

**RELATIONSHIP BETWEEN THE N/P RATIO AND PLANKTON
COMPOSITION AND ABUNDANCE IN INTENSIVE PACIFIC WHITE
SHRIMP (*Litopenaeus vannamei*) CULTURE AT PT TANJUNGBUMI
AKUAKULTUR BANGKALAN EAST JAVA**

Hubungan Rasio N/P dengan Komposisi dan Kelimpahan Plankton pada Budidaya
Udang Vaname (*Litopenaeus vannamei*) Sistem Intensif di PT. Tanjungbumi
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ABSTRACT

Nitrogen and phosphorus balance is an important factor in intensive Pacific white shrimp pond management because it regulates plankton growth and dominance. This study aimed to analyze the relationship between the N/P ratio and plankton composition and abundance in intensive *Litopenaeus vannamei* culture at PT Tanjung Bumi Akuakultur Indonesia, Bangkalan, East Java. Observations were conducted in ponds B3 and B4 during DOC 35–80. The observed parameters included N/P ratio, total plankton abundance, Green Algae, diatoms, Blue Green Algae, Dinoflagellates, Euglenophytes, Protozoa, TAN, nitrite, nitrate, phosphate, and fertilizer application. Data were analyzed descriptively and using Spearman correlation. The results showed that total plankton abundance ranged from 61,000 to 1,780,000 ind/mL, with Green Algae dominating at 74.2–86.3%. The N/P ratio ranged from 8.90 to 20.09 in pond B3 and from 10.07 to 22.74 in pond B4. Combined Spearman correlation analysis showed a significant negative correlation between the N/P ratio and Dinoflagellates ($\rho = -0.613$; $p = 0.004$), while the correlation with Blue Green Algae was negative but not significant ($\rho = -0.245$; $p = 0.297$). These findings indicate that a decrease in the N/P ratio is associated with increasing dominance of harmful plankton, particularly Dinoflagellates. Controlled N/P ratio management is required to maintain plankton community stability in intensive shrimp ponds.

Keywords: Blue Green Algae, Dinoflagellates, phytoplankton, N/P ratio, Pacific white shrimp.

ABSTRAK

Keseimbangan nitrogen dan fosfor merupakan faktor penting dalam pengelolaan kualitas air tambak udang vaname intensif karena berperan dalam mengatur pertumbuhan dan dominansi plankton. Penelitian ini bertujuan menganalisis hubungan rasio N/P dengan komposisi dan

kelimpahan plankton pada budidaya udang vaname (*Litopenaeus vannamei*) di PT Tanjung Bumi Akuakultur Indonesia, Bangkalan, Jawa Timur. Pengamatan dilakukan pada petak B3 dan B4 selama DOC 35–80. Parameter yang diamati meliputi rasio N/P, total kelimpahan plankton, Chlorophyta atau Green Algae, diatom, Blue Green Algae, Dinoflagellata, Euglenophyta, Protozoa, TAN, nitrit, nitrat, fosfat, dan aplikasi pupuk. Data dianalisis secara deskriptif dan dilanjutkan dengan uji korelasi Spearman. Hasil menunjukkan bahwa total kelimpahan plankton berkisar antara 61.000–1.780.000 ind/mL dengan dominansi Green Algae sebesar 74,2–86,3%. Rasio N/P petak B3 berkisar 8,90–20,09, sedangkan petak B4 berkisar 10,07–22,74. Korelasi Spearman gabungan menunjukkan bahwa rasio N/P berkorelasi negatif signifikan dengan Dinoflagellata ($\rho = -0,613$; $p = 0,004$), sedangkan korelasi dengan BGA bersifat negatif tetapi tidak signifikan ($\rho = -0,245$; $p = 0,297$). Hasil ini menunjukkan bahwa penurunan rasio N/P berkaitan dengan meningkatnya dominansi plankton merugikan, terutama Dinoflagellata. Pengelolaan rasio N/P perlu dilakukan secara terukur untuk menjaga kestabilan komunitas plankton pada tambak udang intensif.

Kata kunci: BGA, Dinoflagellata, Fitoplankton, Rasio N/P, Udang Vaname.

INTRODUCTION

Intensive farming of *Litopenaeus vannamei* (Pacific white shrimp) is widely practiced due to its high productivity. However, intensive systems also lead to increased feed and fertilizer inputs, as well as the accumulation of organic matter on the pond bottom. Uneaten feed, feces, and decomposing organic matter can elevate nitrogen and phosphorus levels in the water, affecting water quality dynamics and plankton community structure.

Plankton play a crucial role as primary producers, oxygen sources, natural food, and bioindicators of water quality. Plankton abundance and composition are heavily influenced by nutrient availability, particularly nitrogen and phosphorus. Under balanced conditions, beneficial plankton communities—such as green algae and diatoms—can dominate. Conversely, nutrient imbalances can trigger a proliferation of harmful plankton groups, such as blue-green algae and dinoflagellates.

The nitrogen-to-phosphorus (N/P) ratio is frequently used to characterize nutrient balance in aquatic environments. An N/P ratio of approximately 16:1 is recognized as a general benchmark for phytoplankton growth. Ratios that are too low indicate nitrogen limitation relative to phosphorus, potentially favoring the dominance of specific plankton groups better adapted to such conditions.

In intensive shrimp ponds, N/P ratio dynamics are influenced by feed, fertilizers, microbial activity, water exchange, and the duration of the culture period. Therefore, understanding the relationship between the N/P ratio and plankton composition is essential for effective water quality management. This study aims to analyze the relationship between the N/P ratio and plankton composition and abundance in intensive *Litopenaeus vannamei* culture systems.

RESEARCH METHODS

Place and Time

The research was conducted from March 30 to May 29, 2026, at PT Tanjung Bumi Akuakultur Indonesia, located in Mrandung Village, Klampis District, Bangkalan Regency, East Java Province. Observations were carried out on two *Vannamei* shrimp ponds, designated as B3 and B4.

Research methods

The study employed a field survey method with a quantitative descriptive approach. Data were obtained through water quality observations, plankton counts, and field documentation, as well as the company's technical laboratory data.

Observation Parameters

The primary parameters observed included the N/P ratio, total plankton abundance, and the abundance of green algae, diatoms, blue-green algae, dinoflagellates, euglenophytes, and protozoa. Supplementary water quality parameters included TAN, nitrite, nitrate, phosphate, and fertilizer application.

The N/P ratio reflects the balance between nitrogen and phosphorus availability in the water; both elements are key nutrients for plankton growth. An excessively low N/P ratio indicates that nitrogen is relatively more limiting than phosphorus, whereas an excessively high ratio indicates that phosphorus is relatively more limiting. Changes in this ratio can influence the growth, succession, and dominance of specific plankton groups. To characterize the nutrients available to plankton, nitrogen can be expressed as dissolved inorganic nitrogen (DIN)—the sum of TAN, nitrite, and nitrate, all converted to units of mg N/L:

$$DIN = TAN-N + NO_2-N + NO_3-N$$

Total plankton abundance represents the total number of plankton cells found within a given volume of water. This parameter reflects the level of biological productivity in the water but does not indicate whether the community is dominated by beneficial or harmful plankton. Counting is performed using a hemocytometer. The general formula is:

$$C = \frac{N}{r} \times \frac{1}{V_c} \times DF$$

Description:

- C = plankton abundance (sel/mL);
- N = total number of cells counted;
- r = number of technical tests;
- V_c = the spatial volume calculated for each replicate (mL);
- DF = dilution factor.

The composition of each group is calculated using the formula:

$$\text{Composition of Group I (\%)} = \frac{N_i}{N_{\text{total}}} \times 100$$

Analysis of Plankton and Water Quality

Plankton observations were conducted using a hemocytometer and a microscope. Water samples were homogenized and placed onto the hemocytometer; the plankton were then counted and identified based on dominant groups. TAN, nitrite, and phosphate parameters were analyzed using a spectrophotometer. TAN measurements were performed at a wavelength of 640 nm, nitrite at 543 nm, and phosphate at 880 nm.

Total Ammonia Nitrogen (TAN) represents the sum of nitrogen in the form of unionized ammonia ($\text{NH}_3\text{-N}$) and ammonium ions ($\text{NH}_4^+\text{-N}$). A specific volume of the sample was reacted with phenol-nitroprusside and alkaline-hypochlorite reagents. This reaction forms a blue indophenol compound with an intensity proportional to the TAN concentration. The solution was homogenized and allowed to stand for the color development time specified in the reagent procedure; absorbance was then measured at 640 nm against a reagent blank. Results are reported as mg/L $\text{NH}_3\text{-N}$ or mg N/L, in accordance with the standards used.

Nitrite was analyzed using the diazotization colorimetric method. The sample was reacted with sulfanilamide under acidic conditions to form a diazonium compound. Subsequently, this compound was coupled with N-(1-naphthyl)-ethylenediamine dihydrochloride (NED), producing a purplish-pink color. After the color development time had

elapsed, absorbance was measured at 543 nm against a reagent blank. Nitrite concentration is reported as mg/L NO_2^- -N or mg/L NO_2^- .

Dissolved reactive phosphate was analyzed using the ascorbic acid method. Under acidic conditions, orthophosphate reacts with ammonium molybdate and potassium antimonyl tartrate to form a phosphomolybdate complex. This complex is reduced by ascorbic acid, producing a molybdenum blue color. After the solution was homogenized and the color development time had elapsed, absorbance was measured at a wavelength of 880 nm against a reagent blank. Results were reported as mg/L PO_4^{3-} -P or mg/L PO_4^{3-} , in accordance with the standard curve used.

Data Analysis

The data were analyzed descriptively to characterize changes in the N/P ratio, plankton abundance, and plankton composition across the different DOC treatments. The relationship between the N/P ratio and plankton groups was analyzed using Spearman correlation, given the limited dataset and the observational nature of the data. Correlation results were interpreted at a significance level of $\alpha = 0.05$.

RESULT

Plankton Abundance and Composition

The total plankton abundance in plots B3 and B4 ranged from 61,000 to 1,780,000 individuals/mL. The lowest abundance was observed in plot B3 at DOC 50, while the highest was found in plot B3 at DOC 35. The plankton community comprised Green Algae, diatoms, Blue-Green Algae, Dinoflagellates, Euglenophyta, and Protozoa.

Green Algae constituted the dominant group in both plots, ranging from 74.2% to 86.3%. In plot B3, the highest proportion of Green Algae (86.3%) was recorded at DOC 40, and the lowest (74.2%) at DOC 50. In plot B4, the proportion of Green Algae ranged from 76.6% to 82.1%. These findings indicate that the plankton community was generally dominated by a group that is relatively beneficial to the pond ecosystem.

Dynamics of Blue-Green Algae and Dinoflagellates

Blue-green algae levels in pond B3 ranged from 2.9% to 15.7%, whereas in pond B4, they ranged from 3.6% to 8.5%. The highest BGA value was recorded in pond B3 at DOC 60 (15.7%), exceeding the company's optimal limit of less than 10%. This indicates that pond B3 was subjected to higher levels of harmful plankton stress compared to pond B4.

Dinoflagellate levels in pond B3 ranged from 2.8% to 5.8%, while in pond B4, they ranged from 3.4% to 5.7%. Some dinoflagellate values exceeded the optimal limit of less than 5%, particularly when the N/P ratio was relatively low. This condition warrants attention because dinoflagellates can cause the water to turn reddish-brown and potentially produce compounds toxic to the cultured organisms.

Dynamics of the N/P Ratio

The N/P ratio in plot B3 ranged from 8.90 to 20.09. The lowest value occurred at DOC 50 (8.90), while the highest occurred at DOC 65 (20.09). In plot B4, the N/P ratio ranged from 10.07 to 22.74. The lowest value was observed at DOC 40 (10.07), and the highest at DOC 65 (22.74).

Low N/P ratio values indicate that nitrogen is relatively more limiting than phosphorus. This condition can drive changes in the plankton community structure, particularly an increase in undesirable plankton groups.

Correlation of N/P Ratio with Plankton Groups

Spearman correlation test results indicate that in plot B3, the N/P ratio was significantly negatively correlated with Dinoflagellates ($\rho = -0.636$; $p = 0.048$). This suggests that a decrease in the N/P ratio in plot B3 tended to be accompanied by an increase in Dinoflagellates. In plot B4, the correlation between the N/P ratio and Dinoflagellates was also negative but not significant ($\rho = -0.555$; $p = 0.096$).

In the combined data from plots B3 and B4, the N/P ratio was significantly negatively correlated with Dinoflagellates ($\rho = -0.613$; $p = 0.004$). The correlation with BGA also showed a negative trend but was not significant ($\rho = -0.245$; $p = 0.297$). Meanwhile, the correlation between the N/P ratio and total plankton showed a positive trend approaching significance ($\rho = 0.438$; $p = 0.053$).

Table 1. Spearman correlation of N/P ratio with plankton groups

Plankton variable	Plot B3 ρ	p-value	Plot B4 ρ	p-value	Combined ρ	p-value
Total plankton	0,503	0,138	0,340	0,336	0,438	0,053
Green Algae	0,394	0,260	-0,122	0,736	0,089	0,708
Diatom	-0,055	0,881	-0,553	0,097	-0,298	0,202
BGA	-0,370	0,293	-0,018	0,960	-0,245	0,297
Dinoflagellata	-0,636	0,048	-0,555	0,096	-0,613	0,004
Euglenophyta	0,127	0,727	-0,365	0,299	-0,202	0,394
Protozoa	0,467	0,174	0,160	0,659	0,329	0,157

DISCUSSION

The dominance of green algae in both plots indicates that the phytoplankton community remains dominated by primary producer groups that contribute to photosynthesis, oxygen production, nutrient uptake, and the provision of natural food within the pond ecosystem. In intensive shrimp ponds, Chlorophyta such as **Chlorella** spp. are commonly found, and their abundance is linked to nutrient conditions and water quality parameters. However, green algae dominance cannot serve as the sole indicator of pond health, as excessive phytoplankton biomass can still lead to fluctuations in pH and dissolved oxygen, particularly between day and night. Therefore, assessing pond conditions requires a holistic consideration of abundance, taxonomic composition, community stability, and water quality parameters (Palupi *et al.*, 2022; Mahmudi *et al.*, 2022; Soeprapto *et al.*, 2023).

Increases in blue-green algae (BGA/Cyanobacteria) and dinoflagellates during certain periods indicate a shift in the plankton community structure. This shift warrants attention because some Cyanobacteria and dinoflagellates exhibit opportunistic characteristics and can proliferate in response to changes in nutrient availability, temperature, salinity, light, water residence time, and organic matter accumulation. Research on intensive **Litopenaeus vannamei** (whiteleg shrimp) ponds demonstrates that phytoplankton composition changes throughout the culture period alongside fluctuations in water quality and increased nutrient input from feed (Qiao *et al.*, 2020; Lien *et al.*, 2023). Studies in Indonesia also indicate that phytoplankton abundance and community structure can serve as indicators of water quality changes in intensive and super-intensive **L. vannamei** ponds (Mahmudi *et al.*, 2022; Prasetyono *et al.*, 2024). Low dissolved molar N/P ratios—particularly in plot B3 at DOC 50 and DOC 60—coincided with an increased proportion of potentially harmful plankton groups. At DOC 60, the proportion of blue-green algae (BGA) in plot B3 reached 15.7% when the N/P ratio was approximately 12.20. This value falls below the Redfield ratio of 16:1, which is frequently used as a baseline for the balance between phytoplankton nitrogen and phosphorus

requirements. However, the Redfield ratio is not a universal threshold, as N/P requirements vary across taxa and are influenced by absolute nutrient concentrations, the chemical forms of nitrogen and phosphorus, and environmental conditions. Consequently, the conditions observed at DOC 60 are best interpreted as an indication of nitrogen limitation relative to phosphorus—associated with shifts in plankton composition—rather than evidence that a low N/P ratio is the sole cause of the BGA increase (Jiang et al., 2022; Soeprapto et al., 2023).

The relationship between the N/P ratio and BGA showed a negative trend, though it was not statistically significant. These results suggest a tendency for BGA levels to rise at lower N/P ratios, yet the available statistical evidence is insufficient to establish a consistent relationship. Cyanobacterial responses to nutrients are taxon-specific; nitrogen-fixing cyanobacteria may gain an advantage under inorganic nitrogen-deficient conditions, whereas non-fixing groups remain dependent on available nitrogen forms. Furthermore, BGA abundance can be influenced by temperature, light intensity, water column stability, salinity, aeration, water residence time, organic matter, and competition with other phytoplankton groups. The limited number of observations and differences in management between plots B3 and B4 may also have reduced the statistical strength of the observed relationship. Thus, the N/P ratio should be positioned as one of the ecological predictors, rather than as the sole controller of BGA.

The correlation results indicate a significant negative relationship between the N/P ratio and dinoflagellate abundance ($\rho = -0.613$). In practical terms, this coefficient represents a moderate-to-strong—or reasonably strong—relationship, given the context of field data influenced by numerous environmental factors. The negative direction implies that lower N/P ratios are associated with a higher tendency for dinoflagellate abundance. However, this relationship remains associative and does not yet establish a cause-and-effect link. To date, local studies specifically reporting the Spearman correlation between dissolved molar N/P ratios and dinoflagellates in intensive *Litopenaeus vannamei* (whiteleg shrimp) ponds remain very limited.

The dinoflagellate response to low N/P ratios can be explained by the group's physiological flexibility. Many dinoflagellates are mixotrophic, meaning they can combine photosynthesis with the uptake of dissolved organic compounds or the ingestion of bacteria and other microalgae. This capability allows certain taxa to sustain growth when dissolved inorganic nitrogen is limited or nutrient composition is unbalanced. Dinoflagellates can also utilize urea, amino acids, and other forms of dissolved organic nitrogen; thus, a low DIN-to-phosphate ratio does not necessarily reflect the full range of nitrogen sources available to them. Furthermore, their flagella-driven motility enables vertical migration, allowing them to access light in surface layers and nutrients in deeper layers. This flexibility confers a competitive advantage over obligate autotrophic phytoplankton in stratified waters or environments with nutrient imbalances (Carnicer et al., 2022; Liu et al., 2022).

These findings are contextually supported by local research that identified *Prorocentrum* sp. in intensive *L. vannamei* ponds. The abundance of these dinoflagellates fluctuated throughout the culture cycle and was linked to TAN and water temperature, indicating that dinoflagellate dynamics are governed by the interplay of nutrients and environmental conditions (Ariadi et al., 2023). However, not all dinoflagellates are toxic or detrimental. Ecological risk is determined more by the specific genus or species, abundance, toxin-producing capabilities, and the conditions triggering blooms. The dominance of harmful taxa—such as certain species of *Prorocentrum*, *Alexandrium*, or *Karenia*—can lead to water discoloration, increased community respiration, oxygen depletion at night or during bloom collapse, and the production of metabolites that may compromise shrimp health. Consequently, identification at the genus or species level is essential before classifying a dinoflagellate group as harmful.

A near-significant positive correlation between the N/P ratio and total plankton abundance suggests that an increase in the N/P ratio tends to be accompanied by higher plankton abundance. However, these results do not directly prove that a higher N/P ratio fosters a more stable community. Community stability must be demonstrated through minimal temporal variation, low taxon turnover, or appropriate stability indices. Furthermore, total abundance alone is insufficient for assessing pond health; high abundance can be beneficial if dominated by green algae or diatoms, yet it may elevate risk if dominated by cyanobacteria or harmful dinoflagellates. Therefore, assessments based on community composition provide more insight than relying solely on total plankton abundance (Palupi *et al.*, 2022; Lien *et al.*, 2023; Prasetyono *et al.*, 2024).

Based on these results, managing the N/P ratio requires regulating fertilizer inputs, ensuring efficient feeding, removing sludge, controlling organic matter, maintaining adequate aeration, and routinely monitoring inorganic nitrogen, phosphate, and plankton composition. A significant portion of the nitrogen and phosphorus from feed that is not converted into shrimp biomass enters the water and sediment, driving microbial and phytoplankton community succession during the culture period (Qiao *et al.*, 2020). Therefore, nutrient management should not rely solely on the N/P ratio but also on the absolute concentrations of TAN, nitrite, nitrate, and orthophosphate.

Adding nitrogen fertilizers, such as urea, may be considered a corrective measure if analysis reveals a distinct relative nitrogen limitation. However, application should not be aimed exclusively at achieving a specific ratio. Dosage must be determined through small-scale trials and administered incrementally, taking into account shrimp biomass, alkalinity, pH, TAN, nitrite, dissolved oxygen, and the response of the plankton community. Urea undergoes hydrolysis to form ammonium, which can subsequently be converted to nitrite via nitrification. Consequently, excessive application risks increasing TAN levels and oxygen demand, as well as causing an accumulation of nitrite, which is toxic to shrimp. A safer strategy involves combining nutrient correction with the reduction of uneaten feed, sludge removal, optimized aeration, and post-application plankton monitoring.

CONCLUSION

The N/P ratio is linked to the dynamics of plankton composition in intensive *Litopenaeus vannamei** (Pacific white shrimp) culture. Total plankton abundance in ponds B3 and B4 ranged from 61,000 to 1,780,000 individuals/mL, with green algae dominating at 74.2–86.3%. The N/P ratio ranged from 8.90 to 20.09 in pond B3 and from 10.07 to 22.74 in pond B4.

Spearman correlation analysis revealed a significant negative correlation between the N/P ratio and dinoflagellates based on the combined data from ponds B3 and B4 ($\rho = -0.613$; $p = 0.004$). The correlation with blue-green algae (BGA) was negative but not statistically significant. Thus, a decrease in the N/P ratio tends to be associated with an increased dominance of harmful plankton, particularly dinoflagellates. Controlled management of the N/P ratio is essential to maintain the stability of the plankton community and water quality in intensive shrimp farming systems.

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