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Community Structure of Sea Urchins (Echinoidea) in the Intertidal Zone of Thomas Beach, Uluwatu

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Abstract. Thomas Beach, located in Uluwatu, Province of Bali, is a rocky shore inhabited by sea urchins. The research aims to discover the habitat characteristics and community structure of sea urchins (Echinoidea) in the intertidal zone of Thomas Beach. Data collection was conducted from April to May 2023 during the lowest tide. A quantitative method with modified line transects was used for data collection. Data collected included the number and species of sea urchins, water quality parameters (temperature, salinity, pH, dissolved oxygen, water clarity, and depth), and substrate types. Data were analyzed using Microsoft Excel, including individual density, diversity index, uniformity index, and dominance index. The research findings revealed five species of sea urchins: *Echinotrix calamaris, Echinometra oblonga, Echinometra mathaei*, *Tripneustes gratilla*, and *Stomopneustes variolaris*. The highest density of sea urchins was found in *E. oblonga* (16.91 ind/m^2). The diversity index values ranged from 0.4936 to 0.8721, indicating a low level of diversity. The uniformity index values ranged from 0.4493 to 0.784, suggesting the community is relatively unstable. The dominance index values ranged from 0.5036 to 0.7166, indicating a moderate level of dominance. The aquatic habitat characteristics, based on the research findings, it was determined that a temperature of 30℃, salinity ranging from 31.77 to 32.76, pH of 8, dissolved oxygen (DO) of 5 mg/l, water clarity of 100%, and a depth ranging from 8.4 to 33.93 cm. The substrate type was rocky at station 1, sandy with seagrass at station 2, and rocky sandy at station 3.

***Keywords*:** Coastal Characteristic; Rocky Shore; Line Transect.

I. INTRODUCTION

The Echinoidea class, commonly known as sea urchins or 'Bulu Babi', originate from the Echinodermata phylum. Echinodermata stems from Greek: *'echinos'* meaning spine and *'derma'* meaning skin; therefore, Echinodermata can be interpreted as animals with spiny skin. The spines on sea urchins protect from predators and are locomotive tools [1].

Sea urchins prefer somewhat hard substrates, typically a mixture of sand and coral [2]. Their distribution ranges from shallow intertidal waters to deeper marine environments. Reference [3] states that sea urchins thrive in rocky coastal areas and spend most of their lives in burrows - either self-dug, made by other organisms, or naturally formed.

One such rocky shore in Bali inhabited by sea urchin species is Thomas Beach, located in the Uluwatu region. No specific research on the community structure of sea urchins in Thomas Beach has been conducted, resulting in very limited information. Therefore, additional research is necessary to enhance our understanding of this topic.

II. RESEARCH METHODS

A. Time and Place of Research

The study was conducted at Thomas Beach, Uluwatu, in April - May 2023. Data collection was based on predetermined stations using purposive sampling. Along the Thomas Beach coastline, three station points were chosen based on locations considered to represent the presence of sea urchins in the intertidal zone of Thomas Beach, Uluwatu. The station locations can be seen in Figure 1.

B. Research Methods

The research tools used were as follows: a ruler, a salinity refractometer, a digital pH meter, a digital Dissolved Oxygen (DO) meter, a Secchi disk, a roll meter, a scaled pipe, a Garmin 78s GPS, a laptop, a mobile phone, tissue, a snorkel, the identification book "Encyclopedia of

Echinoidea at Laiwila Beach in East Sumba," and a quadrant transect.

Figure. 1. Research Location Map.

The research was conducted using a quantitative method employing a modified line transect. According to reference [4], observations of the research object used a modified line transect method, which involved observing subjects at equal distances along the transect line and the transect square, with observations taking place 2.5m to the right and left of the line transect. A schematic example of transect placement can be seen in Figure 2.

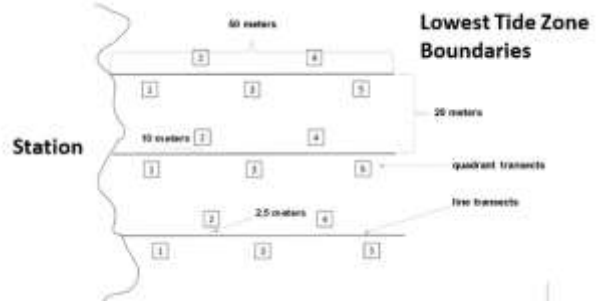

Figure. 2. Schematic Example of Transect Placement at Each Station.

There were 3 transect lines at each station, each 50 meters long, stretched perpendicular to the beach. Each stretched transect line contained 5 quadrant transects measuring 1m x 1m. A descriptive analysis was used to examine the habitat characteristics of sea urchins at Thomas Beach, Uluwatu, by describing the conditions of the sea urchins, water quality, and substrate types in the field based on literature.

C. Research Parameters

a. Water Quality and Substrate Type

The water quality data analysis included temperature, salinity, pH, dissolved oxygen (DO), depth, and clarity to understand the habitat water quality of the sea urchins in the intertidal zone of Thomas Beach, Uluwatu. Water quality measurements were performed *in situ.* Visual observations were conducted to determine the substrate type in the intertidal zone of Thomas Beach, Uluwatu.

b. Sea Urchin Community

The sea urchin community measured the density of sea urchins to determine the number of sea urchins in each quadrant transect. The indices measured included the diversity, uniformity, and dominance indexes. Density is the number of individuals of a species divided by the total area sampled [5] with the following equation:

$$Di = \frac{ni}{A}$$

Noted: Di is the density of individuals of species i (individuals /m²); ni is the number of individuals of species i obtained; and A is the total sampling area.

The diversity of species was calculated using the Shannon-Wiener Diversity Index, which is based on a logarithm to base two [6] with the following formula:

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

Noted: H' is the Shannon-Wiener diversity index, Pi is the probability of species-i out of the total individuals, and S is the number of species.

The interpretation of the diversity index refers to the following Table 1:

TABLE 1
DIVERSITY INDEX

Diversity Index	Description
$H' \leq 1$	Low species diversity
$1 < H' \leq 3$	Medium species diversity
$H' > 3$	High species diversity

The uniformity index value is used to describe the composition of individuals of each species found in a community, calculated using the guideline [5] as follows:

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

Noted: E is the uniformity index; H' is the Shannon-Wiener diversity index; and H'max is the maximum value of the diversity index. The interpretation of the uniformity index refers to the following Table 2:

TABLE 2
UNIFORMITY INDEX

Uniformity Index	Description
$0 < E \leq 0.5$	Suppressed community
$0.5 < E \leq 0.75$	Unstable community
$0.75 < E \leq 1.0$	Stable community

The dominance index value describes whether a certain species dominates in a community. It is calculated using the Simpson's dominance index [5] as follows:

$$C = \sum_{i-1}^{s} Pi^2$$

Noted: C is the Simpson's dominance index; s is the number of species; and Pi is ni/N. The interpretation of the dominance index refers to the following Table 3:

TABLE 3
DOMINANCE INDEX

Dominance Index	Description
$0 < E \leq 0.5$	Low dominance
$0.5 < E \leq 0.75$	Medium dominance
$0.75 < E \leq 1.0$	High dominance

III. RESULT AND DISCUSSION

A. Physical-Chemical Characteristics of the Waters

The results of the physical and chemical parameter observations at all three data collection locations and seawater quality standards according to the Government Regulation of the Republic of Indonesia Number 22 of 2021 yielded the following average results from all three stations.

TABLE 4
AVERAGE PHYSICAL-CHEMICAL CHARACTERISTICS OF THE WATERS AT THREE STATIONS.

Parameters	Stations			Quality Standard
	Station 1	Station 2	Station 3	
Temperature (℃)	30,63 ± 1,54	30,39 ± 0,91	30,01 ± 1,22	28-32
Salinity (‰)	32,2 ± 1,52	31,77 ± 1,83	32,76 ± 1,58	34
pH	8,19 ± 0,51	8,49 ± 0,04	8,27 ± 0,54	7-8,5
DO (mg/l)	5,87 ± 0,59	5,69 ± 0,18	5,81 ± 0,3	>5
Clarity (%)	100 ± 0	100 ± 0	100 ± 0	-
Water depth (cm)	8,4 ± 2,86	18,15 ± 3,32	33,93 ± 11,72	-

The three observation stations recorded an average temperature of 30℃ (Table 4) with salinity ranging between 31.77-32.2‰. The pH of the waters at all three stations was around 8, with dissolved oxygen (DO) levels at 5 mg/l. Clarity was 100% at all depths at all three stations. The average depth ranged between 8.4 and 33.93 cm.

The temperature in the waters of Thomas Beach is around 30℃ at all three observation stations (Table 4). Sea urchins can live at optimum temperatures of 20-31℃ and will experience population disturbances at temperatures below 10℃ [7]. The waters of Thomas Beach have a salinity value ranging from 31-32‰. This aligns with reference [8], which stated that 34‰ is the maximum salinity limit that is good for the life of sea urchins. The pH value in the waters of Thomas Beach is around 8 at all three observation stations. A pH value ranging from 7.5 to 8.5 is the ideal water pH for the life of sea urchins [9].

The average dissolved oxygen (DO) value at the three observation stations is around 5 mg/l. This is in line with reference [10] stated that waters with DO >5 mg/l support the life of sea urchins. The clarity level of the waters at Thomas Beach at all three stations shows a value of 100%, meaning that light can reach the bottom of the water. Water that is not too clear and not too turbid is good for aquatic life [11]. The average depth in the intertidal zone of Thomas Beach ranges from 8.4-33.93 cm at the lowest ebb; according to reference [12], sea urchins can be found from the tidal zone to a depth of 5000 meters.

B. Substrate Characteristics

The intertidal zone of Thomas Beach, Uluwatu, has several different types of substrates at each station. Station 1 has rock and sandy dead coral substrates, where three species of sea urchins were found: *Echinometra oblonga*, *Echinometra mathaei*, and *Stomopneustes variolaris*. The substrate documentation at station 1 can be seen in Figure 3.

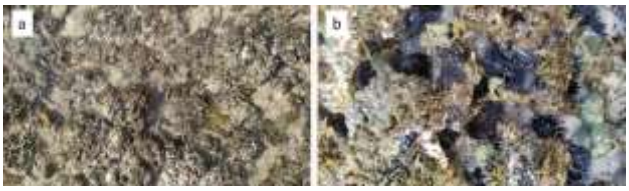

Figure. 3. Station 1 Substrate Documentation.
a) Zoom Out; b) Zoom In

Along the coastline of the intertidal zone of Thomas Beach, there are diverse substrates. Station 1's water substrate is rocks and sandy dead corals (Figure 3). Many *Echinometra oblonga* and *Echinometra mathaei* sea urchins were found at this station, specifically in the crevices of the rocks and dead corals. Reference [13] mentioned that the habitat of *E. mathaei* species is in the holes of dead corals to hide from predators.

The substrate at Station 2 on Thomas Beach, Uluwatu, is characterized by sandy seagrass and some rocks. Five sea urchin species were found at station 2, including *Echinometra oblonga, Echinometra mathaei, Stomopneustes variolaris, Echinotrix calamaris,* and *Tripneustes gratilla.* The substrate at station 2 can be seen in Figure 4.

Figure. 4. Station 2 Substrate Documentation.
a) Zoom Out; b) Zoom In

Station 2 has a sandy seagrass substrate characteristic with a few rocks (Figure 4). More types of sea urchin species were found at this station compared to the other two stations. One of the factors for the higher number of

species found is the influence of the more varied substrate at that station. The more diverse the substrate in a body of water, the more diverse the species of sea urchins that can be found in that water [14].

Station 3 (figure 5) has a stony sand substrate with a little seagrass. *Echinometra oblonga, Echinometra mathaei, and Echinotrix calamaris* are the three species of sea urchins found at station 3. The documentation of the substrate characteristics at station 3 can be seen in Figure 5.

Figure. 5. Station 3 Substrate Documentation.
a) Zoom Out; b) Zoom In

The *Echinotrix calamaris* species was found more at station 3 than the other two. This is presumably because *E. calamaris* prefers habitats dominated by sand and rocks like the substrate at station 3. According to reference [13], the habitat of *E. calamaris* is in sandy areas with seagrass fields and macroalgae.

C. Density of Sea Urchin

The sea urchins in Thomas Beach, Uluwatu's intertidal zone, comprise 5 species. The lowest sea urchin density values from each station on Thomas Beach are *T. gratilla* and *S. variolates*, with a density value of 0.02 and/m^2. The sea urchin density values on Thomas Beach can be seen in Table 5.

TABLE 5
SEA URCHIN DENSITY VALUES

No	Family	Genus	Species	Sea Urchin Density Value/m^2		
				Station 1	Station 2	Station 3
1	Diadematidae	*Echinotrix*	*Echinotrix calamaris*	0	0.33	0.75
2	Echinometridae	*Echinometra*	*Echinometra oblonga*	16.91	0.53	0.95
3	Echinometridae	*Echinometra*	*Echinometra mathaei*	3.2	2.11	3.46
4	Toxopneustidae	*Tripneustes*	*Tripneustes gratilla*	0	0.02	0
5	Stomopneustidae	*Stomopneustes*	*Stomopneustes variolaris*	0.22	0.02	0

The highest sea urchin density was found in the species *E. oblonga* with a 16.91 ind/m2 value. Followed by the species *E. mathaei* with a value of 3.46 ind/m^2. The species *T. gratilla* and *S. variolaris* have the lowest density values of 0.02 ind/m^2.

There are 5 species of sea urchins found in the intertidal zone of Thomas Beach. The high density of this species is presumably because it has a suitable habitat, and its location is still largely untouched by tourists. According to reference [15], *E. oblonga* is often found hiding in crevices and holes of dead corals that are relatively narrow; conditions of substrate and environment like this support the life of *E. oblonga* species.

D. Sea Urchins Diversity, Uniformity, and Dominance Index

From the calculation of the diversity index (H'), it was found that the sea urchins at all three research stations have low diversity, that is, H' < 1. The uniformity index (E) has different results at all three stations, and the dominance index (C) is categorized as medium, 0.5 < C < 0.75. The values of the diversity, uniformity, and dominance indices of sea urchins at Thomas Beach, Uluwatu, can be seen in Table 6.

TABLE 6
DIVERSITY (H'), UNIFORMITY (E), AND DOMINANCE (C) INDEX VALUES OF SEA URCHINS AT THOMAS BEACH, ULUWATU

Community Index	Station		
	1	2	3
H'	0,4936 (low)	0,8721 (low)	0,8613 (low)
E	0,4493 (suppressed)	0,5418 (unstable)	0,784 (stable)
C	0,7166 (medium)	0,5313 (medium)	0,5036 (medium)

The diversity index (H') of sea urchins at Thomas Beach is counted as low with a value of H' < 1. The cause of this is the small number of sea urchin species found and the low-density values that make up the community [5]. Sea urchins' uniformity index (E) has different values at the three stations. Station 1 has a suppressed community condition (E < 0.5), this is caused by the species *E. oblonga* having a much higher density value compared to other sea urchin species found at station 1 (Table 5).

Unlike station 1, the community condition at station 2 is considered unstable (0.5 < E < 0.75). This is due to the greater number of species found at station 2, and there is no species that overly dominates. The community condition at station 3 is considered stable (E > 0.75). This is due to no sea urchin species overly dominating at station 3. The dominance index (C) at all three stations is considered medium (0.5 < C < 0.75). Among the three stations, station 1 is almost approaching a high dominance value (C > 0.75). The *E. oblonga* species has a significantly higher density value than other species at station 1 (Table 5).

IV. CONCLUSION

The habitat characteristics of sea urchins (Echinoidea) in the intertidal zone of Thomas Beach, Uluwatu, have average values of temperature 30°C, salinity 31.77 – 32.76, acidity (pH) 8, dissolved oxygen (DO) 5 mg/l, clarity 100% with a depth ranging from 8.4 cm – 33.93 cm. This indicates that the water conditions are ideal for the life of sea urchins (Echinoidea). Each observation station has different substrate characteristics. Station 1 is dominated by rocky substrate and sandy dead corals, station 2 is dominated by sandy substrate with seagrass and a little

rock, and station 3 is dominated by sandy substrate with rocks and a little seagrass.

Five species of sea urchins were found in the intertidal zone of Thomas Beach, Uluwatu, namely *Echinometra oblonga*, *Echinometra mathaei*, *Stomopneustes variolaris*, *Echinotrix calamaris*, and *Tripneustes gratilla*. The highest density of sea urchins is dominated by the species *E. oblonga* with a value of 16.91 ind/m^2. Thomas Beach has a low diversity index value ranging from 0.4936 – 0.8721. The uniformity index ranges from 0.4493 – 0.784, which is considered unstable. The dominance index is considered medium, with values ranging from 0.5036-0.7166.

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