TECHNICAL REPORT

CLIMATE CHANGE

Sclerochronological Records in Massive *Porites* Corals from Pulau Redang

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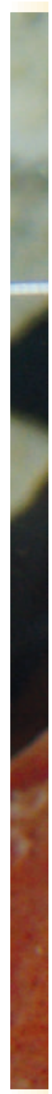

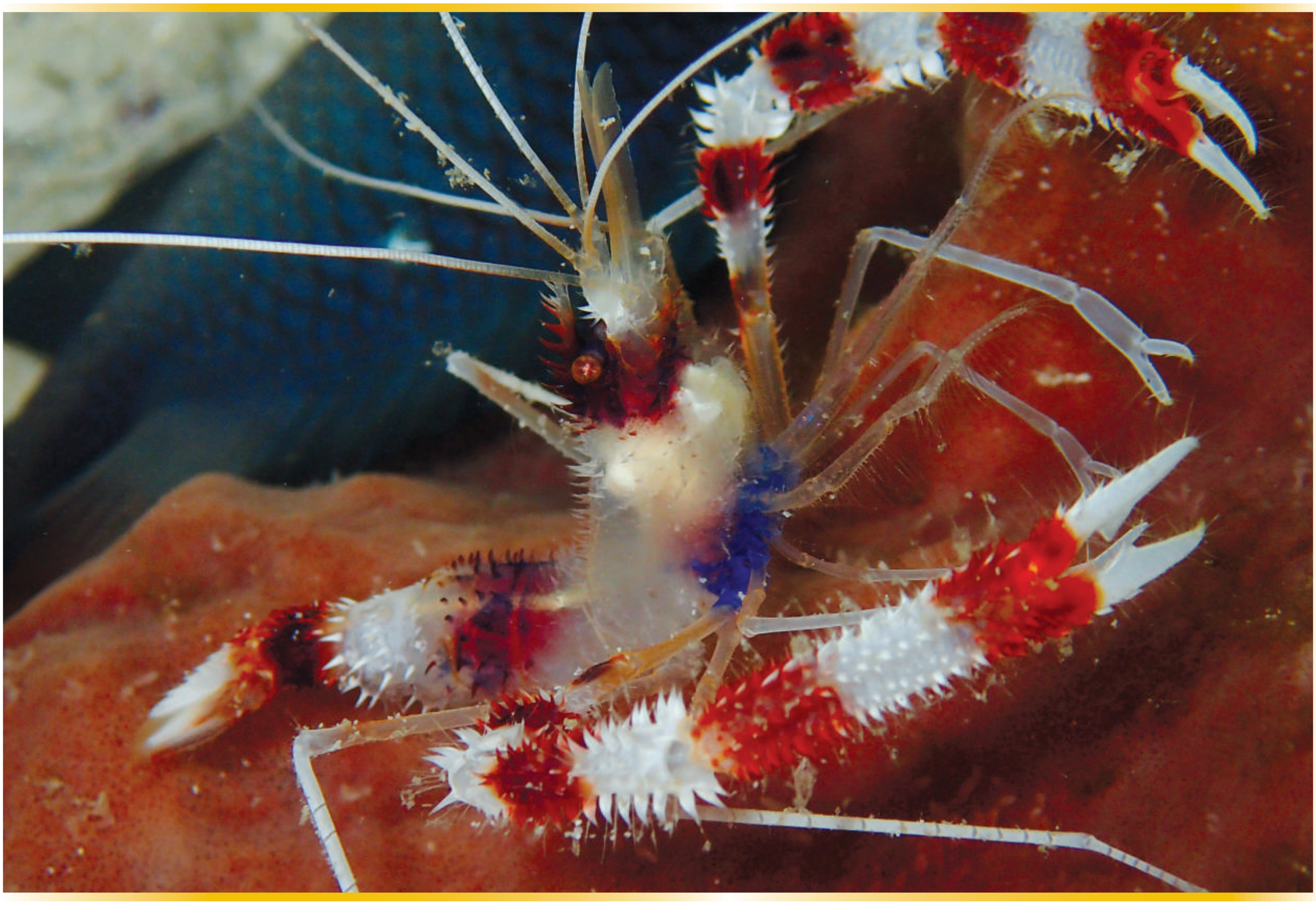

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Sclerochronological Records in Massive *Porites* Corals from Pulau Redang

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Department of Fisheries Malaysia
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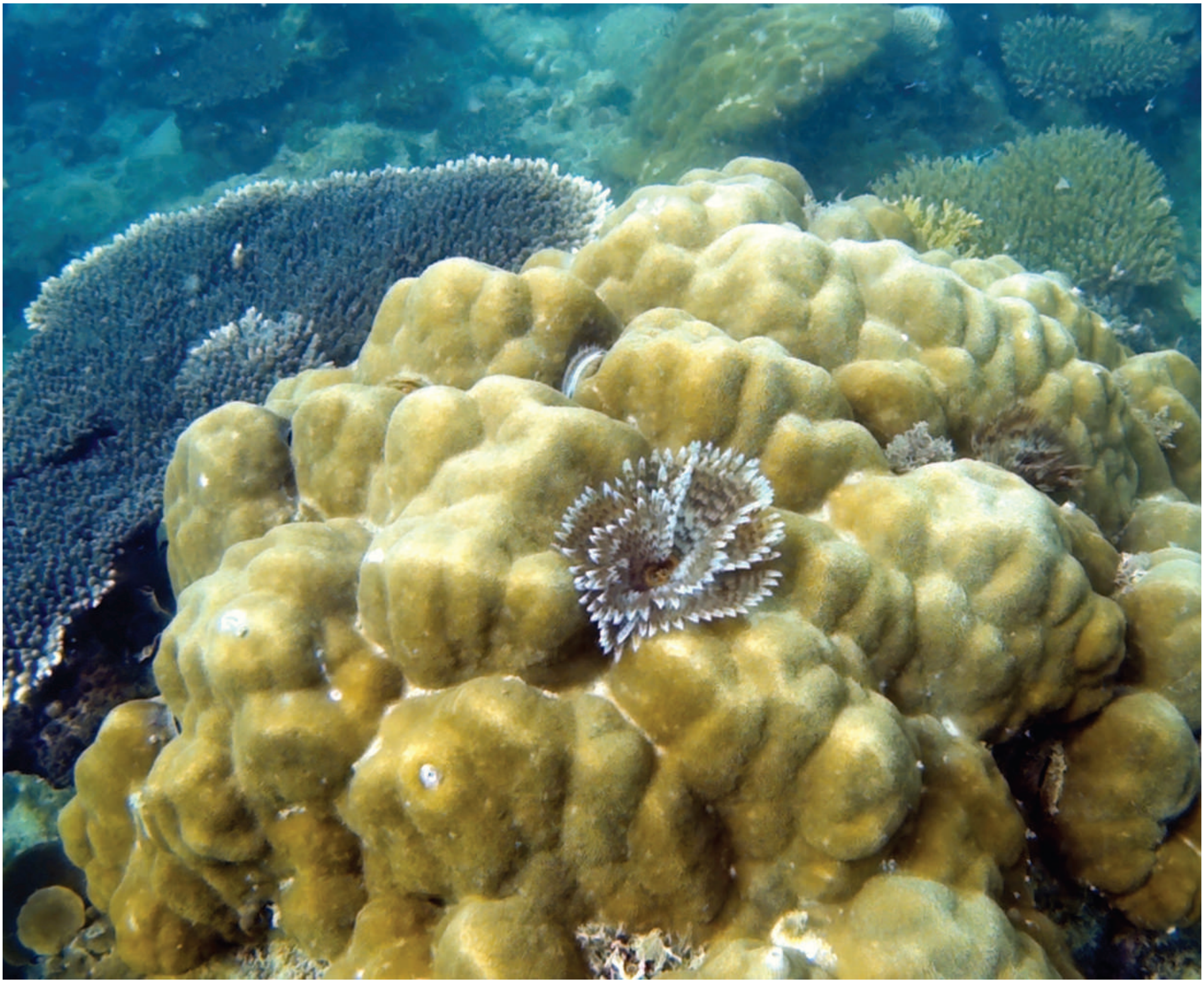

PROJECT INFORMATION

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

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EXECUTIVE SUMMARY

The annual growth bands in skeleton of long lived massive *Porites* corals is a powerful sclerochronological records can be used to understand the coral fitness and growth responses to environmental effects. This study investigated the skeletal growth of massive *Porites* corals in Pulau Redang to provide a follow up data since 2009-2015. A total of nine skeleton cores of massive *Porites* corals from three reef sites around the island were examined under UV light and X-ray to determine the skeletal growth rates. In general, the massive *Porites* corals in Pulau Redang had a linear extension rate range from 1.12-2.90 cm year^{-1}, skeletal bulk density about 0.98-1.56 g cm^{-3} and calcification rate range from 1.27-3.53 g cm^{-2} year^{-1}. From 2009-2015, the trend of coral skeletal growth was found to decline by 19.06% in linear extension rate and 23.52% in calcification rate. No significant trend was found for skeletal bulk density. Reconstruction of the 36 years coral growth by compilation of past 31 year growth records (1980-2010) from Tanzil et al., (2013) and current study (2009-2015) suggested that coral growth is still ongoing decline in link to SST rise. Two sites (i.e. Chagar Hutang and Mak Simpan) showed a significant negative impact from SST rise by reducing the linear extension and calcification rates. The exist of spatial variation in coral growth is suggested that the coral skeletal growth may be affected by the localized water circulation and environmental changes at the particular reef site.

INTRODUCTION

As rise of sea surface temperature (SST) caused by climate change continues to happen, the tropical coral reefs are facing a serious threat that resulted to mass coral bleaching (Lough & Cooper, 2011; Lough & Cantin, 2014). Past mass coral bleaching around Malaysia reefs was reported for the first time during El Niño in 2010 (Tan & Heron, 2011). Besides bleaching, reef-building coral also response to thermal stress by alter their skeletal growth rate and calcification (Lough & Cantin, 2014).

Sclerochronology is the study of periodicities growth records in hard structure or skeleton of organisms (Helmle & Dodge, 2010). Sclerochronological records in skeleton of long lived massive coral species is a powerful measurement to understand coral fitness and stress responses to environmental effects. Coral skeleton has a series of annual growth bands with a pair of alternating high density and low density bands. The annual growth bands in coral skeleton can be illustrated as density banding patterns under x-radiography or luminescence banding patterns under ultra-violet (UV) radiation (Figure 1). Observation of these growth bands serves as a platform to date the annual growth and measure the carbonate growth rate of coral skeleton (Lough & Cantin, 2014).

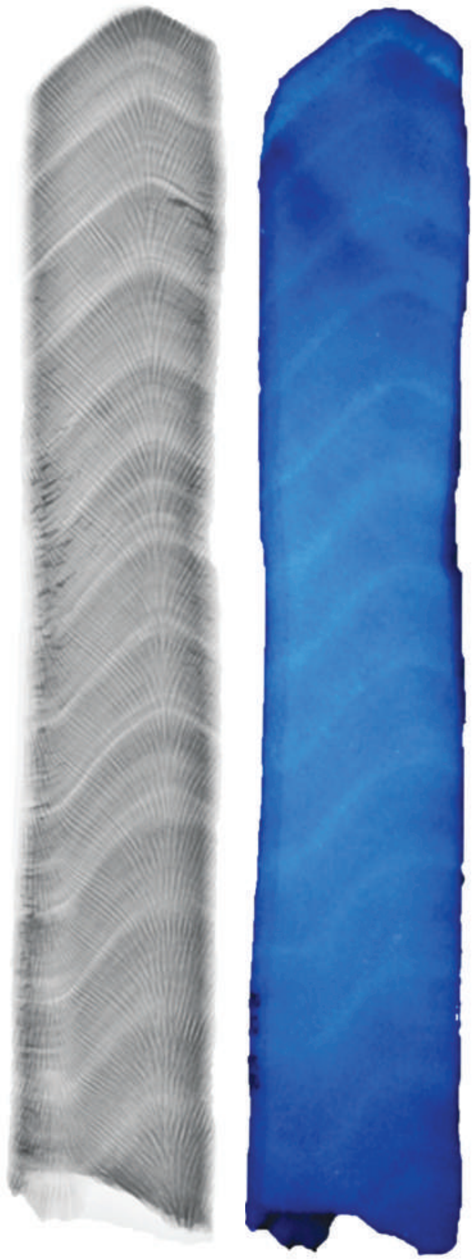


Figure 1. Density banding patterns under X-ray (left) and luminescence banding patterns under UV light (right) of a coral skeleton sample from Pulau Redang.

As coral growth is influenced by the environment factors, interpretation of the coral sclerochronological records can help in understanding the nature of skeletal growth and reconstruct the historical environmental changes of a particular reef area (Hudson et al., 1976).

Rise in SST was found to negatively impact the coral skeletal growth of massive *Porites* corals around reefs of Peninsular Malaysia between 1980 and 2010 (Tanzil et al., 2013). Solely in Pulau Redang, the ~30 years skeletal growth records for massive *Porites* was found to decline significantly (-6.87% skeletal bulk density, -15.21% linear extension rate, -21.3% calcification rate) (Tanzil et al., 2013). As the emerging of seawater warming issue is seen to be critical in future, understanding the location specific coral growth responses and continue monitoring of reef health are crucial to support better management decision-making.

The main objective of this study is to ascertain sclerochronological records in massive *Porites* corals around the Pulau Redang in link to impacts of SST rise and climate change. This study also aimed to provide an update of recent skeletal growth status specifically for the period of 2009-2015 in relationship to spatial variation and environmental gradients around Pulau Redang Marine Park.

METHODOLOGY

STUDY AREA

The study area is a gazette marine park since 1994, locally named Pulau Redang and situated about 25 km from the east coast of Peninsular Malaysia. This island is exposed to northeast monsoon during November - February (Roseli et al., 2015) and the reefs around the island are reported with good coral cover (Reef Check Malaysia, 2015). Three reef sites including Chagar Hutang, Mak Simpan and Pulau Kerengga Besar were sampled for massive *Porites* skeleton cores under permission from the marine park [JTLM 630-7 Jld. 7 (13)] (Figure 2).

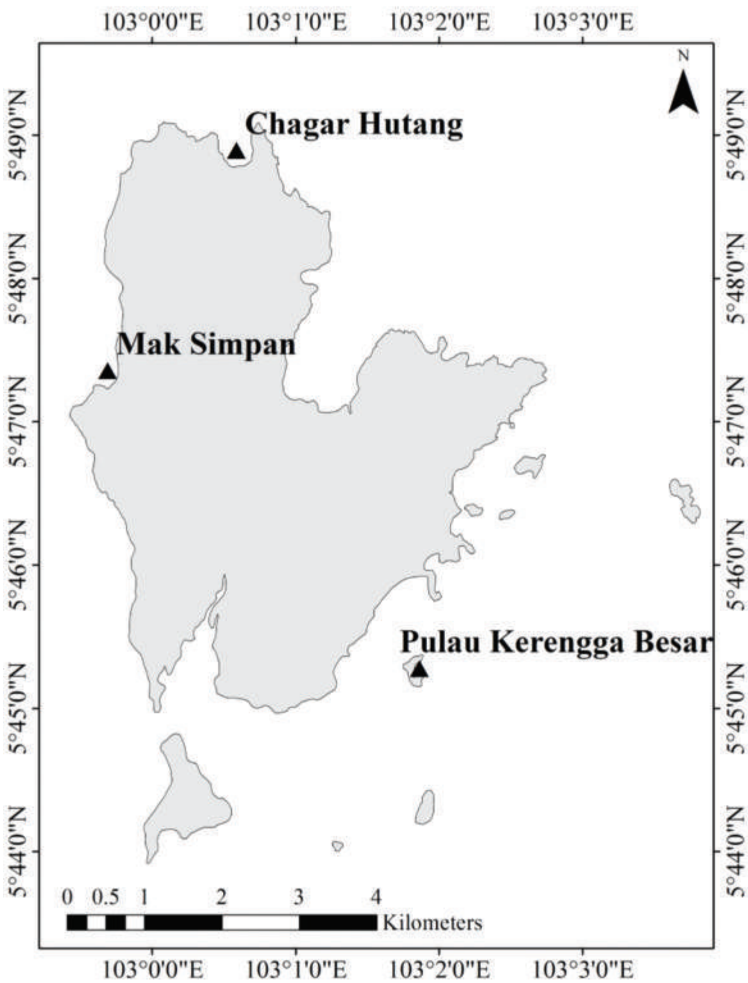


Figure 2. Map of Pulau Redang showing where the coral specimens were collected at Chagar Hutang, Mak Simpan dan Pulau Kerengga Besar

CORAL SKELETON COLLECTION

During May and August 2016, SCUBA diving was performed to conduct *in situ* staining of Alizarin red S on selected massive *Porites* corals. A plastic bag filled with Alizarin red S stain was used to cover the coral head and left for a while for the coral tissue to absorb the stain (Figure 3a). Stain absorbed by coral tissue was deposited in its skeleton and provided a validation mark of the timing of bands formation (Tanzil et al., 2013).

The corals were allowed to grow for few months (May-October 2016) for the uplift of living tissue layer from skeletal layer in order to reduce obstruction on the alizarin mark during growth analysis. Site visit was conducted again in October to collect the coral skeleton cores. A pneumatic drill (Ingersoll Rand 10 mm Air Drill) fitted with 5 cm diameter and diamond bit coral barrel was used to drill the coral head to collect the coral skeleton core (Tanzil et al., 2013) (Figure 3b). After coring, the hole on each coral head was sealed with marine epoxy for the coral polyps to recolonize the removed surface (Figure 3c). A total of nine skeleton cores were collected from three sampling sites and the detailed information of coral skeleton cores collected was presented in Table 1.

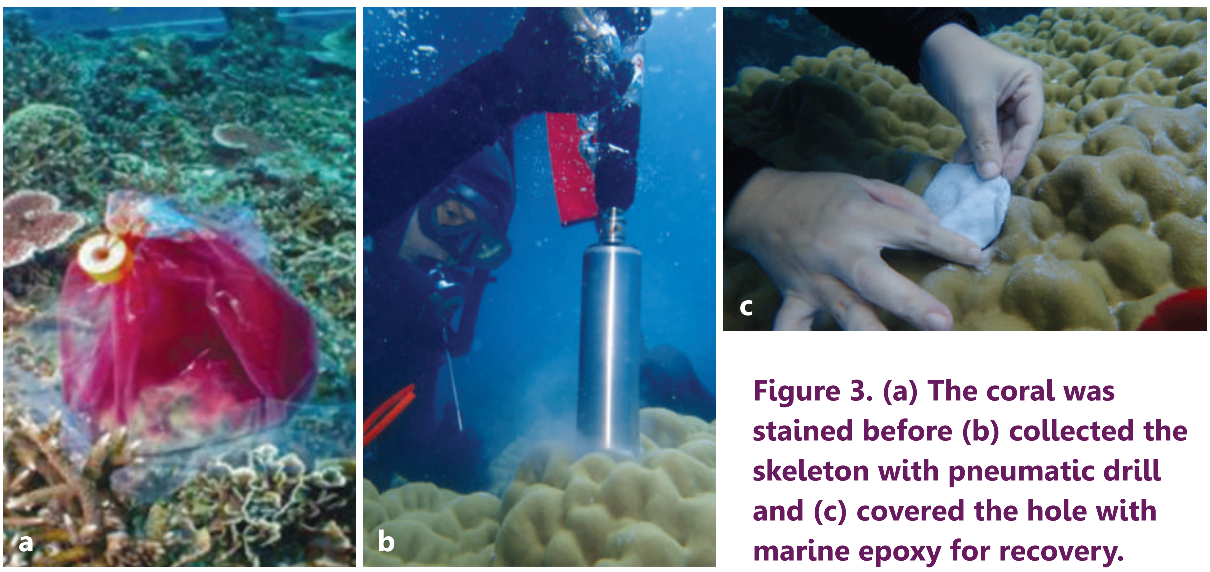


Figure 3. (a) The coral was stained before (b) collected the skeleton with pneumatic drill and (c) covered the hole with marine epoxy for recovery.

Table 1: Information of coral skeleton cores collected in Pulau Redang.

Sampling site (latitude (°N), longitude (°E))	Core labeling code	Core length (cm)	Alizarin stained date (dd/mm/yyyy)	Core collected date (dd/mm/yyyy)
Chagar Hutang (5.81482, 103.00977)	RD CH A	19.00	19 May 2016	24 Oct 2016
	RD CH B	15.50	19 May 2016 & 10 Aug 2016	24 Oct 2016
	RD CH C	25.00	-	24 Oct 2016
Mak Simpan (5.78921, 102.99481)	RD MS A	25.80	-	24 Oct 2016
	RD MS B	25.70	-	24 Oct 2016
	RD MS C	22.00	-	24 Oct 2016
Pulau Kerengga Besar (5.75459, 103.03106)	RD KR D	24.00	-	26 Mar 2016
	RD KR E	27.00	-	26 Mar 2016
	RD KR F	30.00	-	23 Oct 2016

SCLEROCHRONOLOGICAL RECORDS ANALYSIS

In the laboratory, all skeleton cores were bleached with Clorox (containing sodium hypochlorite, NaOCl) for 48 hours to remove living tissue on top of the core and any organic matters on the skeleton (Grove et al., 2010). After bleaching, the cores were air dried and cut into ~10 mm slabs using wet cutter with diamond blade (MK-100 Wet Cutting Tile Saw).

The coral slabs were scanned with digitized X-radiograph to illuminate the density banding patterns and analysis for skeletal bulk density (g cm^{-3}) (Carricart-Ganivet and Barnes, 2007). The luminescence banding patterns of coral slabs were also viewed under UV light (365 nm) (Tanzil et al., 2013). The annual skeletal growth bands were dated for the period of 2009-2015 and validated using Alizarin mark (Figure 4). The annual linear extension rate (cm $year^{-1}$) was defined as the distance from the top of a high density band (bright luminescent band) to its adjacent high density band. The annual calcification rate (g cm^{-2} $year^{-1}$) was calculated as the product of linear extension rate and skeletal bulk density.

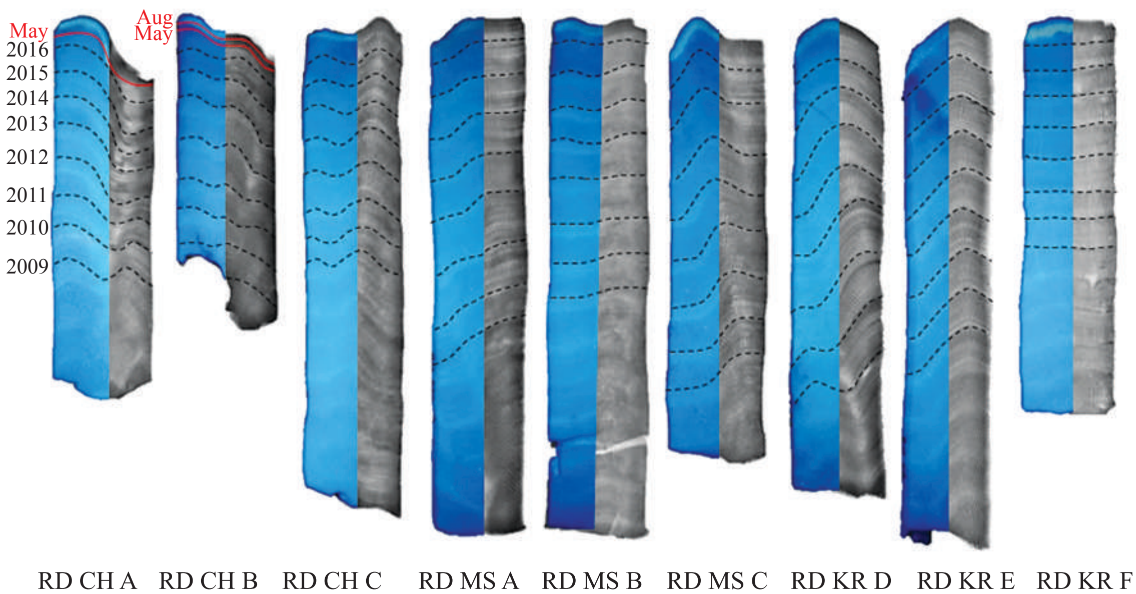
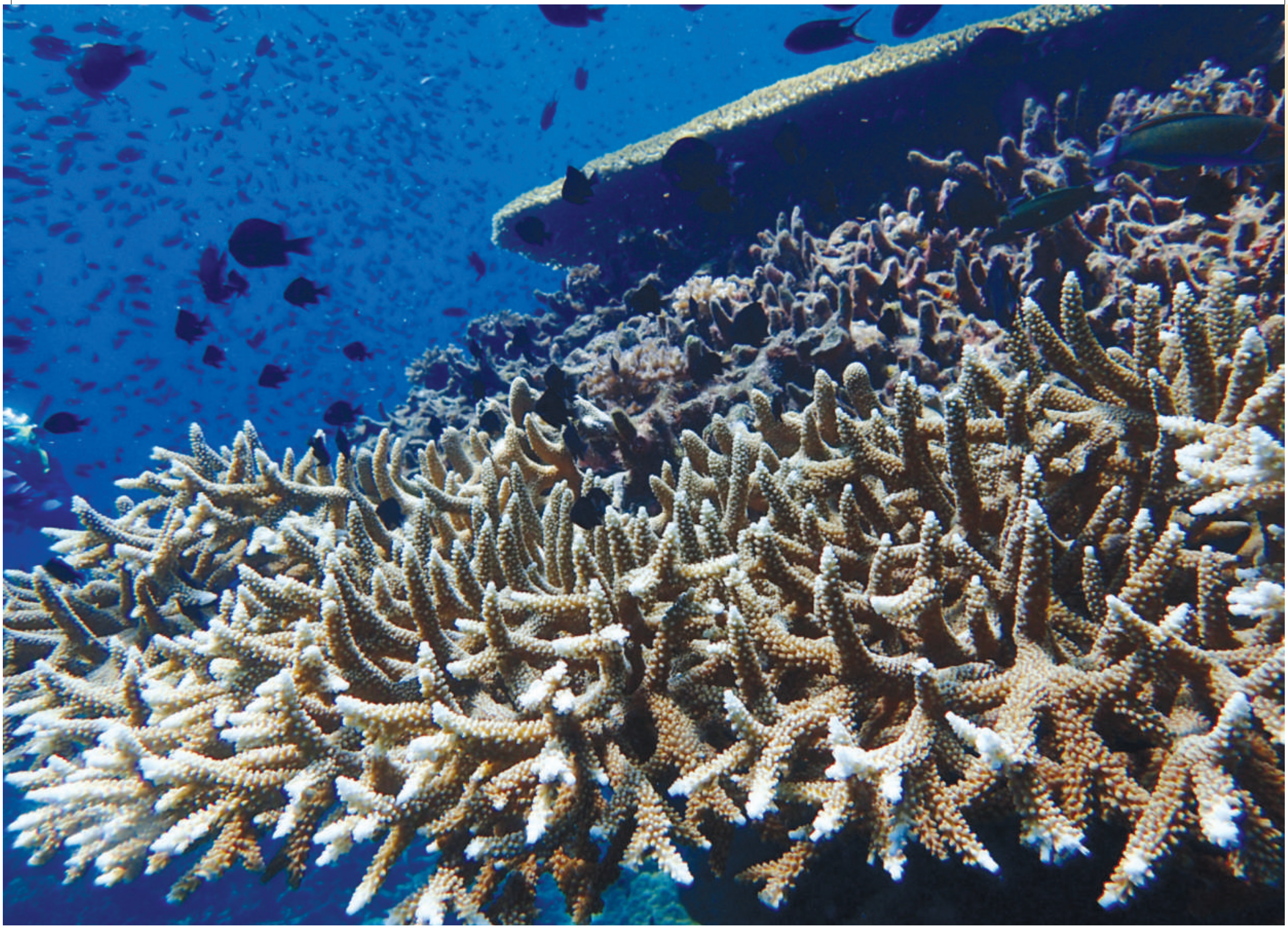


Figure 4. Images of the coral skeletal slabs aligned with UV image (left) and x-ray image (right) of every sample. Black dashes outlined the annual growth bands and red solid lines marked the alizarin stains during May and Aug 2016.



ENVIRONMENTAL PARAMETERS

Physicochemical parameters of seawater were examined to understand the baseline water quality at sampling sites. *In situ* physicochemical parameters of seawater included water temperature, salinity, pH and dissolved oxygen concentration (DO) were measured at depth of 2 m using Hydrolab multi-parameter probe during coral staining and skeleton coring fieldworks on May, August and October 2016. Seawater was collected at same depth using Niskin water sampler and analysed for total alkalinity (TA) using titration method adopted from Hing et al. (2014). Aragonite saturation (Ω_{Ar}) was calculated from salinity, temperature, pH, TA and pressure at depth of measurement using Excel Macro of CO2SYS program (Lewis & Wallace, 1998; Pierrot et al., 2006). Data of monthly SST (°C) over the period 2009-2015 for 1° area grid at Pulau Redang was obtained from HadISST data sets (Rayner et al., 2003) and 12 months data were averaged as the annual SST over the seven years.

OUTCOMES

ENVIRONMENTAL PARAMETERS

Water quality of seawater from all three sites (Chagar Hutang, Mak Simpan and Pulau Kerengga Besar) showed similar pattern in monthly variation (Figure 5). ANOVA analysis suggested the physicochemical parameters of seawater showed no significant difference between three sites ($p > 0.05$) but significantly different between months ($p < 0.05$).

Temperature was found to drop from about 31°C to the lowest temperature of 29.67°C across sampling month from May to October. The pH was found to increase from 7.76 to 8.53 across the three sampling months. DO determined was in range of 5.17-5.63 mg/L with the lowest DO for all three sites were observed during August sampling time. Similar to DO, the salinity in range of 32.66-33.76 psu was observed to have the lowest values during August. Total alkalinity (TA) reached the highest value of 181 mg CaCO3/L during May, while August and October had no much different values within the range 101-107 mg CaCO3/L. Meanwhile, the aragonite saturation (Ω_{Ar}) of each sampling time with range of 1.32-2.79 indicated the supersaturation of calcium carbonate in seawater with $\Omega_{Ar} > 1$ (Shamberger et al., 2011).

Based on SST data retrieved from HadISST, the monthly seasonality of SST showed same trend for the seven years studied with two peaks in May and October and a minimum in January (Figure 6). Monthly SST was within range 26-31°C with the warmer temperature above 30°C was recorded in 2010, 2013, 2014 and 2015.

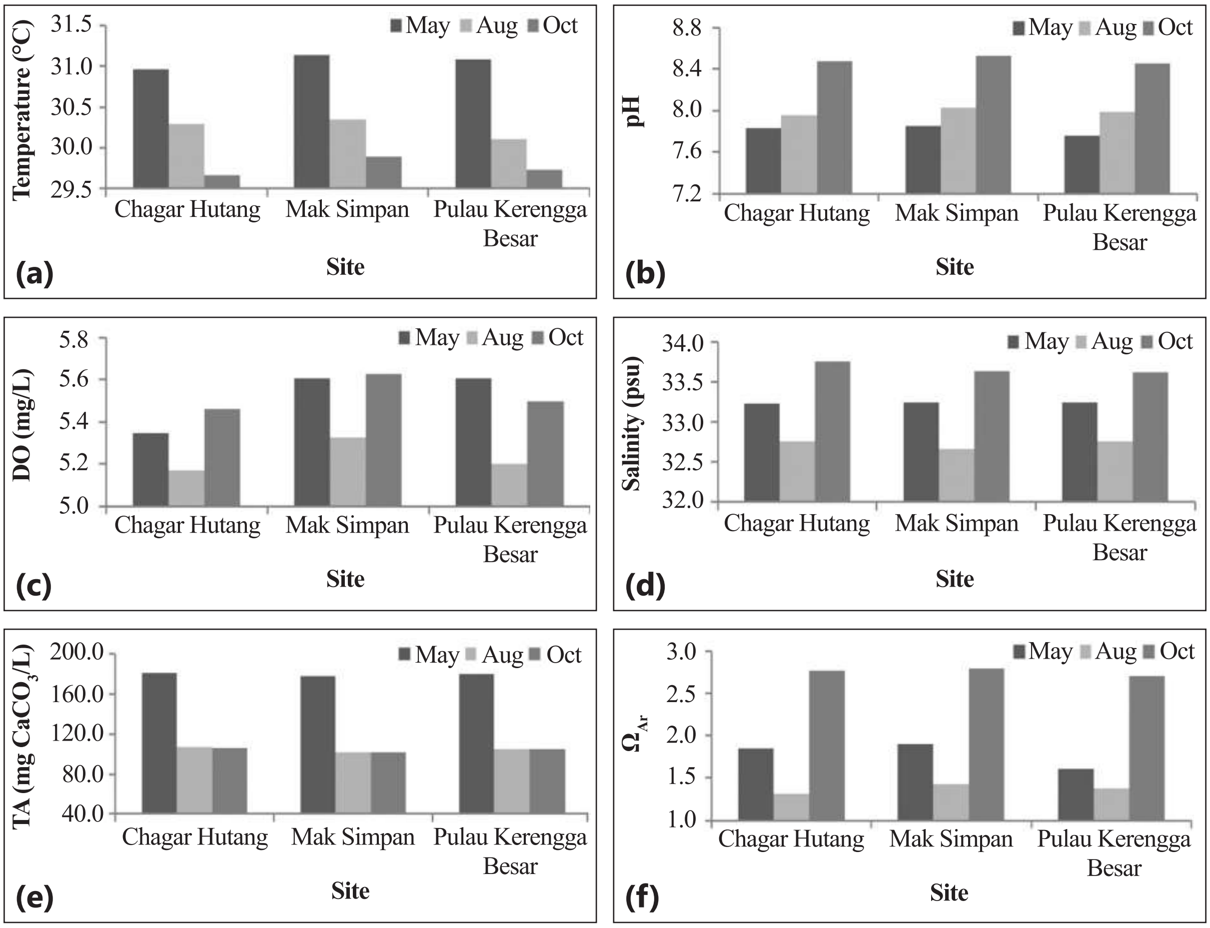


Figure 5. Physicochemical parameters of seawater for (a) temperature, (b) pH, (c) dissolved oxygen (DO), (d) salinity, (e) total alkalinity (TA) and (f) aragonite saturation (Ω_{Ar}) for three sampling sites.

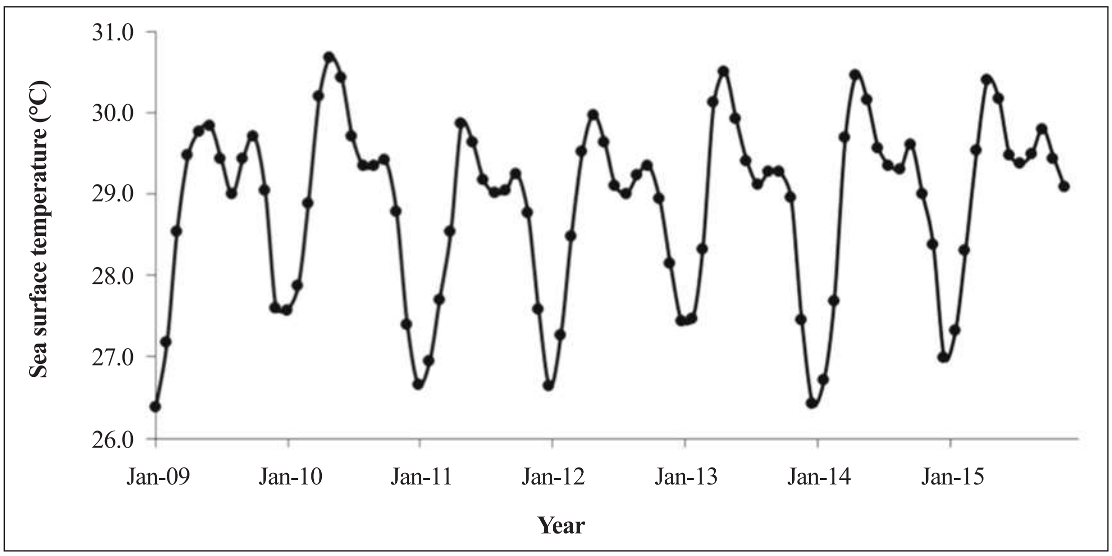


Figure 6. Monthly SST of 2009-2015 retrieved from HadISST 1° gridded data.

SCLEROCHRONOLOGICAL RECORDS

The overall changes in skeletal growth of massive *Porites* corals from Pulau Redang were summarized by linear regression to identify any decreasing or increasing trend of the growth between 2009 and 2015 (Figure 7). The growth of all nine cores had a linear extension rate varied from 1.12-2.90 cm $year^{-1}$, skeletal bulk density about 0.98-1.56 g cm^{-3} and calcification rate about 1.27-3.53 g cm^{-2} $year^{-1}$ over the studied period. The trend of linear extension and calcification rate were observed to decrease significantly by 19.06% and 23.52% over the study period (r = -0.36 & -0.41, p < 0.01). Meanwhile, there was no significant changes found in skeletal bulk density (r = -0.13, p = 0.338). No significant trend or changes of pattern in coral growth (sclerochronological) during the major coral bleaching in 2010.

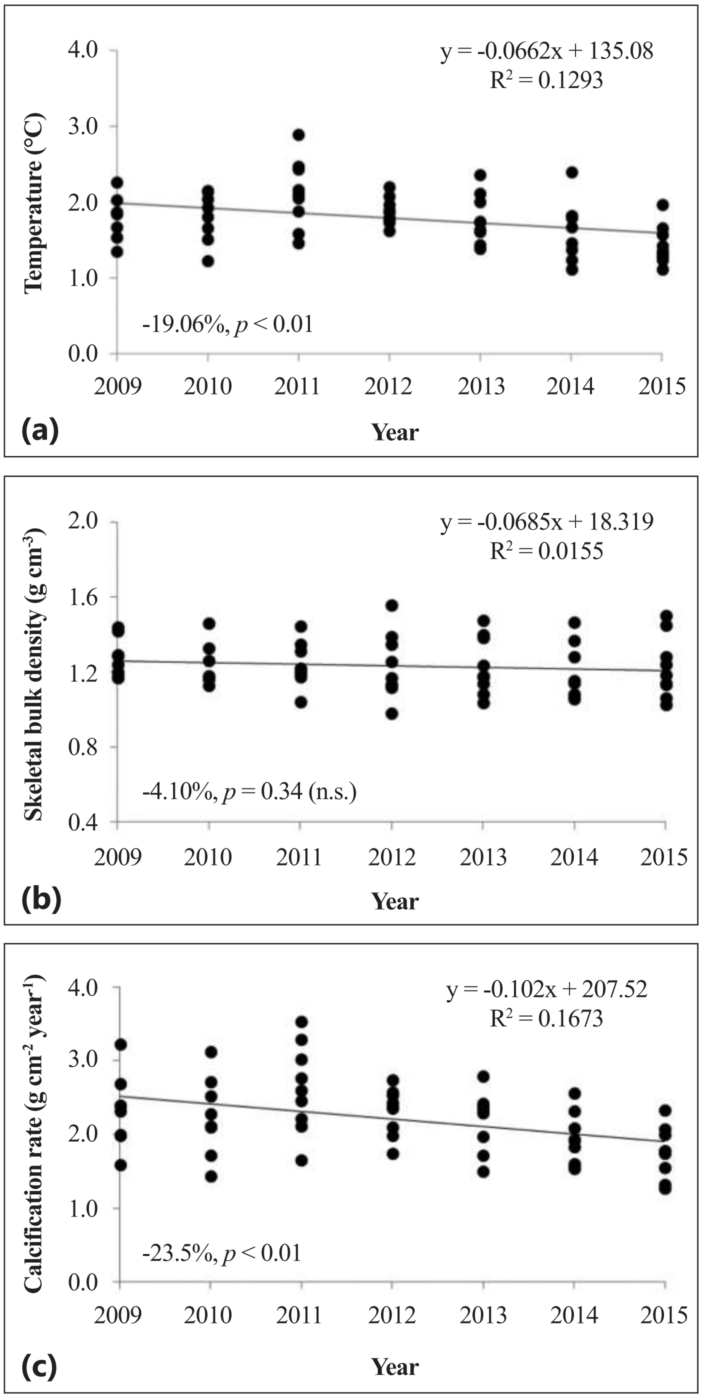


Figure 7. Linear regression and annual percentage of change for corals skeletal growth rate of (a) linear extension, (b) skeletal bulk density and (c) calcification rate in Pulau Redang. *n.s. no significance change.

Table 2. Comparison of trend over time for coral skeletal growth in Pulau Redang using 31 years data and updated 36 years data.

Growth parameter	Tanzil et al. (2013): 31 years (1980-2010)		Updated trend: 36 years (1980-2015)	
	Slope	*p*	Slope	*p*
Linear extension rate	-0.0102	< 0.001	-0.0092	< 0.01
Skeletal bulk density	-0.0027	< 0.01	0.0010	0.069
Calcification rate	-0.0171	< 0.001	-0.0089	< 0.01

The past 31 years coral skeletal growth in Pulau Redang was reported to decline significantly (Tanzil et al., 2013). Compilation of coral skeletal growth data in Pulau Redang from previous study by Tanzil et al. (2013) and current study suggested the trend of the linear extension and calcification rates still decline significantly ($p < 0.01$) (Table 2). Reconstruction the past 36 years of coral skeletal growth response reflected the reducing of coral growth over time may occur at a more rapid rate especially in consequence with the changing of ocean environment due to climate change, ocean acidification and anthropogenic disturbances (Lough & Cooper, 2011).

All skeletal growth parameters showed a significant difference between corals from three sites ($p < 0.01$) (Table 3). Separate correlation was done to examine relationship between site's coral skeletal growths with mean annual SST over seven years studied. Pearson correlation analysis suggested there were at least two sites (i.e. Chagar Hutang and Mak Simpan) showed the negative impact from SST rise by reducing the linear extension and calcification rates since 2009-2015 (Table 3). Such finding is parallel with result from previous study (Tanzil et al., 2013), which observed the important effect of SST on coral skeletal growth in this region. It should be concern to continue monitor the coral growth in future that will be stressed as SST is continuing to rise due to climate change.

Besides SST, coral skeletal growth also varies with the environment adapted at reef area (Lough & Cooper, 2011; Crook et al., 2012). As sea around Malaysia experiences complex hydrodynamic circulation (Akhir, 2014), there may be different pattern of water circulation around an island that influences the local water characteristics. The study areas in Pulau Redang are reef sites that have different geographical characteristics such as Chagar Hutang is a sheltered bay (Zainol et al., 2015), Mak Simpan is protected from strong wave from open sea as it is facing the mainland and the Pulau Kerengga Besar is an offshore rock outcrop reef site (Tanzil et al., 2016). Water circulation will influence nutrient and water quality of seawater and thus drives effect on the coral skeletal growth (Tambutte et al., 2011). However, the water circulation characteristics at these sites are still not well understood. Thus, a more localized study on water dynamic around Pulau Redang is crucial in future to provide a reliable explanation to spatial variation of sclerochronological records at different reef sites.

Table 3. Mean skeletal growth rates, statistical results for spatial variation and relationship with SST for three sites. Significant correlation at p < 0.05*; p < 0.01**

Growth parameter	Site	Mean ± S.D.	Spatial	SST	
			p	r	p
Linear extension rate (cm $year^{-1}$)	Chagar Hutang	1.55 ± 0.26	0.00**	-0.54*	0.02
	Mak Simpan	1.97 ± 0.34		-0.58*	0.01
	Pulau Kerengga Besar	1.82 ± 0.38		-0.38	0.09
Skeletal bulk density (g cm^{-3})	Chagar Hutang	1.32 ± 0.14	0.00**	-0.04	0.86
	Mak Simpan	1.23 ± 0.10		-0.19	0.42
	Pulau Kerengga Besar	1.15 ± 0.12		0.10	0.66
Calcification rate (g cm^{-2} $year^{-1}$)	Chagar Hutang	2.05 ± 0.38	0.04*	-0.49*	0.03
	Mak Simpan	2.42 ± 0.47		-0.60**	0.00
	Pulau Kerengga Besar	2.11 ± 0.56		-0.25	0.27

CONCLUSION

This report assessed a few critical aspects in relationship to climate change.

- Coral growth (linear extension and calcification) were significantly decrease over 2009-2015.
- The increase of sea surface temperature were proven affecting the coral growth (as case study by Tanzil et al., 2013).
- Spatial variation of sclerochronological records exist as localized water characteristics (water circulation, water quality etc.) may vary due to unique geographical characteristic of a particular reef site.
- No significant of coral growth reduction during the major 2010 coral bleaching event.

Recommendations:

Climate change impacts have severely 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. However, long-term records from coral skeleton for 36 years (1980-2015) have significant decline of calcification. Continuous monitoring is important for all Marine Park islands.

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