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Age and Growth of Spotted Mackerel, *Scomber Australasicus* (Cuvier), in the Shelf Waters of Northeastern and Southwestern Taiwan

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本文係以鱗片爲年齡形質來研究臺灣近海之澎佳嶼～釣魚臺及東沙羣島產花腹鯖的年齡與成長。所用材料是1981年11月至1983年10月於蘇澳漁市場採集大型圍網漁業之漁獲。花腹鯖每年大約在 12～1 月形成年輪。澎佳嶼～釣魚臺海域之 1～5 歲魚其尾叉體長分別爲：208.3±7.6 mm，269.3±12.9 mm，306.4±13.9 mm，336.7±15.7 mm 及 362.8±14.8 mm。東沙海域者分別爲：226.9±8.5 mm，281.6±14.1 mm，314.1±13.5 mm，342.5±14.8 mm 及 364.4±14.0 mm。兩海域間之鱗長～尾叉長，尾叉長～體重及成長曲線，皆有顯著差異。

ABSTRACT

Age and growth of spotted mackerel (*S. australasicus*) from the waters off Pengchiahsu-Fishing Island and northern Pratas Islands in the northeastern and southwestern Taiwan respectively were studied from December 1981 to October 1983 by means of scale reading. The results are summarized as follows:

(1) The regression lines between scale radius and fork length are significantly different between two areas,

Pengchiahsu-Fishing Island: $L=100.711+125.289R$
Northern Pratas Islands: $L=104.714+131.987R$

(2) The period of ring formation is estimated as December-January.

(3) Age-length relationship:

Pengchiahsu-Fishing Island: $L_t=420.8\,[1-e^{-0.319(t+1.143)}]$
Northern Pratas Islands: $L_t=414.1\,[1-e^{-0.327(t+1.426)}]$

(4) Length-weight relationship:

Pengchiahsu-Fishing Island: $W=77.263\times L^{3.0958}\times 10^{-7}$
Northern Pratas Islands: $W=207.753\times L^{2.9322}\times 10^{-7}$

INTRODUCTION

The spotted mackerel, *Scomber australasicus* (CUVIER), distributes mainly along the continental shelf of the East China Sea[1], extending northward to Pacific coast of Japan and southward to the South China Sea[2]. The species is one of the most important

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commercial fishes in Taiwan. It was caught mainly from large-typed purse seiner operated in the coastal waters around Taiwan. At present, there are four sets of large-typed purse seiners being operated in the shelf waters of northeastern and southwestern Taiwan. The annual landings of spotted mackerel reached 8,000 Tons, occupying about 40% of the total catches of this type of fishing gear.

Age and growth studies is a baseline study in understanding population structure, forecasting the fishing condition and fisheries management[3]. Tanoue[4] and Okachi *et al.*[5] have studied the age and growth of spotted mackerel from the coast of Kyushu, Japan. In Taiwan, Hanado and Yang[6] estimated the growth curve of spotted mackerel on the basis of monthly changes of length freguency distribution. It is quite subjective in the sense that are often fraught with uncertainties[7]. Woo[8] studied the age and growth of spotted mackerel by means of scale reading. Although two rings were formed annually in *Scomber japonicus*[9~10]. However, Kondo[11] considered that only one ring was formed annually in the present species and Woo[8] consequently considered that the first ring appeared on the scale should not be counted.

Therefore, the problems on age determination and growth study of spotted mackerels in surrounding waters of Taiwan were still not understood. The purpose of this study is to make clear the age-length relationship by means of scale reading on the basis of the landings of large-typed purse seiner operated from the adjacent waters of Taiwan.

MATERIALS AND METHODS

Specimens of spotted mackerel were colleced monthly from November 1981 to October 1983 at Nanfanao fish market from the large-typed purse seiner operated in the waters off Pengchiahsu-Fishing Island and northern Pratas Islands (Fig. 1). A total of 992 specimens were obtained and the sampling data, sample size and range of fork length were recorded monthly as shown in Table 1. Fork length and weight were measured, sexes were identified and gonads were weighed. Scales near the pectoral fin were removed for age determination because the size of scales shows least variant[12]. The removed scales were soaked in 3% KOH solution for several minutes to macerate the slime and the adhering tissue. Then five regular scales of each fish were washed in the clean water and mounted with two glass slides.

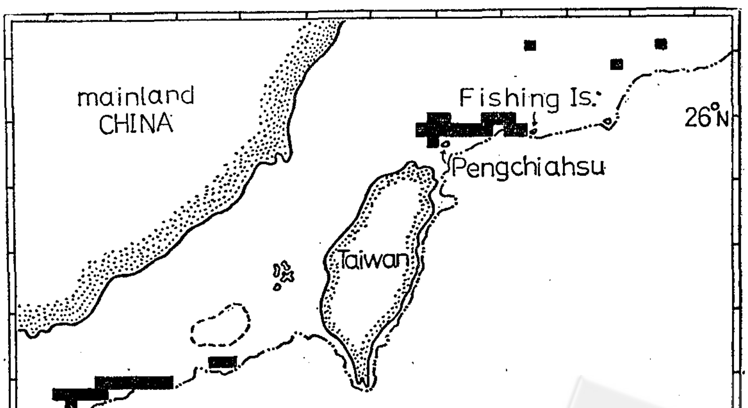


Fig. 1. Map showing the fishing grounds of large-typed purse seiner for spotted mackerel fishery in continental shelf off northeast and southwestern Taiwan. The black blocks indicate the sampling areas of spotted mackerel.

Table 1. Samples of spotted mackerel collected from the waters off Pengchiahsu-Fshing Is. and northern Pratas Islands, Nov 1981–Oct 1983

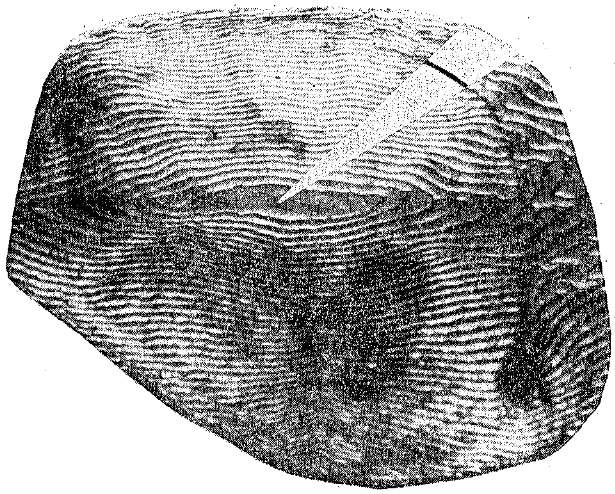
Sampling date	Pengchiahsu-Fishing Is.		Northern Pratas Islands	
	Sample size (No.)	Fork length (mm)	Sample size (No.)	Fork length (mm)
Nov 23, 1981	15	253-287		
29	20	225-285		
Jan 1, 1982	40	231-313		
19	38	270-301		
Feb 27			30	324-357
Mar 17			32	322-368
31			24	332-381
Apr 21			30	329-391
May 16			32	274-358
28			35	328-374
29			31	325-380
June 1	12	291-322		
3	3	256-317		
4	40	292-350		
13			24	334-370
24			15	339-379
July 3	21	287-328		
15	30	308-338		
16	8	308-332		
17	39	298-341		
Aug 13	23	321-364		
18	9	330-365		
Sept 13	20	327-368		
28	17	232-271		
Oct 14	16	322-350		
Nov 7	14	240-297		
18	20	325-360		
24	34	261-321		
Dec 3	7	261-275		
14	9	251-283		
Feb 5, 1983	30	248-365		
Mar 8	41	277-373		
21	23	306-391		
Apr 3	6	339-352		
22			9	318-362
May 4			24	304-353
14			24	297-349
June 19	20	295-328		
Aug 6	19	298-334		
Sept 2	49	238-272		
13	14	210-262		
Oct 5	32	305-346		
8	12	241-264		
Total	682		310	

Annual ring was discriminated according to the pattern and arrangement of ridges in the scale (plate 1) which was similar to that described in the studies of age and growth of *Scomber japonicus*[11].

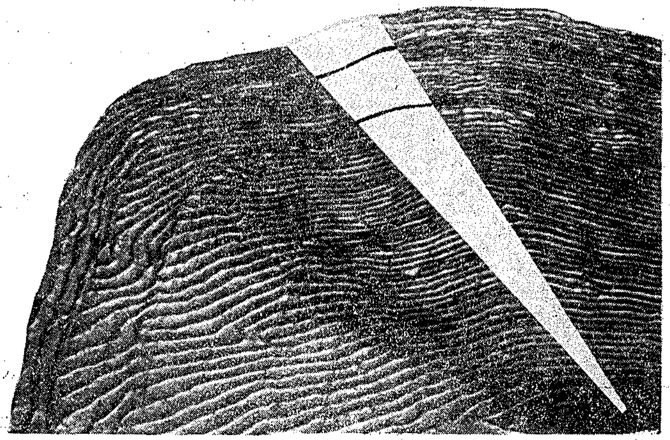
After the annual rings to be confirmed, scale radius and ring radii were measured with a profile projector, Nikon Model 6CT2, at a magnification of 20 times.

Five scales in regular shape were examined for each individuals. Then, scale radius (R) and ring radii (r_i) were measured and the mean R and r_i were calculated, and they were subsequently used to analyze the age and growth.

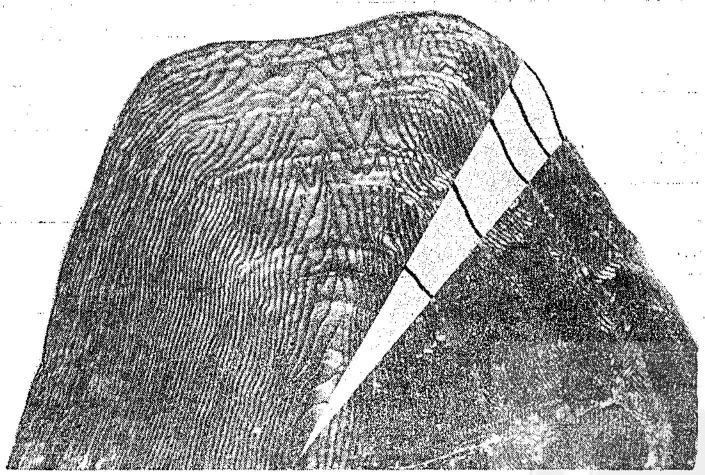
In order to compare the populations between Pengchiahsu-Fishing Island group and



(A)



(B)



(C)

Plate 1. Photographs showing the ring mark on the scale of spotted mackerel. (A), (B) and (C) are the scales of one, two and five ri gs respectively.

northern Pratas Islands group, the relationships between scale radius and fork length, fork length and body weight for the spotted mackerels from the above two regions were tested by Covariance analysis[13].

In addition, the data of surface sea water temperatures from the studied areas were obtained from "Taiwan Fisheries Research Institute" and "Nagasaki Marine Observatory" during October 1982 to October 1983, which were used to interprete the relationships between temperature and time of ring formation and spawning.

RESULTS

1. Validity of the Scale for Age Determination

The ring counts of the scales from 595 fish of Pengchiahsu-Fishing Island and 214 fish of northern Pratas Islands were examined to confirm whether the scale is a reliable ageing character. The following criteria were discussed.

(1) The relationship between fork length and ring counts

As shown in Fig. 2, the fork length frequency distribution of 595 fish from Pengchiahsu-Fishing Island and 214 fish from northern Pratas Islands were classified by ring counts. The mode of histograms of the frequency distribution seemed to shift to the larger value with the increment of rings. It indicates that the number of rings increases with the growth of fish.

(2) Relationship between scale length and ring radius

The relationship between ring radius and scale length of two ring classes (46 fish), three ring classes (36 fish) and four ring classes (21 fish) were plotted in Fig. 3, respectively. It is

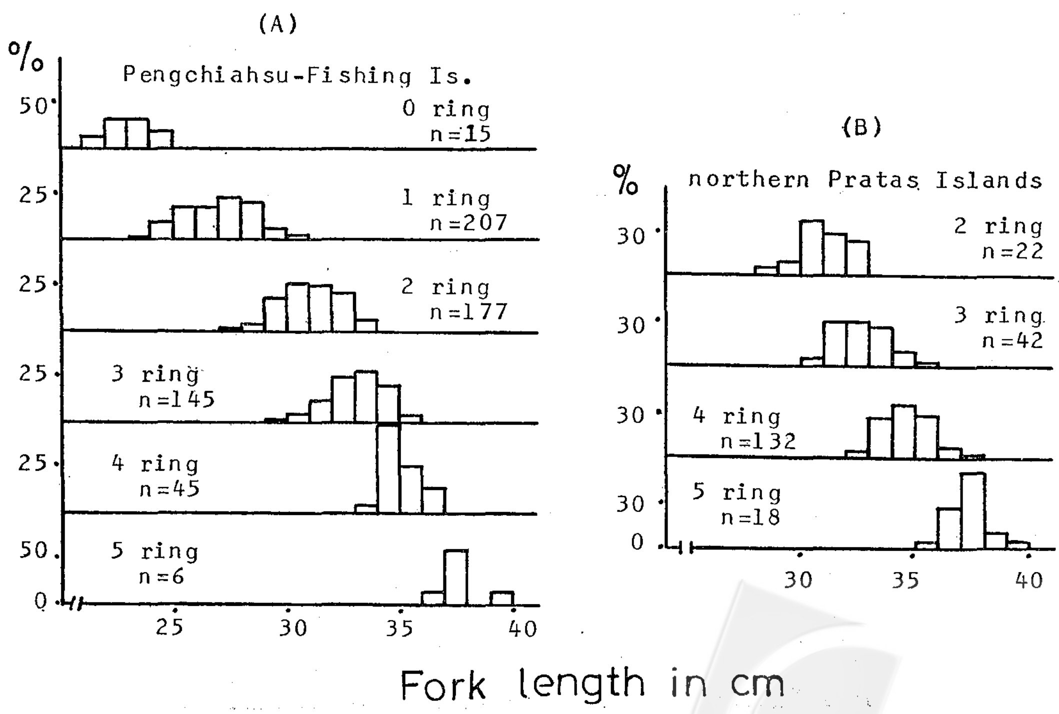


Fig. 2. Lenght frequency distribution, by ring groups, of spotted mackerel collected from the waters off Pengchiahsu-Fishing Is. (A) and from the waters off northern Pratas Islands. *n* indicate sample size (B).

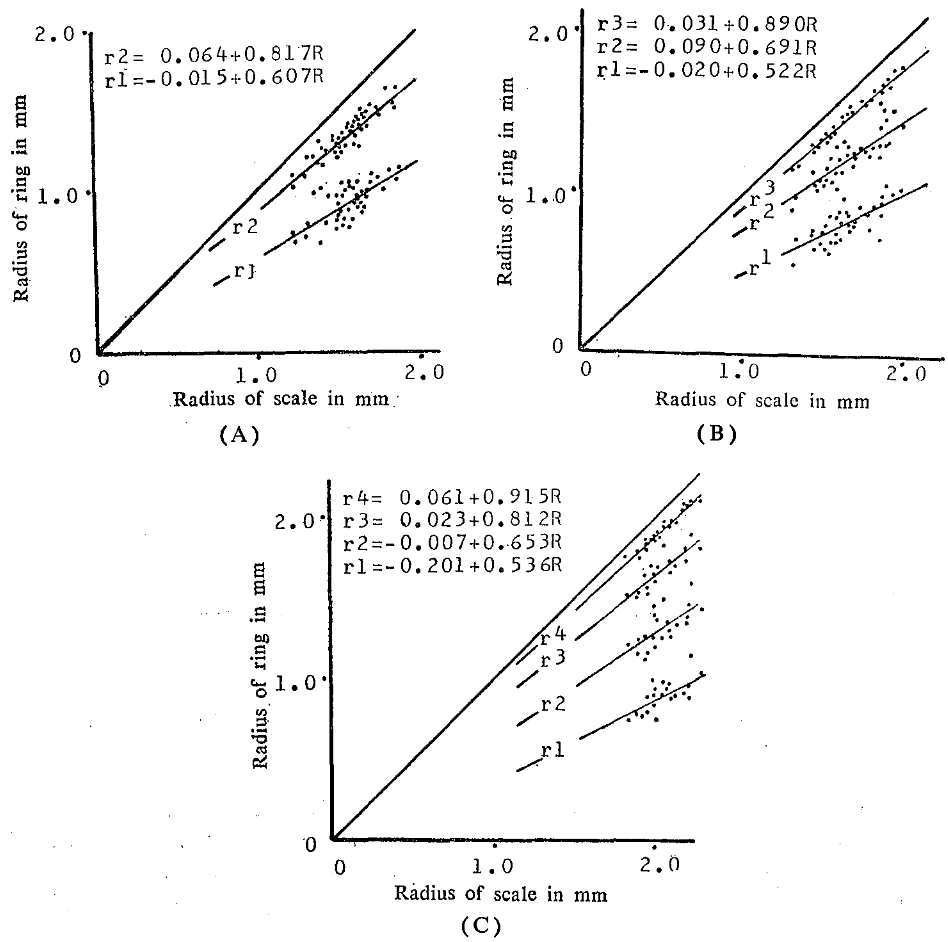


Fig. 3. Relationship between radius of scale (R) and radii of ring (r_i) in spotted mackerel. (A), (B) and (C) are 46, 36 and 21 fishes with two, three and four rings respectively.

clear that ring radius increases with scale length for each ring group. The above regression lines were significantly different. It seems that the position of annual ring are highly definite among different individuals.

(3) Relationship between ring radius and ring counts

As shown in Fig. 4, the ring radius frequency distribution of 580 fish with 1–5 rings were classified by ring groups. The mode of histograms of the frequency distribution of ring radius shifted to large value of ring radius as the number of ring counts increased. And the frequency distribution of the ring radius clearly separated especially in younger ones.

Accordingly, the scales of spotted mackerel was considered to be a reliable character for studying the age and growth.

2. Relationship Between Fork Length and Scale Radius

The fork length in relation to scale radius was plotted (Fig. 5) and calculated by regions:

Pengchiahsu-Fishing Is.: $L=100.711+125.289R$ $(r=0.9399)$..............(1)
Northern Pratas Islands: $L=104.714+131.987R$ $(r=0.8989)$..............(2)

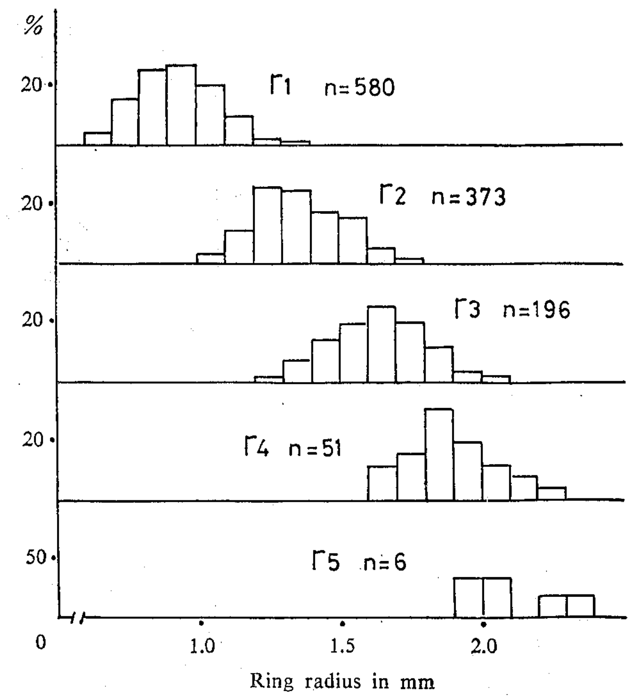


Fig. 4. Ring radius frequency, by ring group, of spotted mackerel collected from the waters off Pengchiahsu-Fishing Is..

where, L is fork length in mm, R is scale radius in mm and r is correlation coefficient. Based on Covariance analysis, it showed that fork length-scale radius relation have significant difference in the adjusted mean between these two regression lines. The populations in these two regions may be different, therefore, the age and growth of spotted mackerel in these two regions were analyzed respectively.

3. Timing of Formation of Age Mark

The ring formation period is estimated from the monthly change of the frequency distribution of the rates of marginal incrememt of the scale of two ring fish. The rates were calculated by the following formula:

$$m=\frac{R-r_2}{r_2-r_1}$$

where, m is the rate of marginal increment of the scales, R is the scale radius, r_1 and r_2 are the radius of the first and second rings on the scales.

The monthly changes of the rate of marginal increment (m) of scale of spotted mackerels were shown in Fig. 6. The mode value m of the histograms located in 0.4 in November 1982, decreasing to the lowest of 0.1–0.2 in February 1983. After that, m value increased gradually to the highest level of 0.5–0.6 in October 1983. The appearance of lowest m value indicated that the growth of ridge on scale slows down. In other words, the ring will be formed at the time when m value is at minimal level. Because the minimal m value appeared only once a year, it is therefore suggested that the ring is formed once a year in December–January.

The mechanism of ring formation is believed to be the result of the reduction in metabolic rate corresponding to the minimal rate of marginal increment of scale. In general, the environmental factors, such as water temperature[14] and physiological change,

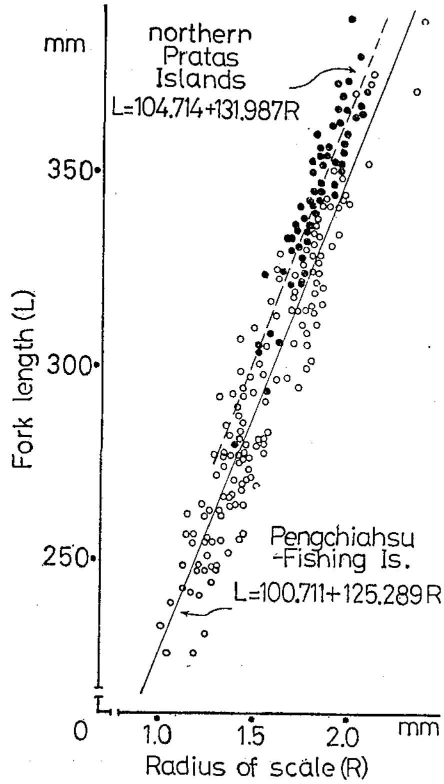


Fig. 5. Relationship between radius of scale and fork length of spotted mackerel collected from the waters off Pengchiahsu-Fishing Is. and from the waters off northern Pratas Islands.

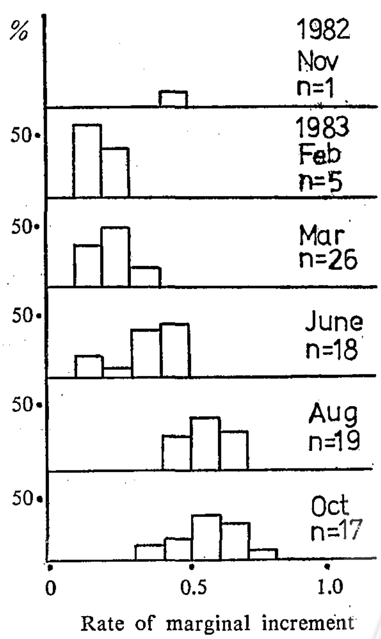


Fig. 6. Monthly changes of the rate of marginal increment in the scale of two ring fish collected from the waters off Pengchiahsu-Fishing Is.

e. g. maturity and spawning[15] are frequently considered to be related to the ring formation.

The spawning season of spotted mackerel were estimated according to the monthly changes of maturity factor which was calculated from:

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

As shown in Fig. 7, the value of MF was small during June through December, increased from January and reached to maximum in February and March and dropped significantly thereafter. Because the maturity factor is an indicator of maturity and spawning, it is expected that mackerel commences its maturity from January with the period of spawning season during February and March.

The monthly changes of water temperature from the waters of Pengchiahsu-Fishing

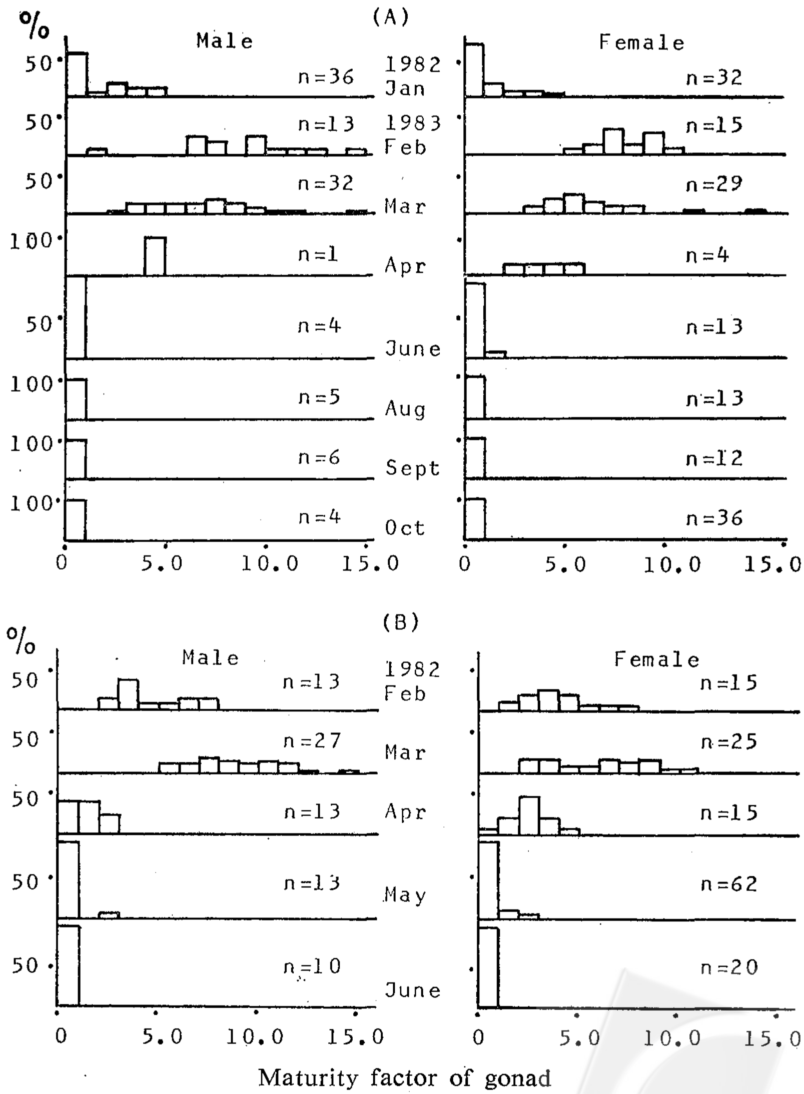


Fig. 7. Monthly changes in the frequency distribution of maturity factor for spotted mackerel were collected from the waters off Pengchiahsu-Fishing Is. (A) and from the waters off northern Pratas Islands (B).

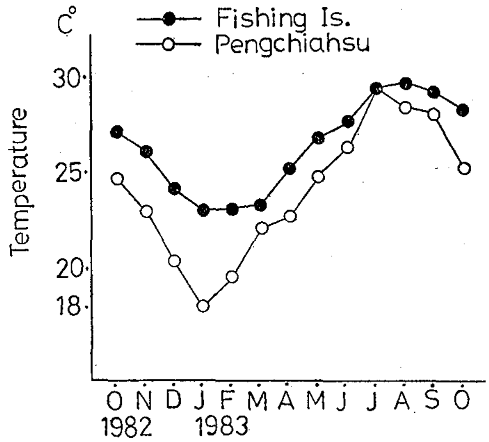


Fig. 8. Monthly changes of surface sea water temperature in the waters off Pengchiahsu and Fishing Island.

Island are shown in Fig. 8. The maximal water temperature (29.5°C) appears in July-August, decreasing gradually and reaching to minimum (18°C) in January. After March, the temperature increased gradually again.

Comparing the relationship among the temporal changes of marginal increment of scale, maturity factor and the water temperature. It is clear that annual ring forms at the time of lowest water temperature when the fish becomes mature for spawning.

4. Mean Ring Radius and Estimated Fork Length at the Period of Ring Formation

The mean ring radius was calculated by ring groups. The ring radii of 1-5 years old fish were 0.860±0.061 mm, 1.346±0.103 mm 1.642±0.111 mm, 1.872±0.125 mm and 2.092±0.118 mm respectively (Table 2) for the fish of Pengchiahsu-Fishing Island. While 0.926±0.079 mm, 1.340±0.108 mm, 1.586±0.113 mm, 1.801±0.127 mm and 1.967±0.115 mm respectively for the fish of northern Pratas Islands (Table 3). The fork length of the fish of 1-5 years old at the time of ring formation were obtained from the equations (1) and (2). They were 208.3±7.6 mm, 269.3±12.9 mm, 306.4±13.9 mm, 336.7±15.7 mm and 362.8±14.8 mm respectively (Table 4) for the fish of Pengchiahsu-Fishing Island and while 226.9±8.5 mm, 281.6±14.1 mm, 314.1±13.5 mm, 342.5±14.8 mm and 364.4±14.0 mm respectively (Table 5) for the fish of northern Pratas Islands.

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

Ring group	Number of specimens	Radius of ring (mm)				
		r_1	r_2	r_3	r_4	r_5
1	57	0.843				
2	52	0.898	1.393			
3	50	0.840	1.320	1.644		
4	34	0.856	1.296	1.626	1.863	
5	6	0.872	1.445	1.715	1.929	2.092
Weighed mean± 95% confidence limits	199	0.860 ±0.061	1.346 ±0.103	1.642 ±0.111	1.872 ±0.125	2.092 ±0.118

Table 3. Average ring radius of each ring group in spotted mackerel collected from the waters off northern Pratas Islands

Ring group	Number of specimens	Radius of ring (mm)				
		r_1	r_2	r_3	r_4	r_5
2	8	0.880	1.277			
3	18	0.980	1.363	1.576		
4	54	0.921	1.345	1.581	1.799	
5	10	0.896	1.326	1.629	1.812	1.967
Weighed mean± 95% confidence limits	90	0.926 ±0.079	1.340 ±0.108	1.586 ±0.113	1.801 ±0.127	1.967 ±0.115

Table 4. Back-calculated fork length at ring formation period for spotted mackerel collected from the waters off Pengchiahsu-Fishing Island

Ring group	Number of specimens	Fork length (mm)				
		L_1	L_2	L_3	L_4	L_5
1	57	206.3				
2	52	213.2	275.2			
3	50	206.0	266.0	306.7		
4	34	207.0	263.0	304.4	336.0	
5	6	210.0	281.8	315.6	340.5	362.8
Weighed mean± 95% confidence limits	199	208.3 ±7.6	269.3 ±12.9	306.4 ±13.9	336.7 ±15.7	362.8 ±14.8

Table 5. Back-calculated fork length at ring formation period for spotted mackerel collected from the waters off northern Pratas Islands

Ring group	Number of specimens	Fork length (mm)				
		L_1	L_2	L_3	L_4	L_5
2	8	220.9	273.3			
3	18	234.1	284.5	312.8		
4	54	226.3	282.3	313.4	342.2	
5	10	230.0	279.8	319.8	343.9	364.4
Weighed mean± 95% confidence limits	90	226.9 ± 8.5	281.6 ±14.1	314.1 ±13.5	342.5 ±14.8	364.4 ±14.0

5. Growth Curve in Length

The back-calculated fork length listed in Tables 4 and 5 was obtained based on the Walford's transformation (Fig. 9) which is used to find out the parameters of Von Bertalanffy growth equation[16~17]. It seems that the spotted mackerel of northern Pratas Islands (414.1 mm) reaches the asymptotic length faster than that of Pengchiahsu-Fishing

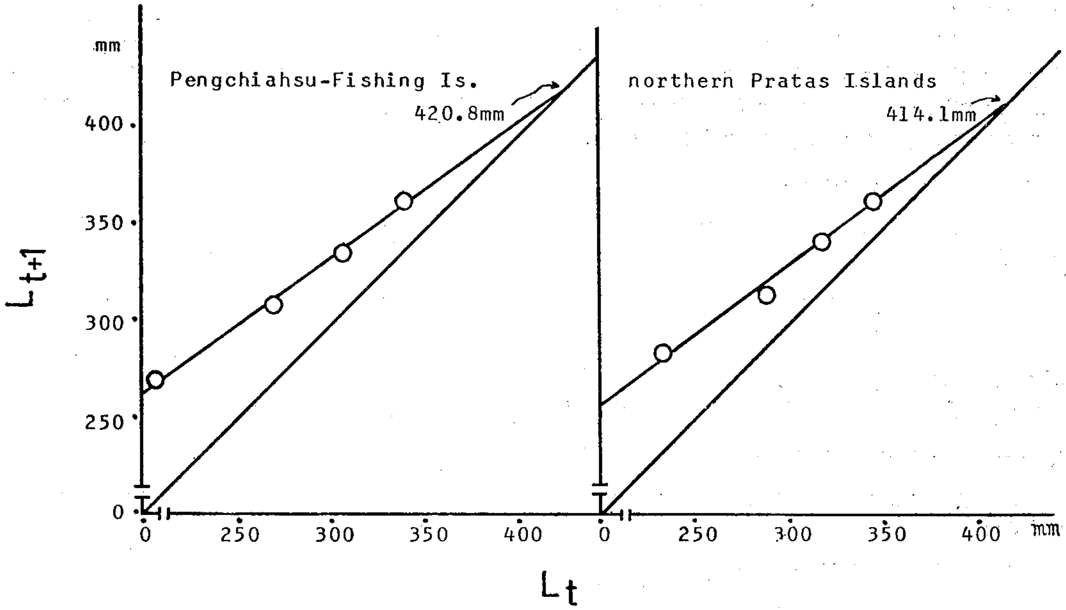


Fig. 9. Walford plots of mean length at $t+1$ years against mean length at t years for spotted mackerel collected from the waters off Pengchiahsu-Fishing Island and northern Pratas Islands.

Island (420.8 mm). The Von Bertalanffy growth equations for these two areas obtained are as follows:

Pengchiahsu-Fishing Is.: $L_t = 420.8\ [1 - e^{-0.319(t+1.143)}]$ .... (3)

Northern Pratas Islands: $L_t = 414.1\ [1 - e^{-0.327(t+1.426)}]$ .... (4)

The theoretical curves deduced for Von Bertalanffy growth equations give a good fit on back calculated fork lengths. Comparing the growth equations of different populations, it

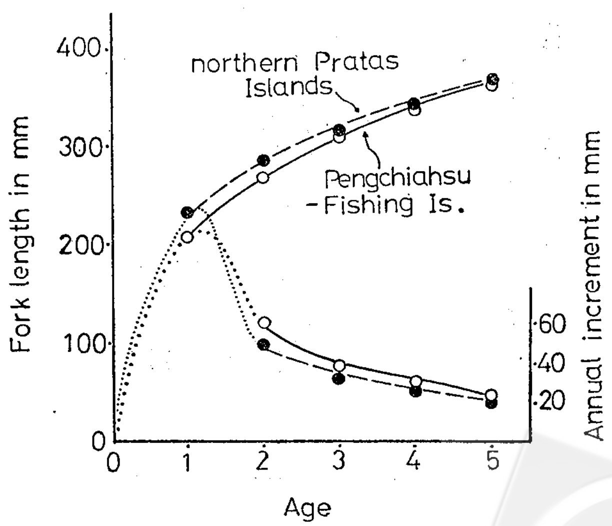


Fig. 10. The growth curves and annual increment in length of spotted mackerel collected from the waters off Pengchiahsu-Fishing Is. and northern Pratas Islands. The black and white circles indicate the back-calculated fork length.

seems that the spotted mackerel of northern Pratas Islands grows better than that from the Pengchiahsu-Fishing Island. However, the annual increment showed inverse relationship for the older fish in these two areas. It means that annual increment of one year old fish of northern Pratas Islands is greater than those of Pengchiahsu-Fishing Island, but it reverses beyond one year old fish (Fig. 10).

6. Length-Weight Relationship

Length-weight relationships for the spotted mackerel were plotted and calculated using pooled data of each month as shown in Fig. 11 and the following equations:

Pengchiahsu-Fishing Is.: $W= 77.263\times L^{3.0958}\times 10^{-7}$ $(r=0.9764)$........... (5)

Northern Pratas Islands: $W=207.753\times L^{2.9322}\times 10^{-7}$ $(r=0.9129)$........... (6)

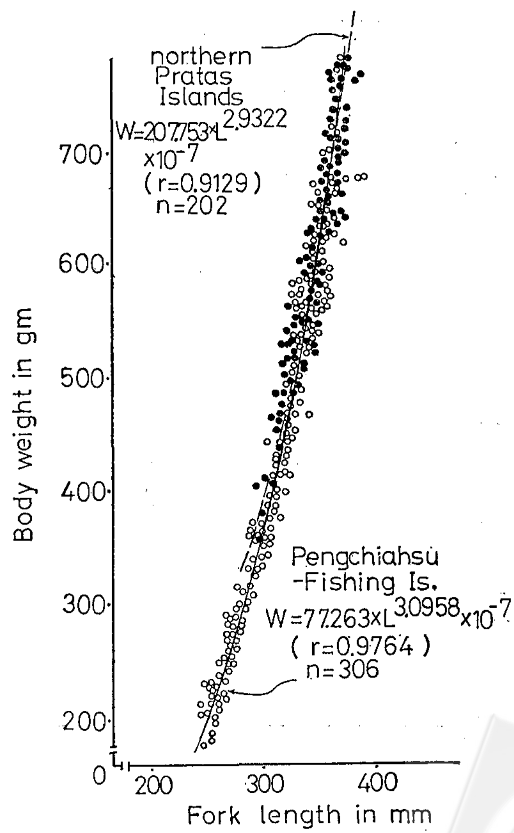
where, W is body weight in gm and L is fork length in mm. By Covariance analysis the two equations showed significant difference at 1% level in adjusted mean.

7. Age-Body Weight Relationship

The growth curves in weight were transformed from Von Bertalanffy equations (3 and 4):

Pengchiahsu-Fishing Island:

$W_t=1027.1\ [1-e^{-0.319(t+1.143)}]^3$.. (7)



Fig, 11. Relationship between the fork length and body weight of spotted mackerel collected from the waters off Pengchiahsu-Fishing Is. and northern Pratas Islands.

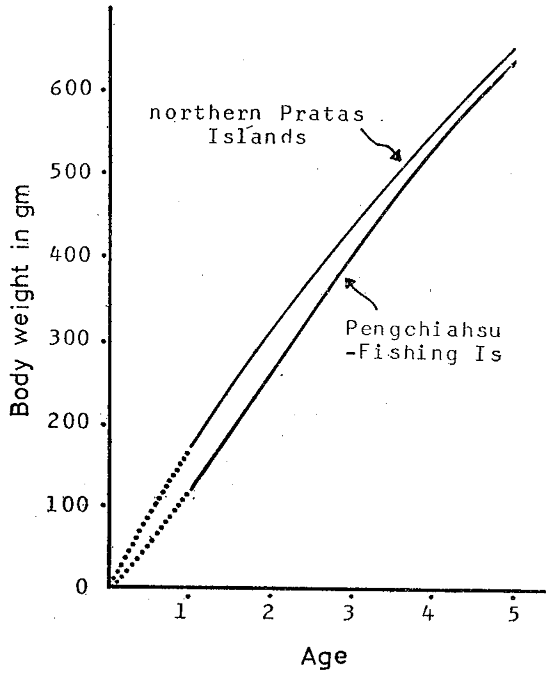


Fig. 12. The growth curves in weight of spotted mackerel collected from the waters off Pengchiahsu-Fishing Is. and northern Pratas Islands.

Northern Pratas Islands:

$$W_t=980.4\ [1-e^{-0.327(t+1.426)}]^3 \qquad (8)$$

The growth curves in weight shown in Fig. 12 indicate that the growth of spotted mackerels of northern Pratas Islands is faster than that of Pengchiahsu-Fishing Island group.

DISCUSSION

The age and growth of spotted mackerel was also studied previously in the adjacent waters of Japan[5,18]. Their estimated lengths at different age groups were considerably larger than those of our results. This phenomenon may be caused by the overestimation of the number of age mark ring, i.e. two rings formed per year, one in July, the other in December-January. However, the above so-called summer ring is not found in the present studies (Fig. 6).

The fork length (Table 5) of spotted mackerel estimated at the ring formation period is close to that of Woo[8]. However, Woo[8] did not recognize the first ring of spotted mackerel and consequently counted the fish with second ring as one year old. Woo's[8] conclusion was based on the comparison of the back-calculated fork length of first ring with monthly mode of fork length frequency distribution and from the idea that two rings was formed annually on the scale of common mackerel, *Scomber japonicus*[9,10].

However, the biological minimum size of spotted mackerel was reported to be 20–25 cm[19], which is close to the estimated fork length (20.1–21.6 cm) at the time of first ring formation rather than the second one (25.7–28.2 cm). In addition, the idea of two rings formed annually was confirmed as a misinterpretation in common mackerel[11]. Meanwhile, it is sure that only one ring was formed annually in the spotted mackerel (Fig. 6). Therefore, the back-calculated fork length of the first ring is considered to be the size of one year old fish.

Comparing the growth curves, the relationships between the scale radius and fork length, and the fork length and body weight, it reveals a significantly geographical difference between the spotted mackerel of Pengchiahsu-Fishing Island and that of northern Pratas Islands. These were a similar case done by Chang and Wu[20] who considered that the spotted mackerels from southern and northern Taiwan belonged two different populations. Therefore, the spotted mackerels of Pengchiahsu-Fishing Island and northern Pratas Islands may also belong to different populations. However, it needs further studies on the population discrimination by other methods to confirm this possibility.

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