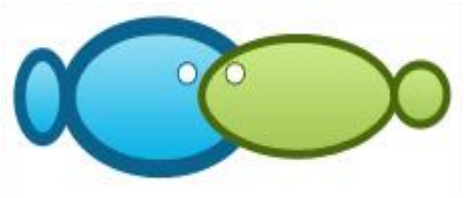

Diseases and health disturbances on scleractinian corals in the West Sumatra Sea, Indian Ocean

Indra J. Zakaria, Anggun Wulandari, Fuji A. Febria, Nofrita, Efrizal

Biology Department of Andalas University, Limau Manis, Padang, West Sumatra, Indonesia. Corresponding author: I. J. Zakaria, indrajunaidi@sci.unand.ac.id

Abstract. The cases of coral reef damage in Indonesia and, specifically, in the sea near West Sumatra have been caused by increases in the rates of disease and health disturbances on reefs. Research on these topics is unfortunately rare. The present paper aimed to understand coral diseases and types of disturbances in the marine area of West Sumatra. We used a survey method and five belts transect (each measuring 20 m x 2 m) to collect samples in the coastal areas of Nirwana Beach, Sikuai Island, and Mandeh from November 2017 until April 2018. The installation of belt transects was carried out at a depth of 2-7 m and was based on the existence of the diseases and disturbances on reefs. The research recorded nine coral diseases and ten types of disturbances. Nirwana Beach had the most cases (18 cases; nine diseases, nine ecological disturbances), followed by the Mandeh coast (14 cases; 7 diseases, 7 ecological disturbances), and the least number of cases were found in the Sikuai Island (10 cases, disturbances only). The diseases found were ulcerative white spots and white syndrome; bleaching, focal bleaching spots, focal bleaching patches, pink pigmentation response; several morphological types of growth anomalies, and irregular white plaques; and trematodiasis. Corals were also damaged by: the crown-of-thorns seastar (*Acanthaster planci*), *Drupella* and *Coralliophila* snails, and fish predation; the development of invertebrate-containing growth anomalies (galls); the competition from overgrowing; cyanobacteria, sponges, red filamentous algae, and crustose coralline algae; the sedimentation.
Key Words: coral diseases, coral reefs, Mandeh Coast, Nirwana Beach, Sikuai Island.

Introduction. Coral reefs in Indonesia are important components of the marine ecosystem, as they provide living resources for various marine biota. Coral reefs retain value and importance from socio-cultural, ecological and economical aspects. Almost one-third of Indonesian people reside in coastal areas and depend on the fertility of coral reef resources (Suharsono 1996).

The fertility of coral reefs is affected by environmental factors, including temperature, salinity and substrate (Harisson & Wallace 1990; Zakaria 2004; Zakaria et al 2019a). Meanwhile, damage to the coral reefs is caused by natural factors and human (anthropogenic) activities (Nyström et al 2000; Zakaria et al 2019b; Zakaria et al 2020). The natural factors are earthquakes, storms, tsunamis, El Niño, abnormal salinity, light insufficiency, bio-erosion, competitors and predation, and biotic factors such as pathogenic and parasitic infections, while human activities include fishing with explosives and poison, careless anchoring on top of the reefs, sedimentation, the disposal of industrial waste, climate change causing coral bleaching and coral exploitation for souvenir purposes (Peters 1997; Hughes et al 2003; Zakaria 2004; Santavy et al 2005; Raymundo et al 2008; Mallela & Grabbe 2009; Wooldrige & Done 2009; Johan 2010; Hughes et al 2018).

Furthermore, most of the research shows that humans might not onlyintroduce new pathogens into the oceans through aquaculture, runoff, human sewage, and ballast water but they might also exacerbate existing opportunistic infections due to stressors such as poor water quality and climate warming (Lafferty et al 2004; Zakaria et al 2016; Magris et al 2018). Climate warming is now established as an important factor in some of the current outbreaks (Miller et al 2006; Bruno et al 2007; Muller et al 2008). Because reef-building corals have a narrow range of thermal tolerance (between 18 and 30°C),

they are extremely susceptible to temperature stress. It is well known that corals bleach at high temperatures. The coral bleaching observed worldwide, following the 1998 El Niño, was the most massive and devastating recorded up to that point (Hoegh-Guldberg 1999). Moreover, the Caribbean thermal anomaly of 2005 was immediately followed by outbreaks of white plague, yellow band disease (Miller et al 2006), and white patch disease in Hawks nest Bay (Muller et al 2008) and in West Sumatra (Anwar et al 2017). All of these causal factors can cause diseases, health disruption, and even the death of coral reefs (Johan et al 2010).

The healthiness of coral reefs is defined by the disease and disruption of their health. The disease is classified as the loss of coral tissue caused by a pathogen, while health disruption can be in the form of tissue loss due to predation, tissue discoloration, growth abnormalities, and competition with other organisms (Willis et al 2004; Beeden et al 2008). According to Raymundo et al (2008) and Beeden et al (2008), coral diseases include the white syndrome, pink blotch, black band disease, ulcerative white Spot and skeletal eroding band. Furthermore, examples of health disruption are crown-of-thorns starfish, *Drupella*, *Coralliophila*, fish bites, bleaching, focal bleaching spots, focal bleaching patches, invertebrate galls, enlarged structures, irregular white plaques, pigmentation response, Trematodiasis, Cyanobacteria, sponges, red filamentous algae and reef degradation by sedimentation, leading to crustose coralline algae colonization.

Research on disease and health disturbances in Scleractinian corals is the most developed area and has been well documented in the Caribbean over the last decade (Porter et al 2001; Weil 2004; Miller et al 2006; Muller et al 2008). Some researchers argue that climate warming has driven part of the increase in damaging outbreaks (Raymundo et al 2008). Research on coral disease has also been carried out in the Indo-Pacific (Harvell et al 2007), Australia (Willis et al 2004), the Philippines (Raymundo et al 2005), Palau (Beeden et al 2008), the Northwestern Hawaiian Islands (Aeby et al 2011), American Samoa (Work & Rameyer 2005), the central Pacific (Work et al 2008), and East Africa (McClanahan et al 2004). Significantly damaging new diseases have been identified in all the surveyed locations.

In Indonesia, this kind of research is considerably scarce: in Padang coastal area (Johan & Syam 2014). A study about the health status of Scleractinian coral resulted in the discovery of several diseases such as black band disease and white syndrome. A more thorough inventory of coral disease and health disturbance in the sea of West Sumatra has not been reported previously. Hence, this study aimed to compile the types of coral disease and health disturbances in this area, as baseline information for further studies and future rehabilitation efforts.

Material and Method. Surveys were conducted from November 2017 until April 2018 at three sites within the administrative sea of West Sumatra Province, namely, Nirwana Beach (1º 00'43" S, 100º 23' 16" E) which has a coral area of approximately 30,000 m^2, the Coastal Region of Mandeh (1º 12' 01" S, 100º 25' 08" E) which has an estimated coral reef area of 45,250 m^2, and Sikuai Island (1º 07' 46" S, 100º 21' 15" E) which has a coral reef area of approximately 12,500 m^2 (Figure 1). Each survey site has specific environmental conditions. Nirwana Beach receives moderate anthropogenic pressure from fishing activities and household waste disposal, while the Coastal Region of Mandeh has considerable sedimentation, resulting from land-clearing on the area of the Mandeh hills. Sikuai Island is considerably pristine compared to other sites. The surveys used scuba, rulers, an underwater camera, GPS apparatus and underwater stationery to assist with data collection.

The research method was based on the Coral Disease Handbook: Guidelines for Assessment, Monitoring & Management (Raymundo et al 2008) and on the underwater cards for assessing the coral health in the Indo-Pacific reefs (Beeden et al 2008) while the coral identification was based on Veron (1998). We used five belt-transects with an area of 200 m^2 (5 x 20 m x 2 m) to collect the data from each location; the transect was set based on the observed presence of coral diseases within the 2–7 m depth of water.

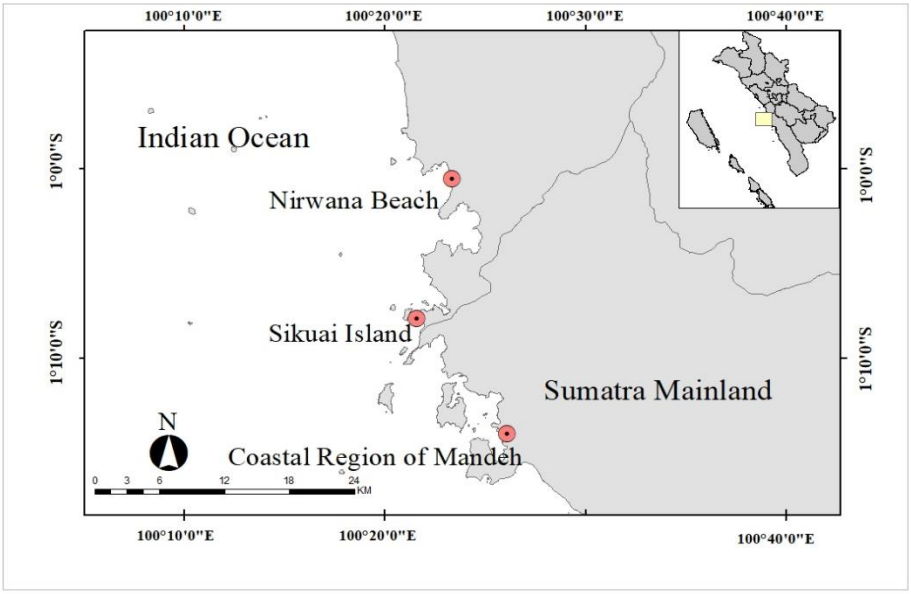

Figure 1. Map of survey locations.

Two aspects of the scleractinian corals' disease and health disturbances in were considered in this study: the type and the prevalence. In every observed coral infection, the taxonomy of coral was identified and the degree of infection was visually determined using an evaluation method for assessing the coral health, before properly documenting the investigation with an underwater camera (Beeden et al 2008; Raymundo et al 2008) and collecting the specimens of coral. The distribution of coral disease was assessed using the positions of all findings recorded with the GPS apparatus. The corals taxonomy was clarified in the laboratory, where samples and the photographs of coral were matched with plates provided in the coral identification books (only until genera) (Suharsono 1996; Veron 1998), while the identification of coral disease was guided by the Coral Disease Handbook: Guidelines for Assessment, Monitoring & Management (Raymundo et al 2008) and by the underwater cards for assessing coral health on Indo-Pacific Reefs (Beeden et al 2008).

The disease prevalence, determined as the proportion of damaged coral colonies compared to the total measured population of coral colonies, was further calculated according to Raymundo et al (2008), as shown below:

$$\text{Prevalence (\%)} = \frac{\text{Number of colonies affected by disease}}{\text{total coral colonies in belt-transect}} \times 100$$

The data were then descriptively analyzed and displayed in the form of tables and photos.

Results and Discussion

Types and prevalence of disease and health disturbance. The survey revealed nine coral diseases and ten health disturbances which were mainly caused by predators, coral bleaching, growth abnormalities, and compromised health conditions (Table 1). The table below shows that Nirwana Beach had the highest incidence rate (18 cases: 9 diseases, 9 health disturbances), followed by the Coastal Region of Mandeh (14 cases: 7 diseases, 7 health disturbances), and Sikuai Island had the lowest incidence rate (10 cases, health disturbances only). From a total of 1,103 coral colonies surveyed at Nirwana Beach, diseases and health disturbances were observed in 996 colonies (the infected ones), while the other 107 colonies were healthy. This means that Nirwana Beach topped the two other survey sites, as at the Coastal Region of Mandeh there were 933 colonies with diseases and health disturbances from a total of 1,188 colonies observed, while at Sikuai

Island there were 450 health disturbance observations from a total of 752 coral colonies surveyed.

Table 1

Type, presence and number of infected coral colonies with disease and disturbances observed on coral reefs in West Sumatra Sea

	Types of diseases	*Number of coral colonies infected*		
		Nirwana Beach	*Sikuai Island*	*Coastal region of Madeh*
Coral diseases	Ulcerative white spots (UWS)	68	-	38
	White syndrome (WS)	2	-	31
	Bleaching (Bw/s)	63	-	97
	Focal bleaching-spots (Bsp)	17	-	-
	Focal bleaching-patches (Bpt)	5	-	7
	Enlarged structures (ES)	6	-	-
	Irregular white Plaques (IWP)	2	-	18
	Pigmentation response (PR)	81	111	96
	Trematodiasis (TR)	25	24	6
Healt disturbances	Crown-of-thorns starfish (COTS)	-	16	-
	Drupella (DRU)	84	26	39
	Coralliophila (COR)	5	6	9
	Fish bites (FISH)	169	76	37
	Invertebrate galls (IG)	28	16	78
	Cyanobacteria (CY)	8	-	-
	Sponges (SP)	26	-	14
	Red filamentous algae (RA)	44	4	8
	Sediment damaged (SD)	62	134	455
	Crustose coralline algae (CCA)	80	37	-
Total number of diseases		18	10	14
Total number of infected coral colonies		996	450	933
Total number of healthy coral colonies		107	302	255
Total number of observed coral colonies		1103	752	1188

Figure 2 shows the prevalence (as percentages) of diseases and health disturbances in the coral colonies, at the study sites. The five highest records were topped by the sediment damage (SD), which was observed on 48.83% colonies in the Coastal Region of Mandeh, 35.37% at Nirwana Beach and 29.80% at Sikuai Island. This was followed by the pigmentation response (PR), which occurred in 24.74% of the colonies at Sikuai Island, 10.34% in the Coastal Region of Mandeh, and 8.11% at Nirwana Beach. Fish bites (FISH) happened in 17.02% of the coral colonies at both Nirwana Beach and Sikuai Island and in 3.95% of the coral colonies in the Coastal Region of Mandeh. Then, bleaching (Bw/S) was recorded in 10.42% colonies in the Coastal Region of Mandeh and 6.32% at Nirwana Beach, and finally, *Drupella* (DRU) was observed in 8.44% of the colonies at Nirwana Beach, 587% at Sikuai Island and 4.15% in the Coastal Region of Mandeh. These top five conditions are categorized as coral health disorders. Meanwhile, the most prevailing coral diseases were ulcerative white spots (UWS), which was only observed at Nirwana Beach (6.82%) and the Coastal Region of Mandeh (4.03%).

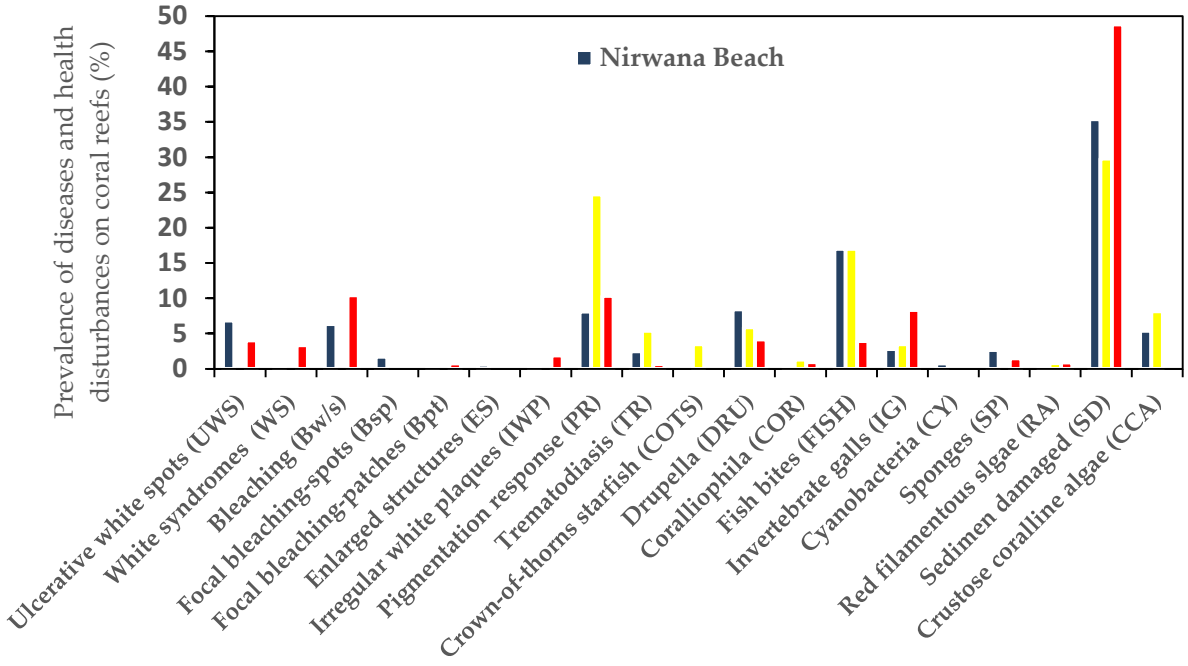

Figure 2. Prevalence of diseases and health disturbances on coral reefs in the West Sumatra Sea (%).

The prominent occurrence observed at Nirwana Beach was suspected to be a consequence of anthropogenic activities such as the disposal of household waste, the oil spilled from passing boats and careless anchoring to the coral reefs. These anthropogenic pressures increased the vulnerability of coral reefs toward diseases and other disturbances. A previous study found that coral reefs become susceptible to diseases once they are physiologically weak, after competing with fast-growing algae or from bleaching (Nugues 2002; Pamungkas et al 2014).

In the Coastal Region of Mandeh, heavy sedimentation, which is thought to be indirectly resulted from the deforestation on the surrounding hilly terrain, might be the major cause of coral diseases and health disturbances. At Sikuai Island, on the other hand, only health disturbances were observed, presumably caused by other sea biotas. Despite the more natural conditions of the habitat in Sikuai Island, *Acanthaster planci* was observed eating the coral polyps.

The coral disease was firstly reported four decades ago (Antonius 1973). Since then, more cases have been recorded through subsequent research (Peters 1997; Hughes et al 2005; Santavy et al 2005; Raymundo et al 2008; Johan 2010). Some of these were observed at the Great Barrier Reef, in the Indo-Pacific region, which included observations on white syndrome, skeletal eroding band, black band disease, brown band disease, growth anomalies, pink spot and black necrosing syndrome (Willis et al 2004). Coral diseases can be defined as a decline in the coral health, accompanied by lesion markings on the coral surface. Some are contagious, while others behave as non-pestilent. There is still a lack of information regarding the causes of coral diseases (Raymundo et al 2008). On the other hand, predation, coral bleaching, growth anomalies, sedimentation, and competitors are among the causes of health disturbances in coral.

Descriptions of coral diseases

***Ulcerative white spots* (*UWS*)**. Ulcerative white spots were observed at Nirwana Beach and in the Mandeh region. Some coral genera which were affected included *Porites*, *Favites*, *Fungia,* and *Herpolitha*. The disease is characterized by whitish, round spots of relatively the same size, exposing eroded coral tissue on *Porites* and *Favites* (Figure 3a, 3b). Meanwhile, on *Fungia* and *Herpolitha*, the wound formed was elliptical, with an

irregular pattern and obscure eroded coral tissue (Figure 3c, 3d). Ulcerative white spots were previously reported in the Philippines (Raymundo et al 2003), Thailand (Scaps et al 2011), the Indo-Pacific, and the Mediterranean (Weil et al 2006) and in Indonesia, one case was observed in East Nusa Tenggara (Abrar et al 2012). This disease is known to infect massive corals such as those from *Porites*, *Acropora*, *Montipora*, *Echinopora*, *Favidae*, and *Heliopora* (Raymundo et al 2003; Beeden et al 2008).

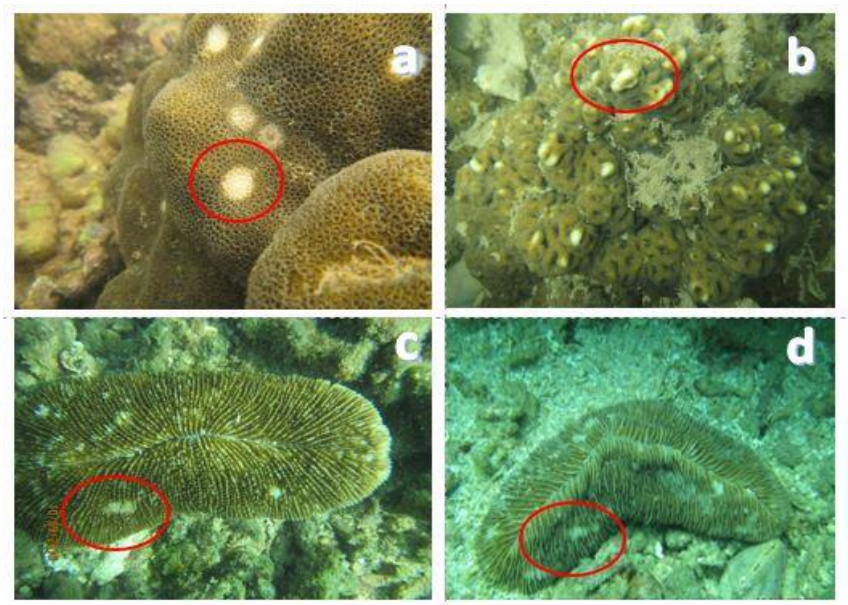

Figure 3. Ulcerative white spots in (a) *Porites*, (b) *Favites*, (c) *Fungia*, and (d) *Herpolitha* (Nirwana Beach) (original).

***White syndrome* (*WS*)**. The white syndrome was only observed at Nirwana Beach and the Coastal Mandeh Region, with *Pavona, Porites* and *Acropora* corals infected. The disease was characterized by a single white spot of eroded tissue, exhibiting a border between the healthy and the infected tissue; the latter did not show microbial activity (Figure 4). The absence of microbial activity on wounded tissue has been previously observed on the Acroporid coral at the Great Barrier Reef as the main trait of this disease (Ainsworth et al 2007). Coral destruction from white syndrome is considerably high, with a tissue loss rate varying from 1.0 to 124.6 cm^2 day^{-1} (Roff et al 2006). As the cause of this disease remains unclear (Willis et al 2004), there might be a correlation between the disease and the frequency of temperature anomalies (Bruno et al 2007).

Figure 4. White syndrome in *Porites* (Coastal region of Mandeh) (original).

***Bleaching* (*Bw/s*)**. Bleaching was recorded at Nirwana Beach and in the Coastal Region of Mandeh. At the first location, the coral reefs seemed to have been impacted by massive bleaching within the previous days, while in the second one, only some colonies

showed this indication. Coral bleaching is mainly caused by environmental stress resulted from an increase or decline in the temperature. We observed bleaching on coral reefs indicated by whitened coral colonies and a lack of symbiont algae (zooxantellae) within the coral tissue, resulting in the white color (Figure 5a). Massive bleaching was previously reported in 2016 in the sea of Water Tourism Park Gili Matra in West Nusa Tenggara Province, where 50% of the coral colony became whitened and another 11% of the colony turned paler (Setiawan et al 2017). Another reported observation occurred at the cluster of Pari islands, Thousand Islands, Jakarta, where the bleaching happened as the temperature increased by 2-3°C (Suharsono 1999). An increment of 0.5°C in temperature in subtropical regions can result in coral bleaching and the pulling out of symbiotic algae from the coral colony (Wilkinson 2008). Any increment in the average sea surface temperature of 30°C can potentially result in coral bleaching (Burke et al 2004).

***Focal bleaching-spots* (*Bsp*)**. This disease is indicated by white spots on the coral surface. It was observed only at Nirwana Beach, on *Porites* coral (Figure 5b). It was recorded in turbid and shallow seawater and was characterized by small, white spots with slight protrusions on the coral surface; it usually followed bleaching. It attacks corals from the genera *Porites*, *Montipora* and *Acropora* (Anwar et al 2017; Beeden et al 2008).

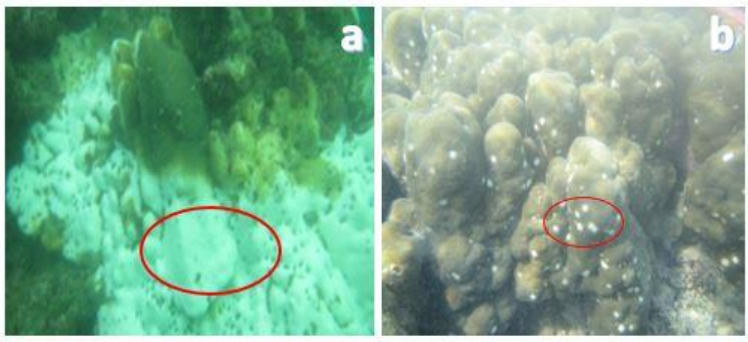

Figure 5. (a) Bleaching on *Porites* (Coastal region of Madeh), (b) Focal bleaching spots on massive *Porites* (Nirwana Beach) (original).

***Focal bleaching-patches* (*Bpt*)**. This disease forms white patches, which were observed in the shallow waters at Nirwana Beach and in the Coastal Region of Mandeh. It mainly attacks *Porites* and *Fungia* corals (Figure 6a-b), characterized by white coloration and clear separation between health and disturbed coral tissue without any in-between band. Bleaching Patches is a rare case that occurs without any trigger from environmental stress and usually attacks massive *Porites* (Beeden et al 2008). Focal bleaching patches on *Fungia* coral were observed in the seawater of Pramuka Island, Seribu Islands, Jakarta and in West Sumatra (Subhan 2011; Anwar et al 2017).

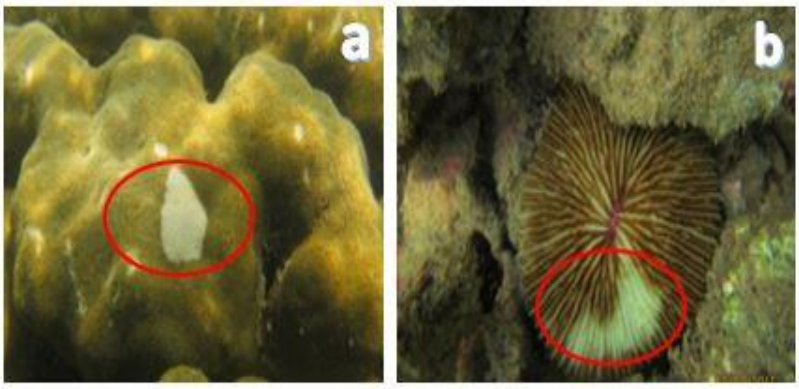

Figure 6. (a) Focal bleaching patches on *Porites* (Nirwana Beach), (b) Focal bleaching patches on *Fungia* (Nirwana Beach) (original).

***Enlarged structures* (*ES*)**. Enlarged structures were only found at the Nirwana Beach area on *Acropora*, *Fungia*, *Favites,* and massive *Porites* corals (Figure 7a-d). They came in the form of abnormal growth, creating protrusions atop the coral colony. They can cause different symptoms in various corals, as they can adapt to the structures of the attached coral. However, they have a similar pigmentation on the abnormal structures: pale or colorless.

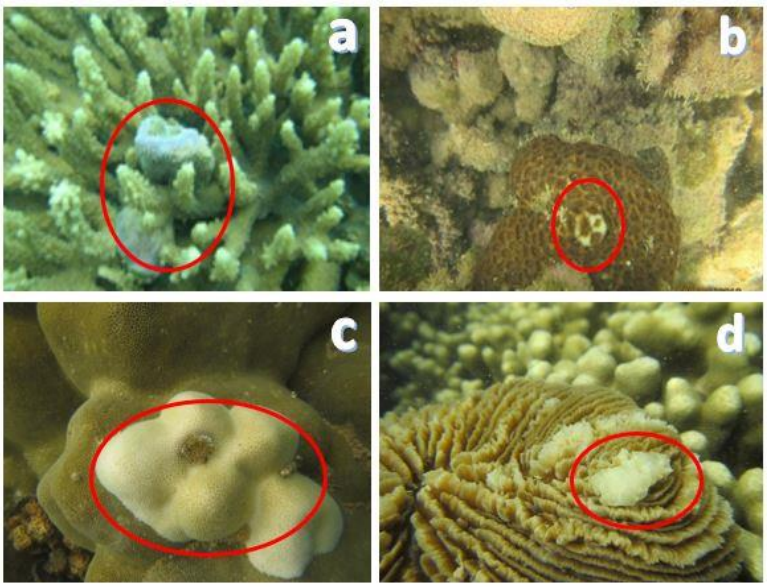

Figure 7. (a) Enlarged structures in *Acropora,* (b) Enlarged structures in *Favites*, (c) Enlarged structures in *Porites*, (d) Enlarged structures in *Cycloseris* (Nirwana Beach) (original).

***Irregular white plaques* (*IWP*)**. Irregular white plaques were found in the shallow water at Nirwana Beach and in the Coastal Region of Mandeh. They only developed on *Porites* coral and were identified by thickening on the coral tissue, resembling a white plague. They can have coral polyps as well (Figure 8). They are included as a disturbance to the coral health, as they are derived from corals' growth anomalies. When spotting this disturbance, there is a risk of confusion, due to the variability of the natural pigmentation. Often, coral with normal pigmentation, with fewer zooxanthellae pigment, without pigment, with or without tiny corallite, will resemble this white plaque (Beeden et al 2008).

Figure 8. Irregular white plaques on *Porites* coral (Coastal region of Madeh) (original).

***Pigmentation response* (*PR*)**. This was found on most of the *Porites* coral at all locations. It caused pink pigmentation, a rounded shape, and thickening of the lining, spots and walls of coralites (Figure 9a). When coral responds to wound inflammation after interactions with other marine biotas, it will be signified by the appearance of pink or violet spots on the surface (Benzoni et al 2010). This usually results from the stress

mechanism that occurs whenever coral interacts with Cirripedia larvae, which attach on the surfaces of living *Porites* coral.

***Trematodiasis* (*TR*)**. Trematodiasis had similar prevalence to PR, it was found only on *Porites* coral. Instead of having thickening, the pink inflamed sections looked more swollen and measured 1–2 mm (Figure 9b). The swelling was caused by the presence of trematode (tapper worms) parasites in the corals. A study in seawaters of Hawaii observed the genus *Podocotyloides* living as a parasite, in coral polyps (Aeby 1993; Johan 2010).

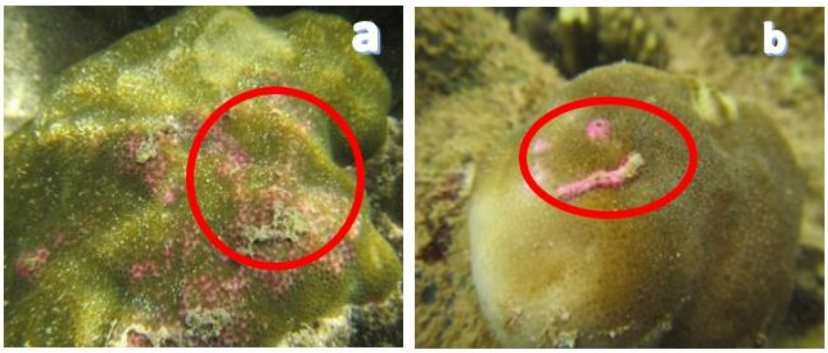

Figure 9. (a) Pigmentation response in massive *Porites* (Sikuai Island), (b) Trematodiasis in *Porites* (Nirwana Beach) (original).

Coral health disturbances

***Crown-of-thorns starfish* (*COTS*)**. The presence of the predatory crown-of-thorns starfish (COTS) were only observed in the waters of Sikuai Island, which was clear and had considerably good coral coverage compared to the other two locations. Meanwhile, the percentage of coral coverage at Nirwana Beach (tourism and mangrove zones) was categorized as bad to very bad with 0–49% of living coral coverage (Anwar et al 2014). The coral coverage in the Coastal Region of Mandeh fell in a similar category with 15–48% of living coral coverage. The coral communities in both locations were affected by sedimentation, which, in turn, promotedthe growth of the crown-of-thorns starfish. This predator feeds mainly on coral polyp and lives in clear and clean seawater. The predated coral can be recognized through white striated, slimy patterns on sections of the damaged tissue; this predator usually starts feeding on the end of the coral colony (Figure 10a).

COTS prefer areas with good coral coverage (Scott et al 2017). It has the potential to destroy vast coral reef ecosystems (Pratchett 2001). An alarming amount of *Achantaster planci* was found to be affected in the seawater of Kasiak Island of Pariaman District, West Sumatra, with an average abundance of 176 ind/1,000 m^2 (Syafrianto et al 2015). At the study site (Sikuai Island), its abundance was 16 ind/200 m^2.

***Drupella* (*DRU*)**. This health disturbance was found in the intertidal zone in all locations. *Drupella* is a gastropod genus that feeds mainly on coral polyps, leaving white traces on the decapitated coral sections. Grazed polyp or coral becomes irregularly deformed and notched in shape. At the study sites, this predator eats the branches of coral colonies (Figure 10b). *Drupella* was observed on *Favites*, *Pavona*, *Acropora*, and *Porites*. Despite being found in abundance, there was no indication of massive destruction on the coral community caused by this genus, at the study sites.

Drupella prefers the *Acropora* coral (Beeden et al 2008). In this study, however, it was observed more on *Porites*, which was recorded as the most abundant coral in all locations, while *the Acropora* coral was observed to suffer the least. *Drupella cornus* was recorded mostly on *Platygyra* whenever the *Pocillopora* and *Acropora* corals were scarce (Cumming & McCorry 1998). In Eilat Gulf, Israel, *Drupella* was found to be eating

Turbinaria, *Pavona*, *Millepora* and *Porites* after it had depleted the branching coral (Shafir et al 2008).

***Coralliophila* (*COR*)**. *Coralliophilla* (Figure 10c) is included in the Muricid or sea slug group. It was found at all study sites in smaller number than *Drupella*. It leaves similar traces on the grazed coral, which are white and eroded coral tissue. It dwells within the coral crevices, where it attaches in between coral colonies. *Coralliophila* causes a small amount of tissue loss, yet the damage still requires energy and time to recover. The predated section of coral then becomes vulnerable to disease and infestation by other organisms. In this study, *Coralliophila* was shown to attack *Favites*, *Pavona*, and *Porites*, while in a previous study it was found to feed mainly on *Porites*, especially the branched ones (Beeden et al 2008).

***Fish bites* (*FISH*)**. Fish bites caused by Parrotfish Scars (Scaridae) and Pufferfish Scars (*Trigger*) were observed at all locations. The first can be identified from white, large scratching marks on the edge of the coral colony (Figure 10d), while the latter leaves smaller marks, rectangular in shape, that are regular and in pairs (Figure 10e). Both predators attacked the massive *Porites*. The compact and rounded shape of a massive *Porites* attracted predation on its tissue from the surrounding fish. The parrotfish scar was mainly observed on large *Porites* (Shafir et al 2008). The biting marks can recover within a given time, or they may be inhabited by pioneering algae from the coral reef.

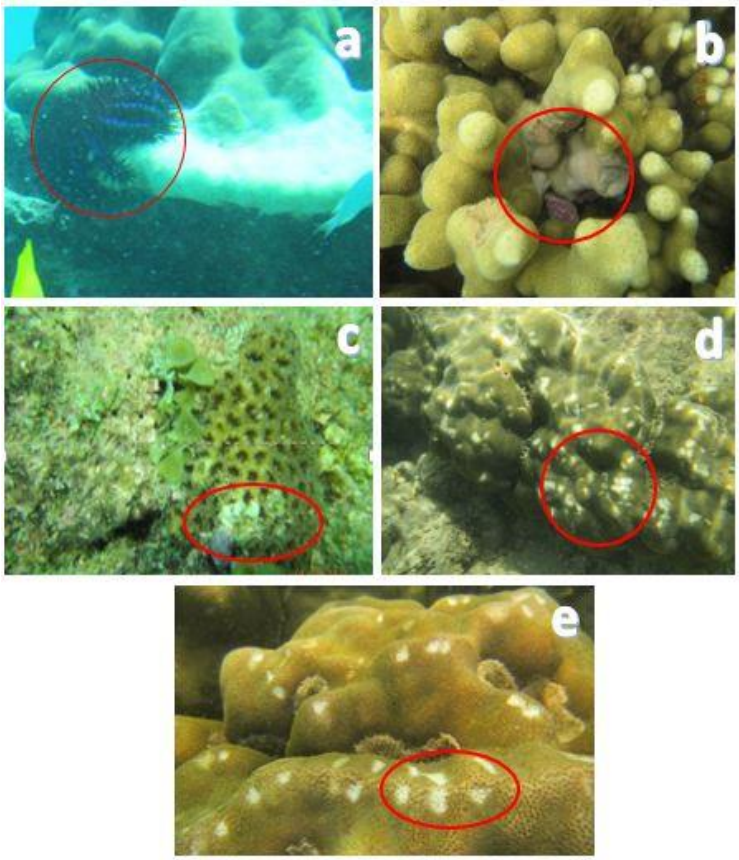

Figure 10. (a) Crown-of-thorns starfish in *Porites* massive (Sikuai Island), (b) *Drupella* in *Porites* (Nirwana Beach), (c) *Coralliophila* in Favites (Coastal region of Mandeh), (d) Parrotfish scars in *Porites* (Nirwana Beach), (e) Pufferfish scars in *Porites* (Nirwana Beach) (original).

***Invertebrate galls* (*IG*)**. Invertebrate galls (IG) are an abnormality observed with coral growth caused by infesting invertebrates dwelling within the coral tissue; it was found at all study sites. It can be recognized from the existence of certain invertebrates inside the coral. It was found in the massive *Porites* and *Galaxea* (Figure 11a-b). It was also

previously recorded in massive *Porites* at Lembata Sea, East Nusa Tenggara Province, Indonesia (Abrar et al 2012).

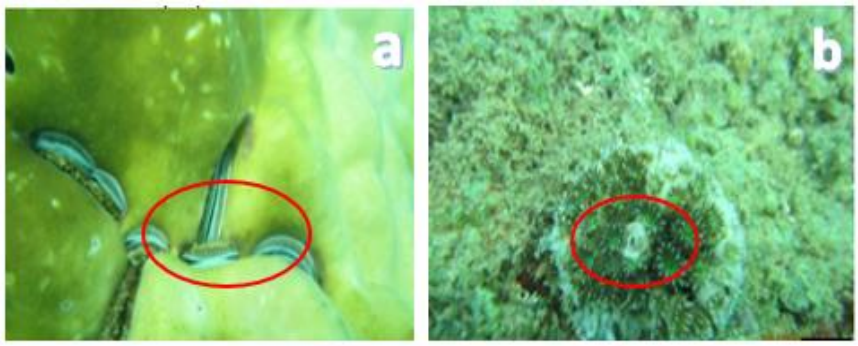

Figure 11. (a) Invertebrate galls in *Porites* (Sikuai Island), (b) Invertebrate galls in *Galaxea* (Nirwana Beach) (original).

***Cyanobacteria* (*CY*)**. As the name implies, this kind of disturbance is caused by cyanobacteria, which, in this study, was observed at Nirwana Beach. In the beach area there were detected high nitrate and phosphate contents. These two elements accelerate photosynthesis in cyanobacteria, as they are used as nutrition sources for the process (Boyett 2006). Infected coral can be detected through the reddish-brown color from algae coverage upon the coral, accompanied by air bubbles as another side product of cyanobacteria photosynthesis (Figure 12a). In severe cases, the filament of the algae can overwhelmingly cover up the coral tissue.

***Sponges* (*SP*)**. Sponges were recorded on Nirwana Beach and the Coastal Region of Mandeh. Sponges live in between coral tissue and compete directly with their host (Figure 12b). As a competitor, they can suppress the hosting coral, eventually causing massive death of coral colonies, as indicated by the white coloration on coral tissues (Beeden et al 2008). Sponges that attacked massive *Porites* and branching *Porites* were also observed in the Lembata Sea, East Nusa Tenggara Province (Abrar et al 2012).

***Red filamentous algae* (*RA*)**. Red filamentous algae were found at Sikuai Island and Nirwana Beach, as indicated by the growth of algae filaments on living coral tissue. Most of the time, the algae filaments accumulated with the sedimentation, suppressing the living function of coral polyps (Figure 12c). Red filamentous algae were found on corals from genera *Galaxea* and *Favia*.

***Sediment damage* (*SD*)**. *The sediment damage* was seen at different levels in each location; it can be recognized from the sediment buildup, which finally killed the living corals (Figure 12d). The coastal Region of Mandeh became the location where this type of disturbance occurred the most, as it is likely impacted by land clearing around its coastal border. In turn, soil erosion increased on the barren ground and brought runoff to the seawater. In contrast, the water around Sikuai Island experienced only a slight occurrence of this disturbance, signified by its clear seawater, which was similarly observed at the mangrove zone of Nirwana Beach. Unfortunately, observations at the settlement and tourism zones of Nirwana Beach showed evidences of an intense sedimentation. Sediment buildup from anthropogenic activities adversely affects the growth of coral and can eventually trigger coral diseases (Haapkyla et al 2009; Liu et al 2012; Hughes et al 2013; Sahetapy et al 2017), especially when the buildup overwhelms the coral surface (Sunarto 2016). Some coral species possess the ability to clean their surface from sediment through the movement of their superficial cilia or by inflating the *coenosarc* using water. The sedimentation of organic-rich substrates atop the coral surface amasses hydrogen sulfide which creates an adverse effect as the main factor in degrading coral mucus, eventually killing the coral (Weber et al 2012; Zakaria et al 2019b).

***Crustose coralline algae* (*CCA*)**. Crustose coralline algae were found at Nirwana Beach and Sikuai Island, this can be seen from the presence of bright blue coraline algae that adhered and covered the surface of the coral (Figure 12e). Coraline algae disturb the health of coral and inhibit the growth of coral polyps. They were observed to exist on corals from the genera *Favia*, *Platygyra*, and massive *Porites*.

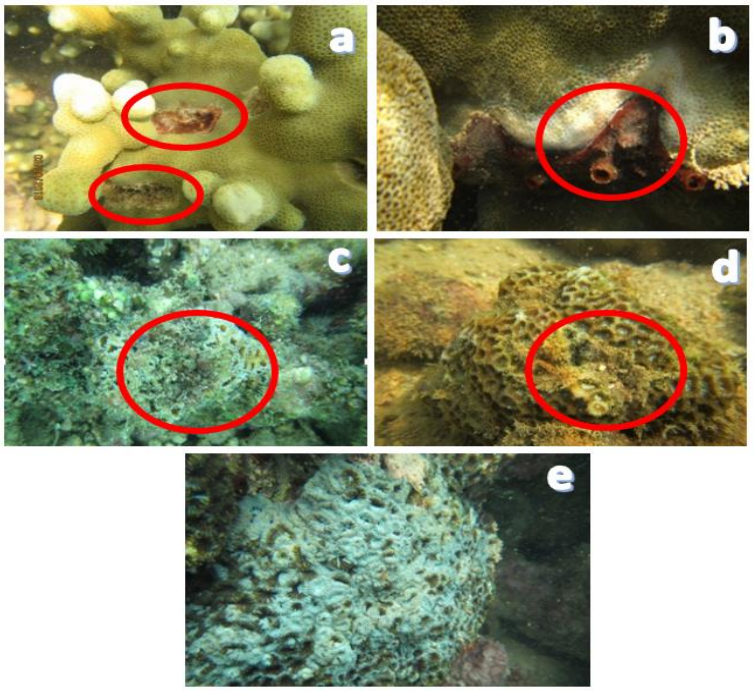

Figure 12. (a) Cyanobacteria in *Porites* (Nirwana Beach), (b) Sponges in *Porites* (Nirwana Beach), (c) Red filamentous algae in *Galaxea* (Nirwana Beach), (d) Sediment damage in *Favites* (Coastal region of Madeh), (e) Crustose coralline algae in *Favia* (Nirwana Beach) (original).

Conclusions. Two reef diseases and 17 types of health disturbance on coral (*Scleractinia*) were identified in the seawater of West Sumatra Sea. Nirwana Beach had the most cases (18 cases; 2 diseases, 16 health disturbances), followed by the Coastal Region of Mandeh (14 cases; 2 diseases, 12 health disturbances) and Sikuai Island (10 cases, health disturbances only). The diseases and health disturbances on coral (*Scleractinia*) in the seawater of West Sumatra included the presence of Ulcerative White Spots and White Syndrome on some coral genera. Meanwhile, the health disturbances were mostly due to predation caused by crown-of-thorns starfish, *Drupella*, *Coralliophila* and fish bites. Health disturbances with whitening indication were caused by bleaching, focal bleaching spots and focal bleaching patches. Several compromised health cases noted in this research were: pigmentation response, Trematodiasis, enlarged structures, Irregular White Plaques, Cyanobacteria, Sponges, sediment damage, invertebrate galls, Red Filamentous Algae and Crustose Coralline Algae.

Acknowledgements. The authors would like to thank the Rector of and Head of the Research Institution and Community Service (LPPM) of Andalas University for giving us this opportunity by approving the funds for this research. This research was funded by the DIPA grant of Andalas University, moderated by the Research-Publication Cluster Grant—Acceleration into Professorial Tenure, Fiscal Year 2018 with the Contract Number (No). 28/UN.16.17/PP.PGB/LPPM/2018.

Conflict of interests. None reported.

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Received: 05 January 2021. Accepted: 21 February 2021. Published online: 28 February 2021.
Authors:
Indra Junaidi Zakaria, Andalas University, Faculty of Mathematics and Natural Sciences, Biology Department, Limau Manis, 25163 Padang, Indonesia, e-mail: indrajz@yahoo.com
Anggun Wulandari, Andalas University, Faculty of Mathematics and Natural Sciences, Biology Department, Limau Manis, 25163 Padang, Indonesia, e-mail: anggun.wulan@gmail.com
Fuji Astuti Febria, Andalas University, Faculty of Mathematics and Natural Sciences, Biology Department, Limau Manis, 25163 Padang, Indonesia, e-mail: fafebria@gmail.com
Nofrita, Andalas University, Faculty of Mathematics and Natural Sciences, Biology Department, Limau Manis, 25163 Padang, Indonesia, e-mail: nofrita_wijaya@yahoo.co.id
Efrizal, Andalas University, Faculty of Mathematics and Natural Sciences, Biology Department, Limau Manis, 25163 Padang, Indonesia, e-mail: efrizal.unand@gmail.com

How to cite this article:
Zakaria I. J., Wulandari A., Febria F. A., Nofrita, Efrizal, 2021 Diseases and health disturbances on scleractinian corals in the West Sumatra Sea, Indian Ocean. AACL Bioflux 14(1):462-477.