



UNIVERSITI PUTRA MALAYSIA

**BIOLOGY AND POPULATION OF SERGESTID SHRIMPS (*ACETES*
SPP.) (DECAPODA: SERGESTIDAE) FROM KLEBANG BESAR,
MALACCA, MALAYSIA**

S. M. NURUL AMIN

FS 2008 12



**BIOLOGY AND POPULATION OF SERGESTID
SHRIMPS (*ACETES* SPP.) (DECAPODA:
SERGESTIDAE) FROM KLEBANG BESAR,
MALACCA, MALAYSIA**

S. M. NURUL AMIN

**DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA**

2008



**BIOLOGY AND POPULATION OF SERGESTID SHRIMPS (*ACETES* SPP.)
(DECAPODA: SERGESTIDAE) FROM KLEBANG BESAR, MALACCA,
MALAYSIA**

By

S. M. NURUL AMIN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

September 2008



DEDICATION

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

To my mother who always kept praying for me to achieve my goal

*To my wife 'Roushon Ara' and son 'Md. Jahin Zawad' who have sacrificed
so much for me during this study period*

*To my eldest brother Md. Zaherul Islam whom I tried to follow
from my boyhood*

and

*To my respective teacher Professor Dr Mohammad Zafar
for his contribution to develop my research career*



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

**BIOLOGY AND POPULATION OF SERGESTID SHRIMPS (*ACETES* SPP.)
(DECAPODA: SERGESTIDAE) FROM KLEBANG BESAR, MALACCA,
MALAYSIA**

By

S. M. NURUL AMIN

September 2008

Chairperson: Associate Professor Aziz Arshad, PhD

Faculty: Science

Taxonomy, morphometric variation, population genetics, reproductive cycle, sex ratio, fecundity, feeding habits, seasonal abundance, growth, mortality, recruitment, yield-per-recruit and status of the stock of *Acetes* spp., locally known as 'udang geragau', from the coastal waters of Klebang Besar, Malacca, Peninsular Malaysia were examined during February 2005 to March 2007. Three species of sergestid shrimps viz *A. indicus*, *A. japonicus* and *A. intermedius* were identified from the study area. Among them, *A. intermedius* was recorded for the first time from Malaysia coast. All morphometric characters amongst the three species were significantly different ($P < 0.05$).

The Random Amplified Polymorphic DNA (RAPD) marker was used to study the population genetic variation of *A. japonicus* collected along the west coast of Peninsular Malaysia. A total of 90 samples of *Acetes japonicus*, comprised of 30 (15



males and 15 females) from Kedah, 30 (15 males and 15 females) from Perak and 30 (15 male and 15 females) from Malacca were used. The percentages of polymorphic bands of the three geographic populations investigated were varied from 57.77% to 87.77%. Genetic distances between populations and cluster analysis from UPGMA grouped the populations into two major clusters. The Perak and Malacca populations were in one cluster, while the Kedah population was clustered by itself indicating it was genetically different. The genetic distance was the highest for the Kedah and the Malacca populations while the lowest was for the Perak and the Malacca populations which probably has a closed ancestral relationship and are from the same species.

The sex ratio of *A. indicus* and *A. japonicus* in the coastal waters of Malacca was in favour of females in most months of the year. The analysis of the annual variation of gonadosomatic index (GSI) showed the continuously breeding of *A. indicus* and *A. japonicus* throughout the year. Size at first sexual maturity of female *A. indicus* was observed at 23 mm and that was > 17 mm of total length for female *A. japonicus*. There were no females with spent ovaries in the samples of both species. The estimated mean fecundity of *A. indicus* was 1666.28 (\pm 46.32) eggs. The mean monthly GSI for females *A. indicus* showed positive and significant ($P < 0.05$) correlation with conductivity ($r = 0.67$), salinity ($r = 0.65$) and TSS ($r = 0.59$). No significant ($P > 0.05$) correlation was found between the mean monthly GSI and the remaining two variables (temperature and dissolved oxygen).

According the Simple Resultant Index (%Rs), the stomach contents of *A. indicus* were comprised of plant matters (22.85%), fine sand and mud (16.19%), crustacean appendages (19.03%), debris (15.46%), unidentified fragments (10.56%),

zooplankton (6.78%), phytoplankton (6.47%), algae (3.49%), shrimp nauplii (1.25%) and mollusc larvae (0.91%). Similarly, diet compositions of *A. japonicus* were made up of plant matters (31.82%), debris (20.06%), phytoplankton (18.45%), fine sand and mud (11.75%), appendages of decapods (6%), unidentified fragments (5.86%), algae (4.17%) and zooplankton (1.80%). These various compositions of food items proved that the two shrimps are bottom feeder omnivore.

The average monthly catch per unit effort (CPUE) of the estuarine push net (EPN) was estimated at 2.50 (\pm 3.42) kg/fisherman/hr. The total catch comprised of three major categories those were *Acetes* shrimps (90%), followed by fish juveniles (9%) and other shrimps (1%). The annual percent composition of *A. indicus*, *A. japonicus* and *A. intermedius* were found to be 57%, 41% and 2%, respectively. The peak catch was observed in the month of October to December. There was no significant correlation ($P > 0.05$) between monthly catches and environmental parameters (temperature, dissolved oxygen, salinity, conductivity and total suspended solid).

The length frequency distribution for *A. indicus* suggested that the population consisted of two dominant age group with mean values of 20.80 (\pm 0.07) mm and 29.85 (\pm 0.09) mm of the total length, respectively. And the population of *A. japonicus* consisted of maximum two age groups, with means of 15.18 (\pm 0.90) mm and 21.56 (\pm 1.03) mm of total length. The population of *A. intermedius* also consisted of maximum two age groups, with means of 19.18 (\pm 0.05) mm and 26.92 (\pm 0.06) mm of the total length. The positive allometric nature of growth for *A. indicus* was observed. However, isometric nature of growth was found in combined

sexes of *A. japonicus*. The positive allometric nature of growth was also observed in female and both sexes of *A. intermedius*. There were significant difference between males and females size-frequency distribution of *A. indicus* (Kolmogorov-Smirnov test: $d_{\max} = 0.42$, $P < 0.05$), *A. japonicus* (Kolmogorov-Smirnov test: $d_{\max} = 0.39$, $P < 0.05$) and *A. intermedius* (Kolmogorov-Smirnov test: $d_{\max} = 0.40$, $P < 0.05$).

The growth, mortality, recruitment and relative yield per recruit of *Acetes* spp. were investigated based on monthly length-frequency data, using FiSAT software. Higher natural mortalities of male *A. indicus* and *A. japonicus* versus the fishing mortalities observed from the study indicated the unbalance position in the stock. Exploitation level (E) of female was higher than males in *A. japonicus* population. This study indicated two major recruitment events per year where two cohorts were produced per year for *A. indicus* and *A. japonicus* populations. The recruitment pattern of *A. intermedius* was continuous with one major cohort per year. Results from the analysis of the exploitation rate (E) based on the fishing mortality estimates, and from the relative yield-per-recruit (Y/R), indicate that the *Acetes japonicus* fishery is over exploited although *A. indicus* and *A. intermedius* fishery were slightly below the optimum level of exploitation. This implies that any further unrestrained increase in fishing effort might overshoot the level giving maximum sustainable yield, thus driving the stock down and leading to economic losses.

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

**BIOLOGI DAN POPULASI UDANG SERGESTID (*ACETES* SPP.)
(DECAPODA: SERGESTIDAE) DARI KLEBANG BESAR, MALACCA,
MALAYSIA**

Oleh

S. M. NURUL AMIN

September 2008

Pengerusi: Professor Madya Aziz Arshad, PhD

Fakulti: Sains

Taksonomi, variasi morfometrik, genetik populasi, kitar pembiakan, kesuburan, tabiat pemakanan, kelimpahan mengikut musim, pertumbuhan, kadar kematian, pemulihan dan hasil perolehan bagi spesies *Acetes* spp., juga dikenali sebagai "udang geragau", telah dikaji di perairan Klebang Besar, Melaka, Semenanjung Malaysia dari Februari 2005 hingga Mac 2007. Sebanyak tiga spesies udang sergestid iaitu *A. indicus*, *A. japonicus* dan *A. intermedius* telah dikenal pasti di kawasan kajian. Antaranya *A. intermedius* direkodkan pertama kali di perairan Melaka. Semua ciri morfometrik antara ketiga-tiga spesies tersebut adalah berbeza secara bererti ($P < 0.05$).

Penanda (RAPD) telah digunakan untuk mengkaji populasi variasi genetik *A. japonicus* yang dikumpulkan di sepanjang persisiran pantai barat Semenanjung Malaysia. Sebanyak 90 ekor udang telah dikumpulkan dari Perak (30), Malacca (30) dan Kedah (30) telah digunakan. Peratus penanda polimorfik untuk ketiga-tiga

populasi yang dikaji adalah di antara 57.77% dan 87.77%. Jarak genetik antara populasi dan analisis kelompok dengan menggunakan UPGMA telah membahagikan semua populasi kepada dua kelompok besar. Populasi daripada negeri Perak dan Melaka digolongkan dalam satu kelompok manakala populasi daripada negeri Kedah dalam satu kelompok tunggal yang menggambarkan perbezaan secara genetik pada kedua-dua populasi ini. Populasi Melaka dan Kedah mempunyai jarak genetik yang paling tinggi manakala jarak genetik yang paling rendah dicatatkan pada populasi Perak dan Melaka, di mana ia berkemungkinan mempunyai hubungan leluhur yang rapat dan berasal dari spesis yang sama.

Nisbah seks bagi *A. indicus* dan *A. japonicus* di perairan Melaka menunjukkan dominasi betina dalam kebanyakan bulan di sepanjang tahun. Analisis variasi tahunan Indeks Gonadosomatik (GSI) menunjukkan bahawa pembiakan berlaku sepanjang tahun bagi *A. indicus* dan *A. japonicus*. *A. indicus* betina didapati mengalami fasa pematangan pertama pada jumlah panjang 23 mm manakala > 17 mm bagi *A. japonicus* betina. Tiada ovari yang tidak berfungsi (kosong) didapati pada betina dalam sampel kedua-dua spesies tersebut. Jangkaan min kesuburan bagi *A. indicus* ialah 1666.28 (\pm 46.32) telur. Min bulanan GSI bagi betina *A. indicus* menunjukkan korelasi positif ($P < 0.05$) dengan konduktiviti ($r = 0.67$), saliniti ($r = 0.65$) dan TSS ($r = 0.59$). Tiada korelasi secara bererti ($P > 0.05$) didapati antara min bulanan GSI dan dua parameter yang lain (suhu dan oksigen terlarut).

Merujuk kepada 'Simple Resultant Index' (%Rs), makanan dalam isiperut *A. indicus* dikelaskan kepada bahagian tumbuhan (22.85%), pasir dan lumpur (16.19%), appendej krustasea (19.03%), debris (15.46%), fragmen yang tidak dapat dikenal pasti

(10.56%), zooplankton (6.78%), fitoplankton (6.47%), alga (3.49%), naupli udang (1.25%) dan larva molaska (0.91%). Somontara komposisi makanan bagi *A. japonicus* pula juga digredkan kepada bahagian tumbuhan (31.82%), cebisan (20.06%), fitotoplankton (18.45%), pasir dan lumpur (11.75%), apendej decapoda (6%), fragman yang tidak dikenal pasti (5.86%), alga (4.17%) dan zooplankton (1.80%). Kepelbagaian komposisi makanan membuktikan bahawa kedua-dua udang tersebut merupakan pomakan omnivor di bahagian dasar laut.

Purata bulanan tangkapan per unit usaha (TPUU) bagi pukat tolak estuari (PTE) didapati mencatat nilai 2.50 (\pm 3.42) kg/nelayan/jam. Komposisi keseluruhan tangkapan terdiri daripada tiga talssa utama iaitu udang *Acetes* (90%), diikuti dengan juvenil ikan (9%) dan lain-lain udang (1%). Peratus komposisi tahunan bagi *A. indicus*, *A. japonicus* dan *A. intermedius* ada masing-masing pada 57%, 41% dan 2%. Tangkapan tertinggi diperolehi dari bulan Oktober hingga Disember. Tiada korelasi yang bererti ($P > 0.05$) antara tangkapan bulanan dan parameter persekitaran (suhu, oksigen terlarut, saliniti, konduktiviti dan jumlah pepejal terampai).

Taburan frekuensi panjang bagi *A. indicus* mencadangkan bahawa populasi terdiri daripada dua kumpulan umur yang dominan dengan min 20.80 (\pm 0.07) mm dan 29.85 (\pm 0.09) mm jumlah panjang masing-masing. Populasi *A. japonicus* terdiri daripada maksimum dua kumpulan umur maksimum dengan 15.18 (\pm 0.90) mm dan 21.56 (\pm 1.03) mm pada min jumlah panjang. Populasi *A. intermedius* juga terdiri daripada dua kumpulan umur dengan 19.18 (\pm 0.05) mm dan 26.92 (\pm 0.06) mm min jumlah panjang. Pertumbuhan alometri positif didapati bagi *A. indicus* di perairan Melaka. Namun pertumbuhan isometrik didapati bagi gabungan seks *A. japonicus*.

Pertumbuhan alometrik positif didapati bagi betina dan gabungan seks *A. intermedius*. Perbezaan bererti didapati bagi taburan saiz-frekuensi jantan dan betina *A. indicus* (Kolmogorov-Smirnov test: $d_{\max} = 0.42$, $P < 0.05$), *A. japonicus* (Kolmogorov-Smirnov test: $d_{\max} = 0.39$, $P < 0.05$) dan *A. intermedius* (Kolmogorov-Smirnov test: $d_{\max} = 0.40$, $P < 0.05$).

Pertumbuhan, kadar kematian, pemulihan dan hasil perolehan relatif per pemulihan bagi spesies *Acetes* telah dikaji berdasarkan data frekuensi panjang bulanan dengan menggunakan perisian FiSAT. Kadar kematian secara semula jadi bagi jantan *A. indicus* dan *A. japonicus* melawan kekerapan tangkapan yang diperhatikan dari kajian menunjukkan ketidakseimbangan pada stok. Aras eksploitasi (E) betina adalah lebih tinggi berbanding jantan bagi populasi *A. indicus* dan *A. japonicus*. Kajian ini menunjukkan dua proses pemulihan besar per tahun i.e., dua kohot dihasilkan per tahun bagi populasi *A. indicus* dan *A. japonicus*. Corak pemulihan *A. intermedius* adalah berterusan dengan satu kohot besar per tahun. Keputusan dari analisis kadar eksploitasi (E) berdasarkan jangkaan kekerapan tangkapan dan hasil relatif per pemulihan (Y/R), menandakan perikanan *Acetes* telah berada dalam tahap optimum berdasarkan prinsip $E_{0.1}$, dan mungkin menghampiri eksploitasi maksimum (MSY). Ini bermaksud sebarang peningkatan kekerapan usaha perikanan tanpa pengawalan boleh melampaui tahap hasil perolehan maksima, akan menjejaskan stok dan menyebabkan kerugian dari segi ekonomi.

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, Associate Professor Dr. Aziz Arshad, the Chairman of my supervisory committee for his guidance, valuable collaboration and inspiration during the research period at UPM. Without his friendly and quality supervision, this work would not have come to complete. I am profound indebted to my co-supervisors Associate Professor Dr. Siti Shapor Siraj and Associate Professor Dr. Japar Sidik Bujan for their advice, critical thought, thoroughness to this thesis and for the continue constructive discussions and suggestions.

I would like to thank to Ministry of Science, Technology and Innovation (MOSTI), Malaysia (Grant No. 05-01-04-SF0613) for providing financial support to carry out this research work. Special thanks to Universiti Putra Malaysia for providing partial financial support through Graduate Research Fellowship (GRF) during the study period. In addition, thanks go to Mr. Ibrahim, fisherman and Mr. Perumal, Science Officer of Marine Science Laboratory and Aquaculture, Institute of Bio Science, UPM for the assistance during field sampling.



My special appreciation goes to my mother, my wife, my son, elder brothers, and sisters for their unfailing support and encouragement for my higher study. My respect and appreciation also goes to Professor Dr. Mohammad Zafar and Dr. Abu Hena Mustafa Kamal, University of Chittagong, Bangladesh and Dr. M. G. Mustafa, Fisheries Biologist (Coordinator), WorldFish Center, Bangladesh for their valuable advice, suggestions and encouragement of the higher study and research.

I would like to express my gratitude and thanks to the officers, technicians, undergraduate and graduate students who helped me throughout this study. I would especially like to thank my friends and lab mates Kabir, Shafiq, Altaf, Shahin, Akter, Hanafi, Said, Jimmy, Efrizal, Leena and Oh who have contributed in ways too numerous to list. Last, but not least, I am thankful to all of my well-wishers whom have helped me in any form.



I certify that an Examination Committee has met on 4 September 2008 to conduct the final examination of S. M. Nurul Amin on his Doctor of Philosophy thesis entitled “Biology and Population of sergestid shrimps (*Acetes* spp.) (Decapoda: Sergestidae) from Klebang Besar, Malacca, Malaysia” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Examination Committee were as follow:

Ahmad Ismail, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Siti Khalijah Daud, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Abdul Rahim Ismail, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Mohd Azmi Ambak, PhD

Dean and Professor
Graduate School
Universiti Malaysia Terengganu
(External Examiner)

HASANAH MOHD. GHAZALI, PhD

Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:



This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

Aziz Arshad, PhD

Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Siti Shapor Siraj, PhD

Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Japar Sidik Bujang, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:



DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or any other institution.

S. M. NURUL AMIN

Date:

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vii
ACKNOWLEDGEMENTS	xi
APPROVAL	xiii
DECLARATION	xv
LIST OF TABLES	xix
LIST OF FIGURES	xxii
LIST OF ABBREVIATIONS	xxxii
CHAPTER	1
1 GENERAL INTRODUCTION	1
1.1 Background of the study	1
1.2 Statement of the problems	4
1.3 Objectives of the study	5
2 LITERATURE REVIEW	6
2.1 Taxonomic status	6
2.2 External morphology	7
2.3 Anatomy	13
2.4 Identification keys	20
2.5 Phylogeny	25
2.6 Population genetics	26
2.7 Geographical distribution	32
2.8 Swarming behaviour	38
2.9 Reproduction	40
2.10 Food and feeding habits	44
2.11 Length-weight relationships	46
2.12 Population dynamics	46
2.13 The fisheries of <i>Acetes</i> spp	48
3 GENERAL METHODOLOGY	57
3.1 Introduction	57
3.2 Methods	57
3.3 Results of water parameters	66

4	TAXONOMY AND MORPHOMETRIC VARIATION AMONGST THE THREE SPECIES OF SERGESTID SHRIMPS (<i>ACETES</i> SPP.)	70
	4.1 Introduction	70
	4.2 Materials and Methods	72
	4.3 Results	82
	4.3.1 Systematic accounts of <i>Acetes</i> spp.	82
	4.3.2 Morphometric variation	95
	4.3.3 Genetic variation of <i>Acetes japonicus</i>	99
	4.4 Discussion	107
	4.5 Conclusions	112
5	SOME ASPECTS OF REPRODUCTIVE BIOLOGY OF <i>ACETES INDICUS</i> AND <i>ACETES JAPONICUS</i> IN THE COASTAL WATERS OF MALACCA, PENINSULAR MALAYSIA	114
	5.1 Introduction	114
	5.2 Materials and Methods	116
	5.3 Results	118
	5.3.1 Reproductive biology of <i>Acetes indicus</i>	118
	5.3.2 Reproductive biology of <i>Acetes japonicus</i>	132
	5.4 Discussion	136
	5.5 Conclusions	140
6	FOOD AND FEEDING HABITS OF <i>ACETES INDICUS</i> AND <i>ACETES JAPONICUS</i> IN THE COASTAL WATERS OF MALACCA, PENINSULAR MALAYSIA	141
	6.1 Introduction	141
	6.2 Materials and Methods	144
	6.3 Results	146
	6.3.1 Food and feeding habits of <i>Acetes indicus</i>	146
	6.3.2 Food and feeding habits of <i>Acetes japonicus</i>	153
	6.4 Discussion	160
	6.5 Conclusions	162
7	CATCH PER UNIT EFFORT OF ESTUARINE PUSH NET AND SEASONAL ABUNDANCE OF SERGESTID SHRIMPS IN THE COASTAL WATERS OF MALACCA, PENINSULAR MALAYSIA	164
	7.1 Introduction	164
	7.2 Materials and Methods	165
	7.3 Results	168
	7.4 Discussion	179
	7.5 Conclusions	182

8	POPULATION DYNAMICS AND STOCK ASSESSMENT OF SERGESTID SHRIMPS (<i>ACETES</i> SPP.) FROM THE COASTAL WATERS OF MALACCA, PENINSULAR MALAYSIA	183
8.1	Introduction	183
8.2	Materials and Methods	186
8.3	Results	196
8.3.1	Population dynamics of <i>Acetes indicus</i>	196
8.3.2	Population dynamics of <i>Acetes japonicus</i>	220
8.3.3	Population dynamics of <i>Acetes intermedius</i>	237
8.3.4	Stock size and MSY	253
8.4	Discussion	254
8.5	Conclusions	260
9	GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS	262
9.1	Discussion	262
9.2	Conclusions	269
9.3	Recommendations	272
	REFERENCES	273
	BIODATA OF STUDENT	291
	LIST OF PUBLICATIONS	296



LIST OF TABLES

Table	Page
2.1 Population parameters of the genus <i>Acetes</i> from different tropical countries	47
3.1 Latitude and longitude of sampling sites and dates of sampling	60
3.2 Monthly variation of different waters parameters in the coastal waters of Klebang Besar, Malacca from February 2005 to March 2007	67
4.1 Sampling sites, sample size, mean length and weight of <i>Acetes japonicus</i> used in this study	74
4.2 A list of RAPD primers used in this population study	77
4.3 Mean \pm standard error, ranges (in parentheses) and F-values (derived from analysis of variance) of each morphometric character (mm) in three species of the genus <i>Acetes</i> (male)	96
4.4 Mean \pm standard error, ranges (in parentheses) and F-values (derived from analysis of variance) of each morphometric character (mm) in three species of the genus <i>Acetes</i> (female)	97
4.5 Number of bands and the size range of the RAPD fragments in primers RAPD kit A of <i>Acetes japonicus</i>	104
4.6 Genetic distances and similarities between populations based on 6 selected RAPD primers	105
5.1 Egg length (μm) of different stages of <i>A. indicus</i> from Klebang Besar, Malacca, Peninsular Malaysia.	121
5.2 Fecundity of <i>A. indicus</i> from the coastal waters of Malacc (n = 32)	129
6.1 Empirical scale of <i>A. indicus</i> and <i>A. japonicus</i> stomach fullness divided into five categories as defined for this study	145
6.2 Percentage of fullness of guts of <i>Acetes indicus</i> in the coastal waters of Malacca during February 2005 to January 2006	147
6.3 Overall diet composition of <i>Acetes indicus</i> ranked by Simple Resultant Index (%Rs) in the coastal waters of Malacca during February 2005 to January 2006	149



6.4	Percentage frequency of occurrence (F_{pi}) of food items in 145 guts of <i>A. indicus</i> in the coastal waters of Malacca during February 2005 to January 2006	151
6.5	Percentage of numerical abundance (C_i) of food items in 145 guts of <i>A. indicus</i> in the coastal waters of Malacca during February 2005 to January 2006	152
6.6	Percentage of fullness category of <i>Acetes japonicus</i> in the coastal waters of Malacca during April 2006 to March 2007	154
6.7	Overall diet composition of <i>A. japonicus</i> ranked by Simple Resultant Index (%Rs) in the coastal waters of Malacca, Peninsular Malaysia	156
6.8	Percentage frequency of occurrence (F_{pi}) of food items in the 150 guts of <i>A. japonicus</i> in the coastal waters of Malacca during April 2006 to March 2007	158
6.9	Percentage of numerical abundance (C_i) of food items in the 150 guts of <i>A. japonicus</i> from the coastal waters of Malacca during April 2006 to March 2007	159
7.1	Monthly variation of catches (kg/fisherman/hr) of estuarine push net (EPN) in the coastal waters of Malacca, Peninsular Malaysia.	169
7.2	Correlation coefficient (r) between <i>Acetes</i> shrimps and waters parameters in the coastal waters of Klebang Besar, Malacca	177
7.3	Monthly catch composition of juvenile fishes (No. of individuals/100 g) in estuarine push net in the coastal waters of Malacca.	178
8.1	Monthly length frequency data of male <i>A. indicus</i> samples collected February 2005 – January 2006 from the coastal waters of Malacca, Peninsular Malaysia	191
8.2	Monthly length frequency data of female <i>A. indicus</i> samples collected February 2005 – January 2006 from the coastal waters of Malacca, Peninsular Malaysia	191
8.3	Monthly length frequency data of male <i>A. indicus</i> samples collected April 2006 – March 2007 from the coastal waters of Malacca, Peninsular Malaysia	192
8.4	Monthly length frequency data of female <i>A. indicus</i> samples collected April 2006 – March 2007 from the coastal waters of Malacca, Peninsular Malaysia	192
8.5	Monthly length frequency data of male <i>A. japonicus</i> samples collected February 2005 – October 2006 from the coastal waters of Malacca, Peninsular Malaysia	193

8.6	Monthly length frequency data of female <i>A. japonicus</i> samples collected February 2005 – October 2006 from the coastal waters of Malacca, Peninsular Malaysia	194
8.7	Length-frequency data for combined sexes of <i>Acetes intermedius</i> samples collected February 2005 – January 2006 from the coastal waters of Malacca, Peninsular Malaysia	195
8.8	Basic population characteristics of <i>A. indicus</i> from the coastal waters of Malacca during February 2005 to January 2006	197
8.9	Length-weight relationship parameters of <i>A. indicus</i> in the coastal waters of Malacca during February 2005 to January 2006	200
8.10	Estimated population parameters of <i>A. indicus</i> in the coastal waters of Malacca, Peninsular Malaysia	205
8.11	Basic population characteristics of <i>A. japonicus</i> in the coastal waters of Malacca, Peninsular Malaysia	221
8.12	Length-weight relationship parameters of <i>A. japonicus</i> in the coastal waters of Malacca, Peninsular Malaysia	224
8.13	Estimated population parameters of <i>A. japonicus</i> in the coastal waters of Malacca during February 2005 - October 2006	228
8.14	Basic population characteristics of <i>A. intermedius</i> in the coastal waters of Malacca during February 2005 to January 2006	238
8.15	Length-weight relationship parameters of <i>A. intermedius</i> in the coastal waters of Malacca, Peninsular Malaysia	241
8.16	Estimated population parameters of <i>A. intermedius</i> (combined sexes) in the coastal water of Malacca during February 2005 – January 2006	244
8.17	Estimation of stock and MSY for <i>A. indicus</i> , <i>A. japonicus</i> and <i>A. intermedius</i> in the coastal waters of Malacca, Peninsular Malaysia	253
8.18	Parameters of length-weight relationship (a and b) for the genus <i>Acetes</i> from various geographical locations	254
8.19	Growth parameters (L_{∞} and K) and computed growth performance index (ϕ') of the genus <i>Acetes</i> from different tropical countries	257
8.20	Mortality parameters (Z, F and M) and computed exploitation rate (E) of the genus <i>Acetes</i> from different tropical countries	258

LIST OF FIGURES

Figure		Page
2.1	Diagram of a male <i>Acetes</i> (after Omori, 1975). am, appendix masculina; antfl, antennal flagellum; antrpd, antennular peduncle; antsc, antennal scale; ch, chela; crn, cornea; end, endopods; eyst, eye stalk; exp, exopod; gc, genital coxa; hs, hepatic spine; lf, lower flagellum; uf, upper flagellum; mxpd, maxilliped; pt, procurved tooth; r, rostrum.	8
2.2	a, antennule; b, antenna of <i>A. sibogae</i> [<i>A. australis</i>] (after Colefax, 1940). a: ER, eye recess; LF and UF, lower and upper flagella; S, stylocerite; ST, statocyst. b: AN 3-5, segments 3-5 of base (peduncle) of flagellum; CARP, carpocerite (segment 1); SC, scaphocerite; SP, spine	10
2.3	Pereiopods of <i>A. intermedius</i> (after Omori, 1975) and pleopods of <i>A. chinensis</i> (after Yoo and Kim, 1973). a, b and c, 1 st , 2 nd and 3 rd pereiopod; d, e and f, 1 st , 3 rd and 5 th pleopods; C, carpus; D, dactylus; I, ischium; M, merus; P, propodus	12
2.4	Foregut of <i>A. indicus</i> (after Patwardhan, 1935). CPV, cardio-phyloric valva; FO, lateral fold; ICO, inferior cardiac ossicle; ILC, infero laterd cardiac ossicle; LT, lateral tooth; MC, mesocardiac ossicle; MT, median tooth; PO, pyloric ossicle; PTC, pterocardiac ossicle; UC, urocardiac ossicle; UPO, urophyloric ossicle; V, lateral valve; ZC, zygo-cardiac ossicle	14
2.5	Petasma of <i>A. japonicus</i> in relation to its total body length (After Lei, 1988). Total body length (mm): a, 6.0 - 7.0; b, 9.0 - 9.5; c, 9.5 - 10.0; d, 10.0 - 10.5	15
2.6	External reproductive organs of <i>Acetes</i> . a, petasma; b, appendix masculina; c,d, ventral view of basal segment of the third pereiopods and third thoracic sternite of adult female and male <i>A. sibogae</i> (after Omori, 1975). CAP, capitulum; FSP, falcate spine; PAS, pars astringens; PEX, pars externa; PM, pars media; PV, processus ventralis	16
2.7	Intrageneric relationship of <i>Acetes</i> (after Omori, 1975).	25
2.8	Distribution of <i>A. erythraeus</i> , <i>A. intermedius</i> and <i>A. vulgaris</i> (after Omori, 1975)	33
2.9	Distribution of <i>A. Americanus</i> , <i>A. binghami</i> , <i>A. marinus</i> , and <i>A. paraguayensis</i> (after, Omori, 1975)	34

2.10	Distribution of <i>A. sibogae</i> , <i>A. johni</i> , <i>A. natalensis</i> , and <i>A. serrulatus</i> (after Omori, 1975)	36
2.11	Distribution of <i>A. chinensis</i> , <i>A. indicus</i> and <i>A. japonicus</i> (after Omori, 1975)	37
2.12	Major global fishing grounds of <i>Acetes</i> (after Omori, 1975). 0, Toyama Bay; 1, Seto Inland Sea; 2, Ariake Sea; 3, Kyonggi Bay; 4, Yingkow; 5, mouth of Luan River; 6, Shihtao; 7, Matsu Island; 8, Tungkiang; 9, Hong Kong; 10, Cavite; 11, Paracale; 12, Iloilo; 13, Nhatrang; 14, Vung Tau; 15, Bac Lieu; 16, Chonburi; 17, Choomporn; 18, Goh Pangi; 19, Penang; 20, Labuan; 21, Kudat; 22, Ponggol; 23, Jakarta; 24, Pelabuhan Ratu; 25, Surabaya; 26, Sandowa; 27, Mergui; 28, mouth of Godavari River; 29, Cochin; 30, Versova; 31, Ambaro Bay; 32, Lingamo; 33, Paramaribo; 34, Cayenne.	49
2.13	Picture of estuarine push net (suongkor). Source: www.fao.org .	50
3.1	Geographical location of the sampling sites in the Peninsular Malaysia. a, Klebang Besar, Malacca; b, Kuala Gula, Perak; c, Pantai Bersih, Pulau Pinang; d, Kuala Sala, Kedah; e, Sungai Berembang, Perlis; f, Sebarang Takir, Terengganu.	58
3.2	Geographical location of the sampling site in the coast of Bintulu, Sarawak	59
3.3	Estuarine Push Net which is used to catch sergestid shrimps in the coastal waters of Malacca, Peninsular Malaysia	61
3.4	<i>Acetes</i> fishing by push net along the coast of Klebang Besar, Malacca Peninsular Malaysia	61
4.1	Morphometric characters used for <i>Acetes</i> shrimp	73
4.2	Photograph of <i>Acetes indicus</i> . a, male (x6) and b, female (x6)	82
4.3	<i>Acetes indicus</i> . a, procurved tooth (x25); b, clasping spine (x40); c, petasma without pars astringens (x50); d, telson of female (x40); e, third thoracic sternite is deeply channelled (x30)	86
4.4	Photograph of <i>Acetes japonicus</i> . a, male (x20) and b, female (x20)	87
4.5	<i>Acetes japonicus</i> . a, clasping spine (x150); b, capitulum of petasma (x130); c, third thoracic sternite (x25); d, Apex of female telson (x100)	90
4.6	Photograph of <i>Acetes intermedius</i> . a, male (x6) and b, female (x6)	91
4.7	<i>Acetes intermedius</i> Omori. a, clasping spine (x130); b, petasma (x100); c, segments of antennular peduncle (x40) (female) (1-1 st segment, 2-2 nd segment; 3 rd -segment) and d, apex of the telson triangular (x30) (male)	94