Coral diseases of mushroom coral (Fungiidae) in Pari Island, Kepulauan Seribu, Jakarta

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Abstract. Coral disease is one of the causes of the decline in the condition of coral reef ecosystems. This study aims to measure coral health based on the abundance and prevalence of coral health categories. The research was conducted in the Pari Island Cluster, Seribu Islands at four stations. The Belt Transect method with 2 x 100 meters was used to calculate coral health and a 30 m Line Intercept Transect (LIT) with three replications to determine substrate cover. The condition of coral reefs can be categorized as moderate to good based on this percentage value. The study results found five genera from the Fungiidae, namely Fungia, Ctenactis, Herpolitha, Heliofungia, and Sandalolitha. The most commonly found genus is the genus Fungia. The health condition of Fungiidae corals in Pari Island is divided into two categories, namely 35% healthy and 65% unhealthy, consisting of changes in tissue color - white (coral bleaching), changes in tissue color - not white (yellow band disease), and compromised health (damage by sedimentation). Yellow band disease is only found in the genus Fungia and is not found in other genera.

Keywords: coral bleaching, coral health, fungia, Jakarta Bay, sedimentation damage, yellow band disease

1. Introduction
Coral reefs are marine ecosystems with very high diversity and productivity. However, recently the coral reef ecosystem has experienced a high level of damage. According to [1], approximately 19% of the world's coral reef ecosystem have been effectively destroyed with no chance of recovery, 15% are at risk of damage under current human pressure over the next 10 to 20 years, and 20% are at long term threat of damage.

This is very unfortunate, considering the benefits coral reef ecosystems provide as natural resources and human utilization. The decline in coral reef ecosystems is influenced by various human activities, namely climate change, land and sea pollution, habitat degradation, overfishing, coastal development, destructive fishing, waste disposal, beach reclamation, shipping activities, recreation, and other activities [2]. Further afield, marine pollution caused by human activities affects genetic diversity of organisms [3]. Compounding these threats are increases in sea surface temperatures, changing weather
patterns and ocean acidification associated with climate change [4-5]. Coral disease has been linked to various stressors, including temperature stress, anthropogenic exploitation and pollution [6].

The threat level to coral reefs in Indonesia reaches 95% and is mainly caused by human activities [7]. Kepulauan Seribu located in front of Jakarta Metropolitan Area represents an ideal case study to assess the effects of human activities on coral reef ecosystems. Values of hard coral cover for Kepulauan Seribu chain were 2% for nearshore reefs within Jakarta Bay (<20 km), 37% for mid-shore reefs (20–45 km) and 22% cover in offshore reefs (>45 km north of the coast of Jakarta) [8].

However, causative agents of many diseases are still largely unknown. Still, it could be assumed that human activities alter environmental conditions in coral reef ecosystems, which can reduce coral resistance to microbial infection or increase the virulence of pathogens [9]. Coral health conditions are classified as healthy, bleached, infected with disease, or experiencing health problems. [10] have categories to identify coral health, namely Tissue Loss-Predation or tissue loss due to predation by other organisms, Tissue Loss-non-Predation or tissue loss not caused by predation, Tissue Discoloration-White or change in tissue color to white, Tissue Discoloration-nonWhite or change in tissue color other than white, Growth anomalies or abnormal coral growth, and Compromised Health or health problems caused by various factors.

Several research on coral disease has been carried out in the Kepulauan Seribu and Indonesia, including research by [11] on coral bleaching in fungal corals (Fungiidae), in Pramuka Island about diseases found on coral reefs [12] in Mansuar Island Raja Ampat [13], and Black Band Disease in Montipora coral [14].

Fungiidae is a family of the order Scleractinia which is commonly known as mushroom coral. In general, Fungiidae lives in the sublittoral areas and the Indo-Pacific subtropical region. Their habitat is generally on coral reefs or other substrates found around coral reefs [15]. Corals from the Fungiidae family were chosen for this study due to their advantages for quantitative ecological surveys. It is relatively easy to calculate individual Fungiidae compared to other sedentary corals [11]. This allows the research to focus on the variations in disease type, proportion of affected individuals, and spatial distribution [11]. In addition, Fungiidae corals are used in the ornamental coral trade in Indonesia.

This research aims to understand the level of coral health in Pari Island and to add studies on coral disease research in Indonesia that are still considered to be limited. This study aims to measure the health level of Mushroom coral (Fungiidae) based on observations of abundance and prevalence of coral diseases and health categories.

2. Materials and Methods

2.1. Time and location of research

The research was conducted 24-25 November 2013 in Pari Island, Kepulauan Seribu, Indonesia (Figure 1). Observations were made in four sites which were spread over the Marine Protected Areas (APL), Bintang Rama, Northwest (Barat Laut) of Pari, and North (Utara) of Pari (Table 1).

| Station          | Coordinate         | Latitude | Longitude |
|------------------|--------------------|----------|-----------|
| APL              | 106° 36’ 42.1” BT | 5° 52’ 13.9” LS |
| Bintang Rama     | 106° 34’ 59.5” BT | 5° 51’ 5.40” LS |
| North Pari       | 106° 36’ 5.20” BT | 5° 50’ 54.2” LS |
| Barat Laut Pari  | 106° 36’ 30.4” BT | 5° 51’ 6.80” LS |
2.2. Water Quality Sampling

The parameters taken for water quality were seawater temperature using a thermometer with units of degrees Celsius (°C), salinity using a refractometer with units of parts per thousand (ppt), dissolved oxygen or dissolved oxygen (DO) using a Digital DO Meter with units of milligrams per liter (mg/l), and the degree of acidity (pH) using a Digital pH Meter. The water quality measurements are only temporary condition, for it has zero repetition and is taken at one particular time.

2.3. Coral Data Sampling

The Line Intercept Transect (LIT) or line transect method was used to collect coral cover. The data obtained included coral structure, colony density, and coral cover. The line transect uses a rolling meter that was stretched for 30 m with three replications at a depth of 5 m.

The belt transect method was used in collecting coral health data [10]. The belt transect is a survey method with a defined area where all corals within the area are counted and the presence of disease recorded. The belt transect method could also measure colony size, coral cover, and mortality percentage [16]. In this research, a belt transect of 2 x 100 meters with one repetition was used, where all Fungiidae corals in the transect area were observed. Observations included identification of Fungiidae corals to the genus level and identification of coral health.

The Coral Finder [17] was used as a reference for identifying Fungiidae corals and the Underwater Cards for Assessing Coral Health on Indo-Pacific Reefs [10] were used as a reference for the identification of coral health.

2.4. Data Analysis

Data analysis for this research included calculation of coral cover and prevalence and abundance of coral health categories. Calculation of coral cover used the following equation according to [16].

\[
\text{Percent cover} = \frac{\text{length of cover category (cm)}}{\text{Transect length (cm)}} \times 100
\]
The category of hard coral cover according to [18] is shown in Table 2 below. The prevalence and abundance of coral disease could be calculated with the following equation [10].

\[
Prevalence = \frac{\text{Total colony with disease (ind)}}{\text{Total number of colonies (ind)}} \times 100
\]  

(2)

The abundance of coral disease could be calculated with the following equation [10].

\[
Abundance = \frac{\text{Total colony with disease (ind)}}{\text{area of transect (m}^2)}
\]  

(3)

The calculations were done using the software Microsoft Excel 2010.

3. Results and Discussion

3.1. Water Quality

Parameters measuring water quality included temperature, salinity, dissolved oxygen (DO), and pH. The water quality measurements are only temporary condition, for it has zero repetition and is taken at one particular time.

| Parameters     | Station          | APL | Bintang Rama | Northwest Pari | North Pari |
|----------------|------------------|-----|--------------|----------------|------------|
| Temperature (°C) |                 | 32.5 | 29.9         | 30.9           | 31.4       |
| Salinity (ppt)  |                 | 32  | 32           | 30             | 30         |
| DO (mg/l)       |                 | 5.9 | 8.2          | 8.9            | 8.9        |

The seawater temperature in Pari Island was between 29.9°C to 32.5°C (Table 3). According to [19], coral reefs develop optimally at a temperature of 25°C to 30°C. The temperature range of 30°C to 35°C can be tolerated by coral reefs. Therefore, the seawater temperature on Pari Island was suitable for reef growth.

The salinity measured at the research stations ranged from 30 to 32 ppt and corresponded to the tolerance range of coral reefs (Table 3). The optimal salinity range for coral reef growth is 32 to 35 ppt according to [19], although a range of 27 to 40 ppt could still be tolerated [20].

The measured dissolved oxygen (DO) content was 5.9 mg/l to 8.9 mg/l (Table 3). According to [21], dissolved oxygen content with a value of more than 5 mg/l is considered good for marine organisms. The measured pH values were 8.07 to 8.31 (Table 3). According to [18], the suitable pH range for coral reefs is 7 to 8.5. Therefore, the pH value in Pari Island was suitable for coral reefs.
3.2. Coral Reef Condition

The percent cover of hard corals ranged from 32% to 74% (Figure 2) and could be categorized as moderate to good based on this percentage value. North Pari Station had the highest hard coral cover at 74 ± 1% and was within the good category. In comparison, the Northwest Pari station had the lowest percentage of hard coral at 32 ± 4% and within the medium category. Bintang Rama Station was also in the medium category with a hard coral percentage of 49 ± 7%. APL station was considered to fall in the good category due to its’ 57 ± 4% hard coral percentage. APL and Bintang Rama stations are tourist spots on Pari Island due to their relatively high coral cover.

The total number of Fungiidae corals found in the 4 stations was 92 individuals (Figure 3). The highest number of Fungiidae coral was found in Bintang Rama station with a total of 39 individuals, followed by APL and Northwest Pari station with 32 and 13 individuals, respectively. While the lowest number found was in North Pari station with only 8 individuals. In APL and Bintang Rama stations, many Fungiidae individuals were found along with high hard coral cover. However, the high hard coral cover does not always show a high number of Fungiidae individuals, as shown in the North Pari station, where only a tiny number of Fungiidae individuals were found at a high hard coral cover area.

Figure 2. Percent coverage of coral reef (SC: Soft Coral; DC: Dead Coral; HC: Hard Coral) at research stations in Pari Island.

Figure 3. Number of individual Fungiidae corals found.
3.3. Mushroom Coral (Fungiidae) Abundance

There were 5 genera of corals from the Fungiidae family found in the research stations of Pari Island, namely Fungia, Ctenactis, Herpolitha, Heliofungia, and Sandalolitha (Figure 4).

![Figure 4. Fungiidae abundance in Pari Island.](image)

The most abundant Fungiidae coral genus found was Fungia with 78 individuals spread over 4 stations, while the least genus found was Heliofungia with only 1 individual. The APL station found 26 individuals of Fungia, followed by 2 of Herpolitha, 2 of Sandalolitha, and 1 individual of Heliofungia. In the Bintang Rama station, 2 genera of coral were found, namely Fungia and Ctenactis with as many as 34 and 5 individuals, respectively. In the Northwest Pari station, 2 genera were found, namely the genus Fungia with 11 individuals and the Ctenactis with 2 individuals. In Pari Utara station, 2 genera were found, namely the genus Fungia with 7 individuals and Ctenactis with 1 individual. The station with the highest abundance of genus Fungiidae family was APL station, where 5 genera of all genera found in all research stations were identified, while stations Bintang Rama, Northwest Pari, and North Pari only found 2 genera. The coral genus Fungia dominated as the most found genus with a high species diversity compared to other genera.

3.4. Health of Fungiidae Corals

The health conditions of Fungiidae corals in Pari Island based on this research were divided into four categories, namely healthy, tissue discoloration-white, tissue discoloration-nonwhite, and compromised health (health problems). (Figure 5).

![Figure 5. Health condition of Fungiidae corals in Pari Island.](image)

Corals can be categorized as healthy if there are no signs of disease infection or symptoms of health problems (Figure 6). At the research stations, there were 35% found in the healthy category. The tissue
discoloration-white category was at 57%, followed by the tissue discoloration-non-white category at 5%, and lastly, the category of compromised health at 3%. In the tissue discoloration-white category, coral bleaching was found with full patterns, certain patterns (patches), stripes (stripes), and spots (focals). Within the tissue discoloration-non-white category, yellow band disease was observed, and sedimentation damage was seen in the compromised health category where corals were covered with sediment.

Figure 6. Healthy Fungiidae coral.

3.5. Coral Bleaching
Coral bleeding was observed in genus *Fungia* and *Ctenactis* which consists of full bleeding, patches, stripes, and spots. In the *Fungia* genus, all types of coral bleaching patterns were found, while in the *Ctenactis* genus, only coral bleeding with full patterns and spots was observed (Table 4).

| Genus           | Bleaching |
|-----------------|-----------|
|                 | Full | Patches | Strip | Focal |
| *Fungia*        | ●    | ●       | ●     | ●     |
| *Ctenactis*     | ●    | -       | -     | ●     |
| *Sandalolitha*  | -    | -       | -     | -     |
| *Herpolitha*    | -    | -       | -     | -     |
| *Heliofungia*   | -    | -       | -     | -     |

*症状：(●)症状存在，(-)症状不存在

The abundance of coral bleeding with full bleeding was 0.03 ± 0.011 ind/m² (Figure 7). This indicated that only one individual Fungiidae coral was exposed to full coral bleeding in an area of 33 m². Coral bleeding with spotted pattern (focal bleaching) has a disease abundance of 0.019 ± 0.007 ind/m². Coral bleaching with stripe pattern (stripes bleaching) only had an abundance of 0.004 ± 0.004 ind/m². This indicates that it was very rare to find Fungiidae corals affected by coral bleeding with striped patterns. Coral bleaching with another pattern (patches bleaching) has an abundance of 0.013 ± 0.006 ind/m². The overall abundance of coral bleaching was 0.065 ± 0.022 ind/m².
The prevalence of coral bleaching with full pattern has the highest value at 26.47 ± 2.74% (Figure 8). This indicates that 26.47% of Fungiidae corals in Pari Island were exposed to full pattern coral bleaching (Figure 9). Coral bleaching with spotted pattern had a prevalence of 17.73 ± 4.67%, bleaching with stripe pattern showed a low prevalence of 2.42 ± 2.42%, while bleaching with other patterns had a prevalence of 9.72 ± 3.46%. Overall prevalence of coral bleaching was 56.33 ± 2.52%.

Fungiidae bleaching in Pramuka Island, Kepulauan Seribu had an abundance of 0.1 ind/m² [12]. Coral bleaching has been found in almost all Indonesian waters, including Sumatra, Sulawesi, Natuna, Java, Bali, Lombok, West Papua, Maluku, and global waters covering the Pacific and Caribbean waters [7, 22, 23].
Coral bleaching is one of the most common types of health problems in Fungiidae corals on Pari Island. The cause of high coral bleaching is rising seawater temperatures. Johan [24] seawater temperature on Pari Island ranges from 24°C to 29.5°C [24]. In 2011, the seawater temperature around Pari Island was 29.39°C ± 0.70 [14].

Coral bleaching is a symptom of coral health problems caused by various environmental stresses [25]. The main causes of coral bleaching include increased and decreased seawater temperatures, intensity of solar radiation, a combination of increased temperature and solar radiation, decreased salinity, bacterial infections [26], high levels of turbidity, sedimentation, and pollution. [2] coral bleaching is a health disorder and not a disease. In coral bleaching, the coral tissue is still alive and well but only loses or has decreased endosymbiotic content of algae (zooxanthellae). Loss of symbiotic algae causes a decrease or even loss of pigmentation in corals, making them appear white.

3.6. Yellow Band Disease

The yellow band disease was only found in the genus *Fungia* and no other genus (Table 5). Yellow band disease was the only disease found and is classified as coral disease.

| No. | Genus  | Yellow Band Disease |
|-----|--------|---------------------|
| 1   | *Fungia* | ●*2                 |
| 2   | *Ctenactis* | -                   |
| 3   | *Sandalolitha* | -                 |
| 4   | *Herpolitha* | -                  |
| 5   | *Heliofungia* | -                   |

*2(●) symptoms found and (-) no symptoms.

The yellow band disease in Fungiidae corals had an abundance of 0.01 ± 0.004 ind/m² (Figure 10) with a prevalence of 7.14 ± 2.01% (Figure 11). Yellow band disease was also found in Fungiidae corals on Pramuka Island, Seribu Islands [13]. The abundance of yellow band disease on Pari Island is low compared to Pramuka Island, which has an abundance of 0.37 ind/m².

![Figure 10](image1.png)  ![Figure 10](image2.png)

*Figure 10. Prevalence and abundance of yellow band disease in Fungiidae in Pari Island.*

Yellow band disease was first discovered in 1970, attacking the coral *Montastrea* in the Caribbean [27]. In 1990, yellow band disease was seen in the Pacific waters, namely in the Gulf of Oman, Arabian Sea [28]. [29] found yellow band disease infection in Fungiidae corals, including the coral genera *Fungia* and *Herpolitha*. [13] found a high prevalence of yellow band disease in Fungiidae corals with a percentage of 68% in Pramuka Island. According to [29], wounds from yellow band disease will appear in waters with temperatures of 26°C to 28°C based on research carried out in Bali and Wakatobi.
Figure 11. Yellow band disease in Fungiidae corals.

According to [30], Yellow band disease is a disease that attacks symbiotic algae, not the corals themselves. A group of microbes infects zooxanthellae in the gastrodermis causing cell damage to the zooxanthellae. Yellow band disease begins with small, ring-like pale patches that continue to widen and increase the area of dead coral. If it is in the advanced phase, the ring-like circle becomes less visible in shape but continues to widen with a spreading speed of 0.5-1 cm/month in one colony. The pallor that appears indicates a decrease in chlorophyll concentration and the lack of zooxanthellae [27, 30].

Pathogens suspected of causing yellow band disease (YBD) are Vibrio bacteria, especially V. alginolyticus and V. harveyi [29–31]. The consequences of YBD infection on corals are slow growth rate, decreased biomass, and decreased ability of coral colonies to reproduce [31].

3.7. Sedimentation Damage

Sedimentation damage was found in the genus Fungia and not in other genera (Table 6). Sedimentation damage is the only type of compromised health found in Fungiidae corals (Figure 13).

| No. | Genus       | Sedimentation Damage |
|-----|-------------|----------------------|
| 1   | *Fungia*    | ● ▲                   |
| 2   | Ctenactis   | -                    |
| 3   | Sandalolitha| -                    |
| 4   | Herpolitha  | -                    |
| 5   | *Heliofungia*| -                   |

▲(●) symptoms found and (-) no symptoms found

Fungiidae corals with sedimentation damage were very few, based on an abundance value of 0.004 ± 0.003 ind/m² (Figure 12) and the prevalence of sediment-covered corals has the lowest value of 2.09 ± 1.27% (Figure 12).

Figure 12. Prevalence and abundance of Fungiidae corals with sedimentation damage in Pari Island.
Sedimentation damage on Fungiidae corals in Pari Island had a very low prevalence. [13] found a similar type of health disorder afflicting Fungiidae corals in Pramuka Island with 9% prevalence. This indicates that the disturbance of sediment cover to Fungiidae corals in Pari Island is lower than in other areas.

According to [2], corals covered with sediment will lose their tissue due to the accumulation of sediment on the surface of corals, polyps, and coral tissue, and are commonly found in murky waters. The causes of sedimentation on coral reefs are cloudy waters, dredging activities, and runoff from the mainland through rivers or direct sedimentation [2, 32].

The impacts caused by sediment cover on coral reefs include changes in the structure of coral populations such as changes in size frequency, decreased average size of coral colonies, changes in growth forms, decreased growth and survival rates, death due to burial, suppresses the density of symbiotic algae (zooxanthellae) and photosynthetic activity, increasing mucus production and respiration, reducing coral reproduction, and resulting in coral degradation [13, 33].

![Figure 13. Sedimentation damage in Fungiidae corals.](image)

High levels of sedimentation cover could result in coral death within a few days, while a low level of sedimentation cover could only result in a decrease in photosynthetic yields in corals[33]. Different types of corals have their responses to the sediment cover [32].

4. Conclusion

4.1. Conclusion

The condition of coral reefs in Pari Island was categorized as moderate to good with the highest hard coral cover found at the North Pari station and the lowest found at the Northwest Pari station. The total number of Fungiidae individuals found was 92, with Bintang Rama station having the highest number of Fungiidae while the North Pari station showed the lowest. Overall, 5 genera of Fungiidae were found with the coral genus *Fungia* being the dominant genus.

The health condition of Fungiidae corals in general, based on observations in Pari Island is 35% healthy and 65% unhealthy, which are divided into the categories of tissue discoloration-white, tissue discoloration-non-white, and compromised health. The tissue discoloration-white category was the dominant category due to the large amount of coral bleaching found. The category compromised health was the least found as very little sedimentation damage was observed. The seawater temperature was found to be warm to high and seen as one of the causes of the higher coral bleaching compared to yellow band disease.
4.2. **Recommendation**

Suggestions for further research related to the health of Fungiidae corals namely focused on one type of disease or coral health disorder periodically to determine the rate of spread of disease or disturbance in Fungiidae corals.

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