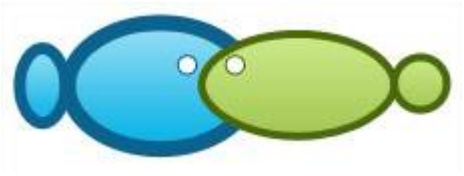

The prevalence of coral health issues in the conservation area of Benteng, Weh Island, Sabang, Indonesia

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Abstract. Coral reefs are ecosystems that are vulnerable to environmental conditions. If the coral ecosystem is healthy, the impact on marine biota associated with corals is also good. However, in several cases, it has been shown that the health of corals in terms of cover in several areas of Indonesian waters has decreased. Therefore, it is necessary to pay attention to the health condition of corals and to study the types of corals that tend to be affected by the disease. This study was conducted in the water conservation area of Benteng, Weh Island, Sabang City, Aceh Province, Indonesia. The purpose of the study was to measure coral cover conditions and health issues based on the prevalence of coral problem categories. Point intercept transect was used to measure coral conditions, and belt transect was used to measure the prevalence of coral health issues. The study results indicated that the coral condition in the conservation area was poor. When observed at the genus level, the highest incidence of coral health issues was experienced by *Porites*, followed by the genus *Montipora*. In terms of the specific type of coral health issues, the highest prevalence was recorded for aggressive overgrowth by macroalgae (40.5%), while the lowest prevalence was observed for focal bleaching-spots (1.03%). Overall, the results showed that the coral health issues found in the water conservation area were competition-aggressive overgrowth by macroalgae, competition-aggressive overgrowth by sponges, competition-aggressive overgrowth by turf algae, focal bleaching-patches, focal bleaching-spots, pigmentation response, predation-fish bites, sediment damage, and tube formers.
Key Words: articulated red algae, coral disease, coral health, prevalence, tube formers.

Introduction. Aceh's marine waters are the greatest natural resource potential for the people of Aceh. A few marine conservation zones have been established in Aceh's marine waters in order to obtain the benefits of marine biodiversity. Conservation is an effort to improve and maintain ecosystems (Afkar & Aldyza 2018), including coral reef ones. Several coral studies have been conducted in the Aceh waters area (Rudi et al 2012a, b; Fadli et al 2012, 2014; Aldyza et al 2015). One of the conservation zones that have been established in Aceh waters is located in the waters of Benteng Weh Island, Sabang City of Aceh Province. It is located in Sukajaya Sub district. It has a core zone area of 1.21 hectares. The core zone is a restricted zone designated to protect the habitat of coral reefs, coral fish, and other biota to avoid rarity of aquatic biota (Aldyza et al 2015). The conservation zone was formed by Panglima Laot Lhok along with the community and the city government as an effort to protect, preserve, and maintain the health of coral reef ecosystems in the waters of Benteng, Weh Island.

The health of coral reefs is determined by diseases and health issues. Diseases are grouped as corals' loss of tissue to various pathogens, while health problems are corals' loss of tissue due to predation, tissue discoloration, growth abnormalities, and competition with other organisms (Beeden et al 2008). Séré et al (2015) further stated that coral diseases have caused real changes in biodiversity and abundance of reef-forming corals.

According to Subhan et al (2020), the sustainability of coral ecosystems depends largely on the impact of human activities such as habitat degradation, climate change, land and marine pollution, development in coastal areas, and illegal fishing gear usage (such as bombs and poisons). These impacts can also precipitate coral health issues. Based on the results of interviews with Panglima Laot Lhok, who oversaw the Benteng waters area, before the formation of the conservation zone, many coral reefs were damaged due to the activities of fishing communities that still used poison and trawl to catch fish. However, after the estabilishment of this protected zone, it is hoped that there will be no more illegal activities that damage corals.

A bleaching phenomenon occurred in the waters of Weh Island in 2010, which had an impact on the decline in coral cover conditions in the Benteng area. Bleaching is generally caused by anomalous sea surface temperature increases that exceed the tolerance range of coral life and its endosymbionts (zooxanthellae) (Hoogenboom et al 2012). Bleaching or loss of coral tissue is a condition where zooxanthellae are lost in the body of coral polyps, which reduces energy production and color pigment substances and eventually causes corals to become white/transparent (Plass-Johnson et al 2015). Furthermore, Saravanan et al (2017) stated that extreme environmental conditions, such as changes in sea temperature, can cause coral polyps to expel zooxanthellae from their intracellular surface as a stress response, resulting in a whitening appearance. The impact of coral bleaching indicates that the coral is unhealthy and vulnerable to disease. In addition, coral damage can also be caused by climate change (Pratchett et al 2013; Pisapia et al 2019; Eddy et al 2021), abiotic factors (e.g. stress due to increased temperature, sedimentation, toxic chemicals, and nutritional imbalances), and biotic factors (e.g. predation and algae overgrowth). Before conducting the research, the team conducted an initial survey in the waters of Benteng to assess the substrate condition. The survey results showed a significant amount of dead coral covered by turf algae. However, data on the exact coverage of healthy coral in the waters of Benteng, Weh Island is yet to be determined.

Declining of coral health can threaten the availability of food and livelihoods of coastal communities. Over time, coral ecosystems can experience ecological changes such as food web modifications, shifts in community structure, reduced habitat, decreased fertility and recruitment, and changes in fishery productivity (Hoegh-Guldberg et al 2019). It is important to conduct further studies to analyze the condition of the corals in Benteng, Weh Island after experiencing a decrease in substrate caused by bleaching. Moreover, the coral health issues in the waters have yet to be studied. Hence, this study aimed to measure coral conditions and health issues based on the prevalence of coral problem categories in the waters of Benteng, Weh Island, Indonesia, to provide preliminary data to devise updated regulations about coral conservations in the future.

Material and Method

Description of the study sites. The study was conducted from August to October 2021 in the conservation area of Benteng, Weh Island, Sabang City, Indonesia (Figure 1), at 5°50'59.3" N and 95°22'20.5" E. Hard coral data were collected using the Point Intersect Transect (PIT) method (Manuputty & Djuwariah 2009) with a transect length of 50 meters which was placed parallel to the coastline. The site was placed as many as 6 replicas of transects at a depth of 2 to 10 meters. Data of coral health issues were collected using the belt transect method along 50 meters, with the widths of the right and left belts being 2.5 meters (250 m^2). The recording of coral health issues is grouped by genus with the same type of disease/issue found in the observation transects, and then summed up overall. For example, if there is one or more genera in the transect with focal bleaching disease, the calculation is done by combining the affected colonies of the genera to determine the total accumulation of infected colonies.

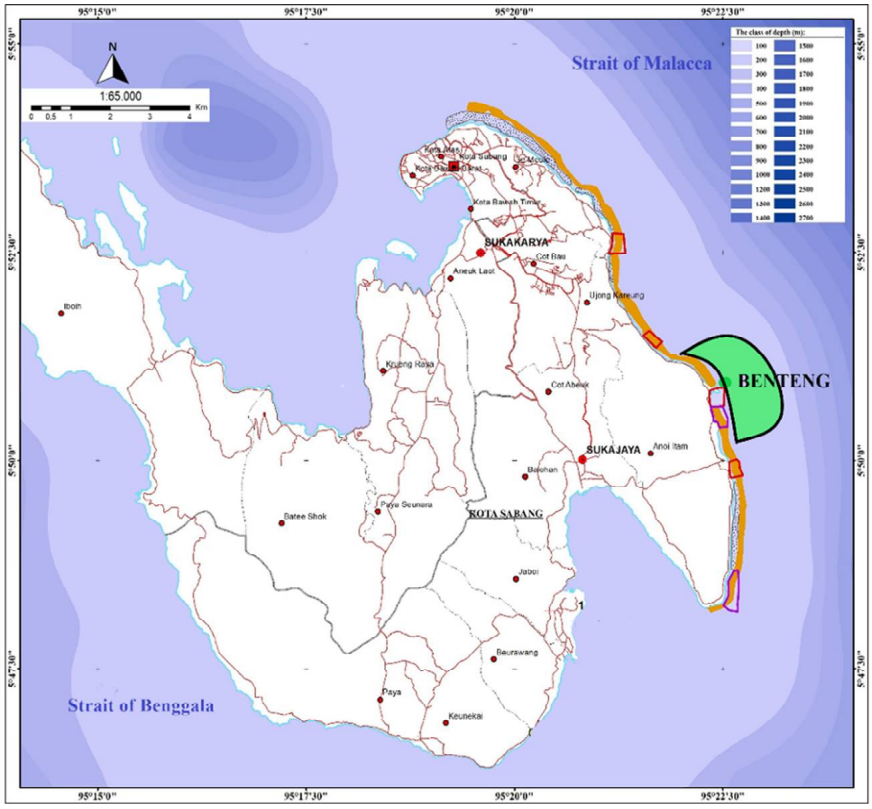

Figure 1. Research location map. The green area is the study site of Benteng, Weh Island, Indonesia.

Data analysis

Coral cover. The percentage of coral cover was determined by dividing the number of points recorded by the total number of points and multiplying the result by one hundred percent (Jokiel et al 2015). The condition of the coral reef ecosystem was evaluated based on the criteria proposed by the Ministry of Environment and Forestry Decree No. 21 of 2001 on the criteria of coral reef damage (Table 1).

Table 1

Criteria of coral reef condition according to the Ministry of Environment and Forestry

Hard coral cover	*Criteria*
HC ≤ 25%	Poor
25% < HC ≤ 50%	Fair
50% < HC ≤ 75%	Good
HC > 75%	Excellent

Coral health issues prevalence. Coral health issues were calculated on each observation transect. Then, coral colonies were summed in groups according to the type of the issues. The prevalence of corals was calculated using the following formula (Al-Hammady & Mohamed 2016):

$$\text{Prevalence (\%)} = \frac{\Sigma \, number \, of \, diseased \, colonies}{\Sigma \, total \, number \, of \, coral \, colonies} \; x \; 100$$

The type of coral health issue was identified in reference to the Coral Disease Handbook (Raymundo et al 2008), the underwater cards for Assessing Coral Health on Indo-Pacific Reefs (Beeden et al 2008), and the database of the Coral Disease and Health Consortium, while the corals were identified in reference to the book of Kelley (2009). Observational data were analyzed descriptively and were displayed in graphs, and photographs.

Results

Coral composition. Based on Table 2, the coral composition in Benteng waters consists of the genera *Gonipora* (0.4%), *Heliopora* (1%), *Millepora* (0.2%), *Montipora* (26%), *Pocillopora* (0.4%), and *Porites* (72%) (see Figure 2). *Porites* and *Montipora* are the genera with the highest percentages compared to other genera. These results are similar to those of the study of Utama & Hadi (2018), which revealed that *Porites* was well-distributed in the eastern waters of Weh Island and became the second most prolific genus after *Montipora*. Before the bleaching phenomenon in 2016, hard corals in the waters of Weh Island had already experienced very severe bleaching that impacted the cover in 2010 (Aldyza et al 2022). According to Guest et al (2016) and Jaroensutasinee et al (2020), besides Indonesian waters, the bleaching also had an impact on the degradation of coral reefs in the waters of Brunei, the Philippines, Singapore, Malaysia, Thailand, and Vietnam. This bleaching caused substrate changes in the waters, which lead to a large percentage of massive corals such as Porites.

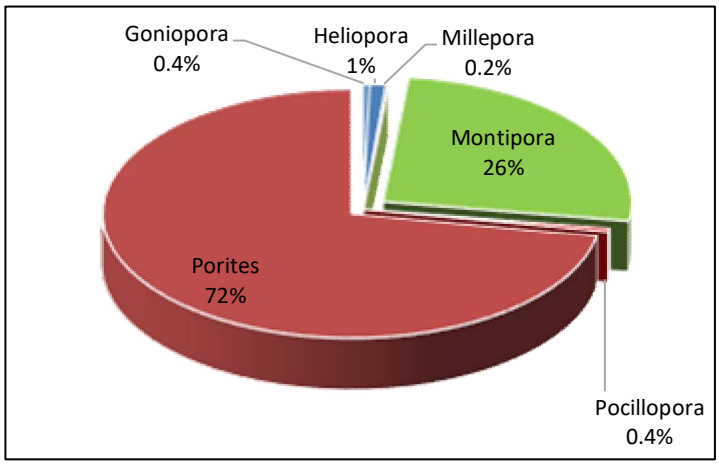

Figure 2. The composition of coral genera in Benteng, Weh Island, Indonesia.

Coral condition. The benthic components in the water conservation area consisted of 20.2% hard coral, 15.5% sand, 16.5% rock, 0.8 rubble, 43% dead coral with turf algae (DCA), and 4% others (e.g ascidians and algae genera *Halimeda* and *Amphiroa*) (Figure 3).

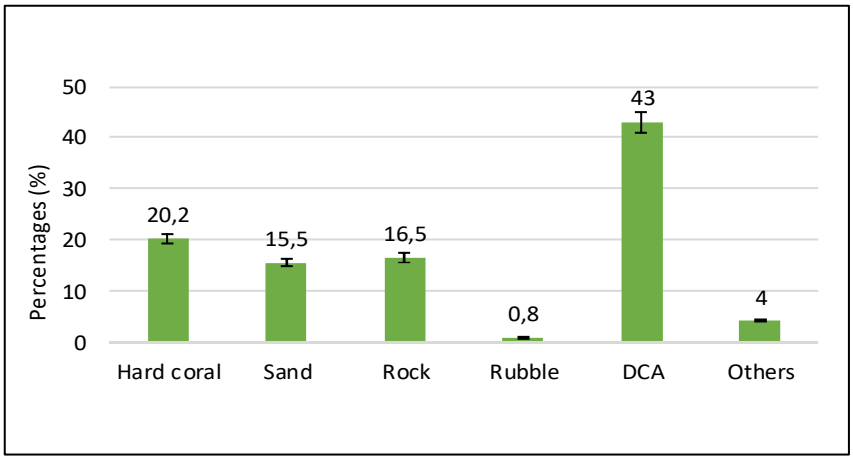

Figure 3. Proportion of benthic components in the waters of Benteng, Weh Island, Sabang, Aceh Province.

Figure 3 shows that the coral cover in the waters of Benteng, Weh Island was in a poor condition (i.e. only 20.7%), DCA exceeding it in value by far (42.7%). This shows that the estabilishment of a conservation zone is not necessarily able to make coral conditions better.

Figure 4 shows that the percentage of coral cover had decreased by 1.5% from 2013 (66.50%) to 2015 (65%). In 2021, the coral cover experienced a drastic decline by 44.8%. The decrease was assumed to be the result of coral bleaching in 2015 to 2016, causing the death of many corals and a change in the hard coral substrate composition.

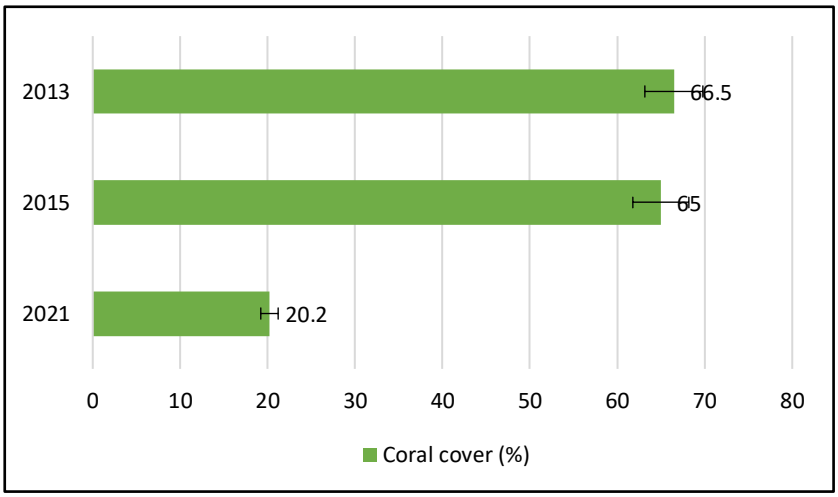

Figure 4. Percentage of coral cover in the waters of Benteng Weh Island, Sabang (data source in 2013 by Hastuty et al (2014), 2015 by Najmi (2016), while the data in 2021 data is the study result).

Prevalence of coral health disorders. The prevalence of coral health issues was calculated based on each type of issues. There were six genera of corals found on transect belts in the waters of Benteng namely *Goniopora*, *Heliopora*, *Millepora*, *Montipora*, *Pocillopora*, and *Porites*. The observational results revealed that the most affected genera by coral health issues were *Porites* and *Montipora*, with 349 and 125 colonies, respectively (Table 2). Based on the results of observations at the sampling locations, the health problems that tend to affect *Montipora* corals are macroalgae growth. This health issue was caused by the presence of macroalgae (seaweed) that grew in the cracks of submassive *Montipora* branching. The abundance of macroalgae sheltered under the corals *Montipora* and *Porites* lead to a competition for both sunlight and oxygen. This is in accordance with the statement of Rasher & Hay (2010) that the abundant existence of macroalgae can result in a decrease in coral fecundity and coral recruitment so that it could minimize the occurrence of a coral recovery process.

Table 2

The total number of coral colonies experiencing health issues

Prevalence	*Goniopora*	*Heliopora*	*Millepora*	*Montipora*	*Pocillopora*	*Porites*
Competition-macroalgae	0	5	1	112	0	78
Competition-sponge	0	0	0	13	0	63
Competition-turf algae	0	0	0	0	1	14
Focal bleaching-patches	0	0	0	0	0	6
Focal bleaching-spots	0	0	0	0	0	5
Pigmentation response	1	0	0	0	0	66
Predation (fish bites)	0	0	0	0	0	29
Sediment damage	0	0	0	0	1	32
Tube formers	1	0	0	0	0	56
Total	2	5	1	125	2	349

Coral health issues. Aggressive macroalgae growth is the most common health issue found in the waters of Benteng, accounting for 40.5%, followed by sponges at 15.7%, and pigmentation response at 13.84%. Macroalgae or seaweed in the waters of Benteng

was found growing abundantly in shallow depths. It also frequently grew in the crevices of porites skeletons that had concave surfaces. According to Rasher & Hay (2010), seaweed could damage corals through allelochemicals. In Figure 5b, articulated red algae that exposed to porites surface caused pink lesions, and it could expand throughout the surface of the colony. This was happened to *Porites*, *Montipora*, *Heliopora* and *Millepora*. In addition to macroalgae, sponge was also found on *Montipora* and *Porites*. It grew and spread on the surface of flat dead coral reefs and spread to healthy corals (Figure 5g).

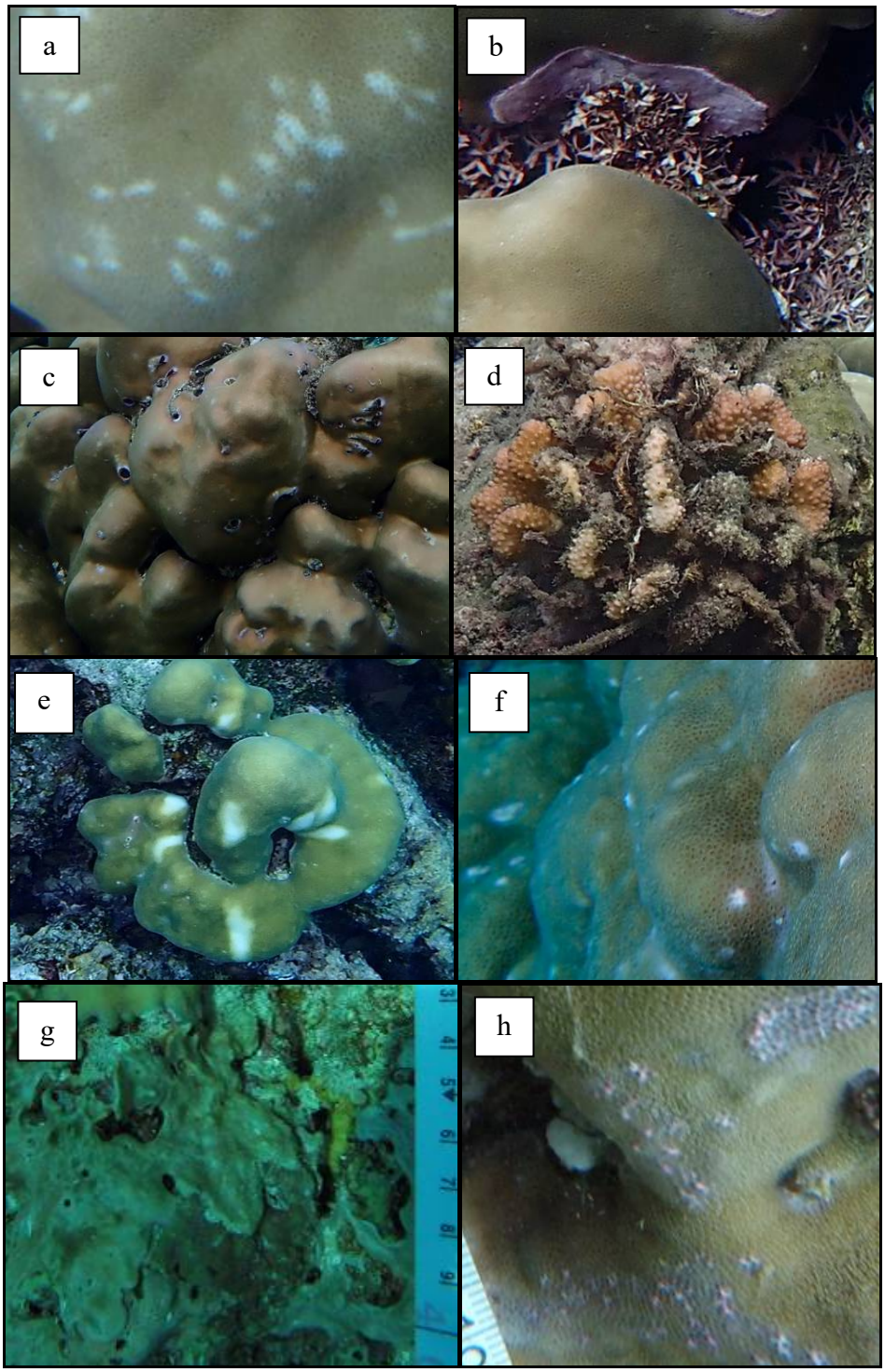

Figure 5. a) Predation (fish bites) on *Porites* sp., b) competition-aggressive overgrowth by articulated red algae on *Porites* sp., c) Tube formers by *Spirobranchus* sp. on *Porites* sp., d) competition-aggressive overgrowth by turf algae and sediment on *Pocillopora* sp., e) focal bleaching on *Porites* sp., f) ulcerative white spots on *Porites* sp., g) competition-aggressive overgrowth by sponges on *Porites* sp., h) pigmentation response on *Porites* sp.

In figure 5d, it can be seen that the combination of turf algae and sediment particles is covering the surface of *Pocillopora*, causing the middle part of the coral to appear white (losing tissue). This indicates that sediment particles attached to the turf algae can also make it difficult for the coral to clean itself, eventually causing the coral to become pale due to the lack of light and nutrients penetration.

Furthermore, focal bleaching was found in *Porites*, which is the phenomenon of loss of randomly scattered coral tissue. There are two types of focal bleaching, namely patches and spots (Figure 5e and f). Focal bleaching is characterized by tissue loss in certain parts and is clearly separated between healthy corals and diseased corals. This is in accordance with the statement of Zakaria et al (2021) that bleaching patches are coral bleaching that is clearly separated from healthy corals without any bands in between. The same thing happens in spot types, but focal bleaching spots are in the form of white spots whose surface is little prominent.

Based on the results that have been presented, the overall total prevalence of diseases that infect and disturb the coral ecosystem in Benteng waters consists of nine types of diseases. These are competition-aggressive overgrowth by macroalgae with a prevalence of 40.5%, competition-aggressive overgrowth by sponges with a prevalence of 15.7%, competition-aggressive overgrowth by turf algae with a prevalence of 3.1%, focal bleaching-patches with a prevalence of 1.24%, focal bleaching-spots with a prevalence of 1.03%, pigmentation response with a prevalence of 13.84%, predation-fish bites with a prevalence of 5.99%, sediment damage with a prevalence of 6.82%, and tube formers with a prevalence of 11.78%. These conditions indicate that the coral ecosystem is in poor condition and it is concerning that the coral condition will worsen in the future.

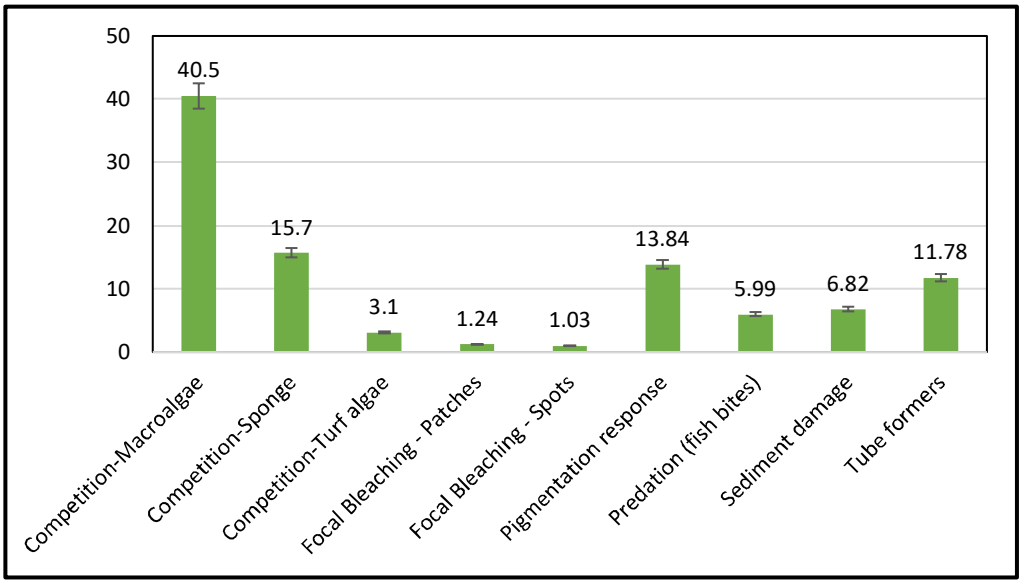

Figure 6. Total prevalence of coral health issues in the waters of the Benteng, Weh Island, Indonesia.

Discussion. Coral reefs ecosystems are easily threatened due to a very narrow temperature range (Rocha et al 2018). Therefore, coral reefs ecosystems need the strong resilience to face environmental pressures. Massive *Porites* corals tend to have a stronger defensive ability against pressure than branching corals such as *Acropora*. This is in accordance with Cantin & Lough (2014) statement that corals derived from different taxon show different susceptibility to temperature pressures. Branched corals are generally more sensitive than massive corals. Dias et al (2018) also suggested that branching corals such as *Acropora* and *Pocillopora* are very sensitive to pressure, so they tend to be more susceptible to bleaching. Furthermore, Darling & Cote (2013) explained that the large and slow-growing corals such as the *Montastraea* and massive *Porites*

species are often tolerant of human disturbance and also less affected in the long term after bleaching.

At the time of observation, very few living corals were found at depths of 2-3 meters due to low water visibility. It probably caused due to stirring water on the beach which carried sand particles trapped inside the water column and the water became murky. A similar case also occurred in the waters in West Aceh, that living corals were not found at a depth of 8 meters due to low water visibility that blocked the entry of sunlight into the waters (Annas et al 2017). This condition could affect coral growth and trigger problems in the process of calcification or skeleton formation.

According to the research from Hastuty et al (2014), the coral ecosystems condition of Benteng Weh Island in 2013 was good (66.50%). *Porites* became the second highest genus after *Montipora*, although *Porites* belongs to corals that are able to withstand the phenomenon of bleaching, but the results showed *Porites* was susceptible to several types of issues. This is similar to the study conducted by Siladharma & Karim (2017), which found that *Porites* tend to experience various types of health disorders and diseases such as sediment damage, pigmentation response, and excessive algae growth.

Furthermore, the pigmentation response was found to be quite high, with a prevalence value of 13.84% that mostly attacked the *Porites*. This is similar to the results of research by Palupi et al (2018), which found that the pigmentation response at the observation site only affected one massive coral from the family Poritidae with a prevalence value of 0.54%. The initial identification of this health problem is the loss of color in coral tissue, which turns pink or purple like dots or spreads. The pink color that appears tends to be lighter than a healthy coral color. This is in accordance with the statement by Luthfi et al (2019) that the pigmentation response is characterized by a change in tissue color that indicates pink or purple.

Cameron & Edmunds (2014) suggest that corallivore fish such as parrotfish have fused jaws that erode the coral surface, damaging tissue and some skeletons. To heal the damage created by corallivore fish, coral tissue must regenerate to fill the void and close the lesions. Based on study results, fish bites was also experienced by *Porites* (Figure 5a). This phenomenon is characterized by whitened bite marks and paired by corallivore parrotfish. However, bite marks caused on the surface of the reef were only in the form of erosion and did not damage the structure of the skeleton.

Sedimentation, which occurs in the coral ecosystems of Benteng waters, is one of the factors that contribute to disrupting coral recovery. Some coral species have the ability to remove sediment through the movement of tentacles found throughout the surface of coral tissue (Aldyza & Afkar 2015). However, the thickness of sediment accumulated on the surface of the colony can also make the tentacles of coral polyps difficult to clear themselves from particles (Jones et al 2019). According to Risk & Edinger (2011), corals are influenced by two conflicting factors. Corals can grow slowly due to increased sediment input, while at the same time they can grow faster in high nutrient conditions that enter the water.

The last health issue was tube formers, that are most commonly found on *Porites* %and also found on *Goniopora*. It was caused by the sea worm *Spirobranchus* sp. associated with corals (Hoeksema et al 2019a). Cases of coral damage by *Spirobranchus* have been recorded in the waters of the Red Sea, which revealed that the operculum on *Spirobranchus* can cause damage to massive corals during the process of the entry and exit of *Spirobranchus* from the tube. The operculum can erode the surface of the coral and cause injury (Hoeksema et al 2018). Tubes that are not overgrown by coral tissue will remain empty or can be covered by algae turf, which is potentially harmful to corals (Hoeksema et al 2019b, 2020).

Coral health issues that occur in coral ecosystems can have a serious impact on coral growth and recovery in the future. Therefore, further studies and monitoring on coral health in Benteng waters conservation need to be carried out regularly, so that the potential for coral resilience in other periods can be identified.

Conclusions. The observations showed that the coral ecosystem in the waters of Benteng Weh Island was in poor condition, i.e. 20.7%. There are 9 types of coral health

issues infected coral ecosystems in the Benteng waters, i.e. macroalgae competition-aggressive overgrowth, sponge competition-aggressive overgrowth, turf algae competition-aggressive overgrowth, focal bleaching-patches, focal beaching-spots, pigmentation response, predation-fish bites, sediment damage, and tube formers. Through research on coral diseases and health disorders, prompt action can be taken to address the coral damage that has occurred. Coral health problems can be addressed through restoration efforts, such as planting coral fragments to fill empty substrates, in the hope of replacing damaged corals. With the collaboration of government, community, and relevant stakeholders in reducing factors that trigger coral diseases, such as climate change, pollution, and human activities that harm marine ecosystems, the health of coral reefs can be improved.

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Conflict of interest. The authors declare that there is no conflict of interest.

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