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Interactive Effects of Stocking Density and Salinity on THE Growth Performance of Litopenaeus Vannamei in Semi-Intensive Pond Culture of Krishna District, Andhra Pradesh, India

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ABSTRACT
A broad industry consensus has formed in the aquaculture sector that the core factors influencing the growth and production performance of Pacific white shrimp (Litopenaeus vannamei) are stocking density and salinity. Meanwhile, water quality parameters including pH, dissolved oxygen, ammonia nitrogen, and temperature are also key conditions for maintaining a suitable environment in aquaculture ponds that supports shrimp growth and survival. To further clarify the actual impacts of these two core factors, this study set up four experimental pond groups with different combinations of salinity and stocking density during the second crop of 2018 in Krishna District, Andhra Pradesh, India. The four groups are: low salinity and low stocking density, low salinity and high stocking density, high salinity and low stocking density, and high salinity and high stocking density. Throughout the full breeding period, the growth rate of Litopenaeus vannamei was continuously monitored, and the average monitored values of all core water quality parameters (including pH, dissolved oxygen, ammonia nitrogen, and temperature) for the four pond groups were synchronously recorded and collated. Based on analysis and inference of all experimental data, this study reached the following core conclusion: stocking density is negatively correlated with the growth and production capacity of Litopenaeus vannamei. Under both low-salinity and high-salinity conditions, the production performance of low stocking density groups outperforms that of high stocking density groups, and high-density farming reduces the overall aquaculture production capacity.
Keywords- *Stocking density; Production; Litopenaeus vannamei; Salinity*

1. INTRODUCTION

Global aquaculture is currently the world's fastest-growing food production sector, and it holds multifaceted core value for safeguarding global food security (Bennett et al., 2018; Dewali et al., 2023; Dewali et al., 2023; Jolly et al., 2023). One core species in global aquaculture is *Litopenaeus vannamei* (common name: Pacific white shrimp), which has risen to this status due to its outstanding advantages suited to commercial farming (Liao & Chien, 2011; Li et al., 2018; De Silva et al., 2021). In recent years, the scale of its cultivation in Andhra Pradesh, India, has expanded rapidly. However, to advance the sustainable farming of this species, pond management and environmental parameters remain core limiting conditions (Bosma and Verdegem, 2011; Chen et al., 2019; Hill et al., 2021). Salinity and stocking density are the most critical factors that determine farming profitability, as well as the growth and survival of farmed shrimp (Suriya et al., 2016; Kotiya and Vadher, 2021; Setyawan et al., 2022). Salinity directly impacts farming performance by influencing key physiological processes in shrimp such as osmoregulation (Rahi et al., 2021; Gao et al., 2016). A 2010 study by Su et al. explored the effects of combined fluctuating salinity and temperature conditions on the growth and energy budget of juvenile *L. vannamei*; a 2001 study by Laramore et al. verified the species' adaptability to low-salinity environments; recent studies by Roy et al. (2020) and Jaffer et al. (2021) further confirmed that the species has a broad salinity tolerance, enabling it to adapt to diverse farming settings in both inland and coastal areas.

Stocking density is the core factor affecting the ecological stability of *Litopenaeus vannamei* culture ponds and the production performance of the shrimp (Liu et al., 2017; Zhang et al., 2022). High-density culture

triggers competition between individual shrimp for feed and living space, which in turn leads to a series of negative effects, including massive accumulation of metabolic waste, elevated ammonia nitrogen in water, continuous deterioration of water quality, and reduced dissolved oxygen levels (Romano and Zeng, 2017; Emerenciano et al., 2022). Multiple previous studies have confirmed the necessity of optimizing stocking density: Praveen Kumar and Krishna (2015) found that the growth performance of Pacific white shrimp declines significantly as stocking density increases; Krishana et al. (2015) proposed that in the semi-intensive culture systems of Andhra Pradesh, India, a suitable optimal stocking density is a necessary condition to maintain sustainable shrimp production; Rahman et al. (2022) and Anand et al. (2023) successively confirmed that in intensive culture systems, optimizing stocking density can simultaneously improve feed conversion ratio, water quality stability, and the economic returns of aquaculture. The field has currently defined the density thresholds for three types of culture models: extensive culture, 1–3 individuals per m^2; semi-intensive culture, 10–50 individuals per m^2; intensive culture, a maximum of 160 individuals per m^2. It is now a widely accepted consensus that stocking density is negatively correlated with shrimp growth. Although existing studies have explored the effects of the interaction between Salinity and stocking density on *Litopenaeus vannamei*, there remains a clear gap in comparative growth data for shrimp raised in high-salinity and low-salinity ponds in the Krishna district of Andhra Pradesh, India. This study therefore carried out a trial in this region during the second production season of 2018, to evaluate the growth rate of *Litopenaeus vannamei* under the conditions of high- and low-salinity ponds, and high and low stocking densities.

2. MATERIAL AND METHODS

This study was carried out in the second crop of 2018 in Krishna District, Andhra Pradesh, India, with *Litopenaeus vannamei* (Pacific white shrimp) as the research subject. A multi-gradient aquaculture experiment was designed with two variable factors: salinity (low/high) and stocking density (low/high), and the core goal of the study was to estimate the growth parameters of the shrimp. Before the experiment started, the ponds were sun-treated to eliminate pest species, their bottom sediments were oxidized, and lime was applied to adjust soil pH to improve pond conditions. Good Management Practices (GMP) were followed throughout the whole process to propagate natural bait and maintain the basic productivity of the ponds. During the culture period, the feeding rate was adjusted based on the standard feeding schedule, as well as the observed growth performance and estimated survival rate of the shrimp. Starting from the 50th day of culture, the average body weight of the shrimp was measured regularly until harvest. Growth performance was recorded weekly for
The entire culture cycle, and the health status of the shrimp was checked synchronously during each sampling event. Water temperature was measured on-site using a mercury thermometer with a range of 0-100°C and an accuracy of 1°C; pH was tested with an ELICO brand pH meter; dissolved oxygen was analyzed in the laboratory via the Winkler titration method, after water samples were collected in BOD bottles and fixed on-site. Salinity and ammonia nitrogen were measured following the standard methods proposed by Grosshoff et al. in 1999. Subsequent work will include formula-based calculation of feed conversion ratio (FCR) and average daily gain (ADG).

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

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

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

3. RESULTS

The *Litopenaeus vannamei* culture experiment conducted for this study was implemented in the second farming season of 2018 in Krishna District. The core variables of the experiment were stocking density and water salinity. A low-density group stocked at 25 individuals per m^2 and a high-density group stocked at 45 individuals per m^2 were set up as controls in low-salinity ponds. Significant differences were observed in the average weekly growth (AWG) of shrimp between the two groups. In low-salinity ponds, the weekly

growth of the low-density group ranged from 1.8 to 1.9 g per week, while that of the high-density group ranged from 1.4 to 1.64 g per week. Growth data collected at two culture time points, 50 days and 99 days, further confirmed that the low-density group had better growth performance. Water quality parameters including pH, salinity, dissolved oxygen, ammonia nitrogen, and water temperature were recorded separately for each group, with no cross-group misclassification. Based on observational data, it is inferred that the higher ammonia nitrogen concentration in high-density ponds may have hindered the growth of the shrimp. All supporting information for the core data presented in this paragraph is detailed in Figure A, Figure B, Figure C and Figure D.

During the second crop in 2018, our research team set up two groups with different stocking densities in high-salinity shrimp ponds to conduct controlled observations: the low stocking density group had a density of 25 individuals/m^2, while the high stocking density group had 50 individuals/m^2. Shrimp in the low-density group had an average weekly growth range of 2.10 g to 2.26 g, with absolute weekly growth of 2.26 g at 50 days of age and 2.10 g at 99 days of age, respectively. The corresponding values for the high-density group ranged from 1.80 g to 2.02 g, with absolute weekly growth of 2.02 g and 1.80 g at the same two ages. This study simultaneously measured the full set of water quality parameters for both groups of ponds, including pH, salinity, dissolved oxygen, ammonia nitrogen, temperature, and other relevant water quality indicators. We finally derived the core conclusion that high stocking density exerts negative impacts on shrimp growth across both low-salinity and high-salinity scenarios. All related data and citations are presented in Figure 1.

4. DISCUSSION

Maintaining suitable water quality parameters is a core prerequisite for achieving optimal growth and survival in the culture of *Litopenaeus vannamei.* During the culture process, uneaten feed, metabolic waste from shrimp, and accumulated nitrogen-containing compounds continuously disrupt the ecological balance of culture ponds and threaten the health of shrimp, so core water quality indicators must be monitored regularly throughout the entire culture cycle. Previous studies by Soundarapandian and Gunalan, 2018; Gunalan et al., 2010 and Parker et al. 1974 all corroborate the importance of water quality management. After comparing the salinity tolerance ranges of *Litopenaeus vannamei* documented by different research teams, observations from this study found that the average weekly growth rate of shrimp in high-salinity environments was higher than that in low-salinity ponds, and the highest average weekly growth rate was recorded in high-salinity, low-density ponds with a salinity of 25 ppt. This trend is consistent with the conclusions of Praveen Kumar and Krishna, (2015); the pH range of 7.83–8.27 measured in this study, which can support better growth and survival of shrimp, also aligns with the conclusions of Wang et al.

This study carried out an empirical investigation of shrimp pond aquaculture. First, it confirmed that dissolved oxygen is the core water quality parameter affecting shrimp metabolism and growth. The dissolved oxygen levels measured in the study's ponds stayed within the range of 5.2–6.8 mg/L, and suitable dissolved oxygen levels correlated with better shrimp growth performance; this trend aligns with the dissolved oxygen data collected previously by Praveen Kumar and Krishna (2015); Hargreaves and Boyd, (2021) across different culture densities. The water temperature measured in this study remained stable at 26–30°C, a range sufficient to support the normal growth of shrimp throughout the full culture cycle. Ammonia nitrogen is another core influencing factor: the ammonia nitrogen levels measured in this study fell between 0.02 and 0.15 mg/L, high-density ponds had higher ammonia nitrogen concentrations, which may drive down shrimp growth performance, and this result is consistent with observations by Suriya et al., 2016; Satanwat, et al., 2023. Finally, this study found that the average weekly growth rate of shrimp in low-density ponds was significantly higher than that of shrimp in high-density ponds, a conclusion that is also corroborated by similar studies conducted by Sookying et al., 2011; Suriya et al., 2016; Mohanty et al., 2017; Samadan, 2018; Tierney et al., 2020 and Kring et al., 2023).

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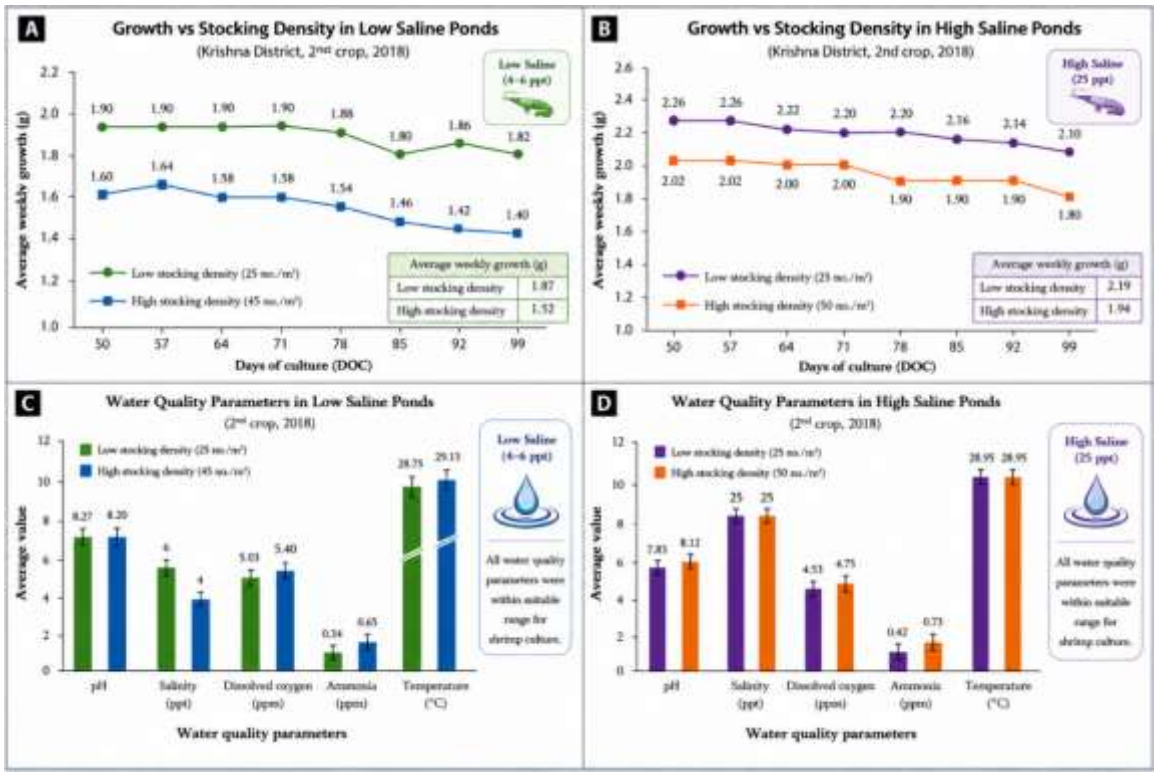

Figure 1. Growth performance and water quality parameters of *Litopenaeus vannamei* cultured under low and high stocking density conditions in low and high saline ponds during the second crop of 2018 in Krishna District, Andhra Pradesh, India. Panels (A) and (B) represent the average weekly growth (AWG) under low and high saline conditions, respectively, while panels (C) and (D) illustrate the corresponding water quality parameters including pH, salinity, dissolved oxygen, ammonia, and temperature recorded during the culture period. Higher growth performance was observed under low stocking density conditions compared to high stocking density ponds.

5. CONCLUSION

This study carried out a *Litopenaeus vannamei* aquaculture experiment in Krishna District, Andhra Pradesh, India, in the second crop of 2018. Its core conclusion is that stocking density is negatively correlated with the shrimp's growth performance. Measured data from groups with different salinity levels show that in low-salinity ponds, the weekly growth of shrimp raised at a density of 25 individuals per m^2 was 1.87 g, which fell to 1.52 g at a density of 45 individuals per m^2; in high-salinity ponds, the weekly growth was 2.19 g at a density of 25 individuals per m^2, and measured 1.94 g at a density of 50 individuals per m^2. Low-density ponds had better water quality conditions that can support shrimp growth, so it is recommended that producers maintain the optimal stocking density, pair it with standardized water quality management, and achieve sustainable aquaculture production.

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