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Estimation of Growth Parameters of Two Species of Mackerel, *Scomber japonicus* and *S. australasicus*, in the Coastal Waters of Taiwan

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ABSTRACT

The seasonal oscillating von Bertalanffy growth equation of *Scomber japonicus* and *S. australasicus* was simulated with ELEFAN (Electronic LEngth Frequency ANalysis) technique, based on the length-frequency data collected from the large purse seiners in the waters off northeastern Taiwan, 1981-1986. The growth parameters of *S. japonicus* were estimated to be L_∞ = 41.07cm, K = 0.49 year^{-1}, t_0 = -0.3, C (seasonal oscillation amplitude) = 0.7 and WP (winter point) = 0.30; while those of *S. australasicus* estimated to be L_∞ = 44.95cm, K = 0.71 year^{-1}, t_0 = -0.2, C = 0.7 and WP = 0.28. The great C-value indicated that both species display strong seasonal growth oscillation. The lowest growth period of the year was from mid February through early March (WP = 0.28 and 0.30), which corresponds to the overwintering and spawning season of the fish's life history. Both L_∞ and K indicated that the coastal waters of Taiwan was more suitable for the growth of *Scomber australasicus* than *S. japonicus*.

Key words: *Mackerel*, Scomber japonicus, S. australasicus, *Electronic length frequency analysis (ELEFAN), Seasonal growth oscillation, Taiwan.*

INTRODUCTION

Common mackerel, *Scomber japonicus* Houttuyn, and spotted mackerel, *S. australasicus* Cuvier & Valenciennes, are two economically important fishes in the coastal waters of Taiwan. Studies on the feeding habits (Chang and Lee, 1970), maturity and spawning (Chang and Wang, 1970; 1971), population structure (Chang and Chen, 1976; Tzeng, 1988), migration by tagging (Chang and Wu, 1977), age and growth (Ku and Tzeng, 1985a; b), and fishery oceanography (Tzeng, 1986) have been conducted. However, knowledge on population biology of these two species is still incomplete.

In general, fishery biologist tries to determine three basic characteristics: (1) mean length at age, (2) distribution of length, and (3) distribution of ages. Age composition of the population is one of the important factor in stock assessment. If age and length relationship of the fish is known, then one can induce age composition from length frequency (Schnute and

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Fournier, 1980). Accordingly, age determination of the fish is essential for estimation of age composition. There are three basic methods for ageing fish, namely (1) ageing by growth rings of hard tissues, (2) tagging experiments, and (3) length frequency analysis.

Ageing with annulus on the scales and other hard tissues prevails in temperate fishes. Annulus formed during winter when water temperture is low. However, the scale-reading techniques are not all applicable for tropical fishes, because of the lack of water temperature fluctuations, which preventes the formation of annulus (Pauly, 1987). Pannella (1971) claimed that otolith growth increment can be used to determine the daily age of larval fish in tropical waters. But reading otolith daily growth increment for adult fish is time consuming and not encouraged. Mackerel is a temperate marine species, their age was determined using scale-reading techniques (Kondo, 1966; Ku and Tzeng, 1985a; b). Reading of annulus on the scales is also time consuming, and easily biased from person to person. Tagging is a direct method but with shortcomings such as stress which causes slow growth (Gulland, 1983), and some fishes are too tender to retain the tag. In the case of mackerel, the return rate of tagged fish was too low for good estimation on growth (e.g. Chang and Wu, 1977).

The analysis of length-frequency distribution for age determination goes way back to the last century (Petersen, 1896). When number of fish vs. length is plotted, each peak on the histogram corresponds to the mean length of the spawned age group. Different approaches, including graphical, computerized parametric and non-parametric methods were developed for possible solutions (Harding, 1949; Cassie, 1954; Tanaka, 1962; Hasselblad, 1966; Bhattacharya, 1967; Tomlinson, 1971; MacDonald and Pitcher, 1979; Schnute and Fournier, 1980; MacDonald and Green, 1986). Bhattacharya's method (1967) was used to analyze the age structure of spotted mackerel in Taiwan (Ku and Tzeng, 1994). The application of computer to length frequency analysis has been improved and softwares developed to carry out the tedious work of distinguishing overlapping length groups (Akamine, 1985; Brey and Pauly, 1986; Pauly, 1987; Erzini, 1990; Fournier et al., 1990). It was generally agreed that the use of length-frequency data and computer in the estimation of growth parameters is inexpensive, more efficient and less bias.

This paper attempts to estimate Bertalanffy's special growth formula of the mackerel populations in the waters off northeastern Taiwan using ELEFAN program (Electronic LEngth Frequency ANalysis, ver.1.10) which was developed by Pauly et al. (1992).

MATERIALS AND METHODS

I. Data processing

A total of 2,683 common mackerels and 5,560 spotted mackerels was collected from Nanfanao fish market during the period from July 1981 to January 1986, except 1984. All fish were landed from large purse seiners who operate in the waters between Pengchia-Yu and Fishing Islands, northeastern Taiwan (Fig. 1). Individual fork length (FL) of fish was measured by punching hole onto a celluloid card placed under the fish's body. Length data were classified at 0.5cm intervals. Daily measurements of the same moonth were combined together.

Only a few samples of common mackerel were available, 4 samples from 1981, 6 from 1982, 3 from 1983, 3 from 1985, and 1 from 1986 (Fig. 2). They appeared to spread on a range far too

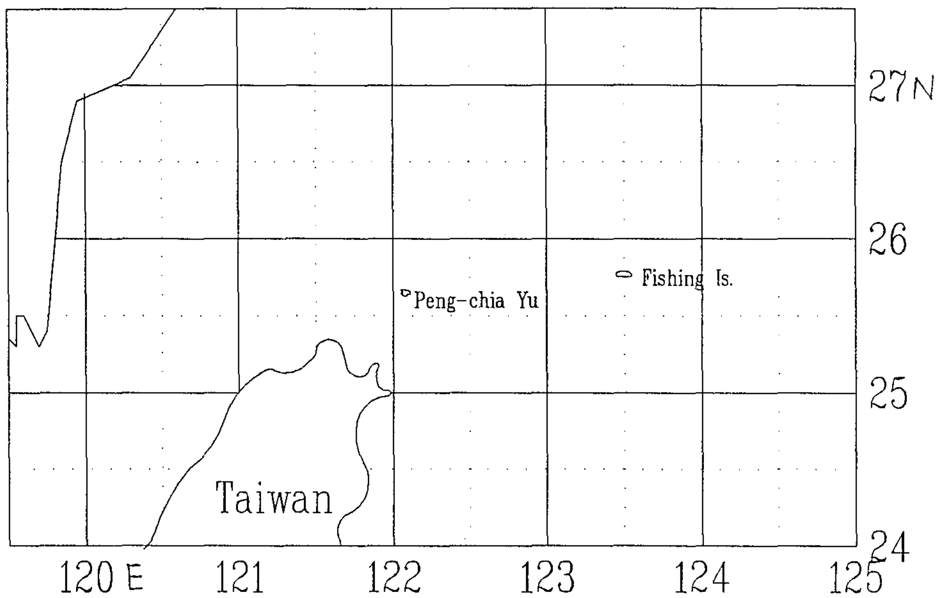

Fig. 1. Map showing mackerel fishing grounds in the adjacent waters off Pengchia Yu and Fishing Island, northeastern Taiwan.

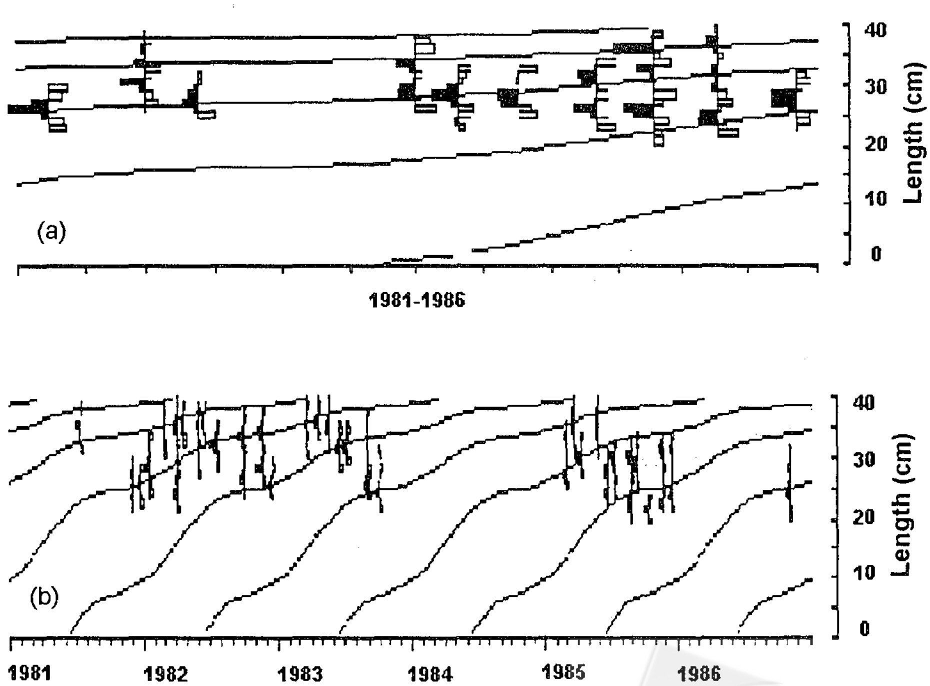

Fig. 2. Reconstructed monthly length-frequency distribution of *S. japonicus* in the year 1981-86 (a), and that of *S. australasicus* by individual month-year from the year 1981 to 1986 (b) with superimposed growth curves as estimated using ELEFAN I program.

large for good estimation, thus all samples from different years were pooled into one single year for the average data series in the time period of 1981-86. In the case of spotted mackerel, the data in the years from 1981 to 1986 were calculated for individual month-year and the result was compared with that of common mackerel.

II. Growth parameter estimation

ELEFAN I routine (Pauly and David, 1982; Pauly and Aung, 1984; Morgan, 1985; Primavera et al., 1987; Pauly, 1987) was used to estimate the growth parameters of both species. The program allowed for calculating the seasonally oscillating von Bertalanffy growth equation (VBGE) proposed by Pauly and Gaschütz (1979) and modified by Pauly et al. (1992). The growth equation is defined as follows:

$$Lt = L\infty \{1-\exp[-k(t-t_0)-S\sin 2\pi(t-t_s)+S\sin 2\pi(t_0-t_s)]\} \quad \text{.......................... (1)}$$

where Lt is the predicted length at age t; $L\infty$ is the asymptotic length; K is the growth coefficient; t_0 is the theoretical age for the fish at length zero; t_s defines the start of the convex segment of a sinusoid oscillation with respect to $t=0$; t_s relates to the winter point (WP) which designates the period of the year when the growth is the slowest, by $t_s + 0.5 = \text{WP}$; and $S = (CK/2\pi)$, where C expresses the relative amplitude of the seasonal oscillation.

The principle of fitting growth curve with ELEFAN I was described by Pauly and David (1981) and Pauly (1987). In addition, Pauly (1979) suggested an empirical expression for a preliminary computation of t_0 from any estimate of K and $L\infty$ as follows:

$$\log_{10}(-t_0) = -0.3922 - 0.2752 \log_{10}L\infty - 1.038 \log_{10}K \quad \text{.............. (2)}$$

III. Comparison of growth performance

The growth performance of the mackerels was compared between species by growth performance index, ϕ. The index was defined by Pauly & Munro (1984) and derived by Moreau et al. (1986) as follows:

$$\phi = \log K + 2\log L\infty \quad \text{.......... (3)}$$

RESULTS

I. Length frequency distribution

The reconstructed monthly length-frequency distribution fitted with a growth curve for the common mackerel, *S. japonicus*, from 1981 through 1986 was shown in Fig. 2a. Common mackerel is a seasonal migratory species, it is more abundant in the study area from June to November, but scarce in other seasons. Fork lengths (FL) of the fish ranged from 19.5 to 36.5cm FL with a mode between 20 and 30cm FL. The length-frequency distribution in most months appeared to have single mode, except for the samples in October and November in 1981 and June in 1982. The pooled length-frequency distribution in 1981-1986 presented two dominant modes, one in 25cm FL and the other in 30cm FL.

The monthly length-frequency distribution for spotted mackerel, *S. australasicus*, during the period from 1981 to 1986 was shown in Fig. 2b. The length of the spotted mackerel ranged from 19.5 to 39.0cm FL, mostly between 20 and 35cm FL. There were two dominant modes, one in 20-25cm FL and the other in 30-35cm FL, respectively. The fish can be caught in this area all-year around, but more abundant from June to December.

II. Seasonal growth oscillation

Growth parameters derived for both species were given in Table 1, respectively. Then these parameters were substituted to equation (1), to derive the seasonally oscillating growths (Fig. 3).

Table 1. Seasonally oscillating von Bertalanffy growth parameters of *Scomber japonicus* and *S. australasicus* estimated from the reconstructed length-frequency distribution of Fig. 2 by ELEFAN computer software. L_∞, K, t_0, C, WP, Rn and ϕ are described in the text.

	S. japonicus	*S. australasicus*
L_∞	41.07	44.95
K	0.49	0.71
t_0	−0.3	−0.2
C	0.7	0.7
WP	0.30	0.28
Rn	0.286	0.212
ϕ	2.92	3.16

The theoretical growth curve of both species displays a strong seasonal oscillation in growth (Fig. 3). The relative amplitude of oscillation (C) was estimated to be 0.7 for both species. This suggests that the growth of the fish during the warmest and coldest month(s) is 70% higher (or lower) than that when no oscillation occurred. The winter point (WP) (the period of the year when growth is the slowest) for *S. japonicus* is 0.30 corresponding to the period of mid February to early March. WP for *S. australasicus* is 0.28 and similar to that of *S. japonicus*, which also corresponds to the period from mid February to early March (Table 1).

Both species grew fastest in the first two years, and slow down thereafter. Values of K and L_∞ are greater in *S. australasicus* than in *S. japonicus*, indicating that the former species grows faster and reaches a greater asymptotic length than the latter. The index (ϕ) also shows similar results.

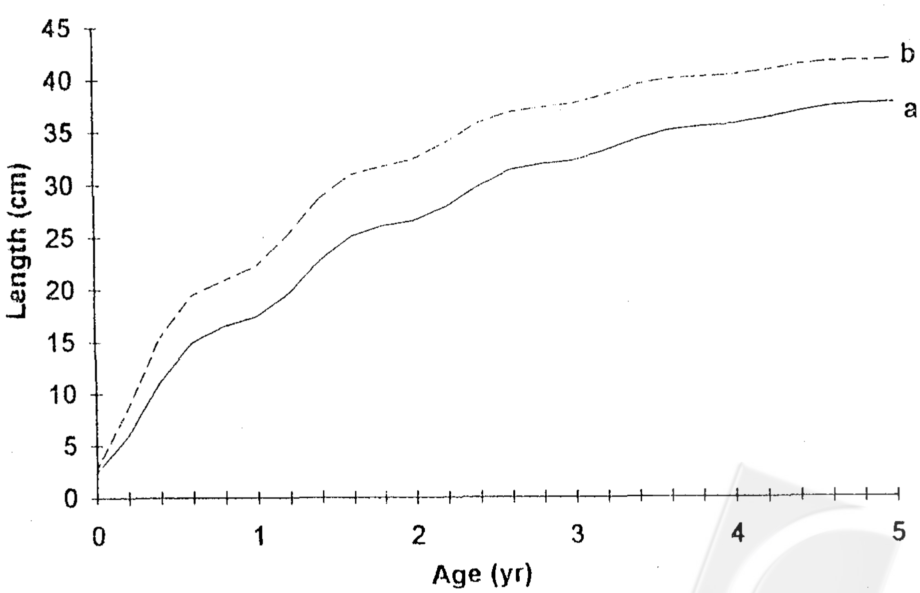

Fig. 3. Seasonally oscillating growth curves for *S. japonicus* (a) and *S. australasicus* (b).

DISCUSSION

Several scientists have examined the reliability of various length-frequency method and their limitations in age and growth assessment (Grant et al., 1987; Hampton and Majkowski, 1987; Castro and Erzini, 1988). These studies demonstrated the difficulty of obtaining reliable age and growth information. The degree of successfulness with any methods depended, in part, on certain characteristics of the species, including growth rate, mortality, recruitment pattern etc. (Erzini, 1990). The low value in goodness of fit (Rn) of both species may be due to multiple recruitment, and difference in annual growth. Kondo (1966) and Iizuka (1967) found that there were 1 to 3 broods per year recruited into the adult stock for the mackerels in the coastal waters of Japan. Furthermore, different stage in the life history contributes differently to each age group in the population. Mackerels migrated into the study area only during the period from autumn to early spring, making it difficult to collect samples all age-classes year-round.

Seasonal oscillation in growth is positively correlated to the variation of water temperature (Pauly, 1987). Surface temperature in the waters off Pengchia-Yu and Fishing Islands, where mackerels were collected, varied between 18°C and 29.5°C (Tzeng, 1988). Since the relative amplitude of seasonal oscillation (C) increased on a scale of approximately 0.1 per 1°C difference (Pauly, 1987). The value of C for both species in this report is approximately 0.7 (Table 1), indicating that there is a strong seasonal growth oscillation with high growth rate in summer and low in winter.

The winter point (WP) represents the fraction of the year when growth is the slowest. The WP of *S. japonicus* and *S. australasicus* was estimated to be 0.30 and 0.28, respectively. This corresponds to the period of mid February to early March. WP is found in the neighborhood of 0.2, i.e., in February in the northern Hemisphere (Pauly, 1987). Our result thus substantiate this phenomenon. Also both species begin maturation in January and spawn from February to March (Ku and Tzeng, 1985a; b). The somatic growth rate of mackerels was lowest during their maturation and spawning periods. Marginal increment of fish scale showed that annular ring formation period of mackerels was from January to February (Ku and Tzeng, 1985a; b). These data indicate that the winter point (WP) is consistent with the scale's annuli formation period and the spawning season of both species of mackerels.

The K-value and $L\infty$-value of *S. australasicus* were greater than that of *S. japonicus* (Table 1), given rise to greater value of growth performance index (ϕ). This indicated that the coastal waters of Taiwan is more suitable for the growth of *S. australasicus* than *S. japonicus*. Fish growth depends on both genetic and environmental factors, such as food, water temperature and stock density (Agnalt, 1989). *S. australasicus* prefers warmer waters, while *S. japonicus* prefers cold ones (Tzeng and Hirano, 1978). The difference in growth performance between these two species, assumingly due to evolutionary adaptation, and the mechanism demands further studies.

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臺灣近海白腹鯖及花腹鯖生長參數的估算

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（1994年8月15日收件；1994年12月15日接受）

本研究係根據1981～86年大型圍網船於臺灣東北部澎佳嶼至釣魚島附近海域所捕獲的白腹鯖及花腹鯖的體長頻度分佈資料，利用ELEFAN（電腦體長頻度分析）程式推算von Bertalanffy季節性振盪生長方程式之參數，以瞭解其生長特性。白腹鯖的生長參數估算結果爲：極限體長（L_{∞}）＝41.07 cm，生長係數（K）＝0.49year^{-1}，體長爲零的理論年齡（t_0）＝－0.3，季節性生長振盪係數（C）＝0.7，生長最低點的月份(WP)＝0.30。在花腹鯖的情形：L_{∞}＝44.95 cm，K ＝0.71 year^{-1}，t_0＝－0.2，C ＝0.7，WP＝0.28。C值很大，顯示兩種魚有極明顯的季節性振盪的生長現象。生長停滯期爲二月中至三月初，此與生活史之越冬產卵期極爲吻合。花腹鯖的極限體長和生長係數皆比白腹鯖者大，顯示臺灣近海比較適合花腹鯖的生長。

關鍵詞：白腹鯖，花腹鯖，電腦體長頻度分析，季節性振盪的生長，臺灣近海。

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