

GASTROPOD BIODIVERSITY AND ENVIRONMENTAL ASSESSMENT IN THE ALOR ARCHIPELAGO, INDONESIA: IMPLICATIONS OF ANTHROPOGENIC ACTIVITIES

FAUZIYAH^{1,*}, Oka Anisa WIRABUANA¹, Nabila APRIANTI², ROZIRWAN¹, Fitri AGUSTRIANI¹, Ellis Nurjuliasti NINGSIH¹, FATIMAH³, YAHYAH⁴

¹ Department of Marine Sciences, Faculty of Mathematics and Natural Sciences, Sriwijaya University, South Sumatra, 30862, Indonesia

² Research Center for Energy Conversion and Conservation, National Research and Innovation Agency (BRIN), B. J. Habibie Science and Technology Park, South Tangerang 15314, Banten, Indonesia

³ Research Organization for Life Sciences and Environment, National Research and Innovation Agency (BRIN), Cibinong, Bogor-West Java postal code 16911, Indonesia

⁴ Study Program of Aquatic Resources Management, Faculty of Agriculture, Marine and Fisheries, Nusa Cendana University, Kupang, Indonesia

Abstract

*Gastropods are vital bioindicators of aquatic ecosystems, reflecting environmental conditions and anthropogenic impacts. This study investigated gastropod composition, abundance, biodiversity, and their relationships with environmental parameters in the Alor Archipelago, East Nusa Tenggara. Sampling using quadrat methods was conducted across four areas: port activities, tourism activities, seagrass ecosystems, and residential areas, with sediment and environmental parameters analyzed. A total of 69 gastropod species were identified, with *Erosaria erosa* being the most abundant (0.158 ind/m²). Seagrass ecosystems exhibited high diversity ($H' > 3$), stable distributions ($E > 0.75$), and clustered patterns ($I_p > 0$), indicating favorable conditions. Degraded areas, such as port activity areas, showed lower diversity, unstable distributions, and higher dominance, associated with reduced dissolved oxygen and anthropogenic stressors. Principal component analysis revealed higher biodiversity linked to natural habitats, while degraded areas exhibited reduced ecological quality. These findings underscore the critical impact of human activities on gastropod communities and emphasize the need for preserving natural habitats to sustain biodiversity and ecosystem functions. This study provides valuable insights for developing sustainable management and conservation strategies in the Alor Archipelago.*

Keywords: Coastal conservation; Ecological health; *Erosaria erosa*; Gastropod abundance; Habitat quality

Introduction

Mollusks play a vital role in maintaining ecological balance and are considered key indicators of ecosystem health [1]. A distinctive characteristic of the Mollusca phylum is the presence of a hard calcium carbonate shell. This phylum is divided into two main classes: gastropods and bivalves [2]. Gastropods, often found in coastal areas, are easily recognized by their single, coiled shells. The term "benthos" refers to marine organisms, both plants and animals, that inhabit the seafloor, including seagrasses, corals, snails, clams, sea cucumbers, and starfish.

* Corresponding author: siti_fauziyah@yahoo.com

Benthic organisms are highly sensitive to environmental changes and exhibit narrow tolerance ranges for physical and chemical conditions [3].

Indonesia's marine and coastal ecosystems are among the most biodiverse in the world, contributing to its global reputation as a biodiversity hotspot [4]. The waters of the Alor Archipelago, in particular, support a highly diverse marine ecosystem [5]. Gastropod diversity in this region is influenced by both biotic and abiotic factors, including light intensity, temperature, substrate type, and current velocity, as well as chemical parameters such as pH, dissolved oxygen (DO), and salinity. Furthermore, biological factors such as plankton abundance, and ecological interactions like competition, predation, and food availability, also affect gastropod diversity. These factors are further shaped by water quality conditions.

However, the Alor region has undergone significant environmental degradation due to anthropogenic activities such as illegal logging and aquaculture [6]. These activities have contributed to the decline of shallow marine fisheries, with some species now at risk of extinction [7]. Specifically, the Kalabahi Port area has experienced ecological changes, resulting in reduced marine biodiversity due to over-exploitation and unregulated port activities [8]. The region encompasses various marine and coastal ecosystems, including coral reefs, mangroves, estuaries, seagrass beds, beaches, open seas, and deep waters, all of which contribute to its rich marine biodiversity. Mollusks such as gastropods, bivalves, octopuses, squids, and cuttlefish are commonly found in these coastal areas, with seagrass beds serving as critical habitats for these species [9]. Alor Regency, a group of islands surrounded by hills and seas, has settlements located within one to three kilometers of the coast, further increasing the pressures on local marine ecosystems.

This study aims to identify the morphology, composition, and abundance of gastropods in the waters of the Alor Archipelago, East Nusa Tenggara. In addition, it seeks to compare gastropod biodiversity between natural and degraded sites and to analyze the relationship between environmental parameters and gastropod diversity in the region. By elucidating these relationships, this research will contribute to a better understanding of the impacts of anthropogenic activities on marine biodiversity in the Alor Archipelago.

Experimental part

Study Area

The Alor Archipelago, located in East Nusa Tenggara, is situated to the north, bordered by the southern Flores Sea and the Ombay Strait, and shares a boundary with Timor Leste. To the east, it is bordered by the Lembata Strait [5, 10]. Alor Island is part of the Alor Regency, with most of the local population relying on agriculture and small-scale fishing for their livelihoods. Additionally, many people continue to engage in shifting cultivation practices, clearing forested areas for farming [5]. Alor is an island at the easternmost edge of the Nusa Tenggara Archipelago, renowned for its natural and cultural richness [11].

This study was conducted from August 21 to September 6, 2023, at four sampling stations along the coastline of the Alor Archipelago, each spanning 100 meters. Station 1 represents port activities, Station 2 represents tourism-related activities, Station 3 represents a seagrass ecosystem serving as a natural habitat for mollusks, and Station 4 represents residential areas (Fig. 1).

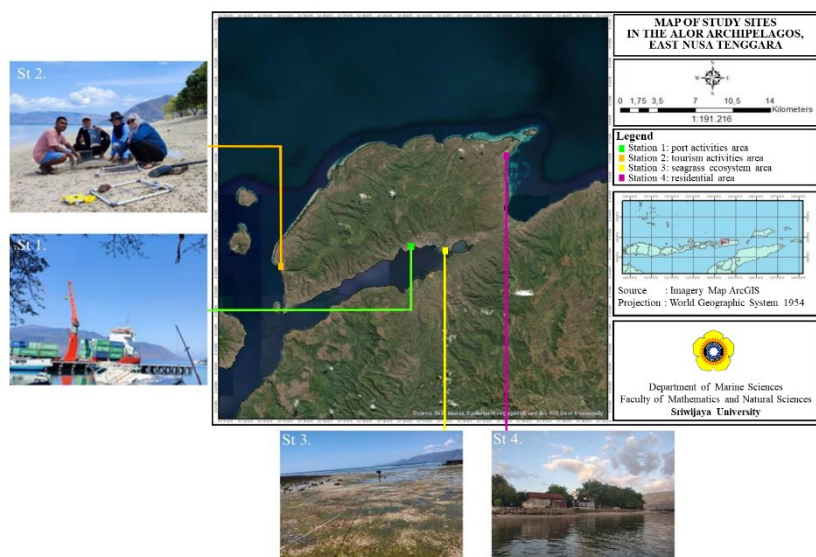


Fig. 1. Location map of sampling stations in the Alor Archipelago, East Nusa Tenggara of Indonesia

Methods

Data collection and sample processing

Physical water parameters (temperature, salinity, pH, dissolved oxygen, turbidity, and current velocity) and sediment fractions were measured in situ at each observation station with three replicates. The following equipment was used: a digital thermometer for temperature [12], a refractometer for salinity [13], a pH meter for pH levels [12], a dissolved oxygen (DO) meter [14], a Secchi disk for turbidity [15], a flow meter for current velocity [12], and a scoop and sieve for sediment sampling [16].

Gastropod samples were collected using a quadrat transect method. At each station, a 1 × 1 m quadrat was used for sampling gastropods, which were identified as epifauna, meaning they live on the sediment surface. Three transect lines were established at each station, with a distance of 100 meters between them. Each transect contained five 1x1 m quadrats, placed alternately at 50-meter intervals [17]. Gastropods were collected manually from the quadrats. After collection, the samples were cleaned and preserved in 70% ethanol solution, following the procedure outlined by [16]. The samples were then stored in a cool box and transported to Palembang for identification and further analysis in the laboratory.

Statistical Analysis

Water quality parameters and sediment fractions were descriptively analyzed using Microsoft Excel. Gastropod abundance was expressed as both total percentage and individual counts per species. Species diversity was assessed using the Shannon-Wiener Index (H') [16,18], Evenness Index (E) [16,19], Simpson's Dominance Index (C) [16,19,20], and Standardized Morisita's Index (I_p) [21–23]. The Shannon-Wiener Index was classified as low ($H' \leq 1$), moderate ($1 < H' \leq 3$), or high ($H' > 3$) [16,20,24]. Similarly, the Evenness Index was categorized into depressed ($0 < E \leq 0.5$), unstable ($0.5 < E \leq 0.75$), and stable ($0.75 < E \leq 1$) [21,25,26]. The Dominance Index was defined as low ($0.0 < C \leq 0.3$), moderate ($0.3 < C \leq 0.6$), and high ($0.6 < C \leq 1.0$) [16,20,24]. Lastly, the standardized Morisita Index was categorized as uniform ($I_p < 0$), random ($I_p = 0$), and clustered ($I_p > 0$) [21–23]. Furthermore, Principal Component Analysis

(PCA) was applied to explore the correlation between water quality parameters, gastropod abundance, Morisita's dispersal, and biodiversity, using XLSTAT 2021 software [27].

Results and discussion

Water parameters

The water quality measurements in the Alor Islands, East Nusa Tenggara, indicated stable and favorable conditions for gastropod growth, as shown in Table 1. The temperature ranged from 28.3 to 29.9°C, aligning with the natural range for marine biota (24-32°C), thus providing optimal thermal conditions for metabolic and reproductive processes in gastropods. Salinity values, averaging 30-32‰, were slightly below the optimal range (32-34‰), likely influenced by freshwater input or tidal mixing, yet still within acceptable limits for gastropod habitation. The pH values, ranging from 7.2 to 8.3, remained within the natural seawater standard (7.0-8.5), which supports shell formation and overall physiological stability in gastropods. Transparency varied significantly across stations, averaging 111.25cm, with clearer waters observed at stations 2 and 3 compared to stations 1 and 4, likely due to differences in sediment load or phytoplankton concentration. Meanwhile, dissolved oxygen (DO) levels between 7.2 and 7.9mg/L exceeded the threshold of >5mg/L, reflecting well-oxygenated waters conducive to aerobic respiration and benthic productivity. Overall, these stable water quality conditions create a suitable habitat for gastropod survival and diversity, while minor spatial variations in salinity and transparency may contribute to differences in species distribution across stations.

Table 1. Environmental parameters of Alor Archipelagos Waters, East Nusa Tenggara, Indonesia

Parameter	Stations				Min	Max	Mean	Seawater Quality Standard for Marine Biota*
	1	2	3	4				
Temperature (°C)	28.3	28.8	28.5	29.9	28.3	29.9	28.8	24-32 (Natural)
Salinity (‰)	32	30	30	31	30	32	30.75	30-34 (Optimal)
pH (ppm)	8.3	7.3	7.2	7.9	7.2	8.3	7.7	7 – 8.5 (Natural)
DO (mg/l)	7.9	7.3	7.2	7.9	7.2	7.9	7.6	>5 (Optimal)
Transparency (cm)	150	80	90	125	80	150	111.2	

Note: station 1 represents the port activities area, station 2 represents the tourism activities area, station 3 represents a seagrass ecosystem area, and Station 4 represents residential areas. * Based on Minister of Environment, (2004)

Based on the current distribution map in Figure 2, surface current patterns in the Alor Archipelago exhibit significant variations in velocity and direction. The currents predominantly flow from the northwest toward the southeast, with speeds ranging between 0.036m/s and 0.36m/s, as shown by the color scale on the right side of the map. According to previous studies [29, 30], current velocities are classified into 4 categories, such as weak current (0-0.25m/s) medium current (0.25-0.50m/s) strong current (0.50-1m/s) and very strong current (> 1m/s). The observed currents in these waters generally fall into the medium category, with the strong current, represented in red, concentrated in the southern part and narrow eastern regions. In contrast, weak current velocities (blue) are observed in the northern region and nearshore areas. The vector directions reveal a consistent flow pattern shaped by local seabed topography and regional hydrodynamic processes. These spatial variations in current speed have ecological implications for gastropod distribution, particularly affecting larval dispersal, settlement, and substrate attachment. Strong currents in the southern region may limit benthic organism establishment, while slower currents in the northern waters provide stable conditions favorable for gastropod

growth and accumulation. Consequently, this current mapping provides essential insights into the habitat dynamics and species distribution of gastropods in the Alor Archipelago.

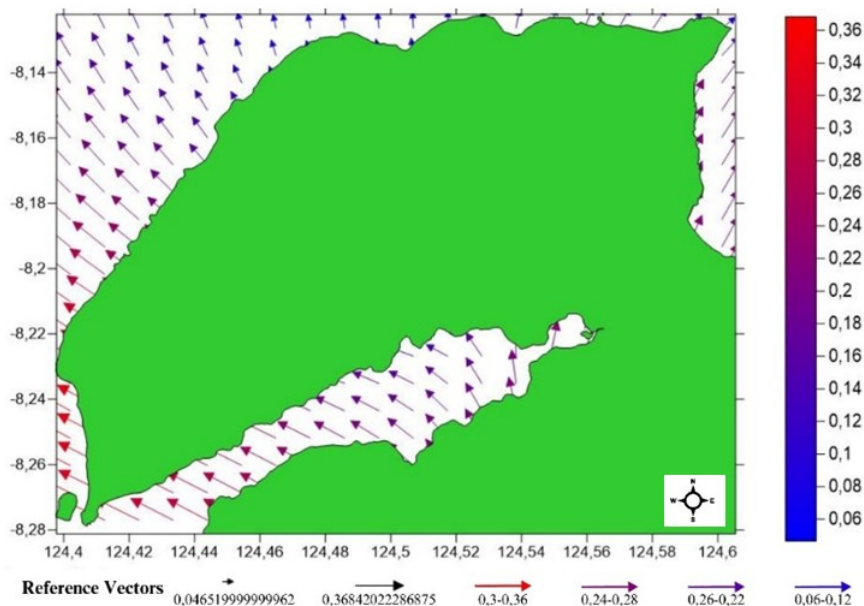


Fig. 2. Map of current direction and velocity in the Alor Archipelago waters, East Nusa Tenggara, Indonesia

Sediment Fraction

Significant variations in sediment composition were observed across the four stations in the Alor Archipelago, as presented in Table 2 and illustrated in the Shepard ternary diagram (Fig. 3). At Station 1, the sediment was predominantly silty sand, with 45.69% sand, 45.82% silt, and 8.49% clay. This composition indicates a relatively high proportion of fine particles, suggesting an area influenced by both terrestrial and marine processes, such as tidal or riverine input. At Station 2, the sediment was largely sand, with 82.74% sand, 0.06% silt, and 17.2% clay, indicating a coarse substrate with limited fine material, which may be characteristic of more dynamic, wave-exposed areas. In contrast, Station 3 exhibited a mixed composition of 50.20% sand, 1.35% silt, and 48.45% clay, categorizing the sediment as sandy clay, likely reflecting a more stable and sheltered environment conducive to the accumulation of finer materials. Finally, Station 4 displayed a predominance of clay, with 13.76% sand, 6.01% silt, and 80.23% clay, a composition typically associated with low-energy environments, where fine particles are more easily deposited. These variations in sediment types across the stations highlight the diverse ecological environments within the study area. Substrate characteristics, such as sand, mud, or coral, play a more critical role in determining the composition and abundance of gastropods in a habitat than geographic location, even across vast areas [31]. Gastropods are commonly found in substrates rich in organic matter, such as mud and clay, as the organic content serves as a vital food source and supports their biological activities [32–34]. These findings underscore the substrate's critical role as a key factor in sustaining gastropod populations. Furthermore, gastropods tend to thrive in coastal areas where environmental conditions are more stable, making them better suited for breeding compared to estuarine regions [32], which are more susceptible to environmental pressures and contamination from mainland waste [35].

Table 2. Sediment types in the Alor Archipelago waters, East Nusa Tenggara of Indonesia

Stations	Fraction Percentage (%)			Sediment Type
	Sand	Silt	Clay	
1	45.69	45.82	8.49	Silty Sand
2	82.74	0.06	17.2	Sand
3	50.20	1.35	48.45	Sandy Clay
4	13.76	6.01	80.23	Clay

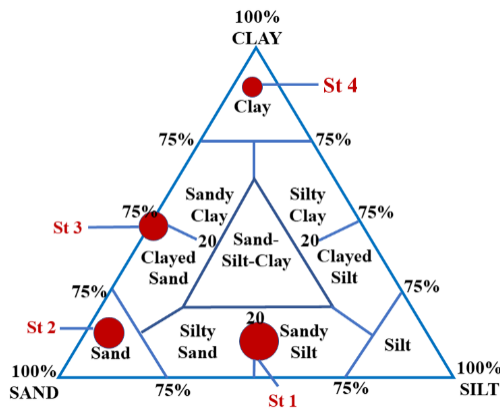


Fig. 3. Sediment classification based on the Shepard ternary diagram

Community Structure and relative abundance

Table 3 presents the distribution and composition of gastropods in the Alor Archipelago, with species illustrations provided in Figure 4. A total of 69 gastropod species from 23 families were identified, with Cerithiidae and Neritidae exhibiting the highest species richness (8 species each), while Batillariidae and Planaxidae were represented by a single species. The gastropod species *Crypraea mariae*, *Erosaria erosa*, and *Bulla ampulla* recorded the highest abundance, with *Erosaria erosa* being the most widely distributed, observed across all stations, whereas *Crypraea mariae* and *Bulla ampulla* were confined to three stations. *Crypraea mariae* had the highest individual count (25), followed by *Erosaria erosa* (23) and *Bulla ampulla* (21), reflecting their varying spatial distributions.

Table 3. Gastropod distribution and composition in the Alor Archipelago waters, East Nusa Tenggara of Indonesia

Family	Spesies	Stations				Total Individuals
		1	2	3	4	
Architectonidae	<i>Architectonica nobillis</i>	+	-	+	+	5
	<i>Architectonica perspectiva</i>	+	-	+	-	2
Batillariidae	<i>Batillaria zonalis</i>	-	-	+	-	1
Cerithiidae	<i>Cerithium eburneum</i>	+	+	+	+	15
	<i>Cerithium lutosum</i>	-	+	+	+	14
	<i>Cerithium tenuifilum</i>	-	+	+	+	12
	<i>Rhinoclavis bretteghami</i>	+	-	+	+	9
	<i>Rhinoclavis butuberculata</i>	+	-	+	-	4
	<i>Rhinoclavis fasciata</i>	-	+	+	+	16
	<i>Rhinoclavis gemmata</i>	-	+	+	-	6
	<i>Clypeomorus chemnitziana</i>	-	-	+	-	1
	<i>Conus emaciatus</i>	+	-	+	+	10
Conidae	<i>Conus generalis</i>	-	-	+	+	2

Family	Species	Stations				Total Individuals
		1	2	3	4	
Bullidae	<i>Conus leopardus</i>	-	-	+	-	1
	<i>Conus sanguinolentus</i>	-	-	+	-	1
	<i>Bulla ampulla</i>	-	+	+	+	21
Nassariidae	<i>Nassarius albens</i>	-	+	-	+	2
	<i>Nassarius margaritifereus</i>	+	-	+	+	6
Neritidae	<i>Canarium urceus</i>	-	-	-	+	3
	<i>Phos muriculatus</i>	-	-	+	-	3
	<i>Nerita picea</i>	-	+	+	-	10
	<i>Nerita polita</i>	-	+	+	-	10
	<i>Nerita textilis</i>	-	+	+	-	13
	<i>Nerita undata</i>	-	+	+	+	16
	<i>Nerita versicolor</i>	-	+	+	+	12
	<i>Nerita albiola</i>	+	-	+	-	8
	<i>Clithon oualaniense</i>	+	-	+	-	9
	<i>Tritea neritea</i>	-	-	+	+	7
Naticidae	<i>Polinices maurus</i>	-	-	-	+	2
	<i>Polinices sebae</i>	-	-	+	+	5
	<i>Polinices tumidus</i>	+	-	-	+	10
Pisaniidae	<i>Engina turbinella</i>	-	-	+	-	1
Columbellidae	<i>Pyrene flava</i>	-	-	+	+	7
	<i>Pyrene punctata</i>	-	+	+	-	11
	<i>Pyrene versicolor</i>	+	+	+	+	8
	<i>Columbella mercatoria</i>	+	+	+	-	5
Littorinidae	<i>Echinolittorina interrupta</i>	-	+	+	-	2
Strombidae	<i>Strombus granulatus</i>	+	+	-	-	5
	<i>Strombus marginatus</i>	-	+	+	+	5
	<i>Strombus microurceus</i>	+	+	-	+	5
	<i>Strombus mutabilis</i>	-	+	-	-	3
	<i>Strombus gibberulus</i>	-	+	+	+	5
	<i>Strombus pipus</i>	-	+	+	+	5
	<i>Peristarmia nassatula</i>	+	+	+	-	3
Tegulidae	<i>Techus fenestratus</i>	-	+	+	+	10
Terebrinae	<i>Techus pyramis</i>	-	-	+	-	6
	<i>Trochus niloticus</i>	+	+	+	-	9
	<i>Terebra areolata</i>	+	-	+	+	6
	<i>Terebra nebulosa</i>	-	+	+	+	11
Pediculariidae	<i>Pedicularia californica</i>	-	+	+	-	4
Muricidae	<i>Thais buccinea</i>	-	-	+	+	6
	<i>Thais bufo</i>	+	+	+	-	6
	<i>Chicoreus capucinus</i>	+	-	+	-	3
Turbinidae	<i>Turbo Agryrostoma</i>	-	+	-	-	1
	<i>Turbo chrysostomus</i>	-	-	+	-	1
	<i>Astrea semicostata</i>	-	-	+	-	1
Tornidae	<i>Cyclostremiscus balboa</i>	+	+	+	-	4
Costellariidae	<i>Vexillum acuticum</i>	-	+	+	+	10
	<i>Vexillum cruentatum</i>	-	+	+	+	10
	<i>Vexillum gruneri</i>	-	+	+	+	7
	<i>Vexillum luculentum</i>	-	+	+	+	6
	<i>Vexillum vulpecula</i>	-	+	+	+	4
Trochoidae	<i>Monilea callifera</i>	+	+	+	-	4
Cypraeidae	<i>Erosaria erosa</i>	+	+	+	+	23
	<i>Erronea ovumchrysostoma</i>	-	+	+	-	12
	<i>Cypraea nucleus</i>	-	+	+	+	8
Planaxidae	<i>Cypraea mariae</i>	-	+	+	+	25
	<i>Planaxis labiosa</i>	+	-	-	-	1
	<i>Hinea brasiliana</i>	+	-	-	+	2
Total Individuals		35	102	248	96	481

Note: (-) is not found, (+) is found, station 1 represented port area, station 2 represented tourism area, station 3 represented seagrass area, and station 4 represented residential area.



Fig. 4. Gastropod species identified in the Alor Archipelago waters, East Nusa Tenggara of Indonesia

In terms of relative abundance (Fig. 5), *Erosaria erosa* and *Polinices tumidus* were the most dominant species, each contributing 3.97% of the total individuals, followed by *Crypraea mariae* (3.69%), *Cerithium eburneum* (3.35%), *Nerita undata* (3.25%) and *Bulla ampulla* (3.20%), underscoring the ecological importance of these species in the gastropod community of the Alor Archipelago.

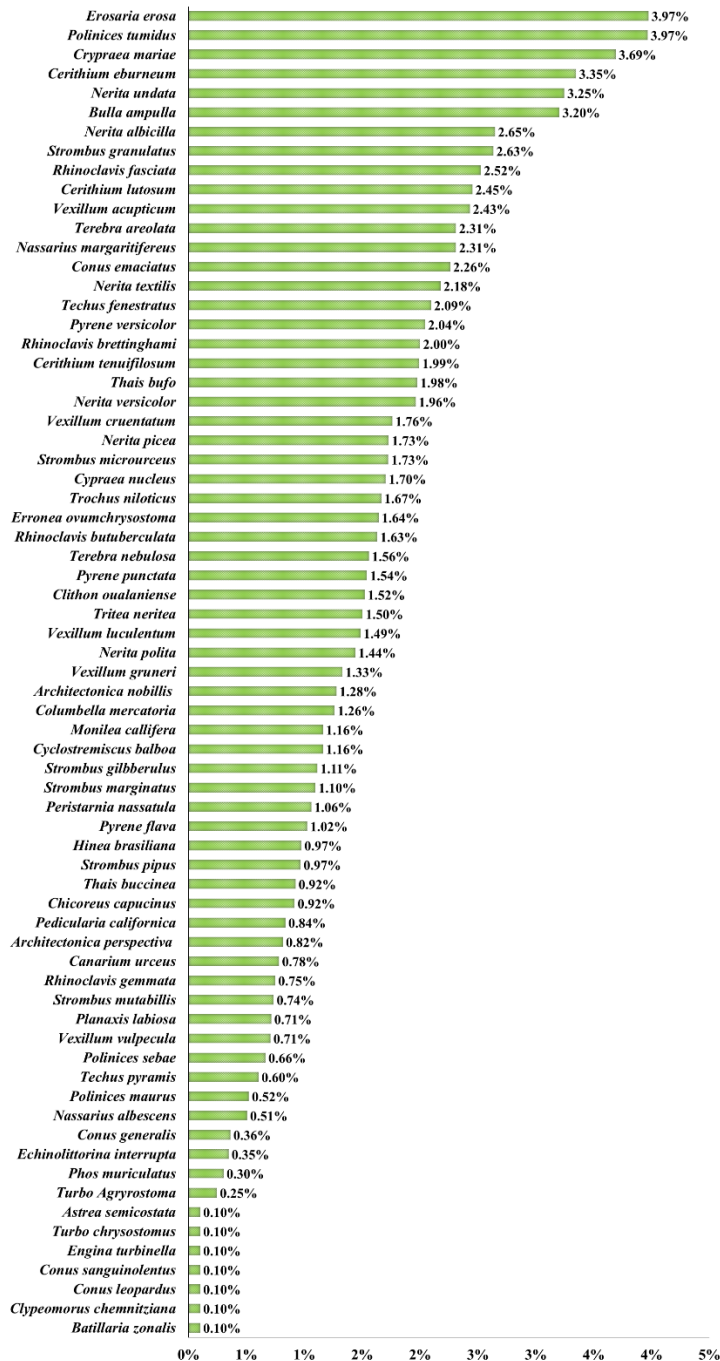


Fig. 5. Gastropod abundance across all stations

Notably, *Nerita undata* demonstrates potential as an indicator of disturbed environments due to its tolerance to environmental stressors, particularly in port areas (station 1). Species of the genus *Nerita* are known for their ability to survive in environments experiencing fluctuating and extreme conditions, especially within intertidal zones [36,37]. Meanwhile, *Erosaria erosa* can be considered an indicator of healthy environments, as it was recorded across all stations and dominated in the seagrass habitats, which are characterized by their ecological stability and richness.

Biodiversity and spatial distribution pattern

The biodiversity indices across the four stations (port areas, tourism areas, seagrass areas, and residential areas) revealed relatively similar ecological patterns (Table 4). All stations exhibited high diversity (H'), low dominance (C), and stable evenness (E), except for the port area, which demonstrated an unstable evenness index. Among the stations, the seagrass area recorded the highest diversity value ($H' = 3.716$) and the lowest dominance index ($C = 0.029$), reflecting a well-balanced ecosystem with minimal species dominance. In contrast, the port area displayed the lowest diversity ($H' = 3.075$), the highest dominance value ($C = 0.051$), and an unstable evenness index ($E = 0.726$), indicating uneven species distribution and ecological stress. The tourism and residential areas showed consistently high diversity and stable species distribution, as reflected in their evenness indices ($E = 0.819$ and 0.811 , respectively). These findings indicate that the seagrass area is the most ecologically favorable habitat, distinguished by high species diversity, even distribution, and low dominance, underscoring its vital role in maintaining ecosystem stability. In contrast, the port area reflects significant ecological stress, likely attributed to pollution from port-related activities. Contaminants, such as chemical waste and oil spills from shipping activities, may create conditions where only pollution-tolerant species can survive [20]. Less adaptable species may migrate to less polluted areas, while others may experience population declines or local extinction [38]. Despite the port area's current high species diversity index, these ecological stressors highlight the urgent need for targeted conservation and management strategies to mitigate pollution and ensure long-term biodiversity preservation in this area.

Table 4. Diversity, evenness, and dominance indices across stations in the Alor Archipelago, East Nusa Tenggara, Indonesia

Stations	Diversity index (H')		Evenness index (E)		Dominance index (C)	
	Value	Category	Value	Category	Value	Category
1. Port areas	3.075	high	0.726	Unstable	0.051	Low
2. Tourism areas	3.467	high	0.819	Stable	0.037	Low
3. Seagrass areas	3.716	high	0.878	Stable	0.029	Low
4. Residential areas	3.434	high	0.811	Stable	0.038	Low

The Morisita index (I_p) values from the four stations, as shown in Table 5, reveal distinct spatial distribution patterns of species. The seagrass area exhibits a clustered distribution ($I_p = 0.6$), indicating species aggregation, often linked to favorable environmental conditions and resource availability. Conversely, the port area ($I_p = -0.5$) and tourism area ($I_p = -0.1$) display a dispersed distribution, suggesting evenly spaced species, which may result from environmental stress or anthropogenic disturbances. The residential area ($I_p = 0.0$) shows a random distribution, reflecting neutral conditions where species neither aggregate nor disperse significantly. These findings are consistent with the biodiversity indices, where the seagrass area demonstrated the

highest diversity and ecological balance, while the port area exhibited signs of stress, evident in its dispersed species distribution and lower diversity values.

Table 5. Spatial distribution pattern across stations in the Alor Archipelago, East Nusa Tenggara, Indonesia

Stations	Morisita Dispersal Index (Ip)	
	Value	Category
1. Port areas	-0.5	Uniform
2. Tourism areas	-0.1	Uniform
3. Seagrass areas	0.6	Clustered
4. Residential areas	0.0	Random

Environmental parameters and their impact on the biodiversity index

The PCA biplot (axes F1 and F2: 93.48%) provides valuable insights into the correlation between environmental variables and gastropod diversity indices across stations in the Alor Archipelago (Fig. 6). Axis F1 accounts for 75.65% of the variance, while axis F2 explains 17.83%, together revealing three distinct station clusters. The first cluster (green) comprises port activity areas (e.g., Station 1), characterized by high salinity, pH, and water clarity (brightness) but lower dissolved oxygen (DO) levels. These conditions correlate with a higher dominance index (C), reflecting reduced biodiversity likely driven by anthropogenic activities, such as port operations, which deplete oxygen and negatively affect gastropod abundance.

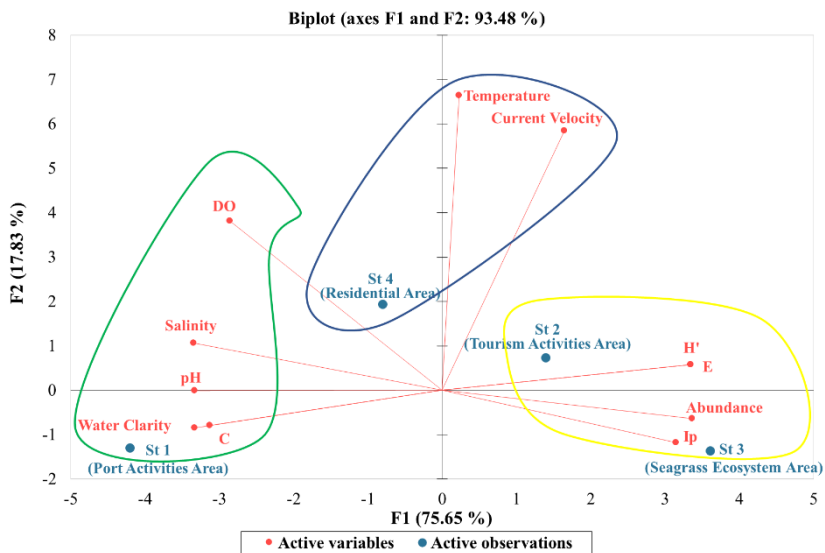


Fig. 6. PCA Biplot illustrating study sites associated with biodiversity, abundance, and environmental parameters in the Alor Archipelago, East Nusa Tenggara

The second cluster (blue) represents residential zones (e.g., Station 4), where temperature and current velocity emerge as the dominant environmental factors. These variables are typically associated with reduced gastropod diversity and abundance, further underscoring the impact of human activities in modifying habitat quality.

In contrast, the third cluster (yellow) includes tourist areas and seagrass ecosystems (e.g., Stations 2 and 3), which demonstrate high biodiversity (H'), evenness (E), abundance, and dispersion (Morisita Index, Ip). This pattern aligns with previous findings on the east coast of

Aceh, where areas with significant human activity were reported to harbor higher gastropod populations [20]. Seagrass ecosystems play a crucial role in sustaining gastropod populations by offering essential habitats that support feeding, protection, and growth, while also contributing to nutrient cycling and sediment stabilization [39–42]. These results underscore the ecological importance of seagrass habitats as biodiversity hotspots, which continue to support diverse gastropod communities despite pressures from tourism activities.

Anthropogenic impacts, including pollution and habitat degradation, significantly reduce biodiversity and abundance in disturbed coastal zones [32,43,44]. The observed patterns align with previous studies reporting higher biodiversity in less disturbed habitats, such as natural seagrass ecosystems and marine reserves [45]. Furthermore, environmental physicochemical parameters remain critical to gastropod growth and survival [46]. Natural factors, including seasonal changes, upwelling, and water currents, significantly influence temperature, salinity, and DO levels [47]. For instance, lower temperatures and salinity enhance DO-binding capacity, positively impacting intertidal gastropod diversity [48]. Conversely, human activities, such as pollution, reduce seawater pH and DO levels, impairing gastropod respiration, metabolism, and other biological processes [49–51]. Overall, these findings underscore the substrate's and environmental conditions' pivotal roles in sustaining gastropod populations. Conservation of seagrass ecosystems and mitigation of anthropogenic impacts are essential for maintaining biodiversity and ecological balance in the Alor Archipelago.

Conclusions

This study successfully identified the composition, abundance, and ecological indices of gastropods in the waters of the Alor Archipelago, East Nusa Tenggara, revealing the significant influence of environmental factors on their distribution and diversity. The generally favorable water quality conditions in the region support gastropod growth, while variations in sediment composition and current patterns shape species distribution across different stations. The diversity index (H') of gastropods in the Alor Archipelago was classified as high, with no evidence of species dominance, as reflected by the low dominance index (C). Most stations demonstrated a stable evenness index (E) and variations in spatial distribution patterns (I_p). Seagrass ecosystems exhibited the highest gastropod diversity, emphasizing their critical role as essential habitats for gastropod survival. Conversely, port and tourism areas showed reduced diversity and altered species distribution, indicating ecological stress driven by anthropogenic impacts. These findings highlight the ecological importance of preserving seagrass ecosystems and provide valuable insights for developing strategies to support sustainable coastal resource management in the Alor Archipelago.

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