

Echinoderms diversity and substrate preferences in the Seribu Islands, Indonesia

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Abstract. Echinoderms are a group of marine invertebrates that play a crucial ecological role in maintaining the balance of coastal ecosystems through their functions as predators, detritivores, and controllers of benthic communities. Over the past few decades, The Seribu Islands face various anthropogenic and environmental challenges that significantly threaten the diversity of Echinodermata, including habitat degradation, coral bleaching, nutrient pollution, sedimentation from coastal reclamation, eutrophication, and human activities such as overfishing, intensive tourism, illegal fishing, and infrastructure development, all of which contribute to a significant decline in the overall diversity and abundance of Echinodermata populations. This study aims to analyze the diversity and substrate preferences of the Seribu Islands, Indonesia. Data were collected in April to May 2025 in the intertidal zone using the quadrat transect method. The results showed that the diversity in the two study locations, Pulau Tikus and Tidung Kecil Island, was relatively low ($H' < 1$), with diversity index values of 0.874 and 0.895, respectively. The dominance value in the moderate category, at 0.4648 on Tikus Island and 0.5408 on Tidung Kecil Island, indicates that several species are relatively prominent in the community but do not dominate. Additionally, the evenness value indicates a moderate level of evenness, with values of 0.5990 and 0.6458 at each location. This indicates that individuals are relatively evenly distributed among species, although the balance is not at an optimal level. Overall, these conditions indicate that the environments on both islands have limitations that lead to relatively low species diversity, with some species surviving better and controlling certain resources, while others are disproportionately underrepresented. The principal component analysis shows how differences in habitat preferences separate the distributions of certain species in the marine environment. *Archaster typicus* and *Opheodesoma grisea* prefer habitats with abundant sand, fine sediment, and seagrass. On the other hand, *Diadema setosum* and *Holothuria leucospilota* have a strong preference for coral areas and tend to avoid sand and seagrass. Meanwhile, *Echinothrix calamaris* is in the middle, with little positive association with sand. *Holothuria atra* and *Culcita novaeguineae* have a more neutral preference.

Keywords: abundance, biodiversity, echinoderms, Seribu Islands, substrate preferences.

Introduction. Echinodermata is a phylum of marine invertebrates that play a crucial role in maintaining the balance of coastal ecosystems as predators, detritivores, and regulators of benthic communities (Zhukova 2023). In tropical regions such as Indonesia, echinoderms support coral reef and intertidal biodiversity through complex biotic interactions (Angellia & Nugrahapraja 2023; Firmaningrum et al 2021), including algal control (Fong et al 2024) and substrate engineering (Vimono et al 2025). However, over the past few decades, anthropogenic activities, such as overfishing, unregulated tourism, pollution, port-related sedimentation, and climate change, have caused drastic declines in echinoderm biodiversity and ecosystem degradation (Sulardiono et al 2022).

Echinoderms are predominantly benthic and exhibit selective substrate preferences (Hernández et al 2025), such as the affinity of *Archaster typicus* for fine-textured sand and seagrass versus *Diadema setosum* for coral areas, which drive spatial distribution and community assembly, which can be quantified via Principal Component Analysis (PCA) to reveal adaptations to habitat disturbances (Nugroho et al 2023). Although prior studies on the Seribu Islands exist, they lack comprehensive comparisons

across ecologically contrasting sites such as Tikus and Tidung Kecil, limiting insights into community variation and dominance.

The Seribu Islands are a marine conservation hotspot, with diverse intertidal habitats such as sand, seagrass, live/dead coral, and rocky crevices, making them ideal for biodiversity research (Assa & Wibisono 2020). Tikus Island, located at the easternmost tip of Pari Island, experiences minimal anthropogenic pressure due to its isolation, providing a baseline for natural echinoderm communities (Andriyani et al 2021; Fatihah et al 2023). In contrast, Tidung Kecil Island, a government-managed mangrove conservation area, exhibits high biodiversity, influenced by tourism and diverse substrates, and thus represents a disturbed reference site (Andriyani et al 2021). The Seribu Islands are a coral island chain that harbours rich marine biodiversity, making it a compelling subject for any research (Wouthuyzen & Abrar 2020). Tikus Island is located at the easternmost tip of Pari Island and is relatively isolated, resulting in low anthropogenic pressure. This condition makes it an ideal location for assessing marine biodiversity, including that of Echinodermata. In contrast, Tidung Kecil Island is a government-managed mangrove conservation area characterized by diverse substrates, including seagrass beds, sandy bottoms, live coral, and dead coral (Nurmasari et al 2023). Its intertidal zone is known for high biodiversity and provides suitable habitats for Echinodermata (Kaligis et al 2024).

Although several studies on Echinodermata have been conducted in the Seribu Islands, most remain limited to specific sites and do not offer a comprehensive overview of community variation among small islands with differing ecological conditions. Tikus Island, with minimal anthropogenic influence, and Tidung Kecil Island, shaped by conservation and tourism activities, represent contrasting coastal ecosystems that are valuable for comparative analysis. Accordingly, this study aimed to examine the diversity, abundance, dominance, and evenness of Echinodermata at both sites and to evaluate the relationship between Echinodermata communities and available substrate types. The findings are expected to update the biodiversity data of Echinodermata in the Seribu Islands and provide a scientific basis for coastal ecosystem management and conservation efforts in the region.

Material and Method

Description of the study sites. Two islands in the Seribu Islands were considered as study areas: Tikus Island and Tidung Kecil Island. The field observation was conducted through visual observation and a desktop study. The sampling sites were marked using Global Positioning System (GPS) (Figure 1).

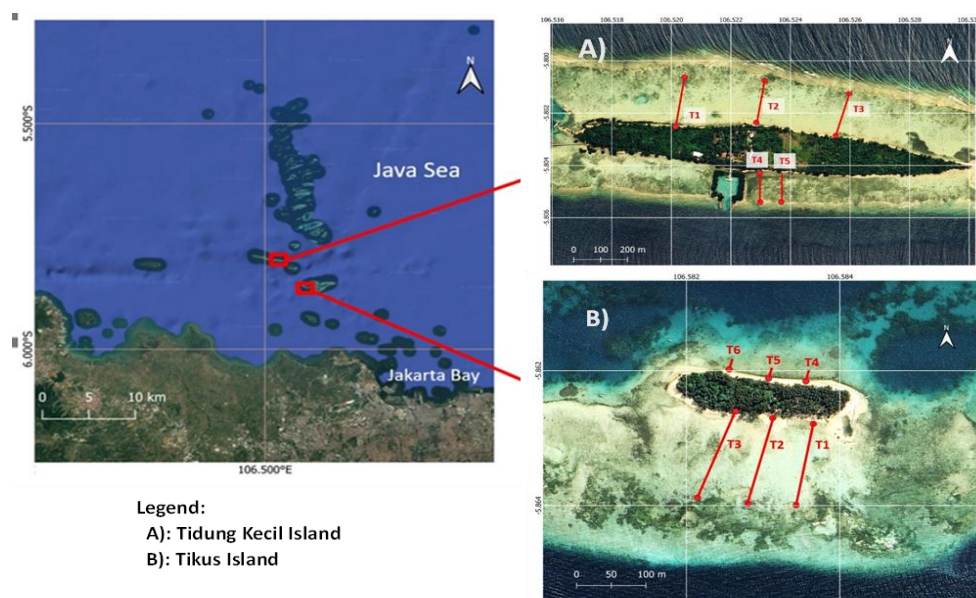


Figure 1. Study sites at Tikus Island and Tidung Kecil Island, Seribu Islands, Jakarta, Indonesia.

Sampling method. Sampling was conducted from April to May 2025. This study applied the quadrat transect method, which provides an overview of the population condition of organisms relative to size and enables the determination of the number of individuals, species composition, and their distribution (Triatmojo & Ario 2018). At each site, three transect lines were established perpendicular to the shoreline, extending toward the reef edge within the intertidal zone. Quadrat frames measuring 1 × 1 m were systematically placed along each transect. The spacing between transects and their lengths were adjusted based on the size of each island and the topography of the reef flat to ensure safe and representative data collection. On Tikus Island, three transects were established on the southern side, each measuring 150 m in length and consisting of 11 quadrat plots of 1 × 1 m². On the northern side, three transects of 15 m in length were employed due to the short coastal distance adjacent to a slope lead to the deeper muddy pool make it unsafe to move forward. On Tidung Kecil Island, three transects were established on the northern side, each 210 m in length and comprising 15 quadrat plots of equal size. The spacing between transects was set at 300 m, while the distance between plots within each transect was 15 m. On the southern side, two transects of 90 m in length were established, with an inter-transect distance of only 70 m, considering safety factors related to tides and weather conditions.

All echinoderms encountered within the quadrats were counted, and their species were recorded. To ensure accurate identification, one specimen from each observed species was collected as a reference for further laboratory analysis. Data obtained from each quadrat were subsequently used to calculate diversity, dominance, evenness, and relative abundance at each study site. To understand the relationship between the echinoderm population and habitat preference, two approaches were used. Firstly, the macrohabitat preference was determined by echinoderm density and substrate type. Secondly, microhabitat preference depends on echinoderm density and sediment grain size. Substrate data were collected simultaneously with echinoderm observations in each quadrat plot. Records of substrates to estimate the percent coverage of seagrass, corals, rubble, and sand were based on a 55 cm x 55 cm grid divided into 4 subplots, following the Seagrass Monitoring Guide (Rahmawati & Irawan 2017).

Sediment samples were collected using a spoon to a depth of approximately 5 cm and then stored in labelled plastic bags for subsequent laboratory analysis. Three replicates were obtained inside the plot. Sediment type analysis was performed using the dry sieving method to separate sediment fractions. The grain size categories analyzed in this study were divided into seven fractions by dry sieving. The classification of each fraction was: >2 mm (granule); 1–2 mm (very coarse sand); 0.5–1 mm (coarse sand); 0.25–0.5 mm (medium sand); 0.125–0.25 mm (fine sand); 0.0063–0.125 mm (very fine sand); and <0.0063 mm (silt/clay) following the Wentworth scale (Wentworth 1922).

Identification of specimens. Identification was carried out by directly observing the morphological characteristics of Echinodermata samples with the eyes and under a microscope. The morphological traits examined followed the diagnostic key provided in the Monograph of Shallow Water Indo-West Pacific Echinoderms (Clark & Rowe 1971).

Data analysis. The analysis of Echinodermata diversity was conducted using several ecological indices: the Shannon-Wiener index (H') to measure diversity, the dominance index (D) to identify the species that dominate within the community, and Pielou's evenness index (J') to assess the relative distribution of species across each transect. The diversity of Echinodermata was assessed using several ecological indices. The Shannon-Wiener index (H') was employed to evaluate community diversity based on species richness and the evenness of individual abundance. An H' value below 1 indicates low diversity and an unstable community; values between 1 and 3 suggest moderate diversity, whereas values above 3 reflect high diversity and relatively favourable aquatic conditions (Febrian et al 2022). The dominance index (D) was used to measure the extent to which a community is dominated by particular species. Low D values indicate the absence of dominance, while values approaching 1 suggest dominance by one or a few species (Sirait et al 2018). Additionally, Pielou's evenness index (J') was applied to

describe the relative distribution of individuals among species within the community. J' values near 0 denote low evenness, whereas values approaching 1 indicate a uniform distribution across species.

The diversity index was calculated using the following formula (Shannon 1948):

$$H' = - \sum_{i=1}^s p_i \ln(p_i)$$

Where:

H' - diversity index;

S - total number of species;

p_i - proportion of individual number of species i (n) compared to total individual number from all species (N).

The dominance index was calculated using the following formula (Simpson 1949):

$$D = \sum_{i=1}^s \left(\frac{n_i}{N} \right)^2$$

Where:

D - dominance index;

n_i - number of individuals for each species;

N - total number for all species

The evenness index was calculated using the following formula (Pielou 1966):

$$J' = H' / \ln S$$

Where:

J' - evenness index;

H' - Shannon-Wiener diversity index;

S - total number of species.

The relationship between substrate characteristics and the presence of Echinodermata was analyzed using average substrate cover percentage (seagrass, sand, coral), and microhabitat preference was analyzed using the presence of Echinodermata and sediment composition. Echinodermata abundance data were transformed using the Hellinger method to reduce the influence of rare species and to accommodate the typically uneven distribution of ecological data (Legendre & Gallagher 2001). The average substrate cover percentages and the average sediment composition were transformed using the arcsine-square-root transformation, which is more appropriate for percentage data near 0 or 100% (Warton & Hui 2011). Subsequently, both transformed datasets were analyzed using PCA. PCA was employed to reduce the dimensionality of multivariate data to a few principal components without losing critical information, thereby enabling clearer visualization of the relationships between Echinodermata distribution, substrate characteristics, and sediment composition (Hirst & Jackson 2007; Rossel & Arbizu 2020).

Results. The study was conducted on 2 small islands in the Seribu Islands, Tikus Island and Tidung Kecil Island. Tikus Island, located at the easternmost part of the Pari Island cluster, is presumed to experience low anthropogenic pressure due to its remote and uninhabited condition. The intertidal zone of Tikus Island is divided into two sections, the southern and northern parts. In the northern section, there is a deeper pool with the slope is only less than 18 m from the shoreline. This pool resembles a shallow lagoon, with steeper topography, fine sand and mud substrates, and even some scattered debris. Such conditions result in a narrow intertidal zone in the northern part of Tikus Island, influencing the distribution of organisms in this area. In contrast, the southern section of Tikus Island has a wider intertidal zone characterized by fine and coarse sand, coral

rubble, coral reefs, seagrass beds, and patches of algae. These conditions make the southern part of Tikus Island a representative site for examining echinoderm distribution, and it was thus selected as the primary focus of observation. The intertidal zone of Tidung Kecil Island was examined by considering the physical differences between the northern and southern sides of the island. The geomorphological contrast between the two sides is evident: the northern side possesses a broader intertidal zone due to its gently sloping shoreline. This condition exposes a wider substrate area during low tide. Conversely, the southern side has a relatively narrow intertidal zone due to its steep shoreline, resulting in limited substrate exposure during low tide.

Species composition of echinoderms. A total of 7 echinoderm species belonging to 3 classes, Asteroidea, Echinoidea, and Holothuroidea were recorded across the two study sites (Table 1).

Table 1

Composition and abundance of echinoderm species recorded at the intertidal zones of Tikus Island and Tidung Kecil Island, Seribu Islands

Class	Species	Tikus Island	Tidung Kecil Island	Total
Asteroidea	<i>Archaster typicus</i>	17	-	17
	<i>Culcita novaeguineae</i>	-	2	2
Echinoidea	<i>Diadema setosum</i>	23	10	33
	<i>Echinothrix calamaris</i>	1	-	1
Holothuroidea	<i>Holothuria leucospilota</i>	1	-	1
	<i>Holothuria atra</i>	-	1	1
	<i>Opheodesoma grisea</i>	-	1	1
Total		42	14	56

Both species richness and the number of individuals were higher on Tikus Island than on Tidung Kecil Island. The species *D. setosum* was observed at both sites and was the most abundant species. Differences in individual abundance and species composition between the two islands are presumed to be associated with varying environmental conditions and substrate heterogeneity. The southern intertidal zone of Tikus Island exhibits greater substrate diversity and lower anthropogenic pressure, thereby providing a wider range of microhabitats for benthic species. In contrast, the intertidal area of Tidung Kecil Island is characterized by more homogeneous substrates and relatively higher exposure to human activities. Local communities are known to occasionally harvest sea cucumbers (Holothuroidea) and sea urchins (Echinoidea) for consumption or sale, which likely contributes to the reduced abundance of echinoderms on Tidung Kecil Island.

Ecological indices. Ecological indices were applied to assess the structure and stability of echinoderm communities, encompassing diversity (H'), dominance (D), and evenness (J'), which serve as key indicators of ecosystem condition at both study sites. The values of each index for Tikus Island and Tidung Kecil Island are presented in Table 2.

Table 2

Ecological index values of echinoderms at Tikus Island and Tidung Kecil Island

Study site	Diversity (H')	Category (H')	Dominance (D)	Category (D)	Evenness (J')	Category (J')
Tikus Island	0.8738	Low	0.4648	Moderate	0.5990	Moderate
Tidung Kecil Island	0.8953	Low	0.5408	Moderate	0.6458	Moderate

The Shannon-Wiener diversity index (H') indicated that echinoderm diversity at both study sites was relatively low (Table 2). On Tikus Island, the H' value was 0.8738, while on Tidung Kecil Island it was 0.8953, both values fall within the category of $H' < 1$, signifying low diversity. This low index reflects an uneven distribution of individuals among species and dominance by one or several species, particularly *D. setosum*. Such conditions suggest a less stable community with low evenness. The reduced diversity on Tidung Kecil Island is likely influenced by anthropogenic activities, such as traditional harvesting of marine biota and the intensity of tourism around the jetty, whereas on Tikus Island, it may be related to limited substrate types and habitat conditions in the intertidal zone.

The Simpson dominance index (D) described the degree of species dominance within echinoderm communities at both sites. On Tikus Island, the D value of 0.4648 was categorized as moderate, indicating that no single species completely dominated, although *D. setosum* had the highest abundance, followed by *A. typicus*. These two species occupied different substrates, with *D. setosum* typically found in coral substrates and *A. typicus* in sandy substrates, thereby reducing direct competition and maintaining relative community balance. On Tidung Kecil Island, the D value of 0.5408 was also moderate. The higher D value in Tidung Kecil island showed a 54% probability of interspecific encounter. The data and field observation showed higher number of *D. Setosum* individuals, which accounted for more than half of the total individuals recorded. Other species, such as *C. novaeguineae*, *H. atra*, and *O. grisea*, were found in limited numbers. The dominance pattern of *D. setosum* is consistent with the findings of Aryanto et al (2019) in the coastal waters of Bontang City and may indicate community imbalance driven by anthropogenic pressures or environmental changes.

The evenness index (J') illustrated the distribution of individuals among echinoderm species at both sites. On Tikus Island, the J' value of 0.5990 was categorized as moderate, suggesting that the individual distribution was neither entirely uniform nor highly skewed. On Tidung Kecil Island, the J' value of 0.6458 also fell within the moderate category. The higher J number on Tidung Kecil Island indicating that some species were slightly dominant. Here we recorded higher number of *D. Setosum* while other species such as *C. novaeguineae*, *H. atra*, and *O. grisea* were recorded in smaller numbers. Despite this dominance, echinoderm communities at both sites still exhibited species diversity. These results are consistent with Tala et al (2021) at Lakeba Beach, Southeast Sulawesi ($J'=0.4919$; moderate category), which similarly demonstrated light to moderate dominance. Such findings suggest relatively stable ecosystems that nonetheless show signs of community imbalance due to anthropogenic pressures or differences in species adaptability.

Substrate characteristics. The presence and distribution of Echinodermata are strongly influenced by substrate type, which functions as a physical support for benthic organisms. Substrate variations such as sand, coral rubble, dead coral, and seagrass found in both locations create ecological conditions that affect species abundance and diversity.

Relationship between echinoderms and substrate (PCA). PCA plots illustrating the relationship between echinoderms abundance and substrate or sediment type on Tikus Island (Figure 2). The upper plot shows the relationships among four echinoderm species (*E. calamaris*, *D. setosum*, *H. leucospilota*, *A. typicus*) and three substrate types (% corals, % sands, % seagrass). Vectors that are adjacent and pointing in the same direction show a strong positive correlation. *E. calamaris* is positively associated with % corals. *A. typicus* is related to % sands and % seagrass. Meanwhile, vectors pointing in opposite directions indicate a negative correlation. *E. calamaris* has a negative relationship with % sands and % seagrass. *D. setosum* and *H. leucospilota* are in different quadrants of % sands and % seagrass, indicating different preferences or the absence of a strong relationship with the substrate. The lower plot shows the same echinoderm species across different sediment grain sizes, from silt to granules. *A. typicus* is closely associated with finer sediments, such as very fine sand, fine sand, and silt. *E. calamaris* is closely related to coarser sediments (medium sand to granule). *D. setosum*

is on the opposite side of all the listed sediment types, suggesting that this species may not like or is rarely found in areas with high concentrations of that type of sediment.

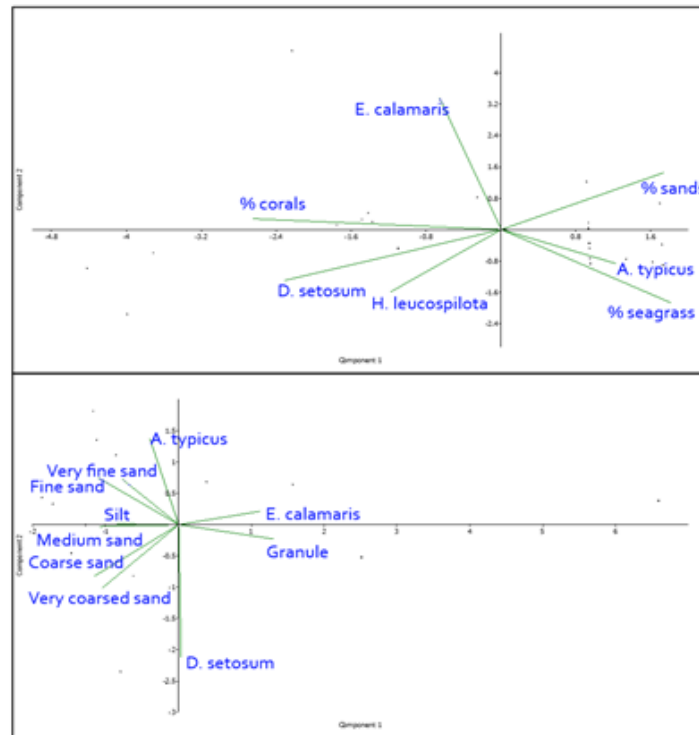


Figure 2. PCA of echinoderms abundant and type of substrates (above) and PCA of echinoderms abundant and sediment type (below) in Tikus Island.

The relationship between echinoderm abundance and substrate or sediment type in Tidung, Kecil Island, is illustrated in Figure 3. The upper plot shows the relationship between five echinoderm species and three substrate types.

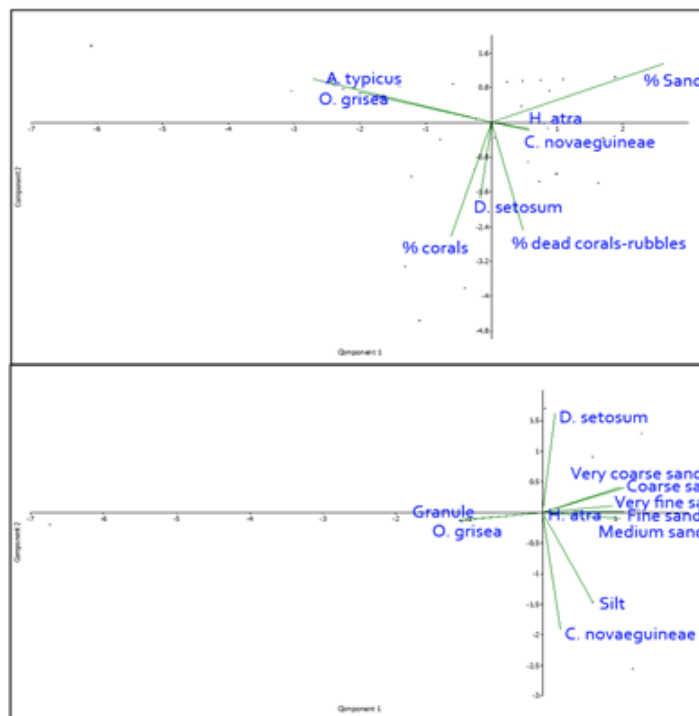


Figure 3. PCA of echinoderms abundant and type of substrates (above) and PCA of echinoderms abundant and sediment type (below) in Tidung Kecil Island.

H. atra and *C. novaeguineae* are strongly related to the percentage of sand (% sand). *D. setosum* is related to the percentage of dead corals/rubbles (% dead corals-rubbles). Species associated with sand (*H. atra*, *C. novaeguineae*) have a negative relationship with the percentage of live corals (% corals). *A. typicus* and *O. grisea* are on the left side of the plot, indicating that they are not closely related to the type of substrate measured on the right side (sand, coral, debris). The bottom plot shows the relationship between the same echinoderm species and more specific sediment textures: *H. atra* and *C. novaeguineae* are closely associated with different sand types (fine, medium, coarse, and very fine). *D. setosum* is associated with very coarse sand. *C. novaeguineae* also shows a relationship with silt. Species associated with sand and silt have a negative relationship with larger granules. *O. grisea* is on the left side of the plot, related to the granule, and is not closely related to other types of sand or silt on the right side.

Discussion. The low diversity of echinoderms in this study is in line with several previous studies in Indonesian, especially in the intertidal zone or areas affected by human activities. At Tikus Island, species distributions exhibited distinct habitat associations. *E. calamaris*, *D. setosum*, and *H. leucospilota* were positively associated with coral cover, indicating a preference for habitats with complex physical structures, such as living corals, which provide shelter and food resources. Notably, *H. leucospilota* also occurred on sandy substrates beneath coral structures, reflecting its adaptive capacity to utilize multiple substrate types. In contrast, *A. typicus* was positively associated with sand and seagrass cover, consistent with its preference for shallow sandy habitats enriched with organic. The dominance of sandy substrates with low coral and seagrass cover at Tikus Island is presumed to limit Echinodermata diversity, given the critical role of coral and seagrass habitats in supporting benthic communities.

The results showed that *E. calamaris* and *D. setosum* were positively correlated with granules (>2 mm), whereas *A. typicus* was associated with finer sediments (≤ 0.25 mm). This finding aligns with Purwati et al (2011), who reported the preference of *A. typicus* for fine sand and areas with low seagrass cover. Sediment grain size influences the availability of space, substrate stability, and access to food, thereby shaping distinct species distribution patterns. Meanwhile, *H. leucospilota* was observed in sandy areas beneath living coral structures, consistent with Harith et al (2018), who noted that this species typically inhabits sheltered shallow zones with fine sandy substrates among corals. Such conditions provide an ideal habitat for feeding activities while offering protection from predators.

O. grisea was correlated with seagrass cover, consistent with Bachmid et al (2020) & Setyastuti (2016), who reported its preference for dense seagrass areas. *D. setosum* was associated with both live and dead coral, reflecting its dependence on hard substrates (Alqodri et al 2023; Kurniawan et al 2023). *C. novaeguineae* exhibited affinity for sand and dead coral (Ahmad et al 2023), whereas *H. atra* was predominantly found on coarse sand and coral rubble (Hartati et al 2018; Kalidi et al 2023). These findings underscore that substrate variation (coral, sand, and seagrass) is a key factor shaping the distribution of Echinodermata species at Tidung Kecil Island.

O. grisea was associated with granule sediments (>2 mm), which are porous and rich in organic matter, supporting its deposit-feeding activity (Selanno et al 2014). *C. novaeguineae* was linked to silt sediments (<0.0063 mm) around dead coral, serving as microhabitats for movement and shelter (Siburian et al 2023). *H. atra* occupied very fine sand–very coarse (0.0063–2 mm) within seagrass beds enriched with organic matter (Manuputty et al 2019), while *D. setosum* tended to occur on coarse sand (0.5–1 mm) and hard substrates such as live and dead coral (Clark & Rowe 1971). Variation in sediment grain size and substrate type (sand, seagrass, live coral, dead coral, coral rubble) generates habitat heterogeneity that influences the ecological preferences and distribution of each species (Alamsyah et al 2022).

Conclusions. From an ecological standpoint, both Tikus Island and Tidung Kecil Island exhibit echinoderm communities with low diversity, moderate dominance, and moderate evenness. These three indices indicate simplified communities that are numerically

dominated by a few tolerant species, particularly *D. setosum*. Species diversity is classified as moderate, with ecological pressure beginning to appear. The species *D. setosum* dominates the population, resulting in uneven species evenness in the distribution of individuals. *D. setosum* is also the most abundant and adapts well to sandy and coral substrates. Substrate variation and sediment size influence the distribution of Echinodermata, with each species selecting a specific habitat according to its preferences.

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Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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