



UNIVERSITI PUTRA MALAYSIA

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

ABU HENA MUSTAFA KAMAL.

FS 2005 32



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

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
Universiti Putra Malaysia
July 2005



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

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

By

ABU HENA MUSTAFA KAMAL

July 2005

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.

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.

Fakulti: Sains

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 koloid. 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 mengandungi 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.

ACKNOWLEDGEMENTS

All the praise and admiration for Allah, the Almighty, Beneficial and the most Merciful, who has enabled me to submit this thesis.

It is my pleasure to express my profound sense of gratitude and indebtedness to my respected research supervisor Dr. Hishamuddin Omar, the Chairman of my supervisory committee for his guidance and inspiration during the research period. I am profound indebted to my co-supervisors Dr. Misri Kusnan and Associate Professor Dr. Faridah Abdullah, Department of Biology, Universiti Putra Malaysia for their kind supervision and suggestions to carry out my research works properly.

I would like to express my thanks Associate Prof. Dr. Siti Shapor H. Siraj, the Head of the Department of Biology and staff members for providing the suitable environment and facilities during this research. I am grateful to the Malaysian Government for financial support through Intensification of Research in Priority Areas (IRPA) projects no. 01-04-0529-EA001.

I would like to express my sincere thanks to Prof. Dr. Sasekumar of Universiti Malaya, Associate Prof. Dr. Jambari, Associate Prof. Dr. Aziz Arshad of Universiti Putra Malaysia, National Historical Museum, Chiba, Japan and Museum and Art Gallery of the Northern Territory, Australia for identification of polychaeta and mollusca. The technical help provided by Prof. Dr. Shirayama in University of Tokyo and Drs. Idris Abdul Ghani in Universiti Putra Malaysia is also greatly acknowledged. My sincere thank goes to Prof. Dr. Claude E. Boyd, University of Auburn, USA for



providing the literatures on soil and water properties, which help me a lot to compile this thesis. Thank you once again Prof. for your contribution.

I would like to appreciate the cooperation of Dr. Farshad the Ex Technical Manager of Progressive Aquaculture Sdn Bhd, Perak and Dato Prof. Dr. Alang Perang Abdul Rahman B. Zaiuddin Chairman of Farmer's Organization Authority Malaysia (Lembaga Pertubuhan Peladang) for allowing me to collect samples from shrimp ponds in Malacca. Special thank goes to Dr. S. Shamarina, Department of Biology, Universiti Putra Malaysia for helping statistical analysis. My appreciate goes to the Vice Chancellor of University of Chittagong and Director of Institute of Marine Sciences, University of Chittagong for giving permission to come Malaysia to compile my thesis work.

My sincere respect to my parents, my wife, elder brothers and sisters for their unflinching support and encouragement for my higher study. Heartfelt thanks are due to all of my friends/elders for their suggestion, encouragement and help during the work especially; Dr. Yap C. K., Dr. Farshad, Dr. Hamid, Loo Khi Kin, Ms Ang, Kennedy, Saufi, Halim, Azmain, Mahmood, Nurul Vai, Nurul Vabi, Jahed Vai, Mahfuza Apa, Navid, Helen, Amin, Vabi and En Hidir.

Last, but not least, I am thankful to all of my well-wishers whom have helped me in any form.



TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APROVAL SHEETS	x
DECLARATION	xii
LIST OF TABLES	xvii
LIST OF FIGURES	xx
LIST OF PLATES	xxi
 CHAPTER	
 I INTRODUCTION	 1
Background of the Study	1
Statement of the Problems	2
Significance of the Study	5
Objectives of the Study	7
 II LITERATURE REVIEW	 8
Taxonomy and Biological Features of <i>P. monodon</i> Fabricius	8
Feeding Biology	9
Nutrition and Growth Requirement of <i>P. monodon</i> Fabricius	11
Protein and Amino Acids	12
Lipid and Fatty Acids	13
Carbohydrates and Energy	15
Fiber and Ash	16
Vitamins	16
Culture of Tiger Shrimp <i>P. monodon</i> Fabricius	17
Selection of Sites for <i>P. monodon</i> Fabricius Culture	19
Shrimp Farm and Pond Design	21
Preparation of Culture Pond	24
Liming	24
Fertilization of Pond and Phytoplankton Management	25
Water Intake in the Pond	26
Selection of Fry and Acclimatization	27
Stocking Density	28
Food and Feeding	29
Water Management	33
Water Exchange	33
Aeration	35
Nutrients in Pond Ecosystem	37
Roles of Natural Foods in Pond	38
Stomach Content of Shrimps	40
Microorganisms in Pond Ecosystem	41



Physico-Chemical Parameters of Culture Pond Water	42
Temperature and Salinity	43
Dissolved Oxygen	44
Hydrogen ion Concentration (pH)	45
Turbidity	45
Ammonia	46
Nitrite and Nitrate	46
Hydrogen Sulfide (H ₂ S)	48
Phosphate	48
Light	49
World Wide Production of Shrimp	49
III GENERAL MATERIALS AND METHODS	51
Location of the Study Ponds.	51
Period of Study and Collection of Sample	51
Description of Culture Protocol	51
IV PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOIL AND WATER IN <i>P. MONODON</i> CULTURE PONDS	54
Introduction	54
Materials and Methods	56
Analysis of Macro and Microelements of Pond and Sediment Water	56
Collection and Analysis of Pond Soils	56
Analysis of Soil pH	57
Analysis of Soil Texture	57
Analysis of Total Phosphorus	59
Analysis of Total Nitrogen	59
Analysis of Total Sulphur	60
Analysis of Total Carbon (TC)	61
Analysis of Organic Matter (OM)	61
Analysis of Organic Carbon (OC)	62
Cation Exchange Capacity (CEC)	62
Analysis of Soil Macro and Microelements.	62
Digestion of Soil	62
Statistical Analysis	63
Results	63
Physical and Chemical Factors of Pond Soils	63
Elements in Pond Soils	67
Macro elements	67
Microelements	68
Macro and Microelements in Pond and Sediment Water	70
Discussion	75
Physical and Chemical Factors of Pond Soils	75
Elements in Pond Soils	83
Macro elements	83
Microelements.	86
Pond and Sediment Water Macro and Microelements	89

V	ABUNDANCE AND COMPOSITION OF MACRO AND MEIOBENTHOS IN <i>P. MONODON</i> CULTURE PONDS	92
	Introduction	92
	Materials and Methods	93
	Collection of Macro and Meiobenthos	93
	Shannon Diversity Index	93
	Statistical Analysis	94
	Results	94
	Abundance and Composition of Macrobenthos	94
	Abundance and Composition Meiobenthos	99
	Discussion	104
	Macrobenthos	104
	Meiobenthos	108
VI	ZOOPLANKTON COMMUNITY IN COMMERCIAL <i>P. MONODON</i> CULTURE PONDS	111
	Introduction	111
	Materials and Methods	112
	Collection of Zooplankton	112
	Shannon Diversity Index	113
	Statistical Analysis	113
	Results	113
	Discussion	118
VII	FEEDING BEHAVIOUR AND FOOD PREFERENCE OF DIFFERENT STAGES OF POND CULTURED TIGER SHRIMP <i>P. MONODON</i>	122
	Introduction	122
	Materials and Methods	123
	Collection of Shrimps	123
	Estimation of Foregut Content	123
	Results	124
	Discussion	131
VIII	DIVERSITY AND COMPOSITION OF SOIL FUNGI IN <i>P. MONODON</i> CULTURE PONDS	136
	Introduction	136
	Materials and Methods	137
	Sampling of Sediment	137
	Preparation of Agar Media	138
	Isolation of Soil Fungi by Soil Dilution Plate Method	139
	Agar Slant Preparation	139
	Identification of Fungi	140
	Results	140
	Discussion	141



IX	EFFECTS OF PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS ON GROWTH, SURVIVAL AND PRODUCTION OF <i>P. MONODON</i> IN PONDS	144
	Introduction	144
	Materials and Methods	145
	Pond Water Parameters	145
	Detection of Pond Water Parameters	145
	Analysis of Total Suspended Solid (TSS)	145
	Analysis Biochemical Oxygen Demand (BOD ₃)	146
	Pond and Sediment Water Nutrients	147
	Collection of samples	147
	Analysis of Pond and Sediment Water	147
	Determination of Water Nitrate (NO ₃ ⁻)	147
	Determination of Water Ammonium (NH ₄ ⁺)	148
	Determination of Water Phosphate (PO ₄ ⁻)	148
	Determination of Total Sulphur (TS)	149
	Analysis of Water Chlorophyll	149
	Collection of Shrimps and Production Parameters of Shrimp	150
	Statistical Analysis	151
	Results	151
	Physico-chemical Factors of Water	151
	Chlorophyll Content of Water	155
	Pond and Sediment Water Nutrients	155
	Production Parameters of Shrimps	157
	Discussion	160
	Physico-chemical Factors of Water	160
	Chlorophyll Content of Water	164
	Pond and Sediment Water Nutrients	165
	Production Parameters of Shrimps	167
X	GENERAL DISCUSSION AND CONCLUSIONS	171
	REFERENCES	181
	APPENDIX	208
	VITAE	210



LIST OF TABLES

Table	Page
1 Food habit of <i>Penaeus monodon</i> in the wild at different development stages (Adopted from Pascual, 1988a)	10
2 Recommended protein levels in commercial shrimp feed as fed basis (Akiyama and Chwang, 1989)	13
3 Recommended lipid levels in commercial shrimp feed as fed basis (Akiyama and Chwang 1989; Chen, 1993)	14
4 Lime requirements of bottom mud based on pH and texture (Avault, 1999)	25
5 Recommended temperature and salinity acclimation times for penaeid post larvae (Maugle, 1987)	28
6 Different stocking density levels for <i>P. monodon</i> and expected production ranges per hectare per crop (Apud, 1988)	30
7 Standard feeding time, frequency and feeding distribution for semi intensive shrimp farm (Apud, 1988; Akiyama, 1993)	32
8 Standard feeding rates of semi intensive tiger shrimp farm (Apud, 1988; Akiyama, 1993)	32
9 Conceptual water exchange rates for tiger shrimp farm (C P Aquaculture Business Development Department, 1992)	35
10 Safe concentrations of NH_4^+ , $\text{NH}_3\text{-N}$ and nitrite-N for <i>P. monodon</i> at various stages	47
11 Physical and chemical parameters (mean \pm standard error) of soil from shrimp culture ponds	65
12 Physical and chemical parameters (mean \pm standard error) of soil throughout the culture period in old culture ponds	65
13 Physical and chemical parameters (mean \pm standard error) of soil throughout the culture period in new culture ponds	66
14 Macro elements concentrations (mean \pm standard error) of soil from shrimp culture ponds	67
15 Concentrations of soil macro elements (mean \pm standard error) of old and new <i>P. monodon</i> culture ponds throughout the culture period	68
16 Microelements concentrations (mean \pm standard error) of soil from shrimp culture ponds	69
17 Concentrations of soil microelements (mean \pm standard error) of old <i>P. monodon</i> culture ponds throughout the culture period	69
18 Concentrations of soil microelements (mean \pm standard error) of new <i>P. monodon</i> culture ponds throughout the culture period	70
19 Macro and microelements concentrations (mean \pm standard error) of culture pond water	71
20 Macro and microelements concentrations (mean \pm standard error) of sediment water of culture ponds	71
21 Concentrations of pond water macro and microelements (mean \pm standard error) of old <i>P. monodon</i> culture ponds throughout the culture period	72
22 Concentrations of pond water macro and microelements (mean \pm standard error) of new <i>P. monodon</i> culture ponds throughout the culture period	72

23	Concentrations of sediment water macro and microelements (mean \pm standard error) of old <i>P. monodon</i> culture ponds throughout the culture period	74
24	Concentrations of sediment water macro and microelements (mean \pm standard error) of new <i>P. monodon</i> culture ponds throughout the culture period	74
25	Comparison of macro elements ranges in shrimp pond soils from regional studies with the present results	84
26	Concentration of soil macro elements of the culture ponds and their category according to Boyd <i>et al.</i> (1994b)	84
27	Concentration of soil microelements (mean \pm standard error) of the culture ponds and it category according to Boyd <i>et al.</i> (1994b)	87
28	Comparison of water and sediment water chemical properties with regional studies	91
29	Species composition of macrobenthos from old and new culture ponds during the culture period	95
30	Shannon diversity index and evenness of macrobenthos throughout the culture period of the studied ponds	96
31	Species composition of meiobenthos from old and new culture ponds during the culture period	100
32	Shannon diversity index and evenness of meiobenthos throughout the culture period of the studied ponds	102
33	Species composition of zooplankton from old and new culture ponds during the culture period	114
34	Shannon diversity index and evenness of zooplanktons throughout the culture period of the study ponds	116
35	Frequency of stomach studied in different ages and sizes of <i>P. monodon</i> from old culture ponds during the culture period	126
36	Frequency of stomach studied in different ages and sizes of <i>P. monodon</i> from new culture ponds during the culture period	127
37	Natural food organisms and their estimated quantity in the stomachs of PL ₁₅ stocked in the old and new culture ponds	128
38	Natural food organisms and their estimated quantity in the stomachs of post larvae at 1 st week of the culture in old and new culture ponds	129
39	Natural food organisms and their estimated quantity in the stomachs of post larvae at 4 th week of the culture in old and new culture ponds	129
40	Natural food organisms and their estimated quantity in the stomach of shrimp at 7 th week of the culture in old and new culture ponds	129
41	Natural food organisms and their estimated quantity in the stomach of shrimps at 10 th week of the culture in old and new culture ponds	130
42	Natural food organisms and their estimated quantity in the stomach of shrimp at 13 th week of the culture in old and new culture ponds	130
43	Natural food organisms and their estimated quantity in the stomach of 12 specimens of shrimp at 16 th week of the culture in new culture ponds	130
44	Soil fungi isolated from shrimp culture ponds during the culture period (cfu/g X 10 ²)	141
45	Physico-chemical parameters (mean \pm standard error) of old and new culture ponds throughout the culture period	151
46	Physico-chemical parameters (mean \pm standard error) of old <i>P. monodon</i> culture ponds throughout the culture period	152

47	Physico-chemical parameters (mean \pm standard error) of new <i>P. monodon</i> culture ponds throughout the culture period	152
48	Pond water and sediment water nutrients (mean \pm standard error) of <i>P. monodon</i> culture ponds	156
49	Concentrations of pond water and sediment water nutrients (mean \pm standard error) of old <i>P. monodon</i> culture ponds throughout the culture period	157
50	Concentrations of pond water and sediment water nutrients (mean \pm standard error) of new <i>P. monodon</i> culture ponds throughout the culture period	157
51	Relationship between the pond status and production parameters during the culture period.	158
52	Growth performance of tiger shrimp <i>P. monodon</i> cultured at different culture ponds	158
53	Estimated feeding areas of old and new culture ponds of tiger shrimp <i>P. monodon</i> .	159
54	Comparison of shrimp production, stocking density and culture duration from regional studies with present study	170

LIST OF FIGURES

Figure		Page
1	Life cycle and ecology of <i>P. monodon</i> in different stages and habitats (Adopted from Brock and Moss, 1992)	9
2	A speculated food web model in an extensive shrimp culture pond ecosystem (Kildow and Huguenin, 1974)	18
3	A semi intensive shrimp pond ecosystem and its function (Funge-Smith and Briggs, 1998)	19
4	A typical lay out design of semi intensive culture ponds (C. P Shrimp News, 1993a)	23
5	Population of macrobenthos in old culture ponds during the culture period	96
6	Population of macrobenthos in new culture ponds during the culture period	96
7	Percent composition of macrobenthos in old culture ponds during the culture period	98
8	Percent composition of macrobenthos in new culture ponds during the culture period	99
9	Population of meiobenthos in old culture ponds during the culture period	101
10	Population of meiobenthos in new culture ponds during the culture period	101
11	Percent composition of meiobenthos in old ponds during the culture period	103
12	Percent composition of meiobenthos in new ponds during the culture period	103
13	Relationship between total macrobenthos and shrimp growth in old culture ponds during the culture period	107
14	Relationship between total macrobenthos and shrimp growth in new culture ponds during the culture period	107
15	Relationship between total meiobenthos and shrimp growth in old culture ponds during the culture period	109
16	Relationship between total meiobenthos and shrimp growth in new culture ponds during the culture period	109
17	Population of zooplankton in old culture ponds during the culture period	115
18	Population of zooplankton in new culture ponds during the culture period	115
19	Percent composition of zooplankton in old culture ponds during the culture period	117
20	Percent composition of zooplankton in new culture ponds during the culture period	117
21	Total rainfall (mm) of Malaysia within the sampling period April 2001 July 2002 (Source: Malaysian Metrological Department 2001-2002)	153
22	Air temperature (°C) of Malaysia within the sampling period April 2001-July 2002 (Source: Malaysian Metrological Department 2001-2002)	153
23	The growth (g) of <i>P. monodon</i> cultured in old and new culture ponds throughout the culture period	159

LIST OF PLATES

Plate		Page
1	Old shrimp culture pond in Malacca	52
2	New shrimp culture pond in Malacca	53
3	Some of the macrobenthos found in old and new culture ponds during the culture period; [A] <i>Stenothyra polita</i> [B] <i>Cerithidea cingulata</i> [C] <i>Fairbankia</i> sp. (x12) [D] <i>Syncera brevicula</i> (x8) [E] <i>Gelonia ceylonica</i> [F] <i>Anadara granosa</i> (x10) [G] <i>Syncera</i> sp. (x10) [H] <i>Namalycostis abiuma</i> (x8) [I] <i>Capitella capitata</i> (x10) [J] Spionidae (Family; x8) [K] <i>Notomastus</i> sp. (x10) [L] <i>Cypridina</i> sp. (x25)	97
4	Some of meiobenthos found in the old and new shrimp culture ponds throughout the culture period; [A] <i>Euterpina acutifrons</i> (x40) [B] <i>Nitokra affinis</i> (x32) [C] <i>Euterpina</i> sp. (x32) [D] <i>Tisbe</i> sp. (x25) [E] <i>Tegastes</i> sp. (x40) [F] <i>Cerithidae</i> larvae (x20) [G] Nerillidae (Family; x10) [H] <i>Spirina</i> sp. (x25) [I] Parasitic mites (Hydrachnellidae; x32) [J] <i>Sabatiera</i> sp. (x40) [K] <i>Puparium</i> larvae (Diptera; x32) [L] Syllidae (Family; x8)	102
5	Some of the zooplankton found in the shrimp culture ponds [A] <i>Acartia</i> sp. (x12) [B] <i>Labidocera</i> sp. (x12) [C] <i>Oithona</i> sp. (x25) [D] Crustacean larvae (x20) [E] <i>Brachionus</i> sp. (x40) [F] <i>Sagitta</i> sp. (x8)	116
6	Appendages or body parts of natural food organisms found in the stomachs during different sampling period [A] Phytoplankton (4 th week; x32) [B] Crustacean appendages (7 th week; x8) [C] Ostracodes (7 th week; x16) [D] Gastropod (10 th week; x20) [E] Crustacean mouth organ (10 th week; x16) [F] Polychaetes (10 th week; x20) [I] Rotifer (13 th week; x12) [G] Polychaetes (16 th week; x10) [H] Mysid (Crustacean) appendage (16 th week; x10)	128
7	Mature surface and typical conidial head of isolated fungi from shrimp pond sediments [A] <i>Trichoderma</i> sp. [B] <i>Penicillium decumben</i> [C] <i>P. oxalicum</i> Cont'd	142
7 Cont'd	[D] <i>Penicillium chrysogenum</i> series [E] <i>Aspergillus flavus</i> group [F] <i>Aspergillus flavipes</i>	143

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