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The Effects of Mangrove Ecosystem on Mud Crabs (*Scylla serrata*) in East Lombok, Indonesia

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Abstract: Mangrove ecosystems play a crucial role in supporting the survival and growth of mud crabs (*Scylla serrata*) by providing shelter, breeding grounds, and food sources. This study aims to analyze the relationship between mangrove diversity and density with the population dynamics of *S. serrata* in East Lombok, Indonesia. The research was conducted across three study sites: Jerowaru, Seruni Mumbul, and Sugian, using purposive sampling to determine mangrove and crab distribution. Data were collected through vegetation analysis and crab sampling using line transects and quadrat plots. The findings indicate that Jerowaru has the highest mangrove density, reaching 1,233 plants/ha, dominated by *Rhizophora mucronata* (800 plants/ha). Seruni Mumbul has the highest species diversity, with nine species recorded, while Sugian, despite experiencing degradation, still supports significant *S. serrata* populations with a total density of 42 individuals/100m². Correspondence Analysis (CA) reveals that juvenile crabs are more associated with *Avicennia officinalis* at low density (<10 plants), *Sonneratia alba* at medium density (10–15 plants), and *Rhizophora mucronata* at high density (>15 plants). Meanwhile, adult *S. serrata* are strongly linked to high-density *Rhizophora mucronata* and *Sonneratia alba* (>15 plants).

Keywords: East Lombok; Mangrove ecosystem; Population dynamics; *Scylla serrata*; Mud crab

Introduction

Mangroves are among the most productive coastal ecosystems and play a crucial ecological role. These ecosystems provide various environmental services, such as coastal protection against erosion, carbon sequestration, and habitat for numerous fish species and other marine organisms (Santiti & Herison, 2018). Mangroves thrive optimally in brackish to saline waters with salinity levels ranging from 5 to 30 ppt, water temperatures between 24 and 32°C, and a pH of 6.5–8.5 (Endah Wahyuningsih et al., 2024). Suitable substrates for mangrove growth include mud, clayey sand, or a mixture of sand and clay, which support root stability and vegetation growth (Matatula, 2019). However, the existence of mangrove ecosystems is increasingly threatened by human activities such as deforestation, land conversion, and pollution, which may lead to biodiversity loss and ecosystem imbalance (Adi et al., 2022). Therefore, efforts to protect and manage mangrove ecosystems sustainably are crucial to ensuring the continued provision of their ecological services.

One species that heavily relies on mangrove ecosystems is the mud crab (*Scylla serrata*), a member of the Portunidae family. Mud crabs hold high economic value and have become one of Indonesia's primary export commodities (Wijianto & Narti, 2021). Biologically, this species contains a high protein content—approximately 49.88% in males and 52.36% in females—and healthy fats, particularly omega-3, which play an essential role in cardiovascular health (Amalo et

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al., 2020). Additionally, the water content in mud crabs ranges between 82.22% and 82.34%, depending on their habitat conditions (Praing et al., 2012). The rising market demand for mud crabs has driven intensive harvesting activities, posing a potential threat to their natural population.

Mangroves serve as the primary habitat for mud crabs by providing shelter, breeding grounds, and food sources, such as detritus and small organisms (Adnan, 2023). The complex root structures of mangroves offer safe hiding places from predators and facilitate the reproductive processes of mud crabs (Hastuti et al., 2019). Additionally, mud crabs contribute to the ecosystem by aiding in the decomposition of organic matter, thus supporting nutrient cycling in coastal environments (Karniati et al., 2021). This species is highly adaptable to various aquatic conditions, including brackish and marine waters, with temperature ranges of 29.4–31.7°C and pH levels of 7.2–8.9 (Putri et al., 2022; Hastuti et al., 2019). Consequently, the health of mangrove ecosystems significantly influences the survival and population dynamics of mud crabs. However, the increasing demand for mud crabs does not align with their declining population in natural habitats. Several factors, including land conversion, overfishing, and habitat degradation, contribute to this population decline (Indarjo et al., 2020; Sari et al., 2023).

The conversion of mangrove forests into residential areas, industrial zones, and aquaculture farms has resulted in the loss of essential habitats for this species. In certain regions, such as North Kulisusu Bay and the Aru Islands, land conversion and excessive exploitation have significantly reduced mud crab catch yields (Sari et al., 2023; Saputera et al., 2017). A study in Tarakan City revealed that the exploitation rate of mud crabs had reached 70.57% for males and 87.61% for females, far exceeding their natural regeneration capacity (Indarjo et al., 2020). Furthermore, mangrove ecosystem degradation in Bengkulu has also been linked to the decline of mud crab populations due to habitat loss (Oktamalia et al., 2019). Therefore, conservation strategies and sustainable resource management approaches are essential to maintaining ecosystem balance and ensuring the long-term viability of mud crab populations (Fauzi et al., 2022).

East Lombok is one of the regions with extensive mangrove forests and high biodiversity. Previous research indicates that mangrove ecosystems with higher species diversity tend to support larger mud crab populations compared to degraded mangrove areas (Gust, 2017). More complex habitat structures not only provide protection for mud crabs but also enhance food availability. However, limited research has specifically explored the relationship between mangrove ecosystems and the biological aspects of mud crab populations in this region. Therefore, this study aims to analyze the relationship between variations in mangrove diversity and density with the population dynamics of mud crabs in East Lombok. The findings of this study are expected to contribute to scientific knowledge in mangrove conservation and sustainable fisheries management, while also raising local community awareness regarding the importance of preserving mangrove ecosystems as a vital biological resource that supports the livelihoods of coastal populations (Alfira et al., 2018).

Method

This study was conducted in the mangrove ecosystem of East Lombok from September until October 2024, where data collection was carried out using a purposive sampling method to determine station points. The research site was divided into three stations, each representing distinct mangrove ecosystem characteristics, with each station further subdivided into three substations. The specific locations of the study sites are illustrated in Figure 1.

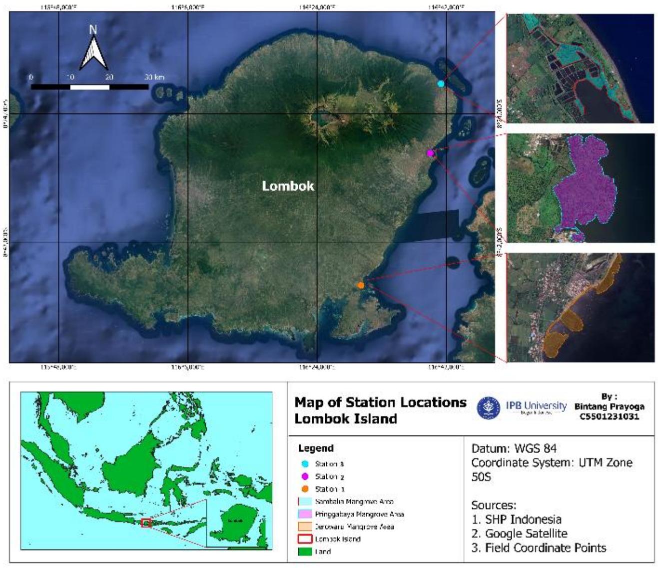

Figure 1. Research Location

Station 1 is located in Teluk Jor, Jerowaru, an area where the mangrove ecosystem is relatively well-preserved due to its designation as an ecotourism site by the local community. Conservation efforts, including maintenance and monitoring by the village and local residents, have helped sustain biodiversity and ensure the ecological sustainability of the mangrove ecosystem in this region. Station 2 is situated in Seruni Mumbul Village, Pringgabaya, where the high intensity of human activities exerts significant pressure on the mangrove ecosystem. These activities include alterations in water flow due to infrastructure development and the exploitation of natural resources, which can disrupt the ecological balance of mangroves. Meanwhile, Station 3 is located in the mangrove ecosystem of Sugian Village, Sambalia, which has undergone significant degradation due to land conversion into aquaculture ponds by local residents. These varying conditions across the stations represent different levels of environmental influence on the mangrove ecosystem. Data collection at each station was conducted using 9 plots to ensure comprehensive assessment and comparability of environmental conditions across the different locations.

The study employed a purposive sampling technique to determine data collection sites, while the sampling method was conducted systematically (Bengen, 2001). Purposive sampling was chosen to ensure that the selected stations represented various environmental conditions affecting the mangrove ecosystem. This approach allowed the study to capture variations in ecosystem health, ranging from well-preserved areas to those experiencing moderate pressure and severe degradation. Additionally, the purposive selection of locations aimed to assess how differences in mangrove ecosystem conditions influence the biological aspects of mangrove crabs, providing a more comprehensive understanding of the relationship between mangrove ecosystem quality and the life of mud crabs (*Syclla serrata*). Data collection was carried out at three stations with distinct environmental characteristics. Mangrove vegetation data were collected using a line transect method extending from the land toward the sea. At each station, three line transects were established, and within each transect, three quadrat plots measuring 10 m × 10 m were placed at 50-meter intervals. The detailed procedures for this methodology are illustrated in Figure 2.

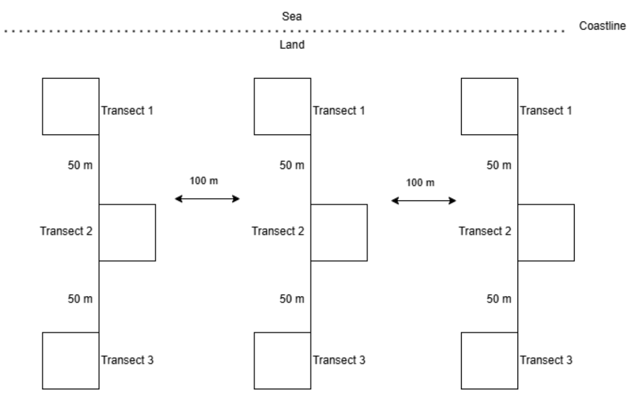

Figure 2. Sampling Schemes

Crab sampling was conducted at the same coordinate points as the mangrove vegetation survey. Mud crab (*Scylla serrata*.) samples were collected using a 100-meter-long line transect, with three quadrat plots measuring 10 m × 10 m at each transect, spaced 50 meters apart. These line transects were positioned perpendicular to the shoreline, with the first quadrat plot placed at the point where mangrove vegetation was first observed (Katili et al., 2017). Subsequently, six to nine foldable traps were randomly placed within each quadrat plot. These traps were deployed during low tide and retrieved the following day. The sampling process was conducted over four to five days at each research station (Bonine et al., 2008). The collected samples were then examined and measured, including the number of individuals, carapace width and body weight.

The data analysis in this study included the estimating of the abundance of *Scylla serrata* based on the number of mud crabs found at each research site. The classification of carapace width size was determined according to Walpole's (1992) method. The size classes of each species were categorized into three groups: small, medium, and large. The relationship between mud crabs and mangrove habitat characteristics across the three research stations was analyzed using Correspondence Analysis (CA) (Bengen, 2001).

Result and Discussion

Mangrove Species Diversity

The distribution of mangrove species across three villages, Jerowaru, Seruni Mumbul, and Sugian, exhibits variations in species composition at each location, as shown in Table 1.

Table 1. Variety of Mangrove Species

Species Name	Location Point		
	Jerowaru	Seruni Mumbul	Sugian
Rhizophora mucronata	✓	-	-
Sonneratia alba	✓	✓	✓
Rhizophora apiculata	✓	✓	✓
Avicennia officinalis	-	✓	✓
Rhizophora stylosa	-	✓	✓
Avicennia marina	-	✓	✓
Aegiceras floridum	-	✓	-
Avicennia alba	-	✓	-
Bruguiera gymnorhiza	-	-	✓
Xylocarpus granatum	-	-	✓
Aegiceras floridum	-	✓	-
Ceriops tagal	-	✓	-

Source: Primary data collection in 2024

Among these locations, Jerowaru Village has the lowest species diversity, with only three species identified: *Rhizophora mucronata*, *Sonneratia alba*, and *Rhizophora apiculata*. This is primarily due to the fact that the mangrove area in Jerowaru Village serves as a mangrove rehabilitation zone, where only a few species with high survival rates are present (Bayu *et al.* 2024). In contrast, Seruni Mumbul Village has the highest species diversity, with nine recorded species: *Sonneratia alba*, *Rhizophora apiculata*, *Avicennia officinalis*, *Rhizophora stylosa*, *Avicennia marina*, *Aegiceras floridum*, *Avicennia alba*, *Aegiceras floridum*, and *Ceriops tagal*. Meanwhile, Sugian Village has an intermediate level of species diversity, with seven identified mangrove species: *Sonneratia alba*, *Rhizophora apiculata*, *Avicennia officinalis*, *Rhizophora stylosa*, *Avicennia marina*, *Bruguiera gymnorhiza*, and *Xylocarpus granatum*. Although the species count in this village is lower than that in Seruni Mumbul, the presence of species such as *Bruguiera gymnorhiza* and *Xylocarpus granatum* suggests habitat variations that accommodate mangrove species with different ecological preferences (Loupatty *et al.* 2023; Djohan *et al.* 2015).

Differences in species richness across the villages can be attributed to environmental factors such as substrate type, salinity levels, and tidal exposure (Ahmed *et al.* 2010). *Sonneratia alba* frequently dominates areas adjacent to the sea due to its high adaptability to elevated salinity and muddy substrates (Pradnyawati, 2018; Ihsan *et al.* 2023).

Mangrove Density

Mangrove density refers to the number of individual mangrove trees within a specified area, typically expressed in plants per hectare (plants/ha) (Karniati et al., 2021). This density varies depending on mangrove species, environmental conditions, and human activities. The mangrove density recorded in the three study locations is shown in Table 2.

Table 2. Mangrove Density for Tree Category (Stem Diameter > 10 cm)

Species Name	Number of Plants (Plants/Hectare)		
	Jerowaru	Seruni Mumbul	Sugian
Rhizophora mucronata	800	-	-
Sonneratia alba	389	267	600
Rhizophora apiculata	44	33	-
Avicennia officinalis	-	122	122
Rhizophora stylosa	-	-	22
Avicennia marina	-	44	111
Avicennia alba	-	233	-
Xylocarpus granatum	-	-	33
Total	1.233	700	889

Source: Primary data collection in 2024

The distribution and density of mangrove species in Jerowaru, Seruni Mumbul, and Sugian exhibit patterns that reflect the specific ecological conditions of each location. In Jerowaru Village, the total density reaches 1,233 plants/ha, with *Rhizophora mucronata* being the dominant species (800 plants/ha), supported by substrate stability and minimal anthropogenic disturbances. The presence of rehabilitation and ecotourism initiatives further contributes to the dominance of *Rhizophora spp.* in this area (Bahri et al., 2024).

In Seruni Mumbul Village, the mangrove density is lower (700 plants/ha), with *Sonneratia alba* (267 plants/ha) and *Avicennia alba* (233 plants/ha) as the predominant species. This reflects their adaptation to muddy-sandy substrates and fluctuating salinity due to the proximity to a river estuary (Mbaba, 2024). Meanwhile, in Sugian Village, *Sonneratia alba* dominates (600 plants/ha), followed by *Avicennia officinalis*, *Avicennia marina*, and other species in smaller numbers. The dominance of *Sonneratia alba* in Sugian signifies its adaptation to intertidal zones frequently inundated by seawater (Gesang et al., 2019).

The variation in species distribution across the three locations is influenced by environmental factors such as salinity, substrate type, and human disturbances. Jerowaru benefits from stronger ecosystem protection due to its tourism and rehabilitation functions, while Seruni Mumbul experiences more diverse resource utilization, including non-timber forest product-based economies. Sugian serves as a conservation area but still faces pressures from aquaculture and coastal community activities (Wijianto et al., 2024).

Table 3. Mangrove Density for Sapling Category (Stem Diameter 2-10 cm)

Species Name	Number of Plants (Plants/Hectare)		
	Jerowaru	Seruni Mumbul	Sugian
Rhizopora mucronata	1.600	-	-
Sonneratia alba	356	667	1.155
Rhizopora apiculata	133	578	133
Avicennia oficinalis	-	755	222
Rhizopora stylosa	-	356	-
Avicennia marina	-	622	1.022
Avicennia floridum	-	133	-
Avicennia alba	-	489	-
Bruguiera gymnorhiza	-	-	267
Xylocarpus granatum	-	-	89
Total	2.089	3.600	2.889

Source: Primary data collection in 2024

Data in Table 3 shown the distribution and density of mangrove saplings (2–10 cm stem diameter) in Jerowaru, Seruni Mumbul, and Sugian, illustrating variations that reflect the ecological conditions of each site. In Jerowaru, *Rhizophora mucronata* dominates with 1,600 plants/ha, highlighting its adaptation to stable muddy substrates and low environmental stress (Syah, 2024). Seruni Mumbul has the highest sapling density, totaling 3,600 plants/ha, with *Avicennia officinalis* (755 plants/ha) and *Avicennia marina* (622 plants/ha) as the dominant species. These findings suggest that muddy-sandy substrates and an open environment influenced by seawater facilitate mangrove growth. In Sugian, *Sonneratia alba* leads with 1,155 plants/ha, followed by *Avicennia marina* (1,022 plants/ha), indicating adaptations to aquaculture-adjacent areas. The presence of species such as *Bruguiera gymnorhiza* (267 plants/ha) and *Xylocarpus granatum* (89 plants/ha) in Sugian, absent from other locations, reflects specific and heterogeneous environmental conditions (Isyrini et al., 2017). A study by Tufliha et al. (2019) Regency, found that high sapling and seedling densities indicate robust mangrove regeneration potential.

The seedling density across the three villages—Jerowaru, Seruni Mumbul, and Sugian—shown in table 4 demonstrates significant variation. In Jerowaru Village, total seedling density reaches 38,889 individuals per hectare, with *Rhizophora mucronata* being the dominant species (30,000 plants/ha), followed by *Sonneratia alba* (8,889 plants/ha). Seruni Mumbul exhibits the highest total seedling density at 243,333 plants/ha, with *Sonneratia alba* and *Rhizophora apiculata* as dominant species (30,000 and 20,000 plants/ha, respectively). Additionally, *Avicennia floridum* and *Ceriops tagal* contribute significantly, with densities of 77,778 plants/ha each. In Sugian Village, total seedling density is recorded at 84,444 plants/ha, with *Avicennia marina* leading (25,556 plants/ha), followed by *Rhizophora apiculata* (12,222 plants/ha) and *Sonneratia alba* (6,667 plants/ha).

Tabel 4. Mangrove Density for Seedling Category (Stem Diameter <2 cm)

Nama Spesies	Number of Individuals (Individuals/ha)		
	Jerowaru	Seruni Mumbul	Sugian
Rhizopora mucronata	30.000	-	-
Sonneratia alba	8.889	30.000	6.667
Rhizopora apiculata	-	20.000	12.222
Avicennia oficinalis	-	-	8.889
Avicennia marina	-	-	25556
Avicennia floridum	-	77.778	-
Avicennia alba	-	6.667	-
Bruguiera gymnorhiza	-	-	16.667
Xylocarpus granatum	-	-	14.444
Aigeceras floridum	-	31.111	-
Ceriops tagal	-	77.778	-
Jumlah	38.889	243.333	84.444

Source: Primary data collection in 2024

A high seedling density, particularly in Seruni Mumbul, signifies strong mangrove regeneration potential. According to a study by Dewi et al. (2021), high seedling density reflects an environment conducive to mangrove seedling growth and development. However, variations in density across villages may result from differences in environmental conditions, anthropogenic pressures, and species interactions (Pratama et al., 2019).

The Abudance and Morphology of Scylla serrata

Based on data collected from three research locations—Jerowaru Village, Seruni Mumbul Village, and Sugian Village—the number of *Scylla serrata* individuals observed exhibited significant variation, as illustrated in Figure 3.

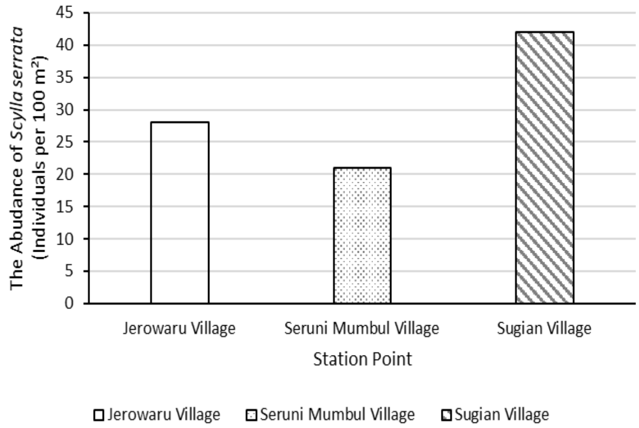

Figure 3. The Abudance of Scylla serrata in 3 Locations

The site with the highest number of individuals was Sugian Village, with a total of 42 individuals per 100m², followed by Jerowaru Village with 28 individuals per 100m². The site with the lowest number of individuals was Seruni Mumbul Village, with a recorded capture of 21 individuals per 100m².

The variation in individual counts may be influenced by several environmental and ecological factors. A study conducted by Fadlon et al. (2018) n Langsa City, Aceh, demonstrated that factors such as mangrove vegetation density, water quality, and food availability play a crucial role in determining the abundance and distribution of *Scylla serrata* within a habitat. Additionally, fishing pressure may also affect crab population density in a given area. Research by Safitri & Sofiana (2024) in the mangrove area of Pering, Natuna Regency, indicated that intensive harvesting activities without sustainable management can significantly reduce the *Scylla serrata* population.

The carapace width of *Scylla serrata* individuals in the three villages—Seruni Mumbul, Jerowaru, and Sugian—also exhibited notable variation. The following figures illustrate the distribution of carapace widths observed.

In Jerowaru Village, as shown in Figure 4, the carapace width distribution was dominated by individuals within the 42.9–48.4 mm range, accounting for 10 individuals. This data suggests that the majority of the crab population in this area has reached a growth phase where the carapace size remains relatively stable within this range.

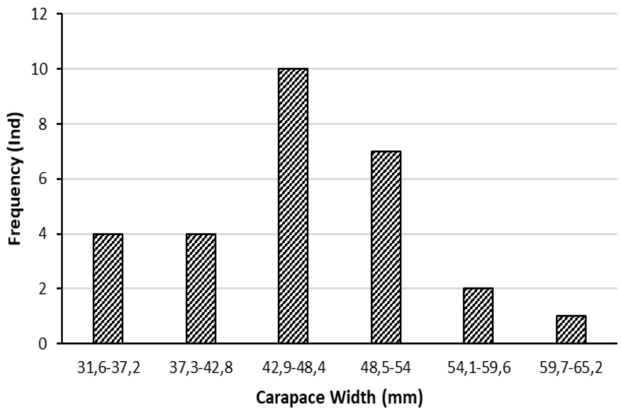

Figure 4. Frequency of the Class Size of *Scylla serrata* at Jerowaru Village

In Seruni Mumbul Village, the data presented in Figure 5 indicate that most crabs had a carapace width ranging from 52.3 to 58.8 mm, with the highest frequency reaching nine individuals. This distribution reflects a different growth pattern compared to Jerowaru Village, with larger carapace sizes indicating a dominance of more mature individuals.

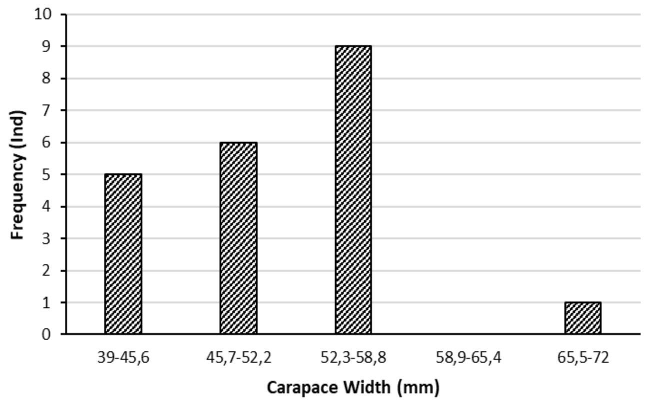

Figure 5. Frequency of the Class Size of *Scylla serrata* at Seruni Mumbul Village

Meanwhile, in Sugian Village, the data shown in Figure 6 revealed a more diverse carapace width distribution compared to the other two villages. Two dominant size ranges were observed: 33–46.7 mm with 15 individuals and 46.8–60.4 mm with 16 individuals. This diversity suggests that the crab population in Sugian Village includes individuals at various growth stages, from juveniles to fully mature adults.

The variation in size distribution may be attributed to differences in ecological conditions across locations, including food availability, population density, and exploitation rates. According to Sari et al. (2023), environmental factors such as salinity and water temperature significantly influence *Scylla serrata* growth. Additionally, high fishing pressure may result in a dominance of smaller individuals within the population, as larger individuals are more frequently captured (Farhaby, 2017).

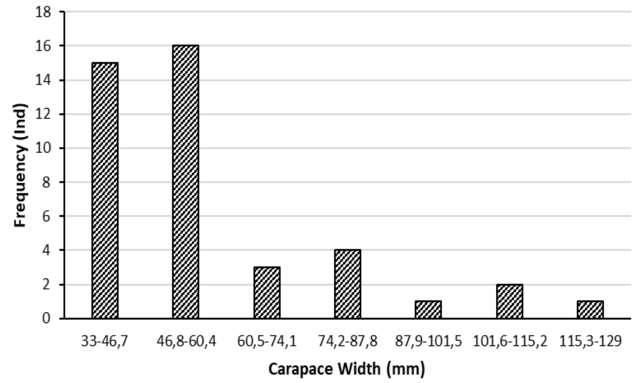

Figure 6. Frequency of the Class Size *of Scylla serrata* at Sugian Village

Mangrove Habitat Structure

The substrate in mangrove ecosystems consists of various types with different compositions, ultimately influencing mangrove density and the abundance of organisms inhabiting areas with distinct substrate characteristics (Velati & Pratikto, 2024). Table 5 presents data on the substrate structure observed at the three research locations.

A study conducted in three villages, each comprising three substations, revealed that the mangrove ecosystem substrate was predominantly composed of sandy clay loam, with sand content ranging from 31.2% to 93.87%. This sand content was significantly higher than that of other textural fractions, such as clay, which ranged from 4.42% to 15.86%, and silt, which varied between 1.71% and 57.88%. Fine-textured substrates are generally preferred by *Scylla serrata*, as they facilitate burrowing and concealment (Yunus et al., 2023).

Soil organic matter (SOM) content in the substrate is often used as a key indicator to assess the primary productivity of a region, including mangrove ecosystems. Based on the measurements obtained, the SOM content in the mangrove areas of Jerowaru Village (Station 1), Seruni Mumbul Village (Station 2), and Sugian Village (Station 3) ranged from 1.43% to 5.24%.

Table 5. Substrate Fraction and Organic Matter Soil of Mangrove Ecosystems

Sub Station	Substrate Fraction (%)				Substrate Texture	Soil Organic Matter
	Clay	Dust	Sand	Total		
1.1	8.84	6.09	85.07	100	Sandy Loam	1.43
1.2	15.86	6.81	77.33	100	Sandy Loam	2.70
1.3	11.70	8.03	80.27	100	Sandy Loam	2.70
2.1	8.58	43.15	48.27	100	Loam	4.07
2.2	8.58	30.62	60.80	100	Sandy Loam	2.38
2.3	6.50	55.10	38.40	100	Dusty Loam	5.24
3.1	4.42	1.71	93.87	100	Sandy	3.63
3.2	7.02	14.85	78.13	100	Sandy Loam	1.94
3.3	10.92	57.88	31.20	100	Dusty Loam	3.78

Source: Unram Soil laboratory Test, 2024

According to the classification proposed by Risma et al. (2023), SOM content in sediment is categorized into five levels: very low (<1.0%), low (1.01%–2.00%), moderate (2.01%–3.00%), high (3.01%–5.00%), and very high (>5.00%). Based on this classification, the SOM content in the mangrove ecosystems of the three studied villages falls within the low to very high categories. Low SOM levels indicate limited primary productivity in the sediment substrate of these areas, directly affecting the food chain and the availability of organic matter-dependent biota (Jasmine, 2014). Good water quality is crucial for the survival and growth of *Scylla serrata*. Table 6 presents the data on water quality parameters obtained from research conducted at three different stations, namely Jerowaru Village (Station 1), Seruni Mumbul Village (Station 2), and Sugian Village (Station 3).

Table 6. Water quality data at 3 stations

Sub Station	Water Quality		
	pH	Salinty (ppt)	Temperature (°C)
1.1	7.70	35.0	29.6
1.2	7.40	35.0	28.5
1.3	7.10	36.0	26.7
Average	7.40	35.6	28.3
2.1	7.65	35.0	28.2
2.2	7.83	34.0	27.0
2.3	7.53	32.0	27.9
Average	7.67	33.7	27.7
3.1	8.06	35.0	29.05
3.2	8.05	35.0	29.0
3.3	8.05	33.0	29.5
Average	8.05	34.3	29.2

Source: Primary Data Collection in 2024

The results indicate that Jerowaru Village recorded both the highest and lowest temperatures compared to the other two locations, with the highest temperature reaching 29.6°C at Substation 1.1 and the lowest at 26.7°C at Substation 1.3. However, the temperature differences among the three villages were relatively small, with an average range of 27°C to 29°C. The optimal temperature for *Scylla serrata* growth is approximately 30°C, while 29°C is also considered favorable for growth and survival rates (Karim et al., 2015). Conversely, temperatures below 25°C may inhibit the growth of *Scylla serrata* (Ardian et al., 2022).

The highest salinity was recorded in Jerowaru Village at 36 ppt in Substation 1.3, while the lowest salinity was found in Seruni Mumbul Village at 32 ppt in Substation 2.3. Salinity is a critical environmental factor influencing the growth and survival of *Scylla serrata* (Hastuti et al., 2016). In general, *Scylla serrata* can survive within a salinity range of 10 to 30 ppt, but optimal growth occurs at salinity levels between 10 and 20 ppt (Sitaba et al., 2017).

In addition to temperature and salinity, pH levels also play a significant role in the survival of *Scylla serrata*. The highest pH value was recorded in Sugian Village, with an average of 8, while the lowest pH value was found in Jerowaru Village at 7.1 in Substation 1.3. pH is a crucial parameter in mangrove ecosystems that influences the survival of *Scylla serrata*. According to research by Zamdial et al. (2022), a pH range of 6.50–7.50 is classified as a moderately suitable condition for *Scylla serrata* survival.

Relationship between Scylla serrata and Mangrove Density

The distribution of mud crabs (*Scylla serrata*) in the mangrove ecosystem was analyzed using Correspondence Analysis (CA). This study applied two types of CA: the first examines the relationship between mangrove species density and research stations, while the second investigates the association between *Scylla spp.* size classes and research stations. The results of both analyses are shown in Figures 6 and 7.

According to the Correspondence Analysis results shown in Figure 6, the relationship between mangrove density and research locations is concentrated on two main axes, contributing a total of 58.83%, with the first axis (F1) accounting for 31.36% and the second axis (F2) contributing 27.47%. The analysis revealed several association groups between mangrove species and research substations. *Rhizophora mucronata* with high density exhibited a strong association with Substations

1.2 and 1.1. Meanwhile, Substations 1.3, 3.1, and 3.2 demonstrated a stronger correlation with *Sonneratia alba* at high density. Additionally, *Sonneratia alba* at medium density was associated with Substations 2.1 and 3.3. *Avicennia alba* at high density showed a strong relationship with Substation 2.2, whereas *Avicennia officinalis* at low density was more closely associated with Substation 2.3.

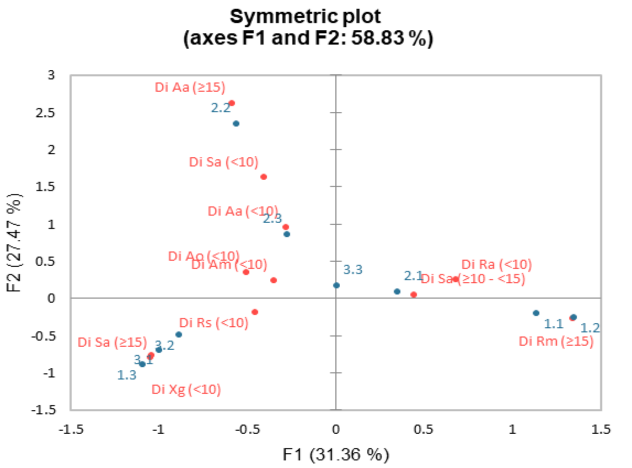

Figure 6. CA results based on mangrove vegetation density for each species and research station

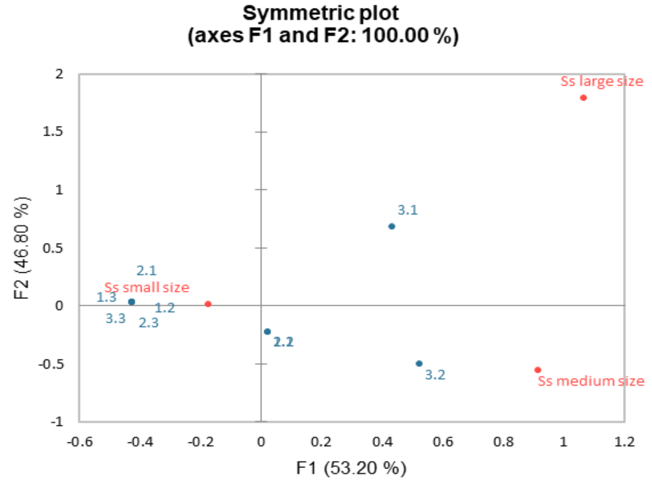

Figure 7. CA results of Scylla serrata size class and research station

Meanwhile, the CA results shown in Figure 7 indicate that the two primary dimensions fully explain the data variability (100%), with the first axis (F1) contributing 53.20% and the second axis (F2) accounting for 46.80%. The analysis results show that Substations 3.3, 1.2, 2.1, 2.3, and 1.3 tend to be concentrated in the lower-left quadrant, indicating a stronger association with small-sized *Scylla serrata*. Conversely, Substations 1.1, 2.2, and 3.2 are located in the upper section and are closer to medium-sized *Scylla serrata*, suggesting that this size class is more dominant in these locations. Meanwhile, large-sized *Scylla serrata* individuals are positioned on the right side of the plot and are closely associated with Substation 3.1, indicating a dominance of large-sized individuals at this site.

The findings from both graphs suggest that small-sized *Scylla serrata* are more frequently found in mangrove ecosystems dominated by *Avicennia officinalis* at low density, *Sonneratia alba* at medium density, and *Rhizophora mucronata* at high density. In contrast, medium-sized *Scylla serrata* exhibit a stronger association with habitats characterized by high-density *Rhizophora mucronata*, *Avicennia alba*, and *Sonneratia alba*. On the other hand, large-sized *Scylla serrata* individuals are strongly associated with high-density *Sonneratia alba*. Ecologically, high mangrove density is known to play a crucial role in supporting the abundance of mud crab (*Scylla serrata*) populations, as reported in the study by Sari et al. (2023).

Conclusion

The mangrove crab (*Scylla serrata*) found in the three mangrove ecosystems—Jerowaru Village, Seruni Mumbul Village, and Sugian Village—primarily consists of juvenile individuals, with only a small proportion classified as sub-adults or adults. The growth pattern exhibits negative allometry, while the condition factor indicates good suitability for consumption. The spatial distribution of these crabs tends to be clustered.

The survival of *Scylla serrata* is influenced by mangrove density. Smaller individuals are predominantly found in habitats with low-density *Avicennia officinalis* (<10 plants), medium-density *Sonneratia alba* (10–15 plants), and high-density *Rhizophora mucronata* (>15 plants). Meanwhile, medium-sized individuals are more commonly associated with high-density mangrove habitats, particularly those dominated by *Rhizophora mucronata*, *Avicennia alba*, and *Sonneratia alba*. In contrast, larger individuals exhibit a strong association with high-density *Sonneratia alba* habitats.

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Author Contributions

All authors have made substantial contributions to the development and completion of this manuscript, including the research design, data collection, analysis, and interpretation of results. Each author has actively participated in drafting, reviewing, and refining the manuscript to ensure its accuracy, coherence, and scholarly quality. Their collective efforts and collaboration have been essential in producing this final work.

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Conflicts of Interest

The authors declare no conflict of interest

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