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THE DIVERSITY OF STONY CORAL AND THE TENDENCY TO BLEACH BASED ON LIFEFORM IN THE TENGAH PATCH-REEF OF KARIMUNJAWA ISLANDS

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ABSTRACT

Coral reefs, the habitat of tens of thousands of marine species, are an ecosystem with the highest biodiversity. Several threats, however, have impaired coral reefs. One having a potentially catastrophic effect is the increasing temperature of the ocean that leads to a coral bleaching event. This study aimed to determine the diversity of stony coral based on their lifeform, to assess the condition of reefs by measuring percent cover of live coral, and to determine the bleaching occurrence based on the stony coral lifeform in the Tengah patch-reef of Karimunjawa National (Marine) Park. The research was a visual survey with line intercept transects (LIT) used to collect data. The data were presented as percent cover of living coral and their lifeforms. The result showed the diversity of coral in the Tengah patch-reef was very high as indicated by the presence of all coral lifeforms in the study site. The most diverse lifeform was found at 10 m depth with 13 lifeforms, while the lowest lifeform was found at 3 m depth with ten lifeforms. The most extensive live coral cover was found at 3 m depth estimated around 73.71%, and the the lowest coverage was found at 10 m depth, no more than 50.42%. The bleaching event was found in *Acropora* branching and *Acropora* digitate at the 3 m depth.

Key Words: Karimunjawa, *coral reef*, *lifeform*, *bleaching*

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INTRODUCTION

The coral reef is a typical tropical coastal ecosystem with net primary production reaching 2,500–11,680 gCm^{-2}year^{-1} from 1962 to 1977 (Gordon & Kelly, 1962; Stoddart, 1969; Kohn & Helfrich, 1957; Nair & Pillai, 1972; Lewis, 1977). Light intensity, salinity, and temperature are environmental factors influence stony coral growth rate. The minimum light intensity for coral growth is 450 μmol photons m^{-2}s^{-1} (Guan *et al.*, 2015). The coral endosymbiont living in coral tissue requires light to continuously supply nutrients for its host (Muscatine & Cernichiari, 1969). Salinity is another limiting factor for hermatypic coral, which can withstand only in water salinity of 28.7–40.4 psu (Guan *et al.*, 2015). Coral can grow optimally in water temperature of 30–31°C (Helfinalis, 1998; Ramli, 2003) but tolerate water temperature of 21.7–29.6°C (Guan *et al.*, 2015). Coral exposure to water temperature rise by 0.74°C is reported to cause bleaching.

The bleaching event is the loss of the symbiotic algae or its pigment as a response of tropical stony coral, Cnidaria, and some mollusks to various environmental stresses (Westmacott *et al.*, 2000; Fitt *et al.*, 2001). Bleaching is commonly caused by anomalies of sea surface temperature rise that exceeds the temperature tolerance of coral and its endosymbionts, the dinoflagellates *Symbiodinium* known as zooxanthellae (Hoogenboom *et al.*, 2012). In some corals, bleaching can stop tissue growth, skeleton formation, and inhibit sexual reproduction. The coral can survive if the exposure to temperature rise is brief, but lethal if the susceptibility is prolonged (Rani, 2001). Each coral lifeform has a different response to temperature rise. *Acropora* is reported to bleach more severely relative to other lifeforms (Rani, 2001; Baird *et al.*, 2009, Schoepf *et al.*, 2015; Guest *et al.*, 2016). The coral bleaching response depends on the sensitivity level of zooxanthellae to withstand the temperature rise.

Studies on the coral condition in Karimunjawa Islands have been done by several scholars such as Edinger *et al.* (1998), Suryanti *et al.* (2011), Joseph (2013), Biondi *et al.* (2014), Ekayogiharso *et al.* (2014), Sulisyati *et al.* (2014), Andaris *et al.* (2015), Larosa *et al.* (2015), and Januardi *et al.* (2016). Razak (1998) reported that the coral bleaching on the western shore of Menyawakan Island was up to 19.5% in stony coral. Manuputty & Budiyanto (2000) reported the coral bleaching event in Karimunjawa covered 20.37–21.03% of the reef at 3 m depth. The massive bleaching event occurred in 1998 has significantly reduced the coral health of Karimunjawa reefs (Burke *et al.*, 2002). The Indonesian Reef Check Network technical report summarized the Indonesian coral condition and three mild bleaching events occurred from 1998–2006, including the occurrence in Karimunjawa in December 2006 (Habibi *et al.*, 2008).

However, research on the bleaching response trend based on coral lifeform in Tengah patch-reef of Karimunjawa Islands has never been reported. This study aimed to determine the stony coral diversity based on their lifeform, to assess the condition of the reef by measuring percent cover of live coral, and to determine the bleaching occurrence based on the stony coral lifeform in the Tengah patch-reef of Karimunjawa National (Marine) Park. The results were expected to be used as a reference to predict the first lifeforms to suffer bleaching in the event of environmental changes.

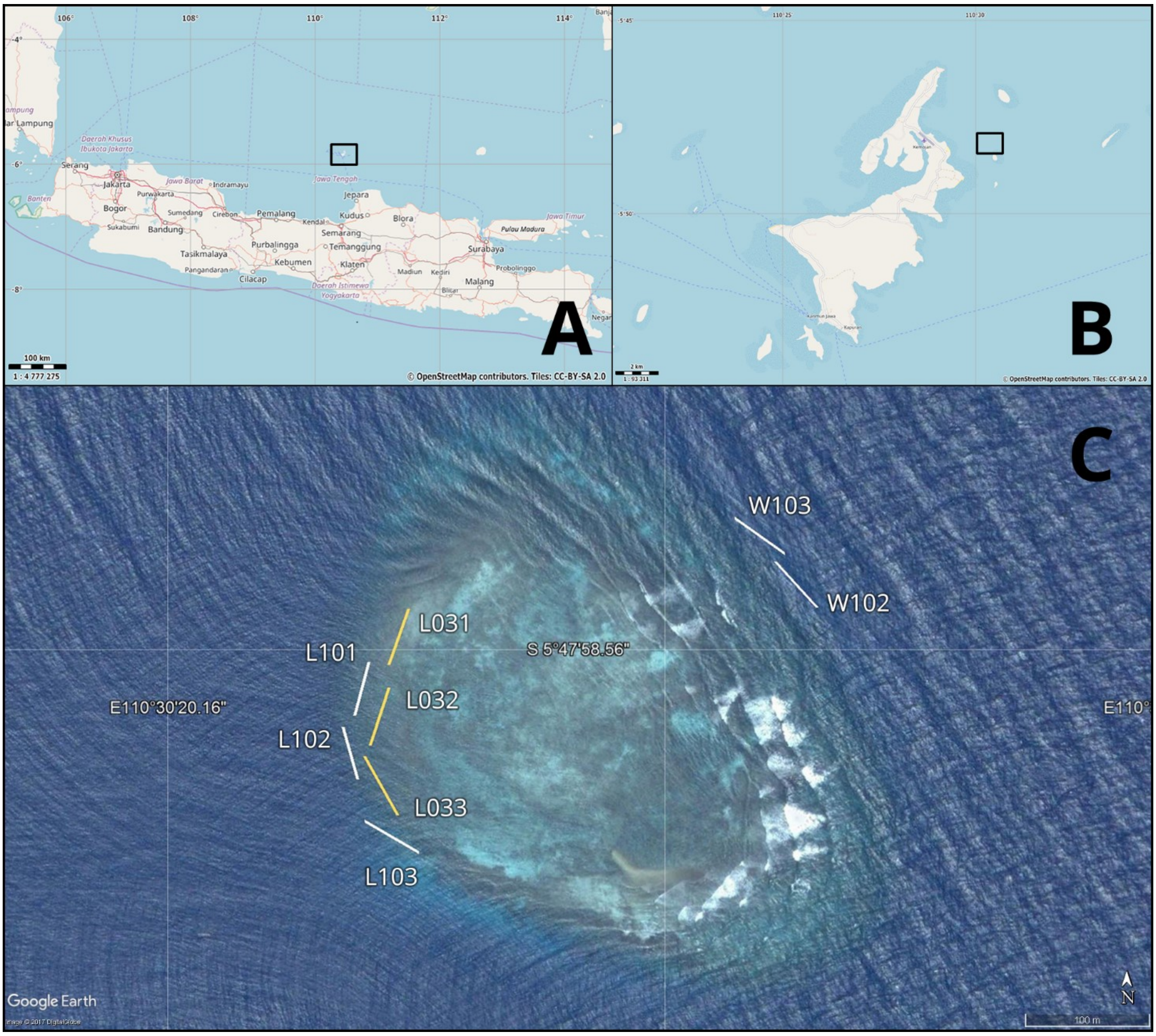

Figure 1. The map of Java Island showing Karimunjawa Islands (A). The map of Karimunjawa Islands showing the area of Tengah patch-reef (B). The Google Earth imagery of Tengah patch-reef in 2017 showing transect position at 3 m depth (yellow transects of L031, L032, L033) and 10-meter depth (white transects of L101, L102, L103, W102, W103)

METHODS

The fieldwork was conducted in August 2011 in the Tengah patch-reef of Karimunjawa Islands. We applied Line Intercept Transect (LIT) to estimate the coral lifeform diversity and the live coral cover of the reef (English *et al*., 1997). Stratified random sampling was implemented to cover eight 50-meter length transects with a 10-meter interval in the study site. A series of three transects were set parallel to the reef rim each at 3 and 10 m depths on the leeward side, while on the windward side, only two transects were placed at 10 m depth due to less coral, and no coral was found at 3-meter depth (Table 1). The bleaching coral was marked on the recorded lifeforms along the transect.

Table 1. Transect code and placement

Depth	Leeward	Winward
3 meter	L031, L032, L032	-
10 meter	L101, L102, L103	W102, W103

Coral diversity was analyzed based on coral lifeform category and presented as lifeforms composition. The percentage of live corals cover was measured using formulas of English *et al.* (1994), to describe coral reef health condition. The criteria for coral health determination was referred to Gomez & Yap (1988) and the Regulation of The State Minister of Environment No. 4/2001. The percent cover of live coral was divided into four criteria, 0–24.9%, 25–49.9%, 50–74.9%, and 75–100% representing poor, moderate, good, and excellent coral reef health conditions respectively. The bleaching data was presented as a ratio of a bleaching coral per lifeform to the total bleaching coral (%). The lifeform with the highest bleaching occurrence was assumed as the most vulnerable coral to face bleaching due to environmental stress.

RESULTS AND DISCUSSIONS

There were 13 coral lifeforms observed in the Tengah patch-reef of Karimunjawa Islands (Table 2), consisting of *Acropora* and non-*Acropora* lifeforms. The *Acropora* lifeform covered *Acropora* branching, *Acropora* encrusting, *Acropora* submassive, *Acropora* digitate, and *Acropora* tabulate. The non-*Acropora* lifeform comprised of branching coral, encrusting coral, foliose coral, massive coral, mushroom coral, *Heliopora*, *Millepora*, and submissive coral. The number of coral lifeforms found in the Tengah patch-reef was considered high by the occurrence of all coral lifeform categories. This finding was different compared to the works of Guntur *et al.* (2016) and Rosi *et al.* (2016) conducted in Mandangin Island of Sampang Regency which only found 2–5 lifeforms. Similar studies done by Ginoga *et al.* (2016) reported six lifeforms in East Ratatotok Village of South Minahasa Regency.

In this study, the lowest lifeform diversity was recorded on transect L032 with six lifeforms at 3 m depth, i.e., *Acropora* branching, *Acropora* digitate, *Acropora* tabulate, branching coral, encrusting coral, foliose coral, and massive coral. The highest lifeforms diversity was also found at 3 m depth with nine lifeforms on transect L031 and L033. The L031 transect included *Acropora* branching, *Acropora* encrusting, *Acropora* digitate, *Acropora* tabulate, branching coral, encrusting coral, foliose coral, massive coral, and mushroom coral. The L033 transects consisted of *Acropora* branching, *Acropora* submassive, *Acropora* digitate, *Acropora* tabulate, branching coral, encrusting coral, foliose coral, massive coral, and mushroom coral.

This study found *Acropora* branching and foliose coral dominated the coral diversity at 3 m depth. The abundance of those two lifeforms was due to the high sediments carried by the current. Suharsono (1996) suggested that sediments in the water column determine the coral lifeforms in the affected area. He reported *Acropora* branching and foliose coral tends to grow or better adapted in the high sediment waters, whereas *Acropora* tabulate tends to inhabit in clear water or with low sedimentation.

The highest lifeform diversity in this study was shown by 10 m depth on the W102 transect with 11 lifeforms including *Acropora* branching, *Acropora* submassive, *Acropora* digitate, *Acropora* tabulate, branching coral, encrusting coral, foliose coral, massive coral, mushroom coral, submissive coral, and *Millepora*. The lowest coral diversity at this depth was observed on W101 transect with seven lifeforms composed of *Acropora* branching, *Acropora* tabulate, branching coral, encrusting coral, foliose coral, massive coral, and mushroom coral.

The highest coral diversity was found on transect W102 because it is situated on the windward side. This side facing directly to wind that brings constant and strong water flows causes the coral to grows optimally. According to Andaris (2015), water circulation is essential for coral growth due to its oxygen and food supply, as well as flushing of the coral surfaces thus clearing sediments to keep the photosynthetic endosymbiont obtains sufficient light.

The prevailing surface current in Karimunjawa waters is tidal current that moves from the east to southwest with the surface current speed recorded varies from 0.003 to 0.008 m.sec^{-1} (Yulvia *et al.*, 2012), 0.055 to 0.350 m.sec^{-1} (Yusuf *et al.*, 2012), and 0.05 to 0.10 m.sec^{-1} (Suryanti *et al.*, 2011). The pattern of current in the Karimunjawa Islands is mostly caused by the climate oscillation in Indonesian waters (Sya'rani & Suryanto, 2006), which also depends on the seasons, areas, and types of currents (Tomascik *et al.*, 1997).

Table 2. The diversity of lifeforms and percent cover of coral in the Tengah patch-reef, Karimunjawa Islands

Lifeforms	**Transects (%)**							
	L031	**L032**	**L033**	**L101**	**L102**	**L103**	**W101**	**W102**
Acropora								
Acropora branching	12,36	20,00	10,75	11,89	0,80	10,90	15,45	23,09
Acropora encrusting	1,76	–	–	–	4,40	–	–	–
Acropora submassive	–	–	0,56	–	7,00	5,10	–	3,70
Acropora digitate	2,83	–	1,99	0,72	–	–	–	3,23
Acropora tabulate	10,40	16,52	9,38	2,55	–	–	3,99	5,54
Total lifeform	4,00	2,00	4,00	3,00	3,00	2,00	2,00	4,00
Total coral cover	27,35	36,52	22,68	15,16	12,20	16,00	19,44	35,56
Non-*Acropora*								
Branching	6,22	19,18	14,33	6,71	–	7,80	8,86	6,93
Encrusting	7,07	2,21	8,58	9,44	0,20	4,10	6,32	3,23
Foliose	12,52	8,30	22,37	15,24	2,40	9,20	6,68	9,93
Massive	12,58	11,17	7,09	17,86	2,60	5,90	15,56	4,39
Mushroom	2,46	–	0,52	0,59	0,60	0,70	0,42	1,85
Heliopora	–	–	–	–	–	0,10	–	–
Millepora	–	–	–	–	2,40	0,20	–	3,69
Submassive	–	–	–	–	–	–	–	4,85
Total lifeform	5,00	4,00	5,00	5,00	5,00	7,00	5,00	7,00
Total coral cover	40,85	40,86	52,89	49,84	8,20	28,00	37,84	34,87
Other								
Algae	0,06	0,57	0,17	–	–	–	4,81	–
Sponge	–	–	–	1,27	–	0,10	–	–
Sand	–	–	–	19,42	58,60	16.30	1,89	–
Soft Coral	0,24	1,40	–	0,70	0,20	0,40	6,03	1,62
Rubble	31,52	20,65	24,25	13,61	20,80	39,20	30,00	27,94
Total of lifeform	**9,00**	**6,00**	**9,00**	**8,00**	**8,00**	**9,00**	**7,00**	**11,00**
Total of percent cover	**68,20**	**77,38**	**75,57**	**65,00**	**20,40**	**44,00**	**57,27**	**70,43**

Table 3. Bleaching based on lifeforms of coral in the Tengah patch-reef, Karimunjawa Islands

Lifeforms	Transects (%)							
	L031	L032	L033	L101	L102	L103	W101	W102
Acropora								
Acropora branching	-	0.45	0.91	-	-	-	-	-
Acropora encrusting	-	-	-	-	-	-	-	-
Acropora submassive	-	-	-	-	-	-		-
Acropora digitate	0.71	-	-	-	-	-	-	-
Acropora tabulate	-	-		-	-	-	-	
Non-*Acropora*								
Branching	-	-	-	-	-	-	-	-
Encrusting	-	-	-	-	-	-	-	-
Foliose	-	-	-	-	-	-	-	-
Massive	-	-	-	-	-	-	-	-
Mushroom	-	-	-	-	-	-	-	-
Heliopora	-	-	-	-	-	-	-	-
Millepora	-	-	-	-	-	-	-	-
Submassive	-	-	-	-	-	-	-	-

Acropora branching was found as the most abundant lifeform (23.09%) on the transect W102 located on the steep windward slope. This finding is in agreement with Suharsono (1996) and Saptarini (2017) reporting that the dominant coral species in a habitat depends on the environmental topology such as *Acropora* branching that usually lives on the reef slopes. Manuputty (1990, 2008) states that the dominant branching coral colony in a reef is due to the quick recovery ability of *Acropora* spp. They are well adapted to hydrological changes and grow well especially on windward side or on reef flats with a constant strong water flows, a physical water condition that keeps the coral surface clean from any sediment particles. This condition explains why *Acropora* spp is the coral group with the most extensive cover and distribution on the windward side.

Budiyanto (2000) showed that coral bleaching and mortality occurred in Karimunjawa Islands were mainly species from the genus *Acropora*. According to Rani (2001), reef-building corals have different sensitivity to adapt the temperature rise. For example, massive corals are more adaptable to temperature rise than *Acropora*. Therefore massive corals tend to have a better recovery. Baird (2008) corroborates that *Acropora* spp are more susceptible to bleaching with the various impact due to the different sensitivity of *Symbiodinium* and coral species in response to the temperature rise. According to Hughes *et al*. (2003), extensive geographic variation in bleaching threshold in a species of coral provides indirect evidence that the evolution of temperature tolerance of corals is in progress.

In this study bleaching event only occurred at 3 m depth, while at 10 m depth no bleaching coral was located. This because the extreme temperature rise primarily occurs in the shallow waters. According to Coles & Jokiel (1977) and Rani (2001), the increase of coral mortality during the bleaching event is determined by the increment of temperature and the exposure to the water condition above the average maximum summer temperatures. A small increase in water temperature from the threshold (2–3°C) might result in extensive deaths in coral communities. The water temperature recorded in the Tengah patch-reef at the time of observation was 30°C, within the mean water temperature of Karimunjawa Islands recorded by Yulvia *et al*. (2012) of 30.0–30.5°C. A normal and tolerable temperature by the coral, but the daily tidal condition strongly influences the maximum sea surface temperature. Also, the lower low water level of tide can also expose corals to direct sunlight. Some corals can adapt and survive the stress of temperature rise and will have better opportunity to withstand in the next bleaching events.

The water salinity was recorded 32 ‰ at the time of the study, which is a normal condition for coral growth and within the average water salinity in Karimunjawa Islands (Yulvia *et al*., 2012). According to Dahuri (2003), euryhaline hermatypic corals cannot survive outside the salinity range of 32–36 ‰. However, Supriharyono (2000) suggested that every coral species has different salinity tolerance threshold.

The live coral cover showed that the Tengah patch-reef at the 3 m depth has more cover (73.71%) compared to the 10 m depth (50.42%) (Table 2). At 3 m depth, the cover was found only in the leeward side from 68.20 to 77.38%, demonstrating a good coral reef condition according to Gomez & Yap criteria (1988) and the Regulation of The State Minister of Environment No. 4/2001. This good coral condition is caused by optimum sunlight intensity used by zooxanthellae inside the coral tissue for photosynthesis (Hadie, 2008; Mukholladun, 2016). This record supports Giyanto & Budiyanto (2008) finding that the stony coral has a maximum growth rate at 3 m depth in the Gulf of Lampung.

The average live coral cover at 10 m depth was 50.42%, which falls under a good criterion coral reef health. However, the lowest live coral cover was also found on transect L102 and L103 with a value of 20.44% and 44.0%, a poor and moderate coral reef health, respectively. Both transects were on the leeward side characterized by sand dominating substrates. The presence of sand and mud are not a favorable substrate for planula according to Thamrin

(2006). The highest live coral cover in this study was 70.43% on W102 transect on the windward side. The strong current flows on the windward side help cleaning up the corals from sediment (Thamrin, 2006).

CONCLUSION

The diversity of corals on the Tengah patch-reef of Karimunjawa Islands was high indicated by the occurrence of all coral lifeforms. The highest coral diversity was observed at 10 m depth with 13 lifeforms, and the lowest was at 3 m depth with ten lifeforms. The live coral cover reached 73.71% at 3 m depth and 50.42% at 10 m depth, both indicating a good coral reef health. The bleaching event was detected on *Acropora* branching, and *Acropora* digitate less than 1%, suggesting the high sensitivity and vulnerability of *Acropora* lifeform to exposed environmental stresses.

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