



Density and distribution of *holothuria leucospilota* along the coast of dedap island, pulau abang waters



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ABSTRACT

The black rubber sea cucumber (*Holothuria leucospilota*) is prevalent along the coast of Dedap Island in Batam, unlike other sea cucumber species that face significant fishing pressure. This study examines the population and distribution of *Holothuria leucospilota* near Dedap Island in Abang Island, Batam. Surveys were conducted at three sites, where we carefully counted and mapped the sea cucumbers. A total of 236 individuals were recorded, with the highest density in Transect I ($0.97/m^2$) and the lowest in Transect 2 ($0.66/m^2$). Our results indicate notable variability in sea cucumber density across the surveyed areas, with some locations showing high abundance and others fewer individuals. The distribution pattern, assessed using the Morisita Index, suggested a clustering tendency, especially in Transect I. We also examined substrate types to better understand these distribution trends. Additionally, water quality assessments showed that conditions across the transects were favourable for sea cucumber survival, with suitable levels of salinity, pH, and dissolved oxygen. These findings are vital for the management and conservation of sea cucumbers in the area.

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INTRODUCTION

Coastal areas are defined as regions where land meets the sea; the coastal ecosystem plays a crucial role and holds the highest value among the Earth's ecosystems in providing services that maintain environmental balance (Suryanti et al., 2019). This coastal region exhibits high organic productivity, generated by its mangrove ecosystems, seagrass beds, and coral reefs. According to (Puryono et al., 2019), the primary productivity of the coastal area ranges from 900 to 4650 gC/m²/year. This area serves as a habitat for a variety of biota, including fish, crustaceans, molluscs (*Pinna* sp., *Lambis* sp., *Strombus* sp.), echinoderms (*Holothuria* sp., *Synapta* sp., *Diadema* sp., *Archaster* sp., *Linckia* sp.), and polychaete worms. These coastal regions exhibit high

organic productivity, with primary productivity ranging from 900 to 4650 gC/m²/year. This area is home to a variety of biota, including fish, crustaceans, molluscs (*Pinna* sp., *Lambis* sp., *Strombus* sp.), echinoderms (*Holothuria* sp., *Synapta* sp., *Diadema* sp., *Archaster* sp., *Linckia* sp.), and polychaete worms.

One of the biota found in coastal areas is the sea cucumber. Sea cucumbers belong to the class Holothuroidea within the phylum Echinodermata (Purcell et al., 2013). They are highly valued marine products, used for food and medicinal purposes. This commodity has been well-known and consumed by coastal communities in Indonesia, as well as being recognised in Europe, Japan, and the United States (Rahantoknam, 2017). According to global statistics reported by the (FAO, 2020), Indonesia is a leading supplier of sea cucumbers among all Southeast Asian nations. Research conducted by (Ardiansyah et al., 2020), indicates that sea cucumber fisheries support the livelihoods of coastal communities in Asian countries, and with the increasing market demand, global production of sea cucumbers has reached 100,000 tons per year.

As noted by (Choo, 2008), sea cucumbers are primarily harvested for export as dried products known as trepang or beche-de-mer, which are considered delicacies in many Asian countries. They possess significant economic potential due to their various beneficial compounds, serving as a source of animal protein, wound healing agents, and anti-inflammatory substances (Elfidasari et al., 2012).

The class Holothuroidea is characterised by high biodiversity within the phylum Echinodermata and can be found in nearly all marine environments (Kerr & Kim, 2001). Sea cucumbers have a unique respiratory system, using water infiltration through their skin and possessing the ability to regenerate lost body parts. They also function as deposit feeders, consuming organic particles found on the seabed (Conand, 2019). Sea cucumbers are benthic animals that inhabit intertidal zones to deep waters, often on sandy, muddy, or rocky substrates. Most species exhibit very specific habitat preferences, such as particular zones within reef habitats, algae, or seagrass beds (Bruckner et al., 2003); (Uneputti et al., 2014). The distribution of sea cucumbers is extensive; they can be found in all the world's oceans, from shallow waters to great depths, often on sandy or muddy seabeds. Their density varies depending on depth and environmental conditions, such as salinity and temperature. Some species are more commonly found in tropical regions, while others prefer colder conditions (Conand, 2019).

Sea cucumbers play a vital role in the ecosystem by decomposing organic materials in sediments, reducing particles, and subsequently releasing nutrients back into the ecosystem. They are a nutritious food source rich in protein and collagen and are significant natural products with medical and pharmacological benefits (Theeratathanakorn et al., 2023a). In addition to their ecological functions, sea cucumbers are also utilised for consumption and medicinal purposes (Elfidasari et al., 2012). Approximately 56 species of sea cucumbers are consumed. They are traded in Indonesia in both dried and frozen forms. Sea cucumbers hold high economic value, serving as both a food source and for the pharmaceutical industry (Setyastuti, 2016). Data from the Indonesian Institute of Sciences (LIPI) indicates that they all belong to the order Aspidochirotida (Holothuroidea). Furthermore, sea cucumbers have been used as medicine for a long time. Traditional remedies derived from them are well-known as tonic foods that address damage to the renal system, reproductive organs, and digestive tract (Setyastuti et al., 2005). Several species include the black sea cucumber, with types reported to be found in Indonesian waters, including *Holothuria atra* Jaeger, 1833; *Holothuria leucospilota* Brandt, 1835; *Holothuria coluber* Semper, 1868; *Holothuria excellens* Ludwig, 1875; and *Holothuria turriscelsa* Cherbonnier, 1980 (Setyastuti, 2016).

Research on *Holothuria leucospilota* has shown its pharmacological potential, indicating that this species could be a source of bioactive compounds for treating Parkinson's disease (Mokhlesi et

al., 2012), *H. leucospilota* also exhibits significant antibacterial and antifungal activity (Pringgien et al., 2014). With the rise of multidrug resistance (MDR) in bacteria, recent studies have explored the effectiveness of *H. leucospilota* extracts against MDR bacterial infections, demonstrating the extract's ability to inhibit the growth of several MDR bacterial strains. These findings underscore the potential of *H. leucospilota* extract as an effective antibacterial agent, making it a valuable candidate for new drug development to combat difficult-to-treat infections.

Research on the density and distribution of the black sea cucumber (*Holothuria leucospilota*) around Abang Island, Batam, aims to address gaps in marine ecological and economic information. Despite the high economic value of sea cucumbers as marine resources, data regarding their presence and distribution in this area remain limited. One challenge is the lack of knowledge among local fishermen about the types and populations of sea cucumbers, reflecting a deficiency in prior research in this region. The dependence of fishing communities on sea cucumbers highlights the necessity for empirical data to support sustainable fishing practices and maximise economic potential. Although *Holothuria leucospilota* is relatively abundant in the study site, this species is not the primary target for fishermen, opening opportunities to understand the ecosystem and the factors influencing sea cucumber presence.

Through density and distribution pattern analysis, this research aims to provide valuable information for the sustainable management of marine resources while raising awareness of the often-overlooked economic potential of sea cucumbers. High population density of sea cucumbers in coastal ecosystems indicates good environmental health. Sea cucumbers play a crucial role in decomposing organic matter and providing nutrients, which enhances soil fertility and supports the growth of other biota (Conand, 2019). This positively impacts biodiversity, attracts more predators and herbivores, and strengthens ecosystem stability (Kerr & Kim, 2001). Economically, fishing communities that rely on sea cucumbers benefit from high density, leading to increased income and resource sustainability (Ardiansyah et al., 2020). Conversely, low density can signal environmental stress due to pollution or overfishing, threatening habitat quality and other species (Suryanti et al., 2019). Consequently, communities dependent on sea cucumbers may face economic challenges due to reduced supply, impacting their livelihoods (Rahantoknam, 2017).

A lack of knowledge regarding the density and distribution pattern of this species reflects insufficient attention to local ecosystems, hindering effective resource management (Setyastuti et al., 2005). An analysis of the density of black rubber sea cucumbers (*Holothuria leucospilota*) in coastal regions has significant ecological and economic implications. Therefore, this study aims to deepen the understanding of sea cucumber density and distribution, along with its effects on ecosystem health and the sustainability of local livelihoods.

RESEARCH METHODS

Research Design

This study employs a quantitative descriptive method aimed at illustrating the population density and distribution patterns of the black rubber sea cucumber (*Holothuria leucospilota*) along the coast of Dedap Island in the waters of Pulau Abang, Batam City. Data collection regarding the aquatic conditions was conducted in situ, with measurements of physical and chemical parameters including dissolved oxygen (DO), pH, temperature, and salinity. This method was chosen to provide accurate and representative data on the environmental conditions affecting the life of sea cucumbers.

Population and Samples

The research was conducted at Dedap Beach, in the waters of Pulau Abang, Galang District, Batam City, geographically located at 0°31'2.37"N and 104°15'4.68"E. Pulau Abang is a cluster of small islands situated south of Batam City, Riau Archipelago Province. This area is a marine tourist



destination, featuring beautiful beaches and well-preserved, natural coral reefs that support a diverse range of marine life. Marine organisms found around Pulau Abang include fish, crabs, squids, sea cucumbers, and sea urchins (Efendi et al., 2024). The research location is indicated in Figure I.

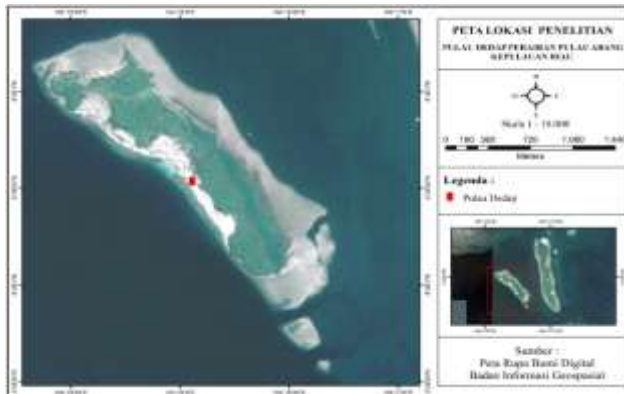


Figure I. Map of Research Location

The research was conducted from August to September 2024. The selection of the research site was based on preliminary information regarding the presence of sea cucumbers in the area and the potential for well-preserved habitats. This study aims to provide a clear understanding of the density and distribution patterns of sea cucumber species in these waters.

Instruments

Some of the main tools used in data collection include ropes used as a gauge in determining transect lines or research boundaries, refractometers used to measure salinity or dissolved salt levels, pH meters used to measure aquatic acid-base levels, DO meters used to measure dissolved oxygen levels in the water, thermometers to measure water temperature, and GPS as a determinant of the coordinate point of the research location. In addition, other tools are also used in supporting sampling such as buckets, nets, gloves, cameras, stationery, and boats.

Procedures

Data collection was conducted through a census of individuals across three transects, each 30 metres long, positioned perpendicularly from the shoreline towards the sea. The placement of the transects was purposively selected at the research site. Sampling (census of individuals of *Holothuria leucospilota*) was carried out along the transect lines within observation plots to the left and right, each measuring 1m x 1m. (Efendi et al., 2024). Observations were recorded, and the number of *H. leucospilota* individuals present in each square plot at the observation site was counted. Subsequently, data on water quality conditions were measured, collected directly from the field, encompassing physical and chemical parameters, including water temperature and salinity.

Data Analysis

The data obtained from the census and observations were analysed both qualitatively and quantitatively. Qualitative analysis included the documentation of scientific names and morphological descriptions of the species *H. leucospilota*, while quantitative analysis was conducted to calculate population density and distribution patterns of this species within its habitat. Population density was calculated by dividing the number of individual sea cucumbers found by the total area sampled (Krebs, 2014). The analysis of population density for *H. leucospilota* is determined by the number of individuals divided by the total sampling area (Krebs, 2014), using the equation:

$$D_i = n_i / A$$



Note:

D_i = Population density of the species

n_i = Total number of individuals of species i

A = Total area sampled

This method provides information on the number of sea cucumber individuals present at each observation site, which will subsequently be used to determine the population status along the coast of Dedap.

The distribution pattern analysis of *H. leucospilota* can be calculated using the Morisita Distribution Index (Morisita, 1959). The Morisita Index (I_d) is a statistical tool used to assess the distribution pattern of a species' population. This value can provide insights into how individuals of the species are distributed across an area. Generally, the value I_d can be interpreted as follows: $I_d < 1$: Aggregate distribution or clustering, $I_d = 1$: Random distribution, $I_d > 1$: Homogeneous distribution. The formula is:

$$I_d = n \frac{\sum x^2 - \sum x}{(\sum x)^2 - \sum x}$$

Note:

I_d = Morisita Distribution Index

n = number of sampling points

$\sum x$ = total number of individuals at each point ($x_1 + x_2 + \dots$)

$\sum x^2$ = total number of individuals at each point squared ($x_1^2 + x_2^2 + \dots$).

RESULTS

Holothuria leucospilota, previously referred to as *Holothuria vagabunda*, exhibits a morphological characteristic of being elongated horizontally and cylindrical. The head section possesses tentacles that function to grasp food at the mouth, while the anus is located at the end of its body (Setyastuti et al., 2005). The body is cylindrical, elongated, black in colour, soft, flexible, and covered with soft papillae; when contracted, it resembles a pear shape, has a soft tegument, and contains Cuvierian tubules (Conand, 2019). The morphology of *H. leucospilota* is illustrated in Figure. 2. The classification of black rubber sea cucumber (*Holothuria leucospilota*) is as follows:

Phylum Echinodermata

Class Holothuroidea (with tube feet)

Order Aspidochirotida (with tentacles peltate)

Family Holothuriidae (with body usually circular and gonads single)

Genus *Holothuria* (Metriatyla) Rowe, 1969

Holothuria leucospilota Brandt, 1835 (Agusta, 2012)



Figure 2. Black Rubber Sea Cucumber (*Holothuria leucospilota*)

Observations and individual censuses of *Holothuria leucospilota* conducted along the coast of Dedap, in the waters of Pulau Abang, revealed variations in individual numbers at each station. Station I recorded 97 individuals, Station II had 66 individuals, and Station III noted 73 individuals. The total number of individuals found was 236. This data indicates that the population density of *Holothuria leucospilota* in the waters of Pulau Dedap varies, likely influenced by environmental factors and habitat conditions. Measurements of population density as shown in the Table.I

Table I. Density of *Holothuria leucospilota*

	Transect I	Transect. 2	Transect. 3
Number of Individuals	97	66	73
Density	0,97 ind/m	0.66 ind/m	0,75 ind/m
Type of Substrate	52 % rocky	87 % sandy	74% sandy

The number of individuals refers to the average count of the observed species in each transect per unit area (m^2). Transect I shows the highest value at 0.97 individuals/ m^2 , indicating nearly one individual sea cucumber per square metre in this area, suggesting it is a dense and healthy ecosystem for this species. Transect II recorded the lowest value at 0.66 individuals/ m^2 , indicating a lower density than Transect I, potentially due to various factors such as environmental conditions, food availability, or disturbances from human activities. Transect III had a density of 0.73 individuals/ m^2 , higher than Transect II but lower than Transect I, indicating a reasonably good potential presence of sea cucumber individuals, yet necessitating further investigation into contributing factors.

The analysis of the distribution pattern of *H. leucospilota* using the Morisita Index indicates that, in general, the distribution pattern of this species is clumped. This can be observed from the index values obtained, which suggest that sea cucumber individuals tend to be found in certain clusters, likely due to supportive environmental factors such as the presence of suitable substrates and food availability.

Table 2. Morisita Distribution Index for *Holothuria leucospilota*

Morisita	Fistribution Index (Id)	Category
Transect I	1.24	Clumped
Transect 2	1.11	Clumped approaching random
Transect 3	0.772	Random

Environmental water quality is a crucial factor influencing the growth and abundance of organisms. Good water quality supports various marine life to reside and thrive. (Yolanda, 2023) states that water quality is a primary benchmark for the sustainability of estuarine ecosystems in terms of physical, chemical, and biological water parameters. Among the environmental parameters applicable in estuaries, temperature, pH, and salinity are key parameters controlling the components present in the water column.

Measurements of water quality at Pulau Dedap included salinity, pH, temperature, and dissolved oxygen (DO), as shown in the Table. 3. The results of the environmental quality measurements in the three transects provide important information regarding the environmental conditions that may influence the presence and distribution of species, including *Holothuria leucospilota*. Salinity across the three transects shows stable values within a range that typically supports marine organism life. Studies on sea cucumbers indicate that optimal salinity ranges from 30-35 ‰, thus, these conditions are generally suitable for the presence of *H. leucospilota*. The pH

values in the three transects fall within a slightly alkaline range (8.4 - 8.6), which also supports the life of sea cucumbers and most other marine fauna. The ideal pH for sea cucumber species typically ranges from 8.0 - 8.3. Therefore, these values indicate that water quality in the area is adequate for the growth and reproduction of the species. Depth in the three transects varies from 1 to 3 meters, which is a common depth for coastal ecosystems. This depth also supports the presence of sea cucumbers and other organisms typically found in intertidal to subtidal zones. The measured DO levels above 8 mg/L indicate very good water quality for the ecosystem. Sea cucumbers require sufficient dissolved oxygen levels for respiration. This value suggests that the water conditions are quite healthy and not adversely affected by harmful pollutants that could reduce DO levels. The temperature across all transects remains stable at 28 °C, which is ideal for many marine species. Constant temperature conditions support the optimal metabolism and biological activity of sea cucumbers and other organisms.

Table 3. Environmental Parameters of the Waters

Transect	Salinity (‰)	pH	Depth	DO	Temperature
1	32‰	8,4	1 - 2 meters	8,4 mg/L	28 °C
2	31.5‰	8,6	1-3 meters	8,2 mg/L	28 °C
3	31.5‰	8,5	1-3 meters	8,2 mg/L	28 °C

DISCUSSION

Density was also measured in individuals per square metre, consistent with the number of individuals counted. The density in Transect I is 0.97 ind/m², indicating that the species is in relatively good condition in this zone. The density in Transect II is lower at 0.66 ind/m², suggesting that this area may have less than ideal habitat conditions to support population growth. Density in Transect III is 0.75 ind/m², reflecting a somewhat healthy population condition, though not as compact as Transect I. This suggests that there is a sufficient presence here, albeit not as optimal as in Transect I. These findings align with the observation that *H. leucospilota* is found in sandy substrates mixed with coral and seagrass vegetation. Its body is black and elongated; when held, *H. leucospilota* contracts into a smaller form. According to (Wulandari et al., 2012), this sea cucumber has a rounded cross-section with a posterior wider than the anterior. The dorsal side is black, while the ventral side is dark brown.

Comparison Among Transects shows significant variations in individual counts and densities across the transects. This may indicate that environmental conditions (such as habitat quality, physical factors, pollution levels, or interactions with other species) influence the distribution of sea cucumbers. The findings of this study are consistent with research by (Al-Rashdi et al., 2007), which indicates that variations in population density across different locations can affect individual size and overall population health. These findings parallel the results observed at Pulau Dedap, demonstrating that the density of *Holothuria leucospilota* varies across transects. As seen in Transect I, which has the highest density, individuals are likely to fare better in terms of size and growth, similar to phenomena noted by Al-Rashdi et al.

All transects indicate the impact of substrate on the density of individual sea cucumbers. Transect I, with 52% rocky substrate, facilitates a more complex habitat, allowing sea cucumbers to hide and forage more effectively. Research by (Mercier & Penney, 2023) confirms that the presence of more complex substrates, such as rocks, often provides shelter and enhances food availability for sea cucumber species within marine ecosystems. Transect II, predominantly consisting of 87% sandy substrate, displays the lowest density. (Al-Rashdi et al., 2007) noted that rocky substrates support higher densities, but also recorded that sandy substrates host fewer sea cucumber species due to limited shelter and a lack of food resources trapped in less complex substrates. These findings align with (Nirwana et al., 2016), which state that the presence of rocky habitats enables



sea cucumbers to find food while also providing cover from predators. This may explain the decrease in the number of individuals found in Transect II. Furthermore, the potential habitat in Transect III, despite having 74% sand, shows better density than Transect II. This may reflect that, although the substrate is more homogeneous, the presence of some rocky elements or other environmental factors such as nutrients and currents could contribute to a relatively better presence of sea cucumber individuals. Habitats with a mix of different substrates can enhance species diversity, offering both shelter and access to food resources. (Bruckner et al., 2003) reinforce the observation that variations in density and size within sea cucumber populations suggest that population density may correlate with the presence of rocky substrates that provide better conditions for growth and reproduction. This is similar to the results in Transect I, which indicate that with good availability of rocky substrates, sea cucumber individuals can grow optimally.

The Morisita Index value (I_d) of 1.24 for Transect I indicates that the distribution pattern of *Holothuria leucospilota* in this transect tends to be hydroscopically or more evenly distributed. Although this value is still above 1, it suggests that despite environmental elements that may influence the presence of sea cucumber individuals, fundamentally they are not uniquely concentrated in specific zones. Potential causes could be due to supportive environmental conditions such as good substrate quality; research by (Theeratathanakorn et al., 2023b) found that *H. leucospilota* was observed in rock crevices and hiding under sand, food availability, or the absence of disturbances from human activities may render this transect more favourable for the sea cucumber species.

In Transect 2, an (I_d) value of 1.11 was obtained, indicating a distribution pattern approaching random but with a slight tendency toward clustering. Despite a distribution that leans towards random, it appears that environmental factors play an important role in population regulation, albeit not significantly enough to cause clear clustering. Potential causes are suspected to be factors such as substrate quality, access to resources, or habitat modifications due to lower environmental disturbances influencing the distribution of this species.

In Transect 3, an (I_d) value of 0.772 was obtained, suggesting that the distribution of *Holothuria leucospilota* in this area is more random, but with a slight tendency towards a homogeneous pattern. This may indicate a more uniform population, but there is also potential for clustering at certain locations that are more favourable. Potential causes in this area may include greater pressure from human activities or environmental ecopreneur influences that could support instability in locations. Insufficiencies in habitat variation or a lack of resources may account for the more uniform distribution pattern. A more uniform pattern suggests that sea cucumber individuals could survive in a less favourable environment.

Overall, the Morisita Index values across all transects indicate variations in the distribution patterns of *Holothuria leucospilota*. With the highest value in Transect I (1.24) and the lowest in Transect 2 (0.772), it is evident that habitat conditions in Transect I are more supportive for the distribution of healthier individuals, while Transect 3 faces more serious challenges. These observations suggest that environmental characteristics may fundamentally impact how populations are distributed. The distribution pattern of *Holothuria leucospilota* in this study indicates that Transect I has a higher concentration of individuals, while Transect 2 shows the lowest density. This is similar to findings by (Lee et al., 2008) regarding how density affects behaviour and interactions among sea cucumber individuals, which could influence their adaptation opportunities in less supportive environments.

Based on the environmental quality measurements in the three transects, it can be concluded that the optimal conditions for the environment: Salinity, pH, DO, depth, and temperature, indicate conditions that support the presence of *Holothuria leucospilota*. The optimal range for water quality that supports the growth and health of sea cucumbers is based on references from

(Lovatelli et al., 2020). The results of the environmental quality measurements indicate that all three transects have optimal salinity, with an average salinity of around 30-31 ‰, which supports the survival of *Holothuria leucospilota* (McLusky & Elliot, 2013). The slightly alkaline pH values (8.4 to 8.6) are also within the ideal range for this marine species (Saarikoski & Viluksela, 1981).

Additionally, the recorded dissolved oxygen (DO) levels above 8 mg/L depict healthy water conditions, vital for aquatic life (Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, 2007). The temperature remains stable at 28 °C, reflecting conditions that support optimal metabolism and biological activity in marine organisms. The recorded dissolved oxygen (DO) content is 7.4 mg/L. According to the Minister of Environment Decree No. 51 of 2004 (Ministry of Environment, 2004), the standard for dissolved oxygen for marine biota is >5 ppm. Based on this, it can be concluded that the range of dissolved oxygen (DO) values at the research site supports the life of *H. leucospilota*. The high levels of dissolved oxygen (DO) are likely due to the measurements being taken during the day when sunlight is bright, allowing for a greater release of oxygen through the intensive photosynthesis occurring in the euphotic layer than the oxygen consumed through respiration. According to the Minister of Environment Decree No. 51 of 2004, good dissolved oxygen conditions for marine biota are those exceeding 5 mg/L.

CONCLUSION

The findings of this study indicate that the population density of *Holothuria leucospilota* varies across each transect, with Transect 1 exhibiting the highest density correlated with the presence of rocky substrates. The complex habitat conditions in Transect 1 allow sea cucumber individuals to hide and forage more effectively, while Transect 2, dominated by sandy substrates, shows the lowest density, likely due to limited shelter and food resources. The distribution pattern analysis suggests that this species tends to cluster, with potential supportive environmental interactions in rocky areas. Furthermore, the environmental quality across all transects lies within the optimal range for the survival of sea cucumbers, with salinity, pH, and dissolved oxygen levels conducive to growth. Therefore, further research is essential regarding the factors influencing individual densities and distributions of sea cucumbers, as well as management efforts to improve habitat conditions.

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