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Advanced Culture Techniques of *Thalassiosira* sp. as Natural Feed for Pacific Whiteleg Shrimp Larvae (*Litopenaeus vannamei*): A Case Study at Center for Superior Shrimp and Shellfish Broodstock Production (BPIU2K) Karangasem, Bali

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Abstract

The stepwise culture technique of *Thalassiosira* sp., is a method used to produce natural feed for Pacific whiteleg shrimp larvae (*Litopenaeus vannamei*) at BPIU2K Karangasem, Bali. *Thalassiosira* sp., a microalgae species is known for its high nutritional content, making it an ideal natural feed for aquaculture. The objectives are to analyze the influence of various culture conditions on the growth and nutritional quality of *Thalassiosira* sp., assess its impact on the growth performance and survival rates of shrimp larvae, and identify potential challenges and solutions in the culture process. The research also identifies challenges in culturing processes, such as maintaining optimal environmental conditions and ensuring consistent nutrient levels. The results demonstrate the effectiveness of the stepwise culture technique in achieving high-density growth of *Thalassiosira* sp., which positively impacts the growth and survival rate of vannamei shrimp larvae. The culture method involves a stepwise process conducted at the BPIU2K Karangasem, progressing from laboratory scale to intermediate (semi-mass) and mass culture. Results show that plankton growth in Erlenmeyer flasks reached a peak density of 12.3 million cells/ml on the fourth day. Observations during the fieldwork indicated that the highest peak of plankton growth occurred on the fourth day, reaching a density of 13 million cells/ ml. Between the second and sixth days, there was a continuous increase in growth, peaking at 1.8 million cells/ml on the sixth day. The advanced culture techniques for *Thalassiosira* sp. as natural feed for vannamei shrimp larvae (*Litopenaeus vannamei*) at BPIU2K, Karangasem, Bali, has demonstrated effective methods for optimizing plankton growth and quality.

Keywords: natural feed, *Litopenaeus vannamei,* shrimp farming, *Thalassiosira* sp.,

I. INTRODUCTION

Aquaculture is an important sector in global food production, with shrimp farming being one of its most valuable components. Pacific whiteleg shrimp (*Litopenaeus vannamei*), also known as whiteleg shrimp, is among the most widely farmed shrimp species due to its high market demand, fast growth rate, and adaptability to varying environmental conditions (Kumaran *et al.,* 2017). The success of vannamei shrimp farming, especially at the larval stage, is heavily dependent on the availability and quality of nutritious feed. At this critical stage, providing high-quality natural feed is essential to support healthy development, improve survival rates, and enhance overall growth

performance (Radhakrishnan *et al.,* 2020).

Thalassiosira sp., a microalgae species commonly used as natural feed in aquaculture, has gained significant attention for its high nutritional content, which includes proteins, lipids, and essential fatty acids. It is particularly suitable as a feed source for vannamei shrimp larvae due to its appropriate size for larval ingestion and ease of cultivation (Tam *et al.,* 2021). Advanced culture techniques of *Thalassiosira* sp. Integrated f biosecure, scalable, and efficient microalgal cultivation practices from pure isolates to large-scale biomass ensuring a stable, high-quality feed source that supports the sustainability and profitability of *Litopenaeus vannamei* hatchery operations can significantly impact the sustainability and profitability of shrimp farming by ensuring a stable supply of this high-quality feed.

The BPIU2K in Karangasem, Bali, serves as a critical center for research and development in aquaculture practices. Here, the focus is on developing and optimizing the culture techniques for *Thalassiosira* sp. to ensure its maximum nutritional value and availability as feed for vannamei shrimp larvae. Understanding the culture conditions, such as water quality parameters, nutrient requirements, and harvesting methods, is vital to improving the yield and quality of *Thalassiosira* sp.

This study aims to explore and implement advanced culture techniques for *Thalassiosira* sp. to enhance its use as a natural feed for vannamei shrimp larvae at BPIU2K, Karangasem, Bali. The objectives are to analyze the influence of various culture conditions on the growth and nutritional quality of *Thalassiosira* sp., assess its impact on the growth performance and survival rates of shrimp larvae, and identify potential challenges and solutions in the culture process. The findings of this study are expected to contribute to the development of more sustainable and efficient shrimp farming practices, which are essential for meeting the growing global demand for shrimp.

II. MATERIALS AND METHODS

2.1 Preparation and Sterilization

The water used as a medium in the culture of *Thalassiosira* sp. is sourced from seawater. One of the most important activities in culturing is the filtration of the culture medium water. The filtration process begins with pumping the water using a pump and directing it to a double filter. The double filter consists of two types: sand and charcoal. Filtration is carried out to clean impurities and turbidity in the medium water and to minimize harmful particles that can disrupt activities in the field. After filtering the medium water, the sterilization process follows by boiling freshwater until it reaches a rolling boil for sterilizing equipment on a laboratory scale and using chlorine in intermediate-scale tanks. According to Mutia *et al.* (2021), sterilizing the culture medium water is crucial to ensure the success of culturing natural feed. One of the objectives of sterilizing the culture medium is to prevent contamination present in seawater, which could hinder the culture activities from being carried out.

2.2 Sterilization of Culture Medium Water.

In a laboratory scale, the filtered culture medium water is stored in a 300-L fiber tank and then sterilized using Halamid (Chloramine T), which contains approximately 28-30% chlorine. Halamid (Chloramine T) is added at a dose of 10 ppm and allowed to sit for about 24 hours. The water treated with Halamid (Chloramine T) is then transferred to a storage tank, such as a container tank, as preparation for the culture medium.

For the intermediate scale, the water is sterilized using Halamid (Chloramine T) at a dose of 10 ppm for 500 L of water in the morning or afternoon, and then allowed to sit for 24 hours to ensure the chlorine dissolves in the water. After 24 hours, the culture medium water is neutralized using sodium thiosulfate at a dose of 10 ppm. According to Mufidah *et al.* (2017), for intermediate scale, calcium hypochlorite is added at a dose of 5-10 ppm for approximately 450 L of water and allowed to sit for 24 hours. Calcium hypochlorite is added in the morning or afternoon. This is because sufficient sunlight helps accelerate the neutralization process, and in this case, neutralization (calcium hypochlorite) is used to sterilize the culture medium water to be used the following day.

2.3 Sterilization of Culture Equipment

The success of natural feed culture activities is influenced by several factors, one of which is that the equipment used must be clean and sterile. In a laboratory scale, the equipment is thoroughly washed using 75% HCl, dish soap/detergent, and then rinsed with running water. The equipment is first rinsed with freshwater,

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then scrubbed with cleaning soap, rinsed again with running water, and finally sterilized by boiling. For Erlenmeyer flasks (1000 mL), sterilization is performed using an autoclave at 121°C for approximately 1 hour. Sterilization before culturing can be done by soaking aeration tubes, weights, and aeration stones in 5 ppm calcium hypochlorite. After that, the equipment is washed with detergent, rinsed with freshwater, and dried (Mufidah *et al.,* 2017).

2.4 Neutralization of Chlorine Residues

Neutralization of chlorine residues in the culture medium is done using sodium thiosulfate ($Na_2S_2O_3$) solution. For laboratory-scale production, the dosage of sodium thiosulfate is 5-10 ppm. For intermediate and large-scale production, the dosage of sodium thiosulfate in the culture medium is 10 ppm. After this, a chlorine test is performed to determine the chlorine residue content in the water by taking a sample of the water to be tested and adding 1 drop of chlorine test solution, then observing any color change. Water that is neutralized and free of chlorine will not show a color change, whereas water containing chlorine will turn yellow to reddish.

2.5 Methods for Preparing Fertilizers and Vitamins

The preparation of fertilizers at laboratory and intermediate scales has significant differences in both the processes and types of mixtures used. At the laboratory scale, several types of fertilizers and vitamins are used: Fertilizer A, a mixture of phosphate and nitrate; Fertilizer B, a mixture of EDTA and $FeCl_3$; and vitamins. Silicate is also added because these fertilizers have small particle sizes and dissolve easily in water. This particle size facilitates or accelerates the absorption of nutrients by *Thalassiosira* sp. cells. The method for preparing the fertilizers involves weighing each ingredient and adding it to a 1-liter glass tube. Then, 1,000 mL of distilled water is added, and the mixture is stirred until dissolved. The tube is then tightly sealed, autoclaved, cooled, and stored in a refrigerator. After that, it can be used as fertilizer in the culture of *Thalassiosira* sp. The dosage of the fertilizer and vitamin mixture can be seen in the Table 1.

At the intermediate scale, fertilizer preparation is done by weighing the fertilizer materials and then placing them into a plastic bucket. Next, they are dissolved using hot water and stirred until all the materials are thoroughly mixed. The dosages of the materials used in the fertilizer preparation can be seen in the Table 2.

Table 1. Dosage for fertilizer preparation at laboratory scale

Code	Types of Fertilizers	Amount of Materials (g)	Fertilizer Concentration in the Solution (ppm)
A	Phospat	20	20.000
	Nitrat	300	300,000
B	EDTA	8.8	8,750
	FeCl3	6.3	6,250
C	Silicate	44.4	44,400
D	B12/ Cyanobalamin	0.1	100
	B1/Thiamin	1.0	1,000
	B7 Biotin	0.1	100

2.6 Culture Methods

The culture of *Thalassiosira* sp. conducted at the BPIU2K Center for the Production of Superior Shrimp Broodstock and Mollusks, Karangasem, uses a stepwise method that includes laboratory scale, intermediate (semi-mass), and mass-scale cultivation. The laboratory scale begins with pure cultures grown in 1-liter Erlenmeyer flasks with an initial cell density of approximately 1×10^5 cells/mL, followed by transfer to 10-liter carboys at a slightly lower inoculation density of around 5×10^4 cells/mL to allow for exponential

Table 2. Fertilizer dosage for intermediate scale preparation

Code	Types of Fertilizers	Amount of Materials
B	Phospate (g)	150
	Nitrate (g)	1,650
	EDTA (g)	36
	FeCl (g)	9
	Urea Water (g)	180
	FeCl3 (L)	3

growth. These are used to seed the next stage. At the intermediate (semi-mass) scale, cultures are transferred to fiberglass tanks (200–500 L) with initial densities of 2–5 × 10^4 cells/mL, depending on volume and light availability. For the mass-scale production, *Thalassiosira* sp. is cultured in round outdoor ponds (1,000–5,000 L) with an initial density of 1–2 × 10^4 cells/mL. All culture stages were conducted in triplicate (n = 3) to ensure data reliability and reproducibility. The starter cultures used throughout were sourced from Balai Jepara, consisting of high-quality isolated strains of *Thalassiosira* sp. According to Khatimah (2018), this stepwise culture approach, also known as continuous culture, is based on gradually scaling up from small to large volumes to maintain control over culture conditions, minimize contamination, and support consistent biomass production.

During field practice activities at BPIU2K, the room temperature in the laboratory is maintained at 19-21˚C using air conditioning. At this temperature, laboratory-scale culture activities run optimally, and the growth of *Thalassiosira* sp. continues to increase in both quantity and quality. For the intermediate scale, the temperature ranges from 28˚C-30˚C, which is still considered good and optimal. According to Febrinawati *et al. (*2020), the optimal growth temperature for *Thalassiosira* sp. culture activities is not more than 25˚C-30˚C. Meanwhile, according to Sopian *et al. (*2019), the optimal temperature for *Thalassiosira* sp. culture on an intermediate scale is around 30˚C.

The salinity during the cultural activities ranges from 29 to 35 ppt. This range is still considered normal and good for the culture process. This aligns with the statement by Nisa *et al.* (2020), which mentions that *Thalassiosira* sp. can tolerate salinity levels between 25-35 ppt. As for the pH of the *Thalassiosira* sp. plankton culture at BPIU2K, it ranges from 8.0 to 8.5, which can be considered optimal for cultivation activities. According to Febrianti *et al.* (2020), the optimal pH for natural feed culture activities ranges from 7 to 9. Ammonia concentrations were measured once a week throughout the *Thalassiosira* sp. culture period. The collected data were compiled and analyzed descriptively by calculating the range and average values to assess water quality stability. The observed ammonia concentrations ranged from 0.18 to 0.36 mg/L, indicating that the culture environment remained within acceptable limits for microalgal growth. These values are well below the maximum threshold of <1 mg/L as specified in the Ministerial Decree of the Environment (Kepmen LH) No. 51 of 2004, thereby confirming that the culture system operated under favorable conditions. No significant fluctuations were observed, suggesting consistent water quality across the culture period.

III. RESULTS

On Day 1, the initial cell density is approximately 7.8 × 10^6 cells/mL, marking the beginning of the growth phase. The density increases gradually over the next few days, indicating healthy cell division and culture growth: Day 2: ~8.5 × 10^6 cells/mL; Day 3: ~10.2 × 10^6 cells/mL; Day 4: Peak density at ~12.4 × 10^6 cells/mL; On Day 5, the cell density declines to around 10.2 × 10^6 cells/mL, suggesting the culture may have entered the stationary phase, where growth rate slows as nutrients become limited or waste accumulates. By Day 6, the density further decreases to about 8.1 × 10^6 cells/mL, indicating the onset of the decline phase due to factors such as nutrient depletion, light limitation, or waste buildup. The Erlenmeyer flask culture of *Thalassiosira* sp. shows a typical microalgal growth curve: lag phase → exponential phase → stationary phase → decline phase. The optimal harvest time appears to be on Day 4, when the plankton density peaks. Harvesting at this stage ensures maximum biomass yield and quality. The plankton density results in the 1000 mL Erlenmeyer culture at the laboratory scale can be seen in Figure 1.

The Figure 2. Plankton density in carboy (cells/mL) Figure changes in plankton density over a 6-day period. The x-axis represents time in days (1 to 6), while the y-axis shows plankton density in cells/mL, ranging from 0 to 16,000,000 cells/mL. On Day 1, plankton

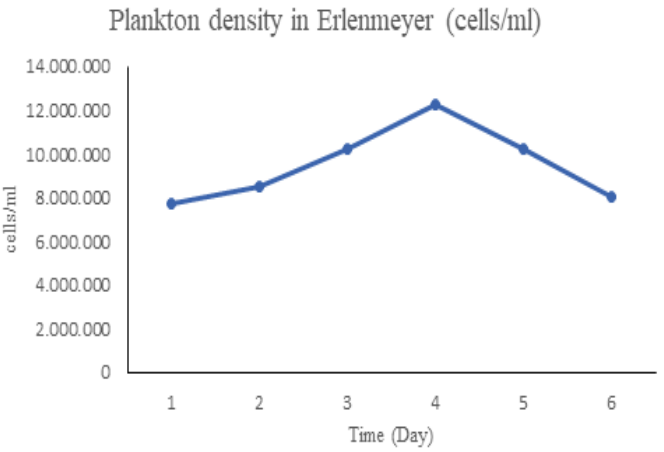

Figure 1. Plankton density in erlenmeyer (cells/mL)

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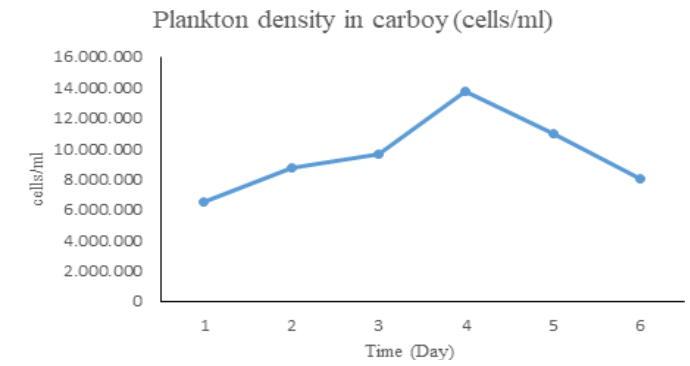

Figure 2. Plankton density in carboy (cells/mL)

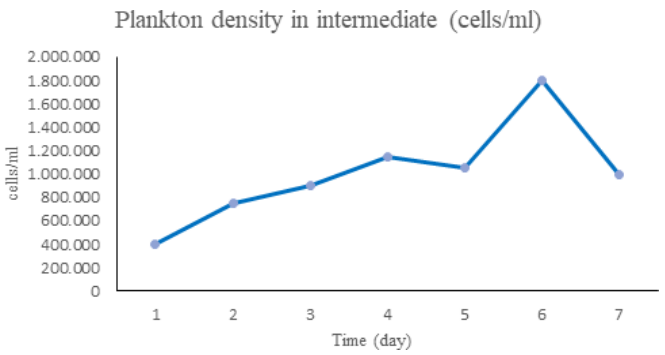

Figure 3. Plankton density in intermediate (cells/mL)

density starts at approximately 6.5 million cells/mL. It increases steadily to around 8.8 million cells/mL on Day 2, and further to about 9.5 million cells/mL on Day 3. The highest density is observed on Day 4, reaching approximately 13.8 million cells/mL. After that, the density decreases, falling to about 11 million cells/mL on Day 5, and further down to 8 million cells/mL on Day 6. Overall, the plankton density shows a growth trend from Day 1 to Day 4, followed by a decline from Day 4 to Day 6. This pattern may indicate a typical bloom cycle, where growth is followed by a depletion phase, possibly due to nutrient limitation or self-shading. The plankton density results in the 10-liter carboy culture at the laboratory scale can be seen in the Figure 2.

3.1 Laboratory Scale (Intermediate)

Figure 3. Plankton density in intermediate (cells/mL) illustrates the changes in plankton density over a 7-day period. The x-axis represents Time (day) from Day 1 to Day 7, while the y-axis shows Plankton density measured in cells/mL, ranging from 0 to 2,000,000 cells/mL. Figure 3. The plankton density begins at around 450,000 cells/mL. The density increases to approximately 750,000 cells/mL on Day 2, then continues to rise slightly to around 900,000 cells/mL on Day 3. On Day 4, the density reaches about 1.1 million cells/mL, followed by a slight decrease to around 1.05 million cells/mL on Day 5. A significant increase is observed on Day 6, peaking at 1.8 million cells/mL, the highest recorded value in this time frame. On Day 7, the density drops to about 1 million cells/mL. In summary, the plankton density in the intermediate container shows a gradual increase from Day 1 to Day 4, a slight dip on Day 5, a sharp peak on Day 6, and a noticeable decline on Day 7. This pattern may suggest fluctuations in environmental conditions or resource availability affecting plankton growth dynamics.The following shows the growth rate of *Thalassiosira* sp. at the intermediate scale (round pond and fiberglass tank), it can be seen in Figure 3.

IV. DISCUSION

4.1 Growth Phases of Thalassiosira sp. at Different Scales

The growth of *Thalassiosira* sp. in laboratory-scale cultures, both in Erlenmeyer flasks and carboys, demonstrated a clear pattern of exponential growth followed by a stationary and decline phase, consistent with findings from previous studies (Sumsanto, 2023; Mufidah, 2017). In the laboratory-scale culture, the peak plankton density occurred on the 4th day, reaching 12.3 million cells/mL in Erlenmeyer flasks and 13 million cells/mL in carboys. This rapid increase in plankton density is attributed to the cells utilizing available nutrients, such as nitrogen compounds, which support rapid division during the exponential phase (Sumsanto, 2023). The transition to the stationary phase on day 5, followed by a decline in density, can be explained by nutrient depletion, changes in environmental factors like light and temperature, and the age of the plankton cells. These observations align with established growth patterns in plankton cultures (Erlangga *et al.,* 2012). On Day 1, the initial cell density in the 1000 mL Erlenmeyer flask culture of *Thalassiosira* sp. was approximately 7.8×10^6 cells/mL, marking the beginning of the exponential growth phase. This phase is characterized by active cell division and a rapid increase in biomass. Over the next few days, the culture exhibited a steady increase in cell density: ~8.5×10^6 cells/mL on Day 2, ~10.2×10^6 cells/mL on Day 3, and reaching a peak of approximately 12.4×10^6 cells/mL on Day 4. This peak indicates the point of maximum cell proliferation and suggests optimal conditions for microalgal growth, such as sufficient nutrient availability, adequate light, and favorable pH and temperature (Borowitzka,

2018). From Day 5 onward, the cell density decreased to ~10.2 × 10^6 cells/mL, suggesting the culture had entered the stationary phase. During this phase, the growth rate slows due to limiting factors such as nutrient exhaustion, light limitation, or accumulation of metabolic waste (Ras *et al.,* 2013). By Day 6, the cell density dropped further to ~8.1 × 10^6 cells/mL, indicating the onset of the decline (death) phase, where cell mortality exceeds cell division. This pattern reflects a typical microalgal growth curve consisting of four phases: lag phase, exponential (log) phase, stationary phase, and decline phase (Chisti, 2007). Based on this growth trend, Day 4 represents the optimal time for harvesting, as cell density peaks and biomass quality are typically highest before metabolic stress affects cell viability. Harvesting at this point maximizes biomass yield and ensures better biochemical composition, which is crucial for downstream applications such as aquaculture feed, biofuel production, or nutraceutical extraction (Mata *et al.,* 2010). The observed growth dynamics are consistent with other studies on diatom cultures under batch cultivation, where peak biomass is often reached within 3–5 days under optimal laboratory conditions.

Figure 2 illustrates the dynamics of plankton density in a 10-liter carboy culture over a 6-day period, reflecting a typical microalgal bloom cycle. The initial plankton density on Day 1 is approximately 6.5 × 10^6 cells/mL, followed by a steady increase to 8.8 × 10^6 cells/mL on Day 2 and 9.5 × 10^6 cells/mL on Day 3. This rising trend indicates an active exponential growth phase, driven by favorable conditions such as adequate nutrient availability, light exposure, and stable environmental parameters (Lananan *et al.,* 2013).

The peak density is reached on Day 4, with a value of around 13.8 × 10^6 cells/mL, suggesting optimal growth conditions and maximum biomass accumulation. However, from Day 5 onward, a noticeable decline in cell density is observed, decreasing to 11 × 10^6 cells/mL, and further to 8 × 10^6 cells/mL by Day 6. This decline phase is likely caused by nutrient depletion, light limitation due to self-shading, or the buildup of inhibitory metabolic byproducts (Borowitzka, 2018; Wang *et al.,* 2013).

This growth pattern is consistent with the classical batch culture lifecycle of microalgae, which typically progresses through four phases: lag, exponential, stationary, and decline. The optimal harvest time for maximizing biomass and quality in such systems is often aligned with the late exponential or early stationary phase—in this case,

Day 4—to ensure high cell viability and nutrient content for downstream applications such as aquaculture feed or biofertilizer. Figure 3 presents the plankton density dynamics of *Thalassiosira* sp. cultured in an intermediate-scale system (such as a round pond or fiberglass tank) over a 7-day period. The culture starts with a relatively low density of approximately 450,000 cells/mL on Day 1, which increases gradually to 750,000 cells/mL on Day 2, and further to 900,000 cells/mL on Day 3, indicating an early exponential growth phase. By Day 4, the cell density reaches about 1.1 million cells/mL, confirming sustained growth under stable conditions (Chinnasamy *et al.,* 2010).

A slight decrease to 1.05 million cells/mL on Day 5 suggests a temporary stress or shift toward the stationary phase, potentially caused by partial nutrient depletion, changes in temperature, or light intensity. Interestingly, on Day 6, the density surges to 1.8 million cells/mL, marking the highest peak in the observation period. This sudden spike may reflect improved environmental conditions or delayed effects of nutrient recycling within the culture system (Ras *et al.,* 2013).

However, by Day 7, the plankton density drops sharply to around 1 million cells/mL, suggesting the onset of the decline phase. This decline could be attributed to factors such as nutrient exhaustion, light limitation due to self-shading, or accumulation of toxic metabolites (Borowitzka, 2018). The fluctuation between Day 5 and Day 7 highlights the sensitivity of large-scale or semi-intensive systems to environmental variability, especially when conditions are not tightly controlled (Zhao *et al.,* 2013). This growth pattern, including the initial lag, exponential rise, peak, and decline, aligns with typical batch culture dynamics seen in microalgal cultivation. Notably, the optimal harvest time appears to be Day 6, when the biomass peaks, offering the highest yield and yield and likely the best nutritional composition.

4.2 Factors Affecting Growth in Intermediate-Scale Cultures

At the intermediate scale, the culture of *Thalassiosira* sp. in 1-ton fiberglass tanks and 10-ton round tanks demonstrated similar growth phases. The initial adaptation phase observed on day 1, with a low plankton density of 300,000 cells/mL, aligns

with Erlangga *et al.* (2012), who describe the lag phase as a period where plankton cells adapt to their new environment before they begin dividing.

Following this phase, the culture entered the exponential phase, with plankton density increasing steadily until day 6, peaking at 1.8 million cells/mL. This exponential growth is indicative of sufficient nutrients and optimal environmental conditions, which are critical in maximizing plankton production (Meritasari *et al.,* 2012).

However, a decline in growth was observed on day 7, with plankton density decreasing from 1.8 million cells/mL to 1.2 million cells/mL, marking the stationary phase. As discussed by Erlangga *et al. (*2021), this phase occurs when plankton growth plateaus due to nutrient depletion and other environmental factors. The decline may have been influenced by external conditions such as heavy rain and cloudy weather, which likely caused fluctuations in water temperature, and possibly insufficient nutrient availability. This phase is crucial, as it indicates the point at which plankton cultures need to be harvested to ensure they are still in a viable, nutrient-rich state for subsequent use in larval feeding.

4.3 Feeding Thalassiosira sp. to Vannamei Shrimp Larvae

The use of *Thalassiosira* sp. as a natural feed for *Litopenaeus vannamei* larvae provides several advantages in terms of nutritional value. As noted in the study, *Thalassiosira* sp. contains 26.1% carbohydrates, 44.5% protein, and 11.8% fat, making it a suitable feed for shrimp larvae, particularly during the zoea to mysis stages. The ability to directly feed plankton from the culture tanks ensures a fresh and continuous supply of nutrients for the larvae, contributing to their growth and survival. The practice of feeding once a day, particularly at the time when the nauplius have transformed into the zoea to mysis stages, ensures that the larvae receive optimal nutritional support at a critical point in their development. This feeding method aligns with Panjaitan *et al. (*2015), who emphasize the importance of providing high-quality natural feed during the early stages of shrimp development. The availability of *Thalassiosira* sp. in the required quantities and its compatibility with the larvae's feeding behavior further strengthens the argument for its use in shrimp aquaculture.

The results of this study suggest that the mass culture of *Thalassiosira* sp. can be an efficient and reliable source of natural feed for *Litopenaeus vannamei* larvae, especially given the high growth rates observed during the exponential phase. Future research could focus on optimizing the culture conditions to prolong the exponential phase and reduce the onset of the stationary phase, which could further enhance productivity. Investigating the impact of different environmental conditions, nutrient sources, and culture techniques could help refine the mass cultivation process, making it even more effective for commercial aquaculture.

Moreover, the integration of biofloc systems in plankton culture could be explored as a way to enhance nutrient recycling and reduce operational costs by utilizing organic waste as a feed source, as discussed in several studies (Avnimelech, 2007; Crab *et al.,* 2010). This could help create more sustainable practices in shrimp farming, where the production of natural feed and the management of plankton cultures are optimized to support larvae growth.

This study confirms that *Thalassiosira* sp. is an effective natural feed for shrimp larvae, with significant growth observed during the exponential phase. The findings also highlight the importance of optimal environmental conditions, nutrient management, and precise harvesting timing for maximizing the efficiency of plankton cultures in aquaculture practices. The results contribute to improving feeding strategies in shrimp farming and pave the way for further research into more sustainable aquaculture practices.

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Moreover, the integration of biofloc systems in plankton culture could be explored as a way to enhance nutrient recycling and reduce operational costs by utilizing organic waste as a feed source, as discussed in several studies (Avnimelech, 2007; Crab *et al.,* 2010). This could help create more sustainable practices in shrimp farming, where the production of natural feed and the management of plankton cultures are optimized to support larvae growth.

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V. CONCLUSION

The advanced culture techniques employed in this study provided an effective and scalable method for producing *Thalassiosira* sp. as a high-quality natural feed for *L. vannamei* larvae. The study's results underscore the importance of a stepwise approach to plankton culture, proper environmental control, and timely harvesting of plankton during the exponential growth phase to ensure maximum nutritional value for the larvae. These findings contribute to improving feeding strategies in shrimp farming and offer valuable insights for enhancing sustainability in aquaculture practices at BPIU2K, Karangasem, Bali.

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