# Diatoms as Bioindicators of Ecological Stability in the Mangrove Ecosystem of Benoa Bay, Bali

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**Abstract.** Mangrove ecosystems play a crucial role in maintaining the ecological balance of coastal environments through various functions, including providing habitats, storing carbon, and protecting shorelines. However, increasing anthropogenic pressures have caused degradation in several mangrove areas, including Benoa Bay, Bali. This study aims to analyze the diatom community structure in the Benoa Bay mangrove ecosystem. Sediment samples were collected from five stations using a purposive sampling method and a Russian corer. The samples were processed and identified based on morphological characteristics using a microscope at 1000× magnification. Three ecological indices were calculated using PAST 4.0 to assess the diatom communities: the Shannon–Wiener diversity index (H'), the dominance index (D), and the evenness index (E). The results showed that the Shannon–Wiener diversity index (H') ranged from 3.328 to 4.243, indicating a high level of diatom diversity across the sampling stations. The other index values showed that the dominance index (D) ranged between 0.021 and 0.076, while the evenness index (E) varied from 0.3667 to 0.6888. The combination of these indices suggests that most sampling stations support a well-balanced diatom community, characterized by low dominance and high evenness, which reflects relatively stable environmental conditions. In contrast, Station 1 showed the highest dominance and lowest evenness, indicating possible environmental stress.
Keywords: diatom, mangrove ecosystem, biodiversity, Benoa Bay

## 1 Introduction

Mangrove ecosystems are among the most important coastal ecosystems, characterized by high biodiversity and providing numerous ecological and economic benefits. They play a crucial role in maintaining the stability of coastal environments by serving as habitats for

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diverse biota, functioning as carbon sinks, preventing coastal erosion, and protecting the mainland from tidal waves and storms [1].

Mangrove ecosystems cover about 15.9 million hectares in 116 countries. Asia holds roughly 6.1 million hectares, or 38% of the global total. Indonesia has the largest area, with an estimated 3.4 million hectares [2].

In Indonesia, despite its significant mangrove coverage, these ecosystems continue to experience degradation in both extent and quality. Natural changes and anthropogenic activities such as coastal reclamation, logging, and land conversion cause this decline. For example, in Benoa Bay, Bali, mangrove degradation has been linked to the reclamation of Serangan Island and the construction of the Bali Mandara Toll Road [3]. These disturbances have led to changes in several environmental parameters, including salinity, pH, and dissolved oxygen (DO) levels.

These environmental changes, in turn, can influence the distribution and abundance of aquatic organisms, including diatoms. Diatoms are microscopic, photosynthetic algae with silica-based cell walls that inhabit a wide range of aquatic environments, including both freshwater and marine environments [4]. They are widely used as bioindicators due to their sensitivity to environmental variations and their ability to preserve ecological signals through the silica frustules they deposit in sediments [5].

Despite the recognized relevance of diatoms as bioindicators, research on their use in mangrove ecosystems, particularly in Benoa Bay, remains limited. Therefore, this study aims to analyze the diatom community structure in the Benoa Bay mangrove ecosystem as an effort to assess environmental changes and support sustainable mangrove ecosystem management.

## 2 Methods

Sediment sampling was conducted at five stations distributed across the mangrove ecosystem of Benoa Bay (Figure 1).

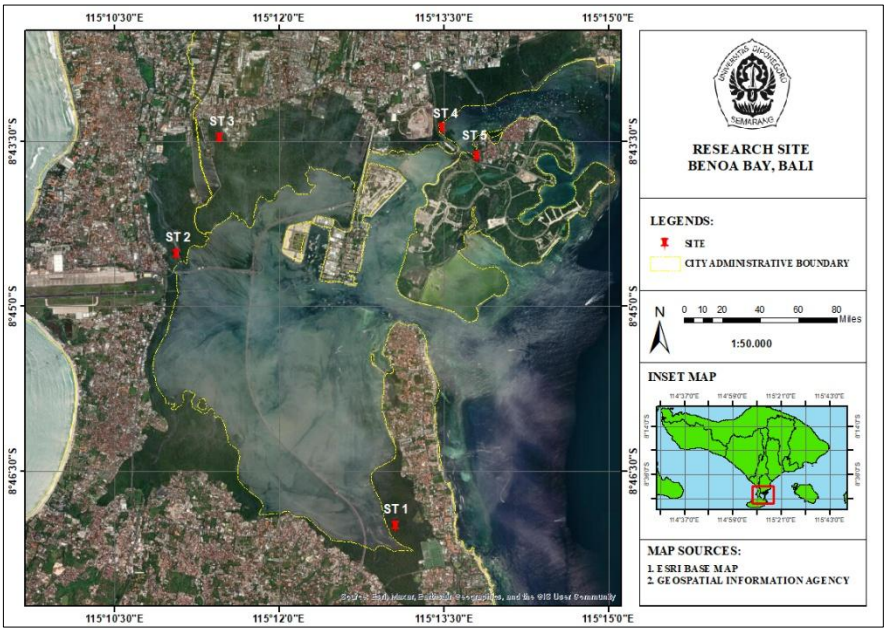


**Fig. 1.** Research Site Map

Sampling points were determined using the purposive sampling method. Sediment samples were collected using a Russian corer by inserting the instrument into the mangrove substrate and retrieving the sediment. The collected sediment was placed in a semi-cylindrical tube to maintain the stability of the sediment layers [6]. The sediment used in this study consisted of surface samples taken from a depth of 0–1 cm. The selected sediment samples were digested using 10% HCl and $H_2O_2$ solutions to separate diatom frustules from the sediment matrix. The samples were then transferred into centrifuge tubes, rinsed with distilled water, and centrifuged to remove residues and the supernatant. After the cleaning process, permanent slides were prepared using Naphrax, a material with a refractive index of 1.73. Microscopic observations were carried out at 1000× magnification. Diatom identification was performed using standard identification keys, as well as the AlgaeBase and Diatom.org databases [7]. Data analysis involved calculating diversity, dominance, and evenness indices using PAST v4.0.

## 3 Results and Discussion

Based on research conducted at the Benoa Bay mangrove ecosystem, 158 species of diatoms were identified, which are classified into 55 genera. The results of the Shannon–Wiener diversity index (H') analysis at five observation stations are presented in Figure 2.

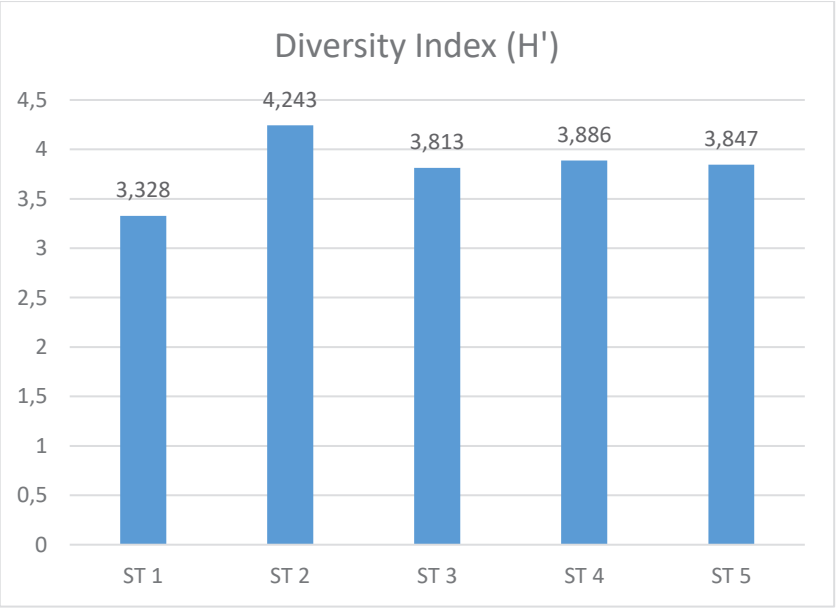


**Fig. 2.** Diversity Index in Benoa Bay

The diatom diversity index values in the Benoa Bay mangrove ecosystem ranged from 3.328 to 4.243, indicating a high level of diversity (H' > 3). The highest value was recorded at Station 2 (H' = 4.243), with 115 species identified and a total abundance of 6,821 individuals per gram (ind·$g^{-1}$). This suggests a well-balanced and diverse diatom community, likely supported by favorable environmental conditions, including adequate nutrient availability, optimal light intensity, and stable substrate characteristics. One of the representative species found at this station was *Tryblionella granulata* (Fig. 3), an epipelic diatom genus with a wide distribution ranging from freshwater to marine environments [8].

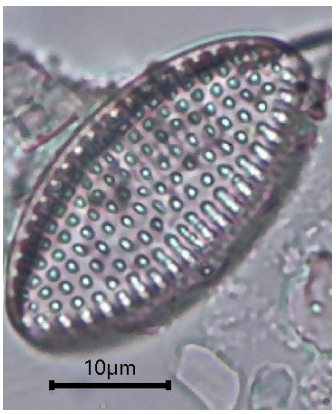


**Fig. 3.** *Tryblionella granulata*

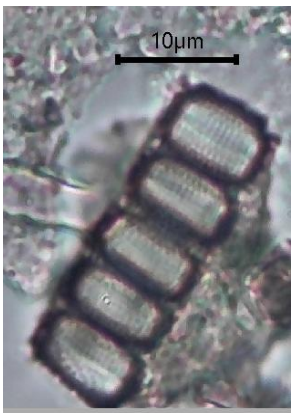


**Fig. 4.** *Paralia sulcata*

Conversely, the lowest diversity index value was observed at Station 1 (H' = 3.328), where 76 species were recorded with a total abundance of 4,935 individuals per gram (ind·gr$^{-1}$). Although still categorized as high diversity, this result indicates that a few species were relatively dominant. The variation in index values among stations may be attributed to differences in physicochemical parameters such as salinity, temperature, or organic matter content. One of the diatom species found at this station was *Paralia sulcate* (Fig. 4), a benthic and planktonic centric diatom commonly occurring in coastal waters [9]. Its thick and robust silica frustule enhances preservation in sediments, making *Paralia sulcata* a valuable bioindicator for paleoenvironmental reconstructions [10][11]. Overall, the consistently high Shannon–Wiener index values across all stations suggest that the mangrove ecosystem in Benoa Bay still supports a high and relatively stable diatom diversity.

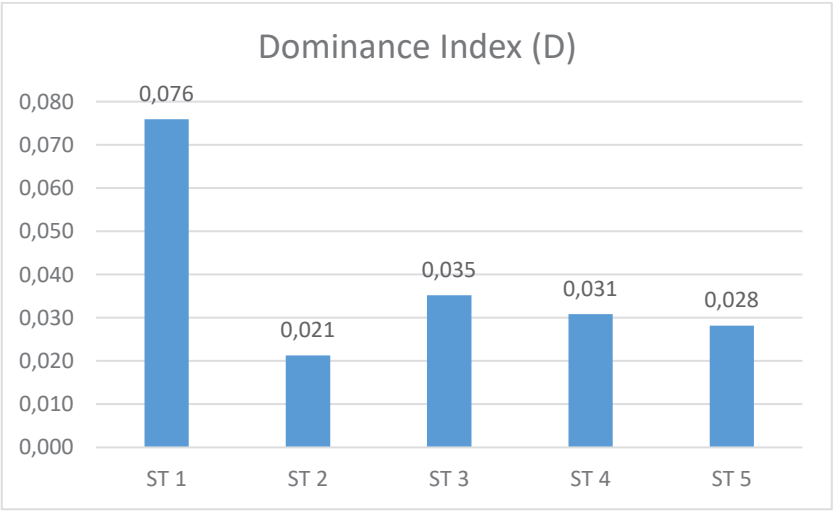


**Fig. 5.** Dominance Index in Benoa Bay

The results of the dominance index (D) analysis are shown in Figure 5. Dominance values ranged from 0.021 to 0.076. The highest value, 0.076, was recorded at Station 1, while the lowest, 0.021, was observed at Station 2. Stations 3, 4, and 5 displayed intermediate values. A high dominance value at Station 1 reflects the prevalence of a few dominant species, mainly centric diatoms such as *Cymatotheca minima*, *Paralia sulcata*, and *Cyclotella*

*meneghiniana*, which are typically found in surface waters [12]. Lower dominance values at Stations 2–5 suggest a more balanced diatom community and a likely more stable ecosystem compared to Station 1. High dominance often indicates environmental stress or resource limitation, while low dominance reflects conditions that are supportive of higher diversity [13].

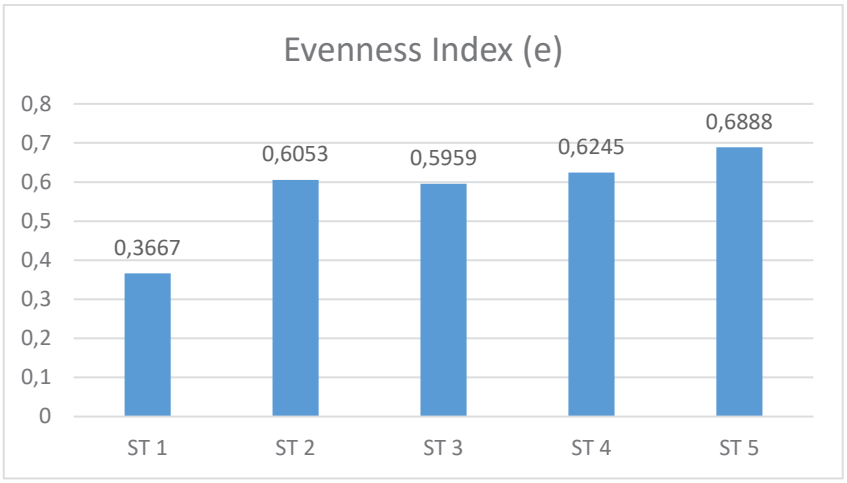


**Fig. 6.** Evenness Index in Benoa Bay

The evenness index (E) analysis results are presented in Figure 6. Evenness values ranged from 0.3667 to 0.6888. The highest value was recorded at Station 5 (E = 0.6888), whereas the lowest was found at Station 1 (E = 0.3667). Stations 2, 3, and 4 exhibited relatively similar evenness values of 0.6053, 0.5959, and 0.6245, respectively. The evenness index measures the distribution of individuals among species within a community. Values approaching 1 indicate a more even distribution, while lower values suggest dominance by one or a few species [14].

Based on these findings, Station 1 shows a low evenness index, indicating dominance by a few species, while Station 5 has the highest value, reflecting a more balanced community. High evenness values suggest stability, while low values may indicate stress or disturbance.

## 4 Conclusion

The results of this study demonstrate that diatoms can be utilized as reliable bioindicators to assess the environmental conditions of the mangrove ecosystem in Benoa Bay, Bali. The Shannon–Wiener diversity index (H') ranged between 3.328 and 4.243, indicating a generally high diversity of diatom species in the study area. This suggests that the mangrove environment continues to provide suitable conditions that support a diverse and relatively stable diatom community. Among all stations, Station 2 and Station 5 showed higher diversity and evenness values, which may indicate better water quality and more balanced ecological conditions. In contrast, Station 1 had a higher dominance index, showing that a few species were more abundant and possibly reflecting environmental stress or local disturbance. Overall, the differences in diversity, dominance, and evenness among stations reflect the spatial variability of environmental factors within the mangrove ecosystem. These findings highlight the importance of using diatom assemblages as indicators for monitoring ecological changes.

## Acknowledgement

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