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QUANTIFICATION OF CORAL REEF BENTHOS FOR CORAL HEALTH ASSESSMENT IN LABUAN MARINE PARK, MALAYSIA

CHE DIN MOHD SAFUAN[1], KHAIRA ISMAIL[2], IDHAM KHALIL[2], AZIZI ALI[1], WEI SHENG CHONG[1], ALBERT APOLLO CHAN[3], MD NIZAM ISMAIL[3], IZARENAH MD REPIN[3], AND ZAINUDIN BACHOK[1, 2*]

[1]*Institute of Oceanography and Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Malaysia.*
[2]*School of Marine and Environmental Sciences, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.*
[3]*Department of Marine Park Malaysia, Ministry of Natural Resources and Environment, 62574 Putrajaya, Malaysia.*

**Corresponding author: zainudinb@umt.edu.my*

Abstract: A coral assessment was carried out utilizing Coral Video Transect (CVT) technique over 12 reef sites in Labuan Marine Park (LMP), Malaysia. The goals of the assessment were to determine the present coral health status and to determine the pattern of coral community in the LMP. Among the four different localities surveyed, Rusukan Besar and Rusukan Kecil Island was mainly predominated by live (C) and dead coral (DC) while the Southern Reef is mainly covered by DC, sand, silt and rock (SR) and C. Kuraman Island significantly different between other localities by the domination of algae (ALG), SR and DC. Majority of the reefs were in 'poor' condition with 58.33% of the reef sites have the percentage of live coral cover between 0.97% - 22.5%. Only 25% and 16.67% of the reef sites were rated as 'fair' and 'good' condition. Overall, the coral reef in LMP was in 'fair' condition and possessed 27.22% of the live coral cover which near to the borderline of 'poor' category. A total of 38 coral genera from 13 different families were recorded. Among all genera, *Acropora* accounted the highest proportion of coral cover followed by *Porites* and *Montipora.* Two coral communities were preoccupying the reefs in LMP based on the cluster and SIMPER analysis: *Acropora-Porites-Montipora* community and *Acropora-Porites-Favites* community. The findings of this study can provide detailed baseline information for subsequent studies as well as for conservation and protection management to the coral reefs of LMP.

KEYWORDS: Hard coral, coral health status, coral condition, coral cover, coral community, South China Sea

Introduction

Southeast Asia (SEA) is known as the global center of coral reefs and possessed 1/3 of the world coral reef area (Burke *et al.,* 2002; Vo *et al.,* 2013). Majority of the coral reefs can be found in South China Sea (SCS) in which harbored approximately 750,000 ha of the reef area (Vo *et al.,* 2013). The reefs can be found distributed in nine different region (Nansha Islands, Xisha Islands, Zhongsha Islands, Dongsha Islands, Hainan Island, Taiwan, Continental Coast of South China, the Vietnamese coast and its offshore islands, and the Philippine coast and its offshore islands) with a various reef types (Zhoa *et al.,* 2015). All major reef types from fringing reefs, patch or platform reefs and atolls exist in the SCS (Vo *et al.,* 2013). The SCS not only has considerable coral reefs but also have an extraordinary diversity of hard corals. Despite having less than 17% of the coral reef area than the Coral Triangle region, this large marginal sea hosts 571 known species of hard corals, a richness that is comparable to the Coral Triangle (Huang *et al.,* 2015).

The coral reefs are known as the 'rainforest of the sea', are among the most diverse ecosystem which not only supporting other marine organism but also economically important to millions of coastal people (Burke *et al.,* 2011). In Indonesia and the Philippines, coral reefs provide annual economic benefits more than US$1 billion per year, respectively (Burke *et al.,* 2002). Although the economic and ecological importance of the coral reefs in SCS

has been highlighted, the reefs are threatened by natural and anthropogenic disturbances. Vo *et al.* (2013) outlined that over-fishing, destructive fishing, sedimentation, pollution, unsustainable fisheries practices, coastal development, coral bleaching, unsustainable tourism and deforestation on upland areas are the most serious threats to the coral reefs in SCS. Coral assessment carried out in several reefs around the region indicates progressive degradation of the coral reefs and its community. For example, dramatic decreased in live coral cover were reported in Wanlitung Reef, Taiwan from 47.5% in 1985 to 17.7% in 2010 (Kuo *et al.,* 2012), the average coral cover in several reef in the Gulf of Thailand such as at the Mun Island and Chang Island have been decreased over the past 16 years from 37.4% in 1995 to 22.2% in 2011 (Phongsuwan *et al.,* 2013) while nutrient enrichment in seawater by terrestrial run-off and upwelling have stimulates the macroalgae growth and shifting the reef communities into macroalgae-dominance in northeastern coast of Hainan Island (Li *et al.,* 2015). These islands are mainly located nearby to the mainland where the influences from anthropogenic activities are relatively more serious.

Malaysia possessed approximately 4,000 km2 of coral reefs area (Burke *et al.,* 2002). An extraordinary diversity of hard corals can be found in Malaysia. A total of 398 species of hard coral can be found in West Malaysia and 248 species in western Sabah (Huang *et al.,* 2015). Malaysia also classified as the region with the highest index relative of rarity (IRR) in SCS and contains a regionally and globally rare coral species such as *Euphyllia paradivisa* and *E. paraglabrescens* (Huang *et al.,* 2016). Majority of the coral reefs in Malaysia can be found along the coast and offshore island (Praveena *et al.,* 2012). However, coral reefs in Malaysia have long been under threat due to the combination of natural and anthropogenic disturbances (Mazlan *et al.,* 2005).

Coral reefs in LMP are under pressure due to destructive fishing practice such as trawling and blast fishing, pollution from the nearby oil industry and shipping lanes as well as runoff and sedimentation (Pilcher & Cabanban, 2000). A few coral assessments has been conducted in LMP to describe the health status of the reefs (Pilcher & Cabanban, 2000; Ransangan et al., 2012; Reef Check Malaysia, 2013; 2016). Generally, the coral reef in LMP is dominated by live coral, followed by dead coral as well as sand, silt and rock. (Pilcher & Cabanban, 2000; Ransangan *et al.,* 2012; Reef Check Malaysia, 2013; 2016). By referring to the classification of coral condition via ASEAN-Australia Living Coastal Resource Project (Chou et al., 1994), the reef in LMP remained in 'fair' condition with majority of the sites contain greater than 25% of live coral cover (Pilcher & Cabanban, 2000; Ransangan *et al.,* 2012; Reef Check Malaysia, 2013; 2016). However, the data presented are spatially limited to represent the status of coral reefs in whole LMP. In this study, a coral assessment was conducted in 12 reef sites around the LMP using CVT technique to determine the coral condition and coral communities that form the reef. A brief comparison with previously published data was used to dismantle the trend in coral condition and reef communities in LMP and to provide an important baseline data in which can serve as a significant and useful standard for future studies.

Materials and Methods

Study Area

The LMP (5°15' N, 115° 07' E) lies at the western of East Malaysia at Federal Territory of Labuan within the SCS region. The marine park consists of three islands namely Kuraman Island, Rusukan Kecil Island and Rusukan Besar Island and is managed by the Department of Marine Park Malaysia. Both Kuraman Island and Rusukan Kecil Island are uninhabited, however there is a resort together with the Marine Park's station in Rusukan Besar Island. The reefs are commonly used for recreational activities such as SCUBA diving, snorkeling and also for artisanal fishing (Pilcher & Cabanban, 2000). LMP is protected to an extent of 1 nautical mile as compared to other marine parks in Malaysia,

which covers up to 2 nautical miles (Reef Check Malaysia, 2013). Three major marine habitats namely coral reef, macroalgae and seagrass can be found in LMP while sand, silt and rock predominantly cover the seafloor (Mustajap *et al.,* 2015). The coral area can be found within 2 m to 20 m depth (Mustajap *et al.,* 2015). Sampling was carried out in four sites during July 2017 and eight sites in September 2017, with a total of 12 reef sites were surveyed around the LMP as shown in Figure 1. Selection of the sites such as in Kuraman, Rusukan Besar and Rusukan Kecil Island were based on the preliminary observation via snorkeling where the selection was not limited to the reefs with high live coral cover but also to the 'poor' condition reef. Three sites classified as Southern Reef (L1, L2 and L3) were selected based on the site suggestion by the Department of Marine Park Malaysia and relocate using the bathymetry map data to obtain the actual coordinate of the reefs.

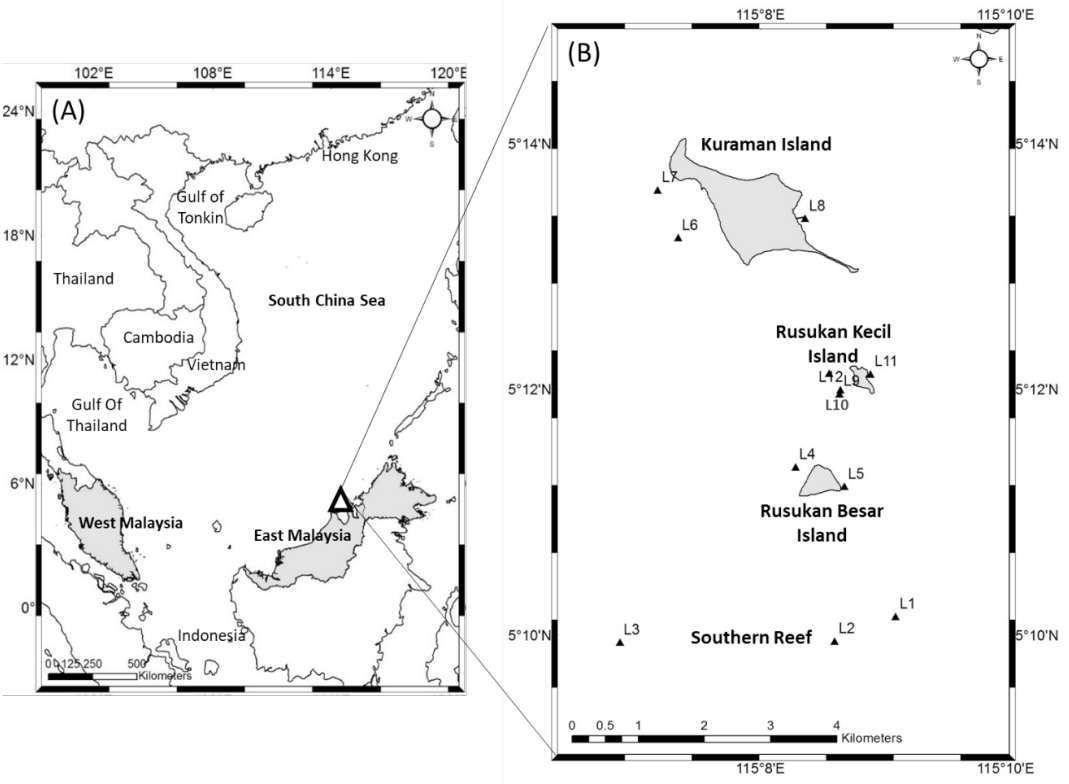


Figure 1: Map of the South China Sea bordering by Southeast Asia countries and the shaded area represents Malaysia (A). The Labuan Marine Park is located in East Malaysia and a total of 12 sites were surveyed within the park (B).

Benthic Survey

The coral reef benthic assessment was conducted using CVT technique following Safuan *et al.* (2015). An underwater camera was used (Panasonic LUMIX FT4 set with underwater mode enclosed in LUMIX 40 m Marine Case) to record the reef floor by pointing down the lens approximately 0.5 m perpendicular from the substrate. To maintain the vertical elevation during the video recording, a 0.5 m reference bar attached to the underwater camera housing was used. At each site, a video was taken along the 100 m transect line by recording four transect segments (20 m per segment) with each was separated by 5.0 m interval (n = 4). The transect

line was overlaid by following the reef contour and parallel to the shoreline.

Data Extraction and Analysis

All the footage were analyzed in the laboratory. In each site, the video was extracted into 200 non-overlapping frames (50 frames per segment) using a Pinnacle Studio 15 software. The video frames were analyzed using Coral Point Count with Excel Extension (CPCe) software to quantify the percentage cover of coral reef benthic component (Kohler & Gills, 2006). With each frame was analyzed with 50 points (Safuan *et al.,* 2015). Results were then summarized into four coral reef benthic components; C, DC, ALG and the abiotic component such abbreviated as SR. Percentage live coral cover was used as an indicator to coral health status as proposed by Chou et al. (1994); excellent (> 75%), good (51% – 75%), fair (26% – 50%) and poor (< 25%). Corals were identified up to genus level by following Veron (2000) to determine the diversity and composition of coral genera in LMP.

Statistical Analysis

One-way Analysis of Similarity (ANOSIM) was used to express the similarities among four different localities; Southern Reef, Rusukan Besar Island, Kuraman Island, Rusukan Kecil Island, using the percentage cover of benthic components and generic composition (Clarke, 1993). Similarity percentage (SIMPER) was performed to determine the percentage contribution of the benthic components and coral taxa that contribute to the similarities among the localities (Clarke, 1993). The cluster analysis together with SIMPROF was used to determine the dominant coral that forms the reefs in LMP (Clarke *et al.,* 2008). All the statistical analysis was done using the PRIMER 6 version 6.1.12. Percentage data of benthic components and coral taxa were transformed into a log (X + 1) prior to statistical analysis.

Results and Discussion

Coral Health Status in Labuan Marine Park

The distribution of major benthic components in LMP was statistically different (significance level = 0.1%) with high similarities (global R = 0.399) in coral reef benthic components among the localities (Figure 2). The benthic components in Kuraman Island were significantly different (significance level > 5%) with other reefs, which possessed low coral cover and high algae abundance. SIMPER analysis revealed that the reef is predominantly occupied by ALG, SR and DC with a percentage contribution of 33.97%, 29.66% and 28.15%, respectively. No clear different (significance level = 10.3%) were found between the Rusukan Besar and Rusukan Kecil Island. Both islands mainly dominated by C with each recorded percentage distribution of 50.69% and 31.68% as well as DC with 45.95% and 45%. Meanwhile, the benthic cover in three sites in Southern Reef are dominated by DC, SR and C.

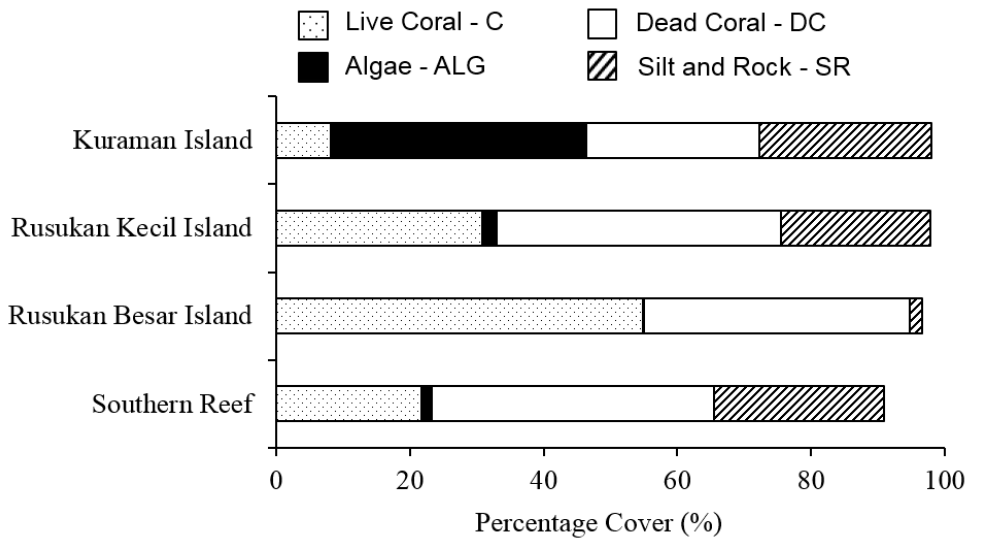


Figure 2: Percentage cover of coral reef benthic components in four different location in Labuan Marine Park. Total percentage cover is less than 100% (excluding the cover of 'unknown' and 'other' categories).

Among all the reef sites, 58.33% of the sites were in 'poor' condition (seven sites), followed by 25% rated as 'fair' (three sites) and 16.67% rated as 'good' (two sites) category (Table 1). None of the reefs was recorded under 'excellent' condition. In comparison with the other reefs in SCS, Malaysia, the reefs in LMP possessed less 'fair' and 'good' condition reefs (Shahbudin *et al.,* 2017). A similar trend of a coral condition can be found in Malacca Straits where the reefs are dominated by 'fair' and 'poor' reefs condition (Safuan *et al.,* 2016; 2018).

Table 1: Detail assessment of coral reef benthic components in 12 sites at Labuan Marine Park. The coral condition was indicated by percentage live coral cover following the ASEAN-Australia Living Coastal Resource Project (Chou *et al.,* 1994). Benthic components were indicated by percentage cover of Line Coral (C), Dead Coral (DC), Algae (ALG) and Sand, Silt and Rock (SR).

Island	Station	Depth (m)	Benthic Cover (%)				Coral Condition
			C	DC	ALG	SR	
Southern Reef	L1	9m	35.57	41.39	0.00	19.15	Fair
	L2	12m	12.71	28.77	0.12	45.04	Poor
	L3	6m	16.98	56.94	4.24	11.84	Poor
Rusukan Besar	L4	1m	49.33	47.56	0.31	0.16	Fair
	L5	2m	60.50	31.98	0.00	3.36	Good
Kuraman Island	L6	4m	18.15	40.72	23.97	15.32	Poor
	L7	2m	3.37	21.82	53.45	18.42	Poor
	L8	3m	0.97	11.35	37.25	49.72	Poor
Rusukan Kecil	L9	3m	22.50	58.03	0.64	16.64	Poor
	L10	2m	44.84	38.30	1.78	11.74	Fair
	L11	2m	7.44	27.76	5.79	57.48	Poor
	L12	8m	52.17	45.32	0.16	0.86	Good

In comparison with previous data, the coral health status in LMP remains in 'fair' condition over the past 17 years (Table 2). However, a lower live coral cover was recorded in this study, which nearing the borderline of 'poor' category. The percentage live coral cover in LMP (27.22%) can be considered as low when compared with the average live coral cover in Malaysia (41.68 ± 0.2%) as indicated by Chelliah *et al.* (2015). Moreover, the highest cover of algae and dead coral were also reported in this study to indicate a potential coral degradation over the past 17 years. Even though few coral assessments were done in LMP (Table 2), no clear comparison can be made to detect a coral degradation over the past 17 years as the reefs were not surveyed along a permanent transect or similar site. However, a three years coral assessment conducted by the Reef Check Malaysia at similar reef sites showed a shifting in coral condition from 'good' to 'fair' with a decrement of 13.73% of live coral cover and increment of dead coral (9.63%) and algae cover (0.83) (Reef Check Malaysia 2013; 2016). This is a good indicator showing the degradation of coral reefs in LMP.

Error! Not a valid link. Table 2: Summary of coral assessment in Labuan Marine Park over the past 17 years. N/A denoted as 'not available'. C-Line Coral; DC-Dead Coral; ALG- Algae; SR-Sand, Silt and Rock.

Source	Method	No. of Transect / Site	Benthic Components (%)				Coral Condition
			C	DC	ALG	SR	
Pilcher and Cabanban (2000)	LIT / 100m	4	32.3	35.6	1.8	21.8	Fair
Ransangan *et al.* (2012)	PIT / 100m	8	46.4	N/A	N/A	N/A	Fair
Reef Check Malaysia (2013)	PIT / 100m	3	55.4	6.46	3.13	23.12	Good
Reef Check Malaysia (2016)	PIT / 100m	3	41.67	16.09	3.96	32.38	Fair
Present	CVT / 100m	12	27.22	38.05	10.26	20.38	Fair

Persistence disturbances from the terrestrial run-off such as sedimentation and nutrient enrichment in seawater have been reported as major threats to the coral reefs in LMP (Pilcher & Cabanban, 2000; Reef Check Malaysia, 2013). Most sediment is being transported into the coastal marine system through rivers (Fabricius, 2005). Sedimentation in LMP is contributed by the river-runoff from the Padas, Klias, Limbang and Lawas rivers, which flow directly into the Brunei Bay (Pilcher & Cabanban, 2000). Sedimentation is known as one of the major threats to coral reefs in Malaysia (Toda *et al.,* 2007; Praveena *et al.,* 2012). Reviewed by Fabricius (2005) found that sedimentation affects the growth, survival, reproduction and recruitment of coral through the coral nutritional intake of symbiosis with zooxanthellae, smothered the coral and decreasing the coral juvenile densities on reefs. Moreover, reduction in light penetration into seawater by the increased suspended particles reduces the photosynthetic carbon fixation by zooxanthellae and affects the coral growth (Erftemeijer *et al.,* 2012). Similar finding of low coral cover (< 25%) was reported in the reefs at the Malacca Straits with the water quality influenced by turbidity and sedimentation (Safuan *et al.,* 2016).

The river-runoff also stimulates the nutrient enrichment in seawater which leading to increasing algae abundance. According to Kuo *et al.* (2012), a shift in reef communities by algae can be influenced by the nutrient

enrichment in seawater. Domination of algae and the high cover of dead coral in several reefs such as in Kuraman Island showed that the reef communities have shifted towards macroalgae-dominance. This is supported by McManus and Polsenberg (2004) which outlined that a phase shift in reef communities occur when the live coral cover is reduced and replaced by the domination of macroalgae and the reef become less resilience because of ecological processes and/or environmental conditions. In Kuraman Island, macroalgae species known as *Sargassum* sp. contribute to the high cover of algae (11.35% - 40.72%) and dominating the reef. Domination of macroalgae can become worse when sediment particle stick to the macroalgae and becoming less palatable and deterring the herbivorous reef fish (Goatley & Bellwood 2013). This fleshy macroalgae can grow up to 2 m tall and form a dense forest which shades the corals underneath and their fronds can cause some tissue abrasion in coral (Fabricius, 2005).

Illegal fishing practices such as blast fishing and trawling are known as one of the major threat to the reefs in East Malaysia (Burke *et al.,* 2002; Waheed *et al.,* 2015) and were reported in LMP since the earlier assessment (Pilcher & Cabanban, 2000). The destructive fishing technique such as blast fishing can cause massive coral mortality by leaving a crater of unconsolidated coral rubble (Waheed *et al.,* 2015). However, no evidence of new or old crater of dead coral was found during the present survey. Other threats such as Marine Park's encroachment by fish and shrimp trawler, the nearby oil industry and shipping lanes were also outlined by Pilcher and Cabanban (2000), however, the effect to coral reefs in LMP is still uncertain.

Coral Community in Labuan Marine Park

The coral reefs in LMP possessed no clear different (significance level = 5.8%) with high similarity (global R = 0.231) in coral genera composition among different localities. In total, 38 genera in 13 different families of hard coral were identified (Table 3). High generic diversity was found in Rusukan Kecil Island and Southern Reef with a total of 34 and 31 identified coral genera. Lower diversity was identified in both Rusukan Besar Island and Kuraman Island. The generic diversity can be considered high as compared to the reefs in Malacca Straits, which is also affected by sedimentation and nutrient enrichment (Safuan *et al.,* 2016; 2018). At all sites, the *Acropora* is the greatest contributor to the percentage live coral cover followed by *Porites* and *Montipora* (Table 3). *Acropora* and *Montipora* are considered as fast growing species and able to expand more rapidly compared to slow growing massive coral (Unworth *et al.,* 2010; Shahbudin *et al.,* 2017). Porites is known to have a high tolerance to sedimentation and are found to dominate the reefs impacted with sedimentation (Toda *et al.,* 2007; Safuan *et al.,* 2016). As postulated by Toda *et al.* (2007), the domination of *Acropora* and *Montipora* under normal condition decreased with the increased sedimentation and turbidity, expanding the distribution of Porites. However, the area with heavy or less sedimentation may be distributed patchily over the study area. Therefore, *Acropora* and *Montipora* could survive in a less sedimented reefs. Based on this, we can conclude that domination of *Acropora* and *Montipora* in LMP were affected by the differentiation of heavy and less sedimented area. The shallow water reefs surveyed in this study could be less affected by sedimentation due to the wave action. This is because, less sediment is deposited in wave-exposed shallow-water areas (Fabricius, 2005). This could explain the domination of *Acropora* and *Montipora* in the study area.

Previously, *Porites, Acropora, Fungia Pocillopora* and *Montipora* were outlined as the major hard corals in LMP (Pilcher & Cabanban, 2000). At present, the coral communities in LMP can be represented by three major group as recognized by SIMPROF analysis (Figure 3). The G1 represents several sites in all localities. SIMPER analysis showed that this group is clustered together by seven coral genera *(Acropora, Porites, Montipora, Seriatopora, Pocillopora, Fungia and Galaxea),* by which *Acropora, Porites* and *Montipora* accounted for the highest proportion of live coral cover. The

G2 represents several sites in SouthernReef and Rusukan Kecil Island with 12 genera *(Porites, Acropora, Favites, Fungia, Montipora, Pocillopora, Platygyra, Favia, Stylophora, Cyphastrea, Turbinaria* and *Symphyllia)* were found accumulating the group. Porites, Acropora and Favites predominantly form the reefs in G2. Meanwhile, only three genera *(Acropora, Porites* and *Favites)* preoccupying the coral community in G3 that consist of two sites in Kuraman Island. The occurrence of *Acropora, Montipora* and *Porites* as a major hard coral in LMP is common and they were commonly found forming the coral community in SCS (Toda *et al.,* 2007; Zhoa *et al.,* 2013). Meanwhile, the domination of *Favites* in G2 and G3 does not generally related to the percentage cover but possibly related to their broader distribution (Table 3). This genus is patchily distributed in sedimented reefs (Dikou & Woesik, 2006; Toda *et al.,* 2007; Safuan *et al.,* 2016).

Table 3: Generic diversity and composition of hard corals in Labuan Marine Park.

Family	Genus	Southern Reef			Rusukan Besar Island		Kuraman Island			Rusukan Kecil Island			
		L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12
Acroporidae	*Acropora*	13.25	0.03	0.63	9.20	36.77	2.93	0.16	0.26	0.15	5.94	1.05	32.65
	Astreopora						0.83					0.32	
	Montipora	1.78	0.21	0.36	36.66		4.54	1.50		0.27	1.14		7.94
Agariciidae	*Pachyseris*		1.37				0.23				0.25		
	Pavona					0.75				0.19			1.51
Dendrophylliidae	*Turbinaria*		0.10	2.25			0.07			0.38	0.69		
Euphyllidae	*Euphyllia*		0.09								0.13		
Faviidae	*Cyphastrea*		0.85	0.47			0.31			0.07			
	Diploastrea	2.11								0.53	0.31		
	Echinopora	0.08				9.71				0.59	2.83		
	Favia		0.12	0.55			0.47	0.10			0.05	0.48	
	Favites	0.01	0.29	2.21	0.06		0.69	0.29	0.04	0.74	0.47	0.10	
	Goniastrea	0.03		1.12			0.33			0.10		0.14	
	Oulophyllia										0.56		
	Platygyra	0.14		0.48	0.03		0.08			0.36	1.53	0.43	
Fungiidae	*Ctenactis*	0.17								0.24			0.12
	Fungia	1.70	0.35	0.07	0.06	1.19				6.45	1.38		1.11
	Heliofungia	0.30	0.08	0.00							0.04		0.04
	Herpolitha	0.16	0.03	0.06						0.93	0.27		
	Podabacia		0.34	0.07								0.07	
	Polyphyllia	0.05	0.08										
Merulinidae	*Hydnophora*		0.14								0.99		
	Merulina									0.74	0.84		
Mussidae	*Lobophyllia*	0.66	0.09				0.23				7.73		
	Scolymia		0.02	0.05									
	Symphyllia	0.12	0.20	0.15			0.17			0.29	0.79		
Oculinidae	*Galaxea*	0.22		0.50	0.17	1.92	0.21			0.05	0.88	0.11	0.07
Pectiniidae	*Echinophyllia*									0.12	0.86		
	Mycedium										1.85		
	Oxypora		1.21							0.09			
	Pectinia	0.02	0.06	0.06						0.18	1.03		
Pocilloporidae	*Pocillopora*	3.04	0.06		0.07	4.75	0.02			0.72	0.89	0.25	2.50
	Seriatopora	4.50			2.10		1.48		0.40		0.46		1.29
	Stylophora										2.12	0.82	0.93
Poritidae	*Alveopora*		0.22										
	Goniopora		0.47	0.41	0.66								
	Porites	5.31	1.68	2.19	0.14	1.95	3.25	0.09	0.27	5.90	2.95	3.65	3.73
Non-Scleractinian Coral	*Millepora*	0.42		1.49		0.56	0.04			0.14	3.08		
13	38	20	23	19	10	8	17	5	4	22	27	11	11

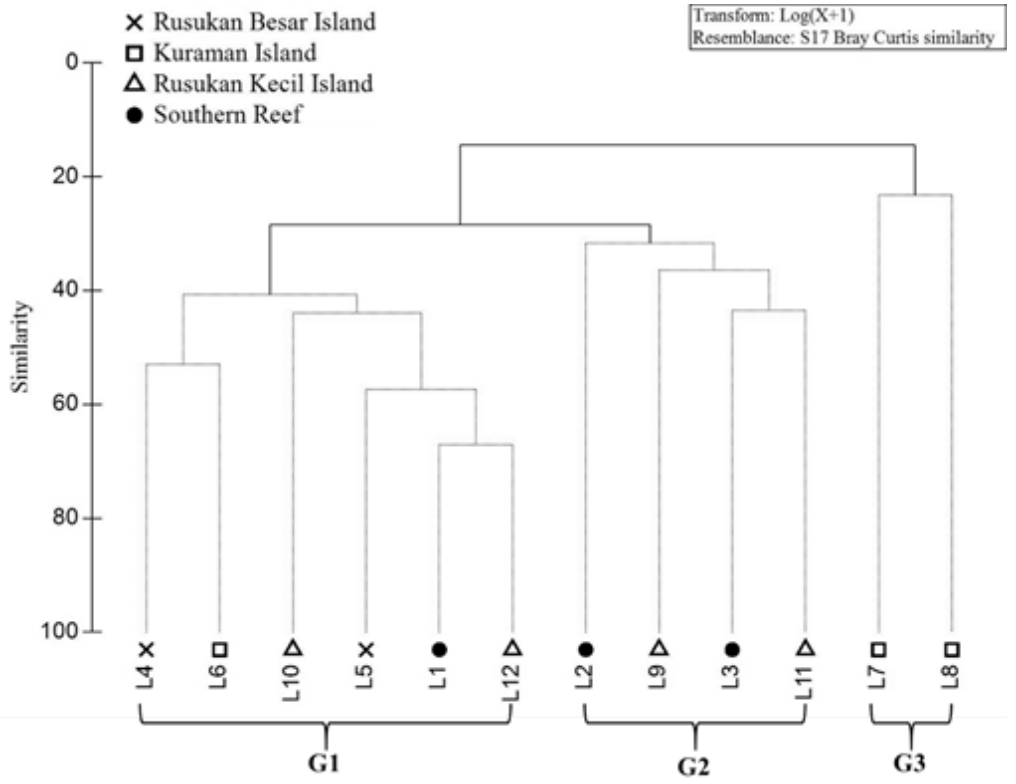


Figure 3: Separation of 12 reef sites given by a sequence of SIMPROF test on standard hierarchical clustering. Redline indicated the non-separated reef sites (at $p < 0.05$) by SIMPROF. Separation was based on percentage cover of coral genera.

Conclusion

The present study shows a baseline data of coral reef benthic components to describe the coral health status in LMP. The coral reef is predominantly covered by sand, silt and rock followed by dead coral, live coral and algae while the reef communities mainly formed by *Acropora, Porites, Montipora* and *Favites* coral. Coral conditions in the LMP varied from 'good' to 'poor', with none of the sites exhibiting an 'excellent' condition. Majority of the sites were categorized as 'poor' condition with a percentage live coral cover near to the borderline of 'poor' category. Domination of the reef floor by dead coral and algae indicates that some of the reefs possibly show a phase-shift in reefs communities from coral-dominance to algae-dominance. However, no clear evidence to show changes of the reef communities as the data presented is limited to one-off sampling and cannot provide a clear comparison with previous data because of the difference in location and number of the site survey. It is difficult to evaluate quantitative loss of coral cover caused by the various disturbances due to lack of detailed surveys, but the data presented in this study can be used for a future reference. The data mainly collected from the surrounding islands and the selection of the reef sites is not limited to the 'best site' to comprehend the coral health status in LMP. Management of coral reefs requires repetitive data for understanding and predicting the coral health status in the face of multiple disturbances. A significant step such as conducting a long-term monitoring along a permanent transects can be taken to understand the trend and pattern of coral health status in the future. The use of

video sampling will be appropriate to provide a permanent data which can be reviewed or reassessed for future comparison.

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