Production and economic performance of *Penaeus vannamei* Boone, 1931 cultured in HDPE-lined circular tanks across increasing stocking densities: a commercial case study

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Abstract. The increasing demand for aquaculture production under limited land availability requires efficient intensive culture systems. This commercial case study evaluated the production performance and economic viability of whiteleg shrimp, *Penaeus vannamei* Boone, 1931, cultured in an HDPE-lined circular tank system under commercial farm conditions across three sequential production cycles with progressively increasing stocking densities (318-467 ind m^{-2}). Progressive intensification was associated with higher biomass production, increasing total biomass from 1,500 to 2,015 kg and yield from 4.78 to 6.42 kg m^{-2}. However, this was accompanied by a decline in survival (94-80%) and a slight increase in feed conversion ratio (FCR) (1.20-1.29), indicating trade-offs between production and biological performance. Most water quality parameters remained within acceptable ranges throughout the culture period, although total ammonia nitrogen (TAN) increased across successive production cycles as stocking density increased. Despite higher production costs, economic performance improved, with net profit increasing from USD 2,852.80 to USD 4,730.17 and return on investment (ROI) from 58.78% to 66.61%. Annual production reached 5,300 kg, with an overall ROI of 63.63% and a benefit-cost ratio of 1.64. These findings suggest that HDPE-lined circular tank systems can support profitable intensive shrimp production under space-limited conditions when supported by appropriate feeding, aeration, and water quality management. Because the study was conducted in a single commercial production system using sequential, non-replicated production cycles, the findings should be interpreted as operational observations rather than definitive evidence of stocking density effects. Further replicated studies are needed to determine the optimum stocking density for maximizing productivity, economic returns, and biological performance.
Keywords: benefit-cost ratio, intensive shrimp farming, profitability, return on investment, water quality management.

Introduction. Aquaculture is one of the fastest-growing food production sectors and plays a vital role in global food security, nutrition, and livelihoods (Béné et al., 2015). Global fisheries and aquaculture production have increased in recent years, reflecting the rising demand for aquatic food (Costello et al., 2020; Food and Agriculture Organization of the United Nations, 2022). However, continued expansion is increasingly constrained by limited land and water resources, requiring more efficient production systems.

Shrimp farming is among the most economically important sectors of aquaculture, with whiteleg shrimp, *Penaeus vannamei* Boone, 1931, being the most widely cultured species worldwide (Food and Agriculture Organization of the United Nations, 2022). This species is favored because of its rapid growth, tolerance to a wide range of environmental conditions, and suitability for intensive culture systems (Briggs et al., 2004; De Silva et al., 2021). However, conventional pond-based shrimp farming remains vulnerable to disease outbreaks, environmental degradation, and water quality deterioration, which can reduce production efficiency and profitability (Lightner 2011; Tran et al., 2013; Food and Agriculture Organization of the United Nations, 2024).

To overcome these challenges, tank-based production systems have emerged as promising alternatives to conventional pond culture because they improve water circulation, waste removal, and environmental control (Timmons et al., 1998; Badiola et al., 2012). Previous studies have primarily focused on recirculating aquaculture systems (RAS) and biofloc technology (BFT), which enhance water quality and productivity through water reuse and microbial processes (Badiola et al., 2012; Xu & Pan, 2012; de Melo Filho et al., 2020). Although these systems offer significant production advantages, they generally require greater technical expertise, infrastructure, and management complexity (Emerenciano et al., 2013; Asiri & Chu, 2020).

In contrast, simple HDPE-lined circular tank systems operated under commercial farm conditions remain comparatively less studied, particularly in terms of production performance and economic viability. Information describing the commercial performance of these systems across successive production cycles remains limited despite their potential as an intensive shrimp production system.

Therefore, this study aimed to evaluate the production performance, water quality, and economic returns of *P. vannamei* cultured in HDPE-lined circular tanks under commercial farm conditions across three sequential production cycles with progressively increasing stocking densities.

Material and Method

Animal welfare statement. All culture, sampling, and handling procedures were conducted under routine commercial farming conditions to minimize stress and unnecessary harm to the shrimp. Farm management practices, including biosecurity, water quality management, feeding, and harvesting, were conducted in accordance with standard aquaculture welfare practices as outlined in the Philippine Code of Good Aquaculture Practices (GAqP).

Description of the study site and production system. This study was conducted from February to November 2022 in Quezon Province, Philippines. The study site is located in a coastal area with environmental conditions suitable for intensive shrimp culture. The culture facility is situated approximately 2.6 km inland and utilizes brackish water sourced from a deep well. The production system consisted of two high-density polyethylene (HDPE)-lined circular tanks, each with a surface area of approximately 314 m^2, a water depth of 1.0 m, and a maintained operating volume of approximately 314 m^3. One tank served as a reservoir for water treatment, while the other functioned as the grow-out tank. Aeration was provided using a 2-hp Roots blower connected to diffuser hoses throughout the culture period. During the first month of culture, only the Roots blower was operated continuously. Beginning in the second month, a 1-hp paddlewheel aerator was added to meet the increasing oxygen demand associated with higher shrimp biomass. The system layout and major components are illustrated in Figure 1.

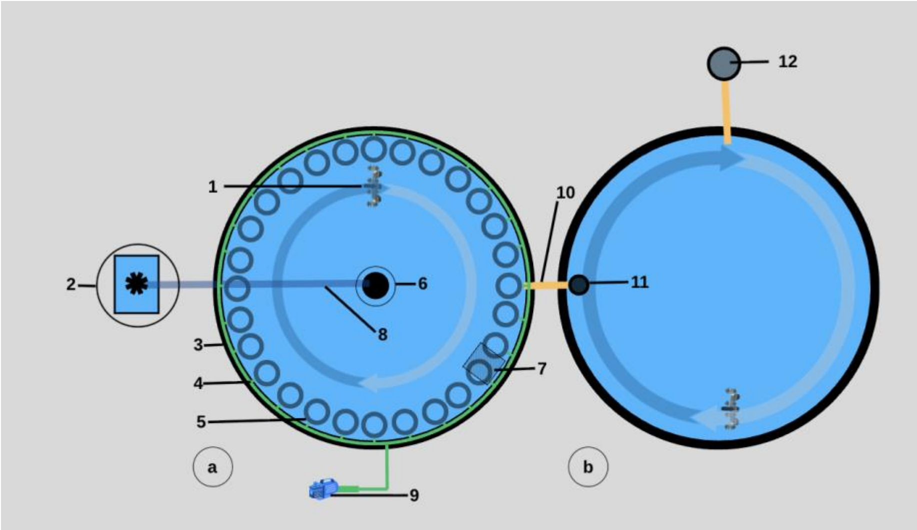

Figure 1. Schematic diagram of the circular tank system used in the study. (a) Grow-out tank showing: (1) paddlewheel aerator; (2) drain outlet; (3) high-density polyethylene (HDPE) liner; (4) aeration lines; (5) diffuser hose; (6) central drain; (7) feeding tray; (8) drain pipe; (9) Roots blower. (b) Reservoir tank showing: (10) water inlet pipe; (11) submersible pump; and (12) deep-well water source.

Culture management. Production performance was evaluated over three successive culture cycles within one year. The farm implemented three progressively increasing stocking densities (318, 366, and 467 individuals m^{-2}) as pilot production trials to evaluate the technical and economic feasibility of increasing culture intensity under commercial conditions. The selected stocking densities were based on the range reported by Arambul-Muñoz et al. (2019). *P. vannamei* post larvae (PL9-PL10) obtained from a commercial hatchery were acclimated prior to stocking. The initial stocking biomass was approximately 1.00, 1.15, and 1.40 kg per tank for Cycles 1, 2, and 3, respectively.

Prior to stocking, the culture tanks were thoroughly cleaned and disinfected, and culture water was treated with calcium hypochlorite (20 mg L^{-1}) before transfer from the reservoir tank. As part of the farm's biosecurity protocol, the culture tanks were covered with green netting to minimize bird access and reduce the risk of pathogen transmission. Hand-spray alcohol dispensers were also installed beside the culture tanks to ensure workers disinfected their hands before entering the culture area.

Shrimp were fed a commercial diet five times daily at 0700, 1030, 1400, 1730, and 2100 h following the manufacturer's recommended feeding schedule. Under the farm's feeding protocol, the feeding rate was initially maintained at approximately 8% of the estimated biomass during the first month of culture and was gradually reduced to approximately 2% during the final month. Daily feed allowances were adjusted based on biomass estimation and feed tray observations, consistent with standard shrimp feeding management practices (Kungvankij & Chua, 1986).

Water quality management and monitoring. To maintain suitable water quality, approximately 20% of the culture water was exchanged daily for five consecutive days each week throughout the culture period. Sludge accumulated at the tank bottom was removed daily through the central drain by opening the drain pipe until the discharged water changed from dark-colored sludge to relatively clear water.

Water quality parameters were monitored twice daily at 0500 h and 1500 h. Temperature was measured using a laboratory glass thermometer. Salinity was determined using an ATAGO MASTER-S28M handheld refractometer. Dissolved oxygen (DO), pH, total ammonia nitrogen (TAN), alkalinity, calcium, and magnesium were measured using commercially available Advance Pharma (Thailand) AQUA Test Kits, following the manufacturer's instructions.

Growth sampling and data collection. Shrimp sampling was conducted every seven days throughout the culture period to monitor growth performance, estimate biomass, and adjust feeding rates. During each sampling event, representative shrimp were randomly collected from different areas of the culture tank to determine average body weight and estimate standing biomass.

As part of the farm's production strategy, partial harvesting was conducted when standing biomass reached approximately 3.5 kg m^{-2}. At this stage, approximately 15% of the shrimp population was harvested using a cast net to reduce stocking biomass and maintain favorable culture conditions for the remaining stock. The final harvest was performed by completely draining the culture tank. The three production cycles were harvested after 63, 78, and 91 days of culture for Cycles 1, 2, and 3, respectively. Harvest schedules were determined according to the farm's production strategy and were based on the initial stocking density, with production cycles stocked at higher densities maintained for longer culture periods before final harvest. Data obtained from the periodic sampling and harvests were used to evaluate growth performance, survival, biomass, and overall production performance across the three production cycles.

Production and economic analysis. Production performance was evaluated using standard parameters, including average daily growth (ADG), survival rate (SR), feed conversion ratio (FCR), and yield. The formulas used were as follows:

$$ADG = (\text{final weight} - \text{initial weight}) / \text{culture period}$$

$$SR (\%) = (\text{number of harvested shrimp} / \text{number of stocked shrimp}) \times 100$$

$$FCR = \text{total feed given} / \text{biomass gain}$$

$$Yield = \text{total biomass} / \text{culture area}$$

Economic analysis included total cost, revenue, net profit, return on investment (ROI), and benefit-cost ratio (BCR). These parameters were calculated using standard economic formulas adapted from previous studies (Wijayanto et al., 2017; Kusna et al., 2023).

Total cost was calculated as:

$$TC = TFC + TVC$$

Revenue was calculated as:

$$TR = P \times Q$$

Net profit was calculated as:

$$\pi = TR - TC$$

$$ROI (\%) = (\pi / TC) \times 100$$

$$BCR = TR / TC$$

where:
TC - total cost;
TFC - total fixed cost;
TVC - total variable cost;
TR - total revenue;
P - price;
Q - quantity of shrimp produced;
π - net profit.

Data analysis. Data were analyzed using descriptive statistics. Comparisons were made across production cycles to evaluate trends in production performance and economic outcomes under increasing stocking density.

Results. Water quality parameters recorded during the culture period are presented in Table 1. All measured water quality parameters were within acceptable ranges during the three production cycles. Water temperature differed among cycles, with the highest mean recorded during Cycle 2, whereas Cycles 1 and 3 exhibited relatively similar values. TAN was higher in the later production cycles than in the first cycle.

Table 1

Water quality parameters (mean ± SD) recorded during three production cycles of *Penaeus vannamei* cultured in an HDPE-lined circular tank system.

Parameter	*Cycle 1*	*Cycle 2*	*Cycle 3*
Temperature (°C)	26.60±0.89	29.20±1.30	27.0±0.71
DO (mg L^{-1})	4.80±0.84	4.40±0.55	4.20±0.84
pH	7.84±0.23	7.68±0.30	7.56±0.21
Salinity (ppt)	22.40±1.14	26.0±1.58	22.60±1.14
TAN (mg L^{-1})	1.05±0.72	1.7±0.45	2.40±0.55
Alkalinity (mg L^{-1})	200.0±25.50	234.0±15.17	190.0±18.26
Calcium (mg L^{-1})	286.0±28.81	330.0±23.45	278.0±27.02
Magnesium (mg L^{-1})	751.33±79.36	887.0±55.65	678.30±77.02

Production performance. Production performance across the three culture cycles is presented in Table 2. Higher stocking densities were accompanied by increases in biomass production and yield. In contrast, the SR declined, and the FCR increased across production cycles. Final body weight was greater in Cycles 2 and 3 than in Cycle 1, whereas ADG was highest in Cycle 2.

Table 2

Production performance of *Penaeus vannamei* cultured in an HDPE-lined circular tank system across three production cycles under increasing stocking densities

Parameter	*Cycle 1*	*Cycle 2*	*Cycle 3*
Stocking density (ind m^{-2})	318	366	467
Culture duration (days)	63	78	91
Final body weight (g)	20.0	36.0	36.0
Average daily growth (g day^{-1})	0.32	0.46	0.40
Survival rate (%)	94.0	86.0	80.0
FCR	1.20	1.24	1.29
Total biomass (kg)	1,500	1,785	2,015
Yield (kg m^{-2})	4.78	5.68	6.42

Yield, feed conversion ratio, and survival. Figures 2-4 illustrate the responses of yield, FCR, and SR to increasing stocking density. Yield increased with stocking density, whereas FCR and survival exhibited opposite trends, with higher FCR and lower survival observed at greater stocking densities.

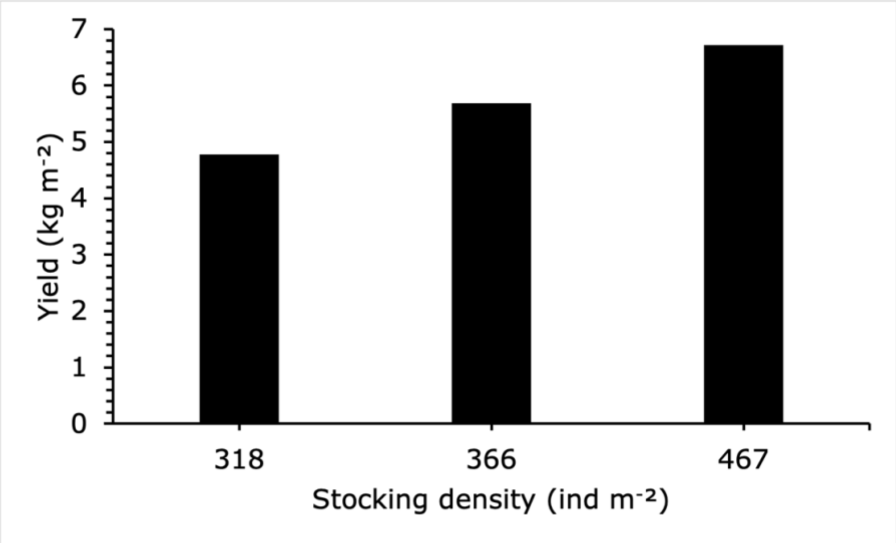

Figure 2. Yield (kg m^{-2}) of *Penaeus vannamei* at increasing stocking densities across successive production cycles.

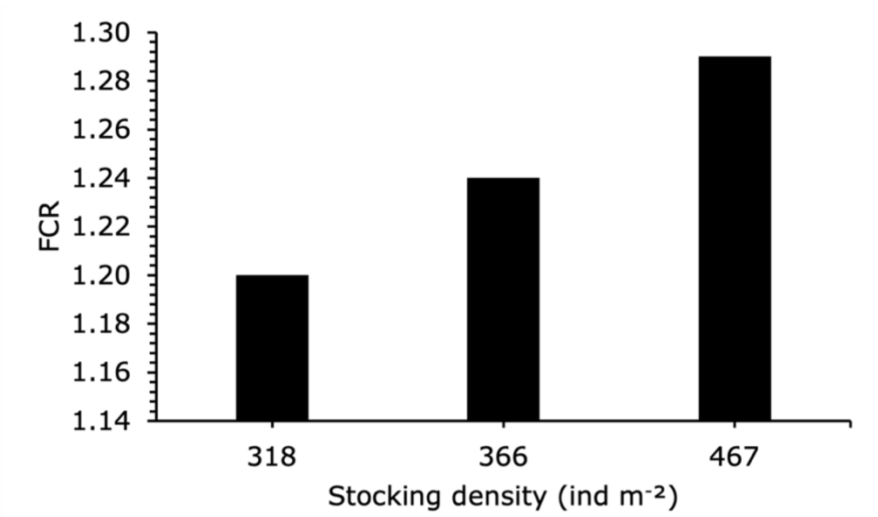

Figure 3. Feed conversion ratio of *Penaeus vannamei* under increasing stocking densities.

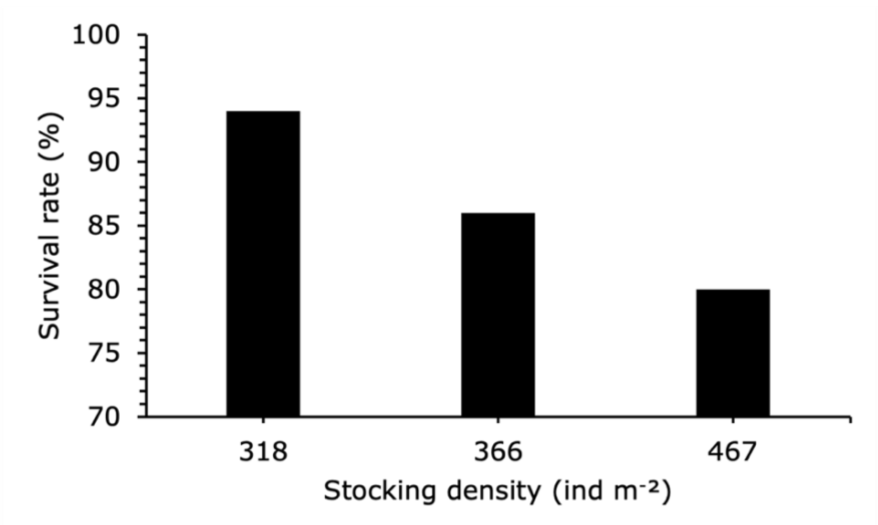

Figure 4. Survival rate (%) of *Penaeus vannamei* across different stocking densities.

***Economic performance**.* Economic performance across the three production cycles is summarized in Table 3. Economic indicators generally improved with increasing stocking density. Although total production cost and cost per kilogram increased across production cycles, gross revenue, net profit, ROI, and BCR also exhibited positive trends, with the highest economic performance observed in Cycle 3.

Table 3

Economic performance of *Penaeus vannamei* production across three culture cycles.

Parameter	*Cycle 1*	*Cycle 2*	*Cycle 3*
Total production cost (USD)	4,853.63	5,990.17	7,101.02
Cost per kg (USD kg^{-1})	3.24	3.36	3.52
Gross revenue (USD)	7,706.42	9,825.69	11,831.19
Net profit (USD)	2,852.80	3,835.51	4,730.17
Net profit per kg (USD kg^{-1})	1.90	2.15	2.35
ROI (%)	58.78	64.03	66.61
BCR	1.59	1.64	1.67

Cost structure and annual performance. The distribution of production cost components is shown in Figure 5. Feed represented nearly half of the total production cost, while labor, depreciation, fry, and energy comprised the remaining major cost components. Other production expenses accounted for only a minor share of the overall cost.

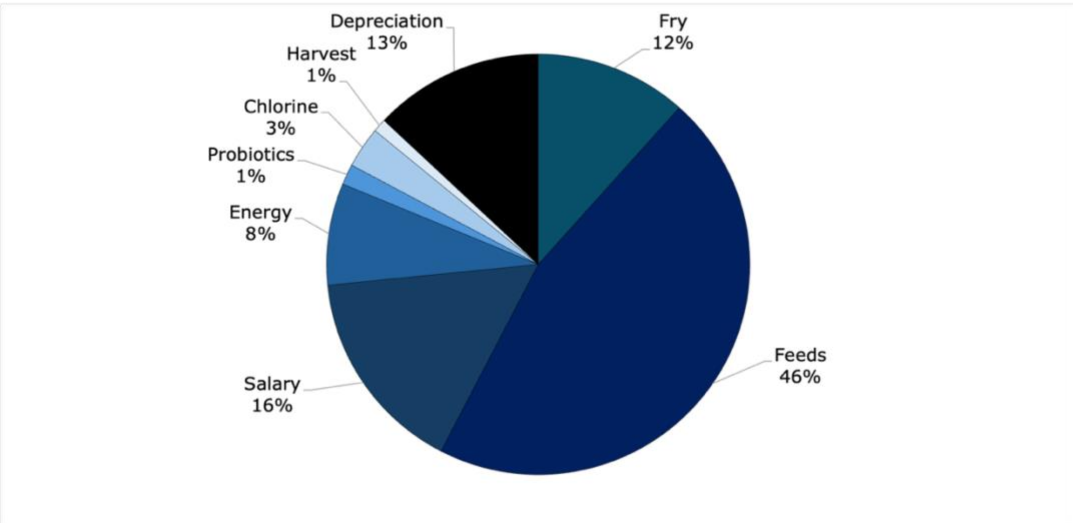

Figure 5. Percentage distribution of total production costs across three production cycles.

Annual production and economic performance are summarized in Table 4. The HDPE-lined circular tank system demonstrated positive annual production and profitability, with favorable ROI and BCR, indicating its economic viability under intensive culture conditions.

Table 4

Annual production and economic performance of *Penaeus vannamei* cultured in an HDPE-lined circular tank system.

Parameter	*Value*
Total annual production (kg)	5,300
Annual yield yield (kg m^{-2} $year^{-1}$)	16.88
Total production cost (USD)	17,944.82
Total revenue (USD)	29,363.30
Total net profit (USD)	11,418.48
Overall ROI (%)	63.63
Overall BCR	1.64

Figure 6 shows that both production cost and net profit per kilogram increased with stocking density, with the greatest economic return per kilogram achieved in Cycle 3.

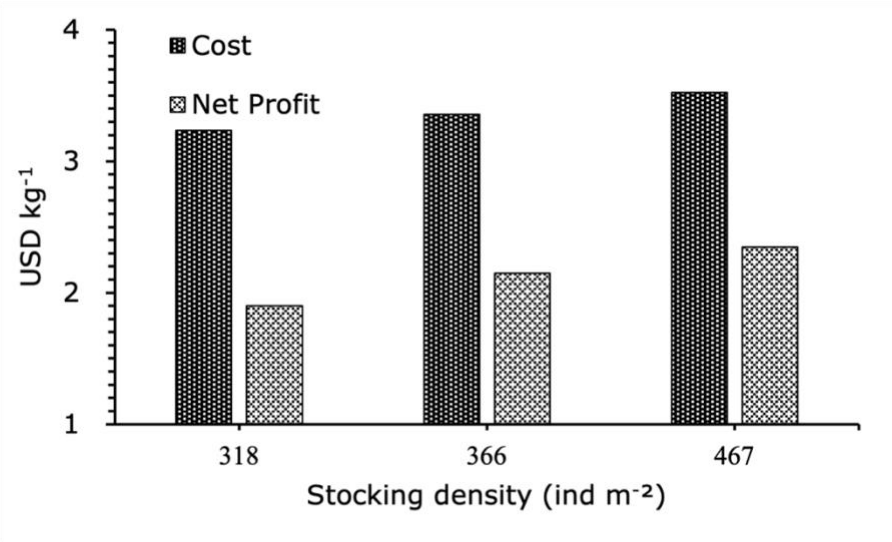

Figure 6. Cost (USD kg^{-1}) and net profit (USD kg^{-1}) of *Penaeus vannamei* production at different stocking densities.

Discussion. The present commercial case study evaluated the production and economic performance of *P. vannamei* cultured in an HDPE-lined circular tank system under progressively higher stocking densities. Because the three production cycles were conducted sequentially in a single commercial tank without replication, the findings should be interpreted as operational observations rather than direct evidence of stocking density effects. Nevertheless, the observed production responses were consistent with previous studies demonstrating that the biological constraints associated with intensive shrimp culture can be minimized through appropriate culture management (Façanha et al., 2016; Arambul-Muñoz et al., 2019; Gamberoni et al., 2026).

The gradual reduction in survival likely resulted from the progressive increase in standing biomass, which increased physical interactions and competition for available space. Such effects become particularly important during molting, when shrimp are more susceptible to cannibalism and physiological stress. Similar density-dependent reductions in survival have been reported in intensive *P. vannamei* culture (da Costa et al., 2016; Façanha et al., 2016). Despite these biological constraints, the relatively high survival achieved throughout the production cycles suggests that routine water quality management, continuous aeration, and biosecurity measures reduced, although did not completely eliminate, the negative effects associated with intensive stocking.

Growth performance likewise appeared to be influenced more by environmental conditions and culture duration than by stocking density alone. Because the production cycles were conducted sequentially under commercial farm conditions, each cycle experienced different seasonal conditions, making it difficult to isolate the influence of stocking density on growth. The relatively higher ADG observed during the second production cycle coincided with water temperatures that were closer to the reported optimum range for *P. vannamei*. Previous studies have shown that growth and metabolic performance improve as temperature approaches the species' optimal range, with maximum growth generally occurring between approximately 28 and 32°C (Walker et al., 2011) and optimum production achieved around 28-30°C (Ponce-Palafox et al., 1997). In contrast, the comparatively lower ADG observed during the first and third production cycles may reflect the combined influence of cooler environmental conditions and differences in culture duration. Shrimp growth generally follows a sigmoid pattern, characterized by rapid growth during the early stages of culture followed by a gradual decline in growth rate as shrimp approach market size (Tanjung et al., 2022). Consequently, the longer culture duration in the third production cycle may have contributed to a lower calculated ADG despite achieving a final body weight comparable to that of the second cycle.

Despite the decline in survival and the variation in growth rate among production cycles, biomass production continued to improve because the greater number of stocked shrimp compensated for the observed mortality. This response was likely enhanced by the farm's biomass management strategy, in which partial harvesting was conducted once standing biomass approached approximately 3.5 kg m^{-2}. Periodic removal of marketable shrimp reduced biomass loading, allowing the remaining population to continue growing under less crowded conditions while maintaining suitable water quality. Similar benefits of partial harvesting have been reported in intensive shrimp production, where reducing standing biomass decreases competition, improves growth and survival, and enhances overall production efficiency (Estrada-Pérez et al., 2016; Da Silveira et al., 2022). These findings suggest that partial harvesting is an effective management strategy for sustaining production under intensive culture conditions.

Despite progressive intensification, feed utilization remained efficient throughout the study. The slight increase in FCR indicates that greater biomass likely increased competition for feed and reduced feeding efficiency, as similarly reported by Façanha et al. (2016) and Bardera et al. (2021). Nevertheless, the comparatively low FCR suggests that adaptive feeding practices minimized these effects. Feed rations were initially calculated from standing biomass and feeding rates, while continuously adjusted using feeding tray observations, allowing feed inputs to closely match shrimp consumption and reducing feed wastage. Martínez-Córdova et al. (1998) likewise demonstrated that feeding trays improve feed management by optimizing feed allocation, resulting in better feed conversion, enhanced growth, and reduced nutrient accumulation in culture water. Together with continuous aeration and routine water quality management, these practices likely contributed to maintaining efficient feed utilization despite increasing biomass.

The ability of the production system to maintain water quality within acceptable ranges despite progressively greater biomass further demonstrates the effectiveness of the management practices implemented throughout the culture period. Although TAN increased during the later production cycles, all measured water quality parameters remained within recommended ranges for intensive *P. vannamei* culture (Venkateswarlu et al., 2019; Durai et al., 2021; Sharma et al., 2023). Water temperature also remained within the species' suitable culture range, although the slightly higher temperature recorded during the second production cycle was closer to the range associated with maximum growth of *P. vannamei* (Walker et al., 2011), which may partly explain the differences in growth performance discussed previously. The gradual increase in TAN was expected because greater biomass and feed inputs increase the accumulation and microbial decomposition of nitrogenous organic wastes derived from uneaten feed and feces (Durai et al., 2021). Despite this increase, continuous aeration, routine sludge removal, and scheduled water exchange likely maintained favorable culture conditions, preventing excessive deterioration of water quality as culture intensity increased.

The production system evaluated in this study shares characteristics with several intensive *P. vannamei* production technologies while differing in its approach to environmental management. Conventional intensive ponds rely primarily on aeration and water exchange but remain susceptible to waste accumulation and spatial variation in DO as biomass increases (Ruiz-Velazco et al., 2010). BFT improves water quality through microbial assimilation of nitrogenous wastes but requires continuous aeration and careful management of the carbon-to-nitrogen ratio and suspended solids (Ray et al., 2011; Xu et al., 2025). RAS provide the highest level of environmental control through continuous water treatment and solids removal, but require substantially greater infrastructure, technical expertise, and operating costs (Badiola et al., 2012; Nugraha et al., 2023). Positioned between these systems, the HDPE-lined circular tank combines the operational simplicity of pond culture with several engineering advantages commonly associated with tank- and RAS-based production. Continuous circular water movement promotes uniform mixing, DO distribution, and centralized solids removal, reducing localized organic matter accumulation and facilitating routine sludge management (Timmons et al., 1998).

Together with continuous aeration, these hydrodynamic characteristics likely contributed to maintaining stable culture conditions despite increasing biomass. Similar benefits have been reported for circular tank and recirculating systems, where improved water circulation and solids removal support stable environmental conditions and sustained production performance (Badiola et al., 2012; Kurniawan et al., 2025). Consequently, HDPE-lined circular tanks represent a practical intermediate production strategy for commercial shrimp farming by providing improved environmental control without the complexity of conventional RAS.

Collectively, the biological performance achieved under this production system translated into favorable economic outcomes. Although production intensification increased expenditures for feed and farm operations, the additional harvest biomass generated sufficient revenue to offset these costs, resulting in improved economic performance. This indicates that the greater investment required for intensified production was compensated by the additional marketable biomass produced. Similar economic responses have been reported for intensive shrimp farming, where higher production levels improve financial performance despite increased operating costs (Engle et al., 2017; Rego et al., 2017). Likewise, Asmild et al. (2024) demonstrated that larger and more intensive *P. vannamei* production systems achieve greater economic efficiency through increasing returns to scale and more effective utilization of production resources.

Feed remained the dominant operating expense, emphasizing its importance in determining farm profitability. Similar observations have been reported by Mansaray et al. (2018), who identified feed as the largest production cost in commercial *P. vannamei* farming. Engle et al. (2017) likewise recognized feed as the principal variable cost associated with production intensification, while Asmild et al. (2024) noted that feed continues to dominate operating expenditures even in technologically advanced shrimp production systems. Consequently, optimizing feed utilization through accurate biomass estimation, feeding tray-based ration adjustment, and minimizing feed wastage represents the greatest opportunity for improving profitability in intensive HDPE-lined circular tank systems.

Beyond production and economic performance, the management practices implemented in this study also demonstrate the potential sustainability advantages of HDPE-lined circular tank systems. High production from a relatively small culture area indicates efficient land utilization compared with conventional pond culture. Furthermore, the use of a separate reservoir, scheduled water exchange, centralized sludge removal, and routine biosecurity measures may facilitate water quality and waste management while reducing the risk of pathogen introduction. These operational characteristics suggest that HDPE-lined circular tanks provide a practical option for sustainable intensive shrimp farming where land availability, water resources, and biosecurity are important production considerations.

Limitations of the study. This study was conducted as a commercial case study using a single HDPE-lined circular tank over three successive production cycles without experimental replication. Consequently, differences observed among production cycles should not be attributed solely to progressively increasing stocking density, as temporal variation in environmental conditions and routine farm management may also have influenced production and economic performance. Accordingly, the findings should be interpreted as commercially relevant observations from an operational production system rather than controlled experimental evidence.

Conclusions. This commercial case study demonstrates that HDPE-lined circular tank systems can support intensive *P. vannamei* production while maintaining favorable economic performance under progressively increasing stocking densities. Although increasing production intensity resulted in reduced survival and a slight increase in FCR, these biological trade-offs coincided with greater biomass production and improved economic returns, suggesting that progressively higher stocking densities may be economically advantageous under the management conditions observed in this commercial system when supported by appropriate feeding, aeration, and water quality management. The findings also suggest that the circular tank configuration provides an effective production environment by facilitating water circulation and solids removal, thereby supporting intensive culture under space-limited conditions. However, because the study was conducted as a commercial case study using successive production cycles without replicated experimental units, the results should be interpreted as operational observations rather than definitive causal effects of stocking density. Future studies incorporating replicated trials are needed to determine the optimum stocking density that maximizes productivity, biological performance, and economic returns in HDPE-lined circular tank systems.

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Authors Contributions. Conceptualization: EDSRE; Methodology: EDSRE; Formal analysis: EDSRE, LFCB; Investigation: EDSRE; Data curation: EDSRE; Writing - original draft: EDSRE; Writing - review & editing: EDSRE, LFCB; Supervision: EDSRE.

Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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References

Arambul-Muñoz, E., Ponce-Palafox, J. T., Claro De Los Santos, R., Aragón-Noriega, E. A., Rodríguez-Domínguez, G., & Castillo-Vargasmachuca, S. G. (2019). Influence of stocking density on production and water quality of a photo-heterotrophic intensive system of white shrimp (*Penaeus vannamei*) in circular lined grow-out ponds, with minimal water replacement. *Latin American Journal of Aquatic Research*, *47*(3), 449-455. https://doi.org/10.3856/vol47-issue3-fulltext-7

Asmild, M., Hukom, V., Nielsen, R., & Nielsen, M. (2024). Is economies of scale driving the development in shrimp farming from *Penaeus monodon* to *Litopenaeus vannamei*? The case of Indonesia. *Aquaculture*, *579*, 740178. https://doi.org/10.1016/j.aquaculture.2023.740178

Asiri, F., & Chu, K.-H. (2020). A novel recirculating aquaculture system for sustainable aquaculture: enabling wastewater reuse and conversion of waste-to-immune-stimulating fish feed. *ACS Sustainable Chemistry & Engineering*, *8*(49), 18094-18105. https://doi.org/10.1021/acssuschemeng.0c06375

Badiola, M., Mendiola, D., & Bostock, J. (2012). Recirculating aquaculture systems (RAS) analysis: Main issues on management and future challenges. *Aquacultural Engineering*, *51*, 26-35. https://doi.org/10.1016/j.aquaeng.2012.07.004

Bardera, G., Owen, M. A. G., Façanha, F. N., Alcaraz-Calero, J. M., Alexander, M. E., & Sloman, K. A. (2021). The influence of density and dominance on Pacific white shrimp (*Litopenaeus vannamei*) feeding behaviour. *Aquaculture*, *531*, 735949. https://doi.org/10.1016/j.aquaculture.2020.735949

Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G. I., & Williams, M. (2015). Feeding 9 billion by 2050—Putting fish back on the menu. *Food Security*, *7*(2), 261-274. https://doi.org/10.1007/s12571-015-0427-z

Briggs, M., Funge-Smith, S., Subasinghe, R., & Phillips, M. (2004). *Introductions and movement of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific*

(RAP Publication No. 2004/10). Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific.
Costello, C., Cao, L., Gelcich, S., Cisneros-Mata, M. Á., Free, C. M., Froehlich, H. E., Golden, C. D., Ishimura, G., Maier, J., Macadam-Somer, I., Mangin, T., Melnychuk, M. C., Miyahara, M., de Moor, C. L., Naylor, R., Nøstbakken, L., Ojea, E., O'Reilly, E., Parma, A. M., Plantinga, A. J., Thilsted, S. H., & Lubchenco, J. (2020). The future of food from the sea. *Nature*, *588*(7836), 95-100. https://doi.org/10.1038/s41586-020-2616-y
da Costa, F. P., Gomes, B. S. F. F., Pereira, S. D. N. A., & Arruda, M. F. (2016). Influence of stocking density on the behaviour of juvenile *Litopenaeus vannamei* (Boone, 1931). *Aquaculture Research*, *47*(3), 912-924. https://doi.org/10.1111/are.12550
Da Silveira, L. G. P., Krummenauer, D., Poersch, L. H., Fóes, G. K., Rosas, V. T., & Wasielesky, W., Jr. (2022). The effect of partial harvest on production and growth performance of *Penaeus vannamei* reared in biofloc technology system. *Aquaculture*, *546*, 737408. https://doi.org/10.1016/j.aquaculture.2021.737408
de Melo Filho, M. E. S., Owatari, M. S., Mouriño, J. L. P., Lapa, K. R., & Soares, H. M. (2020). Application of nitrification and denitrification processes in a direct water reuse system for Pacific white shrimp farmed in a biofloc system. *Aquacultural Engineering*, *88*, 102043. https://doi.org/10.1016/j.aquaeng.2020.102043
de Silva, M. L. I., Ranjula, M. A. S., Thanuja, M., Katuwawala, D. M., & Sumanapala, A. P. (2021). Review on impacts of *Penaeus vannamei* on aquaculture. *Wildlanka*, *9*(1), 149-170.
Durai, V., Alagappan, M., & Yuvarajan, P. (2021). Importance of water quality management in whiteleg shrimp (*Penaeus vannamei*) farming. *AgriCos e-Newsletter*, *2*(9), 17-20.
Emerenciano, M., Gaxiola, G., & Cuzon, G. (2013). *Biofloc technology (BFT): a review for aquaculture application and animal food industry*. In M. D. Matovic (Ed.), Biomass now: Cultivation and utilization (pp. 301-328). IntechOpen. https://doi.org/10.5772/53902
Engle, C. R., McNevin, A., Racine, P., Boyd, C. E., Paungkaew, D., Viriyatum, R., Tinh, H. Q., & Minh, H. N. (2017). Economics of sustainable intensification of aquaculture: Evidence from shrimp farms in Vietnam and Thailand. *Journal of the World Aquaculture Society*, *48*(2), 227-239. https://doi.org/10.1111/jwas.12423
Estrada-Pérez, A., Ruiz-Velazco, J. M. J., Hernández-Llamas, A., Zavala-Leal, I., & Martínez-Cárdenas, L. (2016). Deterministic and stochastic models for analysis of partial harvesting strategies and improvement of intensive commercial production of whiteleg shrimp (*Penaeus vannamei*). *Aquacultural Engineering*, *70*, 56-62. https://doi.org/10.1016/j.aquaeng.2015.11.003
Façanha, F. N., Oliveira-Neto, A. R., Figueiredo-Silva, C., & Nunes, A. J. P. (2016). Effect of shrimp stocking density and graded levels of dietary methionine on the growth performance of *Penaeus vannamei* reared in a green-water system. *Aquaculture*, *463*, 10-18.
Food and Agriculture Organization of the United Nations. (2022). *The state of world fisheries and aquaculture 2022: Towards blue transformation*. https://doi.org/10.4060/cc0461en
Food and Agriculture Organization of the United Nations. (2024). *The state of world fisheries and aquaculture 2024: Blue transformation in action*. https://doi.org/10.4060/cd0683en
Gamberoni, P., Bögner, M., Kreuz, E., Slater, M. J., Bierbach, D., & Wuertz, S. (2026). Impact of different stocking densities on growth performance, welfare and physiology of *Litopenaeus vannamei* in RAS. *Scientific Reports*, *16*, 9087. https://doi.org/10.1038/s41598-026-42332-2
Kungvankij, P., & Chua, T. E. (1986). *Shrimp culture: Pond design, operation and management* (NACA Training Manual Series No. 2). Food and Agriculture Organization of the United Nations, Network of Aquaculture Centres in Asia, and Southeast Asian Fisheries Development Center, Aquaculture Department. https://www.fao.org/4/ac210e/ac210e00.htm

Kurniawan, A., Amin, A. A., Pramudia, Z., Susanti, Y. A. D., Al Zamzami, I. M., Moehammad, K. S., & Prayogo, T. B. (2025). Evaluating water quality in white shrimp aquaculture: A case study in round ponds with Venturi pump systems during the blind feeding phase. *Aquaculture Studies*, *25*(2), AQUAST1743. https://doi.org/10.4194/AQUAST1743

Kusna, M., Prayitno, S. B., Sarjito, & Wijayanto, D. (2023). Estimated economic losses due to white spot syndrome virus (WSSV) disease in intensive vannamei shrimp culture business in Kendal Regency. *AACL Bioflux*, *16*(5), 2615-2625.

Lightner, D. V. (2011). Virus diseases of farmed shrimp in the Western Hemisphere (the Americas): a review. *Journal of Invertebrate Pathology*, *106*(1), 110-130. https://doi.org/10.1016/j.jip.2010.09.012

Mansaray, M., Hayford, A., Xiaojun, J., Lin, Z., & Xinhua, Y. (2018). Economic analysis of white-leg shrimp (*Penaeus vannamei*) production: Case study of Rudong County of Nantong City, Jiangsu Province, China. *Asian Journal of Agricultural Extension, Economics & Sociology*, *26*(4), 1-13. https://doi.org/10.9734/AJAEES/2018/42919

Martínez-Córdova, L. R., Porchas-Cornejo, M. A., Villarreal-Colmenares, H., Calderón-Pérez, J. A., & Naranjo-Páramo, J. (1998). Evaluation of three feeding strategies on the culture of white shrimp *Penaeus vannamei* Boone, 1931 in low water exchange ponds. *Aquacultural Engineering*, *17*(1), 21-28. https://doi.org/10.1016/S0144-8609(97)00010-1

Nugraha, M. A. R., Dewi, N. R., Awaluddin, M., Widodo, A., Sumon, M. A. A., Jamal, M. T., & Santanumurti, M. B. (2023). Recirculating aquaculture system (RAS) towards emerging whiteleg shrimp (*Penaeus vannamei*) aquaculture. *International Aquatic Research*, *15*(1), 1-14. https://doi.org/10.22034/IAR.2023.1973316.1361

Ponce-Palafox, J., Martinez-Palacios, C. A., & Ross, L. G. (1997). The effects of salinity and temperature on the growth and survival rates of juvenile white shrimp, *Penaeus vannamei*, Boone, 1931. *Aquaculture*, *157*(1-2), 107-115. https://doi.org/10.1016/S0044-8486(97)00148-8

Ray, A. J., Dillon, K. S., & Lotz, J. M. (2011). Water quality dynamics and shrimp (*Penaeus 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

Rego, M. A. S., Sabbag, O. J., Soares, R., & Peixoto, S. (2017). Financial viability of inserting the biofloc technology in a marine shrimp *Litopenaeus vannamei* farm: A case study in the state of Pernambuco, Brazil. *Aquaculture International*, *25*(1), 473-483. https://doi.org/10.1007/s10499-016-0044-7

Ruiz-Velazco, J. M. J., Hernández-Llamas, A., & Gómez-Muñoz, V. M. (2010). Management of stocking density, pond size, starting time of aeration, and duration of cultivation for intensive commercial production of shrimp *Penaeus vannamei*. *Aquacultural Engineering*, *43*(3), 114-119. https://doi.org/10.1016/j.aquaeng.2010.08.002

Sharma, K., Gulati, R., Poonam, Singh, S., & Rani, A. (2023). Mineral fortified inland low saline water for shrimp culture. *Acta Scientific Agriculture*, *7*(5), 35-43. https://doi.org/10.31080/ASAG.2022.07.1264

Tanjung, L. R., Prihutomo, A., Nawir, F., Chrismadha, T., & Widiyanto, T. (2022). Productivity assessment of an intensive whiteleg shrimp *Penaeus vannamei* farm based on Powersim-simulated growth rates. *Aquaculture International*, *30*(4), 2179-2196. https://doi.org/10.1007/s10499-022-00895-7

Timmons, M. B., Summerfelt, S. T., & Vinci, B. J. (1998). Review of circular tank technology and management. *Aquacultural Engineering*, *18*(1), 51-69. https://doi.org/10.1016/S0144-8609(98)00023-5

Tran, L., Nunan, L., Redman, R. M., Mohney, L. L., Pantoja, C. R., Fitzsimmons, K., & Lightner, D. V. (2013). Determination of the infectious nature of the agent of acute hepatopancreatic necrosis syndrome affecting penaeid shrimp. *Diseases of Aquatic Organisms*, *105*(1), 45-55. https://doi.org/10.3354/dao02621

Venkateswarlu, V., Seshaiah, P. V., Arun, P., & Behra, P. C. (2019). A study on water quality parameters in shrimp *Penaeus vannamei* semi-intensive grow-out culture

farms in coastal districts of Andhra Pradesh, India. *International Journal of Fisheries and Aquatic Studies*, *7*(4), 394-397.
Walker, S. J., Neill, W. H., Lawrence, A. L., & Gatlin, D. M., III. (2011). Effects of temperature and starvation on ecophysiological performance of the Pacific white shrimp (*Penaeus vannamei*). *Aquaculture*, *319*(3-4), 439-445. https://doi.org/10.1016/j.aquaculture.2011.07.015
Wijayanto, D., Nursanto, D. B., Kurohman, F., & Nugroho, R. A. (2017). Profit maximization of whiteleg shrimp (*Penaeus vannamei*) intensive culture in Situbondo Regency, Indonesia. *AACL Bioflux*, *10*(6), 1436-1444.
Xu, W. J., & Pan, L. Q. (2012). Effects of bioflocs on growth performance, digestive enzyme activity and body composition of juvenile *Litopenaeus vannamei* in zero-water exchange tanks manipulating C/N ratio in feed. *Aquaculture*, *356-357*, 147-152. https://doi.org/10.1016/j.aquaculture.2012.05.022
Xu, W., Zhang, B., Zhao, Y., & Cao, Y. (2025). Effect of stocking density on water quality, harmful nitrogen control, and production performance of *Penaeus vannamei* in biofloc-based systems with limited water exchange. *Fishes*, *10*(7), 326. https://doi.org/10.3390/fishes10070326

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