Gastropod Diversity as a Bioindicator of Mangrove Ecosystem Health for Coastal Disaster Mitigation in the Tuban Mangrove Center, East Java

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Abstract
Mangrove ecosystems play a crucial role in coastal disaster mitigation and serve as habitats for gastropods, which have the potential to act as bioindicators of mangrove ecosystem health, currently under significant environmental pressure. However, information regarding gastropod diversity as a bioindicator of mangrove ecosystem health in the Mangrove Center Tuban, East Java, remains limited. Therefore, this study aims to analyze gastropod diversity as a bioindicator of mangrove ecosystem health in supporting coastal disaster mitigation and achieving SDG 14 in the area. The research was conducted from February 3 to April 27, 2025 using a survey method at three observation stations. Sampling used 5 × 5 m² quadrat transects with 1 × 1 m² subplots at five points at each station. Samples were collected directly, measured morphometrically, and identified based on morphological characteristics using taxonomic literature and the WoRMS database. Data analysis included diversity, evenness, dominance, abundance, and relative abundance indices. The results recorded 13 species from 8 gastropod families with a diversity index (H') of 1.0 (moderate), an evenness index (E) of 0.41 (moderate), and a dominance index (C) of 0.60 (moderate). The dominant species was Littoraria articulata and the highest abundance at Station 3 (2.02 individuals/m²). Moderate gastropod diversity and relatively low abundance indicate that the health of the mangrove ecosystem in the Mangrove Center Tuban area is still suboptimal to moderately adequate for coastal disaster protection. These findings highlight the importance of sustainable mangrove management and conservation in supporting SDGs 14 (Life Below Water).

Keywords: diversity, gastropods, bioindicators, mangroves.

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INTRODUCTION

Mangrove ecosystems represent characteristic vegetation in tropical coastal areas that play a vital role in coastal disaster mitigation, including tidal floods, sea level rise, and storm surges, as well as coastal erosion. They effectively attenuate wave energy and enhance sediment stability through dense, complex root systems (Rahman et al., 2025). Beyond serving as natural coastal shields, mangrove ecosystems provide critical habitat for diverse marine organisms, including gastropods, which contribute to maintaining coastal ecosystem balance through organic decomposition and nutrient cycling (Baiti et al., 2025).

Data indicate that the sustainability of mangrove ecosystems currently faces substantial pressures. Of the total 3,364,080 hectares of mangrove coverage in Indonesia, 3,121,239 hectares are in good condition, whereas 188,363 hectares are moderately degraded, and 54,464 hectares are severely degraded or sparse (Directorate of Social Resilience Statistics, 2022). One region experiencing significant degradation of mangrove coverage driven by high coastal economic activities and industrial growth is Tuban Regency (Rudianto et al., 2022). This degradation stems from factors such as land conversion, aquaculture development, and coastal erosion, leading to the loss of coastal land and residential areas, shifts in local livelihoods, and population decline (Prayogo & Sudianto, 2025; Ervianto & Hariyanto, 2021; Palisu et al., 2022).

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The health status of mangrove ecosystems can be analyzed through gastropod diversity. These organisms typically inhabit muddy, sandy, or rocky substrates, or attach to mangrove roots. Owing to their low mobility and high sensitivity to environmental fluctuations, gastropods serve as reliable bioindicators of surrounding ecosystem conditions (Isroni et al., 2023; Akbar et al., 2024). Their utility as bioindicators is further supported by studies demonstrating that gastropod diversity and abundance are closely linked to the overall health and density of mangrove ecosystems (Maha et al., 2024; Rudiansi et al., 2024), as healthy mangroves support high gastropod diversity (Wonawai, 2024).

Numerous studies on gastropod diversity have been conducted along the northern coast of East Java, identifying various gastropod families such as Cerithiidae, Potamididae, Neritidae, Muricidae, Littorinidae, and Ampullariidae, which reflect local substrate characteristics and environmental pressures (Isroni et al., 2023; Kristanti & Binawati, 2025; Prasetia et al., 2022). However, most existing studies remain predominantly descriptive and have not adequately integrated gastropod diversity data with their bioindicator function and their relationship to mangrove ecosystem services in coastal disaster mitigation. Consequently, further comprehensive research addressing these interconnected aspects is urgently needed.

One potential location for further investigation is the Tuban Mangrove Center, located in Jenu Village, Jenu District, Tuban Regency. This area features varied substrates—including mud, sand, and mixed substrates—and serves as a nursery and conservation site for species such as *Avicennia* sp., *Rhizophora* sp., *Bruguiera* sp., *Hibiscus tiliaceus*, and *Calophyllum inophyllum* to maintain coastal sustainability and support marine biota, including gastropods (Baiti et al., 2026; Wicaksono et al., 2023). Given the escalating environmental pressures and changing coastal dynamics in Tuban Regency, assessing mangrove health at the Tuban Mangrove Center is critical. Nonetheless, no empirical studies have addressed this specific topic to date.

Addressing these gaps, research on gastropod diversity as a bioindicator of mangrove ecosystem health in the Tuban Mangrove Center is imperative to provide scientific evidence supporting environmental conservation and coastal disaster mitigation. This initiative aligns with the Student Creativity Program (PKM) Theme 8 and contributes directly to Sustainable Development Goal 14 (Life Below Water), which focuses on the protection and sustainable management of marine and coastal ecosystems. Therefore, this study aims to analyze gastropod diversity as a bioindicator of mangrove ecosystem health to support coastal disaster mitigation and advance SDG 14 targets in the Tuban Mangrove Center, East Java.

MATERIALS AND METHODS

Collection and Sampling Location

This study was conducted from February 3 to April 27, 2025. The research and gastropod sampling were carried out at the Tuban Mangrove Center, Jenu District, Tuban Regency, East Java, adjacent to the main Tuban highway and residential areas of Jenu Village. The research location and gastropod sampling sites are illustrated in **Figure 1.**

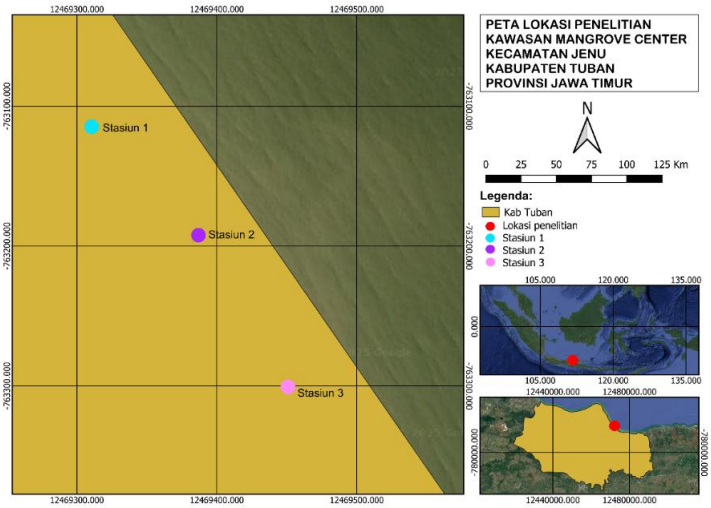


Figure 1. Map of Research Location in the Tuban Mangrove Center Area
Source: Google Earth (2025)

Sampling Technique

Gastropod sampling was conducted using a survey method to establish sampling stations. A total of three sampling stations were designated, spaced approximately 100 meters apart along a coastline of roughly 400 meters. Station 1 was located at the river estuary (the confluence of the river and sea) and Station 2 at the beachfront; both featured sandy-muddy and slightly rocky substrates. Station 3 was situated in a coastal area with a sandy-muddy and rocky substrate. At each station, sampling was performed across three transects representing the upper, middle, and lower intertidal zones extending seaward, as shown in **Figure 2**. Each transect comprised three 5x5 plots containing five 1x1 subplots each, yielding a total of 27 plots and 135 subplots (Figure 3). Gastropods within each subplot were observed from the substrate surface down to a depth of 5 cm, documented using a smartphone camera, collected in plastic bags, and labeled accordingly per plot.

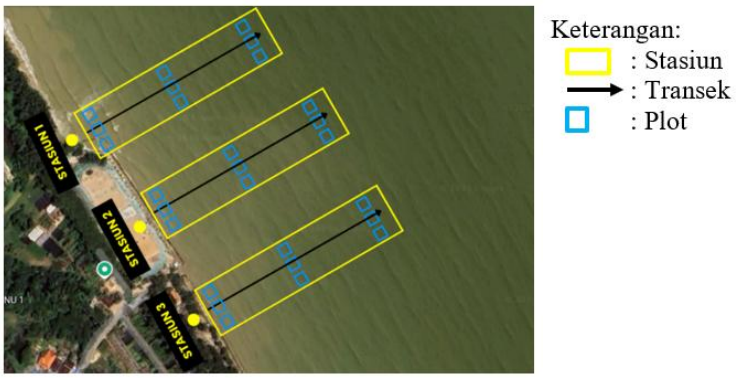


Figure 2. Transect Scheme
Source: Google Earth (2025)

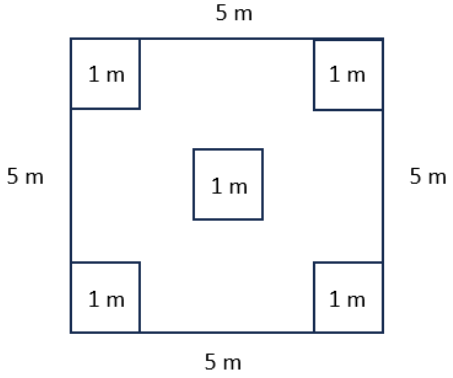


Figure 3. Quadrate Transect Scheme
Source: Yugovic et al. (2024)

Sample Preservation

Gastropod samples collected from each plot were transferred to collection bottles and preserved in 70% ethanol. Specimen bottles were labeled with information including plot number, collection time, geographical coordinates, and sampling site.

Morphometric Measurement and Identification

Morphometric measurements of gastropod samples were carried out at the Taxonomy Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, using vernier calipers. Measurements included shell length (measured from the apex to the anterior tip of the shell), shell width (measured across the widest portion of the main body whorl), aperture diameter (measured across the widest point of the aperture), and aperture height (measured vertically from the top to the bottom of the aperture). Gastropod identification was performed by observing morphological characteristics, including shell size, color, aperture shape, spire, and whorls. Taxonomic identification referred to Dharma (2005) and the World Register of Marine Species (WoRMS) database to identify specimens down to the species level.

Data Analysis

Data analysis was conducted by calculating community structure indices, including abundance, relative abundance, diversity index, evenness index, and dominance index.
Abundance was calculated using the formula by Brower and Zar (1977):

$$\mathrm{K} = \frac{\sum Ni}{A}$$

Descriptions:
K: Abundance (ind/m^2)
Ni: Number of individuals of species I (ind)
A: Total sampled plot area (m^2)

Relative abundance was calculated using the formula from Odum (1993):

$$\mathrm{KR} = \frac{ni}{N}\ x\ 100\%$$

Descriptions:
KR: Relative abundance (%)
ni: Number of individuals of species I (ind)
N: Total number of individuals across all species (ind)

The diversity index was determined using the Shannon-Wiener formula (Odum, 1993):

$$H' = -\sum_{t=1}^{s} \mathrm{Pi}\ \ln \mathrm{pi}$$

Descriptions:
H': Diversity index
Pi: Proportion of individuals belonging to species i (Pi =$\Sigma\ ni/N$)
ln: Natural logarithm
The diversity criteria were categorized as follows:
H > 3,0 : Very high diversity
1,6 < H < 3,0 : high diversity
1,0 < H < 1,5 : moderate diversity
H < 1 : low diversity

The evenness index was calculated using the formula by Brower and Zar (1977):

$$E = \frac{H'}{ln\ S}$$

descriptions:
E : Evenness index
H' : Diversity index
S : Species richness (total number of species)
ln : Natural logarithm
The evenness criteria were categorized as follows:
0,6 < E = 1,0 : High evenness
0,4 < E = 0,6 : Moderate evenness
0 < E = 0,4 : Low evenness

The dominance index was calculated using the Simpson index formula (Odum, 1993):

$$C = \sum (\frac{ni}{N})^2$$

Descriptions:
C : Simpson dominance index
ni : Number of individuals of species i
N : Total number of individuals in the population
The dominance index (C) criteria were categorized as follows:
00,0 < C < 0,30 : low dominance
0,30 < C < 0,60 : moderate dominance
0,60 < C < 1,00 : high dominance

RESULTS

Research conducted at the Tuban Mangrove Center revealed distinct variations in gastropod composition across sampling stations. A total of 12 species belonging to 8 families were identified, as shown in Figure 4 and Table 1.

Table 1. Gastropod species composition recorded at the Tuban Mangrove Center

Family	Spesies	Station			Total (ind)
		I	II	II	
Nassariidae	*Nassarius dorsatus*	-	1	1	2
	Nassarius jacksonianus	-	-	2	2
Muricidae	*Indothais lacera*	-	-	1	1
	Indothais rufotincta	1	2	-	3
Neritidae	*Nerita chamaeleon*	-	1	2	3
	Nerita polita	-	-	1	1
Littorinidae	*Littoraria articulata*	-	48	77	125
	Echinolittorina vidua	1	-	2	3
Cerithiidae	*Cerithium zonatum*	2	2	2	6
	Clypeomorus subbrevicula	2	1	3	6
Trochidae	*Monodonta labio*	-	1	-	1
Babyloniidae	*Babylonia spirata*	-	-	1	1
Ampullariidae	*Pomacea canaliculata*	8	-	-	8
Total		14	56	92	163

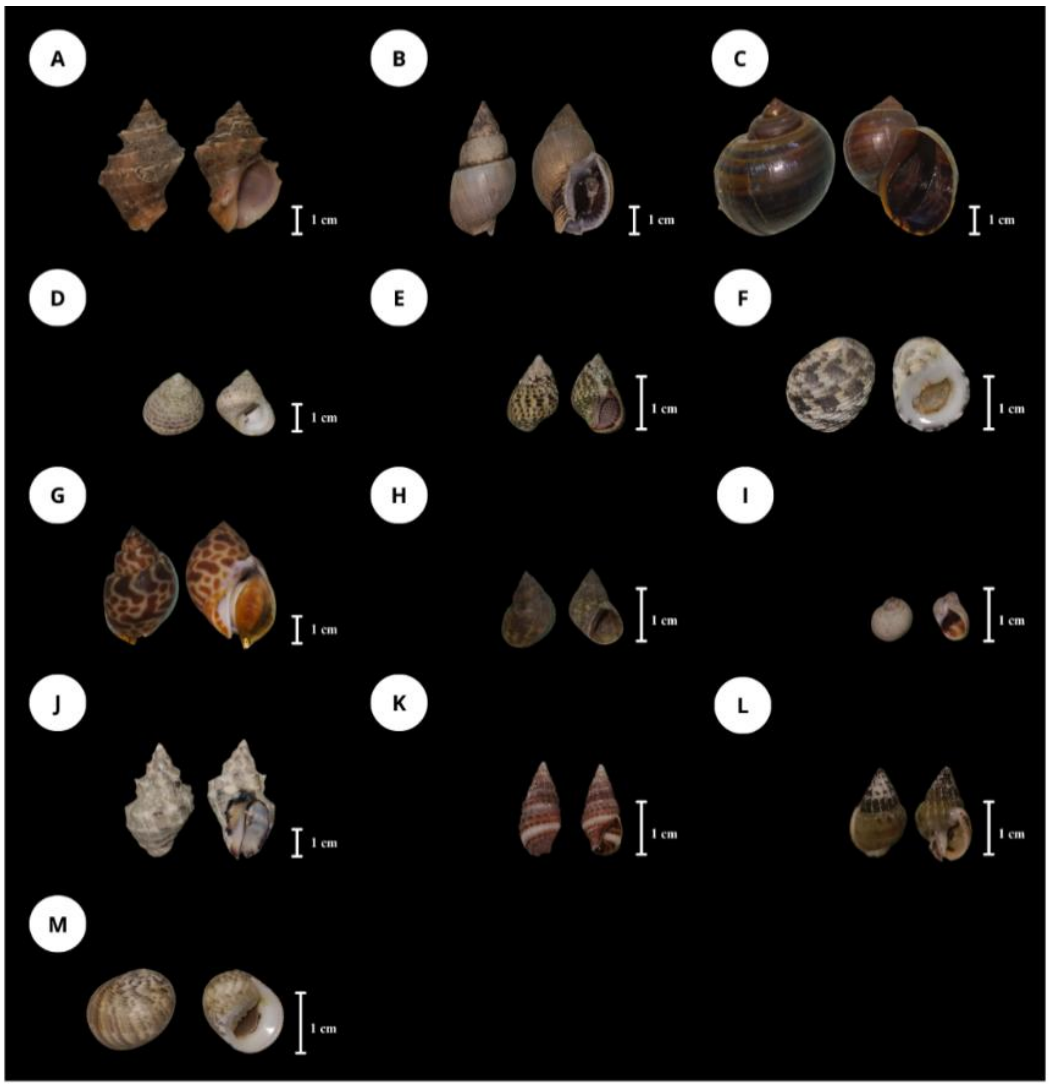


Figure 4. Gastropod species recorded at the Tuban Mangrove Center, East Java. A. Indothais lacera (Born, 1778); B. Nassarius dorsatus (Röding, 1798); C. Pomacea canaliculata (Lamarck, 1822); D. Monodonta labio (Linnaeus, 1758); E. Clypeomorus subbrevicula (Oostingh, 1925); F. Nerita chamaeleon Linnaeus, 1758; G. Babylonia spirata (Linnaeus, 1758); H. Littoraria articulata (R. A. Philippi, 1846); I. Echinolittorina vidua (A. Gould, 1859); J. Indothais rufotincta (K. S. Tan & Sigurdsson, 1996); K. Cerithium zonatum (Wood, 1828); L. Nassarius jacksonianus (Quoy & Gaimard, 1833); M. Nerita polita Linnaeus, 1758.

Community structure metrics including abundance (K), relative abundance (KR), diversity (H'), evenness (E), and dominance (C) are detailed in Tables 2 and Tables 3.

Table 2. Abundance (K) and relative abundance (KR) of gastropods at the Tuban Mangrove Center

Family	Species	Stastion					
		I		II		III	
		K	KR	K	KR	K	KR
Nassariidae	*Nassarius dorsatus*	-	-	0,02	1,79	0,02	1,09
	Nassarius jacksonianus	-	-	-	-	0,04	2,17
Muricidae	*Indothais lacera*	-	-	-	-	0,02	1,09
	Indothais rufotincta	0,02	7,14	0,04	3,57	-	-
Neritidae	*Nerita chamaeleon*	-	-	0,02	1,79	0,04	2,17
	Nerita polita	-	-	-	-	0,02	1,09
Littorinidae	*Littoraria articulata*	-	-	1,07	85,71	1,71	83,70
	Echinolittorina vidua	0,02	7,14	-	-	0,04	2,17

Family	Species	Stastion					
		I		II		III	
		K	KR	K	KR	K	KR
Cerithiidae	*Cerithium zonatum*	0,04	14,29	0,04	3,57	0,04	2,17
	Clypeomorus subbrevicula	0,04	14,29	0,02	1,79	0,07	2,24
Trochidae	*Monodonta labio*	-	-	0,02	1,79	-	-
Babyloniidae	*Babylonia spirata*	-	-	-	-	0,02	1,09
Ampullariidae	*Pomacea canaliculata*	0,18	57,14	-	-	-	-
Total		0,3	100	1,23	100	2,02	100

As indicated in Table 2, the highest gastropod abundance was recorded at Station 3 (2.02 ind/m²), followed by Station 2 (1.23 ind/m²) while Station 1 recorded the lowest abundance (0.30 ind/m2). The greater abundance at Stations 2 and 3 is likely driven by higher organic matter concentrations in the substrate, providing essential dietary resources for benthic gastropods (Supusepa et al., 2022). Although Station 1 shares substrate characteristics with Station 2, its estuarine location exposes it to anthropogenic disturbance and land-based runoff, which may impede optimal organic matter accumulation. Overall, gastropod abundance across all three stations remains low (0.30--2.02 ind/m²) which is attributed to sparse mangrove canopy coverage. In terms of species dominance, *Pomacea canaliculata* dominated Station 1 (57.14%), whereas *Littoraria articulata* dominated Stations 2 and 3 (85.7% and 83.70%, respectively), making *L. articulata* the most predominant species across the study area.

Table 3. Diversity (H'), evenness (E), and dominance (C) indices of gastropods at the Tuban Mangrove Center

Index	Value	Category
Species Diversity (H')	1,0	Moderate
Species Evenness (E)	0,41	Moderate
Species Dominance (C)	0,60	Moderate

The species diversity index (H' = 1.00) at the Tuban Mangrove Center falls into the moderate category (Table 3), indicating moderate ecological pressure, fair ecosystem stability, and moderate primary productivity (Awwalia et al., 2025). Proximity to human activities along the coast further accounts for this moderate diversity level (Nurhayati et al., 2025). The species evenness index (E = 0.41) and dominance index (C = 0.60) both fall into moderate categories, reflecting unequal population distribution due to the pronounced dominance of species such as *L. articulata.*

DISCUSSION

Two species belonging to the family Nassariidae were recorded, *Nassarius dorsatus* and *Nassarius jacksonianus*. Nassariidae species, which naturally inhabit seagrass beds and intertidal environments, generally exhibit medium-sized shells 1-3 cm, a conical shell shape, dextral coiling, an open oval aperture, and 3 to 5 whorls (Afnani et al., 2024). The family Muricidae was also represented by two species: *Indothais lacera* and *Indothais rufotincta*. Muricids are characterized by prominent spines or nodular ornamentation across the shell surface (Pedro et al., 2023). They feature dextral coiling, a conical shell form, 3 whorls, and an oval aperture. The shell lengths of *I. lacera* and *I. rufotincta* were 5 cm and 4.5 cm respectively. Species in this family typically inhabit dead coral flats and rocky substrates (Haumahu & Uneputty, 2022).

The family Neritidae comprised two species: *Nerita chamaeleon* and *Nerita polita*. Typically inhabiting mangrove habitats, neritids are characterized by dextral coiling, globose shells, small shell size 1-2 cm multiple whorls, a white outer lip, and 1 to 4 inner labial teeth (Djoemharsjah et al., 2023). The family Littorinidae was represented by *Littoraria articulata* and *Echinolittorina vidua*. Littorinids inhabit substrate surfaces, prop roots, trunks, and canopy leaves of mangroves. They typically feature

small, thin conical shells 0.5 cm-1.5 cm broad circular apertures, dextral coiling, 3 whorls, and an acute spire tip (Rupmana et al., 2021).

Two species of the family Cerithiidae were identified: *Cerithium zonatum* and *Clypeomorus subbrevicula*. Typically found in sandy substrates, cerithiids possess medium-sized conical shells 2-6 cm, dextral coiling, an elongated oval aperture, and a pointed apex (Armansyah et al., 2022). The family Trochidae was represented solely by *Monodonta labio*, characterized by a shell size 3 cm, an oval and robust shell structure, a rough surface, dextral coiling, a short spire apex < 1 mm, non-spinous dorsal surface, 3 whorls, a circular aperture, and 10 denticles on the outer lip. Trochids typically inhabit sandy substrates and attach to rocky surfaces (Asmarani et al., 2025).

The family Babyloniidae was represented by a single species, *Babylonia spirata*, which presented an average shell length of 4.5 cm a conical shell form, a yellowish-white background color covered with brownish-orange spots, dextral coiling, 3 whorls, and an oval aperture. Its natural habitat includes sandy and muddy sea floors (Susetyo et al., 2023). Finally, the family Ampullariidae was represented by *Pomacea canaliculata*, with an average shell length of 5 cm, a globose yellow-to-dark-brown shell, dextral coiling, 3 whorls, faint brown transverse bands extending to the apertural rim, and an oval aperture. This species exhibits high adaptability across freshwater environments, including rice fields, rivers, lakes, and marshes (Hanuninda et al., 2025). Its occurrence at Station 1 is attributable to the station's location at a river estuary, where freshwater gastropods can be washed downstream into the marine environment.

As summarized in Figure 4 and Table 1, the gastropod community across the Tuban Mangrove Center comprised 8 families and 12 species. This modest species richness is likely influenced by the sandy-muddy and slightly rocky substrate conditions, as well as the moderate canopy density of the mangrove vegetation. This finding aligns with Prasetia et al. (2022) in the Palang mangrove ecosystem, Tuban, where a similar sandy-muddy substrate yielded 4 families and 9 species. Conversely, Rupmana et al. (2021) reported higher diversity (7 families, 20 species) in the dense, muddy mangrove forests of Sutera Village, North Kayong. Spatial distribution patterns showed that Ampullariidae occurred exclusively at Station 1 (river estuary), whereas Nassariidae, Muricidae, Trochidae, and Babyloniidae were distributed across stations within the upper and middle intertidal zones. In contrast, Neritidae, Littorinidae, and Cerithiidae predominantly occupied Station 2 and Station 3 in the lower intertidal zone.

Gastropods serve as reliable environmental bioindicators due to their low mobility and sensitivity to environmental changes (Akbar et al., 2024). The moderate and stable gastropod diversity reflects a reasonably healthy habitat supporting adequate substrate conditions and organic nutrient supply. However, the overall low gastropod abundance suggests that mangrove canopy density in the Tuban Mangrove Center remains suboptimal, as gastropod abundance is positively correlated with mangrove tree density (Rudiansi et al., 2024). Reduced mangrove density compromises the ecosystem's capacity to attenuate wave energy, stabilize coastal sediments, and mitigate shoreline erosion (Rahman et al., 2025). Consequently, the current health status of the mangrove ecosystem at the Tuban Mangrove Center provides only partial coastal disaster protection. Comprehensive monitoring incorporating vegetation density, water quality parameters, soil pH, temperature, and sediment profile is recommended. Sustainable restoration and management of the Tuban Mangrove Center are essential to bolster coastal protection in alignment with SDG 14 (*Life Below Water*) objectives (Arfan et al., 2024).

CONCLUSION

A total of 12 gastropod species belonging to 8 families were recorded in the Tuban Mangrove Center, East Java, with a moderate species diversity index (H' = 1.00). Gastropod abundance peaked at Station 3 (2.02 ind/m^2), though overall abundance across all three stations remained low. Community structure was dominated by *Pomacea canaliculata* at Station 1 (57.14%) and *Littoraria articulata* at Stations 2 and 3 (85.71% and 83.70%, respectively). Both the species evenness index (E = 0.41) and dominance index (C = 0.60) fell within moderate ranges. Overall, based on the moderate gastropod diversity and

low population abundance, the health of the mangrove ecosystem at the Tuban Mangrove Center ranges from suboptimal to moderately effective in supporting coastal disaster mitigation. Consequently, sustainable management and ecosystem restoration are imperative to enhance coastal protection in alignment with Sustainable Development Goal 14 (*Life Below Water*).

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All authors contributed to the field observations, data and sample collection, as well as the determination of the research topic and location. Andini Dwi Cahyani was responsible for drafting the methodology, results and discussion, performing data analysis, and manuscript editing. Ghina Ana Ammas was involved in sample documentation and drafting the introduction and abstract. Kurnia Putri Ratnamaya contributed to the literature review and drafting the conclusion. Reni Ambarwati provided supervision and guidance throughout the study, as well as final manuscript alignment and editing.

CONFLICT OF INTEREST

There is no conflict of interest.

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