Biodiversity of the “Karang Jeruk” Coral Reef Ecosystem in Tegal Regency, Central Java, Indonesia

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Abstract. "Karang Jeruk" is a Fish Sanctuary whose existence is expected to provide protection for the biota in it. The purpose of this study was to collect and conduct baseline analyzes of the condition of coral reef ecosystem. The results for the ecological index are the Diversity Index (H') is 1.7362 (depth 3 m) and 1.8382 (depth 10 m), so that the diversity is moderate with moderate ecological pressure. Uniformity Index (E) is 0.7864 (3 m depth) and 1.0362 (10 m depth) so that it is included in the high population uniformity category. Simpson Dominance Index (C) is 0.2405 (3 m depth) and 0.2211 (10 m depth), including the species dominance category is low. The percentage of coral cover is 1.30% - 69.28% in the damaged to good category. Diversity Index data (H ') is 1.5157 (3 m depth) and 1.3896 (10 m depth), so that the diversity is moderate with moderate ecological pressure. Uniformity Index (E) is 0.7062 (3 m depth) and 0.6353 (10 m depth) so that it is included in the high population uniformity category. Simpson Dominance Index (C) is 0.2920 (3 m depth) and 0.3497 (10 m depth), including the species dominance category is low.

1. Introduction

Coastal resource management is an effort that must be pursued continuously and sustainable. Natural resources have a limit of maximum capacity, which if the utilization has reached a peak, productivity will definitely decline. One of the coastal resources that has enormous potential, but endangered due to the pressure of utilization is coral reefs. Nowadays, the existence of the coral reef ecosystem is threatened and faced with various main problem, that is decreasing coral habitat habitat as a result of exploitation pressure of excessive or unfriendly fishing and coral exploitation.

It should be noted that although the coral reef ecosystem is a vital habitat, it is prone to disturbance and slow growth. If it is damaged, it will take a very long time to recover. Coral reef ecosystem is a vital habitat, but prone to disturbance and slow growth. If it is damaged, it will take a very long time to recover.
Tegal Regency has a unique marine ecosystem and plays an important role for the sustainability of marine life cycle and capture fisheries productivity. Typical ecosystem of coral reefs that have many massive coral clusters and the local community calls these coral clusters with the name "Karang Jeruk".

The geographical condition of "Karang Jeruk" located in the northern waters of Tegal Regency, with a position open to the impact of the waves, has a great degradation effect. In addition, the area is also one of the fishing locations for Tegal and surrounding areas. Conservation activities of “Karang Jeruk” area has been carried out several times through Artificial Coral Reefs to community empowerment activities. This effort is made to empower the community by actively involving the community with every activity of the planning, implementation and monitoring phase. The hope of community empowerment is to increase understanding, knowledge, and collective awareness to safeguard, preserve and preserve coral reefs in the “Karang Jeruk” area.

Although it is widely acknowledged that coral reefs have been severely threatened, information on the status and condition of coral reefs is limited. This lack of information impedes effective decision making regarding coastal resources. Considering “Karang Jeruk” as one of fishery source for Tegal and its surrounding area, so research is needed to assess the condition of coral reefs.

"Karang Jeruk" is a Fish Sanctuary whose existence is expected to provide protection of biota in it, so that the biodiversity resources can be more defended. Therefore, as a basis for rehabilitation and conservation efforts, the research to determine the condition of “Karang Jeruk” of Tegal Regency needs to be done. The objective of this research is to collect and conduct baseline analyzes on the condition of "Karang Jeruk" Tegal Regency. This research focuses on the condition of coral reef ecosystems and reef fish.

2. Materials And Methods

2.1. Study Area
The object of this research is “Karang Jeruk” area in Tegal Regency waters area located at 109°11,85’ – 109°12,15’ EL dan 06°48,55’ – 06°48,70’ SL with 4 research stations that are on the north, south, east and west on the coral reef area, while determining sampling point by using Global Positioning System (GPS).
2.2. Data Retrieval Techniques

a) Data of Hydro-Oceanographic Condition.

Data collection is done by doing the measurement directly at the time of survey. The hydro-oceanographic data measured were as follows:

1. Temperature, measured using a thermometer;
2. Salinity, measured using refractometer;
3. The current pattern, measured by a float removed and measured distances and directions taken in units of time;
4. Depth, measured using a scale-weighted rope;
5. Brightness, measured by using Secchi disk by drowning into the waters in such a way, then recording the scale contained on the secchi rope at the time of the plate is clearly visible and at times not seen clearly.

From the data recorded then calculated using the formula:

\[ D = \frac{K_1 + K_2}{2} \]  

Information:
- \( D \) = Depth of Water Brightness
- \( K_1 \) = Depth at secchi plate is clearly visible
- \( K_2 \) = The depth on the secchi plate is not obvious

6. Basic substrate, visually observed during underwater surveys.

b) Data of Type and Abundance of Coral Fish.

The method used is visual census and Line Intercept Transect (LIT) that has been adjusted and modified in accordance with the needs and capabilities and facilities available. The length of the transect is 20 meters made parallel to the coastline. Area of observation of each transect is 200 square meters (20 m x 5 m x 2 m) with observation distance 5 meters on the right and left of the transect line (English et al., 1997).

Fish data analyzed at each observation location can be divided into three major groups:

1. Type of Fish Indicator
   This group is the type of fish that live most strongly associated with corals, or very dependent on the presence of corals in a coral waters. Types of fish included in the type of fish indicator from clans of Chaetodon, Forcipiger, Parachaetodon, Caradion, Hemitaurichthys, Chelmon and
Heniochus, included in Chaetodotidae tribe. In the calculation of this type of fish is very easy in the area of observation, because the nature of his own life, there are paired or only in small groups and very rare in large groups.

2. Type of Target Fish
The types of fish in this group are those that have significant economic value that live in association with coral reef ecosystems. This type of fish can also be distinguished over several specific groups. Qualitative data collection of solitary or small fish can be done in such way as observation of indicator fish species. However, for certain types of fish whose high abundance can be calculated by estimation. For example, Caesionidae, Acanthuridae and Siganidae. Several types of Labridae tribe turned out to be the target fish for fishermen especially in the Chelinus clan.

3. Type of Major Fish
This type of fish is small, generally 5 - 25 cm, with various coloring characteristics so known as ornamental fish. This group is generally found abundant, both in the number of individuals and types, and tend to be territorial. These fish have been on coral reefs throughout their lives, represented by the family Pomacentridae, Apogonidae, Labridae and Blediidae.

c) Data of Cover Coral Condition.
This data is conducted by underwater surveys to determine the diversity and percentage of live coral cover. According to English et al. (1997), the method used is the Line Intercept Transect (LIT) with 20 meters transect length and 3 repetitions. Technical implementation in the field is the diver put the string with a length of 80 meters parallel to the coastline, then LIT is determined on the intercept transect 0 - 20 m, 30 - 50 m and 60 - 80 m. Each type of biota through which a line transect is recorded and identified down to the genus level.

2.3. Data Analysis Technique
a) Percentage of Coral Cover.
Data analysis techniques used in this study using qualitative deskriptif analysis. The percentage of total for coral cover was analyzed using Formulation (English et al., 1997):

\[ \text{Cover} = \frac{\text{length of intercept per category}}{\text{transect length}} \times 100\% \]  

(2)

Percentage of live coral cover was assessed using standard criteria of coral reef damage.

| No | Criteria   | Categories | Cover (%) |
|----|------------|------------|-----------|
| 1  | Damaged    | Bad        | 0 – 24,9  |
| 2  |           | Medium     | 25 – 49,9 |
| 3  |           | Good       | 50 – 74,9 |
| 4  |           | Very Well  | 75 – 100  |

Source: Decree of the Minister of State for the Environment No. 4 of 2001

b) Ecological Index.
Analysis of coral and reef condition data using ecological index as follows:
1. Diversity Index (H'):

\[ H' = -\sum \frac{n_i}{N} \times \ln \frac{n_i}{N} \]  

(3)

Information:
\[ H' \] = Diversity Index
\[ N \] = Total length of category
\[ n_i \] = Length of category i
If $H' = 0$ then the community consists of a single species or species and if the value is near maximum then all species are distributed equally to the community.

The index value is:

- $H' < 1$ = small diversity, very strong ecological pressures
- $1 < H' < 3$ = moderate diversity, moderate ecological pressures
- $H' > 3$ = high diversity, equally balanced ecosystems

2. Uniformity Index (E):
The uniformity index (E) is used to see the balance of individuals within the fish and coral community. The values range from 0 to 1, by the formula:

$$E = \frac{H'}{H'_{\text{max}}}; \quad H'_{\text{max}} = \ln S$$  \hspace{1cm} (4)

Information:
- $E$ = Uniformity Index
- $H'$ = Diversity Index
- $S$ = The total number of categories

The criteria of uniformity index value are as follows:

- $E < 0.4$ = small population uniformity
- $0.4 < E < 0.6$ = moderate population uniformity
- $0.6 > E \leq 1$ = high population uniformity

3. Simpson Domination Index (C):
The Simpson Domination Index (C) is used to determine the extent to which a group of biota dominates other groups, by formula:

$$C = \sum_{i=1}^{N} \left( \frac{n_i}{N} \right)^2$$ \hspace{1cm} (5)

Information:
- $C$ = Dominance Index
- $N$ = Category type
- $n_i$ = Length of category $i$
- $N$ = Total length of category

The criteria of dominance index are as follows:

- $0 < C \leq 0.5$ = low dominance
- $0.5 < C \leq 0.75$ = moderate dominance
- $0.75 < C \leq 1$ = high dominance

3. Results and Discussion

Geographically, “Karang Jeruk” is located at $109^\circ11.85' - 109^\circ12.15' \ E \ dan \ 06^\circ48.55' - 06^\circ48.70' \ S$ with an area of about $3,600 \ m^2$. If drawn straight line parallel to fisherman Munjungagung Village, Kramat District, Tegal Regency with distance from the nearest coastline 3.15 miles. The waters of “Karang Jeruk” have a sign easily recognizable by the presence of lighted flare towers.

Taking data of hydro-oceanography condition, fish data and coral condition data is done on 4 stations, they are:

a. Station I: Located on the west side of “Karang Jeruk” ($109^\circ11.57,088'E - 06^\circ48,36,853'S$)
b. Station II: Located on the north side of “Karang Jeruk” ($109^\circ12.7,955'E - 06^\circ48,35,258'S$)
c. Station III: Located on the east side of “Karang Jeruk” ($109^\circ12.16,180'E - 06^\circ48,41,008'S$)
d. Station IV: Located on the south side of “Karang Jeruk” ($109^\circ12.5,012'E - 06^\circ48,42,464'S$)
First, identification of the hydro-oceanography condition of each station, with the results presented in Table 2.

Table 2. Data of Hydro-Oceanographic Conditions of Coral Reef Waters of Tegal Regency

| Variable          | Station I                        | Station II                       | Station III                       | Station IV                       |
|-------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Position          | 109°11'57.088"E - 06°48'36.853"S | 109°12'7.955"E - 06°48'35.258"S | 109°12'16.180"E - 06°48'41.008"S | 109°12'5.012"E - 06°48'42.464"S |
| Salinity          | 33‰                             | 34‰                             | 33‰                             | 33‰                             |
| Water Temperature | 31°C                             | 31°C                             | 31°C                             | 31°C                             |
| Brightness        | 3 m                              | 3 m                              | 3 m                              | 3 m                              |
| Depth             | 3 m                              | 7 m                              | 4 m                              | 3 m                              |
| Current Speed     | 0,1m/dt                          | 0,1m/dt                          | 0,1m/dt                          | 0,1m/dt                          |
| Flow direction    | West                             | West                             | West                             | West                             |
| Substrate         | Coral - sand                     | Coral - sand                     | Coral - sand                     | Coral - sand                     |

Next is the identification of existing biota including species and abundance of fish and coral conditions.

Table 3. Ecological Index of Fish Types at Observation Locations

| Station | (H') | 3 meters | 10 meters | 3 meters | 10 meters | 3 meters | 10 meters | 3 meters | 10 meters | 3 meters | 10 meters |
|---------|------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|
| I       | 1.5334 | 1.5906 | 0.7374 | 1.5906 | 0.2782 | 0.2983 |
| II      | 1.6121 | 1.6096 | 0.8285 | 0.8983 | 0.2312 | 0.2330 |
| III     | 2.2105 | 1.8835 | 0.8896 | 0.8180 | 0.1267 | 0.2045 |
| IV      | 1.5888 | 2.2690 | 0.6900 | 0.8379 | 0.3258 | 0.1485 |
| Average | 1.7362 | 1.8382 | 0.7864 | 1.0362 | 0.2405 | 0.2211 |

Table 3 above can be seen that the ecological index of the existing fish species in the research location shows that for the Diversity Index (H') the average value is 1.7362 (depth 3 m) and 1.8382 (depth 10 m), so that moderate diversity with moderate ecological pressure. As for the Uniformity Index (E) the average value is 0.7864 (3 m depth) and 1.0362 (10 m depth) so that it is included in the high population uniformity category. Then based on the Simpson Dominance Index (C) the average value is...
0.2405 (3 m depth) and 0.2211 (10 m depth), the type dominance category of each station is low, indicating no dominance of one type of fish.

Table 4. Percentage of Coral Cover in “Karang Jeruk”

| No | Station | Total % Live Coral Cover |
|----|---------|--------------------------|
|    |         | 3 meters | 10 meters |
| 1. | Station I | 9.36 | 9.84 |
| 2. | Station II | 1.90 | 1.36 |
| 3. | Station III | 39.04 | 32.60 |
| 4. | Station IV | 68.96 | 44.24 |

In the table above, it can be seen that the percentage of coral cover at Station I is 9.36% - 9.84%, Station II is 1.36% - 1.90%, Station III is 32.60% - 39.04% and Station IV is 44.24% - 68.96%. The highest percentage of coral cover is at Station IV and the lowest is at Station II. Judging from the percentage at each station, "Karang Jeruk" is categorized as damaged to good (1.30% - 69.28%). The condition of "Karang Jeruk" has decreased from year to year, from several observations the results obtained are:

1. In 2007 the percentage of coral cover was 31.76% - 75.84% (Central Java Marine and Fisheries Service, 2007);
2. In 2008 the percentage of coral cover was 20.00% - 49.37% (Zuhry, 2008);
3. In 2011 the percentage of coral cover was 24.87% - 53.33% (Central Java Marine and Fisheries Service, 2011);
4. In 2013 the percentage of coral cover was 17.83% - 51.50% (Central Java Marine and Fisheries Service, 2013);
5. In 2015 the percentage of coral cover was 9.67% - 47.33% (Zuhry, 2015); and
6. In 2019 the percentage of coral cover was 1.30% - 69.28% (Central Java Marine and Fisheries Service, 2019).

![Coral colonies are commonly found in the waters of Tegal regency](image)

Figure 3. Coral colonies are commonly found in the waters of Tegal regency

Table 5. Ecological Index of Coral Types at Observation Sites

| Station | (H') | (E) | (C) |
|---------|------|-----|-----|
|         | 3 meters | 10 meters | 3 meters | 10 meters | 3 meters | 10 meters |
| I       | 1.5641 | 1.3427 | 0.7118 | 0.6900 | 0.2551 | 0.3131 |
| II      | 0.9154 | 0.6217 | 0.5688 | 0.3863 | 0.4685 | 0.6990 |
| III     | 1.6178 | 1.8613 | 0.7780 | 0.8084 | 0.2344 | 0.1789 |
| IV      | 1.9655 | 1.7328 | 0.7663 | 0.6566 | 0.2099 | 0.2078 |
| Average | 1.5157 | 1.3896 | 0.7062 | 0.6353 | 0.2920 | 0.3497 |

The ecological index data of coral species at the study sites at all stations showed that for the Diversity Index (H') the average value is 1.5157 (3 m depth) and 1.3896 (10 m depth), so that the diversity is moderate with moderate ecological pressure which indicates that the “Karang Jeruk” ecosystem is in a
recovery condition. As for the Uniformity Index (E) the average value is 0.7062 (3 m depth) and 0.6353 (10 m depth) so that it is included in the high population uniformity category which indicates that there is an effort to defend oneself slowly towards a better condition. Then based on the Simpson Dominance Index (C) the average values are 0.2920 (3 m depth) and 0.3497 (10 m depth), including the species dominance category of each low station where there is no dominance of any of the coral genera.

Figure 4. Dead Coral Algae, Rubble and Sand Found in Coral Waters of Tegal Regency.

Based on the results of research, it is known that there are problems faced in the management of the “Karang Jeruk” ecosystem. This problem is the decrease in the percentage of coral cover caused by natural and human factors. The most dominant natural factor is high sedimentation caused by churning of waves and ocean currents. Meanwhile, the human factor is caused by fishing activities by lowering the anchor around the reef. This is indicated by the large number of dead corals that have been covered with algae (DCA) and also rubble (rubble).

The existence of reefs has an important ecological role for various marine life such as shelter, feeding ground and spawning ground. In addition, corals also have important economic values for the community (Oktarina et al., 2014). This potential is recognized by the community to lead to exploitation of coral reefs which have an impact on the destruction of coral reefs.

Therefore, it is necessary to maximize conservation efforts of "Karang Jeruk", to increase the participation of the community and related institutions. According to Elliff and Kikuchi (2016), even though coral reefs are in a damaged condition due to factors of climate change and exploitation pressures, in some places they can still provide benefits for coastal communities. So that a good management strategy is needed to restore the natural resilience of coral reefs. Community-based natural resource management is based on the belief that natural resource management in a certain area will be more efficient and effective if the management is carried out by the community itself. This is based on the consideration of the existence of people who are physically close and have a very high interaction with these natural resources. The interactions shown by the dependence of the community on the preservation of natural resources for their survival.

In addition, according to Christie and White (2007) based on experience in the field and empirical evidence from around the world that the Marine Protect Area (MPA) is a very good program to repair the level of damage to coral reefs that have occurred. Hilmi et al. (2017) stated that the key to successful management of coral reef resources is collaborative management, namely by utilizing local community cultural norms, history and political will that are incorporated into one policy.

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