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Identification of Harmful Algal Bloom-Causing Phytoplankton and Water Quality Status in Hurun Bay, Lampung, Indonesia

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Abstract:

Harmful algal blooms (HABs) have been increasingly reported in coastal waters subjected to anthropogenic nutrient enrichment. This study aimed to identify phytoplankton genera associated with HABs in Hurun Bay, Lampung, and to evaluate the supporting physical and chemical water quality parameters. Sampling was conducted at three locations representing different anthropogenic pressures: harbor (BBPBL pier), aquaculture (floating net cages), and coastal tourism (Kyokko Beach). Phytoplankton samples were collected using vertical towing and identified microscopically, while water quality parameters included temperature, salinity, pH, dissolved oxygen, nitrate, and phosphate. Ten HAB-associated phytoplankton genera were identified, dominated by Chaetoceros (8,487 ind L^{-1}), Bacteriastrum (2,960 ind L^{-1}), and Nitzschia (2,707 ind L^{-1}). Nitrate concentrations ranged from 3.368 to 3.422 mg L^{-1} and phosphate from 0.333 to 0.421 mg L^{-1}, indicating elevated nutrient conditions relative to the marine water quality standards. The physical parameters remained within the range suitable for phytoplankton growth. The combination of elevated nutrient concentrations and the presence of bloom-associated phytoplankton genera suggests that Hurun Bay possesses environmental conditions conducive to phytoplankton proliferation under favorable circumstances. These findings provide baseline ecological information for HAB risk assessment and highlight the need for nutrient monitoring and management in coastal systems.

Keywords: phytoplankton, HABs, eutrophication, coastal water quality, Hurun Bay

INTRODUCTION

Harmful algal blooms (HABs) constitute a major ecological manifestation of nutrient enrichment in coastal marine environments. Increased loading of nitrogen and phosphorus derived from anthropogenic sources, such as aquaculture, municipal wastewater, agricultural runoff, and maritime activities, is widely acknowledged as a primary factor promoting phytoplankton proliferation and bloom formation (Yñiguez et al., 2020). In nutrient-enriched waters, the phytoplankton community composition often shifts toward opportunistic taxa capable of rapid growth, some of which may produce toxins or cause ecosystem disruption. HAB events can reduce dissolved oxygen concentrations, alter food-web dynamics, and lead to substantial economic losses in fisheries and aquaculture (Hu et al., 2022).

Recent studies indicate that harmful algal bloom events have increased in frequency and geographic extent in many coastal ecosystems, driven primarily by nutrient enrichment, coastal development, and climate-related environmental changes (Paerl et al., 2020). Semi-enclosed tropical embayments are particularly vulnerable due to high solar radiation, warm temperatures, and limited water exchange that promote phytoplankton growth and retention (Paerl et al., 2018). Several genera commonly associated with HAB events in tropical waters include diatoms such as Chaetoceros and Nitzschia, as well as dinoflagellates such as Alexandrium and Prorocentrum, which may cause hypoxia, toxin production, or mechanical stress on aquatic organisms (Trainer et al., 2019). Even non-toxic blooms can negatively affect aquaculture systems by reducing water transparency, clogging fish gills, and altering biogeochemical cycles (Wells et al., 2019).

Hurun Bay in Lampung coastal waters is a semi-enclosed system exposed to increasing anthropogenic pressure. The bay supports floating net cage aquaculture, coastal tourism, and harbor activities, all of which may contribute to nutrient enrichment through feed waste, organic discharge, and terrestrial runoff. In addition to these inputs, the semi-enclosed nature of the bay implies relatively limited water exchange and increased water retention, conditions that can facilitate nutrient accumulation and enhance phytoplankton proliferation in coastal systems. These hydrodynamic characteristics are widely recognized as key factors controlling eutrophication processes and the development of harmful algal blooms in tropical embayments.

Previous studies conducted in Hurun Bay have reported indications of eutrophication and the presence of HAB-associated phytoplankton. (Lestari & Wahono, 2022) documented the dominance of Nitzschia under nutrient-enriched conditions and reported that a substantial proportion of the phytoplankton community consisted of HAB-associated taxa, including Chaetoceros, Nitzschia, and Pseudo-nitzschia. However, these studies primarily focused on phytoplankton occurrence and abundance without explicitly linking community composition to environmental drivers, particularly nutrient concentrations, and physicochemical parameters across different anthropogenic zones. Consequently, integrated assessments combining phytoplankton composition and environmental conditions remain limited in Hurun Bay.

Accordingly, this study aimed to (1) identify phytoplankton genera associated with harmful algal blooms in Hurun Bay and (2) evaluate key physical and chemical water quality parameters that may support bloom development. By integrating phytoplankton composition with environmental measurements, this study provides baseline ecological evidence for HAB risk assessment and nutrient management strategies in Lampung coastal waters.

MATERIAL AND METHODS

Study Area and Sampling Design

This study was conducted from March to April 2025. Laboratory analysis was carried out at the Balai Besar Perikanan Budidaya Laut Lampung, while field sampling was performed in Hurun Bay, Pesawaran, Lampung, Indonesia. Sampling locations were selected to represent gradients of anthropogenic activity within the bay. Three stations were established: the BBPBL pier area (harbor activity), floating net cage aquaculture zone, and coastal tourism area (Kyokko Beach). These sites were selected using purposive sampling to reflect differences in human pressure across the coastal system.

This study used a descriptive case study approach. At each sampling station, three independent vertical tows were conducted as biological replicates. Each tow was performed from near-bottom depth to the surface using the same plankton net to ensure comparable sampling effort. The resulting samples were treated as independent replicates, representing local variability in phytoplankton distribution within each station.

Phytoplankton Sampling and Identification

Phytoplankton samples were collected using a plankton net with a mesh size of 25 µm, which primarily targeted the microphytoplankton fractions. Sampling was conducted using a vertical towing method from near-bottom depth to the surface. Vertical towing was selected to integrate phytoplankton distribution across the water column and capture spatial variability in the semi-enclosed coastal system, where vertical mixing may influence phytoplankton distribution.

Each tow was conducted from an approximate depth of 3–5 m to the surface. The estimated volume of filtered water was calculated based on the towing depth and net mouth area, providing a standardized basis for abundance estimation. Although vertical towing may underrepresent smaller picophytoplankton fractions compared to bottle sampling, this method is widely used for assessing bloom-forming taxa, which are generally dominated by micro-sized phytoplankton. The use of vertical towing in this study was considered appropriate for detecting bloom-associated phytoplankton genera, particularly diatoms and dinoflagellates, which typically occur within the microplankton size range of this study. This approach allows for integrated sampling of the water column in relatively shallow coastal environments where vertical gradients are less pronounced.

The samples were subsequently analyzed microscopically in the laboratory. Identification was conducted at the genus level based on morphological characteristics observed under light microscopy. Phytoplankton abundance was calculated using a Sedgwick-Rafter counting chamber and expressed as the number of individuals per liter. Prior to counting, the samples were homogenized by gentle mixing. A 1 mL aliquot of the concentrated sample was transferred to a Sedgwick–Rafter counting chamber. Phytoplankton cells were counted using a light microscope at 100–400 × magnification. For each sample, three chamber counts were performed to reduce counting error, and the average value was used to estimate phytoplankton abundance expressed as individuals per liter.

Chlorophyll-a concentration, a widely used proxy for phytoplankton biomass, was not measured in this study. Therefore, direct quantification of total phytoplankton biomass was not available. The assessment of bloom potential in this study was based on phytoplankton composition and nutrient condition. Future studies are recommended to include chlorophyll-a measurements to provide a more comprehensive evaluation of bloom dynamics.

Water Quality Measurement

The water quality parameters measured included both physical and chemical variables that influence phytoplankton dynamics.

In situ measurements included temperature and dissolved oxygen using a DO meter, salinity using a refractometer, pH using a pH meter, water transparency using a Secchi disk, and depth measurements at each sampling station.

Water samples (approximately 5 L) were collected using a vertical water sampler for laboratory analysis of nutrient concentrations, particularly nitrate and phosphate concentrations. Nutrient concentrations were analyzed spectrophotometrically following the standard procedures described by Strickland and Parsons (1972). Nitrate concentrations were determined using the cadmium reduction method, while phosphate concentrations were measured using the molybdenum blue method. Absorbance readings were obtained using a UV–Vis spectrophotometer, and nutrient concentrations were calculated based on calibration curves prepared from standard solutions. The detection limits were approximately 0.01 mg L^{-1} for nitrate and 0.005 mg L^{-1} for phosphate.

Data Analysis

Data analysis in this study was limited to descriptive statistics. Phytoplankton abundance and spatial distribution were summarized across sampling stations without inferential statistical testing due to the exploratory nature of the dataset. Water quality parameters were compared qualitatively with ecological suitability ranges for marine phytoplankton reported in previous studies.

RESULTS AND DISCUSSION

Phytoplankton Composition Associated with HAB Risk

A total of ten phytoplankton genera associated with harmful algal blooms (HABs) were identified in Hurun Bay (Table 1). The phytoplankton community was dominated by diatoms, particularly Chaetoceros (8,487 ind L^{-1}), followed by Bacteriastrum (2,960 ind L^{-1}), and Nitzschia (2,707 ind L^{-1}). Several dinoflagellate genera with known toxic potential, including Alexandrium, Pyrodinium, and Prorocentrum, were also recorded.

The dominance of diatom taxa indicates that the phytoplankton community in Hurun Bay is currently structured by conditions that favor fast-growing and opportunistic species. Diatoms are known to respond rapidly to nutrient enrichment due to their efficient nutrient uptake and high growth rates, allowing them to dominate in eutrophic coastal environments (Paerl & Otten, 2013; Smayda, 1997). Although toxin-producing dinoflagellates were present, their relatively low abundance suggests that environmental conditions may currently favor diatom-dominated assemblages rather than stratification-driven blooms.

Table 1. Composition and abundance of HAB-associated phytoplankton in Hurun Bay

Order	Family	Genus/Species	HAB category	Abundance (ind L^{-1})
Bacillariales	Bacillariaceae	*Nitzschia* sp.	Potentially toxic	2,707
Bacillariales	Bacillariaceae	*Pseudo-nitzschia* sp.	Potentially toxic	1,647
Gonyaulacales	Goniodomataceae	*Alexandrium* sp.	Toxic	2,273
Gonyaulacales	Ostreopsidaceae	*Pyrodinium bahamense*	Toxic	960
Prorocentrales	Prorocentraceae	*Prorocentrum* sp.	Potentially toxic	980
Peridiniales	Protoperidiniaceae	*Protoperidinium* sp.	Potentially toxic	373
Chaetocerotales	Chaetocerotaceae	*Bacteriastrum* sp.	Non-toxic bloom former	2,960
Chaetocerotales	Chaetocerotaceae	*Chaetoceros* sp.	Non-toxic bloom former	8,487
Chaetocerotales	Chaetocerotaceae	*Chaetoceros socialis*	Non-toxic bloom former	2,600
Thalassiosirales	Skeletonemataceae	*Skeletonema* sp.	Non-toxic bloom former	880

Spatial Variability in Phytoplankton Abundance

Phytoplankton abundance varied among sampling stations, reflecting differences in anthropogenic pressure within the bay (Table 2). The aquaculture station exhibited the highest phytoplankton densities, consistent with increased nutrient inputs from uneaten feed and metabolic waste. The harbor station showed moderate abundance, likely influenced by sediment resuspension and organic inputs associated with vessel activity. In contrast, the coastal tourism station displayed comparatively lower phytoplankton abundance, suggesting a relatively lower nutrient input or enhanced water exchange.

Table 2. Spatial distribution of HAB-associated phytoplankton abundance across sampling stations

Genus/Species	Pier station (S1–S3)	Aquaculture station (S1–S3)	Coastal station (S1–S3)	Total (ind L^{-1})
Nitzschia sp.	587, 413, 160	47, 307, 533	147, 60, 453	2,707
Pseudo-nitzschia sp.	373, 200, 27	53, 133, 227	160, 173, 300	1,647
Alexandrium sp.	240, 160, 147	87, 473, 220	467, 247, 233	2,273
Pyrodinium bahamense	180, 140, 107	160, 107, 33	100, 60, 73	960
Prorocentrum sp.	100, 53, 80	127, 153, 47	107, 207, 107	980
Protoperidinium sp.	73, 40, 40	100, 47, 20	13, 13, 27	373
Bacteriastrum sp.	320, 93, 47	133, 487, 560	393, 307, 620	2,96
Chaetoceros sp.	833, 487, 500	1007, 707, 947	1547, 947, 1513	8,487
Chaetoceros socialis	347, 260, 167	160, 640, 547	307, 80, 93	2,6
Skeletonema sp.	27, 153, 53	33, 193, 160	80, 47, 133	880

Such spatial heterogeneity is typical of semi-enclosed coastal systems where localized nutrient sources drive differences in phytoplankton distribution. The elevated abundance observed in aquaculture areas supports the role of mariculture activities as a significant source of nutrient enrichment in tropical coastal waters.

Water Quality Conditions Supporting Bloom Development

The elevated nutrient conditions were accompanied by high abundances of HAB-associated phytoplankton, particularly Chaetoceros (8,487 ind L^{-1}), Bacteriastrum (2,960 ind L^{-1}), and Nitzschia (2,707 ind L^{-1}). These taxa are commonly reported in nutrient-enriched coastal environments and are known for their rapid growth responses to increased nutrient availability (Paerl & Otten, 2013; Smayda, 1997).

High densities of Chaetoceros have been associated with eutrophic conditions and may cause mechanical irritation to fish gills, particularly in aquaculture systems (Paerl & Otten, 2013; Smayda, 1997). The co-occurrence of elevated nutrient concentrations and high phytoplankton abundance suggests that nutrient enrichment is a key driver of phytoplankton proliferation in Hurun Bay.

Nutrient Concentrations

The nitrate and phosphate concentrations measured in Hurun Bay are presented in Table 3. Nutrient analysis was conducted using spectrophotometric methods following the Indonesian National Standard (SNI 06-2480-1991) for nitrate determination using the brucine sulfate reaction, with absorbance measured at a wavelength of 410 nm.

Table 3. Nutrient concentrations in Hurun Bay

Station	Nitrate (mg L^{-1})	Phosphate (mg L^{-1})
Pier (BBPBL)	3,368	0,333
Aquaculture (Floating Net Cage)	3,419	0,399
Coatal Tourism (Kyokko Beach)	3,422	0,421

Nitrate concentrations in Hurun Bay ranged from 3.368 to 3.422 mg L^{-1}, while phosphate concentrations ranged from 0.333 to 0.421 mg L^{-1} across sampling stations. These values are substantially higher than the Indonesian seawater quality standards for marine biota, which set threshold concentrations of 0.008 mg L^{-1} for nitrate and 0.015 mg L^{-1} for phosphate.

The observed nutrient levels indicate strong nutrient enrichment in Hurun Bay. Elevated nutrient concentrations of this magnitude are widely associated with increased phytoplankton biomass and the potential development of eutrophic conditions in coastal systems (Anderson et al., 2021).

Ecological Implications for Coastal Management

Nitrate concentrations in Hurun Bay ranged from 3.368 to 3.422 mg L^{-1}, while phosphate concentrations ranged from 0.333 to 0.421 mg L^{-1}. These values greatly exceed the Indonesian seawater quality standards for marine biota, which set threshold concentrations of 0.008 mg L^{-1} for nitrate and 0.015 mg L^{-1} for phosphate (Ministry of Environment of Indonesia, 2004). Therefore, the elevated nutrient concentrations indicate substantial nutrient enrichment in Hurun Bay and may increase the risk of phytoplankton proliferation and harmful algal bloom development. The molar nitrogen-to-phosphorus (N:P) ratio was calculated based on the measured nitrate and phosphate concentrations to evaluate potential nutrient limitations. The observed N:P ratios ranged from approximately 12 to 16, which are close to or slightly below the Redfield ratio (16:1). This indicates that nitrogen may be relatively limited in the system under the current conditions. Such nutrient conditions can influence phytoplankton community structure and may favor the growth of opportunistic or bloom-forming taxa in nutrient-enriched coastal environments (Peñuelas et al., 2012).

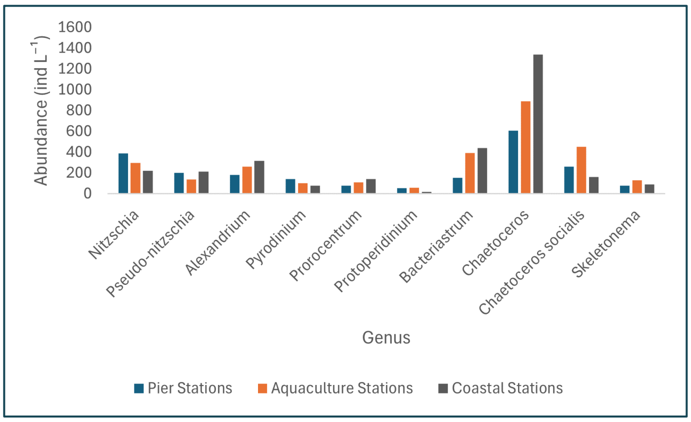

Figure 1. Spatial distribution of HAB-associated phytoplankton abundance across sampling stations in Hurun Bay

CONCLUSION

Hurun Bay exhibits elevated nutrient concentrations indicative of eutrophic conditions, with nitrate and phosphate levels far exceeding marine water quality standards, accompanied by high abundances of HAB-associated phytoplankton, such as Chaetoceros, Bacteriastrum, and Nitzschia. These findings suggest that nutrient enrichment plays a key role in shaping phytoplankton communities and may support bloom development under favorable conditions in the future. Future monitoring should prioritize genera such as Chaetoceros (aquaculture impact), Nitzschia, Pseudo-nitzschia (toxin potential), and Alexandrium (harmful dinoflagellates). Management efforts should focus on controlling nutrient inputs, particularly from floating net-cage aquaculture and land-based runoff, through improved feed practices and routine water quality monitoring. However, this study is limited by single-time-point sampling and the absence of chlorophyll-a and toxin analyses, which should be addressed in future research to better assess HAB dynamics in Hurun Bay.

AUTHOR CONTRIBUTION

Conceptualization: Novriadi
Methodology: Novriadi, Yanti Ariyanti, Jeane Siswitasari Mulyana, Gres Maretta
Investigation: Faraisha Putri Ariana
Data Curation: Faraisha Putri Ariana
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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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