Indian Journal of Marine Sciences
Vol. 38(1), March 2009, pp. 57-68

Population structure, growth, mortality and yield per recruit of segestid shrimp, *Acetes japonicus* (Decapoda: Sergestidae) from the coastal waters of Malacca, Peninsular Malaysia

S. M. Nurul Amin[1], A. Arshad[1, 2], S. S. Siraj[2] and B. Japar Sidik[3]

[1]Laboratory of Marine Science and Aquaculture, Institute of Bioscience, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Department of Aquaculture, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[3]Department of Animal Science and Fishery, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia, Bintulu Campus, 89007 Bintulu Sarawak
[E-mail: smnabd02@yahoo.com]

Received 7 June 2007; 16 November 2007

Present study consists the population structure, growth, mortality and relative yield recruit of *A. japonicus* from the coastal waters of Malacca, Peninsular Malaysia. FISAT software has been used to examine the monthly data. The asymptotic length (L_α) and growth co-efficient (K) was estimated as 29.08 mm and 1.4 y^{-1}. The growth performance index (φ′) was calculated as 3.073. The exponent (b) of the length-weight relationship was found to be 3.063 (± 0.015). The asymptotic weight was calculated as 187.72 mg. Total mortality coefficient (Z) was estimated at 5.16 yr^{-1}. The natural mortality (M) and fishing mortality (F) was calculated as 2.35 yr^{-1} and 2.81 yr^{-1}, respectively. Exploitation rate (E) of *A. japonicus* was estimated as 0.54. The recruitment pattern was continuous throughout the year with one major peak. The relative yield per recruit analysis predicted the maximum exploitation rate (E_{max}) = 0.52. The current exploitation rate E is slightly higher than predicted E_{max}. The stock of *A. japonicus* was found to be over exploited in the investigated area.

[**Keywords**: Population dynamics, *Acetes Japonicus*, Malaysia]

Introduction

The sergestid shrimps of the genus *Acetes,* family sergestidae, are one of the economically important organisms in Asian and African waters[1]. There are several accounts of *Acetes* fishery from Malay Peninsular[2,1,3&4]. In west Malaysia, *Acetes* (Local name 'udang geragau') supports a considerable subsistence fishery[5] which is based mainly on *A. japonicus* and *A. indicus*[1]. The world-wide geographical distribution of *Acetes* has been summarized by Omori and Holthuis[6].

The shrimp of the genus *Acetes* plays a substantial role in the food webs of coastal waters, acting as predators[7]. It appears in a very large swarm in the shallow inshore coastal waters, which is brackish with a salinity of 30 ppt or less, during certain seasons of the year[2]. Only a very small proportion of the catch is disposed off as fresh shrimp but the greater part is sun dried and sold as dried shrimp or processed into a paste known locally as 'Belachan' or pickled whole to give a product known as 'Chinchalok[2]. The annual landing of *Acetes* in Malaysia was 7,528 tons during 2004[8].

Spectacular schools or swarms of *Acetes,* particularly in coastal Asia, are the bases of important commercial fishes for consumption by humans and domestic animals[4,9,1,10,11&12]. The commercial importance also derives from the use and potential of *Acetes* as a food organism for aquaculture industry[13&14]. These combined features make *Acetes* excellent candidates for population dynamic studies. In spite of greater abundance and importance of the genus *Acetes* in the fishery of Asian countries, very little information is available on the population parameters like growth and motilities so far except the studies carried out by[15,16,17,18].

Knowledge of various population parameters like as asymptotic length (L_∞) and growth coefficient (K), motilities (natural and fishing) rate and exploitation level (E) are necessary for planning and management of *A. japonicus* resources. Lack of knowledge on the population structure and proper evaluation of the exploitation of this resource emphasize the importance of a detailed study to facilitate better

Address for correspondence:
Laboratory of Marine Science and Aquaculture Institute of Bioscience, Universiti Putra Malaysia 43400 UPM Serdang, Selangor, Malaysia

management of the resource. There are many tools for assessing exploitation level and status of stock. Of these, FiSA T (FAO-ICLARM Stock Assessment Tools) has been most frequently used for estimating population parameters of shrimps[19,20,21,22&23] because primarily it requires only length-frequency data. The objectives of the present study were to estimate the key population parameters and exploitation rate (E) of *A. japonicus* in order to assess the stock status of the species around the coast waters of Malacca, Peninsular Malaysia.

Materials and Methods

Collection of data

Monthly fresh samples of *A. japonicus* were collected between February 2005 and January 2006 from commercial push net catches landed at Klebang Besar (N 02°13.009′ and E 102° 11.921′) Malacca (Fig. 1). *Acetes* shrimps were caught by the push net (triangular shape) known locally as 'Sungkor', as described by Omori[-1] in the coastal waters of Klebang Besar, Malacca. Dimensions of the net were 5-6 m in length, 4.0-4.5 m in wide and 3.0-3.5m in height. The mean mesh sizes were 3.2 (± 0.27) cm at the anterior section, 0.75 (±0.05) cm at the middle and 0.5 (±0.08) at cod end (stretched). After collection, samples were fixed in 10% formalin solution in the field and analyzed after 2-3 days of preservation. In the laboratory, *A. japonicus was* identified using a Nikon dissecting microscope. Sex of *A. japonicus* was determined by the presence or absence of petasma on the first pleopod and clasping spine on the lower antennular flagellum[1]. The works of Omori[-1] were followed during the identification of *A. japonicus.* Total length (TL) of 3516 individuals (Table 1) was measured from the tip of the rostrum to the tip of the telson to the nearest 0.1 mm using vernier caliper. Total weight was measured by an electronic balance to the 0.1 mg accuracy.

Data analysis

To estimate the population structure, the length-frequency data of *A. japonicus* were analyzed by using the MINTAB Version 14 and SPSS Version 11.5. The differences in the size-frequency distributions of population between sexes were determined by the Kolmogorov-Smimov two-sample test[24]. Student's *t*-test was used for comparison of the mean total length of males and females[25].

Size-frequency distributions of *A. japonicus* in 1-mm interval were plotted for each month.

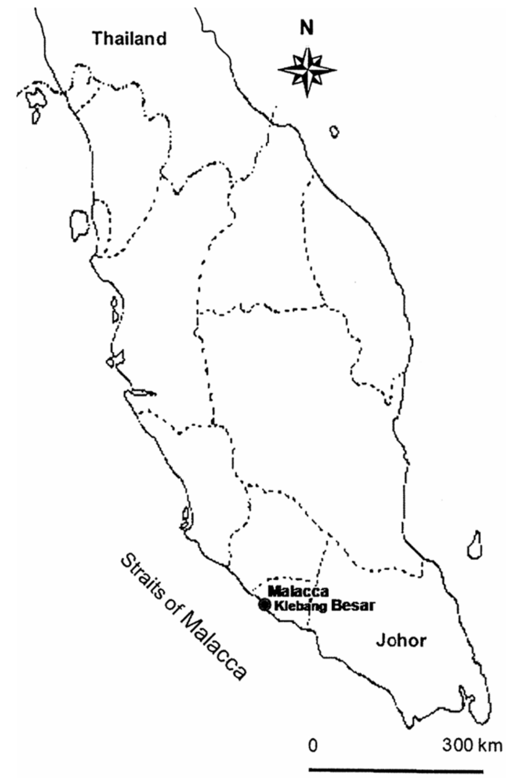

Fig. 1—Sampling location (dot) in the coastal waters of Malacca, Peninsular Malaysia

Table 1—Length-frequency data of *A. japonicus* from the coastal waters of Malacca, Malaysia.

ML	F	M	A	M	J	J	A	S	O
8.5								6	
9.5								32	
10.5						3	1	73	
11.5					3		2	144	4
12.5		1	8		15	7	12	223	9
13.5	13	9	21	1	16	32	31	216	20
14.5	52	23	27	11	23	21	87	244	20
15.5	96	28	37	11	23	25	102	157	18
16.5	99	16	41	6	23	21	76	48	16
17.5	78	8	30		20	18	38	12	10
18.5	38	8	47		15	13	37	7	10
19.5	38	13	48	3	8	12	68	4	11
20.5	31	16	48	6	4	16	47	7	6
21.5	33	15	63	5		12	24	9	6
22.5	50	17	55	3	13	2	5	18	8
23.5	34	13	19	2	2		1	16	6
24.5	22	3	7		1			9	1
25.5	5	2						2	
26.5	1							2	
27.5	2								
	592	172	451	48	166	182	531	1229	145

Bhattacharya's method, implemented from the package FiSAT[26], was used to identify the modes in the polymodal length-frequency distributions of *A. japonicus.* All the identified size/age groups were derived from at least three consecutive points and selection of the best results was based on the following criteria: (a) the values of separation index (SI) for the different age groups; (b) the number of the identified age groups and (c) the standard deviation (SD)[27].

To establish the length-weight relationship, the commonly used relationship W=a L^b was applied[28&29], where W is the weight (mg), L is the total length (mm), a is intercept (condition factor) and b is the slope (growth coefficient, i.e., shrimp relative growth rate). The parameters ‘a’ and ‘b’ were estimated by least squares linear regression on log-log transformed data: Log_{10} W = Log_{10} a + b Log_{10} L. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regression[30]. Additionally, 95% confidence limits of the parameters a and b and the statistical significance level of r^2 were estimated.

Monthly length-frequency distributions of *A. japonicus* were analyzed using the FiSAT computer Programme[26]. The parameters of the von Bertalanffy growth function (VBGF), asymptotic length (L_∞) and growth co-efficient (K) were estimated using ELEF AN- I routing[31] incorporated into the FiSAT software. K scan routine was conducted to assess a reliable estimate of the K value. The estimated L_∞ and K were used to calculate the growth performance index (φ′) 32 of *A. japonicas* using the equation:

$$\varphi' = 2\log_{10} L_\infty + 10g_{10}K$$

Potential longevity (t_{max}) of the species was calculated from the Pauly's formula[33]: t_{max} = 3/K. The inverse von Bertalanffy growth equation[34] was used to find the lengths of the *A. japonicus* at various ages. Then VBGF was fitted to estimate the length-at-age curve using non-linear squares estimation procedures[35]. The VBGF is defined by the equation:

$$L_t = L_\infty[1 - e^{-k(t-t_0)}]$$

where L_t = mean length at age t; L_∞ = asymptotic length; K = growth co-efficient; t = age of the *A. japonicus* and t_0 = the hypothetical age at which the length is zero[36].

Total mortality coefficient (Z) was estimated by using the length converted catch curve[33] and the method of Jones and van Zaling[37]. Natural mortality rate (M) was estimated using empirical relationship of Pauly[38]:

$$\text{Log}_{10}M = -0.0066 - 0.279\text{Log}_{10}L_\infty + 0.6543\text{Log}_{10}K + 0.4634\text{Log}_{1O}\,T$$

where M is the natural mortality, L_∞ the asymptotic length, K the growth co-efficient of the VBGF and T the mean annual habitat water temperature °C. Once Z and M were obtained, fishing mortality (F) was estimated using the relationship:

$$F=Z-M$$

where Z is the total mortality, F fishing mortality and M, the natural mortality. The exploitation level (E) was obtained by the relationship of Gulland's[39]:

$$E = F/Z = F/\,(F+M)$$

The ascending left arm of the length-converted catch curve was used to analyze the probability of capture of each length class according to the method of Pauly[40]. By plotting the cumulative probability of capture against mid-length, we obtain a resultant curve from which the length at first capture Lc was taken as corresponding to the cumulative probability at 50%.

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length frequency data as described in FiSA T. This routine reconstructs the recruitment pulse from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse. Input parameters were L_∞, K and t_0 (t_0=0). Normal distribution of the recruitment pattern was determined by NORMSEP[41].

The estimated length structured virtual population analysis (VPA) and cohort analysis was carried out from the FiSAT routine. The values of L_∞, K, M, F, a (constant) and b (exponent) were used as inputs to a VPA analysis. The t_0 value was taken as zero. The method was published by fry[42] and subsequently modified by many authors. Practical reviews of VPA methods were, among others given by pault[33] and Jones[43].

The relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) were estimated by using the model of Beverton and Ho1t[44] as modified by Pauly and Soriano[45] and incorporated in FiSA T software package. The input requirements in the procedure were the values of L_c/L_∞ = 0.31 and M/K = 1.68. From the analysis, the maximum allowable limit of exploitation (E_{max}) giving maximum relative yield-per-recruit was estimated. Also $E_{0.1}$, the exploitation rate at which the marginal increase in relative yield-per-recruit is 10% of its value at E = 0 and $E_{0.5}$, the exploitation rate corresponding to 50% of the unexploited relative biomass-per-recruit (B/R), were estimated.

Results

Population structure

A total number of individuals collected for this study was 1083 (30.80%) for male and 2433 (69.20%) for female, respectively. According to the annual size-frequency distribution, there was significant difference between the males and females (Kolmogorov-Smimov test: dmax = 0.39, P < 0.001) (Fig. 2). The mean total lengths were 14.83 (± 2.03) mm and 17.58 (± 3.77) for male and female, respectively. In the males, the minimum and maximum total lengths were 8 mm and 20 mm, and in the females, they were 9.50 mm and 29 mm, respectively (Table 2). The mean total length of the female was 2.75 mm longer than that of the male, and it was significantly different (t-test, p < 0.001). Monthly size frequency distributions (Fig. 3) identified the modal lengths with cohorts in different months. The length frequency distribution of different months suggested that the population consisted of maximum two age groups, with means of 15.18 (± 0.90) mm and 21.56 (± 1.03) mm of total length.

Length-weight relationship

The parameters of total length-body weight relationships for different groups (males, females and combined sexes) are presented in Table 2. The regression between TL (total length) and TW (total weight) for the males and females showed positive relationship, respectively (Fig. 4). The length-weight relationship equations were established as:

Log TW = 2.3215 Log TL -1.534, r^2 = 0.82 for male *A. japonicus*
Low TW = 3.186 Log TL -2.547, r^2 = 0.94 for female *A. japonicus*
Low TW = 3.063 Log TL - 2.396, r^2 = 0.93 for combined sexes of *A. japonicus*

Growth parameters

The observed and the predicted extreme length (L_{max}) were found to be 27.50 mm and 27.45 mm, respectively (Fig. 5). The range at 95% confidence interval for extreme length was calculated as 26.01-28.90 mm. This initial extreme length value was used into ELEFAN-I, incorporated in FiSAT package[26] producing the optimum growth curve. The best value of VBGF growth constant (K) was estimated as 1.4 yr^{-1} by ELEFAN-I. The response surface (Rn) was calculated as 0.168 which selected the best combination of growth parameters are:

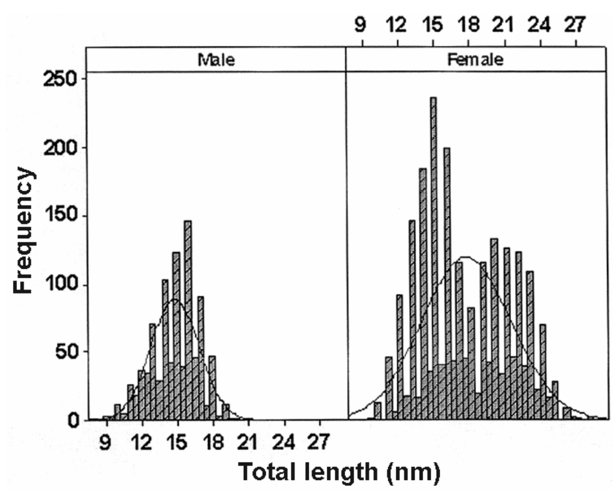

Fig. 2—Annual length-frequency distribution of males and females of *A. japonicus* collected from the coastal waters of Malacca, Peninsular Malaysia

Table 2—Length-weight parameters of *A. japonicus* from the coastal water of Malacca, Malaysia

Sex	N	TL range	TW range	a	b (SE)	95% CI of b	r^2
M	1083	8-20	4.20-33.80	0.0293	2.3215 (0.04)	2.250-2.393	0.82 (p < 0.05)
F	2433	9.50-29	4.10-102.70	0.0028	3.186 (0.016)	3.155-3.218	0.94 (p < 0.05)
B	3516	8-29	4.10-102.70	0.004	3.063 (0.015)	3.034-3.092	0.93 (p < 0.05)

N, sample size; TL range, minimum and maximum total length (mm); TW range, minimum and maximum total weight (mg); a and b, parameters of the length-weight relationship; SE, standard error of the slope b; r^2, coefficient of determination

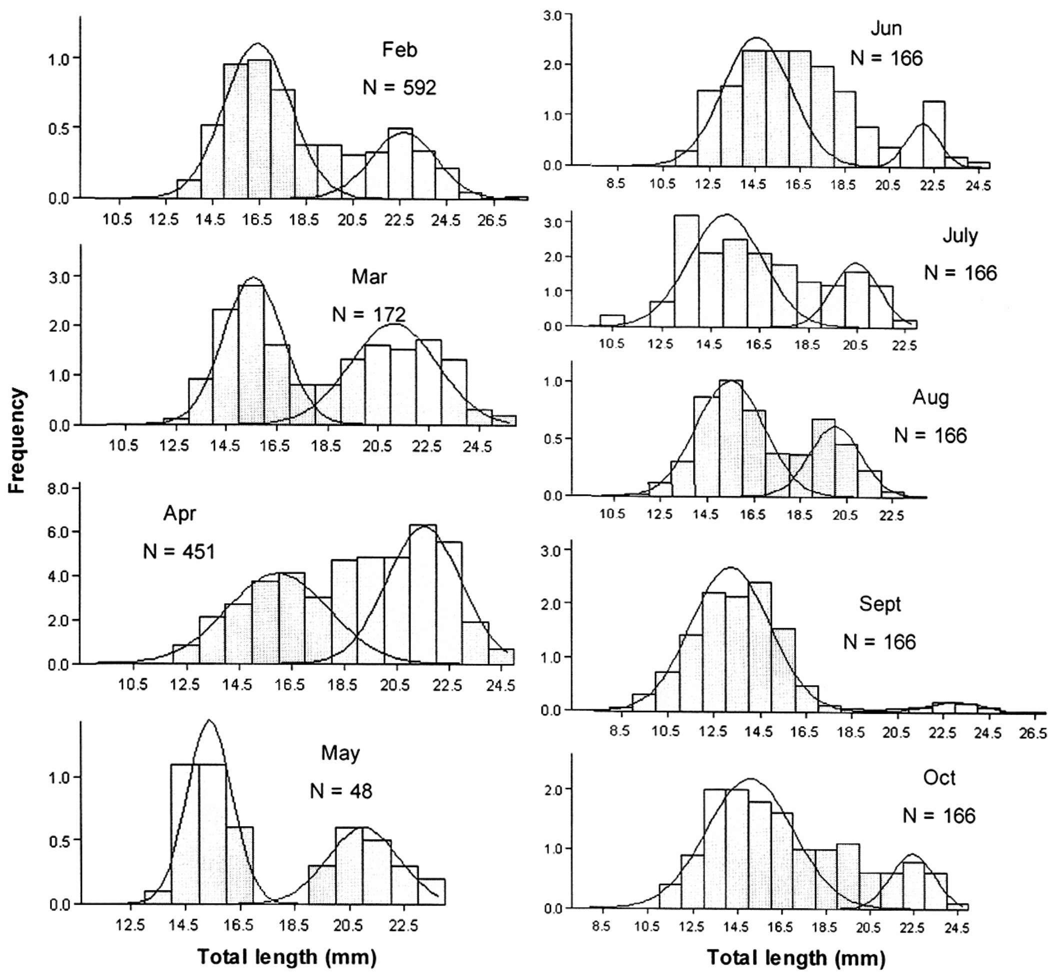

Fig. 3—Monthly length frequency distributions of the *A. japonicus* caught in the coastal waters of Malacca, Peninsular Malaysia

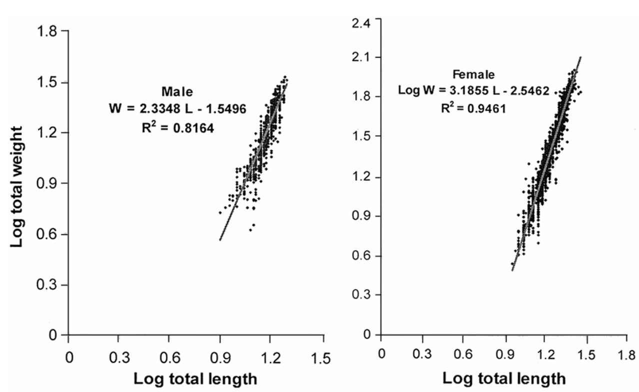

Fig. 4—Length weight relationship for *A. japonicus* in the coastal water of Malacca, Peninsular Malaysia

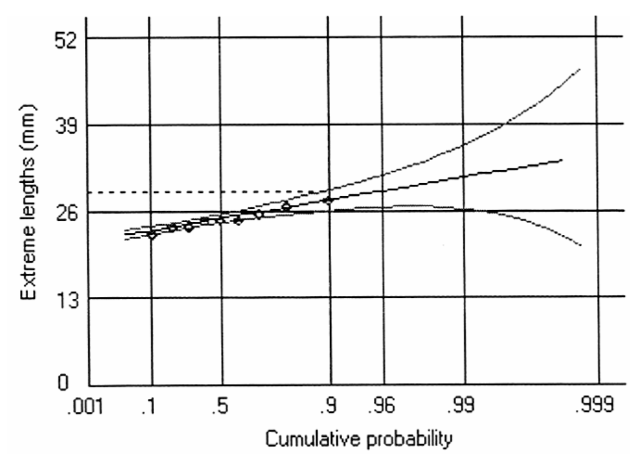

Fig. 5—Predicted maximum length of *A. japonicus* based on extreme value theory[46]. The predicted maximum length value and the 95% confidence interval is obtained from the intersection of overall maximum length with the line b and a, c respectively.

L_∞ = 29.08 mm and K = 1.40 yr^{-1}. The optimized growth curve was superimposed on the restructured length-frequency histograms (Fig. 6). The calculated value for the growth performance index (φ') of

A. japonicus during the present investigation was 3.073. This value was close to the φ'-values recorded in the literature[15&16] but slightly higher than the value recorded by Oh and Jeong[18].

Age and growth

The application of Bhattacharya's method through FiSAT determined model lengths of *A. japonicus* ranging from 17 mm (in 13.22 September) to 22.97 mm (in September), with satisfactory separation index (Table 3). The two dominant modal groups of *A. japonicus* were identified reflecting different annual cohorts. Therefore, the monthly size frequency distributions suggested that the population consisted of only two age groups, with modes at approximately 15 mm and ≥ 22 mm total length. Using the estimated value of the growth coefficient (K= 1.4 yr^{-1}), the longevity (t_{max} = 3/K) was calculated as 2.14 years approximately. It is assumed as in the ELEFAN-I analysis that the value of the third parameter of the von Bertalanffy growth function t_0 be zero[31]. Therefore, the sizes attained by *A. japonicus* were 6.16 mm, 10.76 mm, 14.64 mm, 17.70 mm, 19.98 mm and 21.91 mm at the end of 2, 4, 6, 8, 10 and 12 months of age, respectively. The absolute increase is presented in Fig. 7. Table 4 shows the length and age relationships of the estimated Bertalanffy's model

Table 3—Identified age groups from the length-frequency analysis of *A. japonicus* during the monthly sampling, using Bhattacharya's method

Months	Age groups	Mean TL (mm)	SD (mm)	SI
February	1	16.42	1.41	-
	2	22.65	1.39	2.38
March	1	15.27	1.05	-
	2	21.01	1.77	2.36
April	1	15.98	1.92	-
	2	21.54	1.43	2.25
May	1	15.40	0.82	-
	2	21.00	1.29	2.40
June	1	14.62	1.49	-
	2	22.00	0.73	2.64
July	1	15.11	1.49	-
	2	20.45	0.97	2.35
August	1	15.51	1.43	-
	2	20.0	1.12	2.23
September	1	13.22	1.70	-
	2	22.97	1.19	2.29
October	1	15.08	1.94	-
	2	22.44	0.98	2.52

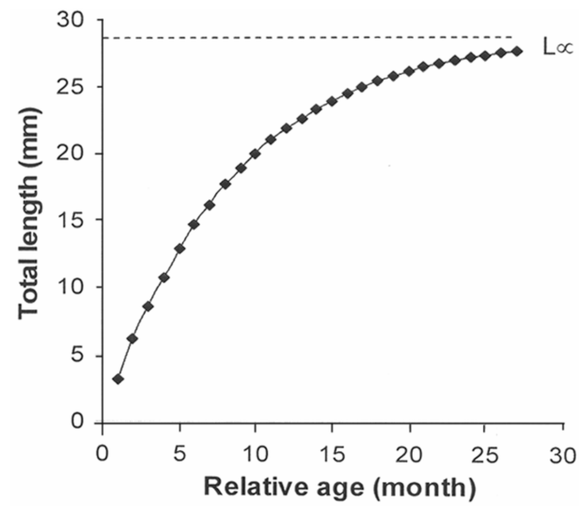

Fig. 7—Plot of age and growth of *A. japonicus* based on computed growth parameters (L_∞ = 29.08 mm and K = 1.4 yr^{-1})

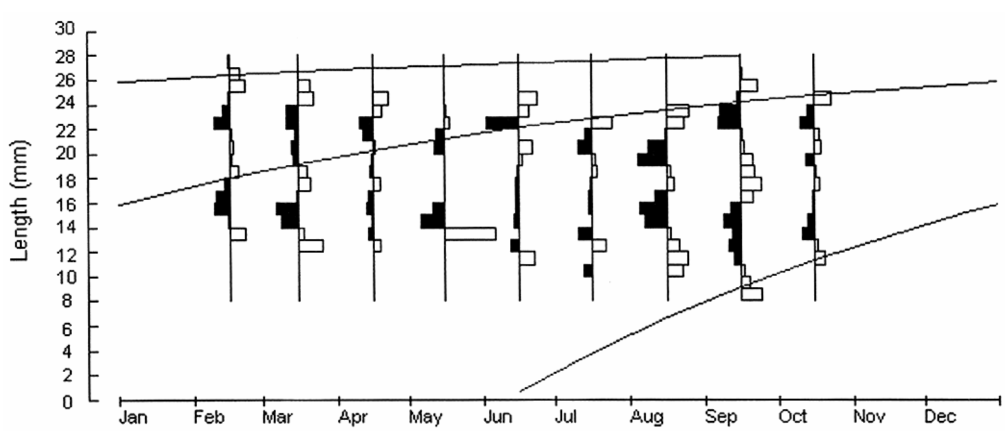

Fig. 6—von Bertalanffy growth curves (L_∞ = 29.08 mm and K = 1.40 yr^{-1}) for *A. japonicus* superimposed on the restructured length-frequency histograms. The black and white bars are positive and negative deviation from the "weighted" moving average of three length classes and they represent psedo-cohorts.

Table 4—Length-at-age key for *A. japonicus* from coastal waters of Malacca, estimated using the VBGF parameters (L_∞ = 29.08 and K = 1.40 yr^{-1})

Relative age (month)	Total length (mm) 3.08	Growth rate (dL/dT)
1	3.08	-
2	6.16	3.08
3	8.59	2.43
4	10.76	2.17
5	12.93	2.17
6	14.64	1.71
7	16.17	1.53
8	17.70	1.53
9	18.90	1.20
10	19.98	1.08
11	21.06	1.08
12	21.91	0.85
13	22.67	0.76
14	23.43	0.76
15	24.03	0.60
16	24.56	0.53
17	25.09	0.53
18	25.52	0.43
19	25.90	0.38
20	26.27	0.37
21	26.57	0.30
22	26.84	0.27
23	27.10	0.26
24	27.31	0.21
25	27.50	0.19
26	27.69	0.19
27	27.83	0.14

Table 5—Population parameters of *A. japonicus* from the coastal water of Malacca, Malaysia

Population parameters	*A. japonicus*
Asymptotic length (L_∞) in mm	29.08
Asymptotic weight (W_∞) in mg	187.72
Growth co-efficient (K yr^{-1})	1.40
Growth performance index (φ')	3.073
Natural mortality (M yr^{-1})	2.35
Fishing mortality (F y^{-1})	2.81
Total mortality (Z yr^{-1})	5.16
Exploitation level (E)	0.54
Allowable limit of exploitation (E_{max})	0.52
Sample number (N)	3516

using growth parameters L_∞ = 29.08 mm, K = 1.04 yr^{-1} and t_0 = 0. The total lengths correspond to the relative age since the value of t_0 =0. Therefore the actual age, could not be calculated based on length data only.

Mortality and exploitation rate

Total mortality coefficient (Z) was estimated as 5.16 yr^{-1} using length converted catch curve (Fig. 8a)

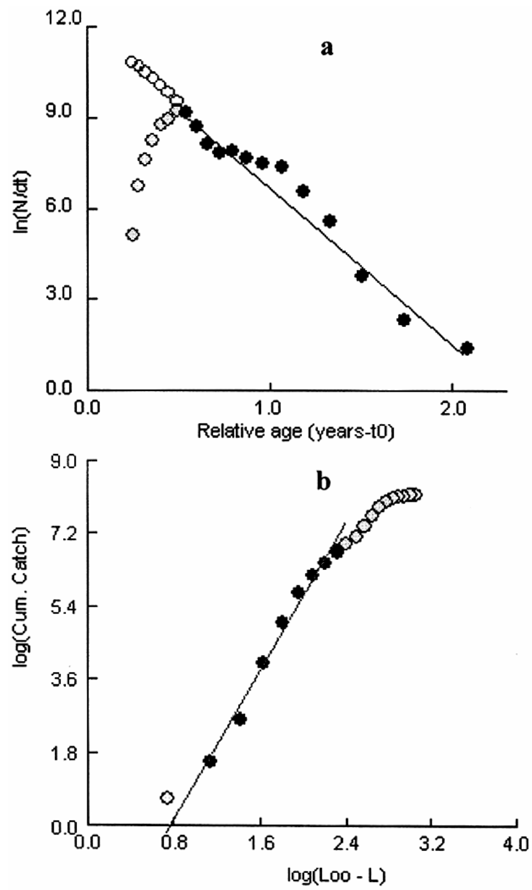

Fig. 8(a & b)—Length converted catch curve (a), the darkened full dots represent the points used in calculating through least square linear regression and the open dots represent the point either not fully recruited or nearing to L_∞ ; Jones and van Zalinge plot (b) for the estimation of total mortality (Z) of *A. japonicus.*

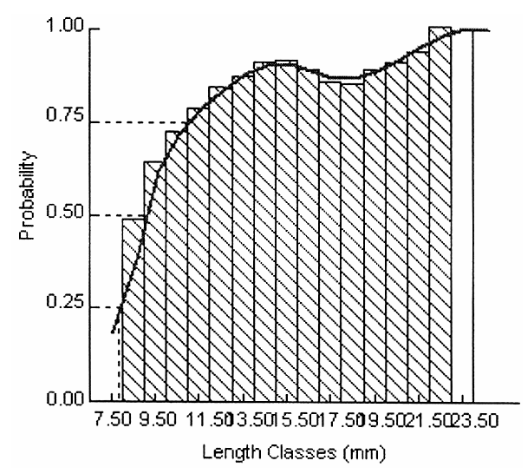

Fig. 9—Probability of capture of each length class of the *A. japonicus* (L_{25}% = 7.88 mm, L_{50}% or Lc = 9.01 mm and $L_{75\%}$= 10.98 mm)

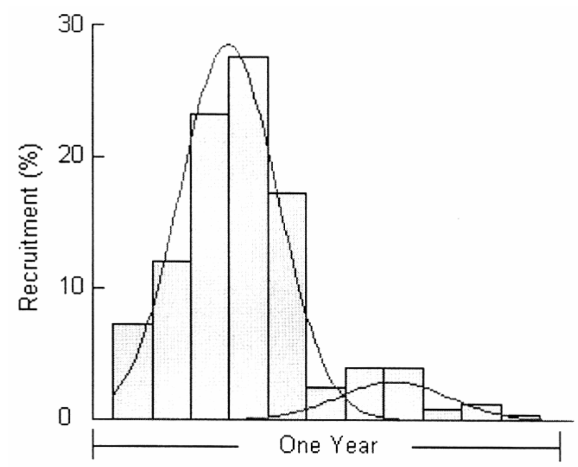

Fig. 10—Recruitment pattern of *A. japonicus* in the coastal waters of Malacca, indicating one major peak pulse per year

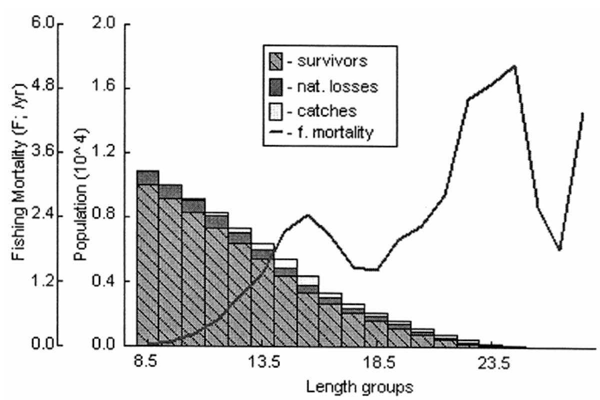

Fig. 11—Length based virtual population analysis of *A. japonicus* in the coastal water of Malacca, Peninsular Malaysia

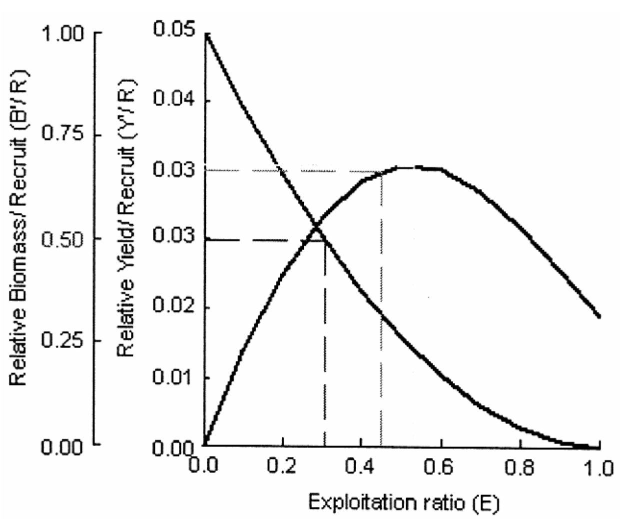

Fig. 12—Relative Y/R and Y/R of *A. japonicus* using knife-edge procedure in the coastal water of Malacca, Peninsular Malaysia

while the Jones and van Zalinge method (Fig. 8b) gave a value of Z = 4.99 yr^{-1}. Natural mortality (M) was estimated at 2.35 yr^{-1}. Based on Z from length converted catch curve, fishing mortality (F) was found to be 2.81 yr^{-1} (Table 5). From these figures, an exploitation rate (E) of 0.54 was obtained for the *A. japonicus* fishery in the coastal waters of Malacca, Peninsular Malaysia which seemed to be above the optimum level of exploitation (E = 0.50).

Length at first capture

The length at first capture (the length at which 50% of the shrimp becomes vulnerable to the gear) was calculated as a component of the length converted catch curve analysis (Fig. 9). The value obtained was $L_{50}\%$ = 9.01 mm from the analysis of probability of capture. The length at which 75% of the shrimps are retained in the gear was estimated as $L_{75}\%$ = 10.98 mm.

Recruitment Pattern

The recruitment pattern of *A. japonicus* was continuous throughout the year with one major peak (Fig. 10). The percent recruitment varied from 0.37 to 27.47 % during the study period. The highest recruitment peak occurred between April and June. The highest (27.47%) and lowest (0.37%) percent recruitment was observed in the months of May and November (Fig. 10).

Virtual population analysis

Virtual population analysis (VPA) performed on *A. japonicus* indicated that (Fig. 11) the minimum and maximum fishing moralities were recorded as 0.02 yr^{-1} and 4.67 y^{-1} for the mid lengths of 8.5 mm and 22.5 mm, respectively. The fishing mortality (F) was comparatively high over the mid lengths from 13 to 16 mm and 19-22 mm.

Relative yield per recruit and biomass per recruit

The relative Y/R and B/R analysis of *A. japonicus* were computed using knife-edge procedure. The maximum allowable limit of exploitation level (**E_{max}**) that gives the maximum relative yield-per-recruit was estimated at 0.52 (Fig. 12). $E_{0\cdot1}$, the level of exploitation at which the marginal increase in relative yield per recruit is 10% of the marginal increase computed at a very low value at E, was 0.45. The exploitation level ($E_{0\cdot5}$) which corresponds to 50% of the relative biomass per recruit of the unexploited stock was 0.30. The response of the yield per recruit of the *A. japonicus* in the coastal waters of Malacca was demonstrated using yield isopleths (Fig. 13) to both variation in L_{50}% and fishing pressure as indicated by the exploitation rate E over a wide range of both the parameters.

Discussion

The size structure of the population in the investigated area consists of a relatively higher percentage of the females than the males. The females attained a greater size indicating a size dimorphism.

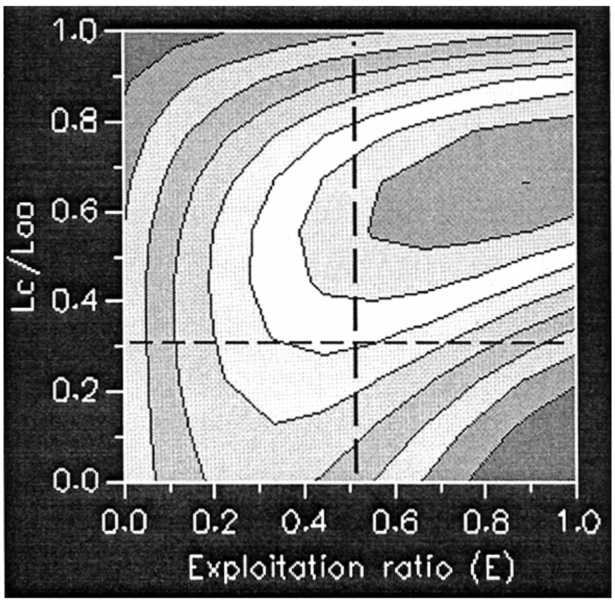

Fig. 13—Yield isopleths for the *A. japonicus* in the coastal waters of Malacca, Peninsular Malaysia.

The growth coefficient 'b' of length-weight relationship generally lies between 2.5 and 3.5 and the relation is said to be isometric when it is equal to 3 reported for most aquatic organisms[47,48]. Table 6 summarizes previously published values of the coefficients a and b for the genus *Acetes.* The values of b show considerable variation, ranging from 2.155[49] to 3.108[15]. In the present case, the estimated b is 3.063 for both sexes and it lies between the values mentioned by Carlander[47] and Le Cren[48], which is not significantly higher than isometric value (3) at 5% level. This indicates that the isometric nature of growth in combined sexes of *A. japonicus.* In the case of the males, the estimated b is 2.3215 and it is significantly lower from then the isometric value (3) at 5% level. The relationship between total length against total weight suggested that as total length increases weight is heavier in the females than in the males. Regression analysis on the log-transformed data showed a strong relationship of both sexes (r^2 = 0.82 for males and r^2 = 0.94 for females) and was significant ($p< 0.05$).

The estimated L_∞ and K value is 29.08 mm and 1.40 yr^{-1} for the present study of *A. japonicus.* Comparisons with population parameters obtained in other studies (Table 7) show that differences exist for different species of the genus *Acetes* from different areas in the world. The highest value of L_∞ (40.0 mm) is for *A. chinensis*[16] and the lowest value (31.0 mm) for *A. indicus* is in Bangladesh[15]. The highest (1.70 yr^{-1}) value of K is observed in Bangladesh[15] for *A. indicus* and lowest value of K (0.69 yr^{-1}) is

Table 6—Parameters of length-weight relationship (a and b) for the genus *Acetes* from various locations

Location	Species	a	b	r^2 -	Growth type	Source
Bangladesh	*A. indicus*	0.0047	3.108	0.98	Isometric	Zafar *et al.*[15]
Bangladesh	*A. chinensis*	0.0107	2.908	0.98	Negative allometric	Zafar *et al.*[16]
Bangladesh	*A. erythraeus*	0.0051	3.106	0.99	Isometric	Zafar *et al.*[57]
China	*A. joponicus*	0.1302	2.155	-	Negative allometric	Lei[49]
Japan	*A. japonicus*	0.1566	2.231	0.96	Negative allometric	Uye[58]
Japan	*A. sibogae*	0.0085	2.985	0.98	Isometric	Ikeda and Raymont[59]

Table 7—Growth parameters (L_∞ and K) and computed growth performance index (φ′) of the genus *Acetes* from different tropical countries

Location	Species	L_∞ (mm)	Kyr^{-1}	φ′	Z	E	T (°C)	Source
Malaysia	*A. japonicus*	29.08 TL	1.40	3.073	5.16	0.54	31°C	Present study
Bangladesh	*A. indicus*	31.00 TL	1.70	3.22	6.07	0.22	28°C	Zafar *et al.*[15]
Bangladesh	*A. erythraeus*	37.00 TL	1.20	3.21	4.72	0.24	28°C	Zafar *et al.*[17]
Bangladesh	*A. chinensis*	40.00 TL	1.60	3.40	5.39	0.21	28°C	Zafar *et al.*[16]
Korea	*A. chinensis* (F)	13.51 CL	0.69	2.10	3.93*	-	-	Oh and Jeong[18]
Korea	*A. chinensis* (M)	10.48 CL	0.84	1.97		-	-	Oh and Jeong[18]

observed in Korean waters[18] for *A. chinensis*. The index of phi prime[50] is suitable for comparing and computing the overall growth performance of different species of shrimp stocks. The phi prime for this species with the present estimates of L_∞ and K is 3.073. Though phi prime value is supported to be more or less constant for a family or for similar taxa, the range here (Table 7) is low except for the report of Oh and Jeong[18].

Generally, shrimps are not long lived crustaceans[22&51]. The estimated longevity (t_{max}) for *A. japonicus* is almost 2.14 years of age, indicating that it is short-lived. The overall average growth rate of *A. japonicus* appears to be a relatively moderate growing species compared to *Acetes indicus*[15]. Similar studies[52,53,54&55] have been reported through length converted age method which also been followed in this study.

Higher fishing mortality (2.81 yr^{-1}) verses the natural mortality (2.35 yr^{-1}) observed for *A. japonicus* in the present study (Table 5) indicates the unbalance position in the stock. Total mortality (Z) estimated by length converted catch curve for *A. japonicus* (5.16 yr^{-1}) in the coastal waters of Malacca is close to the value (5.39 yr^{-1}) obtained by Zafar *et al.*[16] in the coastal waters of Bangladesh (Table 7). Exploitation level (E) was computed as 0.54 indicates the fishery of *A. japonicus* in the coastal waters of Malacca is over exploited. This is based on the assumption that a stock is optimally exploited when fishing mortality (F) equals natural mortality (M), or E = (F/Z) = 0.5[39].

This study elucidate that the recruitment pattern of *A. japonicus* is continuous with one main recruitment event per year (Fig. 10). Two recruitment peaks per year for the *A. chinensis* are reported in the other locations[16&18]. There is no published report on recruitment of *A. japonicus* in Malaysia. However, it has been reported that the *Acetes* spawns throughout the year in the tropics and subtropics, spawning peaks can be recognized and these almost always lie in the warmer months[56]. Spawning patterns in these areas (tropical and subtropical) are probably related to monsoonal influences on precipitation and wind direction[9]. In the present study, it is observed that the major spawning occurs during the months of June (Fig. 6) in the investigated area which follows the south-west monsoon.

The length at first capture is an important input in the computation of relative yield-per-recruit and relative biomass-per-recruit. The maximum allowable limit of exploitation rate (E_{max}) giving maximum relative yield-per-recruit (Y/R), was estimated as 0.52. This compares well with the exploitation rate (E) of 0.54 established for *A. japonicus* in the present study, and approximates to the 0.50 optimum level of exploitation reported by Gulland[39]. This is a further indication that the fishery is above the optimal exploitation. However, the present exploitation rate of the fishery (0.54) is also above the more conservative yield concept ($E_{0.1}$ = 0.45), where the marginal increase in relative yield-per- recruit is 10% of its value at E = O. This reveals that the fishery is probably being over exploited in terms of relative yield-per-recruit. Results from the analysis of the exploitation rate (E) based on the mortality estimates, and from the relative yield-per-recruit (Y/R), indicate that the fishery is above the level of optimum based on the $E_{0.1}$ principle. Thus, the fishing pressure on the stock is excessive. More yields could be obtained by a reasonable decrease in the effort (Fig. 13) without necessarily leading to over exploitation.

Acknowledgement

The authors would like to express sincere gratitude to the Third World Academy of Science (TWAS) for financial support of this study and to Mr. Ibrahim, fisherman and Mr. Perumal, scientific officer of Marine Science Laboratory, UPM for the assistance during field sampling.

References

1 Omori, M., The systematic, biogeography and fishery of epipelagic shrimp shrimps of the genus *Acetes* (Crustacea, Decapoda, Sergestidae). *Bull. Ocean Res. Inst.,* (1975) 1-91.

2 Pathansali, D., *Acetes* (Sergestidae) from the Malay Peninsula. *Bull. National Mus. Singapore,* 33 (8) (1966) 59-63.

3 Johnson, D.S., Prawns of the Malacca Straits and Singapore waters. *J. Mar. Biol. Assoc. India,* 18 (1976) 1-54.

4 Mistakidis, M.N. *The crustacean resources and related fisheries in the countries bordering the South Chine Sea,* (FAO) 1973, FAO South China Sea Fisheries development and Coordinating Programme No.7, 39 pp.

5 Tham, A.K., The food and feeding relationships of the fishes of Singapore straits. Colonical Office Fishery Publications, No.1. His Majesty's Stationery Office, 1950, 35 pp.

6 Holthuis, L.B., *FAO Species Catalogue. Shrimps and Prawns of the World, An noted Catalogue of Species of Interest to Fisheries,* (FAO) 1980, Fish. Symp. No. 125 (1), pp. 1-271.

7 Xiao, Y. & Greenwood, J.G., The biology of *Acetes* (Crustacea: Sergistidae), in: *Oceanography and Marine Biology Annual Reviews,* edited by Ansell, A.D., R.N. Gibson and M. Barnes, (UCL Press, London) 1993, pp. 259-444.

8 DOF, *Yearbook of Fishery Statistics,* (Department of Fisheries, Malaysia) 2004.

9 Omori, M., The biology of Pelagic shrimps in the ocean. *Advan. Mar. Biol.,* 12 (1974) 233324.

10 Omori, M., Zooplankton fisheries of the world: *A review. Mar. Biol.,* 48 (1978) 199-205.

11 Malley, D.F. & Ho, S.C., Prawns and others invertebrates. in: *Coastal resources of West Sabah: An Investigation into the Impact of Oil Spill,* edited by Chua, T.E. & J.A. Mathias, (University Sains Malaysia, Pulau, Penang) 1978, pp. 88-108.

12 Chullasom, S. & Martosubroto, P., *Distribution and important biological features of coastal fish resources in Southeast Asia,* (F AO Fish. Tech. Pap., No. 278) 1986, 1-84.

13 Kungvankij, P., Tacon, AG., Corre, K., Pudadera, B.P., Taleon, G., Borlongan, E. & Potestas, I.0., *Acetes* as prime food for *Penaeus mono don* larvae, paper presented at the conference on the *First Asian Fisheries Forum, Manilla, Philippes,* Asian Fisheries Society, Manilla, Philippines, 1986.

14 Ung, E.H. & Itoh, S., A comparison of nutritional characteristics between Antarctic euphausiid meal *(Euphausia superba)* and tropical sergestid meal *(Acetes* sp.), paper presented on Program of the *First International Marine Biotechnology Conference* Tokyo, Japan, 1989.

15 Zafar, M., Mustafa, M.G., Amin, S.M.N. & Akhter, S., Studies on population dynamics of *Acetes indicus* from Bangladesh coast. *The J National. Ocea. Mar. Inst.,* 14 (1&2) (1997) 1-15.

16 Zafar, M., Mustafa, M.G. & Amin, S.M.N., Population dynamics of *Acetes chinensis* in the Kutubdia channel of Bangladesh coastal waters, *Ind J Fish.,* 45(2) (1998a) 121-127.

17 Zafar, M., & Amin, S.M.N., Population dynamics of *Acetes erythraeus* in the Kutubdia channel of Bangladesh coastal water, *Ind J Fish.,* 49 (2) (2002) 141-146.

18 Oh, C-W. & Jeong, I-J., Reproduction and population dynamics of *Acetes chinensis* (Decapoda:Sergestidae) on the western coast of Korea, Yellow Sea. *J Crust. Biol.,* 23 (4) (2003) 827-835.

19 Jayawardane, P.A.A.T, McLusky, D.S. & Tytler, P., Estimation of population parameters and stock assessment of *Penaeus indicus* (H. Milne Edwards) in the western coastal waters of Sri Lanka. *Asian Fish. Sci.,* 15 (2002) 155-166.

20 Jayawardane, P.A.A.T, Mc Lusky, D.S. & Tytler, P. Population dynamics of *Metapenaeus dobsoni* from the western coastal waters of Sri Lanka. *Fish. Manag. Eco,* 10 (2003) 179-189.

21 Paraconstantinou, C. & Kapiris, K., Distribution and population structure of the red shrimp *(Aristeus antennatus)* on an unexploited fishing ground in the Greek Ionian Sea. *Aquat. Living Resour,* 14 (2001) 303-312.

22 Etim, L. & Sankare, Y., Growth and mortality, recruitment and yield of the fresh-water shrimp, *Macrobrachium vollenhovenii,* Herklots 1851 (Crustacea, Palaemonidae) in the Fahe reservoir, Cote d'Ivoire, West Africa. *Fish. Res.,* 38 (1998) 211-223.

23 Enin, U.I., Lowenberg, U. & Kunzel, T., Population dynamics of the estuarine prawn *(Nematopalaemon hastatus* Aurivillius 1898) off the southeast coast of Nigeria. *Fish. Res.,* 38 (1996) 17-35.

24 Sokal, R.R. & Rohlf, F.J., *Introduction to biostatistics, 2nd Edition,* (Freeman Publication, New York) 1995.

25 Zar, J.H., *Bio statistical Analysis, 3rd Editionn,* (Prentice-Hall, Englewood Cliffs, New Jersey) 1996.

26 Gayanilo, F.C. Jr., Sparre, P. & Pauly, D., *The FAO-ICLARM Stock Assessment Tools (FiSAT) Users Guide,* (FAO Computerized Information Series, Fisheries, No. 8, FAO, Rome) 1996, pp. 126.

27 Gayanilo, Jr. F.C., Soriano Jr, M. & Pauly, D., *A draft guide to the Complete ELEFAN,* (ICLARM) 1989, Software 2, pp. 70.

28 Ricker, W.E., Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board, Canada,* 191 (1975) 382.

29 Quinn II, T., Deriso, R.B., *Quantitative Fish Dynamics,* (Oxford University Press, New York) 1999.

30 Scherrer, B., *Biostatistique,* (Morin, Montreal, Paris) 1984.

31 Pauly, D. & David, N., ELEFAN-I BASIC program for the objective extraction of growth parameters from Length frequency data. *Meeresforsch,* 28(4) (1981) 205-211.

32 Pauly D. & Munro, J.L., Once more on the comparison of growth in fish and invertebrate. ICLARM, *Fishbyte,* 2 (1) (1984) 21.

33 Pauly, D., *Fish population dynamics in tropical waters: a manual for use with programmable calculators,* (ICLARM) 1984, ICLARM Contrib. 143, pp. 325.

34 Sparre, P., & Venema, S.C., *Introduction to Tropical Fish Stock Assessment, part 1-Manual* (FAO), 1992, FAO Fish. Tech. Pap. 306/1, pp. 37.

35 Pauly, D., Soriano-Bartz, M., Moreau, J. & Jarre, A., A new model accounting for seasonal cessation of growth in fishes. *Aust.* J *Mar. Fresh. Res.,* 43 (1992) 1151-1156.

36 Dulcic, J. & Kraljevic, M., Age, growth and mortality of damselfish *(Chromis chromis* L.) in the eastern middle Adriatic. *Fish. Res.,* 22 (1995) 255-264.

37 Jones, R. & van Zalinge, N.P., Estimations of mortality rate and population size for shrimp in Kuwait waters. *Kawait Bull. Mar. Sci.,* 2 (1981) 273-288.

38 Pauly, D., On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J Cons. CIEM,* 39(3) (1980) 175-192.

39 Gulland, J.A., *The fish resources of the Ocean. Fishing News (Books),* (Farnham) 1971, pp.255.

40 Pauly, D., A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. *ICLARM Conf. Proc.,* 13 (1987) 7-34.

41 Pauly, D. & Caddy, J.F. *A modification of Bhattacharya's method for the analysis of mixtures of normal distributions,* (FAO, Rome) 1985, FAO Fisheries Circular 781, pp. 16.

42 Fry, F.E.J, Statistics of a lake trout fishery. *Biom,* 5 (1949) 27-67.

43 Jones, R., *Assessing the effects of changes in exploitation pattern using length composition data (with notes on VPA and cohort analysis),* FAO Fish. Tee. Pap. , (256), *(FAD)* 1984, p. 118.

44 Beverton, R.J.H and Holt S.J, *Manual of methods for fish stock assessment: Part Il Tables of yield function,* (FAO Fish. Biol. Tech. Pap. 38 (4), Version 1) 1966, pp. 67.

45 Pauly, D. & Soriano, M.L., Some practical extensions to Beverton and Holt's relative yield-per-recruit model, presented on *The First Asian Fisheries Forum,* Asian Fisheries Society, Manila, Philippines, 1986.

46 Formacion, S.P., Rongo, J.M. & Sambilay, V.C., Extreme value theory applied to the statistical distribution of the largest lengths offish. *Asian Fish. Sci.,* 4 (1991) 123-135.

47 Carlander K., *Handbook of Freshwater Fishery Biology, Vol.1,* (Iowa State University Press, Ames, IA) 1977.

48 Le Cren, E.D., The length-weight relationship and seasonal cycle in gonadal weight and condition in the perch *(Perca fluviatilis). J Ani. Eco.,* 20 (1951) 271-279.

49 Lei, M, Studies in the biology of *Acetes japonicus* Kishinouye in the eastern coastal waters of Guangdong Province, China, in: *Selected Oceanic Works in. China,* (Ocean Press, Bejing) 1988, pp. 234-243.

50 Munro, J.L. & Pauly, D.A, simple method for comparing the growth of fishes and invertebrates. *ICLARM Fishbyte,* 1 (1) (1983) 5-6.

51 Dineshbabu, A.P., Manissery, J.K., Morphometric relationships and growth of the 'ridge back shrimp *'Solenocera choprai* (Decapoda/Crustacea) from Mangalore (southwest coast of India). *Indian J Mar. Sci.,* 36 (2007) 65-70.

52 Al-Barwani, S.M., Arshad, A., Amin, S.M.N., Japar, S.B., Siraj. S.S. & Yap, C.K., Population dynamics of the green mussel *Perna viridis* from the high spat-fall coastal water of Malacca, Peninsular Malaysia, *Fish. Res.,* 84 (2007) 147-152.

53 Amin, S.M.N., Rahman, M.A, Haldar, G.C. & Mazid, M.A., Studies on age and growth and exploitation level of *Tenualosa ilisha* in the coastal region of Chittagong, Bangladesh. *J Inland Fish. Soc. India,* 33 (2001) 1-5.

54 Amin, S.M.N. & Zafar, M., Studies on age, growth and virtual population analysis of *Coilia dussumieri* from the neritic water of Bangladesh. *J Biol. Sci.,* 4 (2004) 342-344.

55 Blaber, S.J.M., Staunton-Smith, J., Milton, D.A., Fry, G., Velde, T.V., Pang, J., Wong, P., & Boon-Teck, O., The Biology and Life-history Strategies of *Ilisha* (Teleostei: Pristigasteridae) in the Coastal Waters and Estuaries of Sarawak. *Estuar. Coast. Shelf Sci.,* 47 (1998) 499-511.

56 Nataraj, S., On some species of *Acetes* (Crustacea, Sergistidae) from Travancore. *Records of the Indian Museum,* 45 (1947) 139-147.