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Age and Growth of Common Mackerel (*Scomber japonicus*) in the Waters of Northeastern Taiwan, with Particular Reference to the Subpopulation Discrimination

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臺灣東北部海域白腹鯖之年齡、成長及其族羣判別

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為了瞭解澎佳嶼～釣魚臺海域白腹鯖來遊羣之年齡成長及其族羣構造，本研究自1981年7月至1983年10月於蘇澳漁市場採集在該海域作業之大型圍網漁船所捕獲白腹鯖，以胸鰭附近之鱗片當做年齡形質，來研究其年齡及成長。白腹鯖之鱗長～體長關係為 $L=124.759+114.943R$。每年1～2月時形成一個年輪。產卵期為2～3月。一年魚之尾叉長估計為 217.9±9.2 mm，二年魚為 268.5±13.7 mm。體長與體重之關係為 $W=40.0967\times L^{3.2028}\times 10^{-7}$。本海域白腹鯖之成長比中國東海及日本海南部各系羣為慢。由成長的傾向來看，澎佳嶼～釣魚臺海域之白腹鯖與中國東海南部羣可能為同一族羣。

ABSTRACT

Age and growth of common mackerel, *Scomber japonicus* (HOUTTUYN), from the waters off Pengchiahsu and Fishing Islands in northeastern Taiwan was studied by means of scale reading of 613 specimens collected from SU-AO fish market during the period from July 1981 to October 1983. The relationship between scale radius (R) and fork length (L) was represented by the equation, $L=124.759+114.943R$. The age ring mark was formed once a year during January-February when the water temperature was lowest and the gonad condition of the fish was in maturity stage prior to the spawning season. The back calculated fork length of one-year-old fish was 217.9±9.2 mm while that for two-year-old one was 268.5±13.7 mm. The length (mm) and weight (gm) relationship was estimated as: $W=40.0967\times L^{3.2028}\times 10^{-7}$.

Judging from the information on the pattern of ring radius and age-length relationship, it is suggested that the common mackerels occurring around Pengchiahsu and Fishing Islands are the migrating groups of the south East-China-Sea subpopulation as proposed by Ōuchi and Hamasaki (1979).

INTRODUCTION

Common mackerel, *Scomber japonicus* (HOUTTUYN), is one of the most important commercial fish in Taiwan. In the winter, catches are landed by the newly developed large-typed purse seiner from the waters off Pengchiahsu and Fishing Islands.

Common mackerel distributed from southern Hokkaido, Korea, mainland China and

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northern tip of Taiwan[1]. There are four subpopulations around the western Japan Sea and the East-China-Sea; namely, Sakai group, Tsushima-west Kyushu group, west East-China-Sea group and south East-China-Sea group[2].

There are many publications on the age and growth of the Japanese common mackerel[2~7]. As for the Taiwanese common mackerel population very few studies have been carried out so far except the taxonomical revision by Chang and Lee[8]. The present study emphasizes mainly on the study of age and growth and population structure of the common mackerel in the waters off Pengchiahsu and Fishing Islands.

MATERIALS AND METHODS

A total of six hundred and thirteen specimens were collected on monthly basis (Table 1), from the large-typed purse seiner which was operated in the waters off Pengchiahsu and Fishing Islands (Fig. 1) during July 1981 and October 1983.

While brought back to the laboratory, the fork length and body weight of specimens

Table 1. Samples of common mackerel collected from the waters off Pengchiahsu-Fishing Is., July 1981– Oct 1983

Sampling date	Sample size (No.)	Range of fork length (mm)
July 25, 1981	30	216-289
Aug 25	9	230-243
26	28	235-267
Sept 6	31	228-258
25	10	236-259
Oct 17	38	222-261
Nov 5	40	210-243
Dec 6	32	228-274
Feb 27, 1982	35	220-252
Mar 18	32	226-274
June 1	12	257-320
3	30	246-308
4	34	254-292
July 7	1	241
9	16	239-264
Sept 28	19	221-268
Oct 14	26	230-245
Nov 6	11	240-280
Dec 3	35	224-257
14	30	234-255
22	28	246-296
July 20, 1983	14	235-288
Aug 17	17	269-304
Sept 12	6	210-233
Oct 8	49	217-251
Total	**613**	

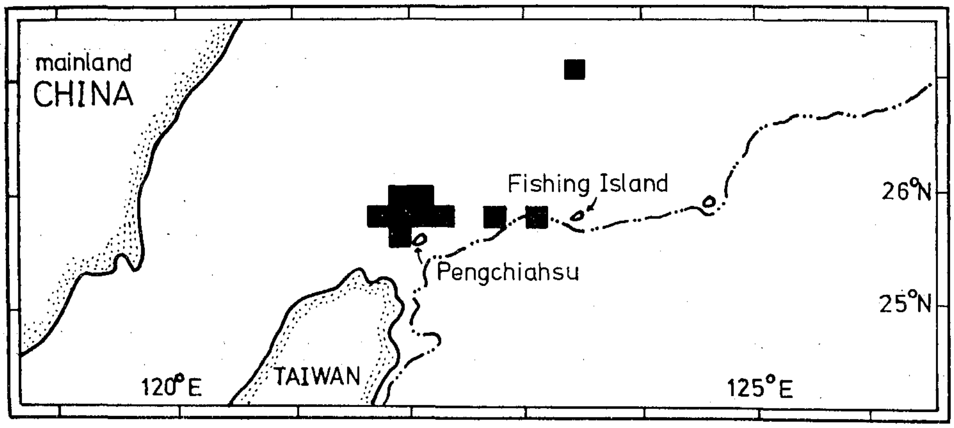

Fig. 1. Map showing the fishing grounds of large-typed purse seiner for mackerel fishery in the continental shelf off northeastern Taiwan. The black blocks indicate the sampling area of common mackerel.

were measured, sex of the fish was identified and their gonads were weighed thereafter. Several scales near the pectoral fin were removed and soaked in 3% KOH solution for several minutes to macerate the slime and the adhering tissue. Then five regular scales of each fish were chosen and washed with clean water and mounted with two glass-slides.

The annual ring was determined when cessation of growth on scales was found[3]. 393 out of 613 individuals (64%) had been clearly observed with rings. The already prepared scale specimens were examined and their scale radius (R) and ring radii (r_i) were measured (Plate 1) with a profile projector (model Nikon 6CT2) at a magnification of 20 times. Then, mean values of R and r_i of each fish specimen were calculated.

Surface sea water temperature around Pengchiahsu and Fishing Islands was adopted from the records kept in Taiwan Fisheries Research Institute and Nagasaki Marine Observatory during July 1981 and December 1982. These data were used to interprete the possible mechanism of ring formation.

In order to compare the ring pattern of the scale of common mackerel from the present studied area with that in other areas, the average relative distance of the ith ring was calculated according to the equation:

$$D_i = \frac{\sum_{j=1}^{N} \left(\frac{r_{ij}}{R_j}\right)}{N} \times 100\%$$

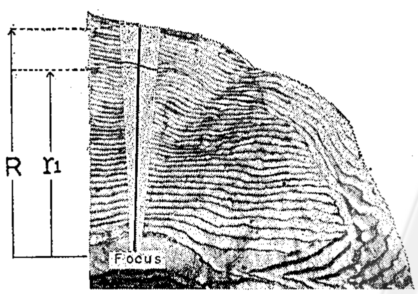

Plate 1. Photograph showing the ring mark on the scale of common mackerel with the measurement of ring radius (r_1) and scale radius (R).

where, D_i is average relative distance of ith ring, r_{ij} is the radius of ith ring for the jth individual, R_j is the radius of scale of the jth individual and N is the number of individuals examined.

RESULTS

1. Regularity of Ring Formation

In order to confirm whether the ring on the scales is reliable for age determination, the following criteria are considered.

(1) *Fork length and number of ring counts*

Fork length frequency distribution of 393 fish shown in Fig. 2 indicates that modal lengths of fish are shifting to the right side while number of rings increases.

(2) *Scale length and ring radius*

Relationship between ring radius and scale length of 26 fish with two rings were plotted in Fig. 3. It indicates that ring radius of each ring group increases in size with scale length. Thus, the position of ring mark on the scales are considerably similar among different individuals with the same number of rings.

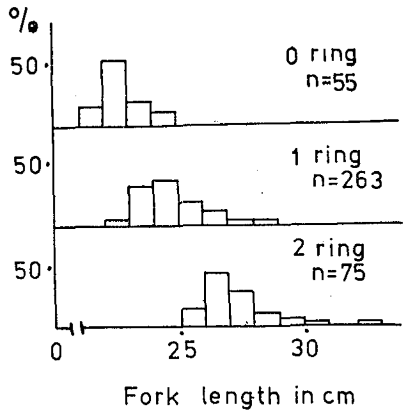

Fig. 2. Length frequency distribution, by ring group, of the common mackerel collected from the waters off Pengchiahsu-Fishing Is.. *n* indicates sample size.

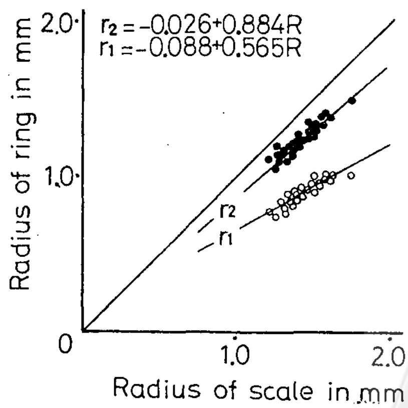

Fig. 3. Relationship between radius of scale and radii of ring in common mackerel, 26 fishes with two rings.

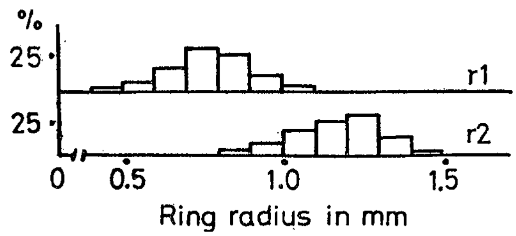

Fig. 4. Ring radius frequency distribution by ring group of common mackerel collected from the waters off Pengchiahsu-Fishing Is..

(3) *Ring radius and number of ring counts*

From the radius frequency distribution of 263 one-ring fish and 75 two-ring fish in Fig. 4, it is shown that the modal ring radius, r_1 and r_2 are significantly separated. Evidently, the ring radius becomes larger as the number of rings increases.

Accordingly, the ring mark on the scales of common mackerel is considered to be a reliable indicator for studying age and growth.

2. Relationship Between Fork Length and Scale Radius

When scale radius (R; mm) were plotted against fork length (L: mm) (Fig. 5) the relationship between fork length and scale length was fitted by the following linear regression line (r=0.9395),

$$L = 124.759 + 114.943\,R \quad (1)$$

3. Spawning Season and Time for Ring Formation

The spawning season of common mackerel were estimated according to the monthly changes in distribution of maturity factor (MF),

$$MF = \frac{\text{gonad weight in gm}}{\text{body weight in gm}} \times 100\% \quad (2)$$

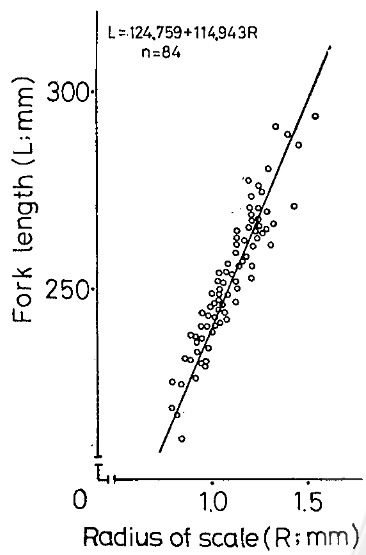

Fig. 5. Relationship between radius of scale and fork length in common mackerel collected from the waters off Pengchiahsu-Fishing Is..

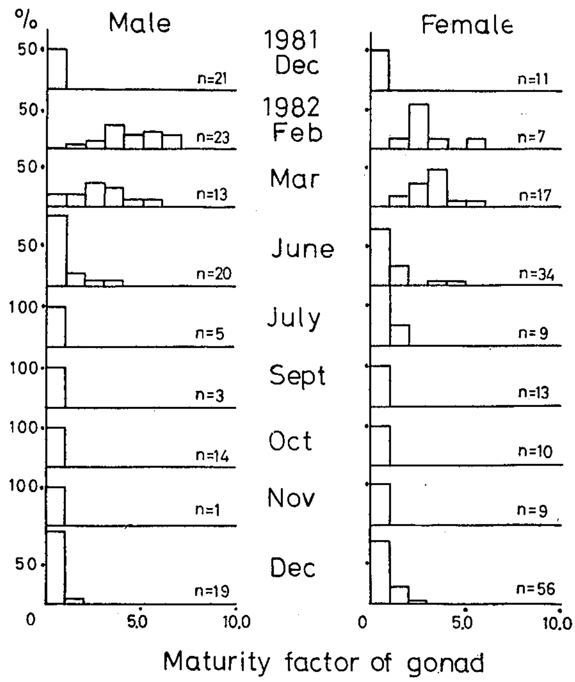

Fig. 6. Monthly changes of frequency distribution of the maturity factor of common mackerel.

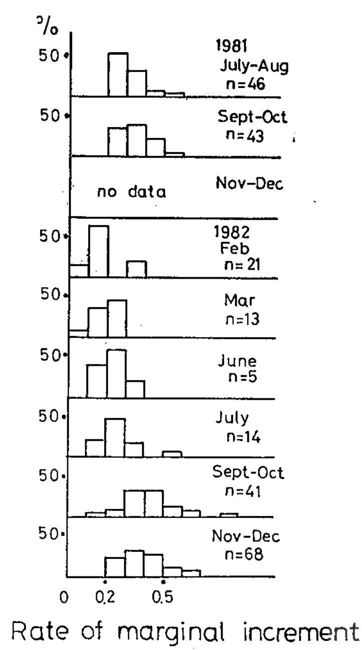

Fig. 7. Monthly changes of the rate of marginal increment in the scale of common mackerel collected from the waters off Pengchiahsu-Fishing Is..

As shown in Fig. 6, the value of MF is low in December, increasing to the highest level in February-March, and decreasing thereafter. Therefore, it is estimated that the common mackerel commences its maturation from January and spawns in between February and March.

The time for ring formation was estimated from the monthly changes of the frequency distribution of the rates of marginal increment (m) of the scale of common mackerel. The rate was calculated by:

$$m=\frac{R-r_n}{r_n-r_{n-1}} \tag{3}$$

where, R is the scale radius, r_n is the radius of last ring and r_{n-1}, the $(n-1)th$ ring on the scale.

The monthly change of the rate of marginal increment (m) of the scale of one-ring fish was shown in Fig. 7. The mode of m value located at 0.2–0.3 in July-August, and shifted to 0.3–0.4 in September-October. The m value decreased to the lowerest (0.1–0.2) in February and increased gradually to the highest level again in September-October. Theoretically, the ring was formed when m value was in lowerest level. It is also found in this study that the ring is formed once a year, in between January and February.

4. Mean Ring Radius and Back Calculated Fork Length at the Time of Ring Formation

The ring radius on the scale of common mackerel were calculated by ring groups. The weighed mean of ring radii in one year old fish was estimated 0.811 ± 0.080 mm, while that in two year old one was 1.250 ± 0.119 mm (Table 2). By adopting formula (1), the fork length at the time of ring formation was estimated as 217.9 ± 9.2 mm for one year old fish and 268.5 ± 13.7 mm for two year old fish (Table 3).

The migrating common mackerels in the waters off Pengchiahsu-Fishing Island comprised of three age groups, namely 0^+, 1^+ and 2^+, their size are almost entirely shorter than 300 mm (Table 1).

Table 2. Mean ring radius of each ring group in common mackerel collected from the waters off Pengchiahsu-Fishing Island

Ring group	Number of specimens	Radius of ring (mm)	
		r_1	r_2
1	66	0.813	
2	34	0.806	1.250
Weighed mean	100	0.811±0.080*	1.250±0.119*

*: 95% confidence limits.

Table 3. Back-calculated fork length at ring formation period for common mackerel collected from the waters off Pengchiahsu-Fishing Island

Ring group	Number of specimens	Fork length (mm)	
		L_1	L_2
1	66	218.2	
2	34	217.4	268.5
Weighed mean	100	217.9±9.2*	268.5±13.7*

*: 95% confidence limits.

5. Length—Weight Relationship

Relationship between fork length and body weight was obtained from the following equation:

$$W=aL^b \quad (4)$$

where, L is fork length in mm, W is body weight in gm, and a, b are initial growth index and growth coefficient respectively.

As shown in Fig. 8, the relative growth equation of length and weight of 252 individuals was estimated by least square method as follow:

$$W=40.0967\times L^{3.2028}\times 10^{-7} \qquad (r=0.9312) \quad (5)$$

6. Comparison of Ring Radius Pattern Among Different Subpopulations

The relative distance of the first ring is 76.0% on the scales of common mackerels collected from the waters off Pengchiahsu and Fishing Islands, which is very close to that of the south East-China-Sea group (75.7%) (Table 4). Although the data of second ring was lacking for south East-China-Sea group, it is anticipated that the obtained 65.2% from the present study is very close to that of south East-China-Sea group due to the geographical cline.

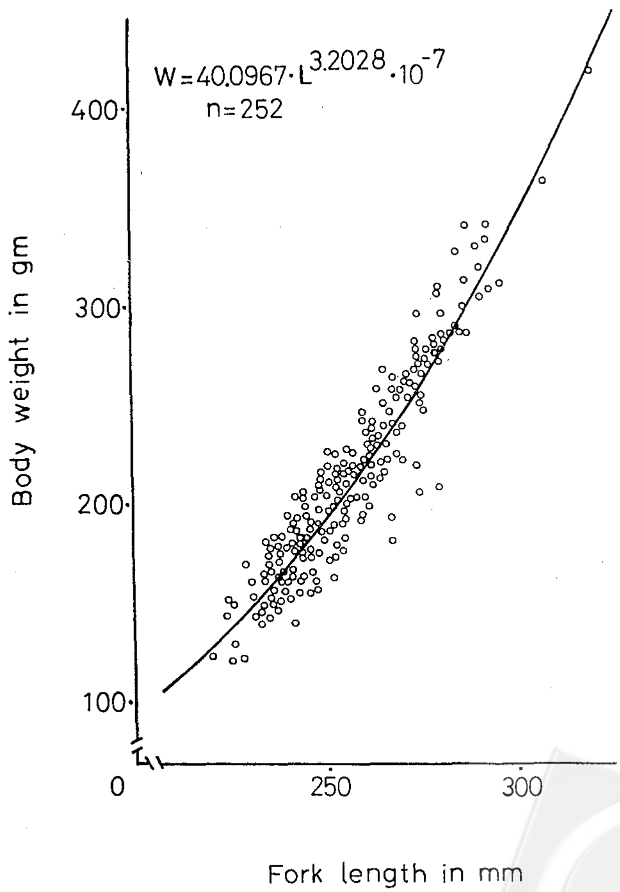

Fig. 8. Relationship between fork length and body weight in common mackerel collected from the waters off Pengchiahsu-Fishing Is..

Table 4. Relative distance of the *i*th ring radius on the scales of common mackerel

Age	Fishing ground	No. of specimens	Relative distance of ring radius		Authors
			1st ring	2nd ring	
1	Sakai	50	69.1	—	Ōuchi and Hamasaki, 1979
	Tsushima-west Kyushu	221	73.6	—	〃
	middle East-China-Sea	79	73.2	—	〃
	south East-China-Sea	58	75.7	—	〃
	west East-China-Sea	139	83.4	—	〃
	Pengchiahsu-Fishing Is.	151	76.0	—	the present study
2	Sakai	52	48.5	84.9	Ōuchi and Hamasaki, 1979
	Tsushima-west Kyushu	150	63.4	88.3	〃
	middle East-China-Sea	28	65.0	89.2	〃
	west East-China-Sea	94	70.2	91.9	〃
	Pengchiahsu-Fishing Is.	44	65.2	89.5	the present study

DISCUSSION

The time for ring formation is considered to relate to the changes of environmental factors, e. g. water temperature and the physiological conditions, e. g. maturity and spawning[9~10].

It is estimated that annual rings on the scales of common mackerels around Pengchiahsu and Fishing Islands is formed in January–February (Fig. 7). As shown in Fig. 9, the maximal water temperature around Pengchiahsu and Fishing Islands appears in July–August, decreases gradually to the lowest in January–February, and increases again thereafter. On the other hand, as shown in Fig. 6, common mackerel commences its maturation from January and spawns in between February and March. Evidently, the time for ring formation corresponds to the period of lowest water temperature and the onset of gonad maturity. It is also observed for that of the subpopulations in the waters of western Kyushu and eastern Tsushima Islands[6]. Therefore, the mechanism of ring formation of

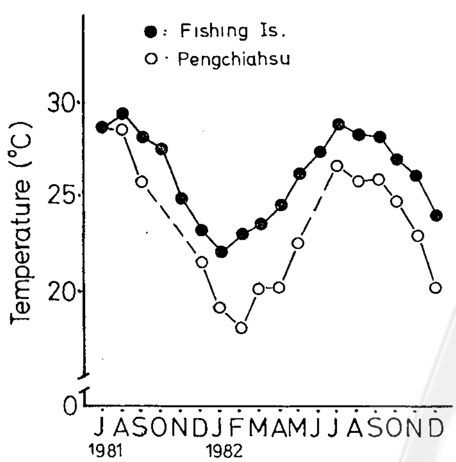

Fig. 9. Monthly changes of surface sea water temperature in the waters off Pengchiahsu and Fishing Is..

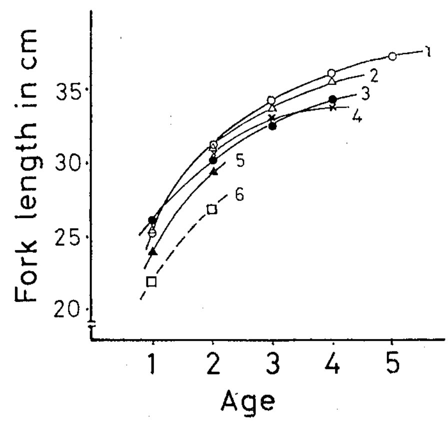

Fig. 10. Comparison of growth curves of common mackerel in six different groups; 1: west Kyushu group, 2: Sakai group, 3: west East-China-Sea group, 4: west Saishu group, 5: south East-China-Sea group (Ōuchi and Hamasaki, 1979) and 6: Pengchiahsu-Fishing Is. group. (the present study).

the common mackerel is believed under the effects of the changes of the environmental factors as well as the physiological conditions.

When comparing the estimated fork length at the time of ring formation for the common mackerel in the present studied area (Table 2) with those of other groups in the neighboring areas (Fig. 10), it shows a significantly geographical cline with decreasing growth rate from north to south. This is extremely different from most of southernly distributed fish with higher growth rate under the higher water temperature.

Many studies suggest that there are different subpopulations of common mackerels occurring in the western Japan-Sea and East-China-Sea(11). The common mackerels from the above areas are divided into four subpopulations, namely; Sakai, Tsushima-west Kyushu, west East-China-Sea and south East-China-Sea groups(2). Due to similarity in the growth curves (Fig. 10) and the relative distances of the first ring on the scales (Table 4) between the common mackerels from the south East-China-Sea and the present studied areas, it is considered that the common mackerels in the waters around Pengchiahsu and Fishing Islands is identical with the subpopulation of south East-China-Sea group.

In addition, although the samples of common mackerels were collected randomly during the present studies, the fish older than two years were rarely found. It is a similar case seen in the south East-China-Sea group(2). The common mackerels from the south East-China-Sea and the waters off Pengchiahsu and Fishing Islands are considered to be similar in fishing condition. However, the distribution and migration of this subpopulation is still not fully understood and needs to further study.

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