ENVIRONMENTAL PARAMETERS AND GROWTH PERFORMANCE OF GREEN MUSSEL, *Perna Viridis* IN MARUDU BAY

AFIZAH BINTI MOHD TAIB

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UNIVERSITI MALAYSIA SABAH

2017

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AFIZAH BINTI MOHD TAIB

THESIS SUBMITTED IN FULFILLMENT
FOR THE DEGREE OF MASTER OF SCIENCE

BORNEO MARINE RESEARCH INSTITUTE
UNIVERSITI MALAYSIA SABAH

2017

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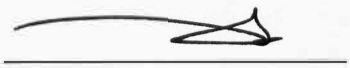

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MY1211004T

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2. CO-SUPERVISOR

Dr. John Madin Signature

ACKNOWLEDGEMENTS

First, praise to Allah, the Almighty, on whom ultimately we depend for sustenance and guidance. Second, I would like to express my sincere gratitude to my supervisor Associate Prof. Dr. Julian Ransangan, for his guidance, constructive comments, patience and continuous encouragement throughout the completion of this dissertation. Without him this thesis, would not have been completed. My sincere appreciation also goes to my co-supervisor Dr. John Madin and Prof. Dr. Kishio Hatai for their invaluable advice and immense knowledge.

I thank University Malaysia Sabah and Ministry of Higher Education for providing me the scholarsip to support my study. My sincere appreciation is also extended to the Borneo Marine Research Institute and Department of Fisheries Sabah for allowing me to use equipment and facilities throughout my study. I extend my heartfelt thanks to all lecturers and staffs of the Borneo Marine Research Institute for their co-operation.

I am also deeply indebted to Mr. Tan Kar Soon for his valuable suggestions to this dissertation. I also wish to thank my colleagues and friends: Ms. Suraini Lajimin, Ms. Asrazitah Abd Razak, Mrs. Veronica, Mr. Tamrin, Ms. Noor Syarinah, Ms. Nurul Ain and Ms. Noor Amalia for their assistance, encouragement and valuable inputs throughout my study period.

Last but not the least, I would like to thank my loved ones, my parents Mohd Taib bin Latif and Isah binti Ajak and my whole family who have supported me throughout the entire completing process of this dissertation. You encouraged me to remain strong and helped me putting pieces together. I will be grateful forever for your love.

Afizah Mohd. Taib

10 August 2017

ABSTRACT

Green mussel (*Perna viridis*) is one of the most highly demanded bivalve species that fetches high market price in the Southeast Asian region. However, market supply of this species is still very much dependent on traditional farming using wild seeds. The complete cycle aquaculture of this species is still not reliable in this part of the world. The present study was conducted to determine the population parameters and effect of environmental factors to growth performance of this species in Marudu Bay after the occurrence of massive mortality. One year sampling period started in April 2013 to March 2014 was carried out. In which, monthly water quality, morphometric measurement of green mussel samples and analyses of water nutrients and chlorophyll-a were conducted throughout the sampling period. The population parameters of the green mussel were analysed by using the FiSAT software based on the length frequency data. The relationship between the green mussel density and the environmental factors was analysed by using bivariate tests. The growth of raft-grown green mussel population showed high asymptotic length ($L\infty$), growth coefficient (K) and growth performance index (φ') estimated at 113.4 mm, 1.7 $year^{-1}$ and 4.34, respectively.The study revealed that the green mussel experienced high mortality rate(Z=3.4/year, F=1.6/year, M=1.8/year) and low percentage of recruitment every month (ranged from 1.51% to 18.59%). However, the water quality at the farm site was found to be ideal for green mussel cultivation. In general, this study had demonstrated that Marudu Bay is a potential area for green mussel farming. However, insufficient numbers of mussel spawners available in the bay after a mortality event could have influenced the low recruitment rate. Nevertheless, changes in environmental parameters, such as increase in water temperature and water velocity may have disturbed or delayed the attachment process of green mussels on substrates, hence resulting in low settlement density. The low dissolved oxygen and high amount of phosphorus may have also affected the settlement density of the green mussel in the bay. This study recommends that the sustainability of green mussel farming in Marudu Bay could be enhanced by the addition of healthy broodstock, controlled harvesting, use of new culture substrates and culture techniques, spat production in hatchery and minimizing pollution into the bay.

ABSTRAK

PARAMETER PERSEKITARAN DAN PRESTASI PERTUMBUHAN KUPANG SUDU (Perna viridis) DI TELUK MARUDU

Kupang (Perna viridis) adalah antara spesis bivalvia yang mempunyai permintaan serta harga pasaran yang tinggi di rantau Asia Tenggara. Walaubagaimanapun bekalan pasaran bagi spesis ini sangat bergantung kepada kaedah perladangan tradisional mengunakan benih liar. Kitaran akuakultur yang lengkap bagi spesis ini juga masih tidak boleh dipraktikkan di rantau ini. Kajian ini dilakukan untuk menentukan parameter populasi dan kesan factor persekitaran terhadap prestasi pertumbuhan spesis ini di teluk Marudu selepas berlaku kematian yang tinggi. Persampelan selama setahun telah dijalankan bermula pada April 2013 sehingga Mac 2014, dengan mengambil ukuran kualiti air dan morphometrik kupang setiap bulan. Analisis terhadap nutrisi air dan klorofil-a juga dilakukan sepanjang tempoh persampelan dijalankan. Parameter populasi dianalisis mengunakan perisian FiSAT berdasarkan data frekuensi kepanjangan. Hubungkait diantara kepadatan kupang dan faktor persekitaran pula dianalisa menggunakan ujian bivariat. Pertumbuhan populasi kupang dikawasan sangkar ternakan menunjukkan kepanjangan asimptot($L\infty$), pekali pertumbuhan (K) dan indeks prestasi pertumbuhan (φ') yang tinggi, masing-masing dianggarkan pada nilai 113.4 mm, 1.7 setahun dan 4.34. Kajian ini menunjukkan bahawa kupang di Teluk Marudu mempunyai kadar kematian yang tinggi (Z=3.4 setahun, F=1.6 setahun, M=1.8 setahun) dan peratusan perekrutan yang rendah setiap bulan (kadar daripada 1.51% kepada 18.59%). Tetapi, kualiti air dikawasan sangkar menunjukkan keadaan yang sesuai untuk pertumbuhan kupang. Kajian ini secara umumnya menunjukan bahawa Teluk Marudu merupakan kawasan penternakan kupang yang berpotensi. Tetapi, kekurangan jumlah induk kupang di teluk ini selepas kematian yang tinggi mungkin mempengaruhi kadar perekrutan yang rendah. Selain itu, perubahan pada parameter persekitaran seperti kenaikan suhu dan kelajuan arus air boleh mengganggu atau melambatkan proses pelekatan kupang kepada substrat, seterusnya menyebabkan jumlah kepadatan yang sedikit. Pengurangan oksigen terlarut dan pertambahan kepekatan nutrient fosforus di Teluk Marudu juga mungkin menjejaskan jumlah kepadatan pelekatan kupang. Olehitu, untuk mengekalkan kemampanan akuakultur kupang di Teluk Marudu, beberapa saranan telah dikenalpasti termasuklah penambahan stok induk yang sihat, penuaian terkawal, pengunaan substrat kultur dan teknik yang baru, penghasilan spat dari hatceri dan mengurangkan pencemaran di sekitar teluk tersebut.

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LIST OF ABBREVIATION

ABG	-	Asian Bag Mussel
ANOVA	-	Analysis of Variance
BLAST	-	Basic Local Alignment Search Tool
CTAB	-	Cethytrimethylammonium bromide
DNA	-	Deoxyribonucleic acid
DO	-	Dissolved Oxygen
DOF	-	Department of Fisheries
DON	-	Dissolved Organic Nitrogen
DOP	-	Dissolved Organic Phosphorus
DTAB	-	Dodecyltrimethylammonium bromide
EDTA	-	Ethylenediaminetetraacetic acid
FAO	-	Food and Agriculture Organization of the United Nations
GM	-	Green Mussel
H&E	-	Hematoxylin and Eosin
HDPE	-	High Density Polyethylene
IPTG	-	Isopropyl β-D-1-thiogalactopyranoside
ITS	-	Internal transcribed spacer
IUPAC	-	International Union of Pure and Applied Chemistry
MATRADE	-	Malaysia External Trade Development corporation
$MgCl_2$		Magnesium Chloride
N	-	Nitrogen
N_2	-	Nitrogen Gas
NCBI	-	National Center for Biotechnology Information
NED	-	N -(1-naphthyl)ethylenediamine dihydrochloride
NH	-	Ammonia
NO_2	-	Nitrite
NO_3	-	Nitrate
O_2	-	Oxygen Gas
OIE	-	Office International des Epizooties
OM	-	Organic Matter
OPO_4-P	-	Ortophosphate
P	-	Phosphorus

PCR	-	Polymerase Chain Reaction
PO_4	-	Phosphate
QPX	-	Quahog Parasite Unknown
RNA	-	Ribonucleic Acid
SPSS	-	Statistical Package for Social Sciences
SS	-	Single Strand
TAE	-	Tris-acetate-EDTA
TE	-	Tris-EDTA Buffer
USEPA	-	United States Environmental Protection Agency
X-Gal	-	Bromo-chloro-indoltl-galactopyranoside

LIST OF SYMBOLS

%	-	Percentage
Φ′	-	Growth Performance Index
π	-	Pi
°C	-	Degree Celsius
µl	-	Microliter
µM	-	Micromolar
5X	-	5 Times Concentrated
'a'	-	Condition Factor
'b'	-	Growth Coefficient
bp	-	Base Pair
cm	-	Centimeter
E	-	Exploitation Level
et al.,	-	And Others
F	-	Fishing Mortality
g	-	Gram
h	-	Hour
Ind./m^2	-	Individual Per Meter Square
K	-	Growth Coefficient
L_∞	-	Asymptotic Length
M	-	Natural Mortality
M^2	-	Meter Square
Mg/ml	-	Miligram Per Mililiter
min	-	Minutes
ppt	-	Parts Per Thousand
rpm	-	Revolution Per Minutes
w/v	-	Weight/Volume
/Year	-	Per Year
Z	-	Total Mortality

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Research Background

Green mussel, *Perna viridis* or locally known as siput sudu, is a commercially important species for aquaculture in the Southeast Asian region. Green mussel is a popular mariculture species due to its high potential in aquaculture. It has been intensively cultivated in Malaysia, Thailand, Philippines, Singapore and India (McCoy and Chongpeepien, 1988; Vakily, 1989; Rajagopal *et al.*, 1998; FAO, 2013; Awan *et al.*, 2012). Mussel cultivation activities in Thailand, Philippines and Malaysia were initiated in 1980s' (Silas, 1980). Meanwhile in Sabah, green mussel aquaculture was introduced in early 1990s'. The production of green mussel in Sabah was low at initial stage but continuous effort by the Sabah Fisheries Department has tremendously improved the production. For example, mussel production in the Sabah in 2003 recorded nearly 100% increment compared to the one in 1993 (DOF, 2005). The positive economic growth of the mussel industry in Sabah has encouraged the Sabah Fisheries Department to widen the mussel farming operation throughout the state including Marudu Bay. As the result, more job opportunities were created and allowed coastal community to generate more income to support their livelihood. Unfortunately, in late 2009 the green mussel farm in Marudu Bay was seriously affected by massive mortality. The mortality event wiped out almost all the juvenile and adult mussels, leaving only small quantity of survived mussels on culture ropes. Since then, the production of green mussel in the bay had drastically gone down, deserted and caused huge economic loss to farmers.

Maintaining the sustainability of green mussel stocks depends on the location with availability of food, good water nutrients and optimum environmental condition (Sivalingam, 1977; Cheong, 1982; Alfaro, 2006; Kripa and Mohamed, 2008; Lenzi*et al.*, 2013). Green mussel is a filter feeder bivalve that utilizes phytoplankton, zooplankton and other suspended particulate organic carbon to

grow (Baird and Milne, 1981; Ren*et al.*, 2000). Abundance of food especially phytoplankton in farming site can enhance the productivity of green mussel. As growth of phytoplankton is enhanced by high uptake of dissolved nutrients such as nitrogen and phosphate, adequate amount of water nutrients indirectly promotes rapid growth and high biomass to mussel population (Littler and Littler, 1980; Gordon *et al.*, 1981; Peckol and Rivers, 1995). Besides, high density green mussel population is also highly dependent on the suitable ranges of environmental parameters such as temperature, salinity, and dissolved oxygen, in the farming site (Nordin and Choo, 1985; Shamsudin, 1992) due to the fact that growth performance, abundance and distribution of mussel are all affected by environmental factors (Sivalinggam, 1977; Aypa, 1990; Hickman, 1992).

Therefore, in order to know the current status of green mussel population in Marudu Bay after the mortality event, the current study was conducted. This study was accomplished by monthly sampling on green mussel growth performance, recruitment pattern, survival, and also the environmental parameters for a one year period. The methodology used to assess the green mussel population structure was mainly based on the length frequency (Al-barwani *et al.*, 2006) of the mussel found every month and analyzed using the FiSat software (Gayanilo *et al.,* 1995). Moreover, the environmental parameters data were statistically analysed by Statistical Package for Science Social (SPSS) version 18. Besides, samples of green mussel collected in 2011, 2012 and 2013 were analyzed for the presence of parasites by using microscopic observation (fresh tissue and histopathology),PCR and DNA sequencing.

1.2 Problem Statement

Mass mortality of green mussel in Marudu bay occurred in late 2009 until 2011and caused economic loss to the mussel farmers. However, the main cause of the mass mortality event is still not known. Previous studies have identified several factors which can lead to mussel mortality including physiochemical, hydrodynamic, food, predation, and disease outbreaks (Appukuttan, 1980; Beales and Lindley, 1982; Vakily, 1989; Smaal, 1991; Gulshad, 2003; Schiel, 2004; Peperzak and Poelman, 2008; Yap, 2012; Heinonen, 2014). Among these factors, the environmental parameters and food availability are the most reported causes of massive mortality

of farmed bivalves. For example, sudden increase in water temperature causes mortality to green mussel and other bivalves species under experimental condition (Hiebenthal *et al.*, 2012; Sreedevi *et al.*,2014; Sauvage *et al.*, 2009; Solomieu *et al.*, 2015). Furthermore, Alforo (2006) found the mortality of *Perna canaliculus* in northen New Zealand was due to limited food supply. Besides, sudden mortality events can also be caused by parasitic infestation.For example, the *Marteilosis* or mollusc disease caused by *Marteilia* spp. can result in death and devastating consequences to the bivalve aquaculture (Balseiro *et al.,* 2007). Thus, detection of parasites and measurement of environmental parameters in the culture area of green mussel in Marudu Bay may help to discover the root cause of the mortality event.

Massive mortality has lessened the population of green mussel in Marudu Bay, where low productivity of green mussel was observed since 2010 to 2012. However, in early 2013, the population of green mussel in Marudu Bay has shown sign of recovery, where spats are spotted attached to the seeding ropes. The cultivation of green mussel in Marudu Bay is heavily dependent on the availability of natural seed supply because alternative source of seeds via hatchery is not yet established in the country (Yap *et al.*, 1979; Helm *et al.*, 2004; Alfaro *et al.*, 2011). Availability of wild green mussels in the farming area showed a positive sign of the bivalve sustainability in the area. Therefore, this study was conducted to seek the answers to the question on whether or not self-restoration and recovery of the mussel population in Marudu Bay are possible.

1.3 Significant of Study

Physiochemical parameters of water, water nutrients and chlorophyll are essential to establish the relationship between growth and abundance of green mussel in Marudu Bay. Such data, if analysed accordingly, could also provide information pertaining to recruitment, growth and mortality of green mussel in the bay after a mass mortality event. In addition, this study also serves as a review of the mussel aquaculture practices in the bay that could benefit the farmers and the government agencies to coming out a sustainable management plan for green mussel aquaculture in the state of Sabah.