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Research article

Ecological characteristic of hermit crabs in Lhokseumawe mangrove forest, Aceh, Indonesia

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Abstract

The study was conducted between August and September of 2021 in order to determine the density, ecological index, distribution pattern, geographic distribution, environmental factors, and the relationship between hermit crabs and environmental factors. Hermit crabs were gathered using a quadratic transect and sample plots, while environmental variables were measured in situ. PCA and CCA multivariate statistics were used to determine the characteristics and correlation between hermit crabs and environmental factors. Hermit crabs were discovered to be comprised of two species (*Clibanarius longitarsus* and *C. infraspinatus*) and one family (Diogenidae), with the highest density found in the *C. longitarsus* species (1.22 ± 0.57 – 4.68 3.53 ind/m^2), diversity index is categorized as moderate (2.0<H'≤3.0), the dominance is low (0<C≤0.5), the distribution pattern is clustered (Iδ>1), the geographical distribution is abundant (>80%), and environmental factors are categorized as good. In addition, Stations I and II have high DO, TOM, mangrove density, *C. longitarsus*, and *C. infraspinatus* parameters, whereas Station III has high salinity, pH, and temperature, with salinity, mangrove density, and TOM being the most influential parameters on hermit crab density.

Keywords: Clibanarius, ecological index, distribution, environmental parameter

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Introduction

Hermit crabs are crustaceans from the decapoda order (Negri et al., 2014; Gan et al., 2015; Hyzny et al., 2016; Marin, 2016; Jung et al., 2018) and members of the Anomura infra order (Reese, 1969; Gan et al., 2015; Marin, 2016; Hyzny et al., 2016; Danin et al., 2020) as well as the superfamily Paguroidea (Fraaije et al., 2015; Gan et al., 2015; Marin, 2016; Hyzny et al., 2016; Lima et al., 2018), where the superfamily Paguroidea has members of more than 1000 – 1100 species (De Grave et al., 2009; McLaughlin et al., 2010; Nirmal et al., 2017) which belong to 5 or 6 families (De Grave et al., 2009; Nirmal et al., 2017).

Hermit crabs have a significant ecological role in the marine environment (Reese, 1969). They are an important link in the food web, serving as the main food source for economically valuable fish species (Nirmal et al., 2017). They are classified as part of the macrofauna (Danin et al., 2020) and have an asymmetrical body that allows them to live inside gastropod shells (Gan et al., 2015). Hermit crabs can be found in a wide range of habitats, from polar regions to tropical seas, with a preference for intertidal environments (Danin et al., 2020). Due to their diverse and widespread distribution, hermit crabs have developed various behavioural and physiological adaptations that contribute to their diversity and distribution (Nirmal et al., 2017). Reese (1969) states that hermit crabs are a fascinating and unique group of organisms, and one of the habitats where they can be found is mangrove forests.

Mangrove forests are a variety of tropical and subtropical forests that thrive in coastal areas or river estuaries and are impacted by the fluctuating levels of sea tides (Gaut, 2018; Schaduw, 2019). Mangrove forests have a crucial role in supporting a significant portion of global biodiversity. They offer a wide range of ecosystem services and contribute to the welfare of coastal communities, particularly in fisheries. As a result, they generate income for traditional and peripheral groups (Polania et al., 2015). According to Alongi (2018), mangrove forests primarily develop in regions with low latitudes, favouring warm weather (Bryan-Brown et al., 2020). They are recognized as one of the most productive wetlands globally (Hartati & Harudu, 2016). Presently, the decrease of mangrove forests is primarily

caused by human activities (Hartati & Harudu, 2016; Gillis et al., 2017; Davidson et al., 2018), resulting in significant harm (Eddy et al., 2015). Mangrove forests are considered healthy only in regions with minimal human intervention (Nurdiansah & Dharmawan, 2018). Pramudji & Dharmawan (2016) made a similar assertion, stating that the growth of the population and the development of coastal regions (caused by human activity) are exerting significant pressure and leading to the deterioration of mangrove forests. According to UNEP (2014), human activities such as aquaculture, agriculture, pollution, and urbanization pose a threat to mangrove forests worldwide. For instance, in Cameroon, the area of mangrove forests has decreased by 30% in just 20 years due to urbanization (Atheull et al., 2013).

In addition to the aforementioned factors, the primary causes of the reduction in many species are overexploitation, habitat loss, and climate change events (Dulvy et al., 2014). Monitoring the composition and species richness of living organisms is crucial for developing effective management and conservation strategies (Ramdani et al., 2018). Species richness, also known as biodiversity, plays a vital role in maintaining ecosystem functioning (Tilman et al., 1996). Kihia et al. (2015) reported that the degradation of mangrove forests and other human disturbances have created unfavorable conditions for the survival of delicate organisms like gastropods and hermit crabs. Consequently, several studies have been conducted on hermit crabs by experts such as Ragagnin et al. (2018), Tidau & Briffa (2019), Lavers et al. (2020), and Mukhopadhyay et al. (2022). Furthermore, Permana et al. (2018) and Rahayu & Pratiwi (2022) have conducted similar studies in Indonesia. Nevertheless, there is a dearth of scientific data on the occurrence of hermit crabs in mangrove forest ecosystems, particularly in Aceh Province and Lhokseumawe City. Surprisingly, no research has been undertaken on this subject. Hence, it is imperative to conduct this study to determine the density, ecological index, distribution patterns, geographic distribution, environmental factors, characteristics, and relationships between hermit crabs and environmental factors in the mangrove ecosystem of Lhokseumawe.

Methods

The study of hermit crabs in Lhokseumawe mangrove forest was carried out in August – September 2021, consisting of three observation stations. Station I is located around the mangrove reforestation area with coordinates 05˚09'20.33" N and 97˚08'38.77" E, while Stations II and III are located around the mangrove forest adjacent to community ponds with their respective coordinates being 05˚ 09'17.98" N and 97˚08'41.02" E (Station II) and 05˚09'15.40" N and 97˚08'43.40" E (Station III) (Figure 1).

In the mangrove forest of Lhokseumawe, hermit crabs were collected using a method called quadrant transects. These transects were 40 meters long and were pulled from the outermost mangrove stands towards the sea, perpendicular to the coastline. The quadrant transects were then divided into sample plots measuring 10 x 10 meters. For each plot, 5 subplots measuring 1 x 1 meter were created. The observation stations, consisting of 3 quadrant transects, were determined using purposive sampling. This resulted in a total of 180 observation subplots. The hermit crabs were discovered in the 1 x 1 m subplots, manually collected through hand picking, and subsequently placed into a polyethylene plastic bag that was appropriately tagged with a permanent marker and filled with sufficient 70% alcohol. In the meantime, it is transported to the laboratory for the purpose of identification and analysis.

Simultaneously, water quality parameters including temperature, salinity, pH, and dissolved oxygen were measured in situ using a thermometer, hand refractometer, pH meter, and DO meter respectively. Additionally, sediment total organic matter (TOM) was obtained from secondary data sourced from Siregar et al. (2024), while mangrove density data for different tree categories were collected from the study conducted by Putri et al. (2024). The density of hermit crabs in the mangrove forest was determined using the Odum (1996) equation. The hermit crab ecological index was analysed using the Shannon-Weaver diversity index and Simpson's dominance index, with the criteria for each ecological index referring to Setyobudiandy et al. (2009). The distribution pattern of hermit crabs in the mangrove forest was examined using the Morisita index

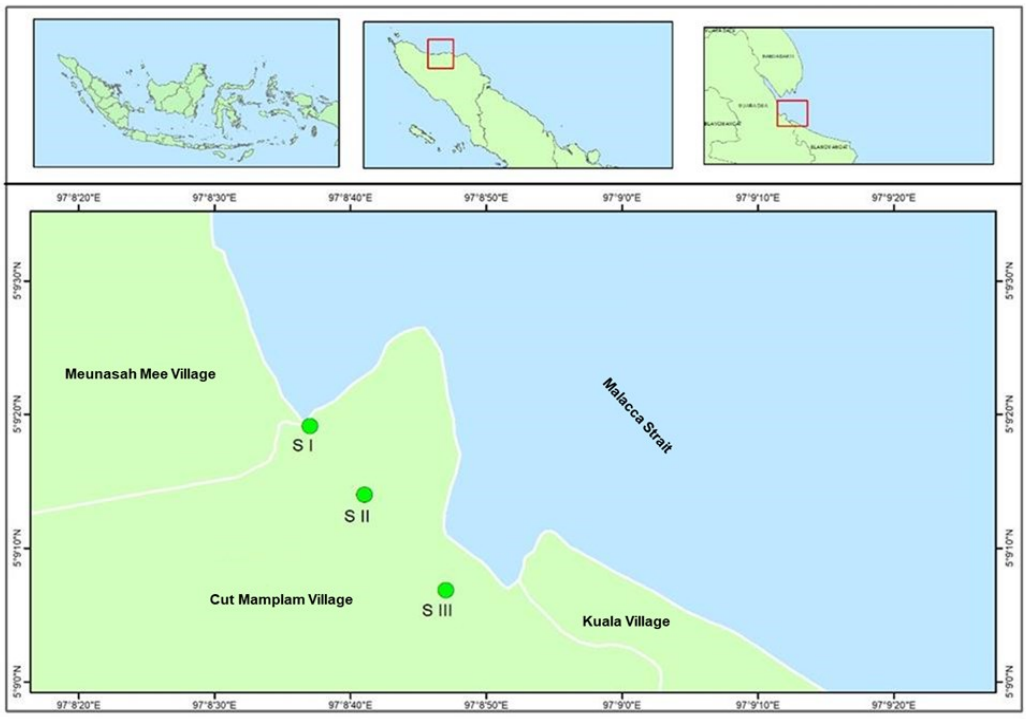

Figure 1. Sampling location

(Morisita, 1959), while the spatial distribution conditions of hermit crabs were determined based on the research conducted by Sreelekshmi et al. (2020).

Data analysis

The characteristics of environmental factors in the presence of hermit crabs in the mangrove forest were determined using multivariate Principal Component Analysis (PCA) statistics. The relationship between the density of hermit crabs and environmental factors such as temperature, salinity, pH, dissolved oxygen (DO), bottom organic matter (TOM), and mangrove density were evaluated using multivariate Canonical Correspondence Analysis (CCA) statistics. These analyses were conducted using the PAST 3 program.

Result

Density and ecology index

Clibanarius longitarsus and *C. infraspinatus*, Diogenidae hermit crabs were found in Lhokseumawe mangrove forests. There were 539 *C. longitarsus* and 1 *C. infraspinatus*, with the highest density in the mangrove forest near the pond. *C. longitarsus* density ranged from 1.22 ± 0.57 to 4.68 ± 3.53 ind/m^2, while *C. infraspinatus* ranged from 0.00 ± 0.00 to 0.02 ± 0.03 (Table 1). the Shannon-Weaver diversity index of hermit crabs is highest at Station I (H' = 2.25 ± 0.09), followed by Stations III (2.15 ± 0.08) and II (2.08 ± 0.11). The Simpson dominance index is highest at Station III (0.16 ± 0.03), followed by Stations II (0.15 ± 0.02) and I (0.12 ± 0.01) (Table 1).

Geographic distribution and distribution patterns

The distribution pattern of hermit crabs in Lhokseumawe mangrove forest is characterized as clustered, with an index value (Iδ) greater than 1, as shown in Table 2. This data suggests that the distribution of resources or environmental elements needed for hermit crabs is not uniform. The Morisita index values at Station I, Station II, and Station III are 4.09, 5.29, and 5.41 respectively. The highest Morisita index is observed at Station III, while the lowest is observed at Station I. The distribution of hermit crabs in the mangrove woods of Lhokseumawe mangrove forests is highly plentiful, with a relative frequency above 80% (Table 2).

Environmental factor

The environmental conditions of the hermit crab habitat in Lhokseumawe mangrove forests indicate that the water quality exhibits consistent concentrations across different locations, including temperature, salinity, pH, and dissolved oxygen (DO). However, there are variations in the concentrations of TOM parameters and mangrove density. The water temperature ranges from 31.23 ± 1.18 to 31.71 ± 0.82°C, salinity ranges from 28.89 ± 1.39 to 29.78 ± 0.69‰, pH ranges from 7.21 ± 0.25 to 7.45 ± 0.07, dissolved oxygen ranges from 6.97 ± 0.79 to 7.14 ± 0.66 mg/L, TOM ranges from 8.60 ± 0.49 to 13.12 ± 1.34%, and mangrove density ranges from 416.67 ± 188.56 to 841.67 ± 255.52 ind/ha (Table 3).

Characteristics and relationship of hermit crabs to environmental factors

The environmental characteristics of hermit crabs can be described using a Principal Component Analysis (PCA). The PCA analysis reveals that the variety of habitat characteristics can be explained by two main axes. The total variance explained by these axes is 100.00%. The first axis (F1) explains approximately 55.09% of the variance, while the second axis (F2) explains 44.91% (Figure 2a). Moreover, Figure 2a demonstrates that the correlation circle diagram of the intersection between the first and second axes of PCA analysis for the DO and TOM parameters exhibits a positive correlation on the F1 axis. Conversely, the temperature and pH parameters display a negative correlation on the F1 axis. Additionally, the salinity and mangrove density parameters exhibit a negative correlation on the F2 axis.

In addition, Figure 2a illustrates that the distribution of observation stations in Lhokseumawe mangrove forests, with respect to the environmental factors of hermit crabs, can be

Table 1. Density and ecological index of hermit crabs in Lhokseumawe mangrove forest. Ind = Individual; H' = Shannon-Weaver diversity index; C = Simpson's dominance index.

St.	Species	Density (ind/m^2)	Ecology index			
			H'	Criteria	C	Criteria
I	*C. longitarsus*	3.08 ± 2.01	2.25 ± 0.09	Moderate	0.12 ± 0.01	Low
	C. infraspinatus	0.00 ± 0.00				
II	*C. longitarsus*	4.68 ± 3.53	2.08 ± 0.11	Moderate	0.15 ± 0.02	Low
	C. infraspinatus	0.02 ± 0.03				
III	*C. longitarsus*	1.22 ± 0.57	2.15 ± 0.08	Moderate	0.16 ± 0.03	Low
	C. infraspinatus	0.00 ± 0.00				

Table 2. Distribution patterns and geographical distribution of hermit crabs in Lhokseumawe mangrove forests. *Sreelekshmi et al., (2020).

Station	Morisita index (Iδ)	Distribution pattern	Relative frequency (%)	Geographic distribution*
I	4.09	Grouping	100.00	Abundant
II	5.29	Grouping	91.67	Abundant
III	5.41	Grouping	100.00	Abundant

Table 3. Environmental factors of hermit crab habitat in Lhokseumawe mangrove forests. [a]Siregaret et al., (2024); [b]Putri et al., (2024); Ind = Individual; TOM = Total organic matter; MAN = Mangrove density

Station	Location	Environmental factors					
		Temperature (°C)	Salinity (‰)	pH	DO (mg/L)	[a]TOM (%)	[b]MAN (ind/ha)
I	Reforestation	31.23 ± 1.18	29.56 ± 1.39	7.21 ± 0.25	7.14 ± 0.52	13.12 ±1.34	841.67 ± 255.52
II	Aquaculture	31.57 ± 0.96	28.89 ± 1.39	7.29 ± 0.18	7.14 ± 0.66	9.02 ± 0.60	416.67 ±188.56
III	Aquaculture	31.71 ± 0.82	29.78 ± 0.69	7.45 ± 0.07	6.97 ± 0.79	8.60 ± 0.49	516.67 ± 169.49

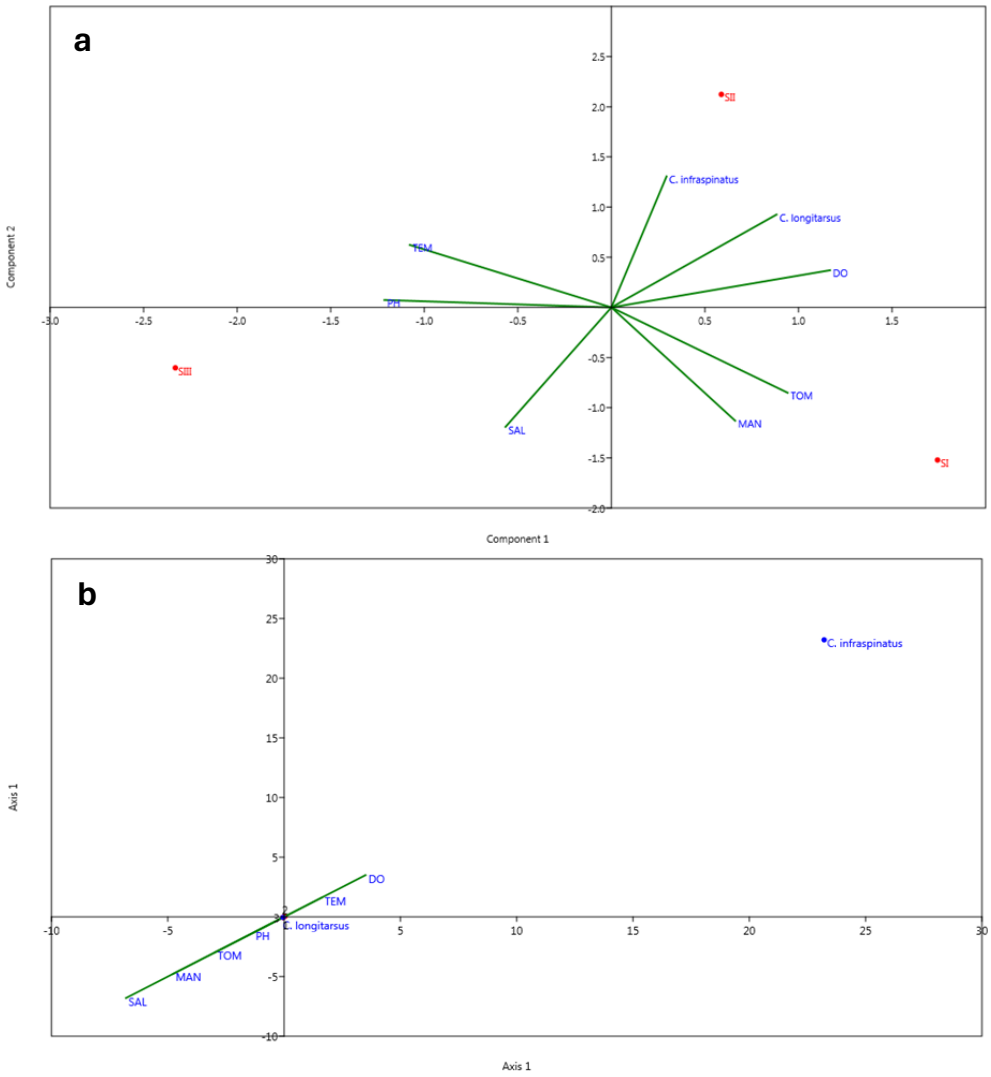

Figure 2. Characteristics and relationship of hermit crabs to environmental factors in Lhokseumawe.
a = PCA; **b** = CCA

categorized into two groups. The first group comprises Stations I and II, while the second group solely includes Station III. The relationship between the density of hermit crabs and environmental factors is primarily influenced by salinity concentration, mangrove density, and TOM. These parameters have the highest impact on the density of hermit crabs, as indicated by a 100% explanatory relationship (Figure 2b). The availability of natural food sources for hermit crabs in the mangrove forests such as algae (periphyton), is believed to be closely related to salinity, mangrove density, and TOM.

Discussion

The presence of elevated populations of *C. longitarsus* in the mangrove forests around the aquaculture area suggests that the aquaculture area offers a greater abundance of food resources compared to reforestation regions, where the food source primarily consists of food remnants and/or shrimp excrement. Stimulates the proliferation of microscopic organisms (such as microalgae), which serve as nourishment for hermit crabs. Arbi (2012) states that the diversity index value of a species can be influenced by factors such as the number of species or individuals, the relative abundance of certain species, the quality of the supporting substrate, and the conditions of the species' habitat. Nuraina et al. (2018) defined the dominance index as an ecological parameter that quantifies the degree of centralized control exerted by a species in a community. This control or dominance might be concentrated in a single species, multiple species, or numerous species (Indriyanto, 2015).The Morisita index is a metric employed to assess the spatial distribution pattern of a species or population. This

index is unaffected by the specific type of distribution, number of samples, and average values. Consequently, it yields consistent results that are not influenced by population density or sample size (Widiyanti et al., 2020). Sulistiyowati et al. (2021) state that the clustered distribution pattern of an organism can be attributed to two elements: environmental conditions and intrinsic characteristics, such as reproductive behaviour.

According to Ali et al. (2013) temperature is a crucial factor in regulating the state of aquatic ecosystems. They found that higher water temperatures can lead to an increase in the metabolic rate of aquatic species, as stated by Mainassy (2017). Nguyen et al. (2015) defined salinity as a key factor in determining the characteristics of mangrove habitats, which can range from freshwater to hypersaline conditions. Meanwhile, Rukminasari et al. (2014) observed that the pH of surface seawater in Indonesia is usually found within the range of 6.00 to 8.50 but can vary depending on the location. The water pH readings in this study closely resemble the water pH measurements obtained by Rusnaningsi (2012) in the Pangkal Babu mangrove forest, located in the West Tanjung Jabung Regency of Jambi Province. Similarly, the pH levels of water in various locations within the mangrove ecosystem have been measured. These locations include Barru Regency (Malik, 2013), Dudepo Island, Anggrek District, North Gorontalo Regency (Usman et al., 2013), Basaan I Village - Southeast Minahasa Regency (Wantasen, 2013), Perancak - Bali (Susiana, 2015), and Ngurah Rai Bali Forest Park (Imamsyah et al., 2020).

Conclusions

Hermit crabs in Lhokseumawe mangrove forest consist of two species (*C. longitarsus* and *C. infraspinatus*) and one family (Diogenidae), with the highest density in *C. longitarsus*, moderate diversity, and low dominance. In addition, hermit crabs are clustered and abundant in the mangrove forests where environmental factors are still relatively good with DO and TOM parameters forming a positive correlation, while temperature and pH parameters forming a negative correlation. Hermit crab prevalence is largely affected by salinity concentration, mangrove density, and TOM.

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Authorship contribution

Fitriani: Conceptualization, methodology, investigation, resources, sample processing and analysis, data curation, formal analysis, visualization, writing - original draft preparation, writing - review and editing. **Erlangga**: Methodology, writing - review and editing, supervision. **Syahrial:** Conceptualization, methodology, formal analysis, writing - original draft preparation, writing - review and editing, supervision. **Riri Ezraneti:** writing - review and editing. All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Data availability

Datasets generated during and/or analysed throughout the present study are available from the corresponding author upon reasonable request.

Conflict of interest

On behalf of all authors, the corresponding author states that there are no conflicts of interest.

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