UNIVERSITI PUTRA MALAYSIA

ZOOPLANKTON COMMUNITY STRUCTURE IN COASTAL WATERS OFF THE STRAIT OF MALACCA WITH EMPHASIS ON JELLYFISH

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

July 2016

This work is dedicated to my:

beloved parents;
Abd Razak B. Mohd. Ali & Fatimah Sarah Bt Daros
for endless prayers and unconditional support

loving brothers and sisters
for love, patience and tolerance

And to those special people in my life who support me throughout the course of this work.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman : Fatimah Md. Yusoff, PhD
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Jellyfish population is now reported to be increasing in many areas due to the environmental changes such as eutrophication and overfishing. However, jellyfish has been largely understudied and the absence of quantitative long-term data for the studied area impedes drawing conclusions on potential increasing densities. This study gives a comprehensive overview of the spatio-temporal distribution patterns of jellyfish in relation to pollution levels with turbidity and nutrient levels as the main markers in three areas namely Matang mangrove area (MM), Kuala Selangor coastal waters (KS) and Port Dickson coastal waters (PD). In each area, zooplankton and jellyfish samples were collected by the horizontal tow of a plankton net (140 µm mesh size) and bongo net (500 µm mesh size) at four different stations, bi-monthly between June 2010 and April 2011. Physico-chemical parameters were measured *in situ* using multi-parameter sonde (Model Hydrolab Surveyor 4). Water transparency was determined by Secchi disk and the turbidity was measured using turbidimeter at 2-m depth intervals. Water samples for the determination of total suspended solid (TSS), chlorophyll *a* and nutrients analyses were collected using a Niskin water sampler. Zooplankton and jellyfish abundance and biomass, chlorophyll *a* and nutrients were determined according to the standard methods. Salinity and dissolved oxygen concentrations in MM were significantly lower compared to the other two sites. Total suspended solid in KS was significantly higher compared to MM and PD. However, Turbidity, chlorophyll *a*, total nitrogen and total phosphorus in MM and KS were significantly higher compared to PD. A total of 12 zooplankton groups were recorded from the study areas throughout the sampling period. MM, KS and PD were dominated by copepods which comprised 79%, 74% and 79% of the total zooplankton. Among the sampling areas, KS (8243.1 ± 1344.9 ind. m^{-3}) had the highest total mean density of zooplankton followed by MM (5486.3 ± 977.5 ind m^{-3}) and PD (1389.0 ± 244.4 ind. m^{-3}). The zooplankton density in Port Dickson coastal waters was significantly lower compared to Matang mangrove area and Kuala Selangor coastal waters. Zooplankton biomass in KS, MM and PD were 13.2 ± 4.5 mg m^{-3}, 11.3 ± 1.9 mg m^{-3} and 7.5 ± 1.9 mg m^{-3} respectively. There was no significant difference in the zooplankton biomass between the three areas. The jellyfish community comprised three major groups (Hydromedusa, Siphonophora and Ctenephora). Nineteen hydromedusae, two siphonophores and two ctenophores were recorded and a total of 23 species from 16 genera of jellyfish were identified from three different areas. Jellyfish density was significantly higher in Matang mangrove area (14.95 ± 3.60 ind. m^{-3}) than those in Kuala Selangor coastal waters (1.53 ± 0.90 ind. m^{-3}) and Port Dickson coastal waters (0.84 ± 0.25 ind. m^{-3}). Similarly, the jellyfish biomass was highest in Matang mangrove area (162.12 ± 58.66 mgWW m^{-3}) followed by Kuala Selangor coastal waters (22.65 ± 5.90 mgWW m^{-3}) and Port Dickson coastal waters (15.32 ± 2.97 mgWW m^{-3}). Generally, ctenophores were the most important group in MM, which dominated by *Pleurobrachia* sp. Meanwhile, hydromedusae (*Eirene brevigona*) and siphonophores (*Lensia subtiloides*) were dominated in KS and PD respectively. There was no significant difference in the species diversity ($p>0.05$) between the study areas. Jellyfish diversity in MM, KS and PD were H' = 0.71 ± 0.18, H' = 0.85 ± 0.25 and H'=1.08 ± 0.21 respectively. Soluble reactive phosphorus, chlorophyll *a*, total suspended solids, temperature and transparency are the main variables explaining the spatial and temporal distribution of jellyfish. This study also showed that besides the environmental parameters, location also influences the distribution of jellyfish. The jellyfish showed preference in the area which have more shelter (Matang mangrove area) compared to open waters (Kuala Selangor and Port Dickson coastal waters). This study provides baseline information to measure the potential increase of jellyfish abundance in MM, KS and PD.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

STRUKTUR KOMUNITI ZOOPLANKTON DI PERAIRAN SELAT MELAKA DENGAN PENEKANAN KEPADA OBOR-OBOR

Oleh

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Populasi obor-obor kini dilaporkan meningkat di banyak kawasan disebabkan oleh perubahan persekitaran seperti eutrofikasi dan penangkapan ikan yang berlebihan. Walau bagaimanapun, kekurangan kajian serta ketiadaan data kuantitatif bagi jangka panjang berkenaan obor-obor di kawasan kajian menghalang dari membuat kesimpulan berkenaan peningkatan kepadatan obor-obor. Kajian ini memberi gambaran menyeluruh taburan obor-obor secara ruang-masa berkaitan dengan tahap pencemaran dengan menjadikan kekeruhan dan tahap nutrien sebagai penanda utama di tiga kawasan iaitu kawasan bakau Matang (MM), perairan pantai Kuala Selangor (KS) dan perairan pantai Port Dickson (PD). Zooplankton dan obor-obor disampel dengan menggunakan jaring plankton (saiz 140 µm) dan jaring bongo (saiz 500 µm) di empat stesen yang berbeza di kawasan kajian pada setiap dua bulan antara Jun 2010 dan April 2011. Parameter psiko-kimia diukur secara *in situ* menggunakan pelbagai-parameter sonde. Kecerahan air ditentukan dengan menggunakan cakera Secchi dan kekeruhan diukur menggunakan turbidimeter pada julat kedalaman 2-m. Sampel air untuk menentukan jumlah pepejal terampai (TSS), klorofil dan nutrien analisis diambil menggunakan persampelan air Niskin. Kepadatan dan biomass zooplankton dan obor-obor, klorofil dan nutrien dianggarkan mengikut kaedah biasa. Kemasinan dan kepekatan oksigen terlarut di MM adalah lebih rendah berbanding dengan kedua-dua tempat yang lain. Jumlah pepejal terampai di KS adalah lebih tinggi berbanding MM dan PD. Kekeruhan, klorofil, jumlah nitrogen dan jumlah fosforus di dalam MM dan KS adalah lebih tinggi berbanding dengan PD. Sebanyak 12 kumpulan zooplankton direkodkan daripada kawasan kajian sepanjang tempoh pensampelan. MM, KS dan PD dimonopoli oleh kopepod yang terdiri daripada 79%, 74% dan 79% daripada jumlah zooplankton. Antara kawasan persampelan, KS (8243.1 ± 1.344.9 ind m^{-3}) mempunyai jumlah purata kepadatan zooplankton paling tinggi diikuti oleh MM (5486.3 ± 977.5 ind m^{-3}) dan PD (1389.0 ± 244.4 ind m^{-3}). Kepadatan zooplankton di perairan pantai Port Dickson adalah lebih rendah berbanding dengan kawasan bakau Matang dan perairan pantai Kuala Selangor. Biojisim zooplankton di KS, MM dan PD masing-masing adalah 13.2 ± 4.5 mg m^{-3}, 11.3 ± 1.9 mg m^{-3} dan 7.5 ± 1.9 mg m^{-3}. Tiada perbezaan yang signifikan dalam biojisim zooplankton di antara ketiga-tiga kawasan. Komuniti obor-obor terdiri daripada tiga kumpulan utama (Hydromedusa, Siphonophora dan Ctenephora). 19 hydromedusae, dua siphonophores dan dua

ctenophores dicatatkan dan sebanyak 23 spesies daripada 16 genus obor-obor telah dikenal pasti dari tiga kawasan yang berbeza. Kepadatan obor-obor adalah lebih tinggi di kawasan bakau Matang (14.95 $\pm$ 3.60 ind. m^{-3}) berbanding di perairan pantai Kuala Selangor (1.53 $\pm$ 0.90 ind. m^{-3}) dan perairan pantai Port Dickson (0.84 $\pm$ 0.25 ind. m^{-3}). Begitu juga biojisim obor-obor adalah paling tinggi di kawasan bakau Matang (162.12 $\pm$ 58.66 mgWW m-3) diikuti dengan perairan pantai Kuala Selangor (22.65 $\pm$ 5.90 mgWW m-3) dan perairan pantai Port Dickson (15.32 $\pm$ 2.97 mgWW m-3). Secara umumnya, ctenophores merupakan kumpulan yang paling penting di MM, yang didominasi oleh *Pleurobrachia* sp. Sementara itu, hydromedusae (*Eirene brevigona*) dan siphonophores (*Lensia subtiloides*) masing-masing mendominasi di KS dan PD. Tiada perbezaan yang signifikan dalam kepelbagaian bio obor-obor di antara ketiga-tiga kawasan. Kepelbagaian bio obor-obor di MM, KS dan PD masing-masing adalah H'= 0.71 $\pm$ 0.18, H' = 0.85 $\pm$ 0.25 dan H'= 1.08 $\pm$ 0.21. Fosforus reaktif larut, klorofil, jumlah pepejal terampai, suhu dan kecerahan air adalah pembolehubah utama yang menjelaskan pengagihan obor-obor dari segi ruang dan masa. Kajian ini juga menunjukkan bahawa selain parameter alam sekitar, lokasi juga mempengaruhi taburan obor-obor. Obor-obor menunjukkan keutamaan di kawasan yang mempunyai tempat perlindungan (kawasan bakau Matang) berbanding perairan terbuka (perairan pantai Kuala Selangor dan Port Dickson). Kajian ini menyediakan maklumat asas bagi mengukur potensi peningkatan kepadatan obor-obor di MM, KS dan PD.

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I certify that a Thesis Examination Committee has met on 14 July 2016 to conduct the final examination of Siti Balqis bt Abd. Razak on her thesis entitled "Zooplankton Community Structure in Coastal Waters Off the Strait of Malacca with Emphasis on Jellyfish" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
℃	Degree Celcius
µg	Microgram
µm	Micrometer
cm	Centimeter
g	Gram
l	Liter
mg	Milligram
ml	Milliliter
mm	Millimeter
N	Normal
NAOH	Sodium hydroxide

CHAPTER 1

INTRODUCTION

1.1 Background of study

Coastlines and river banks have been the focus area of human civilization and urbanization for centuries. Antrophogenic activities such as industrial, agricultural, recreational and land-used activities along the coastlines have resulted in many habitat changes and water pollution (Smith *et al*, 1999; Rezai *et al*, 2009). The negative consequences of this unsustainable development are obvious in Asian regions which have larger populations compared with other parts of the world (Islam and Tanaka, 2004). In Malaysia, increased of suspended particles and turbidity is one of the main forms of pollution due to unsustainable land-used practices, associated with logging, agriculture and industrial developments. The existence of suspended matter such as clay and silt, organic and inorganic matter from the anthropogenic activities which drain into the coastal waters resulted in increased nutrient and turbidity levels in the water. Changes in turbidity levels and nutrient concentrations would in turn modify the environmental conditions and eventually affect the structure and functions of the coastal ecosystems.

Coastal ecosystems are rich in biodiversity, including zooplankton and provide productivity to support almost one billion people every year in Asia alone. Zooplankton plays an important role in the marine food web by controlling phytoplankton production and linking the primary production and higher trophic levels (Zaleha *et al*., 2006; Ferdous and Muktadir, 2009). Similarly, jellyfish also play an important role in constructing coastal and estuarine ecosystems as they provide food for upper trophic level, such as sea turtles, sea-birds and some fishes (Suchman and Brodeur, 2005). There are edible and non-edible jellyfish. The edible jellyfish is popular as delicacies and used in biomedical research and industries (Omori and Nakano, 2001). Meanwhile, the non-edible jellyfish are usually considered to be nuisance because they interfere with human activities by stinging swimmer, clogging power plant intake, burst fishing nets and contaminated catches, killing of farmed fish and indirectly gave negative impacts to coastal economic and ecology (Mills, 2001; Purcell *et al*., 2007; Richardson *et al.*, 2009; Straehler-Pohl and Jarms, 2010).

Water pollution including increased nutrients and turbidity levels caused by anthropogenic activities provide competitive advantage to jellyfish since it can survive in the disturbed marine ecosystem due to their wide adaptation capacity to pollution. High water column turbidity will enhance the population of jellyfish as they are a tactile predator in contrast to fish which are visual predators (Aknes, 2007; Pitt *et al.*, 2008). Furthermore, they also have a fast growth rate, broad diet, ability to tolerate hypoxia and capacity to fragment and regenerate (Richardson *et al*., 2009). In addition, studies reported that some species of jellyfish have the ability to form resting cysts in harsh environment and rapidly reproduce in a favorable environment (Arai, 2001; Boero *et al*, 2008). Jellyfish blooms are important event in coastal waters as they control plankton dynamics through predation of zooplankton and ichthyoplankton (Miglietta *et al*., 2008). While the increase of jellyfish blooms become common in several locations in the world, basic knowledge of jellyfish populations is still lacking in most regions including in the Strait of Malacca.

The Strait of Malacca is located on the Western Malaysian Peninsular with a total coastline of 1000 km (Rezai, 2003). The Strait consists of many ecosystems, including mangrove forests, coral reefs and seagrass beds lining the coastline (Yoshida *et al.*, 2012) which support local subsistence fishing as well as international commercial fisheries. The Strait is among the most important fishing grounds and international waterways since the 7th century. In recent years, it has become a center of commercial and recreational activities besides numerous aquaculture and mariculture which include fish cages as well as cockle, mussel and oyster beds.

1.2 Problem statement

Zooplankton communities in coastal waters are of major importance in the food web structures and for ecosystem health. Zooplankton including jellyfish is a useful indicator that could reflect the changes of the aquatic ecosystems caused by pollution and various disturbances since they respond directly and quickly to many physical, chemical and biological changes in the ecosystems (Marques *et al.*, 2007). Recent studies suggest that jellyfish may also benefit from the anthropogenic activities, and thus its population may increase globally (Mills, 2001; Purcell *et al*., 2007; Pauly *et al*., 2009). Jellyfish blooms affect human activities economically (Brotz *et al*., 2012) and ecologically (Richardson *et al.*, 2009). In Malaysia, the study of jellyfish population is still lacking. This study provides baseline information to measure the potential increase of jellyfish abundance in the Strait of Malacca and the implication of water pollution to the jellyfish biodiversity.

1.3 Objectives

This study was undertaken with the following objectives:

1. To determine the environmental conditions in three areas of the coastal waters with three different levels of pollution, especially with regard to turbidity levels and nutrient concentrations.
2. To compare the distribution and composition of zooplankton groups in three different coastal waters and to relate with the environmental parameters.
3. To compare the jellyfish species diversity, abundance and biomass in coastal ecosystems with different turbidity and nutrient levels.

For this study, three coastal ecosystems (Matang mangrove area, Kuala Selangor coastal waters and Port Dickson coastal waters) with different sources of pollution in terms of nutrients and turbidity were selected to test the following hypothesis:
Null hypothesis (H_o): There is no difference in jellyfish density in the three coastal areas with different turbidity and nutrient levels.
Alternative hypothesis (H_A): There is a difference in jellyfish density in the three coastal areas with different turbidity and nutrient levels.

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