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Distribution Pattern of Black Sea Cucumber (*Holothuria atra* Jaeger, 1833) at the Intertidal Ecosystem of Bilik Coastal, Baluran National Park

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Abstract. Baluran National Park (BNP) is a natural resource conservation area known for its diverse land and water ecosystems. The intertidal ecosystem of Bilik Coast is home to sea cucumbers (*Holothuria atra*), which have both ecological and economic value. It is important to note that *H. atra* is a protected species in the BNP conservation area. Therefore, studying the distribution pattern of *H. atra* in the intertidal ecosystem of Pesisir Bilik is crucial. This study aims to determine the type of distribution pattern of *H. atra* and describe its spatial distribution. Purposive sampling was conducted at maximum low tide, and biotic data were collected using the Global Positioning System (GPS) to obtain coordinates. Biotic data were measured at 9 points as a representative area. The type of distribution pattern of *H. atra* was analyzed using the Nearest Neighbor Index using ArcGIS 10.7 which shows the type of distribution pattern and describes its spatial distribution. The research results showed that the distribution pattern of *H. atra* was categorized as clustered based on the result of R (ratio) < 1 (0.458). *H. atra* species were distributed in seagrass communities, macroalgae communities, open areas, and coral reef communities.

1 Introduction

Baluran National Park (BNP) is a natural resource conservation area located administratively in Situbondo Regency, East Java. The park has a high potential for biodiversity, particularly in its intertidal ecosystem. This ecosystem is a narrow area that lies between the highest and lowest tides [1]. One such ecosystem can be found at Bilik Coastal. As reported by [2], the intertidal ecosystem of Bilik Coastal serves as a habitat for various sea cucumber groups. One of the most frequently encountered species in this area is *Holothuria atra*.

Holothuria atra, commonly known as the black sea cucumber, belongs to the Aspidochirotida family within the phylum Echinodermata. This species has an elongated cylindrical body shape and maintains its black color even after preservation [3]. The ventral part of the body contains tube feet which serve as a means of locomotion, while the dorsal

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part has small, tight papillae that function as sensory organs [4]. Sea cucumbers typically have their bodies covered in fine sand as a form of adaptation to high temperatures. The anterior end of *H. atra* contains its mouth, which is equipped with peltate tentacles that function to capture food particles [5]. As mentioned in [6], sea cucumbers with peltate tentacles are classified as deposit feeders. According to [7], *H. atra* is capable of processing up to 19 kg of sediment per year per individual. *H. atra* has the potential to act as a keystone species and maintain ecosystem balance. According to [8], it also serves as a food source for predators such as crabs, mollusks, and fish in the form of eggs, larvae, and young.

The species *H. atra* is commonly found in Indo-Pacific waters, including Java, Sumatra, Papua, Sulawesi, Riau, and Nusa Tenggara in Indonesia. These sea cucumbers inhabit sandy coastal areas, seagrass beds, and coral reefs [2]. In Indonesia, the *H. atra* species is considered to have low economic value [9]. According to [10], there is a risk of over-exploitation of low-value sea cucumber species, including *H. atra*. This could lead to a decrease in the number of *H. atra* and result in ecological losses. Furthermore, the reduction in their population may affect the natural distribution pattern.

The distribution pattern refers to the arrangement of individuals within their habitat. The distribution pattern refers to the arrangement of individuals within their habitat. As stated by [11], there are three types of distribution patterns: even, random, and clustered. It is rare for organisms in nature to be randomly distributed, as noted by [12]. Each individual can be found in certain locations and not in others. According to [13], distribution can be influenced by various factors, such as habitat preference, environmental conditions, competition, and predator presence. In the shallow waters of BNP, *H. atra* was found in seagrass beds, areas with macroalgae growth, open areas, and coral reefs [2].

The population density of *H. atra* in the BNP area is adequately protected as a conservation area. Any changes in the population density of *H. atra* are likely due to natural factors. Therefore, it is important to study the pattern of population distribution in the intertidal ecosystem of Bilik Coastal BNP, based on the importance value of *H. atra*. This distribution pattern will describe the distribution of *H. atra* species and can also provide additional information regarding the area occupied by *H. atra* in the intertidal ecosystem of Bilik Coastal BNP.

2 Methodology

2.1 Research location

The research was conducted in February 2021 - January 2022. Sampling and data collection were carried out in the intertidal ecosystem of Bilik Coastal Baluran National Park with coastline coordinates between 7°45'6.96"S and 114°22'26.36"E to 7°45'0.26" S and 114°22'8.87"E (Figure 1). Species identification, description, and data analysis of *H. atra* were carried out at the Ecology Laboratory, Department of Biology, Faculty of Mathematics and Sciences, University of Jember.

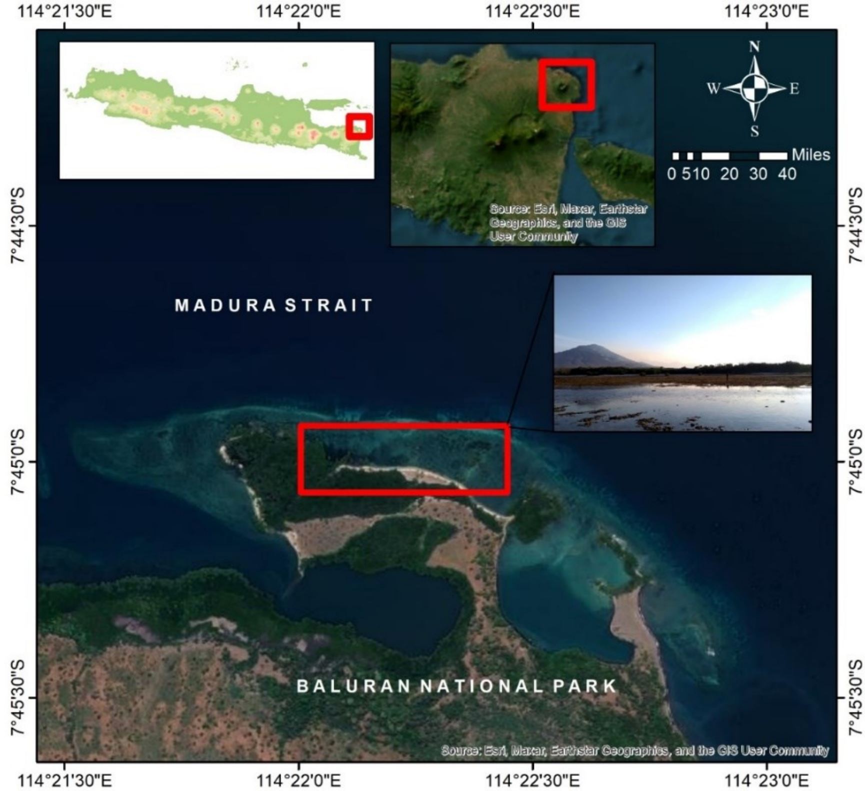

Fig. 1. The research location is the Bilik Coastal Intertidal Ecosystem BNP

2.2 Sample collection

The research method used is purposive sampling [7]. Technically this method is by means of a structured trip down the research area from the edge to the shoreline so that it covers the intertidal area (Figure 2). Each *H. atra* was found marked with a Global Positioning System (GPS), along with supporting data on the substrate and the area occupied (seagrass community, macroalgae community, open area and coral reef community). If found in the seagrass and macroalgae community, the seagrass and macroalgae are collected, documented and then the type code is recorded, for example (S1, 2, 3 (Seagrass), M1, 2, 3 (Macroalgae)) and so on. If found in an open area, record the code occupied (SF (sand flat) / CS (coral shoal)). Meanwhile, if found in coral reef communities, live or dead corals are observed and recorded with the code (LC (live coral) / DC (dead coral)). The species of seagrass and macroalgae that were most commonly found in *H. atra* were identified.

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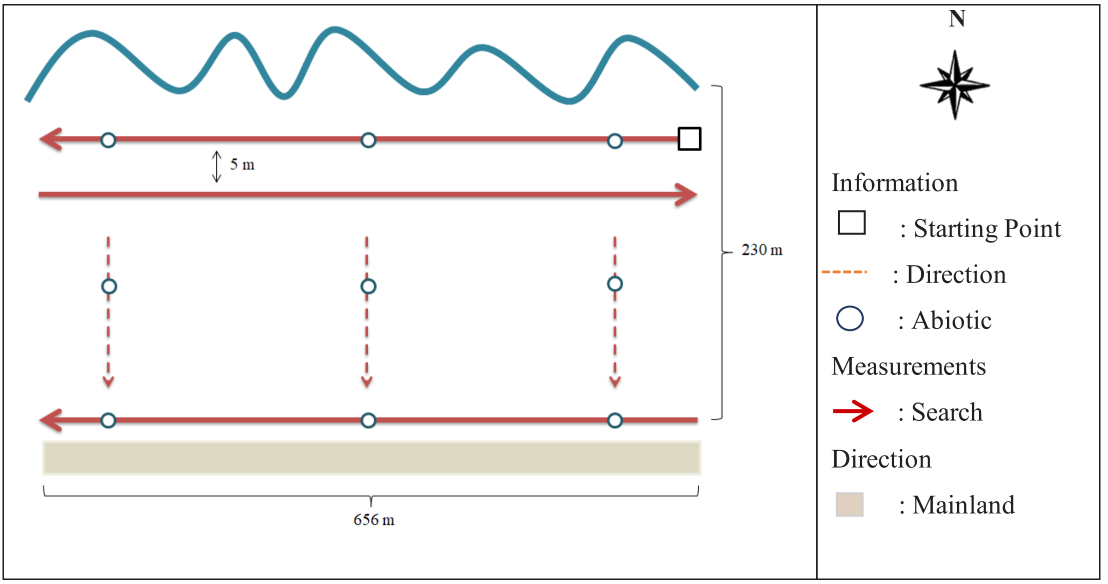

Fig. 2. design of data collection at the research location

2.3 Abiotic Data Measurement

Abiotic data recorded included salinity, temperature, water pH, and substrate. Water salinity measurements were carried out using the Atago refractometer. This tool is first calibrated by cleaning the tip with distilled water. Then, dripping seawater on a clean prism glass closed and directed at sunlight, then read the scale printed on the tool. Measurement of water temperature and pH using a pH meter Hanna PI 98170. Observation of the substrate was carried out when collecting biotic data by observing and holding it directly. Then, each type of substrate was found to have *H. atra*.

Abiotic data measurements were conducted at nine randomly selected points, including three points on the edge, three points on the midline, and three points on the shoreline, each with three repetitions (see Figure 2). The structure is logical, with causal connections between statements, and the content is as close as possible to the source text, without any additional aspects added. The measurements were taken during high tide and recorded in the abiotic data observation table. Each measurement result is recorded in the abiotic data observation table.

2.4 Data Analysis

2.4.1 Analysis of the Spatial Position of the Black Sea Cucumber (Holothuria atra Jaeger, 1833) in the Intertidal Ecosystem of the Bilik Coastal BNP

Biotic supporting data in the form of seagrasses and macroalgae which were most commonly found in the presence of *H. atra* at the study site were identified based on the books of [14] and [15]. The spatial distribution of *H. atra* based on the findings in several areas was visualized using the ArcGis 10.7. The stages begins by overlaying the coordinate point data for the presence of *H. atra* and the area it occupies (seagrass communities, macroalgae communities, open areas, coral reef communities). The coordinate points of the area occupied by *H. atra* are described using points, then connected between one point and another using a line so that a polygon (spreading coverage) is formed. The polygon shows the spatial mapping of the area occupied by *H. atra* [16]. The polygon is depicted in different colors as the difference in each area occupied by *H. atra* including seagrass communities, macroalgae communities, open areas and coral reef communities. Each Polygon has a different area which can be seen in the ArcGis program features.

2.4.2 Determination of the type of population distribution pattern of the Black Sea Cucumber (Holothuria atra Jaeger, 1833) Based on the Nearest Neighbor Index

The spatial distribution pattern of *H. atra* was determined based on the R-value (ratio) of the Nearest Neighbor Index (NNI). The R-value of the NNI can be found using equation 1 as follows [13].

$$R=\frac{r\,A}{r\,E} \quad (1)$$

Where R is the spread pattern ratio; r_A = The average distance observed; r_E is the Expected average distance ($r_E = \frac{1}{2\sqrt{P}}$); P = The density of points in each square kilometer is the number of points (N) divided by the area (A)

Based on the R-value (ratio) of the Nearest Neighbor Index (NNI), the type of distribution pattern can be categorized if: R = 1, then the distribution pattern is random; R < 1, then the distribution pattern is clustered; and R > 1, then the distribution pattern is even.

The Average Nearest Neighbor tool in ArcGIS 10.7 can be used for Nearest Neighbor analysis. Input the coordinates of the *H. atra* encounter point and the area of the research area into ArcMap. The results obtained are in the form of a graphical description of the Nearest Neigbor analysis including the NNI ratio, Z-score, p-value, average observed distance, and expected average distance.

The distribution map of the presence of *H. atra* was visualized using ArcGis 10.7. The stages include base map rectification, map overlay, and map layout. The rectification stage is preparing a base map of the research location obtained from Google Earth Pro 2020, then registering the map. After the rectification stage, overlay the coordinates (points) of the *H. atra* encounter. The measurement results of abiotic supporting data in the form of salinity, pH, and temperature were entered into the Microsoft Excel 2010 application, and then analyzed descriptively. The data displayed is the range of values obtained during direct measurements.

3 Results and Discussion

3.1 Spatial Position of the Black Sea Cucumber (*Holothuria atra* Jaeger, 1833) in the Intertidal Ecosystem of Bilik Coastal BNP

Bilik Coastal has a wide intertidal area with a maximum length of ± 230 meters and a coastline of ± 656 meters. Based on the calculation of the species of *H. atra* in the intertidal ecosystem of the Bilik Coastal BNP, a total of 377 individuals were found and spread over a research area of 138.216 m^2. This species was found in four areas, namely seagrass communities, macroalgae communities, open areas, and coral reef communities (Figure 3).

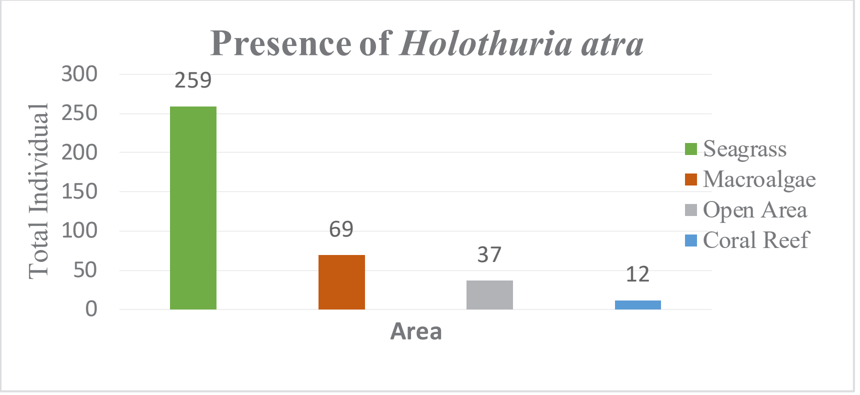

Fig. 3. Total individual of *Holothuria atra* in each occupied area

The seagrass community in the intertidal ecosystem of Bilik Coastal BNP is the area where *H. atra* is most commonly founded. There were 259 individuals of this species found and occupying a seagrass area of 82.265,54 m2 (Figure 4). The presence of *H. atra* was mostly found in seagrass-covered areas with various types of substrates such as sand, muddy sand, and sand with dead coral fragments. Referring to [17], also reported that the highest population of *H. atra* in Sri Lanka waters were found in seagrass areas. Referring to [2] also reported that the most common sea cucumbers found in the shallow waters of the BNP were *H. atra* and most commonly found in seagrass areas with a density of 5-15 individuals/m2.

The species of seagrass that was most commonly found in *H. atra* at the study site was *Thalassia hemprichii*. According to [7] reported that in Bilik Coastal, *Thalassia hemprichii* was found growing on sand and rocky sand substrates. This is also supported by [14] which states that this seagrass lives on a sand substrate, soft mud substrate or dead coral debris. Seagrass *T. hemprichii* is characterized by leaves that are bifurcated, not separated, have a ribbon-like shape and flat leaf margins with rounded leaf tips and rhizomes that are segmented, long and strong so that it is easier for them to absorb nutrients [14].

The macroalgae community was able to support the existence of *H. atra*, there were 69 individuals occupying a macroalgae area of 15.858,48 m2 (Figure 4). The results of observations at the study site indicated that the species of macroalgae that was more commonly found in the presence of *H. atra* was the brown algae *Sargassum* sp. This species of algae grows 0.5 - 1 meter high and during high tide most of the intertidal area becomes covered by *Sargassum* sp. General morphology of *Sargassum* sp. which is all brown. This species of thallus is numerous and dense with a sharp shape at the end. This algae has a cylindrical stipe with many branches [15]. Algae *Sargassum* sp. in the Bilik Coastal intertidal ecosystem, was found living attached to the coral substrate and dead coral fragments. According to [18], the algae *Sargassum* sp. is usually found in clear waters and has a basic substrate of coral, dead coral, or massive objects on the bottom of the water.

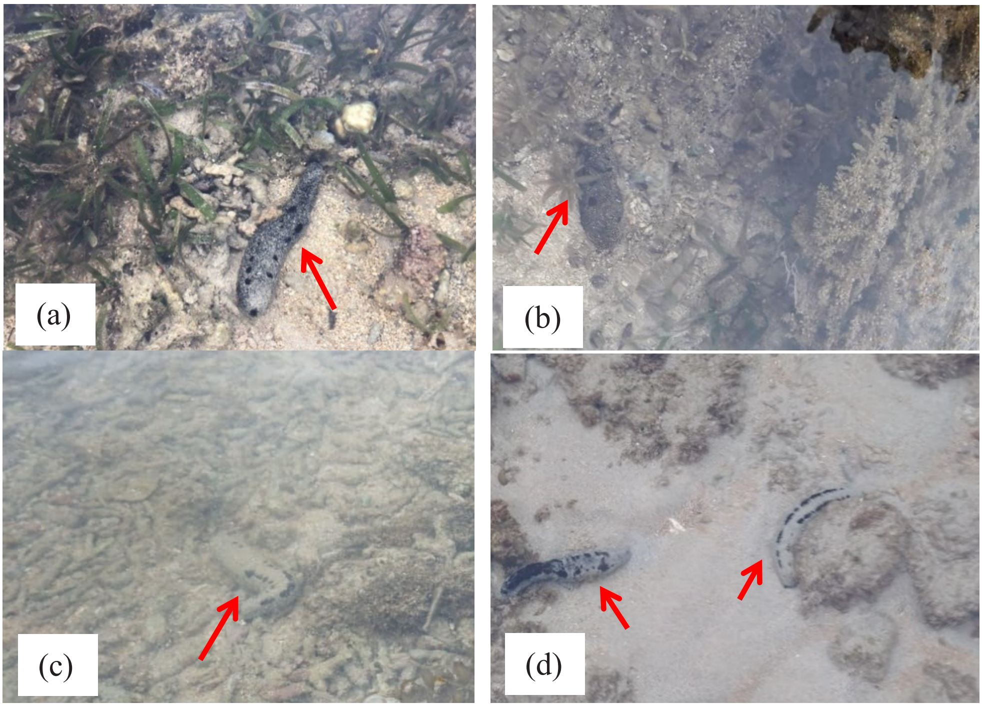

Fig. 4. Existence of *Holothuria atra* in occupied areas
(a) Seagrass; (b) Macroalgae; (c) Coral Fragments; (d) Sand Flat

Generally, *H. atra* is found living under the shelter of *Sargassum* sp. This is thought to be related to the feeding behavior of *H. atra* as deposit feeders, namely detritus or residual organic matter deposits. So in that area, most of the *H. atra* were found because they were able to support the existence of this black sea cucumber. This is supported by [19] that macroalgae and seagrass areas are areas that have abundant accumulation of nutrients and detritus.

The open area at the study site also found the presence of *H. atra*. There were 37 individual sea cucumbers found occupying an open area (rubble rubble, sand flat) covering an area of 3638.53 m^2 (Figure 4). The presence of *H. atra* in this area shows that this sea cucumber is able to adapt well. The most common form of adaptation of *H. atra* is coating its body with fine sand in response to sunlight because generally there is no shade in open areas. This is supported by [20], that sand that sticks to *H. atra's* body will reflect light so that its body temperature becomes lower.

The coral reef community at the study site was also found to have *H. atra*, there were 12 individuals found in the coral reef community including live and dead coral with an area of 1.704,67 m^2 (Figure 4). Referring to [21], in his research in the Gulf of Mannar, India also stated that *H. atra* was also found in coral reef areas. This species can be found in the coral reef community at the research location. It is suspected that coral reefs are able to provide a good place for *H. atra*. According in [22] states that tropical waters have various ecosystems that can break up seawater currents such as seagrass and coral reef ecosystems so that the sea cucumbers in these ecosystems will be protected from strong currents. In addition, organic matter is likely to be carried away by currents in the ecosystem. Based on some of the descriptions above it can be seen that most *H. atra* choose areas that are more profitable so that the distribution of *H. atra* clusters in areas with suitable conditions to support its existence.

3.2 Distribution Pattern Type of Black Sea Cucumber (*Holothuria atra* Jaeger, 1833) at Bilik Coastal Intertidal Ecosystem in BNP Based on the Nearest Neighbor Index (NNI)

The distribution pattern of *H. atra* in the Bilik Coastal intertidal ecosystem in BNP is classified as clustered. This is based on the spatial analysis of the Nearest Neighbor Index (NNI) with a ratio value of less than 1 (0.458) (see Figure 5). *H. atra* species tend to cluster in certain areas of the study site, such as seagrass and macroalgae areas (see Figure 6). The clustered distribution of *H. atra* is believed to be a result of varying resource availability in different areas, allowing the species to select the most suitable location. This is supported by [23], which suggests that specific factors lead to the clustering of sea cucumbers in areas that provide favorable conditions for their survival.

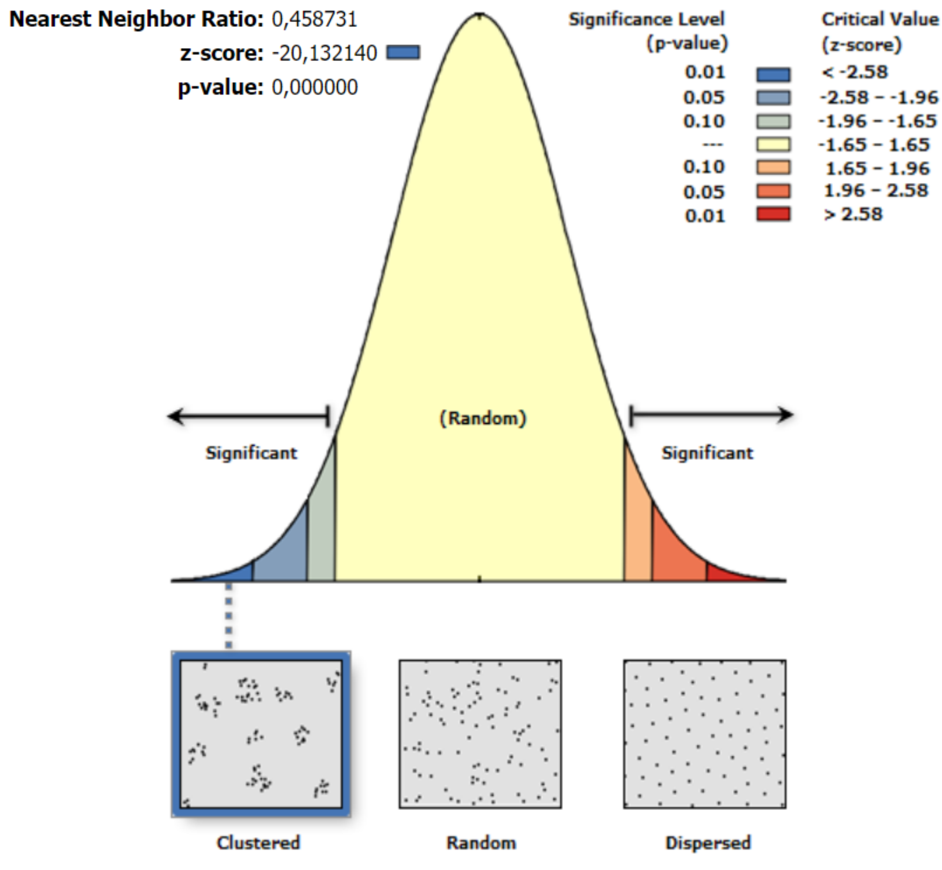

Fig. 5. Distribution pattern of *Holothuria atra* based on NNI analysis

The sea cucumber species *H. atra* was found in almost all study areas, including seagrasses, macroalgae, open areas, and coral reefs. This is likely due to its ability to adapt well to various habitats, as noted by [2]. One way to adapt to the intense sunlight is by covering the body with fine sand. According to [2], *H. atra* tends to be abundant in the shallow waters of BNP, with up to 9,935 individuals occupying various areas such as seagrass beds, macroalgae-covered areas, dead coral, rocks, and sand.

H. atra species are typically found in clusters in specific areas, such as seagrass and macroalgae communities, at the study site. According to [24], sea cucumber groups are generally sensitive to sunlight and tend to choose seagrass and macroalgae areas for protection. The availability of abundant food sources is also thought to contribute to the clustering of *H. atra* in this area. According to [9], the distribution patterns of sea cucumber populations can be influenced by environmental conditions, food availability, protection against predators, as well as currents and waves. Abiotic conditions, such as salinity, pH, and water temperature, were also measured at nine points as representative of the entire data collection area, and they can influence the presence of *H. atra* at the study site (see Table 1).

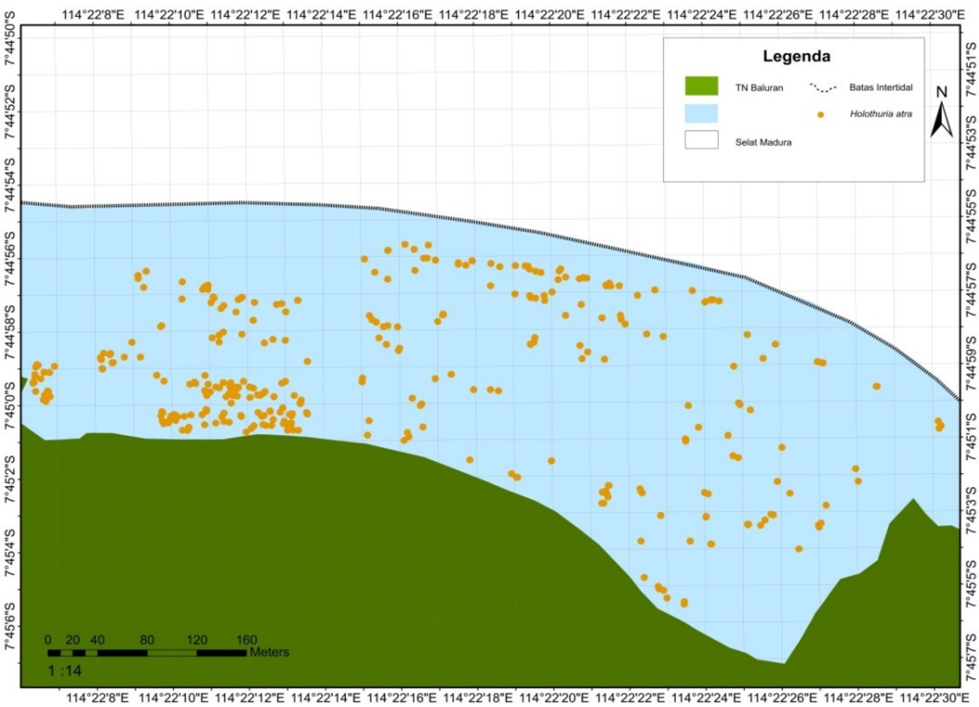

Fig. 6. Distribution pattern of *Holothuria atra* based on NNI analysis

Table 1. Abiotic factors in the intertidal ecosystem of Bilik Coastal BNP

Parameter	Value Range
Salinity ‰	32,7 - 33,3
Temperature ^{0}C	28,3 - 29,8
pH	7,3 - 7,8

Salinity values at the study sites ranged from 32.7 to 33.3‰. According to [25], a normal salinity range of 30 to 37‰ can support the survival of sea cucumbers from the genus Holothuria. The temperature measurements ranged from 28.3 to 29.8 °C, which supports the presence of *H. atra* at the location site. This is likely due to the influence of temperature on the growth of *H. atra*. According to [26], the optimal water temperature for the survival of *H. atra* is 29 °C. In addition to salinity and temperature, pH is another abiotic factor that affects the existence of *H. atra*. The pH values measured at the study site ranged from 7.3 to 7.8. According to [27], the suitable pH range for sea cucumbers is between 7.5 and 8.6. This indicates that the water pH at the study site is still conducive to the survival of *H. atra*. Based on the abiotic range values obtained, it appears that the environmental conditions at the study site are suitable for the *H. atra* species to exist.

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