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The Diversity of Molluscs in Seagrass Ecosystem of Wondama Bay, West Papua, Indonesia

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Abstract

Papua, Indonesia is located in the Coral Triangle and is home to many marine creatures. Some areas of Papua, however, remain underexplored, particularly in terms of the diversity of mollusc and their seagrass bed habitat. This research aims to document benthic mollusc and seagrass species in Wondama Bay Regency and assess how habitat, temperature, and geographic location affect mollusc diversity and composition. Field data collection was conducted at nine sampling stations. A total of 197 benthic mollusc species was recorded, consisting of 53 species from 19 families of bivalves and 144 species from 40 families of gastropods. This suggests that mollusc species in Wondama Bay Regency still need further exploration which could reveal additional species. The bivalve Tellina sp. and gastropod Mitrella scripta were found in all nine sampling areas. Furthermore, nine species of seagrasses were recorded, with Enhalus acoroides and Cymodocea rotundata found at all sites. The number of seagrass species in our study is considerably high. The seagrass species richness ranged from three to eight species, while the percent cover varied from 13 % to 65 % across sites. This research found that temperature, seagrass species, and geographic location did not significantly impact the mollusc species composition among sites. Whereas, seagrass coverage showed as an important driver of mollusc community assemblages, highlighting the importance of seagrass bed protection for mollusk diversity. This finding may assist stakeholders in advancing marine conservation efforts and encouraging the sustainable utilization of marine resources particularly in Wondama Bay Regency, Papua.

Keywords: *Bivalvia, Biodiversity, Gastropoda, Richness, Papua*

Introduction

Papua, located in the eastern part of Indonesia, at the center of the Coral Triangle region, is considered a pristine area of great interest for scientific exploration (Schultze-Westrum 2001; Palomares and Heymans 2006; Hoeksema 2007). Papua has diverse habitats, including coral reefs, seagrass beds, mangroves, rocky shores, soft sediments, and marine lake ecosystems (Mangubhai *et al.,* 2012; Becking *et al.,* 2024). The coastal areas of this region are home to many marine species (McKenna *et al.,* 2002; Palomares and Heymans, 2006). One of the most diverse organisms in these tropical coastal regions is Mollusca, a group of soft-bodied animals (McKenna *et al.,* 2002; Wells, 2002). Phylum Mollusca has various forms and sizes, with some living in shallow water areas, mainly benthic, meaning they live in or on the substrates (Dharma, 2005; Huber, 2010; Aji *et al.,* 2018). Class Bivalvia and Gastropoda are the two most diverse and commonly found molluscs in coastal areas, especially in seagrass ecosystems (Dharma, 2005; Huber, 2015; Aji and Widyastuti, 2020).

Seagrass is a flowering plant in shallow marine waters (Rahmawati *et al.,* 2022). Seagrass beds, in particular, serve as important habitats for many marine organisms, including molluscs (Aji and Widyastuti, 2020; Paramasivam and Venkataraman, 2022). Seagrass beds provide services for marine animals, such as nursery areas, food, reproduction sites, and protection from predators (Rahmawati *et al.,* 2022). Thus, seagrass availability is important for benthic mollusc communities (Rueda *et al.,* 2009; Paramasivam and Venkataraman, 2022). Some molluscs are grazers or detritus feeders, primarily obtaining their food source from seagrass leaves (Rueda *et al.,* 2009). Depending on the cover and species of seagrass, the mollusc species found in those seagrass beds may vary (Rueda *et al.,* 2009; Aji and Widyastuti, 2020; Paramasivam and Venkataraman, 2022). Furthermore, geographic location and temperature can play a role in shaping

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benthic biota community composition (Aji *et al.,* 2024). Seagrass and mollusc species composition differ between temperate, subtropical, and tropical areas due to temperature variations (Rueda *et al.,* 2008; Arbi, 2011; Islami *et al.,* 2018; Paramasivam and Venkataraman, 2022). Some mollusc species from class Bivalvia, such as those in the Mytilidae family, may survive extremely high temperatures (Huhn, 2016; Aji *et al.,* 2023). Hence, understanding the condition and community composition of molluscs and their seagrass habitats is essential for improving coastal conservation practices.

Seagrass in Indonesian waters consists of 16 species, with an overall cover average of around 42%, ranging from 5% to 81% (Rahmawati *et al.,* 2022). Specifically, based on the seagrass monitoring program held by the Indonesian government, in the Papua region there were reported eight species of seagrass in Raja Ampat, eight species in Cendrawasih Bay, eight species in Padaido islands, and six species in Biak island (Rahmawati *et al.,* 2022). Moreover, research on mollusc diversity in the Papua region is still limited compared to other parts of Indonesia (van der Meij *et al.,* 2009; Arbi, 2011; Eisenbarth *et al.,* 2018; Heryanto, 2018; Islami *et al.,* 2018), mainly due to the high costs and logistical challenges of conducting exploration in Papua. There have been few reports on the diversity and composition of molluscs in Papua's coastal ecosystem, such as in Raja Ampat (Wells, 2002) and Biak Island (Aji and Widyastuti, 2017, 2020). By exploring new geographic locations, researchers may discover mollusc species that are new to science or new records from specific areas. One of the underexplored regions for mollusc inventories is Wondama Bay Regency. Wondama Bay is part of Cendrawasih Gulf National Park in West Papua, Indonesia. While some studies have reported on the population and community structure of biota in Wondama Bay, such as whale shark (Suruan *et al.,* 2016), phytoplankton (Alianto *et al.,* 2018), reef fish (Madiyani *et al.,* 2018) and mangrove (Dharmawan and Widyastuti, 2017), there is limited information on mollusc and seagrass from this region.

The research aims to provide information on the diversity of molluscs in seagrass ecosystems of Wondama Bay. Specifically, our objective is to document the species list of molluscs and determine environmental factors, including habitat characteristics, temperature, and geographic location, that influence the diversity and composition of molluscs in seagrass ecosystmes of Wondama Bay. This information may help stakeholders support marine conservation efforts and promote the sustainable use of marine resources.

Materials and Methods

Sampling locations and characteristics

Field data collection was conducted in Wondama Bay Regency at nine stations, with the distance between stations at least 3 km, to capture the spatial variation of Wondama Bay: Yende (Station 1), Kayob (Station 2), Nupu (Station 3), Sombokoro (Station 4), Batewar (Station 5), Anandoyari (Station 6), Imbursore (Station 7), Paraibo cape (Station 8), Ruruitua (Station 9) (Figure 1) during wet season from 9 to 19 February 2016. Geographically, Wondama Bay Regency (0°15' - 3°25' S and 132°35' - 134°45' E) borders Ransiki District of Manokwari Regency to the North, Yaur District of Nabire Regency to the East and South, and Kuri and Idor Districts of Bintuni Bay Regency to the West. Physical data, such as temperature and pH, were measured in situ using digital temperature and pH meters. Additionally, habitat characteristics, including substrate types (mud, muddy sand, sandy mud, rubble) and beach profiles of coastal areas on each station, were observed.

Seagrass and mollusc data collection

Seagrass data was collected using the line and quadrat transect method, following the seagrass monitoring guidebook (Rahmawati *et al.,* 2017). Data collection occurred during low tide to facilitate more accessible sampling. A 100 m transect line was laid out perpendicular to the coastline, and square frames measuring 50 x 50 cm were placed at 10 m intervals from the shore. Seagrass species within the frames were identified, and their coverage percentage was recorded according to Rahmawati *et al.,* (2017).

For mollusc data collection, shore gleaning was conducted by walking around the seagrass beds and the beach, including mangrove and rocky shore habitats. Macro-molluscs (more than 1cm in size) were sampled qualitatively based on their occurrence (present/absence) at each site. Representative samples were collected for further identification in the laboratory and deposited as a reference collection at the Technical Implementation Unit for Marine Life Conservation – Indonesian Institute of Science, Biak, Papua. Morphological identification was performed using the guidebooks of Wilson *et al.,* (1993), Abbott and Dance (2000), Dharma (2005), and Huber (2010, 2015). The latest taxonomy and nomenclature provided by MolluscaBase (Molluscabase eds 2024) were adhered for classification.

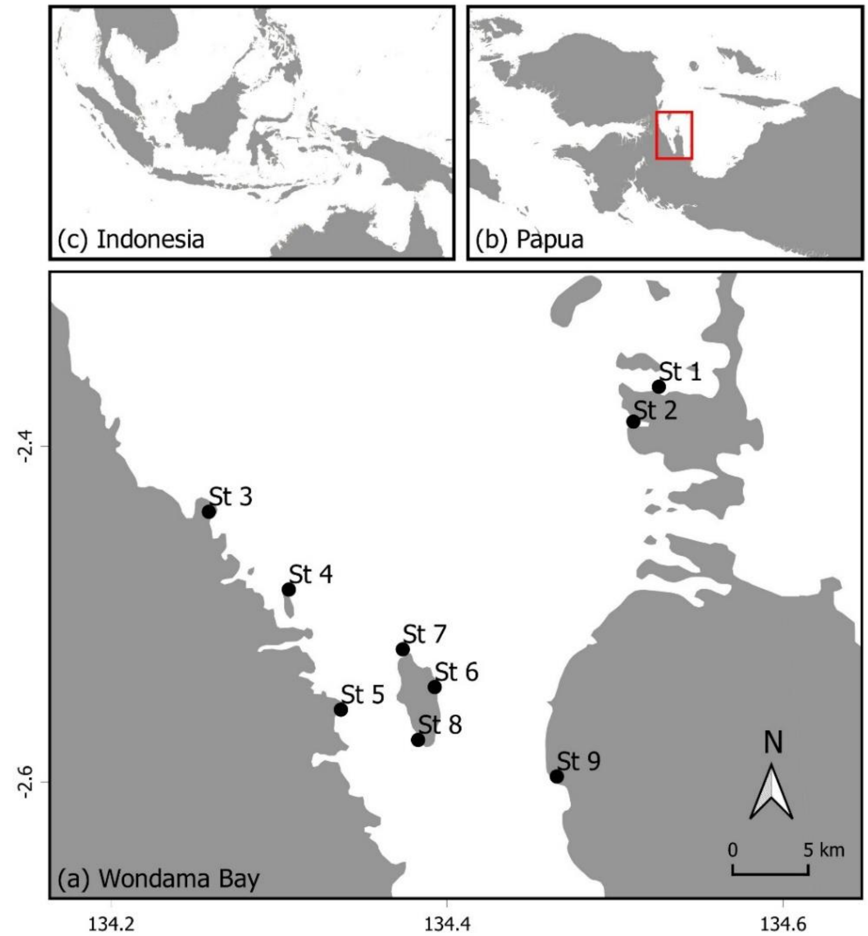

Figure 1. Study area in (a) Wondama Bay Regency including nine sampling sites, (b) West Papua Province, and (c) Indonesia.

Data analysis

Species accumulation curve with 999 permutations was conducted to evaluate whether most species was collected or not. After checking the normality assumptions, Pearson correlation (*r*) tests were conducted to examine the relationships between mollusc richness and seagrass cover, mollusc richness and seagrass richness, mollusc richness and temperature, and seagrass richness and temperature using R v.4.0.2 (R Core Team 2023), with the results visualized through the ggplot2 package (Wickham, 2016). Moreover, the similarity in mollusc community composition between sites was evaluated using the presence/absence of species data for each site. The Jaccard index was calculated to measure this without applying transformations or standardization (Real and Vargas,, 1996). This index was applied through pairwise comparisons between all sites. The similarity levels were determined by dividing the size of the intersection by the size of the union of the sample sets (Jaccard, 1908). Additionally, the composition of mollusc communities among sites was visualized using unconstrained ordination non-metric multidimensional scaling (NMDS; Legendre and Gallagher, 2001) using the vegan package in R (Oksanen *et al.,* 2019). Finally, an envfit analysis with 999 permutations to obtain r^2 and p-values (Oksanen *et al.,* 2019) was then performed to analyze the effect of explanatory variables (seagrass coverage, seagrass species, geographic location, and temperature) on the mollusc community assemblage across sites.

Results and Discussion

Characteristics and environmental condition

The habitat characteristics and environmental conditions of sites in the present study are presented in Table 1. Environmental parameter of temperature ranged between 26.8°C (St. 8) and 32°C (St.7). Ph ranged from approximately 7.36 (St. 9) to 8.1 (St. 4). According to Lee *et al* (2007), a temperature range between 23°C and 32°C supports maximum photosynthesis rates and optimal growth for tropical or subtropical seagrass species. Moreover, benthic molluscs in tropical regions can tolerate temperatures as high as 36°C (Huhn, 2016; Aji *et al.,* 2023). Most substrate types in our sampling locations were sandy mud, mud, muddy sand, sand, and rubble. The substrate is commonly recognized as a characteristic for seagrass beds. Furthermore, the beach profiles of our study sites were mostly characterized by mangroves, coconut trees, rocky shores, villages, and docking spots. Most of the sites had mangroves, except at Station 1. According to Dharmawan and Widyastuti (2017), Wondama Bay had 18 species of true mangroves, with a relatively high canopy cover of 82±6 %, dominated by genus *Rhizophora*.

Seagrass species diversity and coverage

This study recorded nine species of seagrasses (*Thalassia hemprichii*, *Enhalus acoroides*, *Cymodocea rotundata*, *Halodule uninervis*, *Halodule pinifolia*, *Halophila ovalis*, *Syringodium isoetifolium*, *Cymodocea serulata*, and *Halophila minor*) which belong into two families (Cymodoceaceae and Hydrocharitaceae) from the sampling locations (Figure 2, Table 1). The seagrass species *Enhalus acoroides* and *Cymodocea rotundata* were found at all nine sites. Rahmawati *et al* (2022) confirmed that those two seagrass species are widely distributed across Indonesian waters. However, *Halophila minor* was only found in station 5. The highest number of seagrass species was found at Station 8, with eight species, while the lowest was found at Station 2, with only three species. From our understanding, a seagrass inventory in Wondama Bay has been reported by Tebay *et al.* (2020) at three sites in Aisandami village, where three seagrass species were found: *Thalassia hemprichii*, *Enhalus acoroides* and *Halophila ovalis*. The number of seagrass species in our study is considerably higher compared to other parts of Papua. Several reports on seagrass species from the Papua region found six species in Raja Ampat (Rizqi *et al.,* 2019), eight species in Padaido Islands (Aji *et al.,* 2018), eight species in Biak Island (Aji and Widyastuti, 2020), eight species in Salawati island, eight species in Batanta island (Rondonuwu *et al.,* 2019), and seven species in small islands of northern Papua (Nugraha *et al.,* 2021).

A higher diversity of seagrass species in a single location is believed to enhance the formation of a robust seagrass community, as each species plays a unique role. Some species are effective at trapping sediment and acting as barriers to currents, while others serve as substantial nursery grounds and food sources for many marine creatures as well as for megaherbivores such as dugongs and sea turtles (Rueda *et al.,* 2009; Nugraha *et al.,* 2021; Rahmawati *et al.,* 2022). Based on the characteristics of seagrass

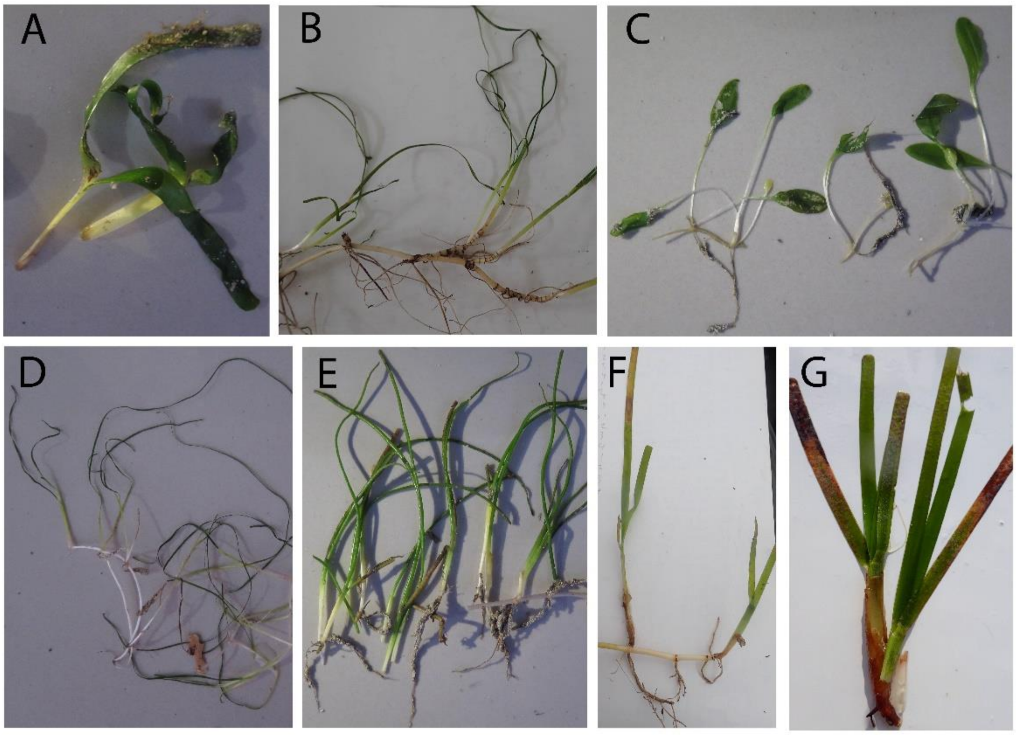

Figure 2. Some seagrass species from Wondama Bay Regency, West Papua, Indonesia. Note: A. *Thalassia hemprichii*, B. *Halodule uninervis*, C. *Halophila ovalis*, D. *Halodule pinifolia*, E. *Syringodium isoetifolium*, F. *Cymodocea rotundata*, and G. *Cymodocea serulata.*

Table 1. Habitat characteristics and environmental parameters from nine sampling locations in Wondama Bay Regency. Note: Th= *Thalassia hemprichii*, Ea= *Enhalus acoroides*, Cr= *Cymodocea rotundata*, Hu= *Halodule uninervis*, Hp= *Halodule pinifolia*, Ho= *Halophila ovalis*, Si= *Syringodium isoetifolium*, Cs= *Cymodocea serulata*, Hm= *Halophila minor.*

St	Name location	Latitude	Longitude	Seagrass cover	Seagrass species	Temp (°C)	pH	Substrates	Beach profiles
1	Yende, Roon Island	02.38551 S	134.53829 E	38.92	Th, Ea, Cr, Hu, Hp, Ho, Si	29.7	7.69	sandy mud, mud	coconut trees
2	Kayob, Roon Island	02.38522 S	134.51095 E	12.86	Ea, Cr, Hp	30.2	7.71	muddy sand	mangroves, small village
3	Nupu, Windesi	02.43895 S	134.25823 E	45.56	Th, Ea, Cr, Hu, Ho	30.0	7.6	sandy mud	mangroves, coconut trees
4	Sombokoro, Windesi	02.51179 S	134.39609 E	42.67	Th, Ea, Cr, Cs, Hp, Ho, Si	31.0	8.1	sandy mud	mangroves
5	Batewar, Windesi	02.55682 S	134.33682 E	35.38	Th, Ea, Cr, Hu, Hp, Ho, Hm, Si	28.0	7.63	muddy sand, rubble	mangroves, nearby dock
6	Anandoyari, Yop Island	02.54339 S	134.39269 E	46.15	Th, Ea, Cr, Hu, Hp, Ho, Si	31.2	7.97	sandy mud, rubble	coconut trees, mangroves
7	Imbursore, Yop Island	02.52088 S	134.37366 E	65	Th, Ea, Cr, Hu, Hp, Ho, Si	32.0	7.75	sand, rubble	mangroves, rocky shores
8	Paraibo, Yop Island	02.57487 S	134.38280 E	55.71	Th, Ea, Cr, Cs, Hu, Hp	26.8	7.64	sandy mud, rubble	mangroves
9	Ruruitua, Wasior	02.59666 S	134.46537 E	35.42	Ea, Cr, Hp, Ho	28.8	7.36	sandy mud, rubble	mangroves

habitats, life cycles, and meadow structures proposed by Kilminster *et al.* (2015). Small-sized seagrass species belong to opportunistic and colonizing groups—such as *Halophila ovalis*, *Cymodocea rotundata*, *Halodule uninervis*, *Halodule pinifolia*, and *Syringodium isoetifolium*—generally have rapid growth rates and short lifespans (Kilminster *et al.,* 2015; Rahmawati *et al.,* 2022). They may easily be uprooted from the substrate if conditions or disturbances become too severe. In contrast, larger seagrass species, such as *Enhalus acoroides* and *Thalassia hemprichii,* are considered persistent groups (Kilminster *et al.,* 2015). They tend to grow slowly but have strong adaptations to withstand pressure or extreme conditions. However, they require more time to recover than opportunistic and colonizing groups (Kilminster *et al.,* 2015; Nugraha *et al.,* 2021). Hence, a more diverse seagrass species in the ecosystemlead to more resilient ecosystem to disturbances.

In the present study, the average seagrass percent cover was 42%, with the highest seagrass cover recorded at Station 7 with 65%, whereas the lowest was at Station 2 with around 13%. For comparison, the percent cover of seagrass in other parts of Papua was reported to be 32% in Raja Ampat (Rizqi *et al.,* 2019), 42% in Padaido islands (Aji *et al.,* 2018), 36% in Biak island (Aji and Widyastuti, 2020), 32% in Salawati island, 28% in Batanta island (Rondonuwu *et al.,* 2019), and 59% in small islands of northern Papua (Nugraha *et al.,* 2021). According to the Ministry of Environment Regulation no 200, the year 2004, seagrass cover in Wondama Bay (42%) is classified as being in fair condition, falling within the range of 30 to 59%. While, according to Rahmawati *et al* (2014), it can be classified as medium (26-50%). It has been reported that seagrass cover in Indonesian waters declined from 42% in 2018 to around 34% in 2021 (Rahmawati *et al.,* 2022), likely due to anthropogenic pressures such as coastal development, human activities, tourism, and destructive fishing. Therefore, continued monitoring of seagrass conditions in Indonesian waters, especially in the Wondama Bay Regency, is needed for a more effective conservation approach to the seagrass ecosystem and its association with biota found in that ecosystem (Tebay *et al.,* 2020).

Mollusc species composition and community structure

This research is the first documentation on mollusc diversity in Wondama Bay. This study recorded a total of 197 benthic mollusc species from our sampling sites, with the species list presented in Table 2 and 3. Nevertheless, species accumulation curve did not approach an asymptote (Figure 3), indicating that the sampling effort (n= 9 stations) has not been sufficient to collect most species. Species diversity depends on the number of samples (Azovsky, 2011), suggesting that more species could be found in the Wondama Bay by increasing the number of sampling stations.

Table 2. The presence of mollusc Bivalvia from nine sites in Wondama Bay Regency

Family	Genus	Station									Species number
		1	2	3	4	5	6	7	8	9	
Arcidae	*Anadara*			+	+				+		2
	Tegillarca								+		1
Cardiidae	*Fragum*			+		+			+	+	2
	Vasticardium	+	+	+	+	+	+	+	+		6
Chamidae	*Chama*								+		1
Cyrenoididae	*Polymesoda*		+		+						1
Glycymerididae	*Tucetona*								+		1
Isognomonidae	*Isognomon*		+								1
Lucinidae	*Codakia*							+		+	2
	Anodontia			+				+			1
	Fimbria							+			1
Mactridae	*Mactra*		+	+			+				2
Malleidae	*Malleus*									+	1
Margaritidae	*Pinctada*							+	+		1
Mytilidae	*Modiolus*								+		1
Nuculanidae	*Nuculana*				+				+		1
Ostreidae	*Crassostrea*								+		1
	Ostrea			+							1
Pharidae	*Pharella*			+							1
	Siliqua		+								1
Psammobiidae	*Asaphis*			+							1
	Gari			+							1
Pteriidae	*Pteria*		+								1
Spondylidae	*Spondylus*			+			+	+	+	+	2
Tellinidae	*Quidnipagus*					+					1
	Scutarcopagia	+		+		+					1
	Tellina	+	+	+	+	+	+	+	+	+	1
	Tellinella	+		+	+	+	+			+	1
Veneridae	*Antigona*			+				+			1
	Dosinia	+	+		+	+			+		2
	Gafrarium			+					+		1
	Lioconcha	+	+		+	+	+			+	4
	Meretrix			+		+				+	1
	Pitar		+	+	+					+	3
	Timoclea				+	+					1

The lowest mollusc diversity was found at station 1, with only 23 species, while the highest was found at stations 3 and 8, with 74 species (Figure 4). The species richness of molluscs from class Bivalvia was 53 species (Table 2), which is lower than that of Gastropoda with 144 species (Table 3). Several studies on the diversity of molluscan fauna in the Papua region has been reported such as seven gastropod species in mangrove forests of Nabire (Maitindom *et al.,* 2024), 63 gastropods in coastal area of Liki island (Sujarta *et al.,* 2022), 177 gastropods and 62 bivalves in Padaido islands (Aji *et al.,* 2018), 123 gastropods and 33 bivalves in Biak island (Aji and Widyastuti, 2020), 530 gastropods, and 159 bivalves in Raja Ampat (Wells, 2002). The high number of species recorded by Wells (2002) compared to the other regions in Papua is due to the use of a rapid assessment method across 44 sites, covering all habitats and employing diving activities in coral reef ecosystems. This suggests that mollusk species in Wondama Bay Regency still need further exploration, particularly in coral reefs, which could reveal additional species.

The most commonly found bivalve species across the sampling sites (9 stations) of Wondama Bay was *Tellina* sp. and the second was *Tellinella virgata,* which was found in 6 stations. The substrate in our sampling areas is mostly fine sediment or sandy mud, suitable for those tellinid clams. The *Tellina* sp. and *Tellinella virgata* belong to the family Tellinidae (Huber, 2010). Tellinid clams specialize in deep burrowing and typically have narrow, thin shells. They usually position themselves horizontally in the sediment, lying on the left valve (Arruda *et al.,* 2003; Rueda *et al.,* 2009). They function as deposit feeders, supported by a long and mobile inhalant siphon that captures deposited particles and collects organic material from their surroundings (Arruda *et al.,* 2003; Rueda *et al.,* 2009). Among gastropods, *Mitrella scripta* was the only species found at all sites.

Canarium urceus occurred at eight stations, while other species found at seven stations included *Polinices aurantius*, *Nassarius albescens*, *Nassarius globosus*, and *Natica fasciata*. These widely distributed gastropods in Wondama Bay represent different trophic groups and feeding types within the ecosystem. The *Mitrella scripta*, *Polinices aurantius*, and *Natica fasciata* act as predators, *Canarium urceus* as grazers and detritus feeders, and *Nassarius albescens* and *Nassarius globosus* as scavengers (Molluscabase eds, 2024). This indicates that molluscs play a role in the ecosystem as herbivores, omnivores, and carnivores, facilitating the transfer of energy from lower trophic levels, such as producers, into higher trophic levels (Rueda *et al.,* 2009; Huber, 2010; Aji *et al.,* 2023).

Table 3A. The presence of mollusc Gastropoda from nine sites in Wondama Bay Regency.

Family	Genus	Station									Species Number
		1	2	3	4	5	6	7	8	9	
Acteonidae	*Pupa*			+							1
Ancillariidae	*Ancilla*	+									1
Angariidae	*Angaria*						+		+		1
Bullidae	*Bulla*								+	+	1
Bursidae	*Tutufa*								+		1
Cerithiidae	*Cerithium*	+	+	+	+	+	+	+	+	+	5
	Pseudovertagus							+			1
	Rhinoclavis			+	+		+		+		3
Chilodontaidae	*Euchelus*								+		1
	Herpetopoma								+		1
Columbellidae	*Mitrella*	+	+	+	+	+	+	+	+	+	2
Conidae	*Conus*						+		+		5
Costellariidae	*Vexillum*	+	+	+	+	+	+		+	+	8
Cymatiidae	*Monoplex*	+				+					2
Cypraeidae	*Cypraea*				+			+	+		2
	Mauritia						+	+		+	2
	Monetaria			+			+	+	+	+	1
	Palmadusta							+			1
Ellobiidae	*Ellobium*			+	+						1
	Pythia						+				1
	Tralia					+					1
Fissurellidae	*Amathina*					+					1
	Emarginula			+							1
Haminoeidae	*Aliculastrum*			+		+			+	+	1
	Atys			+					+		2
Liotiidae	*Liotinaria*								+		1
Littorinidae	*Littoraria*	+	+	+	+	+	+	+	+		4
	Littorina			+		+					1
Melongenidae	*Thalessa*									+	1
Mitridae	*Imbricaria*					+					1
	Nebularia							+			1
	Pterygia					+					1
Muricidae	*Chicoreus*		+	+							1
	Drupella			+							1
	Ergalatax								+		1
	Mancinella		+						+		1
	Morula								+	+	1
	Semiricinula		+	+					+		2
	Taurasia		+				+				1
Nassariidae	*Nassarius*	+	+	+	+	+	+	+	+	+	12
Naticidae	*Mammilla*							+			1
	Natica			+	+	+	+	+	+	+	3
	Naticarius					+		+	+		1
	Notocochlis						+				1
	Polinices		+	+	+	+	+	+	+		6

Table 3B. The presence of mollusc Gastropoda from nine sites in Wondama Bay Regency.

Family	Genus	Station									Species number
		1	2	3	4	5	6	7	8	9	
Neritidae	*Nerita*	+	+	+			+	+	+		10
	Neritodryas								+		1
	Vittina			+							1
Olividae	*Oliva*			+	+	+	+	+	+		7
Ovulidae	*Ovula*								+		1
Phasianellidae	*Phasianella*			+		+			+		1
Pisaniidae	*Cantharus*	+									1
	Pollia				+						1
	Engina						+				1
Planaxidae	*Fissilabia*			+							1
Potamididae	*Telescopium*				+						1
	Terebralia		+	+	+				+		1
Pseudomelatomidae	*Inquisitor*					+					1
Pyramidellidae	*Milda*			+	+		+		+	+	1
Seraphsidae	*Terebellum*								+		1
Strombidae	*Canarium*	+		+	+	+	+	+	+	+	3
	Conomurex						+			+	1
	Euprotomus		+		+						1
	Gibberulus				+	+	+	+	+		2
	Harpago							+			1
	Lambis				+						1
Tegulidae	*Tectus*								+	+	1
Terebridae	*Oxymeris*			+			+		+		3
	Terebra		+			+					1
Tonnidae	*Tonna*					+					1
Trochidae	*Trochus*									+	1
	Monodonta			+				+	+		2
	Rochia							+	+		1
Turbinidae	*Astralium*								+		1
	Lunella			+					+		1
	Turbo						+				1
Turridae	*Unedogemmula*		+	+		+	+	+	+		1
	Turris								+		1
Volutidae	*Cymbiola*						+		+	+	1

Furthermore, it was noticed that class Bivalvia consisted of 19 families, represented by Arcidae, Cardiidae, Chamidae, Cyrenoididae, Glycymerididae, Isognomonidae, Lucinidae, Mactridae, Malleidae, Margaritidae, Mytilidae, Nuculanidae, Ostreidae, Pharidae, Psammobiidae, Pteriidae, Spondylidae, Tellinidae, and Veneridae. Meanwhile, Gastropoda consisted of 40 families, including Acteonidae, Ancillariidae, Angariidae, Bullidae, Bursidae, Cerithiidae, Chilodontaidae, Columbellidae, Conidae, Costellariidae, Cymatiidae, Cypraeidae, Ellobiidae, Fissurellidae, Haminoeidae, Liotiidae, Littorinidae, Melongenidae, Mitridae, Muricidae, Nassariidae, Naticidae, Neritidae, Olividae, Ovulidae, Phasianellidae, Pisaniidae, Planaxidae, Potamididae, Pseudomelatomidae, Pyramidellidae, Seraphsidae, Strombidae, Tegulidae, Terebridae, Tonnidae, Trochidae, Turbinidae, Turridae, and Volutidae. All of those mollusc families found in Wondama Bay are commonly found in tropical coastal areas and play different roles in the ecosystems (Dharma, 2005; Arbi, 2011; Huber, 2015; Heryanto, 2018; Islami *et al.,* 2018; Molluscabase eds, 2024).

As can be seen from Figure 5, there was no correlation between mollusc species richness and seagrass percent cover (r= 0.37, p= 0.32) and seagrass species richness (r= 0.035, p= 0.93) and temperature (r= -0.45, p= 0.22), nor between seagrass species richness and temperature (r= 0.078, p= 0.84). Next, the Non-metric multidimensional scaling (NMDS) ordination plot illustrates the variation in mollusc assemblage composition across sites (Figure 6). *Cymbiola vespertilio* and *Monetaria annulus* were likely indicator species at stations 8 and 9, while *Cerithium citrinum* was mainly found at stations 1, 2, and 5. Snail *Nerita* sp. was found only at stations 1 and 2, and *Natica fasciata* was present at most sites but absent from stations 1 and 2. Additionally, envfit analysis indicated that temperature (r^2= 0.2046, p= 0.508), seagrass species richness (r^2= 0.5945, p= 0.069), geographic location UTM_Northing (r^2= 0.6225, p= 0.053), and UTM_Easting (r^2 = 0.5739, p = 0.086) did not significantly impact mollusc species composition across sites. However, seagrass percent cover (r^2= 0.7896, p= 0.003) was identified as a prominent driver of mollusc community assemblages.

The temperatures in Wondama Bay are relatively consistent across the sites and are suitable for benthic molluscs. Tropical mollusc species can even thrive in areas with temperatures as high as 36°C (Huhn, 2016; Aji *et al.,* 2023). The impact of temperature is likely to affect species richness and composition of benthic organisms over a long monitoring

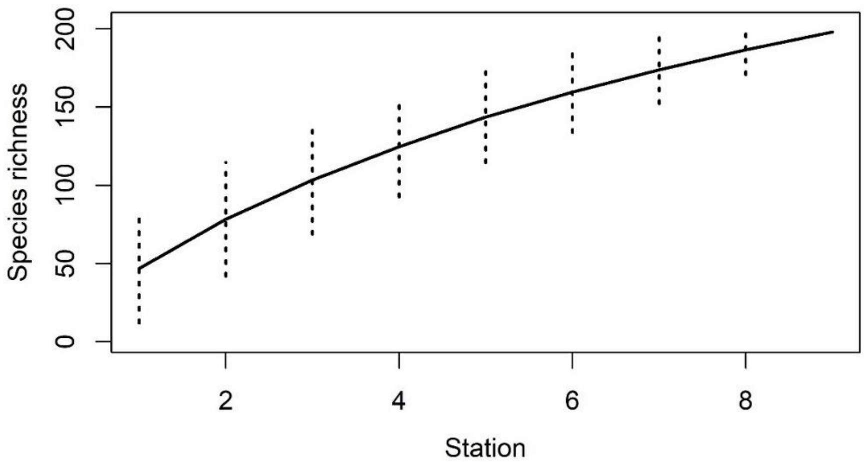

Figure 3. Species accumulation curve of mollusc species in Wondama Bay Regency.

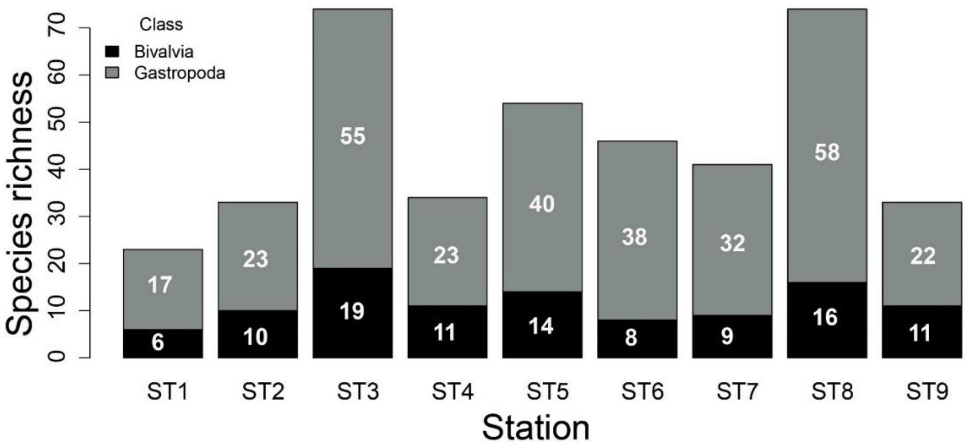

Figure 4. The number of mollusc species from nine sampling areas in Wondama Bay Regency. Note: the total species number of Bivalvia and Gastropoda classes is displayed inside the bar graph.

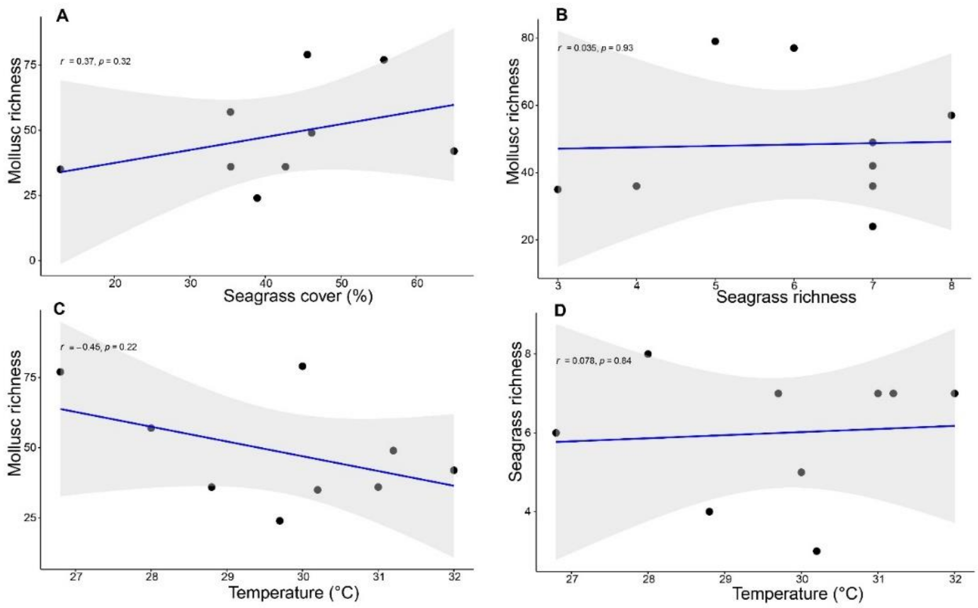

Figure 5. Pearson correlations among (A) mollusc species richness and seagrass cover, (B) mollusc species richness and seagrass species richness, (C) mollusc species richness and temperature, and (D) seagrass species richness and temperature.

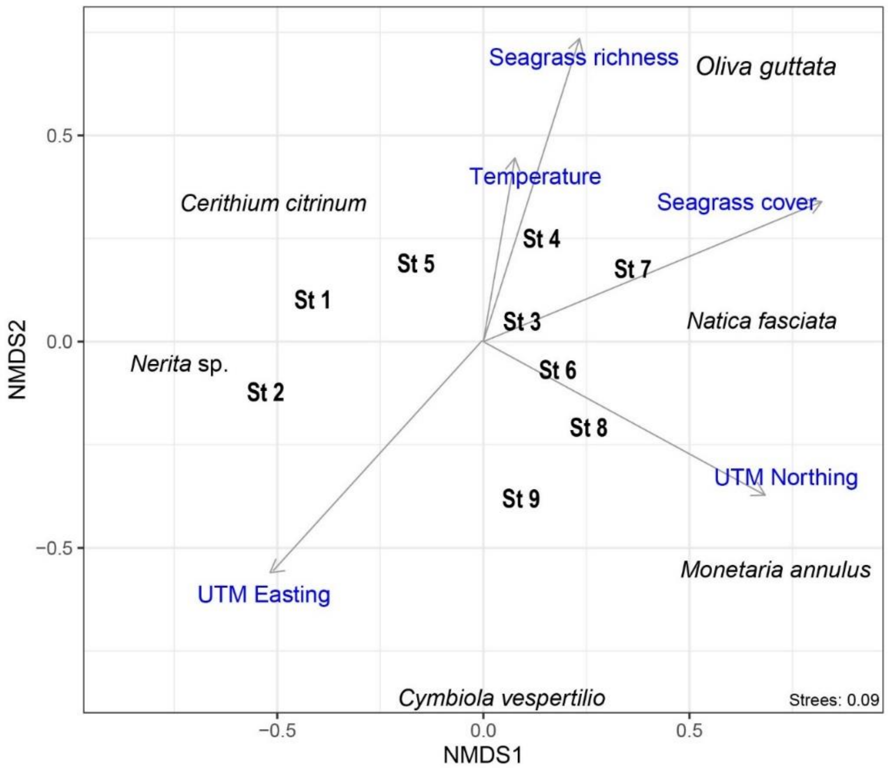

Figure 6. Non-metric multidimensional scaling (NMDS) ordination plot of mollusc assemblages from nine sites in Wondama Bay Regency, West Papua, Indonesia, based on Jaccard distances between sites. Mollusc species that have significant influence on reshaping the species composition among sites are shown *Cerithium citrinum* (r^2= 0.6928, p= 0.028), *Nerita* sp. (r^2= 0.7818, p= 0.021), *Natica fasciata* (r^2= 0.7818, p= 0.021), *Monetaria annulus* (r^2= 0.7893, p= 0.006), *Cymbiola vespertilio* (r^2= 0.7787, p= 0.029), *Oliva guttata* (r^2= 0.7226, p= 0.046). The arrows represent environmental (temperature), geographic location (UTM_Northing and UTM_Easting), and habitat characteristics (seagrass cover and seagrass species).

period with increasing temperature (Aji *et al.,* 2024). Temperature fluctuation influences benthic molluscs composition, though this is more common in temperate regions *(Rueda et al.,* 2008), as tropical areas have steady temperatures year-round. Similarly, geographic location did not influence mollusc composition, as the sites were too close. Wondama Bay is part of the Indo-West Pacific, where most mollusc species are widely distributed in tropical regions with similar climatic conditions, suggesting that the mollusc species found at our nine sites represent mollusc species from the Indo-West Pacific (Huber, 2010; Molluscabase eds, 2024).

Interestingly, only seagrass cover influenced mollusc composition, but not species richness. Additionally, the number of seagrass species did not determine mollusc richness and composition. This suggests that the number of mollusc species and their composition across our study sites could be influenced by human activities. Molluscs are a valuable source of income for local communities, providing food and materials for the ornamental and shellcraft industries (Islami *et al.,* 2018; Aji and Widyastuti, 2020). Thus, mollusc species richness may decrease because of the rising human consumption of protein from molluscs and the growing number of shell collectors. Benthic molluscs, such as gastropods and bivalves, are easily collected from their habitats, especially during low tide. As a result, large numbers of molluscs can be collected. Hence, if marine conservation programs are not properly managed, this could lead to a decline in mollusc diversity and reduce their population. Future research should consider measuring the impact of human activities in Wondama Bay, as these may influence mollusc species richness and composition within the ecosystems. Molluscs are important biota due to their role in the coastal ecosystems and their economic contribution to human life (Arbi, 2011; Eisenbarth *et al.,* 2018; Islami *et al.,* 2018).

Conclusion

This study identified nine seagrass species in total, with *Enhalus acoroides* and *Cymodocea rotundata* present at all sampling sites. The mollusc species found in Wondama Bay were relatively diverse, totaling 197 species, including 53 bivalves and 144 gastropods. The most widespread bivalve species was *Tellina* sp., while *Mitrella scripta* was the most common gastropod found at all sites. Seagrass species, temperature, and geographic location had no significant influence on mollusc species composition across the sites. However, seagrass percent cover did affect mollusc community assemblages among sites. Future research should consider the impact of human activities, as this may be a key factor influencing mollusc and seagrass composition in Wondama Bay Regency, West Papua. This present study collected samples in 2016 that may not represent the current conditions (the year 2025), as the distribution of molluscs may change due to seagrass and environmental changes as occurred. Climate change and anthropogenic (human activity) pressures are the two major stressors that have severely impacted coastal ecosystems, including seagrass beds. Nevertheless, our study could serve as the first assessment of molluscs diversity in the seagrass ecosystems of Wondama Bay. The results of this study can, therefore, be used as baseline data for monitoring seagrass ecosystems and their associated biota (e.g. molluscs) in the bay. Future sample collection during the wet and dry seasons is recommended to analyze seasonal variations in mollusc community compositions.

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