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THE INFLUENCE OF STOCKING DENSITIES ON WHITE SHRIMP (*Litopenaeus vannamei)* REARED USING INTENSIVE SYSTEM: PRODUCTION PERFORMANCE AND WATER QUALITY

Pengaruh Pola Padat Tebar Udang Vaname (*Litopenaeus vannamei*) yang Dipelihara dengan Sistem Intensif: Kinerja Produksi dan Kualitas Air

Liga Insani*, Diklawati Jatayu, I Gede Rezza Mahendra, Made Wisnu Wiyasa, Bayu Kurnianto, Adriansyah

[1]Fish Cultivation Study Program, Jembrana Marine and Fisheries Polytechnic,

Pengambengan Village, Negara District, Jembrana 82112, Bali

*Corresponding Author: liga.insani@gmail.com

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ABSTRACT

The increasing trend of vaname shrimp cultivation production encourages farmers to increase their cultivation production. The success of vaname shrimp cultivation can be seen from the ability to measure the capacity of shrimp biomass in maintenance activities and stocking density patterns based on the maximum capacity of the pond in each plot. The purpose of this study was to analyze vaname shrimp cultivation activities for a period of 2 years (2023-2024) in intensive system ponds based on different stocking density patterns at 140 shrimp/m^2 and 190 shrimp/m^2. This study was carried out for 6 cultivation cycles, each cycle was carried out for 100 days. The results of statistical tests showed that the shrimp stocking density pattern had a significant effect ($p < 0.05$) on biomass, productivity, survival and feed conversion ratio. The average survival rate of 140 shrimp/m^2 stocking density was 85.33%, biomass was 3,327.75 kg, FCR was 1.44 and productivity was 30.8 tons/ha. The average survival rate with a stocking density of 190 shrimp/m^2 was 73.66%, biomass 1,981.87 kg, FCR 1.59 and productivity 12.38 tons/ha. This shows that biomass, SR, and productivity decreased while FCR tended to increase in cultivation with a stocking density of 190 shrimp/m^2. The results of water quality showed an increase in the Total Organic Matter value of 110-250 mg/l at a stocking of 190 shrimp/m^2. This shows that there is an increase in organic matter in the maintenance pond which affects the survival of shrimp in the pond so that it affects the biomass and productivity of whiteleg shrimp. A stocking density of 140 shrimp/m^2 can be recommended for application in intensive whiteleg shrimp cultivation.
Keywords: intensive system, stocking density, water quality, whiteleg shrimp

ABSTRAK

Tren produksi hasil budidaya udang vaname yang semakin meningkat memacu para petambak untuk meningkatkan hasil produksi budidayanya. Keberhasilan budidaya udang vaname salah satunya dapat ditinjau dari kemampuan mengukur kapasitas biomassa udang

pada kegiatan pemeliharaan serta pola padat tebar berdasarkan kapasitas maksimal kolam pada setiap petakan. Tujuan penelitian ini adalah untuk menganalisis kegiatan budidaya udang vaname dengan kurun waktu 2 tahun (2023-2024) pada tambak sistem intensif berdasarkan pola padat tebar yang berbeda di 140 ekor /m^2 dan 190 ekor /m^2. Parameter penelitian meliputi biomassa, tingkat kelangsungan hidup, rasio konversi pakan, dan produktivitas udang vaname selama 6 siklus diolah menggunakan MS. Excel dan dianalisis secara statistik menggunakan T-Test dengan tingkat kepercayaan 95% (a=0.05). Hasil uji statistik menunjukkan bahwa pola padat tebar udang berpengaruh nyata (p < 0,05) terhadap biomassa, produktivitas, kelangsungan hidup serta rasio konversi pakan. Rata-rata tingkat kelangsungan hidup padat tebar 140 ekor/m^2 sebesar 85,33%, biomass sebesar 3.327,75 kg, FCR 1,44 serta produktivitas di 30,8 ton/ha. Rata-rata kelangsungan hidup dengan padat tebar 190 ekor/m^2 sebesar 73,66 %, biomass 1.981,87 kg, FCR 1,59 serta produktivitas 12,38 ton perhektar. Hal ini menunjukkan bahwa biomass, SR, dan produktivitas menurun sedangkan FCR cenderung meningkat pada budidaya dengan padat tebar 190 ekor /m^2. Hasil kualitas air menunjukkan terjadinya peningkatan nilai *Total Organic Matter* sebesar 110-250 mg/l pada tebaran 190 ekor /m^2. Hal ini menunjukkan bahwa terjadi peningkatan bahan organik pada kolam pemeliharaan yang berpengaruh terhadap kelangsungan hidup udang di tambak sehingga berpengaruh terhadap biomassa dan produktivitas udang vaname. Padat tebar 140 ekor/m^2 dapat direkomendasikan untuk diterapkan pada budidaya udang vaname sistem intensif.
Kata Kunci: kualitas air, padat tebar, sistem intensif, udang vaname

INTRODUCTION

Whiteleg shrimp (*Litopenaeus vannamei*) is still a strategic mainstay for efforts to achieve national shrimp production targets (Syah *et al*., 2017). Whiteleg shrimp production continues to be increased to meet domestic and international market needs because it is one of the leading commodities (Zaidy *et al.,* 2021). On the other hand, world whiteleg shrimp production continues to increase every year. Based on data from the Food and Agriculture Organization (FAO), Indonesia is one of the largest producers of cultivated shrimp in the world along with countries in Southeast Asia (Anderson *et al*., 2017). Indonesia is the fourth largest shrimp exporting country with a contribution of 6.6 percent of total world shrimp exports in 2022 (FAO, 2022).

The increasing trend in production of vaname shrimp cultivation has encouraged farmers to increase their cultivation production (Wahyudi *et al.,* 2022). There are several factors that can affect the productivity of vaname shrimp in addition to genetic factors. One of the technical factors includes cultivation patterns, stocking density, use of facilities and infrastructure and pond design (Ariadi *et al.,* 2021). While non-technical factors include water quality conditions, the presence of pests and diseases and a stable cultivation ecosystem (Islam *et al.,* 2014).

Shrimp cultivation with an intensive system pattern needs to be reviewed regarding standard operating procedures and maximum biomass capacity and also the stocking density pattern that has been carried out. It is important to know the maximum biomass capacity in the maintenance pond during cultivation activities. These efforts can be supported by the support of facilities and infrastructure such as water wheels as the need for oxygen supply in vaname shrimp cultivation (Anggakara, 2012). The water wheel is a technology that is able to maintain oxygen needs in shrimp cultivation. In addition to looking at the biomass capacity in the maintenance pond, it is also necessary to pay attention to the carrying capacity of the pond environment, this carrying capacity will decrease along with the increasing age of cultivation, because the older the cultivation period, the greater the burden of cultivation waste produced (Ariadi *et al*., 2019).

The success of vaname shrimp cultivation can be seen from the ability to measure the capacity of shrimp biomass in maintenance activities and stocking density patterns based on the maximum capacity of the pond in each plot. These indicators can be measured through several technical parameters such as Biomass, Survival Rate (SR), Feed Conversion Ratio (FCR) and the maximum capacity of shrimp biomass in an area per square meter.

This research aims to analyze vaname shrimp cultivation activities in 6 production cycles with a period of 2 years (2023-2024) in intensive system ponds based on different stocking density patterns. The target to be achieved from this study is to re-update the standard operating procedures that have been applied so that in the future it can minimize the risk of cultivation failure and can maximize production capacity based on environmental carrying capacity and sustainability in vaname shrimp cultivation activities.

METHODS

Time and Place

This research was conducted for two years in January 2023-November 2024 in Pengambengan Village, Negara District, Jembrana, Bali.

Tools and Materials

The tools used in this study include HDPE pools with an area of 1,600 m2 as many as 2 units per cultivation cycle, 1 HP 1 PHASE waterwheels 6 units in each plot, digital scales, nets, water quality measuring instruments, pumps, generators. The materials used in this study include PL10 vaname shrimp, commercial feed, probiotics, molasses, captain, minerals, multivitamins and adhesives.

Research Procedures

This research was conducted for 6 cultivation cycles, each cycle was carried out for 100 days. Preparation of the container began with cleaning the plot, then filling it with water to a height of 100 cm and continued with the installation of a water wheel. Furthermore, water treatment was carried out by spreading Cupric Sulfate at a dose of 2.5 ppm and TCCA at a dose of 30 ppm. Spreading of $CaCO_3$ captan at a dose of 10 ppm 3 times a week. Commercial probiotic culture at a dose of 0.5 ppm containing Lactobacillus plantarum, Lactobacillus fermentum, Bacillus subtilis and Pseudomonas putida plus 1 ppm molasses (1:2) for 48 hours and spread in the maintenance pond.

Vaname shrimp fry (Post Larva-10) were given artificial feed (commercial) using the Blind Feeding method on DOC 1-30 with a dose of 2-3kg/100 thousand tails. Mansyur and Suwoyo (2012), explained that this program was carried out by providing feed without sampling the weight of the shrimp with a growth target of 2-3 g/tail. The blind feeding method is only carried out for one month or the shrimp reach DOC 30. The goal is to increase the desired amount of shrimp weight (Renitasari *et al.,* 2021).

The next feed program uses the Demand Feeding method. The demand feeding method is a feed program based on checking in the anco with a dose of 1-3% given to DOC 31-harvest with an addition of 5-10% if it runs out and a reduction of 10-30%, if the feed in the anco is still left (Syafaat *et al.,* 2016). The use of feed indicators in the anco can help estimate the level of daily shrimp feed requirements so that feed efficiency can be controlled properly.

The feed given is mixed first with multivitamins, minerals, and pellet adhesives and then given four times a day. Siphoning is carried out starting from DOC 30, in the morning and evening. Water reduction and addition are carried out as much as 5-10% up to DOC 40. Furthermore, water changes are carried out using a flow through system (FTS). The flow through system is a system for continuously flowing water in a certain amount (Wahyudi *et al.,* 2022)

Salinity, temperature, dissolved oxygen, and pH measurements are carried out every day. Measurements of ammonia, nitrite, and nitrate are carried out every ten days using the Salifert Test Kit. Shrimp weight sampling is carried out every seven days.

Research Parameters

The parameters observed during the study consisted of stocking density, biomass, survival rate (SR), feed conversion ratio (FCR), cultivation productivity, and water quality. The formula for density, biomass, SR, FCR, and productivity is as follows:

1. Stocking density

   Stocking density is the number of shrimp per square meter. The calculation of stocking density is done when spreading the fry by counting the number of fry in 1 bag, then multiplying it by all the bags to be spread. The result of the total fry (tail) is divided by the area of the pond (m^2).

2. Biomass

   Biomass is the total weight of live shrimp during the end of the study. Biomass in this study is the total weight of shrimp maintained for 100 days in grams. Shrimp biomass calculation can be done by weighing all the weight of the shrimp.
3. Survival Rate (SR)

   Survival rate is the ratio of the number of individuals alive at the end of maintenance to the initial number. Survival is calculated using the formula (Effendie, 1997):

$$SR = N_t/N_0 \times 100\%$$

Description:

SR = survival rate (%)
Nt = Total number of shrimp at the time of stocking (tail)
N0 = Total number of shrimp at the beginning of maintenance (tail).

4. Feed Conversion Ratio

   The feed conversion ratio is the comparison of the amount of feed given during the study with the weight gain at the end of the study. The feed conversion ratio (FCR) is calculated using the formula according to Djarijah (1995), namely:

$$FCR = F / [(Wt + D) – Wo]$$

Description:
FCR = feed conversion ratio
F = Total weight of feed given during the experiment (g)
Wt = Total biomass of test animals at t (g)
W0 = Total biomass of test animals at the beginning of maintenance (g),
D = Total biomass of test animals that died during the experiment (g)

5. Cultivation productivity is adapted from Wahyudi et al, (2022) with the formula:
   PB = total amount of biomass production results/total volume of cultivation media (tons/ha)

Data Analysis

The research data including biomass, survival rate, feed conversion ratio, and productivity of vaname shrimp for 6 cycles were processed using MS. Excel and analyzed statistically using T-Test with a confidence level of 95% (a=0.05).

RESULT

The results of the study on vaname shrimp cultivation for six cycles, namely within a period of two years (2023-2024) with two different stocking densities (density of 140 fish/m2 and 190 fish/m2) showed significantly different results ($p < 0.05$). The results of statistical tests showed that the shrimp stocking density pattern had a significant effect on biomass, productivity, survival rate and feed conversion ratio.

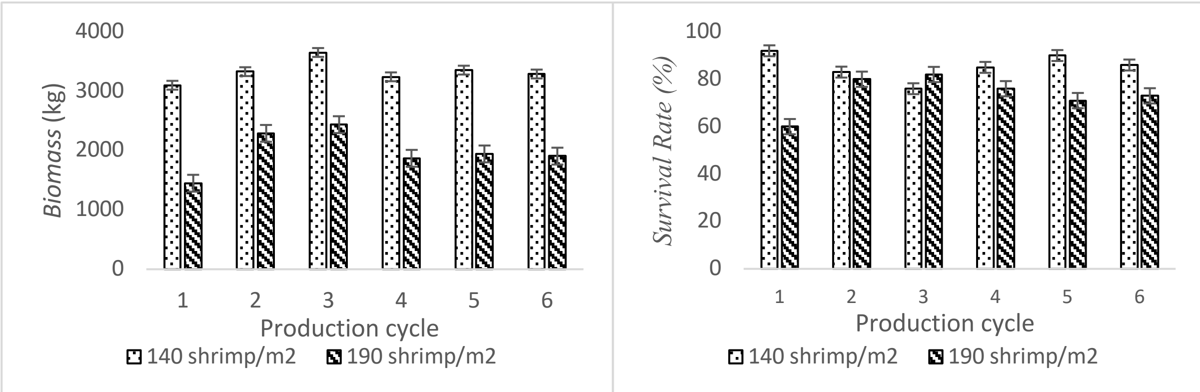

Figure 1. Biomass and Survival Rate of whiteleg shrimp in 6 cultivation cycles with different stocking densities.

Figure 1 shows that the shrimp biomass obtained in different stocking patterns shows that the stocking pattern of 140 fish/m^2 tends to be higher when compared to the stocking density pattern of 190 fish/m^2. The highest biomass was obtained in cycle 3 with a density of 140 fish/m^2 of 3652 kg while the lowest biomass was obtained in cycle 1 with a density of 190 fish/m2 of 1449 kg. The survival rate in shrimp cultivation with a low stocking density pattern of 140 fish/m^2 tends to be higher when compared to the stocking pattern of 190 fish/m^2. The highest survival rate was obtained in cycle 1 with a stocking density of 140 fish/m^2 of 92% while the lowest survival rate was in cycle 1 with a stocking density of 190 fish/m^2 of 60%.

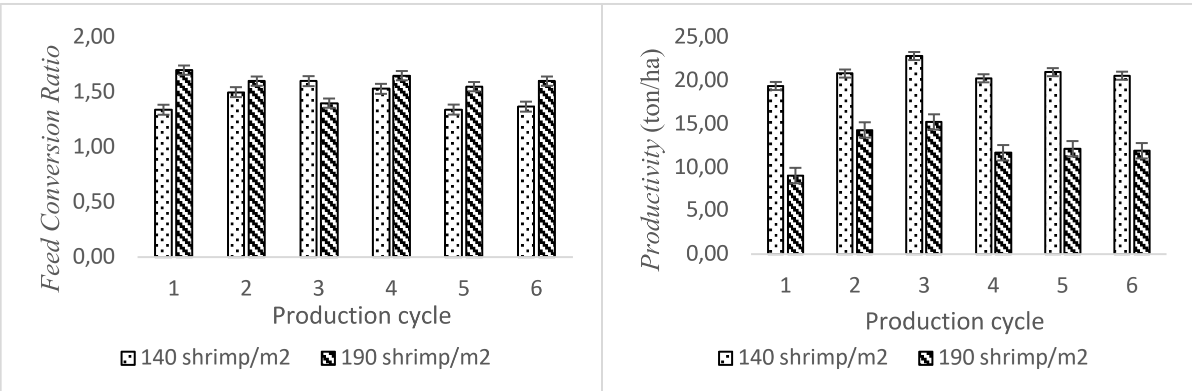

Figure 2. Feed Conversion Ratio and Productivity of vaname shrimp cultivation over a two-year period (2023-2024) with different stocking density patterns.

Based on Figure 2, the highest FCR was obtained at a stocking of 190 fish/m2 in cycle 1 of 2023 of 1.7 while the lowest FCR was obtained with a stocking density of 140 fish/m^2 in cycle 1 of 2023 of 1.34. FCR with a stocking density pattern of 140 fish/m2 tends to be lower and shows good results for the sustainability of shrimp farming activities. In terms of productivity of vaname shrimp per hectare, the highest value was obtained at a stocking of 140 fish/m^2, namely between 19.37 - 20.97 tons/ha, while the lowest productivity was obtained at a stocking of 190 fish/m2, namely between 9.06 - 15 tons/ha. This shows that productivity with the highest stocking density pattern tends to be smaller when compared to the low stocking density pattern. This also correlates with low survival rates, biomass and FCR which tend to be high.

Water Quality

The range of water quality monitoring results shows varying values, but it can be seen that the water quality at low stocking density shows that the water quality is more optimal. The difference is shown in the measurement of water quality parameters such as TOM, Ammonia and vibrio bacteria. TOM in the 190 fish/m^2 stocking pattern tends to be high compared to the 140 fish/m^2 stocking pattern. The same thing is also shown in the Ammonia value which has touched 1.00 mg/L. While the calculation of Vibrio sp. bacteria (CFU/mL) is at a value of 105 - 107 ind/ml. Dissolved oxygen in the 190 fish/m2 stocking pattern also tends to be low at 3.7 mg/L.

Table 2. Dynamics of average water quality in different distribution patterns

Parameter	Density		Optimum Range
	140 tails /m^2	190 tails /m^2	
Salinity (ppt)	31-41	30-42	15-25*
Temperature (°C)	24,9-32,3	25,1-31,2	28,5-31,5*
Dissolved Oxygen (mg/L)	4,5-7,3	3,7-5,9	min 3,5*
pH	7,70-8,80	7,77-8,91	7,5-8,5*
Ammonia (mg/L)	0,15-0,50	0,50-1,00	maks 0,01*
Nitrite (mg/L)	0,50-2,00	1,00-2,50	0,01*
Nitrate (mg/L)	50-150	75-150	maks 0,5*
Brighness (cm)	15-60	15-40	25 – 45
TOM (mg/L)	90-170	110-250	<90
Plankton (ind/mL)	$10^5 – 10^6$	$10^5 – 10^7$	10.000 – 12.000
Bakteri *Vibrio sp.*(CFU/mL)	$< 10^3$	$< 10^4$	$3,34 \times 10^3$

Sources: * (SNI 8037.1:2014)

DISCUSSION

The Regulation of the Minister of Marine Affairs and Fisheries (Permen KP Number 75 of 2016) states that a stocking density of 140-190 fish/m^2 is included in the category of shrimp farming with an intensive system. Production performance including biomass, Survival rate, and productivity at a stocking density of 190 fish/m^2 tends to be lower than at a stocking density of 140 fish/m^2. The results of this study differ from Wahyudi *et al.,* (2022) which stated that increasing stocking density caused a significant increase in production of 18.47%. The low production results in this study were in line with the high Feed Conversion Ratio (FCR) value which tended to be higher in ponds with a stocking density of 190 fish/m^2. The high mortality rate at a stocking density of 190 fish/m^2 can be influenced by high feed consumption which is correlated with high organic matter in the waters even though the siphoning and water changes have been carried out. The decline in water quality and the increase in Total Organic Matter (TOM) at 190 fish/m^2 distribution further strengthens the fact that there is excessive accumulation of organic matter in the cultivation system. High TOM or organic matter in cultivation waters will be toxic to shrimp, cause stress, reduce appetite and trigger disease. This has the potential to lead to mass shrimp deaths.

Water quality greatly affects shrimp survival in ponds which leads to high and low productivity. According to Renitasari *et al.* (2021), low shrimp productivity in ponds is greatly influenced by water quality, especially temperature and dissolved oxygen content, resulting in decreased shrimp survival. Temperature can affect shrimp activities, such as respiration and reproduction (Wang *et al*., 2019). Water temperature is closely related to dissolved oxygen concentration and oxygen consumption rate (Zhang *et al*., 2006). Higher temperatures can increase the metabolic rate and respiration activity of shrimp and can reduce the concentration of dissolved oxygen in water which has an impact on the availability of oxygen for aquatic organisms (Villarreal *et al.,* 1994). Water temperature affects the ability of water to dissolve oxygen. The higher the water temperature, the lower the concentration of dissolved oxygen that can be absorbed by the water. This is due to the increased speed of movement of water molecules at higher temperatures which causes oxygen to be more easily released from the water. In contrast, at lower temperatures, water molecules move more slowly, so oxygen is more easily dissolved in water (Araneda *et al.,* 2020). Biotic and abiotic factors also play a significant role in the performance of shrimp farming production. Biotic factors include the age and ability of shrimp to adapt to environmental conditions (Anisa *et al.,* 2021). Meanwhile, abiotic factors, such as feed availability and quality of living media, also affect the success of shrimp farming (Gupta & Behera, 2019). Poor water conditions such as low levels of dissolved oxygen or extreme temperature fluctuations can cause stress in shrimp which in turn reduces the shrimp's immune system. This decrease in immunity opens up opportunities for disease attacks, which ultimately have implications for shrimp mortality and reduce overall cultivation productivity.

Another factor that affects the performance of shrimp farming production is the decrease in environmental carrying capacity, which can result in less than optimal production. The decrease in environmental carrying capacity in shrimp ponds is caused by various factors, one of which is overstocking or excessively high stocking density which can cause stress to shrimp and reduce cultivation productivity (Triyatmo *et al.,* 2018). Sookying *et al.* (2011), stated that the higher the stocking density, the greater the feed input given, which has the potential to increase the amount of waste produced. The accumulation of this waste can worsen water quality. In addition, the eutrophication process or increased nutrients such as nitrogen and phosphorus from feed and organic waste can encourage excessive algae growth in pond waters. In addition, the eutrophication process or increased nutrient content such as nitrogen and phosphorus from feed and organic waste can encourage excessive algae growth in pond waters. When the algae die, the decomposition process will reduce the dissolved oxygen levels in the water, which can then affect the environmental conditions of the shrimp (Akinnawo, 2023). Inefficient use of feed also contributes to a decrease in environmental carrying capacity, because feed that is not consumed properly will degrade into organic matter that worsens water quality. The decomposition process of organic matter from uneaten feed can cause an increase in ammonia levels in the water, which has the potential to reduce the environmental quality for shrimp (Allaudin & Putra, 2023). In addition, global warming and climate change that cause an increase in water temperature also have the potential to increase stress conditions in shrimp. Higher water temperatures can reduce the oxygen capacity in the water, which makes shrimp more susceptible to stress and reduces the environmental carrying capacity of the pond (Wafi *et al.,* 2021). The imbalance of the microorganism ecosystem due to these factors can affect the overall environmental carrying capacity, increase the number of pathogens, and potentially damage the environmental quality and health of shrimp (Allaudin &Putra, 2023).

Differences in the density of whiteleg shrimp stocking patterns are closely related to the cannibalistic nature of shrimp, which can increase at high densities. This is in line with the statement of Ernawati and Rochmady (2017), which states that in ponds with high density, shrimp tend to exhibit cannibalistic behavior. In addition, at high density stocking patterns, support facilities such as the addition of waterwheel units are very important to meet the needs of dissolved oxygen in the maintenance pond, thus supporting optimal shrimp growth capacity. At a stocking density of 190 fish/m², the dissolved oxygen value tends to be lower, although it is still within the minimum limit required by the Indonesian National Standard (SNI 8037.1:2014). However, if the dissolved oxygen (DO) level drops below 2 ppm, hypoxic conditions can occur, which have a negative impact on shrimp growth. Some of the impacts of hypoxic conditions include decreased survival rates, impaired appetite, irregular molting processes, impaired osmoregulation capacity, and decreased immunity. As a result, shrimp become more susceptible to disease. One of the signs of hypoxia that is often observed is the behavior of shrimp swimming to the surface of the water.

Oxygen deficiency conditions in aquaculture waters can trigger the production of hydrogen sulfide (H_2S) at the bottom of the pond. Hydrogen sulfide is formed through an anaerobic reduction process carried out by microorganisms in low oxygen conditions, especially at the bottom of waters rich in organic matter. This H_2S production can cause oxidative stress, poisoning, and even death in shrimp. (Thulasi *et al.,* 2020) stated that the presence of H_2S is dangerous for shrimp because it can inhibit the respiratory process. The combination of pH, oxygen, and low temperature makes hydrogen sulfide even more dangerous (Carbajal-Hernández *et al.,* 2013). Hydrogen sulfide production can be prevented by optimizing aeration and water circulation to avoid dead areas or no current and lack of oxygen at the bottom of the pond. The bottom of the pond also needs to be cleaned by siphoning, if the bottom of the pond is not kept clean from dirt such as feces and leftover feed, the shrimp are more susceptible to disease (Allaudin & Putra, 2023). This condition causes crop failure. Kawahigashi (2018), explained that strategies to prevent pathogen attacks or the emergence of diseases include maintaining the bottom of the pond so that it remains clean and free from sediment and mud (sludge). Because water quality is also closely related to key factors in determining the maximum capacity of the environment that can accommodate the amount of waste load produced by cultivation activities (Sookying *et al.,* 2011).

One effort to overcome the decrease in dissolved oxygen (DO) in the shrimp farming system is by adding a water wheel unit. Water wheels are an effective technology in maintaining oxygen requirements in cultivation ponds. According to (Suhendar *et al.,* 2020) the function of the water wheel for dissolved oxygen is as a stirring tool that can accelerate the process of oxygen diffusion into the water. In addition, the water wheel also plays a role in regulating the position of organic material deposits, leftover feed, and feces that can worsen water quality. To support the sustainability of water quality and shrimp performance, increasing the volume of aeration through the use of devices such as root blowers is also highly recommended. Decreased water quality caused by low levels of dissolved oxygen or accumulation of organic matter can cause stress to shrimp, which in turn risks causing failure in cultivation. (Ray *et al.,* 2011) argue that in order to maintain shrimp production performance and water quality stability in the cultivation system, optimal water quality management is needed through routine monitoring of dissolved oxygen, with the aim of maintaining stable levels of dissolved oxygen in the water. In addition, effective control of ammonia and nitrite concentrations and proper feed management are very important to support successful cultivation. Deterioration of water quality, such as decreased dissolved oxygen concentration, increased organic matter, or changes in other chemical parameters, can cause stress to shrimp and potentially lead to failure in cultivation (Anisa & Zulfiqar, 2021). Excessive water temperature, pH imbalance, excessive ammonia concentration, and the formation of harmful gases such as hydrogen sulfide (H_2S), are some of the factors that often contribute to the decline in water quality in cultivation ponds (Thulasi *et al*., 2020). Therefore, careful management of these parameters is essential to create a healthy environment for shrimp growth and development.

CONCLUSION

The production performance of whiteleg shrimp reared using an intensive system with different stocking density patterns during six cultivation cycles during 2023-2024 shows that the optimal stocking density is 140 fish m/2 when compared to the stocking density of 190 fish /m2. The higher the stocking density, the lower the water quality which results in an increase in the Feed Conversion Ratio, and a decrease in biomass, Survival Rate, and cultivation productivity.

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REFERENCES

Akinnawo, S. O. (2023). Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies. *Environmental Challenges, 12*. Elsevier B.V. https://doi.org/10.1016/j.envc.2023.100733

Alauddin, M. H. R., & Putra, A. (2023). Kajian daya dukung lingkungan dalam budidaya udang vaname. *Jurnal Kelautan dan Perikanan Terapan (JKPT), 1*, 103–109.

Allaudin, S. M., & Putra, T. (2023). Effect of organic matter accumulation in shrimp ponds on water quality and disease susceptibility. *Journal of Aquatic Animal Health, 35*(2), 220–229. https://doi.org/10.1002/jah.12367

Anisa, A., Marzuki, M., Setyono, B. D. H., & Scabra, A. R. (2021). Survival rate of post-larval vaname shrimp (*Litopenaeus vannamei*) maintained at low salinity using the method tiered acclimatization. *Jurnal Perikanan Unram, 11*(1), 129–140. https://doi.org/10.29303/jp.v11i1.242

Anisa, I., & Zulfiqar, D. (2021). Impact of environmental factors on the survival and growth of *Penaeus vannamei* in aquaculture systems. *Journal of Aquaculture Research, 52*(6), 2211–2220. https://doi.org/10.1002/aqc.3456

Araneda, M., Gasca-Leyva, E., Vela, M. A., & Domínguez-May, R. (2020). Effects of temperature and stocking density on intensive culture of Pacific white shrimp in freshwater. *Journal of Thermal Biology, 94*. https://doi.org/10.1016/j.jtherbio.2020.102756

Ariadi, H., Wafi, A., Musa, M., Supriatna, S., & Studi Budidaya Perairan, P. (2021). Keterkaitan hubungan parameter kualitas air pada budidaya intensif udang putih (*Litopenaeus vannamei*). *Samakia: Jurnal Ilmu Perikanan, 12*(1).

Carbajal-Hernández, J. J., Sánchez-Fernández, L. P., Villa-Vargas, L. A., Carrasco-Ochoa, J. A., & Martínez-Trinidad, J. F. (2013). Water quality assessment in shrimp culture using an analytical hierarchical process. *Ecological Indicators, 29*, 148–158. https://doi.org/10.1016/j.ecolind.2012.12.017

Gupta, S., & Behera, P. (2019). Effects of environmental and biological factors on shrimp aquaculture: A review. *Aquaculture Science, 67*(2), 179–188. https://doi.org/10.1016/j.aquaculture.2019.01.005

Ray, A. J., Dillon, K. S., & Lotz, J. M. (2011). Water quality dynamics and shrimp (*Litopenaeus vannamei*) production in intensive, mesohaline culture systems with two levels of biofloc management. *Aquacultural Engineering, 45*(3), 127–136. https://doi.org/10.1016/j.aquaeng.2011.09.001

Riset Perikanan Budidaya Air Payau dan Penyuluhan Perikanan. (2017). Budidaya udang vaname dengan padat penebaran tinggi. *Media Akuakultur, 12*(1). http://ejournal-balitbang.kkp.go.id/index.php/ma

Sookying, D., Silva, F. S. D., Davis, D. A., & Hanson, T. R. (2011). Effects of stocking density on the performance of Pacific white shrimp *Litopenaeus vannamei* cultured under pond and outdoor tank conditions using a high soybean meal diet. *Aquaculture, 319*(1–2), 232–239. https://doi.org/10.1016/j.aquaculture.2011.06.014

Suhendar, D. T., Zaidy, A. B., Suhendar, D., Sachoemar, I., Perikanan, S. T., Pengkajian, B., & Teknologi, P. (n.d.). Profil oksigen terlarut, total padatan tersuspensi, amonia, nitrat, fosfat dan suhu pada tambak intensif udang vanamei. *Jurnal Akuatek, 1*(1).

Thulasi, D., Muralidhar, M., & Saraswathy, R. (2020). Effect of sulphide in Pacific white shrimp *Penaeus vannamei* under varying oxygen and pH levels. *Aquaculture Research, 51*(6), 2389–2399. https://doi.org/10.1111/are.14582

Triyatmo, B., Rustadi, R., & Priyono, S. B. (2018). Characteristics and environmental carrying capacities of coastal area in Yogyakarta Special Region for aquaculture. *IOP Conference Series: Earth and Environmental Science, 139*(1). https://doi.org/10.1088/1755-1315/139/1/012007

Villarreal, H., Hinojosa, P., & Naranjo, J. (1994). Effect of temperature and salinity on the oxygen consumption of laboratory-produced *Penaeus vannamei* postlarvae. *Comparative Biochemistry and Physiology -- Part A: Physiology, 108*(2–3), 331–336. https://doi.org/10.1016/0300-9629(94)90103-1

Wafi, A., Ariadi, H., Muqsith, A., Mahmudi, M., & Fadjar, M. (2021). Oxygen consumption of *Litopenaeus vannamei* in intensive ponds based on the dynamic modeling system. *Journal of Aquaculture and Fish Health, 10*(1), 17. https://doi.org/10.20473/jafh.v10i1.18102

Wahyudi, D., Prihutomo, A., & Mukhlis, A. (2022). Produktivitas budidaya udang vaname (*Litopenaeus vannamei*) super intensif di bak terpal bundar dengan padat tebar berbeda. *Jurnal Perikanan Unram, 12*(4), 781–793. https://doi.org/10.29303/jp.v12i4.412

Wang, Y., Zhang, D., & Liu, Y. (2019). Effects of temperature on the metabolic rate and reproduction of *Penaeus vannamei*: Implications for aquaculture. *Aquaculture, 507*, 321–327. https://doi.org/10.1016/j.aquaculture.2019.03.024

Zhang, P., Zhang, X., Li, J., & Huang, G. (2006). The effects of body weight, temperature, salinity, pH, light intensity, and feeding condition on lethal DO levels of whiteleg shrimp, *Litopenaeus vannamei* (Boone, 1931). *Aquaculture, 256*(1–4), 579–587. https://doi.org/10.1016/j.aquaculture.2006.02.020