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Analysis of Phytoplankton Diversity in *Litopenaeus vannamei* Shrimp Ponds at Marine Science and Techno Park of UNDIP, Teluk Awur, Jepara

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Abstract

Phytoplankton are autotrophic microorganisms that play a crucial role in *Litopenaeus vannamei* (Pacific white shrimp) pond ecosystems, serving as bioindicators of water fertility and pollution levels. This study aimed to assess the water quality conditions of *L. vannamei* ponds at MSTP UNDIP, Teluk Awur, Jepara, using phytoplankton-based biological indices, including the diversity index, uniformity index, and dominance index. A purposive sampling method was applied in two culture ponds of 200 m² and 1000 m². Water quality parameters measured included temperature, brightness, salinity, pH, dissolved oxygen (DO), total suspended solids (TSS), ammonia, nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), alkalinity, and total bacterial count. A total of 16 phytoplankton genera from four classes were identified: Chlorophyta (*Chlamydomonas, Chlorella, Oocystis, Tetraselmis,* and *Westella*), Cyanobacteria (*Anabaenopsis, Lyngbya,* and *Spirulina*), Bacillariophyta (*Cyclotella, Navicula, Streptotheca,* and *Thalassiosira*), and Dinoflagellata (*Dinophysis, Gyrodinium, Gonyaulax,* and *Gymnodinium*). Phytoplankton abundance ranged from 460,000 to 780,000 cells/mL, with diversity index values of 1.04–1.94, uniformity index values of 0.47–0.93, and dominance index values of 0.19–0.57. The findings indicate that phytoplankton diversity in MSTP UNDIP *L. vannamei* ponds is classified as moderate, suggesting a relatively even species distribution. However, the dominance of *Chlorella* sp. may contribute to water instability, making the pond environment more susceptible to environmental fluctuations

1. Introduction

Pacific white shrimp (*Litopenaeus vannamei*) is one of Indonesia's primary export commodities in the fisheries sector due to its high nutritional value and increasing global demand (Mustafa *et al.*, 2023; Asmild *et al.*, 2024). According to Mustafa *et al.* (2023), *L. vannamei* is a high-value aquaculture species that can be cultivated at high stocking densities and on a large scale. Additionally, *L. vannamei* is favored in aquaculture due to its resilience against diseases and relatively high survival rate (Purnamasari *et al.*, 2017).

One of the major challenges in *L. vannamei* aquaculture is the decline in water quality, which negatively impacts shrimp production (Tumwesigye *et al.*, 2022; Yusoff *et al.*, 2024). Poor water quality in shrimp ponds can lead to disease outbreaks and increased mortality, resulting in economic losses (Iber and Kasan, 2021). According to Yessy *et al.* (2024), changes in water color to reddish-green are an indicator of deteriorating pond water quality. This decline is often attributed to excessive feeding, where uneaten feed accumulates at the pond bottom. The decomposition of protein-rich feed generates ammonia, a toxic compound that can inhibit shrimp growth. To mitigate this issue and ensure shrimp survival, other organisms capable of assimilating inorganic nitrogen are required.

Phytoplankton, as primary producers, play a crucial role in nitrogen uptake through photosynthesis, simultaneously contributing to oxygen production (Jahan, 2023). They also serve as natural water quality regulators by utilizing metabolic waste and uneaten shrimp feed as energy sources (Apresia *et al.*, 2024; Heriyati *et al.*, 2024; Janah *et al.*, 2024). The composition and abundance of phytoplankton communities can serve as bioindicators of pond fertility, providing insight into water quality conditions in shrimp farming systems (Amengual-Morro *et al.*, 2012; Mustika *et al.*, 2023).

At the Marine Science and Techno Park (MSTP) UNDIP, Teluk Awur, Jepara, *L. vannamei* is cultivated using an intensive aquaculture system supported by infrastructure such as settling ponds, water treatment ponds, shrimp rearing ponds, and waste processing ponds. The water quality in these ponds can be assessed based on phytoplankton abundance and diversity. Environmental variations influence phytoplankton community structure and species composition, making phytoplankton diversity an essential parameter for evaluating pond water quality. Therefore, this study aims to analyze phytoplankton diversity and its impact on the water quality of *L. vannamei* ponds

2. Material and methods

2.1 Study Area and Sampling Procedure

This study was conducted to assess phytoplankton composition and water quality parameters in *Litopenaeus vannamei* shrimp ponds located in the Marine Science and Techno Park (MSTP), Diponegoro University (UNDIP), Teluk Awur, Jepara, Indonesia. Water samples were collected from two box-shaped shrimp ponds with different surface areas: Pond UM1 A (200 m²) and Pond UM2 A (1000 m²). The ponds were stocked with *L. vannamei* at a density of 300 individuals/m², and the cultivation water underwent sedimentation and treatment before being introduced into the system. Sampling was performed once a week for three consecutive weeks to compare results from different pond sizes (Figure 1).

Water samples were collected using a 40 L bucket and subsequently filtered through a 5 µm plankton net. The filtered samples were transferred into 200 mL sample bottles and preserved with 10 drops of 4% Lugol's solution. For laboratory analysis, an additional 600 mL of surface water was collected in sample bottles and stored in a cool box to maintain sample integrity. Sampling was conducted between 07:00 and 09:00 WIB.

2.2 Water Quality Parameter Measurement

Water quality parameters measured included temperature, transparency, salinity, pH, dissolved oxygen (DO), suspended solids (MPT), ammonia (NH_3), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), alkalinity, and total bacterial load. Daily measurements of temperature, transparency, and pH were conducted *in situ* using standard field instruments. Salinity was measured on-site, while DO was measured weekly. Other parameters were analyzed in the laboratory following standard procedures.

2.3 Phytoplankton Identification and Enumeration

Phytoplankton samples were examined under a microscope to determine species composition and abundance. A hemocytometer was used for cell counting, and samples were observed under a 10×40 magnification. Phytoplankton identification was performed using the taxonomic reference by Botes (2003) and the AlgaeBase database (www.algaebase.org). Cell density was calculated using the following formula (Isnansetyo and Kurniastuty, 1995):

$$Density = N \times 10^4 (\frac{cell}{mL})$$

where:

- N = average number of phytoplankton cells per counting chamber grid,
- 10^4 = conversion factor to determine cell density per mL of water.

2.4 Phytoplankton Community Analysis

Phytoplankton diversity and ecological indices were determined using the following formulas:

1. Shannon-Wiener Diversity Index (H') (Astriana *et al.*, 2022):
2. $H' = -\sum Pi \, In \, P$

where:

- H' = species diversity index,
- $P_i = n_i/N$ (proportion of each species),
- n_i = number of individuals of species i,
- N = total number of phytoplankton individuals.

Diversity index criteria:

- $H' > 3$: High diversity (stable community)
- $1 < H' < 3$: Moderate diversity (moderately stable community)
- $H' < 1$: Low diversity (unstable community)

2. Pielou's Evenness Index (E):

$$E = \frac{H'}{H_{max}}$$

where:

- E = evenness index,
- H' = species diversity index,
- H_{max} = maximum diversity index (ln S),
- S = total number of species.

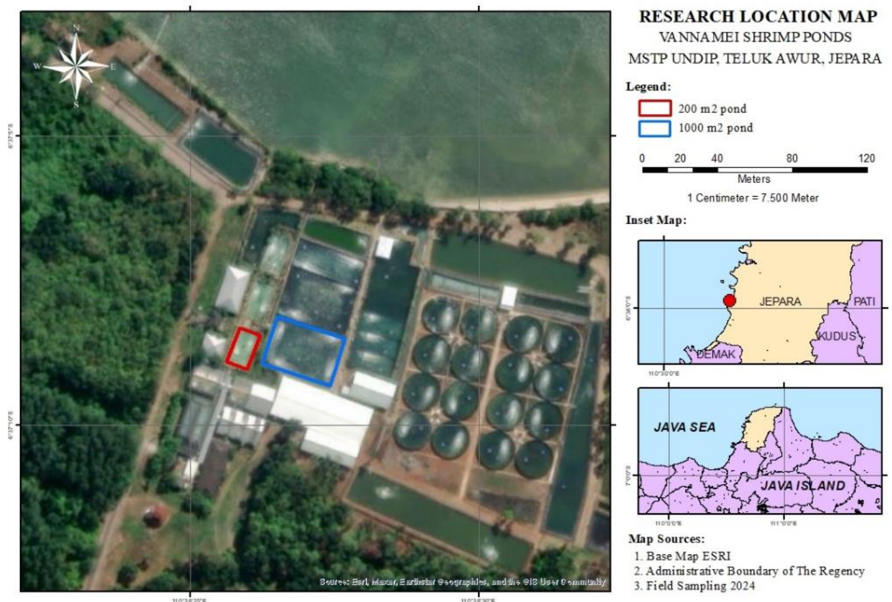

Figure 1. Research Location Sampling Point at vannamei Shrimp Pond MSTP UNDIP Teluk Awur, Jepara

Evenness index criteria:

- $E > 0.6$: High uniformity (even species distribution, no dominance)
- $0.4 \leq E \leq 0.6$: Moderate uniformity (some species dominance begins)
- $E < 0.4$: Low uniformity (uneven species distribution, high dominance)

3. Simpson's Dominance Index (D):

$$D = \sum(Pi)^2 \ or \ D = \sum(\frac{in}{N})^2$$

where:

- D = dominance index,
- $P_i = n_i/N$.

Dominance index criteria:

- $0.0 < D \leq 0.5$: Low dominance
- $0.5 < D \leq 0.75$: Moderate dominance
- $0.75 < D \leq 1.0$: High dominance

Statistical Analysis

The relationship between phytoplankton abundance and water quality parameters was analyzed using Principal Component Analysis (PCA) in XLSTAT software. PCA was applied to extract key patterns from multivariate datasets and visualize relationships among variables graphically (Barokah et al., 2016). This statistical approach helps simplify complex data, making it easier to interpret and identify significant correlations between phytoplankton community structure and environmental factors.

Description:

N = Average number of phytoplankton cells observed in the square box.

10^4 = The actual cell density in 1 mL of media/water.

Phytoplankton analysis was carried out using ecological indices including the diversity index, uniformity index and dominance index. The diversity index is a mathematical depiction to make it easier to obtain or analyze information about an organism. This index is used to determine the diversity of phytoplankton at the research location using the Shannon Wiener diversity index formula as follows.

Description:

H' = Species diversity index

Pi = ni/N (proportion of phytoplankton types)

in = Number of individuals of one phytoplankton species

N = Number of all individual phytoplankton

The criteria for the species diversity index are categorized into 3, including the following (Astriana and Larasati, 2021).

H' > 3 : High species diversity (stability of phytoplankton community in stable conditions)

1 < H' < 3 : Medium species diversity (medium phytoplankton community stability)

H' < 1 : Low species diversity (unstable phytoplankton community stability)

The uniformity index is an index that functions to determine the distribution pattern of phytoplankton in a body of water. The uniformity index is obtained by comparing the diversity index value with the maximum value using the following formula.

$$E = \frac{H'}{H_{max}}$$

Description:

E = Uniformity index

H' = Species diversity index

H_{max} = Maximum diversity index (lnS)

The uniformity index criteria are categorized as follows.

E > 0.6 : High uniformity (even distribution, no species dominance, equal/equal life opportunities)

0.4 ≥ E ≥ 0.6 : Moderate uniformity (fairly even distribution, starting to become dominant in one species, life chances are starting to become unequal)

E < 0.4 : Low uniformity (uneven distribution, species dominance, unequal life chances)

The dominance index is an index used to see which species dominates other species in a body of water. The dominance index is calculated using the Simpson formula as follows.

$$D = \sum(Pi)^2 \ or \ D = \sum(\frac{in}{N})^2$$

Information:

D = Dominance index

Pi = ni/N

in = Number of individuals of each phytoplankton species

N = Number of all individual phytoplankton

The dominance index criteria are categorized as follows.

0.0 < D ≤ 0.5 (low dominance)

0.5 < D ≤ 0.75 (medium dominance)

0.75 < D ≤ 1.0 (high dominance)

The relationship between phytoplankton abundance and water quality parameters in vannamei shrimp ponds was analyzed by conducting tests Principal Component Analysis (PCA) using XLSTAT software. The PCA method is a statistical method that aims to obtain important information from a dataset with many variables presented in graphical form to visualize the relationship between each variable. This method is used on complex data with lots of variables or information to make it simple, making it easier to analyze the data.

3. Results

3.1 Phytoplankton Composition and Abundance

The phytoplankton community in vannamei shrimp ponds varied over the three-week observation period, with three major groups identified: Chlorophyta, Cyanobacteria, and Bacillariophyta, along with the presence of Dinoflagellates. Phytoplankton composition and abundance fluctuated between the 200 m² and 1000 m² ponds, reflecting potential differences in environmental conditions and resource availability (Tabel 1).

During the first week, *Chlorella* was the most dominant species in both ponds, with abundances of 440,000 cells/mL in the 200 m² pond and 250,000 cells/mL in the 1000 m² pond. The presence of *Lyngbya* (Cyanobacteria) was notable, particularly in the 1000 m² pond, where it reached 60,000 cells/mL. *Boats* (Bacillariophyta) and *Cyclotella* were more abundant in the larger pond, suggesting that diatom proliferation may be influenced by pond size and water conditions.

In the second week, the total phytoplankton abundance remained relatively stable, with a slight increase in the 200 m² pond (630,000 cells/mL) and a minor decrease in the 1000 m² pond (680,000 cells/mL). *Tetraselmis* showed significant growth in both ponds, reaching 190,000 cells/mL in the 200 m² pond and 170,000 cells/mL in the 1000 m² pond. *Gyrodinium* was also prominent, with an increasing trend observed from week one to week three.

Table 1. Abundance of Phytoplankton Species in vannamei Shrimp Ponds MSTP UNDIP Teluk Awur, Jepara

Species	Week I		Week II		Week III	
	Pond 200 m²	Pond 1000 m²	Pond 200 m²	Pond 1000 m²	Pond 200 m²	Pond 1000 m²
Chlorophyta						
Chlamydomonas	0	30000	0	0	0	0
Chlorella	440000	250000	230000	280000	240000	200000
Oocystis	10000	0	0	80000	0	0
Tetraselmis	30000	10000	190000	170000	80000	0
Westella	0	0	0	0	0	40000
Cyanobacteria						
Anabaenopsis	10000	0	0	0	0	0
Lyngbya	20000	60000	80000	30000	90000	20000
Spirulina	10000	0	0	0	0	0
Bacillariophyta						
Cyclotella	0	30000	10000	0	0	10000
Boats	50000	100000	10000	0	0	0
Streptotheca	0	70000	10000	90000	200000	0
Thalassiosira	0	80000	0	0	0	0
Dinoflagellates						
Dinophysis	10000	0	0	0	0	0
Gonyaulax	0	0	40000			
Gyrodinium	10000	40000	30000	30000	110000	80000
Gymnodinium	0	20000	0	0	60000	110000
Total Abundance	590.000	690.000	630.000	680.000	780.000	460.000
Number of Genus	9	10	8	6	6	6

By the third week, the total phytoplankton abundance increased in the 200 m² pond (780,000 cells/mL) but declined sharply in the 1000 m² pond (460,000 cells/mL). *Streptotheca* exhibited a notable bloom in the smaller pond, reaching 200,000 cells/mL, while *Gymnodinium* proliferated in the larger pond, reaching 110,000 cells/mL. The number of genera recorded was highest in the first week, with 9 genera in the 200 m² pond and 10 in the 1000 m² pond, decreasing to 6 genera in both ponds by the third week.

The differences in phytoplankton abundance and diversity between the ponds suggest that pond size and environmental factors such as nutrient availability, light penetration, and grazing pressure may influence community structure. The decline in total phytoplankton abundance in the 1000 m² pond by the third week could indicate increased nutrient limitation or top-down control by filter-feeding organisms.

3.2 Biological Indices of Phytoplankton Community

The biological indices, including the Diversity Index (H'), Uniformity Index (J'), and Dominance Index (D), were analyzed to assess the ecological stability and structure of the phytoplankton community in both the 200 m² and 1000 m² ponds over three weeks (Table 2).

Table 2. Phytoplankton Biological Index in vannamei Shrimp Ponds MSTP UNDIP Teluk Awur, Jepara

Biology Index	Week I		Week II		Week III	
	Pond 200 m²	Pond 1000 m²	Pond 200 m²	Pond 1000 m²	Pond 200 m²	Pond 1000 m²
Diversity Index	1.04 (medium)	1.94 (medium)	1.62 (medium)	1.51 (medium)	1.67 (medium)	1.44 (medium)
Uniformity Index	0.47 (high)	0.84 (high)	0.78 (high)	0.84 (high)	0.93 (high)	0.80 (high)
Dominance Index	0.57 (medium)	0.19 (low)	0.25 (low)	0.27 (low)	0.21 (low)	0.29 (low)

The Diversity Index (H') ranged from 1.04 to 1.94 across the observation period, indicating a medium level of diversity in both ponds. The 1000 m² pond exhibited a higher diversity in the first week (1.94) compared to the 200 m² pond (1.04), suggesting a more balanced distribution of phytoplankton species in the larger pond. However, as the weeks progressed, the diversity in the 1000 m² pond declined slightly, while the 200 m² pond showed an increasing trend, reaching its highest value in the third week (1.67). This indicates a shift in community composition, possibly due to changes in environmental conditions such as nutrient availability and grazing pressure.

The Uniformity Index (J') remained consistently high (>0.47) in both ponds, indicating a relatively even distribution of phytoplankton species. The 1000 m² pond had a slightly more uniform distribution across all weeks, with values remaining stable at 0.84, whereas the 200 m² pond exhibited an increasing trend, reaching its highest value (0.93) in the third week. This suggests that species abundance became more evenly distributed over time in the smaller pond.

The Dominance Index (D) showed an inverse relationship with diversity and uniformity. In the first week, the 200 m² pond had a higher dominance value (0.57), indicating that a few species were more dominant in this pond compared to the 1000 m² pond (0.19). As the weeks progressed, the dominance index decreased in the 200 m² pond (0.21 in the third week), suggesting a more balanced community with reduced species dominance. Conversely, in the 1000 m² pond, the dominance index increased slightly from 0.19 in the first week to 0.29 in the third week, reflecting a potential increase in the dominance of specific phytoplankton species.

Overall, the biological indices indicate a dynamic phytoplankton community structure influenced by pond size and environmental factors. The higher diversity and lower dominance observed in the 1000 m² pond during the early weeks suggest a more stable ecosystem, while the increasing diversity and uniformity in the 200 m² pond indicate an improving balance in the phytoplankton community over time.

3.3 Water Quality and Phytoplankton Community Dynamics

Water quality parameters were monitored throughout the study to assess their influence on the phytoplankton community structure and shrimp health in both the 200 m² and 1000 m² ponds. Variations in these parameters may impact phytoplankton composition, abundance, and overall pond productivity (Table 3).

Table 3. Water Quality Parameters in vannamei Shrimp Ponds MSTP UNDIP Teluk Awur, Jepara

Parameter	Week I		Week II		Week III	
	Pond 200 m²	Pond 1000 m²	Pond 200 m²	Pond 1000 m²	Pond 200 m²	Pond 1000 m²
Temperature (°C)	25,8 – 30,0	27,6 – 30,7	26,7 – 30,7	26,8 – 31,9	26,0 – 29,1	26,7 – 31,5
Brightness (cm)	25 – 35	25 – 30	25 – 30	25 – 30	25 – 35	20 – 35
Salinity (ppt)	23 – 25	23 – 26	24 – 25	23 – 25	20 – 24	20 – 25
pH	7,87 – 8,26	7,75 – 8,15	7,74 – 8,52	7,65 – 8,29	7,73 – 8,13	7,62 – 8,28
DO (mg/L)	5,92	4,36	4,23	4,16	5,19	4,9
MPT (mg/L)	1415	1220	1420	990	785	650
Ammonia (mg/L)	0,25	4,00	0,47	1,95	1,00	1,50
Nitrit (mg/L)	1,00	0,60	0,80	1,00	0,05	1,00
Nitrate (mg/L)	3,84	1,92	3,84	2,97	3,77	3,56
Phosphate (mg/L)	0,14	0,38	0,25	0,54	0,26	0,28
Alkalinity (mg/L)	170,15	215,17	150,12	195,16	125,1	150,12
Total bacteria (cfu/ml)	$6{,}1\times10^3$	$1{,}6\times10^3$	$8{,}2\times10^3$	$2{,}3\times10^4$	$2{,}0\times10^4$	$3{,}3\times10^4$

The water temperature ranged from 25.8°C to 31.9°C, with the 1000 m² pond exhibiting slightly higher temperatures (maximum 31.9°C in Week III) compared to the 200 m² pond (maximum 30.7°C in Week II). Temperature fluctuations can influence phytoplankton growth rates, metabolic processes, and nutrient cycling. The observed range remained within the optimal conditions for *Litopenaeus vannamei* culture, although higher temperatures may promote the proliferation of certain phytoplankton species.

Water transparency, measured as brightness, varied between 20 cm and 35 cm. The 200 m² pond showed relatively stable transparency, whereas the 1000 m² pond exhibited reduced brightness in Week III (20 cm), likely due to increased phytoplankton blooms or suspended particles. Decreased transparency can limit light penetration, affecting the photosynthetic efficiency of phytoplankton communities. Salinity levels fluctuated between 20 ppt and 26 ppt, with a slight decline in Week III, particularly in the 200 m² pond (minimum of 20 ppt). This reduction may have been influenced by freshwater input from rainfall or water exchange. Changes in salinity can alter phytoplankton community composition, as different species exhibit varying tolerance levels to salinity fluctuations.

The pH remained within a range of 7.62 to 8.52, with slightly higher values recorded in the 200 m² pond. This range is considered suitable for shrimp farming and phytoplankton growth. However, minor fluctuations in pH could impact enzymatic activity, nutrient solubility, and the availability of essential elements for phytoplankton proliferation.

Dissolved oxygen (DO) levels varied between 4.16 mg/L and 5.92 mg/L, with lower values recorded in the 1000 m² pond. The lowest DO concentration (4.16 mg/L) in Week II suggests increased respiration, possibly due to elevated microbial or phytoplankton biomass. A decline in DO may affect the metabolic functions of both shrimp and phytoplankton, particularly in larger ponds with higher organic matter accumulation.

Total suspended solids (MPT) showed a decreasing trend over time, with the most significant decline observed in the 1000 m² pond (from 1220 mg/L in Week I to 650 mg/L in Week III). This reduction may be attributed to sedimentation, biological filtration, or decreased phytoplankton activity. The decrease in suspended solids can enhance light penetration, potentially favoring the growth of certain phytoplankton taxa. Nutrient concentrations varied throughout the study period. Ammonia levels were significantly higher in the 1000 m² pond during Week I (4.00 mg/L) but declined over time. In contrast, the 200 m² pond maintained lower ammonia concentrations, suggesting more efficient nitrogen assimilation or microbial processing. Nitrite levels fluctuated, with the highest concentration (1.00 mg/L) recorded in Week III in the 1000 m² pond, which may indicate incomplete nitrification. Meanwhile, nitrate levels remained relatively stable, with slightly higher concentrations in the 200 m² pond (up to 3.84 mg/L), reflecting ongoing nitrification processes. Phosphate concentrations were higher in the 1000 m² pond, particularly in Week II (0.54 mg/L), which may have promoted phytoplankton growth and altered species dominance.

Alkalinity decreased over time, particularly in the 200 m² pond, where it declined from 170.15 mg/L in Week I to 125.1 mg/L in Week III. Lower alkalinity reduces the buffering capacity of water, which may contribute to pH instability and affect shrimp molting cycles and phytoplankton community balance.

Bacterial abundance increased progressively in both ponds, with higher counts recorded in the 1000 m² pond (up to 3.3×10^4 cfu/ml in Week III). The increase in bacterial populations may be linked to organic matter decomposition, nutrient cycling, and microbial interactions with phytoplankton. A high bacterial load may also contribute to competition for nutrients and influence phytoplankton succession.

Overall, the observed water quality variations influenced the phytoplankton community structure, particularly in the 1000 m² pond, where nutrient fluctuations and bacterial abundance were more pronounced. These findings suggest that larger pond sizes may experience more dynamic environmental conditions, potentially affecting phytoplankton composition and shrimp productivity. Further analysis is required to establish correlations between water quality parameters, phytoplankton diversity, and shrimp performance.

3.4 PCA Analysis

The PCA test produced two PCA axes with a total contribution of 64.73%, which means that water quality parameters had an influence on all sampling locations of 64.73%. F1 and F2 are factorial axes which represent a linear combination of original variables or initial data before processing. F1 and F2 with percentages of 34.57% and 30.16% represent data equal to that percentage or the percentage of data diversity explained in the main components (Figure 2).

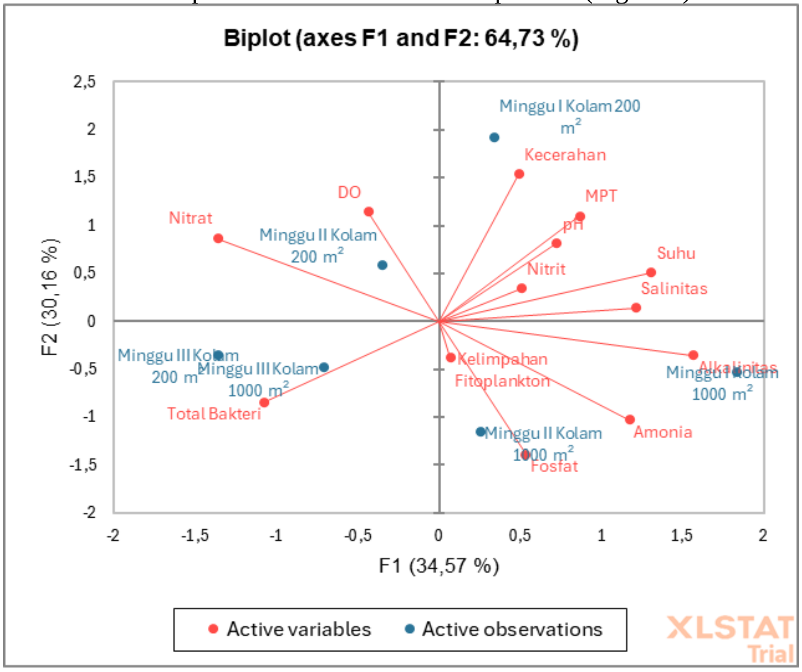

Figure 2. PCA Test Results for Phytoplankton Abundance and Water Quality Parameters of *L. vannamei* Shrimp Ponds at MSTP UNDIP, Teluk Awur Jepara

4. Discussion

The phytoplankton community identified in this study belonged to the phyla Chlorophyta, Cyanobacteria, Bacillariophyta, and Dinoflagellata. Chlorophyta exhibited the highest composition in vannamei shrimp ponds at MSTP UNDIP, Teluk Awur, Jepara, with five genera identified: *Chlamydomonas*, *Chlorella*, *Oocystis*, *Tetraselmis*, and *Westella*. Kristiana *et al.* (2024) reported that Chlorophyta is commonly found in shrimp aquaculture due to its adaptability to diverse environmental conditions. Aisyah *et al.* (2023) stated that the optimal temperature for Chlorophyta growth is 30–35°C. Water temperatures in this study ranged from 25.8 to 31.9°C, which, though slightly below the optimal range, still supported Chlorophyta growth. The most consistently observed genus from Chlorophyta was *Chlorella sp.*, indicating its strong adaptability. Edi *et al.* (2021) reported that *Chlorella sp.* assimilates organic waste from vannamei shrimp culture, contributing to pond ecosystem balance.

Cyanobacteria exhibited the lowest genus diversity, with only three genera identified. Their limited presence may result from low tolerance to environmental fluctuations (Azis *et al.*, 2020). Barçante *et al.* (2020) reported that Cyanobacteria thrive in phosphate-rich environments (>1 mg/L). Phosphate levels in this study ranged from 0.14 to 0.54 mg/L, insufficient for significant Cyanobacteria proliferation. Jia *et al.* (2022) noted that high pH (7.5–11) inhibits Cyanobacteria photosynthesis. The observed pH range (7.62–8.52) likely restricted their growth.

Among Cyanobacteria, *Lyngbya sp.* was the most frequently encountered genus. *Lyngbya sp.* as a filamentous, unbranched cyanobacterium with segmented structures (Ardiansyah and Rijal, 2023). Takarina and Wardhana (2017) noted that its highest density occurs at 31.43°C, aligning with the study’s temperature range. However, *Lyngbya sp.* presence in shrimp ponds is undesirable due to toxin production, degrading water quality and posing health risks (Thawabteh *et al.*, 2023).

The correlation analysis shows relationships between water quality parameters (red axes) and sampling locations (blue dots). A smaller angle between red axes indicates a strong positive correlation, such as between phytoplankton abundance and phosphate levels. The highest phosphate concentration (0.54 mg/L) was recorded in a 1000 m² pond during Week II, with a phytoplankton abundance of 680,000 cells/mL. The lowest phosphate level (0.14 mg/L) was observed in a 200 m² pond during Week I, with an abundance of 590,000 cells/mL. A negative correlation was observed between phytoplankton abundance and nitrate levels, where higher nitrate concentrations (3.84 mg/L) corresponded to lower phytoplankton counts. The phytoplankton diversity index indicated moderate diversity, suggesting susceptibility to environmental fluctuations. Dominance by *Chlorella sp.* and elevated ammonia levels contributed to this. Astriana *et al.* (2022) stated that ammonia enhances phytoplankton growth at <0.2 mg/L but excessive levels reduce diversity. Ammonia levels in this study ranged from 0.25 to 4.00 mg/L, exceeding safe limits.

The evenness index suggested a relatively uniform distribution of phytoplankton genera. The dominance index was generally low, except in a 200 m² pond during Week I, where *Chlorella sp.* reached 440,000 cells/mL. Water clarity ranged from 20 to 35 cm, below the recommended 20-40 cm for optimal vannamei shrimp cultivation (Inayah *et al.*, 2023). Reduced clarity resulted from increased phytoplankton density, which elevated turbidity and limited light penetration (Akbarurrasyid *et al.*, 2022). Suspended solid (MPT) levels ranged from 650 to 1420 mg/L, exceeding the recommended 50–300 mg/L (Suwoyo and Tampangallo, 2015). High MPT levels were attributed to organic particulates from feed and shrimp waste, as well as inorganic particulates like fine sand. Excessive turbidity can hinder aquatic photosynthesis (Isman *et al.*, 2022).

Ammonia and nitrite concentrations exceeded safe thresholds. Romadhona *et al.* (2016) reported that ammonia levels above 0.45 mg/L impair shrimp growth, while 1.29 mg/L is lethal. Similarly, nitrite levels >0.5 mg/L are toxic. These elevated levels likely resulted from organic waste accumulation. Nitrate concentrations ranged from 1.92 to 3.84 mg/L, slightly exceeding optimal standards. Krisiyanto *et al.* (2021) suggested that 0.9–3.5 mg/L is ideal for phytoplankton survival. Excessive nitrogen and phosphorus inputs can trigger eutrophication (Hamuna *et al.*, 2018). Alkalinity levels ranged from 125.10 to 215.17 mg/L. Suwoyo and Hendrajat (2021) recommended 124-165 mg/L for shrimp aquaculture. Some values exceeded this range, potentially affecting shrimp physiology and pond stability.

5. Conclusions

Phytoplankton composition in vannamei shrimp ponds varied over three weeks, with the dominant groups being Chlorophyta, Cyanobacteria, Bacillariophyta, and Dinoflagellates. Chlorella was consistently abundant, while species such as Lyngbya and Streptotheca fluctuated, influenced by pond size and environmental factors. The 200 m² pond showed an increase in phytoplankton abundance, while the 1000 m² pond exhibited a decline in the third week, likely due to nutrient limitations or grazing pressure. Biological indices indicated a dynamic community structure. The 1000 m² pond initially exhibited higher diversity, which decreased over time, whereas the 200 m² pond demonstrated increasing diversity and uniformity, suggesting a more balanced ecosystem. Water quality parameters fluctuated but remained within the suitable range for shrimp culture. Differences in ammonia, dissolved oxygen, and pH likely influenced phytoplankton dynamics, highlighting the interrelationship between environmental factors and community structure.

Ethics approval

No permits were required.

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Author contributions

NAAK is responsible for formal analysis, data curation, project administration, and funding acquisition. SS, and EY contributed to investigation, conceptualization, resource acquisition, methodology, writing – review & editing, and writing the original draft.

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Declaration of competing Interest

None

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