The percentage of coral reef cover in Saonek Kecil Island, Raja Ampat, West Papua

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Abstract. Raja Ampat archipelago is located in the heart of the world’s coral triangle which is the center of the richest tropical marine biodiversity in the world. The Saonek Kecil Island has a location close to the Waisai Harbour (±2 km of sea routes). The Island that has no inhabitants and has a location close to harbour activities potentially damage coral reefs. This research was conducted by Line Intercept Transect (LIT) method that calculate the length of each colony form of growth (life form) of coral reefs on the line transect which stretched along the 50 metres parallel to the coastline at each station to obtain the percentage cover data, diversity index, uniformity index, and dominance index. The results of research percentage cover of coral reef in the waters of Small Saonek Island reach 68.80% – 79.30% by category according to the decision of the Minister of State for the Environment number 4 of 2001 about the damage the reefs criteria included in the category of good – very good. As for the value of diversity index (H’) of 0.487 – 0.675 (medium-high), uniformity index (J) 0.437 – 0.606 (medium-high), and dominance index (C) 0.338 – 0.502 (medium-high).

1. Introduction

Indonesia has a marine area, including ZEEI, of 5.8 million km², which is three fourths of the total area of Indonesia. The area contains 13.466 islands and is surrounded by 95,200 km long coastline, the second longest after Canada [1]. The ocean has the greatest wealth and biodiversity in the world that is one of them is the coral reef ecosystem [2]. The Raja Ampat Island located at the heart of the world's triangle coral (Coral Triangle) and is the center of the richest tropical marine biodiversity in the world. The archipelago is located in the westernmost point of main island in Papua, stretching over an area of approximately 4.6 million hectares. Raja Ampat has a high number of animal species with the discovery of 1.104 species of fish, 699 species of mollusks, and 537 species of coral animals [3].

According to Coremap [4], stated that coral reefs can be affected by natural conditions and human activities. Threats can come from water pollution, waste, tourism activities, cultivation activities, and destructive fishing practices. Unlike the large Saonek Island that has a population, the condition of uninhabited Saonek Kecil island can be potentially vulnerable to excessive fish and coral reefs exploitation because of minimal supervision. Periodic observation of the structure of coral reef ecosystem communities that suffer from natural or human damage should be managed. Observation of
the percentage of hard corals and coral recruitment indicated the extent of its ability to recover naturally [5].

Saonek Kecil is located near the Wasai Port (± 2 km sea lane). The island is near to harbor activity that can potentially damage the coral reef ecosystem since coral reefs and benthic foraminifera always change as a response to the environmental changes, either naturally or anthropogenically [2]. The anthropogenic damages include sedimentation, eutrophication, waste pollution, and exploitation of fish and coral reefs in large numbers [6]. Thus, to support the efforts of coral reef ecosystem’s management, a complete and accurate data are required. The data obtained can be a reference to the authorities to determine the direction of the management policy.

2. Methodology

The preparation was done by checking all research equipment. Hand refractometer and water quality checker’s sensor were washed using distilled water. The sampling location was in Saonek Kecil island due to the presence of coral reefs that spread along the coast of the Island. Furthermore Adi et al. [7], explained that determination of the research station was done purposefully (purposive sampling) based on the consideration that the location of the selected station represented the waters of the island as a whole. Survey of the research location was conducted by using motorized rubber boat around the waters of Saonek Island. The data collection was determined by 3 points of purposive sampling, where the points’ coordination was then plotted with the help of GPS (Global Positioning System). Station I was at the north of the island, Station II was on the eastern part of the island, and Station III was on the western part of the island. No data was collected in the southern area of Saonek Kecil Island because of the coastal topographical condition of the area that was not an area of protected waters. Measurement of the coral reef growth (life form) used line transects by mounting a 50 meter roll meter parallel to the coastline [8].

Data collection of percentage of coral cover used Line Intercept Transect (LIT) method. This method is often used to determine the percentage of coral cover [10]. The researcher snorkeled along the line transect that was stretched for 50 meters along the research stations while recording and collecting the data. The data collection was done in the morning at 09.00 WIT since it has the lowest tidal of ± 1 m depth. Percentage of cover is the percentage of area covered by coral growth. It is obtained by measuring the coral colony intercepted by the transect line. The length of coral intercept along the transect line was divided by the length of the line transect and multiplied by 100% to give the percentage value of the cover [10]. Water quality measurements were performed at each research station. Measurement of salinity used hand refractometer, current velocity was measured with steel ball, brightness was determined with sechi disk, while temperature, pH, and TDS (Total Dissolved Solids) were all assessed using water quality checker.

2.1 Place and Date of Research

The study was conducted in April 2016. The data collection of the percentage of coral cover was conducted in the waters of Saonek Kecil Island, South Waigeo District, Raja Ampat Regency as part of the Ekspedisi NKRI Koridor Papua Barat 2016.

2.2. Tools and Materials

The tools used were swimming aids for feet (fins), snorkeling equipment, underwater camera, steel ball, drop pipette, Global Positioning System (GPS), hand refractometer, buoy (life jacket), motorized boat, water quality checker, chest table, waterproof paper, roll meter, raffia strap, sechi disk, and bottle marker; while the material for the research was distilled water.

2.3. Data Analysis

The data collected was quantitative, while the presentation was done descriptively. The coral cover percentage was obtained from measurement of coral life form (coral intercept) by using the formula [8, 10]:

\[
\text{Percentage of coral cover} = \frac{\text{Length of coral intercept}}{\text{Length of transect}} \times 100%
\]
\[ L = \frac{L_i}{N} \times 100\% \tag{1} \]

Notes:
- \( L \) = Percentage of coral cover (%)
- \( L_i \) = Length of life form (colony intercept) of category \( i \)
- \( N \) = Transect length (50 m)

The percentage of coral cover data was compared with the Decree of the State Minister of Environment No. 4 of 2001 on the criteria of coral reef damage with 0 - 24.9 % categorized as broken, 25 - 49.9 % as medium, 50 - 74.9 % as good, and 75 – 100 % as excellent. According to Legendre [11] calculations of diversity index \( (H') \), uniformity \( (E) \), and dominance \( (C) \) in coral analysis used the following formula:

\[ H' = - \sum_{i=1}^{q} \pi_i \log \pi_i ; \pi_i = \frac{n_i}{N} \tag{2} \]

Note:
- \( H' \) = Shannon diversity index
- \( n_i \) = Length of coral \( i \) species on the line transect
- \( N \) = The length of total coral colonies on the line transect.

The uniformity index \( (E) \) is used to see balance of individuals within the coral reef community. The value is a comparison between the value of diversity with its maximum diversity that ranges from 0 to 1. Pielou in [16] stated the formula for uniformity \( (J) \) as the following:

\[ J = \frac{H'}{H_{\text{max}}} = \left( - \sum_{i=1}^{q} \pi_i \log \pi_i \right) / \log q \tag{3} \]

Notes:
- \( J \) = Evenness uniformity index
- \( H' \) = Shannon diversity index
- \( \pi_i = \frac{n_i}{N} \)
- \( q \) = Total number of coral species

The dominance index \( (C) \) is used to determine the extent to which a group of coral biota dominates other groups. The value of this index ranges from 0 to 1. If the index value is close to 0 then there is no dominant coral group, whereas if the index value is close to 1, then there is a dominant coral group. [11] states the formula of dominance index as the following:

\[ C = \sum_{i=1}^{q} \pi_i^2 = \sum_{i=1}^{q} \left( \frac{n_i}{N} \right)^2 . \tag{4} \]

Note:
- \( C \) = Dominance Index
- \( n_i \) = The length of the \( i \)-coral coral species on the line transect
- \( N \) = The length of the total coral colonies on the line transect
- \( q \) = The total number of corals.

3. Results and Discussion

3.1. The Geographical condition of Saonek Kecil island

Saonek Kecil Island is part of the South Waigeo District. The island has an area of ± 1.175 m² and is an uninhabited island. Access to the island takes ± 15 min from the navy post of TNI AL Waisai by
motorboat. The island has a wooden dock, lush vegetation, and there is a church that is no longer used by the people. The northern boundary of the island lies at coordinates 0 ° 26'56,490 "North Latitude, 130 ° 48'3,645" East Longitude, and it is bordering with the Siwindores Bay and Waigeo Island. Northeast of the island is bordering with the Port of Waisai with a distance of ± 2 km of sea lane. East Boundary of the island lies at coordinates 0 ° 274,279 "North latitude, 130 ° 48'12.451" East longitude; while the southern boundary of the island is at coordinates 0 ° 27'15.325 "North latitude, 130 ° 48'6,349" East longitude, and the western boundary of the island is at coordinates 0 ° 27'5,051 "North Latitude, 130 ° 47'57,542" East Longitude. from its eastern to the western part, the island is surrounded by the Dampir Strait, however the southwestern part of the island is bordering with the island of Saonek Besar with a distance of ± 2.5 km of sea lane.

3.2 The Percentage of coral coverage and index

The samples from Station 1 (North) consisted of 7 types of coral growth form with total coral cover percentage of 70.42 % containing Soft Coral (SC) 30.40 %, Coral Submassive (CS) 8.90 %, Coral Massive (CM) 9.14 %, Coral Encrusting (CE) 14.38 %, Acropora Submassive (ACS) 2.44 %, Acropora Ddigite (ACD) 2.78 %, and Acropora Branching (ACB) 2.98 %. Another 29.58 % of the sample included Sand (S) 21.70 %, Rubble (R) 6.48 %, and Dead Coral Algae (DCA) 1.40 %. Samples from Station 2 (East) were 5 types of coral growth form with total coral cover percentage reached 79.30 % consisting of: Soft Coral (SC) 31.20 %, Coral Massive (CM) 22.90 %, Coral Entrusting (CE) 23.40 %, Acropora Submassive (ACS) 0.40 % and Acropora Branching (ACB) 1.40 %. Another 20.70 % included Sand (S) 5.60 % and Rubble (R) 15.10 %.

![Figure 1. Percentage diagram of coral reef category.](image)

The samples from Station 3 (West) were 8 types of coral growth form with total coral cover percentage reaching 68.80 % with the details: Coral Foliose (CF) 2.40 %, Soft Coral (SC) 13.90 %, Coral Subclassive (CS) 0.80 %, Coral Massive (CM) 36.70 %, Coral Encrusting (CE) 5.40 %, Acropora Submassive (ACS) 0.90 %, Acropora Ddigite (ACD) 5.70 %, and Acropora Branching
While another 31.20% was in the form of Rubble (R). Percentage diagram for coral cover category can be seen in figure 1, while for non-coral reef category is shown in figure 2.

Figure 2. Percentage diagram of non-coral reef category

The data of coordinate’s location of the research are shown in table 1. Diversity Index (H’), Uniformity Index (J), and Index Dominance (C) at each research station can be seen in table 2. Water quality at each research station is displayed in table 3. Conditions at all research stations are shown in figure 3.

Table 1. Coordinates of research stations.

| Station 1 (North) | Station 2 (East) | Station 3 (West) |
|-------------------|------------------|------------------|
| S 00° 26’ 984” E 130° 48’ 023” UTM 0036-5026 | S 00° 26’ 956” E 130° 48’ 077” UTM 0070-5038 | S 00° 27’ 072” E 130° 48’ 007” UTM 0033-5010 |

Table 2. Index value of research station.

| Index          | Station 1 (North) | Station 2 (East) | Station 3 (West) |
|----------------|-------------------|------------------|------------------|
| Diversity (H’) | 0,675             | 0,511            | 0,487            |
| Uniformity (J) | 0,606             | 0,459            | 0,437            |
| Dominance (C)  | 0,502             | 0,323            | 0,338            |

Table 3. Water quality of saonek island station.

| Parameter             | Station 1 (North) | Station 2 (East) | Station 3 (West) |
|-----------------------|-------------------|------------------|------------------|
| Salinity (‰)          | 30                | 30               | 31               |
| Current Velocity (m/s)| 0,033             | 0,05             | 0,033            |
| Depth (m)             | 0,5               | 1                | 1                |
| Temperature (°C)      | 31,8              | 33,9             | 30,5             |
| pH                    | 8,05              | 8,41             | 8,13             |
| TDS (mg/l)            | 0,8               | 0,9              | 0,9              |
3.3. Analysis of coral cover
The result obtained by LIT (Line Intercept Transect) method was compared with the Decree of the State Minister of Environment No. 4 of 2001 on the standard criteria for coral reef damage. At Station 1 (North) the percentage of coral cover total reached 70.42% and it was categorized as good. The dominant coral species was Soft Coral (SC) 30.40%. The Acropora Branching (ACB) was the least with a percentage of 2.38%. Abiotic rate of closure at this station was 28.18%, which consisted of Rubble (R) 6.48%, and Sand 21.70%. It is better for a coral reef ecosystem if the percentage of live coral cover is greater than the percentage of abiotic cover [12]. The percentage of corals in this water was in good category because the location of the research station is leeward waters. Leeward is a reef area protected from the coming wind [4], closed coral habitats rarely experience changes in temperature, salinity, and nutrient levels caused by strong current and wave movements with average annual temperature and salinity of 23-25 °C and 32-35 ‰, respectively. Growth of soft coral species blooms when the hard coral is in a critical or damaged condition. These corals grow well in low-brightness water conditions and high nutrient content [13]. According to the results, the dominant coral species where was the Soft Coral (SC) of 31.20%.

![Figure 3. Research location.](image-url)

Station 2 (East) had 79.30% of total coral cover and it was included in the excellent category. The dominant coral species was Soft Coral (SC) at 31.20%. Acropora Submassive (ACS) had the lowest percentage of 0.40%. Abiotic closure rate was seen from the amount of Rubble (R), which was 15.10%, and Sand (S) (5.60%). At this station, the percentage value of coral cover was the highest compared to other research stations, due to there was strong current at this station. According to Manuputty [14], dynamic (choppy) waters have benefits for coral growth, such as the availability of higher oxygen than in calm waters. When there is a wave, most of the oxygen is tied up and accumulated in the water column and leaching occurs easily on the surface of the reef. At this station, the dominant coral species was soft corals because during the lowest tide phase, the water level was not lower than the height of the coral reefs, thus coral reefs were not exposed to direct sun and air.
Moreover, soft coral is a coral group that could grow easily in a short time compared to rock corals. Water movement caused by The currents makes the soft corals to survive, adhere to hard substrates, and support high growth processes [14].

The percentage of coral cover in Station 3 (West) reached 68.80 % that made it included in the good category. The dominant coral type there was the Coral Massive (36.7 0%) and Coral Submassive had the lowest percentage of 0.80%. Coral damage rate of 31.20 % included Rubble and it was the highest if compared to the two previous research stations. The lowest percentage of coral reefs was found in this location since the waters of the western part of Saonek Island included reef zone flat that was adjacent to the waters of the Dampir Strait. Moreover Luthfi [15], stated that reef zone flat has uncertain environmental conditions due to the very low water volume at the lowest tide causing many hard corals to be exposed to the air. Salinity that rises sharply during the lowest tide limits the types of hard corals that can grow. The lack of currents and waves to supply nutrients is also another factor inhibiting the growth of hard corals.

The water salinity of Saonek Island was 30-31 ‰, which was in accordance with the salinity of Indonesian waters in general that ranges from 30-35 ‰ [16]. According to the Decree of the State Minister of Environment No. 51 of 2004 on sea water quality standards, salinity tolerance for marine life, especially coral reefs, is ± 5 ‰ of natural salinity value that is 33-34 ‰ at seasonal average. Therefore, having such salinity made it possible for coral reef to survive and grow at the research stations. Moreover Seveso et al. [17], stated that salinity changes can provide cellular damage to coral reefs caused by disruption of physiological regulatory process.

Current velocity at the study site including the calm current was 0.033-0.05 m/s. Saonek Island is part of the South Waigeo District, which is a protected water area [3]. Current velocity may change at any time depending on the weather and seasonal conditions. Current velocity affects coral growth both directly and indirectly since the strength of a current is associated with distribution of oxygen and nutrients and decreased rate of precipitation [18].

The Temperature at the research location ranged from 30.5-33.9 ºC. According to the Decree of the State Minister of Environment No. 51 of 2004 about sea water quality standard, temperature tolerance for marine life, especially for coral reefs, is ± 2 ºC from natural temperature that is 28-30 ºC. Tolerance of coral reefs towards high temperature can go up to 36- 40 ºC. At temperature lower than 18 ºC, coral reefs cannot develop [19]. The high temperature at the study site was caused by the depth of the research location, which was only 0.5 m so that penetration of the sunlight could increase the temperature to be higher than the normal temperature. Temperature affects the metabolic rate of an organism. A temperature rise of 10 ºC will cause the required oxygen consumption for an organism's metabolic activity to increase twice. Some corals can withstand temperature of 14 ºC but their rate of calcification decreases. The effects of temperature changes on corals can lead to decreased feeding responses, reduced reproduction rate, mucus, and decreased photosynthesis and respiration [20].

The degree of acidity or pH at the study site did not have a significant difference, which was between 8.05- 8.41. According to the Decree of the State Minister of Environment No. 51 year 2004 about seawater quality standard, pH tolerance for marine life especially coral reefs was ± 0.2 from 7 - 8.5 unit pH. In general, the pH of sea water did not change much, because the carbon dioxide the water has a strong buffering capacity. Good pH values for coral reefs range from 6-9 [16].

Climate change and the various disasters that often occur these days are alarming. The impacts are varied, including coastal changes in some areas. Some areas are reduced due to the erosion and abrasion of the sea, but there are also areas that are increasing due to the high rate of sedimentation [21]. The TDS measurements resulted in 0.8-0.9 mg/L. According to the Decree of the State Minister of Environment No. 51 of 2004 on seawater quality standards, suspended solids tolerance for marine life especially coral reefs, was ± 10% from seasonal concentration of a maximum value of 20 mg/L. Effendi [22] stated that TDS is usually caused by inorganic materials in the form of ions that are commonly found in waters.
3.4. Coral reef index analysis

The diversity index value of 0.487-0.675 shows the diversity of coral reefs at the research locations, which fell into the medium-to-high category. The coral reefs had low ecological pressures to achieve ecosystem balance. It caused abundant types of coral found in the study sites. The results showed that the highest diversity index of 0.675 was obtained at Station 1 (North) with 70.42% percentage of closure, while the highest percentage was in Station 2 (East). The result of the total coral cover was 79.30%.

The uniformity index value of 0.437-0.606 belonged to the medium-high category. This value indicated that each form of the coral reef (life form) at the study site has relatively equal number and they did not vary much from one to another. The high uniformity index values in the study site indicated a balanced coral reef ecosystems; a relatively similar number indicated that the level of competition between coral species was low. The distribution of uniform species (life form) can have an inverse relationship with biological activity in an environment. The lower the value of uniformity, the higher the biological activity, such as food production, life cycle, and inter-tropical energy flow. Seasonal weather changes and pollution can increase competition among species and decrease the value of uniformity [10].

The dominance index value of 0.323-0.502 was included in the medium-high category. The numbers indicated that there was a group of dominant forms of coral growth (life form) at the study site. If the value of the dominance index (C) is near zero, it indicates that there is no dominant biota and it is usually followed by a high uniformity (E) value. Conversely, if the value of the dominance index (C) is close to one, then it illustrates that in the waters there is one dominant biota and it is usually followed by a low uniformity value [23].

Overall, the coral reefs on the island of Saonek Kecil are in good condition. The extent of damage caused by natural factors can be seen from the minimal coral bleaching that is due to the exposure of corals to the air and direct sunlight at the lowest tide phase. In addition to the absence of anthropogenic activity on the island of Saonek Kecil, it is also worth to consider that the stress on the coral reef ecosystem does not come from humans. Damage to the coral reefs caused by humans, such as destructive fishing with explosives, is no longer found because it is now strictly regulated. This condition is also supported by the local wisdom in the form of prohibition of fishing at a certain time (sasi). This customary law was even written on a dock at Mayalibit Bay District shown in figure 4.

Figure 4. Local rule written on a dock.

This regulation shows that the Raja Ampat’s people participate in keeping the sea as renewable resources by giving the ecosystem time to recover before re-using it. Management of coastal areas like this is expected to continue in order to create sustainable natural resources to generate a positive impact on the environment as well as for the wider community. By analyzing the dynamics and the importance of the coastal areas, it is absolutely necessary that the management is carried out seriously using an integrated system, considering many interests may intersect with each other [24]. In addition, according to Pursetyo [25], the coastal ecosystems, such as mangroves, can provide jobs, whether by
providing seed for the fishery industry or wood for firewood, paper materials, and construction materials with sufficiently high economic value. Today, mangrove ecosystem is getting developed for recreational facilities or as a tourism place to increase state revenues. To improve the welfare of the people dependent on coral reef ecosystems, there is an adaptive management plan that includes strong fisheries regulations, consistent periodic monitoring, and integration of land and marine management practices [26]. The custom regulation indirectly becomes one of the supporting factors that can improve fishery yield and increase tourist attraction. This is in accordance with data of production volume of fishery products at Raja Ampat Regency in 2010-2014, which was 222.36-4,352.48 tons. The number of foreign and domestic tourists visiting the area also increased in 2011-2015 from 6,405 people to 14,190 people [27]. Coral reef-based tourism in the Coral Triangle has a positive impact on the economic sector, but it may have a negative potential for the social and environmental sectors, thus an approach is needed to evaluate the sustainability of the activity [28].

4. Conclusions

Based on the research it can be concluded that the percentage of coral cover of Saonek Kecil Island reached 68.80- 79.30% that was categorized as good- excellent according to the Minister of Environment Decree No. 4 in 2001 on the standard criteria of coral reef damage. The index value of diversity (H’) was 0.487- 0.675 (medium- high), uniformity index (J) was 0.437- 0.606 (medium-high), and dominance index was (C) 0.338- 0.502 (medium- high).

It is necessary to observe at different depth and to add more research stations to find out more accurate result of coral reef condition on Saonek Kecil island. Research on the percentage of coral cover on the Saonek Kecil island should be done periodically, at least every 5 years according to the Decree of the Minister of Environment No. 4 of 2001 on the standard criteria of coral reef damage, to be able to determine the condition of coral reefs regularly related to update the status of the territory.

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