The abundance of coral disease and compromise health in Sabu Raijua Waters, East Nusa Tenggara

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Abstract. Coral die-offs can be caused by several factors, one of which is the infectious coral disease. Currently, limited data and information are available regarding coral diseases abundance and distribution in Indonesia including Sabu Raijua waters, East Nusa Tenggara. This research aimed to investigate the types and abundance of coral disease and determine the compromise health condition on 12 sites in Sabu-Raijua waters on Sawu Marine National Park. The research showed coral conditions varied from bad to poor. There were eight coral disease types, the highest abundance found atromentous necrosis (0.12 col/m²) in station 11 (Menia 1), and nine compromise health with the highest number of CH types was found at station 12 with its abundance from 0.02 to 0.33 col/m². The disease abundance were classified as low on the sites, no evidence due to environmental factors. However, a regular survey has to be carried out in the area to monitor the progress and incidence of the coral diseases and measure their future impacts on the coral reef ecosystem of the national park.

Keywords: coral condition; coral disease; compromise health; tumor

1. Introduction
Fishery production is partly derived from coral reef ecosystem fisheries, such as grouper, lobster, seaweed, octopus, squid, other molluscs, and other reef fish. The condition of coral reefs will have an impact on fishery production in coral reef ecosystems. Althogh, the fishing by destructive methods, such as using bombs and poison, has a higher income than fishing by gear usually used by fishermen [1], but the impact toward coral damage is increasing plus coral mortality due to coral disease and global warming.

The condition of Indonesia's coral reefs was reported in 2019 were found 33.82% in poor condition, 37.38% in bad condition, 22.38% in good condition, and 6.42% in excellent condition out of 1153 coral reef areas observed [2]. The closest coral condition from the research site on Sabu Island and Raijua Island, namely on Rote Ndao Island, was 23.98% [3]. The condition of corals is poor, where live coral cover is taken by 50%, has a lower fishery production than the condition of corals that are not under pressure from natural and human factors [4].

Coral mortality is widely reported in Indonesia, both caused by human activities [1] and by nature. Naturally, it can be caused by global warming, reported coral bleaching [5], waves, volcanic eruptions [6], and tsunamis [7]. However, mortality due to coral disease is still underreported. Research on disease in the waters of Lembata, East Nusa Tenggara, were found 14 species of coral infected with disease and compromise health [3]. No specific research has been carried out at Sabu-Raijua waters related with coral disease.

This study determines the abundance of coral disease and compromise health problems in Sabu Raijua Waters, Sawu Sea. Hopefully, this data can contribute as primary data to increase data availability on the spread of coral disease throughout Indonesia. Some description of coral disease and CH as shown on table 1.
2. Coral disease observation methods

2.1. Research sites

The research was conducted in the waters of Sabu Raijua Regency with 12 observation sites from 19-21 March 2021. The observation sites' location was in the Utilization zone, Traditional fisheries, and

| Disease/Compromise health | Description |
|---------------------------|-------------|
| **White syndrome (WS)**   | The exposed part of the colony is narrow, the white skeleton and the white surface are relatively regular. |
| **Tumor**                 | The colony’s surface is rough and irregular, without zooxanthellae pigmentation. |
| **Black Band Disease (BBD)** | It was characterized by thick black tissue sections that rush across infected coral colonies, leaving an empty coral skeleton. |
| **Atromentous Necrosis (AtN)** | There is multifocal to irregular tissue loss showing a plain white skeleton covered by a characteristic greyish-black color. Colonial wounds begin with small white spots followed by tissue loss and coalescence of adjacent wounds. The exposed skeleton may be covered by a thin white film, which deposits of black sulfur may accumulate, giving the lesion a greyish appearance. |
| **Brown Band Disease (BrBD)** | Brown, linear or annular bands on the surface between living tissue and exposed skeleton, although thin white bands between brown bands and healthy tissue are occasionally present. The boundaries of the wound are usually not apparent. Tissue loss may be rapid and begins at the branch’s base but may spread to adjacent branches at early infection points. The bands consist of mobile ciliates, which may contain *zooxanthellae* from feeding tissue. |
| **Focal Bleaching (FBL)** | The multifocal bleaching pattern was spread throughout the colony. The boundary between the white part and the healthy tissue is often not apparent—the first stage of ulcerative white spot or atromentous necrosis. |
| **Bleaching (BL)** | Areas of focal, multifocal-to-merging, or diffuse tissue discolouration. Loss or reduction in the number of endosymbiotic algae (*zooxanthellae*) from coral tissue. There is tissue but with reduced or absent pigmentation. Bleaching may affect the entire colony, top surface, bottom, or indistinct parts with an irregular pattern of tissue loss. |
| **Skeletal Eroding Band (SEB)** | Black or dark green "salt-and-pepper," mottled, diffuse band. May form dark bands several mm to cm wide at the interface between healthy tissue and freshly exposed skeleton or diffusely scattered patches on the exposed skeleton. The mottled appearance is caused by the boring ciliates eroding the skeleton. |
| **Growth anomalies, galls (Up Normal Growth-UpNG)** | Focal to multifocal skeletal deformation is associated with organisms (i.e., crabs, barnacle)—deformation caused by deposition of the skeleton around the resident invertebrate in an unusual pattern. The resulting wound may be focal or multifocal, and a thickened coenosteum mass is circular to irregular, a polyp raised several mm above the colony surface. |
out of the zone. A more detailed explanation is shown in table 2. The research was conducted on two islands, seven locations on Sabu Island and five locations on Raijua Island. Based on the management area, there are four groups, namely the traditional sustainable fisheries zone (Stations 2,4,7,9), utilization (1,3,6,8), local wisdom (Station 5), and open access (Station 10, 11, and 12). A more detailed explanation of the research station position can be seen in figure 1.

Table 2. Existing Zonation in Sabu Rajua.

| Station | Name                              | Latitude   | Longitude   |
|---------|-----------------------------------|------------|-------------|
| 1       | Bodae, Sabu Timur                 | -10.4633   | 122.0166    |
| 2       | Loborai, Sabu Timur               | -10.5200   | 121.9995    |
| 3       | Deme, Sabu Liae                   | -10.5721   | 121.9346    |
| 4       | Waduwala, Sabu Liae               | -10.6222   | 121.8474    |
| 5       | Ledeunu, Raijua                   | -10.6139   | 121.6381    |
| 6       | Bolua, Raijua                     | -10.6425   | 121.5604    |
| 7       | Kolorae, Raijua                   | -10.6387   | 121.535     |
| 8       | Molie, Hawu Menara                | -10.5669   | 121.698     |
| 9       | Daieko, Hawu Menara               | -10.5434   | 121.739     |
| 10      | Raemedia, Sabu Barat              | -10.4667   | 121.8384    |
| 11      | Menia, Sabu Barat 1               | -10.4489   | 121.8387    |
| 12      | Menia, Sabu Barat 2               | -10.4353   | 121.8552    |

Figure 1. Observation stations for coral disease and compromise health on Sabu and Rajua Islands, East Nusa Tenggara. The observation locations consist of Station 1 (Badae), 2 (Loborai), 3 (Dene), 4 (Waduwala), 5 (Ledeunu), 6 (Bolua), 7 (Kolorae), 8 (Molie), 9 (Daieko), 10 (Raemedia), 11 (Menia 1) and 12 (Menia 2).
2.2. Research method

The study used a belt transect method with a length of 20 m and a width of 50 cm along the transect line. Three transect replicates were performed on each observation site. The first transect and subsequent transects are spaced 5 meters apart. The type of coral disease observed was adjusted to the explanation of table 1. Meanwhile, disturbance to corals was adjusted according to [9].

Figure 2. The abundance of coral disease in each study on Sabu and Raijua Islands, East Nusa Tenggara. Based on abundance, there were 11 genera impacted by disease, the highest abundance of disease types was found at Station 11 (0.12 col/m$^2$), followed by station 7 and station 8, namely the atromentous necrosis (AtN) disease species with an abundance of 0.10 col/m$^2$.

Figure 3. The abundance of compromised health at each observation station on Sabu Island and Raijua Island. Stations with the least compromised health (CH) were found at station 7, where only two types were CA (0.05 col/m$^2$), SP (0.03 col/m$^2$) (Figure 3). Meanwhile, the highest number of CH types was found at station 12. There were ten types of CH, followed by station 11 (9 types), station 1 (9 types), station 4 (9 types), station 10 (8 types), and station 6 (8 types). The highest abundance of CH were found on station 6 in Raijua island and 11 in Sabu island by macro algae (MA) with abundance 0.33 and 0.30 col/m$^2$ for both station respectively. Then following by abundance of gastropod as corals predator, Drupella sp in station 6, and CA in station 11 (0.27 col/m$^2$).
3. Result and discussion

3.1. Result

There were eight types of coral disease found at 12 observation stations, as shown in figure 2. No coral disease was found at station 2, station 3, and station 6. Meanwhile, at station 10, only Atramentos Necrosis (AtN) was found. Likewise, station 9 only found FBL. For station 7 and station 9, with the same type of disease AtN and FBL. Most types of disease (table 1) were found at station 1 with four types of disease, namely WS, AtN, BrB, and FBL. Overall, coral disease and compromise health (CH) were found in 23 genera of corals, with a total abundance by type exposed to coral health disorders of 3.95 col/m$^2$ with the lowest abundance (0.02 col/m$^2$) and the highest (1.42 col/m$^2$). Meanwhile, the lowest coral disease was 0.02 col/m$^2$, and the highest was 0.58 col/m$^2$. The affected coral genera can be seen in table 3.

Based on water temperature data taken from NOAA, the average monthly value in each location is shown in figure 4. Temperature changes appear to have increased on average, were in December 2020, there was an increase of 0.81°C, in January 2021 experienced an increase of 0.10°C. However, the temperature decreased by 0.66°C and again increased in March 2021 by 0.30°C. Mainly temperature volatile along five months.

| Coral species       | CH   | Disease | Total |
|---------------------|------|---------|-------|
| Acropora sp         | 0.53 | 0.03    | 0.57  |
| Astreopora sp       | 0.02 | 0.00    | 0.02  |
| Cyphastrea sp       | 0.02 | 0.00    | 0.02  |
| Echinopora sp       | 0.08 | 0.07    | 0.15  |
| Echinopora sp       | 0.03 | 0.00    | 0.03  |
| Favia sp            | 0.08 | 0.00    | 0.08  |
| Favites sp          | 0.02 | 0.02    | 0.03  |
| Fungii sp           | 0.00 | 0.02    | 0.02  |
| Galaxea sp          | 0.30 | 0.00    | 0.30  |
| Gardiniozerois sp   | 0.03 | 0.00    | 0.03  |
| Goniastrea sp       | 0.07 | 0.05    | 0.12  |
| Goniopora sp        | 0.10 | 0.00    | 0.10  |
| Leptastrea sp       | 0.02 | 0.00    | 0.02  |
| Merulina sp         | 0.03 | 0.00    | 0.03  |
| Montastrea sp       | 0.07 | 0.00    | 0.07  |
| Montipora sp        | 0.12 | 0.13    | 0.25  |
| Pectinia sp         | 0.07 | 0.02    | 0.08  |
| Physogrya sp        | 0.02 | 0.00    | 0.02  |
| Platygyra sp        | 0.05 | 0.00    | 0.05  |
| Pocillopora sp      | 0.55 | 0.02    | 0.57  |
| Porites sp          | 1.42 | 0.18    | 1.60  |
| Stylophora sp       | 0.27 | 0.00    | 0.27  |
| Symphyllia sp       | 0.05 | 0.02    | 0.07  |
| Turbinaria sp       | 0.05 | 0.03    | 0.08  |
| **Total**           | 3.95 | 0.58    | 4.53  |
Discussion

There were six types of coral disease found in the waters of Sabu Raijua, none in conditions of abundance outside normal limits. Coral mortality or low live coral cover is not caused by coral disease infection. However, it is caused by other factors such as destructive fishing gear and increased temperatures in certain seasons that can cause mass coral bleaching, as happened in 1997, 2010, and 2016 in Indonesia [1].

During an outbreak, the prevalence of coral disease was recorded at 12.53% for BBD disease in the Thousand Islands. At the same time, this study, the highest abundance was found at 0.12 col/m² at station 11 (Menia 1) in the waters of Sabu Raijua. The coral disease attacks 24 genera of coral disease from 8 types of coral disease. Meanwhile, there are nine categories of compromise health (CH) in the waters of Sabu Raijua. The survey at the location of the Thousand Islands only found two types of BBD disease, WS and AtN, that infect corals Acropora sp, Montipora sp, and once BBD was found, Astreopora sp. BBD in the Seribu Islands experienced a peak in the transition season with a prevalence of 31.64% [11]. Observations of coral disease in the Ayau Islands and the Asian Islands found BBD, WS, BL, and ten types of coral health disorders [10,9].

Figure 4. Surface temperature conditions of each observation station (Source: Global Ocean Ostia Sea Surface Temperature and Sea Ice Analysis obtained from the Marine Copernicus website processed using ODV software. Data with a resolution of 0.05 degrees and observations in different zones found compromise health (CH) and disease cases. The highest disturbance was found in the utilization zone of 105 colonies (cases) of CH, while the coral disease was not found in that zone. While outside the zone had the highest total CH and disease with 116 colonies consisting of 95 cases of CH and 21 colonies of coral disease cases. At the same time, the lowest cases occurred in the traditional sustainable fisheries zone as shown in table 4.

Table 4. The number of coral colonies exposed to coral health problems and coral diseases

| Zone                        | CH  | Disease | Total |
|-----------------------------|-----|---------|-------|
| Open access                 | 95  | 21      | 116   |
| Utilisation                 | 105 |         | 105   |
| Traditional sustainable fisheries | 53  | 16      | 69    |
| **Total**                   | **253** | **37**  | **290** |

3.2. Discussion

There were six types of coral disease found in the waters of Sabu Raijua, none in conditions of abundance outside normal limits. Coral mortality or low live coral cover is not caused by coral disease infection. However, it is caused by other factors such as destructive fishing gear and increased temperatures in certain seasons that can cause mass coral bleaching, as happened in 1997, 2010, and 2016 in Indonesia. several locations in Indonesia [1].
Temperature fluctuations often occur in nature, where these conditions cannot be controlled because they occur naturally. An increase in temperature could affect the escalation rate of coral disease transmission and the growth rate of pathogens [12]. The increase in temperature was also observed during the dry season until the transition season in the Thousand Islands. There was an increase in White Syndrome (WS) in the dry season until the peak temperature increase. Black Band Disease (BBD) exists throughout the year, but outbreaks occur at peak temperature conditions in the transition season [11].

Comparison of locations with other countries in Micronesia, Guam, from 15 observation sites found six types of diseases that infect eight coral families with prevalence ranging from 0.2-12.6%. The corals attacked by the disease are Porites, Acropora, Pocillopora [13].

4. Conclusion
As many as eight types of coral disease which impacted 11 genera corals. Disease type dominance found on AtN in station 11 (Menia 1), whereas compromise health found nine types on 24 genera’ corals with dominance on micro algae in station six (Bolua). Disease and compromise health could caused coral dead, that management coral reefs area is need it to develop.

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References
[1] Sala R, Kabera Y and Rumereb V 2011 Destructive fishing in COREMAP II area, Raja Ampat Journal of Indonesian Coral Reefs 30-40.
[2] Hadi T A, Giyanto, Siringoringo R M, Budiyanto A, Johan O, Abrar M, Sari N W P, Sadarun B and Prayudha B 2020 Potential stock of stony corals in Indonesia IOP Conference Series: Earth and Environmental Science 441 011001.
[3] Abrar M, Bachtiar M and Budiyanto A 2012 Struktur komunitas dan penyakit pada karang (scleractinia) di Perairan Lembata, Nusa Tenggara Timur Indonesian Journal of Marine Sciences 17 109-118.
[4] Achmad A R, Munasik and Permata D W 2013 Kondisi ekosistem terumbu karang di Rote Timur, Kabupaten Rote Ndao, Taman Nasional Perairan Laut Sawu menggunakan metode manta tow Journal of Marine Research 2 211-219.
[5] Sampayo E M, Ridgway T, Bongaerts P and Hoegh-Guldberg O 2008 Bleaching susceptibility and mortality of corals are determined by fine-scale differences in symbiont type PNAS 105 10444-10449.
[6] Tomascik T, Mah A J, Nontji A and Moosa M K 1997 The Ecology of Indonesia Seas Publication Paripilus Edition 7 136-144.
[7] Tun K, Chou L and Yeemin T 2018 Status of coral reefs in Southeast Asia Region:2018 Ministry of the Environment of Japan and Japan Wildlife Center Tokyo Japan 58 p
[8] Raymundo L J, Couch C S, and Harvell C D (eds) 2008 Coral disease handbook Guidelines for assessment, monitoring and managing GEF-CRTR program Currie Communications, Australia 121 pp
[9] Johan O, Purwanto, Rumengan I and Awaludinnoer 2020 Kelimpahan Penyakit Karang di Kepulauan Ayau dan Asia, Kabupaten Raja Ampat Jurnal Riset Akuakultur 15 1-9.
[10] Simarangkir O R, Yulianda F and Boer M 2015 Pemulihan Komunitas Karang Keras Pasca Pemutihan Karang di Amed Bali Jurnal Ilmu Pertanian Indonesia 20 158-163.

[11] Johan O, Zamani N P, Smith D and Sweet M J 2016 Prevalence and Incidence of Black Band Disease of Scleractinian Corals in the Kepulauan Seribu Region of Indonesia Diversity 8.

[12] Indra and Zulfrizal Amhri 2016 Prevalensi Penyakit Band Diseases Pada Karang Bercabang Di Perairan Pembangkit Listrik Tenaga Uap (Pltu) Paiton, Probolinggo Undergraduate thesis Institut Teknologi Sepuluh Nopember Surabaya.

[13] Myers R L and Raymundo L J 2009 Coral disease in Micronesian reefs: a link between disease prevalence and host abundance Diseases of Aquatic Organisms 87 97-104.