# Population Dynamics of the Jinga Prawn, *Metapenaeus affinis* (H. Milne Edwards, 1837), in Terengganu Waters, East Coast of Peninsular Malaysia

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*Abstract.* - Growth parameters of *Metapenaeus affinis* or Jinga prawn were estimated based on modal progression analysis of length frequency distributions. Estimates of growth parameters were K = 0.86 - 0.91 year $^{-1}$, $L_\infty$ = 4.75 - 4.80 cm (carapace length) for female, and K = 0.81 year $^{-1}$ and $L_\infty$ = 3.95 - 4.10 cm (carapace length) for male. Estimates of total mortality (Z) using the two different growth parameters were 3.31 - 3.98 for females and 4.42 - 4.92 for males. Based on the values of mortality, the exploitation rates were found to be in the range of 0.18 - 0.32 for females and 0.39 - 0.50 for males, with a mean value of 0.36 for both sexes. Considering $E_{0.1}$ as a management guideline for the overall stock of *M. affinis* (semi-resident and migrant stock) off Terengganu waters, relative yield per recruit was estimated to reach the optimum when E = 1 for both sexes. This indicated that the exploitation rate of this species is still under the optimum level.

**Keywords:** *Metapenaeus affinis*, population dynamics, prawn fishery, Terengganu waters, Malaysia.

*Abstrak.* - Parameter tumbesaran *Metapenaeus affinis* atau udang merah ros telah dianggarkan berdasarkan analisis modal progresion dengan menggunakan taburan frekuensi kepanjangan. Parameter tumbesaran yang dianggarkan ialah K = 0.86 - 0.91 tahun $^{-1}$, $L_\infty$ = 4.75 - 4.80 cm (panjang karapas) bagi udang betina, dan K = 0.81 tahun $^{-1}$ dan $L_\infty$ = 3.95 - 4.10 cm (panjang karapas) bagi udang jantan. Anggaran jumlah kematian (Z) dengan menggunakan dua parameter tumbesaran yang berbeza adalah 3.31 - 3.98 bagi udang betina dan 4.42 - 4.92 bagi udang jantan. Berdasarkan anggaran nilai kematian, kadar eksploitasi adalah diantara 0.18 - 0.32 bagi udang betina dan 0.39 - 0.50 bagi udang jantan yang memberikan nilai purata 0.36 bagi kedua-dua jantina. Dengan menggunakan $E_{0.1}$ sebagai panduan pengurusan bagi keseluruhan stok *M. affinis* (stok berhijrah dan separa menetap) di perairan Terengganu, hasil relatif per rekruitmen dianggarkan mencapai paras optimum bila E = 1. Nilai ini menunjukkan kadar eksploitasi bagi spesies ini masih di bawah paras optimum.

## Introduction

*Metapenaeus affinis* or Jinga prawn is one of the important species of penaeid prawn in Malaysia. The species is mainly found on muddy or sandy-mud bottom from inshore to offshore waters with depth of less than 55 meters (Carpenter and Niem, 1998). The main gear used to exploit this resource is the trawl. It was estimated that more than 30% of the overall prawn landing in most parts of Peninsular Malaysia consisted of this species. Abdul Hamid and Syed Abdullah (1992) estimated nearly 53% of the Terengganu annual prawn landings in the early 1990s comprised of *M. affinis*.

Although *M. affinis* is important, little is still known about their population dynamics. Indeed, the landing statistics of this species were recorded to include the catch of other congeners.

To date only a few prawn resource surveys on the east coast of Peninsular Malaysia have been undertaken, and thus the information on penaeid prawn stock such as *M. affinis* is still lacking.

To be able to estimate the effect of fishing on this resource, more information on the parameters associated with their populations dynamics is needed. A study was thus conducted to estimate growth parameters, mortality and the exploitation rate of *M. affinis*. Relative yield per recruit estimates of this species were also made. The outcome of this study can provide useful information for the development of a prawn fishery management scheme in the east coast of Peninsular Malaysia.

## Materials and Methods

*Sampling procedure*

A commercial trawl was employed in monthly surveys to collect prawn samples. One to two days sampling surveys were conducted in the inshore water (of less than 5 nautical miles from the shore) between Kuala Terengganu river estuary and Kuala Ibai, for a 13-month period from February 1994 to February 1995. This area is known as one of the main fishing grounds for penaeid prawns during the north-east monsoon.

*Length and weight measurement*

Prawn samples were sorted into male and female before they were measured (cm) and weighed (g) individually. The carapace length, a distance from inside of the eye socket to the posterior margin of the carapace (FAO, 1981) was measured using an electronic caliper. The total length, a distance from tip of rostrum to tip of telson, was also recorded for comparison purposes. Generally, a 0.2 cm class interval was used in building the monthly length frequency distributions to show better segregation between the age groups.

*Growth parameters*

The growth parameters of this species were estimated primarily by analyzing the length frequency distributions of the monthly samples. The prawn's growth pattern was assumed to follow the von Bertalanffy growth curve (Garcia and Le Reste, 1981; Sparre and Venema, 1992), which is expressed as:

$$l_{(t)} = L_\infty (1 - e^{-K(t-t_0)})$$

where, $l_{(t)}$ = Length at age t
$L_\infty$ = The asymptotic length
$K$ = Curvature parameter (parameter expressing the rate at which $L_\infty$ is reached)
$t_0$ = Theoretical age at which the size of prawn is zero

In this study, two kinds of relationships were examined using both graphical methods of Bhattacharya (1967) and the ELEFAN that is incorporated in the FiSAT program (Gayanilo *et al.*, 1996). These methods were used to obtain estimates of mean length-at-age and age composition from length frequency distribution of the samples. The Bhattacharya method (1967) incorporated in the FiSAT program was employed to split the major cohorts from the mixture of length-frequency distributions, and also to estimate the mean length of each cohorts (Sparre and Venema, 1992).

The growth parameters, K and $L_\infty$, were then estimated by employing Modal Progression Analysis from the Gulland and Holt (1959) plot method and also from iterative procedures using ELEFAN in the FiSAT program.

*Total mortality rates*

The total instantaneous mortality rate (Z) of *M. affinis* was estimated by employing the catch curve method using length-frequency data (Gulland, 1983; Pauly *et al.*, 1984; Spare and Venema, 1992) that is incorporated in the FiSAT program. For comparison, Z parameters were also estimated from the Beverton and Holt (1957) method.

*Natural mortality rates*

In this study, the natural mortality (M) rate was estimated using the empirical approach described by Pauly *et al.* (1984). The average sea water temperature used was 27°C (FAO, 1994).

*Exploitation rate*

After obtaining the fishing mortality (F=Z-M), the exploitation rate (E) was estimated from the equation $E = F/Z$. The assessment of whether a stock is lightly ($E < 0.5$) or heavily exploited ($E > 0.5$) was based on the assumption that a stock is optimally exploited when $F = M$ or $E = 0.5$ (Gulland, 1971).

*Recruitment*

The computation of the recruitment structure of this species was performed using the FiSAT computer program.

*Relative yield per-recruit*

The analysis of relative yield per recruit was based on the model developed by Beverton and Holt (1957), after modification by Pauly and Soriano (1986) and incorporated into the FiSAT computer program.

## Results

*Length-weight relationship*

The carapace length (cm) of females sampled in this study varied between 1.1 and 4.2 cm, while their weight ranged between 1.6 and 40.0 g. The carapace length (cm) of males ranged between 1.3 and 3.2 cm, while their weight varied between 2.1 and 22.0 g. The following length-weight relationships were obtained:

female $W = 1.0011\ L^{2.5349}$

male $W = 1.0522\ L^{2.5692}$

*Growth parameters*

*Modal Progression Analysis*

The monthly length-frequency distributions for *M. affinis* are shown in Tables 1 and 2. Sampling was unsuccessful in March 1994 due to bad weather. The mean length results from using Battacharya's method are shown in Figs. 1 and 2. An average length value was assumed to represent an age-length group or cohort. There are between one to four modes shown by both male and female of this species. The mean lengths of these modes are assumed to come from members of the same cohort, and are joint together to denote the approximate growth path of each cohort.

The growth path suggested that there was only one major cohort for the female population existing in the fishery during February 1994. This major cohort continuously contributed to the fishery till January 1995. The second and third cohorts in the female population appeared in April and June 1995. These cohorts were still in the fishery during the end of the sampling period in February 1995. Only one major cohort was evident for the male population, being quite distinct from April 1994 to February 1995.

Growth parameters for both sexes estimated using Gulland and Holt plots are shown in Figs. 3 and 4. The input data used for both sexes were growth increments data derived from monthly means of the growth path based on the Bhattacharya analysis. The growth parameters obtained for females were K = 0.91 year $^{-1}$ and $L_\infty$ = 4.75 cm (Fig. 3) while the growth parameters for males derived from this analysis were K = 0.81 year $^{-1}$ and $L_\infty$ = 3.95 cm (Fig. 4).

**Table 1 :** Monthly length-frequency distribution of female *M. affinis* from Terengganu waters

| **Mid-length** | **1994** | | | | | | | | | | **1995** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **(cm)** | **11/2** | **Mar** | **26/4** | **30/5** | **22/6** | **20/7** | **23/8** | **27/9** | **19/10** | **21/11** | **20/12** | **11/1** | **9/2** | **Total** |
| 0.9 | | | | | | | | | | | | | | |
| 1.1 | | | | | | 2 | | | | 1 | 1 | | | 4 |
| 1.3 | | | | | | 3 | 1 | 3 | 1 | 3 | 7 | | | 18 |
| 1.5 | | | 2 | | | 3 | 3 | 6 | 2 | 5 | 5 | | | 26 |
| 1.7 | 1 | | 9 | 2 | | 2 | 6 | 10 | 3 | 14 | 10 | | 1 | 58 |
| 1.9 | 11 | | 7 | 6 | | 1 | 2 | 12 | 5 | 21 | 16 | 11 | 4 | 96 |
| 2.1 | 25 | | 5 | 3 | 2 | 3 | 3 | 8 | 5 | 29 | 20 | 22 | 7 | 132 |
| 2.3 | 33 | | 4 | 2 | | 6 | 12 | 11 | 2 | 25 | 37 | 41 | 17 | 190 |
| 2.5 | 37 | | 3 | 1 | | 2 | 27 | 22 | 3 | 30 | 35 | 51 | 25 | 236 |
| 2.7 | 50 | | 3 | 4 | | 2 | 22 | 18 | 12 | 48 | 52 | 43 | 50 | 304 |
| 2.9 | 27 | | 6 | 5 | | | 18 | 14 | 56 | 32 | 74 | 25 | 28 | 234 |
| 3.1 | 13 | | 6 | 6 | | 2 | 13 | 12 | 2 | 20 | 71 | 30 | 30 | 205 |
| 3.3 | 17 | | 2 | 3 | | 2 | 5 | 7 | 1 | 25 | 48 | 27 | 20 | 157 |
| 3.5 | 17 | | 3 | | | | 7 | 10 | 1 | 16 | 24 | 15 | 10 | 103 |
| 3.7 | 12 | | | | | | 2 | 3 | | 29 | 10 | 12 | 2 | 70 |
| 3.9 | 5 | | | | | | 3 | | | 12 | 13 | 12 | 6 | 51 |
| 4.1 | 5 | | | | | | | | | 4 | 11 | 2 | 2 | 24 |
| 4.3 | | | | | | | | | | 2 | 2 | 2 | | 6 |
| **Total** | **253** | | **50** | **32** | **2** | **28** | **124** | **136** | **42** | **316** | **436** | **293** | **202** | **1,914** |

**Table 2 :** Monthly length-frequency distribution of male *M. affinis* from Terengganu waters

| Mid-length (cm) | 1994 | | | | | | | | | | 1995 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **11/2** | **Mar** | **26/4** | **30/5** | **22/6** | **20/7** | **23/8** | **27/9** | **19/10** | **21/11** | **20/12** | **11/1** | **9/2** | **Total** |
| 1.1 | | | | | | | | | | | | | | |
| 1.3 | | | 1 | | | | | | | | 2 | | | 3 |
| 1.5 | | | 3 | | | | | | | 4 | 2 | | | 9 |
| 1.7 | | | 3 | | | | | | | 10 | 14 | 1 | | 28 |
| 1.9 | 3 | | 14 | 1 | | 2 | | 2 | 1 | 26 | 33 | 8 | 1 | 81 |
| 2.1 | 18 | | 15 | 6 | | 4 | 5 | 5 | 1 | 49 | 29 | 35 | 11 | 178 |
| 2.3 | 41 | | 9 | 8 | | 5 | 17 | 16 | 5 | 72 | 57 | 55 | 34 | 319 |
| 2.5 | 42 | | 9 | 6 | 1 | 5 | 28 | 20 | 5 | 115 | 138 | 50 | 68 | 487 |
| 2.7 | 45 | | 1 | 3 | | | 9 | 1 | 1 | 52 | 90 | 50 | 48 | 300 |
| 2.9 | 41 | | | | | | | | | 7 | 51 | 25 | 19 | 143 |
| 3.1 | 1 | | | | | | | 1 | | 1 | 13 | 7 | 3 | 26 |
| 3.3 | | | | | | | | | | | 3 | | | 3 |
| 3.5 | | | | | | | | | | | | | | |
| **Total** | **191** | | **55** | **24** | **1** | **16** | **59** | **45** | **13** | **336** | **420** | **231** | **184** | **1,577** |

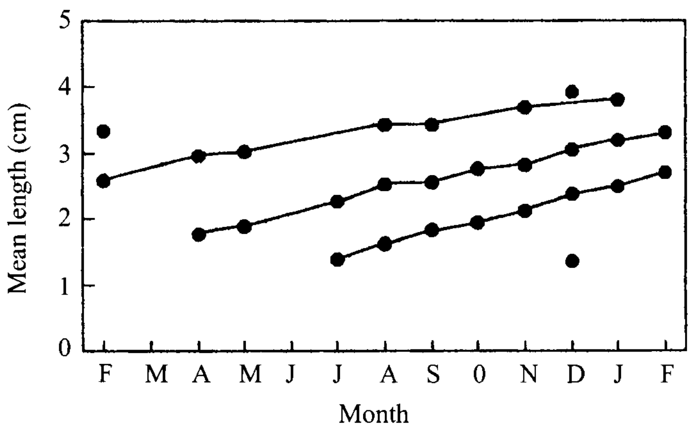


**Figure 1 :** Mean size of female *M. affinis* during successive month based on the results of Bhattacharya analysis

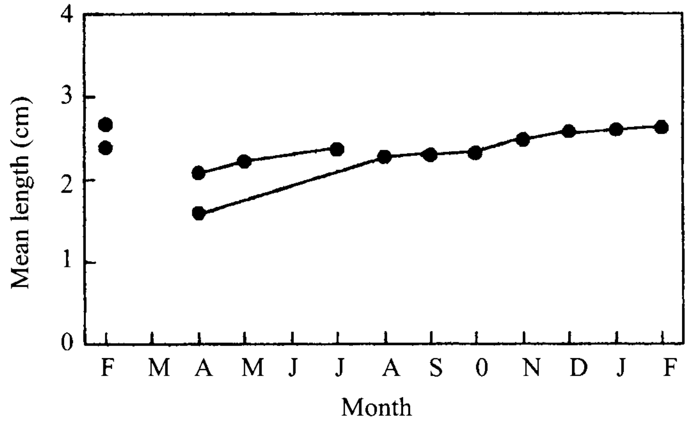


**Figure 2 :** Mean size of male *M. affinis* during successive month based on the results of Bhattacharya analysis

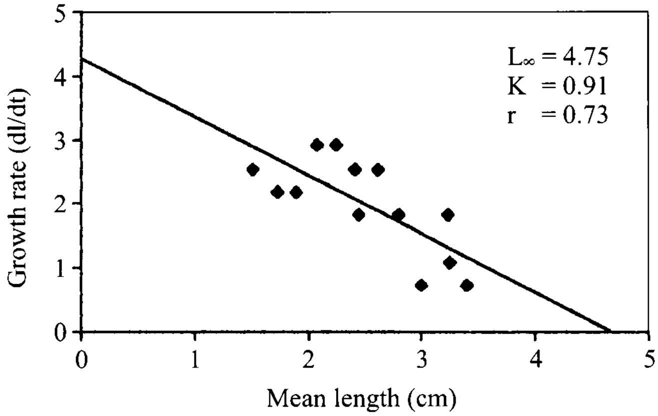


**Figure 3 :** Gulland and Holt plot for female *M. affinis*

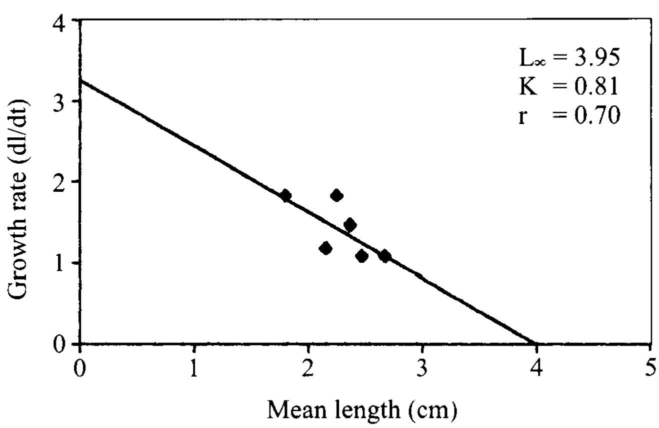


**Figure 4 :** Gulland and Holt plot for male *M. affinis*

*ELEFAN Program*

The greatest estimate of ESP/ASP or Rn value selected from the restructured length-frequency curve of female *M. affinis* was 0.20. This estimate corresponded to K = 0.86 year $^{-1}$ and $L_\infty$ = 4.80 cm. The greatest estimate of ESP/ASP value for male was 0.31, corresponding to estimates of K and $L_\infty$ of 0.81 year $^{-1}$ and 4.10 cm, respectively. The fitting growth curves for both sexes of *M. affinis* plotted against the length-frequency distribution derived from ELEFAN I are shown in Fig. 5. The female population has two major cohorts but only one major cohort for the male population. These results were similar to the Bhattacharya analysis output.

The estimates of $L_\infty$ derived from the above two methods were in terms of carapace length (CL) and the results are presented in Table 3.

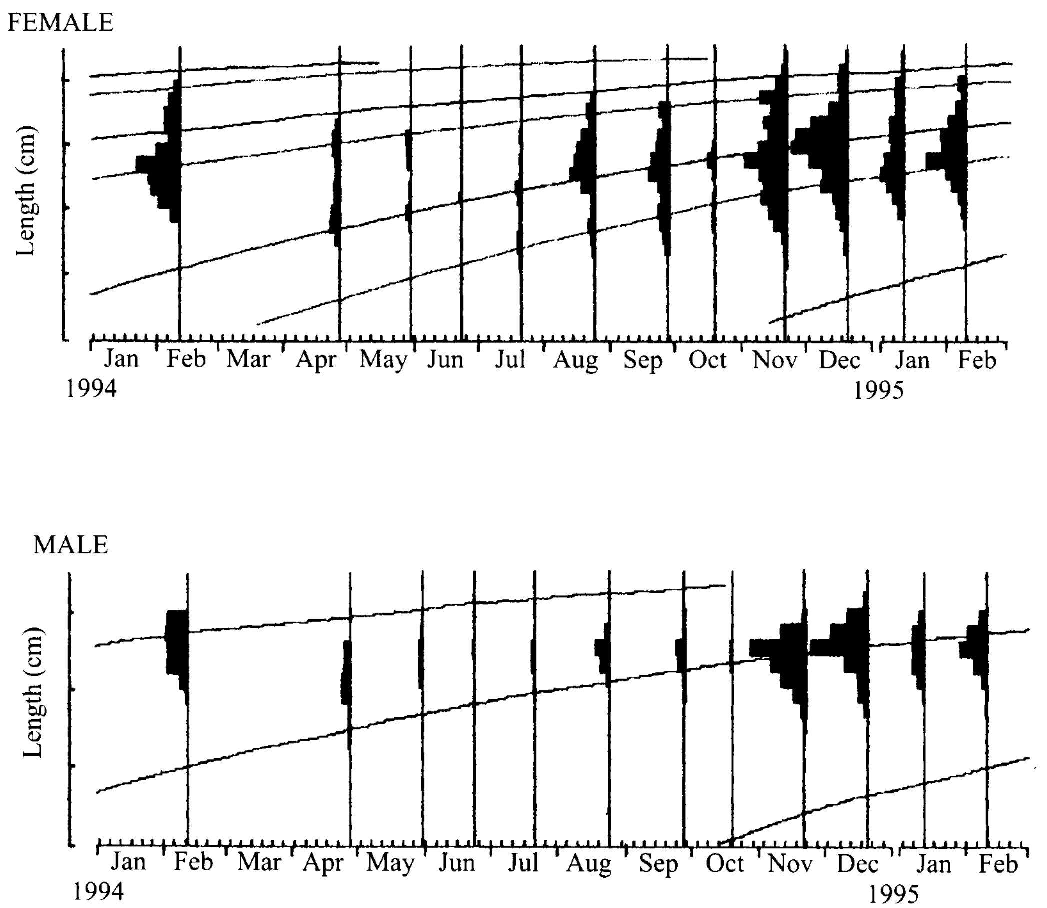


**Figure 5 :** Superimposed growth curves on length frequency distributions of female and male of *M. affinis* as fixed by FiSAT

**Table 3 :** The estimated growth parameters of *M. affinis* derived from length-frequency distributions

| Sex | Method | Growth Parameters K (year $^{-1}$) | Growth Parameters $L_\infty$ (cm) |
|---|---|---|---|
| Female | Gulland and Holt Plot | 0.91 | 4.75 |
| | ELEFAN | 0.86 | 4.80 |
| Male | Gulland and Holt Plot | 0.81 | 3.95 |
| | ELEFAN | 0.81 | 4.10 |

*Total mortality rates*

The estimates of total mortality rate (Z) for both sexes of *M. affinis* were derived from length-converted catch curve analysis and the Beverton and Holt model. The Beverton and Holt model requires the estimates of growth parameters as well as length at which all prawn of that length and longer are under full exploitation (L') and mean length ($\bar{x}$) of prawn of L' and longer. The lower limits (L') of carapace length under full exploitation were 2.6 cm and 2.4 cm for females and males, respectively. The mean sizes ($\bar{x}$) were 3.00 cm for females and 2.64 for males. Total mortality rate (Z) estimates for both sexes of *M. affinis* are shown in Table 4.

**Table 4 :** The estimated total mortality rates (Z) for *M. affinis* derived from analysis of catch curve and Beverton and Holt model

| Input data | Length-Converted Catch Curve | | Beverton and Holt Model | |
|---|---|---|---|---|
| | Female | Male | Female | Male |
| Gulland and Holt Plot | 3.35 | 4.75 | 3.98 | 4.42 |
| ELEFAN | 3.31 | 4.55 | 3.87 | 4.92 |

*Natural mortality rates*

The natural mortality rates (M) ranged from 2.65 to 2.76 for females, while that of males ranged from 2.66 to 2.69. The average value of M for both sexes of *M. affinis* was 2.69 year $^{-1}$.

*Exploitation rates*

The estimates of exploitation rate (E) ranged from 0.18 to 0.32 with the mean value of 0.26 for females, while for the males, this ranged from 0.39 to 0.50 with the mean value of 0.44. The mean value of exploitation rate (E) for both sexes was 0.36.

*Recruitment*

The recruitment pattern for both sexes of *M. affinis* given by the FiSAT program is shown in Fig. 6. Since $t_0$ is set to equal to zero, the time scale of the recruitment pattern was designated as a relative time of one year. This species showed two recruitment peaks per year. Two main spawning periods probably existed, the first was during early northeast monsoon (November – December), and the second was during late northeast monsoon (February-March).

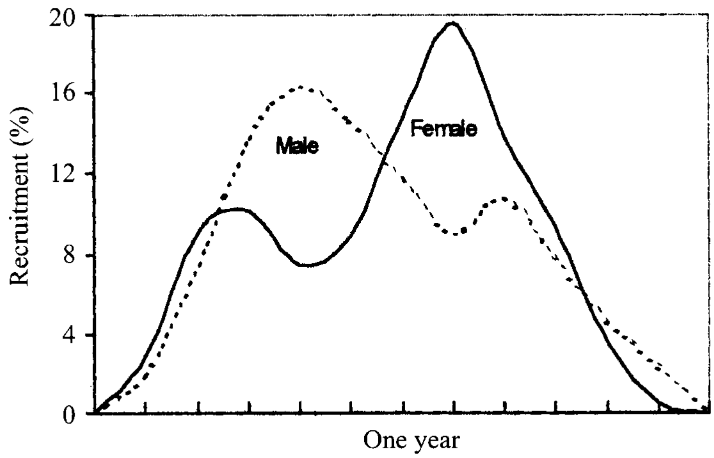


**Figure 6 :** Recruitment pattern of male and female *M. affinis*

*Relative yield per-recruit*

Employing different combination values of $L_\infty$, K, $L_c$ (mean length at first capture) and M, relative yield per recruit for both sexes of *M. affinis* was estimated, and the results shown in Table 5 and Fig. 7. The analysis showed $L_c$ at 2.43 cm for female and 2.20 cm for male, and provided values of $C = L_c/L_\infty$ at around 0.51 for female and 0.52 for male. By taking $E_{0.1}$ (exploitation rate at which the marginal increase of relative yield per recruit is 0.1 of its value at E = 0) as a management guideline, the relative yield per recruit reached an optimum level when the exploitation rate E = 1.

## Discussion

Penaeid prawn resources on the east coast of Peninsular Malaysia are believed to comprise of two parts: coastal semi-resident stocks that show seasonal variation in abundance throughout the year, and migrant stocks that appear within the inshore waters during the northeast monsoon period from November to March (Pathansali, 1976). During the northeast monsoon, for biological reasons, the migrant stocks migrate toward the more conducive inshore waters. Small trawlers (of less than 25 gross tonnage) are allowed to fish in the inshore waters during this period, which lead to higher prawn landings. When the northeast monsoon wind changes to become the southwest monsoon (May-September), the remaining migrant stocks migrate offshore and become less vulnerable to the inshore waters fishing gear.

**Table 5 :** The estimated relative yield per-recruit of *M. affinis* on combination values of $L_\infty$, K, $L_C$ and M

| | $L_c / L_\infty$ | M/K | $E_{max}$ | $E_{0.1}$ | $E_{0.5}$ |
|---|---|---|---|---|---|
| | 0.51 | | 1 | 1 | 0.38 |
| Female | 0.45 | 3.03 | 0.87 | 0.77 | 0.36 |
| | 0.35 | | 0.67 | 0.61 | 0.32 |
| | 0.52 | | 1 | 1 | 0.38 |
| Male | 0.45 | 3.30 | 0.92 | 0.81 | 0.36 |
| | 0.35 | | 0.69 | 0.62 | 0.32 |

Note : $L_c$ is 2.43 cm for female and 2.20 cm for male

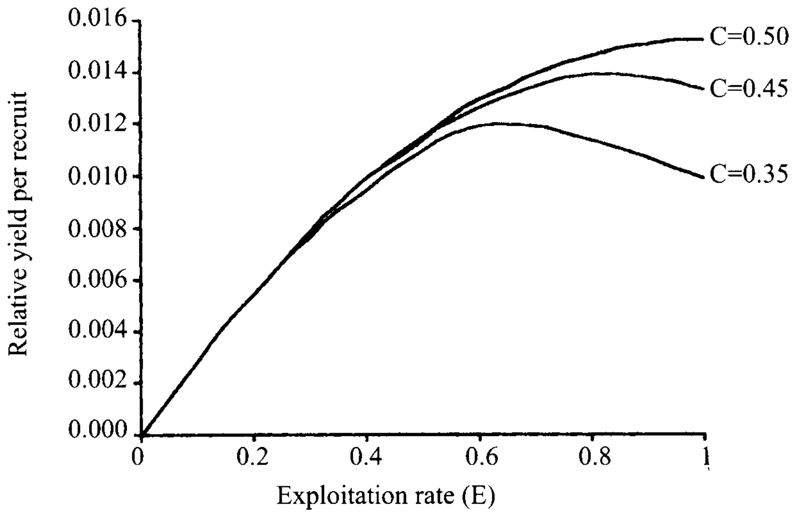


**Figure 7 :** Relative yield per recruit of *M. affinis* at different levels of C, ($C=L_\infty/L_c$) by employing M/K=3.03 for female and 3.30 for male

In the present study, estimation of growth parameters of *M. affinis* was based on length frequency samples taken from the inshore fishing grounds. Since this is a first attempt to study the population parameters of this species, the semi-resident and migrant stocks of *M. affinis* were treated as a single stock.

Two major cohorts of female and one cohort of male *M. affinis* population have been distinguished. The first cohort of the female population originated between October and November (early period of the northeast monsoon), while the second cohort originated between February and March (late period of the northeast monsoon). Only one cohort of male population can be distinguished to originate between October and November.

The recruitment of this species was probably related to the water movement of this region. There are now conjectures that during the northeast monsoon, prawn larvae may also have drifted down into the east coast waters via ocean currents from the north (*i.e.* from the Gulf of Thailand and Vietnam waters). The drifted juveniles mingle with those from the resident stock, and settle down during the transition period of April-May, when the wind-induced surface current is rather weak. They later grow continuously to form new recruits for the next prawn fishing season.

Using the methods of ELEFAN and Gulland-Holt, female *M. affinis* was shown to have a larger $L_\infty$ value than male, indicating sexual dimorphism of size in the species. The carapace length obtained were 4.75 to 4.80 for females and 3.95 to 4.10 for males. These results support earlier observations by other workers (Chua and Rajamanickam, 1978; Vibhasiri, 1988). Chua and Rajamanickam (1978) estimated the $L_\infty$ for female and male *M. affinis* from the west coast of Peninsular Malaysia at total lengths of 17.3 cm and 15.0 cm respectively. While in the Gulf of Thailand, Vibhasiri (1988), obtained the $L_\infty$ values of 17.4 cm for female and 15.0 cm for male.

The growths of female and male *M. affinis* were well described by the von Bertalanffy growth curve. Growth parameter, K, was estimated as 0.86-0.91 year $^{-1}$ for females, and 0.81 year $^{-1}$ for males. K estimates for both sexes from Gulland and Holt Plot and ELEFAN showed little variability, the difference being around 0.01 to 0.05. The obtained K values were consistent with those of Vibhasiri (1988), which were 0.84 year $^{-1}$ (female) and 0.85 year $^{-1}$ (male), suggesting the similarities of the stocks.

Estimation of total mortality rate for both sexes using the length-converted catch curve resulted in some lower values of Z compared to those obtained from using the Beverton and Holt model. This might be because Beverton and Holt (1959) model is best applied to long living and slow growing species (Gayanilo *et al.*, 1996) but had since been corrected by Ault and Ehrhardt (1991), and thus applicable to short-lived tropical species. The value of Z derived using this model is rather sensitive to the input parameters of $L_\infty$, K, cut-off length (L') and mean length (x).

In the present study the average value of M for both sexes of *M. affinis* was 2.69 year $^{-1}$. This obtained value was within the reported range for penaeid prawn, i.e. M value should probably be higher than 2.0 year $^{-1}$ (Cobb and Caddy, 1989). This value is however slightly lower than that obtained by Vibhasari (1988) in the Gulf of Thailand (*i.e.*, M = 3.0 year $^{-1}$). However, this M value is higher compared to the congener *Metapenaeus ensis* reported by Mohd Zaki (1991) (*i.e.* M = 2.0 year $^{-1}$).

Based on the mortality rates obtained, the ranges of exploitation rates were 0.19 - 0.32 and 0.40 - 0.46 for female and male, respectively. The overall average exploitation rate was 0.34. This value still did not exceed 0.5, suggesting the stock was lightly exploited. This is comparable to the exploitation rate (E = 0.41) of *M. ensis* as reported by Mohd Zaki (1991) for the east coast of Johor.

The chances of prawn mortality from natural causes before achieving its potential growth, as given by M/K (Gulland, 1983), are somewhat larger for this species. However, the moderate values of relative sizes at first capture (*i.e.* C = 0.51 for females and 0.52 for males) provided some buffering stability to the stock. These values however indicated that both sexes are fairly exploited.

Taking $E_{0.1}$ as a management guideline for *M. affinis*, the relative yield per recruit reaches an optimum level at E = 1. This suggests that the exploitation rate of this species was probably under optimum level. However, it should be borne in mind that the resource was a mixture of both semi-resident and migrant stocks, whereby significant changes in any of the vital elements will substantially affect the value of its yield per recruit.

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