CLIMATE CHANGE

CORAL REEF COMMUNITIES OF PULAU REDANG MARINE PARK TERENGGANU

Lee Jen Nie
Yusri Yusuf
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Marine Park and Resource Management Division
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Ministry of Agriculture and Food Industry

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2020

Climate Change: Coral Reef Communities of Pulau Redang Marine Park, Terengganu

Publisher

Department of Fisheries Malaysia
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Level 3, Wisma Tani
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Bibliography Citation

Lee, J.N., Yusuf, Y., Md. Nizam, I. & Chan, A.A. (eds). 2020. Climate Change: Coral Reef Communities of Pulau Redang Marine Park, Terengganu. Marine Park and Resource Management Division, Department of Fisheries Malaysia, Ministry of Agriculture and Food Industry, Putrajaya, Malaysia, 64 pp.

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Climate Change : Coral Reefs Community in Pulau Redang Marine Park, Terengganu /
Editors: Lee Jen Nie, Yusri Yusof, Md. Nizam Ismail, Albert Apollo Chan.
ISBN 978-967-0633-69-5
1. Climatic changes--Malaysia--Pulau Redang (Terengganu).
2. Coral reefs and islands--Malaysia--Pulau Redang (Terengganu).
3. Taman Laut Pulau Redang (Terengganu, Malaysia).
4. Government publications--Malaysia.
I. Lee, Jen Nie. II. Yusri Yusof.
III. Md. Nizam Ismail. IV. Chan, Albert Apollo.
551.609595122

Cover Photos

All photos by Lee Jen Nie, otherwise stated.

Printed in Malaysia by

Gempita Maju Sdn Bhd
7-1, Jalan 3/1,
Taman Seri Merdeka,
68000 Ampang, Selangor

Contents

PROJECT INFORMATION iv

EXECUTIVE SUMMARY v

PREFACE vii

INTRODUCTION 1

METHODOLOGY 8

Sampling Locations 8

a. Environmental Parameters 9

b. Coral Bleaching Monitoring 9

c. Fish Community 10

d. Reef Assessment 10

RESULTS 11

a. Environmental Parameters 11

b. Coral Bleaching Monitoring 14

c. Fish Community 15

d. Reef Assessment 25

SUMMARY AND RECOMMENDATION 29

REFERENCES 30

APPENDIX 31

Project Information

Project Title: ELUCIDATION OF CLIMATIC EFFECTS ON THE CORAL REEFS COMMUNITY IN PULAU REDANG MARINE PARK, TERENGGANU

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We would like to thank all officers and supporting staffs from Universiti Malaysia Terengganu, Universiti Kebangsaan Malaysia, Redang Mutiara Beach Resort, and SeaMonkey Redang dive center for making this succesful project.

Executive Summary

This document reported changes of coral reefs communities in 2016 with few monitoring in a year. No observation of major coral bleaching was recorded. The components of this project, 1) environmental parameters, 2) bleaching monitoring, 3) fish community and 4), reef assessment.

- A total of 572 colonies of corals were measured using Coral Watch. Major bleaching event was predicted to happen in Pulau Redang, as predicted by NOAA. However, during the first sampling in May 2016, minor bleaching was observed. When we interviewed the local operators, more severe bleaching was seen before the sampling. However, they recover soon after before the sampling in May. Less than 10% of corals were bleached during monitoring. Quick recovery of corals from pre-bleaching in April from local observation.
- Fish composition of 142 species from 31 families were recorded. High number of schooling fishes were observed at Pulau Lima and Terumbu Kili.
- Reef health condition were generally fair, and the highest 65.7% at Terumbu Kili. *Acropora*, *Pocillopora* and Fungiidae had the highest coral cover.
- 31 genera of hard coral were recorded, and showed a sharp decline from previous study by Harborne et al. (2000).
- However, most of the health of coral reefs depends on the total coral cover. This study found out that low coral cover such as 23% coral cover at Pulau Kerengga consist of highest number of coral with 22 genera, meanwhile 33% of coral cover at Mak Simpan recorded highest diversity of fish with 66 species.

Preface

We've all had moments when we feel connected to the sea. Days by days, we heard too many stories and information on the decline of the marine ecosystem especially caused by coral bleaching and climate change. At the end of 2015, it was predicted that major coral bleaching would hit our coral reefs by a strong El Niño event. The agency from the Department of Fisheries Malaysia (formally known as Department of Marine Park Malaysia) and key partners formed the team to organize and undertake monitoring of the predicted bleaching event in 2016. Luckily the bleaching does not hit us badly and unlucky for the team to not further explore the effect of this devastating phenomenon.

This book presented parts of the data collected during the event. We are hoping by sharing this information will further spur citizen-science and long-term monitoring, which will be a way forward for our future. Together with the Department of Fisheries Malaysia, we also published other management and monitoring protocols for public usage after the events. As a team, we hope the information will provide a detailed insight of coral reefs surrounding Pulau Redang for proper management of these important resources.

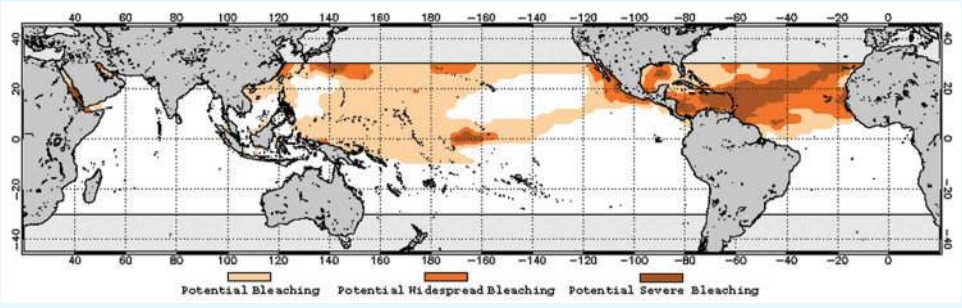
Nonetheless, we (scientists and management team) have been working closely to better understand and manage coral reefs ecosystem in Malaysia. In many ways, we believe everyone can contribute differently to the coral reefs. We would like to express our deepest gratitude for the financial support provided by the Department of Fisheries Malaysia and facilities support by the Universiti Malaysia Terengganu. Not forgetting all members and partners for their generous support and kind cooperation for many years.

Lee Jen Nie
Yusri Yusuf
Md Nizam Ismail
Albert Apollo Chan

INTRODUCTION

Coral reefs ecosystems around Malaysia generate goods and services (e.g. food, coastal protection, tourism) that can be considered important for Malaysia's socio-economic growth (Lee et al., 2012). However, the declines of coral reefs health are closely linked to rising sea surface temperature, SST (in relationship to climate change). Records and warning of coral bleaching in 2009-2010 (Figure 1) had not highlighted the area of Malaysia to be impacted of the major event. However, during 2010, the bleaching highly impacted the reefs in Malaysia with first photographic event observed by Tan & Heron (2011), and further reported by Guest et al. (2012) of lower bleaching and mortality indices compared to Pulau Weh and Singapore. The bleaching details for corals in Pulau Redang were recorded with healthy coral in Mac 2010, and bleached in September 2010 (Figure 2).

(a)



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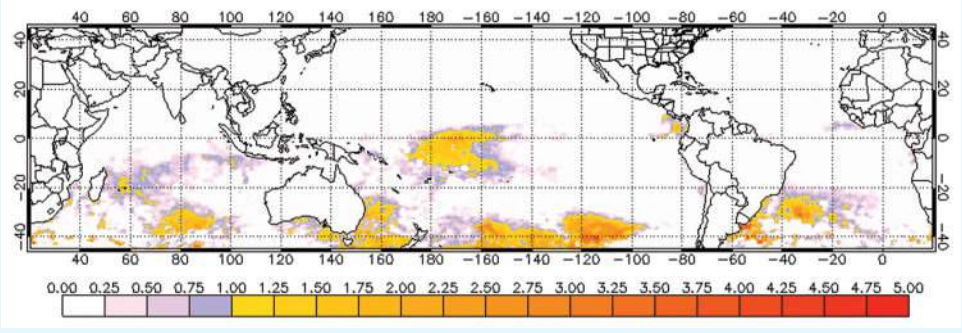


FIGURE 1: NOAA report for coral reef watch coral bleaching thermal stress outlook from (a) July to October 2009, and (b) coral bleaching hotspots recorded in April 2010. (*Source*: NOAA Coral Reef Watch)

(a)

(b)

FIGURE 2: Coral reef was in healthy condition in (a) March 2010 before the sea surface temperature increase to 32˚C in May that cause major bleaching impact to the reef during the surveyed in (b) September 2010 at Pulau Redang. (*Source*: Personal record from Lee, J.N. & Norhayati, A.)

Carbonate growth is a long term measurement and is important for their fitness and ecological success. By looking at the growth of carbonate organisms (such as corals for linear extension, or molluscs for wall thickness), repercussions on the recovery and resilience of coral reef ecosystem can be determined. Climate change has already impacted coral reefs in Peninsular Malaysia, and corals are highly vulnerable to its potential effects. Previous and on-going projects in Pulau Redang, showed decline of coral growth (calcification rate -21.3% and was negatively impacted by the increase of SST (Tanzil et al., 2013).

Ocean acidification (OA) is also an emerging global problem. Many marine organisms that produce calcium carbonate shells or skeletons are greatly impacted by the increasing CO_2 level and decreasing pH in seawater, apart from the increasing SSR. Both increase of OA and SST have been shown to significantly reduce the ability of reef-building corals to produce their skeletons. Subsequently weaken the health of the coral reef ecosystem, and besides that, there are many other disturbances to the coral reef health including tourism activities, coastal development and sedimentation. Previous report in Pulau Redang Carrying Capacity for year 2011, has shown the present of tourism activities such as snorkeling and diving impacted the reef ecosystem, even though value is very minimal (Lee et al., 2012). Meanwhile, sedimentation rate in Pulau Redang was recorded low with less than 5mg/cm^2/day (Lee & Mohamed, 2011).

Coral cover with 149 species in Pulau Redang Marine Parks were generally good (mean 43.7%) with low variation pattern between each sites (Harborne et al., 2000). Branching *Acropora* had higher percentage cover in Chagar Hutang, Pulau Lima and Pulau Lang Tengah while non-*Acropora* corals were found dominating the sampling site in Teluk Mat Delah, Pulau Ling and Terumbu Kili (Harborne et al., 2000). The transect conducted in the marine parks in year 2000 generally had higher cover of non-*Acropora* corals, such as *Favia*, *Pavona*, *Ctenactis*, *Pocillopora*, *Porites*, and *Galaxea*, compared

to *Acropora* corals such as *Montipora* and *Astreopora*. In Chagar Hutang and Terumbu Kili, little anthropogenic impacts were found (Harborne et al. 2000). *Diadema*, edible sea cucumbers and *Tridacna* were seen regularly in the marine parks and that the dead corals seen were believed to be impacted by the bleaching event in 1998 (Harborne et al. 2000). Sighting of *Acanthaster planci* (Crown-of-Thorns, COT) and/or *Drupella* snails, recorded in all sites on the Reef Check transect were believed to be the cause of damage in Pulau Ling, Pulau Lang Tengah and Terumbu Kili.

Another field study carried in May and October 2011 found that *Pocillopora* dominated the hard corals in Terumbu Kili, where no obvious siltation and anthropogenic input were seen (Lee et al., 2012). In Pulau Ling, Mak Cantik and Pulau Paku Besar, *Acropora* were seen dominating the hard coral cover with low anthropogenic impact. In House Reef of Redang Marine Park Center, despite green fins rules were introduced, debris and solid waste were found in the site during the field survey. The dominant coral found in Pulau Lima was foliose *Montipora*, instead of branching *Acropora* that was recorded in 2000 (Lee et al., 2012). In overall, non-*Acropora* was dominant compared to *Acropora* corals at 60.2% and 39.8% respectively.

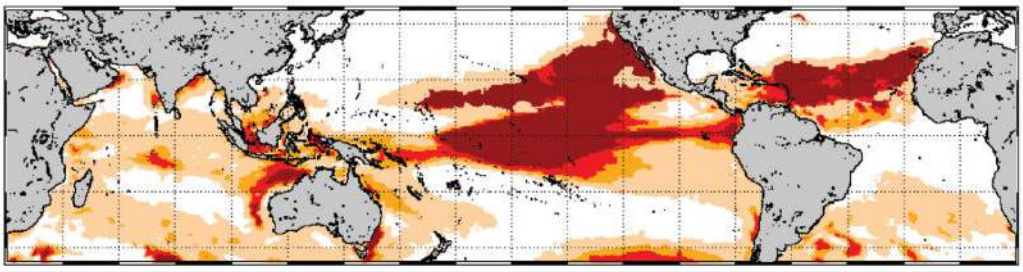
Some very uncommon fishes sighted in the Marine Parks in 2011 were the white-tip reef sharks, barramundi cod and bumphead parrotfish. Fish survey found that indicator reef fishes; Butterflyfish, Sweetlips, Snapper, Barramundi cod, Humphead wrasse, Bumphead parrotfish, Moray eel, and Grouper increased in overall during the October survey compared to survey carried out in May 2011 (Lee et al., 2012). It is believed that the abundance was in relation with tourists as peak season was in May where presence of snorkelers and divers in the reef vicinity might have caused disturbance to the fishes, and monsoonal changes that also affected the fish abundance (Lee et al., 2012).

The water quality determination in Pulau Redang was also carried out in May and October 2011. Earlier survey found that the water quality was generally good and clean but, the oil and gas concentration exceeded the Class I (for Preservation, Marine Protected Areas, Marine Parks) of Malaysia Marine Water Quality Criteria and Standards (MMWQS) that might contributed by the boats and ferried parked in the area. These concentrations however, did not exceed the Class II (for Marine Life, fisheries, coral reefs, recreational and mariculture) of MMWQS (Lee et al., 2012). The overall water quality recorded in May was generally good and safe for water activities.

Survey conducted again in October recorded a good marine water quality. The river water collected near Redang Lagoon and Redang Pelangi were polluted as high concentration of chlorophyll, turbidity and *E.coli* was recorded (Lee et al., 2012). The high concentration of chlorophyll might have caused the turbidity and *E.coli* concentrations to increase too however, *E.coli*, usually does not survive in sea water. In overall, the water quality in P. Redang was good except for Redang Lagoon and Redang Pelangi area which needed monitoring as to prevent the area from becoming polluted (Lee et al., 2012).

Understanding the nature and cause of changes in coral reef ecosystem though manipulative field and laboratory studies is essential in order to pre-empt possible undesirable outcomes of the ecosystem. It will also provide better understanding to better manage the resilience of coral reefs to anthropogenic and climatic impacts in the future. This was based on the early warning of major bleaching event that was release by NOAA (Figure 3). Marine Park Malaysia (Division of Research and Resource Inventory) also made an effort to observe the bleaching events in Malaysia, and reported low bleaching incident in Pulau Redang (Figure 4).

(a)



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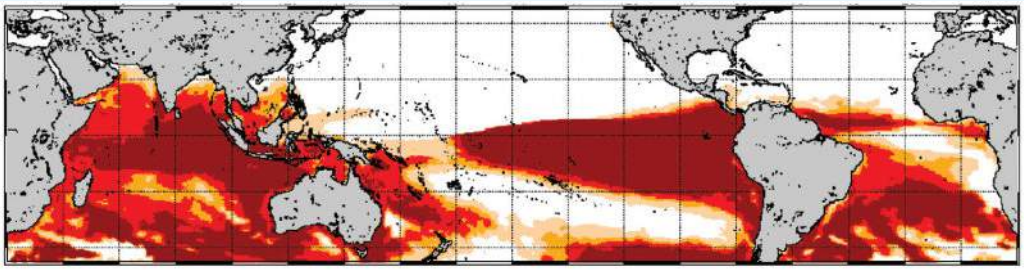

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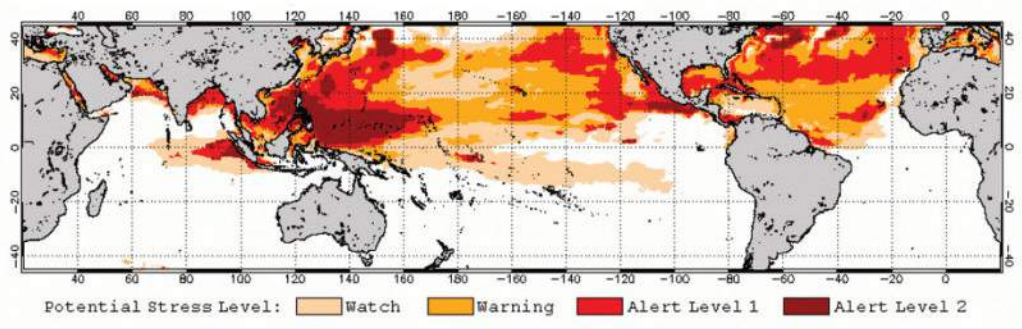

FIGURE 3: NOAA released warning for major coral bleaching on October 2015, for the thermal stress for (a) Oct-Jan 2016 and (b) Feb-May 2016, which highly suspected to impact Malaysia reefs, and continue to release another warning for June-September 2016 in June 2016. The warning system have increase the local agencies to be aware of the current situation. (*Source*: NOAA Coral Reef Watch)

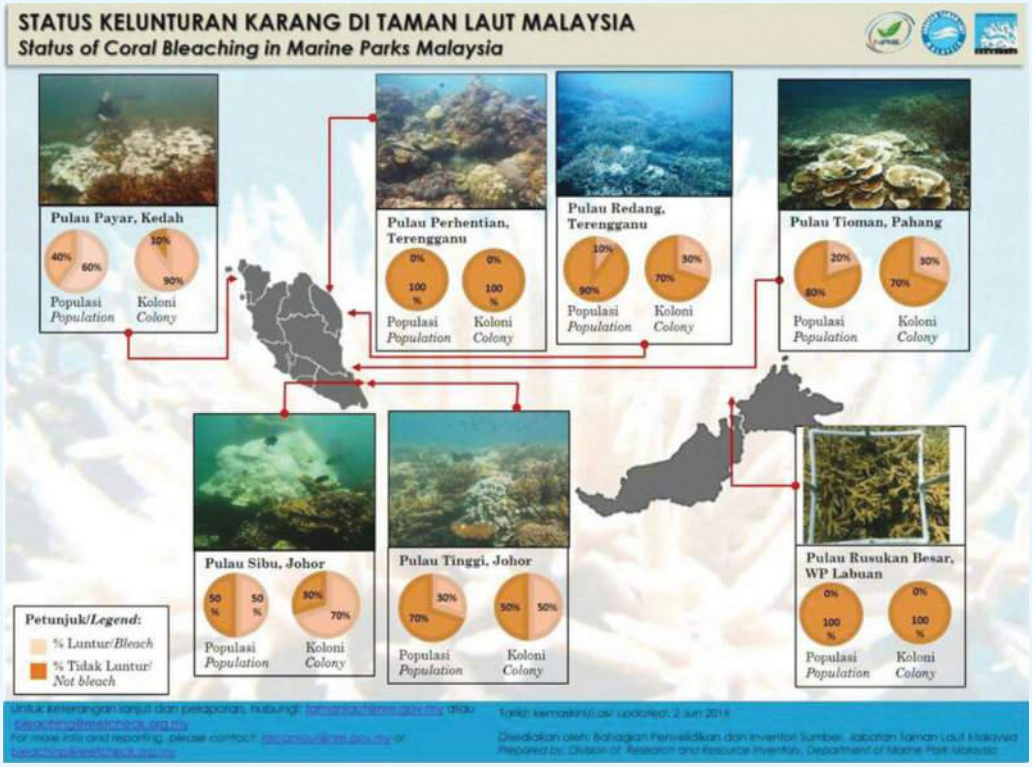

FIGURE 4: Status of coral bleaching in Marine Parks Malaysia that was release by the Department of Marine Park Malaysia on 2nd June 2016. (*Source*: Department of Marine Park Malaysia)

METHODOLOGY

Sampling Locations

The selected reefs were identified to monitor and collect coral reef informations surrounding Pulau Redang with locations from north (Chagar Hutang; CH), south (Terumbu Kili; TK), east (Pulau Lima; PL) and west (Pasir Mak Simpan; MS) (Figure 5). Pulau Kerengga (KR) was selected as a control site, as the coral growth in the location was reported for 30 years (1980-2010) and has good coral cover of 59% (Lee et al. 2012; Tanzil et al. 2013). The climatic and oceanographic conditions of Pulau Redang are characterized

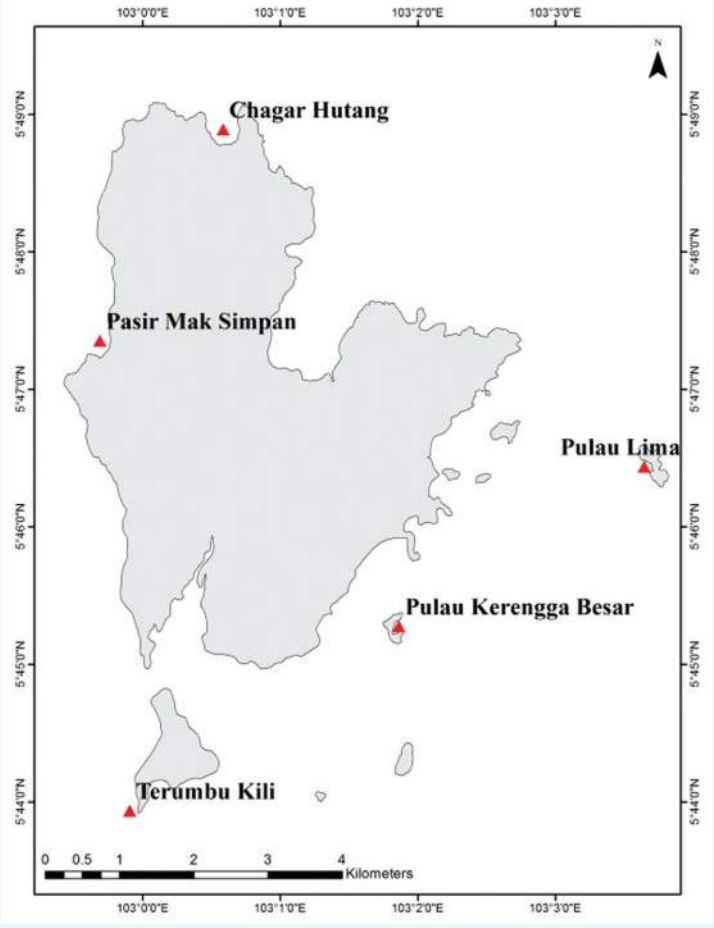

FIGURE 5: Map of the study area around Pulau Redang, showing general reef sampling sites for five locations.

by heavy rain and rougher seas during the northeast monsoon (November-February), experiencing less wind and rain during southwest monsoon (April-October). Sampling was conducted in 18-20 May, 9-12 August and 22-24 October 2016. Permanent transect of 50 m (shallow; ~3-5 m and deep; ~10-12 m) was laid in all sampling locations, except Chagar Hutang and Mak Simpan (only shallow transect).

a. Environmental Parameters

Temperature loggers were deployed at all sampling locations. Total alkalinity in the surface water were monitored and recorded as base-line data in Pulau Redang during each sampling period of this study. The long-term records of various environmental parameters (including sea temperature, surface wind speed and rainfall amount) were obtained through meteorological archives (MET department), satellite data, as well as published records from literature. These environmental parameters data retrieval is the on-going part of this study which involves 6 months of *in situ* measurements, which not only update the records of the environmental conditions but is also used to verify remotely sensed environment.

In situ temperature data were collected from the beginning of sampling (May) till the end of sampling (October), for Chagar Hutang and Pulau Lima (11 m). Department of Marine Park Malaysia also collected *in situ* temperature data at Pulau Redang Marine Park Jetty. Two other loggers (located at Mak Simpan and Pulau Lima, 3 m) that were deployed at the beginning, were broken during the sampling period.

b. Coral Bleaching Monitoring

Coral colonies at/nearby the permenant transect were measured for the actual colour of the bleached and healthy corals according to Coral Health Chart (Sieback et al. 2006). The coral charts that corresponds to the

concentration of symbionts (zooxanthellae) in the coral provides a simple way to quantify coral health. This method was used globally to monitor bleaching event.

c. Fish Community

Herbivorous reef fishes play a critical role in coral reef resilience by limiting the growth of algal community especially after the coral bleaching event. Herbivorous reef fishes are diverse and they composed of several functional groups that play different roles. The community of coral reef fishes were monitored using the same transect from coral bleaching monitoring, to determine the changes in the reef fishes community. Total number of individual for each coral reef fishes were recorded along the belt transect of 5m x 50 m (250 m^2 area). Each transect were observed three times according to the different sampling period.

d. Reef Assessment

Photo quadrat (0.5 x 0.5 m) were taken along the coral bleaching monitoring transect of 50m in shallow and deeper water. Semi-quantitative (e.g. coral community) and quantitative samples (e.g. coral cover, genera, size classes, algae community) were determined using Coral Point Count with Excel extension (CPCe) (Kohler & Gill, 2006).

RESULTS

Environmental Parameters

Temperature data from *in situ* logger at Marine Park Redang Jetty, Pulau Lima and Chagar Hutang showed similar pattern of sudden decrease of temperature from 31.5˚C in mid-May 2016 to 29˚C in early Jun 2016 (Figure 6). All locations have slight differences of water temperare with the range of less than 0.5˚C. The pattern/changes of sea surface temperature in 2016 was different from 2010. During the previous major bleaching event, the temperature peak at 32˚C in May 2010, and stay in the range of 31-32˚C for more than a month before gradually decrease to 30˚C by September 2010 (Figure 7).

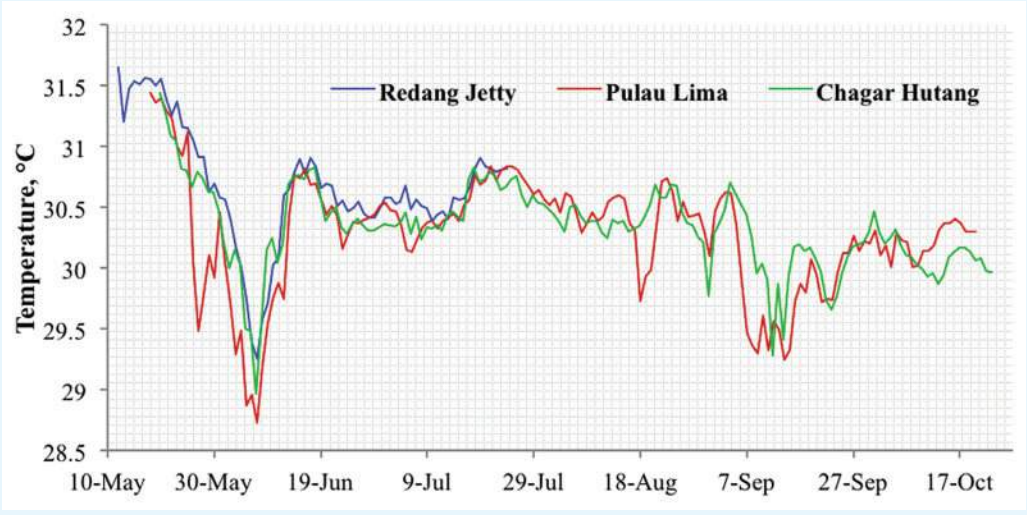

FIGURE 6: Graph showing the temperature reading for MP Redang Jetty, Chagar Hutang, Pulau Lima between 28.7-31.5˚C between May to October 2016.

The seasonal pattern of sea surface temperature were also obtained from HadISST (satellite data) and local Meteorology Department at Kuala Terengganu (Figure 8). Similar pattern were observed for both data. However, air temperature recorded by Meteorology Department were slightly lower then the satellite or *in situ* data.

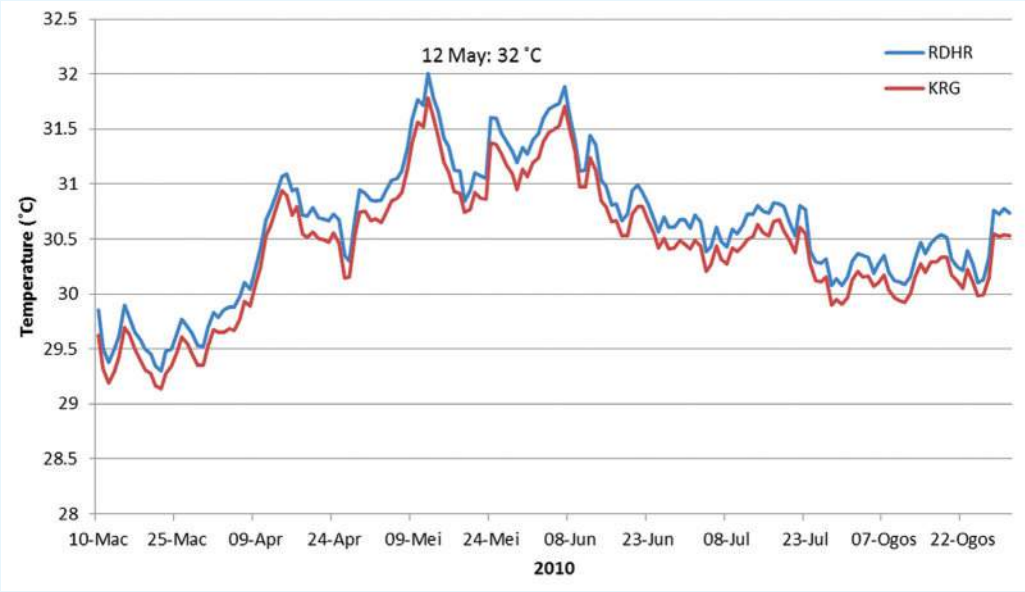

FIGURE 7: Sea surface temperature using insitu logger at Pulau Kerengga (KRG) and Teluk Kalong House Reef (RDHR) in 2010 mark the highest temperature at 32˚C on 12 May.

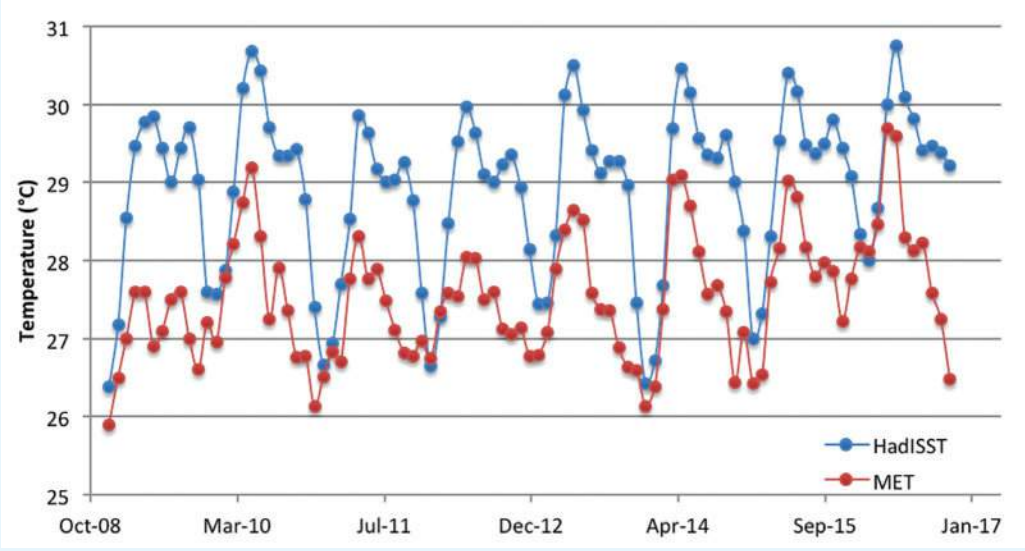

FIGURE 8: Temperature data retrieve from satellite and meteoroloty department showed similar patterns of temperature.

Apart from physical data, water quality parameters were also collected during each sampling. Temperature, (˚C); (b) Conductivity, (mS/cm); (c) Dissolved oxygen (mg/L); (d) Dissolved oxygen saturation (%); (e) pH; (f) Salinity (pss); (g) Total alkalinity ($CaCO_3$, mg/L) (Figure 9).

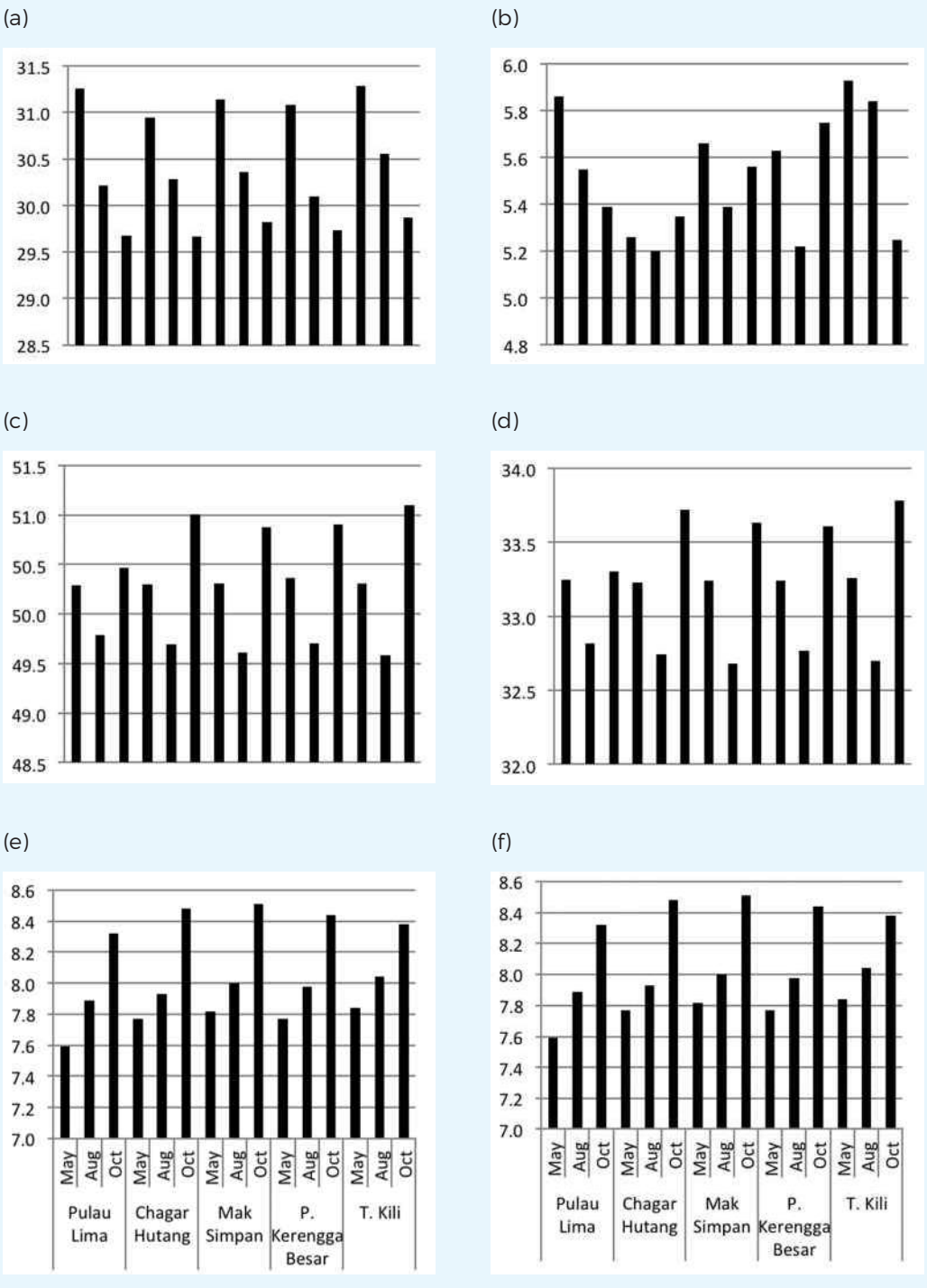

FIGURE 9: Physical parameters for (a) temperature, (˚C); (b) dissolved oxygen (mg/L); (c) conductivity, (mS/cm); (d) salinity (pss); (e) pH; and (f) total alkalinity ($CaCO_3$, mg/L) at each selected site for all sampling.

Coral Bleaching Monitoring

A total of 572 colonies of corals were measured using Coral Watch. Major bleaching event was predicted to happen in Pulau Redang. However, during the first sampling in May 2016, only minor bleaching event was observed. When we interviewed local operators, more severe bleaching were reported before the sampling. However, they recover soon after before the sampling in May. Monitoring was still conducted, and the result shows that bleaching was less than 10%, during May 2016. Most of the corals recovered within the next few months (~3 months) even though some bleaching (CW2; Figure 10) were observed in August and October 2016 (Pulau Lima; Table 1). The bleached corals were partially bleached due to local disturbance. All locations showed increase of healthy coral (CW4-6) from May to October 2016, except at Terumbu Kili (Table 1). Minor bleaching were observed at Terumbu Kili for mushroom coral. No significant differences were observed between sites and months.

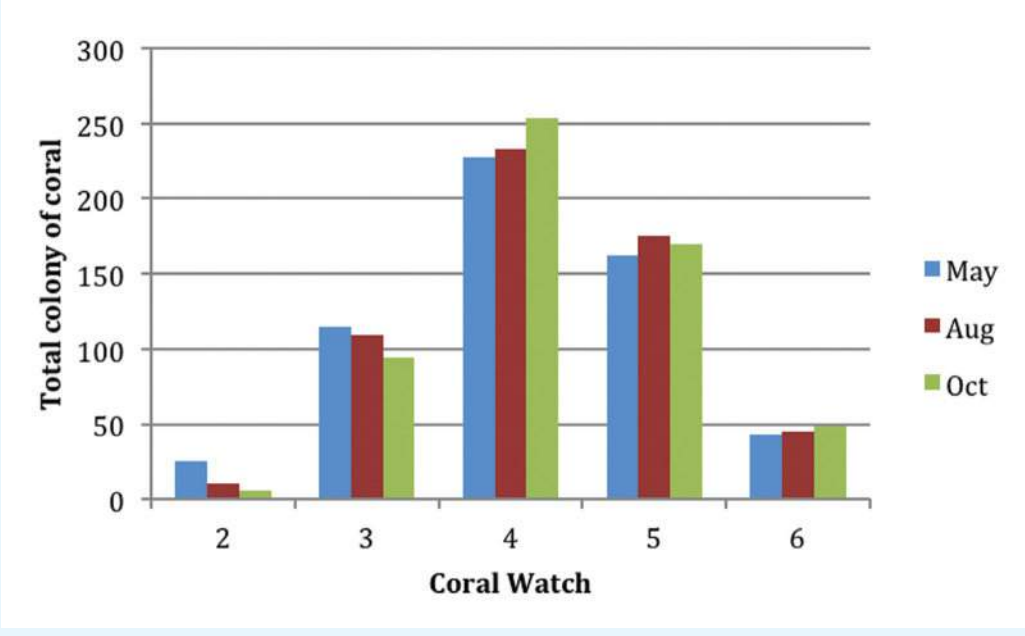

FIGURE 10: Coral score (Coral Watch) shows between 2-6 in all surveyed. Coral from score 3 and above indicating healthy reefs. Small numbers of coral colony were counted in score 2. (2-6) in May, August and October 2016.

TABLE 1: Coral colonies at Pulau Lima, Pulau Redang were categorized using coral health colour according to Coral Watch.

Sites	Month 2016	Percentage colony (%, Coral Watch Colour)					
		CW2	CW3	CW4	CW5	CW6	CW4-6
Pulau Lima	May	4.3	26.9	48.4	20.4	0.0	68.8
	Aug	0.0	21.5	40.9	37.6	0.0	78.5
	Oct	0.0	5.4	64.5	28.0	2.2	94.6
Pulau Kerengga	May	3.6	15.2	40.6	28.3	12.3	81.2
	Aug	0.0	14.5	42.8	29.7	13.0	85.5
	Oct	0.0	12.3	45.7	31.2	10.9	87.7
Terumbu Kili	May	0.0	26.2	31.1	31.1	11.5	73.8
	Aug	0.0	24.6	32.8	32.8	9.8	75.4
	Oct	0.0	31.1	32.8	26.2	9.8	68.9
Chagar Hutang	May	8.7	15.7	41.7	26.8	7.1	75.6
	Aug	3.9	16.5	47.2	25.2	7.1	79.5
	Oct	1.6	18.9	43.3	28.3	7.9	79.5
Mak Simpan	May	5.2	19.6	35.3	33.3	6.5	75.2
	Aug	3.3	21.6	36.6	30.7	7.8	75.2
	Oct	2.6	19.0	35.9	32.0	10.5	78.4

Fish Community

Fish composition at Pulau Redang were observed for each species and total abundance were collected at each stations at each station during every sampling (Figure 11). The total number of species recorded at Pulau Redang were 142 species from 31 families of coral reef fishes (Table 2). No significant changes of coral reef fishes were observed over time at each location. Mak Simpan recorded the highest species diversity when compared to the other sites. Large community of *Lutjanus lutjanus* were found schooling at Terumbu Kili during the sampling.

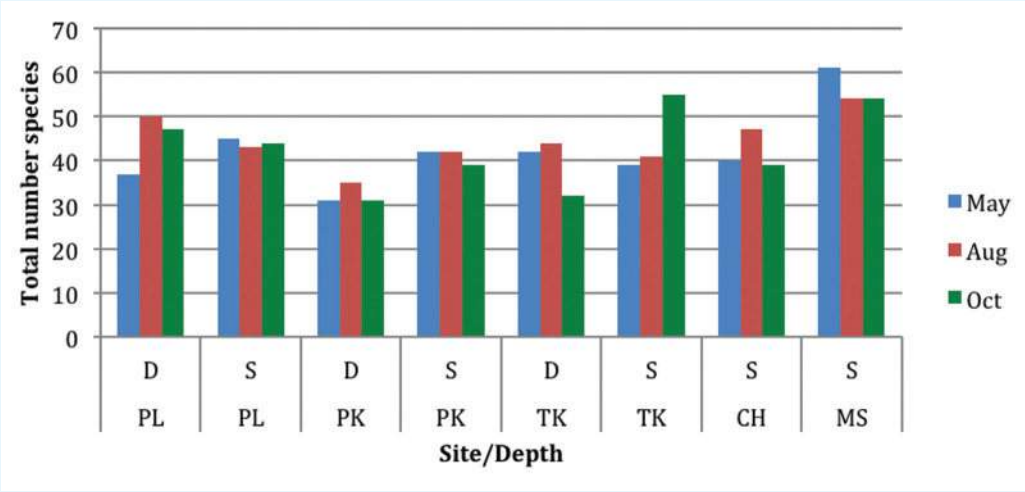

FIGURE 11: Total number of coral reef fish species at Pulau Lima (L), Chagar Hutang (CH), Mak Simpan (MS), Pulau Kerengga (KR) and Terumbu Kili (TK) for each sampling conducted in 2016.

TABLE 2: List of coral reef fishes at each specific location (PL-Pulau Lima, CH-Chagar Hutang, MS-Mak Simpan, PK-Pulau Kerengga, TK-Terumbu Kili) at May, Aug and Oct 2016.

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
FAMILY	**DASYATIDAE**																								
Taeniura	*lymma*																						1		
FAMILY	**MURAENIDAE**																								
Siderea	*prosopeion*											1													
Siderea	*thyrsoidea*							1																	
FAMILY	**SYNODONTIDAE**																								
Synodus	*variegatus*						1				1					1									1
FAMILY	**HOLOCENTRIDAE**																								
Myripristis	*kuntee*			4		1			1	2	1		1							3	1				
Sargocentron	*rubrum*			1	1		3	1				1	1						1	1	6				1
FAMILY	**SERRANIDAE**																								
Cephalopholis	*boenack*			2	3	3	8		5	6	5		3			2						9	3		
Cephalopholis	*cyanostigma*	3	1		4	1		3	7	2	1	4	7	3	1	1	4		2	6	1		1	2	2
Cephalopholis	*formosa*																			1					
Cephalopholis	*microprion*	1	5	2	5			8	6			11	6	12	3	3	8	4	8	2	14	1		3	8
Ephinephelus	*fasciatus*					1				1				1					2		1				
Plectropomus	*areolatus*																							1	
Plectropomus	*maculatus*									3									2						
FAMILY	**PSEUDOCHROMIDAE**																								
Pseudochromis	*fuscus*				1											2								3	5
Pseudochromis	*ransonneti*				1																				

Continued

Continue **TABLE 2**

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
FAMILY	**APOGONIDAE**																								
Apogon	*compressus*		3		20								40		2			2		61					
Apogon	*cyanosoma*							120		5	5	70							5	50	18	30		1	
Apogon	*trimaculatus*												2							2					
Archamia	*fucata*																			412					
Archamia	*macroptera*												50												
Cheilodipterus	*artus*	3											85	25	3				7	10					
Cheilodipterus	*intermedius*													4						900					20
Cheilodipterus	*quinquelineatus*	2	23	20	37			60		5	30	70	60	21	50		36		9	62	2	30			14
Cheilodipterus	*macrodon*	1	1										12							52					
Rhabdamia	*gracilis*							3																	
FAMILY	**ECHENEIDAE**																								
Echeneis	*naucrates*									1															1
FAMILY	**CARANGIDAE**																								
Carangoides	*ferdau*																			1					
FAMILY	**LUTJANIDAE**																								
Lutjanus	*lutjanus*							15k					15k	100				40	158						
FAMILY	**CAESIONIDAE**																								
Caesio	*caerulaurea*		3		1			60				150		25	2		6			170					
Caesio	*cuning*			7				141	23			9													
Caesio	*teres*							6																	
Pterocaesio	*chrysozona*	5			20							13							30						

Continued

Continue **TABLE 2**

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
FAMILY	**NEMIPTHERIDAE**																								
Pentapodus	*caninus*			3	2			1				1					2			1	4				
Scolopsis	*affinis*										1	1		1			1								
Scolopsis	*bilineatus*		1					1										1		1					
Scolopsis	*ciliatus*							5				6									1				
Scolopsis	*lineatus*											1			2					1	10	1			
Scolopsis	*margaritifer*	2					1	1		1		2		2		1	1	1	2				2		2
Scolopsis	*monogramma*																								1
FAMILY	**LETHRINIDAE**																								
Lethrinus	*erythropterus*															1	1								
FAMILY	**MULLIDAE**																								
Parupeneus	*barberinus*			1																					
Upeneus	*tragula*																							1	
FAMILY	**PEMPHERIDAE**																								
Pempheris	*oualensis*						7				2		10		5										
Pempheris	*venicolensis*																	3		1		1			
FAMILY	**KYPHOSIDAE**																								
Kyphosus	*chinerascens*																		1						
FAMILY	**EPHIPPIDAE**																								
Platax	*tiera*					1		1																	
FAMILY	**CHAETODONTIDAE**																								
Chaetodon	*adiergastos*															2	1			1			1		
Chaetodon	*baronessa*				1												1							1	2

Continued

Continue **TABLE 2**

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
Chaetodon	*octofasciatus*	20	16	37	46	10	21	16	18	18	21	30	28	12	10	28		13	17	21	21	35	18	11	24
Chelmon	*rostratus*																		1						
Coradion	*chrysozonus*	3			1			1				1		1			2		1	1				1	
Coradion	*altivelis*																								2
FAMILY	**POMACANTHIDAE**																								
Chaetodontoplus	*mesoleucus*	2			2				5	2		7	3	2	3				1	7	3		1		2
Centropyge	*tibicen*																		1						
Pomacanthus	*annularis*	2			1											2	1								
Pomacanthus	*sexstriatus*													2											
FAMILY	**POMACENTRIDAE**																								
Abudefduf	*bengalensis*			1	3					1	15		1			2	4			1					2
Abudefduf	*sexfasciatus*		4	4	15			14	12			15	1		5	28	6	11	1	2	30	12			15
Abudefduf	*vaigiensis*		3		24			6			2						1	21			1				2
Amblyglyphidodon	*aureus*								1																
Amblyglyphidodon	*curacao*	95	122	62	108	37	83	7	1	12	68		95	30	86	5	255	64		47	1	32	1	5	225
Amblyglyphidodon	*leucogaster*	86	27	36	7		1	10	13			27	24	77	6		2	44	20	1	20				2
Amphiprion	*clarkii*	3			5	3							3	3	8		3		5	2					3
Amphiprion	*frenatus*												2				2			1					
Amphiprion	*ocellaris*	26	31		7	6				19				20	37			66	30				13		
Amphiprion	*perideraion*		17		7		10			2	10				15		4	28							5
Cheiloprion	*labiatus*	15	19		9		48				34			23	20		20	11	19			54			13
Chromis	*atripectoralis*	1	15		320		19	5	400		100	60	400	7	4		320	20	21	180	9	106		5	388
Chromis	*cinerascens*							80	12			23								2	5				
Chromis	*viridis*			20	40		20		50	5	50											60			

Continued

Continue **TABLE 2**

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
Dascyllus	*reticulatus*	155	10	18	25	3		330	176	13		240	80	126	26	12	12	36	99	146	341		3	4	40
Dascyllus	*trimaculatus*							73	2	2		295	5		1			1	1		35				
Dischistodus	*fasciatus*																					2			
Dischistodus	*melanotus*				6												7							2	10
Dischistodus	*perspicillatus*			2	16												3								11
Hemiglyphidodon	*plagiometapon*	26	25	4	9			4				1	5	29	20	2	14	16	56	5	3			3	18
Neoglyphidodon	*melas*	13	19	26	50	34	41	7	9			5	29	1	9			41	25	34	2	43	34	25	35
Neoglyphidodon	*nigroris*		26	3			4			24	53			11	27	19	16	7		10	2	4		1	1
Neopomacentrus	*anabatoides*	85	250	5	20				1000	20			300		20		10	1000		250		40			
Neopomacentrus	*cyanomus*	30		30	12			20	200			15		300		20	50							5	24
Plectroglyphidodon	*lacrymatus*				6		14				7						18					41		2	8
Pomacentrus	*adelus*							46		15		7		4		23	5		2	3	2	4	253	11	
Pomacentrus	*alexanderae*	220		65	35	81		236		217		390		740	9	100	25	75	710		365			150	20
Pomacentrus	*chrysurus*			67	14	8	6		1	9	3					11	1					10	9	8	4
Pomacentrus	*coelestis*	2		31	3	8		2		8		2				16			10		2		10	5	
Pomacentrus	*cuneatus*				1	1		1		11		180		14		5			26		69		24	10	2
Pomacentrus	*grammorhynchus*	20	36	8	24		63	2			52	1		24	44	3	16	19	22	2	2	57		5	34
Pomacentrus	*milleri/cuneatus/ grammo*					47	3	216	11																
Pomacentrus	*moluccensis*	79	18	33	379	5	93	180	210	4	54	88	40	134	28	54	170	64	244	120	110	127	6	64	193
Pomacentrus	*philippinus*		2	185	37	67	19	5	4	85	8					125	35		1			57	146	88	48
Stegastes	*lividus*													5											
Stegastes	*obreptus*						9		3		4			1	2	1	1			5		1			2

Continued

Continue **TABLE 2**

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
FAMILY	**LABRIDAE**																								
Cheilinus	*chlorourus*	1	2	2	1	1	5			1	2	5	1	1		3	1	3	1	1			3		3
Cheilinus	*fasciatus*	8	12		2		2		6			12	10	11	9	1	2	7	10	15			1		3
Cheilinus	*trilobatus*		3									1								4					
Coris	*pictoides*						1																		
Diproctacanthus	*xanthurus*	6			5				4			1	2	2		2		5	6	4		13	2	5	11
Epibulus	*insidiator*	2	9	1	2		1		7			5	9	2	4		2	6	2	11		1	3	2	3
Gomphosus	*varius*		1				2		1		2		1				1			1					1
Halichoeres	*chloropterus*				1		2		1	1		1		2		9	4	2		2		2	3	8	4
Halichoeres	*hortulanus*			9	1	1			2							1	1								
Halichoeres	*marginatus*		1	1	1									2		3	2								1
Halichoeres	*melanochir*																						6	1	7
Halichoeres	*prosopeion*				4	7				8						2	4								
Halichoeres	*scapularis*																	1							
Halichoeres	*vrolikii*	6	21		6		13	1	3	1	7		1	4	9	4	12	1	2	5		29		13	24
Hemigymnus	*melapterus*		6		4	1	6		1	3	4	3	4	6	1	3	2	1		1		5	6	1	1
Labroides	*dimidiatus*	5	6	1	4	2	6		1	4	6	3		5	4	2	5		8	3		5		2	4
Oxycheilinus	*diagrammus*	3		1	5	2	1		4	3	3	5	5	5	4	3	9	4	12	7		2	1	4	9
Pseudocheilinus	*hexataenia*		4						1					1	1			1							
Pteragogus	*cryptus*	3	3									2		4	1	1	1		10						
Stethojulis	*bandanensis*		6	3	1		1									2						2		1	4
Stethojulis	*trilineata*								2																
Thalassoma	*lunare*	4	55	20	14	2	14		68	8	11	1	60	5	27	23	25	17	4	5		15	10	19	11

Continued

Continue **TABLE 2**

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
FAMILY	**SCARIDAE**																								
Bolbometopon	*muricatum*															20									
Chlorurus	*sordidus*		6	5			2			1				1	2			7		1		13		3	
Scarus	*altipinnis*		1																			1			
Scarus	*forsteni*																	2							
Scarus	*ghobban*	3			1		4	2		1			1	6	4	4		11	1		2		7	2	
Scarus	*niger*		12				1							1	2			4	1						
Scarus	*prasiognatus*																					1			
Scarus	*rubroviolacens*										1							1	2						
Scarus	*rivulatus*	3	6	27		3	3	10		7	1			4	4	34		1	7			1	24	8	3
FAMILY	**SPHYRAENIDAE**																								
Sphyraena	*flavicauda*						100			20								200					4		
FAMILY	**TRIPTERYGIIDAE**																								
Helcogramma	*striatum*			6		12	3		4							5									
FAMILY	**BLENNIIDAE**																								
Ecsenius	*bicolor*			3		1										2						1			
Ecsenius	*yaeyamaensis*			5	2	2	1			1															
Meiacanthus	*grammistes*															1									
Salarias	*fasciatus*				2		20				2				2							5			
FAMILY	**GOBIIDAE**																								
Gobiodon	*citrinus*					1																			
Istigobius	*decoratus*				3												1								

Continued

Continue **TABLE 2**

		May 2016								Aug 2016								Oct 2016							
		PL	PL	CH	MS	PK	PK	TK	TK	PK	PK	TK	TK	PL	PL	CH	MS	PL	PL	TK	TK	PK	PK	CH	MS
	Depth	D	S	S	S	D	S	D	S	S	D	D	S	D	S	S	S	S	D	S	D	S	D	S	S
FAMILY	**SIGANIDAE**																								
Siganus	*canaliculatus*							1													3	4	2		
Siganus	*corallinus*										1						2			4					4
Siganus	*guttatus*		2		3	1								4	6		3	1							
Siganus	*virgatus*							2			1	1	2							7	3		1		
Siganus	*vulpinus*						2		1	1			2												
FAMILY	**BALISTIDAE**																								
Balistoides	*viridescens*		**1**															**1**							
FAMILY	**MONACANTHIDAE**																								
Aluterus	*scriptus*		1																						
FAMILY	**TETRAODONTIDAE**																								
Arothron	*nigropunctatus*												1												
Arothron	*stellatus*										1														
FAMILY	**DIODONTIDAE**																								
Diodon	*liturosus*															1									
Total species		37	45	40	61	31	42	42	39	42	35	44	41	50	43	47	54	44	47	55	32	39	31	39	54
Total numbers		944	836	761	1390	353	664	16689	2276	554	568	1767	16392	1826	528	595	1141	1864	1606	2649	1089	857	599	486	1283

Reef Assessment

No changes of benthic composition from triple sampling in May, Aug and October 2016 were observed. Thus coral bleaching recovery was not observed in this study. Generally, Chagar Hutang (shallow) shows 25.55% of live coral cover (hard coral and soft coral) in 'Fair' condition. The highest percentage of benthic cover at Chagar Hutang was Rubble (RB) with 51.40%. The level of live coral cover in Mak Simpan is 33.88%, in 'Fair' condition. Composition of RB at Mak Simpan is also high, at 39.75%. Kerengga Besar (shallow) shows live coral cover at 53.52% in 'Good' condition. Kerengga Besar (deep) had live coral cover of 23.54% and categorised in Poor condition and RB cover was the highest in Kerengga besar (deep) at 39.42%. Pulau Lima (shallow), Pulau Lima (deep), Terumbu Kili (shallow) and Terumbu Kili (deep) had live coral cover of 29.95% (Fair), 50.16% (Good), 65.71% (Good) and 31.44% (Fair) respectively. Pulau Lima deep and shallow areas had very high NIA among benthic composition at 49.25% and 26.41% respectively. The level of NIA at Terumbu Kili in shallow and deep area are also high at 17.39% and 43.89%. Coral condition in the study were varied from Good to Poor condition. No sites exhibiting an Excellent condition. The live coral cover in all sampling sites range from 23.54% to 65.71% (Figure 12). 50% of the sites were in good condition, while 37.5% were in fair condition. The remaining 12.5% were in poor condition.

A total of 31 genera from 13 families of hard coral were identified at Pulau Redang (Table 3). Sampling sites at shallow water area had total number of hard coral genera lower than the deep water area. Pulau Kerengga Besar (deep) showed the highest number of coral genera at 22 while both shallow water area of Terumbu Kili and Pulau Lima showed the lowest number of coral genera of four (4). Chagar Hutang (shallow), Mak Simpan (shallow), Pulau Lima (deep) and both depths of Pulau Kerengga Besar had high total number of coral genera, more than 15. Both depths of Terumbu Kili and Pulau Lima (shallow) had a low total number of coral genera which were less than 10.

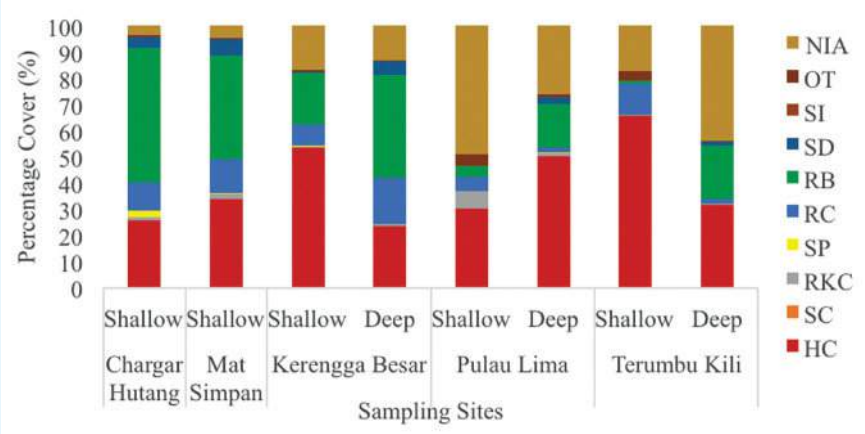

FIGURE 12: Average percentage of substrate components from May, Aug and Oct 2016 sampling.

Genus *Acropora* was identified at each sampling sites with the highest at Pulau Lima (shallow) with 98% area covered (Figure 13). While sampling sites for both depths at Terumbu Kili were dominated by *Pocillopora* with 60% and 49% at shallow and deep area respectively. Genus *Porites* was found dominant at Chagar Hutang (shallow), Mak Simpan (shallow) and Pulau Kerengga Besar (shallow) with more than 30% area covered at each sampling sites. While family Fungiidae was identified more than 40% coverage at Terumbu Kili (deep) and Pulau Lima (deep). 'Others' that represent in Figure 13 indicate the minority genera found with the percentage area covered were less than 1%.

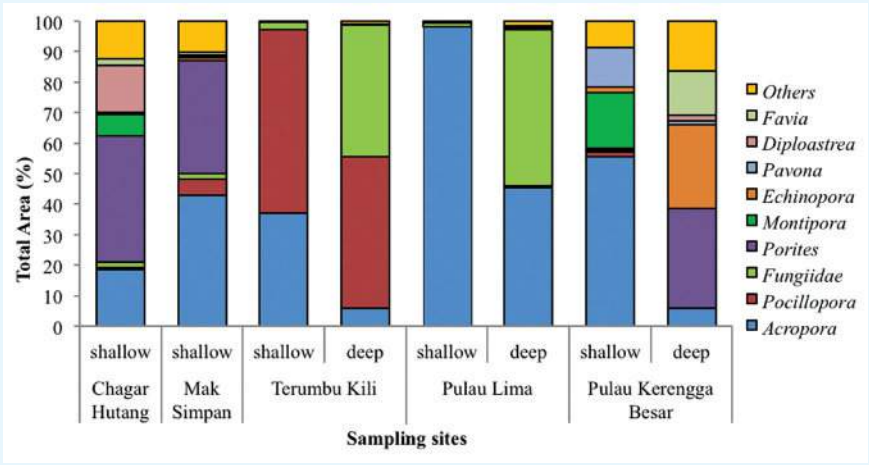

FIGURE 13: Total cover area of each coral genera from photo quadrate along 50 m transect line.

TABLE 3: List of hard coral genera accoring to family and genus at each specific depth and location.

Family	Genus	Chagar Hutang	Mak Simpan	Terumbu Kili		Pulau Lima		Pulau Kerengga Besar	
		shallow	shallow	shallow	deep	shallow	deep	shallow	deep
Acroporidae	*Acropora*	/	/	/	/	/	/	/	/
	Astreopora	/							
	Montipora	/						/	
Pocilloporidae	*Pocillopora*	/	/	/	/	/	/	/	
	Seriatopora				/		/		
Euphyllidae	*Euphyllia*						/		
	Physogyra						/		
Agariciidae	*Pavona*	/	/		/		/	/	/
	Coeloseris	/							
	Pachyseris	/	/				/		/
	Leptoseris	/	/		/				/
Pectiniidae	*Echinophyllia*	/						/	
	Pectinia		/				/	/	
Merulinidae	*Merulina*								/
Dendrophylliidae	*Turbinaria*			/				/	/
Mussidae	*Lobophyllia*	/							/
	Symphyllia	/	/					/	/
Faviidae	*Diploastrea*	/	/						/
	Leptastrea		/					/	/

Continued

Continue **TABLE 3**

Family	Genus	Chagar Hutang	Mak Simpan	Terumbu Kili		Pulau Lima		Pulau Kerengga Besar	
		shallow	shallow	shallow	deep	shallow	deep	shallow	deep
	Caulastrea			/	/		/	/	/
	Favites	/	/		/		/	/	/
	Goniastrea		/						/
	Platygyra	/					/	/	/
	Leptoraria								/
	Echinopora	/	/				/	/	/
	Favia	/	/		/		/	/	/
Trachyphylliidae	*Trachyphyllia*	/							/
Poritidae	*Alveopora/Goniopora*	/	/			/	/	/	/
	Porites	/	/		/		/	/	/
Oculinidae	*Galaxea*	/					/	/	/
Fungiidae		/	/	/	/	/	/	/	/
Unidentified		/	/				/	/	/
TOTAL	21	16	4	9	4	17	18	22	

SUMMARY AND RECOMMENDATION

This study assessed few critical aspects of climate change and coral reef because the increase of sea surface temperature were proven affecting the coral growth (as case study by Tanzil et al. 2013). Based on the components of this project, 1) environmental parameters, 2) bleaching monitoring, 3) fish community and 4), reef assessment, it is found that:

- Generally the water quality at Pulau Redang waters is in good condition.
- Major bleaching was not observed as predicted by NOAA. Less than 10% of corals were bleached during monitoring. Quick recovery of corals from pre-bleaching in April was reported by locals.
- Fish composition of 142 species from 31 families were recorded.
- Reef health condition were generally fair, and the highest coverage of 65.7% was recorded at Terumbu Kili. *Acropora*, *Pocillopora* and Fungiidae had the highest coral cover.
- 31 genera of hard coral were recorded, and is much lower than previous study by Harborne et al. (2000).

Recommendations:

- Climate change impacts have severly recorded around the globe, and Pulau Redang was not spare for the consequences. Short term study over 6 month (May-Oct 2016) have not showed any significant impacts of climate change to the ecosystem.
- Ecological data (eg: benthic composition, hard coral genera, fish composition) strongly suggest that **Pulau Kerengga Besar**, **Chagar Hutang** dan **Mak Simpan** should be properly manage expecially during major events such as major bleaching, local anthropogenic and oil spills. Those three location have shown high diversity of corals and fishes.

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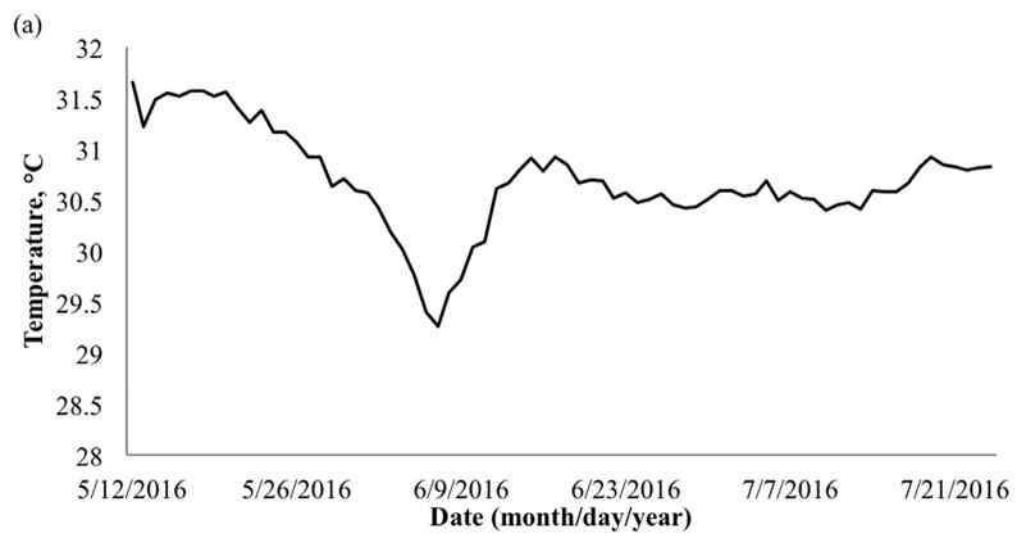
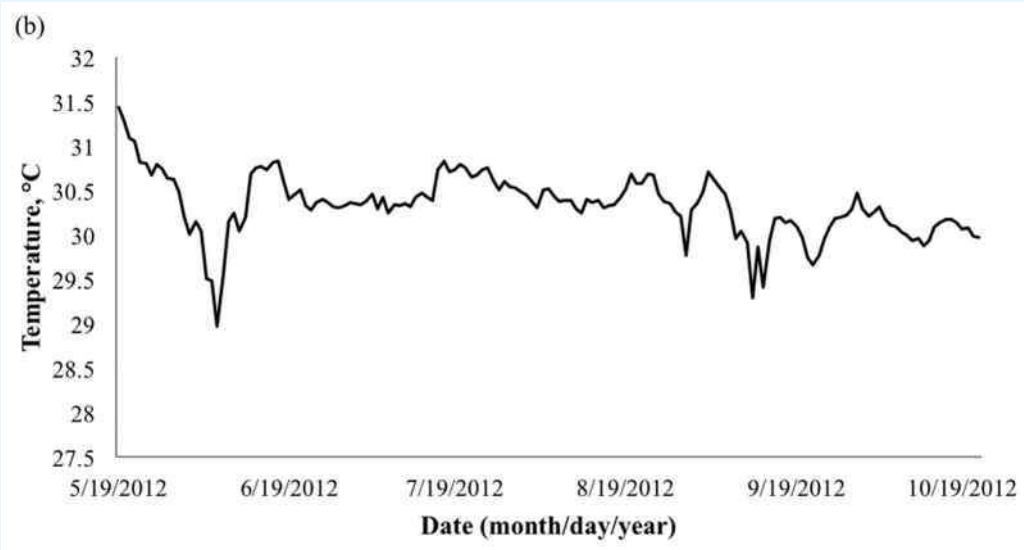
APPENDIX

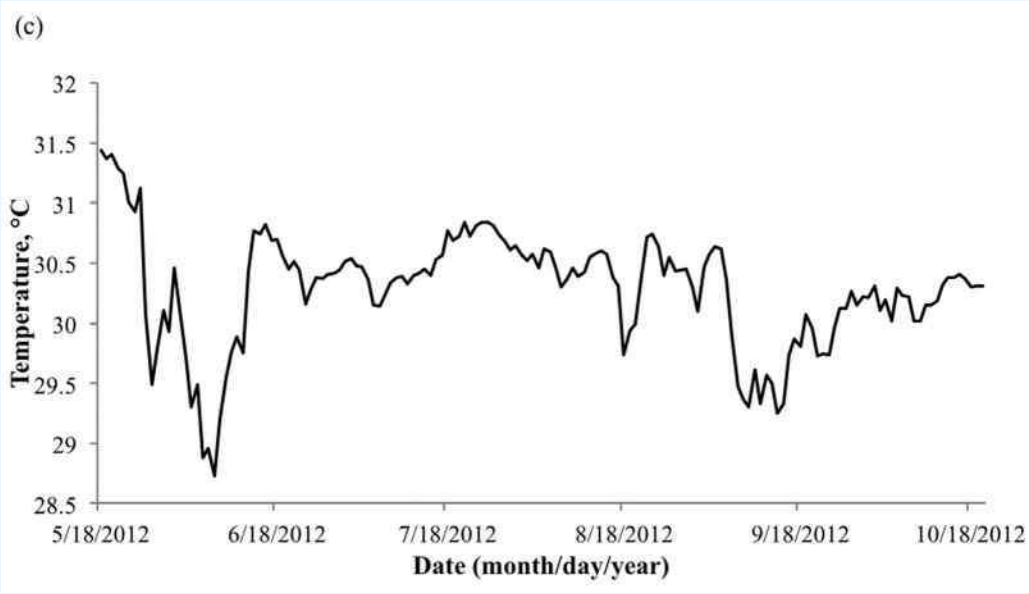
Temperature data from Pulau Redang Marine Park Jetty.



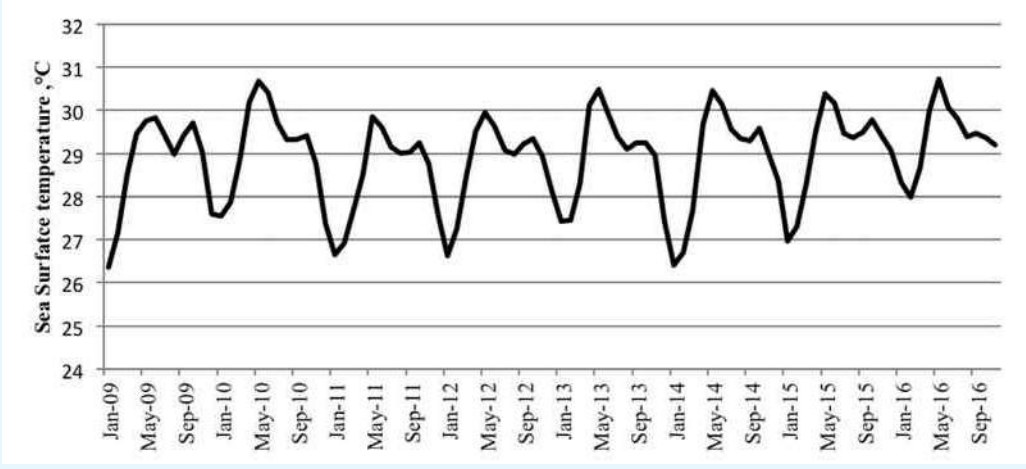
Temperature data from Chagar Hutang.



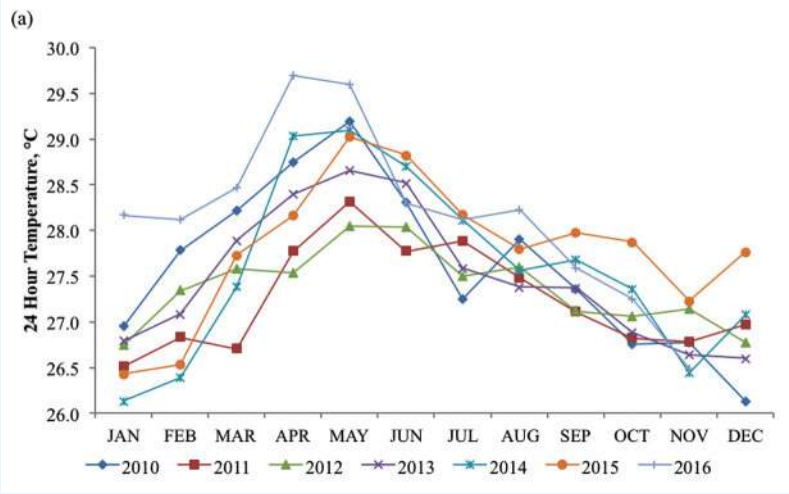
Temperature data from Pulau Lima.

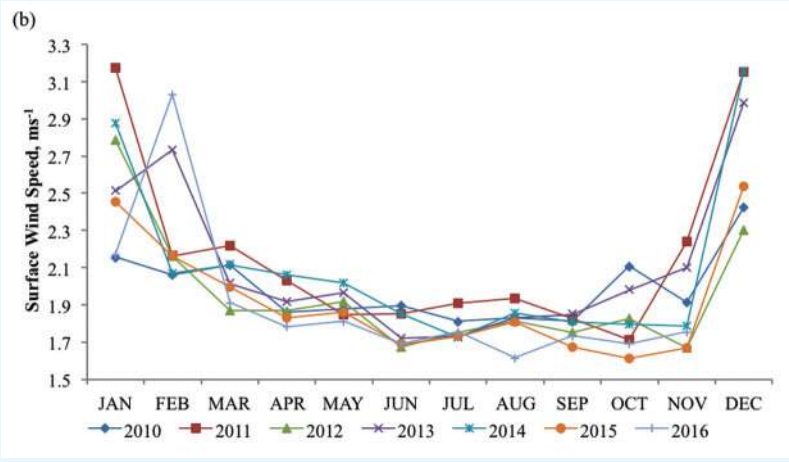


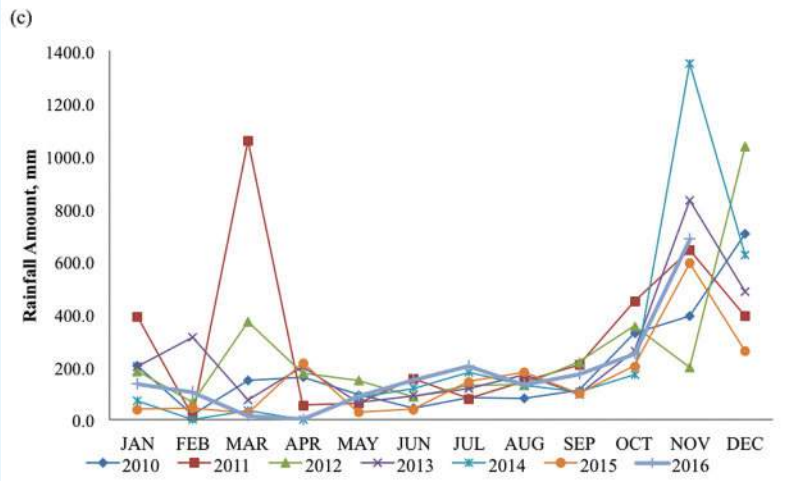
Sea surface temperature of Kuala Terengganu by hadISST.



Meteorology Department data for temperature, wind speed, and rainfall from Kuala Terengganu.







OUTCOMES

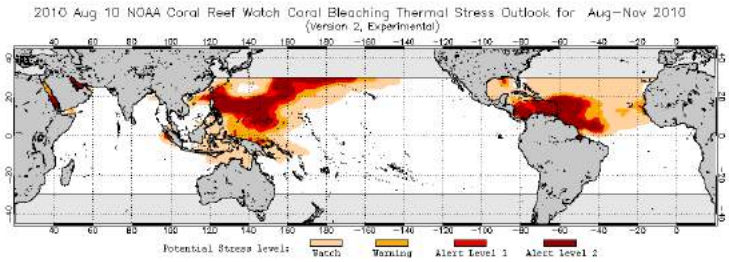
Previous Report

Ong, C.K., Lee, J.N., Md Nizam, I., & Chan, A.A. (2019). Climate change: sclerochronological records of massive *Porites* corals from Pulau Redang. Division of Marine Park, Department of Fisheries, Ministry of Agriculture & Argo-Based Industry, Putrajaya, Malaysia. 24 pp.

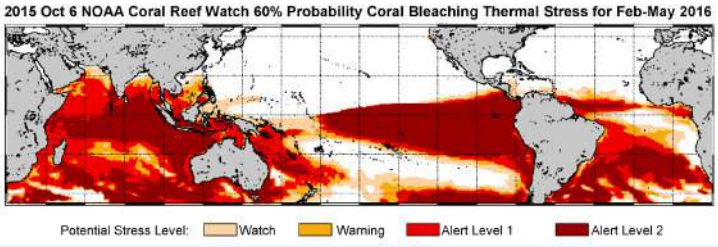
LIST OF CORAL PRESENTIONS

1. Seminar Penyelidikan Jabatan Taman Laut Malaysia 2017 (7 Mac 2017 Universiti Malaysia Terengganu, Terengganu)
2. 4th International Symposium of Marine and Fihseries (20 May 2017 Makassar, Indonesia) - as below

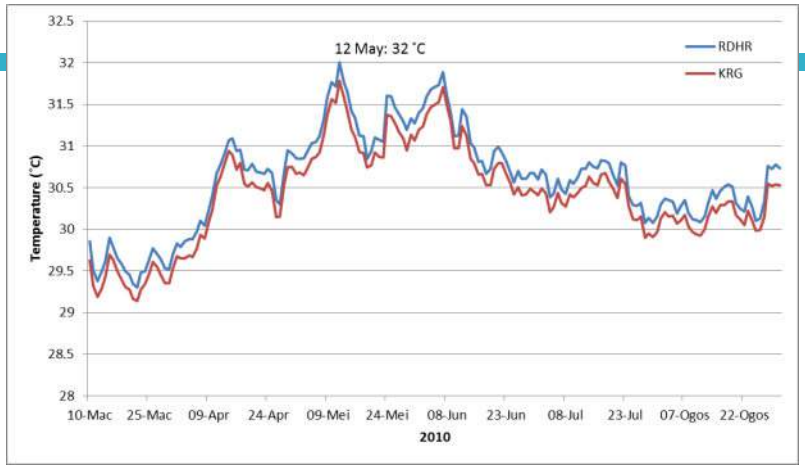
2010



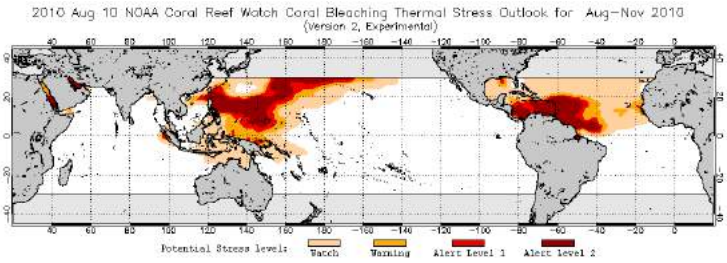
2016



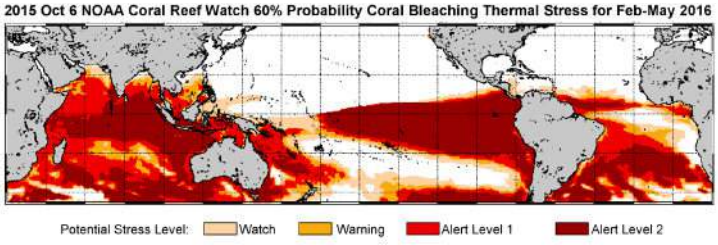
2010 temperature data.....

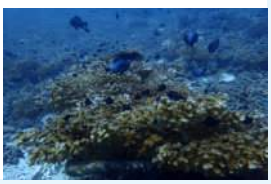


2010



2016





Objectives & Concept

A. Reef assessment
-To determine the benthic cover, and lifeform of corals

B. Fish community
-To assess the fish diversity and composition.

C. Carbonate changes (*Porites* coral and *Drupella* snail)
-To determine the changes of growth responses over time in relation to climate change related factors.

Sites

Sampling

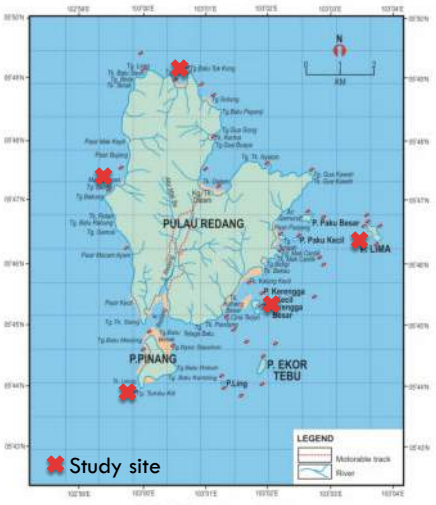
1st: 18 -21 May 2016

2nd: 9 – 13 Aug 2016

3rd: 22 – 24 Oct 2016

Permanent transect of 50 m

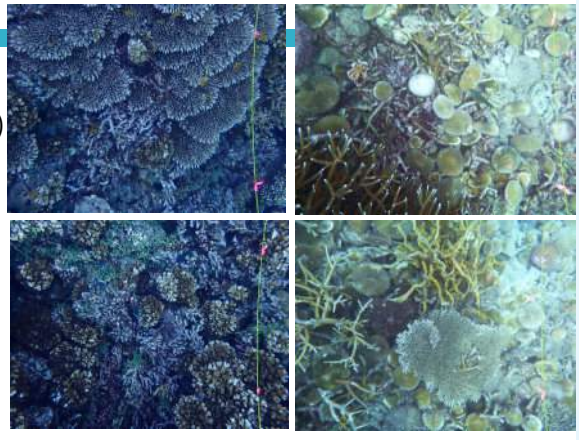
Site	Shallow	Deep
Pulau Lima	/	/
Terumbu Kili	/	/
Pulau Kerengga	/	/
Chagar Hutang	/	
Mak Simpan	/	



Methods

A. Reef assessment
-Photo quadrate (0.5m x 0.5m)
-100 photos per transect
-Total cover area (CpCE)

B. Fish community
-Belt transect (50m x 5m)



Methods

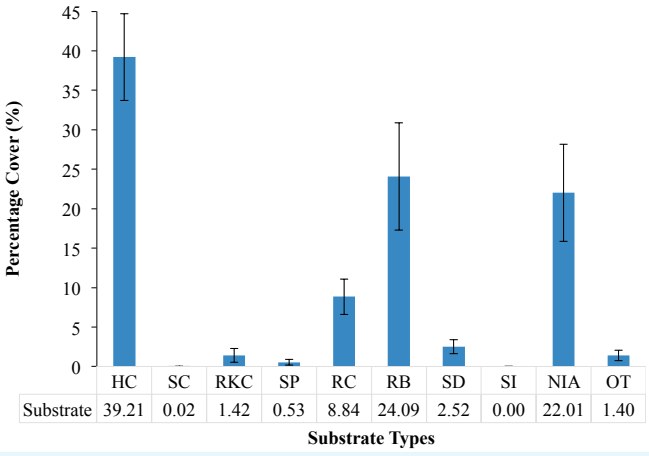
C. Carbonate changes

Porites coral-coring

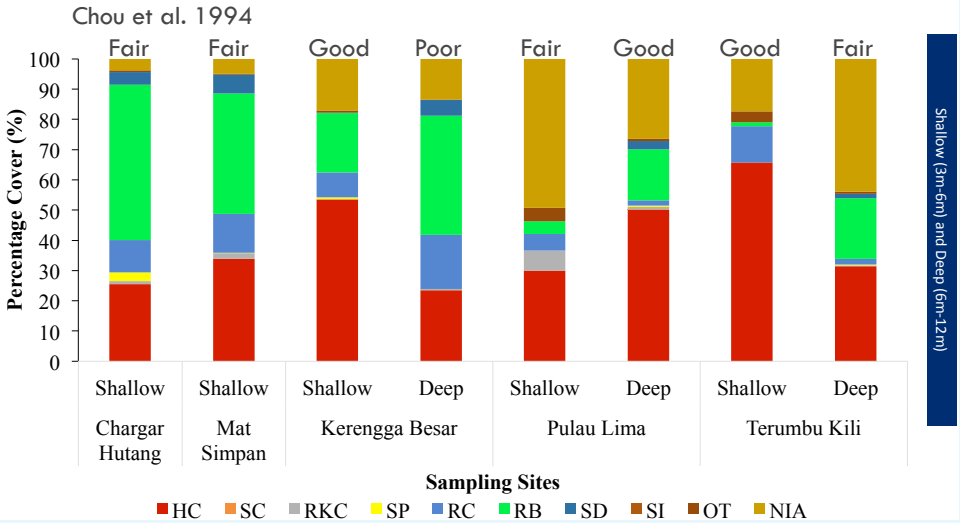
Drupella snail-collection

RESULTS and DISCUSSION

A. Reef assessment



Chou et al. 1994



Total of 31 genera from 13 families of hard corals were found from 5 selected sites around Pulau Redang

Sampling Sites		Total number of hard coral genera
Chagar Hutang	Shallow	21
Mak Simpan	Shallow	16
Terumbu Kili	Shallow	4
	Deep	9
Pulau Lima	Shallow	4
	Deep	17
Pulau Kerengga Besar	Shallow	18
	Deep	22

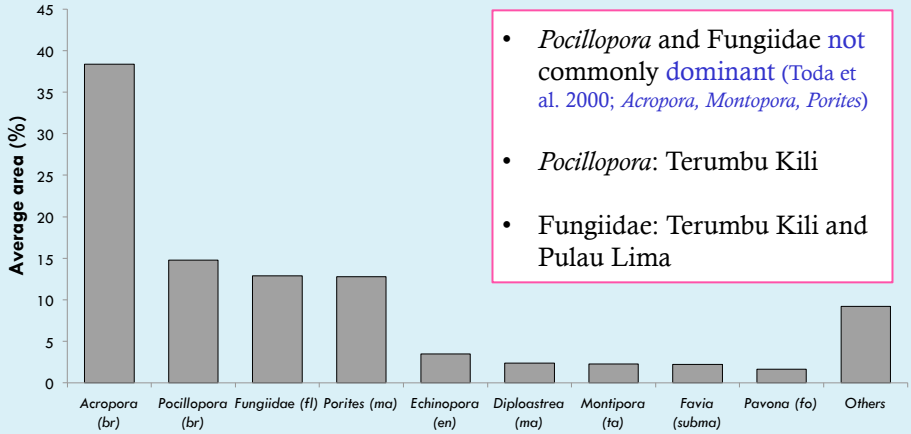
Deep water area had a higher total number of hard coral genera

Comparison of total number of hard coral genera over time

Total number of hard coral genera	Sampling sites	Reference
54 genera	Chagar Hutang, Pulau Lima, Terumbu Kili	Harborne et al. (2000)
35 genera	Pulau Lima, Terumbu Kili (and Ekor Tebu, Batu Bulan, Batu Bara)	Safuan et al. (2015)
31 genera	Chagar Hutang, Pulau Lima, Terumbu Kili, Mak Simpan (and Pulau Kerengga Besar)	Present study

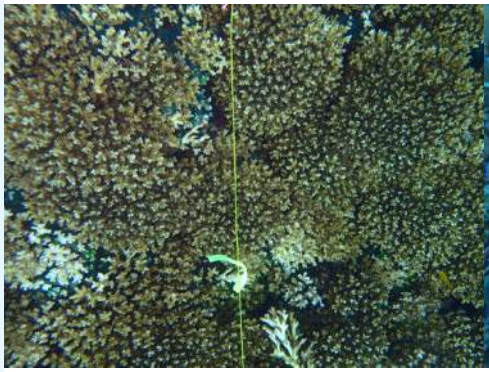
Decreasing number of hard coral genera found

Hard coral genera cover

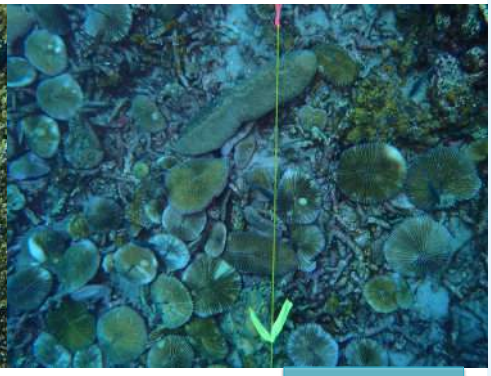


- *Pocillopora* and Fungiidae not commonly dominant (Toda et al. 2000; *Acropora, Montopora, Porites*)
- *Pocillopora*: Terumbu Kili
- Fungiidae: Terumbu Kili and Pulau Lima

Terumbu Kili



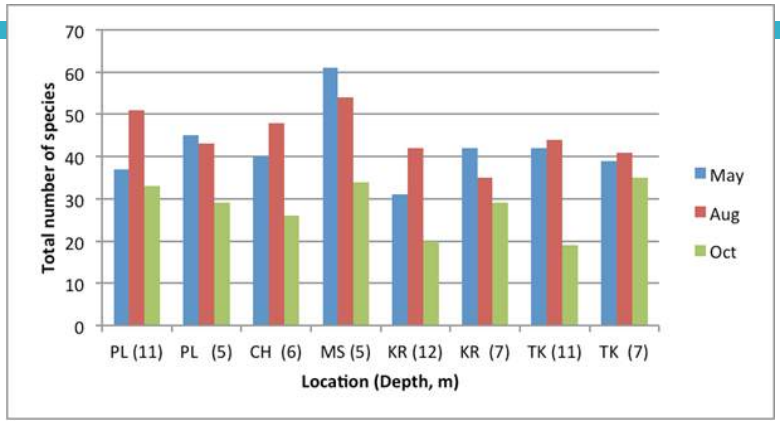
Pulau Lima



Jennie 2016

B. FISH COMPOSITION

141 species in total



Example of fishes found at Chagar Hutang and Mak Simpan

Lethrinus erythropterus

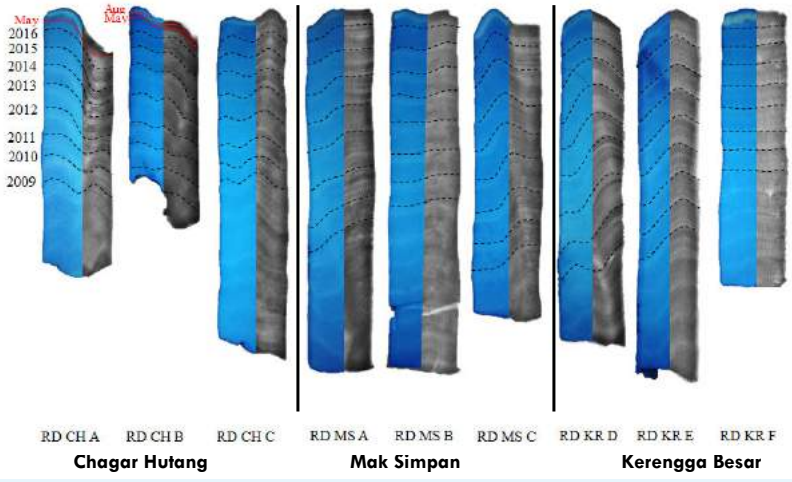
Dischistodus melanotus

http://www.casc.it

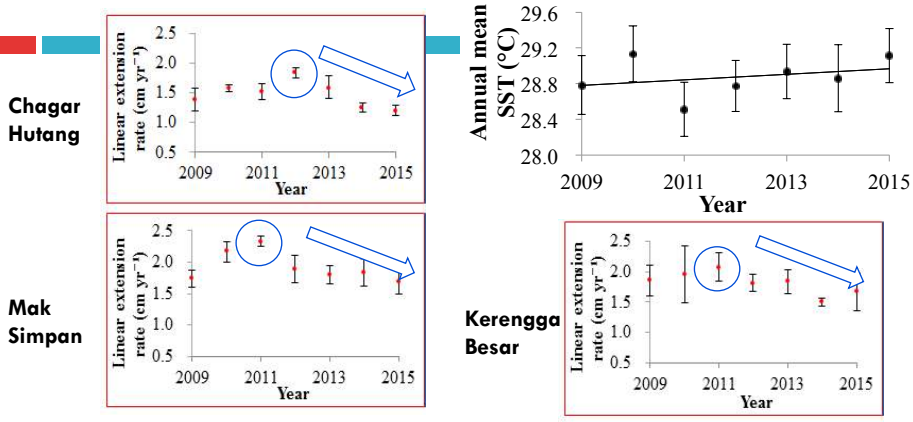
Pseudochromis fuscus

http://fishesofaustralia.net.au/

Carbonate growth rates: Coral (*Porites*)



Trend of linear extension rates vs SST



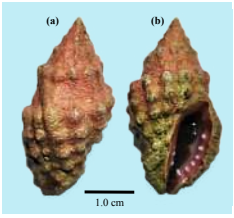
Site variation in coral skeletal growth

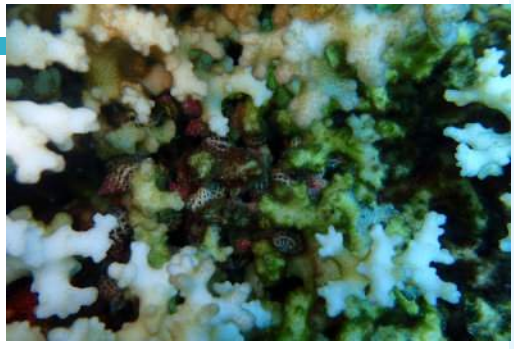
Parameter	*p* - value	Description
Linear extension rate	**0.000**	Chagar Hutang ≠ Mak Simpan & Kerengga Besar
Skeletal bulk density	**0.028**	Chagar Hutang ≠ Mak Simpan & Kerengga Besar
Calcification rate	0.165	No significant different between three sites

Bold text: significant value ($p < 0.01$ or 0.05)

Carbonate growth rates: *Drupella rugosa* (Born, 1778)

- Common name – Rock / Murex snails
- Known as corrallivorous
- Diet – eat live coral tissue, stripping from calcium carbonate skeleton using a specialised radula
- Juvenile prefer 'fine-branching' rather than 'open-branching' or 'heavy-branching' corals
- East coast of Peninsular Malaysia, influence of coral reefs health & population in Pulau Redang, P. Tioman & P. Tinggi are *Drupella* spp. & *Achanthaster planci* (Harborne et al., 2000)

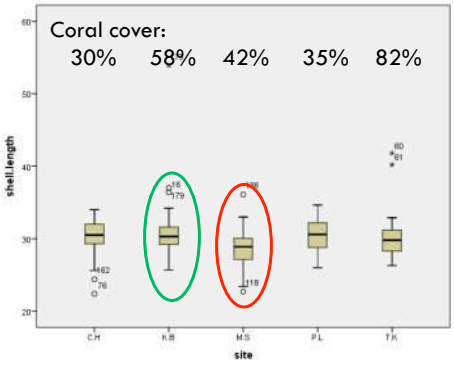




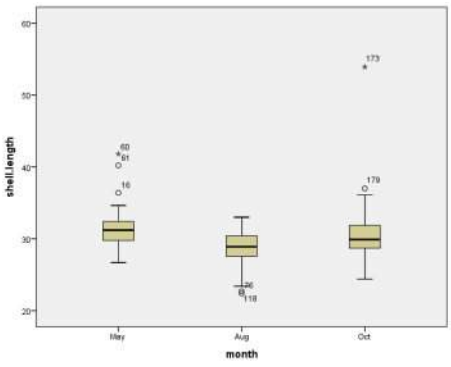
Jennie 2016

Jennie 2016

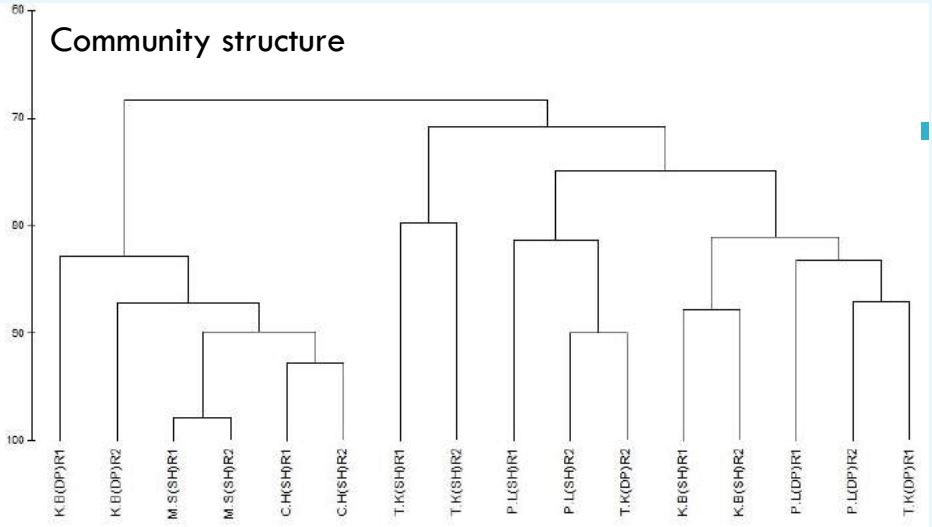
Shell length vs. Sites

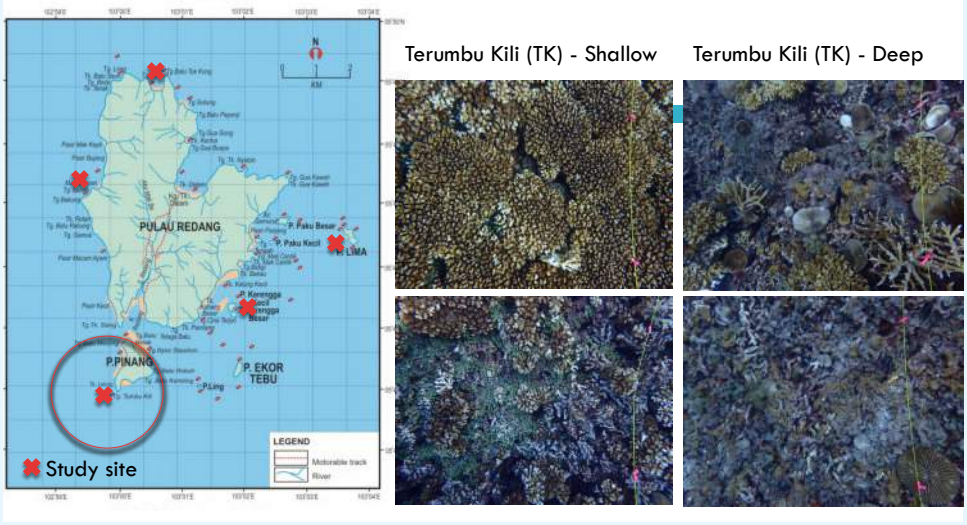


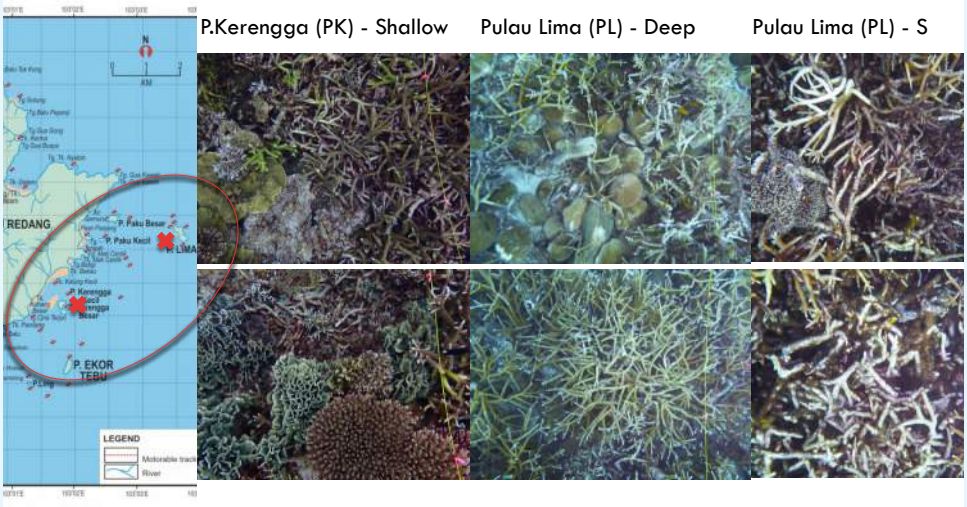
Shell length vs. Months

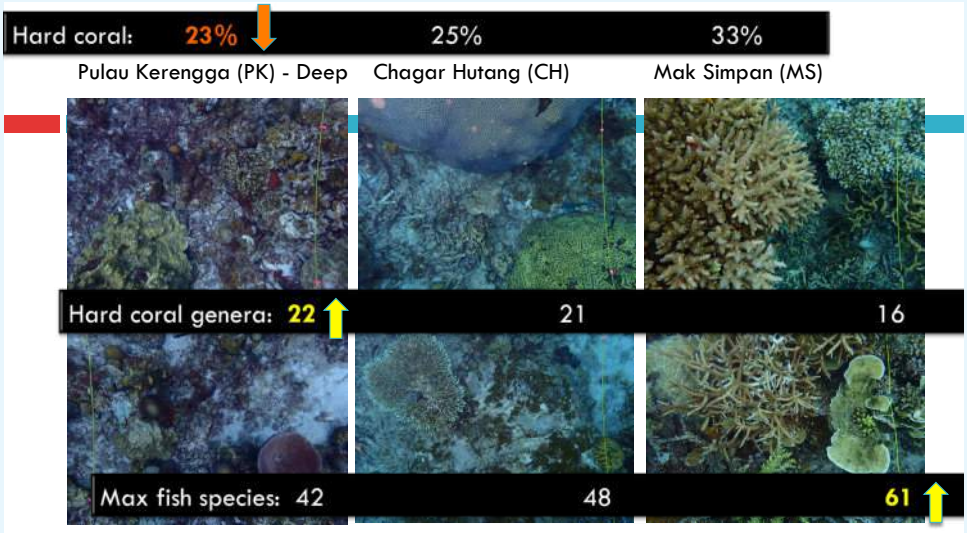


Community structure




Terumbu Kili (TK) - Shallow
Terumbu Kili (TK) - Deep
PULAU REDANG
P.PINANG
P. EKOR TEBU
P. LIMA
LEGEND
Study site


P.Kerengga (PK) - Shallow
Pulau Lima (PL) - Deep
Pulau Lima (PL) - S
REDANG
P. EKOR TEBU
LEGEND


Hard coral: 23% 25% 33%
Pulau Kerengga (PK) - Deep
Chagar Hutang (CH)
Mak Simpan (MS)
Hard coral genera: 22 21 16
Max fish species: 42 48 61

Conclusion

-Reef health condition: Fair (HC: 23-65%)

-Coral genera: 31 and decreasing (54; Year 2000)

-Fish: 141 species

-Coral growth: decrease significantly; Chagar Hutang

-*Drupella*: outbreak; alarming issue; Chagar Hutang

"Coral reef health is determine by live coral cover (HC & SC)"
Is this adequate?

Team members and Acknowledgement

- Dr. Izwandy Idris (UMT) - Invertebrate Biology & Taxonomy
- Dr. Nursalwa Baharuddin (UMT) - Thermal Biology
- Dr. Asnor Azrin Sabuti (UIA) – Water quality & Chemistry
- Yusri Yusuf (UMT) - Reef Fishes Community
- Kee Alfian Abd Adzis (Independent Consultant) - Coral Reef Ecology
- Liyana Amir (UKM) – Geochemistry
- Md Nizam Ismail –JTLM
- Albert Apollo Chan – JTLM
- Students (Chai Kee, Maziana, Farah, Acap, Jeet, Gan, Aimi, Ikhwan, Ben, Amar, Shida)

Universiti Malaysia Terengganu

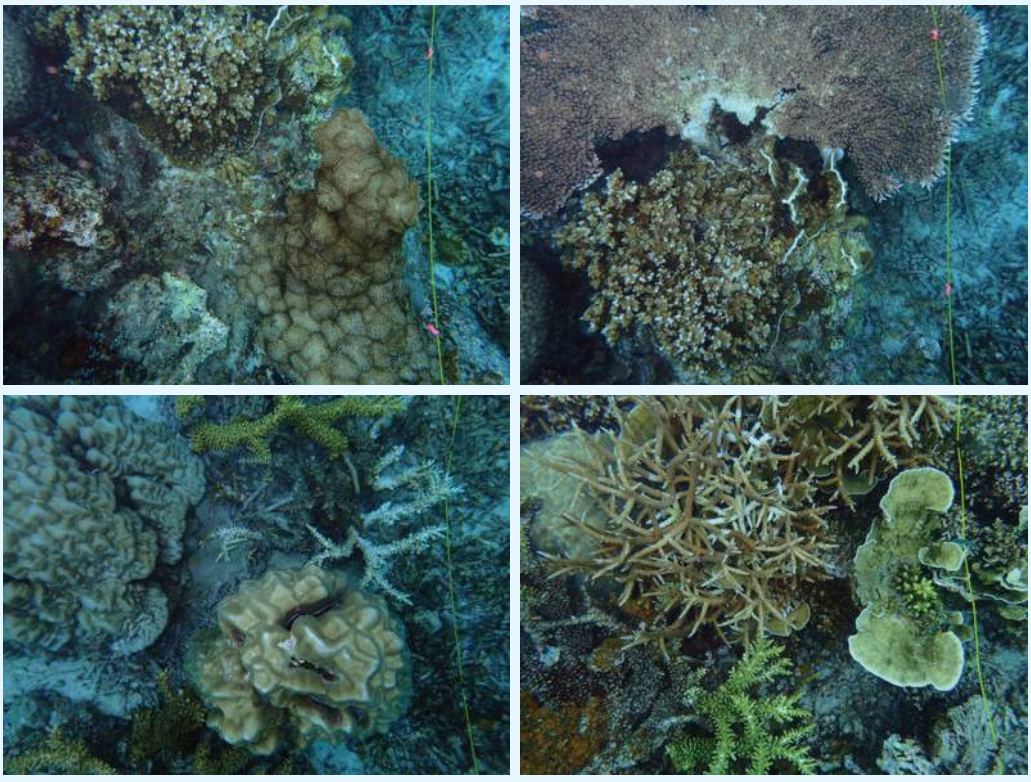
UMT

Jabatan Taman Laut Malaysia

الجامعة الإسلامية العالمية ماليزيا
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

Universiti Kebangsaan Malaysia
The National University of Malaysia

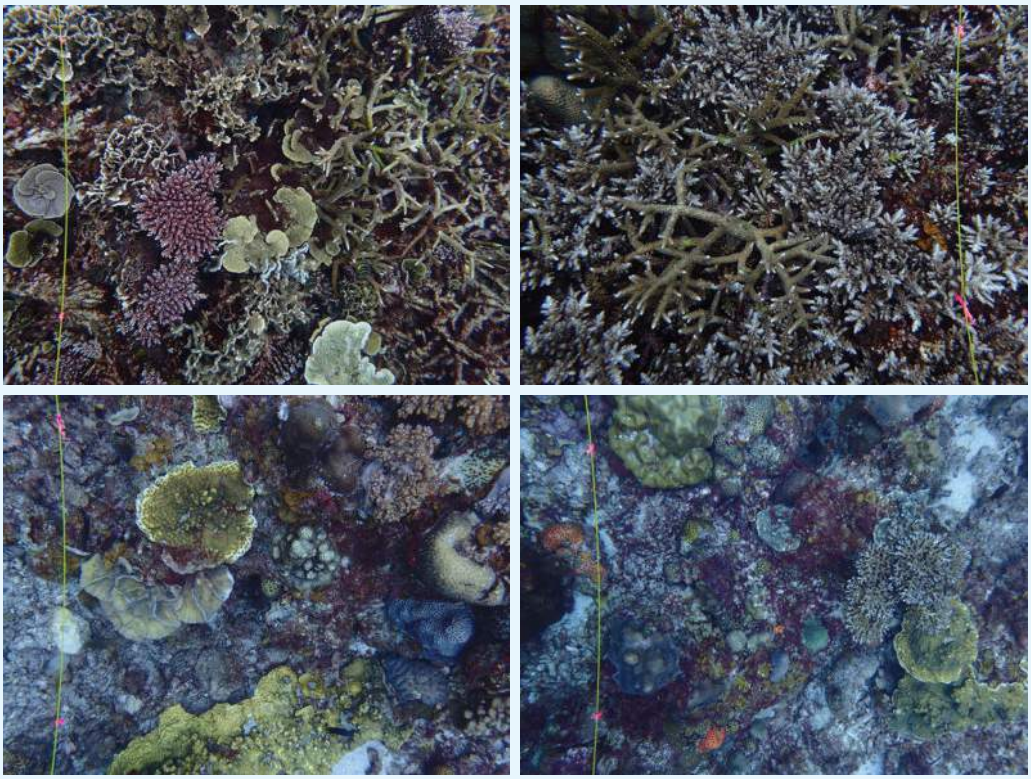
Thank you.



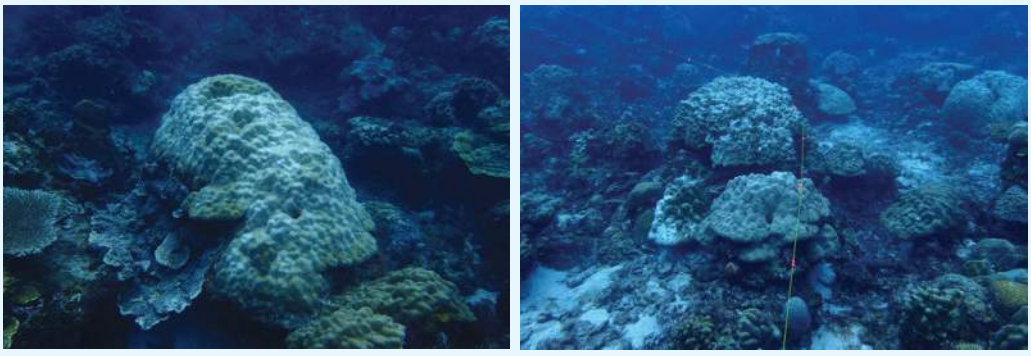
Chagar Hutang (top) and Mak Simpan (bottom) coral reefs are mixture of massive, table and encrusting corals. Variety of coral reefs and other marine organisms can be found in the shallow reefs.

Mild bleaching were observed in May 2016 (left - Mak Simpan; right - Chagar Hutang)

Same area at Mak Simpan during 2016 (left) and after Pabuk Storm in 2019 (right). Massive corals are still standing, tilted or overturned. Most branching corals were broken and killed.

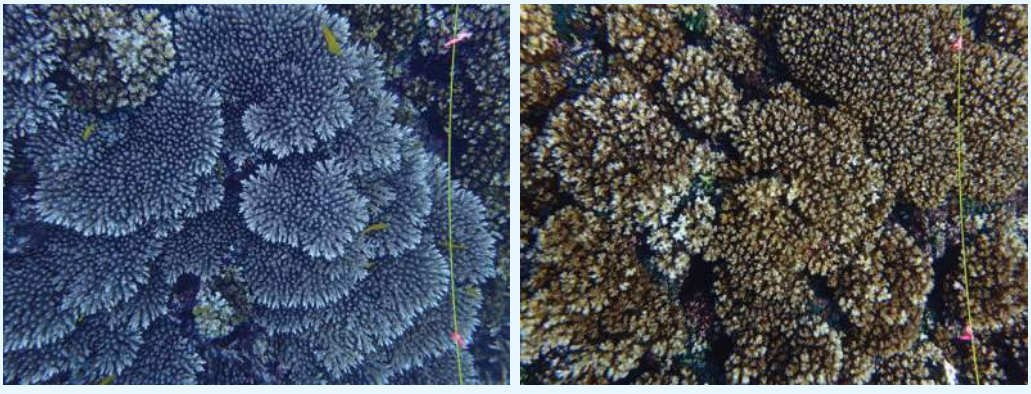


Pulau Kerengga Besar reefs are more dominant with branching and lace corals such as *Acropora* and *Pocillopora* at 5 m (top) and more encrusting and massive corals such as *Porites* and *Favites* at 12 m (bottom).

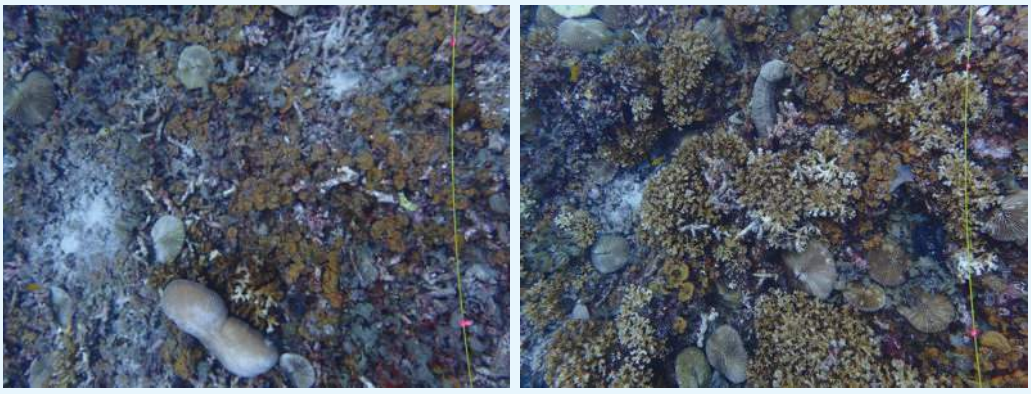


Mild and partial bleaching of *Porites* corals at Pulau Kerengga Besar from shallow (left) and deep (right) reef in May 2016.

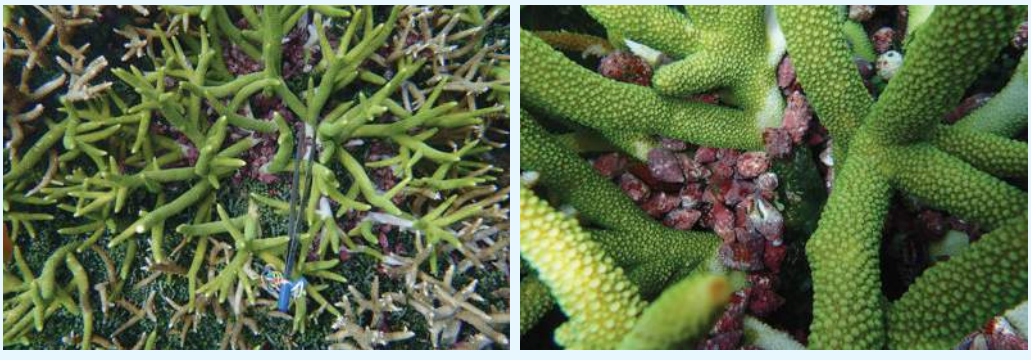
Giant clam at the same area in Pulau Kerengga Besar were healthy (left) and partial bleached (right).



Terumbu Kili, 5 m (left - table *Acropora*; right - lace *Pocillopora*)

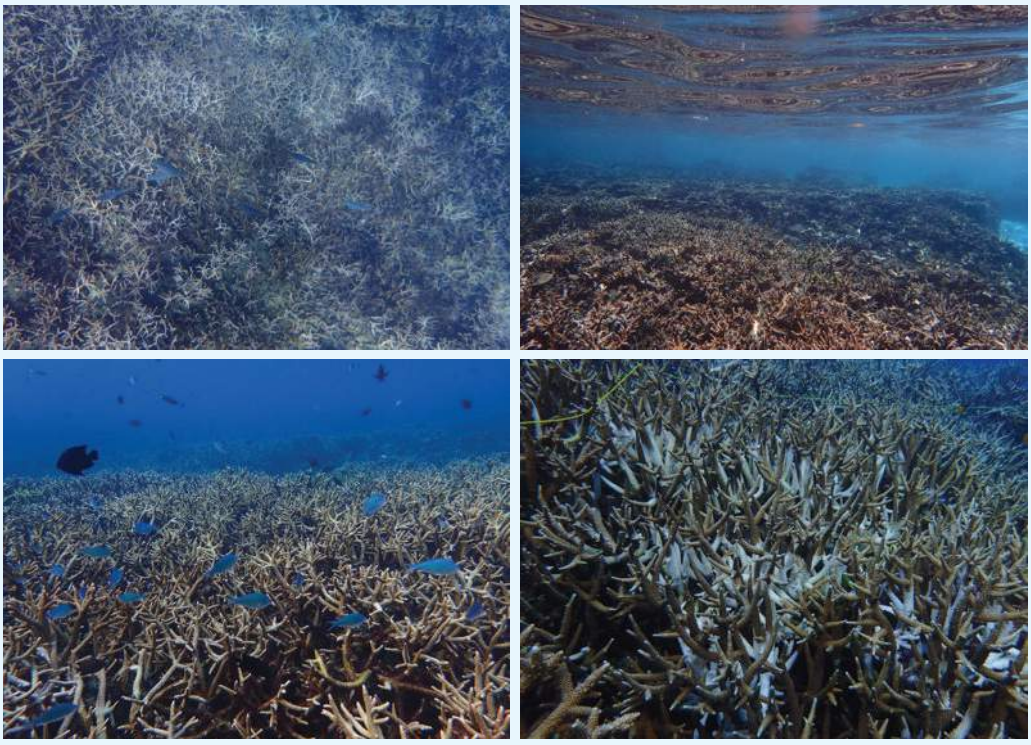


Terumbu Kili, 10 m (mixture of macroalgae, mushroom coral and others)



Terumbu Kili, 2 m (high cover of branching *Acropora*, but highly infested by *Drupella*)

Terumbu Kili, 6 m (left - school of fish; right - pouch of Tiger cowrie's eggs)



Branching *Acropora* dominated the reefs at Pulau Lima from shallow (top) to deeper (bottom) water. Patches of dead corals can be observed due to predation by Crown of Thorns (COT) and *Drupella* snails.

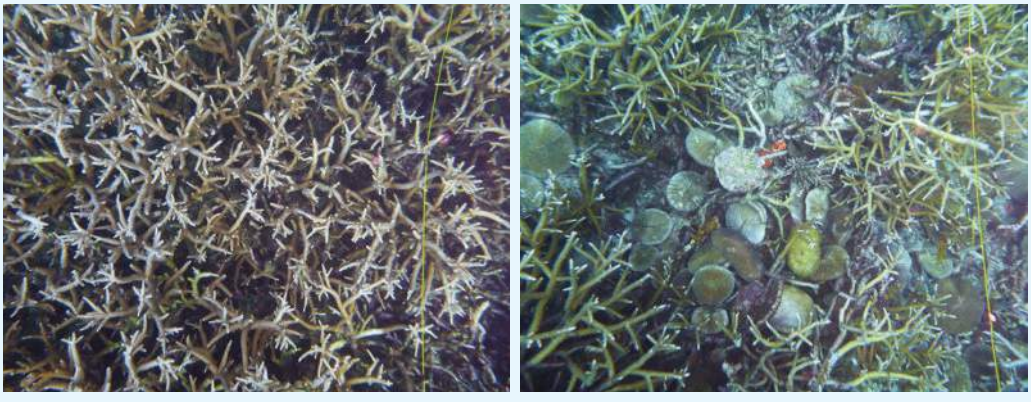
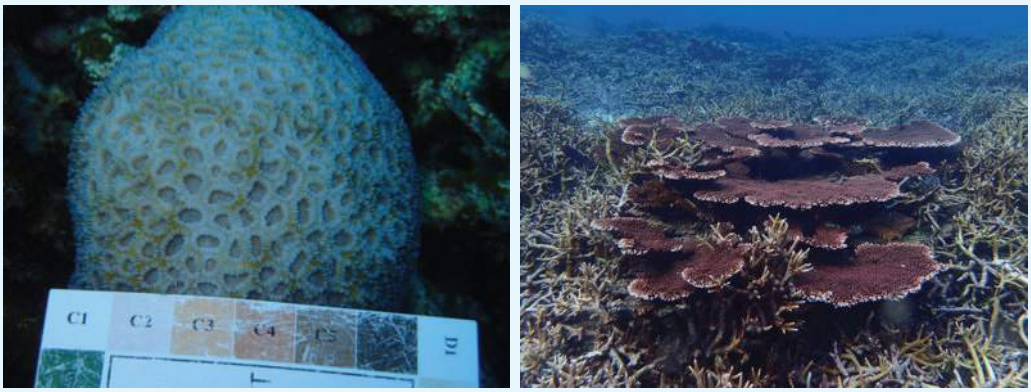


Photo quadrates at shallow (left) and deep (right) reef of Pulau Lima.



Severe bleached (left) and healthy (right) corals at Pulau Lima in May 2016.

The beauty of Pulau Redang apart from the coral reef ecosystems. Sandy beaches, rocky areas and forests also play an important role to coral reefs.

Identification of marine fishes and invertebrates. (Photos by Yusri Yusuf)

Abudefduf bengalensis

Amphiprion clarkii

Amphiprion ocellaris

Apogon compressus

Arothron stellatus

Balistoides viridescens

Cephalo microprion

Cephalopholis cyanostigma

Identification of marine fishes and invertebrates. (Photos by Yusri Yusuf)

Chaetodon baron

Chaetodon adiergastos

Cheilinus fasciatus

Cheilodipterus macrodon

Chlorurus sordidus

Cowri

Cushion starfish

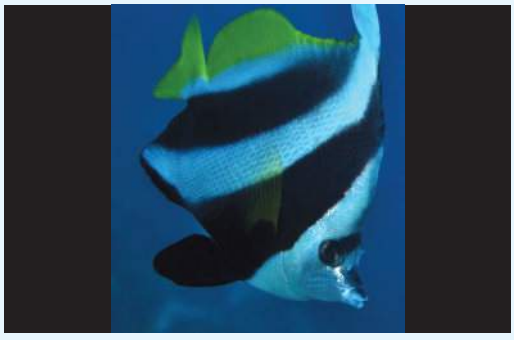
Dascyllus reticulatus

Identification of marine fishes and invertebrates. (Photos by Yusri Yusuf)

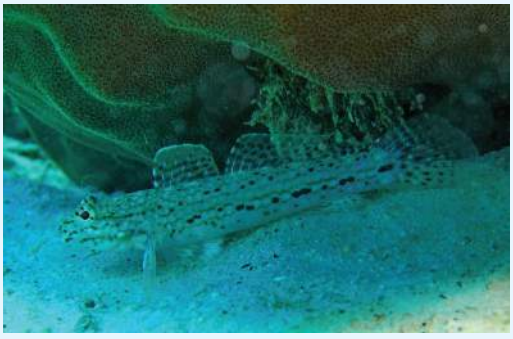
Dischistodus perspicillatus

Epib insi

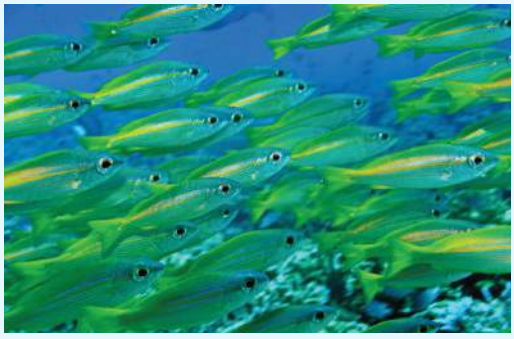
Gomphosus varius



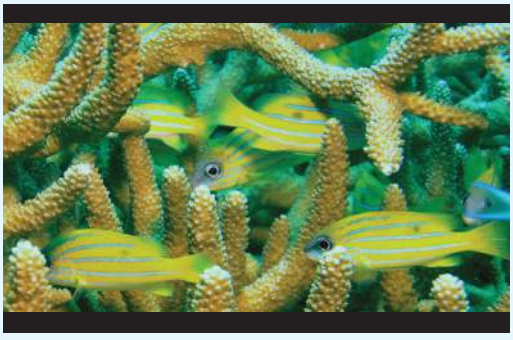
Heniochus acuminatus



Istigobius decoratus



Lutjanus lutjanus



Lutjanus quinquelineatus

Oxycheilinus digramma

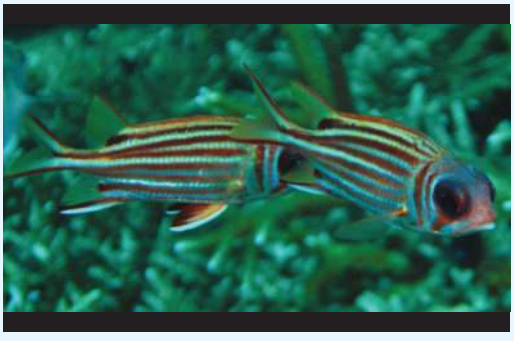
Identification of marine fishes and invertebrates. (Photos by Yusri Yusuf)

Pearsonothuria graeffei

Platax teira

Pomacanthus annularis

Pteragogus cryptus



Sargocentron rubrum

Scarus ghobban

Scarus rivulatus

Scolopsis bilineata

Identification of marine fishes and invertebrates. (Photos by Yusri Yusuf)

Siderea thysoidea

Sphyraena flavicauda

Stichopus chloronotus

Synodus variegatus

Tiger cowri

Tridacna maxima

Tridacna squamosa

Tube worm

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ISBN 978-967-0633-69-5
9 789670 633695