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The relationship between crustacean diversity and population dynamics of Blood Cockle *Tegillarca granosa* in the coastal area of West Langsa, Aceh Province, Indonesia

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Abstract. *Mawardi, Sarong MA, Suhendrayatna, Irham M. 2024. The relationship between crustacean diversity and population dynamics of Blood Cockle* Tegillarca granosa *in the coastal area of West Langsa* (*Aceh Province, Indonesia*)*. Biodiversitas 25: 690-699.* Coastal areas serve as a transitional zone between land and sea, influenced by tidal fluctuations and river estuary currents. Coasts are ideal habitats for spawning and nurturing various crustaceans and bivalves. The aim of this study is to determine the relationship between the Shannon-Wiener diversity index of crustaceans and population dynamics of *Tegillarca granosa* (Linnaeus, 1758) (Arcidae, Bivalvia) in three different locations. The study utilized a survey method with sampling conducted using transects from the coastline towards the land in coastal areas covered with mangroves, employing transects measuring 5 meters by 5 meters. All samples collected at the study locations were fixed for identification. A total of 1,583 Crustacea individuals belonging to 17 species were sampled. The Shannon-Wiener diversity index of crustaceans ranged from 1.99 to 2.31, categorized as moderate. The highest number of individuals of *T. granosa* was in November, while the lowest number of individuals was recorded in July. Males of *T. granosa* were more dominant than females across all study sites. There was a positive correlation between the crustacean diversity index and *T. granosa* specimens, but a negative correlation with the crustacean dominance index. Seawater salinity, showed a positive correlation with crustacean diversity and the population dynamics of *T. granosa.*

Keywords: Invertebrate communities, mangrove habitats, species diversity

INTRODUCTION

The coastal areas serve as a transitional zone between land and sea, influenced by tidal fluctuations and river estuary currents (Laignel et al. 2023). These regions experience significant changes in water salinity between the rainy and dry seasons. During the fall season, the salinity tends to be lower due to the influx of rainwater through river estuaries. Contrary, in the dry season, salinity reaches higher as seawater dominates during high tides (Kitheka 1997). Abundant mangroves play an important role as a nutrient source for the surrounding area, preventing erosion, and filtering sediment during the fall period (Mitra 2020). The mangrove ecosystem is an ideal habitat for spawning and feeding communities such as Crustacea, Gastropoda and Bivalvia (Azmi et al. 2022; Isroni et al. 2023; Mawardi et al. 2023). Bivalves and crustaceans share similar habitats with similar characteristics in coastal areas covered by mangrove (Islamy and Hasan 2020; Setyadi et al. 2021). Mangroves, characterized by their long roots, play an important role in coastal areas and serve as sediment protectors and habitats for a variety of coastal fauna (Spalding et al. 2014; Hasan et al. 2022; Hasan et al. 2023).

Crustaceans and bivalves are highly dominant groups of macroinvertebrates found in coastal areas, play the role in maintaining the balance of mangrove ecosystem (Mahilac et al. 2023). In mangrove habitats, crustaceans are decomposers and detritus feeders, exerting a significant impact on carbon productivity (Ginantra et al. 2023; Swasta et al. 2023). *Tegillarca granosa* (Linnaeus, 1758) (Arcidae, Bivalvia) primarily inhabits in coastal areas with stable water circulation (Kim et al. 2022). Water salinity for *T. granosa* populations is a crucial factor besides optimal salinity range between 24‰ and 32‰ (Mawardi et al. 2021). Filter feeder, *T. granosa*, preys on plankton and various plankters carried by currents during high and low tides (Buhadi et al. 2013). The filter-feeding behavior of blood cockles presents a significant potential impact on larvae stages of various crustaceans (Fankboner and Reid 1990). Food chain between crustaceans and blood cockles in coastal areas indicates a positive correlation between the populations of these two assemblages (Kritsanapuntu and Chaitanawisuti 2019).

The findings of several studies indicate that the foods of blood cockles consist of plankton and various species of microorganisms easily filtered by these clams (Rittenschober et al. 2013). The high demand for cockles as a consumable by consumers makes them the most consumed among bivalves globally (Smaal et al. 2019). The potential threat to this oyster population, which is continually fished without sustainable management, is increasing. Food scarcity is a fundamental issue affecting populations of aquatic organisms (Prakash 2021). Loss of mangroves and environmental degradation of coastal habitat are placing ecological pressure on blood mussel populations (Bahtiar et al. 2022).

Crustacean species are coastal aquatic biota that are routinely exploited by local communities for consumption and commercial use. However, until now there is still limited information regarding the diversity of crustaceans found in the coastal areas of Aceh Province. Recent study carried out in the coastal waters of Langsa City revealed only three species of Penaeid shrimps (Muhammadar et al. 2021). However, there is a lack of information regarding the global diversity of crustaceans in the coastal areas of Langsa City. It is crucial to conduct research to understand the diversity of crustaceans in the West Langsa coastal area and its connection to the population dynamics of *T. granosa*, which coexists in the same habitat associated with mangrove vegetation. This data can serve as a reference for various stakeholders in formulating policies for environmentally friendly and sustainable coastal area management, considering that coastal areas are habitats for various species forming complex ecosystems.

MATERIALS AND METHODS

Study area

The samples were collected in the coastal areas of West Langsa, Aceh Province, Indonesia from July to November 2023. Aceh Province, particularly the city of Langsa, boasts the largest mangrove vegetation area in Southeast Asia, covering 8,000 hectares (Safuridar et al. 2022). This location is situated in the eastern coastal region of Aceh, directly connected to the Malacca Strait (Figure 1). Data collection took place at three distinct locations with varied environmental conditions, encompassing differences in both mangrove vegetation and water salinity (Table 1).

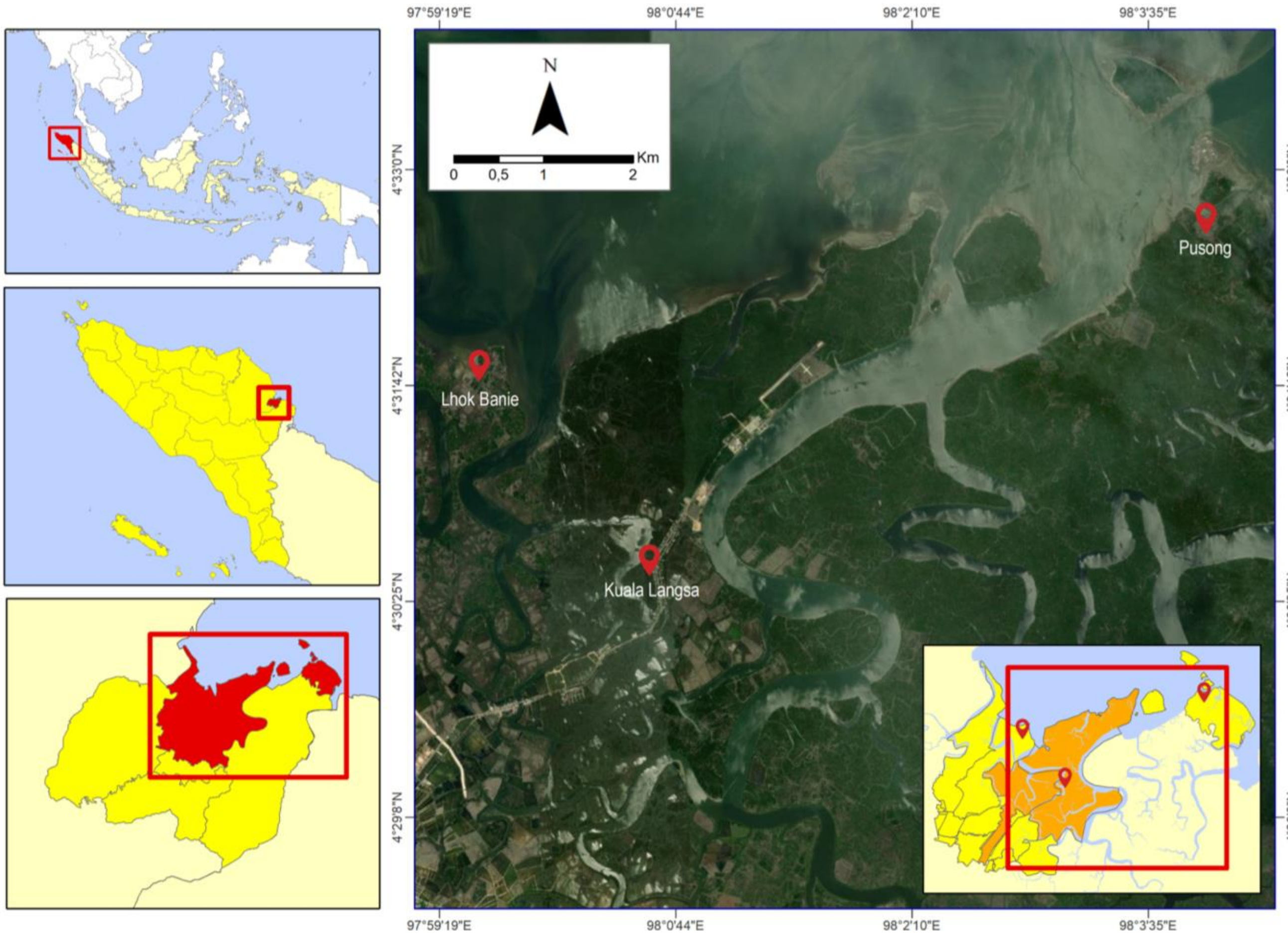

Figure 1. Reserch location in West Langsa District, Aceh Province, Indonesia

Table 1. Research location characteristics

Location	Coordinates	Location characteristics
Lhok Banie	4°31'55.6"N 97°59'38.0"E	The Lhok Banie location is a mangrove area far from residential areas, dominated by mangrove vegetation of the *Rhizophora stylosa* and *Sonneratia alba* species. This area is often flooded at high tide, the sediment is dominated by sand and clay.
Pusong	4°32'43.0"N 98°03'56.8"E	The Pusong location is a mangrove area far from residential areas, dominated by mangrove vegetation of the *Rhizophora mangle* and *Rhizophora mucronata* species. This area is close to the coast and is often flooded with water at high tide, the sediment is dominated by silt and clay.
Kuala Langsa	4°30'41.4"N 98°00'34.6"E	The Kuala Langsa location is a mangrove area close to community settlements, dominated by mangrove vegetation of the species *Bruguiera gymnorrhiza* and *Rhizophora stylosa.* This area is rarely flooded because it is far from the coast, the sediment is dominated by silt and clay.

Data collection

Sampling of crustaceans and blood cockles in coastal areas was conducted at three predetermined locations. Samples were collected along a transect that extends from the coast towards the mainland in coastal areas covered with mangrove vegetation. Sampling at each research location consisted of five transects and each transect consisted of four plots with a plot size of 5 x 5 m. *Tegillarca granosa* sampling was carried out for 5 months (July to November). Meanwhile, crustacean samples were taken once in September. Sampling took place during daylight hours at low tide, using a hand shovel to excavate crustacean burrows and blood cockles at depths of 10-20 cm in each research plot (Setyadi et al. 2021). All samples collected at the research locations were placed in sample bottles and fixed with 4% formalin, then transported to the University Samudra Biology Laboratory for identification, based on morphological similarities among crustacean species, including color, body size, legs and claws shapes, and various other morphological features (Ginantra et al. 2023; WoRMS 2024). The water parameters measured include water salinity, water pH and water temperature. Water salinity is measured using a hand refractometer. This water parameter is important to measure considering that coastal areas have unique characteristics, especially water salinity which varies greatly from one location to another. Not all crustacean species have the ability to adapt to differences in high or low water salinity, so water salinity is a limiting factor for several crustacean and bivalve species. Sediment samples were also taken at the three research locations using a scope, two samples each at each location. The sediment that has been put into the container is then analyzed based on the fraction percentage in the soil and plant research laboratory, Faculty of Agriculture, Syiah Kuala University.

Data analysis

After identifying all crustacean samples based on the number of species found at the research locations, the Shannon-Wiener Diversity Index (H') was analyzed to determine the level of crustacean diversity. This analysis categorizes diversity as high ($H' \geq 3$), moderate ($1<H'<3$), or low ($H' \leq 1$) (Krebs 1989). Additionally, the Simpson Dominance Index (C) was analyzed to determine the dominance of crustaceans at the three different locations. The Simpson Dominance Index is divided into three criteria, low dominance ($0<D \leq 0.5$), medium dominance ($0.5<D \leq 0.7$), and high dominance ($0.75<D \leq 1$) (Magurran 1988). To understand the relationship between crustacean diversity, the population dynamics of *T. granosa,* and various environmental parameters, a Principal Component Analysis (PCA) was conducted using the software Unscrambler X Prediction Engine.

RESULTS AND DISCUSSION

Crustacean diversity index

In the coastal areas of West Langsa (Aceh Province), the research revealed 1583 individual crustaceans at three varied research locations, influenced by high/low water salinity and sediment with dominance of silt/clay/sand, serving as the habitat for crustaceans associated with mangrove vegetation and various other aquatic species. These crustaceans comprised 17 species categorized into 8 families (Figure 2). The Pusong area had the highest number of crustacean species and families, with a total of 17 species from 8 families. The lowest number of species and families of crustaceans were found in the Kuala Langsa area, with 10 species from 6 families (Figure 3). Pusong area has both the highest number in species and individuals, which indicates this area provides a suitable habitat for crustaceans and offers an adequate food source. The highest number of collected species and individuals in all three research locations belonged to the Ocypodidae family, with a total of 7 species. Five families were found with only one species each, including Grapsidae, Diogenidae, Odontodacylidae, Palaemonidae, and Sergestidae (Figure 4).

The Shannon-Wiener Diversity Index of crustaceans at the three research locations varies, ranging from 1.99 to 2.31, categorizing them as moderate diversity. The highest Shannon-Wiener Diversity Index was observed in the Pusong area, while the lowest is in the Kuala Langsa area (Figure 5A). The relatively stable environment in these areas provides nutrients, contributing to the creation of a still complex food chain cycle. The high sources of nutrients in the environment positively impact the diversity of various crustacean species, which is relatively higher compared to areas close to residential areas. Areas close to human settlements, with relatively high human activities, have a negative impact on crustacean diversity. High levels of noise and domestic waste entering the environment cause pollution, resulting in a low crustacean population (Shen et al. 2021). Based on the results of the dominance index analysis, the three research locations found varying dominance indices, with a dominance index ranging between 0.13-0.16 in the low category (Figure 5B).

Table 2. Number of *T. Granosa* specimens collected

Sampling	Number of *T. granosa* specimens		
	Lhok Banie	Pusong	Kuala Langsa
July	53	25	20
August	37	53	16
September	56	87	17
October	73	130	18
Npvember	79	128	24
Total	298	423	95

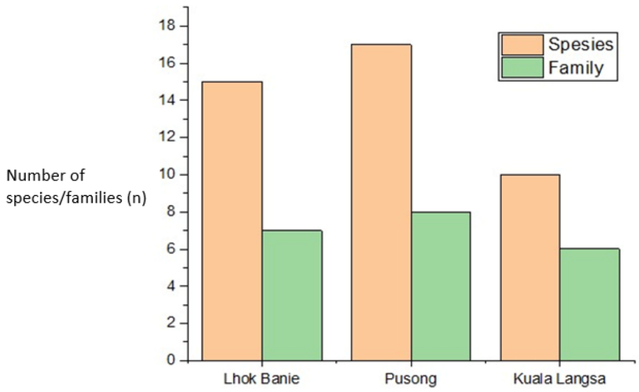

Figure 3. Number of crustacean species and families based on research locations

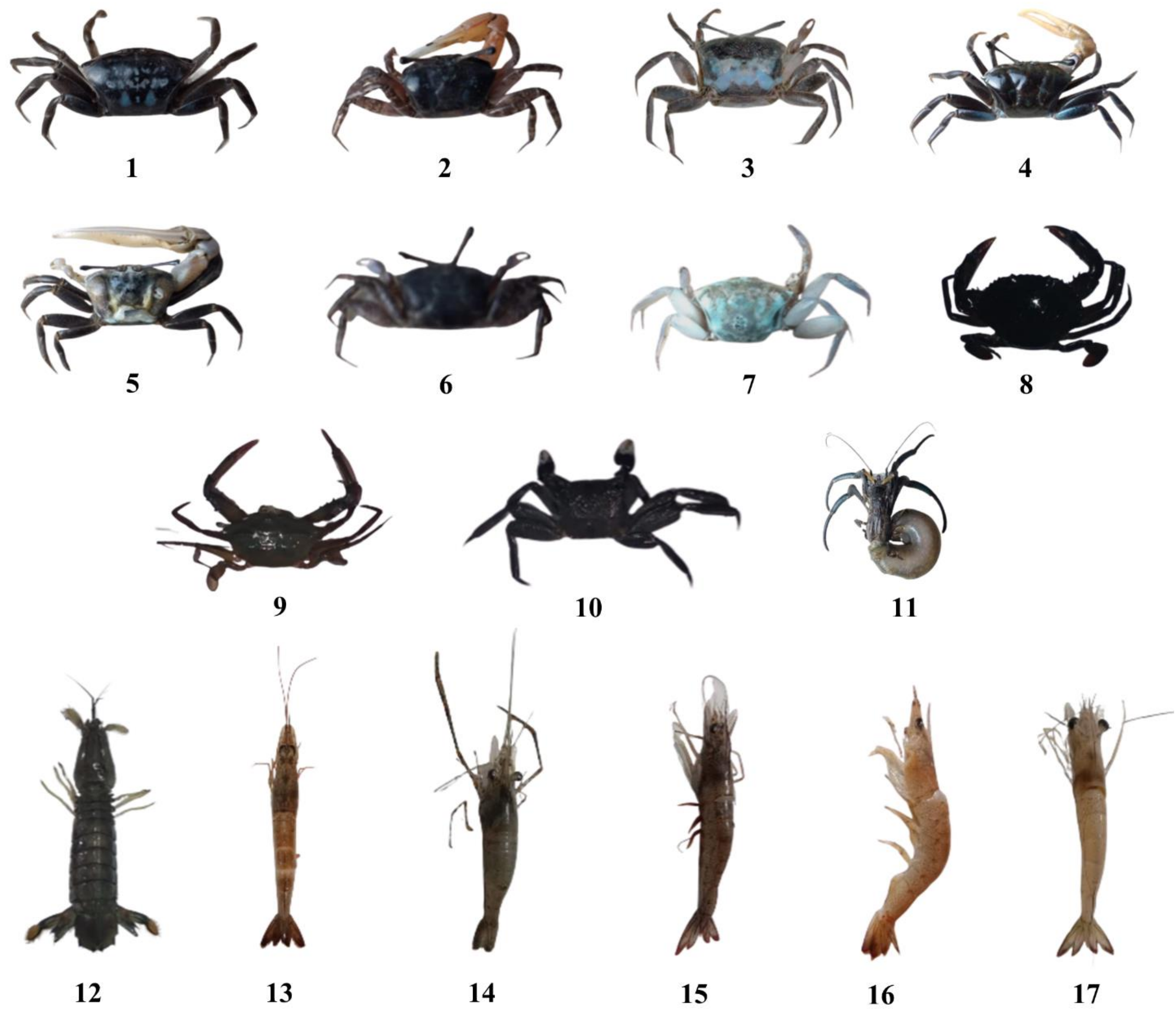

Figure 2. Spesies of crustacean recorded in the study area. 1. *Tubuca coarctata* (H. Milne Edwards, 1852), 2. *Minuca pugnax* (S. I. Smith, 1870), 3. *Gelasimus tetraganom* (Herbst, 1790), 4. *Austruca triangularis* (A. Milne-Edward, 1873), 5. *Gelasimus vocans* (Linnaeus, 1758), 6. *Tubuca bellator* (White, 1847), 7. *Paraleptuca splendida* (Stimpson, 1858), 8. *Scilla serrata* (Forsskal, 1775), 9. *Callinectes sapidus* (Rathbun, 1896), 10. *Hemigrapsus nudus* (Dana, 1851), 11. *Pagurus longicarpus* (Say, 1817), 12. *Odontodactylus scyllarus* (Linnaeus, 1758), 13. *Penaeus marguensis* (De Man, 1888), 14. *Machrobranchium rosenbergii* (De Man, 1879), 15. *Penaeus monodon* (Fabricius, 1798), 16. *Acetes indicus* (H. Milne-Edwards, 1830), 17. *Penaeus setiferus* (Linnaeus, 1767)

Population of *Tegillarca granosa*

A total of 816 specimens of *T. granosa* were collected at the research locations, sampled monthly from July to November 2023. The highest number of *T. granosa* was found in the Pusong coastal area with 423 specimens, while the lowest number of *T. granosa* was observed in the Kuala Langsa coastal area with 95 specimens (Table 2).

In general, the morphology of *T. granosa* is very difficult to differentiate between males and females, however, based on morphometric data, male *T. granosa* is taller in size than female, as well as total weight (Figure 6). Males are heavier than females. The easiest difference to identify the sex of *T. granosa* is based on gonad color, male *T. granosa* has a grayish cream gonad color, while females have brick red and orange gonad colors (Saputra et al. 2019).

Male blood cockles were consistently more dominant number of specimens than females at all research locations, with only August showing an equal number of specimens of both sexes. Pusong exhibited a more dominant number of specimens of blood cockles compared to Lhok Banie and Kuala Langsa (Figure 6A). Suitable environmental conditions and the availability of food in a given area positively impact the abundance of various coastal biota. Conversely, if the environment is less supportive, exacerbated by limited food availability, it can negatively impact the abundance of aquatic populations (Lindegren et al. 2022). Population analysis based on monthly sampling data indicated that the highest peak population was observed in November, during the rainy season, while the lowest population was in July during the dry season. The research results show an increase in the *T. granosa* population from August to November, with a particularly notable surge in November, reaching more than twice the population compared to July (Figure 7B).

Relationship between Crustacean diversity and *T. granosa* population

Environmental physicochemical parameters measured at the research location include water salinity, water pH and water temperature. Physicochemical parameters are measured at one point each month representing each research location (Table 3).

The results of Principal Component Analysis (PCA) indicate that the Pusong location serves as the most optimal habitat for *T. granosa*. There was a strong correlation between the *T. granosa* population and water salinity, but there was not a strong correlation between the *T. granosa* population with the crustacean Shannon-Weiner diversity index and the Simpson dominance index (Figure 8). The highest *T. granosa* specimens were collected at the Pusong location followed by the Lhok Banie location, while the lowest *T. granosa* specimens were collected at the Kuala Langsa location. The months of November and October, which are classified as the rainy season, have the highest number of *T. granosa* specimens, while July, which is classified as the dry season, has the lowest number of *T. granosa* specimens collected.

Feeding habits *Tegillarca granosa*

This research also analyzes the food sources consumed by *Tegillarca granosa* to identify the types of food found in the blood clam's inner mantle. An analysis of the feeding habits of the blood clam was conducted to determine the types of food consumed by this aquatic organism in its habitat in the coastal areas of West Langsa, Aceh Province. The analysis results show that crustacean larvae were found in the blood clam's organ, serving as a food source for the organism (Figure 8). These crustacean larvae were discovered in the blood clam's inner mantle at all three research locations, representing a nutrient-rich food source (Sikorski et al. 2020). The habit of crustaceans routinely molting makes them a food source for various animals, including clams (Haug 2020). During molting, the crustacean's body becomes soft, making it easier for various predators to prey on these organisms (Bashevkin and Morgan 2020).

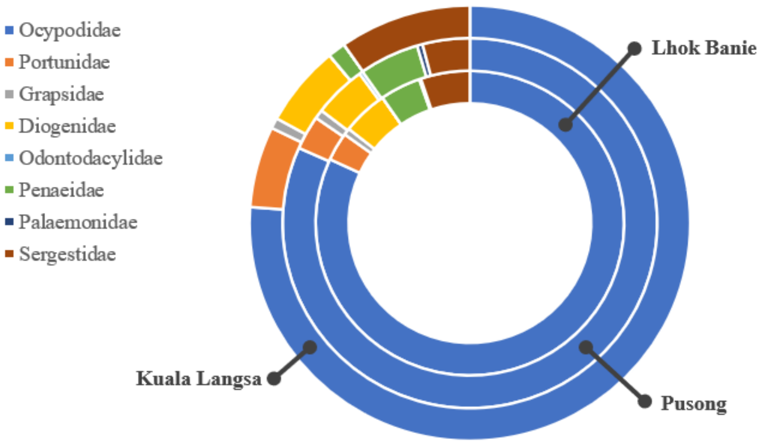

Figure 4. Composition of crustaceans based on number of species in each family collected in the research locations

Table 3. Environmental physicochemical parameters

Sampling	Location								
	Lhok Banie			Pusong			Kuala Langsa		
	Water salinity (‰)	Water pH	Water temperature (°C)	Water salinity (‰)	Water pH	Water temperature (°C)	Water salinity (‰)	Water pH	Water temperature (°C)
July	30	6.8	30	32	6.7	30	26	6.7	30
August	30	6.8	30	32	6.7	30	26	6.7	30
September	26	6.9	29	31	6.8	29	24	6.8	29
October	24	6.9	29	26	6.8	29	23	6.8	29
November	24	6.9	29	26	6.8	29	23	6.8	29

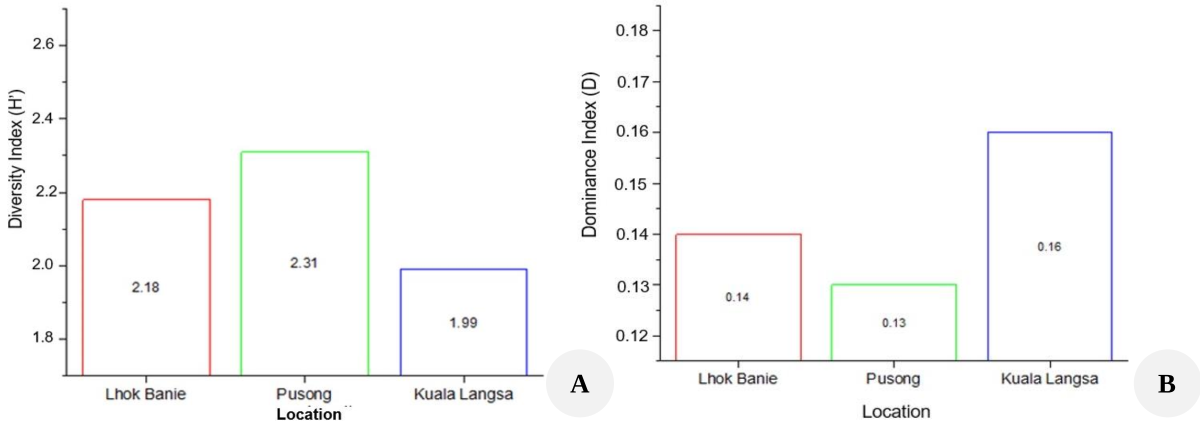

Figure 5. A. Shannon-Weiner Diversity Index. B. Crustacean dominance index based on research locations

Figure 6. Morphology of male and female *T. Granosa*

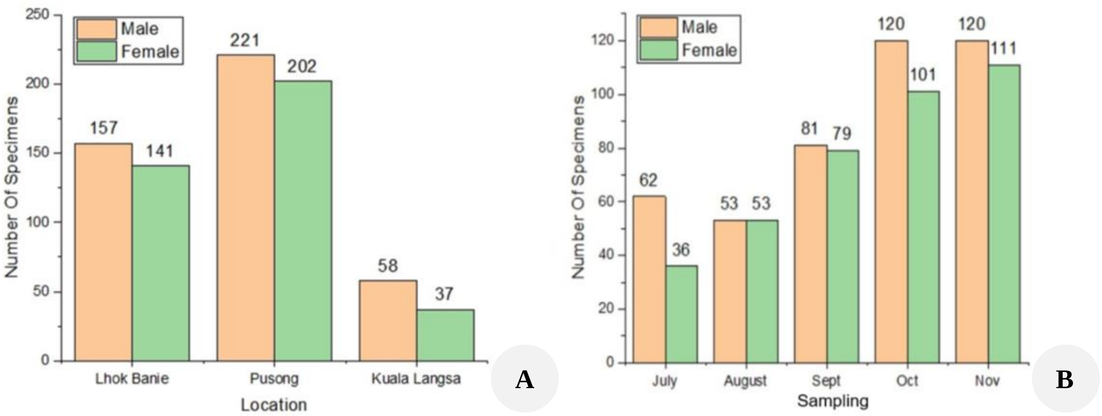

Figure 7. A. *Tegillarca granosa* number of specimens collected based on location. B. Based on monthly data

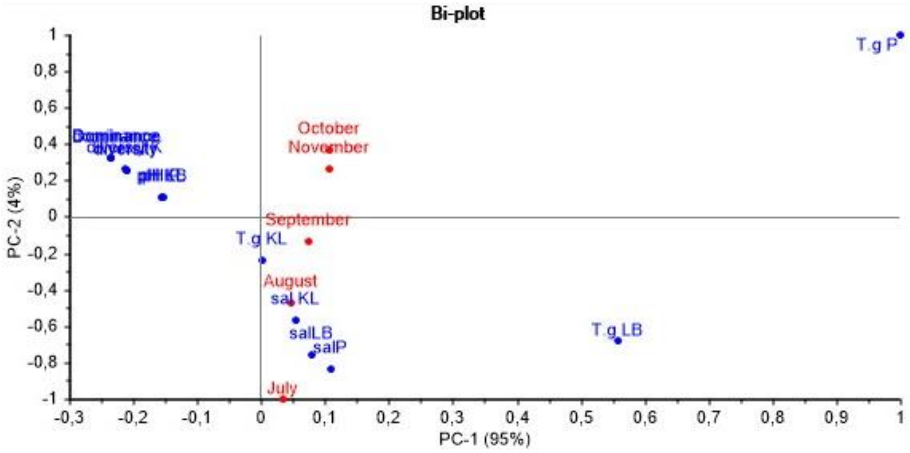

Figure 8. Relationship between crustacean diversity and the number of *T. granosa* specimens, along with various environmental factors

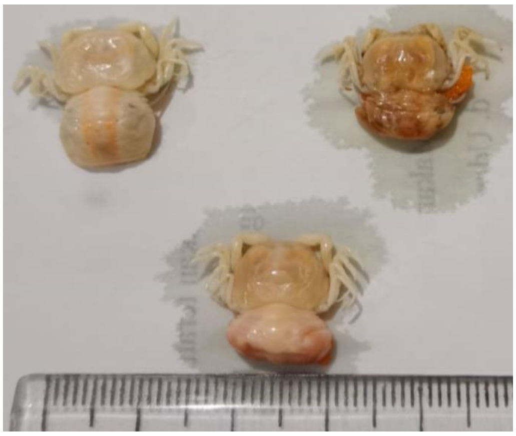

Figure 8. Crustacean larvae found in the *T. granosa* organ

Discussion

Crustaceans are a group of animals that predominantly inhabit aquatic environments, including freshwater, saltwater, and brackish waters. However, these animals are most commonly found in marine and brackish water areas (Ahyong and Huang 2020). The crustacean group is a significant contributor to aquatic animal protein, second only to fish, fulfilling the nutritional needs of communities. These animals are highly sought after worldwide because, in addition to their delicious taste, they also contain high nutritional value (Li et al. 2021; Boyd et al. 2022). The high global market demand for this animal population for commercial purposes has led to the routine exploitation of crustaceans by communities, particularly fishermen, as a promising livelihood to support their families.

The research conducted in the mangrove area of West Langsa, Aceh Province, gathered 17 crustacean species categorized into 8 families. Ocypodidae, Portunidae, and Grapsidae belong to the Crab family, while Diogenidae, Odontodacylidae, Penaeidae, Palaemonidae, and Sergestidae belong to the shrimp family. Ocypodidae is the most dominant crustacean family found in the coastal areas of Aceh. This group of animals is locally known as "*kepiting biola*" and is frequently encountered in coastal regions. Several studies in mangrove areas have reported that the Ocypodidae family is the most dominant in the mangrove regions of Aceh and Bali (Dewiyanti et al. 2018; Ginantra et al. 2021). The size of the "*kepiting biola*" is relatively smaller compared to other crab families found in the research location. The underutilization of this crab family by the community as a food source and for various other purposes has resulted in the dominance of this crab number of specimens compared to other crab species from the Portunidae family (Ginantra et al. 2023). Unlike the Portunidae and Penaeidae families, which belong to the crab and shrimp group and have high demand in the national and international markets, the natural populations of these animals in their habitats are decreasing due to regular exploitation by the community and fishermen (Muhammadar et al. 2021).

The Pusong area, directly bordering the Malacca Strait, exhibits the highest diversity of crustaceans and the population of *T. granosa* compared to the locations of Lhok Banie and Kuala Langsa. The relatively stable environmental conditions, with well-preserved mangrove vegetation and considerable distance from human settlements, make the Pusong area an ideal habitat for various aquatic biota. The coastal region, characterized by dominant mangrove vegetation, provides a favorable environment for gastropods and bivalves, serving as protection against predators (Wanjiru et al. 2023). The more stable water circulation and higher salinity in the area make it a suitable habitat for various crustacean and bivalve species (Pourmozaffar et al. 2020; Mawardi et al. 2023). The flow of seawater towards the mangrove during high tide and vice versa, the flow of water from the land to the sea passing through the mangrove area during low tide, carries various food sources dragged in the water, providing abundant food in various forms (Gondal et al. 2021). The availability of adequate food and suitable habitat conditions contributes to the high diversity of crustaceans in the Pusong area, positively impacting the abundance of bivalve populations (Setyadi et al. 2021).

The diversity of crustaceans has a positive impact on the population of *T. granosa* in coastal areas. Higher crustacean diversity in the research location correlates positively with the number of *T. granosa* specimens in the same area. Conversely, if the crustacean number of specimens are low, it also negatively impacts on small number of *T. granosa* populations. The positive correlation between crustacean populations and blood clams in coastal areas is due to the presence of crustacean larvae as one of the blood clams' food. The abundance of food sources and supportive environmental conditions are crucial factors for the abundance of various benthic species in coastal areas (Herbert et al. 2016; Benjamin et al. 2022). Positive correlations are also found between the dynamics of *T. granosa* populations and various environmental factors, including water salinity, sediment as the blood cockle habitat consists of sandy and clay compositions. Water salinity plays a crucial role in coastal areas, given the extreme fluctuations in salinity changes between the rainy season, dry season, and transitional season in this region (Srisunont et al. 2020).

The high population of crabs and shrimp species provides an abundant food source in coastal areas for various predator species. The increasing size of crustacean population has a positive correlation with the number of blood cockle. This is because crustacean larvae serve as the main food for blood cockles found in the West Langsa area. The filter-feeding process of blood cockles in search of food makes various crustacean larvae and plankton species rich in nutrients a primary food source (Tu et al. 2022). The abundance of this food is a cause of increased blood cockle productivity, influenced by supportive environmental conditions and food sources (Azwar et al. 2023). The availability of food sources and an ideal habitat is a important factor for the abundance of various aquatic organisms, including blood cockles. Crustaceans and bivalves play a crucial ecological role in coastal areas for ecosystem balance and maintaining the food chain cycle in these coastal regions. The abundance of crustaceans and bivalves in coastal areas associated with mangrove vegetation has a strong connection to their habitat (Setyadi et al. 2021).

Tegillarca granosa, one of the Bivalvia species, has become the favorite of the coastal community in West Langsa as a livelihood source for commercial purposes due to high market demand and relatively high prices compared to species like *C. cucullata* and *M. violacea* (Mawardi et al. 2023). The population dynamics of blood cockles have a varied composition in their habitat when examined based on monthly sample collection data. The highest population abundance of blood cockles is found in November, followed by October and September, corresponding to the rainy season. In contrast, the smallest population is found in July, which is still considered the dry season (Bahtiar et al. 2023). The abundance of food sources and more stable environmental conditions are among the reasons for the increase in blood cockle populations in their habitat. During the rainy season, the availability of food is relatively more dominant than during the dry season, as the rainy season is the peak reproductive period for various aquatic biota (Mawardi et al. 2022). In contrast, during the dry season, the availability of food tends to be lower, and the coastal conditions are less stable due to the dominance of seawater in the mangrove vegetation area, leading to an increase in coastal salinity. This, in turn, impacts the productivity of various blood cockle species, causing a decrease (Doinsing et al. 2021).

Environmental parameters play a significant role in the diversity of crustaceans and the abundance of blood cockle populations. Salinity has a positive correlation with the survival of coastal biota in their natural habitat. Salinity ranging from 26 to 32‰ is found to be a suitable habitat for clams, crabs, and shrimps. Areas near human settlements have a negative impact on the composition of *Tegillarca granosa* populations and crustacean diversity (Mawardi et al. 2023). The high activity of communities can lead to a decline in environmental conditions due to the routine entry of domestic waste into the surroundings, resulting in environmental pollution. Some species of animals sensitive to residential noise become threatened, leading to reduced productivity and populations tending to be low (Dudgeon 2019). Ecological degradation of the environment is one of the reasons for the decline in various coastal biota, such as blood cockles and various crustacean species. This is because the environment plays a crucial role as a protector and supplier of nutritious food for various animals, including crustaceans and Bivalvia in aquatic ecosystems (Fankboner and Reid 1990). The abundance of food also plays a crucial role in the growth and population abundance of animals, including coastal biota (Prakash 2021).

The populations of crustaceans and *Tegillarca granosa* found in their natural habitat in coastal areas depend on highly specific environmental conditions, including sediments dominated by a composition of sand and clay and a relatively higher salinity in their suitable habitat (Mawardi et al. 2023). To ensure that various coastal biota, which play a significant role as suppliers of nutritional content for communities worldwide, remain stable in nature, collective efforts are needed to sustainably preserve the environment so that these animals can live and reproduce optimally in their habitats (Pahri et al. 2023). Stable environmental conditions are a key factor with a significant impact on the sustainability of various flora and fauna, including crustaceans and bivalves. Considering that coastal areas serve as the estuary for various pollutant impacts on the environment (Cantonati et al. 2020).

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