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Coral recruitment and its relationship to hard coral cover in the Derawan Islands, East Kalimantan

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Abstract. Coral recruitment is the process when coral larvae settle to the substrate and establish themselves as a reef community. The success of coral recruitment is very important for the sustainability of coral reefs in an area, including the Derawan Islands which develop underwater tourism. Observations on coral reef recruitment were carried out in the Derawan Islands. This study aimed to determine the density of coral recruitment, hard coral cover, and the relationship between coral recruitment and hard coral cover. Data were collected using the Underwater Photo Transect method at 11 stations in the Derawan Islands. The results showed that coral recruitment in the Derawan Islands was low, ranging from 1.41 to 3.13 colonies.m^{-2}. Hard coral cover was categorized as "moderate" with an average of 28.04% (±SE=3.63%). The relationship between coral recruitment and hard coral cover occurred for medium-sized juvenile corals (3-6 cm). Their negative relationship was shown by the presence of more medium-sized juvenile corals in areas with lower hard coral cover. The large availability of stable substrates such as DCA in areas with low hard coral cover can increase the potential for coral reef ecosystems to recover naturally.

Keyword: coral recruitment, hard coral, Derawan

1. Introduction

The Derawan Islands are a group of islands in the Sulawesi Sea, which is in the eastern part of Borneo or Kalimantan, Berau Regency, East Kalimantan Province. The Derawan Islands consist of several islands such as the Panjang Island, Derawan Island, Semama Island, Sangalaki Island, Kakaban Island, and Maratua Island. As a tourist destination, the scenic beauty of the coral reef ecosystem in the Derawan Islands is one of the attractions for tourists to enjoy the underwater scenery [1].

Underwater tourism can not only increase income for the government and local communities but can also cause damage to coral reef ecosystems [2]. Natural succession for corals to maintain their lives is to do reproductive strategy. In coral sexual reproduction, there are stages of the attachment process of coral larvae on the substrate and establish themselves as a reef community, which is known as coral recruitment. Research related to coral recruitment has been carried out in several Indonesian waters [3-13] but nothing has been conducted in Derawan waters. Therefore, this study aimed to determine the density of coral recruitment, hard coral cover, and the relationship between coral recruitment and hard coral cover. The information obtained is expected to be useful for the management of coral reef ecosystems in the Derawan Islands.

2. Methodology

2.1. Sampling design

Data collection was conducted by purposive sampling on six islands in the Derawan Islands in 2019, namely Panjang Island, Derawan Island, Semama Island, Sangalaki Island, Kakaban Island, and Maratua Island. The six islands spread from the west to the east along the Derawan Islands, which are geographically located in the Sulawesi Sea. The western side of the Derawan Islands is the closest to mainland of Kalimantan, while the eastern side is the farthest. Except for Sangalaki Island, the five other selected islands were sampled at two different sites, one representing the back-reef slope on the island's west side and the other representing the front-reef slope on the east side of the island. Because Sangalaki Island is a small island, it was assumed that there was no difference on all sides of the island, so that sampling was only conducted at one site. Thus, there were a total of eleven stations (table 1, figure 1).

Table 1. Coordinate position of observation stations in the Derawan Islands, East Kalimantan.

Station	Location	Coordinat (degree)	
		North latitude	East longitude
St.01	Western Panjang island	2.35846	118.18907
St.02	Eastern Panjang island	2.36914	118.21959
St.03	Western Derawan island	2.29277	118.23479
St.04	Eastern Derawan island	2.29150	118.26238
St.05	Western Semama island	2.12893	118.32226
St.06	Eastern Semama island	2.13890	118.33705
St.07	Western Sangalaki island	2.08313	118.39446
St.08	Western Kakaban island	2.13927	118.52253
St.09	Eastern Kakaban island	2.15264	118.54030
St.10	Western Maratua island	2.21624	118.57993
St.11	Eastern Maratua island	2.28006	118.60307

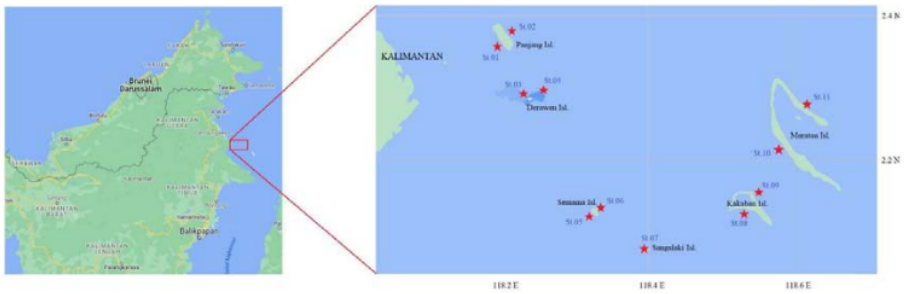

Figure 1. Map of observation stations in the Derawan Islands. East Kalimantan.

2.2. Data collection

Benthic data were collected by diving activity. A 50-meter measure tape was placed parallel to the shoreline at a depth where common corals grow, usually at a depth of between 5-7 meters. Furthermore, data were collected using the underwater photo transect method [14-19]. Benthic and substrate at the bottom of the water were photographed perpendicular to the bottom of the water from a distance of about 60 centimetres. Photo capture began at the position indicating meter 1 on the measuring tape. For the next photo documentation, observer was moved 1 m forward following the direction of the transect. Thus, there were 50 photos for one station with a transect length of 50 meters.

To maintain the consistency of the photo area, a rectangular iron frame with a size of 58cm x 44cm was used (figure 2). Photo analysis was only carried out on the inside of the frame, so for each photo

frame there was an area of 2552 cm^2. The interval between one photo and the next photo was about 1 meter. In total, there were 550 photo frames for all stations (11 stations).

Figure 2. The use of an iron frame as a tool to assist in determining the area of analysis

2.3. Data analysis

2.3.1. Photo analysis to calculate the percent cover of benthic category. The coverage of benthic categories for each photo frame were analyzed using CPCe software [20] with 30 random point selection techniques [18, 19]. There were eleven benthic categories, namely hard coral (HC), dead coral (DC), dead coral with algae (DCA), soft coral (SC), sponge (SP), fleshy seaweed (FS), other biota (OT), rubble (R), sand (S), silt (SI) and rock (RK). Thus, for each station with 50 photo frames there were 1500 points which were analyzed to get the percent cover for each benthic category, which was calculated using the formula:

$$Benthic\ \ category\ (\%) = \frac{number\ of\ point\ of\ benthic\ category}{1500}$$

2.3.2. Photo analysis to measure the size and density of coral recruitment. The value of coral recruitment is obtained by calculating the density of coral juvenile attached to the substrate at each observation station based on the photo-frames. Each juvenile coral in the photo frame was recorded and its size was measured using CPCe software [20] with a measurement scale technique. For calibration, a measuring tape was used which serves as a scale. Coral juvenile size was limited to juvenile corals whose diameter (d) did not exceed 10cm [4, 5] Furthermore, these sizes could be grouped into 3 groups, as "small" (0 cm < d < 3 cm), "medium" (3 cm ≤ d ≤ 6 cm) and "large" (6 cm < d < 10 cm) [4]. For each observation station there were 50 photo frames analysed with an area of 2552 cm^2 for each photo frame, so the area of observation for each station is 50x2552cm^2=127,600 cm^2 or 12.76 m^2.

2.3.3. Statistical analysis. To measures strength of relationship between the coral recruitment and hard coral cover was calculated the Pearson correlation coefficient (r) [21]. If there was a significant relationship, then a regression analysis was carried out to determine the pattern of their relationship described by the equation model.

3. Results

3.1. Percent cover of benthic category.

Dead Coral with algae (DCA) was the dominant benthic lifeform category found in the Derawan Islands with a cover of 35.07% (±SE=2.97%), was followed by hard coral (HC) with a mean cover of 28.04% (±SE=3.63%). The other benthic categories have coverage of less than 12% (figure 3). Due to the hard coral cover in Derawan Islands, which was between 19% and 35%, the coral reef condition in Derawan Islands can be categorized into the "moderate" criteria [22].

Based on observations at 11 stations in Derawan Islands, the lowest coral cover (12.80%) was found at station located on Pulau Panjang (figure 4). This station is close to the mouth of the Berau river which is on the mainland of the eastern part of Kalimantan Island. The mouth of the river directly faces the Derawan Islands' waters. In contrast, the highest coral cover (45.93%) was found at St.07 that was located on Sangalaki Island (figure 4), a small island designated as a Nature Tourism Park that is protected and managed by the BKSDA (Balai Konservasi Sumberdaya Alam) for East Kalimantan. BKSDA is a government agency under the Ministry of forestry and the Environment responsible for conserving natural resources.

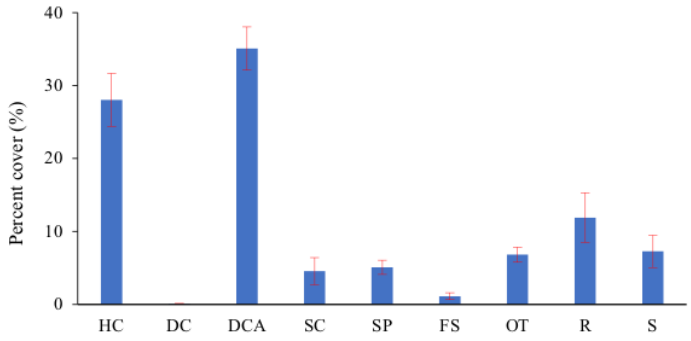

Figure 3. Mean and standard error of each benthic categories in the Derawan Islands.

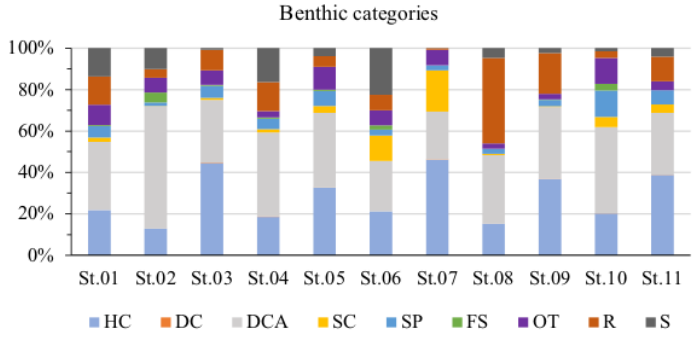

Figure 4. Percentage of benthic categories at each station of observation in the Derawan Islands.

3.2. Density of coral recruitment.

The average density of coral recruitment in the Derawan Islands was 2.27 colonies.m^{-2} ± SE = 0.18 colonies.m^{-2}. The lowest density of coral recruitment was found in St.03 (west side of Derawan Island) of 1.41 colonies.m^{-2}, while the highest density of coral recruitment was found in St.01 (west side of Panjang Island), which was 3.13 colonies.m^{-2} (figure 5). In all observation stations, the density of small-sized coral recruitment was found to be less than the "medium" or "large" size (figure 5). In general, recruitment of large-sized corals appeared to be more dominant than medium-sized or small-sized (figure 6).

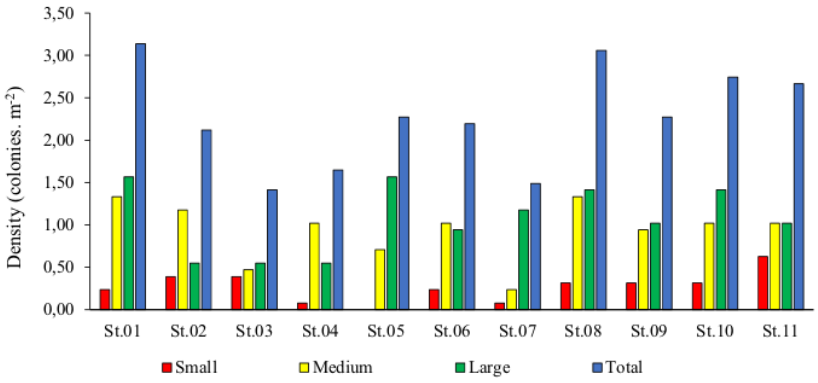

Figure 5. Density of coral recruitment at each station in Derawan Islands.

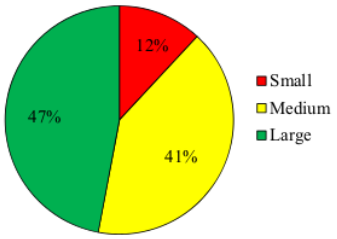

Figure 6. Ratio among the size of coral recruitment

3.3. Relationship between coral recruitment and hard coral cover

A Pearson correlation test between coral recruitment variables and hard coral cover in the Derawan Islands showed a significant linear relationship only occurred between "medium" size and hard coral cover ($p<0.01$). The relationship between them was a negative correlation with a Pearson correlation coefficient (r) of -0.822 (table 2). The density of medium-sized coral recruitment was high at stations with low coral cover. In contrast, the density of medium-sized coral recruitment was low at stations with high hard coral cover (figure 7). The pattern of the relationship between those two variables can be described using the equation $y=-28.961x +55,066$, where x is the density of medium-sized coral recruitment and y is hard coral cover.

Table 2. Pearson correlation (r) and statistical test for relationship between size of coral recruitment and hard coral cover.

Size of colony	Hard coral cover (%)		
	r	*n*	*p*
Small (colony.m^{-2})	0.055	11	0.872
Medium (colony.m^{-2})	-0.822	11	0.002
Large (colony.m^{-2})	-0.037	11	0.913
Total (colony.m^{-2})	-0.485	11	0.131

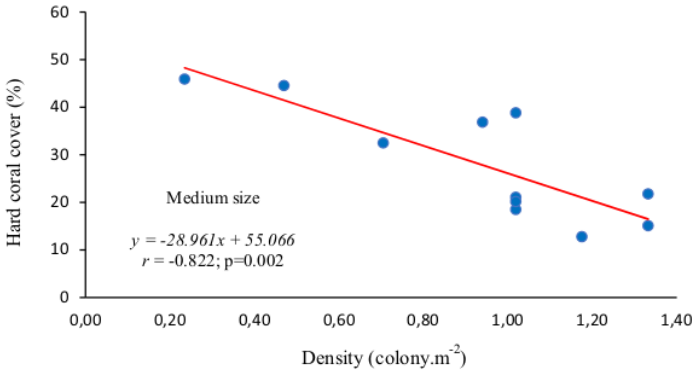

Figure 7. Linear regression model to describe the relationship between medium-size of coral recruitment and hard coral cover

4. Discussion

Coral reefs have high economic value but are very vulnerable to damage. Degradation of coral reefs can be caused by various factors such as sedimentation, which results in a decrease in water quality and human activities that can affect the quality of the waters around coral reefs [23]. The Kalimantan mainland affects the coral reef in the Derawan Islands. Hard coral cover at stations close to the mainland tends to be lower than hard coral cover at stations far from the mainland. On the mainland, many river mouths can drain sediment and other pollution sources into the Derawan Islands' waters. The low quality of the waters close to the mainland coincides with the low level of water clarity on Panjang Island (table 3). Turbid waters can inhibit sunlight from penetrating to the column waters where the hard corals live. Light is a very important factor for corals that contain symbiotic zooxanthellae [24]. Zooxanthellae that live in coral tissue, use light and carbon dioxide through photosynthesis process to produce oxygen and organic compounds. The excess photosynthetic products of zooxanthella are transferred to coral host for growth and other activities [25].

Human activities were also a sources of coral reef degradation in the Derawan archipelago, as it was happened in St.08 (the western side of Kakaban Island). Hard coral cover at this station was low (15.13%). Although Kakaban Island is uninhabited, human activity on this island is quite high. This island is an interesting tourist destination because there is a famous lake on the island. Position of St.8 was very close to the Kakaban Island pier. The low coral cover at this station was probably due to the heavy traffic of guest boats who wanted to visit the lake in Kakaban.

Referring to the Decree of the Minister of the Environment No. 51 of 2004 concerning the quality standard of sea water, all stations in the Derawan Islands (table 3) are still suitable for coral growth.

However, management of river mouths in mainland needs to be improved to protect the environment around Derawan Islands from pollution from mainland.

Hard corals carry out reproductive strategies, both sexually and asexually for their survival by maintaining and recovering coral reef ecosystem. In the sexual process, after fertilization occurs, coral larvae (planulae) are carried by currents before attaching to the substrate and establish themselves as a reef community, which is known as the recruitment process. This process depends on the availability of planulae and the presence of a substrate as a place for the planula to attach.

Parent colony as a source of coral larvae is important in the process of coral recruitment. The high hard coral cover allows corals to carry out the sexual reproduction process and produce planulae, but not all of them will grow into adult corals. Juvenile corals attached to the substrate must compete for space and nutrients with other associated biota, including competing with the corals themselves. Although high hard coral cover will increase the potential for coral recruitment, high hard coral cover can also increase competition for space and nutrients that inhibit the growth process in juvenile corals. Recruitment success may vary within and between localities and is affected by both biotic (predation, competition) and abiotic (environmental variability, disturbances) factors [26].

Competition between juvenile and adult corals might occur in coral reef ecosystems in the Derawan Islands. At stations with high hard coral cover, the density of coral recruitment was low. In contrast, at stations with low coral cover, the density of coral recruitment was low. The relationship between the two variables was significant ($p<0.01$), especially for the recruitment of medium-sized corals.

Table 3. Parameters of water quality in the Derawan Islands, East Kalimantan.

Station	Temperatur (°C)	Salinity (‰)	Water clarity (m)
St.01	29.95	33.56	11
St.02	29.88	33.50	12
St.03	29.55	33.68	13
St.04	29.61	33.70	19
St.05	29.70	33.58	19
St.06	30.03	33.59	13
St.07	30.05	33.63	21
St.08	30.07	33.92	22
St.09	29.79	34.01	23
St.10	30.49	33.85	33
St.11	30.64	34.28	36

5. Conclusion

The density of coral recruitment in the Derawan Islands is low. However, coral reefs have the potential to recover naturally. This is due to the large availability of stable substrates such as DCA for attachment of coral larvae, especially in areas with low hard coral cover. In areas with high coral cover, juvenile corals attached to the substrate must compete for space and nutrients with other biota in the coral reef ecosystem, including competing with hard corals themselves.

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All authors are **the main contributors** and have the same contribution starting from the concept, research design, data analysis, writing, improving the manuscript to approving the manuscript.

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