediaan kalsium dan fosfor dalam pakan ikan rucah dan implikasinya terhadap budidaya lobster. *Jurnal Ilmu dan Teknologi Perikanan Tangkap*, 18(1), 45–53.

Lubis, A. S., Efrizal, S Syaifullah, S. (2024). Feeding ecology analysis of sand lobsters (*Panulirus homarus*). *Acta Aquatica: Aquatic Sciences Journal*, 11(1), 1–4.

Makasangkil, L., Salindeho, I. R. N., S Lumenta, C. (2017). Pengaruh perbedaan jenis pakan terhadap pertumbuhan lobster laut, Panulirus versicolor. *e-Journal Budidaya Perairan*, 5(3).

Mashai, M., Tanaka, M., S Motohashi, R. (2011). Feeding habits of *Panulirus Homarus* in the wild and its feeding preference. *Aquatic Biology Journal*, 56(1), 23-35.

Milton, D. (2012). The ecology of lobster habitats: A review of environmental preferences and ecological roles. *Oceanography and Marine Biology*, 50, 210-223.

Mulqan, M., S.A. Rahimi., dan I, Dewiyanti. 2017. Pertumbuhan Dan Kelangsungan Hidup Benih Ikan Nila Gesit (*Oreochromis niloticus*) Pada Sistem Akuaponik Dengan Jenis Tanaman Yang Berbeda. Jurnal Ilmiah Kelautan dan Perikanan

Unsyiah, 2(1): 183-193.

Munandar, R. A., Sarong, M. A., S Edwarsyah, E. (2018). Pengelolaan Perikanan Lobster (*Panulirus* Sp.) Dengan Metode Ecosystem Approach to Fisheries Management Di Kabupaten Simeulue. *Jurnal Perikanan Tropis*, *5*(1), 1-12.

Mustafa, A. (2013). Pengaruh kedalaman terhadap pertumbuhan lobster. *Jurnal Akuakultur Tropis*, 5(2), 75–83.

Nugraha, A., Suryawan, I. W., S Pratama, K. (2019). Effect of water depth on the growth and survival rate of sand lobster (*Panulirus homarus*). *BIO Web of Conferences*, 156, 03012.

Purnamaningtyas, L., S Nufiani, M. (2017). Makanan utama dan sekunder lobster (*Panulirus homarus*) serta kebiasaan makan pada waktu tertentu. *Jurnal Akuakultur Tropika*, 13(2), 121-129.

Rihardi, I., Amir, S., S Abidin, Z. (2013). Pertumbuhan lobster air tawar (*Cherax quadricarinatus*) pada pemberian pakan dengan frekuensi yang berbeda. *Jurnal Perikanan*, 1(2), 28–36.

Rostika, R., Yusuf, M., S Suriadi, D. (2022). Optimasi kedalaman keramba untuk pertumbuhan lobster pasir (*Panulirus homarus*). *Jurnal Perikanan dan Kelautan*, 14(1), 45–52.

Rostika, R., Gumilar, G., Arafi, M., Lestari, A. D., S Andhikawati, R. (2024). Effect of Different Natural Feeds Containing Calcium and Phosphorus on the Growth Rate of Sand Lobster (*Panulirus homarus*) in Floating Net Cages.

Rostika, R., Triyani, D. A., Haetami, K., S Putra, P. D. N. Y. (2024). Effect of Different Natural Feeds Containing Calcium and Phosphorus on The Growth Rate of Sand Lobster (*Panulirus Homarus*) In Floating NET Cages. *Return: Study of Management, Economic and Bussines*, 3(6), 397-408.

Rostika, R., Haetami, K., Khan, A., Pasaribu, B., C.U., M. I., S Wijayanti, L. A. S. (2025). Food habits of green lobster (*Panulirus homarus*) fed with calcium- and phosphorus-rich feed observed using artificial intelligence “Smart Lobster-Culture”. *Journal of Social Research*, 4(3), Article 2464.

Saragih, F. E., Wijaya, R. F., S Hidayat, M. (2019). Budidaya lobster pasir (*Panulirus homarus*). Universitas Airlangga.

Sholichin, M., Wibowo, E. S., S Susanto, H. (2012). Efektivitas pemberian jenis pakan berbeda terhadap pertumbuhan lobster pasir (*Panulirus homarus*). *Jurnal Perikanan dan Kelautan*, 3(2), 87–94.

Sinaga, S. S., Hakim, R., S Wardoyo, B. (2021). Evaluasi kualitas air pada pemeliharaan lobster pasir (*Panulirus homarus*) di keramba jaring apung. *Jurnal Akuakultur Indonesia*, 20(3), 245–252.

Slamet, B., Sudewi, S., Rusdi, I., Haryanti, H., Astuti, N. W., Fahrudin, F., S Giri, N. A. (2023). The survival rate, growth, and health of scalloped spiny lobster, Panulirus homarus (Linnaeus, 1758) in nursery and grow-out in a concrete tank fed with fresh food and three kinds of dry pellet. *Migration Letters*, 20(8), 864–880.

Suprihadi, S., Nurhayati, N., S Handayani, L. (2023). The potential of fishery waste as an alternative source of natural calcium: a review. *Acta Aquatica: Aquatic Sciences Journal*, 10(2), 163-171.

Syahrizal, S., Agus, A., S Rahmawati, N. (2016). Studi pertumbuhan lobster pasir (*Panulirus homarus*) pada sistem pemeliharaan intensif. *Jurnal Perikanan Tropis*, 11(2), 89–97.

Talat, R., Akhter, Y., S Jamil, K. (2005). Nutritive evaluation of edible trash fish: I. Analysis of mineral composition of trash fishes and their utilization. *International Journal of Zoological Research*, 1, 66-69.

Timumun, R., Saragih, E., S Yuliana, S. (2022). Impact of dietary quality and environmental factors on cannibalism and growth performance of marine crustaceans. *Journal of Aquaculture Research*, 22(4), 345–354.

Tob, A. (2019). *Pengaruh penambahan daun bayam merah terhadap sifat organoleptik nugget ikan teri* (Doctoral dissertation, Poltekkes Kemenkes Kupang).

Utama, M. I. C., Rostika, R., Iskandar., Herawati, T., Hatami, K., S Grandiosa, R. (2023). Analysis of different depths and types of feed on the growth of spiny lobster (*Panulirus homarus*) using the Vietnamese cage method in Pantai Timur, Kabupaten Pangandaran. *Asian Journal of Fisheries and Aquatic Research*, 21(2), 55–64.

Widigdo, B. (2013). *Bertambak Udang dengan Teknologi Biocrete*. Kompas Media Nusantara.

Wiyanto, W., S Hartono, S. (2007). Teknik pemberian pakan efisien untuk mencegah kanibalisme pada lobster. Dalam I. Rihardi, S. Amir, S Z. Abidin (Eds.), Pertumbuhan lobster air tawar (hlm. 42).

Zhufadillah, R., Jaya, I. N., S Putri, N. M. (2018). The effect of different submerged cage depth on the growth of green lobster (*Panulirus homarus*) in the East Coast of Pangandaran District. *International Journal of Science Research*, 2(9), 2995–3003.