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4 authors:

S M Nurul Amin
FAO World Fisheries University

Aziz Bin Arshad
Universiti Putra Malaysia, Serdang Selangor

Japar Sidik Bujang
Universiti Putra Malaysia

Siti Shapor Siraj

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Growth, Mortality and Yield-Per-Recruit of Sergestid Shrimp, *Acetes intermedius* Omori, 1975 (Decapoda: Sergestidae) from Length Frequency Analysis in the Coastal Waters of Malacca, Peninsular Malaysia

S. M. Nurul Amin[1, 2, *], Aziz Arshad[2], Japar Sidik Bujang[2] and Siti Shapor Siraj[2]
[1]Institute of Marine Sciences and Fisheries, University of Chittagong, Chittagong-4331, Bangladesh
[2]Department of Biology, Faculty of Science, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
**E-mail: smnabd02@yahoo.com*

ABSTRACT
Estimates of growth, mortality and relative yield per recruit of the sergestid shrimp, *A. intermedius* in the coastal waters of Malacca, Peninsular Malaysia were obtained from the monthly length-frequency data. The von Bertalanffy growth function (VBGF) estimates were: $L\infty$ = 34.65 mm total length; K = 1.5 yr^{-1} and t_0 = -0.1004 years. Natural mortality rate (M) was 1.5 yr^{-1}. Total mortality coefficient (Z) was estimated as 4.15 yr^{-1} and the exploitation ratio (E = F/Z) was 0.43. The recruitment pattern was continuous throughout the year with one major peak. The relative yield per recruit analysis predicted the maximum allowable limit of exploitation (E_{max}) = 0.65. The current exploitation rate E is less than the predicted E_{max}. Thus, the stock of *A. intermedius* was found to be below optimum fishing pressure (E < 0.50) in the coastal waters of Malacca, Peninsular Malaysia.

Keywords: Growth, mortality, recruitment, *Acetes intermedius*, Malaysia

INTRODUCTION

The sergestid shrimps of the genus *Acetes*, family Sergestidae, are a minor planktonic crustacean group represented by a small number of species, but are one of the economically important organisms in Asian and African waters (Omori, 1975). They occur widely in the west coast of Malay Peninsula (Pathansali, 1966; Omori, 1975; Johnson, 1976) and are locally familiar as udang geragau. The world-wide geographical distribution of *Acetes* has been summarized by Omori (1975) and Holthuis (1980).

The species *Acetes intermedius* occurs in the shallow coastal waters of the Malacca strait, Peninsular Malaysia (Arshad *et al.*, 2007). It is one of the most important commercial shrimp resources and is also an important component of the marine ecosystem in the coastal waters of south-western Taiwan (Chiou *et al.*, 2000). Annual catch of this species was greater than 2,700 tons in south-western Taiwan, and was valued at more than US$ 2,027,680 in 2000 (Chiou, 2002). It migrates from estuaries to offshore waters and performs a diel vertical migration in the coastal waters of south-western Taiwan during the period from June to October (Chiou *et al.*, 2000). Their diel vertical migrations coincide with the time of sunrise and sunset. Further to this, they perform nocturnal upward migration depending on the lunar phase. Such diel vertical migration allows them to avoid diurnal visual predators and may also deter nocturnal predators utilizing the moonlight (Chiou *et al.*, 2003). The feeding activity of this species mainly occurred at night and performs a nocturnal vertical migration to avoid predators and allow for safe feeding (Chiou *et al.*, 2005).

The shrimp of the genus *Acetes* 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

* Corresponding Author

swarms in the shallow inshore coastal waters, which is brackish with a salinity of 30 ppt or less, during certain seasons of the year (Pathansali, 1966). 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' (Pathansali, 1966). The annual landing of *Acetes* in Malaysia was 7,528 tons during 2004 (DOF, 2004).

Spectacular school or swarms of *Acetes*, particularly in coastal Asia, are the bases of important commercial fishes for consumption by humans and domestic animals (Mistakidis, 1973; Omori, 1974, 1975, 1978; Malley and Ho, 1978; Chullasorn and Martosubroto, 1986). The commercial importance also derives from the use and potential of *Acetes* as a food organism for aquaculture industry (Kungvankij *et al.*, 1986; Ung and Itoh, 1989). These combined features make *Acetes* excellent candidates for population dynamics 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 mortalities 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 the asymptotic length ($L\infty$) and growth coefficient (K), motilities (natural and fishing) rate and exploitation level (E) are necessary for planning and management of *Acetes* resources. Lack of knowledge of population structure and proper evaluation of the exploitation of this resource emphasized the importance of a detailed study to facilitate better management of the resource. 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; Papaconstantinou and Kapiris, 2001; Etim and Sankare, 1998; Enin *et al.*, 1996) 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. intermedius* in order to assess the stock position of the species around the coast waters of Malacca.

MATERIALS AND METHODS

Collection of Data

Monthly samples of the *A. intermedius* were collected from Klebang Besar (N 02^{0}13.009/ & E 102^0 11.921$^{/}$) in the Malacca coastal waters, Straits of Malacca (*Fig. 1*) between February 2005 and January 2006. Triangular shape push net (mesh size 3.2 cm at anterior section, 0.75 cm at middle and 0.5 cm at cod end) were used to collect the samples of *Acetes*. The fishing effort was one man per hour and towing length was approximately 1000 m along the coast of Klebang Besar, Malacca. After collection, samples were fixed in 10% formalin solution in the field and analyzed after 2-3 days of preservation. In the laboratory, *A. intermedius* was identified using a Nikon dissecting microscope. The works of Omori (1975) were followed during the identification of *A. intermedius*. Total length (TL) of 995 individuals was measured from the tip of the rostrum to the tip of the telson to the nearest 0.1 mm using vernier calipers.

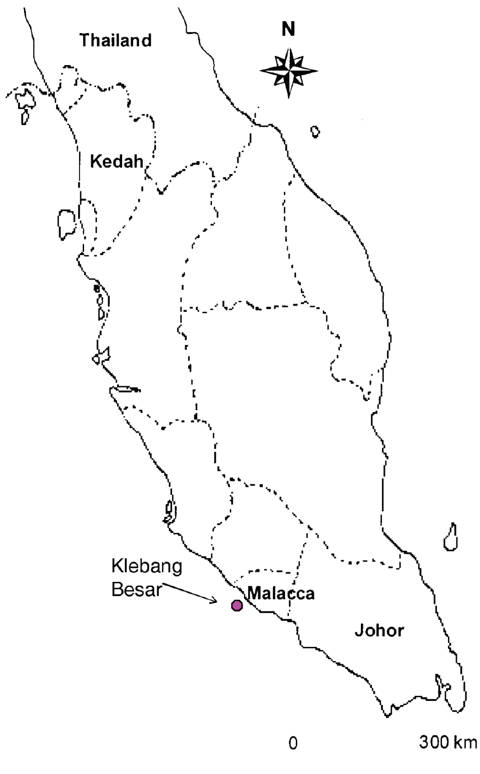

Fig. 1: Sampling location (dot) in the coastal waters of Malacca, Malaysia

Data Analysis

Size-frequency distributions of *A. intermedius* 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. intermedius*. 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) (Gayanilo *et al.*, 1989).

Monthly length-frequency distributions of *A. intermedius* were analyzed using the FiSAT computer programme (Gayanilo *et al.*, 1996). The parameters of the von Bertalanffy growth function (VBGF), asymptotic length ($L\infty$) and growth co-efficient (K) were estimated using ELEFAN-I routing (Pauly and David, 1981) incorporated into the FiSAT software. K scan routine was conducted to assess a reliable estimate of the K value. The theoretical age at length zero (t_o) was obtained from Pauly's (1979) equation:

$$\text{Log } (-t_0) = - 0.392 - 0.275 \log L_\alpha - 1.038 \log K$$

Potential longevity (t_{max}) of the species was calculated from the Pauly (1984) formula: $t_{max} = 3/K$. The estimated L_α and K were used to calculate the growth performance index (φ') (Pauly and Munro, 1984) of *A. intermedius* from the equation: $\varphi' = 2 \log_{10} L_\alpha + \log_{10} K$

Total mortality coefficient (Z) was estimated by using the length converted catch curve (Pauly, 1984) and the method of Jones and van Zaling (1981). Natural mortality rate (M) was estimated using an empirical relationship of Pauly (1980):

$$\text{Log}_{10}M = -0.0066 - 0.279\text{Log}_{10}L\infty + 0.6543.\text{Log}_{10}K + 0.4634 \text{ Log}_{10}T$$

where M is the natural mortality, $L\infty$ the asymptotic length, K the growth co-efficient of the VBGF and T the mean annual habitat water temperature ^{0}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 (1971):

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

The ascending left arm of the length-converted catch curve was used to analysis the probability of capture of each length class according to the method of Pauly (1987). By plotting the cumulative probability of capture against mid-length, we obtained 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 of the stock was determined by backward projection on the length axis of the set of available length frequency data as described in FiSAT. 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 $L\infty$, K and t_0 ($t_0 = 0$). Normal distribution of the recruitment pattern was determined by NORMSEP (Pauly and Caddy, 1985) in FiSAT.

The estimated length structured virtual population analysis (VPA) and cohort analysis was carried out from the FiSAT routine. The values of L_α, 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 (1949) and subsequently modified by many authors. Practical reviews of VPA methods were, among others given by Pauly (1984) and Jones (1984).

The relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) were estimated by using the model of Beverton and Holt (1966) as modified by Pauly & Soriano (1986) and incorporated in FiSAT software package. The input requirements in the procedure were the values of $L_c/L_\alpha = 0.44$ and $M/K = 1.57$. 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

Size Frequency Distribution

Monthly length frequency distributions identified the modal lengths with cohorts in different months (*Fig. 2*). The length frequency distribution of different months suggested that the population consisted of maximum two age groups, with means of 19.03 mm and 27.40 mm of total length. The application of Bhattacharya's method through FiSAT determined model lengths of *A. intermedius* ranging from 17.12 mm (in January) to 31.22 mm (in March), with satisfactory separation index (Table 1). The two dominant modal groups of *A. intermedius* were identified reflecting two different annual cohorts. Therefore, the monthly size frequency distributions suggested that the population consisted of two age groups, with modes at approximately 19 mm and ≥ 26 mm total length.

Growth Parameters

The observed extreme length and the predicted extreme length (L_{max}) were found to be 33.00 mm and 35.62 mm respectively (*Fig. 3*). The range at 95% confidence interval for extreme length was calculated as 30.39 - 40.84 mm. This initial extreme length value was used in ELEFAN-I, included in FiSAT package (Gayanilo *et al.*, 1996) producing the optimum growth curve. The best value of VBGF growth constant (K) was estimated as 1.5 yr^{-1} by ELEFAN-I (*Fig. 4*). The response surface (Rn) was calculated as 0.479 which selected the best combination of growth parameters as: L_α = 34.65 mm and K = 1.50 yr^{1}. The optimized growth curve was superimposed on the restructured length-frequency histograms (*Fig. 5*). The calculated value for the growth performance index (φ') of *A. intermedius* during the present investigation was 3.26. This value

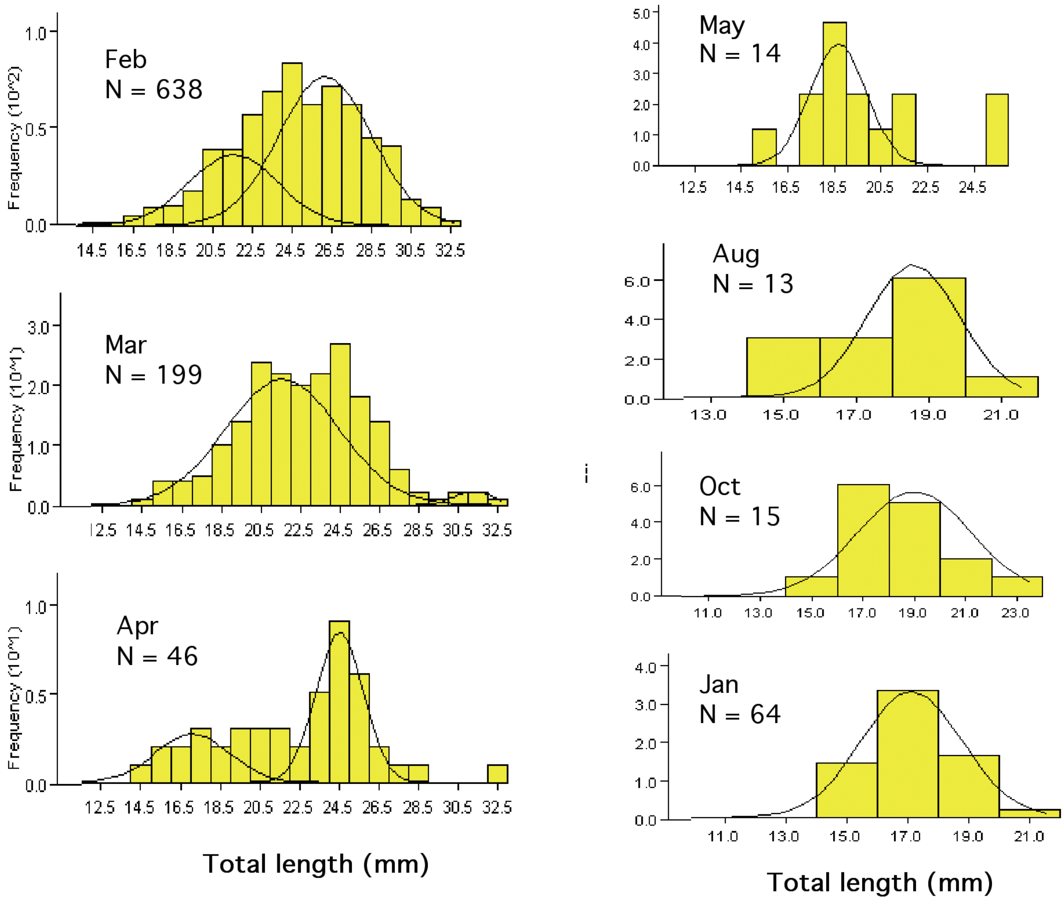

Fig. 2: Monthly length frequency distributions of A. intermedius *caught between February 2005 and January 2006 in the coastal waters of Malacca*

TABLE 1
Identified age groups from the length-frequency analysis of *A. intermedius* during the monthly sampling (Feb 05 - Jan 06), using Bhattacharya's method

Months	Mean TL (mm) of age group	SD (mm)	SI
Febuary-05	19.11	1.79	-
	25.02	2.62	2.14
March	21.92	2.73	-
	30.93	1.26	2.41
April	18.00	2.80	-
	24.83	1.99	2.20
May	19.06	2.40	-
August	19.03	1.27	-
October	19.00	2.21	-
January-06	17.12	1.65	-

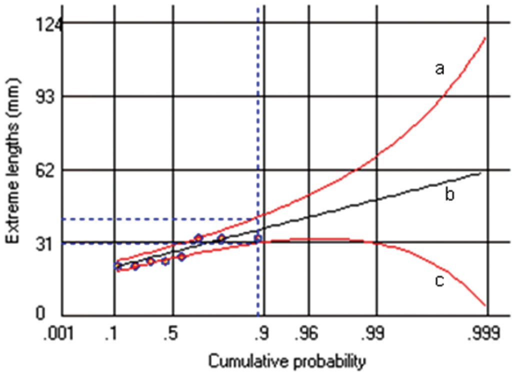

Fig. 3: Predicted maximum length of A. intermedius *based on extreme value theory (Formacion et al., 1991). The predicted maximum length value and the 95% confidence interval is obtained from the intersection of overall maximum length with the line b and a, c respectively*

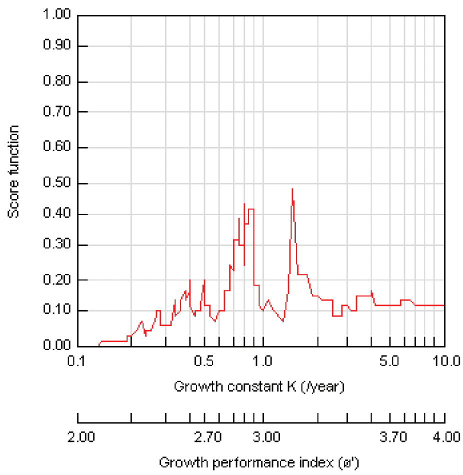

Fig. 4: Estimation of K for A. intermedius *by employing ELEFAN-I*

was close to the (φ/-values recorded in the literature (Zafar *et al.*, 1997; Zafar and Amin, 2002) but slightly higher than the value recorded by Oh and Jeong (2003). Using the estimated value of the growth coefficient (K= 1.5 yr^{-1}), the longevity (t_{max} = 3/K) was calculated as 2 years.

Mortality and Exploitation Rate

Total mortality coefficient (Z) was estimated as 4.15 yr^{-1} using length converted catch curve (*Fig. 6a*) while the Jones and van Zalinge method (*Fig. 6b*) gave a value of Z = 3.50 yr^{-1}. Natural mortality (M) was estimated at 2.35 yr^{-1}. Base on Z from length converted catch curve, fishing mortality (F) was found to be 1.81 yr^{-1} (Table 2). From these figures, an exploitation rate (E) of 0.43 which was obtained for the *A. intermedius* fishery in the coastal waters of Malacca, Peninsular Malaysia seemed to be below 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. 7*). The value obtained was $L_{50\%}$ = 15.29 mm from the analysis of probability of capture. The length at which 25% and 75% of the shrimps are retained in the gear was estimated as $L_{25\%}$ = 13.19 mm and $L_{75\%}$ = 17.31 mm.

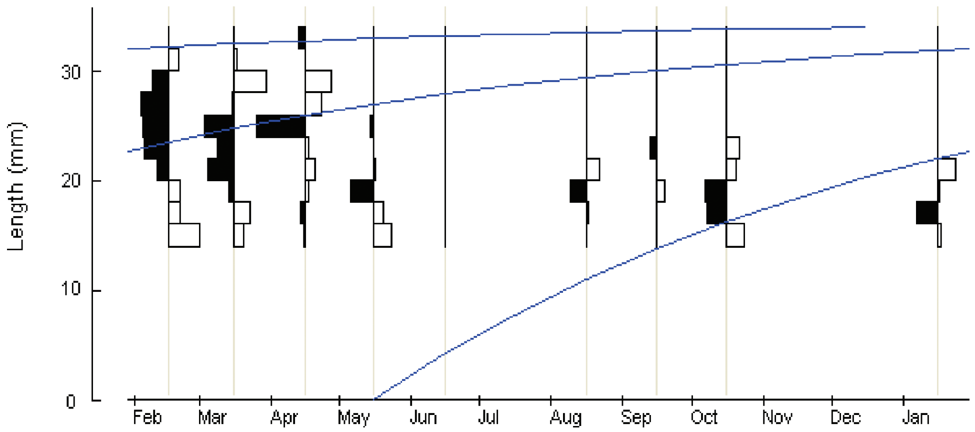

Fig. 5: von Bertalanffy growth curves (L_α = 34.65 mm and K = 1.50 yr^{1}) for A. intermedius *superimposed on the restructured length-frequency histograms. The black and white bars are positive and negative deviation from the "weighted" moving average of three length classes and they represent psedo-cohorts*

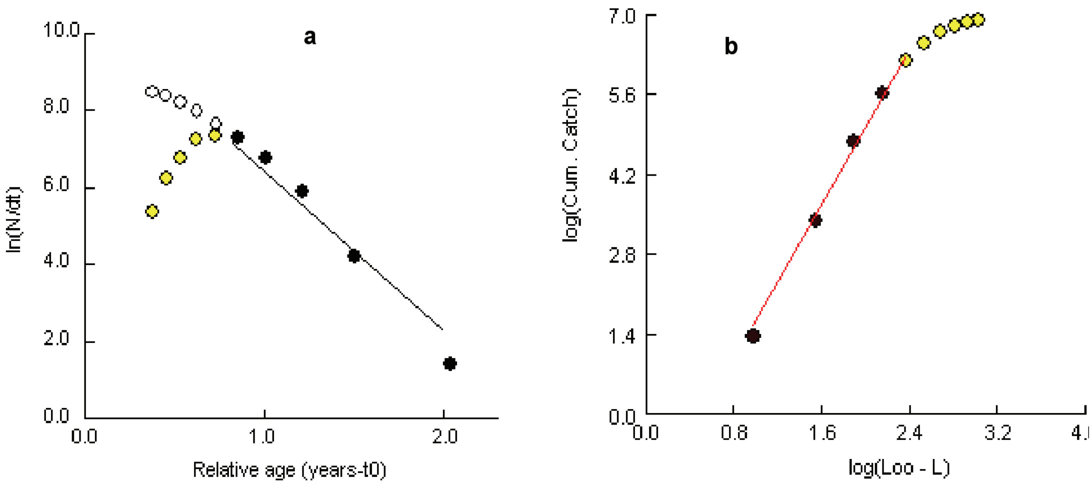

Fig. 6 (a & b): Length converted catch curve (a), the darkened full dots represent the points used in calculating through least square linear regression and the open dots represent the point either not fully recruited or nearing to L_α ; Jones and van Zalinge plot (b) for the estimation of total mortality (Z) of A. intermedius

Recruitment Pattern

The recruitment pattern of *A. intermedius* was continuous throughout the year with one major peak (*Fig. 8*). The percent recruitment varied from 0.73% to 19.01% during the study period. The highest recruitment peak occurred between June and August. The highest and lowest percent recruitment was observed in the months of July and February respectively (*Fig. 8*).

Virtual Population Analysis

Virtual population analysis (VPA) performed on *A. intermedius* indicated that (*Fig. 9*) the minimum and maximum fishing mortalities were recorded for the mid lengths 0.06 yr^{-1} and 2.79 y^{r-1} respectively. The fishing mortality (F) was comparatively high over the mid lengths between 23 mm and 31 mm. This increase is a reflection of recruitment over this length range rather

TABLE 2
Population parameters of *A. intermedius* in the coastal waters of Malacca, Malaysia

Population parameters	*A. intermedius*
Asymptotic length (L_{α}) in mm	34.65
Asymptotic weight (W_{α}) in mg	211.21
Growth co-efficient (K yr^{-1})	1.50
Growth performance index (φ')	3.25
Natural mortality (M yr^{-1})	2.35
Fishing mortality (F yr^{-1})	1.81
Total mortality (Z yr^{-1})	4.15
Exploitation level (E)	0.43
Allowable limit of exploitation (E_{max})	0.65
Sample number (N)	995

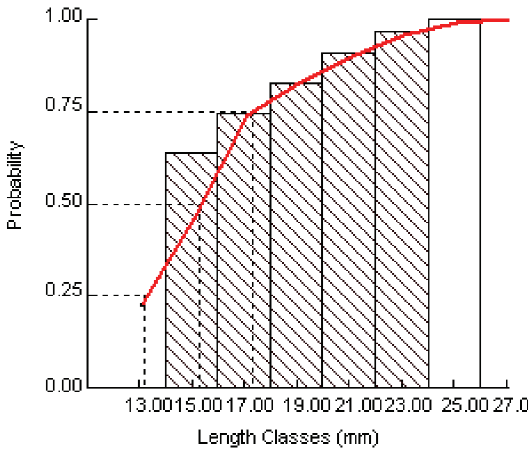

Fig. 7: Probability of capture of each length class of the A. intermedius *(L25% = 13.19 mm, L50% or Lc = 15.29 mm and L75% = 17.31 mm)*

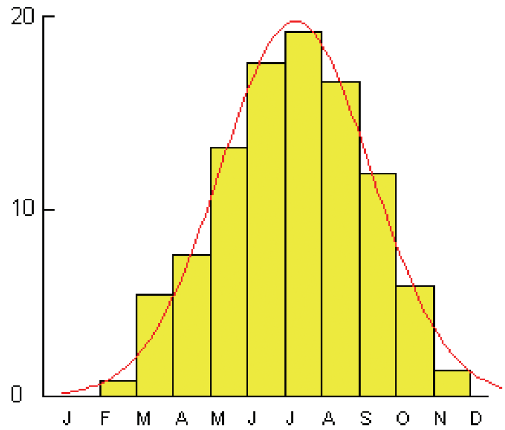

Fig. 8: Recruitment pattern of A. intermedius *in the coastal waters of Malacca, indicating one major peak pulse per year*

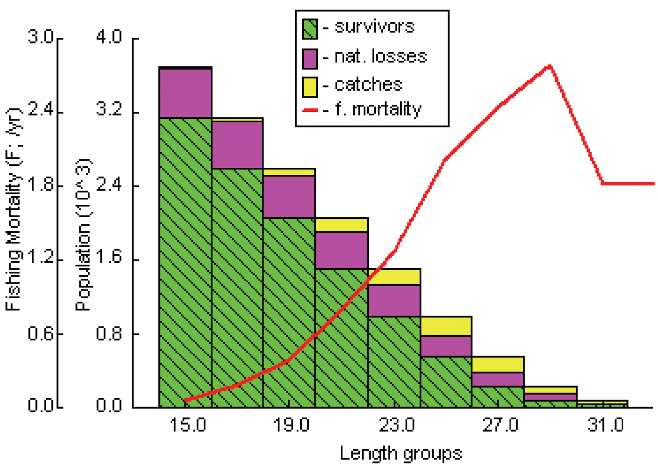

Fig. 9: Length based virtual population analysis of A. intermedius *in the coastal waters of Malacca, Peninsular Malaysia*

TABLE 3
Growth parameters ($L\infty$ and K) and computed growth performance index (φ') of the genus *Acetes* from different tropical countries

Location	Species	L_α (mm)	K yr^{-1}	φ'	E	T (^{0}c)	Source
Malaysia	*A. intermedius*	34.65 TL	1.50	3.25	0.43	310C	Present study
Bangladesh	*A. indicus*	31.00 TL	1.70	3.22	0.22	280C	Zafar *et al.* (1997)
Bangladesh	*A. erythraeus*	37.00 TL	1.20	3.21	0.24	280C	Zafar *et al.* (2002)
Bangladesh	*A. chinensis*	40.00 TL	1.60	3.40	0.21	280C	Zafar *et al.* (1998)
Korea	*A. chinensis* (F)	13.51 CL	0.69	2.10	-	-	Oh and Jeong (2003)
Korea	*A. chinensis* (M)	10.48 CL	0.84	1.97	-	-	Oh and Jeong (2003)

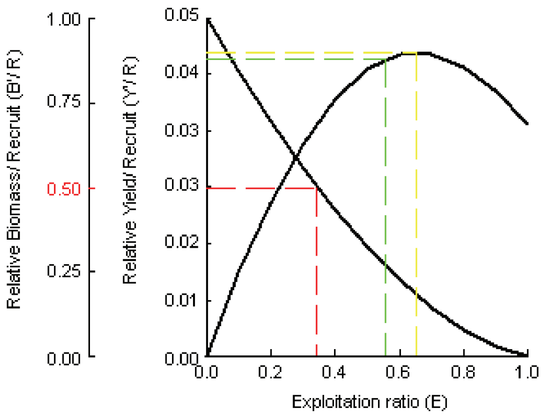

Fig.10: Relative Y/R and B/R of A. intermedius *using knife-edge procedure in the coastal waters of Malacca, Peninsular Malaysia*

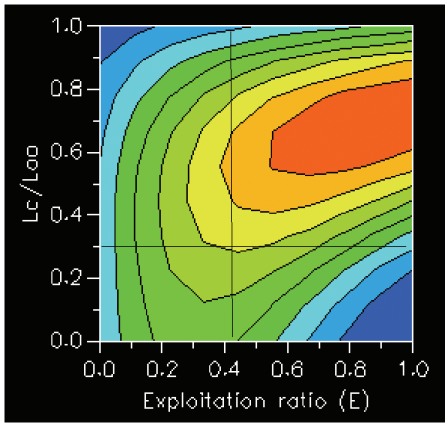

Fig. 11: Yield isopleths for the A. intermedius *in the coastal waters of Malacca, Peninsular Malaysia*

than increased efficiency of the gear with length. F reached a maximum of 2.79 y^{r-1} at 29 mm with an average value of 1.35 y^{r-1}.

Relative Yield Per Recruit and Biomass Per Recruit

The relative Y/R and B/R analysis of *A. intermedius* were computed using knife-edge procedure assumes. The maximum allowable limit of exploitation level (E_{max}) that gives the maximum relative yield-per-recruit was estimated at 0.65 (*Fig. 10*). $E_{0.1}$, 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 0.56. The exploitation level ($E_{0.5}$) which corresponds to 50% of the relative biomass per recruit of the unexploited stock was 0.34. The response of the yield per recruit of the *A. intermedius* in the coastal waters of Malacca was demonstrated using yield isopleths (*Fig. 11*) to both variation in $L_{50\%}$ and fishing pressure as indicated by the exploitation rate E over a wide range of both parameters.

DISCUSSION

The estimated asymptotic length (L_α) is 34.65 mm and VBGF growth co-efficient (K) is 1.50 yr^{-1} for the present study of *A. intermedius*. Comparisons with population parameters obtained in other studies (Table 3) show that differences exist for different species of the genus *Acetes* from different areas in the world. The highest value of L_α(40.0 mm) for *A. chinensis* (Zafar *et al.*, 1998) and the lowest value (31.0 mm) for *A. indicus* (Zafar *et al.*, 1997) are reported from Bangladesh. The highest (1.70yr^{-1}) value of K is observed in Bangladesh (Zafar *et al.*, 1997) and lowest value of K (0.69 yr^{-1}) is observed in Korean waters (Oh and Jeong, 2003) for *A. indicus*. It is observed that the present K value of *A. intermedius* is very close to *A. chinensis* of Bangladesh waters (Table 3). The index of phi prime by Munro and Pauly (1983) is suitable for comparing and computing the overall growth performance of different species of fish/shrimps stock. The phi prime for this species with the present estimates of L_α and K is 3.25 whereas the phi prime values were 3.22 and 3.21 for *A. indicus* (Zafar *et al.*, 1997) and *A. erythraeus* (Zafar *et al.*, 2002) respectively. Though phi prime is supported to be more or less constant for a family or for similar taxa, the range here (Table 3) is low except the report of Oh and Jeong (2003). The estimated longevity (t_{max}) for *A. intermedius* is almost 2 years of age, indicating that it is short-lived.

Total mortality (Z) estimated by length converted catch curve here for *A. intermedius* (4.15 yr^{-1}) in the coastal waters of Malacca is close to the value (3.93 yr^{-1}) obtained by Oh and Jeong (2003) in the western coast of Korea but it is much lower than the value estimated (6.07 yr^{-1}) from Bangladesh coast (Zafar *et al.*, 1997). Higher natural mortality (2.35 yr^{-1}) verses the fishing mortality (1.81 yr^{-1}) observed for *A. intermedius* in the present study (Table 2) indicate the unbalanced position in the stock. Exploitation level (E) was computed as 0.43 indicating that the fishery of *A. intermedius* in the coastal waters of Malacca is under 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 (Gulland, 1971).

This study indicated that the recruitment pattern of *A. intermedius* is a continuous with one main recruitment event per year (*Fig. 8*), i.e. one major cohort is produced per year. But Oh and Jeong (2003) and Zafar *et al.* (1997) reported two recruitment peaks per year for the *A. chinensis*. There is no published report on recruitment of *A. intermedius* 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, 1974). In this study, it is observed that the major spawning occurs in the months of May-June (*Fig. 5*) in the coastal waters of Malacca which follow the southwest monsoon (June -July-August).

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 0.65, compares well with the exploitation rate (E) of 0.43 established for *A. intermedius* in this study, and approximates to the 0.50 optimum level of exploitation reported by Gulland (1971). This is a further indication that the fishery is below optimal exploitation. However, the exploitation rate of the fishery (0.43) is also below the more conservative yield concept ($E_{0.1}$ = 0.55), where the marginal increase in relative yield-per-recruit is 10% of its value at E = 0. This reveals that the fishery is probably being under 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 below the level of optimum based on the $E_{0.1}$ principle. Thus, the fishing pressure on the stock is not excessive. More yields could be obtained by a reasonable increase in the effort (*Fig. 11*) without necessarily leading to over exploitation.

Based on the critical size ratio (L_c/L_α) (which is a proxy to mesh size) and current exploitation ratio (E) (which is a proxy to effort), Pauly and Soriano (1986) have shown that the relative yield isopleths could be grouped into four categories (or quadrants) each with its distinct properties. With L_c/L_α = 0.44 and E = 0.43, our yield isopleths of *Fig. 11* falls into quadrant B. This means that in terms of relative yield-per-recruit, the fishing regime for *A. intermedius* in the coastal waters of Malacca is eumetric, at a developing stage and the small shrimps are caught at a low effort. Everything remaining the same, this situation does not warrant management intervention. However, since open-access fisheries, as in the coast of Malacca, stand the risk of over-capitalization (or over-exploitation), then the critical size ratio (L_c/L_α) should be increased whenever it is necessary to increase the effort.

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