

Research Article

## The Correlation of Coral Reef Cover and Rugosity with Coral Reef Fish Density in East Java Waters

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### Abstract

A coral reef is one of the most complex and specific ecosystems in a tropical area. It is identified by its high productivity and biodiversity. This research aims to discover the percentage of coral reef cover and rugosity, as well as the fish abundance in several locations in East Java, Indonesia. In addition, this research aims to investigate the correlation of coral reef cover and rugosity with the density of coral reef fish. This research was conducted in three locations, i.e., Bangsring Waters of Wongsorejo District, Banyuwangi Regency; Gili Noko Bawean Island, Gresik Regency; and Kramat Island, Gili Genting District, Sumenep Regency. This research employed the Line Intercept Transect (LIT) method to calculate the percentage of coral reef cover, the Chain Intercept Transect (CIT) method to determine the coral reef rugosity, and the Belt Transect method to estimate the fish abundance. From this research, it was revealed that the highest coral reef cover was in Bawean waters, while the highest rugosity was in Bangsring waters. In addition, the highest coral reef fish density was in Bangsring waters. Meanwhile, the coral reef fish density did not correlate with the percentage of coral reef cover. In contrast, it correlated with the coral reef rugosity.

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## 1. Introduction

A coral reef is an underwater ecosystem, which plays a critical role as a life source for marine biodiversity. It functions to maintain the stability of sea ecology condition, as a place to breed and shelter, and as the habitat for diverse sea animals (Dahuri, 2000). Furthermore, the coral reef ecosystem has aesthetical value as a tourism area, high germ plasma source reserve, barrier of a wave, and coastal erosion (Sawyer, 1992). Nevertheless, the coral reef ecosystem is susceptible to damage, which may lead to a degradation of coral reef cover. As a matter of fact, the coral reef has a significant role in the coast society life. Sedimentation, water pollution, destructive fishing gear, and harmful tourism activities are threats of devastating coastal and marine environments (Hartoni et al. 2012).

East Java is a province surrounded by several islands and waters which still have good coral reef covers. Some of those are Bawean Island in Gresik, Gili Genting Island in Sumenep, and Bangsring waters in Banyuwangi. Meanwhile, the coral reef in East Java is spread across various areas, particularly in small islands. As a matter of fact, the type of coral reef in East Java is a fringing reef. It projects on the seaward when the tide is low and will submerge during the high tidal (Luthfi and Anugrah, 2017). There have been flourished studies on the coral reef and coral reef fish in East Java, which are well-documented. Those researches, however, failed to elaborate on the correlation between these two variables.

Reef fish is a sea animal group associating with the coral reef ecosystem. Moreover, it can be found in numerous habitats in the coral reef area. Thus, the coral reef damage badly impacts the abundance, density, and diversity of coral reef fish. Moreover, habitat diversity is a primary factor affecting the number of fish species in the coral reef area. This diverse habitat clearly defines the number of fish in the coral reef ecosystem (Luckhurst and Luckhurst, 1978). Meanwhile, the diversity of coral reef fish closely relates to the complexity of the coral reef surface. The coral reef fish live in the narrow ecological niche. Therefore, there are many species living in the coral reef. It, unfortunately, causes the coral reef fish localized in a particular area of coral reef (Ilham, 2007). Additionally, there have been a number of reports identifying that fish abundance is associated with the coral reef complexity (Hixon and Beets, 1989; Friedlander and Parrish, 1998; Gratwicke and Speight, 2005b, Chong-Seng et al. 2012; Bozec et al. 2013).

This research aims to discover the percentage of coral reef cover and rugosity, as well as the coral reef fish abundance in some areas in East Java. In addition, it also aims to examine the correlation of coral reef cover

and rugosity with the density of coral reef fish.

## 2. Material and Method

This research was administered in three locations, i.e., Bangsring water of Wongsorejo District, Banyuwangi reGENCY on January 2018 at three stations (Figure 1); in Gili Noko island, Bawean, Gresik Regency on February 2018 at four stations (Figure 2); and in Kramat Island, Gili Genting District, Sumenep Regency on April 2018 at four stations (Figure 3). Furthermore, from each station, the data collection was carried out in two different water depths, namely 3-5 m water depths (representing shallow water) and 8-10 m water depths (representing deep water).

### 2.1 Data Collection Method

The research method employed in this research was Line Intercept Transect (LIT) (English et al. 1997) to examine the percentage of coral reef cover. Meanwhile, to investigate the coral reef rugosity, the researchers applied the Chain Intercept Transect (CIT) method (Hill and Wilkinson, 2004). Lastly, the Underwater Visual Census method with Belt Transect (English et al. 1997) was implemented to observe the fish abundance.

### 2.2 Line Intercept Transect (LIT) Method

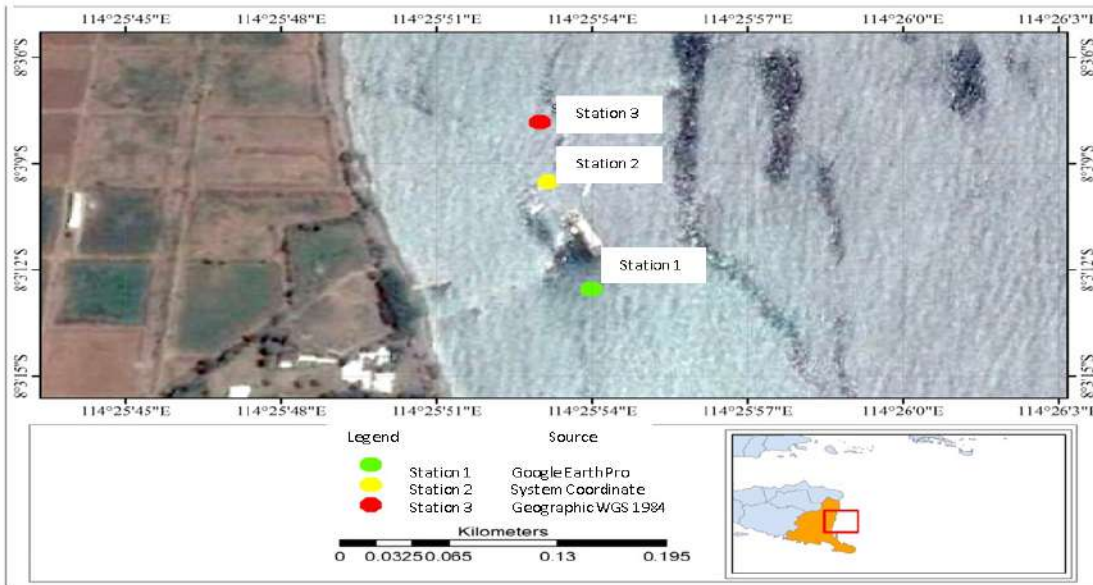
The Line Intercept Transect (LIT) method was employed to discover the percentage of coral reef cover. However, before using LIT, an observation was conducted by snorkeling to find out the data collection stations. This method was conducted by stretching a 100-meter line transect using a rolling meter, placed parallel with the coastline on the same depth (English et al. 1997). Afterward, the length of coral reef growth crossed by the line transect was recorded.

### 2.3 Chain Intercept Transect (CIT) Method

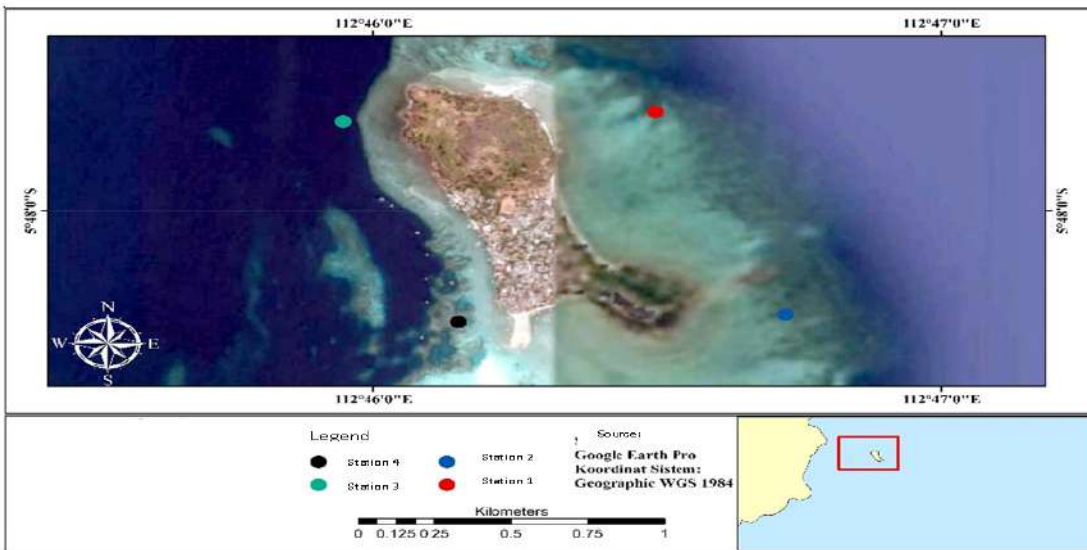
The Chain Intercept Transect (CIT) method was applied to measure the rugosity and complexity of coral reef habitat. After stretching the line transect, the chain transect was put vertically with the line transect of the coastline. The length of it was 4 meters (2 meters on the right side and 2 meters on the left side). The chain transect was put frequently to adjust the coral reef contour on the station 0, and every 10 meters of the 100 meter-line-transect put beforehand (Risk, 1972).

### 2.4 Underwater Visual Census (UVC) Method

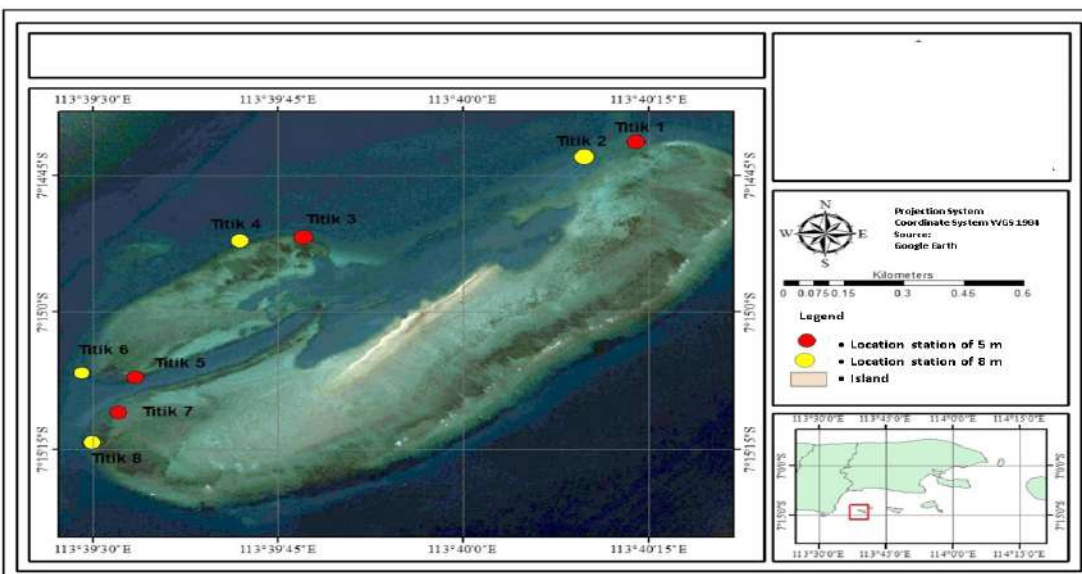
According to English et al. (1997), Underwater Visual Census is a method implemented to determine



**Figure 1.** Research Location Map in Bangsring Village Banyuwangi



**Figure 2.** Research Location Map in Gili Noko Island, Bawean



**Figure 3.** Research Location Map in Gili Kramat Island, Sumenep

the index value related to the coral reef fish abundance. UVC used a 100-meter line transect, with a width of 2.5 meters (left and right) and a height of 5 meters. However, if the survey of coral reef fish was carried out along with the coral reef survey, the fish data had to be recorded first. It aimed to obtain accurate data.

## 2.5 Data Analysis

### 2.5.1 Percentage of Coral Reef Cover

The percentage of coral reef cover was calculated with the following formula (Gomez and Yap, 1988).

$$L = \left(\frac{Li}{N}\right) \times 100\%$$

Note: L= Percentage of coral reef cover (%)  
 Li= The length of life form category *i*<sup>th</sup>  
 N= Transect length (100 meters)

According to Gomex and Yap (1988), there are four criteria of coral reef as follows:

**Table 1.** Criteria of coral reef cover percentage

% Cover	Category
0-24.9	Poor
25-49.9	Fair
50-74.9	Good
75-100	Excellent

### 2.5.2 Analysis of Coral Reef Fish

The fish density value indicates the number of fish individuals per area width in the research location. According to Odum (1988), the fish density can be calculated with this following formula:

$$N = \frac{n}{A}$$

Note: N= Fish individual density (individual/volume unit)  
 n= The number of fish individuals  
 A= The width of the observation area

### Rugosity Analysis

According to McCommick (1994), the observation of coral reef rugosity level was analyzed with this following formula:

$$R = \frac{Ar}{Ag}$$

Note: R= Coral reef rugosity level  
 Ar= Chain length (4 meters)  
 Ag= Vertical transect length

### 2.5.3 The Correlation Analysis of Coral Reef Cover and Rugosity with the Density of Herbivore Coral Reef Fish

The correlation of the percentage of coral reef cover and rugosity with the abundance of herbivorous coral reef fish was calculated using the Multiple Linear Regression method with R software applications. The purpose of Multiple Linear Regression analysis was to measure the intensity of the correlation between two or more variables and predict the estimated Y value over x. According to Nachtsheim et al. (2004), the common form of Multiple Linear Regression was obtained following formula:

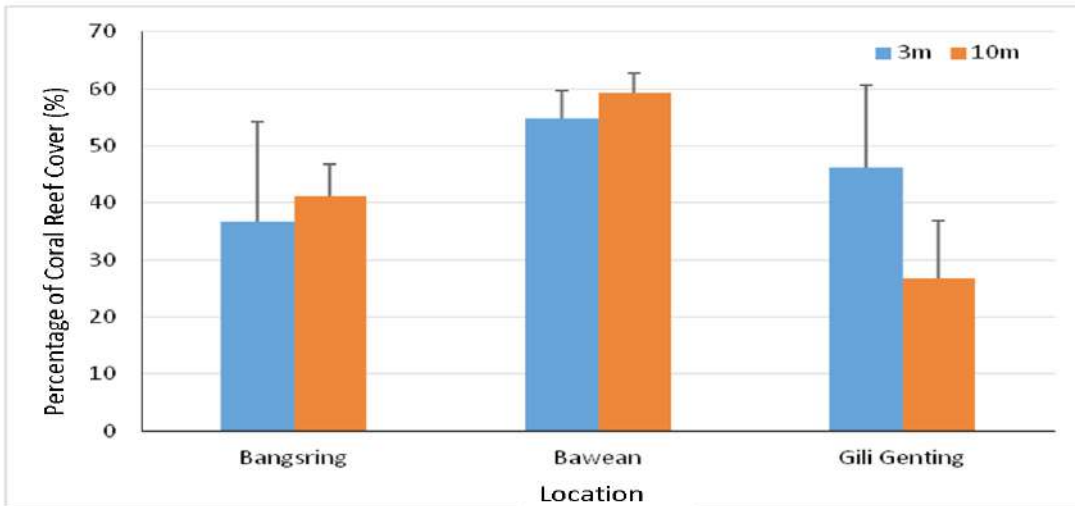
$$Y = a + b_1x_1 + b_2x_2$$

Note: Y= Dependent variable  
 a= Constant  
 b<sub>1</sub>, b<sub>2</sub>= Regression coefficient  
 x<sub>1</sub>, x<sub>2</sub>= Independent variable

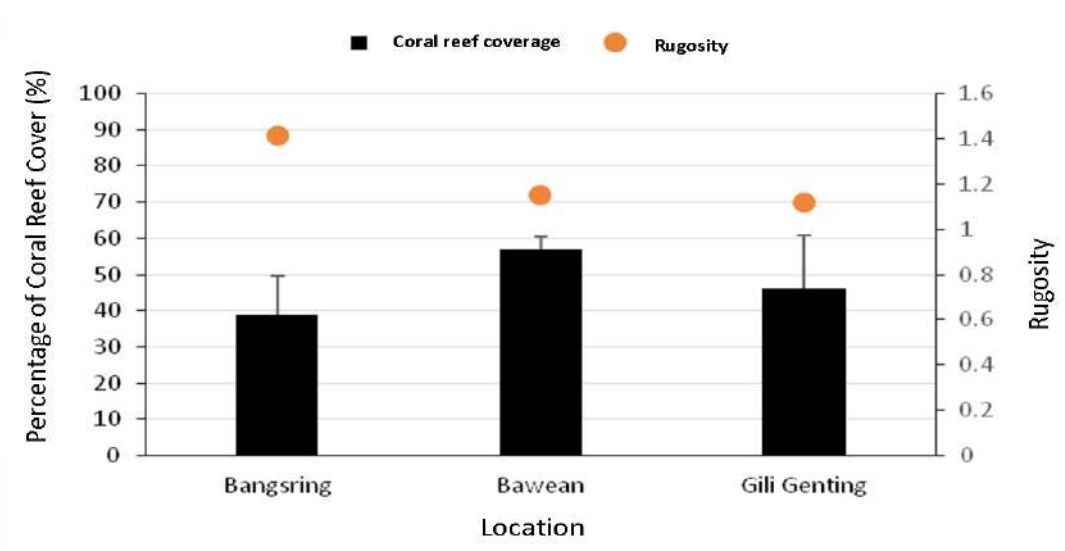
## 3. Result and Discussion

Based on the water depth, the average of coral reef cover in East Java waters was approximately 36.76%±17.51% - 54.87±4.73% for 3m depth, with the highest cover in Gili Noko Bawean Island, and the lowest cover was in Bangsring. On the other hand, in the 10m water depth, the reef cover ranged from 26.67±10.18% - 59.27±3.45%, with the highest cover in Gili Noko Bawean Island, and the lowest was in Gili Genting Island (Figure 4).

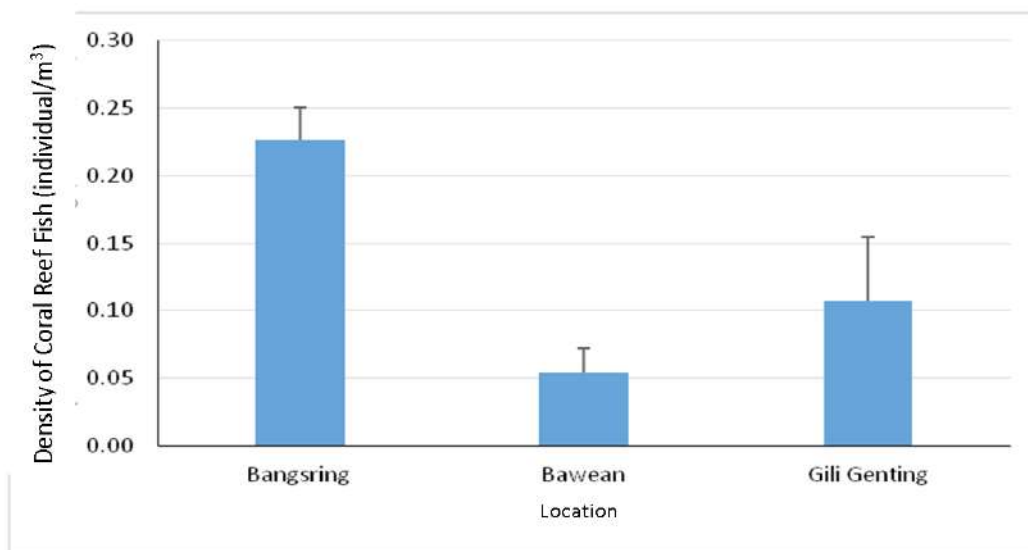
The coral reef cover in the depth of 3m was lower than in the depth of 10 m, except in Gili Genting Island. It was suspected due to destructive fishing practices in the shallow depth. In contrast, there were not many activities of fish catching in Gili Genting Island. Hence, coral reef cover was affected by the environmental factor, such as the direct sunlight. The destructive fishing gear or blast fishing would kill small and big fish and damage coral reef functioning as the habitat of coral reef fish (Dahuri et al. 2001; Suparmoko, 2002). In addition to the destructive fishing gear, as for the example in Gili Genting Island, the sunlight is one of the major factors influencing the coral reef cover. In other words, the deeper the waters, the lesser the sunlight intensity is (Nybakken, 1993).



**Figure 4.** The Average Percentage of Coral Reef Cover at Several Locations in East Java in the Depth of 3m and 10m



**Figure 5.** The average percentage and rugosity in several locations in East Java.



**Figure 6.** The Average of Coral Reef Fish Density at Several Locations in East Java

The average coral reef cover in East Java water ranged from  $38.93 \pm 10.77\%$  –  $57.07 \pm 3.23\%$  with the highest coral reef cover in Bawean water; while, the lowest coral reef cover was in Bangsring water. However, Bangsring waters had the highest coral reef rugosity, which reached 1.41% compared to Bawean and Gili Genting waters reaching 1.16% and 1.12% (Figure 5).

The coral reef cover in East Java waters was categorized as fair and good. More specifically, the coral reef covers in Bangsring and Gili Genting waters were classified fair. In addition, the coral reef cover in Bawean waters belonged to the good category. It, however, is the current typical condition of coral reef cover in Indonesia, where the analysis result of the LIPI team in 2018 conducted on 1,067 locations indicated that the reef was in poor condition (36.18%), fair-good (57.26%) and excellent (6.56%).

Meanwhile, the monitoring results at some stations in the waters of East Java identified that the most of the coral conditions in Baluran National were categorized as poor-fair category, the Pasir Putih Situbondo waters were classified as fair category, the Small Islands in Madura mostly had fair-good category, the Bawean waters condition was in the fair-good category, while Trenggalek waters condition was in the poor category (Hadi et al. 2018).

In addition, the rugosity measurement result ranging from 1.12-1.41 was similar to the finding of Azniana (2015) and Muniaha et al. (2017) in Konawe Selatan waters. The rugosity value obtained here ranged from 1.08-1.26 and between 1.17-1.23. Under other circumstances, Rani et al. (2015) gained rugosity value in Barranglompo Island, ranging from 1.51-2.09. Rugosity is a simpler measurement applied to depict the basic surface of waters (Magno and Villanoy, 2006).

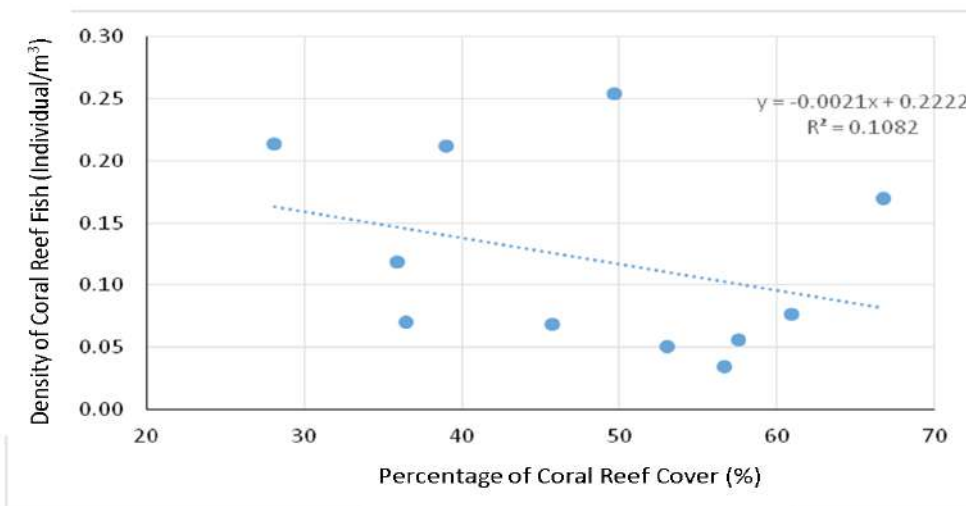


Figure 7. The Correlation of Coral Reef Fish Density with Coral Reef Cover Percentage

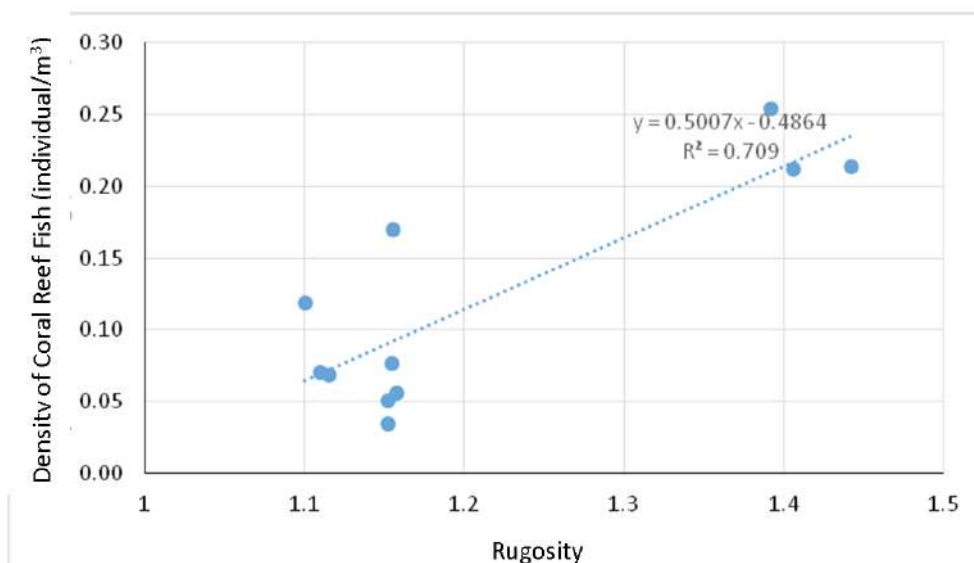


Figure 8. The Correlation of Coral Reef Fish Density with the Coral Reef Rugosity

The converse rugosity and the coral reef cover in East Java waters indicated that despite the dead coral reef, its structure is still intact.

The coral reef fish in East Java waters ranged from  $0.05 \pm 0.02$  –  $0.23 \pm 0.02$  individual/m<sup>2</sup>, with the highest coral reef fish density in Bangsring waters, and the lowest density in Bawean waters (Figure 6). Although the coral reef cover percentage in Bangsring waters was lower compared to other places, Bangsring waters was a successful area for fish house and fish restocking, besides the high coral reef rugosity. Meanwhile, the low coral fish density in Bawean was caused by destructive fishing practices. The coral reef ecosystem is a crucial habitat for the live sustainability of coral reef fish. Most of the coral reef fish population was associated with the special structure and conditions of coral reef biotic. Furthermore, the existence of coral reef fish was affected by the coral reef condition and quality as its habitat (Choat and Bellwood 1991; Allen *et al.* 2003).

The percentage of coral reef cover did not correlate to the coral reef fish density in East Java waters (Multiple Linear Regressions,  $P > 0.05$ ). Notwithstanding, the coral reef fish density likely decreased along with the increase of coral reef cover percentage (Figure 7). The coral reef rugosity significantly impacted the coral reef fish density in the East Java waters (Multiple Linear Regression,  $P < 0.05$ ;  $R^2 = 0.71$ ). Additionally, the coral reef fish density tended to increase along with the intensification of coral reef rugosity (Figure 8).

The coral reef fish density in East Java identified a greater correlation with the coral reef rugosity compared to the coral reef cover (Figures 7 and 8). As a matter of fact, habitat complexity (rugosity) is a critical variable influencing the fish population. Likewise, a more complex habitat generally provides more space for fish shelter to elude from the predators. This finding is in line with other research findings. For example, coral reef rugosity, hole size, and hole density were related to fish abundance in Hawaii (Friedlander and Parrish, 1998). Further, there were many reports indicating that fish abundance was related to habitat complexity (Hixon and Beets, 1989; Friedlander and Parrish, 1998; Gratwicke and Speight, 2005b; Chong-Seng *et al.* 2012; Bozec *et al.* 2013).

The lack of a significant relationship found between fish density, and coral reef cover might be triggered by the specific conditions of coral reefs in East Java. Even, high coral reef fish density was discovered at some locations despite the low coral reef cover. It seems that at some locations with low coral reef cover, there were many soft coral reefs and good structured coral reefs. This research

result was also consistent with the findings of Gratwicke and Speight, (2005b), discerning that a live coral reef cover is not a significant predictor for the fish density in Tortola, Virgin Islands, Great Britain.

Even though it is not a conclusive finding due to unproven correlation and causal analysis, the result confirmed the previous evidence that coral reef fish was easier to find and the number was greater in locations with higher coral reef cover, and lower macroalgae cover (Friedlander and Parish, 1998; Gratwicke and Speight, 2005a; Howard *et al.* 2009; Chong-Seng *et al.* 2012; Tzadik and Appeldorn, 2013), and a complex habitat structure (Tzadik and Appeldorn, 2013). However, the probability of reciprocal correlation between fish abundance and benthic habitat should be concerned. First, the increase of coral reef cover will raise the fish density and vice versa. There had been many studies on the correlation between these variables throughout the world (Syms and Jones, 2000; Pratchett *et al.* 2006; Holbrook *et al.* 2008; Pratchett *et al.* 2011). Secondly, the increase of fish density will add the coral reef cover. Most of those were accurate for herbivore fish (Bellwood *et al.* 2006). Parrotfish, the algae eater, will decrease the macroalgae cover, which further gives a hard substrate on the coral reef (Burkepile and Hay, 2006; Mumby and Steneck, 2008). Moreover, the coral reef strength in Belize increased six times due to the existence of parrotfish (Mumby *et al.* 2014).

#### 4. Conclusions

From this research result, it can be concluded that the coral reef in East Java waters was categorized as a fair-good category, with the highest cover in Bawean waters. Meanwhile, the highest coral reef rugosity is found out in Bangsring Waters. In addition, the highest coral reef fish abundance is also discovered in Bangsring Waters. The coral reef fish density, nonetheless, does not correlate with the percentage of coral reef cover. It, however, significantly correlates with the coral reef rugosity.

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#### Authors' Contributions

WAN analyzed the data, drafted the manuscript and designed the figures. EH, FM and HE collected and analyzed the data. All authors discussed the results and contributed to the final manuscript.

#### Conflict of Interest

The authors declare that they have no competing interests

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