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Echinoderms Community Structure in Pegametan Bay, Buleleng, Bali

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Abstract. Echinoderms are key ecological organisms that play a protective role in balancing the marine ecosystem by breaking down trash or leftover organic material that is not used by other species. Echinoderms are marine biota that are sensitive to changes in water characteristics, so they can be used as bioindicators. Echinoderm habitats can be found in all marine ecosystems, but the highest diversity is found in intertidal areas, which are easily affected by land activity. One of the intertidal areas that is often used by humans is the Bay Area. This research aims to find out the types of echinoderms and analyze the community structure of echinoderms in Pegametan Bay, Bali. The research was carried out using the method of line transect at 18 points for data on the number and types of echinoderms in depth 1x1 m quadrat transect. Based on the observations, it was found that there are 3 classes of echinoderms that live on Bingin Beach (Echinoidea, Asteroidea, and Holothuroidea) with 3 orders, namely Diadematoida, Valvatida, and Holothuriida. The most commonly found species is D. setosum from the Echinoidea class. The structure of the echinoderm community in Pegametan Bay is shown by an average density value of 12.60 ind/m² with a diversity index value of 0.46, which is classified as low diversity; a uniformity index value of 0.36, which is relatively low; and a dominance index of 0.73, which is relatively high. Based on the results obtained, it can be concluded that the diversity index in Pegametan Bay is low, the evenness index is relatively low, and the dominance index is high. The values of temperature, pH, dissolved oxygen (DO), and salinity are still within the standard limits for marine biota.

***Keywords*:** community structure; echinoderms; ecology; pegametan bay

I. INTRODUCTION

Echinoderms are one of the key organisms that determine the biodiversity conditions of marine ecosystems within a food web, serving as herbivores, carnivores, omnivores, or detritivores [1]. According to [2], ecologically, echinoderms play a crucial role in the food chain as keystone organisms that maintain the balance of marine ecosystems by breaking down waste or organic matter leftovers unused by other species, detritus feeders, and other small animals. They also serve as nutrient recyclers, indirectly involved in cleansing marine ecosystems, especially in intertidal or coastal areas. Echinoderms are also marine biota sensitive to any changes in water characteristics, thus serving as bioindicators for assessing the quality and ecological conditions of aquatic ecosystems [3].

The habitat of echinoderms can be found in almost all marine ecosystems, ranging from intertidal areas to deep waters with depths between 0.5 to 40 meters. However, the highest diversity of echinoderms is found in the intertidal zone and shallow coasts [4]. Intertidal or coastal areas are still influenced by terrestrial factors, making them susceptible to human activities. One such area is the vicinity of bays, which are strategically located and heavily utilized by coastal communities for fishing ports and aquaculture, such as Pegametan Bay.

Pegametan Bay is situated in the northwest part of Bali Island, precisely in the Sumberkima Village, Gerokgak District, Buleleng Regency, covering an area of approximately 1,160 km² [5]. The strategic location of Pegametan Bay directly impacts the increasing human activities in the surrounding areas, particularly in aquaculture. These activities may have adverse effects on

the sustainability of intertidal ecosystems in Pegametan Bay, including influencing the structure of echinoderm communities. Hence, research on the echinoderm community structure in the intertidal waters of Pegametan Bay is necessary to gather further information on abundance, diversity indices, evenness indices, and dominance indices present in Pegametan Bay.

Furthermore, research on the Echinodermata Community Structure in the northern waters of Bali has not been conducted. Previous studies have generally been limited to discussing Echinodermata Community Structures in the southern Bali region, such as Wahyuningsih's (2014) study on Echinodermata Community Structure at Samuh Beach and Caraka's (2023) research on Echinodermata at Thomas Beach. Additionally, Sumiarsa and Nugraha (2009) conducted research on copepod abundance in Pegametan Bay, and while there have been studies on the abundance of the Echinodermata Phylum, they were not specifically focused on echinoderms alone due to the broader scope of investigating macrozoobenthos in Pegametan Bay, as seen in Slamet and Arthana's (2007) research.

II. METHODS

Research Period and Location

The study on the echinoderm community structure was conducted in Pegametan Bay, Buleleng, Bali. Data collection took place in November 2023. The research sites were divided into 6 stations with 18 sampling points

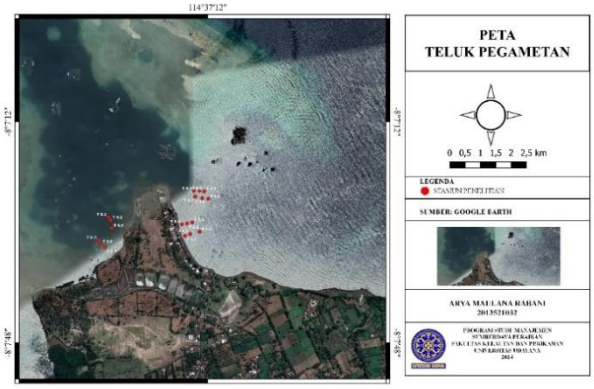

Figure 1. Location

Data Sampling Method

Format and save your graphic images using a suitable graphics processing program that will allow you to create the images (Fig. 1). Most charts, graphs, and tables are one column wide (3 1/2 inches or 21 picas) or two-column wide (7 1/16 inches, 43 picas). We recommend that you avoid sizing figures less than one column wide, as extreme enlargements may distort your images and result in poor reproduction. Therefore, it is better if the image is slightly larger, as a minor reduction in size should not hurt the quality of the image.

This research utilizes a quantitative descriptive research method. The determination of sampling points employs a purposive sampling method. This method is a technique used to select research stations based on specific considerations to ensure the obtained data are more representative [6]. The research stations are divided based on three characteristics: first, Stations 1 and 2 have rocky coral substrates; second, Stations 3 and 4 have sandy coral substrates; and third, Stations 5 and 6 have sandy substrates. Each station is further divided into 3 sampling points, with a distance of approximately 20 meters between each point. Each characteristic is represented by 2 stations (resulting in 6 sampling points). During sampling, water quality is measured, including parameters such as salinity, temperature, pH, dissolved oxygen (DO), and substrate characteristics.

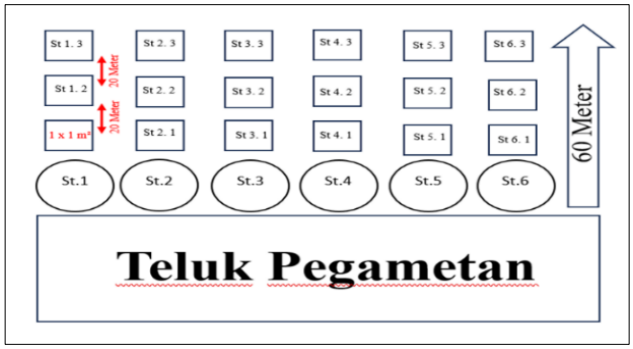

Figure 2. Sampling Procedures

Data Analysis

The field observations are then analyzed using the following formulas:

Abudance

The abundance analysis of Echinodermata is calculated using the abundance index analysis [7].

$$K = \frac{Ni}{A}$$

K: Abundance of Echinoderm (individuals/m^2)
Ni: The number of individuals of a species
A: Area (m^2)

Diversity Index (H')

The diversity value can be determined using the Diversity Index (H'). Diversity can be described as the number of Echinodermata species found in a sampling area. Diversity calculation can utilize the Shannon-Wiener diversity index formula [8] as follows:

$$H' = -\sum_{i=1}^{n} pi \ln pi$$

Pi: ni/N
Ni: Number of individuals -i
N: The number of individuals of a species

The criteria for species diversity index values according to Shannon-Wiener (H') are defined as shown in Table 1.

TABLE 1
RANGE OF VALUES FOR DIVERSITY INDEX

No.	Range of index values	Category
1.	H' > 3	High (Stable)
2.	1 < H' <3	Medium
3.	H' < 1	Poor (Not Stable)

Evenness Index

The evenness index represents the composition of individuals of each species within a community. If the index value is high, it indicates that the presence of each biota species is even, and vice versa. Low evenness indicates uneven presence of each species. The evenness index ranges from 0 to 1. The formula for the evenness index [9] is presented in Table 2.

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

E: Evenness index
H': Diversity index
Ln S: Ln S, where S indicates the number of taxa
S: Total of organism species

TABLE 2
RANGE EVENNESS INDEX

No.	Range of index value	Category
1.	0,75 < E ≤ 1	High (stabil)
2.	0,5 < E ≤ 0,75	Medium
3.	0 < E ≤ 0,5	Poor (Not stable)

Dominance Index

The Dominance Index is calculated using the dominance index formula by Simpson [10]:

$$D = \sum_{\cdot}^{\cdot} \left(\cdot \frac{ni}{N}\right)^2$$

D: Dominance index
ni: The number of individuals for each species
n: The total number of individuals across all species

The dominance index is used to indicate the presence of certain biota species that dominate the waters. The dominance index value ranges from 0 to 1. If the value approaches 0 (<0.5), it means no species dominate, or the community is in a stable condition. According to Simpson [11], when the index value approaches 1 (0.5), it means there are dominating species. This indicates that the community's condition is unstable, and pressure has occurred.

TABLE 3
DOMINANCE INDEX

No.	Range of index value	Category
1.	0,75 < C ≤ 1	High (stable)
2.	0,5 < C ≤ 0,75	Medium
3.	0 < C ≤ 0,5	Poor (not stable)

III. RESULTS AND DISCUSSION

Composition Echinoderm in Pegametan Bay

Substrate plays a crucial role in the life of marine organisms, especially for the phylum Echinodermata, as it serves as a habitat, breeding ground, and feeding ground. Based on observations, substrates found in Pegametan Bay include sandy, sandy coral, and rocky coral substrates. The differences in substrates at each station become one of the factors influencing the differences in the abundance of the phylum Echinodermata [12].

TABLE 4
ECHINODERM IN PEGAMETAN BAY

Kelas		Asteroidea		Echinoidea		Holothuroidea		Total individu
Ordo		Valvatida		Diadematoida		Holothuriida		
Familli		Oreasteridae	Ophidiasteridae	Diadematidae		Holothuriidae		
Genus		Protoreaster	Linckia	Diadema	Echinothrix	Holothuria		
Spesies		*P. nodosus*	*L. laevigiata*	*D. setosum*	*E. calamaris*	*H. atra*	*H. hilla*	
Stasiun	1	0	1	42	0	0	0	43
	2	0	3	46	0	0	0	49
	3	10	2	17	0	2	0	31
	4	7	0	13	1	0	1	22
	5	0	0	64	0	0	0	64
	6	3	0	15	0	0	0	18
Jml.		20	6	197	1	2	1	227

The highest percentage composition of Echinodermata classes in Pegametan Bay is observed in the class Echinoidea (87.22%), followed by the class Asteroidea (11.45%), and the class Holothuroidea (1.32%). The class Echinoidea obtains the highest percentage due to its ability to inhabit various substrates present in the Pegametan Bay area, such as sandy substrates, sandy coral, and dead coral reefs. Additionally, it's known that hard substrates like coral rocks dominate the Pegametan Bay area. This is evidenced by the fact that out of 6 stations, 4 stations have characteristics of hard substrates.

Echinoderm Community Structure in Pegametan Bay

The abundance of Echinoderms in Pegametan Bay ranges from 6 ind/m² to the highest of 21.33 ind/m². As for diversity, the lowest recorded value is 0, while the highest is 1.04. In terms of evenness index, the lowest value observed in Teluk Pegametan is 0, with the highest being 0.58. Lastly, the dominance index ranges from a minimum of 0.41 to a maximum of 1 in Pegametan Bay.

TABLE 5
ECHINODERM COMMUNITY IN PEGAMETAN BAY

Community Structure				
Station	Abudance	Diversity	Evenness	Dominance
1	14.33	0.11 (Low)	0.15 (Low)	0.95 (T)
2	16.33	0.23 (Low)	0.33 (Low)	0.88 (High)
3	10.33	1.04 (Medium)	0.75 (Hig)	0.41 (Low)
4	7.33	0.95 (Low)	0.68 (Medium)	0.45 (Low)
5	21.33	0 (Low)	0 (Low)	1 (High)
6	6	0.45 (Low)	0.25 (Low)	0.72 (Medium)

The sandy substrate in the study is represented by stations 5 and 6. Despite both stations having the same substrate type and level of community activities, they exhibit a significant difference in the abundance of Echinodermata. This difference is suspected to be caused by the location of station 6, which is near the downstream part of the river, where anthropogenic waste from the local community is discharged. This is evidenced by the lowest dissolved oxygen (DO) concentration recorded at this station, which is 6.1 mg/l compared to other stations. Ultimately, this affects the abundance of Echinoderms at Station 6. This is supported by the statement of Zulkifli *et al.* (2011) [18], which mentions that abiotic variables have a significant impact on the abundance of Echinoderm, which have unique ways of seeking suitable habitats.

Next, in the dead rocky coral substrate represented by stations 2 and 1, both of these stations exhibit the highest abundance of Echinoderm right after station 5. These stations have dead coral and hard rocks as substrates, which serve as shelter and food sources for the class Echinoidea. This is reflected in the abundant presence of *Diadema setosum* species in stations 1 and 2, due to the anatomical characteristics of its short spines, facilitating movement and foraging in narrow coral crevices, while its long spines serve as defense against predators and protect from wave impacts [19].

Furthermore, in the sandy coral substrate represented by stations 3 and 4, the species abundance tends to be lower compared to stations represented by dead rocky coral and sandy substrates, except for station 6. This is because the substrate in both stations only serves as a suitable shelter for certain species. In coral reef areas, Echinoidea occupy various habitats such as live coral, dead coral, and coral fragments as they tend to hide for protection from predators [13]. *Diadema setosum* plays a role in controlling microalgae populations, which are competitors of coral organisms for space and resources. This species can live solitary or in groups, depending on the species and habitat.

The diversity index, according to the Shannon-Wiener Index, ranges from 0.11 to 1.04 across all six stations. Generally, diversity in Teluk Pegametan tends to be low (unstable) at several stations, except for station 3. Station 3 shows moderate diversity because the found species are relatively evenly distributed and not highly dominant. This is reflected in the discovery of 4 species from the 3 classes of Echinoderm, namely Asteroidea, Holothuroidea, and Echinoidea. According to Binambuni et al. (2019), moderate diversity indicates sufficient productivity, a balanced ecosystem, and moderate ecological pressure. Manson (1981) [20] states that low diversity and community instability can be caused by the dominance of a single species with uneven distribution. Low species diversity indicates low productivity and suggests heavy pressure and an unstable ecosystem at each observation station.

The average value of the Echinoderm evenness index in Pegametan Bay is 0.25, which is considered low. This indicates that the composition of individuals for each species is not uniform. According to Muzaki *et al.* (2019) [21], there is a relationship between organism evenness and dominance. Evenness reflects the distribution of the number of individuals of a species within a community, while dominance indicates the presence of species with the highest number of individuals in the community. When evenness is low, diversity is also low. Conversely, when dominance is high, diversity tends to be low because the presence of dominant species indicates an uneven distribution of individuals or low evenness. Based on this, it can be concluded that the composition of individuals for each species is not uniform, as indicated by the low value of the evenness index. *Diadema setosum* is one of the species that dominate every observation station in Pegametan Bay. This is because this species tends to live in groups and can thrive on various types of substrates.

The average dominance index in Pegametan Bay is 0.73, which is considered high. This is due to the low diversity or low evenness values, indicating instability within the community. This is consistent with the statement made by Fitriyani *et al.* (2022), that low diversity indices result in high dominance indices [22]. Indarjo *et al.* (2004) also support this by stating that the lower the diversity index, the higher the dominance index, indicating the presence of dominant species within the community [23]. Based on observations, the species that dominates in Pegametan Bay is *D. setosum*, which, if present conspicuously, can serve as an environmental indicator.According to Birkeland (1989), the presence of *Diadema setosum* populations in abundance indicates poor coral reef conditions [24]. This is consistent with the

findings of this study, where the *Diadema setosum* species were found in all research stations, and their presence was prominent at each research station.

The Water Quality in The Pegametan Bay

The water quality parameters at the 6 stations in Pegametan Bay include physical parameters such as water temperature, as well as chemical parameters measured, including pH, salinity, and dissolved oxygen (DO). Differences in water quality parameters as well as substrate at each station, can influence the presence of Echinodermata.

The water quality parameters in Pegametan Bay indicate normal conditions for the survival of Echinodermata. The temperature ranges from 29.5°C to 30.4°C, which falls within the optimal range for Echinodermata growth and development, as described by Nurafni et al. (2019) and Aziz (1996), who suggest optimal temperatures ranging from 25°C to 30°C, with tolerable ranges from 28°C to 34°C [25].

The pH level in Pegametan Bay falls within the range of 8 to 8.5, which is optimal for Echinoderm, as supported by Zulfa (2015), who states that marine organism life is supported within pH ranges of 7 to 8.5. Nurafni *et al.* (2019) also found Echinoderm thriving within pH conditions of 8 to 8.5.

Salinity levels in Pegametan Bay range from 32 to 34 ppt, which is optimal for Echinoderm, as stated by Nurafni *et al.* (2019), who suggest a salinity tolerance range between 30 to 34 ppt. Salinity is crucial for Echinoderm growth and larval development, as it influences their growth and development.

Dissolved oxygen (DO) levels in Pegametan Bay range from 6.1 to 6.6 mg/L, which is considered good for marine life according to Kep.Men.LH No. 22 Year 2021, which suggests DO levels above 5 mg/L are suitable. These optimal DO levels fulfill the oxygen requirements for Echinodermata, supporting their respiration, metabolism, and reproduction processes.

TABLE 6
THE WATER QUALITY

The Water Quality				
Station	Temperature (°C)	pH	Salinity (ppt)	DO (mg/l)
1	29.9	8.5	33	6.6
2	29.9	8.6	32	6.4
3	29.8	8.6	34	6.6
4	29.5	8.6	33	6.5
5	30.4	8.5	34	6.2
6	30.4	8.5	34	6.1

IV. CONCLUSION

The Echinodermata found in Pegametan Bay belong to 3 classes: Asteroidea, Echinoidea, and Holothuroidea, totaling 227 individuals. The species encountered from most to least abundant are Diadema setosum, Protoreaster nodosus, Linckia laevigiata, Holothuria atra, Holothuria hilla, and Echinothrix calamaris. The diversity index of Pegametan Bay is relatively low, while the uniformity index is low, and the dominance index is high. The water quality obtained in the study of Pegametan Bay falls within normal limits.

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