行政院國家科學委員會專題研究計畫成果報告

Preparation of NSC Project Reports

計畫編號：NSC 89-2313-B-002-234-

執行期限：89 年 8 月 1 日至 90 年 7 月 31 日

主持人：葉顯椏　　台大海洋研究所

計畫參與人員：曾宗德　台大海洋研究所

一、中文摘要

使用 MULTIFAN 分析 1993 及 1971 年間採集之兩組東海錦鱗蜥魚之體長頻度資料，估計並比較兩時期成長參數之異同。本研究以分層隨機採樣法收集體長頻度樣本，並將所得之每一體長區間之頻度以每一採樣船中每一類別之總箱數給予加權。1993 及 1971 年期間各收集 11 及 9 個體長樣本。1993 年體長樣本所估得之 von Bertalanffy 成長參數：雌性成長速率為 0.083 1/年、極限體長為 62.4 公分；雄性成長速率為 0.092 1/年、極限體長為 52.8 公分。1971 年體長樣本所估得之成長參數：成長速率為 0.133 1/年、極限體長為 61.7 公分。1993 年成長參數所估得之成長表現指數 (Growth performance index, Φ') 雌、雄分別為 2.51 及 2.41；而 1971 年所估得之Φ' 值為 2.70。比較這些指數值顯示東海錦鱗蜥魚之成長於 1993 年期較 1971 年期為低，其原因可能是漁獲進行時對魚體大小有選擇之故。

關鍵詞：***Saurida tumbil***, 成長，體長頻度分析，***MULTIFAN***

Abstract

Growth parameters of lizard fish (*Saurida tumbil*) in the East China Sea were estimated from length-frequency data by MULTIFAN method were compared between 1971 and 1993. Length-frequency data were collected by stratified random sampling method, the frequency of each length class was weighted through the total boxes of each stratum in each sampled vessel. Numbers of length-frequency samples in both 1993 and 1971 data sets are 11 and 9, respectively. Parameters of the von Bertalanffy growth equation for 1993 were estimated as: K (growth coefficient) = 0.083 year^{-1}, L_∞ (asymptotic fork length) = 62.4 cm fork length (FL) for females and K = 0.092 year^{-1}, L_∞ = 52.8 cm FL for males. Growth parameters for 1971 data set were estimated as: K = 0.133 year^{-1}, L_∞ = 61.7 cm FL. The growth performance index (Φ') for 1993 data set is 2.51 for females and 2.41 for males, and the Φ' value for 1971 data set is 2.70. These indexes show the growth rate of the fish is lower in 1993 than 1971, which may result from the mesh selection.

Keywords: ***Saurida tumbil*, Growth, Length-frequency analysis, MULTIFAN**

Introduction

Using length-frequency data to estimate the growth parameters for an exploited population has been conducted for many years (Pauly *et al.*, 1984). Since the computer software for the analysis of length-frequency data had been developed, applying this procedure to estimate the growth parameters has a rapid increase (e.g., Pauly, 1987; Terceiro *et al.*, 1992). Length-frequency analysis depends on the assumption that length-frequency sample has one or more modes, each of which represents a single age group. The modes are usually recognizable at young ages. When the modes are identified, the mean length of each age group in the length-frequency sample can be determined, and growth equations may be fitted to estimate the parameters. Although a single length-frequency sample may be analyzed to estimate the growth parameters, more reliable estimates can be obtained if analysis is applied to several length-frequency samples simultaneously (Fournier *et al.*, 1990).

Several techniques can be used to analyze multiple length-frequency samples, e.g., ELEFAN (Pauly *et al.*, 1984), MULTIFAN (Fournier *et al.*, 1990), Shepherd's length composition analysis (SLCA, Shepherd, 1987), and projection matrix method (PROJMAT, Rosenberg *et al.*, 1986). MULTIFAN method employs a growth equation to constrain the model to biologically reasonable results, and uses maximum-likelihood method to select the best match between theoretical and observed length-frequency distribution. This method can usually provide unbiased and more precise estimates (Terceiro *et al.*, 1992).

The lizard fish (*Saurida tumbil*) are one of the most widely distributed demersal resources from the sub-tropical area to the tropical area (Yamada *et al.*, 1966). In West Pacific, the species have been exploited in the East China Sea, Taiwan Strait and the South China Sea (Lee, 1994). Study on age and growth for lizard fish in the East China Sea was conducted by direct aging using scales (Yeh *et al.*, 1977). Although a well-conducted growth study based on scales or other hard tissues may obtain precise growth parameters, the length-based methods still remain to be complement or, even more, take the place of ring-reading method for some species (Pauly, 1987). The objectives of this paper are to compare the growth parameters of lizard fish in the East China Sea based on two length-frequency data sets separately collected during the periods of 1993 and 1971 using MULTIFAN method.

Materials and Methods

Two length-frequency data sets of lizard fish from the East China Sea were collected during the periods of 1971 and 1993 (Fig. 1), respectively. Because lizard fish landings are divided into three categories, i.e. large, median and small boxes, according to the different size of fish, the stratified random sampling method was used to collect our length-frequency samples. We randomly sampled each box from a sampled vessel according to the three strata, and recorded its total boxes of landings for large, median and small boxes. In 1993 data set, a total of 11 monthly length-frequency samples were collected from February to December 1993. In 1971 data set, a total of 9 monthly length-frequency samples were collected from January to December 1971.

For each specimen, fork length (L) was measured to the nearest 0.1 cm and body weight (W) was also measured to the nearest 0.1 g. Information on sexes and weight is only available for 1993 data set. The fork length data measured were firstly grouped by interval of 1 cm, and then the total frequency in each length class ($F_{i..}$) was obtained through the following formula:

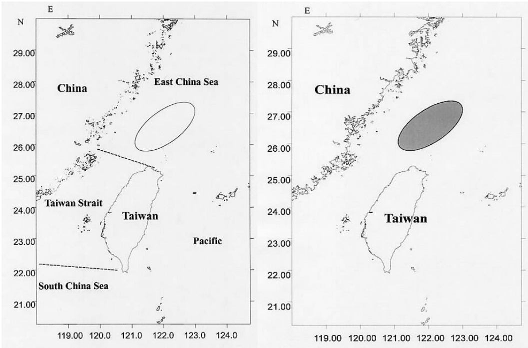
$$F_{i..} = \sum_{k=1}^{n} \sum_{j=1}^{3} f_{ijk} W_{jk}$$

where f_{ijk} denotes the measured frequency in i length interval, j category box (large, median or small boxes) and k sampled vessel, W_{jk} the number of j category box in k sampled vessel. These resultant length-frequency data sets were submitted to MULTIFAN.

MULTIFAN is a likelihood-based technique that processes multiple samples of length-frequency simultaneously to estimate the growth parameters. The main assumptions of MULTIFAN are: (1) the lengths of fish in each age class are normally distributed around the mean lengths at age; (2) the mean lengths at age lie on a von Bertalanffy growth curve; (3) the standard deviations of the actual lengths about mean length at age are a simple function of mean length at age; (4) age at zero length equals zero. A detailed description and its mathematical basis of this method are given in Fournier *et al.* (1990).

MULTIFAN requires the following parameters specified: expected number of age classes; expected initial K values; and mean length of the mode representing the youngest age class. We let the number of age classes be 3, 4, 5, 6, 7, 8, and 9, and let initial values of K be 0.03, 0.08, 0.15, 0.25, and 0.35. Size selectivity for the first age class and length-dependent trend in standard deviations for length-at-age options were also included in the model. The χ^2 test was used to choose the best fit based on the following criteria: (1) no significant improvement in fit by adding any new parameter; (2) no degradation in fit by removing any parameter existed in the model (Fourneir *et al.*, 1990).

The growth performance index Φ' (Pauly and Munro, 1984) was computed to compare the estimates of growth parameters. This index is reflected by $\Phi' = \log K + 2 \log L_{\infty}$, where L_{∞} is the asymptotic fork length expressed in cm.



(a) (b)

Fig. 1 (a) Showed area showing the sampling area of the length-frequency data in the Southern East China Sea. (b) The sampling ares of the lizard fish collected for the measurement of length-frequency data in the Southern East China Sea.

Result

The relationship between fork length (L) and body weight (W) is described by the equation W = a L^b, where b is the growth exponent and a is a constant. The fork lengths of females vary between 11.2 and 50.3 cm, while their weights range between 19.7 and 1458 g. The fork lengths of males range between 11.8 and 39.6 cm, while their weights vary between 17.5 and 736 g. The sample size used to elucidate the relationship between L and W in this study is 1025 for females and 965 for males, respectively. The regression of the log-transformed W against log-transformed L was conducted and then the back transformed power function of W versus L for females and males give the following relationship:

Female: $W = 2.664*10^{-3} L^{3.39655}$, $r^2 = 0.9875$

Male: $W = 2.533*10^{-3} L^{3.42649}$, $r^2 = 0.9849$

A comparison of the slopes of two regressions by ANCOVA shows that there is no significant difference between females and males. Therefore, we combined both sexes data, and then re-estimated the relationship between L and W. The result is as followed (Fig. 2):

$$W = 2.731*10^{-3} L^{3.39523}, r^2 = 0.9855$$

The means of fork length and corresponding standard deviations of lizard fish in three strata (large, median and small boxes) for 1993 and 1971 were showed in

Table 1. In 1971, the means of fork length are 34.57 cm, 26.94, and 17.16 cm and the corresponding standard deviation are 3.646 cm, 2.414 cm and 1.934 cm for large, median and small size, respectively. In 1993, the means of fork length are 35.81 cm, 27.41, and 18.64 cm and the corresponding standard deviation are 4.032 cm, 2.806 cm and 2.213 cm for large, median and small size, respectively.

The length-frequency histograms for both data sets and results of the best fits were shown in Figs. 3-4. In the best fits, most of the estimated modes followed the length-frequency line closely and overlay the peaks well (Figs. 3-4). The estimates of parameters were shown in Table 2.

1993 data set: There were 71, 60 parameters and 7, 6 age classes in the best fits for females and males, respectively. Growth parameters were estimated to be L_∞ = 62.4 cm and K = 0.083 year^{-1}, and L_∞ = 52.8 cm, K = 0.092 year^{-1} for females and males, respectively (Table 2). Mean fork length for each age class was estimated as 15.39, 19.12, 22.55, 25.71, 28.62, 31.30, 33.76 for females and 14.69, 18.04, 21.09, 23.88, 26.42, 28.74 for males (Table 3). The value of Φ' estimated is 2.51 for females, and 2.41 for males.

1971 data set: Eight age classes were identified in the best fit and growth parameters were estimated to be L_∞ = 61.7 cm and K = 0.133 year^{-1}, respectively. Mean fork length for each age class was estimated as 12.28, 18.42, 23.80, 28.50, 32.62, 36.23, 39.40 and 42.16 cm (Table 3). The value of Φ' estimated is 2.70.

The value of t_0 is not determined because the MULTIFAN procedure is incapable of extracting t_0 from length-frequency data. Parameter t_0 is only a location parameter and its absence here does not compromise the accuracy of other computed parameters.

Table 1. Mean fork length and its corresponding standardard deviation (in parentheses) (cm) of *Saurida tumbil* for each market category in 1971 and 1993.

Market size	1971	1993
Large	34.57 (3.646)	35.81 (4.032)
Middle	26.94 (2.414)	27.41 (2.806)
Small	17.16 (1.934)	18.64 (2.213)

Table 2. Parameters of von Bertalanffy growth equation with its standard deviations (in parentheses) and growth performance indexes obtained from the best fit of MULTIFAN for two length-frequency data sets and aging using scale by Yeh *et al.* (1977).

Data and method	1971 length-frequency data set analyzed by MULTIFAN	1993 length-frequency data set analyzed by MULTIFAN		Aging using scales by Yeh *et al.* (1977)	
Parameter | Sex	Sexes combined	Female	Male	Female	Male
Log-likelihood function value	6589.14	7539.41	7498.27		
Significant age Class	8	7	6		
Number of parameters	69	71	60		
K (year^{-1})	0.133 (0.0084)	0.083 (0.0036)	0.092 (0.0057)	0.104	0.118
L_∞ (cm)	61.7 (2.2568)	62.4 (1.7126)	52.8 (1.9674)	74.24	63.69
Growth performance index (Φ’)	2.70	2.51	2.41	2.76	2.68

Table 3. Mean length at age and its corresponding standard deviation (cm) estimated by MULTIFAN.

Year	Age							
	1	2	3	4	5	6	7	8
1971 Sexes combined	12.28	18.42	23.80	28.50	32.62	36.23	39.40	42.16
	(1.68)	(1.80)	(1.92)	(2.03)	(2.13)	(2.22)	(2.31)	(2.39)
1993 Female	15.39	19.12	22.55	25.71	28.62	31.30	33.76	
	(1.50)	(1.64)	(1.78)	(1.92)	(2.06)	(2.20)	(2.33)	
1993 Male	14.69	18.04	21.09	23.88	26.42	28.74		
	(1.29)	(1.29)	(1.29)	(1.29)	(1.29)	(1.29)		

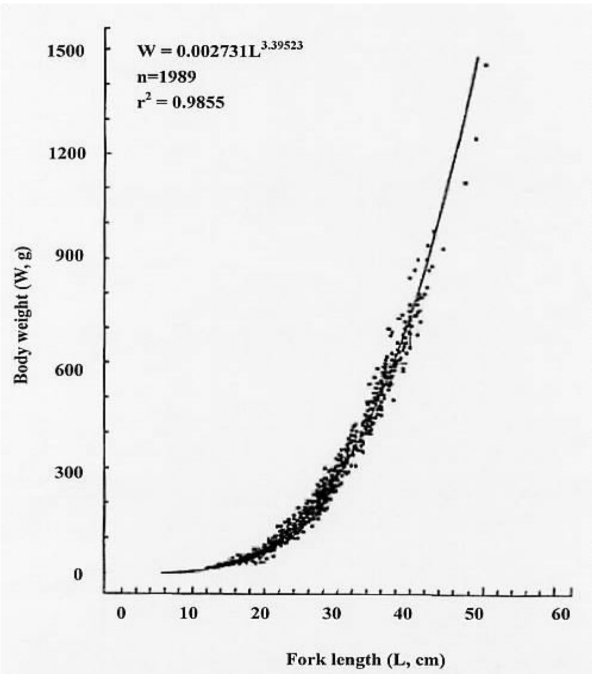
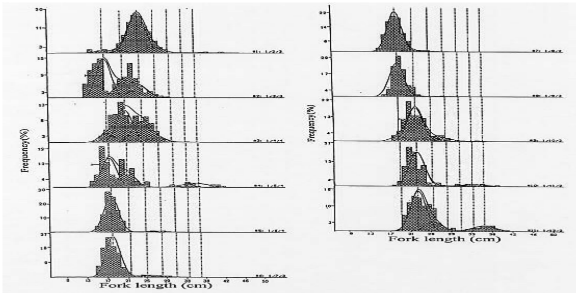
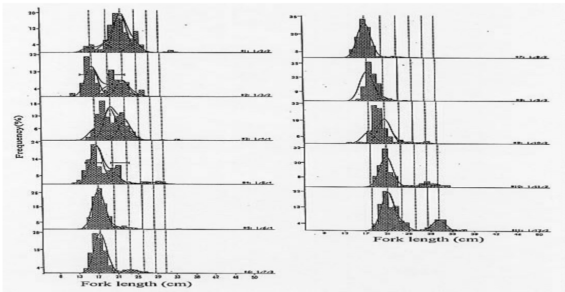


Fig. 2. Relationship between fork length(L) and body weight(W) of lizard fish in the Southern East China Sea



(a)female



(b)male

Fig. 3. Length-frequency data of lizard fish collected in 1993 with a fit of the MULTIFAN The dashed vertical lines represent the estimated mean lengths-at-age in each sample. The inner smooth curves are the estimated numbers at age and the outer smooth curve is the estimated frequency distribution. Sampling date is given in the histogram with the format, year/month/week; year 1 was 1993. (a) female; (b) male

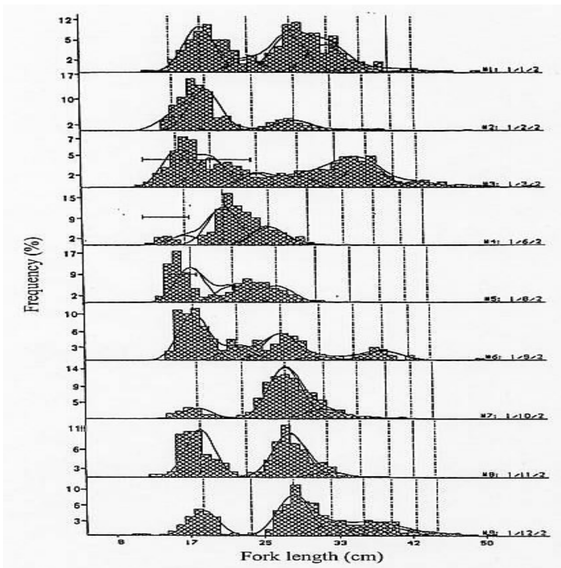


Fig. 4. Length-frequency data of 1971 data set, showing the fit of the MULTIFAN. The dashed vertical lines represent the estimated mean lengths-at-age in each sample. The inner smooth curves are the estimated numbers at age and the outer smooth curve is the estimated frequency distribution. The corresponding sampling date is given in the lower right of each histogram. The format is year/month/week; year 1 was 1971.

Discussion

To accurately estimate growth parameters of population from length-frequency samples, the length-frequency data used must be representative of the population. Because the lizard fish landings are usually divided into three categories, i.e., large, median and small boxes, according to the different size of fish, the length-frequency data collected in fish market using the simple random sampling method cannot represent the length composition of population (Lee, 1994). In this paper, we followed the characteristic of landing goods to adopt three data strata and used the stratified random sampling method to collect our length-frequency samples, so we believe that the length-frequency data used here is a good representing of the population length composition.

Several factors, such as gear selectivity, sample size, the number of sample, and group interval, might also affect the results of MULTIFAN. The presence of modal groups should be perceptible in length-frequency data, with apparent shifts in modal length over time (Wolf, 1989), and these features are observed in our length-frequency samples (Figs. 3-4). It is difficult to obtain good results with small sample size in length-frequency analysis (Erzini, 1990). In this study the sample size was weighted through total catch of each category box in each sampled vessel, so sample size might not be a problem. The number of sample is considered to be proper if the length-frequency data is taken at least over 6 consecutive months (Hoenig *et al.*, 1987). The numbers of sample are separate 11 and 9 for 1993 and 1971 data sets, so we believe that two length frequency data sets used here are proper for estimating growth parameters.

The size selectivity for first age class were included in our analysis, and the results that there is not significant influence on estimates of growth parameters for 1993 data sets, but is significant for 1971 data set. If gear selectivity was not considered in analysis, estimated mean length of the first age class might be larger than actual size and the K tends to be overestimated as well as L_∞ tends to be underestimated (Tzeng and Yeh, 1995).

Different results of MULTIFAN might have resulted from different length interval (Erzini, 1990; Liu *et al.*, 1999). The 1993 length-frequency data set and four length intervals, 0.5, 1.0, 1.5and 2.0 cm were used to examine the effect of length interval. The similar results were obtained using the length intervals of 1.0 and 1.5 cm for females, and no significant differences among the estimates was found using the length intervals of 1.0, 1.5 and 2.0 cm for males. Thus a length interval of 1.0 cm was chosen.

Because (1) one population grow faster than another when young and slower than the other when older and (2) both L_∞ and K are significantly negative correlation, the multivariate techniques is preferred for growth comparison rather than comparison of L_∞ and K individually (Pauly and Munro, 1984; Moreau, 1987). Moreau *et al.* (1986) compared other alternative indices (e.g., $\mu = KL_\infty$) with the growth performance index (Φ'), and showed that Φ' is the best because it exhibited minimum variance. The growth performance index also provides an index of the reliability of estimates since it is suggested that these values of Φ' are similar for the same species (Pauly and Munro, 1984; Bellido *et al.*, 2000). The Φ' value of females (2.51) is higher than the one of males (2.41) in this study, and similar result was also found in Yet *et al.* (1977) (Table 2). These indicate that the female's growth rate is faster than male's. The Φ' value estimated from 1971 length-frequency data set seems to be in reasonable agreement with the results estimated from ring-reading method by Yeh *et al.* (1977), which shows that our estimates of growth parameters are reasonable and using MULTIFAN technique to estimate the growth parameters is suitable for this species (Table 3).

The decrease in stock size resulting

from exploitation can reduce intraspecific competition. And thus it may lead to faster growth of the fish (Law, 2000). The Φ' values obtained from 1993 data set are less than the ones separately estimated from 1971 data set and from direct aging using scales (Yeh *et al.*, 1977) (Table 2). This indicates that growth rate of the fish was higher in 1971 than 1993. This phenomenon contradicts the common knowledge of higher fish growth rate at lower population level. The biomass of lizard fish in the East China Sea have decreased since 1970s (Lin, 1994). Fishing is almost always non-random.

References

Bellido, J. M., G. J. Pierce, J. L. Romero and M. Millan (2000) Use of frequency analysis methods to estimate growth of anchovy (*Engraulis encrasicolus* L. 1785) in the gulf of Cadiz (SW Spain). *Fish. Res.*, **48,** 107-115.

Erzini, K. (1990) Sample size and grouping of data for lengh-frequency analysis. *Fish. Res.*, **9,** 355-366.

Fournier, D. A., J. R. Sibert, J. Majkowski and J. Hampton (1990) MULTIFAN a likelihood-base method for estimating growth parameter and composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyii*). *Can. J. Fish. Aquat. Sci.*, **47(2),** 301-317.

Hoenig, J. M., J. Csirke, M. J. Sanders, A. Abella, M. G. Andreoli, D. Levi, S. Ragonese, M. Al-Shoushani and M. M. El-Musa (1987) Data acquisition for length-based stock assessment: report of working group I. In *Length-based methods in fisheries research* (D. Pauly and G. R. Morgan, eds.). *ICLARM Conference Proceedings* **13,** International Center for Living Aquatic Resources Management, Manila, Philippines, and Kuwait Institute for Scientific Research, Safat, Kuwait, 343-352.

Law, R. (2000) Fishing, selection, and phenotypic evolution. *ICES J. Mar. Sci.*, **57,** 659-668.

Lee, Y. C. (1994) The estimation of joint length frequency of lizard fish (*Saurida undosqumis*) caught from the southern Taiwan Strait using the stratified random sampling method. *J. Fish. Soc. Taiwan.*, **21(1),** 57-68.

Lin, D. R. (1994) Age, growth and total mortality of lizard fish (*Saurida tumbil*) in the southern part of the East China Sea. *Master thesis of Institute of Oceanography.,* National Taiwan University., 69pp. (In Chinese)

Liu, K. M., C. T. Chen and R. H. Yang (1999) Estimates of age and growth on the big bye *Priacanthus macracanthus* in the Northeastern Taiwan Waters. *Fish. Sci.*, **65(2**), 211-217.

Moreau, J. (1987) Mathematical and biological expession of growth fish: Recent trends and further developments. In: *The age and growth of fish* (R. C. Summerfelt and R. C. Hall, eds.). The Iowa State University Press, 18-113.

Moreau, J., C. Bambino and D. Pauly (1986) Indices of overall growth performance of 100 Tilapia (Cichlidae) populations. In: *The first Asia Fisheries Forum* (J. L. MacLea, L. B. Dizon and L. V. Hosillos, eds.). *Asian Fisheries Society.*, Manila, 201-206.

Pauly, D. (1987) A review of the system for analysis of length data in fish and invertebrates. In: *Length based methods in fisheries research* (D. Pauly and R. Morgan, eds.). *ICLARM Conference Proceedings.*, **13,** ICLARM, Manila, Philippines, 7-34.

Pauly, D., J. Ingles and R. Neal (1984) Application to shrimp stocks of objective methods for the estimation of growth, mortality and recruitment related parameters from length frequency data, ELEFAN I and II. In: *Penaeid shrimps-their biology and management* (J. A. Gulland and B. J. Rothschild, eds.). Fishing News Books, Farnham, Surrey, England, 220-234.

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

Rosenberg, A. A., J. R. Beddington and M. Basson (1986) The growth and longevity of krill during the first decade of pelagic whaling. *Nature.*, **324,** 152-154.
Shepherd, J. G. (1987) A weakly parametric method for the analysis of length composition data. In: *Length based methods in fisheries research* (D. Pauly and R. Morgan, eds.) *ICLARM Conference Proceedings.*, **13,** ICLARM, Manila, Philippines, 113-119.
Terceiro, M., D. A. Fournier and J. R. Sibert (1992) Comparative performance of MULTIFAN and Shepherd's length composition analysis (SRLCA) on simulated length-frequency distributions. *Trans. Amer. Fish. Soc.*, **121,** 667-677.
Tzeng, T. D. and S. Y. Yeh (1995) Growth parameters of red-spot shrimp, *Metapenaeopsis barbata*, from the adjacent waters off Taichung Harbor. *J. Fish. Soc. Taiwan.*, **22(1),** 53-68.
Wolf, M. (1989) A proposed method for standardization of the selection of class interval for length-frequency analysis. *Fishbyte.*, **7(1),** 5.
Yamada, U., M. Tagawa and H. Mako (1966) On the feeding activity of the lizard-fish, *Saurida tumbil*, in the East China Sea. *Bull. Seikai Reg. Fish. Res. Lab.*, **34,** 11-25. (In Japanese)
Yeh, S. Y., H. L. Lai and H. C. Liu (1977) Age and growth of lizard fish (*Saurida tumbil*) in the East China Sea and the Gulf of Tonkin. *Acta Oceanogr. Taiwan.*, **7,** 134-145.

附件：封面格式

行政院國家科學委員會補助專題研究計畫成果報告

※※※※※※※※※※※※※※※※※※※※※※※※※※
※　　　　　　　　　　　　　　　　　　　　　　　　　※
※　　東海漁場產狗母之系群判別及資源評估（III）　※
※　　　　　　　　　　　　　　　　　　　　　　　　　※
※※※※※※※※※※※※※※※※※※※※※※※※※※

計畫類別：■個別型計畫　　□整合型計畫
計畫編號：NSC　89－2313－B－002－234－
執行期間：89 年 8 月 1 日至 90 年 7 月 31 日

計畫主持人：葉顯椏
計畫參與人員：曾宗德

本成果報告包括以下應繳交之附件：
□赴國外出差或研習心得報告一份
□赴大陸地區出差或研習心得報告一份
□出席國際學術會議心得報告及發表之論文各一份
□國際合作研究計畫國外研究報告書一份

執行單位：國立臺灣大學海洋研究所

中　華　民　國　九十一　年　五　月　一　日