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Keanekaragaman Fitoplankton Sebagai Bioindikator Perairan Pesisir Mandalika

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Abstract:
The quality of coastal aquatic ecosystems is increasingly affected by anthropogenic activities such as tourism, aquaculture, and land-based runoff. Phytoplankton, as primary producers and sensitive biological indicators, play a crucial role in detecting changes in water quality. This study aimed to assess the diversity and abundance of phytoplankton in the coastal waters of Mandalika, West Nusa Tenggara, Indonesia, using conventional microscopic methods.
Sampling was conducted in April 2024 at three coastal sites—Kuta Beach, Tanjung Aan Beach, and Gerupuk Beach—representing coral reef and seagrass ecosystems. Phytoplankton samples were collected using a 20 µm plankton net, preserved with 5% formalin, and analyzed to the genus level under a compound microscope. Environmental parameters including temperature, pH, salinity, nitrate, and phosphate concentrations were also measured.
The results showed that Bacillariophyceae (diatoms) dominated the phytoplankton communities at all sites, with total abundances ranging from 13,200 to 20,800 cells/mL. Tanjung Aan exhibited the highest phytoplankton diversity, while Kuta recorded the highest phosphate levels (2.5 mg/L), which correlated with increased phytoplankton abundance. The presence of Cyanophyceae and Dinophyceae at certain locations indicated localized nutrient fluctuations and potential early signs of anthropogenic influence.
Overall, the dominance of diatoms suggests mesotrophic to slightly eutrophic conditions across the region. These findings support the application of phytoplankton as reliable bioindicators for monitoring water quality and highlight the effectiveness of conventional microscopy in coastal ecological assessments.
Key Word: *Phytoplankton ; Bioindicator; Mandalika; Coastal Ecosystem; Water Quality.*

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I. Introduction

The quality of aquatic environments is strongly influenced by human activities such as urbanization, agriculture, industry, and tourism. These activities can lead to pollution, eutrophication, and alterations in the physicochemical parameters of water, ultimately threatening the sustainability of aquatic ecosystems [1]. Therefore, continuous monitoring of water conditions is essential, particularly through the use of bioindicator organisms, one of which is phytoplankton.

Phytoplankton are microscopic, photosynthetic organisms that serve as primary producers in aquatic food webs. Due to their high sensitivity to environmental changes, phytoplankton are considered effective indicators for detecting shifts in water quality. Environmental parameters such as temperature, pH, dissolved oxygen, and nutrient concentrations directly influence the composition and abundance of phytoplankton communities. Ecologically, phytoplankton diversity reflects the trophic status of a water body. Oligotrophic waters are characterized by low nutrient levels and primary productivity, mesotrophic waters exhibit moderate levels, while eutrophic waters show high nutrient concentrations, often triggering algal blooms and declining water quality [2,3]. For example, the dominance of Cyanobacteria is commonly associated with eutrophic conditions. Additionally, phytoplankton hold significant economic potential due to their ability to produce bioactive compounds such as antioxidants, enzymes, and fatty acids [4,5].

A study by Utami et al. in Lake Lido, Bogor, demonstrated that the structure of phytoplankton communities was closely correlated with physicochemical parameters of the water, such as temperature, pH, and nutrient concentrations (nitrate and phosphate). The dominance of the genera *Microcystis* and *Oscillatoria* under certain conditions indicated a eutrophic status of the water [6]. This study confirms that phytoplankton communities can be effectively used as bioindicators for assessing water quality, especially in areas exposed to tourism or other anthropogenic activities.

In Indonesia, research on phytoplankton as bioindicators remains relatively limited. Studies in the West Nusa Tenggara (NTB) region, including the coastal area of Mandalika in Central Lombok Regency, have yet to thoroughly explore phytoplankton diversity in the context of bioindicators. Mandalika, designated as a Special Economic Zone (SEZ), has become a hub of various anthropogenic activities such as tourism, marine aquaculture, and capture fisheries, all of which can impact the condition of coastal ecosystems. This study aims to examine the diversity of phytoplankton in the coastal waters of Mandalika and evaluate its potential as a bioindicator of water quality.

II. Material And Methods

Time and Location of Study

This research was conducted in April 2024 in the coastal region of Mandalika, Pujut District, Central Lombok Regency, West Nusa Tenggara Province, Indonesia. Sampling was carried out at three locations: Kuta Beach, Tanjung Aan Beach, and Gerupuk Beach, each representing two important coastal ecosystems—coral reef and seagrass bed ecosystems.

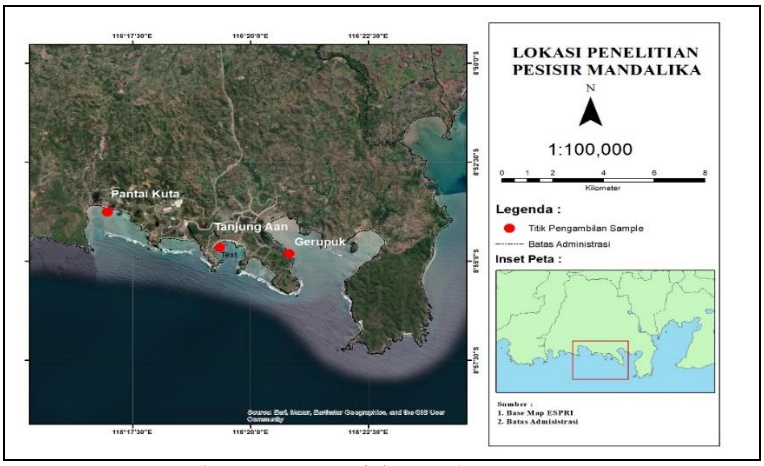

Figure 1. Map of the Study Area

Materials and Equipment

The equipment used in this study included a 20 µm plankton net with 100 mL sample bottles, a 3-liter bucket for seawater collection, a permanent marker, and a camera for documentation. In the laboratory, phytoplankton observations were conducted using a light microscope, dropper pipettes, glass slides and cover slips, as well as stationery and a camera for recording the results. The materials used included 37% formalin, with 5 mL added to each sample bottle as a preservative.

Sampling Technique

Sampling was carried out at three coastal locations in Mandalika—Kuta Beach, Tanjung Aan Beach, and Gerupuk Beach—each representing coral reef and seagrass bed ecosystems. Samples were collected using a 20 µm plankton net, preserved with 5% formalin, and subsequently analyzed microscopically in the laboratory.

Conventional Method

Phytoplankton samples were collected from coral reef and seagrass ecosystems in the Mandalika coastal area using a plankton net. Samples were fixed with 5% formalin and examined under a compound microscope (400x magnification). Taxonomic identification was conducted to at least the genus level based on morphological characteristics.

Data Analysis

Taxonomic identification was conducted to the genus level based on morphological features observed under a light microscope.

Phytoplankton abundance (cells/mL) was calculated using the formula from APHA (2017):

$$N = \frac{nxVt}{vxA}$$

Where:

- **N** = Abundance (cells/mL)
- **n** = Number of observed individuals
- V_t = Total volume of the preserved sample
- **v** = Volume of the sample observed under the microscope
- **A** = Volume of seawater filtered

The resulting abundance data were used to interpret water quality descriptively and were correlated with environmental parameters such as temperature, pH, salinity, and phosphate concentration.

III. Result

Phytoplankton Diversity at Kuta Beach

Based on the research conducted, the following is a comparison of phytoplankton abundance data at Kuta Beach:

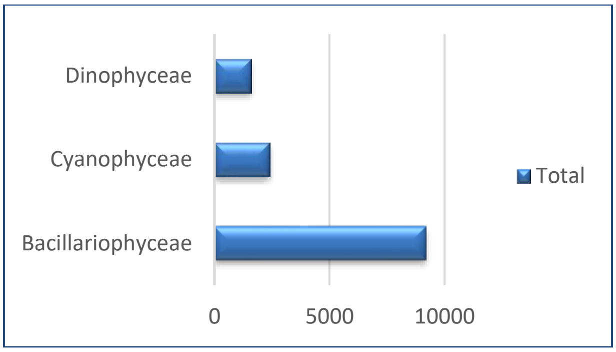

Figure 2. Phytoplankton Abundance at Kuta Beach

The analysis revealed the composition and abundance of phytoplankton classes detected at Kuta Beach. Three classes of phytoplankton were identified: Bacillariophyceae, Cyanophyceae, and Dinophyceae, with a total abundance of 13,200 cells/mL. Bacillariophyceae dominated the phytoplankton community with an abundance of 9,200 cells/mL (69.7%), followed by Cyanophyceae at 2,400 cells/mL (18.2%) and Dinophyceae at 1,600 cells/mL (12.1%).

The dominance of Bacillariophyceae indicates that the waters at Kuta Beach tend to exhibit oligotrophic to mesotrophic conditions. This group, primarily composed of diatoms, is typically associated with aquatic environments that have moderate nutrient levels and stable water quality (Reynolds, 2006). Their high abundance reflects not only good light and nutrient availability but also a relatively balanced and healthy ecological state.

Although less dominant, the presence of Cyanophyceae warrants attention, as this group (Cyanobacteria) can become prevalent under eutrophic conditions and is often linked to nutrient enrichment. Dinophyceae, known for their motility and tolerance to environmental fluctuations, further suggest that the waters at Kuta Beach experience moderate ecological variation, though still within acceptable limits for ecosystem health.

Overall, the composition and abundance of phytoplankton observed at Kuta Beach suggest a relatively good water quality, with no immediate signs of ecological disturbance such as algal blooms. However, the presence of certain taxa associated with nutrient-rich waters can serve as early warning indicators, particularly in coastal areas increasingly exposed to human activities such as tourism and development.

These findings highlight the role of phytoplankton as sensitive bioindicators for detecting subtle changes in water quality and ecosystem health in tropical coastal environments.

Phytoplankton Diversity at Aan Beach

Based on the research conducted, the following is a comparison of phytoplankton abundance data at Aan Beach:

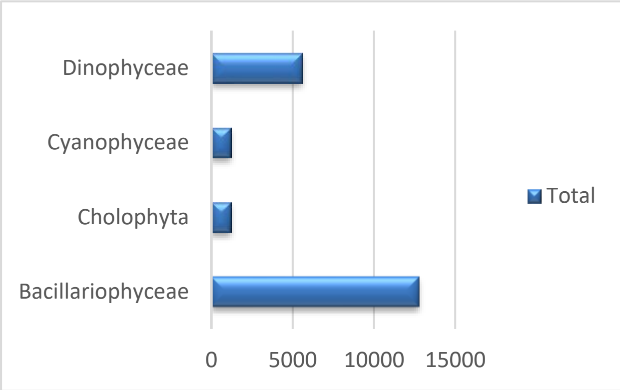

Figure 3 : Phytoplankton Abundance at Aan Beach

The observation of phytoplankton at Tanjung Aan Beach revealed a relatively diverse phytoplankton community. A total of four phytoplankton classes were identified, with an overall abundance of 20,800 cells/mL. The dominant class was Bacillariophyceae, accounting for 12,800 cells/mL (61.5%), followed by Dinophyceae with 5,600 cells/mL (26.9%). In addition, Chlorophyta and Cyanophyceae were each recorded at 1,200 cells/mL (5.8%).

The dominance of Bacillariophyceae once again suggests that the waters in this area are relatively stable and moderately productive, indicative of mesotrophic conditions. Diatoms, which comprise this group, are well known for their ability to thrive under steady nutrient availability and light conditions. Meanwhile, the notable presence of Dinophyceae may reflect fluctuations in nutrient levels, as members of this class are known to respond dynamically to changes in environmental conditions (Smayda, 1977). The detection of Chlorophyta and Cyanophyceae, although in lower proportions, adds to the overall diversity and serves as an early ecological signal. These groups, particularly Cyanophyceae, are often associated with nutrient-rich waters and may indicate localized inputs of organic matter or human-induced disturbances. The presence and composition of these phytoplankton classes can be used as bioindicators of coastal water quality. The community structure at Tanjung Aan points to an environment that is still ecologically balanced, yet shows early signs of variability that should be monitored—especially in light of increasing anthropogenic activities in the area.

Phytoplankton Diversity at Gerupuk Beach

Based on the research conducted, the following is a comparison of phytoplankton abundance data at Gerupuk Beach:

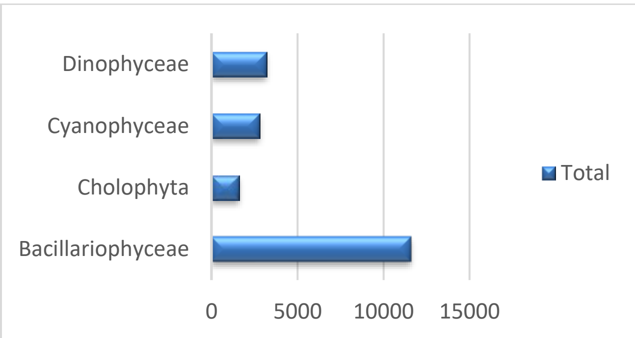

Figure 4 : Phytoplankton Abundance at Gerupuk Beach

Observations at Gerupuk Beach revealed a varied composition of phytoplankton classes. A total of four classes were identified, with an overall abundance of 19,200 cells/mL. Bacillariophyceae was again the dominant class, with 11,600 cells/mL (60.4%), followed by Dinophyceae with 3,200 cells/mL (16.7%), Cyanophyceae at 2,800 cells/mL (14.6%), and Chlorophyta at 1,600 cells/mL (8.3%).

This phytoplankton community structure indicates that the waters in Gerupuk are within the mesotrophic range, with moderate productivity. The dominance of Bacillariophyceae (diatoms) suggests stable environmental conditions and relatively good water quality, as this group is commonly found in well-oxygenated waters with balanced nutrient levels. Their abundance further underscores their role as a key bioindicator in assessing the trophic status of aquatic ecosystems.The notable presence of Dinophyceae and Cyanophyceae reflects potential nutrient fluctuations and localized organic enrichment. Dinophyceae are known for their adaptive responses to changing environmental conditions, while Cyanophyceae, although not dominant, may serve as an early indicator of nutrient input or mild eutrophication. Meanwhile, Chlorophyta, commonly found in shallow and well-lit coastal zones, contribute to the overall ecological diversity and further support the mesotrophic characterization of this site. Given the anthropogenic pressures in the Gerupuk area—such as marine aquaculture and coastal tourism—this phytoplankton profile offers early insight into potential ecosystem shifts. The consistent dominance of Bacillariophyceae across all observed sites strengthens its reliability as a primary bioindicator for coastal water quality monitoring in the region.

Water Quality Measurements

Table no 1: Results of Water Quality Measurements

No.	Environmental Parameter	Coral Aan	Coral Gerupuk	Coral Kuta	Seagrass Aan	Seagrass Gerupuk	Seagrass Kuta
1.	Temperature (°C)	32	32	29	32	32	29
2.	pH	7.7	8.2	8.5	7.7	8.2	8.5
3.	Salinity (ppt)	32	33	34	32	33	340
4.	Nitrate (mg/L)	0	0	0	0	0	0
5.	Phosphate (mg/L)	0.25	0.25	2.5	0.25	0.25	2.5

Based on the measurement of environmental parameters in coral reef and seagrass ecosystems across three locations (Aan, Gerupuk, and Kuta), it was found that temperatures in Aan and Gerupuk were relatively high (32°C), while Kuta recorded slightly lower values (29°C). However, all temperatures remain within the tolerance range for tropical marine organisms (NOAA, 2020). pH values in Aan (7.7) were lower than those in Gerupuk (8.2) and Kuta (8.5). Although these values fall within the normal seawater range (7.5–8.5), lower pH levels may affect the survival of calcifying organisms such as corals (Boyd et al., 2016). Salinity levels, ranging between 32–34‰, indicate stable conditions consistent with typical marine water standards (Effendi, 2003). Nitrate concentrations were 0 mg/L at all sampling points, suggesting the absence of excess nutrients from organic pollution. This supports oligotrophic conditions that are favorable for water clarity and overall ecosystem health (Wetzel, 2001). However, phosphate concentrations at Kuta (2.5 mg/L) were significantly higher compared to Aan and Gerupuk (0.25 mg/L). This elevated phosphate level may indicate potential eutrophication and the risk of excessive algal growth, which can disrupt the balance of marine ecosystems (Odum, 1993).

IV. Discussion

Phytoplankton serve as effective biological indicators due to their sensitivity to environmental fluctuations and their role as primary producers in aquatic ecosystems. The results of this study, based on microscopic observation, revealed variations in phytoplankton abundance and composition across three coastal locations in Mandalika: Kuta, Tanjung Aan, and Gerupuk. These differences reflect the influence of key environmental parameters such as temperature, pH, salinity, and nutrient concentrations.

At Kuta Beach, the highest phytoplankton abundance was recorded, with 13,200 cells/mL in coral areas and 19,200 cells/mL in seagrass areas. The community was dominated by Bacillariophyceae, a class of diatoms commonly associated with stable and productive environments. This high abundance aligns with favorable environmental conditions, including lower temperature (29°C), high pH (8.5), and notably elevated phosphate levels (2.5 mg/L). Phosphate, being a critical limiting nutrient, can significantly enhance phytoplankton growth when present in excess (Wetzel, 2001; Richardson et al., 2007). The dominance of Bacillariophyceae suggests a mesotrophic to eutrophic state, with high primary productivity likely supported by nutrient input from surrounding human activities.

In Tanjung Aan, phytoplankton abundance also reached high values, ranging from 13,200 to 20,800 cells/mL, and was primarily composed of Bacillariophyceae and Dinophyceae. Although phosphate concentrations were lower (0.25 mg/L) than in Kuta, the combination of high temperature (32°C) and pH 7.7 provided suitable conditions for phytoplankton growth. The significant presence of Dinophyceae in this site may indicate greater environmental variability, as this group is known for its adaptive strategies in fluctuating nutrient and light conditions (Smayda, 1997). This composition suggests a mesotrophic environment with moderate ecological productivity.

At Gerupuk, total phytoplankton abundance was slightly lower compared to the other sites, yet the community structure remained consistent, dominated by Bacillariophyceae, Cyanophyceae, and Dinophyceae. Environmental measurements at this site showed high temperature (32°C), pH 8.2, and salinity up to 34 ppt, which may have contributed to a more selective environment favoring tolerant taxa such as Cyanophyceae. The presence of Cyanobacteria, although not dominant, is notable as it may indicate incipient nutrient enrichment, especially in shallow or semi-enclosed coastal waters. Despite the slightly lower abundance, the community composition still reflects a moderately productive system.

In summary, the dominance of Bacillariophyceae across all three sites highlights the overall stability and moderate trophic status of Mandalika's coastal waters. However, the exceptionally high phosphate concentration and phytoplankton abundance in Kuta suggest a localized nutrient enrichment, potentially linked to anthropogenic inputs such as tourism or runoff. These findings reinforce the value of phytoplankton analysis using microscopy as a practical approach for monitoring coastal ecosystem health and detecting early signs of environmental stress.

V. Conclusion

This study demonstrates that phytoplankton diversity in the coastal waters of Mandalika is influenced by variations in environmental parameters such as temperature, pH, salinity, and nutrient concentrations. The microscopic (conventional) method effectively revealed the actual abundance of phytoplankton, with Bacillariophyceae consistently dominating across all sites. This dominance reflects mesotrophic to slightly eutrophic conditions, indicating moderate levels of productivity.

The presence of Cyanophyceae and the increase in Dinophyceae in certain locations may serve as early indicators of anthropogenic pressure, such as nutrient input from tourism or aquaculture. These findings support the use of phytoplankton—particularly diatoms—as reliable bioindicators for assessing coastal water quality. Overall, phytoplankton-based monitoring using conventional microscopy remains a relevant and cost-effective approach for environmental assessment and provides essential insights for the sustainable management of coastal ecosystems.

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