



# Diversity of Echinoderms in the Subtidal Zone of Sintok Island, Karimunjawa National Park, Jepara, Indonesia

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## Authors' contributions

This work was carried out in collaboration among all authors. Author RH designed the study, managed the literature searches, and wrote the first draft of the manuscript. Author NT conducted the fieldwork. Authors NT and WW performed the statistical analysis. All authors read and approved the final manuscript.

## Article Information

DOI: 10.9734/AJFAR/2024/v26i2735

## Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/112631>

Original Research Article

Received: 04/12/2023

Accepted: 09/02/2024

Published: 15/02/2024

## ABSTRACT

**Aims:** To determine the diversity of Echinoderms in the subtidal zone of Sintok Island.

**Study Design:** This study applied a purposive sampling method.

**Place and Duration of Study:** Sintok Island, Jepara, Indonesia, November 2019.

**Methodology:** The belt transect method was used. The transect was drawn 200 m perpendicular from the coastline to the sea. The echinoderms in the 2m area along the transect line are observed for their diversity, the number of individuals from each species is counted, and the substrate is observed. The diversity index of Shannon-Wiener, evenness (uniformity), and dominance indices were analyzed.

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**Results:** The results showed 11 species belonging to 3 classes of Echinoderms found in Sintok Island. Holothuroidea class consisted of *Holothuria atra*, *H. coluber*, *H. edulis*, *H. impatiens*, *Pearsonothuria graeffei*, and *Synapta maculata*. Asteroidea class consisted of *Culcita novaeguineae*, *Linckia laevigata*, and *Protoreaster nodosus*. The Echinoidea class consists of *Diadema setosum* and *Laganum laganum*. *H. atra* was the most abundant species (0.70 ind.m<sup>-2</sup>). The diversity index value (H') of Echinoderm was in the range of 1.21 to 2.01, classified as a moderate condition.

**Conclusion:** The echinoderm species in subtidal areas on Sintok Island could be a good tourist attraction in this national park.

**Keywords:** *Holothuroidea; Asteroidea; Echinoidea; tourism; diversity; Sintok; Karimunjawa.*

## 1. INTRODUCTION

Sintok is one small inhabited island of the Karimunjawa Archipelagos, located in the Northwest of Jepara Regency, Central Java, Indonesia. It comprises beach forest vegetation with a coral barrier in the outer subtidal area rich with seagrass and coral ecosystems. As the beach was white sand, Sintok Island became a tourist destination in Karimunjawa National Park [1]. Tourism activity in Sintok Island is mostly carried out in the subtidal zone. The subtidal zone is the zone close to shore but constantly submerged. Coastal waters, i.e., the intertidal and subtidal zones, experience the most extreme changes due to land processes. For example, the salinity can fluctuate between high salinity in hot, dry winds and low salinity during heavy rain and runoff. Temperature extremes can also exist, as the air temperature changes seasonally. The subtidal communities are less affected than intertidal communities but still experience these changes [2]. In contrast to the other zones, this provides a good habitat for a high diversity of marine plants and animals, including Echinoderm.

Echinoderms are distributed widely and can be found in varied habitats, from intertidal zones to deep seas [3]. Echinoderms can regenerate their body, either broken or damaged by predators. Most animals in this class have a radially symmetrical body and a calcareous endoskeleton with spines. The main group of Echinoderms consists of five classes: Asteroidea, Ophiuroidea, Echinoidea, Crinoidea, and Holothuroidea [4].

Generally, echinoderms live in clear, calm waters and play numerous ecological roles. Sand dollars and sea cucumbers burrow into the sand, providing more oxygen at greater depths of the sea floor and allowing more organisms to live there. In addition, starfish and urchins prevent

the growth of algae on coral reefs [5], this allows the coral to filter-feed more easily. Many sea cucumbers provide a habitat for commensal biota, such as fish, crabs, worms, and snails. Echinoderms are also important in the ocean food chain [6]. According to Setyastuti et al. [7], the highest diversity of Echinoderms can be found on coral reefs and shallow beach habitats. Echinodermata has a variety of shapes, sizes, and colors. Often with five or multiple arms, sometimes their arms were less than five [8]. Echinoderms are also colorful, so they attract tourists to observe them. This activity can be used for education and tourism in the area [9]. Research on diverse echinoderms on several islands in the Karimunjawa National Park has been conducted, such as on Cemara Besar Island [10], in Indoor Wreck, Kemujan Island [11], Cemara Kecil Island [12], in Menjangan Kecil, Karimunjawa, and Kemujan Island [13,14]. One of the locations designated for tourism destinations is the waters of Sintok Island, Karimunjawa National Park. However, there is no data or information about the Echinoderms that inhabit there. Therefore, the present study aims to identify and determine the community structure of echinoderms in the subtidal one of Sintok Island.

## 2. MATERIALS AND METHODS

This research was conducted in November 2019 in the subtidal area of Sintok Island, Karimunjawa, Jepara Regency. There were four stations observation and the geographical positions were as follows: Station 1 (5°47'7.71" S; 110°30'45.65" E), Station 2 (5°46'59.37" S; 110°30'35.81" E), Station 3 (5°46'48.08" S; 110°30'40.28" E) and Station 4 (5°47'1.58" S; 110°30'53.36" BT) (Fig. 1).

The observation used the belt transect method [15]. The transect was drawn 200 m perpendicular from the coastline to the sea. After

the roll meter is installed, the echinoderms in the 2m area along the transect line are observed for their diversity, the number of individuals from each species is counted, and the substrate is observed. Echinoderms were recorded starting

from 0 to 200 m with an observation width of 1 m to the left and right of the transect line so that the observation area was 400 m<sup>2</sup> (Fig. 2). The habitat type and the depth are presented in Table 1.

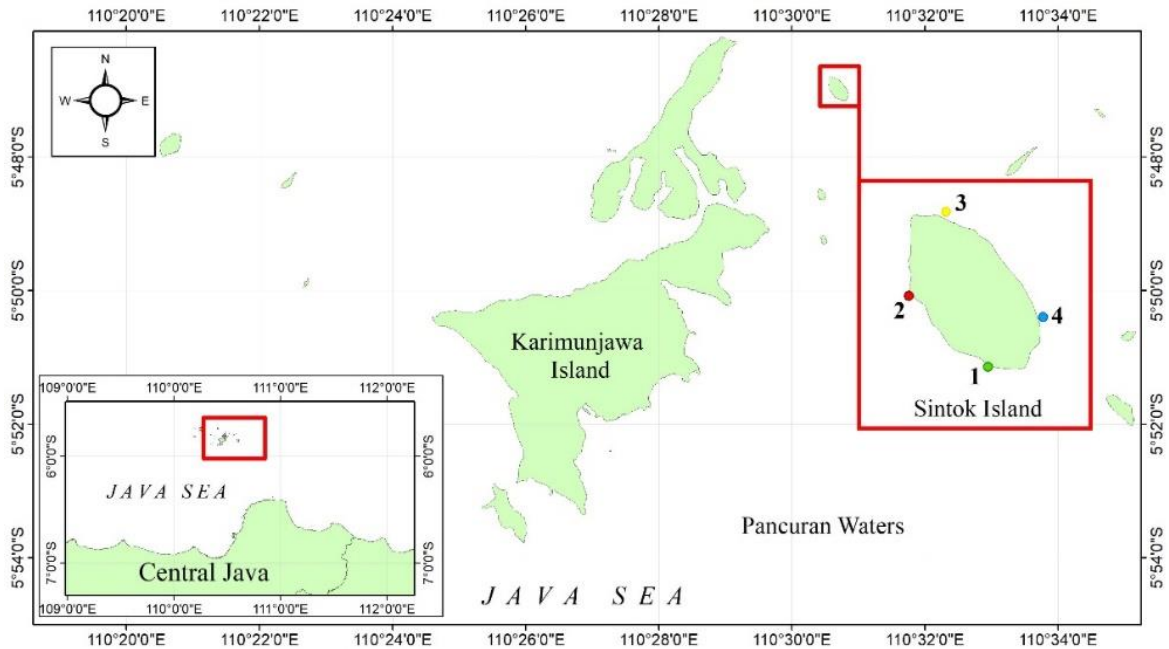


Fig. 1. Map of sampling stations of Sintok Island, Karimunjawa National Park, Jebara, Central Java, Indonesia

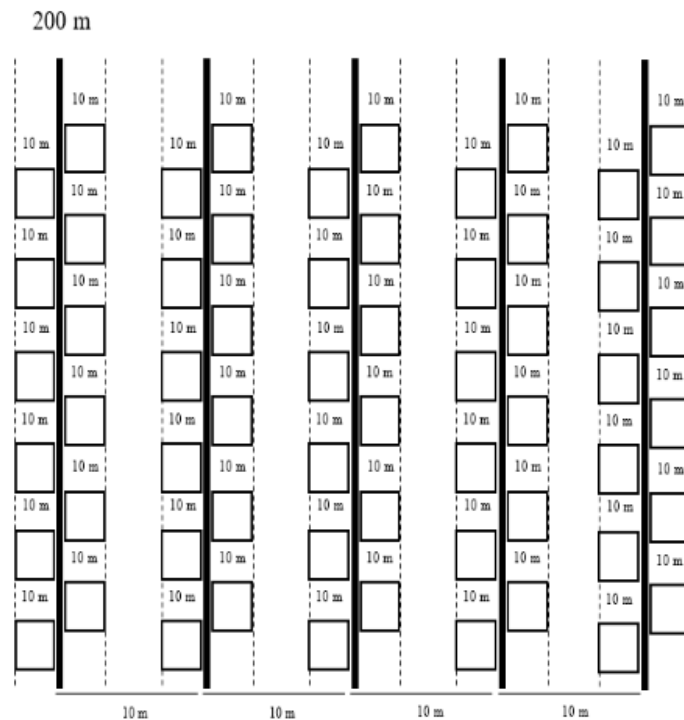


Fig. 2. The transect line position is in each research location on Sintok Island

**Table 1. The bottom substrate and the water depth of each Station in Sintok Island**

No.	Parameter	Station			
		1	2	3	4
1	Habitat type	Sandy bottom and Seagrass	Sandy bottom, Seagrass, and coral	Sandy bottom and Seagrass	Sandy bottom and Seagrass
2	Depth (m)	0.2 – 1.7	0.2 – 1.8	0.1 – 1.2	0.1 – 1.2

The identification of echinoderms is based on [16-20]. Whenever possible, the samples of echinoderm were photographed in situ using a 30MP Waterproof Digital Camera with a 32G Card and Floating Strap, 18X zoom Rechargeable Point, and Shoot Camera for Snorkeling /Swimming. Based on each species' abundance data, the echinoderm community structure was determined as follows. The diversity index of Shannon-Wiener, evenness (uniformity), and dominance indices [21,22] were calculated using the formula below. The benchmark value of diversity, dominance, and evenness was assessed using the criteria of Sumekar and Widayat [23].

$$H' = - \sum_{i=1}^s P_i \log_2 P_i$$

H': Shannon-Wiener Index of Diversity

S: Number of species

P<sub>i</sub>: No. of indiv. of spesieske-i /no.totalindv. (ni/N)

$$E = \frac{H'}{H_{max}}$$

E: Evenness Index

H': Diversity Index of Shannon – Wiener

H<sub>max</sub>: Maximum Diversity Index (log S)

S: Number of species

$$D = \frac{\sum ni (ni - 1)}{N (N - 1)}$$

D: Dominance Index

n<sub>i</sub>: Number individual per species

N: Total individual per species

### 3. RESULTS AND DISCUSSION

#### 3.1 Spesies Composition of Echinoderms

Three classes of Echinoderm were found in the four stations of the subtidal zone of Sintok Island,

namely Holothuroidea, Asteroidea, and Echinoidea. The number of Echinoderms in the subtidal zone of Sintok Island waters was 416 individuals, consisting of 11 species, i.e., *Holothuria atra*, *H. coluber*, *H. edulis*, *H. impatiens*, *Pearsonothuria graeffei*, and *Synapta maculata* (Holothuroidea), *Culcita novaeguineae*, *Linckia laevigata*, *Protoraster nodosus* (Asteroidea), *Diadema setosum*, and *Laganum laganum* (Echinoidea) (Fig. 3).

There were two families of sea cucumbers inhabited in the subtidal zone of Sintok Island, namely the Holothuroiidae and Synaptidae familiys, their integument structure could differentiate them. The Holothuriidae family had a consistent and strong integument, while the Synaptidae family had a limp integument, and all parts of their body were very sticky when touched. According to Hartati and Widianingsih [24], the Holothuriidae family had rounded body cross-sections and tube feet for locomotors, while the Synaptidae family have no tube feet, tentacle ampullae, retractor muscles, respiratory trees, or cuvierian tubules [25]. The body of the latest family was like a worm, and the body walls were thin. Hartati et al. [24] stated that the body surface of sea cucumbers is generally rough due to spicules on the skin walls. The spicula was an endoskeleton that had been reduced to microscopic sizes and was embedded in the dermis layer of the sea cucumber body wall. The shape of the spicula varies and is unique to each species. Therefore, spicules can characterize sea cucumbers' genera and species [27].

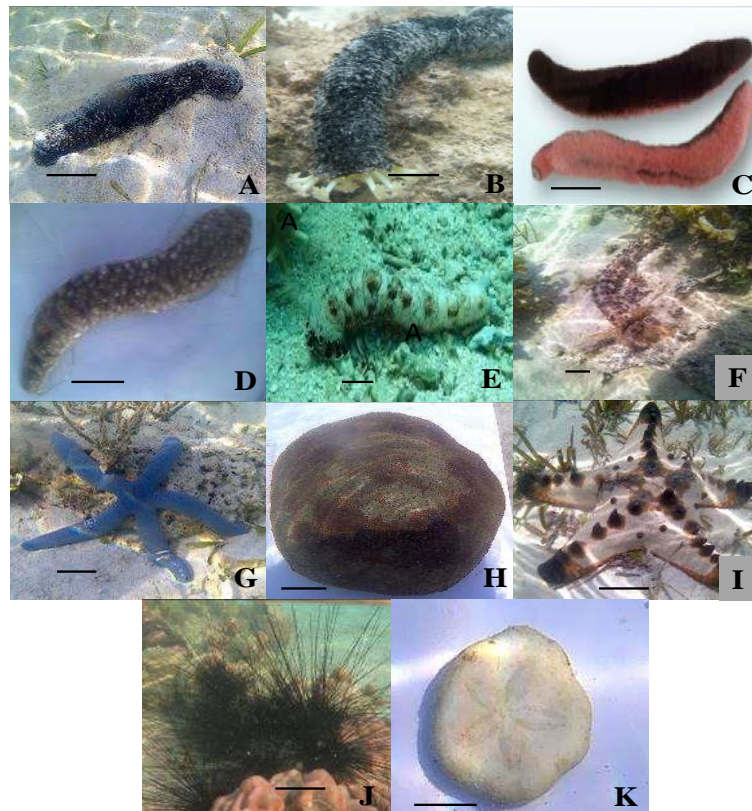
Six species of Holothuroidea, namely *Holothuria atra*, *H. coluber*, *H. edulis*, *H. impatiens*, *Pearsonothuria graeffei*, and *Synapta maculata*, were encountered in the subtidal area of Sintok Island. They had different characteristics. *H. atra* has an elongated body shape and is generally soft and black [26]. There were short papillae. Observations on Sintok Island show that this species is found in seagrass and sand substrates. Its body was often found covered in sand. It is thought to be an effort to defend itself. *H. coluber* had the characteristics of a black body

with a cylindrical shape and thick integument. This species had papilla on its dorsal, which is longer than the *H. atra*, so it has a coarser texture [28]. There were tentacles in the mouth located in the ventral. The tips on the tentacles were light-colored, as were the papillae. Simone et al. [29] stated that the length of *H. coluber* was 18-40 cm. Its body color was black even though it was soaked in alcohol. It has a yellowish-white dorsal papilla, scattered irregularly. The integument was thick and hard, and the mouth was at the ventral and the anus at the terminal. The tentacles on its shield-type mouth were yellow. The tube feet were white and arranged in rows on the ambulacral and interambulacral ventral bodies.

The body of *H. edulis* had a different coloration on the dorsal and ventral sides. On the dorsal part, *H. edulis* is black, while on the ventral part, it is bright pink. It had black papillae on the dorsal side [28]. Morphologically, *H. edulis* had a round cross-body section, the ventral side tends to be flat, and the anal canal is round. Another Holothuroidea species was *H. impatiens*,

characterized by a rough round body texture due to its prominent papillae. Its body shape was cylindrical with flexible integument in the body [24]. The body is grayish-yellow with bright papilla tips and a blackish-brown patch in the dorsal part. The ventral mouth is surrounded by 20 tentacles which are in turn surrounded by a ring of very small conical papillae; the anus terminal with five conical papillae [29]. *H. impatiens* is commonly found under rocks and sometimes in seagrass areas.

*P. graeffei* was also found in the subtidal zone of Sintok Island, it had a light brown color with red-black spots. *P. graeffei* has a rough texture due to the large papillae on its body with light-colored tips [30]. According to Prescott et al. [31], it was characterized by a cream-to-brown body with black spots scattered. It has an oval-shaped body with an abdomen, a transverse fold, and tentacles on the mouth. It was a scavenger and roamed around on the seabed, sifting through the sediment with its feeding tentacle.



**Fig. 3.** Echinoderm species found in the subtidal zone of Sintok Island (A. *Holothuria atra* B. *H. coluber*, C. *H. edulis*, D. *H. impatiens*, E. *Pearsonothuria graeffei*, F. *Synaptam aculata*, H. *Culcita novaeguineae*, G. *Linckia laevigata*, I. *Protoraster nodosus*, J. *Diadema setosum*, K. *Laganum laganum*; black line is 1 cm)

*S. maculata* was the only member of the Synaptidae family found in the subtidal areas of Sintok Island waters. This species had very distinct characteristics compared to other Holothuroidea species. Its body shape resembled a snake. Because the integument is so thin that the body is limp. The rest of the body was typically wrinkled, and its color was a semi-transparent white to pale or yellowish-grey, with a low density of ochre-colored spicules [32]. The anterior part was yellow-brown longitudinally, with white and brown stripes and transversal dark grey blotches, and exhibited dense patches of spicules. The sea cucumber species found in this work were less than those found by Purwati et al. [27], Hartati et al. [33].

The composition of the Asteroidea class consists of two families, i.e., Ophidiasteridae (*L. laevigata*) and Oreasteridae (*P. nodosus* and *C. novaeguineae*). This class has a total of 30 individuals spread over four stations. The blue sea star, *L. laevigata*, is approximately 15 cm long and has five cylindrical and slender arms. Its body was sturdy because of its calcium carbonate skeleton. These organisms usually live on coral reefs, sand, and seagrass beds [34]. Adults are pentamerous radial symmetrical and possess short, yellow tube feet for locomotion [35]. Another sea star with an interesting body form found was *C. novaeguineae*, i.e., large, bulky, and puffed-up cushion star with a pentagonal shape and 5 almost absent arms [36]. Its color can vary widely from red to green and brown. Yokley [37] stated that *C. novaeguineae* has a pentagonal body shape with five short arms and a sturdy structure. This cushion-like body-shaped sea star was also known as a Cushion star. *P. nodosus* was also found during the present study; it possessed rows of spines or "horns" in the aboral, which was used to scare away possible predators. This starfish also had five sturdy shape arms. Each end of the arm was bent upwards. Jonathan et al. [3] stated that the most dominant color of *P. nodosus* was orange, with black blunt spines on its body. This species usually lives in sandy areas [38].

The echinoidea in the subtidal zone of Sintok island consisted of two families, i.e., Diadematidae (*D. setosum*) and Laganidae (*L. laganum*). This class has a total of 40 individuals in all stations. Sea urchins from Diadema are some of the most widespread, abundant, and ecologically important echinoids in tropical regions [39]. *D. setosum* had a black, round body

surrounded by moveable, sharp black spines [40]. It is a typical sea urchin with extremely long, hollow, mildly venomous spines [41]. Besides protecting themselves from predators, these spines were also used for movement apparatus [42]. Because it may harmful to tourists, they might be avoided. In the aboral part of this echinoid, there was an orange anal ring and a blue or green color on the genitals, while on the oral part, there is a mouth. *D. setosum* is commonly associated with coral reefs but is also found on sand flats and seagrass beds [39]. Sand dollar (*L. laganum*) was found on a sandy substrate. This species had a light brownish gray color flat body but changed into white when it died. Small thorns were on the body, and its habitat was sandy or muddy [43]. *L. laganum* also was found in Cemara Besar Island of Karimunjawa Archipelago [10].

The previous study in Karimunjawa National Park found several echinoderm species. [3] Hartati et al. [3] found six species of Asteroidea, i.e., *L. laevigata*, *L. multifora*, *Neoferdifa ocellata* (Family Ophidiasteridae), *Luidia alternate* (Family Luidiidae), *C. novaeguineae* (Family Oreasteridae) and *Acanthaster planci* which belongs to Family Acanthasteridae. and *D. setosum*, *D. antillarum*, *D. savignyi*, and *Echinothrix calamaris* (Family Diadematidae). A study by Hadi et al. [11] in Indonoor Werk of Kemujan Island revealed more diverse echinoderm and found 3 crinoid species since it lay at 12-15 meters depth. Several Holothurian species have inhabited Karimunjawa Island, such as *H. atra*, *H. scabra*, *H. fuscocinerea*, *Stichopus vastus*, *Bohadschia marmorata*, and *P. graffi* [45], and *S. monotuberculatus* [46,14]. In 2021, Hartati et al. [33] found more sea cucumber species diversity in a deeper sea of Nyamuk Island of Karimunjawa National Park, which belonged to two genera (Stichopus and Thelenota), i.e., *S. horrens*, *S. pseudohorrens*, *S. naso*, *S. vastus*, *S. chloronatus*, *S. herrmanni*, *S. monotuberculatus*, *S. ocellatus*, *S. quadrifasciatus*, *Thelenota anax*, and *T. ananas*.

There were 161, 161, 32, and 71 individuals of echinoderm inhabiting 400 meter<sup>2</sup> area in Stations 1, 2, 3, and 4, respectively, and their abundance was shown in Fig. 4. Holothuroidea, especially *H. atra*, was the most abundant (10 -114 individuals per station) compared to other classes. This was related to sandy and seagrass bottoms as their specific habitat [26]. According to de Guzman and Quiñones [47], the difference in sea cucumber

densities may be affected by habitat type, time of sampling, or fishing patterns. In the subtidal area, sea cucumbers could be found more easily in seagrass beds as they are usually exposed than in coral reefs of deeper water, except during extreme ebb tides or whenever they are burrowed [48]. The high density of *H. atra* is also found in the Mindanao Area of the Philippines [49]. The low density of each species in the subtidal area of Sintok Island confirms the resulting study of Sobczyk et al. [8] that the tropical echinoderm communities have high patchiness and low abundance, which is

influenced by increased microhabitat diversity and food availability.

### 3.2 Diversity, Evenness, and Dominance Index

Diversity ( $H'$ ), Evenness ( $E$ ), and dominance ( $D$ ) indexes were used to estimate the condition of the aquatic environment based on its species composition. The value of the diversity index, uniformity, and dominance at the four stations in the waters of Sintok Island is presented in Fig. 5.

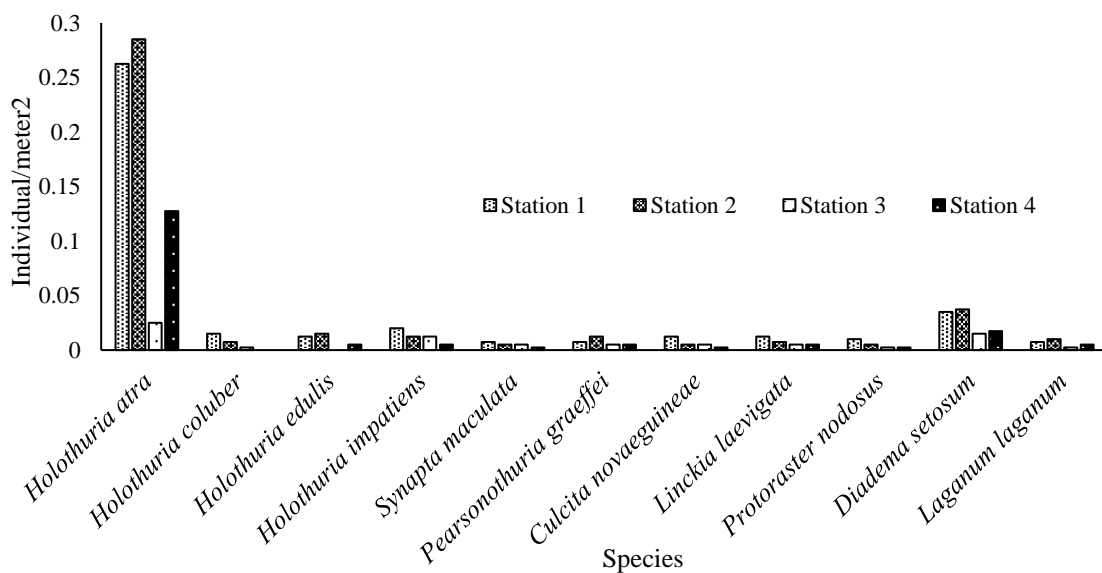


Fig. 4. The abundance of echinoderm species (individual.m-2) found in the subtidal zone of Sintok Island

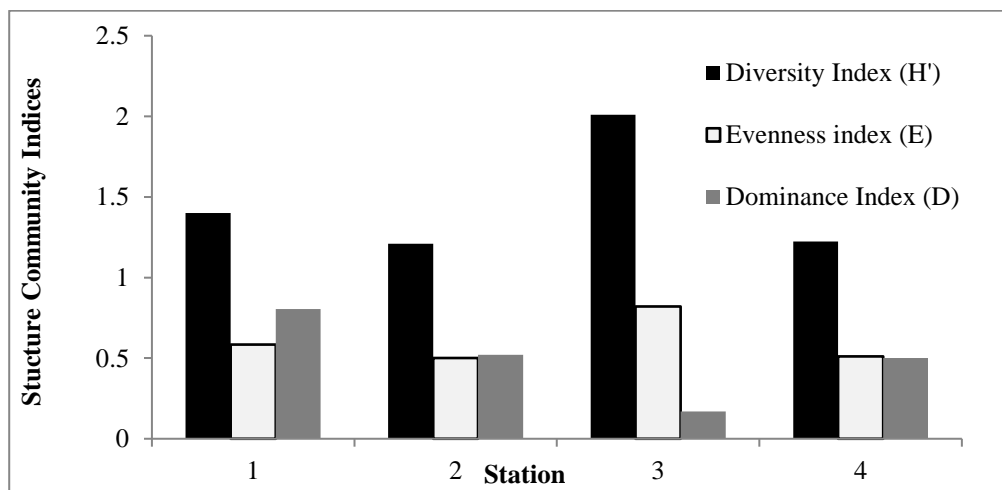


Fig. 5. The Echinoderms species Diversity, Evenness and Dominance Index in the subtidal zone of Sintok island



The diversity index value ( $H'$ ) was varied with the station, which showed the species abundance. The distribution of individuals of each species influenced this. The highest diversity index value was 2.01 at Station 3, and the lowest was 1.21 at Station 2. This value could be affected by several factors, such as the number of individuals per species or the number of species found in an area [50]; it included a medium condition, which indicated the echinoderm community stability in the subtidal zone of Sintok Island. The presence and role of echinoderms as bioturbators in the subtidal area may increase the abundance of other invertebrates or cause shifts in species composition [51].

The four stations' evenness index value ( $E$ ) was 0,5-0,84; the highest was found in Station 3. According to Siburian et al. [52], the evenness index value can describe the stability of a community. A community was stable if it had a species evenness index value close to 1 and vice versa if it had a species evenness index value close to 0. Among the four stations, station 2 has a value close to 0 due to the high *H. atra* abundance value.

The dominance index values ( $D$ ) of four stations showed varied values, in which Stations 1, 2, 3, and 4 were 0.81, 0.52, 0.17, and 0.50, respectively. Station 1 has the highest dominance index, namely 0.81. According to Yusron [53], the dominance value ( $D$ ) is in the range of values from 0 to 1. If the dominance index value was close to 1, then there was a relatively abundant (dominant) species, i.e., *H. atra*. The value of diversity, evenness, and dominance indices showed that the subtidal zone of Sintok Island was still a good habitat for echinoderms. The species in subtidal areas could be a good tourist attraction in this national park.

#### 4. CONCLUSION

The diversity of Echinoderms found in the subtidal zone of Sintok Island consisted of 3 classes, namely Holothuroidea, Asteroidea, and Echinoidea. The species consisted of *Holothuria atra*, *H. coluber*, *H. edulis*, *H. impatiens*, *Pearson othuria graeffei*, *Synapta maculata*, *Linckia laevigata*, *Culcita novaeguineae*, *Protoreaster nodosus*, *Diadema setosum*, and *Laganum laganum*. *H. atra* was found to be the most abundant compared to other species. The average diversity index was 1.46, belonging to moderate conditions. The

habitat was still good for the echinoderm communities.

#### ACKNOWLEDGEMENTS

The authors wish to extend our gratitude to Karimunjawa National Park Authority for the research permits, as well as to the Research Team of the Marine Science Department of Diponegoro University (Thiani, Deto, Wirda, and Widi) for their cooperation and help during fieldwork. There is no funding involve in this research.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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