J. Fish. Soc. Taiwan, **27**(4): 241-251

Estimates of Biological Parameters of Sword Prawn (*Parapenaeopsis hardwickii*) in the Adjacent Waters off Taichung Harbor

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(Received, August 17, 2000; Accepted, September 29, 2000)

ABSTRACT

Seasonal growth parameters, mortality rates and recruitment pattern of female sword prawn (*Parapenaeopsis hardwickii*) were estimated from a length-frequency data set with ELEFAN methods. The 6- month data set was collected from the adjacent waters off Taichung harbor between February and July 1992. Parameters of the von Bertalanffy growth equation with seasonal fluctuations obtained were: L_∞ = 39.0 mm carapace length, K = 1.1 (1/year), C = 0.95 and WP = 0.94 of year. The total mortality coefficient Z was 6.37 (1/year) estimated by seasonalized length-converted catch curve procedure. The average natural mortality coefficient M of 2.07 (1/year) was obtained from the empirical methods of Pauly (1980) and Srinath (1991). The fishing mortality coefficient F was 4.30 (1/year) (F = Z - M). The exploited rate E of 0.67 (F/Z) showed that the sword prawn population is over-exploited. The annual recruitment pattern obtained by back-projecting these length frequency samples onto an arbitrary one-year time axis showed that recruitments occur in two pulses of unequal strength. The longevity t_{max} of sword prawn is 2.74 years.

Key words: *Parapenaeopsis hardwickii, Growth parameters, Mortality, Recruitment pattern.*

INTRODUCTION

Reliable estimates of growth, mortality and other population parameters of exploited populations are essential for their proper assessment and management. Three kinds of data could be used to obtain the information of these parameters. They are (1) length at age data obtained by reading of growth marks on hard parts, (2) growth increment data obtained from mark-recapture experiment, and (3) length frequency data. Length frequency analysis may be currently the only method available and reliable for estimation of growth and mortality parameters of shrimp, since hard body-parts are lost during molting and tagging is not practicable (Baelde, 1994; Etim and Sankare, 1998).

Length frequency analysis may be classified into two groups: statistical decomposition, e.g., MIX (MacDonald and Green, 1985), MULTIFAN (Fournier *et al.*, 1990), and mode progression method, e.g., ELEFAN (Pauly *et al.*, 1984). The former is more statistically intense, providing more statistical detail and the latter is more ad hoc.

Although the growth of crustaceans is discontinuous during the molting period, the von Bertalanffy growth equation (VBGE) is still believed to be a reasonable approximation for Penaeidae (Parrack, 1979; Garcia and Le Reste, 1981; Fre'chette and Parsons, 1983). However, because the growth of shrimp is strongly affected by the temperature (Pauly *et al.*, 1984), suggestion has been made to incorporate

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seasonal fluctuation into the growth curve in order to produce a better description of shrimp growth (Hopkin and Nilssen, 1990).

The ELEFAN method is the most widely utilized procedure to estimate the shrimp population parameters. It also affords the following advantages: (1) it can analyze several length frequency data sets simultaneously; (2) it can fit the VBGE with seasonality; and (3) the model includes an index of the goodness of fit.

The sword prawn (*Parapenaeopsis hardwickii*) is one of the most abundant and economically valuable species among the catch of shrimps in the Taiwan Strait and the East China Sea (Wu, 1985). Study on growth of this species was done by Guo (1993), but several biological parameters, e.g., mortality, recruitment pattern, are still absent. Thus, the objectives of this paper are to estimate the growth parameters, mortality, recruitment pattern and exploitation rate of sword prawn population in the adjacent waters off Taichung harbor using ELEFAN methods based on length frequency data set.

MATERIALS AND METHODS

The specimens used in this study were collected monthly on board of a specific beam trawler operating around the adjacent waters off Taichung harbor (Fig. 1) from February to July 1992. The cod end mesh size of the beam trawler is 18 mm. A total of 6 samples was collected. Sex was identified and separated. Because the sample size of males was too few to analyze, only female data was used in this study. The total sample size is 1416. The carapace length of each prawn was measured to the nearest 0.1 mm. The total weight of each specimen was also recorded nearest 0.1 g to calculate the length-weight relationship. For some individuals, the total length was also measured to the nearest 1 mm. The range of carapace length in our case is between 8.5 and 33.5 mm. The carapace length is defined as from the post-orbital notch of the carapace to the mid-posterior dorsal margin. The total length is defined as from the tip of rostrum to the tip of telson. The carapace length data sets measured were grouped by interval of 1 mm, and then utilized to estimate the biological parameters of sword prawn.

The ELEFAN programs (Gayanilo *et al.*, 1995) were used to estimate biological parameters in this study. The VBGE with seasonality presented by Pauly and Gaschutz (1979) was used to describe shrimp growth. It takes the form

$$L_t = L_\infty(1-\exp(-K(t-t_0)-(CK/2\pi)\sin 2\pi(t-t_s)+(CK/2\pi)\sin 2\pi(t_0-t_s))$$

where L_∞ is the asymptotic length, K the von Bertalanffy growth coefficient, L_t the length at age t, C the amplitude of growth oscillation, t_0 the age of the shrimp at zero length, and t_s is the starting point of sinusoidal growth oscillation. In our computation, WP (winter point) is substituted for t_s such that WP = t_s + 0.5. WP is the time when growth is slowest.

Length-converted catch curve with seasonality (Pauly, 1990) and without seasonality (Pauly *et al.*, 1984) methods were used to estimate total mortality Z. The natural mortality coefficient M was estimated through the methods of Pauly (1980) and Srinath (1991). The Pauly's empirical equation is as follow:

$$\log M = -0.006 - 0.27\log TL_\infty + 0.654\log K + 0.463\log T,$$

where T is the mean water temperature of the habitant for sword prawn expressed in ℃, K is the growth rate per year, and TL_∞ is the asymptotic total length expressed in cm. The Srinath's formula is as follow:

$$M = 0.4603 + 1.4753*K.$$

The fishing mortality F was computed from F = Z - M, and the exploitation rate E was obtained from E = F/Z. Seasonal recruitment pattern of sword prawn was constructed by projecting the length-frequency data available backward onto the time axis (Pauly *et al.*, 1984; Pauly, 1987). We also estimated the longevity of

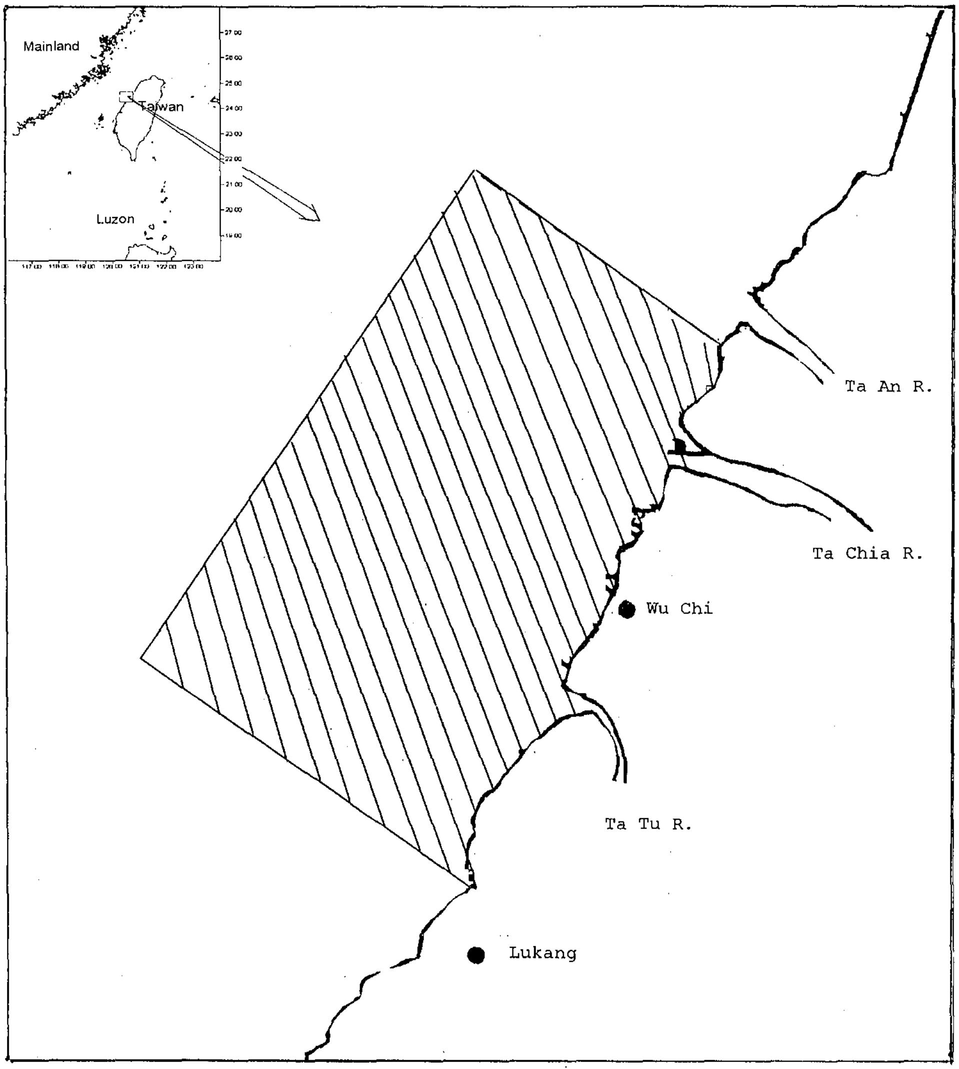

Fig. 1. Shadowed area showing the sampling area in the adjacent waters of Taichung harbor.

the sword prawn from the relationship $t_{max} \approx 3/k$ (Pauly, 1980).

RESULT

The relation between carapace length (CL in mm) and total length (TL in mm) of sword prawn is expressed by the linear equation: TL = a + b * CL. The result was shown below (Fig. 2):

$$TL = 20.2428 + 3.60047\ CL$$

The relationship between body weight (WT) and carapace length of sword prawn is expressed by the exponential equation: $WT = a\ CL^{b}$. The result was shown below (Fig. 3):

$$WT = 0.00227976\ CL^{2.748}$$

The VBGE with seasonal oscillation was used to describe the growth of sword prawn. The restructured data and the growth curve fitted by ELEFAN I was shown in Fig. 4. The parameters estimated

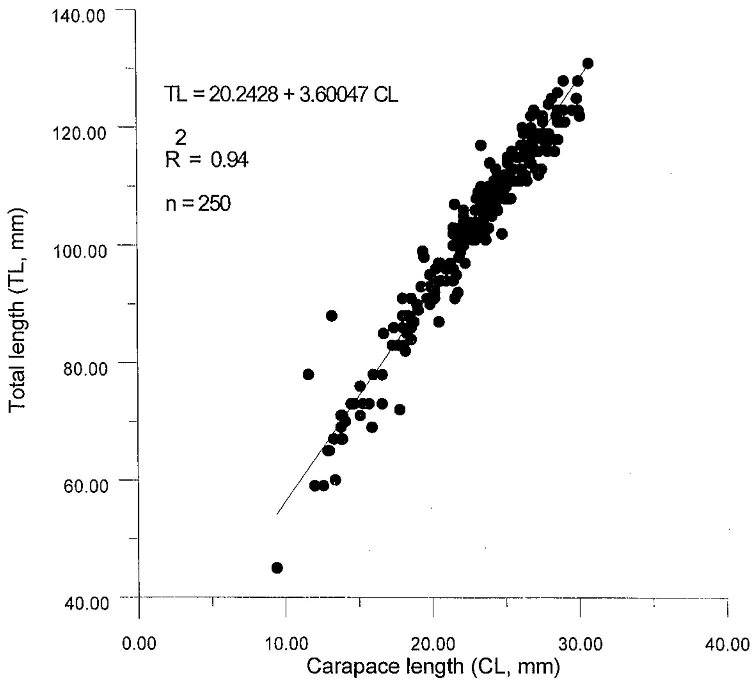

Fig. 2. Relationship between carapace length (CL) and total length (TL) of sword prawn.

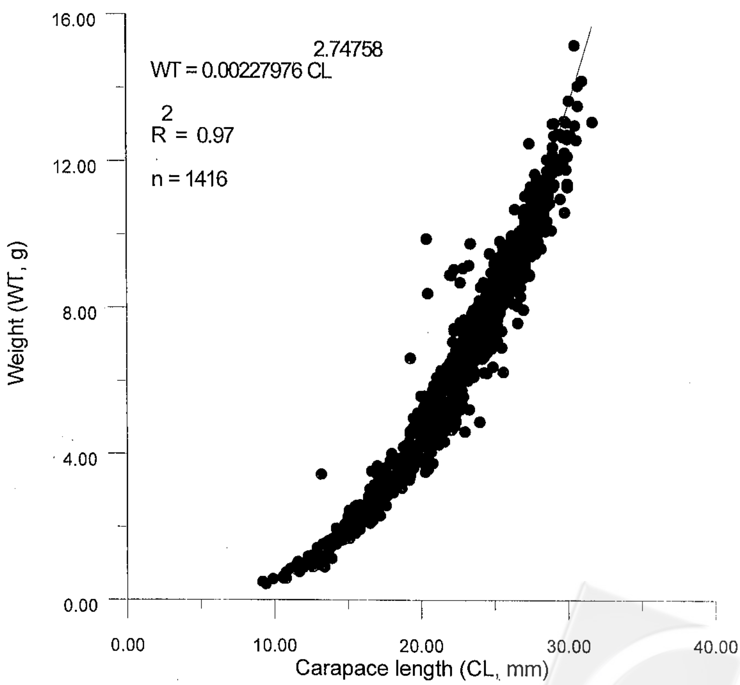

Fig. 3. Relationship between carapace length (CL) and weight (WT) of sword prawn.

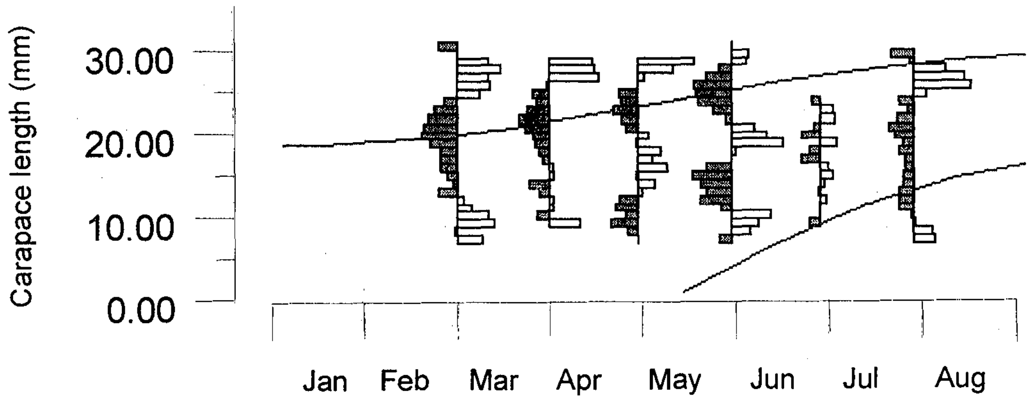

Fig. 4. Restructured length-frequency data and growth curve of sword prawn in the adjacent waters of Taichung harbor.

by this method are: L_∞ = 39 (mm) carapace length; K = 1.1 (1/year); C = 0.95; WP = 0.94 of year and t_s = 0.44 year. The value of t_0 was not estimated since the ELEFAN method is incapable of extracting t_0 from length-frequency data.

The length-converted catch curve with seasonality (Fig. 5) gave the Z value of 6.37 (1/year)(cutoff length = 24 mm). The length-converted catch curve without seasonality (Fig. 6) yielded the Z value of 7.171 (1/year)(cutoff length = 24 mm).

The habitant temperature of sword prawn in adjacent waters off Taichung harbor ranges from 19 ℃ to 28 ℃ (NCOR, 2000). The 23 ℃ was taken and used in the estimation of natural mortality. The asymptotic total length (TL_∞) calculated

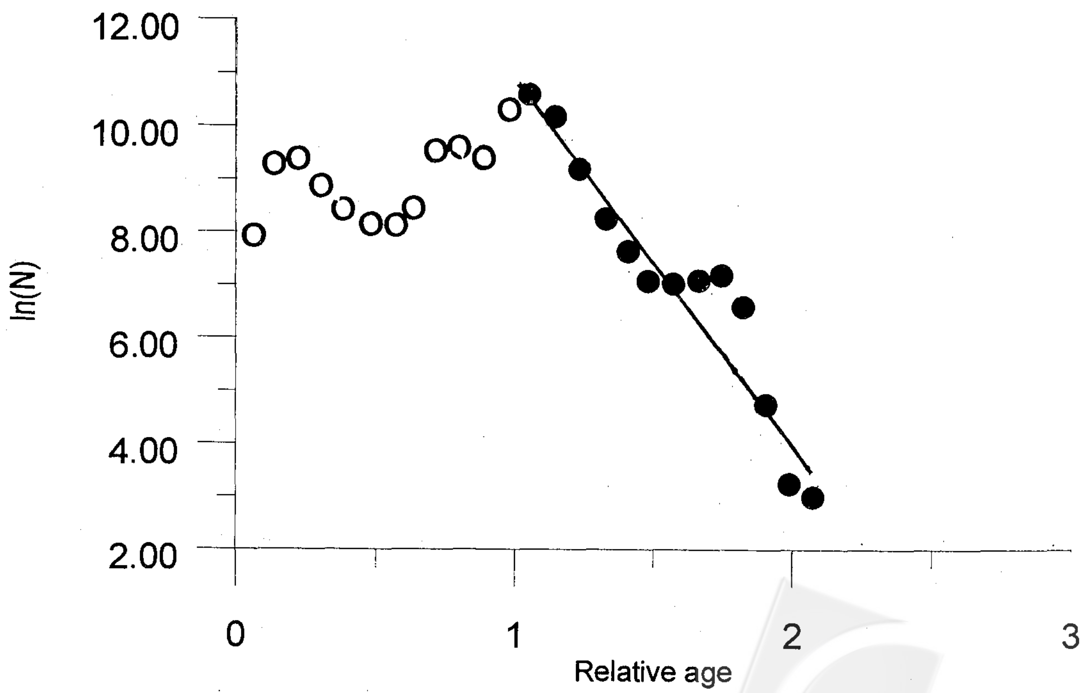

Fig. 5. Length-converted catch curve with seasonality of sword prawn in the adjacent waters of Taichung harbor. The slope of the right descending arm (block dots) of the curve with size changed give an estimate of seasonlized Z. Regression equation: Y=11.74-6.37X, r=-0.95.

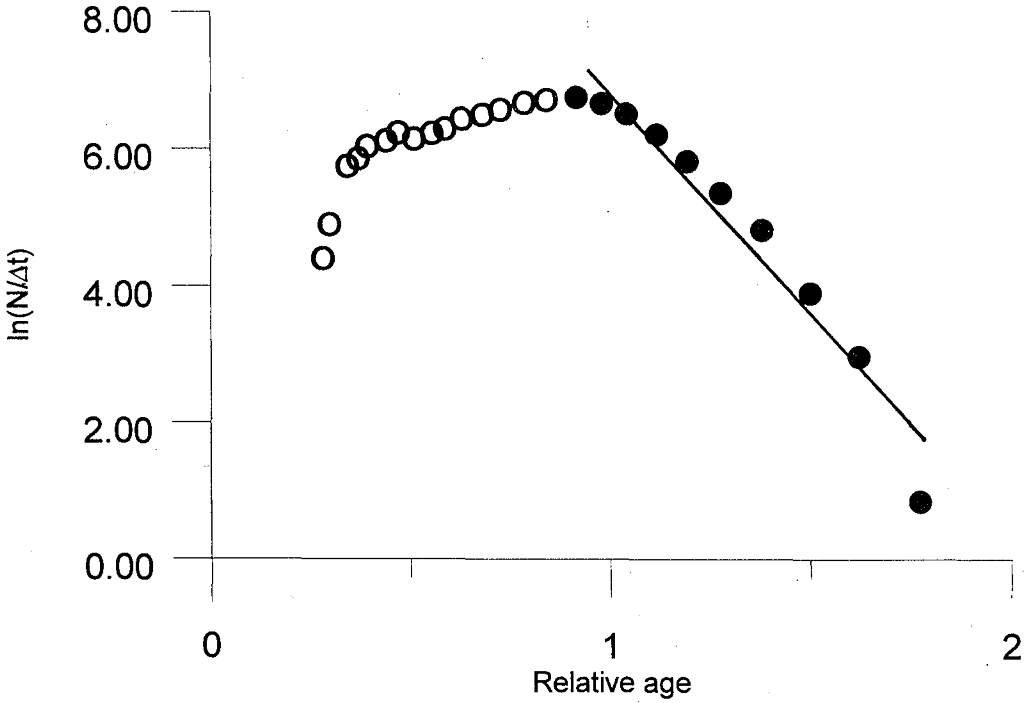

Fig. 6. Length-converted catch curve without seasonality of sword prawn in the adjacent waters of Taichung harbor. The slope of the right descending arm (block dots) of the curve with size changed give an estimate of seasonlized z without seasonality. Regression equation: Y= 13.84-7.17X, r=-0.97.

through the relationship between total length and carapace length was 16.066 (cm). Therefore, the value of M estimated from Pauly's method was 2.06 (1/year), but the one from Srinath's method was 2.08 (1/year). The average M (2.07) and Z with seasonality were used to estimate the fishing mortality. The fishing mortality coefficient F = 4.30 (1/year) was obtained through the relationship: F = Z - M. The exploited rate E was 0.67 (F/Z). The longevity t_{max} of sword shrimp is 2.74 years.

The value of t_0 used in the calculation was zero, so the exact time of recruitment cannot be determined. The recruitment of sword prawn occurs in two pulses of unequal strength (Fig. 7).

DISCUSSION

A basic requirement for the ELEFAN methods is that length-frequency distributions can accurately represent the distribution of population. However, discard of valueless smaller shrimps, gear selectivity and the occurrence of migration may strongly affect the representative of the samples, and may have much influence on estimating population parameters (Baelde, 1994). If smaller shrimps in growth analysis were missed, the estimate of L_∞ will ascend and K will drop. If larger shrimps in growth analysis were missed, the values of L_∞ will be underestimated and K will be overestimated (Tzeng and Yeh, 1995).

Because (1) all length frequency data sets used in this study were collected on board beam trawler instead of at the fish market, where smaller shrimps were discarded; (2) the total length ranges from 54.45 to 140.86 mm obtained in this study that almost contain the whole range of length (Yu and Chen, 1986); (3) the very small mesh size (18 mm) was used, and several authors have reported that there is

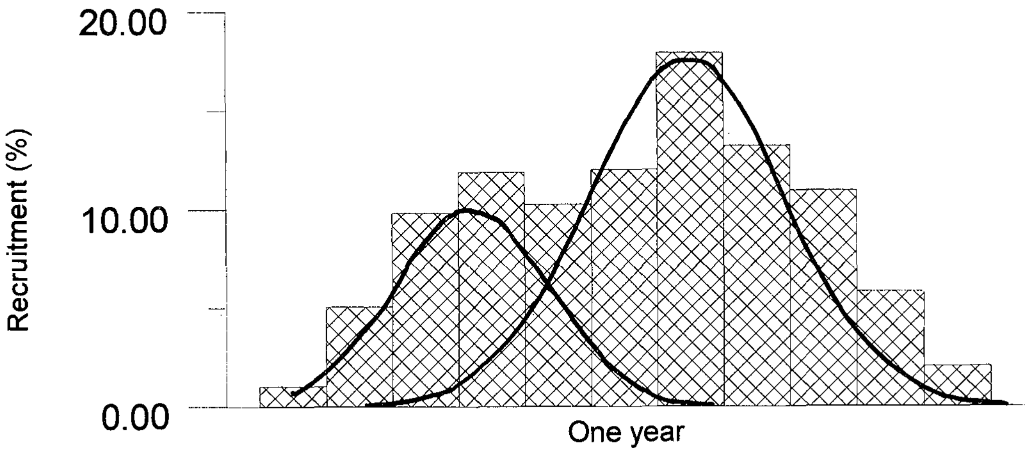

Fig. 7. Recruitment pattern of sword prawn in the adjacent waters of Taichung harbor.

hardly any mesh size selection for shrimp due to their shape (Garcia and Le Reste, 1981), we, therefore, believe that the length frequency data sets obtained in this study are a good representing of the population length composition.

To obtain more reliable estimates of population parameters using ELEFAN methods, several criteria should be also met. The length-frequency data should exhibit peaks with apparent shift in modal length over time (Wolf, 1989). The number of samples and the total number of specimens must be adequate. Hoenig *et al.* (1987) provides a scale of 0-5 on which the adequacy of samples could be judged. A total sample size of 1000 or more, gathered over a period of six months is very good. Our length-frequency data sets meet all these criteria. It displays clear modes that could be followed through time, and has a total sample size of 1416 individuals taken in a period of 6 consecutive months.

Growth seasonality is a well-known phenomenon for shrimps (Pauly *et al.*, 1984). If the seasonal variation do not include into the growth equation, the K would be overestimated and L_∞ would be underestimated (Tzeng and Yeh, 1995). Garcia (1988) has indicated that the seasonal growth equation proposed by Pauly and Gaschutz (1979) can properly describe the seasonal growth of shrimp. It contains an empirical constant C indicating the amplitude of growth oscillation, and another WP showing the time of the year when growth is slowest. The largest deviation of habitant temperature around the sampling area is about 9 ℃; this explained the high value of C (0.95).

The growth parameter k was estimated by Guo (1993) between 1.10 and 1.3 (1/year) in ELEFAN, and between 1.09 and 1.27 (1/year) in MULTIFAN, respectively. Our estimate of the growth parameter seems to be in reasonable agreement with the results given by Guo (1993) (Table 1). However, the fit to the restructured length frequencies is not very good, and obviously several peaks are left unexplained. That was possibly belonging to an extra cohort. Two recruitments occur during one year for sword prawn. This result also agrees with the finding of Guo (1993).

One would expect the length frequencies of the smaller shrimp to contain more reliable information on recruitment pattern than those of large shrimp. Two data sets were constructed to investigate the influences of missing smaller and larger individuals on the estimation of recruitment pattern. One contains the data omitting all shrimp of carapace length 24 mm (cutoff length) and above, but the other contains the data omitting all shrimp of carapace length 24 mm and less. The resultant recruitment patterns were shown in Fig. 8 and Fig. 9.

Table 1. Comparison of growth parameter K of sword prawn.

Sampling area	Sampling dtae	K (1/year)	Method	Author
southwestern coast of Taiwan	1987.11-1988.11	1.15	ELEFAN	Guo (1993)
southwestern coast of Taiwan	1989.3-1989.11	1.10	ELEFAN	Guo (1993)
southwestern coast of Taiwan	1990.2-1990.11	1.22	ELEFAN	Guo (1993)
southwestern coast of Taiwan	1991.1-1991.12	1.28	ELEFAN	Guo (1993)
southwestern coast of Taiwan	1992.1-1993.3	1.27	ELEFAN	Guo (1993)
southwestern coast of Taiwan	1987.11-1988.11	1.1105	MULTIFAN	Guo (1993)
southwestern coast of Taiwan	1988.3-1989.11	1.0875	MULTIFAN	Guo (1993)
southwestern coast of Taiwan	1990.2-1990.11	1.1100	MULTIFAN	Guo (1993)
southwestern coast of Taiwan	1991.1-1991.12	1.2500	MULTIFAN	Guo (1993)
southwestern coast of Taiwan	1992.1-1992.12	1.2500	MULTIFAN	Guo (1993)
Tiachung harbor	1992.2-1992.7	1.11	ELEFAN	Present

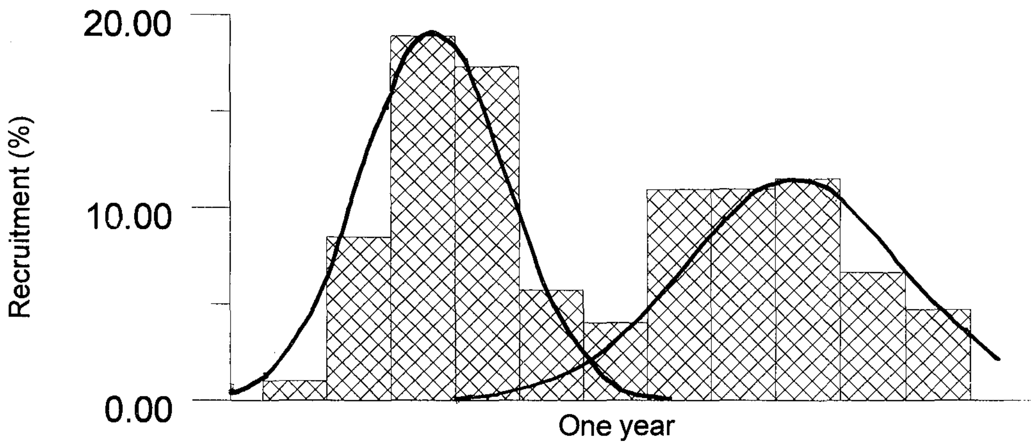

Fig. 8. Recruitment pattern of sword prawn in the adjacent waters of Taichung harbor but excluded all prawns of carapace length 24 mm above.

Two results are very similar. Comparing these with Fig. 7, we found that two peaks were more separate pronouncedly and the strengths of two modes were exchanged. This indicates that the ELEFAN II method of computing the recruitment pattern will be sensitive to the choice of the length-frequency distribution. Therefore, a good representing of the population length composition are also essential for constructing the recruitment pattern using ELEFAN II method.

Length-covered catch curve is feasible, assuming that total mortality is constant from some length upwards (24 mm carapace length in this study). This assumption could be violated by migration out of fishing ground or avoidance of trawl by the larger shrimp. Shrimps often migrate from inshore to offshore as they grow to certain size or life stage (Garcia and Le Reste, 1981). This suggests that total mortality of this study may have been overestimate. Another erroneous origin for determination of total mortality for penaeid is due to growth oscillation. Pauly *et al.* (1995) have shown that when compared with age-structured catch curves, Z from non-seasonalized length-converted catch curve could be overestimated. Seasonal-

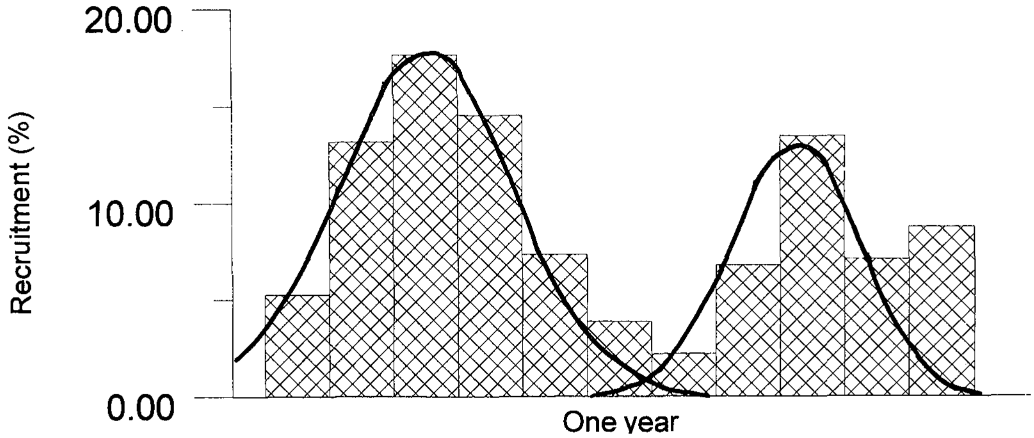

Fig. 9. Recruitment pattern of sword prawn in the adjacent waters of Taichung harbor but excluded all prawns of carapace length 24 mm less.

ized length-converted catch curve produced Z-values equal or similar to age-structure catch curve (Etim and Sankare, 1998). In our present case, the Z from length converted catch curve without seasonality was 12.57% higher than that with seasonality. Due to considerations of the migration patterns of this species future work should cover the entire distributional range in order to improve on mortality estimates.

The empirical equation of Pauly (1980) and Srinath (1991) were used to estimate the natural mortality in this study. Although Pauly's formula was initially constructed for fish species, it has also given reasonable estimates for shrimps (Pauly *et al.*, 1984). The estimate of the M/K ratio locating between 1.0 and 2.5 was considered as more realistic (Mohamed, 1996). The calculated M/K values using 2 M values estimated from Pauly's and Srinath's methods were 1.87 and 1.89, respectively. Thus, the estimates of M are reasonable in this study. However, the estimating natural mortality affects greatly the analysis of yield (Baelde, 1994). The more reliable estimates of natural mortality are still required before it can be established that the fishery is at the optimum level of exploitation.

Relatively high values of mortality (Z = 6.73 1/year) and exploitation rate (E > 0.5) indicate that the sword prawn population is overexploited (Gulland, 1972). This may be due to a year-round exploitation by shrimp trawler. In order to utilize this resource eternally, rational strategy of exploitation and management must impose on this species.

ACKNOWLEDGEMENTS

The authors are gratitude for the funding supported by the council of the agriculture, R.O.C. through contracts 85AST-1.13-FID-04(3). We also thank Mr. P. W. Shi, Dr. T. T. Ju, Miss. J. J. Wu, and Y. C. Chen, for their assistance on collection samples.

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台中港附近海域產劍蝦(*Parapenaeopsis hardwickii*)之生物學參數

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（2000年8月17日收件；2000年9月29日接受）

利用1992年2至7月間，連續6個月之月別體長頻度資料及ELEFAN之方法，來估計台中港附近海域產劍蝦(*Parapenaeopsis hardwickii*)之季節性成長參數、死亡率及加入型態。本研究中只使用雌蝦之體長頻度資料加以分析。應用體長頻度分佈擬合季節性本托蘭裴成長方程式(von Bertalanffy growth equation)，其結果如下：極限頭胸甲長L_∞=39.0 mm，成長參數K = 1.1 (1/year), C = 0.95 and WP = 0.94。利用季節化體長轉換漁獲量曲線估計其全死亡係數Z爲6.37 (1/year)。利用兩種經驗式，估計其平均之自然死亡係數M爲2.07 (1/year)；漁獲死亡係數F利用Z = F + M之關係式求得爲4.30 (1/year)。開發率E爲0.67 (F/Z)，顯示本蝦種已有過度開發之情形。加入型態分析結果顯示，劍蝦每年具有兩個強度不等之加入群。劍蝦之最大年齡估計爲2.74年。

關鍵詞：*Parapenaeopsis hardwickii*，成長參數，死亡係數，加入型態。

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