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Mapping the Level of Macrobenthic Diversity to Evaluate Environmental and Ecosystem Disturbances

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ABSTRACT

Pangpang Bay is used by the local community for aquaculture, traditional fishing and crabbing, drift net cage farming, and ecotourism. Macrobenthos, as key organisms in the food web and bioindicators of pollution due to their sessile nature and varying adaptability, were studied to assess the bay's ecological health. This research aimed to map macrobenthic diversity (Shannon-Wiener Diversity Index, Evenness Index, and Simpson Dominance Index) to evaluate environmental disturbance levels. This research was conducted from June to July 2025. Using purposive sampling, twelve observation stations were established across the bay, from the periphery to the central zone. Data were analyzed descriptively and visualized spatially via GIS (ArcGIS). This study recorded 33 macrobenthic species representing four classes and 25 families. Species richness varied considerably among stations, ranging from 5 species (Stations 5 and 9) to 22 species (Station 12). Results showed moderate pollution levels: Shannon-Wiener Index ($1.0 \leq H' \leq 3.0$) indicated intermediate diversity, consistent with moderately polluted waters. The Evenness Index ($e \approx 1$) revealed high uniformity, with no dominant species, suggesting balanced species distribution. Similarly, the Simpson Dominance Index ($D \approx 0$) confirmed the absence of dominance, aligning with high evenness. Overall, the study classifies Pangpang Bay as moderately polluted based on macrobenthic indices, highlighting the need for sustainable management to mitigate further degradation.

Keywords: ecological assessment, macrobenthos, Pangpang Bay, spatial analysis

INTRODUCTION

Pangpang Bay is one of the most important coastal areas in Banyuwangi Regency, serving as a major centre for marine fishing activities. The Bali Strait borders it to the east and the Indian Ocean to the south (Buwono, 2017). Pangpang Bay presents significant opportunities for marine aquaculture nd captured fisheries (Pramesti *et al.*, 2022). Currently, Pangpang Bay is used by the local community for aquaculture, traditional fishing, crabbing, and drift net cage farming (Suciyono *et al.*, 2024), and ecotourism (Rohaendi *et al.*, 2023).

Pangpang Bay is central to the local economy, supporting Muncar Fishing Port, artisanal and commercial fisheries, and downstream fish processing sectors. The direct consequence of this anthropogenic pressure is heightened environmental pollution, with significant impacts on biodiversity (Suciyono *et al.*, 2024). The observed impacts will substantially alter macrobenthic community structure in the affected habitats (Purba *et al.*, 2015).

Macrobenthos are sedentary animals (Rahayu *et al.*, 2023) that settle on the bottom

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of the water (Jayanti *et al.*, 2018). Responsive to shifts in water quality, making them useful as bioindicators for water quality (Adella, 2023). As bioindicators, macroinvertebrates possess ideal traits, including macroscopic visibility facilitating taxonomic identification, restricted dispersal maintaining site fidelity, and extended life spans that reflect cumulative environmental conditions. As benthic macroinvertebrates, macrozoobenthos function as foundational taxa in aquatic food webs, mediating energy transfer between trophic levels and maintaining ecosystem stability (Rahayu *et al.*, 2023). In addition, the level of macrozoobenthos diversity in aquatic environments can be used as an indicator of pollution or anthropogenic stress (Bendary *et al.*, 2023).

Furthermore, to determine the ecological value of Pangpang Bay, systematic mapping of the macrobenthic community structure using standard biodiversity indices (species diversity, evenness, and dominance) is required. This is the basis for establishing baseline data and monitoring ecosystem disturbance (Biswas & Mallik, 2015). Therefore, this study aims to map macrobenthic diversity (Shannon-Wiener Diversity Index, Evenness Index, and Simpson Dominance Index) to evaluate the level of environmental disturbance.

MATERIALS AND METHODS

Time dan Location

This research was conducted from June to July 2025. The sampling site is located in Pang-Pang Bay, Banyuwangi. The study employed a spatial sampling design with twelve stations systematically arranged along a gradient from the bay's periphery to its central region.

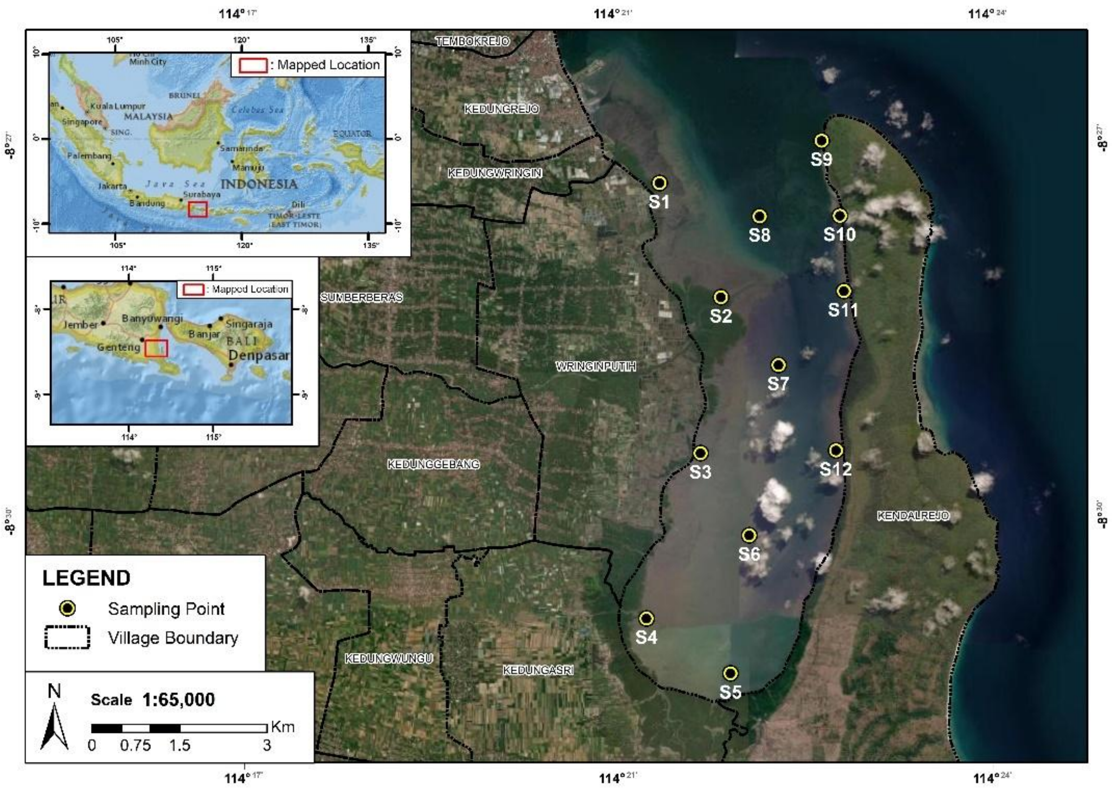

Figure 1. Site study of the essential area of Pangpang Bay, East Java.

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Materials and Equipment

The tools used in this study are an Ekman Grab with dimensions of 150 × 150 × 370 mm, a cool box to store samples before being analysed in the laboratory, a 10% formalin solution, a GPSmap Garmin 78s to determine the coordinates of sampling points, ziploc bags for storing biota, waterproof label paper, notebooks, and a macrozoobenthos identification book. The water quality parameters were measured using a thermometer, a dissolved oxygen meter, and sample bottles for laboratory analysis.

Preparation Sample

Macrozoobenthos samples were collected using an Ekman grab sampler (150 × 150 ×370 mm). All macrozoobenthic specimens were fixed in ziplock plastic bags with 70% ethanol to ensure optimal morphological preservation for laboratory analysis. The collected macrozoobenthic specimens were immediately preserved in situ using 70% ethanol in labelled, airtight ziploc bags. Each sample was subsequently identified at its respective sampling stations. In the laboratory, macrozoobenthic specimens were carefully extracted from their collection bags and gently rinsed with distilled water to remove sediment and debris while preserving the specimens. The specimens were examined using prepared sample loops and identified to the family level based on established taxonomic keys. Taxonomic identification of macrozoobenthos was conducted at the Fisheries Laboratory, University of 17 Agustus 1945 Banyuwangi, using standardized morphological identification keys from the books of Sabelli (1979), Dharma (2005), Edington and Hildrew (1981), Hawking and Smith (1997), Quigley (1977), and using the website from WoRMS (World Register of Marine Species), Waterbugkey, and Bugguide.

Data Analysis

The obtained data will be analysed descriptively based on the calculation results of the diversity index *Shannon-Wiener*, *Evenness*, and dominance index *Simpson* using the formula:

Diversity Index *Shannon-Wiener*:

To evaluate macroinvertebrate species diversity as a bioindicator of water pollution levels;

$$H' = -\sum \left(\frac{ni}{N}\right) \log \left(\frac{ni}{N}\right)$$

H' = Diversity Index
Ni = The number of individuals of species i
N = Total number of individuals

The calculated Shannon-Wiener diversity index values were cross-referenced with the pollution level classification criteria presented in Table 1.

Table 1. Shannon-Wiener diversity index range

H'	Level of Diversity	Level of water pollution
H' < 1,0	Low level of diversity	Severely polluted
1,0 ≤H'≥3,0	Moderate level of diversity	Moderately polluted
H' > 3,0	High level of diversity	Unpolluted

Evenness Index

To evaluate the evenness of macroinvertebrate species distribution within the community

$$e = \left(\frac{H'}{H\,max}\right) = \left(\frac{H'}{log2\,S}\right)$$

e = Evenness Index
H' = Diversity Index
Log2 S =3,3219 log S
S = Number of species

The evenness index was interpreted using these criteria:

e≈0: The community exhibited low evenness, with uneven species distribution, characterised by strong dominance of specific taxa

e≈1: The community shows high evenness, with no single species dominating and individuals evenly distributed across all species.

Dominance Index *Simpson*:

To evaluate the degree of dominance exhibited by a specific species

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

C = Dominance index
Ni = The number of individuals of species i
N = Total number of individuals

The dominance index was interpreted using these criteria:

D≈0: No single species dominates the community, and high species evenness is observed, as indicated by a high evenness index

D≈1: A single dominant species characterises the community, corresponding to a low evenness index

Following the calculation of the Diversity Index (H'), Evenness Index (e), and Dominance Index (D), the derived values were georeferenced and spatially interpolated using ArcGIS to generate thematic maps depicting the spatial distribution of each ecological index across the study area.

Water Quality Analysis

In-situ measurements include temperature and pH using thermometers and pH meters. Laboratory analysis measurements consist of dissolved oxygen, Total Organic Matter, and alkalinity using the titration method, Total ammonia Nitrogen, Nitrite orthophosphate using spectrophotometer methods, Nitrite using test kit methods, and Total Suspended solids using Gravimetry methods.

RESULTS AND DISCUSSIONS

Pangpang Bay comprises a mangrove-dominated wetland ecosystem spanning over 3,000 hectares. Designated as an Essential Ecological Area (EEA) of Indonesia, this site serves as a critical conservation zone for maintaining rich floral and faunal biodiversity (Suciyono *et al.*, 2024). The study area comprises 711 hectares of intact wetland habitat containing 11 identified mangrove species (Ariyanto *et al.*, 2020). The study area comprises Pangpang Bay (8 km length × 3.5 km width; 3,000 ha water area). The distribution patterns and abundance of macrozoobenthos in Pangpang Bay are presented in Table 2.

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Table 2. Macrobenthic abundance (ind/m²) across sampling stations in Pangpang Bay, Banyuwangi

	Family	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Gastrophod	Anabathridae	*Amphithalamus glabrus*	47	33	2	5	65	39		21			85	76
	Mangeliidae	*Mangelia sp.*							76			35		40
		Tenaturris fulgens					37							31
	Ringiculidae	*Ringicula auriculata*		17						11				
	Potamididae	*pirenella cinerascens*	31	19	17	9				17				
		Cerithidea cingulata	38	380	70	200					25	43		47
	Nassariidae	*Nassarius globosus*		67				97		42				138
		Nassarius gaudiosus						45	47		367	49		
		Nassarius pullus		89				87			43			
	Tornatinidae	*Acteocina mucronata*					84	54	68	16			103	163
	Cerithiidae	*Ittibittium parcum*											205	216
		Cerithium echinatum							257					286
	Columbellidae	*Anachis lyrata*					75							236
	Naticidae	*Natica marochiensis*									54		65	387
	Pyramidellidae	*Nisiturris fluminensis*		87										
	Neritidae	*Nerita lineata*	38			14	19							11
	Strombidae	*Laevistrombus canarium*	3											
	Batillariidae	*Batillaria zonalis*	12		17									
Bivalvia	Arcidae	*Anadara sp.*	12	14	11		35	45	56	32			37	39
	Veneridae	*Anomalodiscus squamosus*	43										45	45
		Paphia undulata	53										43	47
		Venus sp.											36	33
	Tellinidae	*Tellina sp.*		203				126	165		85	96	126	
	Veneridae	*Placamen sp.*					23						33	
	Mytilidae	*Mytilus sp.*									43			
	Semelidae	*Abra prismatica*		32		12						6		5
	Psammobiidae	*Hiatula chinensis*		12		14						7		3
	Pharidae	*Pharella javanica*		26		13						16		6
	Placunidae	*Placuna placenta*		13		24						8		13
	Mactridae	*Mactra grandis*		14		17						6		9
Polychaeta	Nereididae	*Platynereis sp.*		35		26						17		11
		Dendronereis pinnaticiris		32		15						12		11
Crustacea	Gecarcinidae	*Cardisoma carnifex*		43		22							17	23

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A total of 33 macrobenthic species, representing four classes and 25 families, were recorded in this study. Species richness varied considerably among stations, ranging from 5 species at Stations 5 and 9 to 22 species at Station 12. The reduced macrozoobenthic abundance in natural mangrove areas appears strongly influenced by anthropogenic pressure, particularly sustained harvesting of molluscs by local communities for subsistence purposes (Purba *et al.*, 2015).

Species abundance analysis in Pangpang Bay revealed *Cerithidea cingulata* as the dominant macroinvertebrate species. This gastropod exhibited preferential distribution in permanently inundated substrate habitats, consistent with its known ecological preferences. *Cerithidea cingulata* demonstrated clear habitat preferences for open-canopy mangrove zones with muddy substrates. The species *Cerithidea cingulata* is the most dominant type of Gastropoda from the Potamididae family at the research site. This distribution pattern likely reflects the predominance of muddy substrates at the study site, where *Cerithidea cingulata* typically lives in liquid mud that provides nutrition (Nurfitriani *et al.*, 2019). These findings align with Al Idrus *et al.* (2021), who identified *Cerithidea cingulata* as both a dominant species in mangrove ecosystems and the dominant gastropod in these communities. As documented, *Cerithidea cingulata* primarily exhibits epifaunal behaviour, inhabiting mud substrate surfaces where it maintains a crawling locomotion pattern. *Cerithidea cingulata* dominated the other species across all research stations. According to Purba *et al.* (2015), this dominance can be attributed to its nature as a benthic species that thrives in muddy substrates, such as those commonly found in ponds

Water Quality Conditions

Based on the results of physical and chemical water quality measurements in Pangpang Bay, Banyuwangi, compared to the quality standards of Kepmen LH No 51 of 2004 for marine biota, the parameters that exceeded the threshold were Total Ammonia Nitrogen at stations 8 and 10, Nitrite at all stations except station 4, Nitrate and Orthophosphate at all stations, and Total Organic Matter at station 6. Ammonia levels in seawater vary greatly and can change rapidly. Ammonia can be toxic to biota if its concentration exceeds the maximum threshold. Nitrate-nitrogen concentrations of more than 0.2 mg/l can cause eutrophication (enrichment) of water bodies and subsequently stimulate rapid growth of algae and aquatic plants (blooming). In addition to natural sources, phosphate inputs into water bodies are caused by human activities (anthropogenic), such as domestic waste disposal, runoff from agricultural activities, and industrial waste (Badamasi *et al.*, 2019).

Table 3. Water Quality Measurement Result

Stations	(◦C)	pH	DO (mg/L)	Alkalinity (mg/L)	TAN (mg/L)	Nitrit (mg/L)	Nitrat (mg/L)	TSS (mg/L)	Ortofosfat (mg/L)	TOM (mg/L)
1	29	7,7	8,94	164	0,031	0,079	10	0,19	0,037	48,96
2	28	7,7	8,13	140	0,015	0,125	15	0,05	0,064	51,264
3	28	7,6	7,72	140	0,031	0,081	10	0,52	0,045	43,792
4	30	8,4	8,2	152	0,232	0,025	10	0,65	0,091	49,296

Continued on next page

Stations	(◦C)	pH	DO (mg/L)	Alkalinity (mg/L)	TAN (mg/L)	Nitrit (mg/L)	Nitrat (mg/L)	TSS (mg/L)	Ortofosfat (mg/L)	TOM (mg/L)
5	30	8,4	7,8	124	0,267	0,105	10	0,68	0,049	51,842
6	30	8,4	7,6	144	0,241	0,125	10	0,81	0,032	60,672
7	31	8,5	7	124	0,201	0,088	10	0,45	0,133	49,072
8	30	8,5	6,7	112	0,317	0,091	10	0,49	0,02	48,032
9	30	8,5	7,1	135	0,241	0,081	10	0,56	0,09	54,742
10	30	8,4	8,7	120	0,331	0,086	15	0,55	0,102	53,088
11	30	8,4	8	152	0,031	0,085	15	0,43	0,043	53,296
12	30	8,4	7,5	124	0,232	0,117	10	0,5	0,062	52,842
Quality standard	28 – 32	7 – 8,5	>6	30 – 500	0,3	0,001 – 0.06	0,008	80	0,015	≤55

The Diversity, Evenness, and Dominance Index

Based on field observations, Stations 12, 11, 6, 2, and 5 supported the healthiest macrobenthic communities, reflected by relatively high diversity, high evenness, and low dominance (Table 4).

Table 4. The Diversity, Evenness, and Dominance Index

Index	Stasiun											
	1	2	3	4	5	6	7	8	9	10	11	12
Diversity (H’)	2,018	2,219	1,160	1,759	1,819	1,855	1,586	1,692	1,167	1,714	2,168	2,388
Evenness (e)	0,918	0,783	0,721	0,708	0,935	0,953	0,885	0,869	0,725	0,744	0,904	0,773
Dominance (D)	0,144	0,172	0,409	0,313	0,178	0,170	0,244	0,202	0,392	0,179	0,139	0,113

Source: Research Results, 2025

Conversely, Stations 3 and 9 exhibited the poorest community structures, with low diversity and evenness but high dominance, indicating that a few species were disproportionately abundant. The other stations (1, 4, 7, 8, and 10) showed intermediate characteristics, representing moderate or transitional ecological conditions. Based on the diversity index values across all stations ($1.0 \leq H' \leq 3.0$), the macrozoobenthos community exhibits moderate diversity. The evenness index approaches $e \approx 1$, indicating high species evenness and an equitable distribution of individuals among species, with no single species dominating. Similarly, the dominance index ($D \approx 0$) confirms the absence of dominant species, consistent with the high evenness observed.

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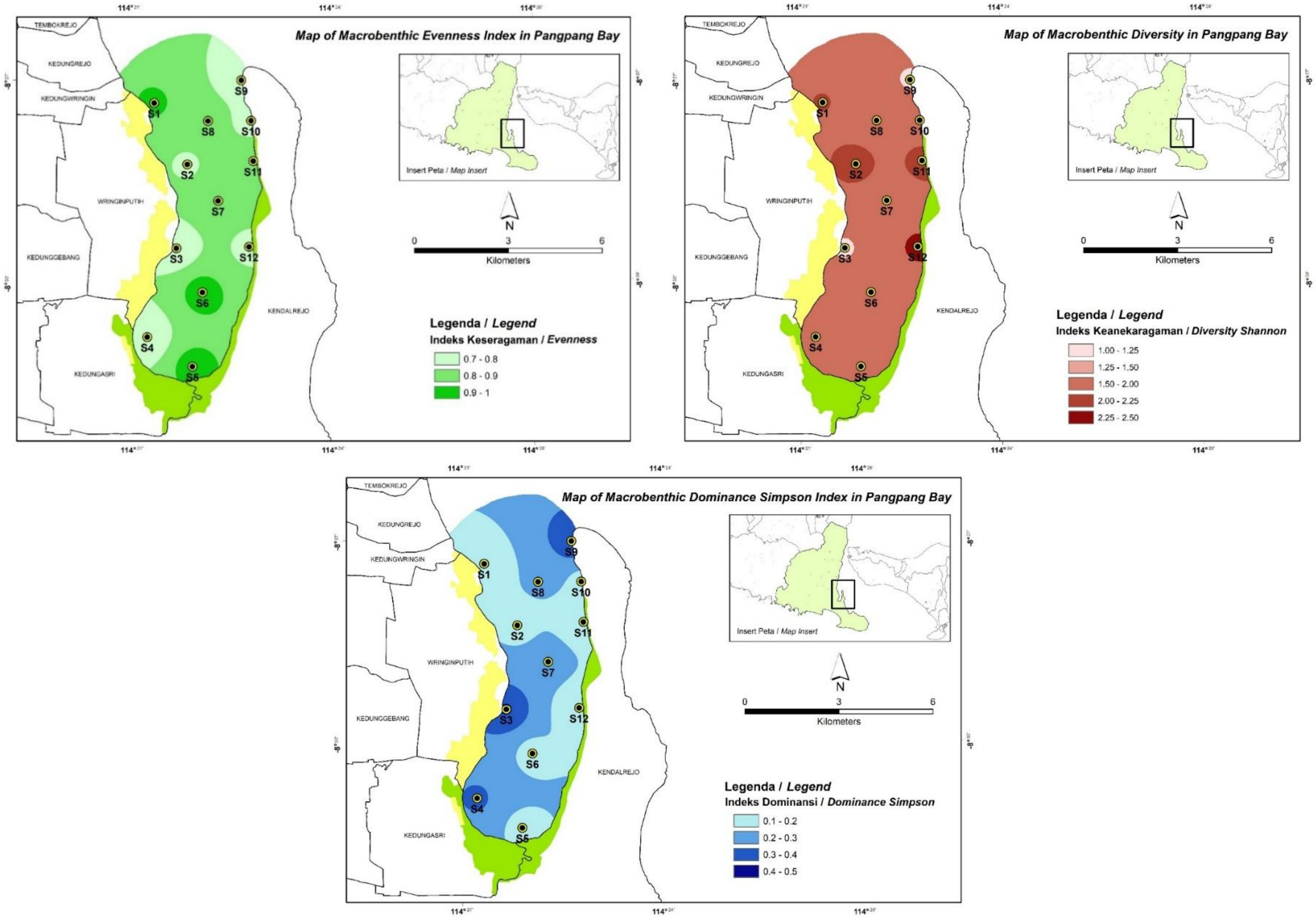

Figure 2. Map of Macrobenthic Diversity Shannon, Evenness, and Simpson Index in Pangpang Bay

Among the twelve stations, Station 3 around the vaname shrimp farming area exhibited the lowest diversity index (H' = 1.160). This reduced diversity was attributed to the dominance of *C. cingulata*, supported by a low evenness value (< 1) and the highest dominance index (D = 0.409) recorded. A low evenness value reflects an uneven distribution of individuals among species, indicating ecological dominance by *C. cingulata*. Such dominance suggests that this species may outcompete others, possibly due to a population surge or preferential access to resources like food in the area. *C. cingulata* exhibited the highest dominance value, indicating its competitive superiority over other organisms. According to Silaen *et al.* (2015) this species typically occurs in greater abundance in perpetually inundated substrates.

Its ecological preference appears to favour open mangrove habitats with muddy substrates. The highest diversity index value (H' = 2.388) was recorded at Station 12, which is distant from the vaname shrimp farming area and urban sources of pollution, indicating moderate species diversity. As a key parameter for assessing community stability, this higher diversity value suggests greater ecological stability in the area (Liu *et al.,* 2021). According to Muhtar et al. (2024), a diversity index value in the range of 1.0 < H' < 3.322 indicates moderate species diversity, reflecting adequate productivity, relatively stable ecosystem conditions, and moderate ecological pressure.

On the contrary, station 3 showed the highest dominance index value among all stations, indicating relatively stable dominance conditions. The dominance index indicates whether certain macrozoobenthos species dominate an aquatic environment. Odum (1993), A value approaching 0 indicates no single species dominates the aquatic environment, suggesting equal opportunity among all individuals to utilise available resources at the observation site. Based on the analysis of macrobenthos' diversity, evenness, and dominance index in Pang-pang Bay, the study site is classified as moderately polluted.

The measured concentrations of total ammonia nitrogen, nitrite, nitrate, orthophosphate, and organic matter all surpassed established water quality standards for protecting marine ecosystems, corroborating this finding. This study underscores the urgent need for sustainable coastal management strategies to mitigate further ecological degradation. The findings provide valuable baseline data for future monitoring programs and contribute to understanding anthropogenic impacts on tropical coastal ecosystems.

CONCLUSION

Based on the research findings, the overall condition of Pang-Pang Bay can be categorized as moderately polluted, as indicated by the moderate level of species diversity. The community structure shows high evenness, with no single species dominating, and this pattern is further supported by the low dominance observed in the macrobenthic assemblage.

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AUTHORS' CONTRIBUTION

SHY: Methodology, Investigation, Formal analysis, Supervision. ASW: Investigation, Data Tabulation, Validation. AFF: Formal analysis, Data curation

CONFLICT OF INTEREST

There is no conflict of interest in this manuscript between all authors upon writing and publishing this manuscript.

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REFERENCES

Adella, C. T. (2023). Identification of Macrozoobentos in the Upstream of the Brantas River, Blitar. Jurnal Perikanan Pantura, 6(2), 333.

Al Idrus, A., Hidayati, B. N., Ajizah, E., Ilahi, W. B., & Syukur, A. (2021). The improvement of molluscs population: as a parameter of success of local scale mangrove conservation on the south coast of Lombok. In IOP Conference Series: Earth and Environmental Science, 913(1), 012047.

Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33–64.

Badamasi, H., Yaro, M. N., Ibrahim, A., & Bashir, I. A. (2019). Impacts of phosphates on water quality and aquatic life. Chem. Res. J, 4(3), 124-133.

Bendary, R. E., Ibrahim, S. M., Goher, M. E., Elsaied, H. E., El Shabrawy, G. M., El Mordy, M. A., & Khalil, M. T. (2023). Taxonomic and functional structure of macrobenthic invertebrate communities and their response to environmental variables along the subbranches of the Nile River (rayahs), Egypt. Environmental Science and Pollution Research, 30(11), 28803-28817.

Biswas, S. R., & Mallik, A. U. (2015). Species diversity and functional diversity relationship varies with disturbance intensity. Ecosphere, 2(4), 1–10.

BugGuide. (2025). BugGuide: Identification, images, & information for insects, spiders & their kin for the United States & Canada. Iowa State University, Department of Entomology. Retrieved June 2025, from https://bugguide.net

Buwono, Y. R. (2017). Identifikasi Dan Kerapatan Ekosistem Mangrove Di Kawasan Identification and Density Mangrove Ecosystem in the Areas Pangpang Bay. Samakia: Jurnal Ilmu Perikanan, 8(1), 32–37.

Dharma, B. (2005). Recent & Fossil Indonesian Shells. ConchBooks, Hackenheim.WoRMS Editorial Board. (2023).

Edington, J. M. (1981). A Key to the Caseless Caddis Larvae of the British Isles. Freshwater Biological Association, Ambleside.

Hawking, J. H., & Smith, F. J. (1997). Colour Guide to Invertebrates of Australian Inland Waters. Murray–Darling Freshwater Research Centre, Albury.

Jayanti, A. D., Fachrul, M. F., & Hendrawan, D. (2018). Makrozoobentos as bioindicator water quality of Krukut River, Depok, West Java, Indonesia. IOP Conference Series: Earth and Environmental Science, 106(1).

Kepmen LH No 51. (2004). Keputusan Menteri Negara Lingkungan Hidup No 51 Tahun 2004 tentang Baku Mutu Air Laut. Lembaran Negara Republik Indonesia, 51, 1–8.

Liu, Y., Zhang, M., Peng, W., Qu, X., Zhang, Y., Du, L., & Wu, N. (2021). Phylogenetic and functional diversity could be better indicators of macroinvertebrate community stability. Ecological Indicators, 129, 107892.

Muhtar, M., Sjam, S., Dewi, V. S., & Rosmana, A. (2024). Arthropods Diversity in Insectary Plant on Cocoa Cultivation Ecosystems. In BIO Web of Conferences, 96, 06003.

Murray–Darling Freshwater Research Centre. (2023). The Waterbug key: Interactive identification of freshwater macroinvertebrates. Retrieved June 2025, from https://www.waterbugkey.org.au

Nurfitriani, S., Lili, W., Hamdani, H., & Sahidin, A. (2019). Density effect of mangrove vegetation on gastropods on Pandansari mangrove ecotourism forest, Kaliwlingi Village, Brebes Central Java. World Scientific News, (133), 98-120.

Odum EP. 1993. Fundamentals of Ecology. Gadjah Mada University Press, Yogyakarta. [Indonesian]

Pramesti, F. F., Sulmartiwi, L., & Andriyono, S. 2022. Molecular Identification of Grouper Fish (Perciformes: Serranidae) Landed From Pangpang Bay, Banyuwangi. Journal of Tropical Marine Science, 5(2), 98-103.

Purba, H. E., Djuwito, & Haeruddin. (2015). Distribution and Diversity of Macrozoobentos at Mangrove Conservation Land at Timbul Sloko Village Sayung Subdistrict Demak Regency. Diponegoro Journal of Maquares, 4, 57–65.

pISSN 2550-0910; eISSN 2579-4817
Available online at https://e-journal.unair.ac.id/JoAS

Quigley, M. (1977). Invertebrates of Streams and Rivers: A Key to Identification. Edward Arnold, London

Rahayu, R. N., Rohyani, I. S., Jupri, A., Savira, D., Genggelang, F. A., & Indriana, R. (2023). Identification of Diversity Macrobenthos as a Bioindicator of Seawater Quality in Teluk Dalem Beach and Senggigi Beach. Jurnal Biologi Tropis, 23(1), 531-538.

Rohaendi, Nendi, Setiawan, F Iwan, Budiyono, Arif, Harmoko, Antonius Alex, W. (2023). Geologi Dan Model Kolaborasi Pengambangan Geopark Ijen, Di Kabupaten Banyuwangi. Geominerba, 8(2), 166–179.

Sabelli, B. (1979). Simon & Schuster's Guide to Shells. Simon & Schuster, New York.

Silaen, I. F., Hendrarto, B., & Nitisupardjo, M. (2015). Distribusi Dan Kelimpahan Gastropoda Pada Hutan Mangrove Teluk Awur Jepara. Management of Aquatic Resources Journal, 2(3), 93–103.

Suciyono, Kenconojati, H., Ulkhaq, M. F., Anggreani, S. F., Santanumurti, M. B., Kadim, M. K., Arbi, U. Y., Amran, R. H., & Imlani, A. H. (2024). Profile of Pangpang Bay (Banyuwangi, Indonesia) based on water, sediment type, and macrobenthic diversity. Egyptian Journal of Aquatic Research, 50(3), 414–423.

World Register of Marine Species. Retrieved June 2025, from https://www.marinespecies.org