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Coral community structure at Celukan Bawang Reefs, Buleleng Regency, Bali Island

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Abstrak

Perairan Celukan Bawang merupakan salah satu kawasan pesisir dengan lokasi strategis di utara Pulau Bali. Ekosistem terumbu karang di sekitarnya terancam oleh berbagai aktifitas seperti perkapalan, PLTU, industri serta tambak udang. Sebagai upaya pemanfaatan lestari, maka perlu diketahui kondisi terumbu karang yang ada dalam bentuk data ilmiah. Penelitian ini bertujuan untuk menghitung tutupan seluruh komponen ekosistem dan struktur komunitas terumbu karang di perairan Celukan Bawang. Pengambilan data tutupan ekosistem terumbu karang, dan struktur komunitas dilakukan pada Bulan Desember 2020. Terdapat dua stasiun dengan aktifitas pesisir yang berbeda. Pengambilan data tutupan ekosistem terumbu karang menggunakan metode UPT, sedangkan data struktur komunitas terumbu karang menggunakan transek sabuk 2 x 20 m. Perbedaan tutupan seluruh komponen ekosistem terumbu karang antar stasiun dianalisa dengan Uji T berpasangan, namun untuk data yang tidak homogen maka dianalisa dengan Uji Kruskal-Wallis. Hasil penelitian menunjukkan tutupan koloni karang hidup pada Stasiun 1 termasuk kriteria buruk, sedangkan Stasiun 2 sedang. Terumbu karang didominasi oleh karang dengan tipe pertumbuhan non-*Acropora massive* dari Faviidae dan *encrusting* dari Pocilloporidae. Secara statistik, semua komponen tutupan ekosistem terumbu karang tidak berbeda antara Stasiun 1 dan 2. Nilai Indeks Keanekaragaman dan Keseragaman Hayati kedua Stasiun yaitu rendah, sedangkan Indeks Dominansi pada Stasiun 1 sedang, namun Stasiun 2 menunjukkan kategori rendah. Kondisi tutupan koloni karang hidup lebih baik di Stasiun 2 diduga disebabkan tutupan komponen abiotik yang lebih tinggi yaitu pecahan karang dan batu yang merupakan media penempelan larva karang.

Kata kunci: *Struktur komunitas; terumbu karang; Celukan Bawang; Buleleng*

Abstract

Celukan Bawang waters have a strategic location in the northern part of Bali Island that threatened its surrounding coral reefs by shipping, power plant, industrial activities, and shrimp ponds. However, there is limited data on its biodiversity status. Therefore, it is necessary to provide factual information regarding the coral reef ecosystem condition in scientific data. This study aimed to measure the coral reef`s components and the community structure. The coverage of coral reef components was collected based on the UPT method, while community structure data was taken in a belt transect within two different sites. All data was collected in December 2020. The difference in coral reef ecosystem components among sites was analyzed with the Paired-T and Kruskal-Wallis tests (for the non-homogenous data). Results showed that the coverage of live coral colonies in Site 1 is categorized as poor, whereas Site 2 is classified as moderate. Reefs were dominated by type growth non-*Acropora* massive from the family of Faviidae and encrusting from the family of Pocilloporidae. Statistically, there were no significant differences in all coral reef ecosystem components among Sites 1 and 2. Diversity and Evenness Indices were similarly low in the two sites. The dominance Index demonstrated that Site 1 was lower than Site 2 (moderate). It might be related to the coverage of the abiotic component, which, despite being statistically insignificant, showed that Site 2 has a higher percentage of rubbles and rocks. Rubble and rock can be a substrate for the coral juvenile to attach.

Keywords: Community structure; Coral reef; Celukan Bawang; Buleleng

1. Introduction

Coral reefs provide ecological and economic services as well as a source of fisheries industry for millions of people. It is decreasing due to local and global pressures, particularly its biodiversity is threatened by the increasing development and enlarging impacts of human activities and climate change (He & Silliman, 2019; O'Hara et al., 2021). Climate changes accelerate thermal stress, coral bleaching, and ocean acidification and increase the average sea surface temperature (Hoegh-Guldberg et al., 2018). Whereas locally, fisheries, pollution, and coastal development have negatively impacted the population and ecosystem of coral reefs (Burke et al., 2011). The ability to identify and determine the local pressures may increase the

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resilience to environmental stress (Claar et al., 2020; Shaver et al., 2018), reduce coral diseases (Lamb et al., 2016), and, importantly protect from the effect of environmental change (Beyer et al., 2018; Côté et al., 2016; Darling et al., 2019).

Moreover, implementing a solution to mitigate the pressures on the marine ecosystem is essential to slow the declining biodiversity and maintain the ecosystem's function. The mitigation of the ecosystem can identify the activity most threatening the ecosystem's integrity and resilience (Tulloch et al., 2015) and predict the ecosystem's response (Grantham et al., 2020). The inability to locate the local pressure may increase the disruptions or parallel interaction of climate change effects, thus declining the conservation effectiveness (He & Silliman, 2019). Therefore, an incentivization of coastal ecosystems is needed to determine the conservation strategy on a local scale and prevent further degradation (Allan et al., 2019; Tulloch et al., 2015).

Celukan Bawang waters located in Celukan Bawang Village, Buleleng Regency, Province of Bali. Its coastal and waters areas have intensive activities, with the largest cargo port in the northern part of Bali Island, a coal-fired steamed Power Plant, a cement plant, shrimp ponds, and a few local settlements (Indrawan et al., 2019; Marfai et al., 2022). Despite these massive land and water activities, there is limited data on the biodiversity of the coastal ecosystems. According to a previous study, only two coastal ecosystems are present: seagrass (Hidayat et al., 2019) and coral reef ecosystems. To the author's knowledge, the coral reef ecosystem status remains unknown. However, the coral reef ecosystem is affected by the high environmental stress occurring in these areas. Furthermore, the surrounding coastal communities are primarily dependent on the sea, and the sustainability of the coastal natural ecosystem must be preserved. Therefore, this study aimed to provide the current condition of the community structure of Celukan Bawang's coral reefs, which may inform preliminary information for management and conservation strategy.

2. Materials and Methods

2.1. Study sites

Data were collected in two different sites of Celukan Bawang reefs during December 2020 at a depth of 3 - 5 m. Each site was located approximately 200 – 250 m from the coastal line. The study sites were determined according to the coastal and waters activities, in which Site 1 has higher activities than Site 2 with the cement manufacturing industry, shrimp ponds, and port. In contrast, there was less population in the coastal areas of Site 2 due to a coal-fired steam power plant, and the sea was the anchoring site for traditional boats (Figure 1).

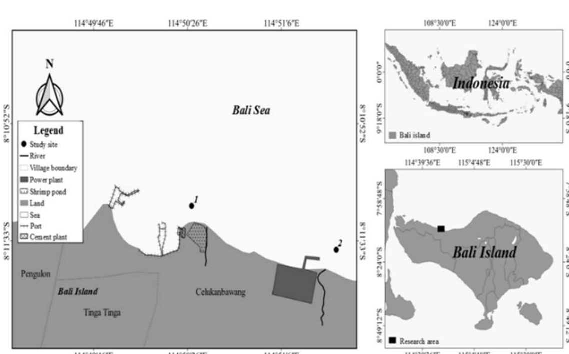

Figure 1. Map of study sites

2.2. Methods

2.2.1. Coral community structure

Samplings were conducted by scuba diving. A 50 m Line Intercept Transect (LIT) method combined with image analysis (Underwater Photo Transect (UPT)) method to obtain data on coral's community composition and structure (Giyanto & Soedarma, 2010). UPT used an underwater digital camera (GoPro Hero 7 Black) mounted on a 40 cm high metal frame with a 58 x 44 cm base. A 50 m transect line was laid straight on the reef substratum for each site and parallel to the coastline (Survey Manual for Tropical Marine Resources. ASEAN-Australian Marine Science Project: Living Coastal Resources. 1994). This transect line was marked every 1 m, and pictures were taken within the frame crisscrossed along the line (Fig. 2). The transect line was replicated at each site. The coral's abundance and ecology indices (Shannon-Wiener diversity and Pielou evenness indices) of corals in each location were measured within a 20 x 2 m belt transect placed on the same UPT method survey area. According to Veron (2008) and Suharsono (2008), all corals were identified at the genera level. The taxonomical arrangement followed the WoRMS Editorial Board (2022) classification.

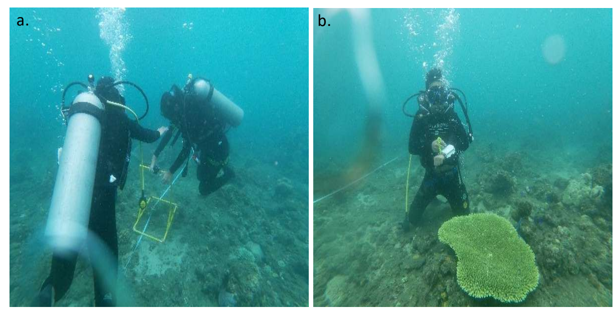

Figure 2. (a). LIT and UPT methods to measure data of the coral community composition and structure. (b). Collecting the coral's abundance and ecology indices in a 20 x 2 m belt transect.

2.2.2. Parameters of water quality

Water quality parameters measured in this study consisted of water temperature, clarity, pH, and surface current (Table 2). The following are the measurement methods of these parameters: water temperature was measured approximately 1 m above the reef, whereas salinity and pH were calculated from the water sampled above the coral reef. They were measured by using a handheld refractometer and pH meter, respectively. Water clarity was determined from a Secchi disk, while the surface current was measured using a Lagrange that was put below the water, and the data was recorded every hour. All parameters data were collected in situ and replicated at each site.

2.3. Data analyzes

2.3.1. Structure community of coral reef

Photos from every transect in each frame were analyzed randomly using the software CPCe (Coral Count with Excel Point extensions) version 4.1. There were 30 random points in each frame (Giyanto & Soedarma, 2010). Thus, the coverage of each component in the coral reef ecosystem was calculated according to equation 1) (Giyanto & Soedarma, 2010).

$$\text{The coverage of coral reef ecosystem's component}(\%)=\frac{\text{number of the component points}}{\text{number of random points}}\times 100 \quad (1)$$

The coverage of live coral colonies was further classified following the criteria standards of the damaged coral reef based on Regulation Law No. 51, 2004 of the Indonesian Environmental Ministry (Table 1). The abundance of each coral family was measured according to equation 2:

$$N=\frac{n_i}{A} \quad (2)$$

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Where N is the abundance of individuals, n_i = the number of individuals in a family, and A = width of the measured area. Based on data on coral colony number and family, Shannon-Wiener diversity (*H'*) and Pielou evenness (*J'*) (Pielou 1966) indices were calculated according to equations 3 and 4, respectively:

$$H'=-\sum_{i=1}^{s}\frac{n_i}{N}\left(\log_2\frac{n_i}{N}\right) \quad (3)$$

$$J=\frac{H'}{\log_2 S} \quad (4)$$

Where n_i is the number of individuals in a family, N is the total number of individuals, and *S* is the total number of families.

Table 1.
The reference criteria of the live coral coverage

Coverage of coral colony	Criteria of the live coral coverage
0-24.9%	Poor
25-49.9%	Moderate
50-74.9%	Good
75-100%	Very Good

2.3.2. Statistical Analyzes

The difference in the component coverage of the coral reef ecosystem between study sites was analyzed with a T-independent test. Data were analyzed for normal distribution and homogeneity tests to meet the assumption of the T-independent test. Furthermore, the difference in the component coverage of the coral reef ecosystem between study sites was analyzed with the Kruskal Wallis Test when it does not meet the assumption. All tests were conducted using SPSS version 25.

3. Result and Discussion

In order to provide the field condition when collecting data, the physical parameter of water qualities was measured (Table 2). There was a slight difference in some water quality parameters between Sites 1 and 2. The sea surface water temperature in Site 1 was higher at 1°C, the surface temperature in Site 1 was lower at 1.6 times, and the salinity level in Site 2 was lower. It is assumed to be related to the differences in sampling time, whereas Site 1 data was collected at noon and Site 1 was in the afternoon during rain. However, the temperature is still in the range for marine organisms except for Site 2, which was relatively low. Despite the differences in salinity levels, both were higher than the reference. According to the reference, the only parameter with a similar level was pH, which is in the range for marine organisms.

Table 2
Mean ± std of water quality parameters in the study sites

Parameters (units)	Site 1	Site 2
Surface current (m/s)	0.16 ± 0.08	0.26 ± 0.09
Temperature (ºC)	27.3 ± 0.7	26.33 ± 0.58
pH	7.7 ± 0.09	7.8 ± 0.08
Salinity (ppt)	37 ± 0.75	35 ± 0.58

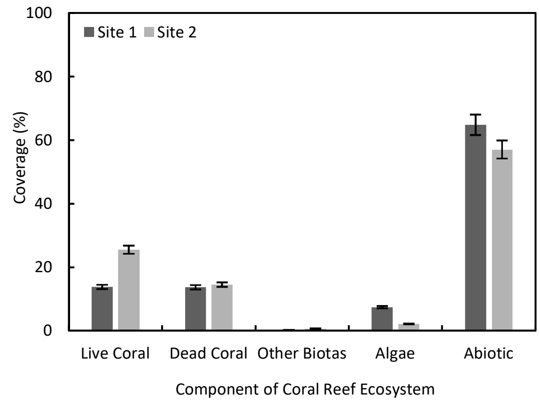

Figure 3. The coverage of coral reef ecosystem components in study sites

According to the T-independent test for the differences among the component of the coral reef ecosystem (Live Coral Colonies, Dead Coral, Other Biotas, Algae) and Kruskal-Wallis (Abiotics), there were no significant differences in each component between site studies (Fig. 3). The live coral colonies criteria, according to the Regulation Law No. 4 2001 of the Indonesian Environmental Ministry, revealed that the live coral colonies' condition in Site 1 is Poor and Site 2 is Moderate. The better state of the live coral colonies in Site 2 is likely supported by the coverage of coral with the growth types of massive non-*Acropora* from the family of Faviidae and encrusting phase from the early phase of family Pocilloporidae that is higher in Site 2 (Fig. 4 & 5). Despite the insignificant differences in the live coral colony abundances between sites (t-independent test, P > 0.05), there were 26 hermatypic coral families recorded in these sites that predominantly consisted of Faviidae (Site 1 = 36 colonies/m^2, Site 2 = 57 colonies/m^2), and Pocilloporidae (Site 2 = 28 colonies/m^2) (Table 3). The more abundant corals in Site 2 indicate their capacity to adapt to the sub-optimal condition for corals to grow. These corals are euryoic species that can grow in an unfavorable environment, such as a high sedimentation rate, due to the anatomy of their polyps that can remove the sediment and increase the surface area to optimize the captured sunlight (Todd et al., 2001; Todd et al., 2004).

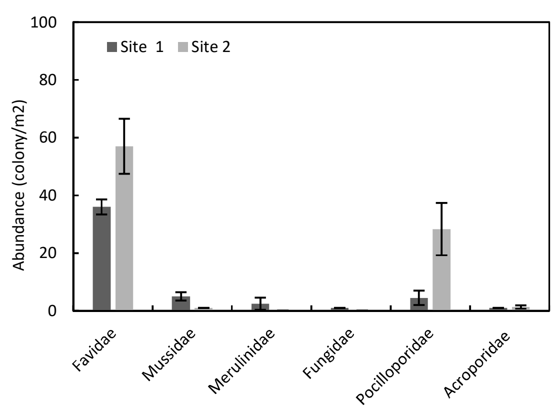

Figure 4. The abundance of coral communities in each study site

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Table 3
Corals observed in the study sites

Coral	
Merulinidae	
Mussidae	
Pocilloporidae	
Fungidae	
Acroporidae	
Faviidae	

The high percentage coverage of Abiotic components in the sites (Site 1 = 65%, Site 2 = 57%) (Fig. 3) indicate the physical, chemical, and biological processes occurring in the coral reefs as the main component of the ecosystem (Luthfi & Priyambodo, 2020). The Rubble and Sand were the predominant Abiotic component where the coverage varied at each site (Fig. 6). It might have resulted from various factors, such as land development, boat anchor, and destructive fishing activities, as Site 2 was close to the area to harbor traditional boats. Conversely, the coverage of Sand was markedly higher in Site 1 (T-independent test, P<0.05), which is argued that caused by the land development in the areas, including the excavation and filling of the sea areas to build the port. The construction of the port may alter the hydro-oceanography patterns, which in turn increased the Sand deposition in the areas as occurred in the Red Sea's coral reefs (Frihy et al., 2004).

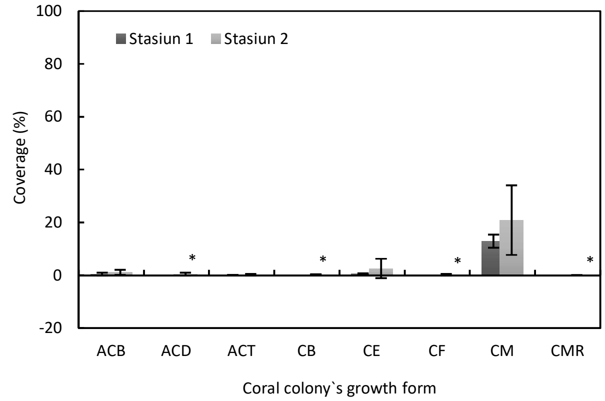

Figure 5. The coverage of coral colonies' growth form in the study sites. Information: ACB is *Acropora Branching*, ACD is *Acropora Digitage*, ACT is *Acropora Tabulate*, CB is *Coral Branching*, CE is *Coral Encrusting,* CF is *Coral Foliose*, CM is *Coral Massive*, CMR is *Coral Mushroom,* * is no data.

It is argued that the better state of the live coral colonies in Site 2 is related to the Abiotic component, which has significantly higher coverage of Rubble (T-independent test, P<0.05). Unsolidified Rubbles provide substrate for the coral juvenile to attach (Fox, 2006; Johns, 2018; Viehman et al., 2018); therefore, it can accelerate the coral's growth and survival rate. In contrast, Sand is an unstable substrate for coral juveniles to attach to, thus might decrease the coverage of live coral colonies as found in Site 1. The differences in Abiotic components were also suggested to contribute to the low and moderate levels in coral's Diversity and Evenness Indices between sites, except for the Dominance Index at Moderate level in Site 1 due to the highest abundance of Faviidae (Table 4). These Diversity Indices may also reveal that Site 2 has a better environment to support coral communities to grow than Site 1. Therefore, it is suggested that the insignificant differences in all coral reef ecosystem components between the sites are likely related to the high percentage coverage of Abiotic components in the areas. Though this study did not directly measure the relationship between these factors, previous studies demonstrated that abiotic factors strongly reduce the coral cover, abundance, and diversities (Chávez et al., 2007; Cruz-Piñón et al., 2003). This component directly or indirectly affects coral growth and diversity (Lirman et al., 2003) by blocking the photosynthetic mechanism, smothering the coral surface, and inhibiting the larva settlement (Erftemeijer et al., 2012), leading to partial mortality (Nugues & Roberts, 2003).

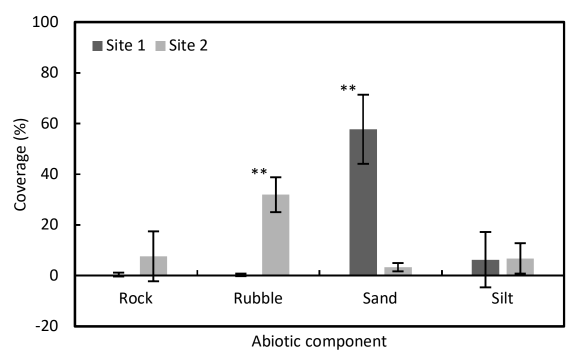

Figure 6. The study sites cover Abiotic components in the coral reef ecosystems. Information: ** is significantly different (T-independent test, $P < 0.05$).

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Table 4
Diversity indices of coral communities in the study site

Diversity indices	Site 1	Category	Site 2	Category
Diversity	0.8±0.34	Low	0.7±0.09	Low
Evenness	0.4±0.17	Moderate	0.4±0.05	Moderate
Dominance	0.6±0.13	Moderate	0.4±0.12	Low

4. Conclusion

In conclusion, results indicate that the coverage of live coral colonies in Site 1 is in Poor criteria, whereas Site 2 is Moderate. However, both sites' diversity and evenness indices are similar (Low and Moderate, respectively). The abundance of Faviidae and Pocilloporidae causes the Dominance Index in Site 2 to be lower than in Site 1. These differences might be due to the coverage of the Abiotic components, which significantly consisted of Sand in Site 1, conversely, Rubble in Site 2. Despite the low coverage of live corals in Site 1, its presence should be conserved by reducing the environmental disturbances produced by anthropogenic activities in the sea and coastal areas.

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