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On the Age and Growth of the White Croaker *Argyrosomus argentatus*

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(Figs. 1–9; Table 1)

The white croaker, *Argyrosomus argentatus*, is widely distributed from northern Japan to the Indian Ocean.[1] But it is considered that this fish is more abundantly distributed in the coastral waters of southern mainland and southward of Japan. The white croaker is a common demersal fish of commercial value and an important fishing resource for the trawl fishery in the East China Sea and the Yellow Sea. In the Seto Inland Sea and its adjacent sea regions the white croaker is caught in considerable quantity by small beam trawls, small set nets or the likes. And consequently it is an important fish there, too.

The age and growth of the white croaker have been reported by many researchers. Namely, the growth of the fishes collected in the East China Sea and the Yellow Sea was estimated by the number of annuli seen on the scales and from the transition of length-frequency distributions of each sample. [2)–10)] The growth of the fish in Mikawa Bay and Tokyo Bay was estimated by means of the scales, too.[2] In the Seto Inland Sea and its adjacent sea regions, the growth of the fish was made clear on the basis of an analysis of the progression of modes in successive length-frequency distributions of the samples collected,[11][12] but it has never been carried out by examination of the scales in the samples collected there.

The study on the white croaker has been carried out as a part of the study of the important kinds of fish for fishery that populates in the Seto Inland Sea. It is the purpose of this study to determine age and growth of the fish by means of the annuli on the scales in order to secure information on the fishery biology of this species in the Seto Inland Sea.

MATERIALS AND METHODS

In the present study 406 individuals of the white croaker were used. Collection of all these fishes was performed monthly for about two years from May in 1975 to January in 1977, in the central region of the Seto Inland Sea. These specimens were 1–3 years old, 100–225 mm in standard length and 21.0–270.9g in body weight.

After each specimen had been measured for it's total length, standard length, body weight and gonad weight, several scales were respectively removed for observation from the part of the first or second row above the lateral line of the upper part of the anal fin of each specimen. After the scales were immersed in 5% KOH solution and sufficiently cleaned in water to remove the mucus, they were mounted between two pieces of slide glass with a drop of glycerin and examined with a projector under the magnification of 20 times.

RESULTS

The scales of this species are of the ctenoid type. The annulus is distinguished by a discontinuity or break in the ridges. The clear annulus appears especially in the lateral field. Namely, the annulus on a scale is definable as the zone which comprises irregularly arranged ridges in the anterior sector and concurrently intercepts the adjacent inner ridges in both lateral sectors.

The measurements of the sample scales taken from this section are as shown in Fig. 1. Namely, the right and left antero-lateral scale radii (R′, R″) are represented by the distance between the focus and the antero-lateral angles, and the right and left antero-lateral annulus radii (r′, r″) are represented by the distance between the focus and the antero-lateral annulus. The average of each value measured on these two axes is put to use as the scale radius (R)* and the annulus radii (r)** of each scale.

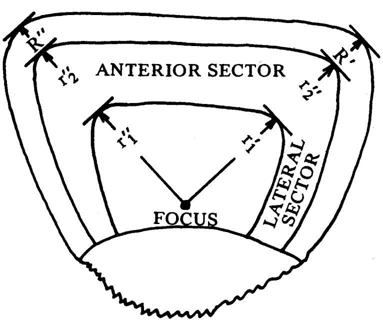

Fig. 1. Schematic diagram of measuring scale radius and annulus radius. R, scale radius; r, annulus radius.

The relationship between scale radius and annulus radii, "similarity," is examined for the scales removed from the various body parts of the specimen with five annuli in its scale. It is observed that in these scales from the same individual the relationship between the scale radius and the radius of a definite annulus can be expressed by linear regression (Fig.2).

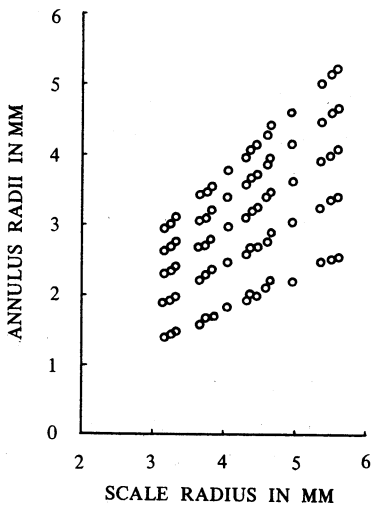

Fig.2. Relationship between scale radius and annulus radii in the scale taken from various body portions of the sample specimen.

The relationship between standard length (L) of the white croaker and the mean radius ($\overline{R}$) of the several scales taken from the fixed body part of the fish is linear, and can be expressed by the equation (1) (Fig. 3).

$$\overline{R} = 0.271\,L - 0.176 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Since there is a variance in the radius of the scale removed from the fixed body part of the equal standard length specimen as shown in Fig. 3, and since the annulus radii vary according

$* \; R = \dfrac{R' + R''}{2}$ $\quad ** \; r = \dfrac{r' + r''}{2}$

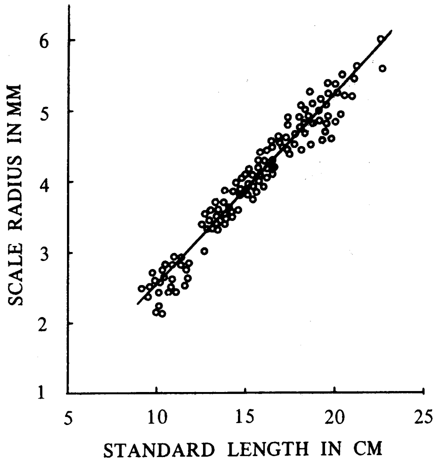

Fig. 3. Relationship between standard length and scale radius.

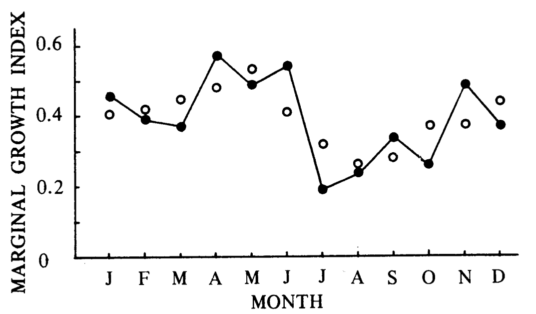

Fig. 4. Monthly changes in marginal growth index, $(\bar{R}-\bar{r}_n)/(\bar{r}_n-\bar{r}_{n-1})$. Open circles are the value of index smoothoed by using the three-place moving averages.

to the scale radius as shown in Fig. 2, the scale radius computed from the standard length with the above empirical equation (1) is termed the "standard scale radius" ($\bar{R}$). By multiplying $\bar{R}$ by the ratio of the measured annulus radius (r) to the measured scale radius (R), the "standard annulus radius" ($\bar{r}$) is obtained.

The value of the marginal growth index, $(\bar{R}-\bar{r}_n)/(\bar{r}_n-\bar{r}_{n-1})$, varies every month and attains its minimum value in July. Moreover the index decreases slightly in February and March but increases in April (Fig.4). Judging from the monthly variation pattern in the marginal growth index smoothed by using the three-place moving averages, the annulus is formed twice a year in the term, from January to March and in July.

Frequency distribution of each "standard annulus radius"

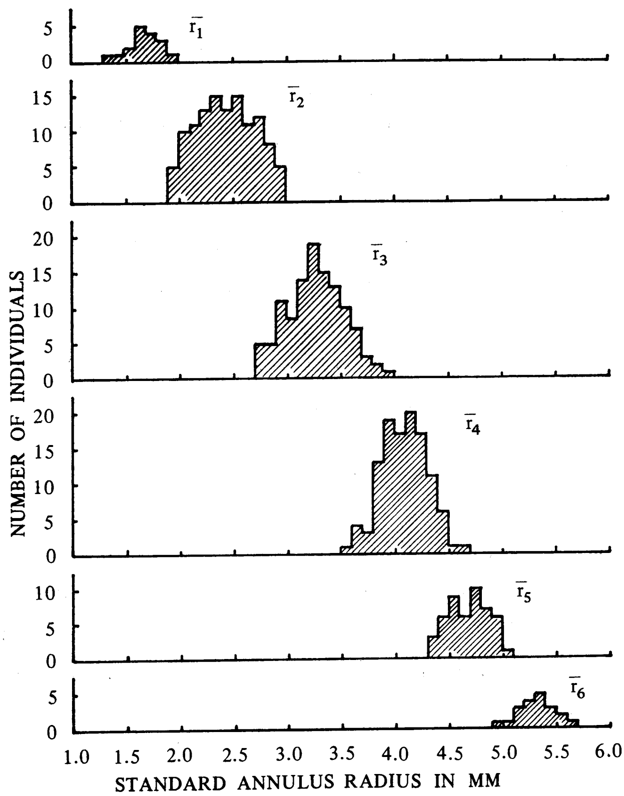

Fig. 5. Frequency distributions of standard annulus radius in each mark.

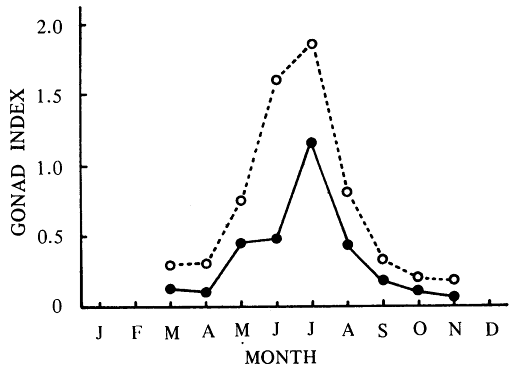

Fig. 6. Monthly changes of the gonad index, $GW\times10^3/L^3$, in the white croaker by sexes. Open circle, female; sold circle, male.

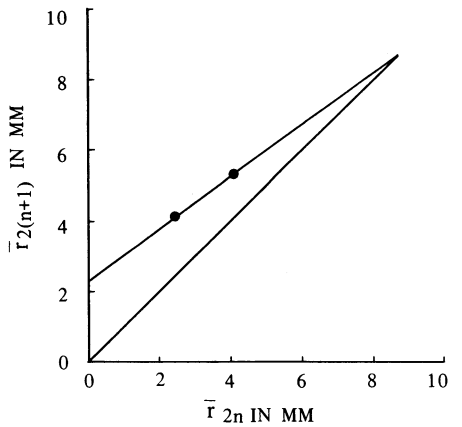

Fig. 7. WALFORD's growth transformation of standard annulus radius

suggests that the first annulus does not show in scales of many specimens, but the annuli from the second on are formed regularly (Fig. 5). From Figs 4 and 5, it is infered that the second, the fourth and the sixth annulus are formed in July every year.

By investigating the monthly trend of the gonad index, (gonad weight $\times 10^3$)/(cube of standard length), of the sample specimens, it is clear that the spawning season lasts from June until August and that its peak is in July (Fig. 6). Accordingly, the fishes are one year old in July, when the second annulus is justly formed.

The phase of the growth curve can be appropriately represented by a straight line, drawn with the mean standard radii of the second, the fourth and the sixth annulus as shown in Fig. 5, by the WALFORD's graphic method. In other words, one point is plotted on the $\bar{r}_4$ on the y axis against $\bar{r}_2$ on the x axis and another point the $\bar{r}_6$ on the y axis against $\bar{r}_4$ on the x axis (Fig. 7). The straight line drawn by joining these points is expressed by the equation (2).

$$\bar{r}_{2(n+1)} = 0.734\,\bar{r}_{2n} + 2.30 \quad \cdots\cdots (2)$$

These results indicate that the data shown in Fig. 7 can be reasonably fitted onto the BERTALANFFY's model. Thus putting t = 0 at the spawning time, the growth of this species in standard length can be expressed by BERTALANFFY's equation (3), where Lt is standard length in centimeters at t years since spawned.

$$Lt = 32.6\,(1 - e^{-0.307t-0.046}) \quad \cdots\cdots (3)$$

The body weight can be computed from the standard length by means of the equation (4), where W is the estimated round weight in grams and L the standard length in centimeters (Fig. 8).

$$W = 3.96 \times 10^{-2} L^{2.793} \quad \cdots\cdots (4)$$

The fish gets the maximum growth rate in 2.83 years after spawn-time, when the standard length is 19.5 cm and the body weight is 159g.

From the results mentioned above, the growth curves peculiar to the white croaker in the Seto Inland Sea are obtained through investigation into factors leading to the age determination by means of scales (Fig. 9). In these curves, the body weight's value is computed from the standard length by means of the equation (4) of length-weight relationship.

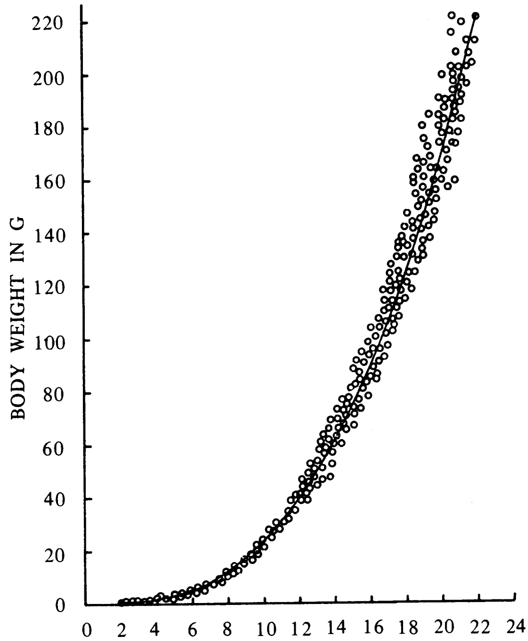

Fig. 8. Length-weight relationship in the white croaker.

DISCUSSION

It has been made clear in this study that an annulus is formed twice a year on the scales of the white croaker but the first annulus is indistinct or missing in scales of many specimens. Yasuda *et al.* have reported that the two annuli seem to be formed annually on the scales of the white croaker collected by trawl-nets in the East China Sea.[5] It has also been reported that it is difficult to distinguish the first annulus and this annulus appears to be a resting zone in winter on the scale of the fish in the East China Sea.[7)8] According to these results, it is considered that annuli in odd numbers are formed in winter and seem to be the resting zone and the ones in even numbers in July as the spawning mark. But Kojima has reported that an annulus seems to be formed once a year on scales of the white croaker caught in the East China Sea.[10]

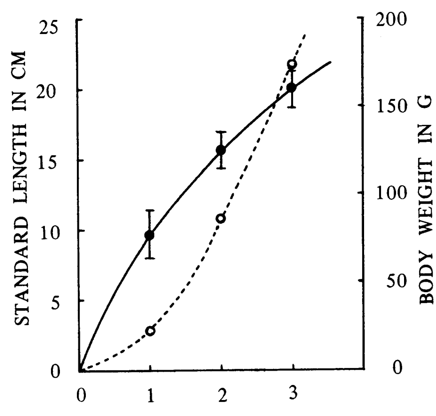

Fig. 9. Growth curves of standard length (open circle) and body weight (solid circle) in the white croaker. Vertical lines with terminal horizontal bars indicate the standard deviations in each length.

It has been calculated statistically from the value of measurement of the sample scales in this paper that the mean standard length of the white croaker of the central region of the Seto Inland Sea is 9.7, 15.7, and 20.2 cm at the full ages of 1,2 and 3 years respectively. These estimated growths in standard length are similar to those reported by Kitamori *et al.*, who studied especially the white croaker collected in Hiuchi-nada of the Seto Inland Sea and clarified the total length in each age group by analysing the progression of mode in successive length-frequency distributions (Table 1).

Table 1. Mean or range of standard length of the white croaker in each age group reported.

Sea region	Authors	1-year-old	2-year-old	3-year-old	4-year-old
Seto Inland Sea (Central region)	KAKUDA *et al.*	(cm) 9.7	(cm) 15.7	(cm) 20.2	(cm) –
Seto Inland Sea (Hiuchi-nada)	KITAMORI *et al.*[12]	~13.1	13.1 ~ 17.2	17.2~ 20.5	20.5~ 23.0
Tokyo Bay	YASUDA[2]	8.7	–	–	–
Mikawa Bay	YASUDA[2]	10.4	16.9	19.1	–
East China Sea & Yellow Sea	YASUDA *et al.*[5]	9	17	24	–
East China Sea & Yellow Sea	SAISHU *et al.*[8]	7.6, 13.3	13.3, 18.3	17.4, 21.5	20.2, 24.3
East China Sea (South) & Yellow Sea (North)	KOJIMA[10]	12.7 12.5	19.6 18.7	22.5 22.2	24.1 23.7

(NOTE)

1) The numerical number on the right shoulder of the authors shows the number of the references of this paper.
2) Each standard length of KITAMORI *et al.*, SAISHU *et al.* and KOJIMA shows the length which is calculated by multiplying total length in the original work by 0.82.
3) Standard length of SAISHU *et al.* is minimum and maximum length converted from the growth curves shown in five groups respectively.

The growth of the white croaker has been reported by many researchers. Especially, in regard to the growth of the white croaker caught in the East China Sea and the Yellow Sea, many reports have been published. The representative values of total length in these reports are transformed to standard length and indicated in Table 1. The mean or range of length in each age group varies for the different sea regions, but in general the fish collected in warmer regions seems to be longer in standard length (Table 1).

MATSUBARA has reported that there are some remarkable morphological differences and variations of local groups among the white croaker and that the body length of southern specimens is much longer than that of the northern ones.[1] The report published from Seikai Reg. Fish. Res. Lab. has been summerized as follows: The white croaker is variable according to the living area. The fish living in an area of higher water temperature grows more quickly than in lower water temperature in general.[8-10] As a result the fish can be separated into five groups which differ in growth in the East China Sea and the Yellow Sea.[8] But KOJIMA has concluded that the fish populating there can be separated into two groups or populations, Yellow Sea group and East China Sea group, by the examination of distribution, migration and morphometric comparison.[13] The fact similar to this result, that fish in warmer area is longer in length, is confirmed in the Seto Inland Sea and its adjacent sea regions.[12]

The maximum growth rate after spawn-time obtained in this study is about the same in the East China Sea and the Yellow Sea.[9]

SUMMARY

A study was carried out to determine the age and the growth of the white croaker,

Argyrosomus argentatus, which is an important resource for fishery in the Seto Inland Sea. This study, based on the samples caught in the central region of the Seto Inland Sea, is one of the serial studies on the fishery biology of the white croaker in the Sea.

General conclusions obtained in this study are as follows:

1) The relationship between standard length (L) of the fish and the mean radius ($\overline{R}$) of the scales taken from the fixed body part is linear, and can be expressed as $\overline{R} = 0.271\ L - 0.176$. In the scales from the same individual, "similarity" is recognized between scale radius and annulus radii.

2) The annulus is formed twice a year on the scales of the fish in winter and July, but the first annulus does not show in scales of many specimens.

3) The mean standard length of the fish of the Seto Inland Sea is 9.7, 15.7 and 20.2 cm at the full ages of 1,2 and 3 years respectively.

4) The spawning season lasts from June until August and its peak is in July.

5) Body weight (W) can be computed from standard length (L) by means of the relationship : $W = 3.96 \times 10^{-2} L^{2.793}$, where W is estimated round weight in grams and L is standard length in centimeters.

6) The growth of the fish can be described by BERTALANFFY's equation, $Lt = 32.6\ (1-e^{-0.307t-0.046})$. And the fish gets the maximum growth rate in 2.83 years after spawn-time, when the standard length is 19.5 cm and the body weight is 159g.

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イシモチ *Argyrosomus argentatus*の年令と成長

角田俊平・松本健二

瀬戸内海の漁業資源として，かなり重要なイシモチの年令と成長を明らかにした。すなわち瀬戸内海の中部水域で漁獲されたイシモチ406個体を用い，体長，体重および生殖腺重量を測定するとともに，鱗を年令形質として鱗径および標示径を測定して，次のような結果を得た。

1）体長と鱗径との関係は一次式（$\bar{R} = 0.271\ L - 0.176$）で示され，標示の相似性が認められること，ならびに標示は一定の周期で形成されることから，鱗は年令形質として適当である。月別に求めた鱗の最終標示を基準とした辺端成長率は年2回，2，3月と7月に極小になること，さらにWALFORDの定差図の吟味から，本種は標示を年2回形成する。しかし第1標示の欠落する個体が多い。

2）産卵期は生殖腺指数の月別変化から6月－8月で，その盛期は7月と推定される。したがって第2標示は孵化後満1年で，第4標示は満2年で，第6標示は満3年で形成される。

3）標示別の標準標示径組成から年令別の平均体長を求めると，孵化後満1年で9.7 cm，満2年で15.7 cm，満3年で20.2 cmとなる。そしてこれらを体長－体重の関係式（$W = 3.96 \times 10^{-2} L^{2.793}$）によって，年令別の平均体重を求めると，満1年で22.6 g，満2年で86.7 g，満3年で175.2 gになる。

4）以上の知見から瀬戸内海のイシモチの成長式は $Lt = 32.6\ (1 - e^{-0.307t - 0.046})$ と表せる。そして成長量が最大を示すのは孵化後2.83年を経過した時で，その時の体長は19.5 cmであり，体重は159 gである。