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Research Article

The Use of Marine Invertebrates As An Early Indicator of Marine Pollution in The Coastal Zone of Negeri Latu, West Seram Regency

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Abstract
The coastal area of Negeri Latu, West Seram Regency, possesses a relatively high marine biodiversity and serves as a vital natural resource for the local community's economy, particularly in the fisheries sector. However, increasing human activities around the coastal region, such as the disposal of domestic waste, garbage, and industrial effluents, have exerted significant pressure on the quality of the marine environment. This study aims to examine the utilization of aquatic invertebrates as early detectors of pollution in the coastal area of Negeri Latu, West Seram Regency. The research employed a quantitative descriptive design. The coastline of Negeri Latu extends approximately 900 meters, along which nine transects were established perpendicular to the shoreline at intervals of 100 meters. Each transect contained 10 observation plots, arranged alternately, each measuring 1 × 1 m, with 10 meters separating the plots. Marine invertebrate data were observed, individual counts were conducted, and identification was performed to determine the composition of the biota. The analysis results indicate that the water pollution status in this area falls within the moderately polluted category. This category signifies a considerable degradation of water quality, although it has not yet reached the level of severe pollution. The decline in water quality is influenced by various anthropogenic factors, especially the high rate of waste disposal into the sea by the local population.

INTRODUCTION

Negeri Latu, also known as Leparissa Amalatu, is a traditional village located on the northwestern coast of Seram Island. Its existence not only reflects a rich cultural heritage but also embodies local wisdom that has evolved (Afnil *et al*., 2024; Basyarewan *et al*., 2025). This village possesses considerable natural potential, particularly in terms of its abundant marine resources.

The wealth of fishery resources in the area plays a vital role in supporting the regional economy (Subagiyo *et al*., 2017). Therefore, the sustainable management of these resources requires serious attention (Anugrah & Alfarizi, 2021). Fisheries can serve as a long-term basis for local economic development if they are managed properly. Conversely, these resources may become depleted in the absence of appropriate regulations or effective management policies (Tribawono, 2018). One of the increasingly critical factors exacerbating this situation is environmental pollution, particularly waste disposal into the ocean (Ningsih, 2018; Sagita *et al*., 2022).

In Negeri Latu, the community's habit of disposing of household waste into the sea has become a growing concern. Although the ocean plays an essential role in daily life—both as a livelihood source and as part of cultural identity—irresponsible waste disposal practices have had devastating impacts. According to San Ferre and Rumansara (2023), waste polluting aquatic environments not only damages marine ecosystems but also threatens the sustainability of fishery resources. Plastic waste, household refuse, and chemicals discharged into the sea disrupt water quality and marine habitats, ultimately causing marine pollution and directly impacting fish catch yields and the survival of marine species.

Pollution entering the marine environment takes various forms; however, one of the most widely discussed is marine debris (Putra *et al*., 2022; Noor *et al*., 2023). Generally, marine debris is defined as solid materials that enter the ocean either through direct disposal or from land via river flows, whether intentionally or unintentionally (Sirajudin *et al*., 2022). The volume of waste as a result of community activities that enter the marine environment will increase if not managed properly. Currently, Indonesia is ranked second to China as the most significant contributor of marine debris globally (Putra *et al*., 2022).

Marine debris can be dispersed by being carried by currents or sinking due to weight gain caused by biofouling (Puspita, 2023). It will undergo fragmentation into smaller sizes due to environmental factors, especially exposure to sunlight. The spread of marine debris is driven by ocean currents—horizontal water movements caused by tidal forces, density differences, and wind action. Dispersed marine debris can negatively impact marine organisms, such as entanglement, injury, or ingestion by marine biota (Putra *et al*., 2022)

According to AF and Natsir (2022), environmental pollution can reduce water quality and adversely affect the marine biota inhabiting these waters. The populations of marine organisms residing in coastal areas, particularly around beaches, are often used as indicators of water quality. This is due to aquatic organisms being entirely dependent on their environment for survival. Several aquatic species, both animals and plants, play important roles as bioindicators of water quality. Biological indicators based on marine biota offer several advantages compared to other physical and chemical measurement methods. First, marine organisms provide a direct reflection of the environmental quality in their habitat. Additionally, marine biota can respond rapidly to changes in water quality and can be observed over extended periods.

Invertebrates are one of the biota used as bioindicators of changes in environmental quality. These organisms are beneficial due to their ease of identification and varying tolerance levels to different biotic and abiotic environmental factors. Therefore, the community structure of macroinvertebrates, a subgroup of invertebrates, is commonly used to assess the condition of aquatic ecosystems. Changes in the presence, abundance, morphology, physiology, or even behavior of these organisms can offer useful information regarding the physical and chemical quality of the aquatic environment in which they live (Zhang *et al.,* 2025).

The study conducted by AF and Natsir (2022), which utilized marine biota as bioindicators of water pollution in Negeri Tulehu, reported a total of 592 individuals comprising six families. The family Littorinidae had the highest number of individuals with 340, followed by Portunidae with 127, Neritidae with 67, Potamididae with 28, Muricidae with 17, and Pectinidae with 13 individuals. Species diversity at Station 1 was measured at H’ = 0.91 (heavily polluted), Station 2 at H’ = 0.88 (heavily polluted), and Station 3 at H’ = 1.43 (moderately polluted) based on the Shannon-Wiener index. The evenness index values were 0.51 (moderate) at Station 1, 0.49 (moderate) at Station 2, and 0.80 (high) at Station 3.

This study’s objective is to assess the status of marine pollution along the coastal waters of Negeri Latu, Amalatu Subdistrict, West Seram Regency, using marine invertebrates as bioindicators.

RESEARCH METHODS

Type of Research

This study employed a quantitative descriptive research design. Quantitative descriptive research is a type of study aimed at systematically describing the characteristics or conditions of a phenomenon using numerical data (Pali, 2000).

Time and Location of Research

The research was conducted in April 2025 along the coastal area of Negeri Latu, Amalatu Subdistrict, West Seram Regency (Figure 1).

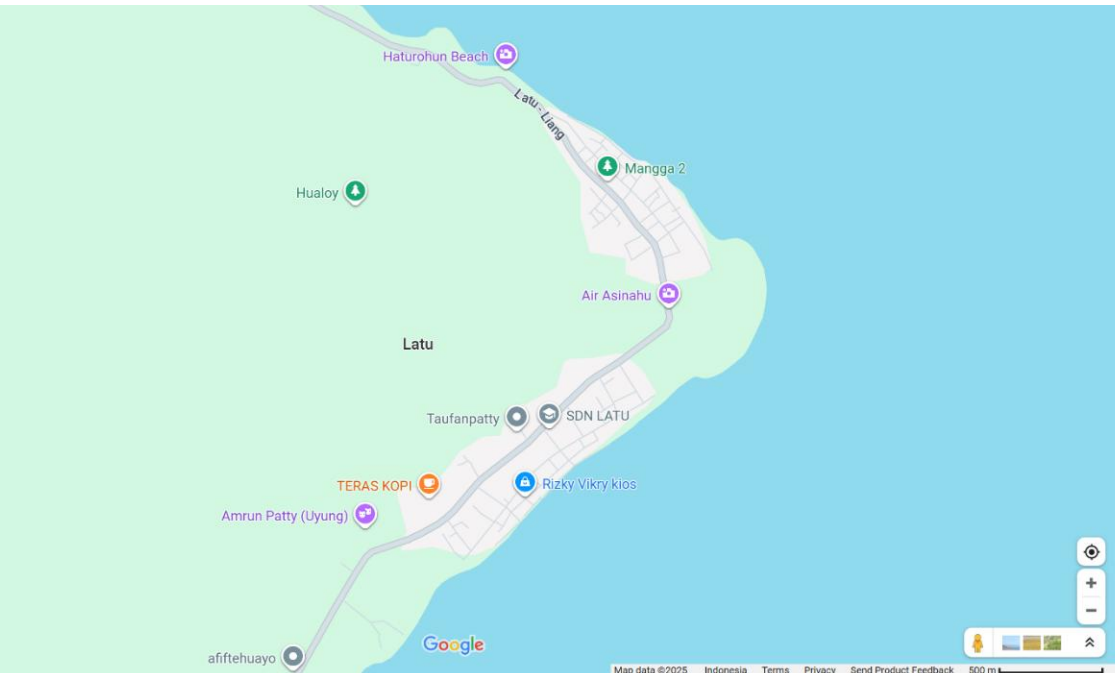

Figure 1. Location of the study area

Tools and Materials

The tools and materials used in this study included a digital camera, measuring tape (roll meter), wooden stakes, flashlights, writing instruments, identification books, and marine biota specimens.

Research Procedure

The research was carried out through the following steps:

1. A preliminary survey of the study site was conducted using the linear quadrat transect method to determine the number of transects required.
2. Preparation of tools and materials necessary for data collection.
3. Establishment of transects and observation plots for biota assessment. The coastline of Negeri Latu extends approximately 900 meters.
4. Nine transects were established perpendicular to the shoreline, with a distance of 100 meters between each transect. On each transect, 10 observation plots (1×1 meter) were systematically placed in an alternating pattern, with 10-meter spacing between plots.
5. Sampling was conducted during low tide, as marine biota are more visible and easier to observe during this period.
6. Direct observation of marine organisms was conducted within each quadrat. All visible species were counted and identified using identification guides. Unidentified specimens were preserved in labeled plastic bags containing 70% alcohol for later identification.
7. Species identification was performed using the guide *Freshwater Snails (Mollusca: Gastropoda) of North America* by J.B. Burch (1982), online resources, and the reference book *Recent and Fossil Indonesian Shells* by Dharma (2005). Identification was based on morphological characteristics such as shell length, width, shape, coloration, presence and type of operculum, and number of whorls.

Data Analysis

The data collected were used to calculate the following ecological indices: density, relative density, frequency, relative frequency, abundance, relative abundance, species diversity, and dominance.

1. Density

   Density refers to the number of individuals per unit area. According to Soegianto (1994), density is calculated as follows:

$$D_i = \frac{n_i}{A}$$

where:

Di = density of the species i (ind/m²)

ni = number of individuals of species i

A = total area of the observation plot

To calculate relative density, the following formula is used:

$$RD_i = \frac{N_i}{\sum N} \times 100\%$$

2. Frequency of Occurrence
   Frequency of occurrence indicates the number of observation plots in which a species is found within a certain area. It is calculated using the formula from Soegianto (1994):

$$F_i = \frac{J_i}{K}$$

Where:
Fi = frequency of species i
Ji = number of plots containing the of species i
K = total number of plots sampled

Relative frequency is calculated as:

$$FR = \frac{F_i}{\sum F} \times 100\%$$

3. Species Abundance
   Abundance reflects the number of individuals of a particular species consistently present in observation plots within a defined area. The calculation follows Krebs (1978):
   a) Abundance:

$$\text{Abundance (ind/m}^2) = \frac{\text{Total individuals of species}}{\text{Area sampled}}$$

   b) Relative abundance:

$$\text{Relative Abundance (\%)} = \frac{\text{Abundance of species}}{\sum \text{Abundance of all species}} \times 100\%$$

4. Species Diversity
   Species diversity is calculated using the Shannon-Wiener index (Odum, 1993):

$$H' = -\sum (P_i \times \ln P_i)$$

Where:
H′ = Shannon-Wiener diversity index
Pi = ni/N
ni = number of individuals of species i
N = total number of individuals
ln = natural logarithm

Interpretation of H′ values: H′ < 1: low species diversity, 1≤H′≤3: moderate species diversity, and H′ > 3: high species diversity.

5. Species Dominance

The dominance index, according to Soegianto (1994), is used to determine the dominance of a particular species:

$$D = \sum P_i^2$$

Where : Pi = ni/N

D = dominance index

Ni = number of individuals of species i

N = total number of individuals

According to Fachrul (2007), the criteria for dominance index values in bivalves are:

- D = 0, No species dominates others; the community structure is stable.
- D = 1, One species dominates others; the community structure is unstable due to ecological pressure

Water quality status was assessed using the Shannon-Wiener Diversity Index (H'), based on the following classification (Sastrawijaya, 2000):

Table 1. Water Quality Criteria (Shannon-Wiener Diversity Index)

No	Diversity Index (H')	Water Quality Status
1	H' > 2,0	Unpolluted
2	2,0 > H' > 1,5	Lightly polluted
3	1,5 > H' > 1,0	Moderately polluted
4	H'<1,0	Heavily polluted

RESULTS AND DISCUSSION

Types of Invertebrates Found Along the Coast of Negeri Latu

The types of invertebrates identified along the coastal area of Negeri Latuare are presented in Table 2.

Table 2. Types of Invertebrates Found on the Coast of Negeri Latu

Phylum	Class	Order	Family	Genus	Species	Σ Individuals
Echinodermata	Echinoidea	Echinoida	Diadematidae	*Echinothrix*	*Echinothrix mathaei*	53
					Echinothrix calamaris	16
				Diadema	*Diadema setosum*	12
			Tripneustidae	*Tripneustes*	*Tripneustes gratilla*	2
			Echinometridae	*Echinometra*	*Echinometra viridis*	5
			Toxopneustidae	*Stomopneustes*	*Stomopneustes variolaris*	7
	Holothuroidea	Holothuroidea	Holothuriidae	*Holothuria*	*Holothuria edulis*	16
					Holothuria scabra	4

	Asteroidea	Asteroidea	Linckiidae	*Linckia*	*Linckia laevigata*	11
					Linckia multifora	5
Mollusca	Gastropoda	Strombida	Strombidae	*Strombus*	*Strombus sp.*	22
		Trochida	Trochidae	*Trochus*	*Trochus sp.*	21
				Turbo	*Turbo bruneus*	64
		Littorinida	Littorinidae	*Nedilittorina*	*Nedilittorina pyramidali*	76
			Nassaridae	*Ilyanassa*	*Ilyanassa obsoleta*	33
		Caenogastropoda	Vasidae	*Vasum*	*Vasum turbinellus*	21
					Vasum sp.	17
			Cypraeidae	*Cypraea*	*Cypraea tigris*	2
					Cypraea sp	47
		Cycloneritida	Neritidae	*Nerita*	*Nerita undata*	2
			Total			**436**

Table 2 shows that two major phyla were identified in the coastal waters of Negeri Latu: Echinodermata and Mollusca. Within the phylum Echinodermata, the class Echinoidea was the most dominant, represented by several orders and families. The order *Echinoida* included the family Diadematidae, with the genus *Echinothrix*, represented by species such as *Echinothrix mathaei* and *Echinothrix calamaris*, along with *Diadema setosum* from the genus *Diadema*. Other echinoid families recorded included Tripneustidae, represented by *Tripneustes gratilla*; Echinometridae, with *Echinometra viridis*; and *Toxopneustidae*, represented by *Stomopneustes variolaris*.

The family Holothuriidae represented the Holothuroidea class, with species such as *Holothuria edulis* and *Holothuria scabra*. In the class Asteroidea, species of the genus *Linckia*, including *Linckia laevigata* and *Linckia multiflora, were found*.

In the phylum Mollusca, the class Gastropoda was dominant, encompassing a variety of orders. The order Strombida included *Strombus* sp., while Trochida was represented by *Trochus* sp. and *Turbo Bruneus*. The order Littorinida was notable for its high number of individuals, particularly *Nedilittorina pyramidalis*. Other significant findings included *Ilyanassa obsoleta* (Nassaridae), *Vasum turbinellus*, and *Vasum* sp. (Vasidae), as well as *Cypraea tigris* and *Cypraea* sp. (Cypraeidae). *Nerita undata*, belonging to the order Cycloneritida, was also recorded in small numbers. A total of 436 individual organisms were identified, reflecting a high level of biodiversity among marine invertebrates in the coastal ecosystem of Negeri Latu.

Based on the research, the species *Nodilittorina pyramidalis* was among the most abundant, with 74 individuals found along the coast of Negeri Latu. The high number of *Nerita pyramidalis* (also known as *Nodilittorina pyramidalis*) observed in the coastal area of Negeri Latu may be attributed to habitat conditions favourable for the species' survival. The coastline of Negeri Latu is dominated by dead coral rock substrates, which provide an ideal surface for *N. pyramidalis* to attach to and seek shelter from predators as well as extreme environmental conditions. Furthermore, the extensive intertidal zone offers ample space for this species to reproduce and forage.

Another species found in high abundance was *Turbo Bruneus*, with 64 individuals recorded. This species exhibits strong adaptive capabilities in response to varying coastal environmental conditions, including fluctuations in salinity, temperature, and the availability of suitable rigid substrates for habitation (Usman & Azizi, 2024). Its widespread presence suggests that *T. bruneus* is well adapted to the local ecosystem, benefiting from morphological and physiological traits that enhance its ability to avoid predation and compete effectively for resources. Additionally, *Turbo bruneus* is known for its high reproductive success, producing large numbers of eggs and exhibiting prolific breeding potential (Saleky *et al*., 2019). This reproductive efficiency, combined with high larval survival rates, likely contributes to the larger population sizes of *T. bruneus* relative to other species in the same environment.

In this study, the species found in the lowest numbers were *Tripneustes gratilla* and *Nerita undata*, with only two individuals each. *Tripneustes gratilla*, belonging to the order Tripneustidae, typically inhabits deeper waters with muddy sand substrates and seagrass beds. This observation aligns with Aziz's (1994) statement that *Tripneustes gratilla* sea urchins are often found in sandy or muddy areas and regions abundant with seagrass, which serve as their food source. Radjab (2004) also noted that *Tripneustes gratilla* prefers seagrass beds as optimal habitats for growth and shelter.

Meanwhile, *Nerita undata*, a member of the family Neritidae, exhibits a limited distribution that is likely related to its narrower habitat preference, as this species predominantly inhabits mangrove ecosystems. The abundant population of *Nerita undata* in mangrove habitats plays a crucial role in the food chain by supporting the survival of higher trophic-level organisms. In addition, *Nerita undata* functions as a decomposer, feeding on organic matter residues found within mangrove forests (Rafi *et al*., 2020). According to Aditya and Nugraha (2020), *Nerita undata* is the most commonly encountered gastropod species on the roots, trunks, and branches of mangroves.

Ecological Index of Invertebrates

The ecological index of invertebrate species identified along the coast of Negeri Latuare is summarized in Table 3.

Table 3. Ecological Index of Invertebrate Species

No	Scientific Name	Density	Relative Density (%)	Frequency	Relative Frequency (%)	Abundance	Relative Abundance (%)
1	*Echinothrix mathaei*	0,589	31,2	0,18	18,18	0,122	31,2
2	*Strombus sp*	0,244	12,9	0,13	13,64	0,05	12,9
3	*Nedilittorina pyramidali*	0,844	44,7	0,03	3,409	0,174	44,7
4	*Diadema setosum*	0,133	7,06	0,04	4,545	0,028	7,06
5	*Ilyanassa obsoleta*	0,367	19,4	0,14	14,77	0,076	19,4
6	*Vasum turbinellus*	0,233	12,4	0,12	12,5	0,048	12,4
7	*Cypraea tigris*	0,022	1,18	0,02	2,273	0,005	1,18
8	*Echinometra viridis*	0,056	2,94	0,03	3,409	0,011	2,94
9	*Holothuria edulis*	0,178	9,41	0,09	9,091	0,037	9,41
10	*Vasum sp*	0,189	10	0,08	7,955	0,039	10

11	*Stomopneustes variolaris*	0,078	4,12	0,03	3,409	0,016	4,12
12	*Trochus sp*	0,233	12,4	0,1	10,23	0,048	12,4
13	*Echinothrix calamaris*	0,178	9,41	0,04	4,545	0,037	9,41
14	*Tripneustes gratilla*	0,022	1,18	0,02	2,273	0,005	1,18
15	*Linckia laevigata*	0,122	6,47	0,07	6,818	0,025	6,47
16	*Linckia multifora*	0,056	2,94	0,02	2,273	0,011	2,94
17	*Holothuria scabra*	0,044	2,35	0,02	2,273	0,009	2,35
18	*Turbo bruneus*	0,711	37,6	0,32	32,95	0,147	37,6
19	*Cypraea moneta*	0,522	27,6	0,38	38,64	0,108	27,6
20	*Nerita undata*	0,022	1,18	0,02	2,273	0,005	1,18
	Jumlah	0,1889	**100**	**0,98**	**100**	**0,39**	**100**

Based on Table 3, *Nedilittorina pyramidalis* exhibited the highest density value (0.844) and relative density (44.7%), making it the most dominant species in terms of population. In contrast, species such as *Cypraea tigris*, *Tripneustes gratilla*, and *Nerita undata* were recorded at very low densities (0.022), representing only 1.18% of the total population, indicating their rarity in the sampling area.

Regarding frequency and relative frequency, *Cypraea moneta* showed the highest relative frequency (38.64%), followed by *Turbo bruneus* (32.95%). Meanwhile, *Cypraea tigris*, *Holothuria scabra*, and *Nerita undata* were among the species with the lowest frequencies, each at 2.27%, indicating their limited presence in the study area.

Regarding abundance, *Nedilittorina pyramidal* once again emerged as the most abundant species (abundance = 0.174; relative abundance = 44.7%). Other species, such as *Cypraea moneta* (0.108; 27.6%) and *Ilyanassa obsolete* (0.076; 19.4%), also showed relatively high abundances, suggesting their important ecological roles in the coastal community.

Overall, *N. pyramidalis* and *T. bruneus* stood out with the highest values across all ecological index parameters: density, frequency, and abundance. These results imply that both species maintain large and stable populations within the study area. Such ecological dominance may be attributed to the availability of suitable resources, such as food and substrate, and their high tolerance to coastal environmental fluctuations. According to Tedersoo *et al.* (2020), species with high population densities tend to dominate habitats due to competitive advantages in resource acquisition.

Furthermore, high frequency and relative frequency values indicate that *N. pyramidalis* and *T. bruneus* were consistently present across multiple sampling sites. A high frequency suggests a wide spatial distribution, while a high relative frequency reflects their dominance over other species. Chen *et al.* (2025) noted that high and relatively frequent species are often considered reliable ecological indicators due to their stable presence under various environmental conditions.

The abundance of *N. pyramidalis* and *T. bruneus* suggests they are the dominant species within this invertebrate community. Their ecological success is likely related to morphological and physiological adaptations such as strong attachment to rocky substrates and tolerance to fluctuations in temperature and salinity (Stickle *et al.,* 2017) that allow them to survive and reproduce more effectively than other species.

The combination of high values across all ecological indices supports the conclusion that *Nedilittorina pyramidal* and *Turbo brunets* are key species in the gastropod community of the Negeri Latucoastal habitat. Their ecological roles are essential in maintaining community stability and biotic interactions such as competition and predation.

Water Pollution Level in the Coastal Waters of Negeri Latu

The calculation results of the diversity and dominance indices are presented in Table 4.

Table 4. Diversity and Dominance Index Values

Ecological Index	Value	Criteria
Shannon Diversity (H')	1,0009	Low Diversity
Simpson Dominance (D)	0,038	No Dominant Species

The results in Table 4 indicate that the Shannon diversity index value of 1.0009 reflects a low level of biodiversity within the aquatic ecosystem. Low biodiversity implies either a relatively small number of species or an unequal distribution of individuals among species within the ecosystem. Conversely, the very low dominance index value (D = 0.038) suggests that no single species dominates the marine community in Negeri Latu.

Based on the diversity index value, the pollution status of the coastal waters in Negeri Latu can be determined using the criteria in Table 1. The interpretation is shown in Table 5.

Table 5. Water Pollution Status in Negeri Latu

Result	Diversity Index (H')	Status
1,0009	1,5 > H’ > 1,0	**Moderately Polluted**

The results presented in Table 5 indicate that the Shannon–Wiener diversity index (H’) value of 1.0009 reflects a low level of invertebrate biodiversity in the coastal waters of Negeri Latu. Based on this result and the pollution classification in Table 1, the waters of Negeri Latu are classified as moderately polluted.

Coastal zones are dynamic ecosystems that are influenced by interactions between terrestrial and marine environments. Coastal pollution arises from both direct and indirect inputs of pollutants, with anthropogenic waste being the predominant contributor. Negeri Latu’s moderate pollution status is primarily attributed to the high frequency of waste disposal activities by the local community into the sea. Organic and inorganic waste materials have become one of the primary drivers of marine water quality degradation.

According to Hamuna *et al*. (2018) and Akbar & Maghfira (2023), the influx of various types of waste and pollutants into coastal waters can cause severe environmental degradation. These contaminants not only deteriorate water quality but also disrupt the balance of marine ecosystems, posing a threat to the survival of aquatic organisms.

Marine pollution caused by waste disposal also affects the physical, chemical, and biological quality of seawater (Elenwo & Akankali, 2015; Landrigan *et al*., 2020). When organic and inorganic materials accumulate in the water, they can lead to eutrophication, characterized by an excessive increase in nutrient content that disrupts the ecosystem balance.

The primary impact of this process is a decline in dissolved oxygen levels, which are essential for the survival of marine organisms (Kulkarni, 2016). Furthermore, accumulated waste in the sea obstructs photosynthesis performed by marine plants and plankton, which play a critical role in the marine food chain (Häder & Gao, 2015).

Additionally, this pollution significantly threatens the quality of marine habitats. Numerous species, such as fish, shrimp, and corals, depend on healthy coastal ecosystems for reproduction, growth, and foraging. Waste accumulating on the seabed or floating in the water column contaminates and damages these habitats. For instance, plastic debris can entangle marine organisms, leading to injury or mortality, while hazardous chemicals contained in waste pollute marine waters and alter biological integrity (Abirami, 2024; Thiagarajan & Devarajan, 2024).

The intensifying pollution further endangers the survival of marine species that rely on coastal ecosystems, including those of high economic value (e.g., commercial fish) and those with critical ecological roles. The ongoing degradation of habitat quality may lead to a decline in fish and other marine populations, thereby affecting overall marine biodiversity and jeopardizing the existence of various species, including apex predators and decomposers that maintain ecological stability.

Moreover, reproductive disruption among marine organisms emerges as a serious concern. Many marine species require clean and stable environments for spawning and reproduction. Continued water pollution interferes with these processes, eventually leading to reduced population sizes of ecologically significant species—many of which are vital to sustaining the livelihoods of coastal communities.

CONCLUSION

On the coast of Negeri Latu, 20 species of invertebrates belonging to the phylum Echinodermata and Mollusca were identified, with a total of 436 individuals recorded. The water pollution status in Negeri Latu is categorized as Moderately Polluted. This indicates that the water quality in the area has experienced a significant level of contamination, although it has not yet reached a severely polluted category.

DECLARATIONS

Author Contributions

F. D. A. T and A. R. P contributed to designing the study, preparing samples and test materials, conducting the study, and preparing the manuscript. M. P. R. R, M. F B and A. P. S contributed to data analysis and curation. N. A. P. S. B. K contributed to proofreading the manuscript.

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Declaration of Interest

The authors declare that this research and the data obtained are not related to any party

Data Sharing Statement

Data supporting this study's findings and conclusions can be provided to other parties upon relevant request.

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