

Exploration of Community Structure and Density of Sea Cucumbers (Holothuroidea) in the Tropical Waters of Abang Island, Batam

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Abstract

Background: Coral reef ecosystems in tropical waters are highly productive and biodiverse, with sea cucumbers (Holothuroidea) serving essential ecological functions as detritivores, contributing to nutrient cycling, sediment bioturbation, and substrate quality. Despite their ecological and economic significance, data on the community structure and density of sea cucumbers in Abang Island remain scarce. This study aimed to assess the species composition, density, and ecological patterns of Holothuroidea in the tropical waters of Abang Island, Batam. **Methodology:** Field surveys were conducted using a transect-quadrat method, with environmental parameters (temperature, salinity, pH, dissolved oxygen) measured in situ. **Findings:** Five species were recorded: *Holothuria leucospilota*, *H. atra*, *H. scabra*, *H. fuscocinerea*, and *H. pardalis*. Species composition was dominated by *H. leucospilota* at Station 1 and *H. fuscocinerea* at Station 2. The highest density was 0.130 ind/m² for *H. leucospilota* at Station 1, and 0.150 ind/m² for *H. fuscocinerea* at Station 2. Community analysis showed greater diversity at Station 1 ($H' = 1.07$) but higher dominance at Station 2 ($D = 0.691$). Pearson correlation indicated that salinity and temperature were the most influential factors affecting abundance, varying by habitat type. These results suggest that habitat characteristics, particularly substrate and vegetation, shape species distribution in small island ecosystems. **Contribution:** This study provides the first baseline data on sea cucumbers in Abang Island, offering novel insights into the linkage between environmental parameters and species-specific distribution patterns, and supporting conservation and sustainable management of these ecologically and economically valuable resources.

Keywords : Abang Island; Community Structure; Density; Environmental Parameters; Sea cucumber



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INTRODUCTION

Tropical waters are recognised for their high biodiversity, particularly in terms of community structure, which encompasses species composition, diversity, abundance, and dominance (Elfidasari et al., 2012). Sea cucumbers (*Holothuroidea*) are integral components of tropical benthic ecosystems, functioning as detritivores that contribute to nutrient recycling, sediment bioturbation, and substrate quality maintenance (Purcell et al., 2016; Theeratatthanakorn et al., 2023). In addition to their ecological functions, sea cucumbers also hold significant economic importance as high-protein seafood and as raw materials for pharmaceutical and cosmetic industries (Misgiati et al., 2024; Anugrah & Alfarizi, 2021). The global trade of dried sea cucumbers (*beche-de-mer*) supports coastal livelihoods and constitutes a high-value commodity in Asian and international markets (Wodi et al., 2024; Setyastuti et al., 2018; FAO, 2020). This dual ecological and socio-economic role underscores the urgency of sustainable management of sea cucumber resources (Parra-Luna et al., 2020; Choo, 2008; Elfidasari et al., 2012).

Abang Island, located in the southern waters of Batam City, Riau Archipelago Province, is characterised by coral reef and seagrass ecosystems that sustain diverse marine biota. As a marine tourism destination, this area faces anthropogenic pressures such as fishing activities and coastal utilisation (Efendi et al., 2024). Despite its ecological and economic relevance, scientific information on the status of sea cucumbers in this area remains scarce. Baseline data are required to support biodiversity conservation and sustainable resource management (Bruckner et al., 2003), particularly in small island ecosystems that are vulnerable to human disturbance.

Although numerous studies have examined sea cucumber diversity and distribution in various regions of Indonesia, such as Maluku, the Seribu Islands, and Gorontalo (Kalidi et al., 2023; Helmiyani et al., 2024; Daud et al., 2023; Nurafni et al., 2020; Uneputti et al., 2014), information on the community structure of *Holothuroidea* in the waters of Abang Island, Batam, remains limited. This knowledge gap constrains understanding of how environmental factors influence species composition and abundance in small island ecosystems. Addressing this gap is essential for establishing a scientific baseline to support conservation and management strategies in the region.

Accordingly, this study aims to identify the species of sea cucumbers present in Abang Island, analyse their community structure based on diversity indices, dominance, and evenness, and examine the relationship between environmental parameters and sea cucumber abundance. The results are expected to provide baseline data on the ecology of *Holothuroidea* in Abang Island, contribute to the broader understanding of tropical benthic ecosystems, and offer practical insights for stakeholders and policymakers in the sustainable management of marine resources.

METHOD

This study employs a quantitative descriptive approach using survey methods to explore the community structure and distribution of sea cucumbers (*Holothuroidea*) in the tropical waters of Abang Island, Batam. Through this

approach, the research aims to provide a comprehensive overview of species composition and abundance of sea cucumbers at the study site.

The research was conducted from August to September 2024, with the study location situated in the tropical waters of Abang Island, Batam, which is renowned for its high marine biodiversity (0°29'27"N 104°15'51"E to 0°31'46"N 104°13'22"E). The waters surrounding Abang Island comprise a cluster of small islands located to the south of Batam City, approximately 50 km from the city centre. Administratively, it falls within the jurisdiction of the Abang Island Village, Galang District, Batam City.

Sampling or Participant

The sampling technique employed in this study was the transect-quadrat method. At each station, three transects of 50 m length were established, laid perpendicular to the shoreline. The starting points of transects were determined purposively to represent dominant habitats (rocky- mangrove at Station 1 and sandy seagrass at Station 2), while ensuring stratification along the coastline. The distance between adjacent transects was set at 20 m to minimise spatial overlap. Along each transect, quadrats measuring 1 × 1 m were placed at 10 m intervals, resulting in five replicates per transect and a total of 15 quadrats per station.

Station 1 was located along the coastline of Dedap Island in the waters of Abang Island (0°29'27"N; 104°15'51"E), while Station 2 was situated in the Red Sand Seagrass area of Abang Island (0°31'46"N; 104°13'22"E). Sampling was conducted during low tide in the morning (08.00– 11.00) to ensure accessibility and visibility of benthic organisms.

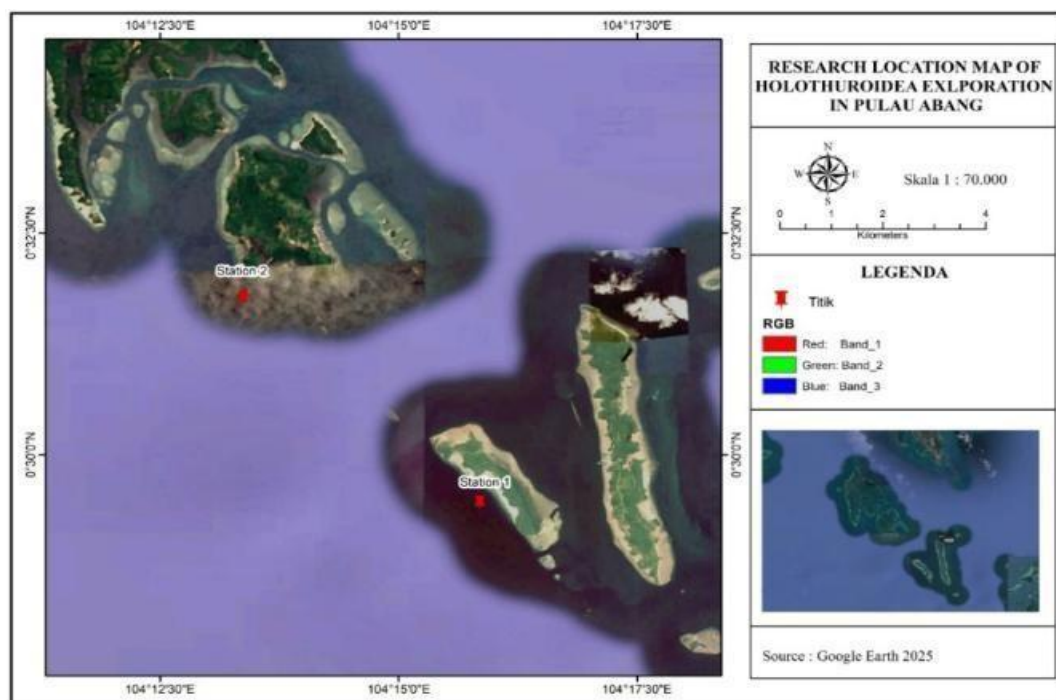


Figure 1. Map of Research Location

All sea cucumber specimens encountered within each quadrat were identified in situ and, when necessary, collected for closer examination. Species identification was based on morphological characteristics using standard identification keys and references (Purcell et al., 2013; Massin, 1999). In addition, expert consultation was carried out to confirm species-level identification. A map of the study sites is presented in Figure 1.

The utilisation of this method enables researchers to obtain more accurate data regarding the abundance and distribution of sea cucumbers across various habitat zones. Each quadrat will be assessed to record the species of sea cucumbers encountered, along with the number of individuals of each species. This technique also facilitates further analysis of the community structure of sea cucumbers based on the existing species composition.

Data Analysis

In this study, the ecological parameters measured include density, which is assessed by counting the number of sea cucumber individuals found within each quadrat. The analysis of sea cucumber density is based on Krebs (2014), represented by the formula:

$$K = \frac{ni}{A}$$

Where:

K = species density (ind/m²)

ni = number of individuals of a species (ind)

A = area of the sampling site (m²)

Species diversity is a crucial indicator in ecology that reflects the health of an ecosystem. The Shannon-Wiener diversity index (H') is frequently employed to measure species diversity within the sea cucumber community. A high diversity index indicates that the ecosystem possesses resilience against environmental changes. The Shannon-Wiener diversity index is calculated as follows (Shannon & Wiener, 1949; Krebs, 1989).

$$H' = - \sum (Pi * \ln(Pi))$$

Where:

H' : Shannon-Wiener diversity index

Σ : Sigma symbol, indicating summation

Pi : Proportion of individuals of the i-th species relative to the total number of individuals (ni / N); ni: Number of individuals of the i-th species

N : Total number of individuals across all species ln: Natural logarithm

Subsequently, the dominance index is computed using Simpson's index (D), which provides insight into the extent of dominance by one or several species within the community (Simpson, 1949):

$$D = \sum P^2 i$$

Where:

D = Simpson's dominance index

n_i = total number of individuals of the i -th species

N = total number of individuals across all species

Another aspect of community structure measured is evenness, assessed through Pielou's index (E), to comprehend the distribution of species within the community (Pielou, 1966).

$$E = \frac{H'}{\ln S}$$

Where:

E = Evenness index

H' = Diversity index ($H_{\max} = \ln S$)

S = Number of species

Following this, statistical analysis using Pearson correlation was conducted to examine the relationship between sea cucumber abundance and environmental parameters, employing SPSS version 25.0 for data processing. Data collection concerning environmental quality, specifically water conditions, is performed *in situ*, measuring physical and chemical parameters that refers to Efendi et al., (2024) include dissolved oxygen (DO), acidity (pH), temperature, salinity, and substrate characteristics. This data is vital for understanding the relationship between sea cucumbers and their habitat. Data collection concerning environmental quality, specifically water conditions, was conducted *in situ* by measuring physical and chemical parameters including dissolved oxygen (DO), acidity (pH), temperature, salinity, and substrate characteristics. Dissolved oxygen, temperature, and salinity were measured using a portable multiparameter water quality meter (YSI Professional Plus), while pH was determined with a calibrated digital pH meter. Measurements were taken directly at each quadrat during sampling to ensure accurate representation of habitat conditions. Substrate characteristics were analysed by collecting sediment samples from each station, which were subsequently examined in the laboratory using the pipette method to determine grain size composition (sand, silt, and clay fractions). This information is essential for interpreting the relationship between sea cucumber abundance and habitat conditions.

RESULT AND DISCUSSION

Result Clear Paramaters

The composition and abundance of sea cucumber species in the waters surrounding Abang Island, Batam, reveal a significant diversity within the Holothuridae family. This study recorded a total of five distinct sea cucumber species, with *Holothuria leucospilota* (black rubber sea cucumber) and *Holothuria fuscocinerea* (rubber sea cucumber) identified as the dominant species. The data on species composition is presented in Table 1.

Tabel 1. Composition of Sea Cucumber Species (Holothuria) at Station 1 & 2

No	Species	Station 1	Station 2
1	<i>Holothuria leucospilota</i>	39	5
2	<i>Holothuria atra</i>	7	5
3	<i>Holothuria scabra</i>	2	3
4	<i>Holothuria fuscocinerea</i>	2	45
Total		52	58

The total population density of sea cucumbers at Station 1 reached 52 individuals, while at Station 2 it was higher at 58 individuals. This indicates that although both stations host the same species of sea cucumbers, Station 2 has a slightly larger population. This difference in density is likely influenced by environmental factors and the local habitat conditions at each station (Magurran, 2004).

Tabel 2. Analysis of Species Abundance

Species	Station 1 (ind/m ²)	Station 2 (ind/m ²)
<i>Holothuria leucospilota</i>	0.130	0.017
<i>Holothuria atra</i>	0.023	0.017
<i>Holothuria scabra</i>	0.007	0.010
<i>Holothuria fuscocinerea</i>	0.007	0.150
<i>Holothuria pardalis</i>	0.007	0.000

From these results, we can observe that *Holothuria leucospilota* has the highest density at Station 1, while *Holothuria fuscocinerea* is dominant at Station 2. The analysis of species density at Station 1 reveals that the highest density is *Holothuria leucospilota* (0.13 individuals/m²), indicating that this species is more dominant compared to others. A higher distribution may suggest a preference for certain habitats. Additionally, there are occurrences of *Holothuria atra*, *Holothuria scabra*, *Holothuria fuscocinerea*, and *Holothuria pardalis*, albeit with significantly lower densities (≤ 0.023 individuals/m²).

The distribution pattern differs with the dominance of *Holothuria fuscocinerea* (0.15 individuals/m²), while *Holothuria leucospilota* and *Holothuria atra* exhibit lower abundances (0.0167 individuals/m²). *Holothuria pardalis* was not found at this station. From this data, we can conclude that *Holothuria leucospilota* is more frequently found at Station 1, likely due to more suitable substrate or environmental conditions. *Holothuria fuscocinerea* dominates Station 2, indicating different ecological preferences compared to other species. *Holothuria pardalis* is only found at Station 1, suggesting limitations in its distribution. The low abundance of some species indicates that their distribution may be clustered, depending on microhabitat conditions, a pattern that has also been reported by Uthicke (1999) in tropical sea cucumber populations where distribution is strongly influenced by habitat heterogeneity and resource availability.

From the initial results and habitat information, several factors could explain the distribution of sea cucumbers. At Station 1, with a sandy mangrove habitat at a

depth of 0 – 1.5 meter, *Holothuria leucospilota* dominates, likely due to its tolerance of shallow water conditions with mangrove root protection. Rock crevices provide shelter from predators and strong currents, which is likely the main reason *Holothuria leucospilota* is more dominant here. Species found in rock crevices may be more resistant to strong currents or more reliant on the physical structure of the substrate for protection (Cañada et al., 2020). Other species found in small numbers may use rocks as temporary protection but are not entirely dependent on rocky substrates. *Holothuria atra*, *H. scabra*, *H. fuscocinerea*, and *H. pardalis* were found in small numbers, possibly due to substrate preferences or competition with dominant species. Mangroves often provide protection from strong currents, which may influence distribution patterns and sea cucumber preferences.

Holothuria fuscocinerea is most dominant at Station 2, at a depth of 1-2.5 m, likely due to its preference for slightly deeper waters with sandy substrates and more stable seagrass vegetation. Pitogo et al., (2018) suggest that seagrass provides protection from currents and functions as a collection site for organic detritus, which can enhance food availability. Rocky sand (Station 1) may provide additional protection for species more tolerant of coarse substrates, such as *Holothuria leucospilota*, which appears more dominant in this area. Sand without rocks (Station 2) may be more suitable for species like *Holothuria fuscocinerea*, Kalidi et al., (2023) declare *H. fuscocinerea* which is more frequently found here and likely prefers finer substrates. Food Availability; sand texture can influence organic content in sediments. Rocky sand often has crevices where organic particles accumulate, impacting food availability for species present. Fine sand typically has more stable sedimentation rates, allowing species like *H. fuscocinerea* to thrive better in seagrass ecosystems. 3. Species Mobility and Behaviour; some sea cucumbers have preferences for specific substrate textures for movement and foraging. *Holothuria leucospilota* is known to be more flexible in rocky environments, while *Holothuria fuscocinerea* may prefer smooth sandy surfaces for its activities.

The community structure of sea cucumbers in the waters around Pulau Abang can be analysed using the Shannon-Wiener diversity index (H') and dominance index (D), as well as the Evenness Index (E). The results of the community structure analysis are presented in Table 3.

Tabel 3. Community Structure Analysis

Ecological Community Structure Index	Station 1	Station 2
Diversity Index (H')	1.070	0.680
Dominance (D)	0.597	0.691
Evenness Index (E)	0.660	0.620

Table 3 indicates that Station 1 has higher diversity ($H' = 1.07$) compared to Station 2 ($H' = 0.68$). Statistical analysis using the Mann-Whitney U test confirmed that this difference was significant ($p = 0.03$), indicating that the variation in diversity between the two stations reflects real ecological differences rather than natural random variation. The higher diversity at Station 1 can be attributed to the rocky substrate that provides more microhabitats for various species. Conversely, Station 2

was dominated by *Holothuria fuscocinerea*, resulting in a lower H' value. This finding inline with Nurcahyo et al., (2024) reported that sea cucumber communities in coral reef ecosystems exhibit higher diversity than those in seagrass ecosystems, due to the more complex physical structure supporting more species.

Dominance (D) is higher at Station 2, primarily due to *Holothuria fuscocinerea* dominating the sandy seagrass habitat. The Simpson dominance index value (D) indicates that Station 2 has higher dominance ($D = 0.691$) compared to Station 1 ($D = 0.597$). *Holothuria fuscocinerea* dominates Station 2, Gustiani et al., (2018) likely due to habitat preference for sandy substrates with seagrass vegetation. At Station 1, although *Holothuria leucospilota* is more abundant, the distribution of species is more even, leading to lower dominance. The research of Helmiyani et al., (2024) shows that high dominance often occurs in ecosystems with little substrate variation and more concentrated food resources.

The evenness index indicates that Station 1 has higher evenness ($E = 0.66$) compared to Station 2 ($E = 0.62$). High evenness at Station 1 suggests that individuals are more evenly distributed among the existing species. This result inline with Husain et al., (2017). Whereas Station 2 has lower evenness due to the dominance of *Holothuria fuscocinerea*, resulting in uneven individual distribution. According to research of Helmiyani et al., (2024) in the Seribu Islands, sea cucumber communities with high evenness tend to be more stable and exhibit more complex ecological interactions.

Visualization of Sea Cucumber Density vs Environmental Parameters - Station 1

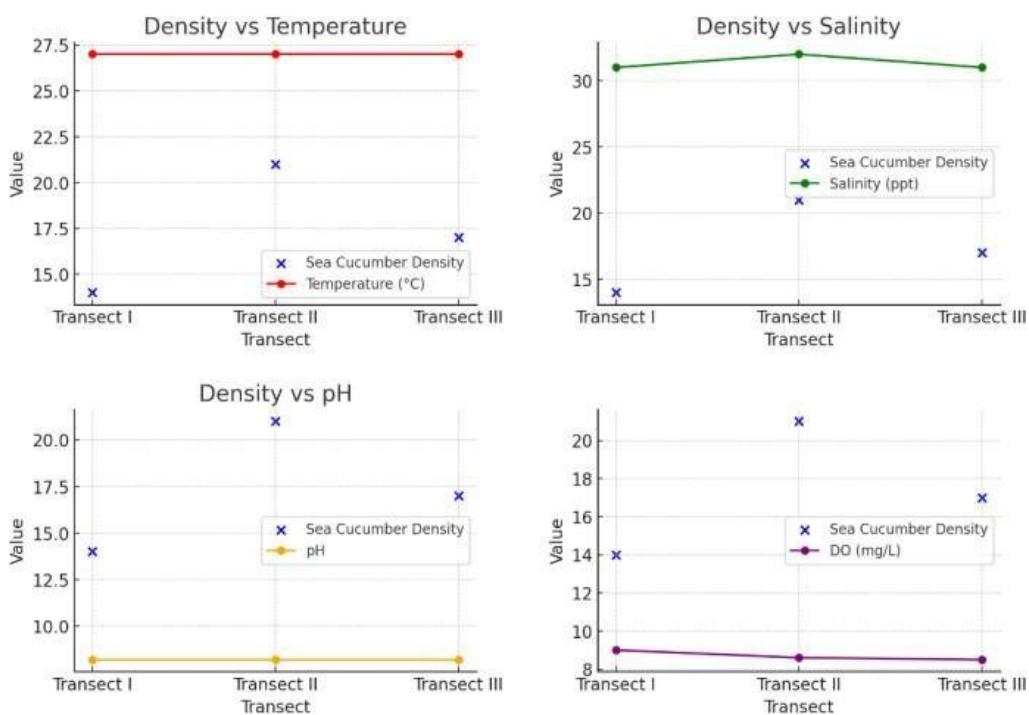


Figure 2. Correlation of Density with Environmental Parameters in Station 1.

The analysis results show that Station 1 has higher diversity and evenness,

while Station 2 is dominated by one main species. This difference is likely due to habitat characteristics, including substrate and vegetation. The rocky substrate at Station 1 supports higher diversity by providing more microhabitats, while the seagrass vegetation at Station 2 creates conditions more suitable for certain species, leading to high dominance. The high diversity at Station 1 underscores the importance of protecting rocky habitats to maintain the balance of sea cucumber communities. The high dominance at Station 2 may indicate that seagrass ecosystems are more vulnerable to environmental changes and overexploitation.

Environmental parameter analysis is a crucial aspect of understanding the distribution and abundance of sea cucumbers in the waters around Pulau Abang. The parameters measured in this study include water temperature, salinity, pH, and water depth. This research examines the relationship between water quality parameters (temperature, salinity, pH, and dissolved oxygen) and the *Holothuria* abundance at two observation stations. The results of the Pearson correlation calculations indicate differences in the correlation patterns between each environmental parameter and sea cucumber abundance at each station. The visualisation of sea cucumber density versus environmental parameters was analysed for two stations, as shown in Figure 2.

The relationship between sea cucumber density and key environmental parameters ; temperature, salinity, pH, and dissolved oxygen (DO) at two coastal stations. At Station 1, the temperature remained constant at approximately 27°C across transects, suggesting minimal influence of temperature variation on sea cucumber density within this range. This finding aligns with [Purcell et al., \(2016\)](#), who reported that tropical sea cucumbers tolerate narrow temperature fluctuations without significant changes in abundance. This result is consistent with [Purcell & Conand, \(2012\)](#) that *Holothuria* is a genus of sea cucumbers highly sensitive to variations in physical- chemical environmental parameters, particularly temperature and pH. Temperature plays a crucial role in regulating metabolic processes and feeding activities of sea cucumbers. Within the optimal range of approximately 27–28 °C.

Salinity exhibited a moderate positive correlation with sea cucumber density, particularly between Transects I and II, where salinity increased from 31 to 32 ppt accompanied by an increase in sea cucumber density. This observation supports [Conand \(2019\)](#) findings of, who emphasised that sea cucumbers thrive in seawater with salinity levels around 30–35 ppt. Salinity also showed a significant effect at Station 1. Studies by [Rahantoknam et al., \(2021\)](#) support that some *Holothuria* species have a relatively wide salinity tolerance but still exhibit specific preferences within certain optimal ranges.

The pH level remained stable near 8.2 throughout the transects, which falls within the known tolerance range of sea cucumbers ([Mercier et al., 2023](#)), indicating no significant effect on their distribution. Dissolved oxygen levels slightly decreased from 9 to 8.5 mg/L, yet showed a positive association with sea cucumber density, consistent with [Diaz & Rosenberg \(1995\)](#) assertion that adequate oxygenation is critical for benthic marine organisms' metabolic activities.

In contrast, Station 2 displayed more variability in sea cucumber density

alongside slightly higher temperature ranges (27 – 28 °C) and lower salinity levels (30 – 31 ppt). Despite minor temperature fluctuations, sea cucumber density did not correlate strongly with temperature, implying that other ecological factors such as substrate quality or anthropogenic disturbances may have a more pronounced effect on distribution (Uthicke et al., 1999).

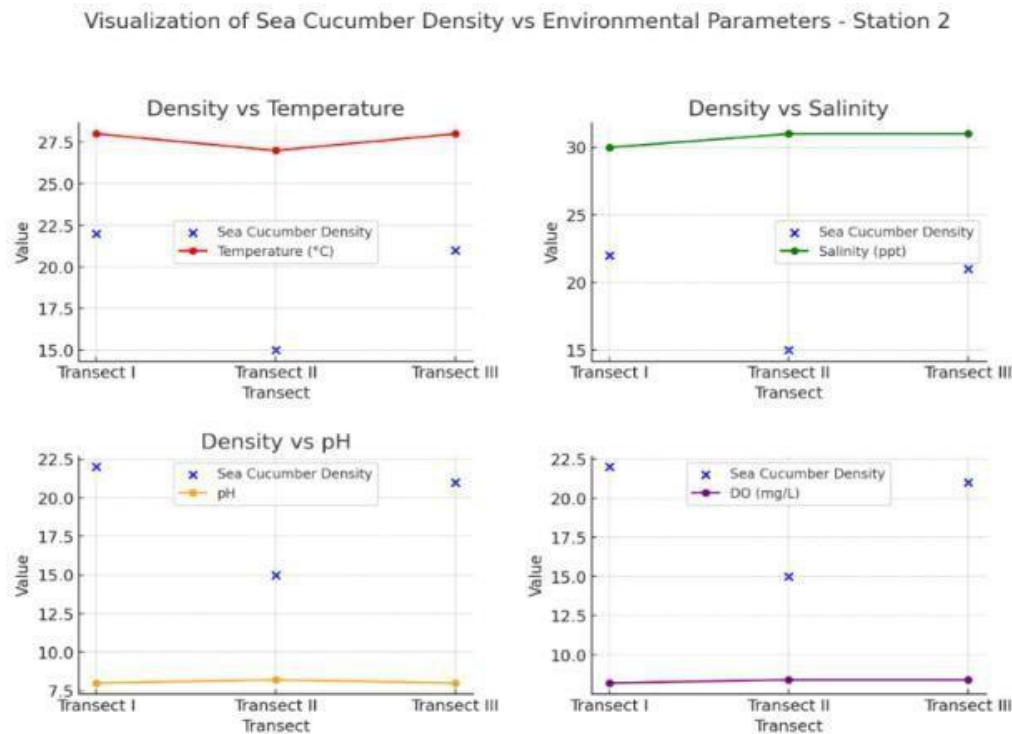


Figure 3. The Correlation of Density with Environmental Parameters at Station 2.

The weaker correlation between salinity and density at this station further suggests that environmental and biological factors beyond the measured parameters influence sea cucumber abundance (Manuputty et al., 2019). pH levels fluctuated modestly between 8.0 and 8.2 without significantly impacting density, corroborating Yuan et al., (2018) that sea cucumbers are tolerant to normal marine pH variations. Lastly, stable DO levels at Station 2 coincided with fluctuating sea cucumber density, indicating that oxygen concentration was not a limiting factor in this location. The negative correlation between DO and density can be explained by the high bioturbation activity of sea cucumbers in low-oxygen substrates. Huo et al., (2018) This indicates that Holothuria can survive in low DO conditions through physiological adaptations such as increased efficiency in oxygen use during respiration.

Overall, the results indicate that salinity and dissolved oxygen are the most influential environmental factors affecting sea cucumber density, particularly at Station 1 where these parameters remained within optimal ranges. Temperature and pH, however, showed limited variation and thus negligible correlation with sea cucumber distribution at both stations. The variability in sea cucumber density that is not explained by these parameters points to the potential role of additional factors such as substrate composition, food availability, and human activities in shaping

local populations.

CONCLUSION

Five species of *Holothuroidea* were successfully identified in the waters of Abang Island, with *Holothuria leucospilota* dominant at Station 1 and *H. fuscocinerea* at Station 2. Station 1 exhibited higher diversity and evenness, while Station 2 was characterized by species dominance. Environmental parameters significantly influenced species distribution, with salinity being the key factor at Station 1 ($r = 0.71$, $p = 0.02$), and temperature ($r = 0.64$, $p = 0.03$) along with pH ($r = 0.59$, $p = 0.04$) as dominant factors at Station 2.

This study provides the first baseline data on sea cucumber community structure in Abang Island, highlighting the role of habitat characteristics (rocky vs. seagrass substrates) in shaping species diversity. The novelty of this research lies in integrating ecological indices with environmental parameters to explain local distribution patterns, which has not been previously reported in this region. The findings contribute to conservation and sustainable management strategies by identifying key species–environment relationships, offering a scientific basis for habitat protection, and supporting the sustainable use of sea cucumbers as both ecological and economic resources.

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