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Research Article

Community Structure and Association of Crinoidea (Echinodermata) with Coral Reef Lifeforms on the Reef Slopes of Pramuka Island, Seribu Islands

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ABSTRACT

Class Crinoidea, or sea lilies, are primitive members of the Echinodermata phylum, playing a crucial ecological role as filter feeders and indicating ecosystem health. Pramuka Island is the administrative center of the Seribu Islands Regency, DKI Jakarta, which is experiencing rapid development and becoming a promising tourism site. These anthropogenic activities may influence the survival of the coral reef ecosystem below the island. Thus, further research on crinoid communities and their relationship with coral reef lifeforms is needed to assess the health of the reef ecosystem amidst increasing anthropogenic activities. The research was done using the belt transect method covering an area of 50×5 m at a depth of 10 m at four research stations, calculating the diversity index, evenness index, dominance index, and density. The association of Crinoidea with coral reef lifeforms was analyzed using the chi-square test. The result showed poor value with an average low diversity index, moderate evenness index, and high dominance index. *Capillaster sentosus*, the most abundant species at every station, indicates habitat suitability rather than ecological disturbance, and serves as a potential bioindicator for Pramuka Island's reef health, though its dominance might signal a decline in other species due to competition. There were six pairs of Crinoidea–substrates found to be positively associated, and four pairs of Crinoidea–substrates that were negatively associated. The associations between crinoids and coral reefs, influenced by crinoid morphology, reef stability, and current flow, highlight the need for conservation efforts to preserve these crucial relationships for biodiversity.

Keywords: association, community structure, coral reef, crinoids, Pramuka island

Introduction

Class Crinoidea, commonly known as the sea lilies, are members of the Echinodermata phylum. Compared to other Echinoderms, crinoids are unique because they are considered 'primitive', they exhibit the least changes from their presumed ancestors, with a fossil record dating back almost 600 million years. This makes them valuable for evolutionary and paleoecology studies (Pechenik, 2015; Xu et al., 2024). Ecologically, their morphology provides habitat for various organisms. With their flower-like structures, they also enhance the aesthetic appeal of coral reefs. As filter feeders, they play a crucial ecological role by capturing significant amounts of organic particles, thus impacting production throughout the food chain. Crinoids would choose their habitat by favorable environmental conditions, making them an excellent bioindicator of ecosystem health (Aziz et al., 1991; Sugni et al., 2025).

Crinoids are frequently found on coral reefs, as they provide a proper substrate to attach to. However, no information explains which coral reef lifeform is preferred by each crinoid species. It is still poorly understood due to the diverse range of habitats they occupy and the various environmental factors that influence their distribution (Sugni et al., 2025). This information will be essential in understanding the relationship between these organisms and how they support each other in the ecosystem.

Pramuka Island is the administrative center of the Seribu Islands Regency, DKI Jakarta, which is experiencing rapid development to support its governmental function. It has also become a promising tourism site in DKI Jakarta. These anthropogenic activities may influence the survival of life beneath the surface, specifically the coral reef ecosystem below the Island (Amfa et al., 2020). The existence of crinoids in Pramuka Island can be utilized to assess the health of the Island's reef ecosystem amidst the growing human activities.

Although there has been extensive research on the macrobenthos community at Pramuka Island, research around crinoid communities still needs to be completed. The last research on the diversity and distribution patterns of crinoids on Pramuka Island was conducted in 2003 by Heri (2024). Therefore, more recent data is needed from different locations to identify whether there are differences in the community structure. These data can also support reef management in the Seribu Islands Regency by providing valuable insights into the health of the reefs, helping to identify areas that require protection or restoration, and facilitating the development of effective conservation strategies that engage local communities and stakeholders. Therefore, this research aimed to (1) analyze the community structure of crinoids in Pramuka Island to gain new data and insights into their condition, and to (2) analyze their association with coral reef lifeforms to understand their interaction in supporting life in the coral reef ecosystem.

Materials and Methods

Time and Location

The research was conducted at the reef slopes of Pramuka Island, Seribu Islands Regency, DKI Jakarta, from February 5th until February 8th, 2024. Data was collected at four stations (Figure 1) based on compass points: Station 1 (southwest), Station 2 (northwest), Station 3 (northeast), and Station 4 (southeast).

Methods

The method used in collecting crinoid and coral lifeforms data was the belt transect method. It was done by stretching three transects by 50 m in 10 m below the surface, parallel to the shoreline. Then, any crinoid and coral lifeform found was documented by sweeping 2.5 m to the left and right, conducting a random sampling (English et al., 1997). The collected data were species, number, and the kind of lifeform (or other substrate found). A few of the crinoids found were also taken and preserved for further identification in the laboratory. Ecological parameters such as temperature, salinity, pH, and turbidity were taken in every station with three repetitions.

The crinoids taken from the field were fixed in 90% ethanol for 1–2 min or until their arms become rigid. They were then preserved with 70% ethanol in collecting jars (Hendler, 2004; Williams & Van Syoc, 2007). The samples were then identified using Clark and Rowe's "Monograph of Shallow-water Indo-West Pacific Echinoderms" identification guide (Clark & Rowe, 1971).

Data Calculation and Analysis

The recorded data were calculated using the diversity index (H'), evenness index (E), and dominance index (D, following standard formulas and criteria in Odum (1971). Density (ind/m^2) was obtained by dividing the number of individuals by the

sampled area (Amfa et al., 2020). The association of crinoids and coral lifeforms was analyzed using Cramer's coefficient chi-square (X^2) analysis with 0.05 probability, following the formula in Illowsky and Dean (2013), with hypotheses as follows (Illowsky & Dean, 2013):

H_0 = crinoid species and coral lifeform are not associated
H_1 = crinoid species and coral lifeform are associated

The Cramer's coefficient chi-square test was performed by comparing the calculated X^2 value with the X^2 critical value. The X^2 critical value with a degree of freedom of 1 and a probability of 0.05 is 3.841. Thus, the chi-square test criteria are as follows (Illowsky & Dean, 2013):

1. If the calculated X^2 value < 3.841, then H_0 is accepted (no association)
2. If the calculated X^2 value > 3.841, then H_0 is rejected (association present)

After obtaining the chi-square test results, the observed frequency (Fo) values were compared with the expected frequency (Fe) values to determine whether the two organisms are positively or negatively associated (Sanjerehei & Rundel, 2020). The criteria for assessing positive/negative association are as follows (Sanjerehei & Rundel, 2020):

1. If the value of Fo > Fe, then it is positively associated
2. If the value of Fo < Fe, then it is negatively associated

Results and Discussion

Crinoids Community Structure at Pramuka Island

A total of nine crinoid species were found across all four research stations (Table 1). *Capillaster sentosus* became the most frequent species, showing potential dominance in the field and suggesting its tolerance to the environmental conditions. Meanwhile, *Phanogenia gracillis* showed

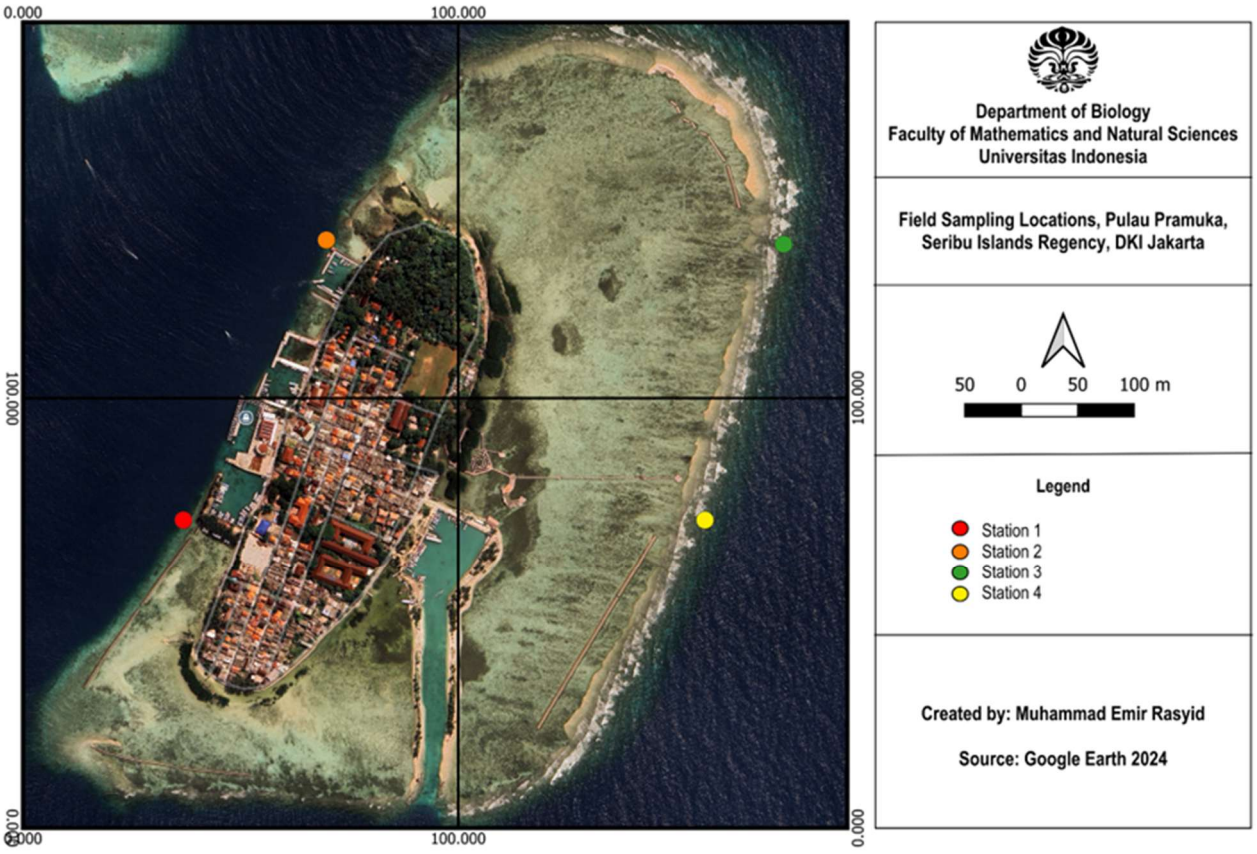

Fig. 1. Field sampling location at the reef slopes of Pramuka Island, Seribu Islands.

the least common species, with only 1 individual found across all stations.

The contrasting number of individuals and species observed in this study is likely influenced by the idea that a high number of individuals will suppress the diversity to reduce the competition among different species. This concept also applies to the opposite condition, namely, a high diversity will reduce the number of individuals to maintain the balance or stability of the ecosystem (Loreau & Mazancourt, 2013).

Table 1. Total number of individual crinoids found in four research stations of Pramuka Island, Seribu Islands.

Species/Station	1	2	3	4	Total
Capillaster sentosus	253	60	313	645	1,271
Comanthus parvicirrus	4	5	15	40	64
Comatella nigra	0	4	1	5	10
Phanogenia gracillis	0	1	0	0	1
Phanogenia multibrachiata	5	3	0	2	10
Stephanometra indica	0	7	2	0	9
Stephanometra tenuipinna	0	3	0	0	3
Himerometra robustipinna	1	3	0	0	4
Colobometra perspinosa	35	0	3	0	38
Total	298	86	334	692	1,410

Based on the density calculations (Table 2), *C. sentosus* held the highest density in every station, particularly at Station 4 (0.86 ind/m^2), indicating strong habitat preference and high tolerance to the local environmental conditions. Meanwhile, three species share the lowest density with 0.0013 ind/m^2, which are *Himerometra robustipinna* (Station 1), *P. gracillis* (Station 2), and *Comatella nigra* (Station 3). The low density observed in these species may suggest limited tolerance to the environmental conditions or may have been outcompeted by *C. sentosus* as the dominant species (Krebs, 1989).

On average, the crinoid community in Pramuka Island exhibits low diversity, moderate evenness, and high dominance (Table 3), with no significant differences in ecological parameters observed across all stations (Table 4). These indices suggest a potential population imbalance, particularly highlighted by the high abundance of *C. sentosus*. A lot of times, low diversity and high dominance indicate an ecosystem degradation is occurring (Sofiyani et al., 2021). However, this phenomenon does not necessarily reflect such an implication. According to reports by Amfa in 2020, the overall macrobenthos community in Pramuka Island is still relatively good, which indicates the environment can support the macrobenthos survival (Amfa et al., 2020). Another previous study by Heri in 2004 also identified dominance of *C. sentosus* (Heri, 2024). Over the span of more than twenty years, the crinoid community structure maintained a similar pattern. Even though *C. sentosus* thrives, and there are a few other crinoid species that still coexist in every station. The dominance might suggest that the environment is more favorable to *C. sentosus* than the other species.

Table 2. Density calculation of crinoids found in four research stations of Pramuka Island, Seribu Islands.

Species/Station	1	2	3	4
Capillaster sentosus	0.3373	0.0800	0.4173	**0.8600**
Comanthus parvicirrus	0.0053	0.0067	0.0200	0.0533
Comatella nigra	0	0.0053	**0.0013**	0.0067
Phanogenia gracillis	0	**0.0013**	0	0
Phanogenia multibrachiata	0.0067	0.0040	0	0.0027
Stephanometra indica	0	0.0093	0.0027	0
Stephanometra tenuipinna	0	0.0040	0	0
Himerometra robustipinna	**0.0013**	0.0040	0	0
Colobometra perspinosa	0.0467	0	0.0040	0

Table 3. Diversity index (H'), evenness index (E), and dominance index (D) calculation results of the crinoid community in Pramuka Island, Seribu Islands.

Index/ Station	1	2	3	4	Average value
H'	0.7734 (low)	1.6828 (moderate)	0.4192 (low)	0.4081 (low)	0.8209 (low)
E	0.4806 (moderate)	0.8092 (high)	0.2605 (low)	0.2944 (low)	0.4612 (moderate)
D	0.7351 (high)	0.5027 (moderate)	0.8803 (high)	0.8722 (high)	0.7476 (high)

Due to crinoid sensitivity to environmental conditions, other species that do not meet these standards may

relocate, which may be the reason they are not commonly found (Baumiller, 2008). Many influences cause a species to dominate a habitat that is shaped by past and present environmental conditions, so it can be said that the causes of a species' dominance always depend on evolution and the environment (Avolio et al., 2019). However, drastic environmental changes linked to human activities can lead to a significant decline in certain species. Species with high adaptive potential may also decline if they are unable to compete with a more tolerant or faster-dispersing species. This decrease can serve as a warning sign for the potential loss of other species that may be outcompeted or become less tolerant of the changing environment, thus affecting the biodiversity or the ecosystem balance (Åkesson et al., 2021; Connell, 1978).

Table 4. Ecological parameters observed across four research stations of Pramuka Island, Seribu Islands.

Parameters/Station	1	2	3	4
Temperature (°C)	29.1	29.5	28.9	29.1
Salinity (ppt)	30	28	30	30
pH	7.1	6.8	7.4	7.7
Turbidity (m)	2.5	2.1	2.5	2.3

Table 5. Association results of crinoids with coral lifeforms and other substrates in Pramuka Island, Seribu Islands.

Substrate/ Crinoidea	Cs	Cpa	Cn	Pg	Pm	Si	St	Hr	Cpe
Massive	+	0	+	0	0	–	0	0	–
Branch	0	0	0	0	0	0	0	0	0
Foliose	0	0	0	0	0	+	0	0	0
Submassive	0	0	0	0	0	0	0	0	0
Tabulate	0	0	0	0	0	0	0	+	0
Sea whip	–	0	0	0	0	+	0	0	0
Sea fan	–	0	0	0	0	0	0	0	+
Sponges	0	0	0	0	0	0	0	0	0
Rocks	0	0	0	0	0	0	0	0	0
Metal	0	0	0	0	0	0	0	0	0

Moreover, the dominance of a species can be used as a key to understanding changes that occur in an ecosystem. The response of a dominant species to any changes in environmental conditions will be the main determinant of whether the habitat will continue to provide the expected ecological function or not (Avolio et al., 2019). In this case, the dominance of *C. sentosus* in Pramuka Island's crinoid community has the potential to further assess the resilience or the vulnerability of the Island's coral reef ecosystem.

Field observations found five types of coral reef lifeforms, namely massive, branch, foliose, submassive, and tabulate. Identification of coral reef lifeforms was conducted visually during field sampling, based on morphological characteristics described by Castro and Huber (2023). In addition, five non-hard coral substrates were also found, namely sea whip (Gorgonian), sea fan (Gorgonian), sponges (Porifera), rocks, and metal. Based on the chi-square calculation (Table 5), only ten out of ninety crinoid–substrate pairs showed significant associations.

Six pairs of crinoid and substrates are positively associated, namely *C. sentosus* with massive coral, *C. nigra* with massive coral, *H. robustipinna* with tabulate coral, *Stephanometra indica* with foliose coral, *S. indica* with sea whip, and *C. perspinosa* with sea fan. A positive association can be interpreted as a facilitation or mutually supportive relationship between the two species, so that they are often found together in the same habitat. Hard coral reefs are optimal for attachment of crinoids. Crinoidea use their cirri—a gripping foot structure—to firmly grip the substrate, thus providing stability (Siburian et al., 2023). Coral reefs also provide Crinoidea with a place to hide from predators, strong currents, and to rest during the day (Aziz et al., 1991). A positive association can be formed when there is the same response from two species to the presence of resources in their habitat. If resources are abundant, then both species will support each other's survival. Conversely, if resources are present in limited quantities, then both species can fluctuate equally (Sanjerehei & Rundel, 2020).

The negative association of four pairs of crinoids with the substrate indicates that there is an opposing relationship. The incompatibility of crinoid morphology with the type of substrate could be one factor why this could happen. Gorgonians (Subphylum Anthozoa, Subclass Octocorallia), such as sea whip and sea fan, tend to have a soft body structure so that they are easily carried away by the current (Pechenik, 2015). This body structure may not be suitable as a substrate for most crinoid species, so they are often avoided, although there are two crinoid species, namely *C. perspinosa* and *S. indica*, which have positive associations with these two animals. In contrast, *C. perspinosa* and *S. indica* have negative associations with hard massive corals, presumably because these two animals have a sharp or thorny proximal pinnule—the first row of the feather-like structure—so that they are very dependent on water currents to get food. Therefore, both species tend to be attached to Gorgonian animals that generally grow in areas with strong currents (Clark & Rowe, 1971; Pechenik, 2015).

The observed associations show how the interaction between coral structure, crinoid morphology, and water flow conditions influences species distribution. This implies that crinoids' substrate preferences are influenced not only by availability but also by their adapted morphology and current dynamics. Therefore, changes in the coral reef health and the environment in general, whether caused by natural events or anthropogenic factors, could have a direct impact on the survival and stability of crinoid populations.

Conclusion

The community structure of Crinoidea on the reef slope of Pramuka Island, Seribu Islands Regency, has a poor value with an average low diversity index (0.8209), moderate evenness index (0.4612), and high dominance index (0.7476). *C. sentosus* was obtained as the species with the highest density in every station. The species dominance is highlighted as habitat compatibility rather than ecological disturbance, and can serve as a potential bioindicator for Pramuka Island's future reef health by monitoring its community structure and its sensitivity to environmental change. However, this dominance may also be a warning for the decrease of other species due to them being outcompeted.

There were six pairs of Crinoidea–substrates found to be positively associated, and four pairs of Crinoidea–substrates that were negatively associated on the reef slope of Pramuka Island, Seribu Islands Regency. These associations are heavily influenced by crinoid morphology, the stability of coral reef structure, and the current flow. These findings can provide insights into the adaptive strategies of crinoids in response to environmental changes. Conservation efforts should focus on maintaining the stability of coral reef structures to support these relationships, which are crucial for biodiversity. Continued research on this topic can help create effective management practices that protect both crinoid populations and their habitats, ensuring the resilience of the reef system in the face of climate change and human impact, especially in Pramuka Island.

Conflict of Interest

All authors have no conflicts of interest to disclose.

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