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CORAL REEF CONDITIONS AT THE SNORKELING SPOTS OF THE KARIMUNJAWA NATIONAL PARK, INDONESIA

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ABSTRACT

Karimunjawa as a marine national park has attracted tourists to come and explore coral reefs. The reefs are under increasing pressure from the development of underwater tourist activities so it is necessary to pay attention to the reef condition to maintain its sustainability. This study was conducted in September 2019 by examining the condition of coral reefs in the most visited snorkeling spots based on information from tour operators, i.e. the Ujung Bintang, Maer and Karang Sendok spots. Data was collected using a 20 m line belt transect to count coral cover and was analyzed using coral morphology triangles to assess the Coral Condition Index (CCI) and Impact Severity Index (ISI). The condition of coral reef cover at the Ujung Bintang and Maer spots were in the "good" category based on the CCI, while at the Karang Sendok spot the corals were in the "bad" category based on the ISI. The three snorkeling spots have competition-adapted (K) morphology, which means that the coral reefs are dominated by non-Acropora corals associated with coral reefs with high waves. The dominant life form at the Ujung Bintang spot was foliose corals, at the Maer spot, it was foliose coral and non-Acropora branching corals, while at the Karang Sendok it was Acropora, which is more vulnerable than foliose and massive corals. The CCI at the three spots was in the "good" category as there are healthy coral colonies, whereas the ISI was in the "poor" category since partially and recently dead coral colonies were found there. The coral colony damage in the spots was dominated by bleached coral colonies and partially dead coral colonies.

Keywords:
Coral Condition Index
Coral morphology triangles
Impact Severity Index

How to Cite

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INTRODUCTION

The type of coral reef in the Karimunjawa National Park is a fringing reef, composed of 182 species of *Scleractinian coral* and 23 species of *Non-Scleractinian coral* that attract tourists for diving activities. In 2019, the Wildlife Conservation Society (WCS), which is one of the partners of the Karimunjawa National Park, carried out Coral Reef Ecosystem Monitoring activities. The survey was conducted at 43 observation points using the PIT (*Point Intercept Transect*) method. Monitoring results show that the percentage of coral reef cover in the Karimunjawa National Park is in the "good" category (average 53.80%), in other words, experienced a significant percentage increase, compared to the percentage of cover in 2016, which was 49.89% (Karimunjawa National Park Hall, 2019). The increase occurred in all zones except the marine utilization zone which is identified as experiencing degradation.

Since Law No. 5 of 1990 was issued by the Indonesian Government, the Karimunjawa National Park has been widely used for tourism, education, research and training activities. The high biodiversity makes this area an ideal natural laboratory for the development of science in Central Java. The Karimunjawa National Park is designated as one of the leading tourist destinations in Central Java; even nationally this area is designated as a major national tourist destination in Indonesia.

Based on the Karimunjawa National Park Hall (2018), the number of tourist visits in Karimunjawa increased from 70.940 people in 2013 to 77.056 people in 2017. The main objective of tourists in the area is to enjoy the beauty of coral reefs all over the islands. For that reason, this area has attracted tourists to come for diving and snorkeling. The increase in the number of tourist visits can contribute to the economic growth of this area, but on the other hand, it has the potential to damage the coral ecosystem. Fudjaja et al. (2020) stated that disorders and damage to coral ecosystems can be caused by factors that are both natural and human activity. Natural causes of damage to coral ecosystems include hurricanes, tsunamis, climate change and natural enemies. Several factors that are caused by human activities include destructive fishing activities, coral mining and the exploitation of construction materials, lime production, tourism and development in coastal areas without ecological wisdom.

Coral reefs play essential economic and ecological functions (Meinita, 2007; Hadi et al., 2019). People can utilize ecological goods and services to make a living from the coral reef ecosystem such as coastal protection, flood control and recreation (Costanza et al., 2014). However, human activities have heavily impacted the biological diversity and productivity of coral reefs worldwide (Burke et al., 2011). So, coral reefs are declining rapidly across the globe because of anthropogenic activities such as pollution, overfishing and physical destruction, as well as changes in ocean temperature, reducing the distribution, abundance and survival of entire coral reef ecosystems (Gattuso et al., 2014; Hoegh-Guldberg et al., 2014). Air pollution, floods, droughts and water pollution are just a few examples of extreme events. These events occur as a result of physical processes and social activities.

Thompson et al. (2014) found that coinciding with these extreme conditions, particularly during the transition of river discharge, there is a high prevalence of coral disease and a reduction in the abundance of juvenile coral, and a shift in community composition. Relatively low environmental stress can cause coral recruitment of more tolerant species. However, in extreme conditions, this recruitment process may not occur as it is caused by a higher level of environmental stress. This indicates that continuing damage to coral reefs will hamper the process of coral recovery due to the decrease in environmental quality.

Coral reef-dependent tourism goes beyond the well-known suite of in-water activities (Spalding et al., 2017). Marine tourism development has also contributed to reef degradation, which can be permanent. The impact of underwater tourist activities on coral reefs has been documented. Keshavmurthy et al. (2019) review coral resilience in the Kenting National Park, Taiwan, and call for conservation efforts that use resilience-based management programs to reduce local stresses. Coral reef damage can be caused by fin kicks, pushing or holding coral, dragging gear, and kneeling/standing on coral.

In order to implement coral reef conservation efforts in the Karimunjawa National Park, park managers need to map potential areas, especially those suitable for tourism development. In addition to these efforts, information on reef damage related to marine tourism development needs to be identified in anticipation of more damage precautions, as well as water quality indicators such as water temperature, salinity and total suspended solids (TSS). This information could be useful for the development of sustainable tourism in Karimunjawa. The research aims to examine potential damage to coral reefs in the tourist snorkeling areas of the park in order to assess the condition of coral reefs. The assessment of coral reef conditions is important for the management and conservation of coral reefs in Karimunjawa as a marine protected area.

MATERIALS AND METHODS

Research methods

Sampling was conducted at the frequently visited snorkeling spots at the utilization zone of the Karimunjawa National Park, as a decree of Ditjen PHKA No. SK.28/IV/Set-3/2012, i.e. the Ujung Bintang and Maer spots located off Menjangan Kecil Island, and Karang Sendok spot located off Menjangan Besar Island (Figure 1). The survey was conducted in September 2019.

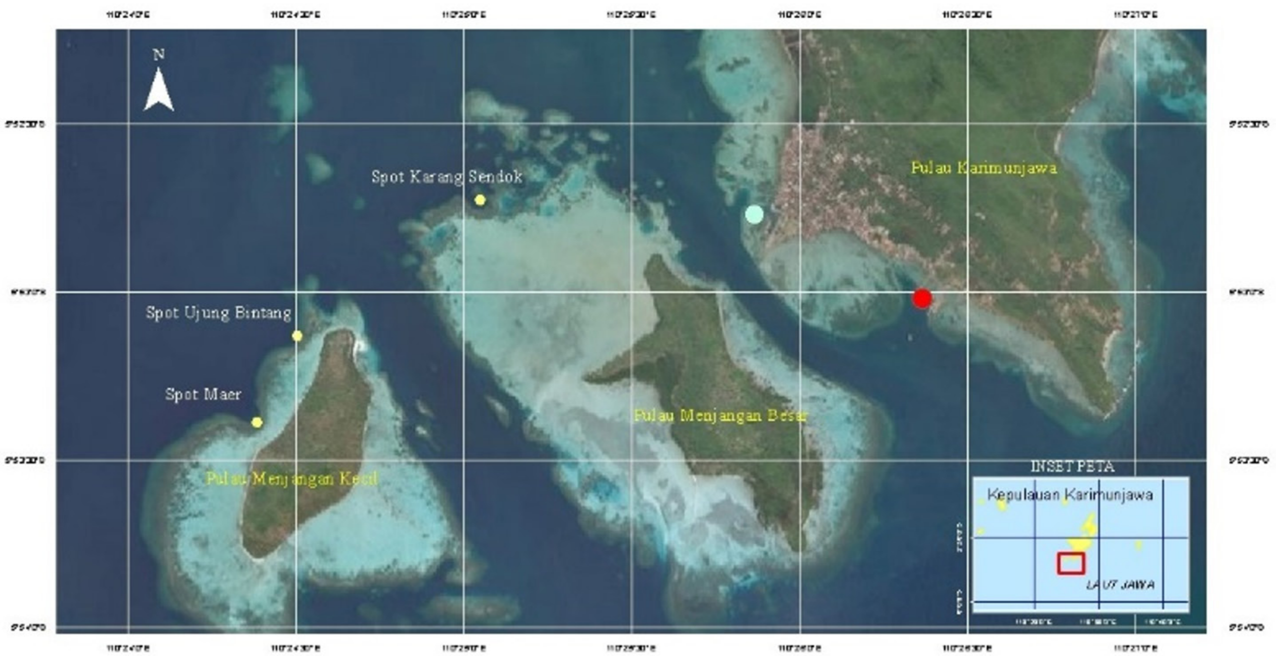

Fig 1. Sampling location

Data were collected by SCUBA diving using a 20 m line transect at a depth of 9, 6 and 3 m at the snorkeling spots to observe the coral life form (Table 1), count coral cover and classify the reef conservation class according to the ternary diagram of competitors–stress tolerator-ruderal. A 20 x 1 m belt transect methods were also used to analyze the Coral Condition Index (CCI) and Impact Severity Index (ISI).

Percentage of coral covers of English et al. (1997) formula:

$$r_x\% = L_x / T * 100$$

where r %: coral cover; L: length within transect; T: transect length; X: category of benthic substrate. Evaluation of coral reefs by linear scale of coral covers (Zamani and Madduppa, 2011): 75% - 100%: excellent; 74.9% - 50%: good; 49.9% - 25%: average; 24.9% - 0%: bad.

Coral morphology triangles

The observation of coral morphology triangles using the line transect method is analyzed by classifying coral morphology into Ruderal (r), Competitors (K) and Stress Tolerator (S) (Table 2).

The classification used in the r-K-S ternary diagram (Figure 2) is as follows: Acropora is categorized as ruderal (r) because it grows fast but is breakable, non-Acropora with a life form of branching or foliose is categorized as competition-adapted (K) because of its slow growth, and it is dominant in Indonesian reefs in a high-wave area (Edinger and Risk, 2000; Pardede, et al., 2016). Massive and sub-massive coral which is more tolerant to sedimentation or eutrophication is classified as stress tolerators (S) (Edinger and Risk, 2000). In Conservation Class (CC) 1, the percentage of coral stress tolerator is ≥60%, CC 2 for the coral competitor (K) and CC 3 for

Table 1. Category of benthic substrate

Benthic category	Code
Acropora	
Branching	ACB
Tabulate	ACT
Encrusting	ACE
Submissive	ACS
Digitate	ACD
non-Acropora	
Branching	CB
Massive	CM
Encrusting	CE
Submissive	CS
Foliose	CF
Mushroom	CMR
Millepora	CME
Heliopora	CHL
Dead Scleractinia	
Dead Coral	DC
(With Algal Covering)	DCA
Abiotic	
Sand	S
Rubble	R

Source: English et al. (1997)

Table 2. Coral morphology with the classification of r-K-S

Factor	Conservation class	Morphology	r-K-S group
Ruderal (r)	CC 3	Acropora, Tabulate (non-Acropora), Heliopora, Millepora	≥50%
Competitors (K)	CC 2	non-Acropora (Branching, Plate, Foliose, Encrusting, free-living)	≥50%
Stress tolerator (S)	CC 1	Massive, sub-massive	≥60%

Source: Kamarumthan et al. (2016)

coral ruderal (r), both have living coral dominance ≥50%; whereas if there is no life form in group r-K-S as described, then it is classified as CC 4, a mix life form (Edinger and Risk 2000; Kamarumthan et al., 2016).

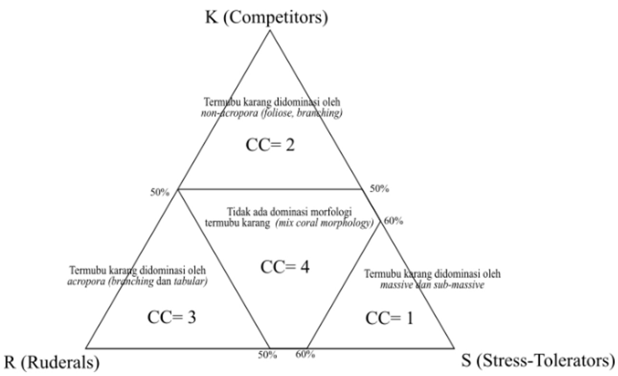

Fig 2. r-K-S coral reef ternary diagram (Edinger and Risk, 2000)

The Coral Condition Index and Impact Severity Index

The method of the Coral Condition Index (CCI) divided coral damage based on the recovery rate, while the Impact Severity Index (ISI) divided coral damage based on the destruction level (Lasagna et al., 2014), as seen in Table 3. A new category is needed to describe possible damage that was mostly found in the tourist area, i.e. the partially dead coral (PDC) category. Many partially dead corals may represent a high distress condition of healthy coral and also illustrate a dynamic changing process in reefs (Dikou and van Woesik, 2006). The CCI and ISI were counted based on the formula of Lasagna et al. (2014).

CCI category: 0.76 – 1: excellent; 0.51 – 0.75: good; 0.26 – 0.50: average; 0 – 0.25: bad

ISI category: 0.76 – 1: very bad; 0.51 – 0.75: average; 0.26 – 0.50: good; 0 – 0.25: excellent

Water quality

Water quality indicators that are measured in the snorkeling spots at the utilization zone of the Karimunjawa National Park include TSS, water clarity, temperature and salinity. All of the variables were measured at the three research stations before and after snorkeling activities at the depth of 9 m, 6 m and 3 m.

Table 3. Evaluation of coral damage category

No	Coral damage category	Code	Explanation
1	Healthy Coral Colonies	HCC	Living coral colonies without any apparent sign of damage
2	Broken Coral Colonies	BCC	Living coral colonies in growth position, but physical-ly fragmented, cracked or broken
3	Upturned Coral Colonies	UPC	Living coral colonies, but broken at the base and lying on a side on the substrate
4	Smothered Coral Colonies	SILC	Living coral colonies with sand or silt deposit on ex-posed surfaces
5	Bleached Coral Colonies	BC	Living coral colonies with transparent tissue due to loss or severe reduction of zooxanthellae
6	Partially Dead Coral Colonies	PDC	Partially dead coral colonies are partially dead coral colonies covered by algae filaments
7	Recently Dead Coral Colonies	RDC	Recently dead coral colonies are dead coral colonies with skeleton exposed and appearing dirty white or covered by a film of sediment and/or algae filaments
8	Total Coral Colonies	TCC	The sum of the healthy and damaged coral colonies
9	Damage Coral Colonies	DCC	The sum of damaged coral colonies (BCC, UPC, SILC, BC, PDC. RDC)

Source: Modified from Lasagna et al.(2014)

RESULTS

Coral cover

The condition of coral cover in the Ujung Bintang and Maer spots, which are in the “good” category, is 52.83% and 66.17%, respectively, while in the Karang Sendok spot it is 48%, which is in the “average” category (Figure 3).

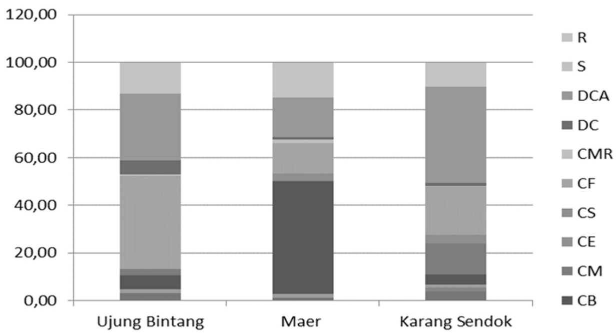

Fig 3. Life form of the reefs in each station

As shown in Figure 3, the average coral life form in the Ujung Bintang spot is dominated by non-Acropora, with 39% of foliose form. At 9 m depth it was 47%, at 6 m depth it was 48%, and at 3 m depth it was 22%. Rubble is mostly found at 9 m depth (24%), the lowest coral cover was at 3 m depth with dead Scleractinia at 52.8%, dead coral (DC) at 18% and dead coral alga (DCA) at 34.7%. The average coral life form in the Maer spot was dominated by non-Acropora, with 47.33% of branching form. At 9 m depth it was 77.5%, at 6 m depth it was 29.5%, and at 3 m depth it was 35%. Rubble is mostly found at 6 m depth (26%), the lowest coral cover was at 3 m depth with 29.5% of dead coral alga (DCA). The average coral life form inter depth in the Karang Sendok spot is dominated by non-Acropora with 20% of foliose form. At 9 m depth it was 17.5%, at 6 m depth it was 17.5%, and at 3 m depth it was 25%. Rubble is mostly found at 6 m depth (14.5%), the lowest coral cover was at 9 m depth (49%) with 2% of dead coral (DC) and 47% of dead coral alga (DCA).

The score of the conservation class

Scoring of conservation class presented in Figure 4 showed that the Ujung Bintang and Maer spots have (K) a high value with conservation class “CC 2”, where the Ujung Bintang spot is dominated by foliose coral and the Maer spot is dominated by non-Acropora branching and foliose coral, whereas the Karang Sendok spot although also in “CC 2” was close to “CC 4” because of the domination of foliose and massive coral.

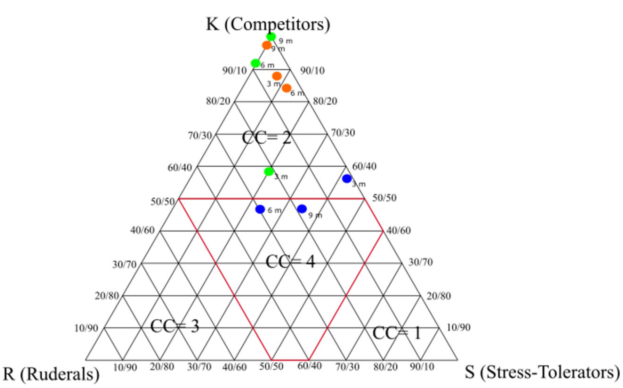

Fig 4. Ternary diagram of conservation coral reefs in each station. Noted: Ujung Bintang spot (green), Maer spot (red), Karang Sendok spot (blue)

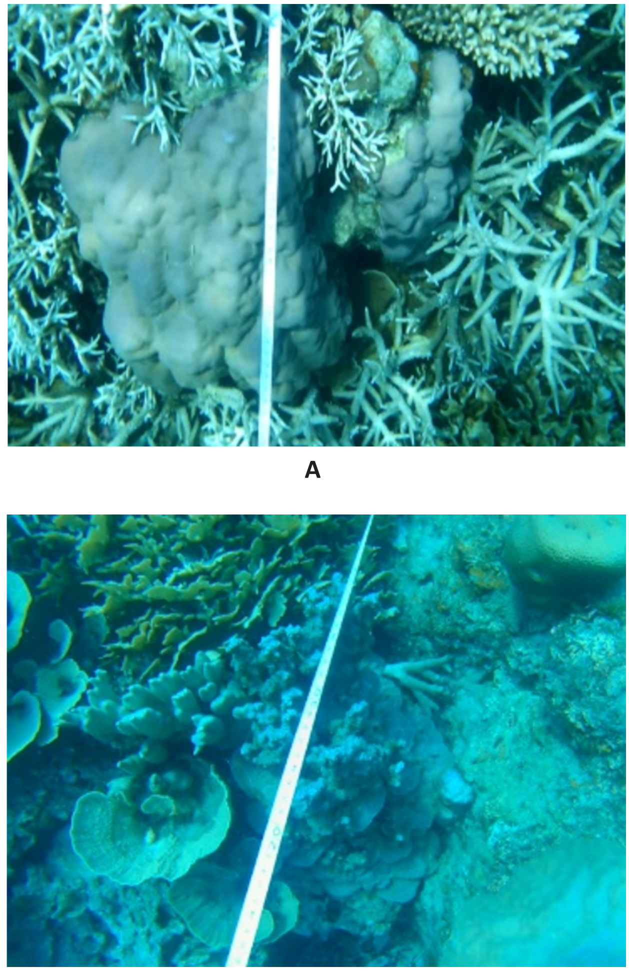

Fig 5. A. Non-Acropora as competition-adapted (K) Foliose-Branching-Encrusting rubble; B. Massive coral as stress tolerator (S) live around Acropora bleaching

The Coral Condition Index (CCI) and Impact Severity Index (ISI)

The average coral colony damage in the Ujung Bintang spot was 53.40%, at 9 m depth it was 47%, at 6 m depth it was 53% and at 3 m depth it was 57%. The average coral colony damage in the Maer spot was 53.06%, at 9 m depth it was 55%, at 6 m depth it was 43.33% and at 3 m depth it was 6.14%. The average coral colony damage in the Karang Sendok spot was 71.70%, at 9 m depth it was 72.15%, at 6 m depth it was 68% and at 3 m depth it was 75.58%. The Coral Condition Index (CCI) value in three snorkeling spots ranges from 0.51 to 0.68 with a recovery rate of the damaged coral colony in the “good” category, while the Impact Severity Index (ISI) value has a score of 0.81 to 0.78 with the level of coral colony damage in the “bad” category (Table 4 and Table 5).

Table 4. Coral Condition Index (CCI) value in each station

Ujung Bintang		**Maer**		**Karang Sendok**	
Healthy Coral Colonies	185	Healthy Coral Colonies	161	Healthy Coral Colonies	75
Broken Coral Colonies	1	Broken Coral Colonies	2	Broken Coral Colonies	6
Upturned Coral Colonies	0	Upturned Coral Colonies	0	Upturned Coral Colonies	0
Smothered Coral Colonies	0	Smothered Coral Colonies	0	Smothered Coral Colonies	0
Bleached Coral Colonies	119	Bleached Coral Colonies	67	Bleached Coral Colonies	49
Partially Dead Coral Colonies	33	Partially Dead Coral Colonies	83	Partially Dead Coral Colonies	87
Total Coral Colonies	338	Total Coral Colonies	313	Total Coral Colonies	217
Coral Condition Index	0,68	Coral Condition Index	0,64	Coral Condition Index	0,51
Category	**Good**	Category	**Good**	Category	**Good**

Table 5. Impact Severity Index (ISI) value in each station

Ujung Bintang		**Maer**		**Karang Sendok**	
Recently Dead Cor-al Colonies	59	Recently Dead Coral Colonies	30	Recently Dead Coral Colonies	48
Partially Dead Coral Colonies	33	Partially Dead Coral Colonies	83	Partially Dead Cor-al Colonies	87
Bleached Coral Colonies	119	Bleached Coral Colonies	67	Bleached Coral Colonies	49
Smothered Coral Colonies	0	Smothered Coral Colonies	0	Smothered Coral Colonies	0
Upturned Coral Colonies	0	Upturned Coral Colonies	0	Upturned Coral Colonies	0
Broken Coral Colo-nies	1	Broken Coral Col-onies	2	Broken Coral Col-onies	6
Damage Coral Col-onies	212	Damage Coral Colonies	182	Damage Coral Col-onies	190
Impact Severity Index	0.78	Impact Severity Index	0.79	Impact Severity Index	0.81
Category	**Bad**	Category	**Bad**	Category	**Bad**

Water quality

Water quality in the three research stations of Ujung Bintang, Maer and Karang Sendok were relatively similar. The temperature was around 27.8-28.1 °C at the depth of 9 m, 28.02-28.3 °C at the depth of 6 m, and 28.5-28.8 °C at the depth of 3 m. The different temperature at the depth of 3 m and 9 m was relatively low (0.3-0.7 °C). Salinity in the three research stations was relatively stable, between 32.5 and 32.8‰, whereas water clarity in Karang Maer was around 8.2-9.4 m, respectively better than in Karang Sendok, which was around 7.2-7.6 m, and in Ujung Bintang, which was around 6.6-7.3 m. The three variables were relatively similar before and after snorkeling. Meanwhile, the TSS level showed differences across stations and times of snorkeling, as indicated in the following figure.

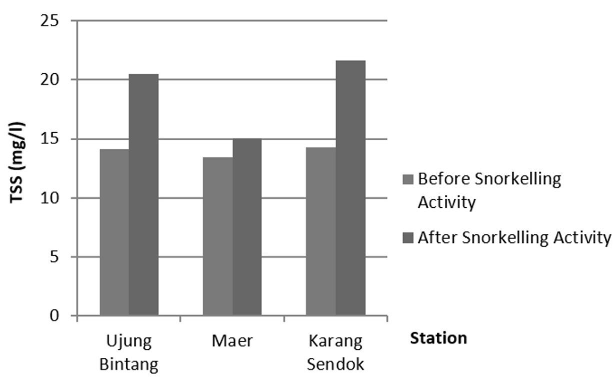

Fig 6. Value of TSS (mg/l) at the three locations, before and after snorkeling

The analysis of TSS value showed that snorkeling tends to increase the TSS value in the coral reef ecosystem. The average of TSS was increased by 6.33 mg/l at Ujung Bintang, by 2 mg/l at Maer and by 7.38 mg/l at Karang Sendok. ANOVA statistical test using two directions indicated the difference between stations and snorkeling times (α<0.05). TSS value at the Maer station was relatively lower than at Ujung Bintang and Karang Sendok, while the snorkeling time was higher after snorkeling than before snorkeling.

DISCUSSION

Karimunjawa waters experienced east and west monsoons, which are influenced by currents from the West to the East (west monsoon) that are characterized by high waves and heavy rainfall; on the other hand, the east monsoon has short waves and low rainfall (Yusuf et al., 2012). On a regional basis, the oceanographic conditions of all islands in the Karimunjawa archipelago were about the same, including Menjangan Kecil and Menjangan Besar as the research sites.

Menjangan Kecil Island has two snorkeling spots, Ujung Bintang on the southwest side and Maer on the west side, whereas the Karang Sendok spot is located on the southwest of Menjangan Besar Island. These three spots have windward reefs that are affected by west monsoons. The spots have rubble benthic substrate with coral morphology characterized by competition-adapted (K) included in conservation class “CC 2”, which is dominated by non-Acropora branching coral as well as foliose coral. However, the Karang Sendok spot is close to “CC 4” because it has 14.24% of ruderal (r) due to being protected from the waves and is vulnerable to tourist activities compared to other spots.

Dominant coral morphology in the three spots was non-Acropora, characteristic of the area with high waves (Edinger and Risk, 2000; Pardede et al., 2016). The waves become a mechanical factor that limits the colony size; when a branching coral grows bigger, it is more easily damaged by wave action because the coral branch cannot withstand the wave due to reef structures being unstable to hold the load of branching. The broken coral fragment could survive and grow into large colonies, while massive life form coral colonies are stronger to hold back the waves. Various human activities also put pressure on environmental conditions that result in coral reef damage. Human densities of more than 16 people per square kilometer have caused many species and individuals to become extinct because of the pollution caused by tourism (Bellwood et al., 2012). Tourists usually bring supplies whose waste may be harmful to the reef ecosystem. The study conducted by Bellwood et al. (2012) also found that human population density is a dominant factor in explaining reef fish loss and erosion of ecosystem function. It is well documented that after a major disturbance on coral reefs, the number of coral reef fish declines as well as the number of herbivorous fish in the long term. The reduction in the number of herbivorous fish is thought to have the greatest impact on ecosystem functioning.

Abrar et al. (2011) found that coral reefs have the resilience to environmental pressures and try to adapt, resist and be tolerant and stable, showing signs of recovery by the formation of a stable community after damage. However, the reliance of an ecosystem function on a limited or distinct group of species is likely to increase susceptibility to future disturbances.

The three spots have the Coral Condition Index in the “good” category and the Impact Severity Index in the “bad” category. The number of healthy coral colonies increases the value of the Coral Condition Index, while a high number of Partially Dead Coral Colonies and Recently Dead Coral make the value of the Impact Severity Index in the “bad” category. The highest number of Partially Dead Coral Colonies is found in the Karang Sendok spot, while bleach Coral Colonies mostly occur in the Ujung Bintang spot. This happens because of water temperature change and sun radiation (UV light), salinity drop, bacterial and virus activities (Welle et al., 2017).

Seasonal changes in temperature and light are the main drivers of seasonal variation in coral pigmentation. The combined effect of temperature and light has also been recognized as the main trigger of severe losses in coral pigmentation, known as coral bleaching, which commonly involves large symbiont declines and minimal loss of pigment per symbiont. Most reefs were exposed to several thermal stress events that caused bleaching over a 28-year period (at 4 °C above average temperatures). Globally, coral reefs were exposed to bleaching stress levels of 4.6 ± 3.4 times during this period. Just over 4% of reefs globally were exposed to mortality-level thermal stress events more than twice per decade. The Middle East and Atlantic regions had the highest proportions of reefs with frequent exposure to severe thermal stress (23% and 12%, respectively) (Heron et al., 2016). In the dry season, the wind velocity is low, with no waves and no turbidity so increased sunlight that penetrates waters can cause coral bleaching in the west monsoon; bleaching occurs due to the salinity drop.

Partially Dead Coral Colonies mostly happen on Scleractinian. Some factors that affect the death of coral are associated with morphology, such as depth, size and shape of the colonies; as well as ecology such as alien species from different areas. The external factors that could affect the death of coral colonies include hurricanes, temperature, predation, competition, disease and anthropogenic pressure (Dikou and van Woesik, 2006). Partially Dead Coral also deals with life dynamics of coral, such as colonies reduction, energy to grow and reproduction. The survival colonies could split (fission/fragmentation) and may be able to create new coral reefs capable to persist during quaternary climatic oscillations (Pandolfi and Jackson, 2006), but the recent increase in scale and frequency of disturbances has resulted in extensive ‘phase shifts’, i.e. changes in community structure and composition (Montefalcone et al., 2011; Mumby et al., 2013), which makes their potential to recovery unlikely (Dudgeon et al., 2010).

In most cases, coral death is caused by high levels of TSS which come from outside of the ecosystem. According to Riska et al. (2019), increased sedimentation causes coral reef degradation in one region, sediment particles that cover coral organisms and reduce the light needed for the photosynthesis process. *Porites* sp. experiences damage due to the accumulation of sediment on the surface of the coral body. Generally, sediment buildup occurs in water areas with currents, and water circulation is not too heavy so that the sedimentary particles cannot be cleaned from the coral body. Sediment that covers coral for a long time can kill corals. If the sediment continues to thicken, then light penetration required by zooxanthellae for photosynthesis is inhibited. Sediment damage is caused by high TSS concentrations, so the sediment covers many coral reefs and corals are stressed by coral polyps covered by the sediment. The adaptation of coral reefs to the sediments that cover them leads to reduced immunity of coral reefs because they secrete too much mucus.

In addition, the effects of sedimentation on the coral reef are a major factor resulting in the death of corals during the recruitment process through the mechanism of smothering. Therefore, it can be concluded that the increase of TSS can impede coral growth and lead to coral death in large quantities (Hanafy, 2012).

According to the Decree of the Minister for Environment No. 04 /2001, the increasing TSS value from 2 to 7.38 and the highest level of 21.64 mg/l can be from moderate to high for the coral reef ecosystem. Nevertheless, the activity done intensively over a long time and in the wider areas enables to elevate TSS values, as in the three locations of this research. The study by Siladharma and Karim (2017) reveals that ulcerative white spot (UWS) was the only disease affecting massive *Porites* colonies at the Selini Beach, Pemuteran village, North Bali Island. This disease has also been documented in fringing reefs of Panjang Island in the Jepara, Central Java (Pamungkas et al., 2014), coral reefs in southeast India (Thinnes et al., 2011) and east Nusa Tenggara (Abrar et al., 2012). Regarding the presence of UWS disease in corals in the coral reefs of Panjang Island waters, Pamungkas et al. (2014) stated it was a result of poor environmental conditions and pressure from tourism. The positive relationship between UWS prevalence and TSS suggests that a high level of TSS could intensify the virulence of this disease. A previous study by Pollock et al. (2014) and Miller et al. (2016) also demonstrated that increased turbidity due to a high level of TSS significantly elevated the coral disease and compromised health prevalences. The high amount of TSS in the seawater column reduces the light intensity which is needed for coral photosynthetic endosymbiont. Consequently, it may diminish the supply of energy from the photosynthetic algae for the coral as the host. Also, the accumulated TSS on the coral surface may provide suitable media for opportunistic microorganisms to grow (Riska et al., 2019). In order to remove the deposited TSS, coral secretes mucus on its surface. This mucus secretion consumes a significant amount of energy that could be invested for growth, defence and reproduction.

Based on the research, snorkeling has a significant effect on coral damage. This damage could also have an impact on coral communities. The potential damage of the three snorkeling spots is quite large and increases in line with an increasing number of snorkelers and their behaviors. As Camp and Fraser (2012) observed, most divers in Florida have physical interaction with the reef during their dive in the initial part of the dive. However, there are several things that corals in this area may be able to recover from. According to Hidayani and Sariah (2017), damaged coral reefs have the potential to recover. Furthermore, it was stated that the ability of coral reef recovery is the ability of an individual colony or a coral reef system, including all its inhabitants, to defend themselves from environmental impacts and maintain the ability to recover and develop. Suryatini and Rai (2020) mention that coral reef communities that survive disturbance, reorganize new coral reef communities in the recovery phase. Furthermore, it was stated that this process takes place depending on the ecological memory of the coral reef ecosystem which is the composition and distribution of organisms. as well as interactions in space and time, including experience (life history) with the environment. Naturally, the response of coral reefs to environmental changes and pressures is to try to survive and show symptoms of recovery until a stable community is formed after being damaged (Hidayani and Sariah, 2017). This is also indicated by the CCI index which is still classified as “good” (>0.5). What needs to be done is to carry out continuous monitoring of the potential for damage, and the recruitment and growth of broken corals. In addition, management needs to be carried out to accelerate recovery based on conservation class status, namely carrying out coral transplantation based on conservation class suitability at each research location. Conservation priorities need to be prioritized at locations with relatively low coral cover, namely the Karang Sendok (48%) and Ujung Bintang reefs (52.83%).

In conclusion, the condition of coral cover in the Karimunjawa snorkeling spots was categorized as “good” in the Ujung Bintang and Maer spots, while in the Karang Sendok spot it was “average”. The three spots have coral morphology of competition-adapted dominated by non-Acropora branching and foliose coral, which is characteristic of reefs with high waves. The Coral Condition Index was in the “good” category, whereas the Impact Severity Index was in the “bad” category since many partial dead corals were found in the Karang Sendok spot. In addition, coral bleaching was mostly found in the Ujung Bintang spot. Snorkeling could also decrease water quality, especially by increasing TSS value that induces coral damage.

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UVJETI KORALJNOG GREBENA ZA RONJENJE NACIONALNOG PARKA KARIMUNJAWA, INDONEZIJA

SAŽETAK

Nacionalni park Karimunjawa privlači turiste da dođu i istraže koraljne grebene. Grebeni su pod sve većim pritiskom razvoja aktivnosti podvodnog turizma pa je potrebno paziti na stanje grebena kako bi se očuvala njihova održivost. Ovo istraživanje provedeno je u rujnu 2019. ispitujući stanje koraljnih grebena na najposjećenijim mjestima za ronjenje na dah (mjesta Ujung Bintang, Maer i Karang Sendok) na temelju informacija turističkih vodića. Podaci su prikupljeni pomoću linijskih pojasnih transekata od 20 m za brojanje koraljnog pokrova i analizirani su korištenjem trokuta morfologije koralja za procjenu indeksa kondicije koralja (CCI) i indeksa ugroženosti (ISI). Stanje pokrova koraljnih grebena na mjestima Ujung Bintang i Maer bilo je u kategoriji “dobro” na temelju CCI, dok su na mjestu Karang Sendok koralji bili u kategoriji “loše” prema ISI. Tri mjesta za ronjenje imaju kompetitivno prilagođenu (K) morfologiju, što znači da koraljnim grebenima dominiraju koralji koji nisu Acropora, a koji su povezani s područjima koraljnih grebena s velikim valovima. Dominantni organizmi na mjestu Ujung Bintang bili su folijski koralji; na mjestu Maer to su bili lisnati koralji i razgranati koralji koji nisu Acropora, dok je na Karang Sendoku to bila Acropora koja je ranjivija od folioznih i masivnih koralja. Na tri mjesta CCI je bio u kategoriji “dobro” jer se tamo nalaze zdrave kolonije koralja; dok je ISI bio u “lošoj” kategoriji jer su tu pronađene djelomično I recentno umrle mrtve kolonije koralja. Oštećenim kolonijama koralja u mjestima dominirali su izbijeljene kolonije koralja i djelomično mrtvekolonije koralja.

Ključne riječi: indeks konicije koralja, koraljni trokut, indeks ozbiljnosti utjecaja

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