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Association of Coral Life Form with Megabenthos, Pasumpahan Island, Padang City

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Abstract: Pasumpahan Island is a popular tourist destination in the Padang area. Increasing tourist activity is suspected to contribute to the degradation of the coral reef ecosystem, as observed during preliminary surveys. Coral reef degradation can significantly impact associated marine organisms, particularly megabenthos species. This study examined the association between coral life forms and megabenthos types through direct field observations. A quadrat method was applied using 5×5 m² plots across nine locations. Data analysis employed 2x2 contingency tables, and association strength was quantified using the Ochiai Index. Researchers identified six coral life forms and four megabenthos types, producing 45 potential association combinations. Results indicated that 39 combinations exhibited no association. The remaining six showed associations, equally divided between positive and negative. Positive associations occurred between mushroom corals and *Acanthaster planci*, massive corals and *Tridacna* spp., and encrusting corals and *Trochus* spp. These relationships were identified as commensal, where species coexist without direct harm. Negative associations were found between massive and encrusting corals, encrusting corals and *Tridacna* spp., and encrusting corals and *Diadema setosum*. The Ochiai Index proved effective in detecting species interactions and supporting coral reef ecosystem assessments.

Keywords: Association, coral, megabenthos, Pasumpahan, Ochiai.

Introduction

The area around Sungai Pisang in Bungus Teluk Kabung District is known for its beautiful small islands and rich coral reef resources, particularly on Pasumpahan Island. Researchers have identified significant degradation in the coral reefs of Pasumpahan Island, indicating the need for focused conservation efforts (Purnama, 2013). Local communities depend heavily on these reef ecosystems for their livelihoods. Increasing human activity in this popular tourist destination poses multiple threats to the sustainability of coral reefs. Both natural processes and anthropogenic factors contribute to the ongoing degradation of the coral reef ecosystem (Zakaria et al., 2019). Preliminary observations have documented visible damage in the form of scattered coral fragments, suggesting that coral reef health is declining on Pasumpahan Island.

Damage to coral reefs on Pasumpahan Island may also result from the presence and activities of organisms inhabiting the coral reef ecosystem, particularly those from the megabenthos group. A decrease in live coral cover correlates with a reduction in megabenthos abundance (Siringoringo et al., 2024). Megabenthos refers to large benthic organisms that are closely linked to the health of coral reef ecosystems. These organisms are categorized into two primary groups based on their utility. The first group includes species with economic value that are commonly harvested or utilized by local communities. The second group consists of non-economic megabenthos, which are not directly exploited. Non economic megabenthos can be further divided into two functional subgroups: coral polyp predators and species with potential as bioindicators of environmental health (Arbi & Sihaloho, 2017).

According to (Giyanto et al., 2014), megabenthos inhabiting coral reef ecosystems are classified into three primary groups. The first group includes species exploited by humans, such as sea cucumbers, clams, lobsters, and *lola* (a marine gastropod). Giant clams, for instance, experience intense harvesting pressure, which may contribute to coral reef degradation (Neo et al., 2015). The second group consists of megabenthos species that negatively impact coral reefs, such as *Acanthaster planci* (crown-of-thorns starfish) and *Drupella* spp. These organisms consume coral polyps, resulting in coral mortality. *Acanthaster planci* is a highly voracious predator that primarily feeds on sessile invertebrates and robust coral species (Hoey et al., 2016). The third group comprises species like sea urchins and blue starfish, which coexist with corals without causing harm. Their presence can serve as an indicator of reef health, with sea urchin dominance often signaling a decline in live coral cover (Ghafari & Fitrianti, 2021).

Coral reef degradation on Pasumpahan Island is expected to influence the diversity of coral growth forms. Strong, unbranched forms generally exhibit greater resilience, whereas branching forms are more fragile and susceptible to physical damage. This study aimed to analyze the associations and interactions between coral growth forms and megabenthos species to assess the nature of their relationships, whether positive or negative.

Suspected coral reef degradation on Pasumpahan Island is expected to significantly impact megabenthos communities, while the presence and behavior of megabenthos may also influence coral reef conditions. The objective was to determine the nature of these associations, specifically whether they are positive, negative, or neutral, in order to support effective coral reef management and conservation strategies.

Materials and Methods

Study area

The research was conducted using a survey method. The selection of observation stations was based on a purposive sampling method, targeting areas with the presence of coral reefs. The observation plots were divided into three stations: plots 1, 2, 3, and 4 (Southwest), plots 5 and 6 (Northeast), and plots 7, 8, and 9 (East) (Figure 1).

A quadrat method was used to observe the megabenthos interacting with the reefs. Each quadrat measured 5x5 meters and was constructed using iron stakes and monofilament nylon rope.

The locations for observing coral reef were determined through the survey method and marked using GPS (Global Positioning System) to collect data at coordinate points. These coordinates were recorded for each plot location. In the placement of each point serving as a fixed reference, its position must be perpendicular to the GPS line on the surface to prevent positional errors caused by water currents (Siringoringo et al., 2023).

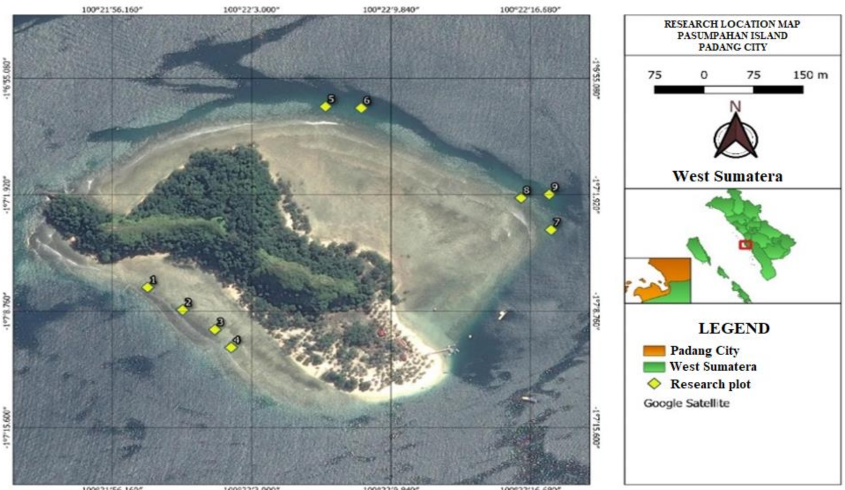

Figure 1. Map of research location in Pasumpahan Island, Padang City, West Sumatera Province, Indonesia

Data Collection on Coral Life Form

Observation plots were set up at each predetermined station within a depth range of 1-5 meters, and data collection was conducted within quadrats measuring 5x5 meters. The collected data includes coral growth forms (life forms), based on the method described by English et al., (1994). Each 5x5 meter quadrat was subdivided into smaller 1x1 meter grids using 2 mm nylon rope to facilitate more straightforward observation, resulting in 25 grids within each plot. This method provided a detailed and structured approach to studying coral growth patterns and their associated biota in the designated plots.

Identification of Megabenthos Species

Megabenthos observations focused on species that have economic value, play a direct role in the ecosystem, and can serve as indicators of coral reef health. The species types and the presence of megabenthos in each plot were systematically observed and recorded to understand their distribution and relationship with the coral reef ecosystem.

Data analysis

Association between Coral Life Forms, between Megabenthos Types and between Coral Life Forms and Megabenthos Types

Associations between coral life forms and megabenthos species were analyzed using 2x2 contingency tables. Results for all pairs were summarized in a half matrix. The strength and direction of associations were measured using the Association Index based on the method by calculating the Association Index (Ludwig & Reynolds, 1988).

Determining whether there is an association between one coral life form and another type of megabenthos is calculated using the Chi-square value (x^2). If the x^2 count value > x^2 table, there is an association. Conversely, if x^2 count < x^2 table, there is no association. The x^2 table value at a 5% confidence level is 3.84 (Ludwig & Reynolds, 1988).

$$x^2 = \frac{(N(ad-bc)^2)}{(m.r.n.s)} \qquad \textbf{(1)}$$

Where:
(a) : types A and B exist
(m) : a + b
(b) : type A exist, type B doesn't exist
(r) : a + c
(c) : type A doesn't exist, type B exist
(n) : c + d
(d) : types A and B doesn't exist
(s) : b + d
(N) : a + b + c + d

The type of interaction is determined by calculating the value of E(α) (Ludwig & Reynolds, 1988) with the formula 2.

$$E(\alpha) = rm/N \qquad \textbf{(2)}$$

Where:
(r) : a + c
(m) : a + b
(N) : a + b + c + d

If $\alpha > E(\alpha)$ means the association is positive, and if $\alpha < E(\alpha)$ it means the association is negative.

The association index was tested by calculating the Ochiai index (Ludwig & Reynolds, 1988) with the following formula 3.

$$\text{Ochiai Index: } OI = \frac{a}{((\sqrt{a+b})(\sqrt{a+c}))} \qquad \textbf{(3)}$$

Associations occur in the range of 0-1; the closer the number is to 1, the stronger the relationship between the two types and vice versa. The association index is 1.00 – 0.75 (very high), 0.74 – 0.49 (high), 0.48 – 0.23 (low) and < 0.22 (very low).

Result and Discussion

Coral Life Form on Pasumpahan Island

The research on Pasumpahan Island identified six coral life forms: Acropora Submassive (ACS), Coral Mushroom (CMR), Coral Massive (CM), Coral Encrusting (CE), Acropora Branching (ACB) and Heliopora (CHL). The coral life forms observed can be seen in Figure 2.

Massive corals are the most commonly found coral life form in the waters around Pasumpahan Island. This coral life form was found in seven out of the nine plots at the research site. Previous studies conducted in this area, which utilized satellite image analysis and field surveys to observe the condition of the seabed substrate, found that the most commonly encountered coral life forms were *Acropora* *branching* and *massive coral* (Fadil et al., 2019; Prarikeslan et al., 2020).

The high occurrence of massive corals is attributed to their boulder-like, robust structure, which gives them a higher survival capability against human activities and natural disturbances compared to other life forms. Massive corals have a shape that results in a low surface area-to-volume ratio, which contributes to their growth and resilience to environmental stress (Kahng et al., 2024). Additionally, massive corals show lower year-to-year growth variability compared to other coral life forms, which contributes to greater growth stability when facing annual environmental changes (Dornelas et al., 2017).

Mushroom corals were also recorded at the study site, though their presence was limited and solitary, with only two individuals observed in separate plots. Their low abundance is likely related to specific habitat preferences. Unlike most coral types, mushroom corals can actively move and relocate. Hoeksema et al., (2019) noted that they prefer certain depths and sandy substrates, making them sensitive to environmental changes. In response to disturbances such as typhoons or competition, these corals may migrate to deeper areas (Ohara et al., 2021).

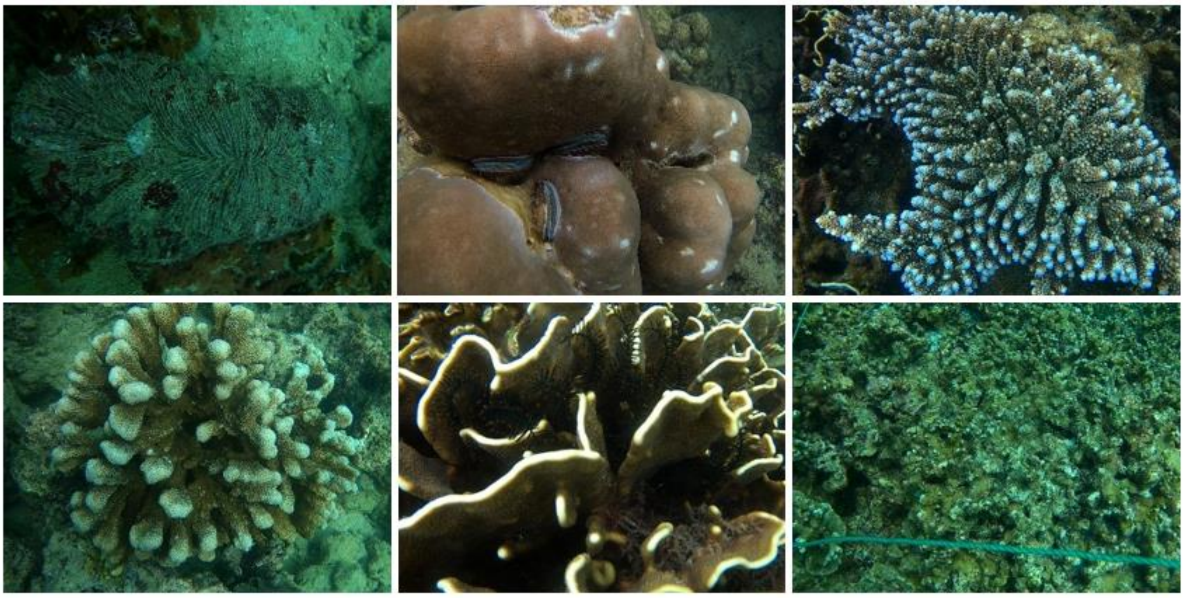

Figure 2. Six coral life forms on Pasumpahan Island: **(upper)** from left to the right: Coral Mushroom (CMR), Coral Massive (CM), Acropora Branching (ACB) and **(lower)** from left to the right: Acropora Submassive (ACS), Heliopora (CHL) and Coral Encrusting (CE).

Types of Megabenthos on Pasumpahan Island

Four types of megabenthos were identified at the study site: *Tridacna* spp. (clams), *Diadema setosum* (sea urchins), *Trochus* spp. (lola snails), and *Acanthaster planci* (crown-of-thorns starfish), as shown in Figure 3. *D. setosum* was the most frequently observed species, found in every plot across the study area. This sea urchin has also been reported as the dominant megabenthos species in other locations, such as Bilik Waters in Baluran National Park (Mutaqin et al., 2020), Tuan Island in Aceh Besar (Dewiyanti et al., 2021) and Setan Island in West Sumatra (Siringoringo et al., 2024). Its widespread presence is strongly influenced by suitable habitat conditions, particularly the availability of food. Microorganisms attached to coral surfaces serve as a primary food source for *D. setosum*. Al-Risqia et al., (2021) found that the density of *D. setosum* is positively associated with specific coral growth forms, such as acropora branching and submassive corals. This suggests that *D. setosum* populations may play a role in shaping coral community structure..

Figure 3. Four types of megabenthos on Pasumpahan Island (from left to the right): *Acanthaster planci* (crown-of-thorns starfish), *Tridacna* spp. (clams), *Trochus* spp. (lola snail) and *Diadema setosum* (sea urchins).

Association of Coral Life Form with Megabenthos

Associations between coral life forms, megabenthos types, and between coral life forms and megabenthos on Pasumpahan Island resulted in 45 pair combinations (Table 2). Only six combinations of these 45 pairs showed significant associations (x^2count > x^2table). This finding suggests that, in most cases, the presence of coral life forms and megabenthos types at the research site are generally not interdependent. Only certain types of megabenthos are associated with the presence of coral reefs at this site.

Table 2. Association matrix between coral life forms, between types of megabenthos and associations between coral life forms and megabenthos types on Pasumpahan Island. Acropora Submassive (ACS), Coral Mushroom (CMR), Coral Massive (CM), Coral Encrusting (CE), Acropora Branching (ACB), and Heliopora (CHL). The "+" symbol in this context typically indicates a positive association, in contrast, a "-" symbol would indicate a negative association and then "*" symbol indicate no association.

No.	*Life form*	Type of Association									
		ACS	**CMR**	**CM**	**CE**	**ACB**	**CHL**	***Tridacna* spp.**	***D. setosum***	***Trochus* spp.**	***A. planci***
1	ACS										
2	CMR	*									
3	CM	*	*								
4	CE	*	*	—							
5	ACB	*	*	*	*						
6	CHL	*	*	*	*	*					
7	*Tridacna* spp.	*	*	+	—	*	*				
8	*D. setosum*	*	*	*	—	*	*	*			
9	*Trochus* spp.	*	*	*	+	*	*	*	*		
10	*A. planci*	*	+	*	*	*	*	*	*	*	

Among the six combination pairs that showed associations, three were positive, and three were negative. The three positive associations were found between Mushroom Coral (CMR) and *Acanthaster planci*, Massive Coral (CM) and *Tridacna* spp., and Encrusting Coral (CE) and *Trochus* spp. The use of different methods and research locations naturally leads to varying results. For instance, a study conducted by Adriyansyah et al., (2023), which utilized Principal Component Analysis (PCA), revealed a strong correlation between the presence of *D. setosum*, *Tridacna spp.*, and *A. planci* with Dead Coral Algae (DCA). Dead corals with more complex structures have been shown to support higher diversity and density of decapods (Madduppa et al., 2019). The limited number of significant associations found in the present study may be influenced by the already degraded condition of the coral reef ecosystem at Pasumpahan Island, which strongly affects the presence of megabenthos. A higher live coral cover is correlated with greater megabenthos diversity, indicating that more complex coral growth forms provide better habitat and structural support for megabenthic communities (Tatipata & Mashoreng, 2019).

The study identified three negative associations between coral life forms and megabenthos on Pasumpahan Island. These associations occurred between Massive Coral (CM) and Encrusting Coral (CE), Encrusting Coral (CE) and *Tridacna* spp., and Encrusting Coral (CE) and *D. setosum*.

The negative associations are primarily attributed to unequal spatial distributions. One species or life form in the pair was present in many observation plots, while the other was found in only a few or was entirely absent from the same plots, resulting in limited or no coexistence. Such patterns are often influenced by interspecies competition or differences in habitat preferences. These factors can lead to spatial segregation, preventing co-occurrence (Pitta et al., 2012). Additionally, varying habitat requirements and potential predation interactions may further explain the observed distribution patterns and the lack of coexistence in negatively associated species pairs (Cordero & Jackson, 2019).

Ochiai Index Value in Associated Life Form Pairs

The calculation of association indices on Pasumpahan Island showed varying index values for the associations between coral life forms and megabenthos types. The strength of these associations was determined using the Ochiai Index, which measured the degree of association between the different species (Table 3). This index helps to quantify both positive and negative associations, giving insight into the dynamics of coral reef ecosystems and the interactions between coral life forms and the megabenthos that inhabit them. The Ochiai index can be used to identify diagnostic species within a vegetation community (De Caceres et al., 2008). The study conducted by (Hu et al., 2022) showed clear variations in values at each stage of desertification, reinforcing the conclusion that environmental changes influence community structure and interactions among plant species.

Table 3. Ochiai Index value in associated life form pairs

No	Associated Types	Interaction Types	Ochiai Index Value	Explanation
1	*Coral mushroom* with *A. Planci*	Positive	0.707	High
2	*Coral massive* with *Coral encrusting*	Negative	0	Very low
3	*Coral massive* with *Tridacna* spp.	Positive	1	Very high
4	*Coral encrusting* with *Tridacna* spp.	Negative	0	Very low
5	*Coral encrusting* with *D. Setosum*	Negative	0.25	Low
6	*Coral encrusting* with *Trochus* spp.	Positive	0.816	Very high

Among the three positive associations identified on Pasumpahan Island, the association between massive coral and *Tridacna* spp. was the strongest, with an Ochiai Index of 1, indicating perfect co-occurrence. This value reflects a high tolerance and compatibility between the two, as *Tridacna* spp. were consistently present alongside massive corals in all relevant plots. Gumilar et al., (2023) found that Tridacninae clams have a strong relationship with coral reef conditions. This indicates that the presence and distribution of Tridacninae clams are highly influenced by the surrounding coral reef environment.

Tridacna spp. was found a lot because rocky corals from life dominated it and formed massive corals. *Tridacna* spp. typically attach themselves firmly to massive corals, using them as a stable habitat. They also create tiny holes in the coral for attachment, which may cause slight damage, but the coral remains alive and continues to support the clams (Syukra et al., 2019). This interaction highlights how the massive coral provides a critical substrate for *Tridacna* spp., allowing both to coexist successfully in the ecosystem.

In contrast, the strongest negative associations were observed between Massive Coral and Encrusting Coral, and between Encrusting Coral and *Tridacna* spp., both with Ochiai Index values of 0. Another negative pair, Encrusting Coral and *D. setosum*, had a low index value of 0.25. *D. setosum* typically prefers hard substrates, such as coral crevices or rocks, and is rarely found on sandy or muddy areas due to limited attachment surfaces (Vindia et al., 2018). These negative associations suggest competitive exclusion or differing habitat preferences. For instance, the dominance of massive coral may inhibit the presence of encrusting coral in the same plots. Likewise, *Tridacna* spp. tend to avoid areas dominated by encrusting corals, possibly due to competition for suitable attachment space. Such patterns highlight spatial competition and niche separation within the coral reef ecosystem on Pasumpahan Island.

Conclusion

This study identified six significant associations out of 45 coral with megabenthos pairings on Pasumpahan Island, three positive and three negative. Positive associations, such as that between massive corals and *Tridacna* spp., suggest shared habitat preferences and stable coexistence, with the strongest association showing an Ochiai Index of 1.0. In contrast, negative associations likely reflect differences in habitat requirements or competitive exclusion, resulting in limited or no co-occurrence. The application of the Ochiai Index proved effective in detecting these interaction patterns, providing valuable insights for monitoring and managing coral reef ecosystems.

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