Assessment of coral reefs health in Nature Recreation Park (TWA=Taman Wisata Alam) Sangiang Island, Banten

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Abstract. Sangiang Island had been established as a Nature Recreation Park (TWA) in Indonesia, that requires comprehensive data support for good management. The rise of marine tourism that increased in TWA Sangiang Island behoove to be a concern, especially in coral reef ecosystem. The study aimed to determined the condition of the coral cover and the biomass composition of coral reef fishes, then to identify parameters that affect coral health and the coral reefs health index in TWA Sangiang Island. The observation was carried out in area near to the estuary (Legon Waru), entry point for shipping (Tembuyung), and diving tourism (Legon Bajo). The highest of biomass of target fish was Legon Bajo (0.013 kg / ha) and the lowest was Tembuyung (0.002 kg / ha). Coral reefs health index values in each station varied from 1 (low) to 4 (high). Coral reefs health index in Legon Waru was strongly influenced by live coral cover, and also in Legon Bajo was influenced by live coral cover, rubble and biomass of target fishes, while in Tembuyung was much influenced by fleshy seaweed cover. The results indicated that the coral reef ecosystem on Sangiang Island wasn’t in good condition as a whole.

1. Introduction

The status of Indonesia’s coral reefs was in very good condition only at 6.56%, good conditions at 22.96%, fair conditions at 34.3%, and bad conditions at 36.18% [1]. The diversity of coral reefs in Indonesia is a habitat for a variety of marine organism [2][3]. One of the locations with coral reefs is Sangiang Island. Geographically, Sangiang Island is located between latitude -5°56'00" to -5°58'00" and longitude 105°49'30" to 105°52'00". Administratively, Sangiang Island was included in the Cikoneng Village Region, Anyer District, Serang Regency, Banten Province [4].

The status of conservation in Sangiang Island was managed by the Ministry of Forestry and had changed several times. In the beginning, Sangiang Island was declared on 23rd May 1985 based on Kepmenhut No. 122/Kpts-II/1985 as a “Cagar Alam” with total area 700.35 Ha. Then the status of the island and the sea area around it was changed to “Taman Wisata Alam (TWA)” on 12th October 1991 with total area 700.30 Ha. For the last time on 8th February 1993, the area of the island was changed to 528.15 Ha. As one of the conservation area, Sangiang Island has high biodiversity potential such as soft coral, blue coral, meliophora, and also Sangiang Island has a potential fish resource such as Chaetodontidae, Pomacentridae, and Acanthuridae. There are 23 locations that tourist can visit for marine tourism activity such as scuba diving, snorkelling, jet ski, sailing, swimming, fishing, and
sunbathing [4]. Unfortunately, the coral reef at Sangiang Island has been experiencing environmental pressure caused by massive marine tourism and high nutrient input from mainland. The method that can be used to determine the condition of coral reefs is the Coral reef health index.

Coral reef health index is useful for helping the management of coral reefs and their associated ecosystems. This method needs comprehensive data, experiences, and high scientific competence to get the value of coral reef index. Many parameters don’t necessarily guarantee for producing better index value. The question that arises, what about the coral reef health index that appropriate to describe health of coral reefs in Indonesia. Kaufman et al [5] included three parameters to determine the coral reef index, such as benthos (coral cover and crustose coralline algae), coral reef fish (the total biomass), and microbe organisms (Vibrio bacterial concentration). The World Bank [6] developed a protocol for measuring coral reef ecosystem health, the coral reef health index value consists of biodiversity indicators (diversity of coral, fish, and endangered species), community structure (coral cover, ratio between corals and algae, abundance of fish, and rugosity), abiotic factors (water quality, ocean colour, and sedimentation rate), and habitat area (area of coral reef, area of mangrove, area of seagrass). Díaz-Pérez et [7] modified the method on the Coral reef index (CRI) and issued the 2D-CHI method that only used the benthos and coral reef parameters. In Indonesia, The Indonesian Institute of Sciences (LIPI) issued the method for calculating the coral reef health index with two main components, the benthic biota component based on coral cover and the reef fish component based on the total biomass of target fish [8]. There are various methods that can be used to determine the health index of coral reefs. However, the method used can be adjusted according to the needs and availability of data.

The status of Sangiang Island as one of the conservation areas in the form of a natural tourism park (TWA) required comprehensive data support to conduct good management. The rise of marine tourism that developed at Sangiang Island behave to be a concern, especially in coral reef ecosystem. The study on coral health needed to be implemented at Sangiang Island to support the management of coral reefs ecosystem. Perhaps from the data can be the basis for obtaining the coral reef index value, then it can assist in the management of the Sangiang Island. The purpose of this study was to determine the condition of the substrate, the composition on biomass of coral reef fish, and to identify parameters that affected coral health and the coral reefs health index in TWA Sangiang Island.

2. Methods
The study was conducted on May 22, 2019, which was located on three stations of the eastern part of Sangiang Island. The first station was in the Legon Bajo, then the second station was in Legon Waru, and the last station was in Tembuyung. Data collection was conducted with the SCUBA diving equipment on reef slopes with depth 3-5 m. Live coral and biota cover and also other types of substrates was taken by using the Underwater Photo Transect (UPT) method. The mark in water used the 75 m line transect with 3 replications (3 x 20 meters). Underwater shooting was done with a digital camera on a quadrant frame measuring 58x44 cm [9]. The taking photos was perpendicular to the frame, that taken with the distance between frames of 1 m, the frame was alternately mounted on the left and right of the line. Data on coral reef fishes were taken using the underwater visual censuses (UVC) method and also with using the belt transects [10]. Belt transects were used along 50 m with width 2.5 m on the right and left, then the total area of observation was 50 x 5 m = 2500 m². The Identification was carried out to the lowest taxonomy level using the guidebook [11].
Figure 1. Study site for taking rehabilitation steps in the Sangiang Island area, Banten. The circle was the stations site for coral reef ecosystems. (1) Legon Bajo (2) Leon Waru and (3) Tembuyung. The transect was installed at three stations. Legon Waru station represented as area near to the estuary, Tembuyung station represented as entry point for shipping, and Legon Bajo represented as area for diving tourism. A visual description of the observation methods can be seen in Figure 2.

Figure 2. The visualization for observation using belt transects in coral reef ecosystem surveys, which included coral cover, coral diversity, disturbance to corals, reef fish biota, and macrozoobenthos biota.

Underwater photo data on each transect was analysed using CPCe (coral point counted with excel extensions) [12]. The percentage analysis of biota cover referred to [13] by calculating the percentage of substrate cover categories obtained from the formula:
The assessment of coral reef condition on using the criteria that developed by Zamani and Madduppa [14].

Table 1. Criteria for coral reef health.

| Parameters   | Criteria for coral reef health |
|--------------|--------------------------------|
|              | Very Good | Good | Fair | Bad   |
| Live coral cover | 75-100%   | 50-74.9% | 25-49.9% | 0-24.9% |
| Algae cover     | 0-24.9%   | 25-49.9% | 50-74.9% | 75-100% |
| Sand cover      | 0-24.9%   | 25-49.9% | 50-74.9% | 75-100% |
| Mortality index | 0.75-1    | 0.50-0.749 | 0.25-0.499 | 0-0.249 |

The biomass of coral reef fish was calculated using the length-weight relationship for each fish species using the formula from Kulbicki et al [15]:

\[ W = aL^b \]  

where \( W \) was the weight of natural fish in gram (g), \( L \) was the fish length (fork length) in cm, \( a \) and \( b \) were the constanta.

The value of coral reef health index was measured using the method that developed by LIPI (The Indonesian Institute of Sciences). The method was determined by two main components, they were benthic biota components that based on coral cover and reef fish components based on the total biomass of target fish. The resilience or recovery factor was calculated based on fleshy seaweed cover and rubble cover. Correspondence analysis was used for statistical analysis. This analysis was able to analyze the closeness between the coral health index parameters and the observation station. It can be determined what parameters were greatly affected the health condition of corals in each station.

3. Results and discussion

The underwater substrate category in the Sangiang Island was dominated by Sand (S), Live Coral (C) and Other Biota (OT). The average of live coral cover found was 24%, categorized in the damaged category, based on Zamani and Madduppa [14]. Percentage of hard coral cover varied between each locations that ranged from 2.50 % to 37.50 %. While, dead coral cover ranges from 5 % to 38%. The lowest percentage of coral cover was found in Tembuyung Station, by 5 % (bad category). In contrast, the highest score was 38 % (medium category) that found in Legon Bajo.
The percentage of coral cover in Tembuyung was very low, because this station was adjacent to a river mouth that flowed from the mainland of Sangiang Island. The river carried sediment particles from the mainland which could disturb coral growth. Burke et al [16] also argued that large amounts of sediment could weaken and kill corals and other benthic organisms, while in low amounts will reduce the ability of zooxanthellae for photosynthesis thereby disrupting coral growth. If it happens for a long time, it will eventually cause a decrease in coral cover.

Branching and foliose form were dominant of corals life form at the observation site. Acropora (branching coral) coral groups were closely related to the rapid recovery of coral cover [17] It also showed that coral reef ecosystems there have low complexity, because branching corals (Acropora) tend to be very vulnerable to disturbance. Acropora was one of the most vulnerable coral groups to disturbance or pressure both natural and anthropogenic [17]. They also argued that various forms of coral life form respond differently to physical disturbance caused by humans with large colonies having...
a higher tolerance than branching colonies. Vulnerability of different morphological forms on coral ecosystem will cause a shift in species domination, that’s why Acropora (branching coral) cover must to be combined with an abundance of massive and submassive corals to show good water quality.

The observation showed that percentage of coral fragment cover was varied between observation stations, from 8 % to 19 % (figure 5). The highest percentage was in Legon Bajo with 19.06 % and the lowest was in Tembuyung with 8 %. These results concluded that the condition of the coral reef ecosystem in the eastern part of Sangiang was in a depressed condition. This was indicated by the discovery of many dead corals at the Legon Waru and Legon Bajo. This dead coral was closely related to the number of irresponsible tourist activities that produced the rubbish in the sea and also found anchor activities on coral reefs. The location with predominantly dead coral was often found the rubble that extended to several meters. The areas filled with rubble were often referred to as Rubble Killing Fields, where corals can’t grow. Rubble always moves dynamically due to the influence of water dynamics (ex; current), that caused the attached coral reefs will die due to upside down or buried [20]. The high cover of rubble will lower the potential for coral reef ecosystem recovery, because coral fragments are very difficult to be able for attaching coral’s larvae, that’s why coral fragments are not the good substrate for coral larvae to grow and develop [21].

![Figure 5. Percentage of coral fragment cover (Rubble) on Sangiang Island.](chart)

Fleshy Seaweed is a term used for the algal macro community that is seen directly, such as Sargassum, Padina, and other macro algae [21]. High fleshy seaweed cover will result in a low level of resilience or potential for coral reef ecosystem recovery. Because fleshy seaweed has a very fast growth rate compared to corals, so it will beat corals in space competition. The observation showed that the percentage of fleshy seaweed was varied at each stations (figure 6). The highest percentage of cover was in Legon Waru by 14 % and the lowest was in Tembuyung by 5.95 %. 
Legon Waru and Legon Bajo were classified as better locations that had good trophic structures in the presence of all types of trophic groups (Figure 7). Unlike Tembuyung, which was more filled with fish from the planktivore group, because Tembuyung station was in front of the freshwater run-off, this reason made the condition of coral reefs and food availability was quite limited for some trophic groups. Fish in the lowest food chain were more commonly found in Waru, while fish with the highest food chain group are more found in Bajo. The specific fish groups such as herbivores and coralivores also only occurred at Legon Waru and Bajo station, so that the availability of algal food and coral polyps in both locations can provide a niche for these two groups.

Figure 7 showed that planktivorous, omnivorous and benthic invertivorous group were classified as the highest abundance at each observation station. The three groups were composed of fishes with size not too large and included into the group of major fish (Mayor). This group played more role as a complement to the food chain. Herbivorous and carnivorous group were more commonly found at Bajo station, while coralivorous groups were more commonly found at Legon Waru station.
Figure 8. Abundance of reef fishes at each station in Sangiang Island.

*Zanclus cornutus* from the family Zanclidae was quite easy to find in several coral reef ecosystems in Indonesia. Siganidae (ex; Baronang) were larger biomass in Legon Bajo that represented by *Siganus virgatus*. Whereas the family of Acanthuridae, Scaridae and Pomacentridae filled many species of herbivorous fish in Sangiang. Herbivorous groups were classified as a key group in the rehabilitation process of a coral reef ecosystem. It will be able to protect coral reefs from space competition with algae. However, several types of herbivorous fish such as from the Siganidae and Scaridae have become target fish for the surrounding community in several locations.

![Trophic Groups](image)

Figure 9. Biomass of target fish at each station in Sangiang Island.

The biomass of target fish at each station had a fairly varied value (Figure 9). The highest biomass was at Legon Bajo Station by 0.013 kg/ha and the lowest was at Tembuyung by 0.002 kg/ha. The lowest biomass in Tembuyung was probably due to its location directly in front of the fresh water run-off, so that the condition of coral reefs and the availability of food was very limited for coral reef fishes.

The coral reef health index value in this study was measured based on two main components, they were from the benthic biota component (ex; coral cover) and the reef fish component (biomass of target fish). Resilience level factor or recovery factor was calculated based on fleshy seaweed cover and rubble cover. The results of the coral health index value in each station varied from 1 to 4. The station that had a coral health index value of 4 was the Legon Waru station, this stated that station had high coral cover...
and low reef fish biomass. Legon Bajo station had the coral health index value of 3, this stated that station had medium live coral cover and low reef fish biomass. Tembuyung station only had the coral health index value of 1, this stated that station had low coral cover and reef fish biomass was also low (figure 10).

![Coral Health Index for each station in Sangiang Island.](image_url)

Figure 10. Coral Health Index for each station in Sangiang Island.

Furthermore, to analyze the coral health index parameters that affected each station used correspondence analysis (CA). Based on the results, it can be seen from the closeness between the coral health index parameters and the observation station (figure 11). The coral health index parameter in the life form of coral cover had the highest proximity to the Legon Waru station and had the farthest distance from the Tembuyung station. This result showed that the health of corals in Legon Waru was very much affected by live coral cover compared to the other two stations. In contrast to the Legon Bajo station, which the distance was quite close to the hard coral parameter, it also had proximity to other health index parameters, they were rubble and biomass of target fish. This showed that the health of corals in Legon Bajo was influenced by hard coral, rubble and biomass of target fish. Based on analysis, Tembuyung had the lowest coral health index that influenced by the presence of fleshy seaweed cover.

![The results of Correspondence Analysis for each station in Sangiang Island.](image_url)

Figure 11. The results of Correspondence Analysis for each station in Sangiang Island.
Coral Reef Health Index is expected to be a management benchmark with certain standards in measuring whether the ecosystem is in good condition or not. The parameters used in determining the index are the coral cover, total biomass of target fish, and the recovery factor which is calculated based on the fleshy seaweed cover and rubble cover.

Restoration of coral reef ecosystems depends on its complexity as a habitat. The attachment of coral juvena is one of the factors that guarantee the recovery of coral reef ecosystems. The presence of reef fish and other biota can be an important part of the recruitment process of coral reefs, but does’nt affect the recovery of coral reefs directly. Several studies had shown that the type of base substrate affected the coral reef fish community as an association biota. For example some studies suggested that complex habitats would provide biodiversity for coral reef fish and also guarantee herbivory processes.

Herbivory is an important ecological mechanism in the resilience of coral reef ecosystems through the process of controlling macroalgae abundance. The dominance of macroalgae cover can induce a negative impact on the coral reef community. Hughes et al argued that uncontrolled macroalgae growth will lead to dominant macroalgae communities in coral reef ecosystems. The existence of the herbivory process will provide free space in the process of attaching coral juvena. Littler et al argued that the low herbivory will increase the abundance of macroalgae or algal turf communities. Furthermore, the presence of filamentous algae will be a coral competitor for space. The low abundance of herbivorous fish is usually an indication that fisheries in the area are no longer to be sustainable.

The existence of rubble cover on the substrate can affect the recovery process of coral reef ecosystems. The rubble become the substrate media for attaching coral reefs when they are stable. However, if it is not yet stable, it will be difficult to become a place for coral reefs, because they are easily moved by currents or waves. Bachtiar et al. argued that coral reefs will have a low resilience index value if coral cover was low, while macroalgae and other fauna cover were high and also sand and mud cover were high.

Based on observations of the coral health index at Sangiang Island it can be hypothesized that the coral reefs have the ability to recover, if the condition of coral cover is maintained and fleshy seaweed cover is decreased by increasing the abundance and biomass of herbivorous fish. This condition must also be followed by reducing anthropogenic pressures such as irresponsible tourism which produced debris.

4. Conclusions

In summary, there are some conclusions that can be drawn from the results of this study. The average of live coral cover in Sangiang Island was 24 %, which included into damaged category. The highest percentage of fleshy seaweed cover was in Legon Waru by 14 % and the lowest was in Tembuyung by 5.95 %. Biomass of target fish was highest in Legon Bajo (0.013 kg/ha) and the lowest was in Tembuyung (0.002 kg/ha). The health of corals in Legon Waru was strongly influenced by live coral cover, while macroalgae and other fauna cover were high and also sand and mud cover were high.

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