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Community Structure of Echinoderms on Bunaken Island, North Sulawesi

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ABSTRACT. Echinodermata are marine invertebrates characterized by their spiny skin, free-living and solitary nature, inhabiting zones ranging from the intertidal to the deep sea. This study aims to examine the community structure of Echinodermata in the waters of Bunaken Island. Data collection was focused on a single observation station and conducted over two days with an effective sampling duration of one hour per day (11:00–12:00 WITA). The study employed a *Timed Roving Survey* method along a habitat gradient, starting with wading techniques in the intertidal zone and continuing with visual census via snorkeling up to a depth of ± 2 meters. Specimens were identified referring to Susetiono (2004) and the World Register of Marine Species (WoRMS) database. The results recorded the presence of 8 species encompassing five major classes: Asteroidea, Crinoidea, Echinoidea, Holothuroidea, and Ophiuroidea. Based on the analysis, the ecological indices obtained were a diversity index of 1.82, an evenness index of 0,87, and a dominance index of 0.19. These values indicate that the Echinodermata community at the study site is in a stable condition, characterized by high uniformity and the absence of specific species dominance within the habitat.
Keyword : Echinoderms, Bunaken, timed roving survey, intertidal, community

INTRODUCTION

The intertidal zone is a transitional area between marine and terrestrial ecosystems characterized by highly dynamic environmental conditions. This zone extends between the highest high tide and the lowest low tide and experiences strong fluctuations in physical and chemical parameters, including temperature, salinity, and wave exposure (Nybakken, 1988). Such variability creates heterogeneous habitats that support high biodiversity, particularly among benthic marine invertebrates (Smith & Roberts, 2020).

Echinoderms are marine invertebrates characterized by a spiny integument, radial body symmetry, and a calcareous endoskeleton. They are free-living and generally solitary, with a wide distribution ranging from shallow coastal waters to depths of approximately 366 m. Echinoderms are especially abundant in coral reef and seagrass ecosystems, where habitat complexity provides shelter and food resources (Jasin, 1984). A notable biological trait of this group is their ability to undergo autotomy and regenerate lost body parts, enhancing survival in physically stressful environments (Clark & Rowden, 2021). Natural predators of echinoderms are relatively limited, consisting mainly of fishes and humans (BTNB, 2010).

Ecologically, echinoderms play an important role in marine ecosystems as components of food webs and regulators of benthic processes. Many species function as detritivores and sediment processors,

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contributing to nutrient recycling and the redistribution of organic matter on the seafloor (Dahuri, 2003; Rossi & Gambi, 2020). Recent studies have highlighted that echinoderm feeding activities influence sediment structure and benthic community composition, particularly in tropical coastal ecosystems (Lee *et al*., 2023).

Based on morphological and anatomical characteristics, the phylum Echinodermata is classified into five major classes: Asteroidea, Ophiuroidea, Echinoidea, Crinoidea, and Holothuroidea (Jasin, 1984). Although echinoderms inhabit a wide range of marine environments, their abundance and diversity tend to be higher in intertidal zones, especially in rocky shores and coral reef flats. High habitat complexity in these areas provides diverse microhabitats that support echinoderm assemblages and influence their population dynamics (Nybakken, 1987; Smith & Roberts, 2020).

The waters of Bunaken Island are globally recognized as part of the Coral Triangle region, known for exceptionally high marine biodiversity. While numerous studies in this area have focused on coral reefs and reef fish communities, quantitative assessments of echinoderm community structure remain limited. This gap is notable

Sampling Design and Data Collection

Data collection was focused on a single observation station representing intertidal and shallow subtidal habitats. Sampling was conducted over two consecutive days with an effective observation duration of one hour per day (11:00–12:00 WITA). The survey employed a *Timed Roving Survey* (TRS) method, which allows flexible exploration of habitat gradients within a fixed time period.

Observations began in the intertidal zone using a wading technique and continued into shallow waters using snorkeling at depths of approximately ±2 m. All echinoderm individuals encountered within the survey area during the allocated time were recorded and photographed *in situ*. This approach enabled direct documentation of species presence while minimizing disturbance to the habitat.

given the sensitivity of echinoderms to habitat degradation and environmental stressors, which makes them valuable indicators of coastal ecosystem condition (Rossi & Gambi, 2020; Lee *et al*., 2023).

Therefore, this study aims to analyze the community structure of echinoderms in the intertidal and shallow subtidal waters of Bunaken Island, including species composition, population density, diversity, evenness, and dominance indices. The results are expected to provide baseline ecological data that support long-term monitoring and sustainable management of coastal ecosystems within the Bunaken conservation area.

METHODS

Study Area and Period

This study was conducted in the intertidal waters of Bunaken Island, North Sulawesi Province, Indonesia, on 7–8 November 2025. Bunaken Island is part of a marine conservation area characterized by coral reef ecosystems, rocky intertidal substrates, and relatively high biodiversity. Sampling was carried out during daytime conditions at low to

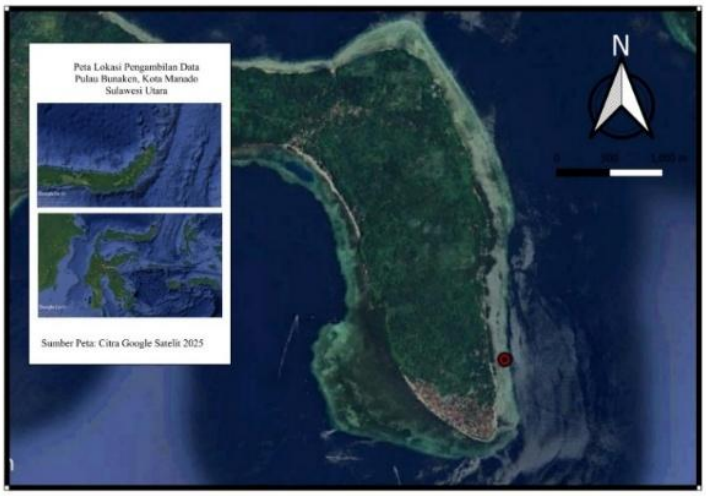


Figure 1. Map of the study area on Bunaken Island, North Sulawesi, Indonesia.

rising tide to allow optimal access to the intertidal zone. The study area is shown in Figure 1.

Data Analysis

Species Density

Species density was calculated following the method described by Krebs (1989) using the following equation:

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

Where:
K = species density (ind m^{-2}),
n_i = number of individuals of species i,
A = total surveyed area (m^2).

Species Diversity Index

Species diversity was calculated using the Shannon–Wiener diversity index (Krebs, 1989), expressed as:

$$H' = -\sum Pi \ ln \ Pi$$

Where:
H' = Shannon-Wiener species diversity index;
Pi = ni / N;
Pi = Number of individuals of the i-th species;
Ni = Number of individuals of the i-th species; and
N = Total number of individuals of all species.

With the diversity index criteria divided into 3 categories, namely:
H' < 1 : Low diversity and low community
1.0 < H < 3 : Moderate diversity and moderate community stability
H' > 3 : High diversity and high community stability

Evenness Index

Species evenness was calculated to describe the distribution of individuals among species using the evenness index (Fachrul, 2007):

$$e = \frac{H'}{InS}$$

Where:
E = evenness index,
H' = Shannon–Wiener diversity index,
S = total number of species.

Evenness values were classified as follows:

- $E < 0.4$: low evenness
- $0.4 \leq E \leq 0.6$: moderate evenness
- $E > 0.6$: high evenness

Dominance Index

Species dominance was assessed using Simpson's dominance index (Krebs, 1989),

calculated as:

$$\boldsymbol{D} = \sum[\ \boldsymbol{ni}\ \boldsymbol{N}\ ]\ \mathbf{2}\ \boldsymbol{n}$$

Where:
D = Simpson's dominance index,
n_i = number of individuals of species *i*,
N = total number of individuals of all species.

Dominance was interpreted as follows (Dairivaldo *et al*., 2025):

- *D* < 0.5: no species dominance
- *D* ≥ 0.5: presence of dominant species

RESULTS AND DISCUSSION

Species Composition of Echinoderms

A total of eight echinoderm species were recorded during the survey in the intertidal and shallow subtidal waters of Bunaken Island. These species represented five classes: Crinoidea (two species), Echinoidea (one species), Holothuroidea (one species), Asteroidea (three species), and Ophiuroidea (one species) (Table 1). The presence of all five echinoderm classes indicates that the study area provides suitable habitat conditions to support a relatively complete echinoderm assemblage despite the limited spatial scale of observation.

Compared to previous studies conducted in other coastal areas of North Sulawesi, the number of species recorded in this study was relatively lower. Earlier research reported higher species richness, such as 27 species at Paranti Beach (Lalombombuida *et al*., 2021), 18 species at Tanamon Beach (Tahe *et al*., 2013), 13 species at Basaan Satu Beach (Budiman *et al*., 2014), and 10 species at Mokupa Beach (Kambey *et al*., 2015). Differences in species richness may be attributed to variations in habitat complexity, sampling intensity, spatial coverage, and local environmental conditions. Coral reef ecosystems, in particular, are known to provide critical habitat for echinoderms by offering shelter, food resources, and protection from predators (Yusron, 2006; BTNB, 2010).

This study was restricted to a specific intertidal zone and therefore covered only a small portion of the habitats available on Bunaken Island. In contrast, previous studies may have surveyed broader areas encompassing a variety of habitat types, including seagrass beds, sandy substrates, coral rubble, and coral reef ecosystems, which provide a wider range of ecological niches for echinoderms. Furthermore, several echinoderm species in Bunaken waters are commonly associated with

Table 1. Classification of echinoderms recorded on Bunaken island

Classification				
Class	Ordo	Family	Genus	Species
Crinoidea	Comatulida	Comatulidae	*Anneissia*	*A. bennetti* (Müller, 1841)
Crinoidea	Comatulida	Comatulidae	*Comaster*	*C. schlegelii* (Carpenter, 1881)
Echinoidea	Diadematoida	Diadematidae	*Diadema*	*D. setosum* (Leske, 1778)
Holothuroidea	Holothuriida	Holothuriidae	*Holothuria*	*H. atra* Jaeger, 1833
Asteroidea	Valvatida	Ophidiasteridae	*Linckia*	*L. laevigata* (Linnaeus, 1758)
Asteroidea	Valvatida	Ophidiasteridae	*Linckia*	*L. multifora* (Lamarck, 1816)
Ophiuridea	Ophiacanthida	Ophiocomidae	*Ophiocoma*	*O. scolopendrina* (Lamarck, 1816)
Asteroidea	Valvatida	Oreasteridae	*Protoreaster*	*P. nodosus* (Linnaeus, 1758)

subtidal habitats and deeper reef environments. Consequently, surveys limited to the intertidal zone may not capture the full diversity of echinoderm species present in the area.

Echinoderms generally exhibit cryptic behavior, occupying microhabitats such as crevices, bene ath coral rubble, or within sandy substrates. Some species, however, are more exposed and may be found moving freely on open substrates or forming aggregations. Many echinoderms are nocturnal, becoming more active at night to forage and reduce predation risk (Brusca, 2003). These behavioral traits likely influenced detectability during daytime surveys and may partly explain the relatively low species richness recorded in this study.

Species Density

Species density varied among the recorded echinoderms (Figure 2). The highest density values were observed for *Linckia laevigata* (0.20 ind m^{-2}) and *Diadema setosum* (0.18 ind m^{-2}). These species are commonly associated with coral reef habitats characterized by hard substrates, which provide suitable surfaces for attachment, movement, and feeding. Their relatively high densities suggest favorable habitat conditions and adequate resource availability within the study area.

In contrast, lower density values were recorded for *Holothuria atra* (0.02 ind m^{-2}), *Linckia multifora*, and *Comaster schlegelii*. The low density of *H. atra* may be related to its preference for sandy substrates and its vulnerability to environmental disturbances, whereas the relatively low abundance of other species may reflect habitat specificity or limited competitive ability. Aziz (1991) noted that species with low economic value tend to experience minimal harvesting pressure, suggesting that density patterns are more strongly influenced by ecological factors than by exploitation.

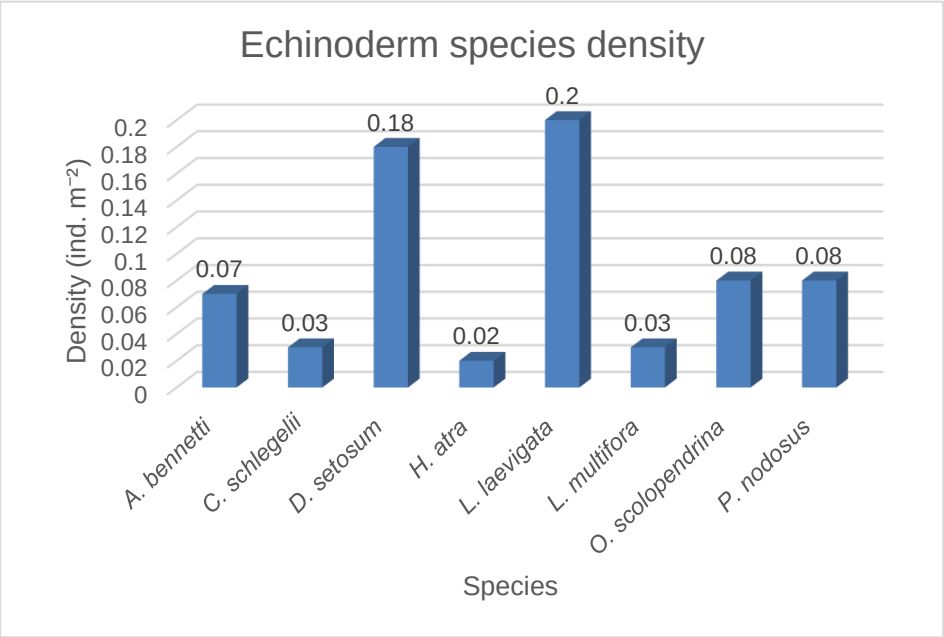


Figure 2. Species density of echinoderms on Bunaken island

Environmental factors such as depth, wave exposure, sediment type, and benthic composition play an important role in shaping echinoderm distribution and population density (Bauer, 1980; Muthiga & McClanahan, 2007). In shallow coastal environments, competition for space and resources may further regulate population size and spatial distribution (McClanahan, 1992; Carpenter & Edmunds, 2006; Lessios, 2016).

Ecological Indices

The calculated ecological indices indicated moderate diversity and high community stability. The Shannon–Wiener diversity index (H') was 1.82, the evenness index (E) was 0.87, and the dominance index (D) was 0.19 (Figure 3). According to established criteria, an H' value between 1 and 3 reflects moderate diversity and suggests a relatively stable community structure.

High evenness values indicate that individuals were relatively evenly distributed among species, with no single species dominating the community. This pattern suggests balanced resource utilization and limited competitive exclusion within the echinoderm assemblage (Supono & Arbi, 2010; Ompi *et al*., 2023a). Conversely, low dominance values further support the absence of dominant species, which is often associated with stable and undisturbed ecological conditions (Odum, 1993).

Variations in diversity and evenness indices are influenced by several factors, including species richness, individual abundance, substrate heterogeneity, and the condition of adjacent coastal ecosystems such as coral reefs, seagrass beds, and mangroves (Sinyo & Idris, 2013; Wahab *et al*., 2018). Communities characterized by uneven individual distribution tend to exhibit lower diversity values, even when species richness is relatively high, indicating ecological stress or disturbance.

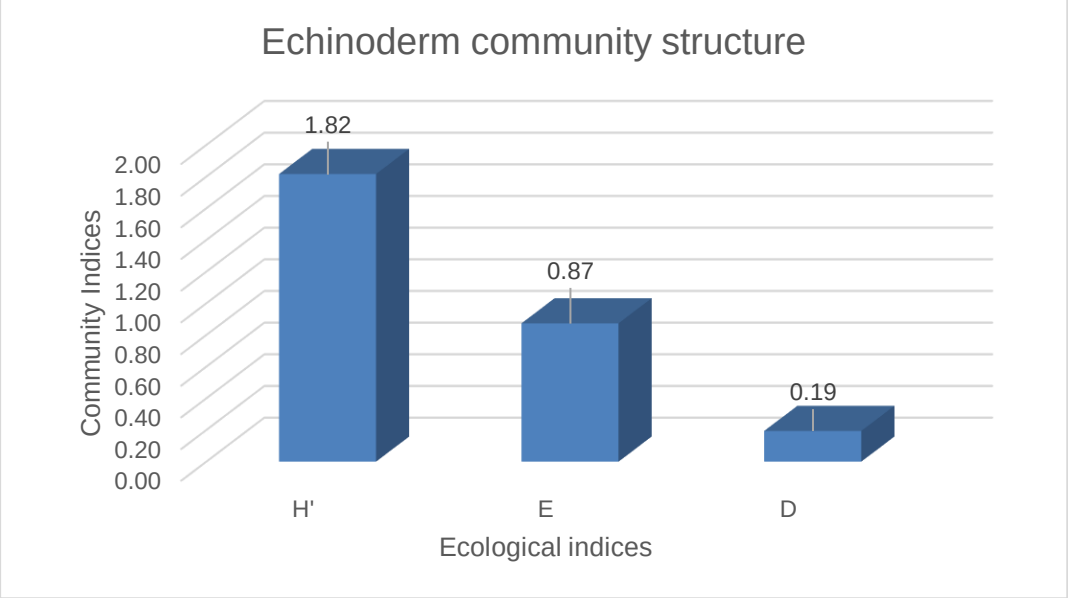


Figure 3. Ecological indices of echinoderms on Bunaken island

Overall, the ecological index values obtained in this study suggest that the echinoderm community in the study area is in a relatively stable condition, with high evenness and low dominance. These findings reinforce the role of echinoderms as useful indicators of ecosystem condition and highlight the importance of maintaining habitat integrity within coastal conservation areas.

CONCLUSION

This study documented eight echinoderm species belonging to five classes—Crinoidea, Echinoidea, Holothuroidea, Asteroidea, and Ophiuroidea—in the intertidal and shallow subtidal waters of Bunaken Island. The occurrence of all five classes indicates that the study area is capable of supporting a representative echinoderm assemblage at the local scale.

The ecological indices revealed a moderate level of species diversity (H' = 1.82), high evenness (E = 0.87), and low dominance (D = 0.19), reflecting a relatively stable community structure with no single species dominating the assemblage. These patterns suggest balanced species distribution and favorable environmental conditions for echinoderm communities.

The results of this study provide baseline ecological information on echinoderm community structure in Bunaken Island waters. This baseline data may serve as a reference for future ecological assessments and long-term monitoring programs, as well as support evidence-based management and conservation strategies in coastal and marine protected areas.

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