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ORIGINAL

Assessment of Intertidal Macroinvertebrate Communities in Pandanan, Sultan Naga Dimaporo, Lanao del Norte

Evaluación de comunidades de macroinvertebrados intermareales en Pandanan, Sultan Naga Dimaporo, Lanao del Norte

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ABSTRACT

Biodiversity, or biological diversity, encompasses the variety of life across all levels of biological organization and serves as a key indicator of ecosystem health. In the context of increasing environmental pressures, evaluating biodiversity is essential for understanding the status and sustainability of natural resources. This study investigated the abundance and diversity of macroinvertebrates in the intertidal zone of Pandanan, Sultan Naga Dimaporo, Lanao del Norte. Findings revealed that cone shells (*Conus* spp.) were the most dominant species, with 646 individuals accounting for 31 % of the total recorded organisms. The ark shell (*Arca antiquata* Linne) and frog shell (*Bursina nobilis*) followed, with populations of 495 (23,78 %) and 215 (10,36 %), respectively. Environmental parameters—salinity, pH, humidity, temperature, and total dissolved solids (TDS)—were found to be within tolerable ranges, supporting favorable conditions for marine life. Diversity indices indicated that station 2 exhibited the highest species richness among the sampled sites. These results highlight the ecological value of the intertidal zone and underscore the need for targeted conservation and management efforts. Additionally, it is recommended that contributory river systems be assessed, as upstream pollution may influence water quality and threaten coastal biodiversity.

Keywords: Biodiversity; Intertidal Zone; Macroinvertebrates; Intertidal Zone; Species Abundance; Coastal Ecosystem.

RESUMEN

La biodiversidad, o diversidad biológica, abarca la variedad de vida en todos los niveles de organización biológica y sirve como un indicador clave de la salud del ecosistema. En el contexto de crecientes presiones ambientales, evaluar la biodiversidad es esencial para comprender el estado y la sostenibilidad de los recursos naturales. Este estudio investigó la abundancia y diversidad de macroinvertebrados en la zona intermareal de Pandanan, Sultan Naga Dimaporo, Lanao del Norte. Los hallazgos revelaron que las conchas de cono (Conus spp.) fueron las especies más dominantes, con 646 individuos que representan el 31 % del total de organismos registrados. Le siguieron la concha de arca (Arca antiquata Linne) y la concha de rana (Bursina nobilis), con poblaciones de 495 (23,78 %) y 215 (10,36 %), respectivamente. Los parámetros ambientales (salinidad, pH, humedad, temperatura y sólidos disueltos totales [TDS]) se encontraron dentro de rangos tolerables, lo que respalda condiciones favorables para la vida marina. Los índices de diversidad indicaron que la Estación 2 presentó la mayor riqueza de especies entre los sitios muestreados. Estos resultados resaltan el valor ecológico de la zona intermareal y subrayan la necesidad de implementar medidas específicas de conservación y gestión. Además, se recomienda evaluar los sistemas fluviales contribuyentes, ya que la contaminación aguas arriba puede afectar la calidad del agua y amenazar la biodiversidad costera.

Palabras clave: Biodiversidad; Zona Intermareal; Macroinvertebrados; Zona Intermareal; Abundancia de Especies; Ecosistema Costero.

INTRODUCTION

Biodiversity is fundamental to the functioning and resilience of ecosystems. It sustains essential services such as water purification, pollination, climate regulation, and food security, all of which are vital for human well-being. Ecosystems rich in biodiversity are more adaptable to environmental changes, enhancing their capacity to maintain ecological balance and support human livelihoods. Recent research underscores the importance of biodiversity in stabilizing ecosystem services and promoting human health.[1,2]

Global and national initiatives, including the Convention on Biological Diversity, have intensified efforts to protect biodiversity in response to its rapid decline due to climate change, habitat degradation, pollution, and overexploitation.[3,4] Moreover, the interconnectedness of biological and cultural diversity highlights how ecosystems and societies co-evolve within complex socio-ecological systems.[5,6] Thus, preserving biodiversity is not only a conservation goal but also a cornerstone of sustainable development and environmental integrity in the face of growing anthropogenic pressures.[7,8]

One of the most dynamic and ecologically important habitats for biodiversity assessment is the intertidal zone between high and low tide lines. It is typically divided into three subzones: high, mid, and low intertidal. These zones vary in terms of exposure to air, moisture, and temperature, directly influencing species composition and distribution. The low intertidal zone, being submerged most of the time, generally harbors the greatest biodiversity due to its relatively stable conditions, while the high intertidal zone experiences longer exposure, posing challenges to organism survival.[9] Marine organisms in these areas must cope with fluctuating salinity, temperature, oxygen levels, and wave action, all which shape community structure and ecological dynamics.

Globally, the decline in biodiversity is alarming, with intertidal habitats particularly vulnerable due to their exposure to both marine and terrestrial stressors.[10] Species diversity in these zones serves as a key indicator of ecosystem health and resilience, reflecting a system's capacity to withstand environmental changes and maintain function.[11] Regular assessments of intertidal biodiversity are thus crucial for informing conservation strategies and managing coastal ecosystems sustainably.

In the Philippines, Sultan Naga Dimaporo in Lanao del Norte is a coastal municipality rich in marine biodiversity, especially along Illana Bay. Of its 37 barangays, 16 are coastal, including Barangay Pandanan, which features a wide intertidal zone used by local communities for subsistence activities such as shellfish gathering. Despite its ecological and economic importance, there is limited scientific data on the biodiversity and environmental conditions of this area. This knowledge gap hinders effective management and conservation planning.

To address this, the present study aims to determine the abundance and diversity of macroinvertebrates in the intertidal zone of Barangay Pandanan and to analyze how selected environmental factors—salinity, pH, temperature, humidity, and total dissolved solids (TDS)—influence species distribution and abundance. The study also seeks to generate baseline ecological data that can support coastal conservation efforts, environmental impact assessments, and biodiversity management strategies. Ultimately, its findings will contribute to a deeper understanding of how intertidal biodiversity responds to environmental variability, both natural and anthropogenic, serving as a foundation for future ecological research and policy development.

Characterization of the study area

This study was conducted in Barangay Pandanan, located in the municipality of Sultan Naga Dimaporo, Lanao del Norte, on the island of Mindanao, Philippines. Geographically, Pandanan is situated at approximately 7,8251°N latitude and 123,6388°E longitude, with an estimated elevation of 6,6 meters (21,7 feet) above mean sea level.

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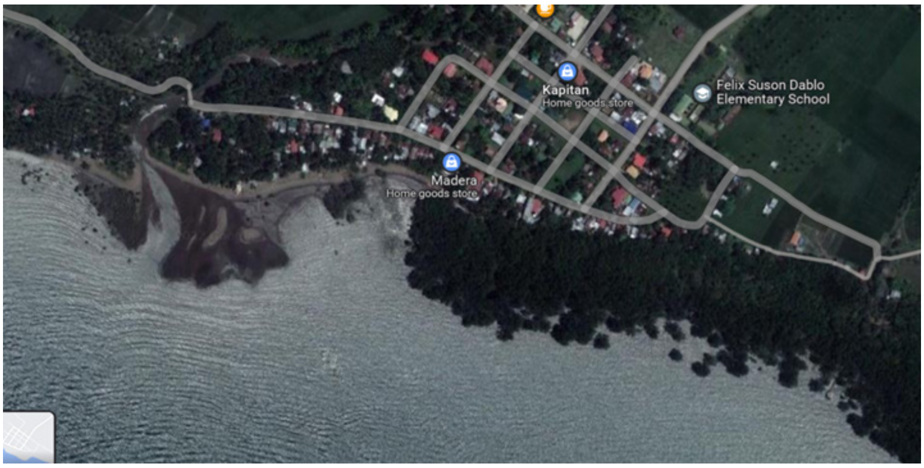

Figure 1. Map of the location of the study

Sampling

The sampling for this study was conducted exclusively during low tide to ensure maximum exposure of the intertidal zone and facilitate accurate macroinvertebrate identification and environmental measurements. Data collection was carried out on three separate occasions, following the lowest tide levels of the month, to enhance consistency and reliability in species observation. Sampling times were carefully planned to coincide with peak low tide events, allowing for optimal accessibility to all designated plots and minimizing potential tidal disturbances during data collection.

The study utilized nine (9) permanent plots, each measuring 1,5 × 1,5 meters, strategically placed across different sections of the intertidal zone. These plots were distributed as follows:

- Three (3) plots near the coastline (one at each end and one in the middle).
- Three (3) plots in the middle of the intertidal zone (one at each end and one in the middle).
- Three (3) plots farthest from the coastline (one at each end and one in the middle).

The littoral zone served as the reference point for quadrant placement, ensuring a standardized approach to sampling. A 50-meter distance was maintained between each quadrant to prevent overlapping data and to provide a representative assessment of species distribution within the intertidal habitat.

Within each plot, macroinvertebrate species were surveyed, and relevant environmental parameters such as salinity, pH, humidity, water temperature, and total dissolved solids (TDS) were recorded. The spatial distribution of the sampling plots is illustrated in figure 2.

Conducting the sampling during the lowest tide periods was critical in ensuring that the entire range of intertidal organisms, including those that are typically submerged at higher tide levels, could be accurately identified and counted. This approach also minimized the risk of data inconsistencies caused by tidal fluctuations, thereby providing a more reliable assessment of biodiversity and environmental conditions in the study area.

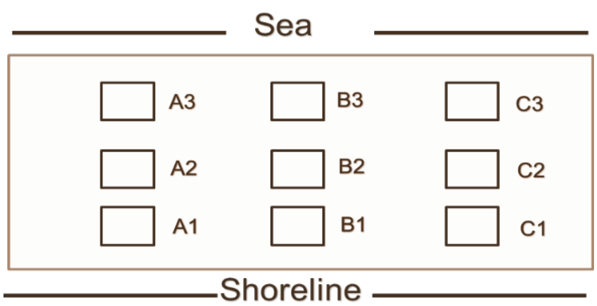

Figure 2. Sampling design of the study

Data Collection

All visible macroinvertebrates were considered during the data collection. Individual samples identified by their common name. The identification of the common name was made possible by the two residents in the community who assisted the researchers during the conduct. Factors such as water salinity, pH level, humidity, temperature and total dissolved solid were measured with respective instruments or meters. The information gathered was tallied. In the data collection, quadrants were used. Quadrants are square frames with an internal grid that were used for sampling the distribution of plants and animals in a particular area.

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Biodiversity Indices

Simpson's Index

Simpson (1949) developed an index of diversity which is a measure of probability--the less diversity, the greater the probability that two randomly selected individuals will be the same species. In the absence of diversity (1 species), the probability that two individuals randomly selected will be the same is 1. Simpson's Index is calculated as follows:

$$D = \sum_{i=1}^{S} \left(\frac{n_i}{N}\right)^2$$

Where:
ni is the number of individuals in species i.
N = total number of individuals of all species.
ni/N = pi (proportion of individuals of species i).
S = species richness.

The value of Simpson's D ranges from 0 to 1, with 0 representing infinite diversity and 1 representing no diversity, so the larger the value of D, the lower the diversity. For this reason, Simpson's index is often as its complement (1-D). Simpson's Dominance Index is the inverse of the Simpson's Index (1/D).

Shannon-Wiener Index

Another widely used index of diversity that also considers both species richness and evenness is the Shannon-Weiner Diversity Index, originally proposed by Claude Shannon in 1948. It is also known as Shannon's diversity index. The index is related to the concept of uncertainty. If, for example, a community has very low diversity, we can be certain of the identity of an organism we might choose randomly (high certainty or low uncertainty). If a community is highly diverse and we choose an organism at random, we have a greater uncertainty of which species we will choose (low certainty or high uncertainty).

$$H = -\sum_{i=1}^{S} p_i * \ln p_i$$

Where:
pi = proportion of individuals of species i
ln is the natural logarithm
S = species richness.

The value of H ranges from 0 to Hmax. Hmax is different for each community and depends on species richness. (Note: Shannon-Weiner is often denoted H').

Evenness Index

Species evenness refers to how close in numbers each species in an environment is. So, if there are 40 foxes and 1000 dogs, the community is not very even. But if there are 40 foxes and 42 dogs, the community is quite even. The evenness of a community can be represented by Pielou's evenness index (Pielou 1966)

$$J = \frac{H}{H_{\max}}$$

The value of J ranges from 0 to 1. Higher values indicate higher levels of evenness. At maximum evenness, J = 1. J and D can be used as measures of species dominance (the opposite of diversity) in a community. Low J indicates that 1 or few species dominate the community.

RESULTS AND DISCUSSION

Species found in the Intertidal Zone of Pandanan, Sultan Naga Dimaporo, Lanao del Norte

Table 1 presents the frequency and percentage distribution of species identified in the intertidal zone of Barangay Pandanan, Sultan Naga Dimaporo, Lanao del Norte. The most abundant species was Daro-daro (Cone shell, Conus sp.), with 646 individuals, comprising 31 % of the total macroinvertebrate population recorded in the area. This species also exhibited high species richness, being present in nearly all nine quadrats sampled.

Following the Cone shell in abundance were Litob (Ark shell, Arca antiquata Linnaeus), with 495 individuals (23,78 %), and Guba-guba (Frog shell, Bursina nobilis), with 215 individuals (10,36 %). Other notable species observed included: Sea star (Nordoa galatheae, 119 individuals, 5,72 %), Liswi or Strawberry conch (Strombus luhuanus Linnaeus, 109, 5,24 %), Hermit crab (Dardanus megistos, 77, 3,70 %), Suso or snail (Potamides sp., 63, 3,03 %), Bulan-bulan or Moon snail (Polinices peselephanti, 45, 2,16 %), Sikad-sikad or Plicate conch (Strombus labiatus, 40, 1,92 %), Bungkawil or Dog conch (Strombus canarium, 38, 1,83 %), Sand dollar (Peronella lesueuri, 26, 1,25 %), Burnay or small white Venus clam (Meretrix lyrata, 26, 1,25 %), Saang or Spider conch (Lambis lambis Linnaeus, 25, 1,20 %), Balat or Sea cucumber (Neothyonidium magnum, 16, 0,77 %), and Habasan or Olive shell (Oliva annulate Gmelin, 10, 0,48 %).

Additionally, species with relatively low population counts included Taktakon (Ribbed turban snail, Turbo intercostalis), Tagmanok (Wing shell, Cyrtopleura costata), and Kumong-kumong (Fiddler crab, Uca rapax), which were observed only in limited quadrats.

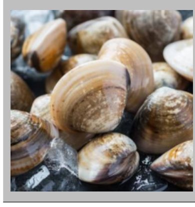
The presence of these diverse marine organisms reflects the biological richness of the intertidal zone. However, while species abundance and diversity are generally positive indicators, they do not necessarily equate to ecosystem health without further ecological context. A diverse assemblage of organisms supports a more complex and stable food web, enhancing energy flow and nutrient cycling within the ecosystem.

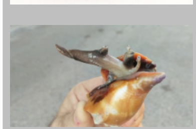
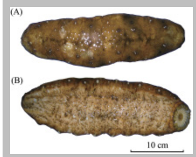
The abundance of marine species in intertidal zones is largely shaped by environmental conditions and ecological dynamics. These habitats are characterized by unique and often extreme conditions—such as tidal fluctuations, salinity changes, and varying wave exposure—that significantly influence species distribution and community structure.(12) Climatic variations have been shown to affect species abundance and distribution, highlighting both the resilience and vulnerability of intertidal communities.(13,14)

Macrobenthic organisms, such as those documented in this study, serve as effective indicators of ecological health. Previous studies affirm that intertidal zones are biodiversity hotspots, supporting high species richness and serving important ecological functions.(15,16) The presence of microalgae and bacteria associated with seaweed further enhances nutrient cycling and ecosystem productivity.(17,18)

Nonetheless, intertidal ecosystems face growing threats from anthropogenic activities, including pollution, habitat degradation, and the broader impacts of climate change. These stressors undermine the stability and persistence of marine life in these zones, making it imperative to implement effective conservation and management strategies.(19,16)

Table 1. Macroinvertebrates organism Dominance found in the Intertidal Zone of Pandanan, Sultan Naga Dimaporo

Common Name		English Name	Scientific Name	Family	Frequency	Percentage
	Daro-daro	Cone shell	Conus sp	Conidae	646	31,00
	Litob	Ark shell	Arca antiquata Linne	Arcidae	495	23,78
	Guba-guba	Frog shell	Bursina nobilis	Bursidae	215	10,36
	Balinsala	Small bivalve clams	-	Veneridae	124	5,96

	Seastar	Sea stars	Nardoa galatheae	Asteriidae	119	5,72
	Liswi	Strawberry conch	Strombus luhuanus Linne	Strombidae	109	5,24
	Hermit Crab	Hermit crab	Dardanus megistos	Paguroidae	77	3,70
	Suso	snail	Potamides sp	Potamidae	63	3,03
	Bulan-bulan	Moon snail	Polinices peselephanti	Naticidae	45	2,16
	Sikad-sikad	Plicate conch	Strombus labiatus	Strobidae	40	1,92
	Bungkawil	Dog conch	Strombus canarium	Strombidae	38	1,83
	Sand Dollar	Sand dollar	Peronella lesueuri	Echinarachniidae	26	1,25
	burnay	Small white venus clam	Meretrix lyrata	Veneridae	26	1,25
	Saang	Spider conch	Lambis lambis Linne	Strombidae	25	1,20
	balat	Sea cucumber	Neothyonidium magnum	Holothuriidae	16	0,77
	Habasan	Olive shell	Oliva annulate Gmelin	Olivadae	10	0,48

	Kumong-kumong	Fiddler crabs	Uca rapax	Ocypodidae	4	0,19
	Tagmanok	Wing shell	Cyrtopleura costata	Pholadidae	3	0,14
	Taktakun	Ribbed turban snail	Turbo intercostalis	Turbinidae	1	0,05
			TOTAL		2082	100 %

Diversity indices of the macroinvertebrates in the intertidal zone

Species diversity serves as a vital parameter for comparing ecological communities, particularly in the context of biotic disturbances, ecological succession, and overall community stability. Table 2 presents the diversity indices of macroinvertebrate communities across the three study stations. Simpson's Diversity Index, which accounts for both species richness and evenness, was used to assess the ecological diversity within these zones. Among the stations, Station 1 exhibited the highest species diversity, followed by Station 3 and Station 2. This suggests that Station 1 harbors the richest and most stable intertidal community, as evidenced by its larger total population count.

Diversity indices, such as Simpson's Index and the Shannon-Wiener Index, are widely utilized in ecological research to evaluate community structure and health. These indices offer insights into species composition, distribution, and ecological balance within an environment.[20] In particular, they are instrumental in identifying the impacts of both natural variability and anthropogenic disturbances. For instance, research conducted in the Antarctic intertidal zone has demonstrated significant seasonal variation in macrobenthic assemblages, yet a notable level of biodiversity persists despite harsh environmental conditions.[20] Similarly, studies in Cheonsu Bay, Korea, have shown that macroinvertebrate diversity and benthic ecological quality are highly responsive to nutrient enrichment and other human-induced stressors, reflecting the sensitivity of these indices to environmental change.[21]

The presence, distribution, and abundance of specific taxa, when analyzed alongside overall diversity metrics, serve as reliable indicators of ecosystem health and resilience. These findings reinforce the ecological importance of macroinvertebrate communities in maintaining balance and functionality within intertidal zones. The complex interplay between biological diversity and environmental factors emphasizes the need for continuous monitoring and assessment to ensure the long-term sustainability of these vulnerable and dynamic ecosystems.

Table 2. Diversity indices of the macroinvertebrates in the intertidal zone of Pandanan, Sultan Naga Dimaporo, Lanao del Norte

Station	Dominance_D	Simpson_1-D	Shannon-Weiner (H)	Evenness_e^H/S	Richness (number of species)	Total Population	Average population size
1	0,25	0,75	1,92	0,40	17	641	37,7
2	0,16	0,83	2,04	0,64	12	769	64,1
3	0,17	0,83	2,09	0,62	13	672	51,7

Environmental Factors Affecting Macroinvertebrates Species Diversity in the Intertidal Zone

Table 3 presents the abiotic parameters influencing species diversity in the intertidal zone of Pandanan, Sultan Naga Dimaporo, Lanao del Norte. The key environmental factors assessed include salinity, pH level, humidity, temperature, and total dissolved solids (TDS). These parameters play a crucial role in determining the abundance and distribution of macroinvertebrates and other marine organisms within the intertidal zone.

Three sampling stations were examined in the study. The salinity levels among the stations showed slight variations but remained within the typical marine range, with an average salinity of 30,39 parts per thousand (ppt). This suggests that the salinity levels in the study area are within acceptable limits for marine life, thereby supporting the survival of diverse macroinvertebrate species.

The pH levels across the three stations were also consistent, averaging 7,28. On the pH scale (0–14), this value indicates a near-neutral environment, which is neither too acidic nor too basic. Such pH conditions are favorable for marine organisms, as they do not impose physiological stress that could negatively impact growth or reproduction.

Humidity levels were recorded at 69,89 % for Station 1, 64,87 % for Station 2, and 64,89 % for Station 3. While these figures reflect a humid coastal environment, they remain below the saturation point of 100 %, which typically leads to condensation. High humidity levels, when paired with elevated temperatures, may contribute to storm formation, though in this context, humidity mainly influences the microclimate of the intertidal habitat.

The recorded average temperature across the three stations was 30,37˚C. Temperature is a critical environmental variable, as it affects metabolic rates, species distribution, dissolved oxygen levels, and chemical reaction rates in marine ecosystems.[22] The observed temperature is within the tolerable range for many marine organisms, making the area suitable as a breeding and nursery ground for macroinvertebrates.

Total Dissolved Solids (TDS) were also measured, yielding an average of 23,35 ppt. TDS includes inorganic salts and minor amounts of organic matter. While high TDS levels can be toxic to aquatic organisms, the observed concentration in this study falls within the lower range for seawater and brackish environments.[23] This suggests a relatively stable water quality that can sustain a healthy community of macroinvertebrates.

The abundance of macroinvertebrate species observed in this study can be attributed to these favorable abiotic conditions. However, human activities such as tourism and gleaning may exert pressure on these ecosystems. Gleaning, in particular, involves the collection of shellfish and other invertebrates for food or livelihood, potentially reducing species abundance over time.

Environmental factors are vital determinants of macroinvertebrate diversity in intertidal ecosystems. Physical features such as substrate type, tidal height, and habitat complexity influence community composition by offering niches and shelter.[24,25] Conversely, anthropogenic stressors like pollution and habitat degradation can disrupt these communities, reducing biodiversity and altering ecological dynamics.[26,27] Water quality parameters—including salinity, temperature, and chemical composition—also directly impact physiological functions and distribution patterns among macroinvertebrates.[28,29,30] Furthermore, recent research highlights that ecological connectivity, facilitated by the dispersal of species between habitats, is crucial for maintaining biodiversity.[31] Hence, understanding and monitoring these abiotic variables is essential for the sustainable management and conservation of intertidal ecosystems, which are increasingly vulnerable to climate change and human intervention.

Table 3. Factors Affecting Macroinvertebrates Species Diversity in the Intertidal Zone

Factors	Station 1	Station 2	Station 3
Salinity	30,9 ppt	30,3 ppt	29,97 ppt
pH Level	7,30	7,38	7,17
Humidity	69,89	64,87	64,89
Temperature	30,44ºC	30,56ºC	30,11ºC
TDS (Total Dissolved Solid)	26,07 ppt	25,2ppt	18,8 ppt

CONCLUSIONS

This study assessed the biodiversity and abundance of macroinvertebrates in the intertidal zone of Barangay Pandanan, Sultan Naga Dimaporo, Lanao del Norte, alongside key environmental parameters including salinity, pH, humidity, temperature, and total dissolved solids (TDS). Results indicated a high diversity of macroinvertebrate species, with cone shells (Conus spp.), locally known as Daro-Daro, emerging as the most abundant. These gastropods, which are predatory and venomous, are generally not harvested for consumption due to their low economic value, contributing to their sustained presence in the area.

Environmental conditions across the study sites were found to be within optimal ranges for marine life, supporting the continued survival and diversity of intertidal macroinvertebrates. However, the observed decline in seagrass cover raises ecological concerns. Seagrasses play a vital role in maintaining the health of coastal ecosystems by stabilizing sediments, improving water quality, and providing critical habitat and food for various marine organisms. Their degradation—likely linked to anthropogenic activities such as gleaning and coastal tourism—poses a significant threat to the integrity of the intertidal zone.

Overall, the findings affirm that Barangay Pandanan's intertidal zone remains a biologically rich habitat capable of supporting diverse macroinvertebrate communities. Nevertheless, human-induced pressures, especially the diminishing seagrass beds, highlight the need for immediate and proactive conservation measures. As the intertidal zone serves as a vital ecological interface for feeding, breeding, and nursery functions, it is imperative to implement sustainable management practices that balance human use with ecological preservation. Protecting this dynamic coastal environment is essential for maintaining biodiversity, ecological resilience, and the long-term health of marine ecosystems in the region.

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None.

CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

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