UNIVERSITI PUTRA MALAYSIA

MARICULTURE POND ECOLOGY WITH EMPHASIS ON ENVIRONMENTAL QUALITY AND PRODUCTION OF PENAEUS MONODON (FABRICIUS)

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By

ABU HENA MUSTAFA KAMAL

Dissertation Submitted in the Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Science
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DEDICATION

To the memory of my late grand father who is no longer to share with me during this moment

To my parents who always inspire and encourage me to achieve my goal

My wife 'Sadia'

To my eldest brother Md. Iqbal whom I tried to emulate from my boyhood

and

The people who are working on sustainable development of fisheries for their livelihood

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

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Chairperson: Hishamuddin Omar, Ph. D.

Faculty: Science

In the present study, mariculture pond ecology with special reference to environmental quality and tiger shrimp *Penaeus monodon* production in old culture ponds (>3 years) and new culture ponds (<1 year) were investigated throughout the culture period in Malacca, Malaysia. The study showed that the cation exchange capacity (CEC) varies with soil texture while soil organic matter varied with the culture pond age. The concentrations of major cations depends on cation exchange capacity of soils attributed partly to chemical bonding or adsorption of colloids. Deposition of nutrient loaded suspended solids through uneaten feeds and other culture activities led to increase in the concentrations of macro and microelements onto the pond bottom at the end of the culture period. The dynamics of macro and microelements in pond and sediment waters were not distinct in old and new culture ponds throughout the culture period, but were influenced by accumulation process of living organisms, water exchange and precipitation of major cation as organic and inorganic particles.

Major groups of the macro and meiobenthos comprised of gastropods, polychaetes, bivalves, crustaceans, ostracods, nematodes, insects and crab larvae. Gastropods were the dominant group of macrobenthos followed by harpacticoid copepod as meiobenthos

throughout the culture period. The growth of shrimp was related with the macrobenthos ($r=0.62$, $p<0.05$) and meiobenthos abundance ($r=0.67$, $p<0.05$) in the culture ponds. The major groups of zooplankton in the ponds were copepods, rotifers, sergestidae, luciferans, gastropod larvae, bivalve larvae, pelagic polychaetes, nematodes, crustacean nauplii, insects and mysids. About 18-30% of the total zooplankton population decreased within one month after the release of post larvae into the ponds which revealed the significance of natural foods in culture ponds in reducing the production cost and increasing pond yield. Stomach content analysis showed that the stomach of shrimps contained a wide variety of items depending on the availability of benthic and pelagic organisms in the ponds. Higher content of natural food items were found in the stomach of shrimps collected from the old culture ponds than the new culture ponds. Although a commercial feed was provided, the juvenile, sub adult and adult *P. monodon* were found to be opportunistic omnivorous scavengers feeding on variety of benthic materials and organisms such as detritus, crustacean, molluscs, polychaetes, rotifers and phytoplankton. In the group of Crustacea, copepods were the major food item preyed by all stages of the shrimps throughout the culture period in the ponds.

The diversity of fungi increased at the end of culture period in both old and new culture ponds. The proliferation of fungi in general could be due to shrimp faeces and high carbon source from uneaten feeds as the culture progressed. The present study revealed that population of fungi in shrimp pond sediments were mostly of the genera of *Aspergillus* and *Penicillium* which were similar to the terrestrial soil fungi. The results showed that many activities such as feeding, nutrient status, stocking density, weather conditions, accumulation of organic matters, biological factors and pond age governed the quality of pond water, shrimp growth, production and pond ecosystem during the culture period.

PERPUSTAKAAN SULTAN ABDUL SAMAD
UNIVERSITI PUTRA MALAYSIA

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

EKOLOGI KOLAM MARIKULTUR DENGAN TUMPUAN KEPADA KUALITI ALAM SEKITAR DAN PRODUKSI *PENAEUS MONODON* (FABRICIUS)

Oleh

ABU HENA MUSTAFA KAMAL

Julai 2005

Pengerusi: Hishamuddin Omar, Ph. D.

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Di dalam kajian ini, ekologi bagi kolam marikultur dengan tumpuan kepada kualiti alam sekitar dan produksi udang harimau *Penaeus monodon* dalam kolam kultur tua (>3 tahun) dan kolam kultur baru (<1 tahun) telah dikaji sepanjang tempoh kultur di Melaka, Malaysia. Kajian ini menunjukkan keupayaan pertukaran kation berbeza mengikut tekstur tanah dan kandungan bahan organik tanah berbeza mengikut usia kolam. Kepekatan kation utama bergantung pada kemampuan pertukaran kation yang sebahagiannya disebabkan oleh tindakbalas kimia atau pengabungan kolloid. Timbuntambah nutrien terhasil daripada pemendakan pepejal terampai, sisa makanan dan aktiviti pengkulturan yang lain menyebabkan peningkatan paras elemen makro dan mikro di dasar kolam di akhir masa kultur. Kajian ini mendapati tidak terdapat perbezaan yang jelas di antara elemen makro dan mikro di dasar kolam dan air dan di antara kolam baru dan kolam lama di sepanjang jangkamasa pengkulturan tetapi ia dipengaruhi oleh organisma hidup, pertukaran air dan pemendakan kation utama sebagai partikel organik dan tak organik.

Kumpulan utama bagi makro dan meiobentos terdiri daripada gastropod, polikit, bivalvia, krustasia, ostracod, nematod, serangga dan larva ketam. Gastropod merupakan

kumpulan makrobentos dominan diikuti oleh kopepod harpacticoid sebagai meiobenthos di sepanjang tempoh kultur. Pertumbuhan udang adalah berkadar terus dengan kehadiran makrobentos ($r=0.62$, $p<0.05$) dan kelimpahan meiobentos ($r=0.67$, $p<0.05$) dalam kolam. Kumpulan utama bagi zooplankton dalam kolam kajian adalah kopepod, rotifer, sergestid, lusifer, larva gastropod, larva bivalvia, polikit pelagik, nematod, naupli krustasia, serangga dan misid. Dianggarkan lebih kurang 18-30% daripada jumlah zooplankton berkurangan dalam masa sebulan selepas pelepasan pasca larva udang ke dalam kolam. Keputusan ini menunjukkan kepentingan makanan semulajadi dalam kolam udang dalam mengurangkan kos makanan dan meningkatkan pengeluaran. Kajian kandungan perut udang mendapati ia mengandungi pelbagai bahan bergantung kepada kehadiran organisma bentik dan pelagik di dalam kolam. Kandungan makanan semulajadi dalam perut udang dari kolam kultur usang adalah lebih tinggi berbanding dalam kolam kultur baru. Juvenil, sub dewasa dan dewasa *P. monodon* adalah 'scavenger' omnivor yang memakan apa sahaja termasuk pelbagai bahan bentik dan organisma seperti detritus, krustasia, serangga, mollusk, polikit, rotifer dan fitoplankton. Dalam kumpulan krustasia, kopepod adalah makanan utama yang dimakan oleh semua peringkat hidup udang sepanjang tempoh kitaran di dalam kolam.

Kajian mendapati diversiti kulat beransur meningkat mengikut jangkamasa pengkulturan dalam kolam usang dan baru. Peningkatan populasi kulat secara amnya mungkin terhasil akibat pertambahan najis udang dan sisa makanan yang mengandung sumber karbon yang tinggi dengan jangkamasa pengkulturan. Kajian ini juga mendapati populasi kulat yang biasa dalam sedimen kolam udang terdiri daripada genus *Aspergillus* dan *Penicillium* yang sama dengan kulat daratan. Keputusan kajian mendapati aktiviti seperti pemberian makanan, status nutrien, kepadatan pelepasan, pengaruh cuaca, pengumpulan bahan organik, faktor biologi dan umur kolam mempengaruhi kualiti air kolam, pertumbuhan udang, produksi dan ekosistem di sepanjang jangkamasa pengkulturan.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

Background of the Study

Shrimp culture has been developed in many countries over the past decade, in which this activity attained great economic and social importance. Among the cultivated shrimps, tiger shrimp *Penaeus monodon* is the most important species for coastal aquaculture in many countries, particularly in Asia and Northern Australia. In those regions, tiger shrimp is more preferred due to its availability, fast growth, hardy quality and high price (Shang, 1986). The most common tiger shrimp production practices are either extensive or intensive culture. The extensive system completely depends on natural productivity while the intensive systems require auxiliary inputs and capital (Folke and Kautsky, 1989).

The world growth of cultured shrimp production is similar to the four phases of the theoretical growth curve of the marketed commodity i.e. development, growth, maturity and decline. The initial development phase started after 1930s, when Motosaku Fujinaga succeeded in spawning the kuruma shrimp *Penaeus japonicus* in Japan (Shigueno, 1975). In the 1970s some of the Asian countries such as those in the Indian subcontinent, Indonesia, Taiwan and Thailand started shrimp culture in traditional tidal trapping ponds and produced about 30,000 tonnes of cultured crustacean as by product from extensive milkfish or mullet culture. The growth phase started in the 1980s. Cultured shrimp production steadily increased to a moderate 100,000 tonnes in the early 1980s, and then entered an exponential growth phase that peaked in 1988, when cultured shrimp output reached 580,000 tonnes worldwide. The maturity phase started between 1988 and 1992 when the production increased slowly.

However, after 1992, the worldwide production experienced slight reduction (Csava, 1994).

The bulk of shrimp farming takes place in the earthen ponds. The major impacts of this industry are the conversion of mangrove forests into culture ponds and discharging of harmful by products into the coastal ecosystems, which ended with negative results through eutrophication (Chua *et al.*, 1989). Due to its profitability, there is always demand to open new mangrove area for shrimp culture. Old unproductive ponds are likely to be abandoned and new ponds are constructed. In long run, this activities is not healthy to the environment because mangrove forest is essential for preventing coastal area from tsunami, land erosion, nutrient trap and cycling, spawning and nursery ground for many commercially important fishery resources including shrimps (Ong, 1982; Ong *et al.*, 1993; Kamarudin personal communication). The environmental problems and impacts caused by shrimp farm and its effluent have to be addressed urgently.

Statement of Problems

In shrimp pond ecosystem, the bottom sediment plays an important role in the balance of culture systems and concomitantly on the growth and survival of aquatic organisms. Shrimps spend much of their time on the pond bottom; therefore, pond bottom conditions are more critical for shrimp than most other aquaculture species. The condition of culture pond soil influences the quality of water. It also serves as a biological filter through the adsorption of the organic residues of food, shrimp excretions and algal metabolites (Chien and Ray, 1990). The culture pond sediment can be divided into two components i.e. the pond soil component (the pond bottom and dykes) and the accumulated sediment component (the sludge that accumulates on the pond bottom during culture) (Briggs and Funge-Smith, 1994). Gradually over the period of time, the compositions of shrimp pond soil altered by residues from feeds and fertilizers, settling of dead plankton and accumulation of sediment and salts (Hopkins *et al.*, 1994). The concentration of nutrients and productivity of phytoplankton in pond waters are related to pH and nutrient concentrations in pond soils (Boyd, 1995b; Boyd and Munsiri, 1996, 1997). In addition, the concentrations of several nutrients and other elements increased over time in shrimp pond soils (Boyd *et al.*, 1994b; Munsiri *et al.*, 1996a; Ritvo *et al.*, 1998a). Differences in the concentrations are most likely related to the properties of different pond bottom condition and possibly due to the action of certain variables i.e. temperature, rainfall, salinity, microbial activity, feeding, liming, fertilizers, water exchange, paddle wheels and other products. At present, the information on effects of element concentrations in pond soil and water on pond productivity and shrimp production is still scanty.

The presence of appropriate natural floral and faunal composition in the pond also determines the success of shrimp farming. Beside the artificial diet, natural organisms such as phytoplankton, zooplankton and benthos are the most important food source in semi intensive culture pond. They are rich in protein, vitamins, minerals and other essential growth elements compared to artificial feed. However, monitoring of natural communities on the affect of shrimp growth has shown the complexity in the earthen pond. Besides, it is difficult to figure out the individual parameter which is responsible for shrimp growth. Probably no single parameter is responsible (Rubright *et al.*, 1981). Generally, application of fertilizer in the culture pond may increase the pond productivity through the increase of phytoplankton abundance which promotes the