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The community structure of Echinodermata (Echinoidea and Holothuroidea) on seagrass ecosystem in Gunungkidul, Yogyakarta, Indonesia

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Abstract. *Nurcahyo FD, Zen HM, 'Azizah HPN, Nugroho GD, Ramdhun D, Yap CK, Indrawan M, Setyawan AD. 2024. The community structure of Echinodermata (Echinoidea and Holothuroidea) on seagrass ecosystem in Gunungkidul, Yogyakarta, Indonesia. Biodiversitas 25: 4561-4571.* Echinoderms, which encompass various classes such as sea urchins and sea cucumbers, play a crucial role in marine ecosystems and contribute significantly to maintaining ecological balance. Therefore, this study was conducted to understand the composition structure of echinoderms (Echinoidea and Holothuroidea) in several beaches of Gunungkidul, Yogyakarta, Indonesia. The survey was conducted on March 2024 at Pringjono Beach, Dadap Ayam Beach, Ngrenehan Beach, Torohudan Beach, and Ngrawah Beach. Data analyzed included species diversity, density and ecological indices of echinoderms (Echinoidea and Holothuroidea) at each beach location. The research findings revealed that across the five beaches of Gunungkidul, Yogyakarta, Indonesia, there were two classes of echinoderms, namely Echinoidea (sea urchins) and Holothuroidea (sea cucumbers), with a total of 7 identified species, namely *Echinometra mathaei, Echinometra oblonga, Heterocentrotus trigonarius, Tripneustes gratilla, Colobocentrotus atratus, Stomopneustes variolaris,* and *Holothuria leucospilota.* Only one beach recorded the presence of sea cucumbers, while the number of sea urchin species varied at each beach. Dadap Ayam Beach recorded the highest number of sea urchin species, followed by Ngrenehan Beach. Additionally, Dadap Ayam Beach exhibited higher values of species diversity and richness compared to other beaches. A total of seven echinoderm species were identified, with a total abundance of 367 individuals/1000 m^2. The beaches in this study showed variations in the diversity and distribution of echinoderms, particularly Echinoidea and Holothuroidea. However, overall species diversity and richness values were generally low, indicating the potential vulnerability of these ecosystems.

Keywords: Diversity, echinoderms, sea cucumbers, sea urchins

INTRODUCTION

Echinodermata originates from the Greek language, where "echinos" means spines and "derma" means skin, commonly known as spiny skinned animals. Echinodermata is divided into five classes: Asteriodea, Crinoidea, Echinodea, Holothuroidea, and Ophiuroidea (Nugroho et al. 2018). The ability of echinoderms to regrow lost, damaged, or severed body parts is one of their characteristics (Purnamasari et al. 2023). Echinoderms are important members of marine ecosystems since they are the main players in food webs and can be carnivores, herbivores, omnivores, or detritivores. The primary habitats of echinoderms include shallow coastal areas, coral reef areas, and calm, transparent waters (Firmaningrum et al. 2021). They may be important in controlling the growth of coral reefs since they are bioturbators, or hunters (Siburian et al. 2023). Salinity, temperature, and dissolved oxygen are only a few of the chemical parameters in the water that affect Echinodermata life. All echinoderms inhabit a variety of marine environments, from coastal areas to depths of 6000 meters (Usman 2020). There are over 6000 species of Echinodermata in the globe, of which 950 are thought to be sea urchins. These species are categorized into 15 orders, 46 families, and 121 genera (Freitas et al. 2022).

Sea urchins hold a dominant position as herbivores in the shallow sublittoral seabed. Echinoidea are important herbivores that control the amount of algae covering hard soils. These species live in a variety of environments on both hard and soft bottoms, from seagrass to depths where 130 seagrass meadows are present (Vafidis et al. 2020). As members of the phylum Echinodermata, sea urchins manage algal biomass through their grazing activities, which is a critical ecological function of ecosystems (Capitão et al. 2020). Sea urchins are the most often used biological model for evaluating the toxicity of different kinds of pollution. This is due to the fact that their early developmental stages, which are crucial in an organism's life cycle represent, a more sensitive time than those of adults (Mazur et al. 2021). Sea urchins help to keep the balance between algae and coral in this ecosystem. This is so because sea urchins consume algae that grow on coral reefs, making them herbivores. As a result, there is less macroalgae on coral reefs, and the area where coral may grow is restored (Tarigan et al. 2020).

Holothuroids, a class of Echinodermata that includes sea cucumbers, are a varied and numerous group. They are one of the five classes that currently exist. Globally, they consist of more than 1400 species and they live in a variety of aquatic settings, from shallow seas to the deepest ocean trenches (Mu et al. 2018). They are well known for their many unusual characteristics, which include eviscerating their body walls, feeding via anal suspension, and releasing their gut contents as a defense strategy. The morphologies of extant species, which were identified as early as 1693, are diverse (Miller et al. 2017). These species have diel and tidal rhythms and are typically found on muddy or sandy soils where they act as deposit feeders (Taylor et al. 2016). Holothurians, sometimes known as sea cucumbers, are slow-moving benthic organisms that can only swim by swishing their bodies or creeping through sand with their tube feet. As keystone species, they usually have a major impact on their ecosystems. The majority of sea cucumbers feed suspension or deposit, ingesting a lot of silt and absorbing organic stuff that is then expelled. It is thought that holothurians, being deposit feeders, aid in the mineralization and regrowth of surface sediments as well as the cycling of nutrients (Aulia et al. 2021).

One of the seagrass ecosystems that serves as a habitat for Echinoderms (Echinoidea and Holothuroidea) is Gunungkidul, Yogyakarta, Indonesia. This seagrass ecosystem is an area with abundant food resources such as algae, small organisms, detritus, dead seagrasses, and leaf litter collected at the seagrass bed, which also serves as a food source for some species of Echinoderms, especially Echinoidea and Holothuroidea. This study aimed to understand the community structure of echinoderms (Echinoidea and Holothuroidea) in seagrass ecosystem of Gunungkidul, Yogyakarta, Indonesia, especially from the waters of Pringjono Beach, Torohudan Beach, Ngrawah Beach, Dadap Ayam Beach, and Ngrenehan Beach.

MATERIALS AND METHODS

Study area

Sampling was conducted in March 2024 at several beaches in Gunungkidul, Yogyakarta, Indonesia. These beaches include Pringjono Beach in Krambil Sawit Village, Saptosari Sub-district, Gunungkidul District, Yogyakarta, Indonesia; Dadap Ayam Beach; Ngrenehan Beach; Torohudan Beach; and Ngrawah Beach in Kanigoro Village, Saptosari Sub-district (Figure 1). Pringjono Beach is located at coordinates -8° 7' 4.306" S, 110° 29' 58.146" E, Dadap Ayam Beach is at coordinates -8° 7' 13.738" S, 110° 30' 26.809" E, Ngrenehan Beach is at coordinates -8° 7' 16.129" S, 110° 30' 51.242" E, Torohudan Beach is at coordinates -8° 7' 21.226" S, 110° 30' 58.666" E, and Ngrawah Beach is at coordinates -8° 7' 30.295" S, 110° 31' 12.729" E. Gunungkidul is one of the districts located in the Yogyakarta, known for its natural beauty and richness (Qurratul'ain 2023). It borders Sleman District to the North, the Indian Ocean to the South, Wonogiri District to the East, and Bantul District to the West. The sample sites were determined based on the fact that no previous studies have examined Echinodae and Holoethurida at these locations.

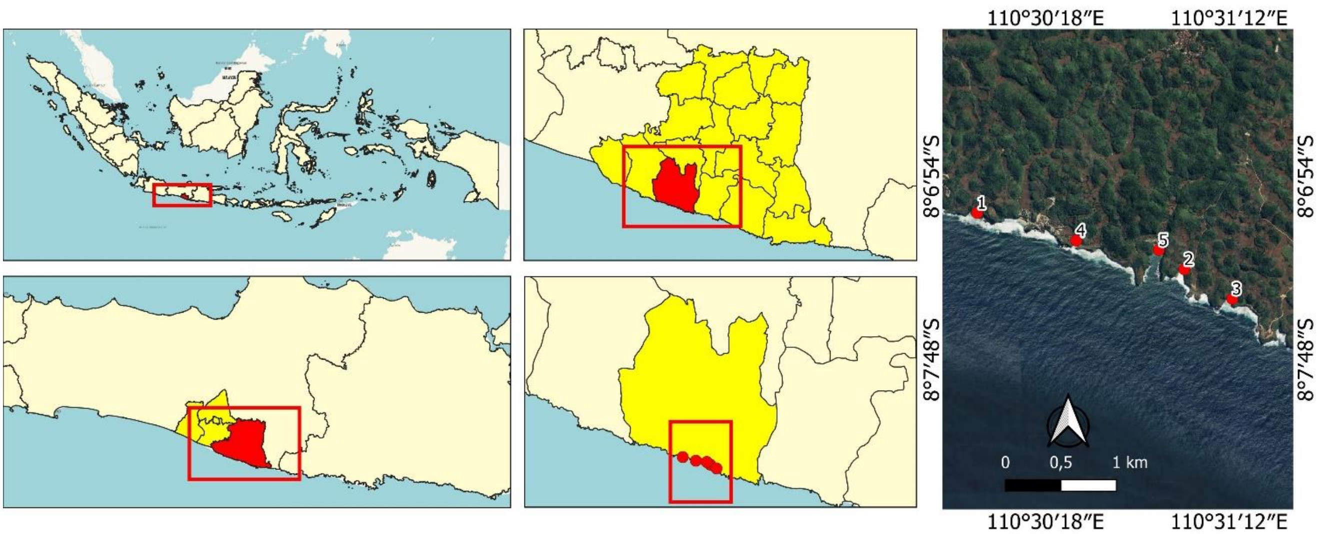

Figure 1. Location of research in beaches of Gunungkidul District, Yogyakarta, Indonesia: 1. Pringjono Beach, 2. Torohudan Beach, 3. Ngrawah Beach, 4. Dadap Ayam Beach, 5. Ngrenehan Beach

Procedures

Sampling was conducted on five different beaches in the intertidal zone covering an area of 1000 m^2 (Aulia et al. 2021). The sampling locations were determined based on the fact that no previous studies have examined Echinoidea and Holothuroidea at these locations. The sampling was carried out by walking along the beach at low tide. The survey was conducted from the end of the coastline to the farthest edge towards the sea, with a plot area of up to 1000 m^2. The observation transects consisted of 10 parallel stripes, each measuring 50 meters in length and 2 meters in width, to systematically cover different parts of the intertidal zone. At each location, observations were purposively made based on substrate characteristics, such as coral, sand, or seagrass. The substrates were chosen to reflect different microhabitats within the seagrass ecosystem. Each site contained multiple plots, each 50 meters by 2 meters in size, ensuring adequate representation of habitat variability. Echinoidea and Holothuroidea specimens on the plots (10 transects) were collected by removing them from the substrate surface using forceps or hands covered with latex. The species collected at each transect were counted and recorded. Additionally, measurements of abiotic variables including, water and soil pH, as well as temperature of water were taken at each research location. To ensure consistency, the same set of measurement was conducted for each transect at every site.

Identification Ehinoidea and Holothuroidea

From the sample plots, one specimen of each species was counted, and one specimen of each species was taken for identification. Firstly, samples were captured using a digital camera and then the identification process was conducted by observing morphological characteristics such as burr color, patterns, and shape. Samples were identified using references from several sources, namely Andilala et al. (2020), Tarigan et al. (2020), Ilmi and Sulistyawati (2021), and Kusarini et al. (2023). The identification of Ehinoidea and Holothuroidea helps in the effort to divide the class into finer clades, which will be beneficial in generating various taxonomic classification systems (Mercier et al. 2024).

Data analysis

In this study, the results of the identification of Echinoidea and Holothuroidea species and morphology are presented in the form of images, followed by descriptive explanations. Meanwhile, the quantitative data obtained through direct observation are analyzed using mathematical models, including Density (D), Species Diversity (H'), and Evenness Index (E), richness index of Margalef (R) which are then described descriptively (Alwi et al. 2020).

Density

To calculate the density, using the Mueller-Dombois and Ellenberg (1974) as follows:

$$\textit{Density}\ (K) = \frac{\textit{Number of Individu}}{\textit{Plot Area}}$$

Diversity index

The diversity index of Simpson is as follows:

$$D = 1 - \sum n(n-1)/N(N-1)$$

Where :

D: Diversity Index

N: Total of all species

n: Number of each species

According to Odum (1993), criteria for the Shannon-Wiener Diversity Index are as follows: H'<1 indicates low species diversity, 1≤H'≤ 3 indicates moderate species diversity, and H'>3 indicates high species diversity

Evenness index

The Evenness index (Prechzsch 2009) is as follows:

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

Where:

E: Evenness index measures the evenness of the distribution of individuals among different species.

H': Diversity index of Shannon-Wiener

S: Total number of species

Ln: Natural Logarithm

The Evenness Index (E) was used to analyze species evenness. According to Pielou (1997), if 0.00<E<0.25, evenness is considered low; if 0.26<E<0.50, evenness is considered somewhat even; if 0.51<E<0.75, evenness is considered relatively even; if 0.76<E<0.95, evenness is considered almost even; and if 0.96<E<1.00, evenness is considered perfectly even.

Richness index

The richness index of Margalef Species Richness Index

$$R = \frac{s-1}{\ln(N)}$$

Where:

R : Richness index.

S : Total number of species

N : Total number of individuals

According to Magurran (1998), if R<3.5, species richness is considered low; if 3.5<R<5, species richness is moderate; and if R>5, species richness is high

RESULTS AND DISCUSSION

A total of 6 species of sea urchins and 1 species of sea cucumber were identified from the study site in Pringjono Beach, Dadap Ayam Beach, Ngrenehan Beach, Torohudan Beach, and Ngrawah Beach (Figure 2). Echinodermata is represented by 7 species from five families: Echinometridae, Toxopneustidae, Strongylocentrotidae, Stomopneustidae, and Holothuriidae. Families with the most species of Ehinodermata are Echinometridae (2 species) and Toxopneustidae (2 species). The other families have only one species. The sea urchins and sea cucumber consisted of 7 species of Echinodermata: *Echinometra mathaei* (Blainville, 1825); *Echinometra oblonga* (Blainville, 1825); *Heterocentrotus trigonarius* (Lamarck, 1816); *Tripneustes gratilla* (Linnaeus, 1758); *Colobocentrotus atratus* (Linnaeus, 1758); *Stomopneustes variolaris* (Lamarck, 1816); and *Holothuria leucospilota* (Brandt, 1835).

The research results show that from five beaches in Gunungkidul, 2 classes of Echinodermata were found, namely Echinoidea (sea urchins) and Holothuroidea (sea cucumbers), which are divided into 5 families and 2 classes. From the data, only one beach recorded the number of sea cucumbers, namely Ngrenehan Beach with 1 species of sea cucumber. The research was conducted during the day, which affected the results of sea cucumbers obtained due to their nocturnal nature. Sampling in the intertidal zone is recommended to be done at night to obtain better results. Meanwhile, the number of sea urchin species varies at each beach, with the highest number recorded at Dadap Ayam Beach with 6 species, Ngrenehan Beach with 5 species, Ngrawah and Pringjono Beaches each with 4 species, and Torohudan Beach with only 1 documented species of sea urchin. This is an improvement compared to the research conducted by Nugroho et al. (2018), which identified 3 species of sea urchins. The species of sea urchins found are *Stomopneustes* sp., *E. oblonga*, and *E. mathaei* in Indrayanti Beach, Gunungkidul, Yogyakarta.

Based on Table 1, *E. oblonga* is the species found in the highest abundance. This is because *E. oblonga* prefers habitats with rocky substrates, such as dead corals and rocks (Caraka et al. 2024). The beaches in the Gunungkidul area, Yogyakarta, have many areas with rocky substrates that are ideal for *E. oblonga* (Tarigan 2020). In terms of habitat, the beaches in Gunungkidul, Yogyakarta, have plenty of algae, which serve as a food source for *E. oblonga*, as well as warm water temperatures suitable for their survival (Misbahuddin 2021). In addition to habitat, the adaptive ability of *E. oblonga*, which has sharp spines to protect itself from predators, means that this species does not have many predators, thereby maintaining its high population (Arkaki and Uehara 2020).

Species description

The description of the morphology and conservation status of Echinodermata species recorded on several beaches in Gunungkidul, Yogyakarta. Each species has distinct characteristics that help them adapt to their environments. Holothuroidea is a class of Echinodermata characterized by a long or cylindrical body composed of calcium carbonate ($CaCO_3$), which results in thick skin, with a soft body. These animals have tube feet on the ventral side, and tentacle crowns at the anterior (mouth) and posterior (anus) parts (Yunita et al. 2022). Holothuroideas can be found in intertidal zones to deep sea and play roles as nutrient decomposers, detritus feeders in food chains, suspension feeders, and aiding in coral reef production, thus playing a crucial role in marine food chains (Jasmadi 2020). In addition, sea cucumbers (Holothuroidea) are important ecological organisms due to their bioturbation (soil weathering) and alkalinization activities on the seafloor (Utzeri et al. 2020).

Most of these species are listed as Not Evaluated (NE) regarding their conservation status, indicating a need for further research to determine their population health, as the current data may be insufficient or inconclusive to assess their overall condition (Alfredsson et al. 2020). However, *H. leucospilota* is classified as Least Concern (LC), suggesting it is currently not at significant risk. The unique adaptations of these species underscore the rich biodiversity within tropical marine ecosystems. A population with greater adaptive potential will make them more resilient to changes in environmental conditions and, thus, more sustainable and suitable for conservation efforts (Teixeira and Huber 2021).

Table 1. List and density of echinodermata species recorded on several beaches Gunungkidul, Yogyakarta, Indonesia

Class	Family	Species	Density (ind/1000 m^2)					IUCN status
			Pringjono	Ngrenehan	Ngrawah	Torohudan	Dadap Ayam	
Echinoidea	Echinometridae	*Echinometra mathaei* (Blainville, 1825)	6	-	2	-	1	NE
Echinoidea	Echinometridae	*Echinometra oblonga* (Blainville, 1825)	6	99	21	-	184	NE
Echinoidea	Toxopneustidae	*Heterocentrotus trigonarius* (Lamarck, 1816)	2	1	3	1	12	NE
Echinoidea	Toxopneustidae	*Tripneustes gratilla* (Linnaeus, 1758)	1	2	2	-	5	NE
Echinoidea	Strongylocentrotidae	*Colobocentrotus atratus* (Linnaeus, 1758)	-	-	-	-	3	NE
Echinoidea	Stomopneustidae	*Stomopneustes variolaris* (Lamarck, 1816)	-	14	-	-	1	NE
Holothuroidea	Holothuriidae	*Holothuria leucospilota* (Brandt, 1835)	-	1	-	-	-	LC

Notes: NE: Not Evaluated, LC: Least Concern

Figure 2. Echinodermata species recorded on several beaches Gunungkidul, Yogtakarta, Indonesia. A. *Heterocentrotus trigonarius*; B. *Stomopneustes variolaris*; C. *Echinometra oblonga*; D. *Tripneustes gratilla*; E. *Echinometra mathaei*; F. *Colobocentrotus atratus*; G. *Holothuria leucospilota*

Heterocentrotus trigonarius *(Lamarck, 1816)*

Heterocentrotus trigonarius is a species of collector urchin belonging to the family Echinometridae, characterized by distinctive morphology. Its spines are reddish-brown, large, long, blunt-tipped, and resistant to breakage. The length of these spines varies, with shorter and blunter spines on the oral side and shorter but less blunt spines on the aboral side. Its test, or outer skeleton, is round and brown, composed of five ambulacral and five interambulacral segments of equal size, classifying it as a regular Echinoidea. Tubercles on the test are prominently raised, especially where long spines attach, with less prominent tubercles on the oral side due to shorter spines in that area (Ilmi and Sulistyawati 2021). The *H. trigonarius* plays an important role in coral reef ecosystems. As an algae eater (herbivore), it helps control algae growth on coral reefs, which, if uncontrolled, can inhibit coral growth (Lawrence et al. 2020). This species is commonly found in coral reefs, rocky areas, and sandy seabeds in tropical regions. It prefers areas with strong currents that bring abundant food particles. The *H. trigonarius* can be found at depths of up to 30 meters.

Stomopneustes variolaris *(Lamarck, 1816)*

Stomopneustes variolaris, known as the black sea urchin, is a species found in the warm waters of the Indian Ocean, distributed throughout tropical and subtropical regions of the Indo-Pacific up to a depth of 18 meters. This species typically has a circular or oval, rigid test (shell), which is seldom flexible. Its anus is located aborally, while the mouth is positioned at the center of the oral surface. Their spines are erect and rigid, with primary spines that are non-massive and secondary spines scattered among the primary ones. These spines are covered by very thin skin, with primary tubercles that are non-perforated but sometimes indented, and solid spines. Interambulacral plates are low, with some primary spines on the ambital plates, while ambulacral plates are paired, with one large ambulacral tubercle associated with three to six arcs, each having three pairs of pores. The mouth structure, known as Aristotle's Lantern, lacks a complete bridge over the V-shaped space at the top of the five pyramids forming the frame (Andilala et al. 2020).

Echinometra oblonga *(Blainville, 1825)*

Echinometra oblonga, one of the four *Echinometra* species in the Indo-West Pacific (IWP), is notable for its black spines. Its main characteristics include a completely dark peristome skin coloration, variation in tube foot spicules where half of the population has triradiate spicules, and variation in gonad spicules with four distinct characteristics. The sperm head morphology of *E. oblonga* is elongated with a length-to-width ratio of about six to one. Despite variations in some characteristics, the combination of spine coloration, peristome characteristics, and spicule types distinguishes *E. oblonga* from other *Echinometra* species in the IWP region (Bronstein and Loya 2013).

Tripneustes gratilla *(Linnaeus, 1758)*

Tripneustes gratilla, or the collector urchin, is an Echinoidea species with a round, spiny body and a hard calcium carbonate skeleton (test) that provides protection and facilitates movement. It uses hydraulic tube feet for locomotion, actively foraging for algae and detritus as food. Its mouth is equipped with Aristotle's Lantern for chewing food. Reproduction occurs through external fertilization, with the gonads serving as storage for essential nutrients and holding high economic value. Larvae develop in a planktonic phase, utilizing energy reserves from eggs before metamorphosing on hard substrates covered with algae and seagrass. Its diverse habitats, such as sandy areas and coral reefs, influence larval development, indicating population adaptations in heterogeneous environments to enhance health and reproduction (Radjab et al. 2020).

Echinometra mathaei *(Blainville, 1825)*

Echinometra mathaei is an abundant sea urchin that plays a crucial role in bioerosion in the Indo-West Pacific (IWP). It has an oval or round-shaped test adorned with spines that are brown or purple in color. These spines aid in protection and the excavation of coral substrates. The gonads of *E. mathaei*, usually orange or yellow, produce gametes and possess spicules for morphological identification. The tube feet are used for movement, attachment, and feeding. This sea urchin grazes by scraping coral surfaces, contributing to bioerosion that affects coral ecosystems. The *E. mathaei* is widely distributed in the IWP across various habitats, from coral reefs to sandy shores (Tamayo and Malay 2019).

Colobocentrotus atratus *(Linnaeus, 1758)*

Colobocentrotus atratus is a dome-shaped sea urchin with dark purple coloring on the aboral side and light magenta on the oral side. In a recent study, five live specimens were found with diameters ranging from 4.5 cm to 7.5 cm. The aboral surface consists of spines modified into a smooth mosaic of polygonal plates with a fringe of flattened spines, while the oral side has a ring of smaller flattened spines and tube feet with sucker tips. These morphological adaptations allow *C. atratus* to withstand heavy wave-swept environments by reducing the risk of dislodgement due to hydrodynamic forces and minimizing spine damage. The morphology also enables extra water storage, helping it survive high temperatures and desiccation during low tide. This herbivorous species grazes on red coralline algae (Pandey and Ganesh 2016). The *C. atratus* lacks spines, which reduces drag but increases lift. Despite this, the loss of spines and subsequent drag reduction make the organism more resistant to the forces of water acceleration, allowing it to exist in the surf zone (Lunt et al. 2017).

Holothuria leucospilota *(Brandt, 1835)*

With a body elongated like a cucumber, *H. leucospilota* can grow up to 20-30 cm in length with a diameter of 4-5 cm. Its body is cylindrical, with the mouth located ventrally and several parapodia irregularly arranged on its dorsal surface (Zhang et al. 2023). Additionally, *H. leucospilota* features a broad body with a thinner anterior compared to the posterior, a smooth body texture, and a relatively thin skin layer. Its ventral mouth is surrounded by 20 large tentacles, and it has a terminal anus. The tube feet on the trivium are large and arranged in 4-5 rows radially, also scattered in the interradial areas, with a diameter of about 480 micrometers. The Cuvierian tubules are very thin and long. The dorsal and ventral tegumental spicules are plate-like and button-shaped, with plates having circular discs with 8 or more pores and buttons having 6 or 8 pores. The ventral tube feet have large plates with numerous pores, while the dorsal podia have long stalks. Podia distribution on the bivium is short and thick in radial and interradial arrangements. This morphology supports the role of *H. leucospilota* as a bioturbator of marine sediments, processing soft substrates and removing organic matter necessary for growth (Eisapour et al. 2022).

Ecological index

Density

In this study, the density results of Echinodae according to Table 2 on Pringjono Beach was 15 individuals/1000 m^2. The highest density was found in the species *E. mathaei* and *E. oblonga* with a count of 6 individuals/1000 m^2, while the lowest density was found in the species *T. gratilla* with a count of 1 individuals/1000 m^2. Only one species was found at Torohudan Beach, resulting in a density of 1 individuals/1000m^2. At Ngrawah Beach, the density was found to be 28 individuals/1000 m^2. The highest density was in the species *E. oblonga* with a density of 21 individuals/1000 m^2, while the lowest densities were found in the species *T. gratilla* and *E. mathaei* with values of 2 individuals/1000 m^2. At Dadap Ayam Beach, the density was found to be 206 individuals/1000 m^2. The highest density was species *E. oblonga* with a density of 184 individuals/1000 m^2, while the lowest densities were found in the species *E. mathaei* and *S. variolaris* with densities of 1 individuals/1000 m^2. At Ngrenehan Beach, the density was found to be 117 individuals/1000 m^2. The highest density was in the species *E. oblonga* with a density of 99 individuals/1000 m^2, while the lowest density was in the species *H. trigonarius* with a density of 1 individuals/1000 m^2. The density of Holothuroidea species was only found at Ngrenehan Beach with a density of 1 individuals/1000 m^2.

The moderate density indicates that the environmental conditions at Pringjono Beach and Dadap Ayam Beach are good enough to support Echinodermata populations. The species *E. mathaei* and *E. oblonga* dominate, indicating that the habitat provides sufficient resources for these species. The low species richness at Ngrawah Beach, and Ngrenehan Beach could be due to limited habitat variation, which only supports a limited number of species. In addition, ecological pressures such as predation or competition may limit species diversity. At time same time, the very low or zero species richness of the Beach indicates that few or no species are found there. This may be due to extreme environmental conditions such as heavy pollution from human activities such as exploitation of natural resources in the sea (Amri et al. 2023).

Shannon-Wiener Diversity Index (H')

The Shannon-Wiener Diversity Index (H') was used to analyze species diversity. In this study (Table 3), the Shannon-Wiener Diversity Index for Echinoidea at Pringjono Beach was 1.18, indicating moderate species diversity. At Torohudan Beach, the index was 0, indicating low species diversity. At Ngrawah Beach, the index was 0.83, indicating low species diversity. At Dadap Ayam Beach, the index was 0.59, which would typically suggest high species diversity, but in this study, it was categorized as low species diversity. At Ngrenehan Beach, the index was 0.62, also indicating low species diversity. Additionally, the Shannon-Wiener Diversity Index for Holothuroidea at Ngrenehan Beach was 0, indicating low species diversity. The moderate species diversity observed at Pringjono Beach may be attributed to favorable environmental conditions, such as the availability of food and habitat heterogeneity, which support various species. On the other hand, the lack of diversity (H'=0) at Torohudan Beach and Ngrenehan Beach for Holothuroidea might result from extreme environmental conditions, habitat degradation, or anthropogenic disturbances. The consistently low diversity observed at Ngrawah, Dadap Ayam, and Ngrenehan Beaches for Echinoidea may be explained by environmental stressors like predation, competition, or physical disturbances, which can limit species survival and diversity (Komyakova et al. 2019).

Evenness Index (E)

In this study, the Evenness Index for Echinodae according to Table 4 on Pringjono Beach was 0.85, indicating a relatively even species distribution. At Torohudan Beach, the index was 0, indicating uneven distribution. At Ngrawah Beach, the index was 0.60, indicating a relatively even distribution. At Dadap Ayam Beach, the index was 0.26, indicating a fairlyeven distribution. At Ngrenehan Beach, the index was 0.43, indicating somewhat even distribution. Additionally, the Evenness Index for Holothuride species was 0, indicating uneven distribution. If the Evenness Index is higher than the growth rate, it indicates a more even distribution of individuals among species. The high evenness index indicates that Echinodermata species in Pringjono Beach are evenly distributed (Febrian et al. 2022). A high evenness index was also found at Ngrawah Beach due to moderate habitat variation and good resource availability. This condition may also be caused by a stable environment, heterogeneous substrates, and abundant food availability, so that no species dominates significantly. The low evenness index in Dadap Ayam Beach, and Ngrenehan Beach indicates that some species dominate. Ecological pressures such as predation, competition, or physical disturbance may be higher, causing an uneven distribution. Zero evenness index indicates that one or a few species dominate or even that only one species is found. This may also be due to extreme environmental conditions or significant habitat degradation, such as pollution or human disturbance.

Table 2. Density of Ehinoidea and Holothuroidea at each beach location in this research

Beach location	Density (individuals/1000 m^2)	Highest density species	Lowest density species
Ehinoidea			
Pringjono Beach	15	*Echinometra mathaei* (6 ind/1000 m^2) *Echinometra oblonga* (6 ind/1000 m^2)	*Tripneustes gratilla* (1 ind/1000 m^2)
Torohudan Beach	1	-	-
Ngrawah Beach	28	*Echinometra oblonga* (21 ind/1000 m^2)	*Tripneustes gratilla* (2 ind/1000 m^2) *Echinometra mathaei* (2 ind/1000 m^2)
Dadap Ayam Beach	206	*Echinometra oblonga* (184 ind/1000 m^2)	*Echinometra mathaei* (1 ind/1000 m^2) *Stomopneustes variolaris* (1 ind/1000 m^2)
Ngrenehan Beach	117	*Echinometra oblonga* (99 ind/1000 m^2)	*Heterocentrotus trigonarius* (1 ind/1000 m^2)
Holothoroidea			
Ngrenehan Beach	1	-	-

Table 3. Shannon-Wiener Diversity Index (H') for Ehinoidea and Holothuroidea at each beach location in this research

Beach location	Shannon-Wiener Diversity Index (H')	Diversity category
Ehinoidea		
Pringjono Beach	1.18	Moderate species
Torohudan Beach	0	Low species
Ngrawah Beach	0.83	Low species
Dadap Ayam Beach	0.59	Low species
Ngrenehan Beach	0.62	Low species
Holothoroidea		
Ngrenehan Beach	0	Low species

Table 4. Evennes Index (E) for Ehinoidae and Holothuroidea at each beach location in this research

Beach location	Evenness Index (E)	Distribution category
Ehinoidae		
Pringjono Beach	0.85	Relatively even species
Torohudan Beach	0	Uneven species
Ngrawah Beach	0.60	Relatively even species
Dadap Ayam Beach	0.26	Relatively even species
Ngrenehan Beach	0.43	Relatively even species
Holothoroidea		
Ngrenehan Beach	0	Uneven species

Margalef Species Richness Index (R)

The Margalef Species Richness Index (R) was used to analyze species richness. In this study (Table 5 and Figure 5), the Margalef Species Richness Index for Echinoidea on Pringjono Beach was 1.10, indicating low species richness. At Torohudan Beach, the index was 0, indicating low species richness. At Ngrawah Beach, the index was 0.90, indicating low species richness. At Dadap Ayam Beach, the index was 1.12, indicating low species richness. At Ngrenehan Beach, the index was 0.63, indicating low species richness. The Margalef Species Richness Index for Holothuride species was 0, indicating low species richness. The low species richness of Pringjono Beach, Dadap Ayam Beach, Ngrawah Beach, and Ngrenehan Beach may be caused by habitat limitations that support only a small number of species. Factors such as less varied substrates or limited resources, as well as ecological pressures such as predation or competition can limit species richness, while very low or zero species richness indicates that few or no species are found there. This may also be due to extreme environmental conditions such as weather factors, heavy pollution or impacts from human activities (Siahaan et al. 2019).

Comparison of ecological ecological index

According to Table 3 and Figure 3, the density value of Echinoidea obtained is 367 ind/1000 m^2. It is higher than the density value of Holothuroidea. The density of a species shows the number of individual species with a certain unit area (Wiraatmaja et al. 2020). The higher the density value per unit area, the higher the number of individuals per unit area. Research by Yusron (2016) said that Echinoidea is a member of the echinoderms group, and its presence is quite large in seagrass because it is mainly influenced by food factors and the way each species eats. Based on Figure 4, the highest diversity index value was obtained at Pringjono Beach with a value of 1.18, categorized as moderate diversity, while other beaches fell into the low diversity category because their values were less than 1. According to Putri et al. (2019), the diversity index value can describe the relationship between species abundance within a community. Species diversity includes the number of species present in the community. Meanwhile, According to Ismaini et al. (2015), species richness reflects the number of species present in a community. The more species detected, the greater the species richness index. In this study, the beach with the highest richness index was Dadap Ayam Beach with a value of 1.12, detecting 6 species, namely *H. trigonarius*, *E. mathaei*, *E. oblonga*, *C. atratus*, *T. gratilla*, and *S. variolaris*, while the beach with the lowest species richness was Torohudan Beach with a value of 0 because only 1 species, namely *H. trigonarius*, was found (Figure 5). Then, the evenness index measures the distribution of individuals within a species in the community. High evenness occurs when individuals are evenly distributed among species. High evenness occurs when the number of individuals per species is almost the same (Pertiwi et al. 2020). The results from the 5 beaches (Figure 6) show that the evenness index 0.348, indicating low evenness. Evenness reflects how species abundance, both in terms of the number of individuals and biomass, is distributed among various species present. The comparison of ecological indices across multiple beach locations reveals nuanced patterns in the distribution and diversity of Echinodae populations. Among the studied sites, Pringjono Beach emerges as a hotspot of moderate species diversity, characterized by a relatively even distribution of species. In contrast, Torohudan Beach exhibits notably low species diversity and richness. According to Carmona et al. (2017) Low species richness will influence the vulnerability of a community to environmental changes.

Table 5. Margalef Species Richness Index (R) for Ehinoidea and Holothuroidea at each beach location in this research

Beach location	Margalef Species Richness Index (R)	Richness category
Ehinoidea		
Pringjono Beach	1.10	Low species
Torohudan Beach	0	Low species
Ngrawah Beach	0.90	Low species
Dadap Ayam Beach	1.12	Low species
Ngrenehan Beach	0.63	Low species
Holothoroidea		
Ngrenehan Beach	0	Low species

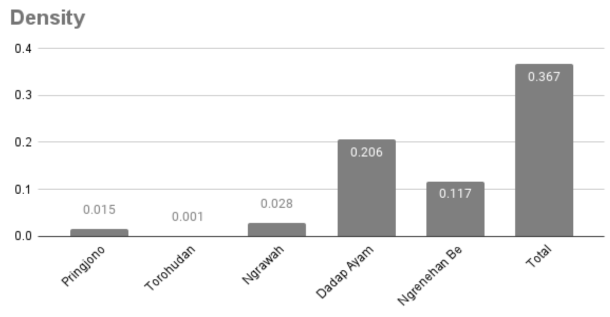

Figure 3. Comparison of density for Ehinoidea and Holothuroidea at each beach location in this research

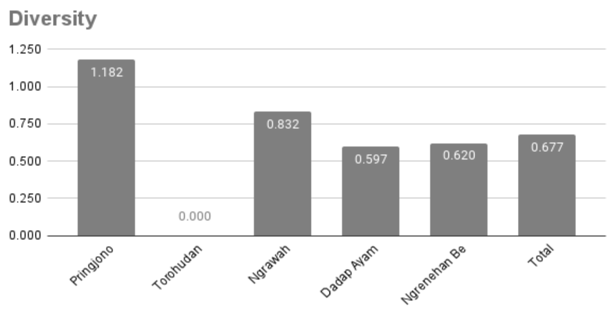

Figure 4. Comparison of Shannon-Wiener Diversity Index (H') for Ehinoidea and Holothuroidea at each beach location in this research

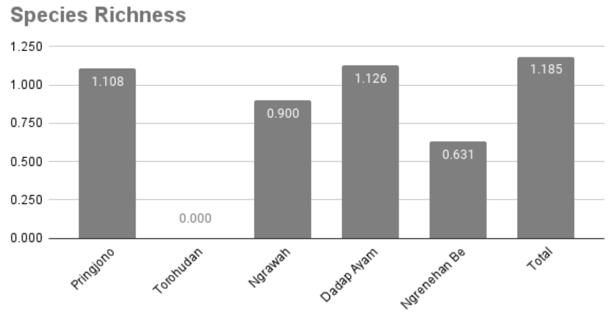

Figure 5. Comparison of Margalef Species Richness Index (R) for Ehinoidea and Holothuroidea at each beach location in this research

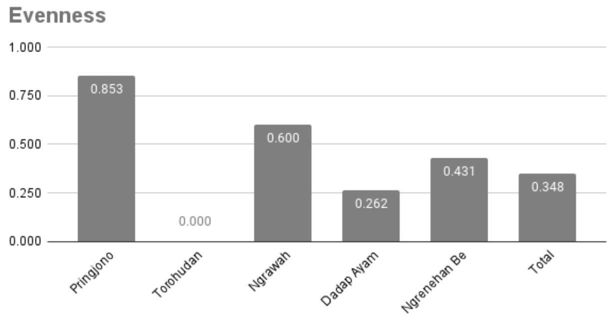

Figure 6. Comparison of Evennes Index (E) for Ehinoidea and Holothuroidea at each beach location in this research

Table 6. Environmental (abiotic) factors on several beaches Gunungkidul, Yogyakarta, Indonesia

Parameter	Location				
	Pringjono	**Ngrenehan**	**Ngrawah**	**Torohudan**	**Dadap Ayam**
Water pH	6.98	7.92	8.26	8.55	8.38
Water temperature (°C)	29-30.8	29.9-31	29-30.3	29-30.3	29-30.1
DO (mg/L)	0.70	2.31	0.49	0.30	1.70

Note: DO: Dissolved Oxygen, pH: Acidity

Abiotic factor

At several research locations on the beaches in the Gunungkidul area, Yogyakarta, there are several abiotic environmental parameters related to the diversity of Echinoidea and Holothuroidea. Where each beach has a different value for each parameter, which causes differences in the amount of diversity obtained. The results of this study based on Table 6 obtained measurements of pH, temperature, Dissolved Oxygen (DO), at the research locations. Measurements at Pringjono Beach obtained a water pH of 6.98, indicating slightly acidic conditions. The water temperature at this beach was recorded at 29-30.8°C, which is relatively high and could affect marine life (Rozirwan et al. 2021). The Dissolved Oxygen (DO) level was very low, at 0.70 mg/L, indicating potentially challenging conditions for some organisms (Liu et al. 2020). Ngrenehan Beach showed a water pH of 7.92, which is close to neutral. The water temperature at this beach was 29.9-31°C, slightly lower than that at Pringjono Beach. The Dissolved Oxygen (DO) content here was higher, at 2.31 mg/L, indicating better conditions for the survival of aquatic organisms (Zhou et al. 2020). At Ngrawah the water had a pH of 8.26, which is slightly alkaline. The water temperature was recorded at 29-30.3°C, while the dissolved oxygen level was very low, at only 0.49 mg/L. Torohudan Beach had more alkaline water, with a pH of 8.55. The water temperature at this beach was the same as at Ngrawah Beach, at 29-30.3°C. However, the DO level was extremely low, at only 0.30 mg/L. Finally, Dadap Ayam Beach showed a water pH of 8.38, with a water temperature of 29-30.1°C. The dissolved oxygen content at this beach was 1.7 mg/L.

Water pH, an indicator of acidity or alkalinity, exhibits significant variation among locations, with the lowest recorded at Pringjono Beach (pH 6.98) and the highest at Torohudan Beach (pH 8.55). Furthermore, water temperature varies across beaches, with the highest recorded at Ngrenehan Beach (31°C). The combination of decreasing water pH and increasing water temperature may impact the biological responses of marine invertebrates (Clements et al. 2021). Differences in Dissolved Oxygen (DO) concentrations are also observed, with the highest recorded at Ngrenehan Beach (2.31 mg/L) and the lowest at Torohudan Beach (0.30 mg/L). It is important to regularly observe the quality of DO in water bodies because a decrease or loss of DO in deep waters can lower water quality by promoting the release of accumulated nutrients from sediments into the water (Jane et al. 2021). The early stages of life are typically highly sensitive to environmental changes, thus posing a threat to population sustainability (Pereira et al. 2020).

In conclusion, the community structure of Echinodermata in the coastal areas of Gunungkidul, Yogyakarta, was revealed, with 7 species identified across five designated stations. There are 367 individual Echinoidea from 4 different families (Echinometridae, Toxopneustidae, Strongylocentrotidae, Stomopneustidae). There is one species and individual of Holothuroidea originating from the family Holothuridae. The density value of Echinoidea obtained is 367 ind/1000 m^2. The highest species density value is obtained by the species *E. oblonga*, which is 310 ind/1000 m^2. Meanwhile, the lowest species density value is obtained by the species *C. atratus*, which is 3 ind/1000 m^2. Then, for the total species diversity index of Echinodermata (Echinoidea and Holothuroidea), it is in the low category with values of 0.67. For the evenness index, it has a value of 0.34, which falls into the low category. Furthermore, for the species richness index, it is in the low category with a value of 1.18.

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