Study of the Japanese Sardine, *Sardinia melanosticta* (TEMMINCK et SCHLEGEL). III.

On Scale - 2

Osamu TAMURA
(Faculty of Fisheries, Nagasaki University, Sasebo)

Introduction

I reported in the preceding paper, "On Scale-1", the outcome of the study of the Japanese sardine, with special reference to "Lea's phenomenon". In this treatise the time of formation of the periodic scale-rings is the subject. I express my gratitude for the instructive advice by Prof. Ikusaku AMEMIYA and for the assistance of Mr. Motokichi MORISHIMA and the late Mr. Kanji TSUTSUMI.

A. Determination of the periodic scale-rings

1. Nature of the scale and periodic scale-rings

Generally speaking, external shapes of scales of many kind of fish vary extremely by the body-parts, and the variability of the periodic rings are also remarkable. For the determination of the periodic rings I compared the variability in respect to each body-part and the reliability of ring-readings in the raw material of the sardine of two rings caught at Mito (Sizuoka Prefecture), 1938, mean body-length 174 mm. Refering to fig 1, I examined nearly the whole scales of each region of 15 body-parts; each number shows alternate scale from anterior to posterior. Refer to plate I, table 1 in regard to the positions of rings.

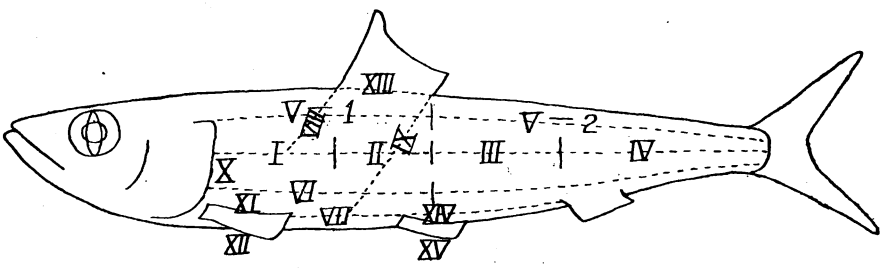

Fig. 1. The position of each body-part compared.

2. Periodic rings for age-determination

Concerning the natures of Periodic rings for the age-determination I described in the previous report of ring-composition, several points must be added as follows:

(1) The ring appearing on side is irregularly discontinuous in many cases at the region passing from side to apex, the ring is clear at apex, appears always at side on the extension. Then, it can be considered as a real ring when there is a ring at apex and side even unclear, but it can not be taken for a real ring when there is a ring only at side even clear.

(2) The reason for considering as "normal position" of rings in the previous treatise

Table 1. Characters of scales of each body-part.

part	largeness of covered portion	shape	ring	$R-r_2'/r_2$	remarks
I	19% > IV	near typical form	can be detected with difficulty	2.1%	uncovered portion large, considerably hard to fall off
II	20% > IV	most typical	clear	2.3%	very easy to fall off
III	16% > IV	typical	most clear	1.9%	more easy to fall than II
IV no.1~4	—	typical	indistinct	2.8%	most deciduous
IV no.5~8	—	irregular	indistinct		
V no. 1	≒ IV	near typical	—	4.1%	deciduous
V no. 2	7% < I		hard to recognize	3.1%	
VI no. 1	25% > IV	upper margin project, projection decrease gradually	—	3.9%	comparatively hard to fall off
VI no. 2	16% > IV		hard to recognize		
VII	12% > I	symmetric laterally, upper margin project	—	6.1%	same
VIII	—	circuli very irregular	—	2.7%	deciduous
IX	10% > IV	upper margin project in dorsal & ventral scale, in median symmetric	comparatively clear, apical portion hard to see	4.7%	deciduous
X no.1~3	—	very irregular	—	—	very hard to fall off
X no.4~6	—	—	considerably clear	—	
XI	anterior part very small, posterior larger gradually	transformed greatly, no. 10 normal	no. 5~ considerably clear	5.3%	most hard to fall off
XII	anterior small, posterior larger	irregular	most indistinct	5.7%	same
XIII	—	elongated, distribution of radii special	many indistinct	—	comparatively hard to fall off
XIV	—	near XI	some clear	—	same
XV	—	irregular	indistinct	—	hard to fall off
XVI	—	tip of uncovered portion project sharply	clear	—	easy to fall off
				mean 2.2% s. e. 0.174	

of ring-composition is that each ring is distant from each other in ratio nearly of 20: 12: 7: 5: 3. (refer to my treatise, Scale 1.: A 2, Real length).

(3) In the scale possessing typical form and a clear ring, the ring can be identified distinctly even thin or narrow, consequently I am apt to decide it as a real ring, contrary to this, in the scale lacking typical form and having many pseudo-rings or injured scales they have unclear rings in many cases and the rings can not be observed distinctly even if they are thick or broad. Therefore it must be judged as a real ring only when it is thicker than a certain thickness, however it is hard to decide practically.

B. Time of formation of periodic rings

1. The ratio of appearance of rings by continuous sampling of 0-year fishes

I examined the samples for ten months from May, 1939 to February, 1940 (failed in September and November). Scales of 5 or more were taken in each individual from lateral axis under dorsal fin. I designated 5/5 the case which all scales had equal rings on same positions, 3/5 the case which only 3 in 5 scales had equal rings on same position, etc. as reliability. Further I expressed the case as 1/5 which only one scale had several rings (chiefly one, rarely two or three rings).

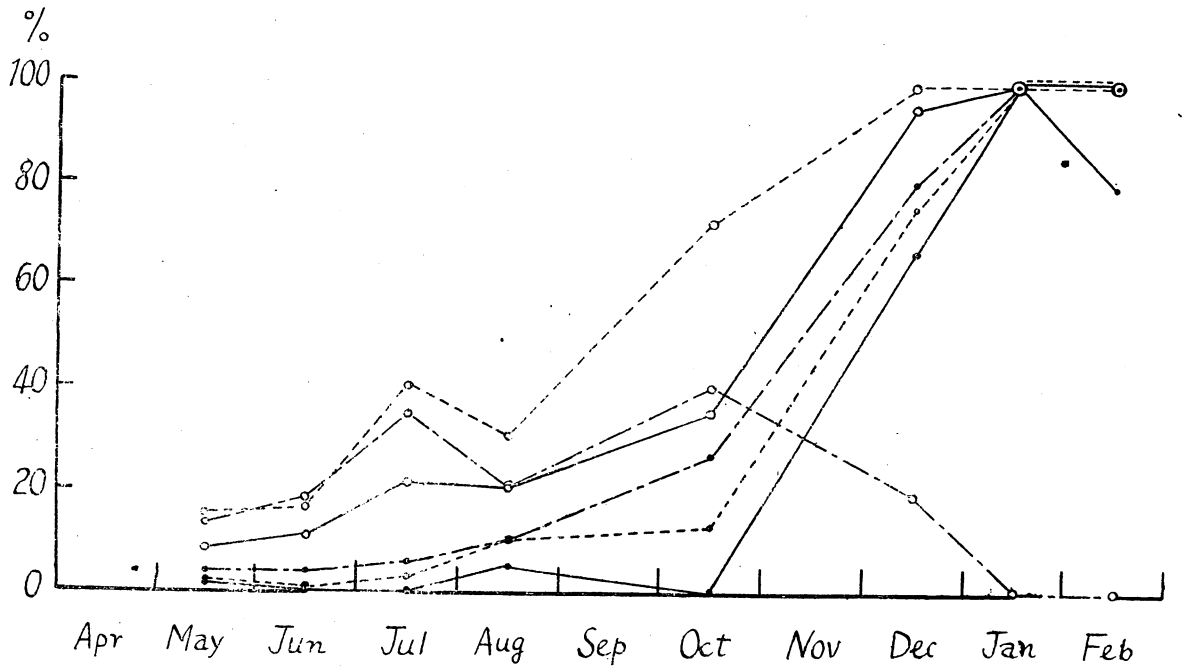

Fig. 2. Ratio of the appearance of the first ring in 0-year fishes (sampled at Misaki)
Note: •——• 5/5, •·····• 4/5 + 5/5, •——– ——• 3/5 + 4/5 + 5/5,
o——o 2/5 + ··· + 5/5, o·····o 1/5 +···+ 5/5, o——–——o 1/5 + 2/5

These are indicated in Fig. 2. The graphs of 5/5 and 5/5+4/5 ascend steeply to higher 70% from very lower 13% between October and December. Many scales sampled at second and third decades of December possessed ring at margin. The ring appeared in samples caught in Jauary or February is observed often on inner side from margin, even though there is a few situating at margin. The graphs of 5/5 + 4/5·····+1/5 and 5/5+4/5·····+2/5 increase slowly with progress of months, in July especially higher, both becomes 100% in January.

From the above-mentioned I can deduce that the so called summer ring may be formed to a certain extent in July or August but the real ring which almost all fishes possess must be formed in July or February, as far as shoals about Miaski (Pacific) are concerned.

2. Distance from last ring to margin

As already Mr. YASUDA (1940) dealt with, the ratio of the distance from last ring to margin for the length of covered portion, namely $R-r_2'/r_2'$ must show minimum value at te time of ring-formation. He denied the advocation of Prof Aikawa (1940) by indicating figure of plotting values in every month, his conclusion that the time of minimum value may be once a year is not apparent by his figure. Further, since this value is very different by age, I used as many as reliable samples having clear rings in each group of each number of rings and compared with each other the average value in every month.

This is indicated in Fig. 3~6, provided that the higher values than $r_{n+1}-r_n/r_{n+1}$ by the reports (Aikawa 1940, Amemiya and Tamura 1949, Yasuda 1950, and Satō 1950) must be these of abnormal growth or exceptional formation. If these values are contained in the distribution, these make indistinct the loop of frequeucy curve by influencing upon the distribution, accordingly these are omitted. As the results of summing up the values of Aikawa, Amemiya and Tamura, and Satō, the following have theapproximate value of $r_{n+1}-r_n/r_{n+1}$ of maximum in the previous month (or in the next previous month) and indicate the minimum (loop) such as:

r_1···14→5% summer; 17→7% winter, r_2···9→6% summer; 10→4% winter,
r_3···8→2% winter, r_4···6→2% summer; ·5→1% winter.

In the values of r_2-r_1/r_2 each mode (by Aikawa, Amemiya & Thmura, Sato) in August separates extremely, but this case seems rather natural, because there can be many chances which the scales of fish are able to be catched immediately before or after the forming of the first ring, if the true ring is formed about August. Further, as the values of r_3-r_2/r_3, r_4-r_3/r_4, and r_5-r_4/r_5 decrease and the positions of minimum values become obscure, these are indicated as the average in each month calculated to adapt to the values of r_2-r_1/r_2 by the Table 2.

From the above-mentioned the following canbe deduced.

(1) There are minimum in summer and winter in the value $R-lr/R$ of r_1, r_2, and r_4. It appears from the Fig. 4~6 that ring will be formed twice a year, but it can not be deduced that the double formation will be effected normally, because, even if two rings can be formed on scales of every individual fish in general,

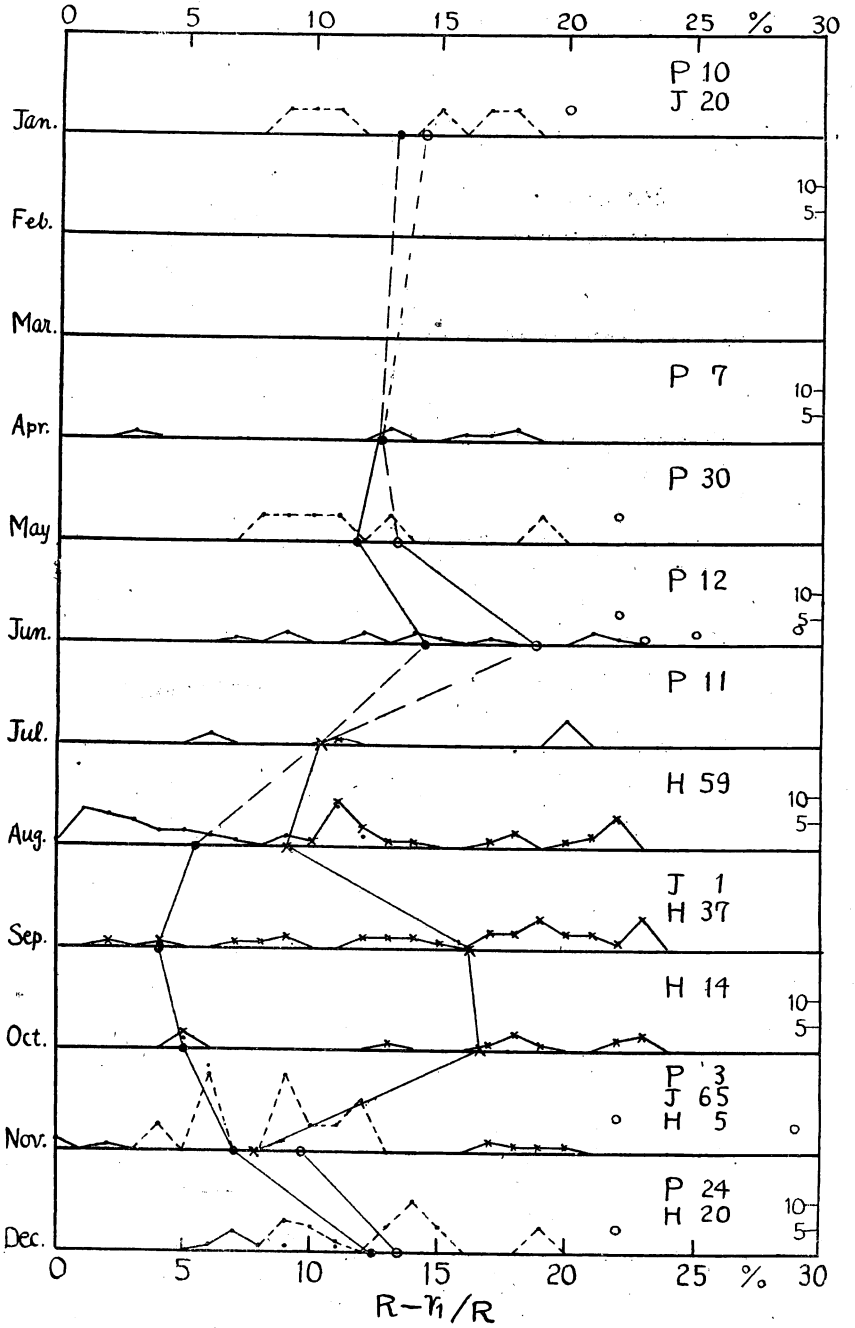

Fig. 3 Note: P……Pacific, J……Japan Sea, H……Hokkaid, K……Kiushu.
•……• …Aikawa, ● …average from (Aikawa+Tamura)
•——• …Tamura, ○ …average from {Aikawa+Tamura+(R-r_1/R>r_2-r_1/r_2)}
×——× …Satō, × …average from (Aikawa+Tamura+Satō)

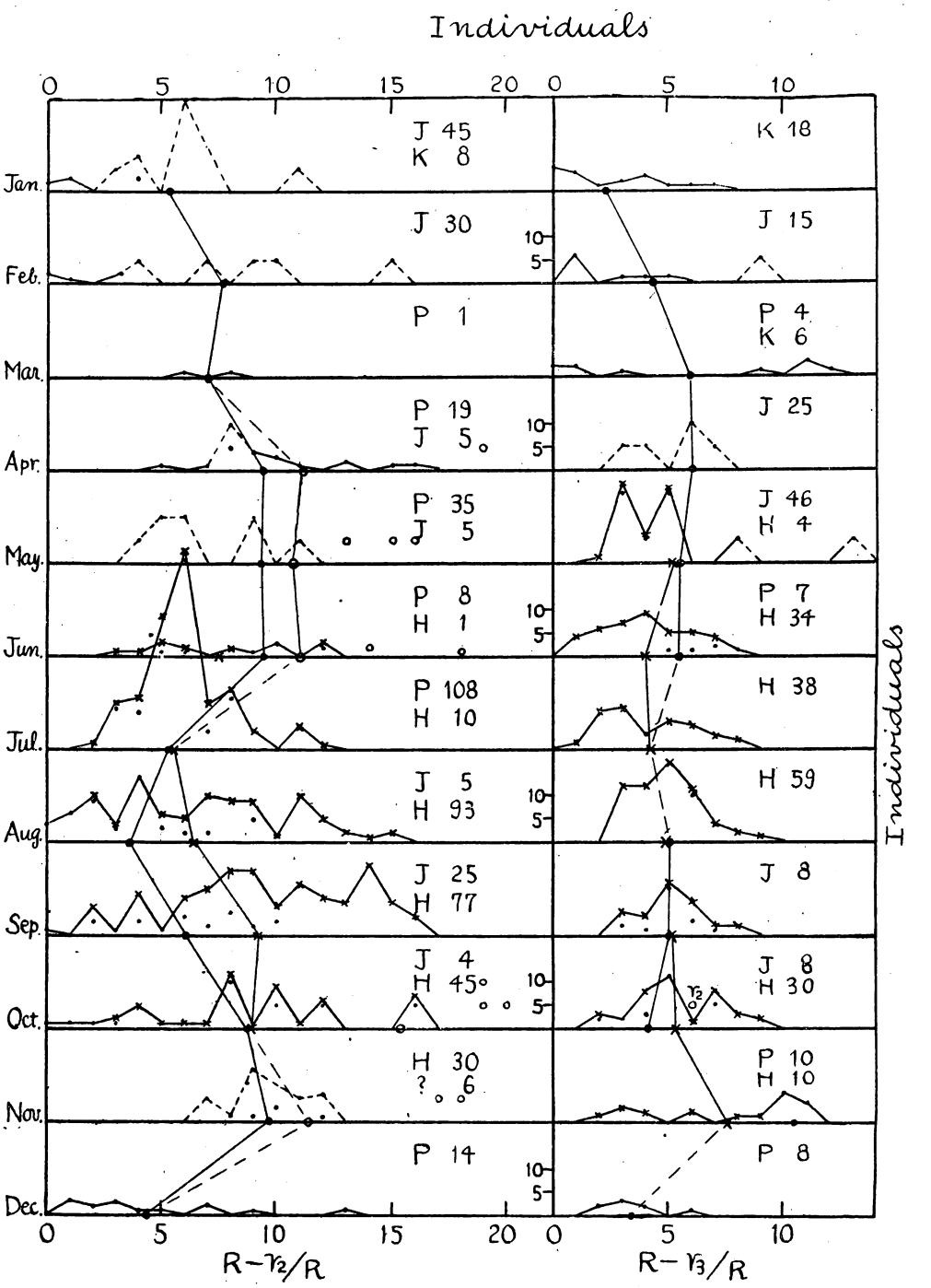

Fig. 4. $R-r_2$, r_3/R in each month.

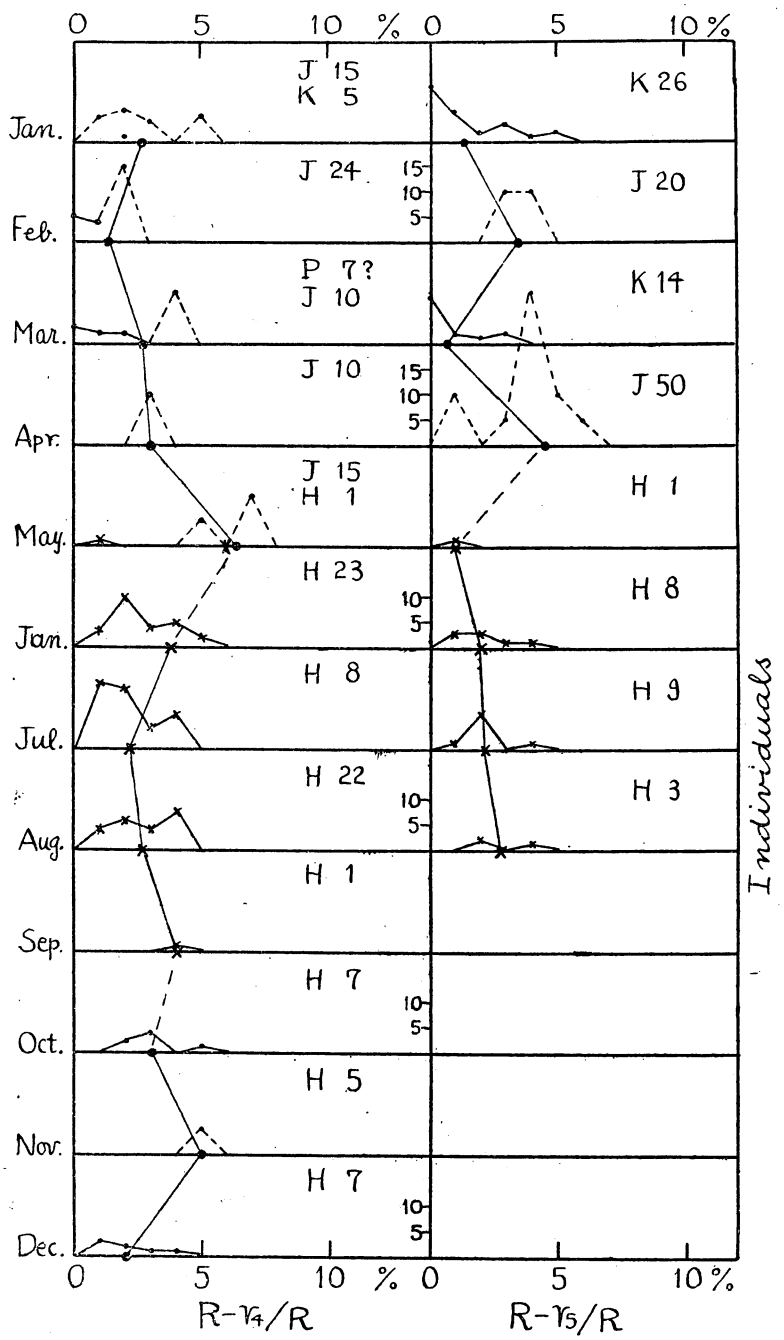

Fig. 5. $R-\dot{r}_{4,5}/R$ in each month.

Table 2. The ratios of $R-r^n/R$ in each ring-class

ring-class	Aikawa	Sato	Amemiya & Tamura	average	$r_{n+1}-r_n/r_{n+1}$	$r_{n+1}-r_n/r_{n+1}$: r_1-r_0/r_1
	mm	mm	mm	mm	%	
r_1	3.18	3.02	3.49	3.20	20.6	1.00
r_2	3.81	3.94	4.33	4.03	13.5	1.53
r_3	4.47	4.69	4.83	4.66	8.3	2.49
r_4	4.93	5.13	5.17	5.08	5.4	3.82
r_5	5.36	5.39	5.36	5.33	—	—

accordingly the following can exist, namely r_1 as winter ring, r_2 as summer, r_3 as winter and r_4 as summer ring, but not these of r_1 as summer, r_2 as winter, r_3 as summer and r_4 as winter ring for instance. There are also no ring-compositions of catch such as composed from the classes of only odd or even number of rings, accordingly the double ring must not be formed.

(2) Then, r_1, r_2 and r_4 may be winter or summer ring respectively, and some fishes may have the winter ring only, other fishes may have the summer ring only.

(3) There are differences of results by investigators in the length of the distance from focus to the last ring and also in R-1r/R of r_1 and r_2 after the summer in the figure (Fig. 3. 4.). The reason of these differences seems to depend on the locality, on the individual variety and also on the disagreement of the standard judgement by the investigators.

(4) Considering however that I have selected only clear ones of small percentage in observed number of scales and moreover the time of the formation must be deduced to be summer and winter, this result may be presumed as follows:
This may arise from containing many scales such as having summer ring accidently which appear at low percentage as indicated in Figure 2, or. the summer ring may come out usually, but some fishes having summer rings may have no winter rings and other fishes having winter rings may have no summer rings.

Therefore, the next hypothesis can be assumed.

a. If the summer and winter ring are both true ring,
   i. the fishes having summer ring may form no winter ring, accordingly r_1, r_2, r_3 and r_4 may be all summer ring;
   ii. the fishes having winter ring may form no summer ring, accordingly r_1, r_2, r_3, and r_4 may be all winter ring;
   iii. the period of ring-formation may be different according to localities;
   iv. there may be difference of period to form ring by year classes, for example, Mr. Yasuda (1950) reported that the sample from Tokyo Bay in autumn, 1942 hat r_1 but that from the same in winter, 1948 had no ring.

b. If the summer ring is pseudo-ring and the winter ring is true ring,

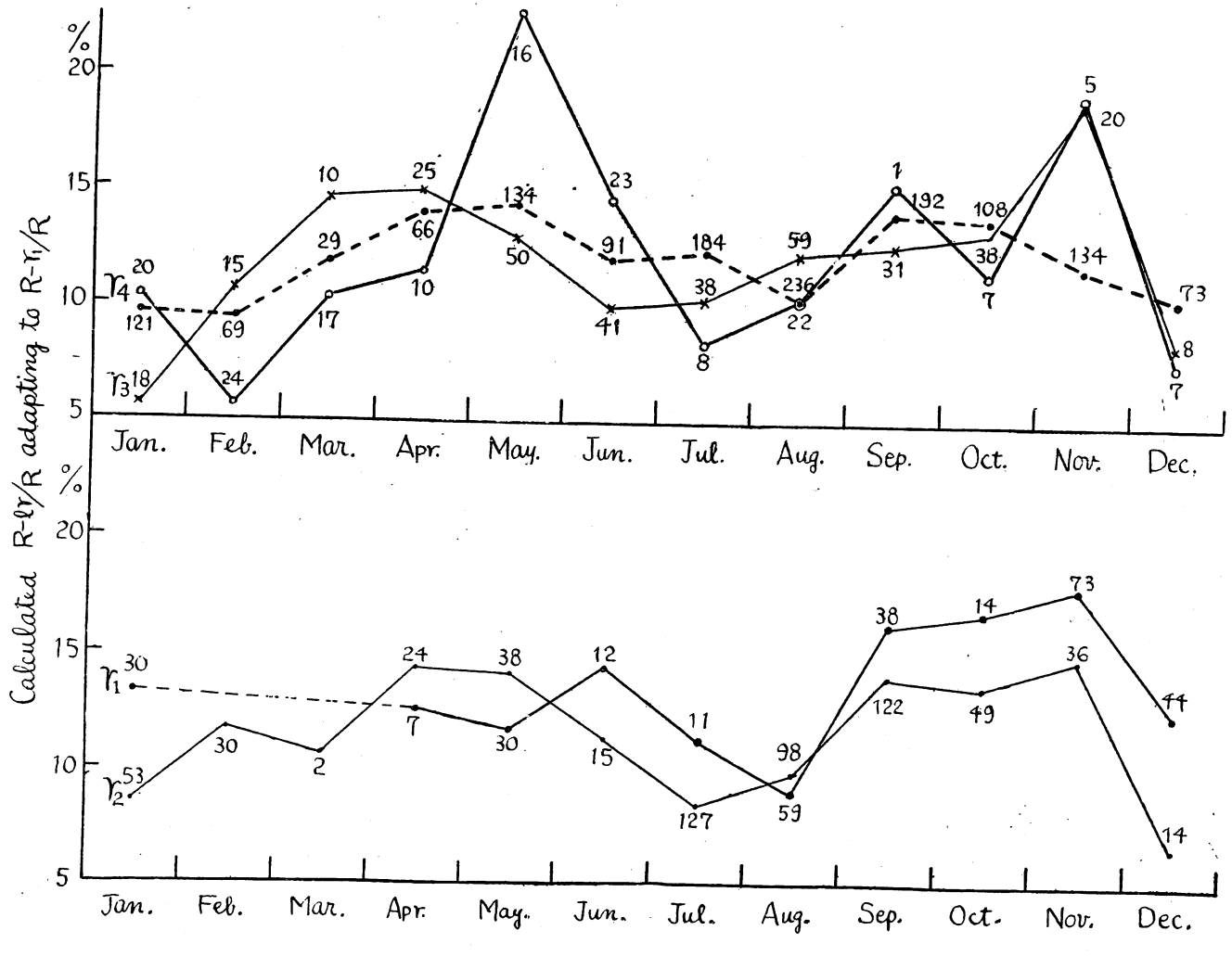

Fig. 6. Calculated R-r/R adapting to R-r1/R in each month.

i. the summer ring may be formed from the resembled cause to spawning ring, appearing only in the damaged fishes, in this case accordingly the values of R-1r/R may be high in summer and the minimum may be indistinct when a large number of scales were observed.

ii. I might have confused the summer ring with the winter ring. In the case of a. i or ii, since the scale forming the summer ring must be in winter and the scale forming the winter ring must be in summer in good condition physiologically, both scale must belong to groups in greatly different conditions. Consequently, in the group having same body-length at same locality, the value of R-1r/R must show only minimum once a year. As the samples of the author include fishes from various localities, the future observation must be carried on the sample having same body-length of same locality, and also the samples having different body-length of different localities must be compared.

Since the instability of the standard reading of scale ring increase the difficulty to solve the problem, the contradiction of the reports by many investigators will not easy to solve without making a clear distinction between true and false ring at least, according to the agreed standard judgement, by means of the adequate discussion in all cases by photograph or others.

3. Relation between the growth of body-length and the calculated body-length at the formation of each ring

According to the real length of the distance from focus to ring, the calculated body-length at the moment of ring-forming disagree remarkably among the data of many reports.

While the actual growth-rate of body-length disagree among the data by several investigators considerably, it is not able to presume the time of the ringformation of r_n by the method of the calculated l_n depending on the growth-rate of body-lenght.

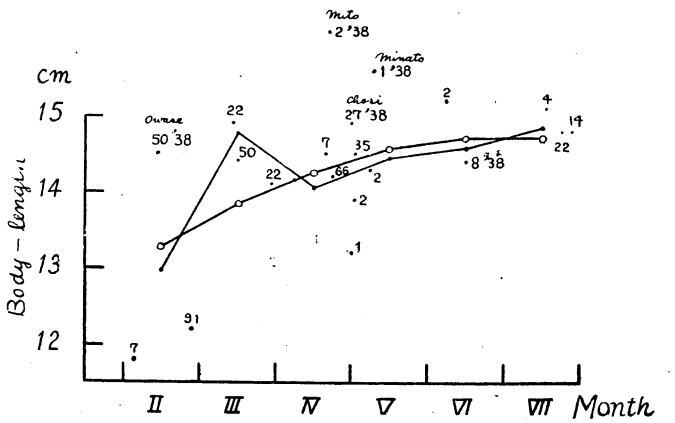

Fig. 7. The growth of 1-ring fishes sampled in the Pacific (1937, Misaki)
Note: •——• experimental value, o——o theoretical value

4. Time of formation of last ring

The calculation of the time of last ring from the relation between the scale-length (R) and last ring is in danger of considerable inaccuracy caused by the large variability of scale, but it seems easy to perceive the general estimate about the time, when a large number of samples are used as data. I tried to calculate it from the reliable data (by which 1_n found) of our samples which were not so sufficient. In the latter formula r_n/r'_n is the correcting factor of the large differences of the growth by individuals or scales.

$$X'=(t_{n+1}-t_n).\ r_n/r_n'.\ (R-r_n')/(r_{n+1}-r_n)$$

(r_n'……distance trom focus to last ring: R……scale-length at the time of sampling: r_n……average distance from focus to n'th-ring of all Japan corrected for the phenomenon of decreasing scale-length, X'……interval between the time of formation of last ring and that of samling, t_n……time of forming r_n).

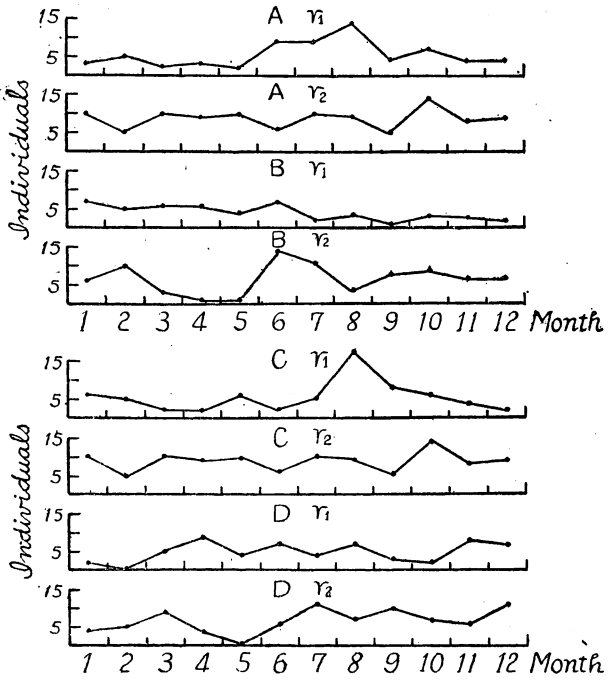

Fig. 8. Presumption of the time of the last ring-formation

When Aikawa's growth-rate is adopted in $t_{n+1}-t_n$, the value of t_2-t_1, t_3-t_2, and so on become 8, 5, 8, 7 months respectively. (Fig. 8. A . In Fig. 8. B, t_n shows that from Yasuda's growth-rate. The figure 8. C and D are the results from assuming the $t_{n+1}-t_n$ as 6 and 12 months respectively. But this inclination is not certain, since there are no agreement of the ring-length and of the standard judgement of scale-reading.

Judging from the former results collectively, it can not be concluded that the rings are formed twice a year, it is presumed rather that there exist the sardines forming the summer ring and too the other sardines forming the winter ring.

There is no knowing what the first ring is to be formed during summer or winter. It may be perhaps partly derived from the differences by locality, considering that the samples of the Pacific are presumed to form first ring during winter, in view of the former b i. Since the cause of this result may deduced to that the summer rings of the samples from Japan Sea may give a strong effect on the distribution of R-1r/R in each month, these tendency may indicate the loop of summer as seen in the Figure 3~6.

C. The cause of the formation of periodic rings

There are several factors considered as the causes of the formation of periodic rings of sardine like other kinds of fishes, water-temperature, food and spawning, etc. Taking into consideration of that the spawning seems to have little effect on the summer or winter ring of O-year fish and there exist accessory rings regarded as the spawning ring, this may be probably adequate to infer as on cause of the periodic rings comming into question.

By the report of Plankton Review (1940) the total amount of plankton and that of diatom of every month (Fig. 9) show both the minimum in December or January or February and in July or August. These agree in several points with the former results, and the water-temperature are also about minimum or maximum in these months, accordingly the ring-formation may be resulted from these factors.

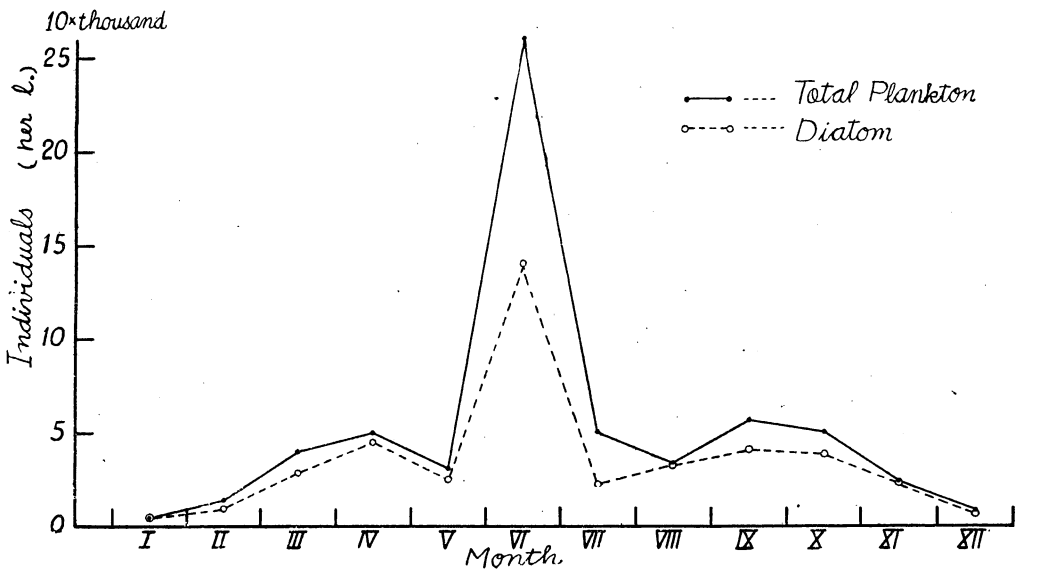

Fig. 9. Monthly fluctuation of plankton
(samples of 12~15 positions, mean of 3 years)

D. Discussion

Mr. Yasuda (1950) compared the distributions of the frequency of ring-length and body-length, and concluded that the r_1', r_2' must be false ring, because the frequency of appearance of r_1', r_2' is few but that of r_3' is many. The value of the r_3'-length

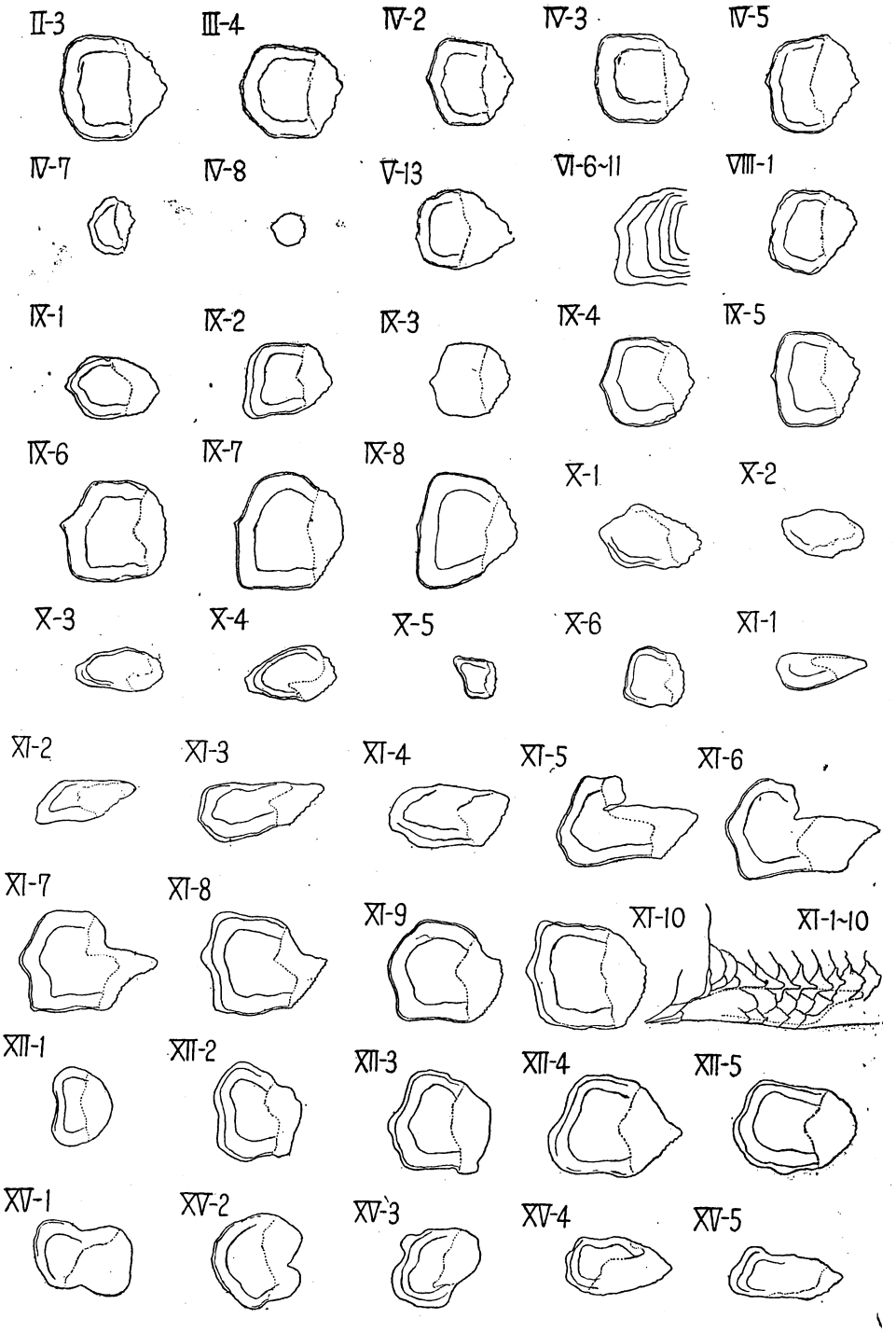

Plate 1. The variation in the shapes or the rings of scales according to body-parts (ca×3/2)

by Mr. Yasuda approaches that of r_2-length by Prof. Aikawa (1940) and the r_1-length by Amemiya and Tamura (1949), but different from the r_1-, r_2-length by Satō & others (1950). Then, the r_1 by Aikawa (1940) is regarded as the pseudo-ring certainly, but the other disagreement may depend upon the difference of the standard to determine rings.

On R-1r/R, the value from the first ring ($r_1=r_3'$) shows minimum in summer (June, July), that from the second ring indicate minimum in spring and summer (April, July) in the samples taken from off Jōban (1942-1943) by Mr. Yasuda (1950), but minimum of the value from r_1 can not be observed in his figure. Having no sample in winter or summer in the report by Satō (1950), the minimum of R-1r/R is unknown.

By M. blackburn (1949) the Australian sardine (*S. neopilchardus*) is presumed to form r_1 in October~December, as well as r_2, r_3, and r_4 mainly in July~August according to the number of scales having the value of $1-1_n$ (body-length——calculated body-length) less than 10mm in each month. His method may be not so different from that of the R-1r/R, as the growth of the fish having $1-1_n$ of less than 10mm is slow in these months relying on the Petersen method.

Putting together the above-mentioned, the possibility of the formation of summer ring may be large, however on the time of formation of each ring, it is necessary to ascertain the month of minimum of R-1r/R, by means of adding more abundant samples from many localities and of many year-classes. In addition, the decision of the time of ring-formation or the certain age-determination will be acomplished, by making agree the standard of scale-reading among investigators in order to coincide with each ring-length, also by making clear the difference of growth between localities or year-classes.

Résumé

1. The form of scale at each body-part, the scale-length and the positions of rings were compared with each other.
2. There were several additiond features of the periodic rings to the former report, "Scale-1".
3. Concerning the time of the formation of the periodic ring, the percentage of O-year fishes possessing the rings on scales, the distance between the last ring and the margin of scales, the method calculating the time of the formation of the last ring were discussed.
4. The time of the formation of the first true ring is winter (about January or February) in samples from the Pacific (Misaki 1934).
5. The ring-formation may be found in both summer and winter, but nobody can confirm the rings to be true or otherwise.
6. The first winter ring will be perhaps the true ring, but in some fishes rings are formed in the summer after the second year too.
7. The cause of the formation of the periodlic rings is presumed to be the effects

of food and water-temperature on scale in the worst conditions at the same time.

References

1. AIKAKA. H. 1940: On the age and race of the Japanese sardine. Res. Oceanogr. Works Jap., xi, no. 2, 81–111.
2. KOKUBO. S. and SUZUKI. A. 1940: Plankton Review, no. 15.
3. YASUDA. H. 1940: On the scale-phase of sardine. Bull. Jap. Soc. Sci. Fish. ix, no. 3, 107–110.
4. AMEMIYA. I. and TAMURA. O. 1948: Study of the Japanese sardine II. Ring-composition. Seibutsu, iii, nos. 3–4, 109–113.
5. 〃 and 〃 1949: Study of the Japanese sardine III. Scale, 1, *Ibid.*, iv, no. 4, 140–145.
6. BLACKBURN. M. 1949: Age, rate of growth, and general life-history of the Australian pilchard in New South Wales. Commonwealth. Sci. Industr. Res. Org. Australia, Bull. No. 242. Div. Fish. Rept., no. 12.
17. SATÔ. S., TANAKA. K., and HONGÔ. K. 1950: Studies on the age of *Sardinia melanosticta*. Paper 1. Journ. Hokkaidô Fish. Exper. St., no. 6, 1–38.
8. YASUDA. H. and OGURA. M. 1950: Growth of Japanese principal fish. I. *Sardinia melanosticta*, xvi, no. 6, 29–35.