The Influence of Pond Construction Material on Plankton Communities and the Correlation of Water Quality Parameters with Harvest Yields in *Litopenaeus vannamei* Aquaculture

Putri Afin Nurhayati* and Rizky Darmawan

Delta Marine Group, Monginsidi Street No. 58, Sidoklumpuk, Sidoarjo, East Java, Indonesia
nurhayatiafin@gmail.com

Abstract. The cultivation of *Litopenaeus vannamei* shrimp is closely linked to the aquatic ecosystem influenced by various factors, with the shrimp pond habitat playing a central role in determining aquaculture success. Shrimp farming performance is commonly assessed by the feed conversion ratio (FCR) and survival rate (SR). Typically, FCR values range from 1.0 to 2.4, where a higher FCR indicates less efficient feed utilization, while a higher SR reflects better shrimp survival. A healthy aquatic ecosystem, supported by intertwined water parameters such as plankton, bacteria, and water chemistry, is essential for optimal shrimp growth. Plankton is known to contribute to the aquatic environment and enhance shrimp development, with evidence suggesting its growth may be affected by the type of pond construction. This study compared plankton species abundance and diversity in concrete and HDPE-lined ponds, finding greater plankton abundance (N) and diversity (H) in concrete ponds. However, plankton presence did not significantly affect FCR and SR at harvest. Instead, FCR and SR showed stronger correlations with total bacteria counts and water chemistry parameters, specifically NH_4, carbonate (CO_3), and bicarbonate (HCO_3). These findings highlight key parameters for future monitoring and evaluation to support shrimp cultivation success. Therefore, implementing a monitoring system focused on total bacteria, NH_4, and bicarbonate levels is recommended to safeguard harvest yields.

Keywords: *Litopenaeus vannamei*, Monitoring System, Plankton Diversity, Shrimp Cultivation.

1 Introduction

Indonesia's favorable natural conditions support a rich diversity of biota in both terrestrial and aquatic environments. Among the key marine products, *Litopenaeus vannamei* (vannamei shrimp) plays avital economic role due to its increasing demand in both-domestic and international demand. As a leading global supplier of vannamei shrimp, the increasing export demand raises selling prices and contributes to national economic

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growth [1]. This underscores the importance of preserving Indonesia's aquatic ecosystems that serve as vital shrimp habitats [2].

Shrimp aquaculture is widespread along Indonesian coasts, including Sumatra, Java, Kalimantan, Sulawesi, Bali, and the Lesser Sunda Islands. Cultivation methods vary, generally classified into traditional, intensive, and super-intensive systems. Key differences lie in the pond construction materials, earth, concrete, or plastic (such as HDPE) which affect the aquatic ecosystem and shrimp habitat. Concrete and HDPE ponds are especially associated with residual plankton and bacterial communities [3]. The growth of these microorganisms can impact pond ecology and potentially lead to contamination, highlighting the need for effective cleaning systems before new cultivation cycles begin [4].

The aquatic ecosystem is critical to shrimp growth and development, with initial stocking density influencing biological and chemical interactions in pond waters. Shrimp excretion, along with introduced plankton and bacteria, forms an interdependent network within the pond ecosystem [5]. Dense shrimp populations and high plankton levels increase ammonium (NH_4) concentrations, which bacteria convert into nitrate and nitrite, a process essential to preventing toxicity [6]. Excess NH_4^+ can reduce dissolved oxygen levels, impacting shrimp health through the nitrogen cycle. Carbon, another byproduct, supports plankton photosynthesis and helps maintain pH stability, crucial for reducing shrimp stress [7]. Additionally, phosphate from uneaten feed and decomposition must be managed to prevent plankton blooms that can cause oxygen fluctuations [8].

Shrimp aquaculture success is often measured by Feed Conversion Ratio (FCR) and Survival Rate (SR) at harvest. FCR reflects feed utilization efficiency, typically ranging from 1.0 to 2.4; lower values mean less feed waste. SR indicates shrimp resilience and longevity, with higher values being preferable [7, 9]. Given the complexity of pond ecosystems and their direct impact on shrimp performance, regular water quality monitoring is essential.

This study seeks to address existing gaps by examining the differences in plankton community structures between concrete and HDPE ponds and investigating how various water quality parameters correlate with shrimp cultivation performance. Specifically, the research objectives are to compare the plankton communities in these two types of ponds and to determine the relationships between key water quality indicators and the feed conversion ratio (FCR) as well as the survival rate (SR) of *Litopenaeus vannamei.*

2 Methods

2.1 Time and Place

The research was conducted from March to July 2024 on the coast of Mapin Beach, Labuhan Alas, Sumbawa, West Nusa Tenggara. The experimental setup included six ponds: three concrete ponds and three HDPE (High-Density Polyethylene) ponds. Each pond measured 2.250 meters, with a total volume of [specify volume in cubic meters]. The initial stocking densities were 177 individuals/m^2 for the HDPE ponds and 217 individuals/m^2 for the concrete ponds. Post-larvae (PL) used for stocking were sourced from Bali and had an average size of 9 to 10 and length in 8-10 mm.

2.2 Procedure

A commercial shrimp feed was administered five times daily at 7:00 AM, 11:00 AM, 12:00 PM, 3:00 PM, 7:00 PM, and 11:00 PM. Aeration was applied and water exchange was conducted periodically with daily water replacement ranging from approximately 7 cm to 60 cm, equivalent to about 5% to 32% of pond water volume per change. Weekly water exchanges totaled 20-30% or more of the pond volume to maintain optimal water quality.

Water samples were collected weekly at 06.00 A.M. Plankton identification was performed by diluting a 100 ml water sample for microscopic examination. Total bacteria enumeration employed the spread plate method on TCBS (Thiosulfate Citrate Bile Salts Sucrose) agar, incubated at 30°C for 24 hours. Water chemistry parameters were measured using test kits from Merck KGaA Salifer according to the manufacturers' protocols.

2.3 Data Analysis

Data from plankton species and abundance were processed and tabulated using Microsoft Excel. Statistical analysis was conducted using PAST version 4.3 software. Differences in plankton diversity (Shannon-Wiener index, H') between pond types. Regression analysis evaluating relationships between water quality parameters and shrimp performance (FCR, SR) to ensure validity of results. FCR and SR data were recorded at the end of the cultivation period to evaluate shrimp growth performance under the different pond conditions.

3 Result and Discussion

The identification results revealed a higher number of plankton genera in concrete ponds (47) compared to HDPE ponds (45). However, the diversity index (H') was higher in HDPE ponds (1.74) than in concrete ponds (1.49). This apparent contradiction can be explained by the concept of community dominance. In concrete ponds, a few plankton genera particularly the green algae genus Chlorella dominated the community, resulting in lower evenness (E = 0.51) despite greater genus richness. In contrast, the HDPE ponds exhibited higher evenness (E = 0.66), indicating a more balanced distribution of genera across taxa.

As shown in Table 1, both pond types shared a majority of genera across various phyla, including Bacillariophyta, Chlorophyta, Ciliophora, and Cyanobacteria; however, specific genera such as Phacus and Favella were uniquely observed in HDPE ponds, while others like *Nitzschia* and *Navicula* appeared only in concrete systems. Dominance index (D) values further support this interpretation, being slightly higher in concrete ponds (0.49) compared to HDPE (0.46), suggesting greater skewness toward dominant taxa in concrete systems. Ecologically, such dominance may lead to reduced functional redundancy and could influence ecosystem processes such as nutrient cycling, primary productivity, and resilience to disturbance.

The more evenly distributed community structure in HDPE ponds may reflect a stable, generalized environment with a higher diversity index, whereas the genus-level dominance in concrete ponds could signify an ecosystem favoring specific taxa potentially beneficial for shrimp growth [10]. Overall, the comparison highlights not just the differences in genus composition, but the underlying ecological dynamics shaping community structure in each pond type.

Table 1. Inventory of Plankton Genera Found in Two Different Ponds

Filum	Family	Genus	Concrete	HDPE
Amoebozoa	Amoebidae	*Amoeba*	1	1
Bacillariophyta	Amphipleuraceae	*Amphipleura*	1	1
	Bacillariaceae	*Nitzschia*	1	1
	Chaetocerotaceae	*Chaetoceros*	1	1
	Coscinodiscaceae	*Coscinodiscus*	1	1
	Diploneidaceae	*Diploneis*	1	1
	Leptocylindraceae	*Cerataulina*	1	1
	Naviculaceae	*Amphora*	1	1
	Naviculaceae	*Gyrosigma*	1	1
	Naviculaceae	*Navicula*	1	1
	Rhizosoleniaceae	*Rizhosolenia*	1	1
	Skeletonemaceae	*Skeletonema*	1	1
	Stephanodiscaceae	*Cyclotella*	1	1
	Streptothecaceae	*Streptotecha*	1	1
	Thalassiosiraceae	*Thalassiosira*	1	1
Charophyta	Coleochaetaceae	*Coleocaete*	1	1
Chlorophyta	Chlamydomonadaceae	*Chlamydomonas*	1	1
	Chlorellaceae	*Chlorella*	1	1
	Golenkiniaceae	*Treubaria*	1	1
	Oocystaceae	*Oocystis*	1	1
	Scenedesmaceae	*Dictyiospaerium*	1	1
	Scenedesmaceae	*Coelastrum*	1	1
Chrysophyceae	Anthophysaceae	*Anthopysa*	1	0
Ciliophora	Colpodidae	*Colpoda*	0	1
	Euplotes	*Euplotes*	1	1
	Favellidae	*Favella*	1	0

	Parameciidae	*Paramecium*	1	1
	Strombidinopsis	*Strombydinopsis*	1	1
	Vorticella	*Vorticella*	1	1
Cyanobacteria	Anabaenopsidaceae	*Anabaenopsis*	1	0
	Arthrospiraceae	*Spirulina*	1	1
	Chroococcaceae	*Croococus*	0	1
	Gloeocapsaceae	*Gleocapca*	1	0
	Microcystaceae	*Mycrocystis*	1	1
	Nostocaceae	*Anabaena*	1	1
	Oscillatoriaceae	*Oscillatoria*	1	1
Cryptophyta	Askenasia	*Askenasia*	1	1
	Cryptomonadaceae	*Cryptomonas*	1	1
Dinoflagellata	Protoperidiniaceae	*Protoperidinium*	1	1
	Gymnodiniaceae	*Gymnodynium*	1	1
	Gyrodinium	*Gyrodinium*	1	1
Euglenozoa	Phacaceae	*Phacus*	1	1
	Euglenaceae	*Euglena*	1	1
Haptophyta	Prymnesiaceae	*Prymnesium*	1	1
Heliozoa	Actinophryidae	*Actinopiris*	1	1
Ochrophyta	Chromulinaceae	*Chromonas*	0	1
Raphidophyceae	Gonyostomataceae	*Gonyostomum*	1	0
Rotifera	Brachionidae	*Branchionus*	1	1
		N	47	45
		D	0.49	0.4
		E	0.51	0.6
		H'	1.49	1.74
		Chao Index	47	45

The physical and chemical water quality parameters measured at multiple sampling points indicate conditions crucial for supporting aquaculture activities (Table 2). Water temperature ranged from 21.5 to 31.8 °C, which is generally suitable for aquatic organisms, though higher temperatures may reduce dissolved oxygen levels due to decreased oxygen solubility. The dissolved oxygen (DO) levels between 4 and 5.92 mg/L are adequate to support metabolic processes and overall health, yet maintaining these levels above critical thresholds is essential to avoid stress or mortality. The pH values ranged between 7.4 and 8.9, suggesting slightly alkaline conditions favorable for most aquatic species but requiring monitoring to prevent extreme fluctuations. Salinity varied between 26 and 48 ppt, reflecting environments from brackish to shallow marine waters, which must align with species tolerance (Table 2).

Among chemical parameters, nitrite (NO_2) and ammonium (NH_4) levels demand careful control due to their toxicity at elevated concentrations, which can endanger cultured organisms. Nitrate (NO_3) and phosphate (PO_4) levels were also monitored; while these nutrients are essential for aquatic life, excessive amounts risk eutrophication and compromised water quality. Carbonate (CO_3) and bicarbonate (HCO_3) concentrations remained relatively stable, acting as buffers that regulate pH and contribute to a balanced aquatic environment. The interconnected nature of these parameters means changes in one can affect others, emphasizing the need for integrated monitoring and management.

Overall, the data suggest that maintaining optimal ranges of these physicochemical variables is vital for promoting growth, health, and productivity in aquaculture systems. Continuous monitoring and adaptive management are necessary to preserve water quality and sustain aquaculture performance effectively. These results align with best practices emphasizing the interplay between water temperature, oxygen, pH, salinity, and nutrient concentrations to support a healthy culture environment.

Table 2. Water Quality Parameters in Each Plot

Parameter	**A1**	**A2**	**A3**	**B2**	**B3**	**B5**
			Physics			
Temperature (°C)	24.8-31.6	24.7-30.3	24.8-31.4	21.5-31.3	24.3-31.8	24.6-30.9
DO (mg/L)	4-5.82	4.01-5.92	4-5.54	4.11-5.91	4.21-5.57	4.21-5.17
pH	7.7-8.7	7.6-8.6	7.6-8.6	7.4-8.9	7.4-8.8	7.4-8.3
Salinity (ppt)	30-42	26-45	26-40	29-48	29-36	31-35
			Chemist			
NO_2 (mg/L)	0.01-0.95	0.01-3	0.01-4	0.01-2.75	0.01-0.95	0.01-0.45
NO_3 (mg/L)	1-11	1-20	1-30	1-20	1-7	1-8
PO_4 (mg/L)	0.05-1.8	0.04-1.8	0.04-1.9	0.04-1.8	0.04-1.8	0.15-1.2
NH_4 (mg/L)	0.1-4	0.1-3	0.1-3.5	0.1-3.2	0.1-4.2	0.3-3.3
CO_3 (mg/L)	8-20	8-20	4-24	4-12	4-12	4-16
HCO_3 (mg/L)	168-220	160-212	160-216	148-188	144-184	156-176

Fig. 1 presents the comparative analysis of Feed Conversion Ratio (FCR) and Survival Rate (SR%) across six experimental plots (A1, A2, A3, B2, B3, and B5). The FCR values, depicted by bars, remained relatively stable in plots A1 to A3 (approximately 1.3–1.4) but increased in plots B2, B3, and B5, reaching values close to 1.6. Conversely, the SR%, represented by the solid line, showed a declining trend from A1 through B5. The highest SR was observed in plot A1, while plots B2 to B5 exhibited a marked reduction, stabilizing around 70%. These findings indicate a potential inverse relationship between FCR and SR, particularly evident in the transition from the A to B plots.

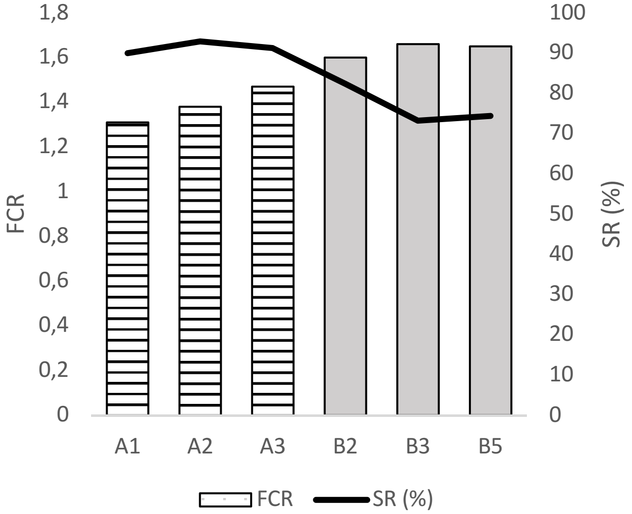

Fig. 1. Differences in FCR and SR in Each Plot

The regression analysis revealed important relationships between environmental variables and both Feed Conversion Ratio (FCR) and Survival Rate (SR) (Table 3). Bacteria and bicarbonate (HCO3) showed the strongest correlations with both FCR and SR, with high coefficients of determination ($R^2 > 0.85$), indicating that higher levels of these factors are associated with better feed efficiency (lower FCR) and higher survival rates. Ammonium (NH4) and carbonate (CO3) had moderate effects on FCR and SR, with NH4 positively influencing FCR but negatively affecting SR, suggesting a potential trade-off or toxicity at high concentrations. Other variables like nitrate (NO_3) and phosphate (PO_4) exhibited weak correlations and minimal impact on the models. These findings suggest that managing bacterial populations and bicarbonate levels in water could improve aquaculture performance, while the low explanatory power of some variables indicates other unmeasured factors may contribute to FCR and SR. This highlights both the strengths and limitations of the current study, and future research could explore more complex, multivariate models to better understand the interplay of environmental factors on aquaculture outcomes. Overall, these results provide useful insights into optimizing water quality for enhanced feed efficiency and survival.

Table 3. Relationship of Environmental Parameters with SR and FCR

Variable Relation		Regression Model	Coefficient of Determination
X	Y		
Plankton (Ind/ml)	FCR	y = -2E-08x + 1.8273	$R^2 = 0.1578$
Bacteria	FCR	y = -0.0078x + 3.0272	$R^2 = 0.8546$
NO_2	FCR	y = -0.0109x + 3.4507	$R^2 = 0.0676$
NO_3	FCR	y = -0.019x + 1.627	$R^2 = 0.0676$
PO_4	FCR	y = -0.0515x + 1.5479	$R^2 = 0.0016$
NH_4	FCR	y = 0.9855x + 0.4735	$R^2 = 0.5112$
CO_3	FCR	y = -0.0211x + 1.7182	$R^2 = 0.5317$
HCO_3	FCR	y = -0.0109x + 3.4507	$R^2 = 0.8974$
Plankton (Ind/ml)	SR	y = 1E-06x + 59.688	$R^2 = 0.2691$
Bacteria	SR	y = 0.4773x – 8.9952	$R^2 = 0.926$
NO_2	SR	y = 19.669x + 74.767	$R^2 = 0.4295$
NO_3	SR	y = 2.9232x + 66.283	$R^2 = 0.4099$
PO_4	SR	y = 2.9232x + 66.283	$R^2 = 0.2062$
NH_4	SR	y = -63.304x + 150.67	$R^2 = 0.6071$
CO_3	SR	y = 1.2771x + 71.512	$R^2 = 0.5584$
HCO_3	SR	y = 0.6331x – 28.218	$R^2 = 0.8649$

The water quality analysis highlighted the significant role of bicarbonate (HCO_3) in influencing shrimp farming success, yet its importance has been under-discussed. Bicarbonate is a central component of the carbonate buffering system, which stabilizes pH by neutralizing acids and bases in water [11]. Higher HCO_3 concentrations increase alkalinity, helping maintain pH within an optimal range (7–9) essential for shrimp health. Stable pH conditions reduce physiological stress on shrimp, which can enhance feed utilization efficiency (reflected in lower FCR) and improve survival rates. This buffering capacity is vital because pH fluctuations can impair metabolic processes and increase vulnerability to pathogens, impacting overall shrimp performance [7].

One of the core findings of this study was the superior FCR and SR values observed in concrete ponds, which coincided with their higher bicarbonate levels. A plausible hypothesis is that the concrete material contributes to elevated alkalinity by leaching minerals such as calcium carbonate into the water, thereby enriching HCO_3 concentrations [12]. Additionally, the porous surface of concrete ponds may promote the development of distinct microbial biofilms that differ from those in HDPE ponds. These biofilms typically consist of diverse microbial communities, including bacteria, algae, and fungi, which play crucial roles in nutrient cycling, organic matter breakdown, and water purification [13]. In shrimp ponds, such biofilms can enhance nitrogen cycling by promoting nitrifying and denitrifying bacteria that reduce toxic ammonia (NH_4^+)

levels, thus improving water quality and shrimp health [6]. Moreover, biofilms can prevent pathogen colonization by competitive exclusion, thereby indirectly supporting higher survival rates.

The interplay between pond construction material, biofilm development, and water chemistry represents a promising avenue for optimizing shrimp aquaculture systems. Investigating the specific microbial communities and mineral leaching characteristics in concrete versus HDPE ponds could provide actionable insights into improving pond design and management for enhanced shrimp growth and sustainability.

4 Conclusion

This study highlights the influence of pond construction material on water quality, plankton diversity, and shrimp performance. Concrete ponds supported more plankton genera, but HDPE ponds exhibited higher diversity and evenness, indicating a more balanced ecological community. Key environmental factors such as ammonium (NH_4), bicarbonate (HCO_3), and total bacteria significantly impacted Feed Conversion Ratio (FCR) and Survival Rate (SR). Higher NH_4 levels were associated with poor shrimp performance, while elevated HCO_3 and bacterial abundance improved both FCR and SR. The superior outcomes in concrete ponds may be linked to higher HCO_3 levels and enhanced microbial biofilms. These findings suggest that managing water chemistry and microbial communities, particularly through pond design can optimize shrimp aquaculture outcomes.

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