



## Growth Performance Of *Litopenaeus Vannamei* In Response To Stocking Density Under Contrasting Salinity Conditions In Andhra Pradesh, India

Anjaneyulu Indraganti<sup>1</sup>, K Madhusudhana Rao<sup>2</sup>, S Chengal Reddy<sup>3</sup>, Vivek Chintada<sup>4</sup>, Sumanth Kumar Kunda<sup>5\*</sup>

<sup>1,2,5\*</sup>Department of Zoology and Aquaculture A.N.U College of Sciences, Acharya Nagarjuna University, Guntur, Andhra Pradesh, India

<sup>3</sup>Department of Fishery Science and Aquaculture, S.V.U College of Sciences, Sri Venkateswara University, Tirupati A.P, India

<sup>4</sup>Department of Zoology, S.V.U College of Sciences, Sri Venkateswara University, Tirupati, Andhra Pradesh, India

**Corresponding author:** Sumanth Kumar Kunda

\*Department of Zoology and Aquaculture A.N.U College of Sciences, Acharya Nagarjuna University, Guntur, Andhra Pradesh, India.

### Abstract

The present study was aimed at establishing information on the growth rates of *Litopenaeus vannamei* cultured for one crop under different salinity and stocking density conditions, namely low salinity with low stocking density, low salinity with high stocking density, high salinity with low stocking density, and high salinity with high stocking density. The average values of pH, salinity, dissolved oxygen, ammonia, and temperature in ponds with low salinity and low stocking density were 8.04, 5ppt, 6.0 ppm, 0.48 ppm, and 28.22°C, respectively. In ponds with low salinity and high stocking density, the corresponding values were 8.39, 6 ppt, 5.53ppm, 0.61ppm, and 28.05°C, respectively. Similarly, the average values of pH, salinity, dissolved oxygen, ammonia, and temperature in ponds with high salinity and low stocking density were 8.31, 20 ppt, 4.92 ppm, 0.61 ppm, and 28.64°C, respectively. In contrast, ponds with high salinity and high stocking density recorded values of 7.98, 18 ppt, 5.13 ppm, 0.66 ppm, and 28.23°C, respectively. The results clearly demonstrated that stocking density exhibited an inverse relationship with shrimp growth. Lower stocking densities resulted in superior growth performance and higher production efficiency, whereas higher stocking densities adversely affected growth and reduced production rates. The findings indicate that optimizing stocking density is essential for maximizing the growth and production performance of *L. vannamei* under varying salinity conditions.

**Keywords:** *Litopenaeus vannamei*; stocking density; salinity; growth performance; pond culture; production efficiency.

### Introduction

Aquaculture is one of the fastest-growing food production sectors globally and plays a significant role in food security, nutritional supply, employment generation, and economic development (Naylor, 2016; Azra et al., 2021; FAO, 2022; Dewali et al., 2023). The rapid expansion of aquaculture production has contributed substantially to meeting the increasing demand for aquatic food products resulting from population growth and changing dietary preferences (Naylor et al., 2021; Verdegem et al., 2023). Among various aquaculture sectors, shrimp farming represents one of the most valuable industries owing to its high export potential and growing international market demand (FAO, 2022). Among the commercially important shrimp species, Pacific white shrimp, *Litopenaeus vannamei*, has emerged as the dominant cultured shrimp species worldwide because of its rapid growth rate, high survival, broad environmental tolerance, and adaptability to intensive farming systems (Wyban & Sweeney, 1991; Boyd & Clay, 2002; Figueredo et al., 2023). The species is native to the Pacific coast of Central and South America but has been successfully introduced into many Asian countries, including India, where it has become the backbone of the shrimp aquaculture industry (Kumaran et al., 2017; Bauer et al., 2023). Andhra Pradesh is recognized as the leading shrimp-producing state in India, contributing a major share of the country's shrimp production and export earnings (Kumaran et al., 2017).

Successful shrimp farming depends on several environmental and management factors, among which stocking density is considered one of the most critical determinants of growth performance, survival, feed utilization, and production efficiency (Arnold et al., 2009; Eid et al., 2020; Emerenciano et al., 2022). Stocking density directly influences the availability of space, feed resources, dissolved oxygen, and other environmental conditions required for normal growth and physiological activities of cultured shrimp (Moss & Moss, 2004; Mugwanya et al., 2022). Excessive stocking density often results in increased competition among individuals, leading to stress, reduced feed intake, poor growth performance, and lower survival rates (Ray & Chien, 1992). Furthermore, high stocking densities can contribute to the accumulation of metabolic wastes and uneaten feed, resulting in the deterioration of water quality and increased susceptibility to disease outbreaks (Hargreaves, 1998). Water quality management is another key factor affecting shrimp production in aquaculture systems. Parameters such as dissolved oxygen, pH, temperature, salinity, and ammonia concentration have direct effects

on shrimp metabolism, growth, survival, and immune responses (Boyd & Tucker, 1998). Dissolved oxygen is essential for respiration and energy metabolism, whereas elevated ammonia concentrations can induce physiological stress and suppress growth (Chien, 1992; Sun et al., 2023). Similarly, pH and temperature influence enzymatic activity, moulting, feeding behaviour, and overall culture performance (Fast & Lester, 1992). Therefore, maintaining optimal water quality conditions is essential for achieving sustainable shrimp production.

Salinity is an important environmental variable influencing the physiological performance and growth of *L. vannamei*. The species is highly euryhaline and can tolerate a wide range of salinity conditions, enabling its culture in both coastal high-salinity ponds and inland low-salinity farming systems (Saoud et al., 2003; Sun et al., 2022). However, variations in salinity may affect osmoregulation, energy expenditure, feed conversion efficiency, and growth performance (Ponce-Palafox et al., 1997). Previous studies have demonstrated that appropriate salinity conditions can enhance shrimp growth and production, whereas suboptimal salinity levels may increase physiological stress and reduce culture performance (Jaffer et al., 2021; Liu, et al., 2023). The interaction between stocking density and salinity is particularly important in shrimp farming because both factors collectively influence pond ecology, water quality dynamics, and shrimp growth. Although several studies have independently examined the effects of stocking density and salinity on shrimp culture performance, information regarding their combined influence under practical farming conditions remains limited. Understanding these relationships is essential for developing efficient culture strategies and improving production sustainability. Therefore, the present study was undertaken to evaluate the growth performance of *Litopenaeus vannamei* cultured under low- and high-salinity pond conditions with different stocking densities. The study further assessed important water quality parameters, including pH, salinity, dissolved oxygen, ammonia, and temperature, to determine their relationship with shrimp growth and production performance. The findings of the study are expected to contribute to the optimization of stocking density management and sustainable shrimp culture practices.

## **2. MATERIALS AND METHODS**

### **2.1 Experimental Design and Pond Management**

The present study was conducted to evaluate the growth performance of *Litopenaeus vannamei* cultured under low- and high-salinity pond conditions at different stocking densities. The experiment comprised four culture conditions: low salinity with low stocking density, low salinity with high stocking density, high salinity with low stocking density, and high salinity with high stocking density. Prior to stocking, all ponds were prepared following standard shrimp farming practices. The ponds were completely dried and tilled to eliminate pests and predators and to facilitate oxidation of the pond bottom soil (Boyd & Tucker, 1998). Liming was carried out to correct soil pH and improve pond productivity. Natural food organisms were promoted through the adoption of Good Management Practices (GMPs), thereby creating favourable environmental conditions for shrimp growth and survival (FAO, 2022).

### **2.2 Shrimp Sampling and Growth Monitoring**

Sampling was initiated on the 50th day of culture and continued at weekly intervals until harvest. During each sampling event, shrimp were collected from the ponds to determine average body weight and assess growth performance. Weekly growth rates were recorded throughout the culture period. In addition, the physical condition and general health status of shrimp were monitored during each sampling operation to evaluate culture performance (Fast & Lester, 1992).

### **2.3 Feeding Management**

Shrimp were fed using commercially formulated feed according to the standard feeding chart adopted for *L. vannamei* culture. Feed quantities were adjusted periodically based on shrimp growth, biomass estimates, and expected survival rates. Feeding management was carried out throughout the culture period to ensure adequate nutrition and optimal growth performance (Wyban & Sweeney, 1991).

### **2.4 Water Quality Analysis**

Water quality parameters were monitored regularly during the culture period. Water temperature was measured directly in the field using a mercury thermometer with a range of 0–100°C and a least count of 1°C. The pH of pond water was determined using an ELICO pH meter. Dissolved oxygen was estimated by collecting water samples in biological oxygen demand (BOD) bottles, fixing the samples immediately at the sampling site, and subsequently analysing them in the laboratory using Winkler's titration method (APHA, 2017).

Salinity and ammonia concentrations were determined according to the procedures described by Grasshoff et al. (1999). The measured water quality parameters included pH, salinity, dissolved oxygen, ammonia, and temperature, which are recognized as critical factors influencing shrimp growth and survival (Boyd & Tucker, 1998).

### **2.5 Growth Performance Indices**

Growth performance was evaluated using feed conversion ratio (FCR) and average daily growth (ADG). These parameters were calculated using the following equations:

$$FCR = \frac{\text{Total weight of harvested shrimps}}{\text{Total feed used}}$$

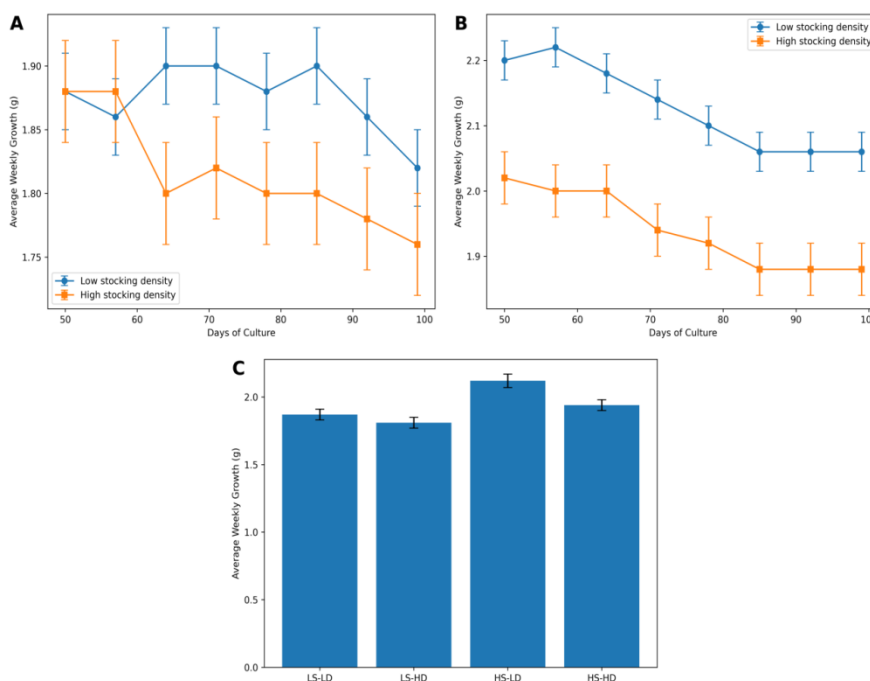
$$ADG = \frac{\text{Total weight gained by shrimps}}{\text{Total days of culture}}$$

These parameters were used to evaluate the growth performance of *Litopenaeus vannamei* cultured under different salinity and stocking density conditions.

### 3. Results And Discussion

In West Godavari District, the average weekly growth of *Litopenaeus vannamei* cultured in low-salinity ponds during the second crop of 2019 ranged from 1.82 to 1.90 g in low-stocking-density ponds and from 1.76 to 1.88 g in high-stocking-density ponds. The average weekly growth was consistently higher in low-stocking ponds compared with high-stocking ponds throughout the culture period. The average water quality parameters recorded in low-salinity ponds with low stocking density were pH 8.04, salinity 5 ppt, dissolved oxygen 6.0 ppm, ammonia 0.48 ppm, and temperature 28.22°C. Under these conditions, the average weekly growth was 1.87 g at a stocking density of 20 shrimp m<sup>2</sup>.

In low-salinity ponds with high stocking density, the average pH, salinity, dissolved oxygen, ammonia, and temperature were 8.39, 6 ppt, 5.53 ppm, 0.61 ppm, and 28.05°C, respectively. The average weekly growth recorded under these conditions was 1.81 g at a stocking density of 45 shrimp m<sup>2</sup>. In high-salinity ponds, the average weekly growth ranged from 2.06 to 2.22 g in low-stocking-density ponds and from 1.88 to 2.02 g in high-stocking-density ponds during the second crop of 2019. Growth performance was consistently higher in low-stocking ponds than in high-stocking ponds. The average water quality parameters observed in high-salinity ponds with low stocking density were pH 8.31, salinity 20 ppt, dissolved oxygen 4.92 ppm, ammonia 0.61 ppm, and temperature 28.64°C. The average weekly growth recorded under these conditions was 2.12 g at a stocking density of 20 shrimp m<sup>2</sup>.



**Figure 1.** Growth performance of *Litopenaeus vannamei* cultured under different salinity and stocking density conditions during the second crop of 2019 in West Godavari District, Andhra Pradesh, India. (A) Average weekly growth in low-salinity ponds under low and high stocking densities. (B) Average weekly growth in high-salinity ponds under low and high stocking densities. (C) Comparative average weekly growth under low-salinity low-density (LS-LD), low-salinity high-density (LS-HD), high-salinity low-density (HS-LD), and high-salinity high-density (HS-HD) culture conditions.

In high-salinity ponds with high stocking density, the average values of pH, salinity, dissolved oxygen, ammonia, and temperature were 7.98, 18 ppt, 5.13 ppm, 0.66 ppm, and 28.23°C, respectively. The average weekly growth recorded under these conditions was 1.94 g at a stocking density of 40 shrimp m<sup>2</sup>. Overall, the results indicated that lower stocking densities resulted in higher average weekly growth rates under both low- and high-salinity conditions. Furthermore, shrimp cultured in high-salinity ponds exhibited better growth performance than those cultured in low-salinity ponds.

Water quality management is a critical component of successful shrimp farming because the accumulation of excess feed, metabolic wastes, and nitrogenous compounds can adversely affect pond ecology and shrimp performance. Regular monitoring of water quality parameters is therefore essential to maintain favourable culture conditions and ensure optimum shrimp growth and survival (Soundarapandian & Gunalan, 2008; Orozco-Lugo et al, 2022). The salinity values observed in the present study were within the tolerance range reported for *L. vannamei*. Gunalan et al. (2010) reported satisfactory growth and survival of *L. vannamei* in brackishwater ponds with salinity levels ranging from 10 to 35 ppt, while Parker et al. (1974) demonstrated that the species can tolerate salinity levels as low as 2.45 ppt. Praveen Kumar and Krishna (2015) reported maximum average daily growth at a salinity of 9.89 ppt. In the present study, the highest average weekly growth was recorded under high-salinity conditions, indicating that salinity may have contributed positively to shrimp growth performance.

The pH values recorded during the study ranged from 7.98 to 8.39, which fall within the favourable range of 7.6–8.6 recommended for *L. vannamei* culture by Wang et al. (2004). Similarly, Praveen Kumar and Krishna (2015) reported pH values ranging from  $7.2 \pm 0.4$  to  $7.9 \pm 0.3$  in shrimp ponds. The average pH observed in the present study supported satisfactory shrimp growth and survival. Dissolved oxygen concentrations observed during the study varied between 4.92 and 6.0 ppm, which are comparable to the values reported by Praveen Kumar and Krishna (2015). Adequate dissolved oxygen availability is essential for respiration, metabolism, and feed utilization in shrimp culture systems. The relatively higher dissolved oxygen levels recorded in low-density ponds may have contributed to improved growth performance.

The average ammonia concentrations recorded in the present study ranged from 0.48 to 0.66 ppm and were within the range reported (Suriya et al. 2016). Higher ammonia concentrations were generally observed in high-stocking-density ponds, suggesting greater accumulation of metabolic wastes (Diao et al., 2023). Elevated ammonia levels are known to induce physiological stress and reduce growth performance in cultured shrimp. The growth data clearly demonstrated an inverse relationship between stocking density and shrimp growth. Lower stocking densities consistently produced higher average weekly growth rates under both salinity conditions, whereas higher stocking densities resulted in reduced growth performance. These findings may be attributed to reduced competition for feed and space, improved water quality, and lower stress levels in low-density culture systems. Similar observations have been reported by Suriya et al. (2016) and Parvathi and Padmavathi (2018), who also found that lower stocking densities enhanced the growth performance of *L. vannamei*. The results of the present study therefore emphasize the importance of optimizing stocking density and maintaining suitable water quality conditions to achieve maximum growth and production efficiency of *Litopenaeus vannamei* under both low- and high-salinity pond culture systems.

## REFERENCES

1. Ababouch, L., Nguyen, K. A. T., Castro de Souza, M., & Fernandez-Polanco, J. (2023). Value chains and market access for aquaculture products. *Journal of the World Aquaculture Society*, 54(2), 527-553.
2. APHA. (2017). *Standard methods for the examination of water and wastewater* (23rd ed.). American Public Health Association.
3. Arnold, S. J., Sellars, M. J., Crocos, P. J., & Coman, G. J. (2009). Intensive production of juvenile tiger shrimp *Penaeus monodon*: An evaluation of stocking density and artificial substrates. *Aquaculture*, 293(1–2), 42–48.
4. Azra, M. N., Okomoda, V. T., Tabatabaei, M., Hassan, M., & Ikhwanuddin, M. (2021). The contributions of shellfish aquaculture to global food security: assessing its characteristics from a future food perspective. *Frontiers in Marine Science*, 8, 654897.
5. Bauer, R. T. (2023). Fisheries and aquaculture. In *Shrimps: their diversity, intriguing adaptations and varied lifestyles* (pp. 583-655). Cham: Springer International Publishing.
6. Boyd, C. E., & Clay, J. W. (2002). Evaluation of Belize Aquaculture, Ltd: A super-intensive shrimp aquaculture system. World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment.
7. Boyd, C. E., & Tucker, C. S. (1998). *Pond aquaculture water quality management*. Springer.
8. Chien, Y. H. (1992). Water quality requirements and management for marine shrimp culture. In A. W. Fast & L. J. Lester (Eds.), *Marine shrimp culture: Principles and practices* (pp. 144–156). Elsevier.
9. Dewali, S., Sharma, N., Melkani, D., Arya, M., Kathayat, N., Panda, A. K., & Bisht, S. S. (2023). Aquaculture: Contributions to global food security. In *Emerging solutions in sustainable food and nutrition security* (pp. 123-139). Cham: Springer International Publishing.
10. Diao, W., Jia, R., Hou, Y., Dong, Y., Li, B., & Zhu, J. (2023). Effects of stocking density on the growth performance, physiological parameters, antioxidant status and lipid metabolism of *Pelteobagrus fulvidraco* in the integrated rice-fish farming system. *Animals*, 13(11), 1721.
11. Eid, A., Ali, B., Al Sayed, K., Marzok, S., Khames, M. K., & Khames, D. K. (2020). Stocking density, Survival rate and Growth performance feed utilization and economic evaluation of *Litopenaeus vannamei* (Boon, 1931) in different cultured shrimp farms in Suez Canal Region. *Egyptian Journal for Aquaculture*, 10(3), 96-114.
12. Emerenciano, M. G., Rombenso, A. N., Vieira, F. D. N., Martins, M. A., Coman, G. J., Truong, H. H., & Simon, C. J. (2022). Intensification of penaeid shrimp culture: an applied review of advances in production systems, nutrition and breeding. *Animals*, 12(3), 236.
13. FAO. (2022). *The state of world fisheries and aquaculture 2022*. Food and Agriculture Organization of the United Nations.
14. Fast, A. W., & Lester, L. J. (1992). *Marine shrimp culture: Principles and practices*. Elsevier.

15. Figueredo, A., Lira, C., Vera-Caripe, J., De Donato, M., & Lodeiros, C. (2023). The Pacific white shrimp, the most cultivated shrimp species, is it *Litopenaeus* or *Penaeus vannamei*?. *Reviews in Aquaculture*, 15(1).
16. Grasshoff, K., Kremling, K., & Ehrhardt, M. (1999). *Methods of seawater analysis* (3rd ed.). Wiley-VCH.
17. Gunalan, B., Soundarapandian, P., Anand, T., & Kotiya, A. S. (2010). Effect of stocking density on the growth and survival of white leg shrimp *Litopenaeus vannamei* (Boone, 1931). *Current Research Journal of Biological Sciences*, 2(5), 283–286.
18. Hargreaves, J. A. (1998). Nitrogen biogeochemistry of aquaculture ponds. *Aquaculture*, 166(3–4), 181–212.
19. Jaffer, Y. D., Ravi, R., Ambasankar, K., & Vijayan, K. K. (2021). Salinity tolerance and physiological response of Pacific white shrimp *Litopenaeus vannamei* under inland saline water culture conditions. *Aquaculture International*, 29(2), 745–758.
20. Kumaran, M., Geetha, R., Antony, J., Vasagam, K. P. K., Anand, P. R., Ravisankar, T., Angel, J. R. J., De, D., Muralidhar, M., Patil, P. K., & Vijayan, K. K. (2017). Prospective impact of white spot syndrome virus disease on shrimp farming in India. *Aquaculture*, 467, 228–236.
21. Liu, Y., Wang, B., Jiang, K., Zhao, Z., Liu, M., & Wang, L. (2023). Effects of salinity training on growth performance, osmotic regulation, and pathogen resistance of post-larval *Litopenaeus vannamei*. *Aquaculture*, 562, 738770.
22. Moss, D. R., & Moss, S. M. (2004). Effects of artificial substrate and stocking density on the nursery production of Pacific white shrimp *Litopenaeus vannamei*. *Journal of the World Aquaculture Society*, 35(4), 536–542.
23. Mugwanya, M., Dawood, M. A., Kimera, F., & Sewilam, H. (2022). A review on recirculating aquaculture system: Influence of stocking density on fish and crustacean behavior, growth performance, and immunity. *Annals of Animal Science*, 22, 873.
24. Naylor, R. L. (2016). Oil crops, aquaculture, and the rising role of demand: A fresh perspective on food security. *Global Food Security*, 11, 17-25.
25. Naylor, R. L., Hardy, R. W., Buschmann, A. H., Bush, S. R., Cao, L., Klingler, D. H., Little, D. C., Lubchenco, J., Shumway, S. E., & Troell, M. (2021). A 20-year retrospective review of global aquaculture. *Nature*, 591(7851), 551–563.
26. Orozco-Lugo, A. G., McLernon, D. C., Lara, M., Zaidi, S. A. R., González, B. J., Illescas, O., & Rodríguez-Vázquez, R. (2022). Monitoring of water quality in a shrimp farm using a FANET. *Internet of Things*, 18, 100170.
27. Parker, J. C., Conte, F. S., & MacGrath, W. S. (1974). Influence of salinity and temperature on survival and growth of shrimp. *Aquaculture*, 4(1), 45–57.
28. Parvathi, A., & Padmavathi, P. (2018). Influence of stocking density on growth performance and survival of *Litopenaeus vannamei* in culture ponds. *International Journal of Fisheries and Aquatic Studies*, 6(2), 120–124.
29. 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*. *Aquaculture*, 157(1–2), 107–115.
30. Praveen Kumar, M., & Krishna, P. V. (2015). Effect of water quality parameters on growth performance of *Litopenaeus vannamei* under different stocking densities. *International Journal of Fisheries and Aquatic Studies*, 3(1), 30–35.
31. Ray, W. M., & Chien, Y. H. (1992). Effects of stocking density and feeding frequency on shrimp production. *Aquaculture*, 99(3–4), 233–240.
32. Saoud, I. P., Davis, D. A., & Rouse, D. B. (2003). Suitability studies of inland well waters for *Litopenaeus vannamei* culture. *Aquaculture*, 217(1–4), 373–383.
33. Soundarapandian, P., & Gunalan, B. (2008). Recent technology for the seed production of white shrimp *Litopenaeus vannamei*. *Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, India*, 1–20.
34. Sun, S. X., Hu, C. T., Qiao, F., Chen, L. Q., Zhang, M. L., & Du, Z. Y. (2023). High dissolved oxygen exacerbates ammonia toxicity with sex-dependent manner in zebrafish. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, 266, 109549.
35. Sun, X., Zhang, H., Wang, Z., Huang, T., & Huang, H. (2022). Phytoplankton community response to environmental factors along a salinity gradient in a seagoing river, Tianjin, China. *Microorganisms*, 11(1), 75.
36. Suriya, M., Biju, I. F., & Kumar, T. T. A. (2016). Effect of stocking density on growth and survival of Pacific white shrimp *Litopenaeus vannamei*. *International Journal of Fisheries and Aquatic Studies*, 4(3), 342–345.
37. Verdegem, M., Buschmann, A. H., Latt, U. W., Dalsgaard, A. J., & Lovatelli, A. (2023). The contribution of aquaculture systems to global aquaculture production. *Journal of the World Aquaculture Society*, 54(2), 206-250.
38. Wang, Y. B., Xu, Z. R., & Xia, M. S. (2004). The effectiveness of commercial probiotics in northern white shrimp *Penaeus vannamei* ponds. *Fisheries Science*, 71(5), 1034–1039.
39. Wyban, J., & Sweeney, J. N. (1991). *Intensive shrimp production technology: The Oceanic Institute shrimp manual*. Oceanic Institute.