Coral Reef Coverage and Reef Fish Abundance in Menyawakan Island, Karimunjawa

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Abstract. Karimunjawa is one of the National Parks in Indonesia, a marine conservation area known for its diverse coral reefs, and mangrove forest. This study aims to determine coral reef status in Menyawakan Island at the northwest part of Karimunjawa Archipelago. Coral coverage as well as reef fish data were collected from the South, West, North, and East side of Menyawakan Island. Surveys were conducted at a depth of 5 and 10 meters, using the Line Intercept Transect (LIT) for coral coverage and visual census for reef fish abundance. The highest coral cover, categorized as good condition, was found in the North side of Menyawakan Island at a depth of 5 m (64.94%). Pomacentrus shows the greatest abundance with 291 individuals on the South side of Menyawakan Island. Overall coral cover in Menyawakan Island is categorized as medium to good condition, while the highest reef fish abundance is dominated with family of Pomacentridae, which are native habitat in coral reef area.

1. Introduction

As a tropical country, Indonesia is one of an ideal place for high diversity of coral reefs to grow. About two third of all coral genus are found in Indonesia, which is why Indonesia is described inside the world coral triangle with approximately 569 species or 67% of total coral species in the world [1]. Study stated that according to satellite imagery mapping, Indonesian coral reefs have an area of 25,000 km² [2]. The development of Indonesian marine tourism sector may increase more damage to coral reefs. Coral reefs are prone to human activities that often result in decreasing coral’s regeneration capability [3]. WCS surveys in 2010 stated around 10% of coral reefs in Indonesia are damaged by tourism activity such as contact with substrate, which resulted in breaking the corals [4].

Karimunjawa National Park is a marine conservation area, approximately 111,625 hectare [5], which recently became popular marine tourism area. It is located 83 km northwest of the city of Jepara, Central Java. Karimunjawa archipelago consists of 27 islands, one of which is Menyawakan Island, located in the northwest of the main Karimunjawa Island. The shallow water of Karimunjawa waters makes it a good spot for snorkelling, with the beauty view of the diverse coral reefs. In addition, most of the food source and income of the local people in Karimunjawa depend on the existence of coral reef ecosystem. With the increasing human activity affecting and decreasing coral reefs health, understanding the status of coral reefs, as well as links between coral ecosystem and reef fish structure become important [6]. Coral reef ecosystems in the area provide important function for marine
environment as well as human life. This ecosystem has the ability to sustain nutrient and became habitat for marine biota such as reef fish, lobster, giant clam, sea cucumber, algae and more. Coral reef can withstand wave currents, thus, preventing coastal abrasion. Human activities such as fish catching, fish cultivation, marine tourism and land use for tourism development has the potential to damage coral ecosystem [7-8].

As a marine conservation area, Karimunjawa is also known as a coral reef tourism spot in Central Java, Indonesia. With the developing number of visits in Karimunjawa, marine tourism activities may affect the coral reef ecosystem. One of the tourism areas is Menyawakan Island, which belong in marine utilization zone. A study by Burke et al. [9] reported that massive bleaching event that occurred in 1998 has reduced the health of coral reef in Karimunjawa, in which the coral reefs in Menyawakan Island was also affected. Since then, various studies on coral reef condition and monitoring in Karimunjawa Islands have been performed such as coral condition on different conservation zonation [10], the characteristics and optimization coral reefs in tourism zone [3,11], and reef fish condition in Karimunjawa national Park [8]. Coral reef health monitoring and information such as diversity index, community structure and ecosystem stability are important to improve management of the islands and prevent additional environmental pressure to the area. The purpose of this research is to determine the coral reef ecosystem condition in one of the tourism zone, by measuring the percentage of coral coverage, reef fish abundance and calculating its ecological index.

2. Materials and Methods
2.1. Coral Coverage
This research was conducted in August 2019 at four sites around Menyawakan Island, Karimunjawa (Figure 1). The collection of data on the percentage of coral reef cover was carried out based on English et al. [12] using the Line Intercept Transect (LIT) method by rolling out a transect along 100 meters, parallel to the coastline. Condition of the environment was observed to investigate the correlation with coral genus abundance and percent cover. The data was collected at the depth of five and ten meters by the assumption that the corals in both depths represented the coral cover in the whole area and that corals can live optimally in shallow water [13-14].

![Figure 1. Data Collection Stations in Menyawakan Island, Karimunjawa](image-url)

The LIT method estimates living coral cover up to genus level, as well as other substrate, algae, dead coral and associated organisms to describe coral community structure [15]. Coral coverage data was determined according to English et al. [12] with the following formula:
2.2. Reef Fish Abundance

Reef fish abundance data was determined according to English et al. [12] by underwater visual census (UVC) method using belt transect. Reef fish data was collected by recording all community fish along the 100 m transect line up to genus level, with an observation distance of 2.5 meters to the right and left, as well as 5 meters above from the transect line at the depth of 5 m, representing shallow water, and 10 m, representing deeper water.

The data was processed to obtain a diversity index in order to determine the community structure and ecosystem stability [16]. Composition of coral in waters can determine the ecological index in those waters. Biodiversity index ($H'$) defines the abundance of compliant biota of a community and describe its species balance in the environment. Uniformity index ($E$) shows a balance of each individual in a coral reef community while dominance index ($C$) determines how far a group of biota can dominate other. Ecological index of coral reef can describe ecological pressure at a location from its environment quality and the composition of biota compiler. The values were calculated using the following formula:

\[
H' = \frac{S}{n_i N} \\
E = \frac{S}{n_i N} \\
C = \frac{n_i}{N} \\
\]

*ni*: Percent substrate cover (%)

*li*: Length of each substrate (cm)

*L*: Total transect length (cm)

\[
H' < 1 = \text{low biodiversity} \\
1 < H' < 3 = \text{medium biodiversity} \\
H' < 3 = \text{high biodiversity} \\
\]

\[
E < 0,4 = \text{Low uniformity, pressured community} \\
0,4 < E < 0,6 = \text{Medium uniformity, labile community} \\
0,6 < E < 1 = \text{High uniformity, stable community} \\
\]

Collected reef fish data was then measured to determine the balance of each individual in coral reef community. The data was processed with the formula of uniformity index based on Krebs [17] as follow:

\[
E = \frac{S}{n_i N} \\
H' = \text{Diversity index} \\
S = \text{Number of species found} \\
\]

Dominance between individuals in a community can be measured with dominance index ($C'$) according to Odum [18]. It is a comparison between the number of a species and the total number of individuals in a community. Dominance index was calculated by the formula as follow:

\[
C = \frac{n_i}{N} \\
C < 0,5 = \text{Low dominance} \\
0,5 \leq C < 1 = \text{Medium dominance} \\
C = 1,0 = \text{High dominance} \\
\]
3. Results and Discussion

3.1. Coral Reef Coverage

The results showed that various biotic substrate were found in Menyawakan Island shallow waters, such as living coral (hard coral and soft coral), dead coral, algae, sponge and other organisms. While abiotic substrate consists of rock, rubble, sand, and silt. Coral reef condition in Menyawakan Island can be determined based on observation on the percentage of living coral coverage.

Living coral cover observation results can be seen in Table 1, with coral cover percentage ranging from 23.13% to 64.94%. According to Ministry of Environment Decree no.4 2001 [19], coral cover percentage below 24.99% are categorized as poor, between 25 – 49.99% are categorized as fair condition, while 50 – 74.99% are categorized good and above 75% are categorized as an excellent condition. Based on the result, coral coverage in Menyawakan Island could be categorized as poor to good condition.

Table 1. Coral Cover (%)

| SITE | DEPTH | Hard Coral (HC) | Dead Coral (DC) | Rock (RC) | Rubble (RB) | Sand (SD) | Nutrient Indicator Algae (NIA) | Sponge (SP) | Other (OT) |
|------|-------|----------------|----------------|-----------|-------------|-----------|-------------------------------|-------------|-----------|
| 1    | 5m    | 23.13          | 2.13           | -         | 49.5        | 16.38     | -                             | -           | 8.88      |
|      | 10m   | 25.05          | 1.00           | 13.13     | 9.75        | -         | -                             | 0.63        | -         |
| 2    | 5m    | 51.90          | 26.38          | 1.25      | 12.58       | 7.9       | -                             | -           | -         |
|      | 10m   | 55.35          | -              | 43.28     | -           | 1.38      | -                             | -           | -         |
| 3    | 5m    | 64.94          | 31.88          | -         | 2.44        | -         | -                             | -           | 0.75      |
|      | 10m   | 56.86          | 3.00           | 28.76     | 4.88        | -         | -                             | -           | 6.5       |
| 4    | 5m    | 44.75          | 35.25          | 11.5      | 4.38        | 3.5       | -                             | -           | 0.63      |
|      | 10m   | 51.67          | 2.25           | 0.5       | 44.76       | -         | -                             | -           | 0.88      |

The highest coral percentage was found in site 3 at the depth of 5 meters, where the living coral covers 64.94% of the area and categorized as good condition. The growth of the coral in site 3 is supported is supported by its location on the north of the island. The north side of Menyawakan Island are closer to Taka Menyawakan, a protected area belongs to the core zone of Karimunjawa National Park, where tourism or marine use is prohibited so the area can maintain its purity as an ecosystem. The lowest living coral percentage (23.13%) was found in site 1 with a depth of 5 meters and considered as poor condition. Site 1 with a depth of 5 meters was dominated mainly by rubble or coral fragments for 49.50%. This condition can be caused by marine activities such as tourism, or fish catching by local fishermen [8].

Previous study by Yusuf [8] showed that the average total genus found in Menyawakan Island are 21, while the average percent cover of coral reach 36.06%. Meanwhile 35 genus are found in this study with Acropora genus showed the highest abundance followed by Montipora and Porites. Acropora has the highest growth rate among all coral genus because they have two coralite system, axial and radial [15]. The ecological index of coral reef in Menyawakan Island (Table 2) showed that there was low dominance, medium to high biodiversity and high uniformity, that resulting a stable community. Another study by Sulisyati et al. [3] found 12 families in shallow water and 8 families in deeper water of Menyawakan Island. Similarly, we also found more genus and species in shallow water than in the deeper water one, with a number of genus and species are 18 genus and 24 species in the shallow and 15 genus and 20 species in the deeper water, respectively.
The results of ecological index calculation of coral community structure shows that coral reefs in Menyawakan island at most depths has medium diversity (1<H'<3) except at 10 m in Site 3 and at 5 m in Site 4 which shows slightly higher value. The Uniformity index at all sites show stable community with high uniformity (0.6 < E <1), while there are low dominance in the coral community (0 < C < 0.5).

**Figure 2.** Coral abundance by genus
Table 2. Coral Reef Ecological Index

| SITE | DEPTH | C   | E   | H’  |
|------|-------|-----|-----|-----|
| 1    | 5     | 0.30| 0.66| 2.38|
|       | 10    | 0.29| 0.68| 2.57|
| 2    | 5     | 0.19| 0.69| 2.89|
|       | 10    | 0.24| 0.68| 2.64|
| 3    | 5     | 0.24| 0.73| 2.43|
|       | 10    | 0.20| 0.71| 3.03|
| 4    | 5     | 0.18| 0.81| 3.07|
|       | 10    | 0.24| 0.68| 2.85|

The results of this study shows similar trend with the findings of Sulisyati et al. [3] that showed high uniformity and low dominance in the community structure. However, the diversity has decreased from high diversity (H’ = 4.2) [3] to medium at most of the site. It is important to identify the cause of this decrease, so that utilization of this area can support sustainable tourism.

3.2. Reef Fish Abundance

During the survey, 41 reef-fish genus from 12 families were found in Menyawakan Island. Most reef fish of Menyawakan Island can be found in site 1 in 5 meters depth with the highest number of 36,160 indiv/ha. Genus of Pomacentrus (544 individuals) was the highest number found in the south part of Menyawakan Island as many as 544 individuals, followed by Abudefduf with 103 individuals in site 3 at the north side of Menyawakan Island.

Pomacentridae was the most dominant family in each site (Figure 3), consisting of genus i.e. Amblyglyphidodon, Pomacentrus, Abudefduf and Dascyllus. This is mainly because of Pomacentridae are mayor fish and commonly found as main community fish in coral reef [10]. Family of Pomacentridae mostly lives in between rocks and coral reefs [8]. The lowest number of individual can be found in site 2 with a depth of 5 meters for 2,400 individuals/ha. The high percentage of coral reefs should be in line with the abundance of reef fish. However, the results showed that the abundance of reef fish was higher in a poor reef condition. Menyawakan Island that consists mostly abiotic component such as dead coral and rubble, this may result in alga that grow on dead coral and invites herbivores fishes like such as Labridae [11].

Another study of Sulisyati et al. [11] showed that 13 families of reef fish out of 18 families were found in Menyawakan Island. Fishes from family of Chaetodontidae, Labridae, Scaridae and Serranidae were found in Menyawakan Island. Chaetodontidae is one of biological indicator fish of coral reefs ecosystem, consumes alga that covers coral reefs, meanwhile Labridae are commonly found in coral reefs as herbivore fish, Serranidae are predator fishes and Scaridae lives in groups [11]. The presence of these genus in Menyawakan Island shows that the reef ecosystem still have the capacity to support the living of reef fish from various trophic level, therefore, the balanced ecosystem needs to be maintained.
Reef fish community in Menyawakan Island has medium biodiversity resulting in high uniformity and low dominance (Table 3). The highest biodiversity \((H' = 2.59)\) index can be found in site 3 at the north side of Menyawakan Island with a depth of 5 meters, categorized as medium biodiversity.

Table 3. Reef Fish Ecological Index

| SITE | DEPTH | \(H'\) | \(C\) | \(E\) | ABUNDANCE (INDIVIDU/HA) |
|------|-------|-------|------|------|------------------------|
| 1    | 5     | 2.06  | 0.18 | 0.63 | 36160                  |
|      | 10    | 2.22  | 0.20 | 0.69 | 14400                  |
| 2    | 5     | 2.16  | 0.15 | 0.80 | 2400                   |
|      | 10    | 2.27  | 0.15 | 0.79 | 3900                   |
| 3    | 5     | 2.59  | 0.11 | 0.80 | 10240                  |
|      | 10    | 2.26  | 0.15 | 0.80 | 3240                   |
| 4    | 5     | 2.27  | 0.15 | 0.78 | 5660                   |
|      | 10    | 2.40  | 0.14 | 0.74 | 116200                 |

This result is similar to the findings of Sulisyati et al. [11], which described medium diversity of reef fish, with high uniformity and low dominance. The high uniformity \((E)\) at both depths (up to 0.80) in present study shows that the environment is labile. Although there are no significant change in reef fish communities during the past 3 years, the diversity tend to decrease and therefore need better management in the future.

3.3. Oceanographic Parameters

Oceanographic parameters can affect the growth of coral reefs. Corals can live above 18°C water temperature. Rising temperature of seawater may cause coral bleaching and leads coral to death. Coral lives in symbiosis with zooxanthellae that gives nutrition by photosynthesis, because of that sunlight intensity also determine areas coral live [1]. This research measured current, salinity, visibility, and temperature condition in field. In late August, Menyawakan Island has current around 0.1 – 0.5 m/s and salinity 35 ‰. Dahuri [20] stated that the ideal salinity for coral growth ranges around 30-35‰.

Figure 3. Reef fish abundance in each transect (per 500 m\(^2\) area)
reefs are able to block sea waves to reach the shore to keep the shore area safe, other than that sea waves also bring larva, nutrition and distributing heat to other area. Visibility of Menyawakan Island was about 4.5 – 8 m means the sea has clear water. Below 50 m where the sun light intensity decreases, corals will be hard to grow. Temperature of Menyawakan Island ranges between 23 – 26°C. The data collection was conducted during the East monsoon, in which the water temperature is usually lower. Water temperature, especially in shallow reefs is predicted to be increasing globally overtime and may cause coral death. The minimum temperature limit for coral growth is 18°C but can live up to 35°C, the optimal temperature for coral growth is between 23-30°C [21]. While the differences of water temperature may cause decrease in growth, reproduction, metabolism and productivity, the temperatures at the four sites of data collecting are still optimal temperatures for coral growth. Karimunjawa archipelago has two season, east wind season and west wind season. East monsoon occurs around June – August and west monsoon around December – February [22]. During the west monsoon, waves and current heading east are much stronger than current tides heading west, meaning that coral reefs located at the west side of the islands are at the risk of receiving more physical pressure than the ones located at the east. This condition affects the stability of coral reefs ecosystem components [3]. However, the highest coral diversity were found on site 3 and 4, which are at the north side of Menyawakan Island and facing directly to wind as well as strong water flows. Water circulation is important to coral reef for its clearing sediments to keep optimal light, and distributing food and oxygen [23].

4. Conclusion
Coral coverage in Menyawakan Island ranges in poor to good condition. Although Acropora was found at most of the area, there was low dominance in the coral community, showing a stable coral reef community with medium diversity that can still support the ecosystem viability. Reef fishes from various trophic levels were found, however, the diversity of the reef fish tend to decrease and therefore need better management in the future.

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