SPATIO-TEMPORAL VARIATION OF SCLERACTINIAN CORAL RECRUITMENT PATTERN ON TERRA-COTTA TILES AND ARTIFICIAL REEF PLATES IN TIOMAN ISLAND, MALAYSIA

BY

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ABSTRACT

Understanding coral recruitment is important in the wake of regional decline of coral reef. This study was aimed to demonstrate three important aspects in recruitment processes: adult coral community structure; spatio-temporal coral recruitment pattern and the impact of sessile benthic organisms on post-settlement processes in Tioman Island, Malaysia. A total of six reef sites were surveyed using coral video transect method namely Genting Village, Renggis Island, Teduh Bay, Dalam Bay, Juara Bay and Benuang Bay. Tioman Island has 'good' coral reef condition with an average of 53% total live coral cover. Twenty eight genera from thirteen families were recorded during adult coral community structure survey with Benuang Bay demonstrated the highest H' and $E_{H'}$ indexes (2.35 and 0.78). Recruitment and post-settlement survival studies were conducted at four reef sites namely Genting Village, Renggis Island, Teduh Bay and Juara Bay. Recruitment densities were determined by quantifying number of coral recruits settled on terra-cotta tiles and artificial reef settlement plates. Coral recruits were categorized as Acroporidae, Pocilloporidae, Faviidae, Poritidae and Fungiidae. A total of 2087 coral recruits were counted in this study with mean recruitment densities 8.76 ± 0.75 recruits per plate. Recruitment dominated by Acroporidae followed by Pocilloporidae, Faviidae, Poritidae and Fungiidae. Recruitment densities varied significantly within spatio-temporal scales, but not between depth, types of settlement plates and plate's orientation. Spawning event was predicted in Tioman Island with major spawning event might begin in August while minor spawning event began in April. Colonization of sessile benthic organism may influence recruitment success during initial settlement period. Bryozoan showed negative correlation with recruitment densities at all reef sites. This research has provided important information in assessing reef resilience towards various disturbances inside marine protected area in Malaysia.

KEYWORDS: Adult Coral Community, Coral Recruitment, Spatio-temporal, Terra-cotta, Artificial Reef Plate, Post-settlement Survival, Tioman Island

الملخص

فهم توظيف الشعاب المرجانية مهم جداً في أعقاب الإنخفاض الإقليمي في الشعاب المرجانية. تهدف هذه الدراسة لإثبات أن هنالك ثلاثة جوانب هامة في عمليات التوظيف: تركيب مجتمع الشعاب المرجانية البالغة, نمط توظيف الشعاب المرجانية المكاني والزماني وتأثير الكائنات الحية القاعية اللاطئة على عمليات ما بعد التسوية. تم استطلاع ما مجموعه ستة مواقع للشعاب المرجانية باستخدام طريقة تسجيل الفيديو وهي: قرية جنتنغ, جزيرة رنغس, شاطىء تيدو, شاطىء دالام, شاطىء جوارا ووشاطىء بينانغ. حالة الشعاب المرجانية في جزيرة تيومان جيدة بمعدل يبلغ 53% من إجمالي الغطاء المرجاني الحي. سجلت ثمانية وعشرين جنسا من ثلاثين عائلة خلال مسح تركيب مجتمع الشعاب المرجانية البالغة في شاطىء بينانغ واثبتت أعلى H و $E_{H'}$ بمؤشرات (2.35 و 0.79). أجريت دراسات التوظيف والبقاء على قيد الحياة بعد التسوية في أربعة مواقع للشعاب المرجانية وهي قرية جنتنغ, قرية رنغس, شاطىء تيدو وشاطىء جوارا. تم تحديد كثافة التوظيف عن طريق قياس عدد الشعاب المرجانية الموظّفة على بلاط تيرا كوتا وصفائح توطين الشعاب المرجانية الاصطناعية. صنّفت الشعاب المرجانية الموظّفة كالتالي: Pocilloporidae, Acroporidae , Poritidae,Faviidae وFungiidae . تم إحصاء ما مجموعه من 2087 شعبة مرجانية موظّفة في هذه الدراسة مع متوسط كثافات التوظيف 8.76 ± 0.75 لكل صفيحة. هيمنت Acroporidae على عملية التوظيف تليها Pocilloporiidae، Faviidae، Poritidae و Fungiidae. تفاوتت كثافة التوظيف بشكل كبير في النطاقات المكانية والزمانية، ولكن ليس بين العمق، أنواع صفائح التوطين وجهة الصفيحة. تم التنبأ بحدوث تفريخ بشكل متعدد ومعين في جزيرة تيومان مع تنبأ حدوث تفريخ في شهر آب بينما حدث تفريخ طفيف في نيسان. توطين الكائنات الحية القاعية اللاطئة قد يؤثر على نجاح التوظيف خلال مرحلة التأسيس الابتدائية. أظهرت المرجانيات علاقة سلبية مع كثافات التوظيف في جميع مواقع الشعاب المرجانية. زودت هذه الدراسة معلومات هامة في تقييم قدرة الشعاب بالاستجابة لمختلف الاضطرابات داخل المنطقة المحمية البحرية في ماليزيا.

كلمات مفتاحية: مجتمع الشعاب المرجانية البالغة, توظيف الشعاب المرجانية, مكاني-زماني, بلاط التيراكوتا, صفيحة الشعاب المرجانية الصناعية, البقاء بعد التوطين, جزيرة تيومان.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Biosciences)

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Muhammad Faiz bin Mohd Hanapiah

Signature……. Date ….....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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Affirmed by Muhammad Faiz bin Mohd Hanapiah

……..……..…… ……..
Signature Date

To my wife, my son, my family and to those who care on coral reef resilience around the world.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS / SYMBOLS

GV	Genting Village
RI	Renggis Island
TB	Teduh Bay
DB	Dalam Bay
JB	Juara Bay
BB	Benuang Bay
CVT	Coral Video Transect
CPCe	Coral Point Count with Excel extension
CCA	Crustose Coralline Algae
%	Percent
°C	Degree Celcius
P	Probability
Cm	Centimeter
H’	Shannon-Weiner Diversity Index
EH’	Evenness Index

CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION

Coral reef, one of the most diverse and complex ecosystem in the world is now vulnerable towards various environmental and human pressure. Natural impacts such as storm events, temperature variation, diseases and biological infestation have periodic detrimental effects on the coral reef. Anthropogenic impacts such as effluent discharge, improper coastal development, over fishing and sedimentation have piled on more pressure to coral reef ecosystem (Bellwood, Hughes, Folke and Nystrom, 2004; Mora, 2008; Jordan, Banks, Fisher, Walker and Gilliam, 2010). Coral decline has been reported in many parts of the world (Gardner, Côté, Gill, Grant and Watkinson, 2003; Hughes, Baird, Bellwood, Card, Connolly, Folke and Kleypas, 2003; Pandolfi, Bradbury, Sala, Hughes, Bjorndal, Cooke and Paredes, 2003) including marine protected area of Malaysia such as Tioman Island Marine Park which is located in the east coast of peninsular Malaysia. Harborne, Fenner, Barnes, Beger, Harding and Roxburgh (2000) reported the average of coral cover in Tioman Island was about 45.3% and annual surveys conducted by Reef Check Malaysia indicated that several sites in Tioman Island are exposed towards environmental and anthropogenic stress (Reef Check Malaysia, 2008). Therefore, elucidating coral recruitment pattern and processes are vital in understanding reef resilience capacity and potential for natural recovery.

Coral recruitment process can be described as survival of larvae until the first observation which includes pre-competency period, settlement on substrate and post-

settlement mortality (Pineda, Reyns, and Starczak, 2009). Larvae released by adult coral develop into competent larvae before settling on substrate and metamorphose into juvenile coral. Several processes are affecting coral recruitment variation such as production of larvae, larvae dispersal pattern, mortality risk during dispersal, settlement success and young juvenile survivorship (Underwood and Keogh, 2001). Coral recruitment has been investigated widely in many reef locations around the world especially in the Indo-Pacific region. Recruitment rates differ among locations and the highest recruitment was reported in Australia's Great Barrier Reef and in the Central Pacific (Harrison and Wallace, 1990). Recruitment process declines with increasing latitude and variation of relative abundance of coral spats also related to changes in latitude with broadcast spawning Acroporids recruits abundantly in low latitude while high latitude dominated by Pocilloporids (Hughes, Baird, Dinsdale, Harriott, Moltschaniwskyj, Pratchett and Willies, 2002). Since the future status of the reef may be better estimated by recruitment process rather than current condition of coral community structures, understanding coral recruitment pattern are important for coral reef conservation and ecosystem management (Dunstan and Johnson, 1998).

Modes of reproduction among coral give significant effects on dispersal of coral larvae in the water column. Coral generally categorized as broadcast spawner and brooded coral based on the modes of reproduction. Broadcast spawner releases gametes during mass spawning events where external fertilization and embryogenesis occur. Fertilized eggs will develop into competent planule and remain in the water for a certain period called pre-competency period. Therefore, planulae larvae of broadcast spawner normally disperse away from natal reef which influenced by current movement until they find suitable substrate to metamorphose. In contrast, brooded adults release fertilized planule larvae which competent enough to settle right

after release. Thus, they have lower dispersal potential and consequently retained within the natal reef.

Coral recruitment pattern varies in spatial and temporal scales (Glassom, Zakai and Chadwick-Furman, 2004; Mangubhai, Harrison and Obura, 2007). Several factors were demonstrated affecting coral recruitment including adult coral densities (Hughes and Tanner, 2000), coral fecundity (Hughes and Tanner, 2000), competition between other benthic organisms (Harrison and Wallace, 1990; Baird and Hughes, 2000), different spatial scales (Dunstant and Johnson, 1998; Baird and Hughes, 2000; Hughes and Tanner, 2000; Soong, Chen, Dai, Fan, Li and Hsieh, 2003), temporal scales (Nozawa and Harrison, 2008), larval dispersal (Harii and Kayanne, 2003), connectivity among reefs (Hughes et al., 2002), hydrodynamic changeability (Amar, Chadwick and Rinkevich, 2007), orientation of the substratum (Birkeland and Randall, 1981), different depth gradient (Baird, Babcock and Mundy, 2003), light intensity (Mundy and Babcock, 1998), chemical cues (Maida, 2001; Baird and Morse, 2004), sedimentation stress (Gilmour, 1999) and also eutrophication level (Tomascik, 1991).

Coral larvae secrete visible calcium carbonate skeleton within several hours after settlement, which leaves record of settlement even after the polyps dies (Richmond, 1985) called recruits. The term coral recruits refer to juvenile coral that is of a size visible to naked eye (approximately 2 mm) to colonies up to 5 cm in size. Coral recruits can be identified into family Acroporidae, Pocilloporidae and Poritidae in Indo-Pacific region during early year of recruitment due to lack of distinguishing morphological features of other juvenile recruits (Babcock, Baird, Piromvaragom, Thomson and Willis, 2003). Quantification of coral recruits on settlement plates gives important knowledge about variation of recruitment densities within different scales.

Post-settlement survival of coral larvae is an important process which can change the settlement pattern (O' Learry and Potts, 2011). Juvenile corals may die after successful settlement through sedimentation, predation and competition among sessile benthic organism. Therefore, density of juvenile recruits within an area could decrease over times which represent post-settlement mortality (Clark, 2000). Successful larvae recruitment often being hampered by the overgrowth of other sessile benthic organisms such as turf algae, bryozoans, barnacles, bivalves and serpulid worms. Dunstan and Johnson (1998) reported significant negative correlation between recruitment abundance and total cover of bryozoan. Post-settlement mortality was reportedly high during the first three months after settlement (Vermeij and Sandin, 2008) and the survival of juvenile recruits increases after 6 – 12 months (Mundy and Babcock, 2000). Therefore, there is general assumption that level of post-settlement mortality depends on initial recruitment densities of coral larvae.

1.2 PROBLEM STATEMENT

To date, there has been less documented study in coral recruitment in Malaysia despite of its important impacts on coral reef management. A single study was conducted on colonization of artificial substrate on the coral reef at Payar Island which concern on overall pattern of sessile benthic colonization rather than comparing coral recruitment densities (Satien, Zulfigar, Alan and Reungchai, 2000). Coral recruitment studies also has been conducted in neighboring countries such as Philippine (Reyes and Yap, 2001), Indonesia (Fox, Pet, Dahuri and Caldwell, 2003; Fox, 2004; Salinas-de-León, Dryden, Smith and Bell, 2013), Thailand (Sawall, Phongsuwan and Ritcher, 2010) and Singapore (Loh, Tanzil and Chou, 2006). Therefore, this study would be vital to

describe the coral recruitment pattern within coral reef ecosystem in Tioman Island, Malaysia.

1.3 STUDY SITES

Tioman Island is situated about 32 nautical miles east from Tanjung Gemuk, Pahang and approximately 19 km long and about 11 km wide. The topography and landscape in Tioman Island consist of mountain peaks, sandy beaches and rocky cliffs (Salleh, Othman, Sarmidi, Jaafar and Norghani, 2012). Tioman Island has been chosen for this study since it has among high coral diversity compared to other islands in Peninsular Malaysia (Harborne et al., 2000). Abundant adult coral colonies might results in better local larvae supply for recruitment process. Six reef sites were chosen for adult coral community structure namely Genting Village (GV), Renggis Island (RI) Teduh Bay (TB), Dalam Bay (DB), Juara Bay (JB) and Benuang Bay (BB) as shown in Table 1.4. Genting Village, Renggis Island and Teduh Bay located on the west coast of Tioman Island while Dalam Bay, Juara Bay and Benuang Bay located on the east coast. Four sites were chosen for coral recruitment and post settlement survival which are Genting Village, Renggis Island, Benuang Bay and Juara Bay respectively (Figure 1.1). Table 1.1 describes each of reef sites in this study in terms of morphology, depth gradient, types of substrate and visibility. Figure 1.2 shows sampling locations in this study.

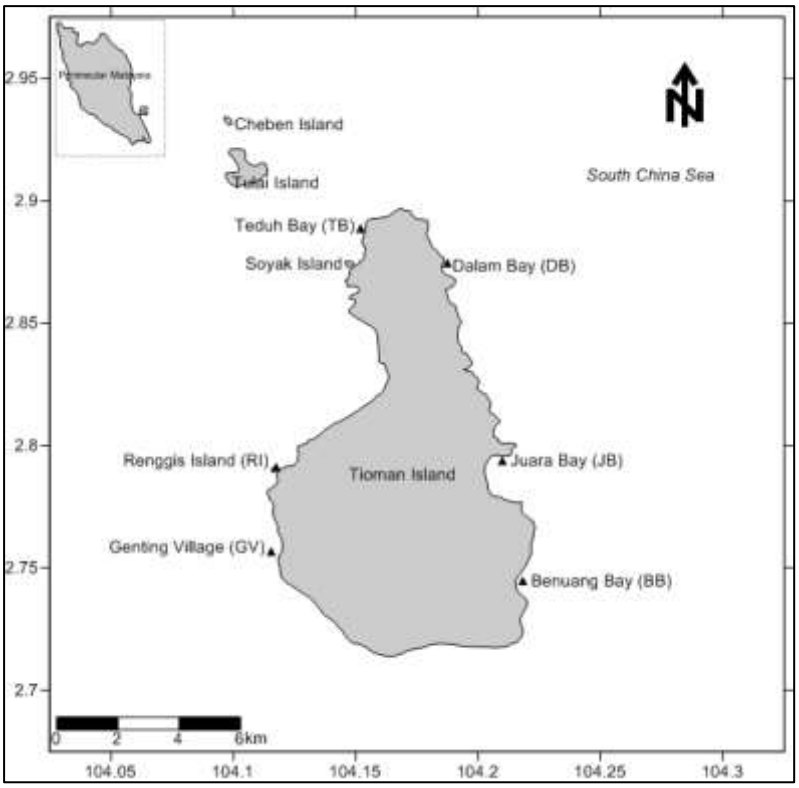

Figure 1.1 Map of study sites. Three sites located on the west coast of Tioman Island which include Genting Village (GV), Renggis Island (RI) and Teduh Bay (TB). Another three sites located on the east coast of Tioman Island namely Dalam Bay (DB), Juara Bay (JB) and Benuang Bay (BB)

Table 1.1 Descriptions of study area. Six reef sites were chosen in adult coral community structure study in Chapter 3. Only four reef sites were chosen for coral recruitment and post-settlement survival studies namely Genting Village, Renggis Island, Teduh Bay and Juara Bay

Sites	Latitude	Longitude	Sites descriptions
Genting Village (GV)	N2.7569°	E104.116°	Genting Village is located on the west coast of Tioman Island. It has shallow reef flat ranging from 3 meters to 10 meters depth. Bottom substrate dominated by sand and some patches of bedrocks.
Renggis Island (RI)	N2.7912°	E104.118°	Renggis Island located on the west coast of Tioman Island. It has narrow and steep sloping reef ranging between 3 meters to 12 meters depth. Bottom substrate dominated by sand.
Teduh Bay (TB)	N2.8887°	E104.152°	Teduh Bay located on the west coast of Tioman Island and adjacent to Salang Village. It has shallow reef flat ranging from 3 to 10 meters deep. Bottom substrate dominated by rocks and boulders.

Table 1.1 – continued

Sites	Latitude	Longitude	Sites descriptions
Dalam Bay (DB)	N2.8746°	E104.188°	Dalam Bay is located on the east coast of Tioman Island. This remote area has wide shallow reef flat ranging from 3 meters to 8 meters depth. Bottom substrate dominated by rocks and boulder. It has good visibility ranging from 7 to 10 meters.
Juara Bay (JB)	N2.7935°	E104.210°	Juara Bay is located on the east coast of Tioman Island. It has patches reef along the slightly steep bottom slope ranging from 5 meters to 15 meters. Sand and rock dominated bottom substrate and this site normally has moderate to poor visibility.
Benuang Bay (BB)	N2.7445°	E104.218°	Benuang Bay is located on the east coast of Tioman Island. This remote area has wide shallow reef flat along the gently sloping bottom ranging from 3 meters to 12 meters depth. Bottom substrate dominated by rocks and boulder. It has good visibility ranging from 7 to 10 meters.

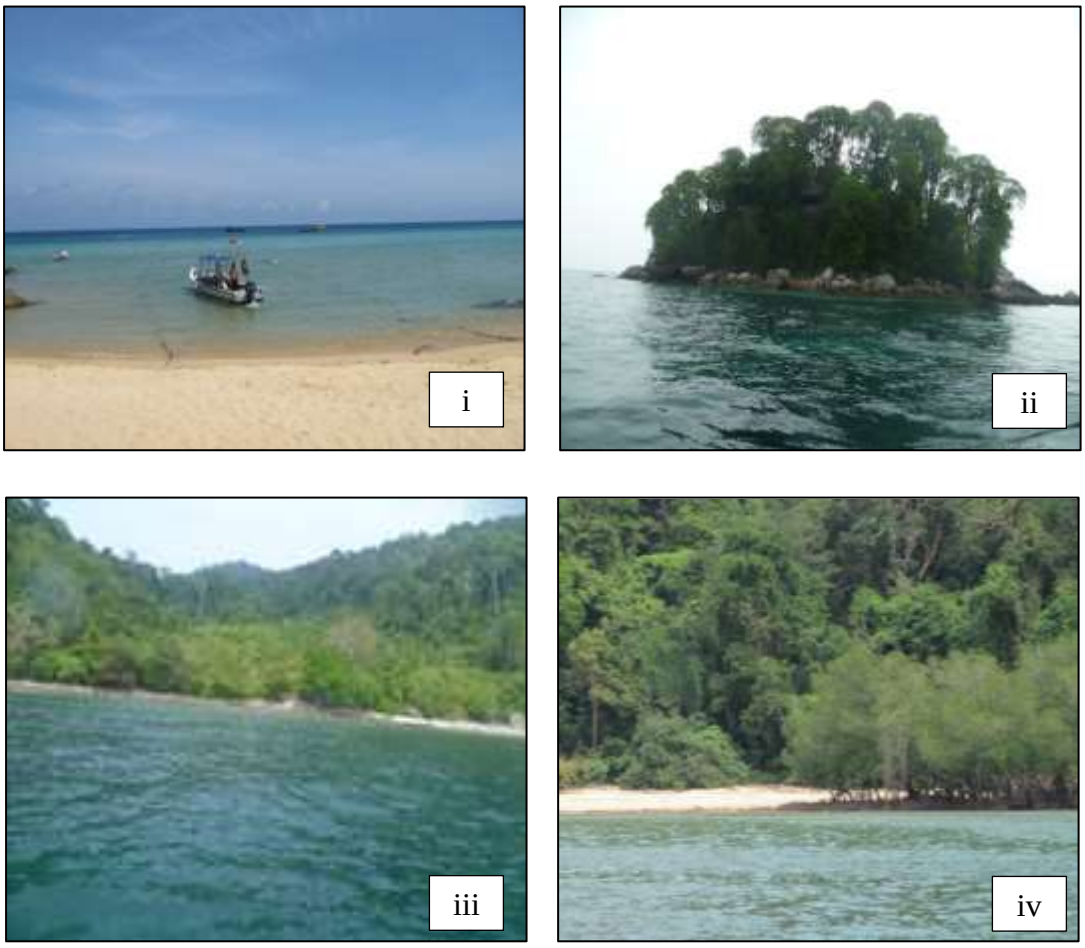

Figure 1.2 Sampling sites in Tioman Island. i) Genting Village; ii) Renggis Island, iii) Teduh Bay; iv) Dalam Bay; v) Juara Bay and vi) Benuang Bay

Figure 1.2 - continued

1.4 SIGNIFICANCE OF THE STUDY

Coral reef is the most important marine ecosystem in Tioman Island especially in increasing fisheries stock and also for tourism industry. Therefore, knowledge about recruitment process is essential in order to estimate the survival and resilience of coral reef in this island. Findings from this research will provide reliable scientific data on factors influencing coral recruitment at several reef sites in Tioman Island. Apart from that, this study also is important to evaluate the potential of artificial reef plates in enhancing coral settlement. Such information is needed in order to implement strategic planning for habitat restoration in the study area.

1.5 RESEARCH OBJECTIVES

1.5.1 General Objective

The primary goal of this study is to give comprehensive description on scleractinian coral recruitment process in Tioman Island. It provides vital information on current reef status in Tioman Island and the ability of this reef to recover through recruitment

process. The study also aims to evaluate the potential of artificial reef plates as suitable substrate to enhance recruitment densities.

1.5.2 Specific Objectives

1. To examine adult coral community structure in Tioman Island as potential larvae supply in recruitment process.
2. To quantify spatio-temporal pattern of recruitment density on terra-cotta tiles and artificial reef plates.
3. To evaluate the impact of other sessile benthic organism on post-settlement survival of coral larvae during initial and post-settlement period.