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The Effect of Current on Coral Growth Form in Selected Areas of Tioman Island, Pahang

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ABSTRACT

Current is a prominent event in the ocean and one of the significant factors that determine the construction of the reef ecosystem. Each individual reef has its unique growth form and the distribution is influenced by current in the particular localities. Interrelation between current and morphological response of coral growth was studied in selected location at Tioman Island. Acoustic Doppler current profile (ADCP) was deployed to collect data of current speed and current direction. MIKE 21 Flow model FM software was used to model the hydrodynamic pattern of the study area. The model was calibrated using secondary field current data with reasonable R^2 value of 0.6096. Using the calibrated model, the mean current speed for two selected stations at the West coast of Tioman Island was 0.035 ms^{-1} and 0.172 ms^{-1}; while the mean current speed for two selected stations at the East coast of Tioman Island was 0.030 ms^{-1} and 0.050 ms^{-1}. Based on the coral growth form distribution at the study area, the type of growth forms at the west coast dominated by ACD and CM coral while in the east coast was dominated by ACD and CP coral respectively. Different growth forms of coral were emerged in response to different current speed. This study showed the distribution of coral growth forms were influenced by the current action.

Introduction

The coral reefs are unique and one of the most important ecosystem in the world which occupying less than 0.2% of ocean seafloor. Although they inhibit very small area, they harbour the highest biodiversity in marine ecosystem and support estimated 0.5 million of marine species globally (Linan-Cabello, 2013). Current and wave stress of the water body are among the critical hydrophysical factors that interact and control reef growth. Furthermore, distributions of coral reefs are influenced by the current in particular localities, which favour the growth (Dollar, 1982; Reaka *et al.*, 2008). A different area of coral reef supports a different growth form of coral, which can be defined by their morphological identification of their physical appearance (Karleskint, 2010). In Malaysia, Tioman Island has one of the highest live coral coverage areas in Peninsular Malaysia (Toda, *et al.*, 2007). As Tioman Island is one of the tourist destinations, monitoring and study the coral influences factor is important. The data and study on influence of current in the coral growth form are limited. Thus, using hydrodynamic model based on numerical modelling is one of the methods to study the current properties in the study area. One of the available two-dimensional computer based modelling system for coastal water and sea is MIKE 21 HD. Numerical model has advantages over conventional empirical analysis in analysing time-dependant processes and unlocking the nonlinearity of the physical process in shallow sea (DHI, 2005). This study determines the morphological response of coral growth form toward currents.

Methodology

Study Area

Four sampling stations at Tioman Island were selected in this study (**Figure 1**). These stations were divided into two different zones: East Coast (Benuang Bay and Dalam Bay) and West Coast (Renggis and Terdau Bay). In between mid of November until March every year, the weather is affected by Northeast Monsoon.

Figure 1. Location of four sampling stations in Tioman Island. Benuang Bay (*02º 55'19.24"N, 104º 11'48.84"E*), Dalam Bay (*02º45'44.55"N, 104º13'57.15"E*), Terdau Bay (*02º53'32.44"N, 104º 07'53.58*), Renggis (*02º49'0.70"N, 104º 07'53.58"E*).

Model Simulation and verification

Modelling current pattern of Tioman Island using MIKE 21 Flow Model FM requires input data, which are bathymetry, tide, tidal potential, wind, and Manning's value data. The bathymetry data were extracted from the Royal Malaysia Navy Chart. Field sampling were conducted twice, from 27th April to 30th April 2015. The tide and tidal potential readings were retrieved for surface elevation time series from Royal Navy Malaysia tide table dated from 27th April 2015 until 30th April 2015 (RMS, 2015). Secondary wind data on the same date from the Department of Meteorology of Malaysia (MET) in time series has been used in the model. Manning's value for the model has been determined from sediment analysis. In-situ current data have been collected using Acoustic Doppler Current Profiler (ADCP). Secondary current data for verification have been recorded in similar sampling locations from July until September 2013. The secondary current data has been used to calibrate and verify the extended simulated current from April to September 2015 in MIKE21 Flow Model FM.

Table 1. Details on model data inputs

No.	Input Data	Details
1.	Bathymetry	Extracted from RMS Chart No. 3445
2.	Tidal data	RMS Tide Table 2015 (27 April 2015 until 30 April 2015)
3.	Tidal potential data/ Tidal constituent parameters	RMS Tide Table 2015
4.	Manning's value	Coefficient 32
5.	Wind Data	Malaysian Meteorological Department 2015

Identification of Coral Growth Form

The identification of coral growth form is used Coral Video Transect (CVT) method (Abdo et al., 2004) adapted from Australian Institute of Marine Science (AIMS) with some modification. The location of transect was selected randomly based on the presence of the coral at the sampling stations. Four transects of 30m length with 2m interval were laid in parallel on the coral to from a quadrat at each station (Figure 2). A total of 16 transects were used in this study. The video of corals communities at each transect was recorded using video camera with the distance of 20cm to 25cm from the corals to avoid the glare images in the video recorded. The video recorded approximately 6 minutes per transect to obtain a clear and sharp image of the corals communities. After the CVT procedures, videos were analysed in the laboratory for data processing and data analysis. Coral Point Counting with excel extension (CPCe) was used to analyse the data from static images extracted from the videos. The video of each transect was cut into 150 static images and 10 intercept point randomly assigned on each images. The coral morphology of each intercept point in the static images was referred to Coral Finder Toolkit to get percentage cover of coral growth form at all sampling stations.

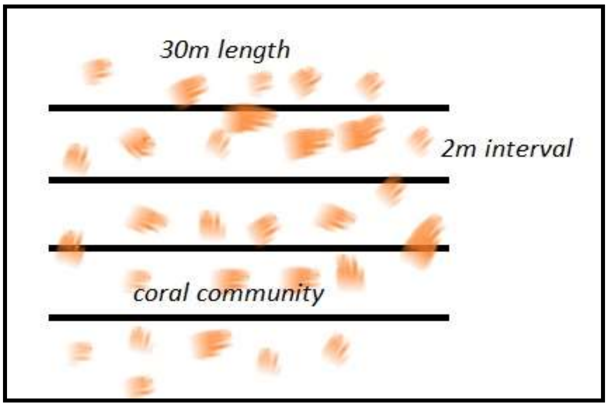


Figure 2. Arrangement of transects at sampling station

Statistical Analysis

Statistical analysis was conducted using PALeontological Statistic (PAST) software. The data was tested to normality test investigate the distribution of the data to determine type of data either parametric or non-parametric. A One-way Anova was conducted to investigate whether there were any significant difference between growth form categories and sampling location. Pair-wise correlation of current speed and coral life form categories were calculated using Pearson correlation to analyse the significant of every variables.

Result and Discussion

Current pattern and hydrodynamic properties

Hydrodynamic properties of sampling stations were successfully simulated using MIKE 21 Flow Model FM. The R^2 of linear regression (0.6096) between calibrated hydrodynamic model and field data gave reasonably reliable data. Wind regime causes the water surface to move, consequently, produce surface friction which causes water to move in the same direction as the wind was blowing. The simulation of hydrodynamic include during the high tides and low tides because the rise and fall of sea level rise will generate tidal current where the current is at maximum speed midway between high tide and low tide (Garrison, 2010). Lowest speed of current occur when the current changes its direction during high tides and low tides. As corals grow within few meters from the shore and water surface, the flow of water will affect the ability of corals to live in term of the drag force produced by the current. The current speed recorded at both zones gave different results. In the east coast zone, Benuang Bay has a speed of 0.030 ms^{-1} and Dalam Bay was 0.050 ms^{-1}. Meanwhile, for the west coast zone, Terdau Bay has a speed of 0.172 ms^{-1} and Renggis has 0.035 ms^{-1}. Terdau Bay experiences the fastest speed due to the geographical location of the sampling station, which located at water channel in between Tioman Island and a small island nearby (Figure 3) which narrow water channel will experience high speed of tidal current during the tidal extreme.

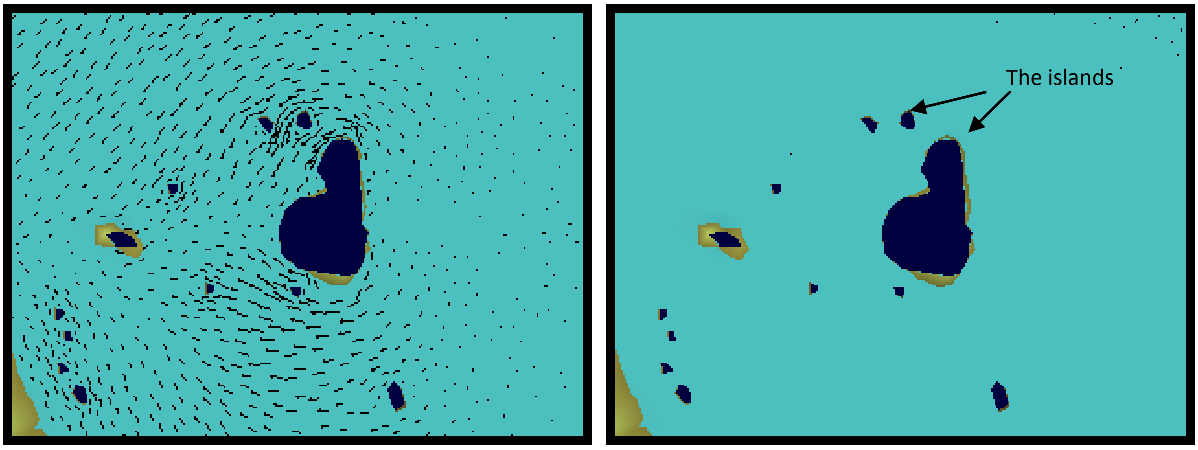


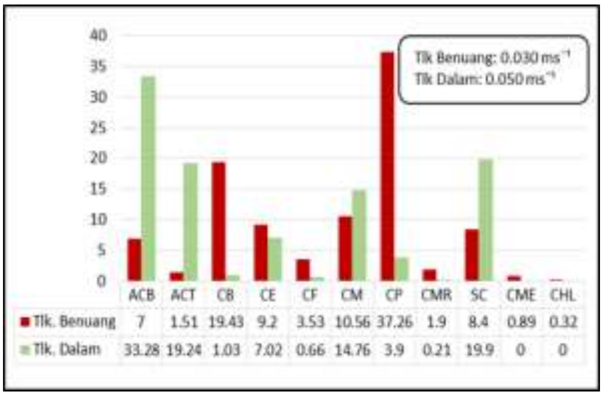
Figure 3. Simulated hydrodynamic patterns during highest speed (left) and lowest speed (right) in Tioman Island.

Distribution of Coral Growth Form

A total of 11 coral growth forms were identified in this study (Table 2). The growth form data were represented in the percentage of coral growth form in the East coast and West coast of Tioman Island (Figure 4). Growth form categories identified in this study mostly are the same, but the dominancy of the growth form of coral was varies. This varies growth form are due to the ability of corals to adapt to the environmental condition in order to survive. The corals in Benuang Bay at 0.030 ms^{-1} were dominated by plate-like growth form (CP) meanwhile at Dalam Bay (0.050 $ms^{-1)}$, *Acopora* branching coral (ACB) was found abundant. On the other hand, in the west coast zone, Terdau Bay with the fastest speed was dominated by massive/submassive form (CM) and at speed of 0.03 ms^{-1}, Renggis was dominated by *Acopora* branching coral (ACB).

Table 2. Coral growth form recorded from the sampling stations

Code	Growth forms	Code	Growth forms	Code	Growth forms
ACB	*Acropora* branching	CF	Foliose	SC	Soft coral
ACT	*Acropora* tabular	CM	Massive/submassive	CME	*Millepora*
CB	Non-*Acropora* branching	CP	Plate-like	CHL	*Heliopora*
CE	Encrusting	CMR	Solidary/ free living		



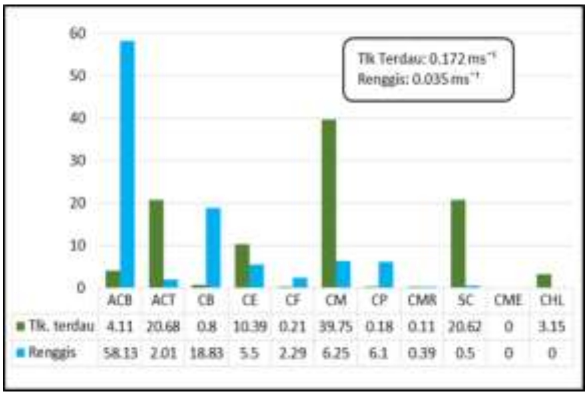


Figure 4. Percentage of coral growth form at East coast (left) and West coast (right) of the island

Coral responses to water flow within their environment in a complicated way which can alter their physical structure. Variation of current flow may influence the reconstruction of reef structure, coral calcification rate and induce specific preferable growth forms such as branched morphology for efficient nutrient uptake or platy form (Monismith, 2007; Roger *et al*., 2013). A study by Jankowski *et al.* (2014) and Dollar (1982) stated that percentage cover of plating coral increasing with the increasing depth and reduced light intensity. Benuang Bay was approximately 10m depth and was observed deeper than other stations from the bathymetry data visualised by the hydrodynamic model. CP in shallow water are fragile and likely to be easily damaged by severe current disturbance, hence relatively abundant in the calm and deeper water (Hughes & Jackson, 1985; Hughes, 1987). The growth form of corals tend to be CF and CP due to the large surface area of these forms to trap light for photosynthesis in a deeper region with limited photosynthetic activities of zooxanthellae, thus limit the rate of calcification of calcium carbonate (Barnes & Hughes, 1999). Moderately severe wave action region and constant stirring from current flow tends to be dominated by branching coral (Barnes & Hughes, 1999). Present of wave action provides high oxygen and create flow on the coral surface accelerate nutrient transport in the coral ecosystem (Wallace, 2011; Shapiro *et al*., 2014). Domination of ACB at Dalam Bay and Renggis may due to faster current flow because ACB have fast axial growing which favour good circulation location and optimum light intensity for photosynthesis. *Acropora* spp. able to rapidly colonize the space left by broken coral given the environmental condition is favourable, the broken branches can outgrow into new colonies. The efficient disturbances prevent monopolization through non-lethal fragmentation and support the diverse species of corals and development of coral reefs (Allison & Magu, 1982). Coral communities in Terdau Bay had CM as dominant morphotype. Strong wave action can be lethal which it can produce great drag force that can break the corals or trimming the structure (Monismith, 2007; Roger, 2013). Toda *et al.* (2007) reported that CM are commonly found in harsh environmental condition. The boulder forms of CM are stable and less likely to break by strong current speed. Coral reef structure can experience a structural shift from branching to massive dominated coral communities in less optimum condition in order to adapt to the environmental stress (West & Salm, 2003; Kenyon *et al*., 2006).

One-way Anova test of the growth form distribution over the sampling stations showed there were no significant differences between the coral growth form and sampling stations with $p \leq 0.05$. Pearson's pair-wise correlation provided statistically significant relationship between hydrophysical disturbance and distribution of coral growth form. There were no significant differences between current speeds and growth form of coral. Biophysical interactions are complicated and complex in an ecosystem, thus the non-linear data producing the contrary result (Daby, 2006). However, there was significant correlation in composition of coral growth form among the sampling stations where the domination of one growth form would outgrow the other growth form. From the analysis, there are significant correlation between CB and CF ($r=0.9469$, $p<0.05$); CP and CMR ($r=0.9995$, $p<0.05$); CP and CME ($r=0.9872$, $p<0.05$); CP and CHL ($r=0.9872$, $p<0.05$); CMR and CME ($r=0.9854$, $p<0.05$); and between CMR and CHL ($r=0.9854$, $p<0.05$). The correlation test was conducted to study the significant association between the variables which is current speed and all growth forms categories. The results of this statistical analysis provided additional indicative information on the composition of coral growth form in coral reef communities whereby dominancy of a particular growth form will associate with another growth form meanwhile supressing certain growth form.

Conclusion

As the conclusion, each of the sampling stations represent different hydrodynamic properties and current pattern. The total number of 11 coral growth forms were identified in this study and have a different morphological response toward different current speed. It can be concluded that current speed is one of the factors influencing distribution of coral growth forms in Tioman Island with consideration that there are also other factors affected coral growth forms such as water quality and water depth.

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