UNIVERSITI PUTRA MALAYSIA

ECOLOGICAL STUDIES ON ZOOPLANKTON FROM THE STRAITS OF MALACCA WITH SPECIAL REFERENCE TO COPEPODS

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By

HAMID REZAEI-MARNANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

November 2002

DEDICATION

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To my son Ocean and my wife Elaheh

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To the memory of my late father who can no longer accompany me on these stormy seas.

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He asked, "And what is the *Sea* to you?"

I answered, "My life's Breath."

The breath of adventure and excitement,

Of challenge and wandering;

Happiness and fulfilment,

Despair and pain;

Of hope and youth,

Patience and yearning.

The breath that God has breathed into my soul, that

I should live with his *sea*.

Jerome Thomas

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy.

ECOLOGICAL STUDIES ON ZOOPLANKTON FROM THE STRAITS OF MALACCA WITH SPECIAL REFERENCE TO COPEPODS

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November 2002

Chairperson : Professor Fatimah Md. Yusoff, Ph.D.

Faculty : Science and Environmental Studies

The purpose of this study was to analyze the zooplankton composition and distribution in relation to spatial and temporal variations in the Straits of Malacca. The distribution of zooplankton was determined using samples collected from 13 to 20 stations during four oceanographic expeditions along the Straits in different periods between 1998 to 2000. Monthly zooplankton samples were also collected from two stations at nearshore and offshore waters off Port Dickson from July 2000 to June 2001.

Copepods comprised an average of 71.3%, 71.2%, 70.9% and 57.9% of the total zooplankton populations during consecutive cruises and were the main group of zooplankton during each sampling period. Total zooplankton densities were higher in the near-coastal area than the offshore area. A spatio-temporal variation of zooplankton standing crop both in terms of biomass and density was not significant.

Higher mean density estimates of total zooplankton (mean of 12,918 ± 5,635 ind. m^{-3}) and that of adult copepods (mean of 2,927 ± 1,085 ind. m^{-3}) were recorded during

cruise II (pre-SW monsoon) compared to other cruises. However, variation of copepods was temporally insignificant but spatially significant. Higher zooplankton densities were obtained at 10-20 m depth stratum than any other depth strata.

Maximum peak of copepod densities collected off Port Dickson waters coincided with NE and pre-SW monsoons when samples were collected horizontally and vertically, respectively. Depth and salinity in associations with other factors explained the distributional patterns of copepods in the studied area.

A total of 119 species of pelagic copepods belonging to calanoids (76), cyclopoids (9), harpacticoids (6) and poecilostomatoids (28) were determined during the course of the present investigation. Of these, nine species are new records for the Straits of Malacca. Two characteristic copepod communities in the northern and southern parts of the Straits were distinguished. The shallow southern part was characterised by high-density values and low species diversity (H' = 2.967), and the dominance of few coastal species such as *Oithona simplex* and *Paracalanus parvus*. The deeper waters of the northern part were characterised by low-density values, relatively high species diversity index (H' = 3.632).

The heavy metal concentrations in mixed zooplankton were relatively low: ranging from 1.19-1013.70 $\mu g\ g^{-1}$ wet weight for copper, 16.54-235.78 $\mu g\ g^{-1}$ wet weight for zinc, 3.92-36.08 $\mu g\ g^{-1}$ wet weight for lead and from 0.32-4.09 $\mu g\ g^{-1}$ wet weight for cadmium. Concentrations of copper and zinc were higher in near-coastal than offshore areas, whereas those of lead and particularly cadmium were higher in offshore areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah.

KAJIAN EKOLOGI KE ATAS ZOOPLANKTON DARI SELAT MELAKA DENGAN RUJUKAN KHAS KEPADA KOPEPOD

Oleh

HAMID REZAEI-MARNANI

November 2002

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Tujuan kajian ini adalah untuk menganalisis komposisi dan taburan zooplankton mengikut faktor ruang dan masa. Taburan zooplankton telah dianalisis dengan menggunakan sampel daripada 13-20 stesen yang telah dikumpul melalui empat ekspedisi oseanografi Selat Melaka dari tahun 1998 hingga 2000. Sampel bulanan kopepod juga telah dikumpul daripada dua stesen di persisiran dan luar persisiran perairan Port Dickson sepanjang Julai 2000 hingga Jun 2001.

Secara puratanya kopepod menyumbang sebanyak 71.3%, 71.2%, 70.9% dan 57.9% daripada keseluruhan populasi zooplankton dalam ekspedisi tersebut dan merupakan komponen zooplankton utama dalam setiap tempoh persampelan. Zooplankton menunjukkan kepadatan yang lebih tinggi di perairan pantai berbanding dengan kawasan perairan yang jauh dari pantai. Hasilan semasa zooplankton bagi kedua-dua unit biojisim dan kepadatan menunjukkan variasi tidak nyata dari segi faktor ruang dan masa.

Anggaran min densiti yang lebih tinggi bagi jumlah keseluruhan zooplankton (min 12,918 ± 5,635 ind. m^{-3}) dan kopepod dewasa (min 2,927 ± 1,085 ind. m^{-3}) telah direkodkan semasa ekspedisi II (Pra-monsun Barat Daya). Walau bagaimanapun variasi taburan plankton kopepod didapati tidak menunjukkan perbezaan mengikut faktor masa tetapi berbeza mengikut faktor ruang. Kepadatan zooplankton yang tinggi dijumpai pada kedalaman 10-20 m berbanding lapisan kedalaman yang lain.

Kepadatan tertinggi kopepod yang di sampel secara mendatar dan menegak perairan Port Dickson didapati bersamaan dengan jangkamasa monsun Timor Laut dan Barat Daya. Faktor sekitaran seperti kedalaman dan saliniti atau melalui gabungan dengan faktor lain didapati mencorakkan taburan kopepod di kawasan kajian.

Sejumlah 119 spesies kopepod pelagik yang terdiri daripada kalanoid (76), siklopoid (9), harpaktikoid (6) dan posilostomatoid (28) telah dikenalpasti. Daripada jumlah ini, sebanyak sembilan spesies adalah rekod baru untuk perairan Selat Melaka. Dua ciri komuniti kopepod di sektor utara dan selatan selat telah dikenalpasti. Sektor selatan selat yang cetek telah dicirikan dengan nilai-nilai kepadatan yang tinggi dengan kepelbagaian spesies yong rendah (H' = 2.967), serta kedominan beberapa spesies zooplankton air cetek seperti *Oithona simplex* dan *Paracalanus parvus*. Perairan yang lebih dalam di sektor utara dicirikan dengan nilai ketumpatan rendah dan kepelbagaian spesies yang agak tinggi (H' = 3.632).

Kepekatan logam berat dalam zooplankton adalah secara relatifnya; berjulat 1.19-1013.70 μg g^{-1} berat basah bagi kuprum, 16.54-235.78 μg g^{-1} berat basah bagi zinc, 3.92-36.08 μg g^{-1} berat basah untuk plumbum dan 0.32-4.09 μg g^{-1} berat basah bagi

kadmium. Kepekatan kuprum dan zink adalah lebih tinggi di kawasan berhampiran pantai daripada kawasan luar pantai, manakala bagi plumbum dan kadmium nilainya adalah lebih tinggi di kawasan luar pantai.

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I certify that an Examination Committee on 14th November 2002 to conduct the final examination of Hamid Rezaei-Marnani on his Doctor of Philosophy thesis entitled "Ecological Studies on Zooplankton from the Straits of Malacca with Special Reference to Copepods" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Hamid Rezaei-Marnani

Date: 28/2/2002

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LIST OF ABBREVIATIONS

ANOSIM	=	Analysis of Similarity
ANOVA	=	Analysis of Variance
APFF	=	Annual Plankton Fluctuation Factor
BIO-ENV	=	Biotic-Environmental
C	=	Centre
Chl. *a*	=	Chlorophyll *a*
Contr.	=	Contribution
CR	=	Cruise
cv	=	Coefficient of variation
Diss.	=	Dissimilarity
Dry wt.	=	Dry weight
HSD	=	Honestly Significant Difference
ind.	=	Individual
IRPA	=	Intensified Research in Priority Areas
km	=	Kilometre
JICA	=	Japan International Co-operation Agency
Log.	=	Logarithmic
MASDEC	=	Malacca Straits Research and Development Centre
Max.	=	Maximum
MDS	=	Multidimensional Scaling
µg	=	micro gram
Min.	=	Minimum
µm	=	micro meter

mg m^{-3}	=	milligram per cubic meter
N	=	North
ND	=	Not detectable
ng	=	nano gram
NE	=	Northeast
NORPAC	=	North Pacific
P	=	Probability
PNE	=	Pre-northeast
PRIMER	=	Plymouth Routines in Multivariate Ecological Research
PSW	=	Pre-southwest
R/V	=	Research vessel
S	=	South
SD	=	Standard deviation
SE	=	Standard Error
SIMPER	=	Similarity Percentages
Stn.	=	Station
SW	=	Southwest
Unid.	=	Unidentified
vs	=	Versus
Wet wt.	=	Wet weight
Zoopl.	=	Zooplankton

CHAPTER I

INTRODUCTION

The Straits of Malacca is partially landlocked and is situated on the Western Malaysian Peninsula with a total coastline of 1000 km (Chin, 1993; Forbes, 1995). The Straits is located in the tropical zone and supports a relatively abundant demersal and pelagic fish and shrimp species (Ooi, 1990). The Straits provides almost 70% of the fishing resources for the Peninsular Malaysia (Chua *et al.*, 1997). It is of particular oceanographic interest due to upwelling processes in One Fathom Bank (Wyrtki, 1961; Uktolseya, 1988). The Straits is deeper in the north and gradually becomes shallower in the south. The Straits is relatively a narrow channel due to the presence of shoals, and shallow depths in certain parts such as the eastern end near Singapore; and this limits its ability to dilute and flush out pollutants.

An understanding of marine planktonic food webs requires information on the density, biomass and the interactions between all trophic levels. A pre-requisite for the proper management of the fishery resources of the Straits area is an understanding of some of the basic biological factors, such as spatial and temporal distributions of zooplankton in relation to environmental parameters due to their importance as the major food item of the pelagic fish has been reported (Subrahmanyan, 1959). Zooplankton constitute one of the important intermediate steps in the food-chain pyramid of the coastal waters, as well as open ocean waters and plays a critical role in the ecology of marine systems by serving as links between phytoplankton and bacterioplankton, and higher trophic levels such as nekton and benthos.