On the Age and Growth of *Nibea albiflora**¹Shunpei KAKUDA*² and Kazuo NAKAI*²

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In order to clarify the age and growth of *Nibea albiflora* in the Seto Inland Sea, samples were collected during one year from the landings picked up from the Sea. Each scale removed from the sample specimen was examined and measured. The results of analysis of the annual ring on the scales show that one annulus is formed once a year, in the month of June and July. As the spawning season runs from May to August and since most specimens of fish spawn in June and July, the time of the formation of the new annulus is approximately in accordance with the spawning season.

The standard length of this species found in the Seto Inland Sea is 151, 238, 305 and 357 mm on an average at the ages of full 1, 2, 3 and 4 years, respectively. The general growth formula for this species is adequately expressed by the following equation ascribed to BERTALANFFY: $L_t = 529 (1 - e^{-0.262t - 0.0736})$.

The growth of the yearling immature fish was studied on samples collected in August, September and November. This growth, on the basis of an analysis of the progression of mean and mode in successive length-frequency distributions of the immature fishes, was discussed as compared with the growth estimated from the monthly changes of the marginal growth index of the scale.

Nibea albiflora (RICHARDSON), Koichi in Japanese, is widely distributed over the coastal waters of western Japan and the southern Tyōsen Peninsula, as well as in the East China Sea and in the Yellow Sea.^{1,2)} In the eastern and central region of the Seto Inland Sea, this fish was caught in considerable quantity in recent years. Consequently, it has become an important fishery resource since this time.

A study on this species has been reported formerly by TAKITA,²⁾ but that author describes mainly the early life history of it. For the analysis of this fish population it is essential to determine their age and growth. Such a study of this species however had never been performed until now.

The study on this particular species has been carried out as part of the general population study of the important kinds of fish for fishery that inhabit in the Seto Inland Sea. In this study we took as purpose to determine the age and the growth of *N. albiflora* by the method of the annual ring on the scales.

Materials and Methods

In the present study, 269 adult and 463 immature fishes of *N. albiflora* were used. All these adult

fishes were collected monthly from the commercial fish catches in the Seto Inland Sea from March 1977 unto June 1978. These specimens were 1-4 years old; 136-435 mm in standard length and 49.0-1479.0 g in body weight. The samples of the immature fishes were caught by small trawls and small set nets in the Kojima Bay of the Seto Inland Sea on August 23, September 27 and November 9, 1977. The number of individuals of the immature samples was 362 in August, 65 in September and 36 in November.

After that the total length, standard length, body weight and gonad weight of each specimen was measured, their several scales were respectively removed from the part by the left pectoral fin for observation and measurement. The scales were immersed in a 5% KOH solution and then properly cleaned in water in order to remove the mucus. They were mounted between two pieces of slide glass and examined with a projector of 20× magnification.

The scales of this species are of the ctenoid type. The annulus on the 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 as recognized in Fig. 1.

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Fig. 1. A scale of a 3-years-old fish and its measured axes of scale radius (R) and annulus radii (r). F indicates the focus of the scale.

The measurements of the sample scales were taken on the two axes of the right and left antero-lateral line. The scale radii (R' , R'') are represented by the distance between the focus and the antero-lateral angles, and the annulus radii (r_n' , r_n'') are the distance between the focus and the antero-lateral annulus (Fig. 1). The mean of measurements obtained on the definite two axes in the several scales taken from a fixed body part of each sample specimen were used as the scale radius (R) and the annulus radii (r_n) of the specimen.

Results and discussion

The relationship between the scale radius and the annulus radii, "similarity", was examined for the scales removed from the various body parts of a specimen of 291 mm in standard length possessing three annuli in each scale. It was observed that in the scales from this specimen the relationship between the scale radius and the radii of the definite annuli can be expressed by three regression lines (Fig. 2).

The relationship between the standard length (L) of *N. albiflora* and their scale radius (R) is shown in Fig. 3. The regression equation of the scale radius (R : mm) on standard length (L : mm) was taken on 228 individuals. It can be expressed by the equation (1).

$$R = -1.05 \times 10^{-5} L^2 + 2.28 \times 10^{-2} L - 4.08 \times 10^{-1} \quad (1)$$

The annulus radii vary according to the scale radius, as shown in Fig. 2. There is a variance also in scale radius in each individual on even scales

Fig. 2. Relationship between scale radius and annulus radii in the scale taken from various body parts of the sample specimen with the 291 mm standard length.

Fig. 3. Relationship between standard length and scale radius in *N. albiflora*.

removed from a fixed body part of equal standard length fish, as shown in Fig. 3. Consequently in order to define the variance in each individual, it is essential to compute the value of the scale radius for the standard length by applying the empirical equation given above (1), and this is termed as the "standard scale radius" ($\bar{R}$). By multiplying $\bar{R}$ with the ratio of the annulus radius ($\bar{r}_n$) to the scale radius (R) in each sample specimen, the "standard annulus radius" ($\bar{r}_n$) is obtained. The frequency distributions of the "standard annulus radius" obtained on each annulus are shown in Fig. 4.

The size of the scale grows in proportion to the growth of the fish. The monthly changes of the marginal growth index, $(R - r_n)/(r_n - r_{n-1})$, which express the relative growth patterns of the scale in a year are shown in Fig. 5. This index, which is given as the average value for each month except

Fig. 4. Frequency distributions of standard radius in each annual ring.

Fig. 5. Monthly changes of marginal growth index.

June, varies every month and attains its minimum value in July. Of the two indices of June in Fig. 5, the small index indicates that the new annulus has been formed; the large one the new annulus has not been formed. Judging from the monthly variation pattern in the marginal growth index, it must be inferred that the annual ring is formed mainly in June and July. Moreover, Fig. 5 shows clearly that in the span of one year this fish grows rapidly from July to October but hardly increases from November to May.

As the gonad index is commonly employed as a reliable factor for the estimation of the fish maturity, the monthly value of the gonad index, (gonad weight $\times 10^3$) / (cube of standard length), is shown for the two sexes in Fig. 6 on an average value taken from each sample specimen. Fig. 6 shows clearly that the spawning season lasts from May to August, and that its peak is in June and

Fig. 6. Monthly changes of the gonad index in the two sexes. Solid circles indicate the male and open circles the female.

Fig. 7. Walford's growth transformation of standard radius of annual ring.

July. Accordingly, it is inferred that the annual ring forms itself when one year elapses after the hatch.

The Walford's graph³¹ drawn with the average value of "standard annulus radii" of each annual ring shown in Fig. 4 proves to be linear, therefore the phase of the growth diagram can be represented by a straight line (Fig. 7). The straight line drawn in Fig. 7 is expressed by the equation (2).

$$\bar{r}_{n+1} = 0.735 \bar{r}_n + 2.31 \quad (2)$$

These results indicate that the data shown in Fig. 7 can be fitted with reason into VON BERTALANFFY's model⁴¹. Thus putting $t=0$ at the spawning time, the growth of this species in standard length can be expressed by the BERTALANFFY's equation (3), where L_t is standard length in millimeters at t years from the spawning.

$$L_t = 529(1 - e^{-0.262t - 0.0736}) \quad (3)$$

The length-weight relationship of *N. albiflora* is shown in Fig. 8. The body weight can be computed from the standard length by means of the equation (4) determined by the method of least squares on individuals, where W stands for the

Fig. 8. Length-weight relationship of *N. albiflora*.

Fig. 9. Growth curves in standard length (dotted line) and body weight (solid line). The solid circle indicates the mean standard length, the vertical line the sample standard deviation and the open circle the mean body weight in each age group.

estimated round weight in grams and L for the standard length in centimeters.

$$W = 1.79 \times 10^{-2} L^{2.995} \quad (4)$$

From the results mentioned above, the growth curve proper to *N. albiflora* in the Seto Inland Sea is obtained through the research of the factors leading to the age determination by the annual ring formation on the scales. Fig. 9 shows the mean of the standard length possessing the sample standard deviation and the body weight together with the growth curves for each age group. The body weight's value by age group plotted in Fig. 9 is computed from the standard length by means

of the equation (4) of the length-weight relationship. As shown in the figure, this fish in the Seto Inland Sea grows 151, 238, 305, and 357 mm in standard length on an average value at the full ages of 1, 2, 3 and 4 years, respectively. These estimated growths in standard length are nearly similar to those reported by TAKITA,²¹ who describes by analysing of the mode in length-frequency distributions that the standard length of *N. albiflora* collected in Ariake Sound is about 170 and 230 mm at the full ages of 1 and 2 years.

The length frequencies of the yearling immature fish collected in Kojima Bay of the Seto Inland Sea on August 23, September 27 and November 9, 1977 are shown in Fig. 10. The standard length was 72 mm in the mean and 75 mm in the mode for the sample of August, 105 mm in September and 135 mm in November in the mean and the mode both. Depending on the estimation from the transition of the marginal growth indices illustrated in Fig. 5, the fishes that hatch out in June are expected to attain 93 mm in August, 112 mm in September and 139 mm in November on an average. The fishes hatching out in July, are expected to attain 63 mm in August, 95 mm in September and 125 mm in November, by the same estimation. Accordingly, the standard length calculated by the preceding method corresponds nearly with the result of the actual measurement of them shown in Fig. 10.

TAKITA²¹ assumes that the immature fishes show a remarkable difference in growth by individuals and have a wide range of 50–180 mm in standard length at the end of the year when the fishes have hatched out.

Fig. 10. Length frequencies of the immature fishes captured in Kojima Bay in August, September and November, 1977.

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