Research Article

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Coral Diseases In The Ambon Waters Of Maluku, Indonesia.

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ABSTRACT

Studies of coral reef diseases in Indonesia, particularly in Ambon waters, Maluku, have been rare. The objectives of this study were to identify the types of diseases in this area, the prevalence and abundance of coral diseases at different depths at different sites. This study was conducted at four sampling sites; Liang, Morela, Kaitetu and Erie with their specific situations, at two different depths which are 3 and 10 metres, parallel to the shoreline. Each site was surveyed twice using the belt transect method over an area of 250 m2 for three months. The type of disease was identified using the Coral Disease Handbook and Decision Tree Table with the help of photographs taken with underwater camera. The result shows four types of diseases, they were black band disease, white syndrome disease, white band disease and white plague disease. The prevalence and abundance of coral diseases were not significantly different between depths (T-test, $p>0.05$). Sampling site Erie had the highest prevalence of diseases due to the environmental pressure that is having a lot of domestic waste.

Keywords : *Coral diseases, prevalence, abundance, environmental pressures, pathogens.*

INTRODUCTION

Coral reefs are one of the ecosystems in tropical waters that are vulnerable to coral diseases. One of the impacts on coral reefs that leads to a decline in the percentage of live coral coverage in a water area is the emergence of coral diseases [1] [2]. For example, an increase in dissolved nitrogen followed by a decrease in water clarity can lead to the occurrence of Aspergillosis, a black band disease [3]. Research on coral diseases in Indonesia is still less compared to foreign research. Some studies on the prevalence of diseases have been conducted [4] [5] [6]; with a prevalence of algae diseases and algae health issues in Lembata Strait, Nusa Tenggara Timur at 42%, Pulau Panjang Strait, Jepara at 74.57%, and in Kessilampe Strait, Southeast Sulawesi at 15% for algae diseases and 14% for algae health issues. Based on these findings, the presence of algae diseases in some straits in Indonesia is becoming increasingly concerning and there is a need for further measures to prevent it. Algae diseases have been reported to cause widespread damage to algae, as seen in the Caribbean, Great Barrier Reef Australia, and several locations abroad [7] [8]. In Maluku Indonesia, the death of algae due to diseases has not yet been a special concern for researchers, proven by the rarity of research revealing algae diseases. The important of this research, therefore is to provide baseline knowledge of coral health issue related to algae diseases, especially in the waters around Ambon Island that have abundant marine resources and biodiversity. This research aims to identify the types of diseases, the prevalence and abundance of coral diseases at different depth at different sites so it can serve as initial data and provide a reference for the damage to the coral algae ecosystem due to environmental conditions.

MATERIALS AND METHODS

Research Locations

This research was conducted from June to August 2022 at four locations, namely Liang, Morela, Kaitetu and Erie in the waters of Ambon Island, Maluku Indonesia (**Figure 1**).

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Figure 1. Map of Study Location in Ambon Island



Tools and Materials

The tools and materials used in this study were scuba set, underwater camera, roll meter, GPS, dab board, pencil, underwater paper, belt transect and identification book. Coral disease identification is based on the Coral Disease Handbook and Decision Tree Table [2]. The use of underwater cameras for documentation was to help in identification of coral diseases.

Data Collection Methods

Coral diseased data was collected at a depth of 3 and 10 m parallel to the shoreline. Transect installation was carried out twice at each station using Belt Transect method measuring at the area of 250m2 at each station [9] [10] [11]. The number of coral colonies infected with disease and the total number of colonies in the transect were recorded.

Data Analysis Method

Prevalence is the percentage of the number of colonies infected with disease to the total number of coral colonies in the water. Prevalence and abundance was calculated using the following formula [2].

$$\text{Prevalence}(\%) = \frac{\sum number\ of\ colonies\ infected}{\sum number\ of\ coral\ colonies} \times 100$$

The abundance of coral colonies infected found at each observation site was calculated by comparing the number of coral colonies infected by disease divided by the area of the transect belt area using the following abundance formula:

$$\text{Abundance} = \frac{\sum number\ of\ coral\ colonies\ infected\ (colonies)}{area\ of\ the\ transect\ belt\ (m^2)}$$

Data analysis was carried out with the help of images in the identification book, with the appearance of infected corals supported by photographs in form of colonies or enlarged parts of colonies. Calculations used Microsoft Excel software.

RESULTS AND DISCUSSIONS

Description of sampling location

Observations of the environmental conditions of the sampling sites were made to see their influence on the presence of coral disease. Four locations coordination of data collection were shown in **Table 1**.

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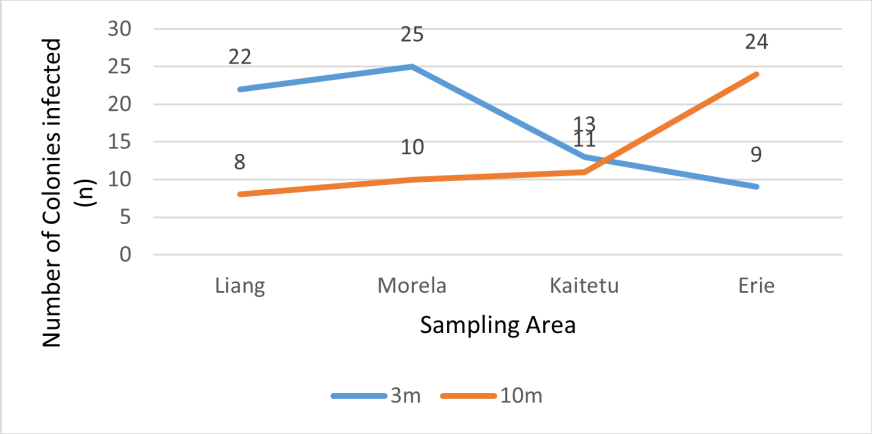
Table 1. Coordination and description of locations for data collection

No.	Location	Latitudes	Longitudes	Descriptions
1	Liang	-3°29'31.90"	128°16'48.80"	A tourist attraction managed by individual, a rocky beach with clear water
2	Morela	-3°31'50.50"	128°12'47.60"	Tourist attraction, facing Seram Island in the North, a white sand beach and clear water
3	Kaitetu	-3°35'22.10"	128° 4'30.70"	Facing Seram Island in the North, a white sand beach and clear water
4	Erie	-3°45'1.70"	128° 7'48.50"	Located in the outer Strait of Ambon, a white sand beach and clear water but household waste was found abundantly on the bottom

Effect of depth on the presence of coral disease

The number of disease-infected colonies at 3m depth was higher at Morela (25 colonies) and Liang (22 colonies) while Kaitetu and Erie were relatively lower at 11 and 9 colonies respectively. At a depth of 10m, in contrast, Morela, Liang and Kaitetu sites only had 9, 8 and 11 colonies respectively, while Erie had 24 colonies (**Figure 2**). Erie waters located very close to a residential area where the waters filled with domestic waste. There has been thick deposition of waste on the bottom of the waters of Ambon Bay [12] [13] [14] allegedly the reason to number of bacteria increase in Erie, means the presence of disease agents around it were high. Environmental factors both biotic and abiotic showing the strongest overall associations with the coral diseases [15] [16].

Figure 2. Number of infected coral per 250m2 from different depth.



Liang and Morela are tourist destinations and the number of colonies with disease was found to be high, it is assumed that the environmental pressure at these sites is stronger than in Kaitetu. Kaitetu, although it location relatively close to Morela, however, there might be an influence of currents push away rubbish causing the number of diseased coral colonies to be lower. The chance to find higher number of diseased coral colonies is determined by the depth, location of settlements, currents and high human activity around them such as tourist's area. Activities that occur at the Morela with tourist levels, especially large snorkeling and diving tourism activities, can cause a level of stress in coral organisms to increase. The activities of diving and snorkeling tourism activities in coral reef areas have an impact on coral reef damage [17].

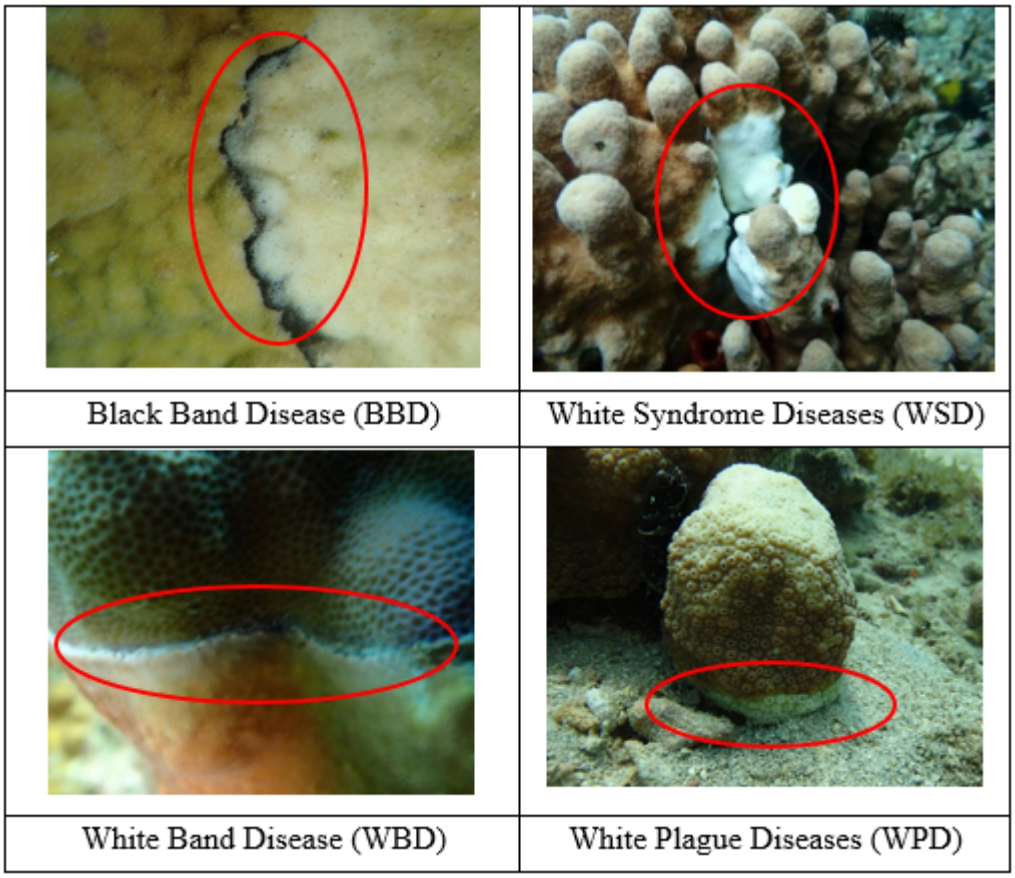
Identification of Coral Disease

Coral diseases found in sampling area namely Black Band Disease (BBD), White Syndrome Disease (WSD), White Band Disease (WBD) and White Plague Disease (WPD) (**Figure 3**). These four types of diseases are much lesser in number than the coral diseases that have been described in Coral Disease Handbook, recorded 12 types of diseases and health disorders [2], while in Japan, it was recorded 10 types of diseases [18]. Previosly studies also found similar number of coral diseases with this study, which is five types [19] in Bintan Waters and only three types in waters of Turun Aban Bangka Regency [20]. From these data of diseases types of Indonesian waters include Ambon waters, the condition of coral reefs are relatively still in good condition. This study also shows the diseases was overall low at both depth of 3 and 10 metres.

Results from documentation showed WSD was found on coral forms of *Acropora* submassive and *Acropora* encrusting. BBD was found on *Acropora* branching and massive corals. WBD was found on *Acropora* branching and *Acropora* submassive corals, while WPD was found on *Acropora* encrusting and coral massive corals.

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Figure 3. Coral diseases found at the study site of Ambon Island waters.



WSD and BBD was diseases dominated in all area while

WBD and WPD was found far less. WBD only noted as 7 and 8 colonies at the depth of 3 and 10 meter respectively; while WPD only at 3m depth found 4 colonies (**Table 2**). WPD however, is known as a very lethal for enormous coral colonies, and it is estimated to have caused more widespread mortality among this type of coral than any other known diseases. An outbreak of WPD had killed up to 38% of one coral species on Florida reefs in 1995 [21]. WPD is a widespread tissue loss disease that affects a variety of scleractinian coral species. The rate of tissue loss range from 1mm/day to more than 10 cm/day, and vary even on a single colony when the extent of the lesion increases.

Table 2. Type of diseases and number of coral colonies per 250m2 infected based on depth.

No	Coral Diseases	Sampling Locations				
		Liang	Morela	Kaitetu	Erie	Total Colonies
Depth of 3 meter						
1	Black Band Disease (BBD)	11	13	1	1	26
2	White Band Disease (WBD)	1	5	0	1	7
3	White Plague Disease (WPD)	0	0	4	0	4
4	White Syndrome Disease (WSD)	10	7	8	7	32
No. of colonies infected		22	25	13	9	69
Total colonies observed		264	249	271	90	874
Depth of 10 meter						
1	Black Band Disease (BBD)	2	3	4	7	16
2	White Band Disease (WBD)	2	1	1	4	8
3	White Syndrome Disease (WSD)	4	6	6	13	29
No. of colonies infected		8	10	11	24	53
Total Colonies observed		168	139	195	134	636

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BBD known caused by a consortium of microorganisms, dominantly *Phormidium corallyticum*, a type of cyanobacteria (blue-green algae), along with sulfur-oxidizing and sulfate-reducing bacteria that leads to coral tissue death by forming a band that slowly moves across the coral surface, exposing bare skeletons. The bacterial activity in the black band produces hydrogen sulfide and anoxic conditions that further contribute to tissue necrosis. This desease was recorded to have affected 42 coral species which is present around the world. This black sheet (mat) of BBD is about ¼ - 2 inches wide on the surface of coral tissue separates healthy coral tissue from the bare white skeleton, it moves rapidly at a rate of about 3 - 10 mm per day.

Coral diseases that dominate in both depth research sites was WSD and BBD, while WPD was absent at 10 meter depth. Penetration of light at both depths was high so the entry of sunlight to the bottom of the water causes the temperature in the water to increase. In the mean time, allegedly bacteria develop very quickly as they growth influenced by light intensity, therefore they tend to be found abundance at high light intensity [22]. This is in line to the result mentioned the infection rate increases with increasing temperature [2].

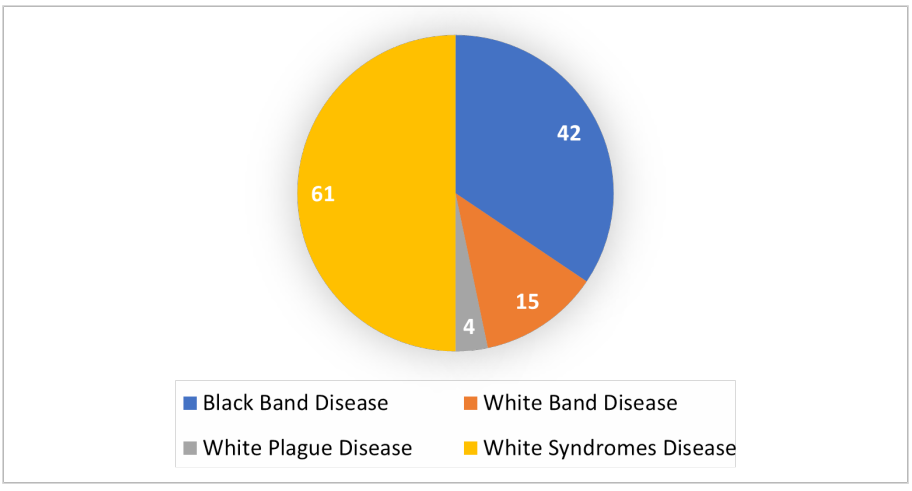
Different bacteria, such as *Vibrio* species, have been implicated in some cases as the cause of WSD but it is still under investigation [23]. WSD manifests as rapid tissue loss from corals, with the exposed coral skeleton appearing white, as it is thought to result from bacterial infections that lead to tissue necrosis. WSD is often associated with thermal stress (increased sea temperatures) and coral bleaching events, it may also be triggered by poor water quality.

WBD is also likely cause by bacterial pathogens suspected as Vibrio but have not been definitively identified. This disease affects Acropora species, creating a white band of dead tissue that progresses from the base to the tips of coral branches. The tissue loss leaves behind the white skeleton of the coral. WBD is commonly associated with warm water temperatures, coral bleaching, and nutrient pollution. Overfishing and other forms of environmental degradation can exacerbate the spread of this disease.

The most commonly disease found in coral colonies in this study was WSD as many as 61 colonies and the least was WPD 4 colonies (**Figure 4**). Coral disease can cause malfunctioning physiological processes in corals. There are three interactions as the beginning of coral disease, namely the presence of a place of attachment of the disease (host) in this case coral, carrier agent factors such as bacteria, fungi, and viruses, and environmental conditions [24].

WSD disease is characterized by the appearance of patches (spots) on the skeleton of the coral with white blanks and irregular in shape. Patches can occur on the upper or lower surface of the branching. The coral tissue appears to flake off, but unevenly, while the rate of coral tissue removal is very fast. Coral tissue generally begins to be covered by filamentous algae within a few days. The exact cause of the sloughing is still unknown, but it may be caused by pathogenic bacteria. This is supported by a statement that the tissue of diseased coral will experience degradation caused by tissue lysis and necrosis [25]. Three diseases in this study that were black band, white plague, white syndromes; already stated as the six most common diseases, accounting together for 76.8% of the 226 studies published [26].

Figure 4. Total coral colonies infected by types of disease.



Prevalence of Coral Disease

Prevalence of coral disease shows the highest evidence at 3 meters depth was in Morela and the lowest in Kaitetu, while at 10 m depth the highest in Erie and lowest in Liang. The average prevalence of coral disease at 3 and 10 meters depth was 8.29% and 8.88% respectively (**Table 3**). The difference of the prevalence of coral diseases on four study sites between depths was

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not significant (T-test, p>0.05), although in Erie, at the depth of 10 meter observation the prevalence was relatively far above at 17.9%. At this site the accumulation of garbage at the bottom of the water is noteable as it might trigger the pathogenic bacteria to grow.

Table 3. Prevalence of coral diseases at the depth of 3 and 10 meter.

No	Study Location	Prevalence of Coral Diseases (%)	
		3 Meter	10 Meter
1	Liang	8.3	4.8
2	Morela	10.0	7.2
3	Kaitetu	4.8	5.6
4	Erie	10.0	17.9
Average		8.3	8.9

Total number of coral colonies recorded in this study at the range of 224-446 with the average of 378 colonies per 250m2 (**Table 4**). This value implies coral colonies present in the belt transect, in average 30.5% of coral colonies infected with disease from the four sampling sites recorded. In average the magnitude of coral disease prevalence in Ambon Island Waters relatively smaller 9% than other findings in several places in Indonesian waters such as at Lembata Waters of East Nusa Tenggara which reached 42% in Budiyanto's research [27], Pulau Panjang Waters of Central Java (73%) [5]. However in Caribbean Waters (>20%) and the Philippines region (8%) [28] were lower compare to this findings. This indicates that the immunity or health of coral biota is still categorized in good condition. Prevalence of BBD alone reported in the Great Barrier Reefs has been found in more than 70% of the 19 total observation sites but the prevalence is relatively low at around 0.1% of the total coral colonies at that location [29].

Table 4. The prevalence of coral disease at each study location.

No	Study Location	Total number of coral colonies observed (n)	Number of coral colonies infected (n)	Prevalence of Coral Diseases (%)
1	Liang	432	30	6.9
2	Morela	388	35	9
3	Kaitetu	466	24	5.2
4	Erie	224	33	14.7
Average		378	30,5	9

The abundance of coral diseases

The abundance of coral infected disease at the depth of 3 and 10 meters falls within the interval of 0.02 – 0.13 col/m2, the highest on WSD (**Table 5**). Recent studies show an alarming increase in the abundance of coral diseases over the past few years, largely driven by rising ocean temperatures and environmental stressors. Warming waters are linked to the spread of diseases like stony coral tissue loss disease (SCTLD), which has caused severe damage to reefs, especially in Florida and the Caribbean. Research also indicates that coral disease prevalence has tripled in the past 25 years, and it is projected that up to 76.8% of global coral populations could be affected by 2100 if warming trends continue [30] [31].

Table 5. The abundance of coral disease at the depth of 3 and 10 meter.

No	Type of disease	Area of Transect (m2)	Number of colonies infected	Abundance of coral diseases (Col/m2)
Depth 3 meter				
1	Black Band Disease (BBD)	250	26	0.10
2	White Band Disease (WBD)	250	7	0.03
3	White Plague Disease (WPD)	250	4	0.02
4	White Syndrome Disease (WSD)	250	32	0.13
Average			**0.069**	

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Depth 10 meter				
1	Black Band Disease (BBD)	250	16	0.06
2	White Band Disease (WBD)	250	8	0.03
3	White Syndrome Disease (WSD)	250	29	0.12
Average			**0.071**	

Coral disease abundance in the study area was highest in WSD at 0.12 col/m2 and the others were less than 0.1 col/m2 with an average value of 0.06 col/m2 (**Table 6**). The abundance of BBD and WBD coral disease is much lower than the abundance found in Thousand Islands, Jakarta. It is known that the cause of the increased presence of the disease is due to factors such as increased temperature and light intensity [32] [33].

Table 6. Coral Disease Abundance at the Study Site.

No	Type of disease	Area of Transect (m2)	Number of Coral Colonies Infected (n)	Abundance of Coral Disease (Col/m2)
1	Black Band Disease (BBD)	500	42	0.08
2	White Band Disease (WPD)	500	15	0.03
3	White Plague Disease (WPD)	500	4	0.01
4	White Syndrome Disease (WSD)	500	61	0.12
Rata-Rata			30,5	0.06

Coral disease can be defined as abnormal symptoms that cause physiological dysfunction in coral health [9]. Two reef diseases and 17 types of health disturbance on coral (Scleractinia) were identified in the seawater of West Sumatra Sea [34]. Diseases of coral caused by biotic and non-biotic as environmental pressures or changes such as pollution, high temperatures, sedimentation, high nutrient levels, particularly nitrogen and carbon compound, predators, and competition with rapidly growing algae. The biotic factor is caused by microorganisms i.e bacteria, parasites, viruses and fungi that are pathogenic in nature. The increase in nutrients from agricultural runoff in coastal waters, such as phosphates, nitrates, ammonia, and dissolved organic carbon, has contributed to the degradation of coral reefs. Water pollution fills the water column, reducing light intensity, which disrupts the coral symbiont, zooxanthellae. Water pollution also causes poor water quality and creates favorable conditions for disease-causing bacteria [35].

Diseases affect coral reefs may caused by different pathogens, environmental stressors, and conditions such as warm water temperatures, pollution and nutrient overload, coral bleaching and physical damage and stress. These diseases are often linked to elevated sea surface temperatures, which weaken corals and create conditions favorable for pathogenic microbes. Physical damage such as overfishing, damage from anchors or divers, and sedimentation can also contribute to coral susceptibility to these diseases. Together, these factors often work in combination to compromise coral health, leading to the spread of these devastating diseases across coral reef ecosystems. Mass coral mortality can lead to extensive ecological disruptions, including a decline in biodiversity and ecosystem stability [36]. Disease outbreaks not only result in the death of coral reef, but it also can cause significant changes in community structure, species diversity and reef-associated organisms as well as the influence of chemical balance of the world's oceans [37]. Preventive measures, resource management, and research into the causes and treatment of diseases is crucial to do continuously to identify and monitor coral disease for remedial actions.

CONCLUSIONS

Based on the results of research in Ambon Island waters, conclusions can be drawn, firstly the diseases of coral found in Ambon Island Waters observed were 4 types, among others: 61 colonies with White Syndrome (WS), 42 colonies with Black Band Disease (BBD), 15 colonies with White Band Disease (WBD), 4 colonies with White Plague (WP). Secondly, the prevalence and abundance of coral disease at a depth of 3 and 10 meter at four locations were not significantly different. Thirdly, among the sampling locations, the highest prevalence of disease found in Erie, this place is the nearest site to Ambon municipality, that might affected by the presence of waste in that area.

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