



Phytoplankton Community Structure in Lake Gedang and Coastal Whiteleg Shrimp Ponds in Bengkulu: Potential Natural Feed Candidates

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Abstract: This study aimed to characterize phytoplankton community structure in Lake Gedang and whiteleg shrimp (*Litopenaeus vannamei*) ponds, compare community characteristics between the two ecosystems, and identify phytoplankton taxa detected in the shrimp digestive tract as preliminary candidates for natural feed. A survey was conducted from September to November 2025 at five stations in Lake Gedang and three stations in shrimp ponds in Bengkulu Province, Indonesia. Phytoplankton were identified microscopically, and community structure was assessed using abundance, the Shannon–Wiener diversity index (H'), evenness (J'), and Simpson's dominance index (C). Differences in abundance were tested using the Mann–Whitney U test, while relationships between abundance and environmental variables were evaluated using Spearman's correlation. A total of 40 species were recorded in Lake Gedang and 92 species in the shrimp ponds, with Bacillariophyta showing the highest species richness (67.50% and 65.22%, respectively). Mean abundance was 95.80 ind/L in Lake Gedang and 239.33 ind/L in the shrimp ponds, with a significant difference between ecosystems ($U = 0.000$; $p = 0.036$). Mean H' , J' , and C values were 2.360, 0.929, and 0.109 in Lake Gedang and 3.560, 0.933, and 0.036 in the shrimp ponds, respectively. No significant correlations were found between phytoplankton abundance and temperature, pH, dissolved oxygen, or total dissolved solids in Lake Gedang. Four taxa—*Anabaena* sp., *Cosmarium pseudoconnatum*, *Golenkinia* sp., and *Ulothrix* sp.—were detected in the shrimp digestive tract. These findings indicate distinct phytoplankton community characteristics between the two ecosystems and provide preliminary evidence that the four detected taxa may be ingested by *L. vannamei*. However, their occurrence does not demonstrate feeding preference or confirm their suitability as natural feed.

Keywords: Phytoplankton; *Litopenaeus vannamei*; digestive tract contents; Lake Gedang; whiteleg shrimp ponds

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INTRODUCTION

Whiteleg shrimp (*Litopenaeus vannamei*) is one of the most important aquaculture commodities worldwide and has become the most widely cultured crustacean species in many producing countries, including Indonesia. Its commercial success is associated with rapid growth, high survival, tolerance to a relatively broad range of environmental conditions, and adaptability to intensive culture systems. However, the continued intensification of shrimp aquaculture increases the importance of efficient feed management and stable water quality, both of which directly influence production performance and environmental sustainability. Feed represents a major operational input in shrimp farming, and the growing demand for sustainable feed resources has stimulated interest in alternative and complementary nutritional sources for *L. vannamei* (Chen et al., 2024). In intensive systems, uneaten feed, shrimp excretion, and other organic residues may increase nutrient loads and alter water quality and plankton community dynamics (Yang et al., 2017; Lemonnier et al., 2016; Yun et al., 2022). Consequently, strategies that simultaneously improve nutrient

utilization, reduce dependence on conventional feeds, and maintain favorable pond conditions are increasingly relevant to sustainable shrimp production.

Phytoplankton and other microalgae are important components of shrimp-pond ecosystems because they contribute to primary production, nutrient cycling, oxygen dynamics, and the aquatic food web. Their abundance and community composition are strongly influenced by environmental conditions, including temperature, pH, salinity, dissolved oxygen, light availability, and nutrient concentrations (Dembowska et al., 2018; Cui et al., 2023). Studies of *L. vannamei* culture systems have further demonstrated that phytoplankton communities vary with water-quality conditions and pond management, making them useful biological indicators of ecological conditions in aquaculture systems (Lemonnier et al., 2016; Yang et al., 2020; Lyu et al., 2021; Inayah et al., 2023). Recent observations from whiteleg shrimp ponds in Indonesia also demonstrate substantial phytoplankton diversity and emphasize the close association between plankton community structure and culture conditions (Maulidhya et al., 2024).

Beyond their ecological functions, microalgae and phytoplankton may provide nutritional benefits to cultured aquatic organisms. Several taxa contain substantial concentrations of proteins, essential fatty acids, vitamins, pigments, and other bioactive compounds, supporting their use as live feed, feed ingredients, or dietary supplements in aquaculture (Becker, 2019; Fang et al., 2022; Abdelhay et al., 2025). A recent review by Ma & Hu (2024) further highlighted the nutritional value of microalgae as sources of proteins, lipids, polyunsaturated fatty acids, carotenoids, vitamins, and other bioactive compounds with applications in sustainable aquafeeds. Experimental studies have also demonstrated that dietary supplementation with selected microalgae can influence growth, physiological condition, and immune responses in *L. vannamei* (Fang et al., 2022; Zhang et al., 2024). In addition, juvenile *L. vannamei* are capable of ingesting and digesting suspended microalgae, while naturally productive pond systems can contribute to the shrimp's dietary intake (Kent et al., 2011; Porchas-Cornejo et al., 2012). These findings indicate that naturally occurring phytoplankton may contribute not only to pond ecological processes but also to the nutritional pathways available to cultured shrimp.

Despite these advances, most previous studies have examined phytoplankton primarily in relation to water quality, pond productivity, or the nutritional performance of selected cultured microalgae. Comparatively less attention has been given to linking the phytoplankton assemblages present in surrounding natural waters and shrimp ponds with the phytoplankton taxa actually detected in the digestive tract of cultured *L. vannamei*. This distinction is important because the occurrence of a phytoplankton taxon in the environment does not necessarily indicate that it is ingested or potentially utilized by shrimp. Conversely, detection in the digestive tract can provide preliminary evidence of ingestion, although it cannot by itself demonstrate feeding preference, digestibility, nutritional value, or suitability as a natural feed source. Integrating phytoplankton community assessment with digestive tract content analysis may therefore provide a useful preliminary approach for identifying locally available taxa that warrant further evaluation as natural feed candidates.

This knowledge gap is particularly relevant in Bengkulu Province, where comparative information on phytoplankton communities in Lake Gedang and nearby whiteleg shrimp ponds remains limited. Lake Gedang represents a natural coastal aquatic ecosystem, whereas shrimp ponds represent managed production systems exposed to different environmental and nutrient conditions. Comparing these two ecosystems provides an opportunity to assess how contrasting habitat characteristics are associated with phytoplankton community structure and to determine whether taxa

present in the surrounding aquatic environment are also detected in the digestive tract of *L. vannamei*. We hypothesized that phytoplankton community characteristics would differ between Lake Gedang and whiteleg shrimp ponds and that some of the taxa recorded in the study system would also occur in the shrimp digestive tract.

Accordingly, this study aimed to characterize phytoplankton species composition, abundance, diversity, evenness, and dominance in Lake Gedang and whiteleg shrimp ponds; compare phytoplankton community characteristics between the two ecosystems; examine the relationships between phytoplankton abundance and selected water-quality variables, including temperature, pH, dissolved oxygen, salinity, and total dissolved solids (TDS); and identify phytoplankton taxa present in the shrimp digestive tract as preliminary candidates for further evaluation as natural feed. By integrating ecological community assessment with digestive tract observations, this study provides baseline information on local phytoplankton resources and establishes a foundation for subsequent studies on nutritional value, digestibility, safety, and controlled feeding performance.

METHOD

Study Area and Research Design

This study employed a survey method with a descriptive-comparative approach to characterize phytoplankton community structure in Lake Gedang and whiteleg shrimp (*Litopenaeus vannamei*) ponds in the coastal area of Bengkulu Province, Indonesia. Field sampling was conducted from September to November 2025. The study consisted of site reconnaissance, water and shrimp sampling, measurement of physicochemical water parameters, laboratory identification of phytoplankton, and statistical analysis.

Five sampling stations were established in Lake Gedang and three sampling stations in the whiteleg shrimp ponds. These stations represented the spatial and environmental characteristics of the two aquatic ecosystems and were subsequently used as the units of analysis for comparisons of phytoplankton abundance between Lake Gedang and the shrimp ponds.

Lake Gedang is a natural coastal lake located near the shoreline. During high tides, seawater can enter parts of the lake, whereas freshwater input is supplied by a spring in the upstream area. Anthropogenic activity around the lake is relatively low, and the site was therefore selected to represent a relatively natural coastal aquatic ecosystem. The five Lake Gedang stations were located at approximately 3°39.494' S, 102°12.809' E (Station I); 3°39.286' S, 102°12.737' E (Station II); 3°39.200' S, 102°12.660' E (Station III); 3°39.165' S, 102°12.620' E (Station IV); and 3°39.105' S, 102°12.657' E (Station V).

The Lake Gedang stations represented different hydrological characteristics. Station I was located near the lake outlet directly connected to the coastal area and had a water depth of approximately 0.5 m. Stations in the central section represented areas with water movement toward the outlet, whereas Station III was positioned in a relatively enclosed area with limited flow. Stations IV and V were located closer to the freshwater spring, where water movement was relatively slow.

The shrimp ponds were located near Lake Gedang in Padang Betuah Village, Pondok Kelapa District, Central Bengkulu Regency, Bengkulu Province. The pond complex covered approximately 10 ha, with individual pond areas ranging from approximately 20 × 70 m to 50 × 100 m. Three sampling stations were established within the shrimp-pond system. Detailed pond-management information could not be reported because these data were considered confidential by the pond owner.

Water Sampling and Environmental Measurements

At each sampling location, 50 L of water was collected and filtered through a No. 25 plankton net. The filtered material was concentrated to approximately 100 mL and transferred into sample bottles. Each phytoplankton sample was preserved with six drops of 5% Lugol's solution before laboratory analysis.

Physicochemical water parameters measured during field sampling included temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), and salinity. Measurements were performed using a water thermometer, water tester, DO meter, and salinometer. These parameters were used to characterize environmental conditions in Lake Gedang and the shrimp ponds. In Lake Gedang, temperature, pH, DO, and TDS were subsequently examined for their relationships with phytoplankton abundance. Salinity was not included in the correlation analysis because complete station-level data were unavailable.

Phytoplankton Observation and Identification

Water samples were transported to the Ecology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Bengkulu, for microscopic examination. Phytoplankton were observed using a binocular microscope. From each 100-mL concentrated sample, approximately 1 mL, equivalent to 20 drops, was examined. Two drops were placed on a glass slide at each observation, covered with a coverslip, and examined microscopically.

The entire area beneath the coverslip was systematically examined using a zigzag scanning pattern. Phytoplankton observed within the field of view were counted, photographed, and sketched when necessary. Morphological characteristics recorded during microscopy were used for taxonomic identification. Observations were conducted using objective magnifications ranging from 10× to 40×.

Taxonomic identification was performed to the genus or species level where possible using freshwater phytoplankton identification references, including Van Vuuren et al. (2006), Sulastri (2018), and relevant taxonomic literature.

Digestive Tract Analysis

Whiteleg shrimp measuring approximately 7–10 cm in body length were collected from the study ponds for digestive tract analysis. Fresh shrimp were dissected aseptically using sterile dissection instruments. The entire digestive tract, including the foregut, midgut, and hindgut, was removed, and its contents were extracted using sterile forceps.

The digestive tract contents were transferred into clean containers and diluted with sterile distilled water. The material was then dispersed and examined using a binocular microscope following the same general microscopic observation procedure used for phytoplankton water samples.

Phytoplankton taxa detected in the shrimp digestive tract were identified based on morphological characteristics and compared with taxa recorded from the aquatic environment. Their occurrence in the digestive tract was interpreted as preliminary evidence of ingestion and was used to identify taxa for further evaluation as potential natural feed. This analysis was not intended to determine feeding preference, nutritional quality, digestibility, or feed performance.

Data Analysis

Phytoplankton abundance was calculated according to the APHA (2017) approach and expressed as individuals per liter (ind/L). Community structure was evaluated using the Shannon–Wiener diversity index:

$$H' = -\sum(p_i \ln p_i)$$

where p_i is the proportion of individuals belonging to the i_{th} taxon. Evenness was calculated as:

$$J' = H'/\ln S$$

where S is the number of taxa, while Simpson's dominance index was calculated as:

$$C = \sum(p_i^2).$$

Phytoplankton abundance and community indices were calculated for each sampling station. Based on the station-level data reported in the study, Lake Gedang consisted of five analytical units ($n = 5$), whereas the shrimp ponds consisted of three analytical units ($n = 3$).

Differences in phytoplankton abundance between Lake Gedang and the shrimp ponds were tested using the Mann–Whitney U test. This non-parametric test was used because the number of station-level observations differed between the two ecosystems and no assumption of normal distribution was required. Spearman's rank correlation analysis was used to assess monotonic relationships between phytoplankton abundance and temperature, pH, DO, and TDS in Lake Gedang. All statistical tests were conducted at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Phytoplankton Composition by Taxonomic Group

A total of 40 phytoplankton species were recorded in Lake Gedang and 92 species in the whiteleg shrimp ponds. The identified taxa belonged to four major groups: Bacillariophyta, Chlorophyta, Cyanophyta, and Euglenophyta. Bacillariophyta exhibited the highest species richness in both ecosystems, comprising 27 species (67.50%) in Lake Gedang and 60 species (65.22%) in the shrimp ponds (Table 1).

Table 1. Phytoplankton composition by taxonomic group in Lake Gedang and whiteleg shrimp ponds

Taxonomic group	Lake Gedang (sp.)	Lake Gedang (%)	Shrimp Ponds (sp.)	Shrimp Ponds (%)	Total Species	Total (%)
Bacillariophyta	27	67.50	60	65.22	87	65.91
Chlorophyta	6	15.00	12	13.04	18	13.64
Cyanophyta	2	5.00	6	6.52	8	6.06
Euglenophyta	5	12.50	14	15.22	19	14.39
Total	40	100.00	92	100.00	132	100.00

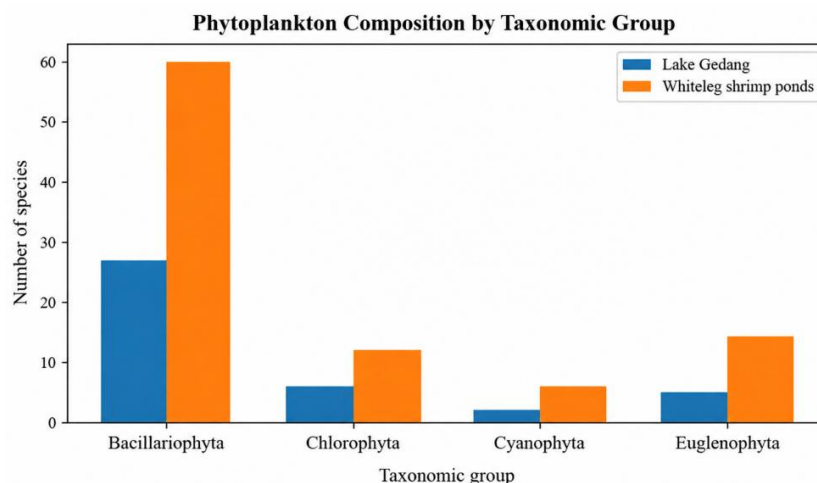


Figure 1. Phytoplankton composition by taxonomic group in Lake Gedang and whiteleg shrimp ponds

Bacillariophyta represented the group with the highest species richness in both ecosystems (Figure 1), accounting for 27 species (67.50%) in Lake Gedang and 60 species (65.22%) in the shrimp ponds. This pattern indicates that diatoms were taxonomically well represented in both aquatic environments. Their occurrence in natural waters and aquaculture systems is consistent with the broad morphological diversity and physiological strategies of this group, which allow diatoms to persist under a wide range of environmental conditions. In shrimp ponds, changes in nutrient availability and physicochemical conditions during the culture period may shape phytoplankton community composition and, under certain conditions, favor diatom development. In natural waters, habitat heterogeneity may provide a wider range of ecological niches for different taxa (Lemonnier et al., 2016; Yang et al., 2020; Lyu et al., 2021).

The high representation of Bacillariophyceae may also be associated with their silica frustules, broad variation in cell morphology and size, and their ability to occupy multiple microhabitats, including the water column, sediments, submerged substrates, and plant surfaces. These characteristics provide diatoms with considerable ecological flexibility and tolerance to environmental variation (Fu et al., 2022).

The difference in species richness between the shrimp ponds and Lake Gedang highlights that taxonomic richness and individual abundance represent complementary dimensions of phytoplankton community structure. The shrimp ponds contained 92 species, compared with 40 species in Lake Gedang, and station-level abundance was also consistently higher in the ponds. Together, these observations indicate that the phytoplankton community in the shrimp ponds was characterized by both greater taxonomic richness and higher individual abundance during the study period.

Phytoplankton Community Structure and Abundance

Phytoplankton abundance in Lake Gedang ranged from 57 to 143 ind/L, whereas abundance in the shrimp ponds ranged from 210 to 287 ind/L. Mean abundance was 95.80 ind/L in Lake Gedang and 239.33 ind/L in the shrimp ponds. Mean values of the Shannon–Wiener diversity index (H'), evenness index (J'), and Simpson's dominance index (C) were 2.360, 0.929, and 0.109, respectively, in Lake Gedang, and 3.560, 0.933, and 0.036, respectively, in the shrimp ponds (Table 2).

Table 2. Phytoplankton abundance and community structure indices at each sampling station

Station	Abundance (ind/L)	S	H'	J'	C
Lake I	57	11	2.288	0.954	0.111
Lake II	143	13	2.351	0.917	0.112
Lake III	94	12	2.249	0.905	0.123
Lake IV	62	16	2.545	0.918	0.094
Lake V	123	12	2.365	0.952	0.103
Pond I	221	43	3.533	0.939	0.037
Pond II	210	39	3.411	0.927	0.038
Pond III	287	55	3.735	0.932	0.032

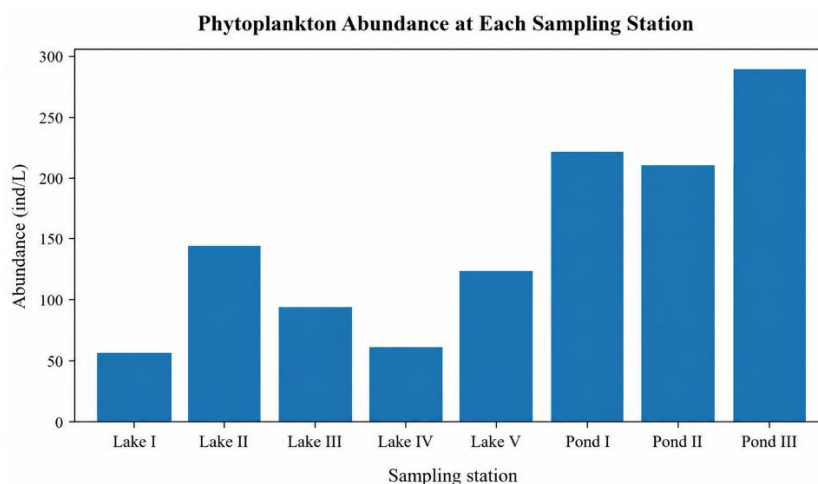


Figure 2. Phytoplankton abundance at each sampling station

The mean H' value was higher in the shrimp ponds (3.560) than in Lake Gedang (2.360), whereas mean J' values were similarly high in the two ecosystems, at 0.933 and 0.929, respectively. Simpson's dominance index was lower in the shrimp ponds (0.036) than in Lake Gedang (0.109). Phytoplankton abundance was also higher in the shrimp ponds, with mean values of 239.33 ind/L in the ponds and 95.80 ind/L in Lake Gedang. This pattern may be associated with the characteristics of aquaculture ponds, which receive nutrient inputs from feed, shrimp excretion, feces, and other organic matter. Decomposition of these materials can release nitrogen and phosphorus that support phytoplankton growth (Burford & Williams, 2001; Páez-Osuna et al., 2003).

In addition to higher abundance, phytoplankton diversity was also higher in the shrimp ponds than in Lake Gedang. This pattern was consistent with the greater number of taxa recorded in the ponds, with 92 species compared with 40 species in Lake Gedang. Nutrient availability and favorable environmental conditions may increase primary productivity while simultaneously supporting the coexistence of multiple phytoplankton taxa, although community responses depend strongly on nutrient balance, light availability, and other environmental factors (Borics et al., 2021; Chorus & Spijkerman, 2021). Thus, the relatively high abundance and diversity observed in the shrimp ponds may reflect the combined influence of nutrient inputs from aquaculture activities and environmental conditions that allow a relatively even distribution of taxa.

The combination of high diversity, high evenness, and low dominance indicates that the phytoplankton community in the shrimp ponds was relatively diverse and that individuals were distributed fairly evenly among the recorded taxa. Lake Gedang likewise exhibited high evenness and relatively low dominance, suggesting that neither ecosystem was strongly dominated by a single taxon. The higher H' values observed in the ponds were consistent with the higher number of taxa per station, particularly at Pond III, where 55 taxa were recorded.

Station-level abundance showed a pattern consistent with the differences in community structure. Pond III had the highest phytoplankton abundance at 287 ind/L, followed by Pond I at 221 ind/L and Pond II at 210 ind/L. In Lake Gedang, abundance ranged from 57 to 143 ind/L. These variations indicate that phytoplankton communities retained considerable spatial variability even though all pond stations exhibited abundance values above those recorded in the lake. In aquaculture systems, such variation may be related to microhabitat conditions, culture stage, organic matter inputs, water exchange, or nutrient distribution. Because the present study was not

designed to test each pond-management factor individually, these mechanisms should be regarded as ecological possibilities rather than established causal relationships. Previous studies have shown that phytoplankton communities in shrimp ponds are dynamic and may respond to changes in nutrient availability, temperature, dissolved oxygen, salinity, and culture development (Yang et al., 2020; Lyu et al., 2021).

Comparison of Phytoplankton Abundance Between Ecosystems

Differences in phytoplankton abundance between ecosystems were evaluated using the Mann–Whitney U test based on station-level abundance values. Lake Gedang comprised five sampling stations ($n = 5$), whereas the whiteleg shrimp ponds comprised three stations ($n = 3$). Mean abundance was 95.80 ind/L in Lake Gedang and 239.33 ind/L in the shrimp ponds, with median values of 94 and 221 ind/L, respectively. The complete statistical results are presented in Table 3.

Table 3. Comparison of phytoplankton abundance between Lake Gedang and whiteleg shrimp ponds

Parameter	Lake Gedang	Whiteleg shrimp ponds
Number of stations (n)	5	3
Mean abundance $\pm$ SD (ind/L)	95.80 $\pm$ 37.48	239.33 $\pm$ 41.65
Median abundance (ind/L)	94	221
Mann–Whitney U		0.000
p-value (two-tailed)		0.036

Descriptively, phytoplankton abundance was higher in the whiteleg shrimp ponds than in Lake Gedang, both in terms of the mean (239.33 vs. 95.80 ind/L) and median (221 vs. 94 ind/L). The Mann–Whitney test yielded $U = 0.000$ and $p = 0.036$. Because $p < 0.05$, phytoplankton abundance differed significantly between Lake Gedang and the shrimp ponds during the study period. These results therefore provide statistical support for the descriptive pattern of higher phytoplankton abundance in the pond stations.

The significant difference in abundance was accompanied by higher taxonomic richness and greater H' values in the shrimp ponds. Together, these findings indicate that the phytoplankton communities differed between the two ecosystem types during the observation period. The observed differences may reflect contrasting ecosystem characteristics, with shrimp ponds representing managed aquaculture systems directly influenced by culture activities. Given that the study included five lake stations and three pond stations, these findings are most appropriately interpreted within the context of the sampled locations. Broader generalization to all coastal ponds and lakes in Bengkulu would require additional spatial and temporal replication.

The higher abundance observed in the shrimp ponds may be related to the productivity and nutrient dynamics characteristic of aquaculture systems. Previous studies have shown that phytoplankton communities in shrimp ponds may change in response to nutrient availability, temperature, dissolved oxygen, salinity, and culture development (Lemonnier et al., 2016; Yang et al., 2020; Lyu et al., 2021). In the present study, these findings provide a basis for future research incorporating direct measurements of nutrient concentrations and more detailed pond-management information to clarify the factors underlying differences in phytoplankton abundance.

Differences in species richness further support this interpretation. The shrimp ponds contained 92 species compared with 40 species in Lake Gedang, while station-

level abundance was also consistently higher in the ponds. This pattern demonstrates consistency among taxonomic richness, abundance, and diversity in describing the phytoplankton communities of the two ecosystems. Accordingly, the results provide complementary information on ecological differences between the two aquatic systems rather than indicating that one ecosystem was inherently superior to the other.

Lake Gedang, as a natural aquatic ecosystem, supported a phytoplankton community with relatively lower abundance but a fairly even distribution of taxa. Abundance ranged from 57 to 143 ind/L, with a mean of 95.80 ± 37.48 ind/L, while the mean Shannon–Wiener diversity index was $H' = 2.360 \pm 0.114$. High evenness ($J' = 0.929 \pm 0.022$) and relatively low Simpson dominance ($C = 0.109 \pm 0.011$) indicate that the community was not strongly dominated by one or a few taxa. This pattern may reflect the characteristics of a natural lake ecosystem, where phytoplankton development is jointly influenced by nutrient availability, light, hydrodynamics, and biotic interactions such as grazing. Such interactions do not necessarily produce high abundance but may support the coexistence of multiple taxa (Borics et al., 2021; Chorus & Spijkerman, 2021). Thus, compared with the shrimp ponds, Lake Gedang was characterized by lower phytoplankton abundance and diversity but retained high community evenness and low dominance.

Relationships Between Phytoplankton Abundance and Abiotic Factors

Differences in phytoplankton community structure between Lake Gedang and the shrimp ponds should also be interpreted in relation to water-quality conditions. Physicochemical parameters can influence phytoplankton composition and abundance because phytoplankton growth responds to temperature, pH, dissolved oxygen, nutrient availability, and other environmental conditions. In aquaculture ponds, changes in water quality and nutrient availability may influence phytoplankton community dynamics throughout the culture period (Yang et al., 2020; Lyu et al., 2021). Relationships between phytoplankton abundance and selected abiotic factors in Lake Gedang are presented in Table 4.

Table 4. Spearman correlations between phytoplankton abundance and abiotic factors in Lake Gedang

Abiotic factor	r_s	p-value	Direction	Decision ($\alpha = 0.05$)
Temperature	-0.205	0.741	Negative	Not significant
pH	0.103	0.870	Positive	Not significant
DO	-0.300	0.624	Negative	Not significant
TDS	0.300	0.624	Positive	Not significant

Temperature showed a weak negative correlation with phytoplankton abundance ($r_s = -0.205$; $p = 0.741$), whereas pH showed a very weak positive correlation ($r_s = 0.103$; $p = 0.870$). Dissolved oxygen exhibited a negative correlation ($r_s = -0.300$; $p = 0.624$), while TDS showed a positive correlation of the same magnitude ($r_s = 0.300$; $p = 0.624$). None of these relationships was statistically significant at $\alpha = 0.05$.

The absence of statistically significant correlations does not imply that temperature, pH, DO, and TDS are ecologically unimportant for phytoplankton. In this study, the analysis was based on five stations; therefore, the correlation coefficients primarily describe patterns within the available observation space. In addition, phytoplankton dynamics are shaped by the simultaneous interaction of multiple factors, particularly nutrient concentrations, temperature, light availability, dissolved oxygen, and hydrological conditions. Studies of shrimp ponds have shown that nutrients and

physicochemical variables can jointly influence phytoplankton community structure (Lemonnier et al., 2016; Yang et al., 2020; Lyu et al., 2021). Thus, the Spearman correlation results provide useful baseline information while highlighting the need for future studies incorporating a broader range of environmental variables.

Abiotic Conditions

Measurements of abiotic factors showed environmental variation between Lake Gedang and the whiteleg shrimp ponds, although the recorded ranges were generally compatible with phytoplankton growth (Table 5).

Table 5. Ranges of abiotic factors during the study period

Parameter	Lake Gedang	Whiteleg shrimp ponds
Temperature (°C)	29.2–32.5	28.2–33.5
pH	6.7–7.5	7.4–8.3
DO (mg/L)	6.4–11.03	8.7–11.1
TDS (ppm)	12.1–87.2	22.3–37.2
Salinity (ppt)	0.86–1.5	2.8–4.7

The abiotic data indicate that Lake Gedang and the whiteleg shrimp ponds differed in their environmental characteristics during the study period. Water temperature ranged from 29.2 to 32.5 °C in Lake Gedang and from 28.2 to 33.5 °C in the shrimp ponds. Temperature is an important environmental driver of phytoplankton dynamics because it can influence metabolic activity, photosynthesis, growth, and community composition. In *Litopenaeus vannamei* ponds, temperature, together with other water-quality parameters, has been associated with the distribution and structure of phytoplankton communities (Ni et al., 2018). Studies of intensive *L. vannamei* culture in Indonesia have also shown that changes in water quality occur concurrently with changes in plankton abundance and composition (Suprakto et al., 2024).

The pH ranged from 6.7 to 7.5 in Lake Gedang and from 7.4 to 8.3 in the shrimp ponds. These ranges indicate that Lake Gedang was characterized by slightly acidic to neutral conditions, whereas the ponds tended to range from neutral to alkaline. Differences in pH may reflect contrasting environmental characteristics and biogeochemical processes between the two ecosystems. Ni et al. (2018) reported that many phytoplankton taxa in *L. vannamei* ponds were associated with temperature, pH, and dissolved oxygen. Accordingly, the observed pH ranges represent important environmental characteristics accompanying phytoplankton community development in each ecosystem.

Dissolved oxygen concentrations ranged from 6.4 to 11.03 mg/L in Lake Gedang and from 8.7 to 11.1 mg/L in the shrimp ponds. These values indicate relatively high oxygen availability during the observation period. Dissolved oxygen is an important parameter in aquatic ecosystems because it is closely associated with organismal respiration and phytoplankton photosynthesis. Ni et al. (2018) identified DO as one of the environmental variables associated with the distribution of many phytoplankton species in *L. vannamei* ponds. Similarly, Suprakto et al. (2024) emphasized the importance of DO in evaluating water quality in intensive *L. vannamei* culture systems and its relationship with plankton community conditions.

TDS ranged from 12.1 to 87.2 ppm in Lake Gedang and from 22.3 to 37.2 ppm in the shrimp ponds. These differences indicate variation in dissolved material between the two ecosystems. TDS provides a general measure of dissolved substances and

forms part of the physicochemical context in which aquatic communities develop. However, in the present study, TDS was not significantly correlated with phytoplankton abundance in Lake Gedang. Therefore, TDS should be interpreted as an environmental characteristic associated with the observed community rather than as a direct causal factor. This interpretation is consistent with studies of phytoplankton communities in *L. vannamei* ponds, which suggest that community responses are influenced by combinations of environmental variables rather than by a single factor in isolation (Ni et al., 2018).

Salinity ranged from 0.86 to 1.5 ppt in Lake Gedang and from 2.8 to 4.7 ppt in the shrimp ponds. These values demonstrate clear differences in salinity between the two ecosystems. Although salinity in the shrimp ponds was relatively low, the conditions still supported the development of diverse phytoplankton communities. Larasati et al. (2026) reported that low-salinity biofloc-based *L. vannamei* ponds supported diverse phytoplankton assemblages, with Bacillariophyceae remaining an important group under both low- and normal-salinity conditions. These findings support the present observation that low salinity did not prevent the development of phytoplankton communities in the shrimp ponds.

Overall, variation in temperature, pH, DO, TDS, and salinity provides important environmental context for interpreting differences in phytoplankton abundance and community structure between Lake Gedang and the shrimp ponds. Previous studies have shown that water-quality variables, particularly temperature, pH, DO, and salinity, are associated with phytoplankton distribution and composition in *L. vannamei* culture systems (Ni et al., 2018). Low-salinity conditions may also support diverse phytoplankton communities in shrimp culture systems (Larasati et al., 2026). The absence of significant correlations between phytoplankton abundance and temperature, pH, DO, or TDS in Lake Gedang therefore does not imply that these factors lack ecological importance. Rather, it indicates that the monotonic relationships detected across the five stations were not statistically strong during the study period.

Phytoplankton as Potential Natural Feed

Based on their occurrence in the shrimp digestive tract, four phytoplankton taxa were identified as preliminary candidates for further evaluation as natural feed (Table 6).

Table 6. Phytoplankton taxa identified as preliminary natural-feed candidates for whiteleg shrimp

Species	Group	Evidence in this study	Potential as natural feed
<i>Ulothrix</i> sp.	Chlorophyceae	Detected in shrimp digestive tract	Preliminary candidate
<i>Golenkinia</i> sp.	Chlorophyceae	Detected in shrimp digestive tract	Preliminary candidate
<i>Cosmarium pseudoconnatum</i>	Chlorophyceae	Detected in shrimp digestive tract	Preliminary candidate
<i>Anabaena</i> sp.	Cyanophyceae	Detected in shrimp digestive tract	Preliminary candidate

From the perspective of natural-feed utilization, the detection of *Ulothrix* sp., *Golenkinia* sp., *Cosmarium pseudoconnatum*, and *Anabaena* sp. in the shrimp digestive tract provides preliminary evidence of ingestion. Three of the four detected taxa belonged to Chlorophyceae, indicating that this group was well represented among the taxa found in the digestive tract. However, their occurrence should be interpreted as evidence of possible ingestion rather than proof of feeding preference or suitability as natural feed.

Kent et al. (2011) demonstrated that juvenile *L. vannamei* can consume and digest suspended microalgae, particularly diatoms. Porchas-Cornejo et al. (2012) further showed that shrimp cultured in ponds with enhanced natural productivity relied more heavily on naturally available food than on formulated feed. However, that study also emphasized that natural food items are not consumed in equal proportions, because prey selection may be influenced by availability, size, and nutritional value. More recent evidence indicates that diatoms can provide essential fatty acids, proteins, and bioactive compounds that support the performance of whiteleg shrimp larvae (Abdelhay et al., 2025). Microalgae have also been recognized as important components of sustainable shrimp aquaculture because they can contribute to nutrient cycling while simultaneously supporting water-quality management (Maulidhya et al., 2024).

CONCLUSION

This study demonstrated that the phytoplankton communities of Lake Gedang and coastal whiteleg shrimp ponds in Bengkulu comprised four major taxonomic groups, with Bacillariophyta exhibiting the highest species richness in both ecosystems. A total of 40 species were recorded in Lake Gedang and 92 species in the shrimp ponds. Mean phytoplankton abundance was 95.80 ind/L in Lake Gedang and 239.33 ind/L in the shrimp ponds, with a significant difference between the two ecosystems based on the Mann–Whitney U test ($U = 0.000$; $p = 0.036$). Both ecosystems were characterized by high evenness and relatively low dominance, while mean phytoplankton diversity was higher in the shrimp ponds. In Lake Gedang, phytoplankton abundance was not significantly correlated with temperature, pH, dissolved oxygen (DO), or total dissolved solids (TDS) across the five sampling stations. Four taxa—*Anabaena* sp., *Cosmarium pseudoconnatum*, *Golenkinia* sp., and *Ulothrix* sp.—were detected in the shrimp digestive tract and may therefore be considered preliminary candidates for further evaluation as natural feed. Overall, these findings provide an ecological basis for further investigation of locally occurring phytoplankton as potential natural food resources for whiteleg shrimp. However, evidence from digestive tract contents remains preliminary because the nutritional composition, digestibility, safety, and feeding performance of these taxa have not yet been evaluated under controlled conditions.

RECOMMENDATION

Future studies should validate the potential of the four phytoplankton taxa detected in the digestive tract of *L. vannamei*—*Anabaena* sp., *Cosmarium pseudoconnatum*, *Golenkinia* sp., and *Ulothrix* sp.—through analyses of nutritional composition, safety, and digestibility, as well as controlled feeding trials. These assessments are necessary to determine their actual suitability and effectiveness as natural feed for whiteleg shrimp.

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