



Response of Phytoplankton Community Structure to Light Availability, pH, DO, and Other Physicochemical Drivers in Kuala Gigieng Coastal Water

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ABSTRACT

Physicochemical gradients particularly light availability, pH, dissolved oxygen (DO), temperature, and salinity are known to structure phytoplankton communities in coastal ecosystems, but the degree to which each driver affects diversity and abundance varies among systems. This study examined the relationships between environmental drivers and phytoplankton community structure at three stations in Kuala Gigieng coastal system. Environmental variables were measured on four temporal occasions per station (salinity, temperature, turbidity, Secchi-derived underwater light intensity, pH, DO). Pearson correlations between station-averaged environmental variables and phytoplankton metrics were examined ($n = 3$). Turbidity was strongly positively correlated with phytoplankton abundance ($r = 0.97$), while light intensity showed a strong negative correlation with abundance ($r = -0.99$). Dissolved oxygen was negatively correlated with abundance ($r = -0.76$) but positively with H' ($r = 0.41$). Salinity exhibited nearly perfect positive correlations with diversity and evenness and a negative correlation with dominance. pH displayed negative correlations with richness, abundance, and diversity. Temperature was moderately positively correlated with abundance ($r = 0.78$). In this system, turbidity and light emerge as dominant correlates of phytoplankton standing stock, while DO and salinity appear more closely linked to diversity patterns. These exploratory results provide a framework for understanding how physicochemical drivers influence phytoplankton community structure in tropical coastal waters.

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1. INTRODUCTION

Light, temperature, pH, dissolved oxygen, and salinity are fundamental physical and chemical factors controlling the distribution, abundance, and diversity of phytoplankton. In the photic zone, light availability governs photosynthetic rates, while turbidity not only restricts primary production through light attenuation but also serves as a proxy for suspended particulate matter and its associated nutrient load (Nachtigall & Heim, 2023). pH regulates enzymatic and physiological processes, influences the speciation of dissolved inorganic carbon, and can reflect both watershed inputs and in-water metabolic activity (Hariyadi, et al., 2020). Dissolved oxygen (DO) is a direct metabolic requirement; low DO (hypoxia) acts as a strong stressor that can exclude sensitive phytoplankton taxa and favour tolerant or opportunistic species (Tahir, 2021). Salinity and temperature shape habitat boundaries along estuarine to marine continua, influencing osmoregulatory costs and metabolic rates. Together, these variables create a multivariate niche space that structures phytoplankton communities.

Coastal and estuarine systems are transition zones where fresh and marine waters mix, generating steep spatial gradients in salinity, turbidity, and nutrient concentrations over short distances. In such environments, the interplay between light limitation (via turbidity) and nutrient availability is particularly dynamic: riverine or land-derived inputs often increase turbidity and simultaneously deliver nutrients, creating a potential trade-off between light-driven growth limitation and nutrient stimulation (Amin & Purnomo, 2021). Moreover, these areas frequently experience diel and seasonal shifts in DO and pH due to respiration-photosynthesis imbalances. A mechanistic understanding of how phytoplankton community attributes (richness, abundance, evenness, dominance) shift along these environmental gradients is fundamental to predicting whole-ecosystem responses to nutrient loading and climate warming, given the basal trophic role of phytoplankton.

The dataset available for this study was collected in a shallow tropical coastal system (Kuala Gigieng, Aceh Besar, Aceh) where salinity ranges from 30 to 35 ppt, indicating a largely marine influenced setting with occasional freshwater pulses. This salinity interval, combined with temperatures exceeding 29 °C, is characteristic of many Southeast Asian and Indo Pacific embayments. The present study focuses solely on phytoplankton community structure and its relationship to environmental drivers. The objectives of this study were: To characterise the spatial environmental gradients (light, turbidity, DO, pH, temperature, salinity) among three sampling stations in a tropical coastal area. To relate station level phytoplankton community metrics (species richness, abundance, Shannon diversity, evenness, dominance) to mean environmental conditions. To explore, via simple correlation, which physicochemical drivers most strongly covary with phytoplankton attributes, while acknowledging the limitations of small spatial replication. Based on theory and prior studies, we hypothesised that Phytoplankton abundance will be positively associated with turbidity (as a nutrient/resuspension proxy) but negatively associated with underwater light intensity, reflecting light limitation at high-turbidity sites despite elevated nutrients. Species richness and diversity (H') will peak at stations with intermediate environmental conditions, particularly in relation to light and DO, and will be lowest where a single stressor (e.g., low DO or high turbidity) dominates.

2. METHODS

2.1. Studi Area and Sampling Design

The study was conducted in a shallow tropical coastal embayment (Kuala Gigieng Embayment located in Baitussalam, Aceh Besar District, Aceh Province). Three stations were selected along an inshore and offshore transect reflecting a gradient of freshwater influence, depth (2–8 m), and distance from a mangrove-lined creek. Station 1 was situated near the mouth of a small tidal creek, Station 2 at an intermediate location with seagrass patches, and Station 3 in a deeper, more marine-influenced area. Sampling was carried out during the dry-to-wet seasonal transition. Physicochemical parameters were measured on four occasions, approximately one month apart, to capture temporal variability. Phytoplankton was collected once at each station during the third sampling event, when conditions were considered representative of the seasonal average.

2.2 Physicochemical Measurements

At each station and each temporal replicate, a calibrated multiparameter sonde (YSI EXO2) was deployed at 0.5 m depth to record temperature (°C), pH, dissolved oxygen (mg L^{-1}), and salinity (ppt). Turbidity (NTU) was measured with a portable turbidimeter using surface water samples. Secchi disk depth (Z_{SD} , m) was determined with a standard 20-cm black-and-white disk, the depth at which the disk disappeared from view was recorded by the same observer. Underwater light intensity was estimated from Secchi depth. The vertical attenuation coefficient for downward irradiance (K_d) was approximated using the empirical relationship $K_d = 1.44 / Z_{SD}$ (Kirk, 2011).

2.3 Phytoplankton Sampling and Data Analysis

For phytoplankton, 1 L of water was collected from 0.5 m depth and immediately preserved with acid-Lugol's solution (final concentration 1% v/v). Samples were stored in amber bottles at 4 °C until analysis. In the laboratory, subsamples (25–50 mL) were settled in chambers for 24 h and examined under an inverted microscope at 200–400× magnification. All phytoplankton cells (including solitary cells, colonies, and filaments) were counted and identified to the lowest possible taxonomic level (generally species) using standard floras (Tomas, 1997). Abundance was expressed as individuals per litre (ind L^{-1}).

Community structure was described by species richness (S), Shannon-Wiener diversity index (H'), Pielou's evenness ($E = H' / \ln S$), and Simpson's dominance index ($C = \sum p_i^2$, where p_i is the proportional abundance of species i) (Pielou, 1966; Shannon & Weaver, 1949). For each environmental variable, the mean and standard deviation (SD) were computed from the four temporal replicates per station. Station-level phytoplankton metrics (single survey) were taken as reported later in other section. To explore potential linear associations, Pearson correlation coefficients (r) were calculated between the six station-averaged environmental variables (salinity, temperature, turbidity, light intensity, pH, DO) and the five phytoplankton metrics (S, abundance, H' , E, C). Because the analysis uses only three spatial points (the three stations), no statistical significance testing was performed; the coefficients are interpreted as measures of effect size and direction, with $|r| > 0.7$ considered indicative of a strong association in this exploratory context. All calculations were performed in R (version 4.2.3).

3. RESULTS AND DISCUSSION

3.1. Environmental Characterisation

Mean environmental values and their temporal variability (SD) at each station are presented in Table 1. Distinct spatial gradients were observed. Station 1, closest to the tidal creek, exhibited the highest mean turbidity (13.83 ± 2.19 NTU), lowest light intensity at 0.5 m (429 ± 77 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$), lowest mean DO (6.1 ± 1.18 mg L^{-1}), and highest mean temperature (31.9 ± 0.92 °C). Station 2, at intermediate distance, had the lowest mean salinity (32.25 ± 1.71 ppt), highest pH (7.86 ± 0.06), and highest light intensity (459 ± 87 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$). Station 3, the most marine-influenced, showed the highest salinity (33.5 ± 0.58 ppt) and DO (6.45 ± 0.44 mg L^{-1}), lowest temperature (31.05 ± 1.34 °C), and turbidity comparable to Station 2 (12.98 ± 0.60 NTU), with an intermediate light intensity (455 ± 74 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$). pH showed little variation among stations (range 7.84–7.86), but Station 2 was slightly higher.

Table 1. Mean \pm SD of environmental variables per station (n = 4 temporal replicates).

Parameter	Station 1	Station 2	Station 3
Salinity (ppt)	33.0 ± 1.41	32.25 ± 1.71	33.5 ± 0.58
Temperature (°C)	31.9 ± 0.92	31.4 ± 1.01	31.05 ± 1.34
Turbidity (NTU)	13.83 ± 2.19	12.96 ± 1.73	12.98 ± 0.60
Light intensity ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	429.0 ± 76.8	459.0 ± 87.5	455.0 ± 74.3
pH	7.84 ± 0.09	7.86 ± 0.06	7.85 ± 0.11
Dissolved oxygen (mg L^{-1})	6.1 ± 1.18	6.3 ± 0.65	6.45 ± 0.44

The strong positive correlation between turbidity and phytoplankton abundance ($r = 0.97$) and the equally strong negative correlation between light intensity and abundance ($r = -0.99$) suggest that, at the scale of these three stations, light attenuation by suspended particles did not limit phytoplankton standing stock; instead, the sites with higher turbidity supported larger phytoplankton populations. This counterintuitive pattern is often observed in nutrient-rich coastal systems where turbidity serves as a proxy for land-derived nutrient inputs or sediment resuspension that fertilise phytoplankton growth (Ainalyaqin & Abida, 2024). Station 1, which was closest to the creek mouth, had the highest turbidity and the highest total abundance, consistent with a nutrient-enriched, fast-growing assemblage. The inverse relationship with light likely reflects the fact that the calculated underwater light intensity is lowest where turbidity is highest, yet nutrients and possibly active vertical mixing enabled greater biomass.

Dissolved oxygen displayed a negative correlation with abundance ($r = -0.76$), indicating that the high-abundance station (Station 1) also had the lowest mean DO. This pattern is typical of eutrophic sites where high respiration from abundant plankton and organic matter decomposition depresses oxygen concentrations (Hasrini, et al., 2024). However, the positive correlation between DO and Shannon diversity ($r = 0.41$) hints that while moderate hypoxia may permit a large total population of tolerant species, it still erodes community evenness and richness. The highest H' was recorded at Station 3, where DO was highest and abundance intermediate, implying a more diverse and less physiologically stressed assemblage.

3.2. Phytoplankton community structure and Correlation Analysis

Phytoplankton metrics at the three stations are reproduced in Table 2. Species richness ranged from 13 (Station 2) to 16 (Station 3). Abundance was highest at Station 1 (3370 ind L^{-1}) and lowest at Station 2 (3010 ind L^{-1}). The Shannon diversity index (H') was highest at

Station 3 (2.31), intermediate at Station 1 (2.15), and lowest at Station 2 (1.98), mirroring the pattern of evenness (E: 0.87, 0.84, 0.79, respectively). Simpson dominance (C) showed the inverse: maximum at Station 2 (0.24) and minimum at Station 3 (0.16). Pearson correlation coefficients between station-averaged environmental variables and phytoplankton metrics are shown in Figure 1 for a heatmap representation. Because of the extremely small sample size ($n = 3$), these values are treated as exploratory and are interpreted with caution.

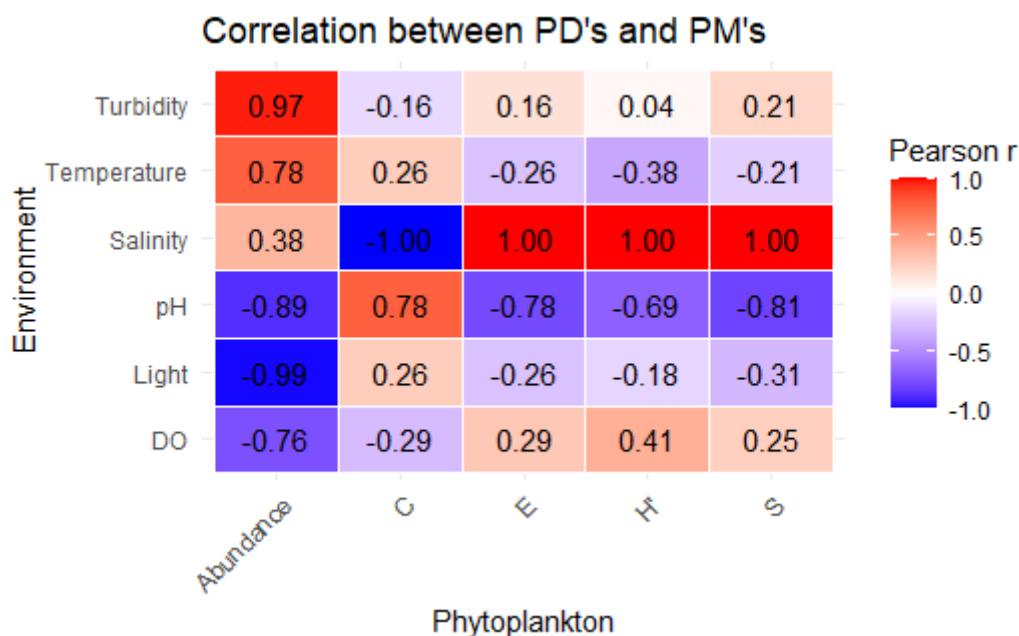


Figure 1: Heatmap of Pearson correlation coefficients between station-averaged physicochemical drivers/PD's (salinity, temperature, turbidity, light intensity, pH, dissolved oxygen) and phytoplankton community metrics/PM's (species richness S, abundance, Shannon diversity H', Pielou evenness E, Simpson dominance C). Colour gradient ranges from blue ($r = -1$, strong negative association) through white ($r = 0$) to red ($r = +1$, strong positive association). Correlations are calculated using $n = 3$ stations and should be interpreted as exploratory indicators of effect size and direction rather than formal tests of significance. Light intensity was derived from Secchi disk measurements as described in the Methods.

Turbidity showed a very strong positive correlation with phytoplankton abundance ($r = 0.97$) and light intensity a correspondingly strong negative correlation ($r = -0.99$). Stations with lower light (higher turbidity) supported higher phytoplankton standing stocks. Dissolved oxygen was negatively correlated with abundance ($r = -0.76$) but positively with H' ($r = 0.41$). Station 1, with the lowest DO, had the highest abundance but not the highest diversity. Salinity exhibited nearly perfect positive correlations with species richness, H', and evenness ($r = 1.00$) and a perfect negative correlation with dominance ($r = -1.00$), driven mainly by the low values at Station 2. pH displayed moderate to strong negative associations with richness, abundance, H', and evenness (r between -0.69 and -0.89), and a positive association with dominance ($r = 0.78$). The pH range was narrow (7.84–7.86), so these correlations should be interpreted cautiously. Temperature was moderately positively associated with abundance ($r = 0.78$) but weakly negatively with diversity indices (Figure 1).

Table 2. Phytoplankton structure community each station

Parameter	Station 1	Station 2	Station 3
<i>Species Richness (S)</i>	15	13	16
<i>Abundance (Ind/L)</i>	3.370	3.010	3.110
<i>Diversity (H')</i>	2,15	1,98	2,31
<i>Species Evenness (E)</i>	0,84	0,79	0,87
<i>Dominance (C)</i>	0,19	0,24	0,16

Salinity showed near-perfect positive correlations with richness, H' , and evenness, and a negative correlation with dominance. The measured range (32.25–33.5 ppt) is narrow, and the correlations are strongly influenced by Station 2, which had the lowest salinity and the lowest diversity. It is plausible that this site, being more influenced by freshwater runoff, may have received humic substances, pollutants, or fluctuating salinity conditions that favoured a few tolerant species, thus lowering evenness and elevating dominance. However, with only three points, the high r values are almost tautological; they indicate that Station 2 was lowest in both salinity and diversity metrics, but this does not necessarily imply a direct causal link.

The negative correlations of pH with most diversity metrics ($r \approx -0.7$ to -0.9) are surprising because pH values were near the typical range for seawater and differences among stations were less than 0.03 units. Station 2 had the highest pH (7.86) and the lowest H' . This pattern is likely coincidental and driven by the covariation of pH with other factors (e.g., Station 2 also had the highest light and the lowest salinity). The small pH variation may reflect local differences in primary production and respiration (Rosanti & Harahap, 2022; Yasinta, et al., 2025; Suhendar, et al., 2020; Patty, et al., 2020; Yolanda, 2023). However, any direct physiological effect on phytoplankton diversity is unlikely at these concentrations.

Temperature was moderately positively correlated with abundance ($r = 0.78$) and weakly negatively with diversity. Warmer water can accelerate metabolic rates and, in combination with nutrients, increase growth rates of small, fast-growing taxa, potentially reducing evenness. Nonetheless, the narrow range of mean temperatures (31.05–31.88 °C) limits this interpretation. The observed pattern—high phytoplankton abundance at a turbid, oxygen-depleted station and higher diversity at a clearer, well-oxygenated marine station—parallels findings from many tropical and subtropical estuaries. In Godavari estuary (India), for instance, phytoplankton abundance peaked in the middle reaches where turbidity and nutrients were high, while diversity was greater in the lower, less turbid zone (Bharathi et al., 2012). Similarly, in the Mekong Delta, high turbidity and nutrient loading promoted blooms of a few tolerant diatom species, reducing evenness (Sharov et al., 2020). The present data suggest that similar mechanisms operate at the studied location, with turbidity-nutrient-DO interactions shaping pelagic communities.

4. CONCLUSION

In this exploratory study of three coastal stations, turbidity, light intensity, and dissolved oxygen emerged as the physicochemical variables most strongly correlated with phytoplankton community structure. Turbidity was positively associated with abundance ($r = 0.97$), while light showed the inverse pattern ($r = -0.99$). DO was negatively related to abundance but positively to diversity, suggesting that although eutrophic, turbid conditions may support high numbers of phytoplankton, they do not promote the highest taxonomic diversity. Salinity and pH exhibited strong correlations that are likely confounded with other spatial gradients. These findings, while limited by the small number of stations, are consistent

with a conceptual model in which nutrient-rich, turbid sites fuel abundant but less diverse phytoplankton assemblages, whereas clearer, well-oxygenated waters with greater marine influence support richer and more even communities. The present results reinforce the importance of controlling turbidity and nutrient inputs to maintain ecosystem health in tropical coastal waters.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

6. REFERENCES

- Ainalyaqin, M. I., and Abida, I. W. (2024). Korelasi kandungan oksigen terlarut dan pH terhadap keanekaragaman plankton di Sungai Kalidami Kota Surabaya. *Environmental Pollution Journal*, 4(1), 895–905.
- Amin, A., and Purnomo, T. (2021). Biomonitoring kualitas perairan pesisir Pantai Lembung, Pamekasan menggunakan bioindikator fitoplankton. *LenteraBio: Berkala Ilmiah Biologi*, 10(1), 106–114.
- Bharathi, M., Sarma, V. V. S. S., Ramaneswari, K., and Venkataramana, V. (2012). Phytoplankton community structure in a tropical monsoonal estuary (Godavari) and its relationship with environmental variables. *Journal of Marine Systems*, 105–108, 70–82.
- Hariyadi, H., Kamil, M., and Ananda, P. (2020). Sistem pengecekan pH air otomatis menggunakan sensor pH probe berbasis Arduino pada sumur bor. *Rang Teknik Journal*, 3(2), 340–346. ISSN: 2599-2090.
- Hasrini, D. A., Soeprobowati, T. R., and Jumari, J. (2024). Stratigrafi diatom di perairan pesisir Morosari, Kabupaten Demak, Jawa Tengah. *Jurnal Ilmu Lingkungan*, 22(5), 1356–1363.
- Nachtigall, S., and Heim, C. (2023). Monitoring the Efficiency of a Catchment Restoration to Further Reduce Nutrients and Sediment Input into a Eutrophic Lake. *Water*, 15(21), 3794.
- Patty, S. I., Nurdiansah, D., and Akbar, N. (2020). Sebaran suhu, salinitas, kekeruhan dan kecerahan di perairan Laut Tumbak-Bentenan, Minahasa Tenggara. *Jurnal Ilmu Kelautan Kepulauan*, 3(1), 77–87.
- Rosanti, L., and Harahap, A. (2022). Keberadaan plankton sebagai indikator pencemaran. *Bioedusains: Jurnal Pendidikan Biologi dan Sains*, 5(1), 182–188.
- Sharov, A. N., Tsvetkov, A. I., Korneva, L. G., and Dinh, C. N. (2020). Phytoplankton of the delta of the Mekong River during the dry season. *Biosystems Diversity*, 28(3), 329–334.
- Suhendar, D. T., Sachoemar, S. I., and Zaidy, A. B. (2020). Hubungan kekeruhan terhadap materi partikulat tersuspensi (MPT) dan kekeruhan terhadap klorofil dalam tambak udang. *Journal of Fisheries and Marine Research*, 4(3), 332–338.
- Tahir, R. B. (2021). Analisis sebaran kadar oksigen (O₂) dan oksigen terlarut (dissolved oxygen) dengan menggunakan data *in situ* dan citra satelit Landsat 8. *Jurnal Informasi, Sains dan Teknologi*, 4(2), 44–51.

Yasinta, R. R., Setiawan, K. Z., Sudarti, and Yushardi. (2025). Analisis pola intensitas cahaya oleh matahari. *Jurnal Studi Multidisipliner*, 9(5), 479–492.

Yolanda, Y. (2023). Analisa pengaruh suhu, salinitas, pH terhadap kualitas air di muara perairan Belawan. *Jurnal Teknologi Lingkungan Lahan Basah*, 11(2), 329–337.