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Macrobenthic Community Structure as a Bioindicator of Environmental Quality at Pier 1, Kota Agung

Struktur Komunitas Makrobenthos sebagai Bioindikator Kualitas Lingkungan di Dermaga 1, Kota Agung

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Abstrak

Penelitian ini bertujuan untuk menilai kualitas perairan di Dermaga 1 Kota Agung dengan menggunakan organisme makrobentos sebagai indikator biologis. Wilayah pesisir seperti Dermaga Kota Agung semakin terpapar tekanan antropogenik akibat aktivitas pelabuhan, pelayaran, dan penggunaan lahan di sekitarnya. Tekanan ini secara perlahan dapat mengubah kualitas air dan struktur komunitas bentik dari waktu ke waktu. Pendekatan deskriptif kuantitatif diterapkan pada tiga stasiun pengamatan yang mewakili kondisi perairan di sekitar dermaga. Pengambilan sampel makrobentos dilakukan menggunakan core sampler berukuran 10 inci dan dianalisis berdasarkan parameter biologi, fisika, dan kimia. Organisme makrobentos yang teridentifikasi berasal dari kelas Gastropoda, Oligochaeta, dan Malacostraca, dengan tingkat keanekaragaman sedang (H' = 1,337–1,567), keseragaman tinggi (E = 0,84–0,98), dan dominansi rendah (D = 0,24–0,37). Nilai Family Biotic Index (FBI) berkisar antara 3,81 hingga 3,86, yang menunjukkan kualitas air tergolong baik dengan tingkat pencemaran organik yang rendah. Parameter fisikokimia seperti suhu, kecerahan air, pH, dan oksigen terlarut berada dalam ambang batas baku mutu lingkungan. Hasil penelitian menunjukkan bahwa kondisi lingkungan di Dermaga 1 Kota Agung relatif baik, hal ini tercermin dari struktur komunitas makrobentos yang seimbang dan parameter fisikokimia yang mendukung.

Kata kunci: *Black Soldier Fly*, konsumsi substrat, indeks reduksi limbah

Abstract

This study aims to assess the water quality of Pier 1 Kota Agung using macrobenthic community structures as biological indicators. Coastal areas such as Kota Agung Pier are increasingly exposed to anthropogenic pressures due to port operations, shipping activities, and surrounding land use. These pressures can subtly alter water quality and benthic community structure over time. A descriptive quantitative approach was applied across three observation stations representing the aquatic conditions surrounding the pier. Macrobenthos samples were collected using a Macrobenthic sample, which was carried out using a 10-inch core sampler and a 10mm mesh, for physical and chemical parameters. The identified macrobenthic organisms belonged to the classes Gastropoda, Oligochaeta, and Malacostraca, showing moderate diversity (H' = 1.337–1.567), high evenness (E = 0.84–0.98), and low dominance (D = 0.24–0.37). The Family Biotic Index (FBI) values ranged from 3.81 to 3.86, indicating good water quality with low levels of organic pollution. Physical and chemical parameters such as temperature, water clarity, pH, and dissolved oxygen were within the standard quality thresholds. The study reveals that the environmental conditions at Pier 1 Kota Agung are relatively good, as indicated by balanced macrobenthic community structures and supportive physicochemical parameters.

Keywords: *Bioindicator, FBI, Macrobenthic community*

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INTRODUCTION

Water quality is crucial for maintaining aquatic ecosystems and supporting fisheries, tourism, and marine transport [1]. Coastal and port areas are prone to industrial, domestic, and shipping pollution, disrupting biodiversity and local economies [2]. Port operations like loading and docking release pollutants such as oil, chemicals, and solid waste that affect benthic communities [3]. Analyzing macrobenthos at Kota Agung Pier is essential, as they are sensitive bioindicators of aquatic environmental conditions. Industrial and domestic waste also contribute to heavy metals and excess nutrients, triggering eutrophication [4]. Therefore, intensive water quality monitoring is necessary to preserve coastal ecosystems.

Macrobenthos are effective as biological indicators due to their sedentary nature and sensitivity to pollution. Changes in macrobenthic communities, such as the dominance of tolerant species and a decline in diversity, reflect environmental stress [5]. Studies at various harbors have demonstrated the effectiveness of macrobenthos in indicating water conditions [6]. For example, research at Tanjung Emas Harbor revealed a reduction in macrobenthic diversity due to organic pollution, similar to findings at Benoa Harbor [7]. The study by Silaban (2024) on the growth patterns and condition factors of spider conch (*Strombus luhuanus*) in the waters of Dullah Laut indicates that macrobenthos have a strong relationship with aquatic environmental quality. This supports the relevance of analyzing water quality parameters based on macrobenthic composition conducted at Pier 1, Kota Agung, Tanggamus. This highlights the importance of conducting research at Pier 1 Kota Agung, which is also exposed to human activities [8]. The bioindicator approach, particularly using macrobenthos such as annelids, mollusks, and small crustaceans, effectively reflects the biological condition of waters through community changes [9].

Coastal areas are particularly vulnerable to pollution due to their function as discharge zones for upstream activities, limited water circulation, and high accumulation of nutrients and sediments from land- and marine-based sources [10]. Pier 1 Kota Agung is a hub of port activities that potentially threaten water quality.

Water quality is fundamental to sustaining aquatic ecosystems and supporting human activities such as fisheries and maritime transport. However, coastal areas near ports are increasingly exposed to pollution from industrial discharge, domestic waste, and shipping operations, which can alter the structure of benthic communities. Macrobenthic organisms are widely recognized as effective bioindicators due to their sensitivity to environmental stress, limited mobility, and direct contact with sediment, making them helpful in assessing long-term ecological conditions.

Pier 1 Kota Agung in Tanggamus Regency is an active port area where environmental monitoring is still limited, particularly using biological indicators. This study aims to assess the ecological conditions at the pier by analyzing the composition and structure of macrobenthic communities, complemented by physical and chemical water quality parameters, to provide insight into the environmental status of this coastal zone.

METHODS

This research was conducted at Pier 1 in Kota Agung, Tanggamus Regency, located at coordinates -5.5015 ° S and 104.6215° E. The study area covers a water surface of 17,131 m^2 at Pier 1 Kota Agung, which was divided into three stations, each spaced 10 meters apart. Each station was equipped with a transect line using the line transect method.

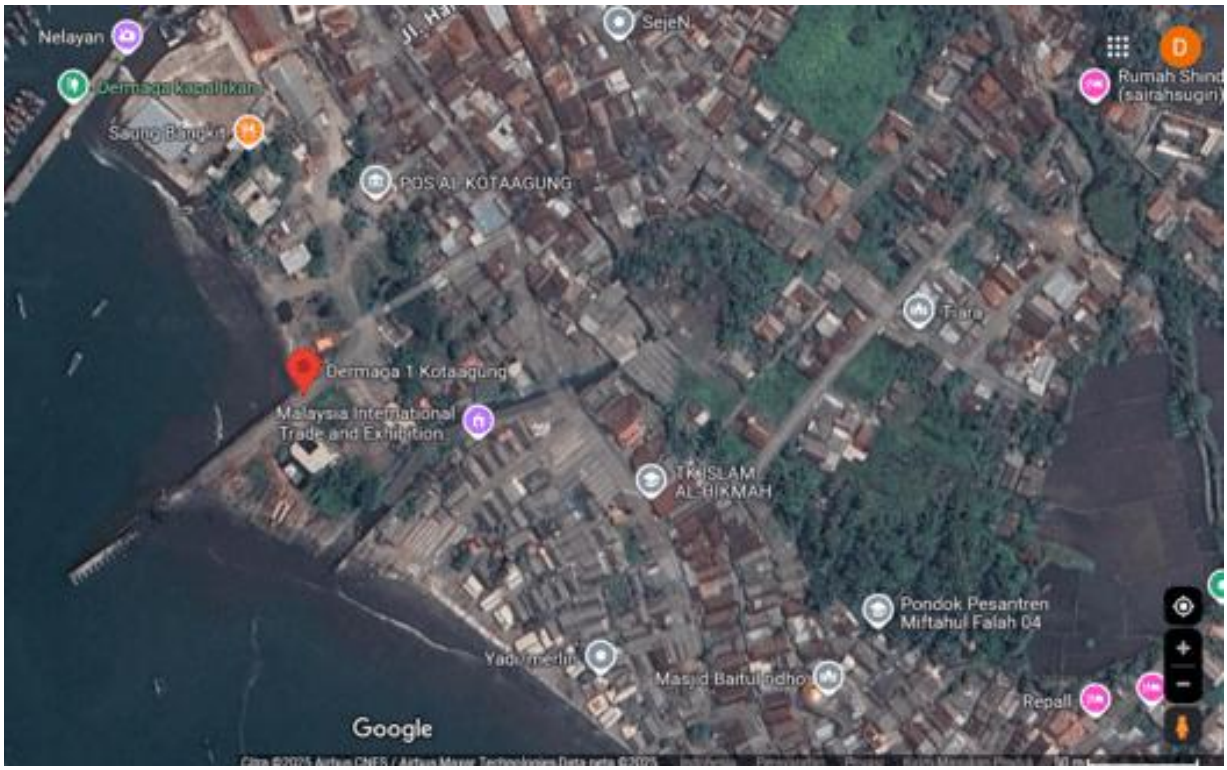

Figure 2. Research Location

Secondary data included physical parameters (water temperature and brightness) and chemical parameters (pH and dissolved oxygen/DO). Samples were collected to analyze physical, biological, and chemical parameters. This study employed a quantitative descriptive design. The samples comprised macrobenthic organisms representing the population based on their abundance and characteristics. The tools and materials used in this research included a GPS, a pH meter, a Secchi disk, a refractometer, a 10-inch core sampler, an analytical balance, a thermometer, a measuring tape, sample bottles, a DO meter, plastic zip bags, pipettes, sieves, and label paper.

Biological indicator sampling was carried out using a 10-inch core sampler. The samples were fixed with 4% formalin, filtered, washed, preserved in 70% ethanol, and identified. Physical indicators included temperature, depth, and water clarity. Chemical indicators included pH, DO, BOD, and COD [11]. All chemical analyses were conducted at the UPTD Health Laboratory Center of Lampung Province.

The collected data were analyzed by calculating the diversity using the **Shannon-Wiener diversity index (H')**
With the following formula [12]:

$$H' = -\sum(pi \cdot lnpi)$$

H′ = Shannon-Wiener diversity index

pi = proportion of individuals of species I to the total number of individuals

$lnpi$ = natural logarithm

Evenness Index (E') was calculated using the formula [12]:

$$H'E' \; In \; S$$

H′ = Shannon-Wiener diversity index

S = Total number of species (species richness)

Dominance Index was calculated using Simpson's Dominance Index [13]:

$$D = \sum \left(\frac{ni}{N}\right)^2$$

pi = proportion of individuals of species I to the total number of individuals

Family Biotic Index (FBI) is calculated using the formula [14] :

$$FBI = \frac{\sum(ni \; x \; ti)}{N}$$

FBI = Value of the macroinvertebrate biotic index

n_i = number of individuals in the i-th family

t_i = Tolerance value of the i-th family

N = Total number of individuals in the macroinvertebrate community

These indices provide a comprehensive understanding of the structure and stability of the macrobenthic community in the study area.

RESULTS AND DISCUSSION

Bioindicator

The identification results of macrobenthos at Kota Agung Pier 1, Tanggamus, across three stations with one repetition at nine different points showed varying numbers at each point. The types of macrobenthos found at each station are presented in Table 1.

Table 1. Identified Macrobenthos

No	Family	Number of Individuals		
		St. I	St. II	St. III
1.	Mytilidae	4	1	4
2	Lymnaeidae	6	2	4
3.	Physidae	8	11	8
4.	Lumbricidae	1	2	1
5	Portunidae	1	-	3
6	Paguroidae	2	2	1
	Total number	**22**	**18**	**21**

Table 1 presents the identification results of macrobenthos at Pier 1 Kota Agung, consisting of three classes: Gastropoda (Lymnaeidae and Physidae), Oligochaeta (Lumbricidae), and Malacostraca (Portunidae and Paguroidae). Their distribution varied across stations, with Gastropoda dominating Stations I and III, while Malacostraca appeared at Station II. These differences reflect variations in community composition due to local environmental factors.

The number of macrobenthos was analyzed using the diversity index (H′), evenness index (E), and dominance index (D) based on established formulas. The calculation results are presented in Table 2.

Table 2. Diversity, Evenness, and Dominance Index

No	Index	Station		
		I	II	III
1.	H'	1.531	1.337	1.567
2.	E	0,96	0,84	0,98
3.	D	0,25	0,37	0,24

Notes :

H'<1	= Low diversity
H'(1-3)	= Moderate diversity
H'>3	= High diversity
0<E<0,5	= Low evenness
E = 0	= Moderate evenness
0,5<E<1	= High evenness
D = 00,0-0,30	= Low dominance
D = 0,31-0,60	= Moderate dominance
D = 0,61-1,00	= High dominance

The analysis results in Table 3 show variations in the values of the diversity index (H'), evenness (E), and dominance (D) at each station. Stations I, II, and III have different H', E, and D values, reflecting variations in the structure of the macrobenthic community. For instance, Station II exhibited the lowest diversity

index (H′ = 1.337), which may be associated with its relatively higher temperature (35.5°C) and lower DO (4.07 mg/L), conditions that can limit species sensitive to thermal or oxygen stress. In contrast, with cooler temperatures and higher DO, Station III recorded the highest diversity (H′ = 1.567) and evenness (E = 0.98), suggesting more favorable conditions for a stable and balanced benthic community.

Physical Parameters

The physical indicators measured were temperature, depth, and brightness at Pier I in Kota Agung. The results obtained in this study are presented in Table 3.

Table 3. Results of Physical Indicators

Indicators	unit	Station			Water Quality Standards According to Government Regulation No. 82 of 2001
		I	II	III	
Temperature	ºC	33,6	35,5	31,3	28-32 ºC
Depth	m	3,97	1,48	1,43	-
Brightness	m	0,29	0,3	0,37	<5m

The physical water quality indicators at Pier I Kota Agung show varying conditions across the three observation stations. The temperature values at Stations I (33.6°C) and II (35.5°C) exceed the standard limit of 28–32°C, while Station III (31.3°C) is within the acceptable range. Depth varies significantly between stations, with Station I being the deepest (3.97 m) and Stations II and III being shallower. Water transparency (brightness) is relatively low at all stations (ranging from 0.29 to 0.37 m) but still meets the regulatory standard of <5 m.

Chemical Indicators

The chemical indicators used to assess water quality at Pier I in Kotaagung are pH and Dissolved Oxygen (DO). The measurement data are presented in Table 4.

Table 4. Measurement of Chemical Indicators

Indicators	Unit	Station			Water Quality Standards According to Government Regulation No. 82 of 2001
		I	II	III	
Ph	-	8,57	8,53	8,56	6 – 8
DO	Mg/l	4,34	4,07	4,7	3 mg/1-6mg1

The chemical water quality indicators at Pier I Kota Agung indicate that pH values at all three stations (I: 8.57, II: 8.53, III: 8.56) are slightly above the upper limit of the standard range (6–8), suggesting alkaline conditions. However, Dissolved Oxygen (DO) levels at all stations remain within the acceptable range of 3–6 mg/L, indicating that the water still

supports aerobic aquatic life.

Family Biotic Index (FBI)

The results of the FBI (Family Biotic Index) calculation are presented in Figure 2.

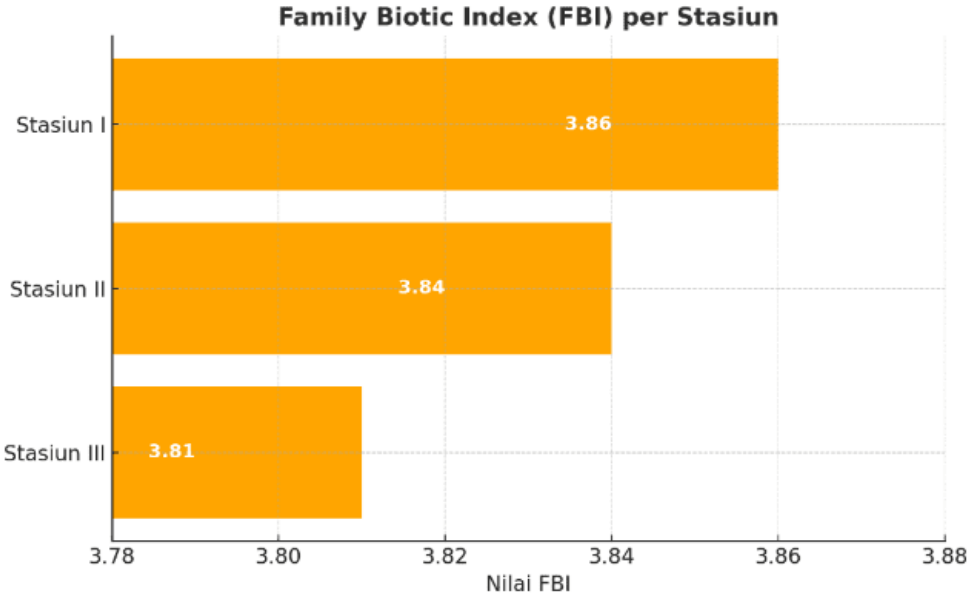

Figure 2. Family Biotic Index

The analysis results in Figure 2 show FBI values of 3.86 at Station I, 3.84 at Station II, and 3.81 at Station III. All values fall within the 3.76–4.25 range, which, according to Hilsenhoff (1988), indicates good water quality with low levels of organic pollution. The highest FBI value at Station I suggests that the macrobenthic community is slightly more pollution tolerant than the other stations. In contrast, the lowest FBI value at Station III indicates a community more sensitive to environmental changes.

Substrate characteristics, human activities, and variations in physical and chemical parameters like temperature, depth, brightness, and dissolved oxygen influence these differences. Although all stations indicate good water quality, Station III provides the most favorable ecological conditions for pollution-resistant organisms.

DISCUSSION

The structure of macrobenthic communities is influenced by the overall quality of the aquatic environment, as reflected in its physical and chemical parameters. In this study, variations in macrobenthic diversity, evenness, and dominance across stations appear to correlate with differences in environmental conditions. Healthier macrobenthic communities were generally found where physicochemical parameters remained within favourable thresholds, indicating that balanced environmental conditions support more stable and diverse benthic assemblages. These findings highlight the integral role of ecological factors in shaping benthic community dynamics and

reinforce the value of macrobenthos as sensitive bioindicators in coastal ecosystem monitoring.

Macrobenthos Diversity

The identification conducted at Pier 1 in Kota Agung revealed that the macrobenthos present belong to two main classes: Gastropoda and Oligochaeta. Within the class Gastropoda, the identified macrobenthos came from Lymnaeidae and Physidae. Meanwhile, in the class Oligochaeta, the identified organisms belonged to the family Lumbricidae. A more detailed description of the characteristics of each identified taxon will be presented in the following section to support the analysis of water quality based on the presence and distribution of macrobenthos at the study site.

Diversity Index

The diversity index often assesses environmental conditions based on biological components. Aquatic environments are considered good or stable when the diversity index is high. Based on the Shannon-Wiener index analysis, the diversity values were H' = 1.531 at Station I, H' = 1.337 at Station II, and H' = 1.567 at Station III. Generally, index values between 1 and 3 indicate moderate or stable diversity.

These values suggest that species diversity in the waters of Pier 1 Kota Agung falls into the moderate category. When linked to physical and chemical water parameters, the water quality remains relatively good and does not show significant degradation. This is further supported by the fact that sampling was conducted in the morning (08:00–12:00 WIB) before fishing activities that could affect water conditions. A low diversity index indicates polluted waters, which aligns with previous research [15]. However, the lowest value among the three stations (H' = 1.337) still reflects a stable and relatively healthy community.

Evenness Index

The evenness index is used to determine whether the distribution of organisms is uniform. The evenness index values at Stations I, II, and III range between E = 0.83–0.97, which fall into the stable category. According to [16] in the book *Terumbu Karang Jakarta*, a community is considered stable when the evenness index lies within the 0.5 < E < 1.00 range. This indicates that the species distribution in the pier waters is relatively even.

Dominance Index

The analysis of the dominance index across the three stations shows values ranging from D = 0.25 to D = 0.37. These values are close to zero, indicating no single species dominance. A low dominance index suggests the absence of species dominance. Although particular species may have higher individual counts at some stations, ecological analysis confirms that the waters are still healthy due to the lack of dominant species.

There is an inverse relationship between

diversity/evenness and dominance—the higher the diversity and evenness, the lower the dominance. A similar pattern is observed at Pier 1 Kota Agung, where dominance values are close to zero, indicating that no species dominates the community, which reflects good environmental conditions.

Dominance can occur when macrobenthos are tolerant of harmful substances. Macrobenthos are effective bioindicators because they are sedentary, widely distributed across zones, long-lived, easy to identify, and exhibit different responses to water quality [17]. At all three stations, the diversity index reaches H'1 (moderate category), while the evenness index approaches 1.00 (stable category). These findings confirm that the waters at Pier 1 Kota Agung exhibit moderate biodiversity and favorable ecological conditions.

Family Biotic Index (FBI)

FBI values range from 3.81 to 3.86, with the highest recorded at Station I and the lowest at Station III. This range falls within the standard threshold of 3.76–4.25, indicating that the waters of Pier 1 Kota Agung are in excellent condition and capable of supporting aquatic life. The FBI values in this study reflect a stable macrobenthic community. The consistency of these values across stations suggests that the habitat remains suitable for macrobenthic organisms, as evidenced by the relatively low dominance index, indicating a well-balanced community structure.

CONCLUSION

Based on the study of the macrobenthic community at Pier 1 Kota Agung, the water quality is classified as good and supportive of aquatic life. This is evidenced by the Shannon-Wiener diversity index (H') ranging from 1.337 to 1.567, indicating moderate diversity; high evenness index (E) values (0.84–0.98), reflecting a uniform distribution of individuals; and low dominance index (D) values (0.24–0.37), suggesting the absence of a significantly dominant species. The Family Biotic Index (FBI) values between 3.81 and 3.86 further indicate that the waters are in good condition with low levels of organic pollution. Additionally, physical-chemical parameters such as temperature, brightness, depth, pH, and dissolved oxygen (DO) remain within the environmental quality standards set by Government Regulation No. 82 of 2001.

CONFLICT OF INTEREST

I hereby declare that there is no conflict of interest in writing this scientific work.

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