

Standardization and Economic Viability of Biofloc based Culture of Pacific White Shrimp (*Penaeus vannamei*) under Andaman and Nicobar Island Conditions

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Abstract

The present study evaluated the production performance and economic viability of *Penaeus vannamei*, cultured in a biofloc system under the environmental conditions of the Andaman and Nicobar Islands. Shrimp post-larvae (PL-10) were reared in 10000 L biofloc tanks at six different stocking densities ranging from 1000 to 6000 shrimp per tanks for a culture period of 100 days. Growth performance, survival, feed conversion ratio (FCR), water quality parameters, and economic returns were assessed. Results revealed significant differences ($p < 0.05$) among stocking densities for growth and survivability. The highest individual growth was observed at the lowest stocking densities of 1000 shrimp/10 m³ L, with final body weight and length reaching 17.2 g and 16.5 cm, respectively. However, the maximum biomass production (24.4 kg) was obtained at 3000 shrimp/10 m³ L, indicating as optimum balance between growth and production efficiency. Survival and FCR deteriorated significantly ($p < 0.05$) at higher stocking densities. Water quality parameters remained within acceptable limits throughout the experiment, confirming the effectiveness of biofloc technology in maintaining a stable culture environment. An extended culture period 120 days with partial harvesting future improved biomass yield, survival, and feed efficiency, resulting in moderate stocking density of 3000 number of PL-10 per unit biofloc tanks

Key words: *Biofloc, Penaeus vannamei, stocking density, Economic viability*

Introduction

The Andaman and Nicobar Islands possess immense potential for brackishwater aquaculture and shrimp farming owing to their vast coastline, rich marine biodiversity, and abundant water resources. The islands comprise about 836 islands with a coastline exceeding 1,900 km and an Exclusive Economic Zone (EEZ) of nearly 0.6 million km², providing substantial scope for marine fisheries and aquaculture development. The islands experience a humid tropical climate, characterized by consistently warm temperatures high annual rainfall, and intense precipitation during both the southwest and northeast monsoons (Krishnan *et al.*, 2011). Despite these advantages, aquaculture development in the islands remains at a nascent stage, with fisheries production largely dependent on capture fisheries. Marine fisheries contribute significantly to the island economy, with tuna, shrimp, crab, lobster, and reef fish forming major commercially important resources. Shrimp demand in domestic and export markets has increased considerably due to high consumer preference and export value.

However, organized shrimp farming and value-chain development in the islands remain limited because of geographical isolation, transportation constraints, limited hatchery infrastructure, high input costs, and inadequate cold-chain and marketing facilities. Another challenge is salinity levels in Island ecosystem. Coastal water salinity generally decreases from around 36 ppt to nearly 30 ppt during the rainy season, while salinity levels in shrimp culture ponds may decline sharply to around 10 ppt due to direct rainfall and freshwater runoff. Such abrupt salinity fluctuations in salinity create challenging conditions for shrimp farming and frequently lead to poor growth, physiological stress and mortality in conventional pond based culture system (Boyd & Tucker, 2012). The population of the Andaman and Nicobar Islands was 3.8 lakh indicating a growing consumer base and increasing economic activities in the region (Andaman and Nicobar Tourism Department, 2023). This increasing population and its popularization for tourism sector have substantially enhanced the demand for high value seafood, particularly shrimp, in hotels, restaurants and local seafood market.

However, local shrimp production remains extremely limited and insufficient to meet the increasing demand. Capture fisheries contribute only a small quantity of shrimp, as trawling activities are highly restricted in the islands owing to the presence of ecologically sensitive coral reef ecosystems and designated marine protected areas (Soundarapandian & Sankar, 2008). Consequently, a major proportion of shrimp consumed in the islands is imported from mainland India, leading to elevated market prices that generally ranging between ₹ 500-600 per kg for *Penaeus vannamei* of 60 to 70 count size. One export front is dominated by capture-based marine products, while scientific shrimp aquaculture has substantial untapped potential for livelihood generation, employment creation, nutritional security, and export enhancement. Despite such strong market demand and favourable climatic condition, shrimp aquaculture in the Andaman and Nicobar Islands is still at an infant stage. At present, only about 5ha of land is utilised for shrimp (*P. vannamei*) farming under conventional pond culture systems. Expansion of shrimp farming is severely constrained due to limited land availability and strict environmental regulations, particularly those associated with protected areas, national parks, mangroves and coastal regulation zone (CRZ) restrictions (Kathiresan & Rajendran, 2005). In addition, the Islands lack commercial shrimp hatcheries, feed manufacturing industries and aquaculture input suppliers. Therefore, farmers are entirely dependent on shrimp feed, seed and other culture inputs transported from mainland India, which substantially increases operational costs and reduces economic profitability. Among various cultured shrimp species, the Pacific white shrimp (*P. vannamei*) has become one of the most commercially important aquaculture species worldwide, owing to its rapid growth, high survival rate, euryhaline nature, and suitability for intensive farming systems (FAO, 2022). In recent years, biofloc technology (BFT) has gained considerable attention as a sustainable and economically efficient aquaculture system for intensive shrimp farming (Avnimelech, 2015). Biofloc system works through the proliferation of heterotrophic microbial consortia that usually assimilate nitrogenous metabolites and convert them into microbial biomass. This process not only improve the water quality by reducing toxic nitrogen compounds

but also generates protein-rich microbial aggregates that serve as a supplemental natural feed source for cultured shrimp (Crab *et al.*, 2012). The technology offers several advantages, including reduced water exchange, enhanced biosecurity, improved nutrient cycling, lower feed conversion ratio (FCR) and higher production from limited culture areas (Emerenciano *et al.*, 2017). Biofloc-based shrimp culture holds particular significance for the Andaman and Nicobar Islands, as the system minimizes direct exposure of culture water to rainfall and thereby mitigates the risk of pronounced salinity fluctuation during monsoon periods. The bio-secure environment of biofloc tanks also reduces the possibility of disease outbreaks and makes the system suitable for small scale backyard farming as well as commercial operations in areas where land availability is limited. Furthermore, the technology can support sustainable shrimp production under Island conditions where freshwater availability, land resources and infrastructure are constrained (Hargreaves, 2013). Among the various management practices in biofloc systems, stocking density is one of the most critical factors influencing shrimp growth performance, survival, FCR, water quality and overall economic profitability (Krummenauer *et al.*, 2011). High stocking densities may increase total biomass yield; however, they often deteriorate water quality and elevate physiological stress, ultimately resulting in reduced growth performance and lower survival rates (Arambul-Muñoz *et al.*, 2019). Conversely, lower stocking densities may enhance individual growth performance; however, they tend to reduce overall production efficiency and economic returns. Under the specific conditions of the Andaman & Nicobar Islands, where aquaculture inputs are costly due to transportation from mainland India, the optimization and standardisation of stocking density are critical for ensuring the economic viability of shrimp farming. Therefore, determining the optimum stocking density and adopting suitable culture management practices are imperative for developing sustainable and economically viable biofloc-based shrimp farming models tailored to islands conditions. Hence, the present study was undertaken to determine the optimum stocking density and evaluate the economic viability of *P. vannamei* culture in a biofloc system under the environmental conditions of the Andaman and Nicobar Islands.

Materials and methods

Experimental setup: Thirty thousand (30,000) PL-10 of White leg shrimp (*P. vannamei*) juveniles (mean weight 0.01g) were procured from BMR Claswin Hatchery and subsequently transported under proper oxygenation to the Marine Hill Research Laboratory, Sri Vijayapuram, Andaman and Nicobar Islands with careful handling throughout the process. Upon arrival at the laboratory, PL-10 Whiteleg shrimp juveniles were carefully transferred into nine uniform, well oxygenated circular tanks (10,000 L capacity) filled with 30 ppt sea water filtered through sand filter at a stocking density of 3000PL/tank, where they were acclimatized for 24 hours. During acclimatization process salinity were maintained between 29.8 to 30.2ppt. After one day, PL-10 Whiteleg shrimp juveniles were randomly stocked into six different treatment groups Viz., SD1(1000PL/10,000L), SD2 (2000PL/10,000L), SD3 (3000PL/10,000L), SD4 (4000PL/10,000L), SD5(5000PL/10000L) and SD6 (6000PL/10,000L). Each treatment was maintained in triplicated following a completely randomized design (CRD). During the experimental period, shrimp juveniles were fed to apparent satiation level four times daily at 7.30 AM, 10.30 AM, 1.30 PM and 4.30 PM. Feed for the whole experiment was procured from CP (Charoen Pokphand) Group Private Limited with powder to crumble particle size. Proximate composition analysis revealed that the commercial feed contained 35 % crude protein and 8% crude lipid. To ensure optimum water quality parameters, tanks were siphoned on a weekly basis 10% to remove sludge to prevent formation of obnoxious gases. Subsequently they were replenished with freshly prepared saline water adjusted to the target salinity level.

Floc preparation and quantification

Initially, biofloc formation in the treatment tanks was initiated by adding an external probiotic (CIBA Floc™, Chennai, India) containing *Bacillus* strain (1×10^9 CFU) at a dose of 1 gm m^{-3} in water, along with a carbon source jaggery. Once the floc volume reached the desired level (8-10 mL/L, measured using Imhoff cone), the biofloc was maintained through the regular addition of jaggery at C:N ratio of 10-15:1.

Water quality parameters

Water sample from each treatment tank were collected in the morning hours at 6-day intervals to assess important water quality parameters. Temperature and pH were measured using a digital probe (HANNA), while dissolved oxygen was recorded in situ using HACC probe. Whereas total ammoniacal nitrogen (TAN), nitrate and nitrite were analysed using visible-spectrophotometer method (APHA, 2006). Floc volume was measured by Imhoff cone.

Sample Collection & Growth parameters

Prior to the commencement of the experiment, initial length and body weight of the specimens were recorded. The survival percentage (%) was calculated by counting the live animals. After completion of the trials, final body weight and length measurements were taken following 24 hours fasting period.

Length and weight measurements

Shrimp length and weight were measured by using scale and balance.

The following formulas were used for the calculation:

$$\text{Survivability (\%)} = (\text{No of shrimp harvested} / \text{No of shrimp stocked}) \times 100$$

$$\text{Total Biomass (kg)} = \text{Average body weight} \times \text{no of shrimp}$$

$$\text{Food Conversion Ratio (FCR)} = \text{Feed given} / \text{weight gain}$$

Economic analysis

Fixed cost component included the tank construction, procurement of tarpaulin sheet, aerator with accessories, inverter and biosecurity nets. Fixed cost remained same for both treatments (100 & 120 days). Operational cost components included seed (3,000 nos.), feed, probiotics, water testing, electricity, jaggery, and labour charges. Gross revenue was calculated based on biomass yield and prevailing market price of the cultured species. **Cost-Benefit Ratio (CBR)** computed as the ratio of gross revenue to the sum of fixed and operational costs.

Statistical Analysis

The data generated from the experiment were first checked for normality and homogeneity of variances. Subsequently, the data were analysed using one way analysis of variance (ANOVA) followed by Duncan's multiple comparison test, using the statistical package for social science (SPSS), version 16.0. The level of significance was set at $p < 0.05$. All results are presented as the mean \pm standard error (SE) of the replicates for each treatment.

Results and Discussion

Growth and production performance of *P. vannamei* at different stocking densities

The effects on growth and production performance of Whiteleg shrimp cultured under graded stocking densities in a biofloc system for 100 days are presented in Table 1. Upon completion of the experiment, most growth parameters showed Significant differences ($p < 0.05$) among treatments. The final length and body weight showed highest values in the SD1 treatment, differed significantly ($p < 0.05$) from all the treatments. Total biomass production showed an increasing trend up to 3000 shrimp per 10,000 L (SD3). Beyond this point, further increases in stocking density resulted in poor growth in shrimp and subsequently a decreased in biomass production. On the other hand, survival percentage decreased significantly with increasing stocking density and the highest survival percentage were recorded in SD1 treatment. Feed conversion ratio (FCR) were also affected by stocking density, with significantly lower values observed at lower densities (SD1-SD3) compared to higher densities, while the highest FCR was recorded in SD6. *P. vannamei* reared at lower stocking densities exhibited significantly higher growth and survival compared to those cultured at higher stocking densities. This outcome may be attributed to the fact that stocking beyond the optimum level intensifies competition for feed and space, elevates physiological stress and deteriorates water quality, ultimately impairing growth and survival performance (Krummenauer *et al.*, 2011; Wasielesky *et al.*, 2006). In contrast, at higher stocking densities both

growth and survival rates declined. The deterioration can be attributed to excessive accumulation of metabolic wastes, disruptions in the moulting cycle that increase the vulnerability to cannibalism by hard shell shrimps and intensified social interactions, all of which collectively compromise shrimp growth performance under crowded conditions. In the present study, Total biomass production showed an increasing trend up to 3000 shrimp per 10,000 L (SD3), after that it is declining. This pattern suggests that moderate stocking densities provide an optimum balance between individual growth and biomass yield. Similar kind of observation also recorded by Ray and Lotz (2017), who observed that intermediate stocking densities in biofloc systems resulted in improved production efficiency. FCR increased significantly with stocking density, indicating that at higher densities shrimp experience stress, which disrupts feed conversion efficiency. Similar findings were reported by Avnimelech (2015), who highlighted that biofloc systems enhance feed utilization through microbial protein recycling. However, when stocking densities exceed optimal levels, this advantage may be compromised due oxygen depletion and elevated stressful conditions, ultimately impairing the feed conversion efficiency of shrimp.

Water quality parameters in biofloc culture system

Various water quality parameters recorded during the entire culture period were summarized in Table 2. In the present experiment, water temperature remained relatively stable (27.6 ± 0.08 to $27.9 \pm 0.10^\circ\text{C}$) throughout the culture period, with no significant variation ($p > 0.05$) among treatments. Similarly, salinity remained constant throughout the culture period. On the other hand, both pH and dissolved oxygen (DO) levels gradually decreased with increasing stocking density in the biofloc system. The SD1 and SD2 groups showed significantly ($p < 0.05$) higher pH levels as compared to SD4, SD5 and SD6 groups, while no significant difference ($p < 0.05$) observed between SD1, SD2 & SD3. In addition, dissolved oxygen (DO) levels exhibited a similar trend, with significantly higher values ($p < 0.05$) were recorded in SD1 and SD2 compared to SD5 & SD6, without showing any significant difference ($p > 0.05$) with SD3 and SD4. In contrast, floc

volume exhibited a reverse trend, where significantly ($p>0.05$) lower values were observed in SD1 and SD2 treatments as compared to other treatments (SD3, SD4, and SD5 & SD6). Different Nitrogenous metabolites (ammonia-N, nitrite-N, and nitrate-N) increased significantly ($p<0.05$) with rising stocking density. In case of ammonia-N, significantly higher values were

observed in the SD5 and SD6 groups compared to SD1 & SD2, without showing any significant difference ($p>0.05$) with SD3 and SD4. Furthermore, nitrite-N concentrations exhibited significantly higher values ($p<0.05$) in the SD5 and SD6 groups compared to all other treatments except SD4. On the other hand, nitrate-N concentration recorded lowest in the SD1 treatment compared to other treatments.

Table.1. Growth and production parameters of *P vannamei* at different stocking densities harvested from biofloc system

Stocking density/10000L	SD-1 (1000 PL)	SD-2 (2000 PL)	SD-3 (3000 PL)	SD-4 (4000 PL)	SD-5 (5000 PL)	SD-6 (6000 PL)	<i>P value</i>
Culture Period	100 days						
Initial length (mm)	10	10	10	10	10	10	
Initial weight	0.01	0.01	0.01	0.01	0.01	0.01	
Final individual length	16.5 ^c	11.6 ^b	10.9 ^{ab}	10.5 ^{ab}	9.7 ^a	9.2 ^a	0.03
Final individual weight (gm)	17.2 ^d	12.5 ^c	11.1 ^{bc}	11.25 ^{bc}	10.63 ^b	8.78 ^a	0.03
Total Biomass(kg)	15.48 ^a	21.25 ^b	24.4 ^d	22.5 ^b	23.4 ^{bc}	21.6 ^b	0.02
Survivability (%)	90 ^e	85 ^d	75 ^c	50 ^b	44 ^a	41 ^a	0.02
FCR	1.22 ^a	1.24 ^a	1.24 ^a	1.36 ^b	1.48 ^c	1.68 ^d	0.04

Table.2. Variation of water quality parameters of Shrimp (*P vannamei*) cultured in different biofloc tanks in 100 days period.

Water quality parameters	Treatments	T1	T2	T3	T4	T5	T6
Temperature (°C)		27.6±0.08 ^a	27.6±0.08 ^a	27.7±0.09 ^a	27.9±0.1 ^a	27.9±0.1 ^a	27.9±0.1 ^a
pH		8.21±0.15 ^b	8.05±0.16 ^{ab}	7.98±0.13 ^{ab}	7.75±0.12 ^a	7.71±0.12 ^a	7.68±0.11 ^a
DO (ppm)		7.32±0.42 ^b	7.29±0.45 ^b	7.1±0.38 ^{ab}	6.88±0.35 ^{ab}	6.75±0.36 ^a	6.56±0.39 ^a
Floc volume (mL/L)		8.8±1.2 ^a	9.2±1.1 ^{ab}	10.5±1.4 ^b	13.4±1.5 ^b	13.8±1.2 ^b	14.5±1.8 ^b
salinity (ppt)		30±0 ^a	30±0 ^a	30±0 ^a	30±0 ^a	30±0 ^a	30±0 ^a
Ammonia-N (ppm)		0.35±0.08 ^a	0.38±0.085 ^a	0.45±0.11 ^{ab}	0.49±0.12 ^{ab}	0.52±0.15 ^b	0.55±0.14 ^b
Nitrite-N (ppm)		1.45±0.25 ^a	1.66±0.36 ^{ab}	1.78±0.47 ^b	2.38±0.55 ^{bc}	2.54±0.56 ^c	2.79±0.63 ^c
Nitrate-N (ppm)		5.56±1.25 ^a	6.32±1.65 ^b	6.62±1.55 ^b	8.42± 1.96 ^c	9.35±1.2 ^{cd}	10.58±3.45 ^d

Water quality parameters observed during the study were found to be within acceptable limits for shrimp culture, confirming that biofloc technology effectively provides a stable and sustainable environment for shrimp production. In the present experiment, water temperature and salinity remained relatively stable throughout the culture period, with no significant variation among treatments. On the other hand, pH and dissolved oxygen (DO) values decreased with increasing stocking density. This decline may be attributed to intensified microbial respiration and organic loading at higher densities, which collectively reduce DO concentrations and lower pH levels (Ebeling *et al.*, 2006). The increase in floc volume with rising stocking density reflects enhanced microbial proliferation driven by greater organic matter availability.

Biofloc particles serve as an additional natural food source, rich in protein, lipids, and vitamins, thereby improving nutrient recycling and reducing dependence on formulated feeds (Hargreaves, 2013). Ammonia-N, nitrite-N and nitrate-N concentrations increased with higher stocking densities, as anticipated due to greater feed input and elevated metabolic waste production. However, these compounds remained below toxic levels, highlighting the efficiency of heterotrophic microbial communities in assimilating inorganic nitrogen and thereby maintaining water quality. Similar findings were documented by Crab *et al.*, (2012) who reported that biofloc technology efficiently converts toxic nitrogenous compounds into microbial biomass, thereby improving water quality and sustainability in intensive aquaculture systems.

Table.3. Production and growth parameters of *P vannamei* from different culture period with partial harvesting of biofloc culture tanks.

Stocking density	3000/Tank		
	100 days	120 days	
Culture period	100 days	120 days	
	final harvest	first harvest (80 th day)	Final harvest (120 th day)
Initial length (mm)	10	10	
Initial weight (cm)	0.01	0.01	
Final length (cm)	9.4	7.6	13.5
Final weight (gm)	10.8	8.5	14.1
Total Biomass(kg)	24.8 ^a	9.8	30.2 ^b
Survivability (%)	76.5 ^a		86.9 ^b
FCR	1.22 ^a		1.13 ^b

Effect of culture duration & partial harvesting on *P. vannamei* production in biofloc culture system

The growth and production performance of Whiteleg shrimp under two different culture durations (100 and 120 days), with partial harvesting conducted after 80-days in the 120-day culture period are summarized in

Table 3. In this case, shrimp cultured in biofloc system for 120days with partial harvesting exhibited better growth performance (final length & weight:13.5 cm& 14.1gm) compared to 100days culture period (9.4 cm; 10.8 g).In addition, total biomass and survival percentage were significantly higher ($p < 0.05$) in the 120days culture period (Biomass: 30.2 kg and survival percentage:

86.9%) than in the 100day culture (Biomass: 24.8 kg and survival percentage: 76.5 %). Feed conversion ratio (FCR) were also influenced by culture duration with partial harvesting, with significantly lower value recorded in 120days culture period compared to 100days culture, indicating more efficient feed utilization throughout the culture period. The result demonstrates that extending the culture duration together with partial harvesting provides optimum condition for shrimp growth and production performance. The culture duration to 120 days with partial harvesting significantly improved biomass production,

survival and feed conversion efficiency compared to the 100 day culture period. Partial harvesting reduces biomass load and competition within the culture unit, thereby improving environmental conditions and promoting compensatory growth of the remaining shrimp. Similar observations were reported by Samocha *et al.*, (2004), who noted that partial harvesting strategies improve carrying capacity and production efficiency in intensive shrimp culture systems. The lower FCR observed during the extended culture period indicates improved feed utilization due to reduced stocking pressure after harvest.

Table.4. Economic analysis of Shrimp production from biofloc system for Andaman and Nicobar Island Condition.

Sl.No	Fixed Cost	Cost (₹)	Operational cost	100 days	120 days
1	Tanks Construction components for 4 metre diameter (Iron rod, Wire mesh PVC pipe,)	16500	Seed(3000 numbers) feed	2100 3000	2100 3000
2	Brick, cement and sand	5000	pro/vitamin, water testing	100	100
3	Labour charges	3500	Electricity	290	350
4	Tarpaulin sheet (4 metre diameter, 650 GSM)	8000	jaggery	250	250
5	Aerator and Accessories (90 W, 120 L/m)	8000	Labour	1354	1625
6	Inverter (one inverter for 4 tanks)	6000	Total Operational cost	7094	7425
7	Biosecurity net	500	Total Revenue	11600	14120
8	Total Fixed Cost	47500	Cost Benefit Ratio	1.64	1.90

Economic analysis of shrimp culture in biofloc system

The economic analysis of Whiteleg shrimp under two different culture durations (100 and 120 days) is presented in Table 4. The total fixed cost for construction of the biofloc unit (comprising construction of tarpaulin tanks, aeration system, inverter and biosecurity net etc) was estimated at ₹47,500. The operational cost was slightly higher in the 120 day culture period (₹7425/-) compared to the 100day culture (₹7094/-). In parallel, total revenue generated from 100 days culture period was ₹11,600, with

a cost benefit ratio (CBR) of 1.64. In contrast, the 120days culture period with partial harvesting generates more revenue of ₹14,120, with a cost benefit ratio (CBR) of 1.90. After completion of the experiment, it was found that extending the culture duration, accompanied by partial harvesting in the biofloc system, provides greater economic returns in terms of profitability under island conditions. Economic analysis revealed that a 120 day culture period with partial harvesting yielded a higher 1.96 cost- benefit ratio compared to shorter culture duration, indicating better economic viability. Feed and seed accounted for the major operational expenses, which

is consisted with previous studies on shrimp bio-floc farming (Emerenciano *et al.*, 2017). The higher revenue generated from extended culture duration was mainly due to increased biomass production and better survival. These findings suggest that biofloc based *P. vananmei* culture with moderate stocking density and partial harvesting can be profitable and sustainable aquaculture practice under the environmental conditions of the Andaman and Nicobar Islands.

Conclusion

The study confirms that biofloc technology can effectively support *P. vannamei* culture under the environmental conditions of the Andaman and Nicobar Islands. Moderate stocking densities combined with partial harvesting ensured an optimum balance between growth, survival, and biomass yield. Economics analysis confirmed that biofloc based shrimp farming can generate higher returns with better cost benefit ratio under island conditions where land, freshwater, and aquaculture inputs are limited and expensive. These findings provide practical guidance for farmers in species selection and culture strategies, helping to reduce risks related to time, space, and cost. Overall, biofloc-based shrimp farming emerges as a sustainable and economically viable option for disadvantaged coastal regions.

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