Re-examination of scale reading method of yellowfin tuna taken in the western and central Pacific Ocean*

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Introduction

Scale reading of yellowfin tuna is found to provide estimates of age and growth less affected by selectivity of fisheries than analysis of length frequency (SUZUKI 1971). The scale method, however, comprises several demerits including unclearness of rings, uncertainity of periodicity of ring formation and unreadable scales of large-sized individuals as pointed out by ZHAROV (1969) and LE GUEN (1971). The previous scale studies failed to describe these defects in detail, and such failure might have hampered further examination of reliability and improvement of scale reading method. The present author examined consistency of scale readings as an approach for clarifying problems involved in different aging methods of tunas.

Acknowledgement

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1. Historical review

Studies on age determination of yellowfin tuna by means of scale started in the 1950's. HIYAMA *at al.* (1953) gave the first description on consistency of ring counts. In their experiment, 19 students read the same 50 scales of yellowfin tuna together with hard tissues of five other species. The result was not encouraging for yellowfin tuna because the resultant composition of ring counts showed conspicuous variation depending on the readers. Nevertheless, NOSE *et al.* (1957) tried to use the scale reading method for age determination of the species, even though insufficient examinations on reliability of the reading and on period of ring formation led them to

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underestimate the growth rate.

Reviewing earlier papers on growth of the tunas, HAYASI (1957) stressed necessity of comprehensive sampling for examination of scale reading; "When the age of fish is to be determined by the use of hard tissues, it is recommended that a large number of samples comprising the fish differing in age or size as well as from different fishing grounds should be examined to establish ring formation period, a subject which has not been studied by any worker except NOSE and others (1955)."

YABUTA *et al.* (1960) established scale reading of the species. The aging method has a defect in that it is not applicable to large-sized fish over 140 cm in body length (Table 1). The readable scales comprised less than 50 percent of their specimens

Table 1. YABUTA *et al.*'s (1960) result of scale reading of yellowfin tuna

Range of body length (cm)	Number of specimens	Number of readable specimens			Number of unreadable specimens
		Subtotal	Agreement	Disagreement	
41 - 50	13	13(100)	13(100)	0	0
51 - 60	18	18(100)	18(100)	0	0
61 - 70	72	70(97)	70(97)	0	2
71 - 80	66	56(85)	56(85)	0	10
81 - 90	147	120(82)	116(79)	4	27
90 - 100	305	206(68)	199(65)	7	99
101 - 110	375	181(48)	172(46)	9	194
111 - 120	470	165(35)	164(35)	1	305
121 - 130	405	68(17)	64(16)	4	337
131 - 140	160	12(8)	11(7)	1	148
141 - 150	40	0	0	0	40
151 - 160	12	0	0	0	12
161 -	4	0	0	0	4
Total	2087	909(44)	883(42)	26(1)	1178(56)

Modified from p. 64 in the original paper.
Numerals in parentheses denote percentage to the number of specimens in each length class.

even for medium-sized fish from 100 to 110 cm. However, a parallel reading between two workers agreed each other quite well, and then proved their definition of scale rings being fairly objective, at least, for small-sized fish.

SCHAEFER *et al.* (1963) concluded that the scale reading was not applicable for age determination of the fish from the eastern tropical Pacific Ocean. Investigations of the eastern tropical Atlantic samples by LE GUEN and CHAMPAGNAT (1968) and LE GUEN (1971) resulted in the same conclusion. ZHAROV (1969) reported that a few recognizable ring appeared on scales of yellowfin tuna from the Atlantic Ocean, but the counts read by different workers did not agree with each other. His measurement of intervals between sclerites also failed to indicate any marks related to age of the fish. On the contrary, YANG *et al.* (1969) determined age of the Atlantic fish together with the Pacific counterpart on the basis of scale reading, though they did not discuss the reliability in detail.

The present literary examination shows that most of works failed to give sufficient description on fundamental matters of the scale reading such as sampling site on fish body, method of scale measurement and definition of the rings (Table 2). It is

Table 2. Views on reliability of scale reading in the past works as aging technique of yellowfin tuna

Author	Evaluation	Reliability of reading	Sampling part on fish body	Measuring technique	Definition of ring
HIYAMA *et al.* (1953)	Impossible	+	−	−	−
NOSE *et al.* (1957)	Possible	−	+	+	+
YABUTA *et al.* (1960)	Possible	+	+	−	+
SCHAEFER *et al.* (1963)	Impossible	−	−	−	−
LE GUEN and CHAMPAGNAT (1968)	Impossible	−	−	−	−
ZHAROV (1969)	Impossible	+	+	−	−
YANG *et al.* (1969)	Possible	−	+	+	+
LE GUNE (1971)	Impossible	−	−	−	−

Plus sign denotes that the author gave description on the items.

conceivable that such insufficient description caused the discrepancy of opinions on reliability of scale reading of yellowfin tuna. Only YABUTA *et al.* (*op. cit.*) and ZHAROV (*op. cit.*) provided materials for further discussion on such technical matters of scale reading.

2. Materials

The present study is mainly based on set of parallel reading of scales of 109 individuals selected from samples taken by YABUTA *et al.* (1960) so as to equally represent each 10-cm interval of body length, 50–59 cm, 60–69 cm, ··· and 150–159 cm. They took scales from a site A′ (Fig. 1), selected 10 to 15 scales from each fish and mounted them between two glass slides. The fish were captured in the western and central Pacific Ocean during 1956 through 1959 (Appendix Table 1). Body length referred in this study denotes a distance from the tip of upper jaw to the shortest ray of caudal fin.

In addition, the present author collected scales for describing the surface sculptures from three individuals, 82, 122 and 142 cm in body length, caught in the western tropical Pacific in September 1970 by a longliner. Another examination to ascertain shrinkage of scales is based on materials from two longline-caught fish, one from the northwestern Pacific caught in October 1972, the other from western equatorial Pacific caught in February 1960.

3. Methods

3-1. Definition of rings

A typical ring appears as " a concentric arc that is formed by branching, crowding,

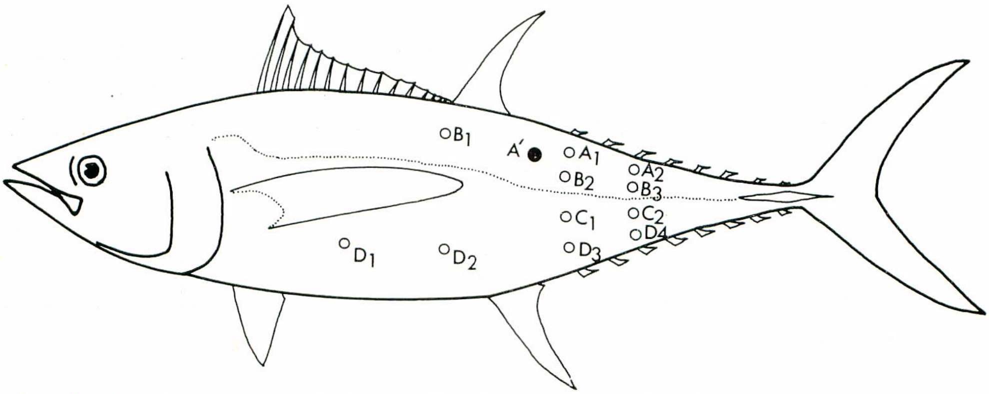

Fig. 1. Sampling parts on body of yellowfin tuna for scale collection.
General position of sampling parts are shown by open circles except YABUTA *et al.* (1960)'s part by a solid circle.
The sampling parts are defined as follows:
A_1 : Just below the anteriormost dorsal finlet.
A_2 : Just below the posterior sixth dorsal finlet, as selected by Yang *et al.* (1969).
A' : Between the second dorsal fin and the anteriormost dorsal finlet and above the lateral line, as selected by Yabuta *et al.* (1960).
B_1 : Between the first and second dorsal fins and between dorsal and lateral lines.
B_2 : Between A_1 and the lateral line.
B_3 : Between A_2 and the lateral line.
C_1 : Between the lateral line and D_3 (about 1/3 from lateral line to ventral line).
C_2 : Between the lateral line and D_4 (about 1/3 from lateral line to ventral line).
D_1 : Below center of the first dorsal fin (about 1/3 from ventral line to lateral line).
D_2 : Below B_1 and about 1/3 from ventral line to lateral line.
D_3 : Above anteriormost ventral finlet and about 1/3 from ventral line to the lateral line.
D_4 : Above posterior sixth ventral finlet and about 1/3 from ventral line to the lateral line.

discontinuation or disturbance of ridges (Plate 1), and that runs parallel to the scale margin on entire sculptured areas of both covered and exposed parts". In addition, a partly faded rings are also read, insofar as they occur correspondingly at the both lateral sides near junctures between covered and exposed parts.

3-2. Measurement of scales

The following definitions were given for the dimensions of scales in the present investigation (Plate 2).

Anterior-posterior axis: A line from the focus to the anterior tip of the scale. Generally speaking, the axis runs almost parallel with the ridges in the lateral regions.

Dorsal-ventral axis: A line passing the focus and crossing orthogonally the anterior-posterior axis.

Scale radius, or R: Distance from focus to anterior tip of the scale.

Ring radius, or r_n: Distance from focus to anterior tip of the n-th ring.

In routine examination, radii of scales and rings were measured on the deck of the Model V-16 Projector of the Nippon Kôgaku K.K. at a 20-time magnification,

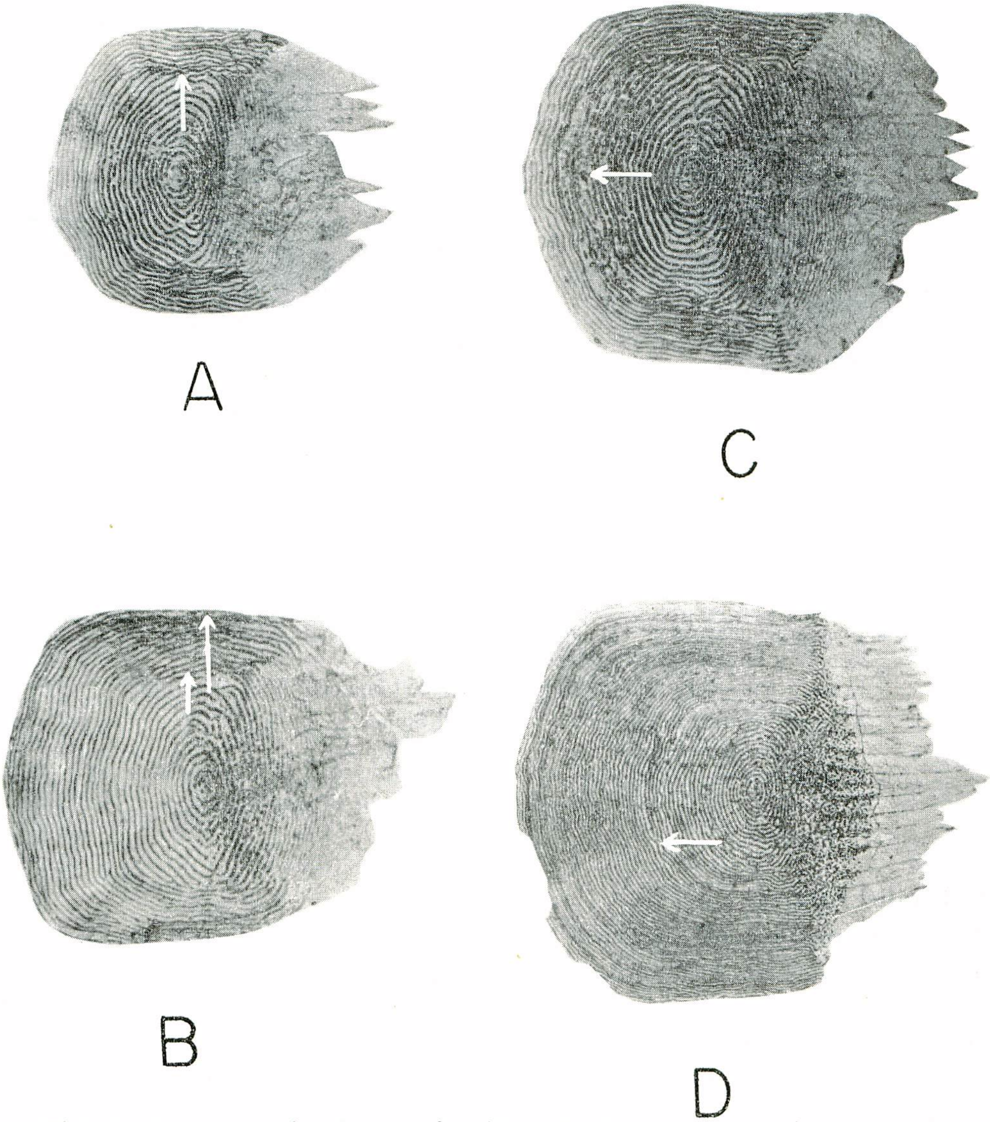

Plate 1. Four types of scale rings found in yellowfin tuna.
A, Branching type (Sample No. 71)
B, Crowding type (Sample No. 21)
C, Discontinuous type (Sample No. 71)
D, Disturbance type (Sample No. 104)
See the relevant samples in Appendix Table 1 for body length, sex and date of fishing.

by a built-in-gauge to the nearest 1 μ. In addition, the author traced positions of rings and focuses as well as outline and anterior-posterior axis *i.e.*, measuring axis, of the scale on a tracing paper. The Model SMZ Binocular Microscope of the Nippon Kôgaku K. K. was also used for detailed observations of scale sculptures.

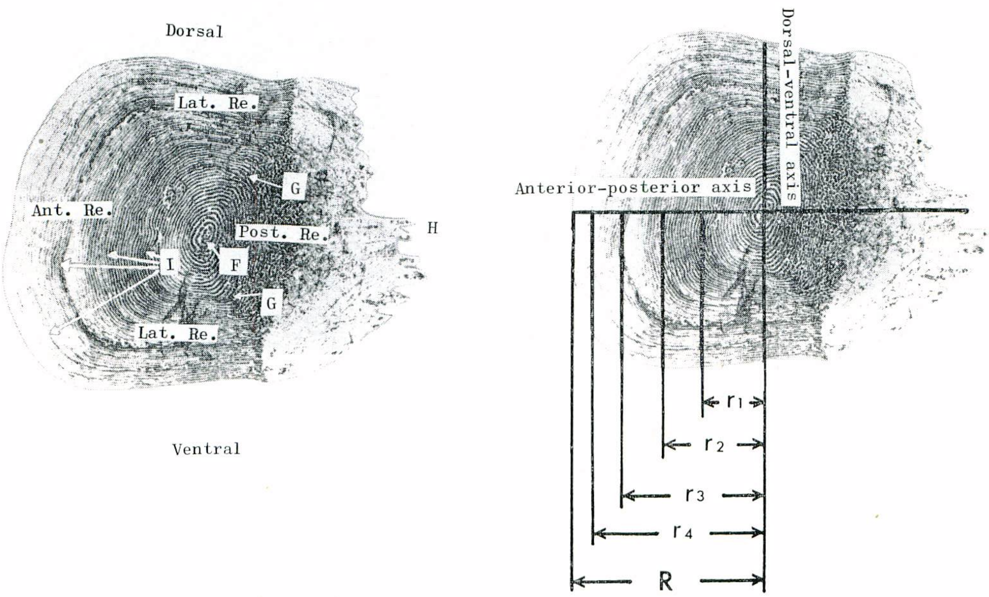

Plate 2. General appearance and measuring axis of a scale of yellowfin tuna for sampling site A′ (in the Plate. 3)
From a fish of 112 cm caught at Lat. 1°S, Long. 172°E in May 1958.

Ant. Re., Anterior region
Lat. Re., Lateral region
Post. Re., Posterior region
F, Focus
G, Juncture
H, Spine
I, Ring
R, Scale radius
r_n, Radius of n-th ring

3-3. Parallel readings

The author read the 109 specimens twice at a time interval of two weeks. Serial order of each slide for reading was determined with the use of random table. Selected from each silde was the fifth scale counted from right top of the first row of scales. The two series of parallel readings classify the 109 specimens into "readable (*A*)" and "unreadable (B)" groups (Table 3). The readable specimens are those determined by ring counts at both examination of the parallel readings. The readable group is divided into "agreement (*Aa*)" and "disagreement (*Ab*)." Unreadable group comprises the scales which could not be read at both (*Ba*) or either one (*Bb*) of the two observations. "Agreement" between the two readings is defined for a case in that the both examinations gave the same number of rings, and in that the two measurements of the same ring differed less than 100 μ with each other except one specimen. In the only exceptional case, the two readings differed by 159 μ for the third ring, but were regarded to be "agreement" for resemblance of relative distances between the rings.

Table 3. Result of parallel reading of yellowfin tuna by the same reader

Range of body length (cm)[1]	Number of specimens,	Number of readable specimens, *A*			Number of unreadable specimens, *B*		
		Subtotal	Agreement	Disagreement	Subtotal	Unreadable at: both observation	either one observation
	N		*Aa*	*Ab*		*Ba*	*Bb*
50	10	10(100)	8(80)	2	0	0	0
60	10	9(90)	7(70)	2	1	1	0
70	10	10(100)	8(80)	2	0	0	0
80	10	9(90)	7(70)	2	1	1	0
90	10	8(80)	6(60)	2	2	2	0
100	10	7(70)	5(50)	2	3	2	1
110	10	5(50)	2(20)	3	5	3	2
120	10	4(40)	2(20)	2	6	4	2
130	10	2(20)	0	2	8	8	0
140	10	3(30)[2]	3(100)	0	7	6	1
150	9	3(33)[3]	3(100)	0	6	6	0
Total	109	70(64)	51(47)	19(17)	39(36)	32	7

1) 50 cm class denotes fish from 50.0 cm to 59.9 cm, 60 cm class from 60.0 cm to 69.9 cm and so on.
2) Scale of a specimen is erroneously small.
3) Scales of the three specimens are erronously small.
Numerals in parentheses denote percentage to the number of samples in each length class.

4. Result

4-1. Morphology of scales

YABUTA *et al.* (1960) and YANG *et al.* (1969) stated that the parts A' and A_2 were the most suitable to collect scale for age determination, respectively (Fig. 1). However, scales from those two sites are hardly identified by external features and the author considers that there is no definite difference between the two parts in facility

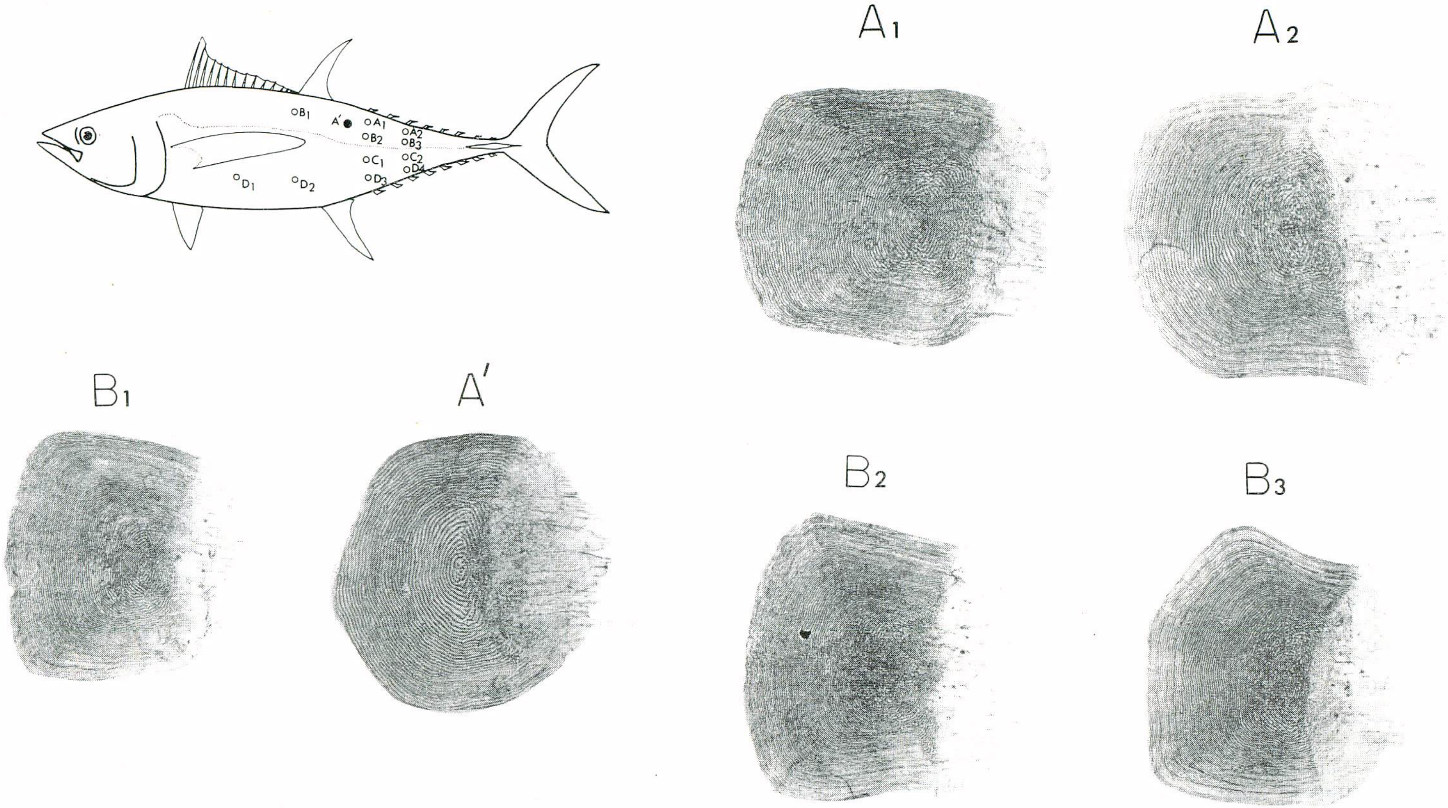

Plate 3. Scales from different sampling parts of yellowfin tuna, except A′*, of 122 cm in body length caught in western tropical Pacific Ocean in September 1970.
See Appendix Table 2 for definition of sampling parts.
* The scale at A′ derived from a yellowfin tuna of 90 cm in body length caught in north-western Pacific in April 1959.

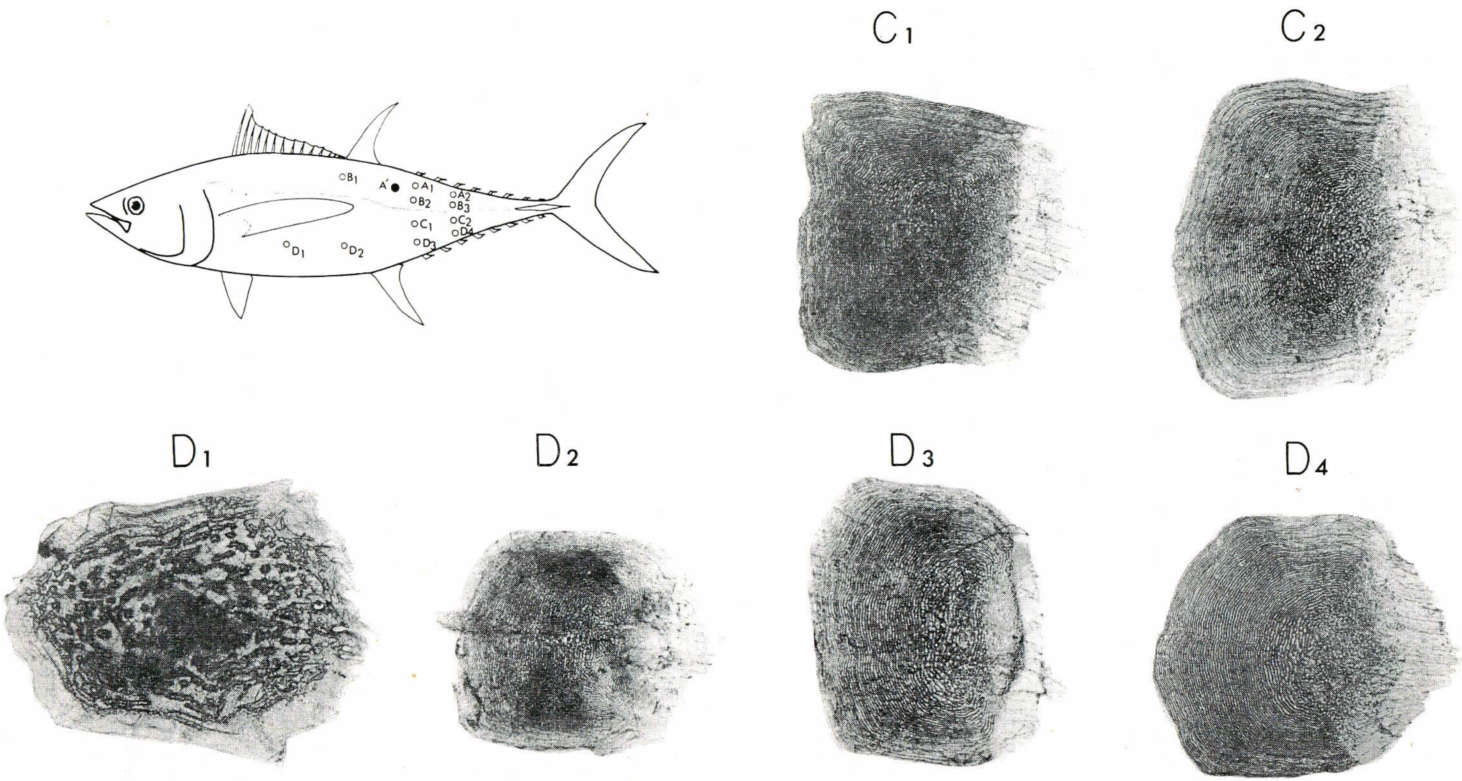

Plate 3. (Continued.)

of scale reading.

As the scales of yellowfin tuna are small and numerous, there is fear that the scales out of the defined site are erroneously taken. In order to provide a clue for eliminating such error at sampling, the author examined morphological difference of scales from 12 body sites (Fig. 1) on a medium-sized specimens of 122 cm in body length.

Scales from the site *A′* for routine sampling in the present study appear oval-rectangle in shape. The anterior, lateral and posterior regions are easily distinguished one from another (Plate 2). Spines are located at the posterior margin of scales from small-sized individuls less than about 100 cm in body length, but disappear in most of larger fish. Most ridges, except a few innermost ones forming semiconcentric circles around the focus, run parallel to the margin on the covered part, but usually fade on the exposed part of the scale. A few small-sized fish have scales with ridges on the exposed part.

The most peculiar scales occur on site D_1 below pectoral fins (Plate 3). The thick and oval-shaped scales have no ridge on surface, and are not useful for age determination (ZHAROV 1969).

The focus appears vague on scale from ventral rows, *C* and *D*, and these scales are inappropriate for age study.

Other scales appear more or less alike those from the site *A′*, even if they differ in radius with each other. In general, the size of scale radii tends to increase toward lateral line, and from posterior to anterior end of body. Arrangement of ridges nearby the focus appears being heavily compressed in *B*, *C* and *D* rows while it takes oval shape in *A* row.

Variation in their depths or magnitudes of grooves appears to be useful as a clue to determine sampling sites from which individual scales derived. The grooves are not clear on the scale in *A* row and perceived as a mere wave, especially in small-sized fish less than about 80 cm in body length. They appeared clearly in *B*, *C* and *D* rows, often even in the small-sized individuals.

An additional study includes observation of transparent and crystaline granules on the covered part of scales. The small-sized fish were found with small and sparsely distributed granules. The marginal part of scale, representing growing area, is found without granules. Both size and density of the granules increase toward the focus (Plate 4). The granules are observed under the microscope focussed at the fibrous tissue of scale. These features resemble to crystals of calcium oxalate and related salts described by KATO (1953) on various freshwater and marine teleosts.

4-2. Parallel reading

Table 3 shows number of specimens of readable and unreadable scales for each length class. Readable specimens comprise 70 to 100 percent for small-sized classes of 100–110 cm or less, but only 50 percent for 110–120 cm class. Only two fish out of 10 in 130–140 cm class were read but the parallel readings failed to give any consistent

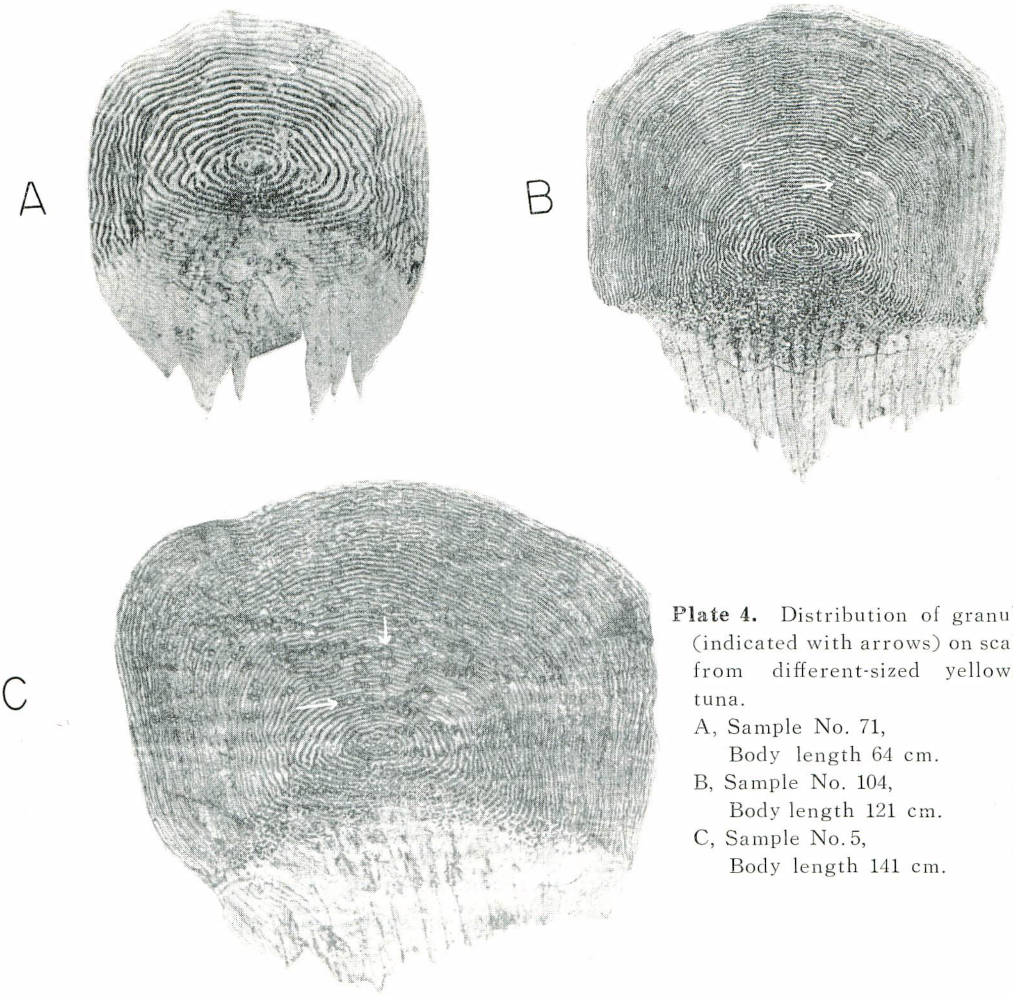

Plate 4. Distribution of granules (indicated with arrows) on scales from different-sized yellowfin tuna.
A, Sample No. 71, Body length 64 cm.
B, Sample No. 104, Body length 121 cm.
C, Sample No. 5, Body length 141 cm.

ring counts. Rise of ratio of readable specimens for the two largest classes may be due to error in the surveys. The scale of a readable fish of 141 cm was 1,617 μ in radius compared to 2,556 μ on the regression line (Fig. 2) given by YABUTA *et al.* (1960). The extraordinarily small radius suggests errorneous collection of the scale from other small-sized fish, or careless measurement or misrecording of the body length. Scale radii of all the three fish of 150 cm class sorted to "readable" group range from 1,808 to 2,030 μ, also far smaller than those on the regression line, 2,782 to 2,865 μ. Therefore, readings of these four large-sized fish will not be discussed in detail.

Ratio of agreement was fairly high, 71 percent or above, for small-sized fish less than 110 cm, but below 50 percent for larger fish. Disagreement between the two series of scale readings is attributable to two factors: inconsistency of ring counts and misidentification of newly forming ring (Table 4). Among 19 specimens of dis-

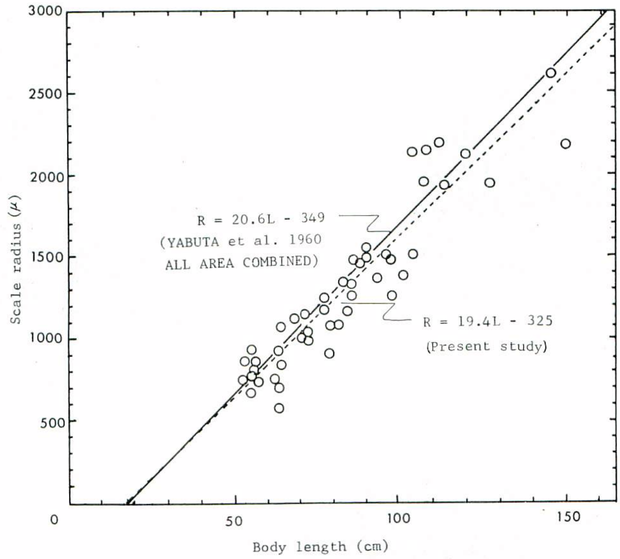

Fig. 2. Relation between body length and scale radius.
Solid and dotted regression lines denote calculation by YABUTA *et al.* (1960) and by the present author with 47 " agreed " specimens. (open circles) respectively.

agreement, *Ab* in Table 3, the former appeared for 18 cases and the latter for five. Readings of four specimens involved two sources of failures. It is rather surprising that miscounts occurred for the inner first to third rings rather than for the outer ones (Table 4). Experience indicates that the rings of those 19 specimens, especially large-sized ones over 100 cm, were hard to recognize probably due to the thickness of the scales. However, it was easy to count rings on scales of 51 specimens for which the two readings agreed with each other.

5. Discussion

5-1. Visibility of scale rings

The present parallel reading is first compared with the relevant set of data by YABUTA *et al.* (1960). Ratios of readable scales are higher by 20 percent in the present study, 64 percent, than in the previous examination by YABUTA *et al* (1960), 44 percent (Tables 1 and 3). Both examinations gave close ratios of agreement 42 percent in the former and 47 percent in the latter. However, two counts of rings of readable scale differ more frequently in the present study than in the previous one, *i.e.*, 19 specimens of disagreements listed in Table 3 comprise 17 percent of all the present specimens, while the ratio is only one percent, 26 specimens shown in Table 1, for readings by YABUTA *et al.* Here it is noted that difference in ratios of agreements between the two investigations, 16 percent (17 minus 1), accords fairly well with difference in ratio of readables, 20 percent (64 minus 44). This accordance suggests

Table 4. Causes of disagreements and number of rings misread.

Length class Body Lengsh (cm)	Number of dis-agreed scale	Sample number	Cause of disagreement	Number of rings misread
50	2	39	F	1
		61	R_1	1
60	2	32	R_1	1
		41	R_1	1
70	2	94	F	1
		84	R_1, F	0
80	2	93	R_2	1
		110	R_1	1
90	2	50	R_3	1
		90	R_2	1
100	2	47	R_2	1
		53	R_3	1
110	3	55	R_2, F	2
		92	R_1	1
		67	R_3, F	1
120	2	37	R_5	1
		104	R_3	1
130	2	57	R_1, R_3	0
		79	R_2	0

(Total) R_1 : 7, R_2 : 5, R_3 : 5, R_5 : 1, F : 5

R_n : Misread n-th ring counted from the focus
F : Difference of evaluation on forming ring in peripheral area of scale

that the present author forcibly read even vague rings which had been frequenrly assigned " unreadable "by the previous authors.

According to ZHAROV (1969) difference among the ring counts of a specimen by different readers reached three rings for " small-sized " individuals : the deviation attained as much as five for " large-sized " fish. The discrepancy of ring counts of the same scale in his study is far lager than the present results, two rings at most as shown in Table 4. Lack of definition of the ring in ZHAROV'S study, however, precludes us from discussing the cause of such discrepancy.

SCHAEFER *et al.* (1963), ZHAROV (1969) and LE GUEN (1971) claimed obscureness of scale rings of yellowfin tuna and feared of unreliability of the ring counts. The present author also found it difficult to read scales of large-sized fish over 110 cm. Of the smaller fish, however, the rings are clear enough as shown in good accordance between different readings. In studies of some other fishes, scale reading was abandoned at the beginning, but later detailed examination of sufficient number of specimens often disclosed presence of readable rings forming at particular season of a year. For the purpose of finding the rings, many readers might have observed merely the widest anterior region of scales of yellowfin tuna. It is enough to look the region

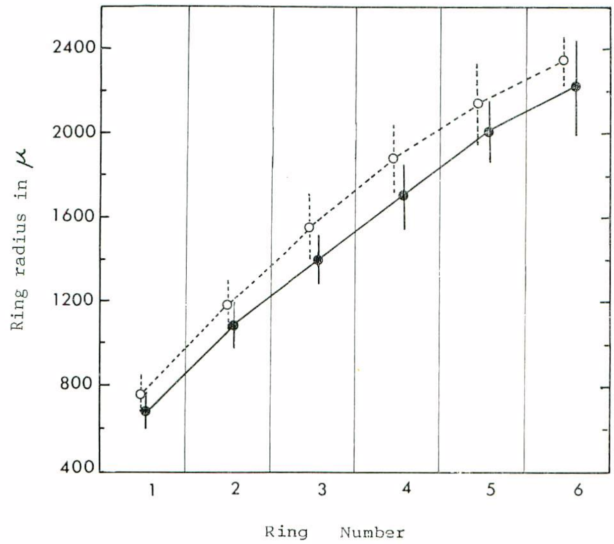

Fig. 3. Two measurements of average radii of the first to sixth rings on scales of yellowfin tuna.
Open and closed circles denote measurement by YABUTA *et al.* (1960) and the present author, respectively. Vertical bars denote standard deviation.

for small fish of about 100 cm or less. But rings of larger fish are often faint in the region. Observing as many as 4,000 individuals, YABUTA *et al.* found it helpful for disclosing the rings to pay attention to the lateral regions. Plate 5 provides an example: six rings appear on lateral regions as the solid curves, but are merely traced on anterior region as the dotted curves.

5-2. Variation of ring radius

As shown in Table 5 and Figure 3, measurements in the present study gave smaller radii of the first to sixth rings than those in the previous study by YABUTA *et al.* (1960). The difference may be attributable to the following causes.

(1) Shrinkage of scale

HOTTA and AIZAWA (1961) and YAMADA (1969) noted shrinkage of vertebrae of Pacific saury and jack mackerel which had been kept in dry. The scales in the present study have been put between glass slides for more than 10 years and assumed to have shrunk. In order to examine the assumption, the present author kept one of two fresh scales frome newly caught fish in a desiccator and the other in the room. Also a scale taken by YABUTA *et al.* was immersed in fresh water. The experiments showed apparent changes of scale radii due to condition of preservations (Fig 4).

The dried scale in the desiccator shrank from 1,020 μ to 960 μ, by about 60 μ or 6 percent, in the first 10 days, but not appreciably during 20 th through 30 th days. The shrinkage was very slight in the other scale kept at room condition, from 1,005 to 985 μ during the 30 days. The readings of immersed scale, kept in air for more than 10 years, showed slight recovery by 50 μ or about 3 percent during two months.

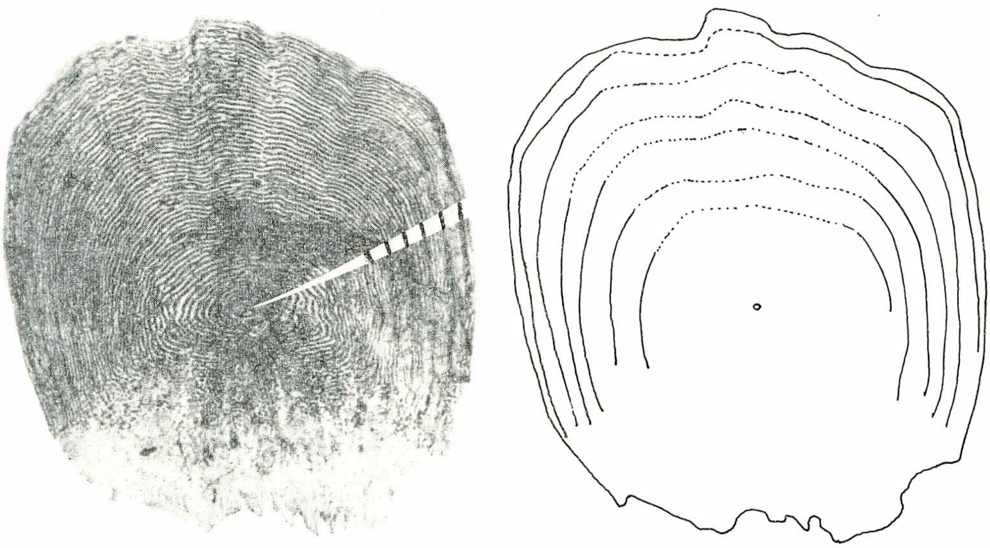

Plate 5. Scale with six rings in the lateral regions from yellowfin tuna of body length 112 cm. See sample No. 54 in Appendix Table 1 for derivation of the scale.

Table 5. Ring radius of agreed specimens (" *Aa* ") in this paper, compared with the radius by YABUTA *et al*. (1960).

Unit : μ

		Ring					
		1st	2nd	3rd	4th	5th	6th
Present study	Number of specimens	47	32	34	15	12	4
1st reading	Mean	685.4	1065.0	1375.5	1692.6	1993.8	2202.0
	S. D.	86.0	112.9	122.4	166.8	142.8	220.8
2nd reading	Mean	693.6	1084.4	1390.4	1708.5	1991.1	2228.8
	S. D.	85.9	109.1	112.4	142.2	118.7	248.5
Average	Mean	691.0	1075.5	1383.2	1700.9	1992.7	2215.8
	S. D.	86.3	107.7	113.8	152.2	130.2	234.2
YABUTA *et al*. (1960)	Number of specimens	886	767	600	241	48	7
	Mean	770	1190	1560	1880	2140	2350
	S. D.	85	115	135	159	185	101

S. D.: Standard deviation

In order to correct bias of the present measurements due to possible shrinkage of the scales, a conversion factor was determined on the basis of two regression lines given by YABUTA *et al*. and by the present study (Formula 1).

$$f_l = R_{yl}/R_l$$

Where, f_l : Conversion factor

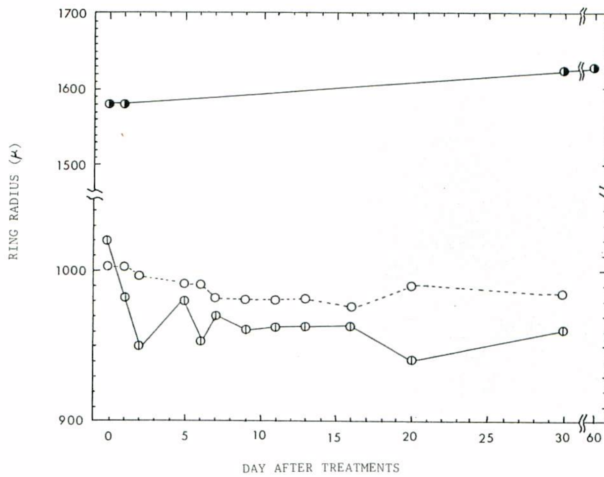

Fig. 4. Change of scale radii of yellowfin tuna kept under different conditions.
◑·········Scale submerged in water (100 cm in body length).
○·········Scale kept in room (62 cm in body length)
⦶·········Scale kept in a desiccator (the same specimen as above kept in room)

R_{yl} : Average scale radius of specimens of the length on the regression line determined by YABUTA *et al.* (Fig. 2),

R_l : Average scale radius of specimens of the length on the regression line determined in the present study (Fig. 2).

The correction increased the ring radii as follows:

1st	2nd	3rd	4th	5th	6th
730 μ	1, 138 μ	1, 464 μ	1, 806 μ	2, 112 μ	2, 349 μ

However, these radii are still smaller than those by the previous study listed in Table 5. Therefore, discrepancy of the ring radii bitween the present and previous studies can not be explained only by the shrinkage of the scales.

(2) Different interpretation of innermost rings

YABUTA *et al.* (1960) assumed that any ring forming at around 0.5 mm from the focus might be a false mark appearing in only some individuals of the same length, or even on only some scales of the same individuals. This definition by the previous study may give larger radii than the present measurements in which all the rings were read regardless of their position on the scale as long as they accord with the definition of ring.

Eventually, the present measurements were found to give smaller growth coefficient than the previous data. According to WALFORD'S transformation of the measurements in Table 5, radii of $n+1$-th rings, R_{n+1} fit to the following regression line on those of n-th rings, R_n, (Fig. 5).

$$R_{n+1} = 449.2 + 0.895\, R_n$$

The regression coefficient, 0.895, corresponds to 0.22 of the annual growth coefficient,

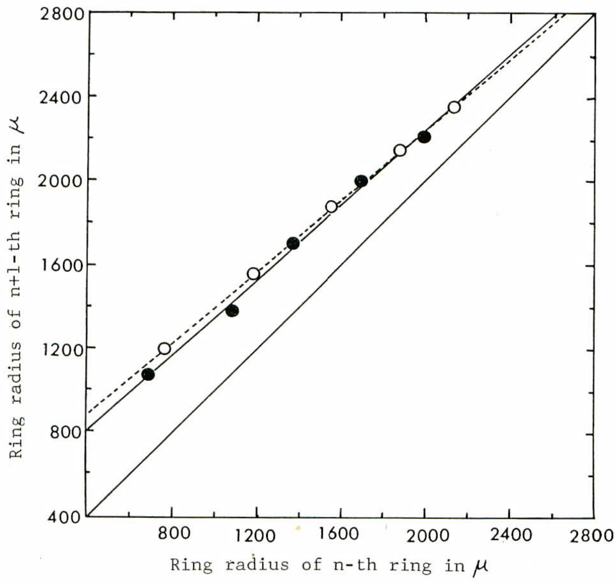

Fig. 5. The WALFORD's graphic representations of average radii on scale of the yellowfin tuna.
Open and closed circles denote measurements by YABUTA *et al.* (1960) and the present author, respectively.

k, in VON BERTALANFFY'S equation. The comparable estimates in the previous studies are 0.33 by YABUTA *et al.* and 0.36 by YANG *et al.* (1969).

5. Conclusion

Scale rings of small-sized yellowfin tuna, about 100 cm or less in body length, are easily read as far as the materials taken from lateral side above the lateral line and posterior to the second dorsal fin. However, with the increase of the body length, it becomes difficult to read the scales from the selected sites of body. In either cases, the rings are often more easily detected at lateral regions of the scale than at anterior region. It is concluded that careful examination would provide a means to define rings objectively on many scales of small-sized fish though such definition can not work for most of larger fish. This seems to encourage scale reading method, at least, for small-sized fish. However, the applicability of scale reading method leaves room for discussion even for small-sized fish because there appeared discrepancy of ring measurements and resultant growth parameters between the present and previous studies that could not be fully explained.

On the other hand, analysis of length composition data also comprises its own defects (SUZUKI 1971). Therefore, attempting to estimate yellowfin growth curve, it is desirable to adopt comparative method on the results from various aging techniques so as not to reach to biassed estimation.

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中西部太平洋のキハダの鱗読方法の再検討

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要　約

キハダ鱗の年令形質としての価値を評価するために鱗相を観察し，これまでに具体的な記述の少ない鱗読の一致度を再検討した。標本は藪田他（1960）が用いた太平洋で主としてはえなわで漁獲された体長50〜160 cmのキハダの鱗の中から，体長 10 cm 階級ごとに 10 個体の鱗を抽出した 合計 109 個体のキハダ鱗（体長 150〜160 cm 級は 9 個体）である。

藪田他（前出）が規定した採鱗部位（図 1 の A′）の鱗は他の部位の鱗と外観からある程度識別できる（図

版３)。輪紋は前域の他に両側域における隆起線の変化にも注意すると容易に判別される（図版５)。

同一人による２回の独立な鱗読の結果は可読率（可読標本数／標本数）64％，一致率(一致標本数／標本数) 47％であった。一致率は藪田他の結果（42％）とほぼ一致するが，可読率は今研究の64％に比べて藪田他の結果は44％，また不一致率（２回とも鱗読可能だが，結果が一致しなかった標本の全標本に占める割合）は今研究が17％，藪田他が１％と異なる。この原因としては，今研究と藪田他の研究における可読率と不一致率の差がそれぞれ20％と16％とほぼ等しいことから，今研究では不明瞭で読みにくい鱗も無理して読んだため，可読率は藪田他の結果よりも高いが，彼等よりも多くの鱗が不一致になったといえる。

不一致の主な原因は輪紋の読みちがえ，および形成中の輪紋の評価の差であり，輪紋の読みちがえ数は最大２輪である（表４)。鱗読の一致した標本（２回とも鱗読可能で，結果が一致した標本）の輪紋別平均輪径は藪田他（前出）の結果と比べて 80～180 μ 小さい（表５)。この差異は鱗の収縮（図４）および焦点から 500 μ 付近にみられる輪紋を藪田他は総べて読まなかったが，今回は輪紋の定義に合致するものは 500 μ 付近にみられる輪紋でも読んだことに起因していると推定される。

多数の鱗読を行なって経験を積むことによって不一致率を減少させることが可能であるとしても，体長約 100 cm を越えると確実に読める個体の割合が 50％ を下廻ることは（表1, 3)，鱗読法の持つ欠点である。また鱗読可能な小型魚についても，輪紋別平均輪径およびそれらから計算された成長係数の本研究と概往の研究結果との差異についてはさらに検討の余地を残している。

一方体長組成のモードの追跡による成長曲線の推定にも多くの問題があることが指摘されており(鈴木1971)，キハダの成長曲線を推定するさいには複数の方法を用いた結果を比較検討して偏よった結論に至ることをさけることが望ましい。

Appendix Table 1. Body length, sex, locality and date of sampling of specimens used for scale reading.

No. of specimen.	Body length (cm)	Sex	Locality	Fishing date
1	55		26° N, 135° E	11-18 Jan., 1957
2	133	♂	10° N, 157° E	10 Oct., 1959
3	105	♂	6° N, 134° E	14 Nov., 1959
4	107	♀	7° N, 133° E	11 Nov., 1959
5	141	♂	4° N, 131° E	23 Aug., 1959
6	85		28° N, 140° E	9- 11 May, 1958
7	62		26° N, 135° E	3 Oct., 1956
8	82		28° N, 140° E	9-11 May, 1958
9	123	♀	6° N, 161° E	7 July, 1959
10	96		33° N, 139° E	26-29 April, 1959
11	78		34° N, 139° E	21 April, 1959
12	53		34° N, 139° E	21 Oct., 1956
13	79		21° N, 143° E	4-23 Nov., 1956
14	151	♂	6° N, 147° W	9 Sept., 1959
15	115		5° N-7° N, 138° W-140° W	Nov., 1958
16	84		28° N, 140° E	9-11 May, 1958
17	127	♂	6° N, 161° E	7 July, 1959
18	55		31° N, 140° E	15-17 March, 1958
19	137		6° N, 161° E	7 July, 1959
20	96	♂	33° N, 139° E	26-29 April, 1959
21	71		34° N, 139° E	21 April, 1959
22	94		33° N, 139° E	26-29 April, 1959
23	56		34° N, 139° E	21 April, 1959
24	101		0° N-8° N, 131° E-137° E	16 Jan., -16Feb., 1959
25	133	♂	10° N, 157° E	11 Oct., 1959
26	154	♀	4° N, 131° W	23 Aug., 1959
27	77		26° N, 135° E	8-17 Feb., 1957
28	130	♂	6° N, 161° E	7 July, 1959
29	106	♂	7° N, 133° E	8 Nov., 1959
30	156	♂	4° N, 131° E	23 Aug., 1959
31	93		28° N, 140° E	9-11 May, 1958
32	64		26° N, 135° E	3 Oct., 1956
33	90		28° N, 140° E	9-11 May, 1958
34	131	♂	10° N, 157° E	10 Dec., 195
35	124	♀	6° N, 161° E	7 July, 1959
36	68		26° N, 135° E	3 Oct., 1956
37	124	♀	6° N, 161° E	7 July, 1959
38	72		26° N, 135° E	1-10 Jan., 1957
39	59		28° N, 140° E	9-11 May, 1958
40	151	♂	5° N, 147° W	Sept.-Dec., 1959
41	61		26° N, 135° E	3 Dec., 1956
42	111		5° N-7° N, 138° E-140° E	Nov., 1958
43	63		26° N, 135° E	3 Dec., 1956
44	86		34° N, 139° E	21 April, 1959
45	97		28° N, 140° E	9-11 May, 1959
46	108		0° N-8° N, 131° E-137° E	16 Nov.-16 Feb., 1959
47	105		7° N, 133° E	11 Nov., 1959
48	115		5° N-7° N, 138° E-140° E	Nov., 1958
49	147	♀	7° S, 133° W	1 Jan., 1959
50	98		33° N, 139° E	26-29 April, 1959
51	57		31° E, 140° E	15-17 March, 1958
52	152	♀	4° N, 131° W	23 Aug., 1959
53	109		0° N-8° N, 131° E-137° E	16 Jan.-16 Feb., 1959
54	112		5° N-7° N, 138° E-140° E	Nov., 1958
55	110	♀	1° N, 170° W	28 Aug., 1959

56	158	♂	4° N, 131° W	23 Aug., 1959
57	130	♂	10° N, 157° E	10 Dec., 1959
58	149	♀	8° S, 133° W	31 Aug., 1959
59	92		28° N, 140° E	9-11 May, 1958
60	90		33° N, 139° E	26-29 April, 1959
61	59		31° N, 140° E	15-17 March, 1958
62	144	♂	4° N, 131° W	23 Aug., 1958
63	131	♂	10° N, 157° E	10 Dec., 1959
64	72		26° N, 135° E	1-10 Jan., 1957
65	132	♂	10° N, 157° E	11 Oct., 1959
66	113	♀	1° N, 177° W	28 Aug.. 1959
67	145	♀	6° S, 129° W	21 Aug., 1959
68	63		26° N, 135° E	3 Dec., 1956
69	83		28° N, 140° E	9-11 May, 1958
70	64		26° N, 135° E	3 Dec., 1956
71	63		26° N, 135° E	3 Dec., 1956
72	81		34° N, 139° E	21 April, 1959
73	145	♀	4° N, 131° W	23 Aug., 1959
74	56		26° N, 135° E	27 Feb.-9 May, 1957
75	101	♂	7° N, 133° E	10 Dec., 1959
76	70		26° N, 135° E	1-10 Jan., 1957
77	149	♀	10° S, 136° W	9 Aug., 1959
78	132		5° N, 137° W	11 Sept., 1959
79	124	♂	6° N, 161° E	7 July, 1959
80	64		26° N, 135° E	3 Oct., 1956
81	135	♂	6° N, 161° E	7 July, 1959
82	88		34° N, 139° E	21 April, 1959
83	72		34° N, 139° E	21 April, 1959
84	104		0° N-8° N, 131° E-137° E	16 Jan.-2 Feb., 1959
85	77		26° N, 135° E	8-17 Feb., 1957
86	86		28° N, 140° E	9-11 May, 1958
87	152		4° N-6° S, 108° W-139° W	24 March-8 May, 1958
88	120	♂	6° N, 162° E	7 July, 1959
89	94		33° N, 139° W	26-29 April, 1959
90	119		7° N-9° N, 135° E-139° E	8-19 **Dec., 1959**
91	112		5° N-7° N, 138° E-140° E	Nov., 1959
92	86		28° N, 140° E	9-11 May, 1958
93	70		26° N, 135° E	8-17 Feb., 1957
94	62		26° N, 135° E	3 Dec., 1956
95	146		7° S, 133° W	2 Sept., 1959
96	113		5° N-7° N, 138° E-140° E	Nov., 1958
97	147		6° N, 147° W	9 Sept., 1959
98	113	♂	5° N-7° N, 138° E-140° E	Nov., 1958
99	152		4° N-6° S, 108° W-139° W	24 March-8 May, 1958
100	120		6° N, 161° E	7 July, 1959
101	140	♂	4° N, 131° E	23 Aug., 1959
102	122	♂	6° N, 161° E	7 July, 1959
103	121	♀	6° N, 161° E	7 July, 1959
104	53		26° N, 135° E	27 Feb.-4 March, 1957
105	104		0° N-8° N, 131° E-137° E	16 Jan.-16 Feb., 1959
106	131	♂	6° N, 161° E	7 July, 1959
107	55		31° N, 140° E	15-17 March, 1958
108	152	♂	4° N, 131° W	23 Aug., 1959
109	87		34° N, 139° E	21 April, 1959