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Age Structure, Growth, Mortality and Yield-Per-Recruit of Sergestid Shrimp, *Acetes indicus* (Decapoda: Sergestidae) From the Coastal Waters of Malacca, Peninsular Malaysia

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Abstract: Age structure, growth, mortality and yield-per-recruit of *Acetes indicus* were examined in the coastal waters of Malacca, Peninsular Malaysia between February 2005 and January 2006. Monthly length frequency data were analyzed using FiSAT software for estimating population parameters, including asymptotic length (L_∞), growth co-efficient (K) and exploitation rate (E) to assess the status of the stock. The L_∞ and K for males were estimated at 29.40 mm and 1.70 year^{-1} and for the females that were 42 mm and 1.20 years^{-1}, respectively. The growth performance index (φ') was calculated as 3.16 and 3.33 for males and females. The growth pattern of males and females showed positive allometric nature of growth (b>3, p<0.05). The maximum life span (t_{max}) of males and females was 1.76 and 2.50 years, respectively. Total mortality (Z) by length converted catch curve was estimated at 4.15 year^{-1} for males and 3.50 year^{-1} for females. The rate of natural mortality (M) for males and females was calculated as 2.65 and 1.91 year^{-1} and the fishing mortality (F) was 1.50 and 1.59 year^{-1} for males and females, respectively. The recruitment pattern of *A. indicus* was continuous throughout the year with two major peaks. The exploitation rate (E) of males was 0.36 and that of females was 0.45. The maximum allowable limit of exploitation (E_{max}) of males and females was 0.71 and 0.57 for the highest yield. The exploitation rates were less than the predicted E_{max} values of males and females. Thus, the stock of *A. indicus* was found to be under exploited in the investigated area.

Key words: Age structure, growth, mortality, *Acetes indicus*

INTRODUCTION

The shrimp of the genus *Acetes*, is mainly used in subsistence fisheries and therefore, commercially important in the Peninsular Malaysia (Amin *et al.*, 2008). Knowledge on the shrimp's population characteristics are important if proper management of those resources is to be effective. Age in crustacean is difficult to estimate because exoskeletons are lost during moulting process (Xiao and Greenwood, 1993). Thus, analysis of length-frequency data has been used to identify year classes (Amin and Zafar, 2003, 2004; Amin *et al.*, 2008; Paraconstantinou and Kapiris, 2001). Length-weight relationships are useful for a wide number of studies, such as estimating population structure (Smith *et al.*, 2008), growth rates and other aspects of fish/shrimps population dynamics (Tsoumani *et al.*, 2006).

The geographical distribution of *Acetes* has been described by Xiao and Greenwood (1993). This species

A. indicus occurs in the central part of the Indo-West Pacific. The distribution ranges from the South China Sea (Dong Hoa) through the Gulf of Siam (Sanudpragarn), Java (Surabaya), Straits of Malacca (Singapore and Malacca) and the Bay of Bengal to the Arabian Sea. The shrimp plays a substantial role in the food webs of coastal waters, acting as predators, feeding on a variety of foods ranging from diatoms, copepods and larvae of decapods to detritus and in turn as prey for many fishes and other predators (Xiao and Greenwood, 1993). It appears in very large swarms in the shallow inshore coastal waters, which is brackish with a salinity of 30 ppt or less, during certain seasons of the year. In West coast of Malay Peninsula, *A. indicus*, along with *A. japonicus*, is commercially exploited from March to November, using the estuarine push net (Arshad *et al.*, 2007).

Spectacular school or swarms of *Acetes*, particularly in coastal waters of Asia, are the bases of important commercial fishes for consumption by humans and

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domestic animals (Omori, 1975, 1978). The commercial importance also derives from the use and potential of *Acetes* as a food organism for aquaculture industry (Kungvankij *et al*., 1986). These combined features make *Acetes* excellent candidates for population dynamics studies. In spite of greater abundance and importance of *Acetes* in the fishery of Asian countries, very little information is available on the population dynamics so far except the studies carried out by Zafar *et al*. (1997, 1998), Zafar and Amin (2002) and Oh and Jeong (2003).

Knowledge of various population parameters like as asymptotic length ($L_∞$), growth coefficient (K), motilities (natural and fishing) rate and exploitation level (E) are necessary for planning and management of *Acetes* resources. There are many tools for assessing exploitation level and status of stock. Of these, FiSAT (FAO-ICLARM Stock Assessment Tools) has been most frequently used for estimating population parameters of shrimps (Jayawardane *et al*., 2002, 2003; Paraconstantinou and Kapiris, 2001; Etim and Sankare, 1998; Enin *et al*., 1996) primarily because it requires only length-frequency data. The objective of the present study was to estimate the population parameters and exploitation level of *A. indicus* in order to assess the stock status of the species around the coast waters of Malacca, Peninsular Malaysia and to provide data that could be useful for management.

MATERIALS AND METHODS

Collection of data: Monthly fresh samples of *A. indicus* 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, Peninsular Malaysia (Fig. 1). *Acetes* shrimps were caught by the push net (triangular shape) known locally as Sungkor, as described by Omori (1975) in the coastal waters of Klebang Besar, Malacca, Peninsular Malaysia. Dimensions of the net were 5-6 m in length, 4.0-4.5 m in wide and 3.0 -3.5 m in height. The mean mesh sizes were 3.2±0.27 cm at the anterior section, 0.75±0.0 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, specimens were identified using a Nikon dissecting microscope (Nikon-122764, Japan). Sexes were determined by the presence or absence of petasma on the first pleopods and clasping spine on the lower antennular flagellum (Omori, 1975). The studies of Omori (1975) were followed during the identification of different species of *Acetes*. Total Length (TL) of 4900 individuals (males 1628 and females 3272) was measured from the tip of the rostrum to the tip of the telson to the nearest 0.1 mm and total weight was taken by an electronic balance of 0.001 g accuracy. The length-frequency distributions for males and females *A. indicus* samples are shown in Table 1 and 2.

Data analysis: To estimate the age structure, the length-frequency data of *A. indicus* were analyzed by using the MINITAB Version 14 and SPSS Version 11.5. The differences in the size-frequency distributions of population between sexes were determined by the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf, 1995). Student's t-test was used for comparison of the mean total length of males and females (Zar, 1996). Size-frequency distributions of *A. indicus* were plotted for each month from February 2005 to January 2006. Bhattacharya's method, implemented from the package FiSAT (Gayanilo *et al*., 1996), was used to identify the modes in the polymodal length-frequency distributions of *A. indicus*. 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) No. of the identified age groups and (c) Standard Deviation (SD) (Gayanilo *et al*., 1989).

To establish the length-weight relationship, $W = a L^b$ was applied (Quinn II and Deriso, 1989), where, W is the weight (mg), L is the total length (mm), a is the intercept (condition factor) and b is the slope (relative growth rate). The parameters a and b were estimated by least squares linear regression on log-log transformed data:

Table 1: Length-frequency data of male *A. indicus* from the coastal waters of Malacca, Peninsular Malaysia

ML	Feb./05	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan./06
14	2		2	2					4	2		4
16	2	2	4	6		10	10		28	26		8
18	4	6	20	34	10	40	4	4	78	42	6	30
20	2	12	12	28	30	100	4	2	92	26	32	84
22	18	2	6	8	32	116			92	34	60	40
24	22	14	4		12	36	2	4	34	64	56	10
26	12	2		2		34			8	18	22	10
28	4	4				6		2	2	10	12	
Sum	66	42	48	80	84	342	20	12	338	222	188	186
Total	1628											

Table 2: Length-frequency data of female *A. indicus* from the coastal waters of Malacca, Peninsular Malaysia

| ML	Feb./05	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan./06
14										6		
16					2	2				2	4	2
18		2	4	18	10	36	8	2	20	54		34
20			6	20	22	76	20	8	100	94	22	62
22	4	6	6	60	28	70	16	10	150	90	38	66
24	4	4	10	110	54	90	8	6	106	90	40	96
26	12	2	6	48	50	78	12		34	86	52	56
28	20	14	4	10	74	92	2		14	32	38	58
30	24	10	26	14	66	72	2		16	12	26	12
32	4	4	14	4	82	50			4		16	22
34	2	6	6	2	56	28			4		12	6
36	2		4	2	12	12			6	4	4	2
38	2	4		2	2	2					4	
40	2	6	2		2					2		
Sum	76	58	88	290	460	608	68	26	454	472	256	416
Total	3272											
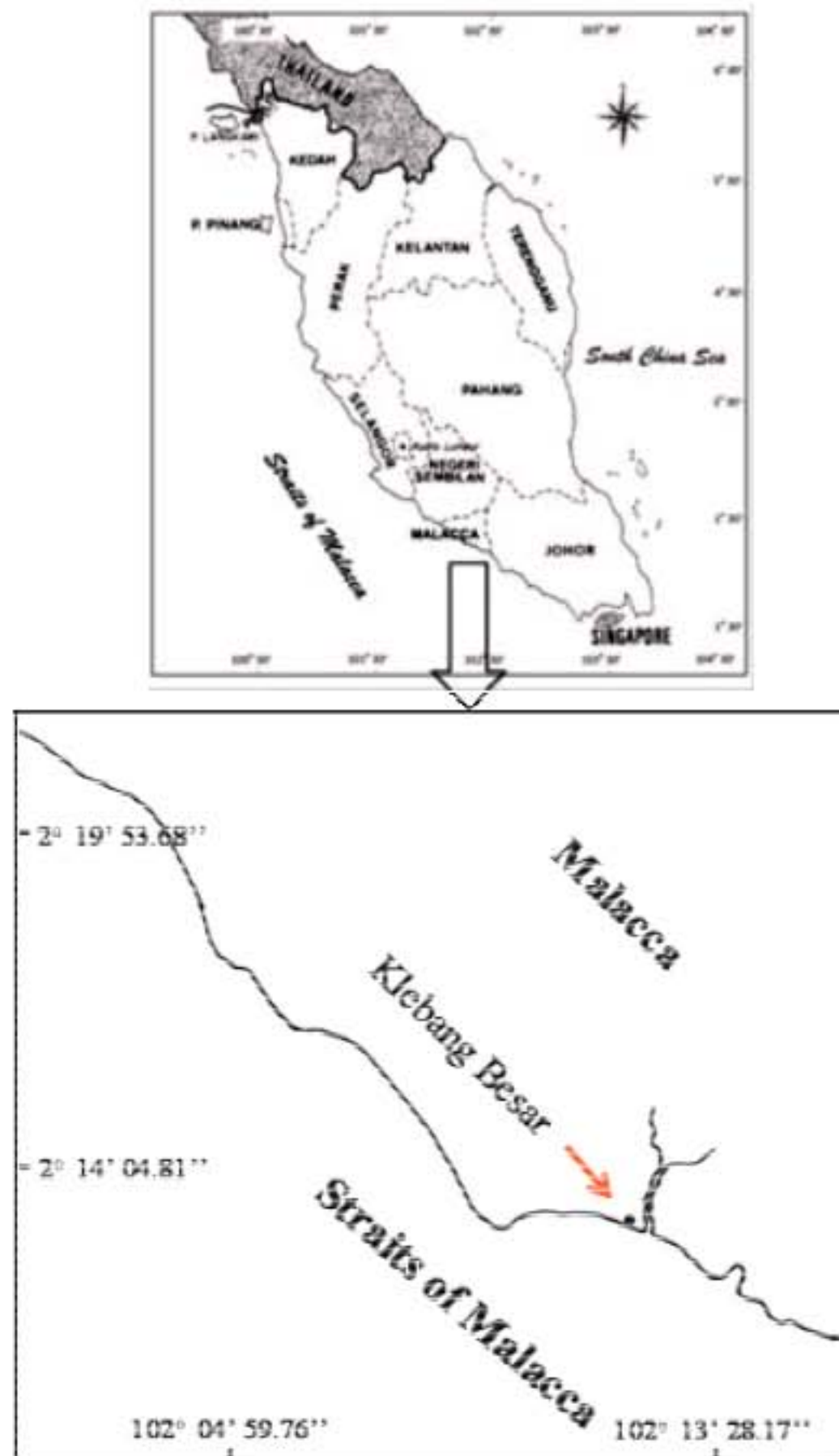
Fig. 1: Sampling station (dot) and location of Klebang Besar, Malacca, Peninsular Malaysia

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 (Scherrer, 1984). Additionally, 95% confidence limits of the parameter b and the statistical significance level of r^2 were estimated.

Monthly length-frequency distributions of male and female *A. indicus* were analyzed using the FiSAT computer programme (Gayanilo *et al.*, 1996). An estimate of maximum length (L_{max}) was obtained using the data described earlier and the extreme value theory (Formacion *et al.*, 1991) as implemented in the FiSAT software. The parameters of the von Bertalanffy Growth Function (VBGF), asymptotic length (L_∞) and growth co-efficient (K) were estimated by means of ELEFAN-I (Pauly and David, 1981). Estimated of L_∞ and K was used to calculate the growth performance index (φ') (Pauly and Munro, 1984) using the equation:

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

Potential longevity (t_{max}) of the species was calculated from Pauly (1984) formula: t_{max} = 3/K. The inverse von Bertalanffy growth equation (Sparre and Venema, 1992) was used to determine male and female of *A. indicus* lengths at various ages. The VBGF is defined by the equation:

$$L_t = L \left[1 - e^{-k(t-t_0)}\right]$$

Where:

L_t = Mean length at age t
L_∞ = Asymptotic length
K = Growth co-efficient
t = Age of the *A. indicus*
t_0 = The hypothetical age at which the length is zero (Dulcic and Kraljevic, 1995)

Once the growth parameters of VBGF were obtained, a linearized length-converted catch curve was constructed using the following formula to estimate total mortality (Z):

$$\ln (N_t/\Delta_t) = a+bt$$

where, N is the No. of individuals of relative age (t) and Δ_t is the time needed for the shrimp to grow through a length class. The slope (b) of the curve with its sign changed gives Z.

Natural mortality (M) was estimated using the empirical relationship of Pauly (1980):

$$Log_{10}M = -0.0066 - 0.279Log_{10}L_\infty + 0.6543.Log_{10}K + 0.4634 Log_{10}T$$

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 (here it was 30.58°C).

Once Z and M were obtained, fishing mortality (F) was estimated using the relationship:

$$F = Z - M$$

where, Z is the total mortality and M, natural mortality. The exploitation level (E) was obtained from E = F/Z (Gulland, 1971).

Ascending left arm of the length-converted catch curve was used to estimate the probability of capture. By plotting the cumulative probability of capture against mid-length of class interval, we obtain a resultant curve from which the length at first capture L_c was taken as corresponding to the cumulative probability at 50%.

The recruitment pattern was obtained by projecting the length-frequency data backwards on the time axis using growth parameters (Moreau and Cuende, 1991). Normal distribution of the recruitment pattern was determined by NORMSEP (Pauly and Caddy, 1985) in FiSAT.

Relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) were estimated according to Beverton and Holt (1966) length-based method as modified by Pauly and Soriano (1986) using the knife-edge selection. From the analysis, E_{max} (maximum exploitation rate giving maximum relative yield-per-recruit) and $E_{0.5}$ (the value of exploitation rate at 50% of the unexploited relative biomass-per-recruit) were estimated.

RESULTS

Size frequency distribution: Between February 2005 and January 2006, total number of individuals collected for this study were 1628 (33.22%) for males and 3272 (66.78%) for females, respectively. In males, the minimum and maximum total lengths were 13 and 29 mm and in females, they were 13 and 41 mm, respectively. The mean total lengths were 21.37±2.86 and 25.44±4.66 mm for males and females, respectively (Fig. 2). According to the annual size-frequency distributions, there were significant difference between males and females (Kolmogorov-Smirnov test: d_{max} = 0.396, p<0.001). The mean total length of females was 4.08 mm taller than that of the males (Fig. 3) and it was significantly different (t-test, p<0.001). Monthly size frequency distribution over 12 months suggested that the population consisted of a maximum of two age groups (Fig. 4) with mean values being 21.01 and 30.98 mm of total length.

Table 3: Estimated length-weight parameters of *A. indicus* from the coastal water of Malacca, Peninsular Malaysia

Sex	N	TL range	TW range	a	b	95% CI of b	r^2	Growth type
M	1628	13-29	9.50-174.10	0.0019	3.307	3.211-3.403	0.85	Allometric (+)
F	3272	14-41	13.30-430	0.0011	3.472	3.422-3.521	0.92	Allometric (+)
B	4900	13-41	9.50-430	0.0014	3.411	3.371-3.451	0.92	Allometric (+)

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; CI: Confidence Interval; r^2: Coefficient of determination
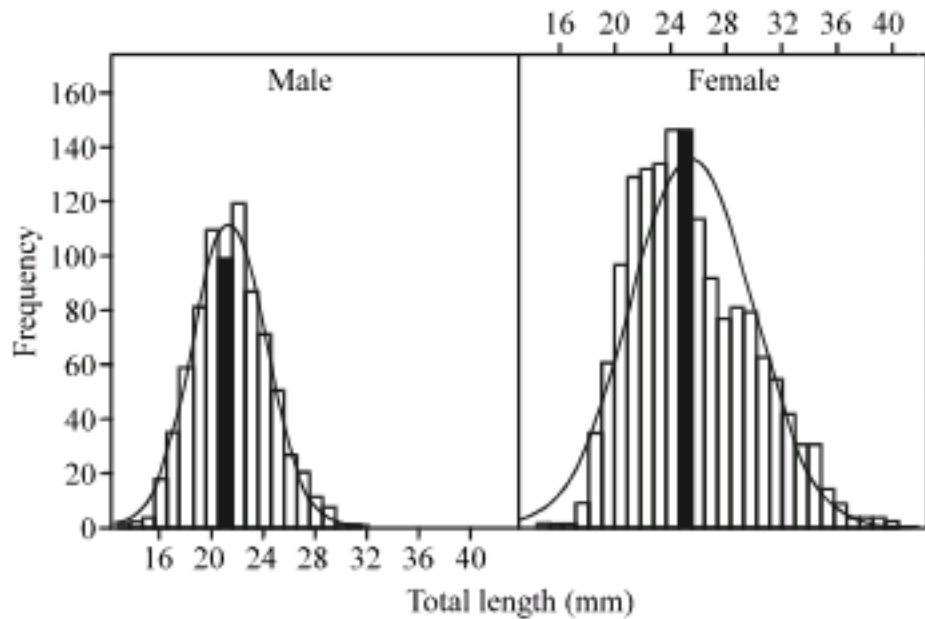
Fig. 2: Annual length-frequency distribution of males and females *A. indicus* collected from the coastal waters of Malacca, Peninsular Malaysia
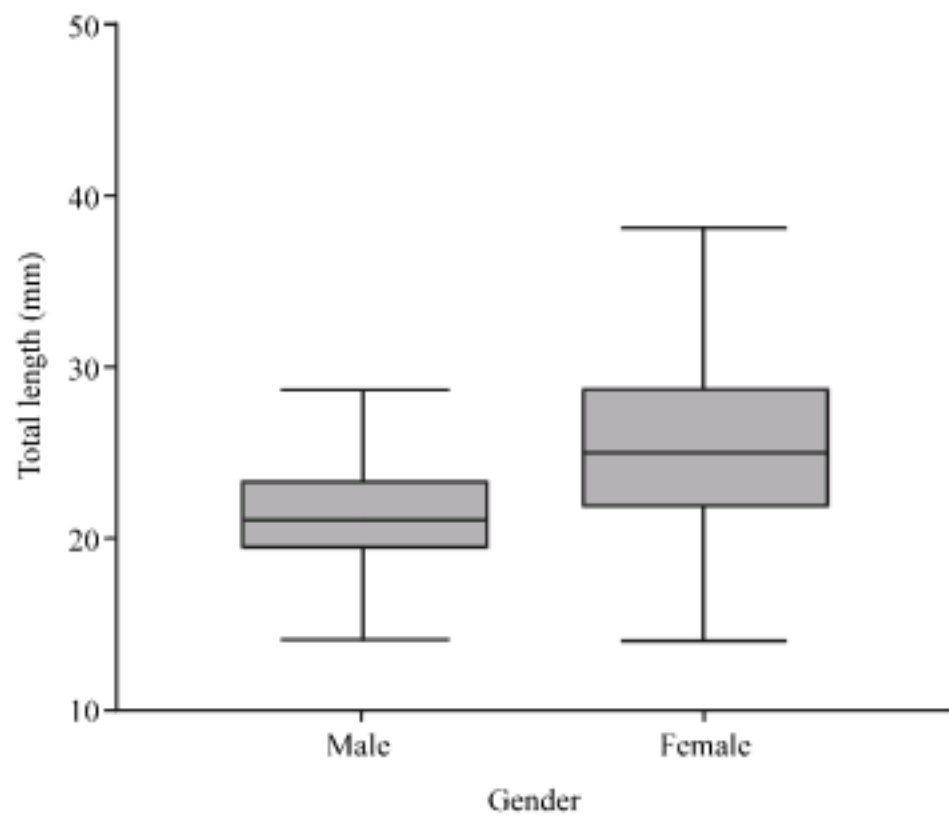

Fig. 3: Box plots of male and female *Acetes indicus* from the coastal waters of Malacca

Length-weight relationships: Length and weight of individuals for determining the length-weight relationships ranged from 13-29 mm and 9.50-174.10 mg for males, 13 to 41 mm and 13.30 to 430 mg for females, respectively (Table 3). The regression between TL (total length) and TW (total weight) for the males and females showed positive relationship (Fig. 5). The parameters of total length-body weight relationship for different groups (males, females and combined sexes) are shown

Table 4: Estimated population parameters of *A. indicus* from the coastal waters of Malacca, Peninsular Malaysia

Population parameters	*Acetes indicus*	
	Male	Female
Predicted extreme length (L_{max}) (mm)	30.16	46.37
95% of L_{max} (mm)	28.60-31.73	42.02-50.71
Asymptotic length(L_∞) (mm)	29.40	42.00
Growth coefficient (K) ($year^{-1}$)	1.70	1.20
Response surface (R_n)	0.205	0.284
Life span (t_{max}) in year	1.76	2.50
Growth performance index (φ')	3.16	3.33
Natural mortality (M) ($year^{-1}$)	2.65	1.91
Fishing mortality (F) ($year^{-1}$)	1.50	1.59
Total mortality (Z) ($year^{-1}$)	4.15	3.50
Length at first capture (L_c) (mm)	14.44	14.79
L_c / L_∞	0.49	0.36
M/K	1.51	1.46
Exploitation rate (E)	0.36	0.45
Maximum exploitation (E_{max})	0.71	0.57

in Table 3 and the length-weight relationship equations were established as:

$$\text{Log TW} = 3.307 \text{ Log TL} -2.7136, \quad r^2 = 0.85 \text{ for male}$$
A. indicus

$$\text{Log TW} = 3.472 \text{ Log TL} -2.9437, \quad r^2 = 0.92 \text{ for female}$$
A. indicus

$$\text{Log TW} = 3.411 \text{ Log TL} -2.8565, \quad r^2 = 0.92 \text{ for combined}$$
sexes of *A. indicus*

Growth parameters: The observed length and predicted extreme length (L_{max}) of males were 28.00 and 30.16 mm, respectively with 95% confidence interval for extreme length was 28.60-31.73 mm. For females the observed length and predicted extreme length (L_{max}) were 40 and 46.37 mm, respectively with 95% confidence interval for extreme length was 42.02 to 50.71 mm (Table 4). The von Bertalanffy Growth Function (VBGF) parameters L_∞ and K in males were obtained for the best fit with L_∞ = 29.40 mm and K = 1.70 $year^{-1}$ (Fig. 6a). For females, these parameters were estimated L_∞ = 42 mm and K = 1.20 $year^{-1}$ (Fig. 6b). The response surface, R_n values were calculated by ELEFAN-I as 0.205 for males and 0.284 for females. The growth performance index (φ') of male was 3.16 and that of females was 3.33.

Age and growth: Based on the growth coefficients, the maximum life span (t_{max} = 3/K) of males was 1.76 years and that of females was 2.50 years. The application of modal progression analysis by Bhattacharya's
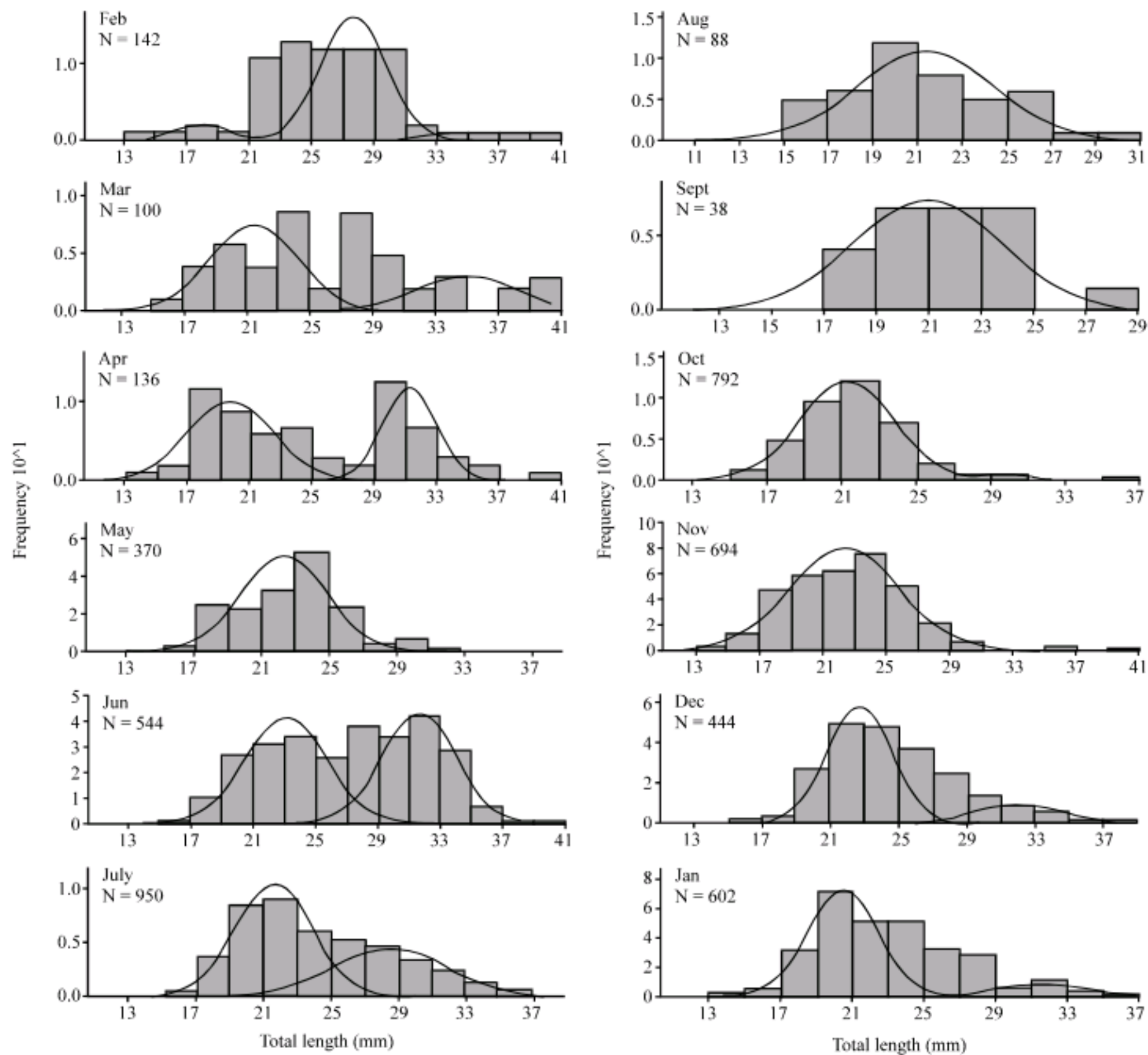
Fig. 4: Monthly length frequency distributions of males and females *A. indicus* caught in the coastal waters of Malacca, Peninsular Malaysia

method determined modal lengths for combined sexes of *A. indicus* between 17 mm in February and 35 mm in March, with satisfactory separation index for combined sexes of *A. indicus* (Table 5). Maximum two well-discriminated modal groups were identified reflecting different annual cohorts (Table 5). Table 6 shows the total length-age relationship estimated from Bertalanffy's model using L_∞ and K parameters of males and females and assuming $t_0 = 0$ (Pauly and David, 1981). Therefore, the sizes attained by males and females *A. indicus* were 23.89 and 28.99 mm at the end of one year age, respectively (Table 6).

Mortality and exploitation: Total mortality (Z) was estimated using the length converted catch curve (Fig. 7).

The dark points of the curve were used by fitting a least square regression line to them. Good fit to the descending right hand limits of the catch curve was considered with mentioned regression line values:

Male : $Y = 11.225 + (-5.312) X$ (r = -0.99)
Female : $Y = 10.398 + (-4.778) X$ (r = -0.99)

The estimated total mortality, Z values were 4.15 and 3.50 year^{-1} for males (Fig. 7a) and females (Fig. 7b), respectively. The natural mortality rate, M values of males was 2.65 year^{-1} and that of females was 1.99 year^{-1}. The fishing mortality rate (F) of males and females was 1.50 and 1.59 year^{-1}, respectively (Table 4). The natural mortality of males (2.65 year^{-1}) was higher than the value
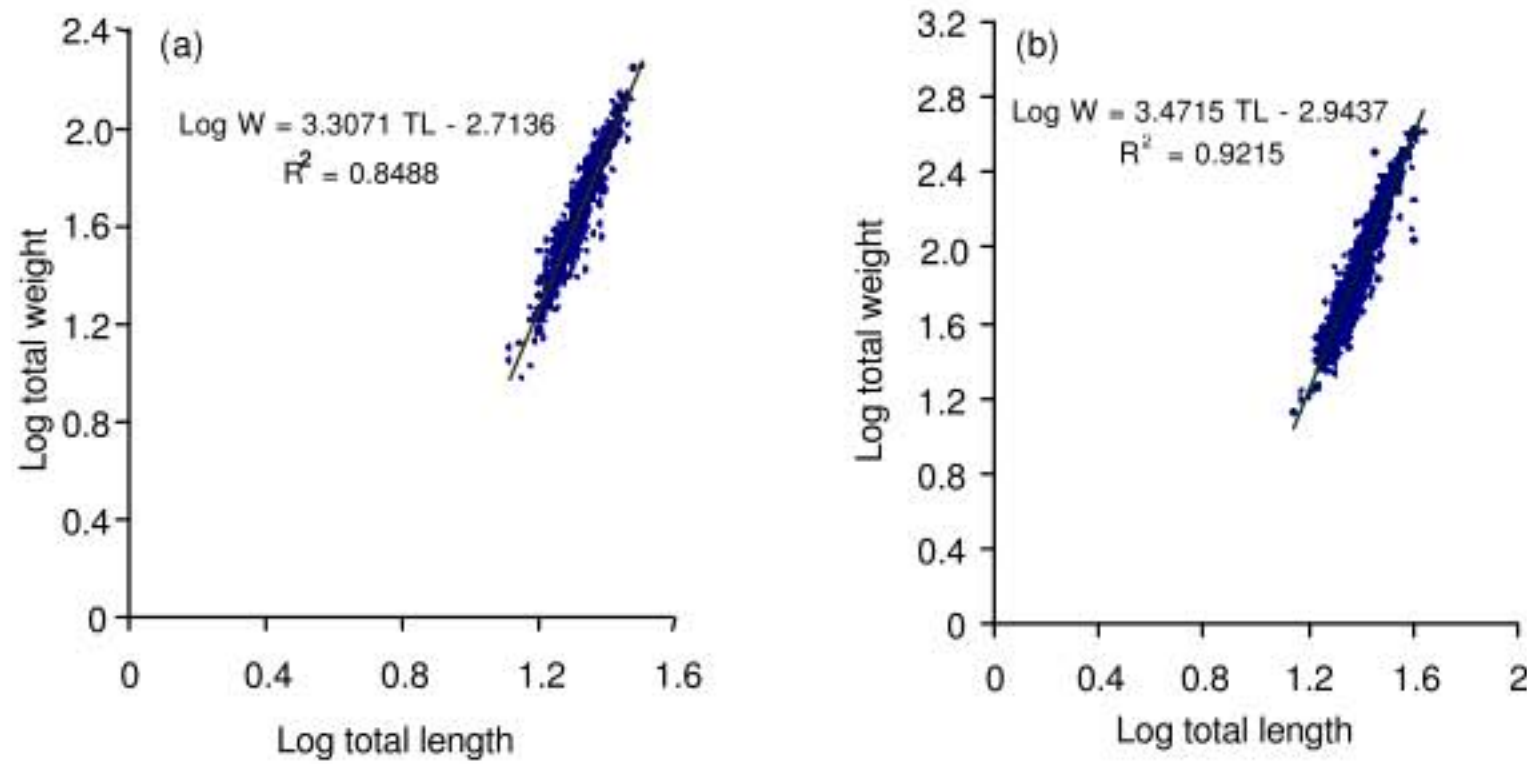
Fig. 5: Length weight relationship of male (a) and female (b) *A. indicus* from the coastal water of Malacca, Peninsular Malaysia
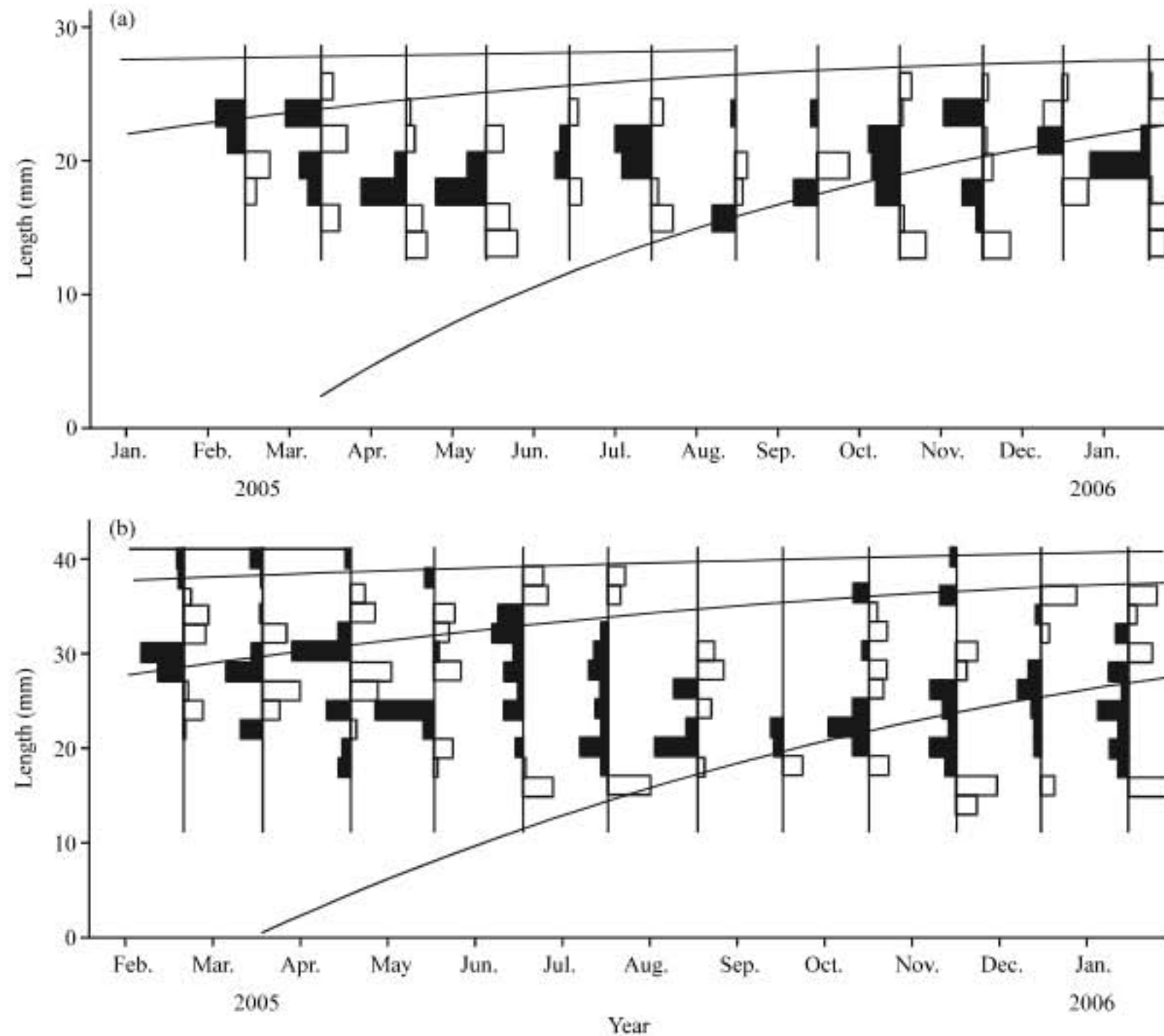

Fig. 6: Von Bertalanffy growth curves of males (a) and females (b) *A. indicus* superimposed on the restructured length-frequency histograms. The black and white bars are positive and negative deviation from the weighted moving average of three length classes and they represent pseudo-cohorts

of females (1.99 year^{-1}) indicating the unbalance position in the stock. From these figures, exploitation rate, E values were obtained 0.36 and 0.45 for males and females in the coastal waters of Malacca, which seemed to be below to the optimum level of exploitation (E = 0.50).

Table 5: Identified age groups from the length-frequency analysis of male and female *A. indicus* during the monthly sampling, using Bhattacharya's method

Months	AG	Mean TL (mm)	SD (mm)	SI
Feb./05	1	17.00	3.40	-
	2	29.00	1.49	2.70
Mar.	1	21.52	2.73	-
	2	35.00	3.13	4.60
Apr.	1	19.67	2.73	-
	2	31.32	1.70	5.21
May	1	22.29	2.29	
Jun.	1	23.14	2.58	-
	2	31.64	2.34	3.46
Jul.	1	21.57	2.31	-
	2	28.47	2.94	2.41
Aug.	1	20.07	3.69	-
Sep.	1	21.00	2.80	-
Oct.	1	21.27	2.55	-
	2	29.68	1.40	4.26
Nov.	1	20.94	2.93	-
Dec.	1	22.67	1.90	-
	2	31.83	2.40	4.26
Jan./06	1	20.45	1.92	-
	2	31.60	3.17	2.63

AG: Age Group, TL: Total Length, SD: Standard Deviation, SI: Separation Index

Table 6: Length-at-age key for *A. indicus* from coastal waters of Malacca, estimated using the VBGF parameters (L_∞ = 29.40 mm, K = 1.70 year^{-1} for males and L_∞ = 42 mm, K = 1.20 year^{-1})

Relative age (month)	Female (mm)	Growth/ month	Male (mm)	Growth/ month
1	3.98	-	3.72	-
2	7.62	3.64	7.02	3.30
3	10.88	3.26	9.87	2.85
4	13.84	2.96	12.36	2.47
5	16.54	2.70	14.57	2.21
6	18.95	2.41	16.48	1.91
7	21.14	2.19	18.15	1.67
8	23.14	2.00	19.63	1.48
9	24.92	1.78	20.92	1.29
10	26.54	1.62	22.04	1.12
11	28.03	1.49	23.03	0.99
12	29.35	1.32	23.89	0.86
13	30.51	1.14	24.61	0.72
14	31.68	1.16	25.33	0.72
15	32.63	0.93	25.88	0.55
16	33.49	0.85	26.37	0.49
17	34.36	0.86	26.84	0.47
18	35.06	0.69	27.21	0.37
19	35.69	0.63	27.54	0.33
20	36.34	0.64	27.86	0.32
21	36.86	0.51	28.10	0.24
22	37.33	0.47		
23	37.81	0.47		
24	38.19	0.38		

Length at first capture: The length at first capture, L_c (the length at which 50% of the shrimps becomes vulnerable to the gear) of *A. indicus* in the coastal waters of Malacca are shown in Fig. 8. The mean L_c value of males and females *A. indicus* was 14.44 and 14.79 mm, respectively during the study period. The $L_{25\%}$ value of males and females was 12.35 and 12.04 mm. The mean length at which 75% of the shrimps were retained in the gear was estimated as $L_{75\%}$ = 16.31 mm for males and $L_{75\%}$ = 17.92 mm for females in the investigated area.
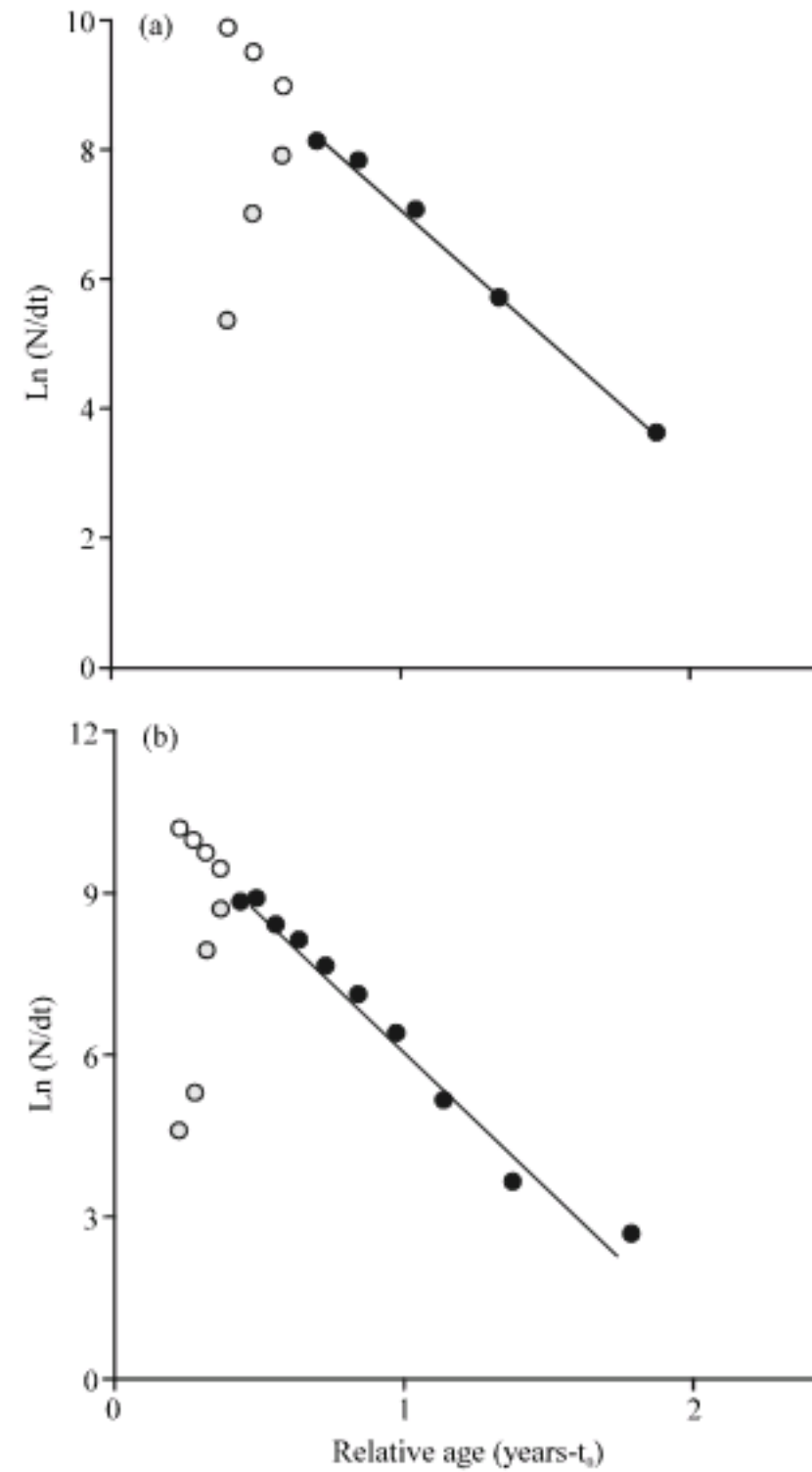

Fig. 7: Length converted catch curve of males (a) and females (b) *A. indicus*; the darkened full dots represent the points used in calculating through least square linear regression and the open dots represent the point either not fully recruited or nearing to L_∞

Recruitment pattern: The recruitment pattern of males was continuous throughout the year, with two major peaks (Fig. 9a). The first spell of males was from February to May with peak in March (11.59%) and the second spell was from July to October with peak in September (13.91%). In case of females, the recruitment pattern was also two spells during the 1-year study (Fig. 9b). The first spell of females was from January to March with peak in January (5.12%). The second spell was August to October with peak in September (21.32%).

Relative yield per recruit (Y/R) and biomass per recruit (B/R): The computed maximum allowable limit of exploitation (E_{max}) that give the maximum relative yield-per-recruit at maximum sustainable yield (MSY) level was 0.71 for males (Fig. 10a) and 0.57 for females (Fig. 10b). The
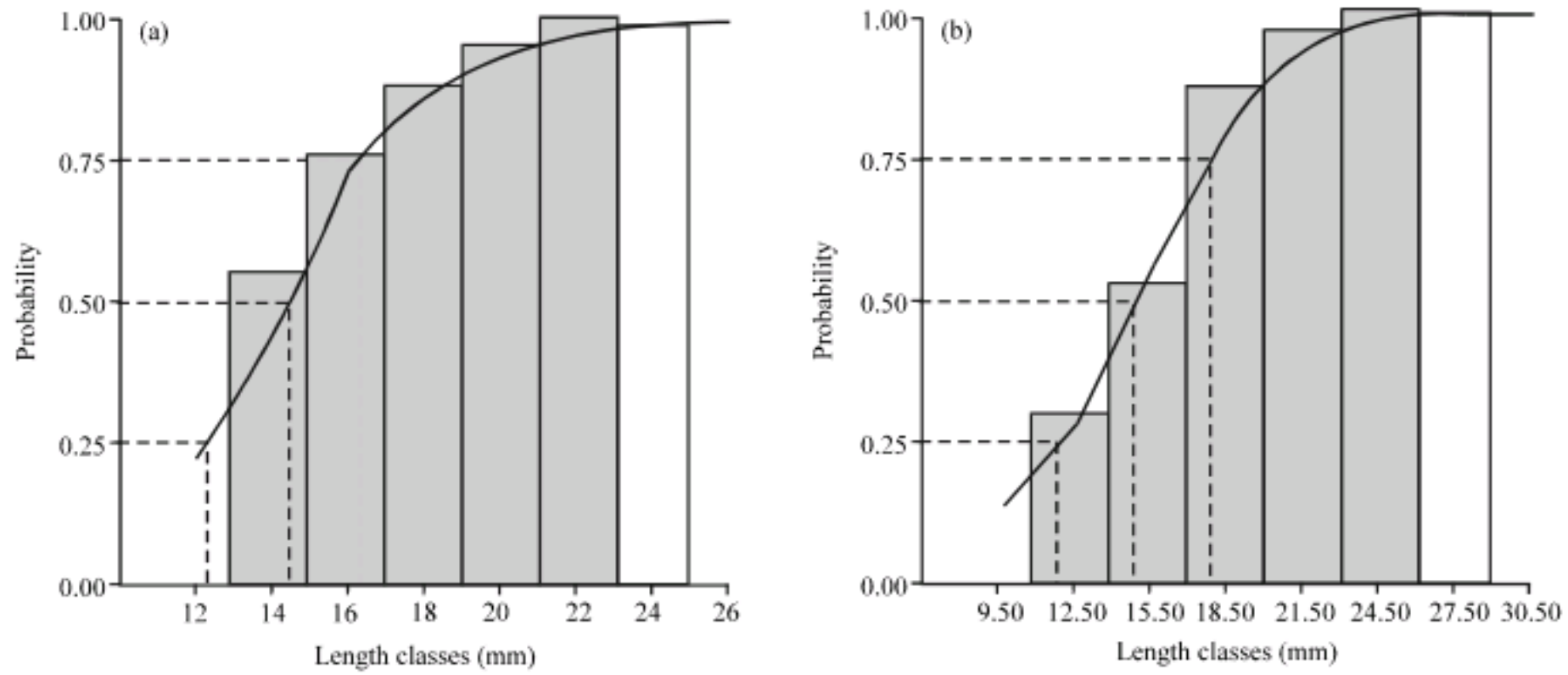
Fig. 8: Probability of capture of each length class of males (a) and females (b) *A. indicus* ($L_{25\%}$ = 12.35 mm, $L_{50\%}$ or L_c = 14.44 mm and $L_{75\%}$ = 16.31 mm for males and $L_{25\%}$ = 12.04 mm, $L_{50\%}$ or Lc = 14.79 mm and $L_{75\%}$ = 17.92 mm for females)
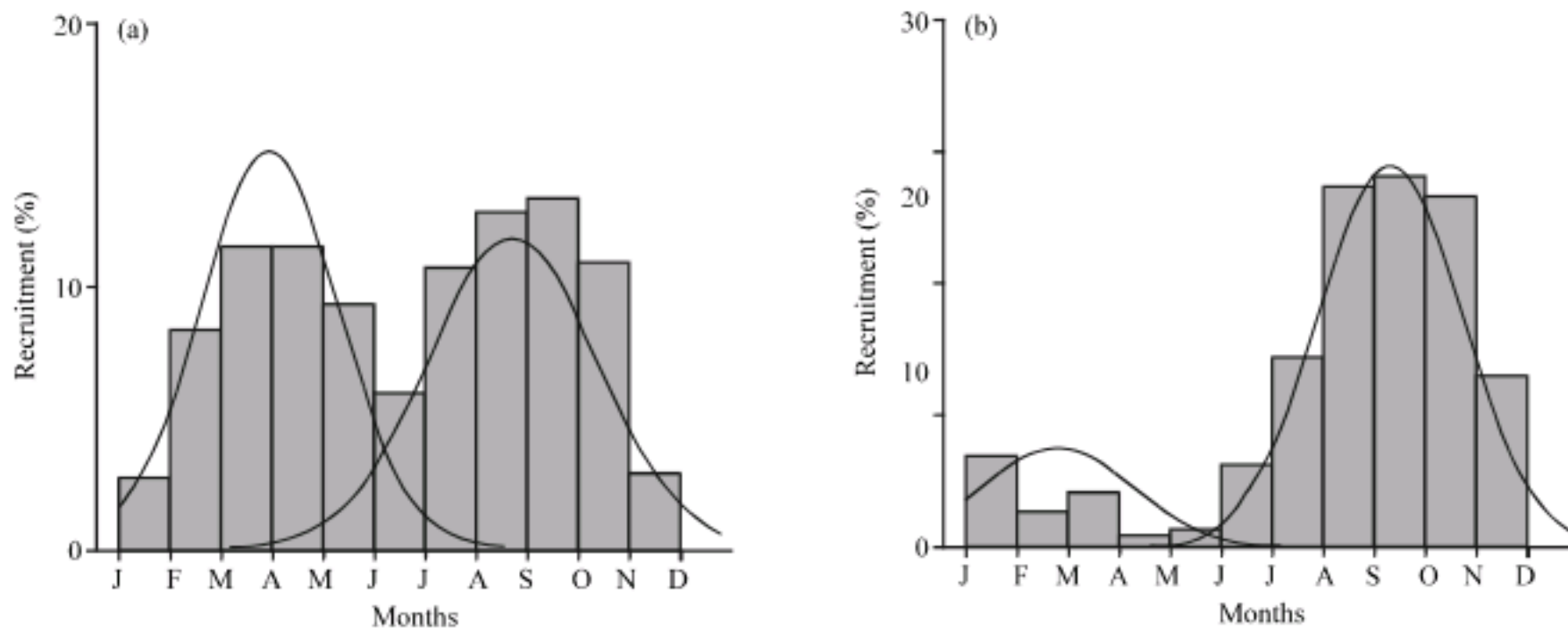

Fig. 9: Recruitment pattern of males (a) and females (b) *A. indius* in the coastal waters of Malacca, Peninsular Malaysia
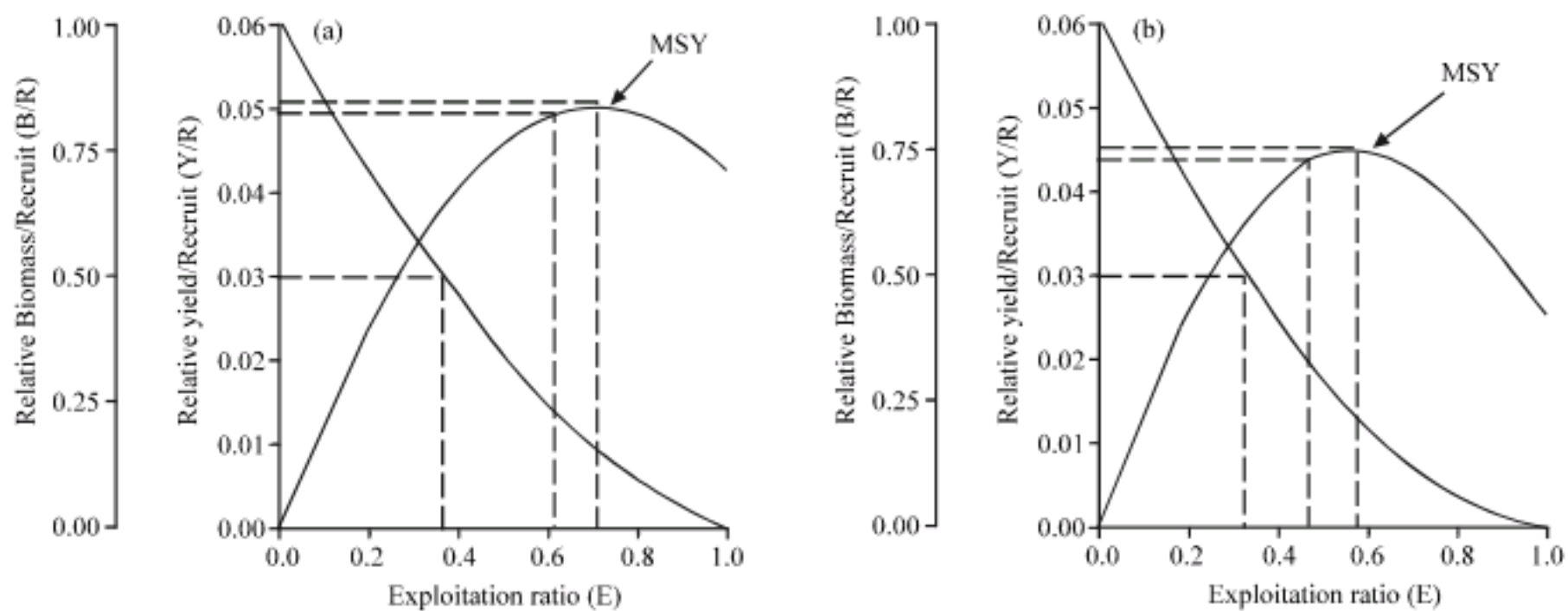

Fig. 10: Yield-per-recruit and biomass per recruit models, showing levels of yield index of males (a) and females (b) *A. indicus*: MSY = Maximum Sustainable Yield

exploitation level ($E_{0.5}$) which corresponds to 50% of the relative biomass-per-recruit of the unexploited stock was 0.36 for males that of females was 0.32, respectively.

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. The growth coefficient b 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 (Ecoutin *et al.*, 2005). Table 7 shows earlier published values of the coefficient a and b for the genus *Acetes*. The values of b show considerable variation, ranging from 2.155 (Lei, 1988) to 3.472 (present study). Estimated b (3.307) of males lies between the values mentioned by Ecoutin *et al.* (2005) and is significantly higher than isometric value (3) at 5% level. In females, estimated b (3.472) is also significantly higher from then the isometric value (3) at 5% level. This indicates the positive allometric nature of growth for *A. indicus* in the coastal waters of Malacca.

Estimated L_∞ and K are 29.40 mm and 1.70 year^{-1} for males. In females they are 42 mm and 1.20 year^{-1}. Comparisons with population parameters from other studies (Table 8) show that differences exist for different species of the genus *Acetes* from different areas in the world. The highest value of L_∞ (42 mm in females) is observed in the present study; the lowest value (31 mm in combined sexes) was in Bangladesh waters (Zafar *et al.*, 1997). The K values are more or less similar to the present value except the reported by Oh and Jeong (2003) stated the lowest values (K = 0.84 year^{-1} in males and

K = 0.69 year^{-1} in females for *A. chinensis*. The index of phi prime by Munro and Pauly (1983) 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 were found to be excellent and varied between 3.16 and 3.33 (Table 8). Though phi prime is supported to be more or less constant for a family or for similar taxa, the range here (Table 8) is low except the report by Oh and Jeong (2003) stated the lowest values (φ' = 1.97 in males and φ' = 2.10 in females for *A. chinensis*).

Longevity of *Acetes*, as in other crustaceans, is difficult to estimate accurately because of the obvious difficulties in ageing these animals and hence estimates are unavailable for both natural and laboratory populations (Xiao and Greenwood, 1993). The maximum age, t_{max} = 3/K (Pauly, 1984) is frequently using for estimating longevity of shrimp (Botter-Carvalho *et al.*, 2007; Niamaimandi *et al.*, 2007; Cha *et al.*, 2004). The estimated maximum age for males and females are 1.76 and 2.50 years in the present study. The mean life span of penaeids is often regarded as <2 year (Dall *et al.*, 1990). Estimated longevity of *Acetes* is less than that of penaeids is well justified because of its smaller size. Yoshida (1949) suggested that *Acetes chinensis* has a life-span of about one year in western Korea. Except this no reports are available for comparison of longevity of *Acetes* so far researcher aware. Maximum of two age groups of combined sexes of *A. indicus* with mean values being 21.01 and 30.98 mm of total length were estimated by Bhattacharya's method. Similar studies were reported on red shrimp *Aristeus antennatus* by Paraconstantinou and Kapris (2001) and on *C. madrasensis* by Amin *et al.* (2008), by the Bhattacharya's method, which also

Table 7: 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.* (1997)
Bangladesh	*A. chinensis*	0.0107	2.908	0.98	Negative allometric	Zafar *et al.* (1998)
Bangladesh	*A. erythraeus*	0.0051	3.106	0.99	Isometric	Zafar and Amin (2002)
China	*A. joponicus*	0.1302	2.155	-	Negative allometric	Lei (1988)
Japan	*A. japonicus*	0.1566	2.231	0.96	Negative allometric	Uye (1982)
Japan	*A. sibogae*	0.0085	2.985	0.98	Isometric	Ikeda and Raymont (1989)

a: Condition factor; b: Growth coefficient; r^2: Coefficient of determination

Table 8: Growth parameters (L_∞ and K) and computed growth performance index (φ') of the genus *Acetes* from different tropical countries

Location	Species	L_∞ (mm)	K year^{-1}	φ'	T (°C)	Source
Malaysia	*A. indicus* (M)	29.40 TL	1.70	3.16	31	Present study
Malaysia	*A. indicus* (F)	42.00 TL	1.20	3.33	31	Present study
Malaysia	*A. intermedius* (C)	34.65	1.50	3.25	31	Arshad *et al.* (2007)
Bangladesh	*A. indicus* (C)	31.00 TL	1.70	3.22	28	Zafar *et al.* (1997)
Bangladesh	*A. erythraeus* (C)	37.00 TL	1.20	3.21	28	Zafar and Amin (2002)
Bangladesh	*A. chinensis* (C)	40.00 TL	1.60	3.40	28	Zafar *et al.* (1998)
Korea	*A. chinensis* (F)	13.51 CL	0.69	2.10	-	Oh and Jeong (2003)
	A. chinensis (M)	10.48 CL	0.84	1.97	-	Oh and Jeong (2003)

M: Male, F: Female, C: Combined sexes

followed in the present study. The estimated ages from the study are presented in Table 6. The overall average growth rate of *A. indicus* showed 1.83±0.78 mm/month for male and 2.30±0.72 mm/month for females which enable it to attain a total length of around 21.96 mm for males and 27.6 mm for females in 12 months. Similar reports are available on other shrimp by Amin and Zafar (2003) and Cha *et al*. (2004) and on fish by Amin and Zafar (2004), Isaac and Ruffino (1996) and Blaber *et al*. (1998), who used length-converted age method for their study.

The recruitment pattern suggests that continuous recruitment consists of two peaks seasonal pulse (Fig. 9). This is in good agreement with Zafar *et al*. (1997) for *A. indicus* and Oh and Jeong (2003) for *A. chinensis*. There are no published reports on *Acetes* recruitment 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 (Nataraj, 1947). Spawning patterns in these areas (tropical and subtropical) are probably related to monsoonal influences on precipitation and wind direction (Omori, 1975). Major spawning was observed in February to March in the coastal waters of Malacca, Peninsular Malaysia (Fig. 6). It is expected that the major recruitment peak (September-October) detected in this study should correspond to the major spawning season.

On the basis of 175 independent data sets Pauly (1980) has made a regression analysis of M (year^{-1}) on K (year^{-1}), L$_\infty$ and T (average annual temperatures). Sparre and Venema (1992) warned against using Pauly's formula for crustaceans, mollusc or cephalopods or any other invertebrates, as the formula does not cover these groups. But in the absence of any data this formula can be used for shrimp (Niamaimandi *et al*., 2007). Pauly *et al*. (1984) noted that the formula can be used for shrimp and any other invertebrates, because these marine organisms generally share the same habitats, resources and predators and that therefore, they are not likely to differ widely in their vital parameters. Hence Pauly's equation allows a rough estimation of M in shrimp stock where L$_\infty$, K and T are known.

The estimated natural mortality rate of *A. indicus* for both sexes in the present study (M = 2.65 year^{-1} in males and M = 1.91 year^{-1} in females) is higher than the estimated values of fishing mortality (F = 1.50 year^{-1}in males and F = 1.59 year^{-1} in females). Higher natural mortalities of *A. indicus* verses the fishing mortalities indicate the unbalance position in the stock. 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 (Gulland, 1971). Estimated exploitation level (E) of females (0.45) is higher than males (0.36) in *A. indicus* population. It is may be for the larger size of females they can not escape from the gear than males. In Bangladesh waters M and F have been estimated at 4.76 and 1.31 year^{-1} for the combined sexes of *A. indicus* (Zafar *et al*., 1997). Higher natural mortality than fishing mortality was also reported from other *Acetes* studies (Arshad *et al*., 2007; Zafar *et al*., 1998; Zafar and Amin, 2002; Oh and Jeong, 2003) in the Asian countries (Table 9). Hass *et al*. (2004) noted production mortality can be influenced by shrimp length, movement and the habitat type. Mortality due to predation is influenced by the characteristics of the predation population. Xu *et al*. (1995) reported that the influences of abiotic factors are probably the most important reasons affects of natural mortality.

In most short-lived species, it is difficult to identify the component age groups and estimate the numbers at each age. Therefore, for estimation of Z, length-frequency data are used and a length-frequency distribution can be converted to an age frequency distribution by means of a length-converted catch curve. Catch curve analysis is feasible, assuming that total mortality is constant from length upwards. This assumption could be violated by migration out of the fishing area of mature shrimp (Niamaimandi *et al*., 2007). In length-catch curve analysis for estimation of total mortality, the initial ascending data points are not included in the regression (Fig. 7a, b). These points represent younger age groups, which are subjected to a lower fishing mortality because they are either not fully recruited or not fully vulnerable to the fishing gear used (King, 1984).

Table 9: Mortality parameters (Z, F and M) and computed exploitation rate (E) of the genus *Acetes* from different tropical countries

Location	Species	M (year^{-1})	F (year^{-1})	Z (year^{-1})	E	E$_{max}$	Source
Malaysia	*A. indicus* (M)	2.65	1.50	4.15	0.36	0.71	Present study
	A. indicus (F)	1.91	1.59	3.50	0.45	0.57	Present study
Malaysia	*A. intermedius* (C)	2.35	1.81	4.15	0.43	0.65	Arshad *et al*. (2007)
Bangladesh	*A. indicus* (C)	4.76	1.31	6.07	0.22	0.88	Zafar *et al*. (1997)
Bangladesh	*A. erythraeus* (C)	3.61	1.11	4.72	0.24	1.00	Zafar and Amin (2002)
Bangladesh	*A. chinensis* (C)	4.26	1.13	5.39	0.21	1.00	Zafar *et al*. (1998)
Korea	*A. chinensis* (C)	-	-	3.93	-	-	Oh and Jeong (2003)

M: Male, F: Female, C: Combined sexes

The level of total mortality, $Z = 6.07$ year^{-1} from Bangladesh waters (Zafar *et al.*, 1997) is higher than present study ($Z = 4.15$ year^{-1} for males and $Z = 3.50$ year^{-1} for females). The values of $E = 0.36$ for males and $E = 0.45$ for females are lower than optimum level of exploitation ($E = 0.50$), suggesting under-exploitation in this fishery (under-fishing occurs if M>F or E>0.50, Gulland, 1971).

Considering our relative Y/R and relative B/R analyses (Fig. 10a, b) our computed exploitation rate, E values ($E = 0.36$ for males and $E = 0.45$ for females) are below the predicted maximum values of $E_{max} = 0.71$ (males) and 0.57 (females). This reveals that the fishery is being under exploited in the coastal waters of Malacca. Results from the analysis of the exploitation rate (E) based on the fishing mortality estimates and from the relative Y/R, indicate that the fishery is below the optimum fishing pressure and probably the catch is below to the full exploitation (MSY). Thus, the more yield could be obtained by a reasonable increase in the effort. This implies that further increase in fishing effort could be possible to get the maximum sustainable yield, thus driving the stock sustain and economic benefit.

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