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Studies on the Ecology of the Herring in the Northern Part of the Okhotsk Sea in Summer—III Geographical Variations in Fork Length and Scale Pattern in 4 Year-Old Group*1

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For the purpose of elucidating the stock system of fish group chiefly composed of 4 year-old fish found around the area of the Ayan in the summers of 1971–1973, fork lengths and scale patterns of 4 year-old fish taken from the different areas in the northern part of the Okhotsk Sea were examined. It was confirmed that the mean fork length of 4 year-old fish around the area of the Ayan was consistently about 1 cm smaller than that of the eastern area of the Okhotsk. Scale patterns also differ considerably among areas and they are divided roughly into the two types of Tauisk and Ayan. The results of analyzing the ratio of distance among the annuli and the fork length estimated at the 1st annulus formation indicate that these two 4 year-old groups with the different scale patterns had lived under different circumstances after the first year of life. However, these fish groups are not always isolated from each other through the stages in development. Comparison of scale ratio R_i/fork length relationships shows that fish group in the area of the Ayan in 1973 is mixture, which arose during the third year of life, of fish with the different scale pattern of Tauisk and Ayan types.

Otherwise, it was found that the fish with the specific values of scale ratio r_2/r_3 could be used as an indicator of presence of fish appeared around the area of the Ayan in each year.

Stock of herring, *Clupea harengus pallasi,* which spawn in the coastal waters from the Tauisk Bay to the waters around the Shantarskie Islands and lives in the northern and central part of the Okhotsk Sea is called the Okhotsk Population. Their distribution and migration during the summer and autumn have been studied by AYUSHIN[1,2], FUKUHARA *et al.*[3], PRAVOTOROVA[4], KHARITONOVA[5], CHERNYAVSKII *et al.*,[6] and other workers. However, very little informations are available on the young herring less than 4–5 years old which are hardly caught by the gill nets of the commercial vessels.

In the previous paper[7], as the result of the examining the materials taken by the surface gill nets composed of fixed series of mesh sizes in 1971–1973 the author reported that the shoals of herring in the northern part of the Okhotsk Sea in summer were separated into the following three fish groups according to their age composition, and each group in general separated from one another geographically: The first group is composed of fish older than 4 years old, and the main part of adult fish is included in this group, the second is chiefly composed of juvenile fish of 2–3 years old, and the third group is chiefly composed of young fish of 4 years old.

However, whether these groups as formed according to the stages in development belong to the same population, i.e. Okhotsk Population, or not is not confirmed, and a particular attention was given to the fish group chiefly composed of 4 year-old fish found consistently around the area of the Ayan in the summers of 1971–1973. It is quite clear that the fish group composed of fish older than 4 years old in the present study area is of the Okhotsk Population[7]. However, remarkable differences were found in several biological characteristics, fork length, maturity index, and body weight/fork length relationship, between the 4 year-old groups in the areas off the Koni Peninsula and Ayan in 1971. For this reason, it was suggested that it is necessary to elucidate the stock system of fish group in the area of the Ayan[8].

The present paper deals with the comparisons of fork lengths and scale patterns of samples of 4 year-old fish taken from the different areas in the northern part of the Okhotsk Sea in the summers of 1971–1973.

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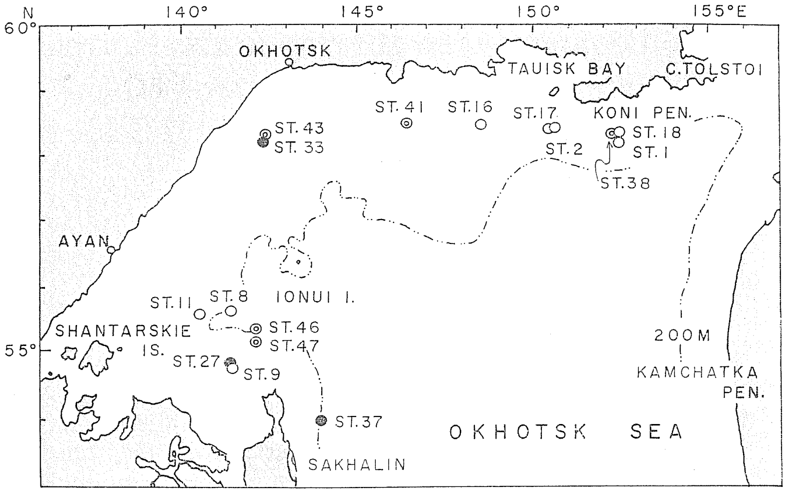

Fig. 1. Locations where samples were collected in the northern part of the Okhotsk Sea from August to September, 1971–1973. ○: 1971, ◉: 1972, ◎: 1973.

Materials and Methods

Samples were collected from the different stations in the northern part of the Okhotsk Sea where experimental fishing for salmon was carried out by the R/V "Oyashio Maru" from August to September, 1971–1973. Only the data of sixteen stations were used, where a large number of 4 year-old herring were caught; the geographical positions of each station are shown in Table 1 and Fig. 1. Although the catch at St. 47 was not so much, it was clearly recognized that the sample well represented the biological characteristics of fish appeared in the area of the Ayan in that year as the result of a preliminary analysis, so the data from St. 47 were also examined. The gill nets used was composed of fixed series of mesh sizes, i.e. 30, 35, 42, 48, 55, 63, 72, 82 mm streched length, and others. The amount of nets was three tans for each mesh size. Individuals of fifty to one hundred fifty fish were sampled at random from the catch by the net with each mesh size. When

Table 1. Dates and locations where samples were collected, and the number of individuals observed and catch of 4 year-old herring

Sea area	No. of fishing station	Date		Location		No. of observed fish		No. of catch (fishes)
				Latitude	Longitude	n	n′*	
Tauisk	1	1971	Aug. 17	58°12′ N	152°28′ E	105	52	1960
	2		18	58°26′	150°30′	52	32	1107
Ayan	8		24	55°39′	141°23′	43	24	1715
	9		25	54°47′	141°33′	63	22	1350
	11		27	55°38′	140°30′	63	35	2153
Tauisk	16		Sept. 1	58°30′	148°30′	102	55	1877
	17		2	58°24′	150°35′	36	13	1048
	18		3	58°20′	152°30′	52	33	606
Ayan	27	1972	Aug. 23	54°49′	141°28′	58	—	420
Okhotsk	33		Sept. 1	58°17′	142°22′	24	—	456
N. Sakhalin	37		5	54°00′	144°00′	89	—	868
Tauisk	38	1973	Aug. 15	58°20′	152°21′	89	56	974
	41		18	58°30′	146°30′	197	110	15222
Okhotsk	43		20	58°20′	142°22′	161	88	14022
Ayan	46		23	55°24′	142°12′	229	131	2491
	47		24	55°12′	142°12′	89	47	109

* Number of scale examined

the catch was poor, all fish caught were sampled.

Because 4 year-old fish were chiefly caught by the nets of 42 and 48 mm mesh, only samples from these two meshes were dealt. They were frozen immediately after capture and examined after melting in the laboratory. Fork lengths were measured to the nearest millimeter for all individuals of fish after scales were removed. Then, body weights, gonad weights, liver weights, and other items were also recorded, however, these data are not included in this report. The surface features of scale was magnified fifty times using a microprojector, and R (scale radius to anterior margin) and r_i (scale radius to each annulus) were measured on recording card along the longest axis from the nucleus of scale to anterior margin.

Student's t-test was used for determining the significance between means. When the variance test (F-test) showed a significant difference, the method of Cochran and Cox (t'-test) was employed in place of the t-test. However, because in the samples used non-normal ones were contained, the χ^2-test for the differences in frequency distributions was also carried out and the results were compared with those of t-test or t'-test.

Comparison of Scale Pattern among Body Parts

Five to ten scales were removed from ten parts (Fig. 2) on the left side of two individuals of fish (242 mm and 235 mm long; 5 years old) respectively

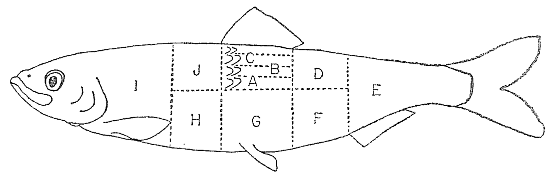

Fig. 2. Body parts from which scales are taken.

and the normal scales of them were observed to compare scale pattern among the body parts. In general, the position of each annulus formed on these scales was clear, but all of them from the body part C and some from G were too unvisible to measure. As shown in Fig. 3, there is a linear relationship with a relatively higher correlation between R and r_i of scales taken from the different body parts, and the positions of each annulus on scales were well corresponded to one another. However, it was also seen that the positions of annulus varied considerably among the body parts in the same individual. For instance, those from E near the tail were outer as compared with the others on the whole. For this reason, scales taken from A or B near the center of fish body—the left side as a rule—were examined. The standard deviations of the position of each annulus on scale, i.e. scale ratio R_i ($r_i \times 10^2/R$) for the scales from the parts designated of above two individuals of fish (a,b) were as follows respectively:

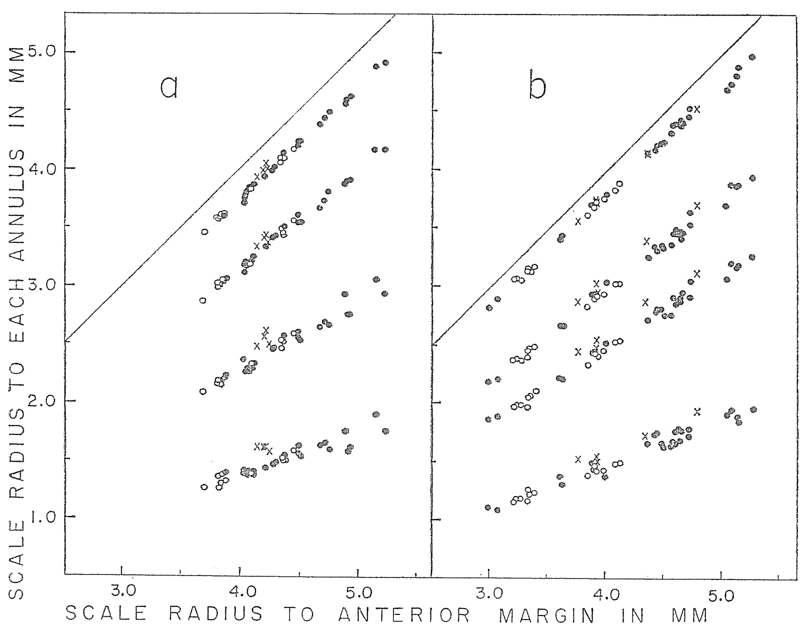

Fig. 3. Comparison of positions of each annulus for scales taken from the different body parts of two individuals of fish (a: 242 mm, b: 235 mm in fork length; 5 years old). Oblique lines pass the origin of co-ordinates at the oblique angle of fourty-five degrees to axis. ○: Scales from body part A and B, ×: Scales from E, ●: Scales from the parts except A, B, C, and E.

Sample a: $\delta_{R_1}=0.89$, $\delta_{R_2}=0.67$, $\delta_{R_3}=0.81$, $\delta_{R_4}=0.29$ (n=11)
Sample b: $\delta_{R_1}=0.81$, $\delta_{R_2}=0.80$, $\delta_{R_3}=0.63$, $\delta_{R_4}=0.62$ (n=13)

Measurements of R and r_i were made on the samples in 1971 and 1973. The number of individual observed were 266 fish and 432 fish, respectively (Table 1). The individuals with abnormal or regenerated scales were omitted to measure, in addition to the fish having no scale in the parts designated.

Results

No significant difference (at P=0.05) was found in the mean fork length and R_i between sexes, therefore, the sexes were combined in the later analysis.

Fork Length

Fig. 4 shows the fork length frequency distributions of 4 year-old fish taken by the two meshes at the sixteen stations in the summers of 1971–1973. According to the period and area of sampling, samples in 1971 were divided into the following three categories: St. (1,2), St. (8,9,11), and St. (16,17,18). As mentioned in the previous paper[8], in 1971 a large number of 4 year-old fish were caught in the areas of the Tauisk and Ayan, however, no appreciable catch was taken in the area of the Okhotsk, where juvenile fish of 2 years old were predominant. As shown in Fig. 4, fork length frequency distributions of 4 year-old fish differed considerably between Tauisk and Ayan, and the difference of means was statistically significant at the 0.1% level (Table 2). This indicates that the mean fork length of sample taken from the area of the Ayan (St. 8,9,11) is significantly smaller than that of the area of the Tauisk.

The difference of length frequency distribution between meshes is larger in the later sample (early September, St. 16,17,18) than the earlier (mid August, St. 1,2) in the same Tauisk area. This shows that the size of 4 year-old fish in the later period ranged widely. The difference of means was significant at the 0.1% level, but the χ^2-test showed that the difference in frequency distributions was not significant between the two samples.

In 1972, because the 1969 year-class was the least abundant, particularly from the eastern area of the Okhotsk only a small number of 4 year-old fish were obtained; nevertheless, a large catch was seen

Table 2. The t-test for the homogeneity of means and χ^2-test for that of frequency distributions of fork length in 4 year-old herring between stations, 1971 and 1973

Stations	Mesh size of 42 mm						Mesh size of 48 mm					
	t	df	P	χ^2	df	P	t	df	P	χ^2	df	P
St.1,2–St.8,9,11	t'=11.10	220	<0.001	87.75	10	<0.001	7.196	102	<0.001	41.77	7	<0.001
St.1,2–St.16,17,18	t'=4.02	276	<0.001	12.55	9	0.20–0.10	2.526	67	0.025–0.01	7.27	6	0.30–0.20
St.8,9,11–St.16,17,18	t'=7.78	242	<0.001	56.67	10	<0.001	10.953	113	<0.001	68.65	9	<0.001
St. 38–St. 41	0.563	208	>0.50	4.77	9	>0.50		—			—	
St. 38–St. 43	3.742	178	<0.001	17.74	9	0.05–0.025		—			—	
St. 38–St. 46	8.942	184	<0.001	57.43	10	<0.001		—			—	
St. 38–St. 47	7.790	125	<0.001	47.39	9	<0.001		—			—	
St. 41–St. 43	3.391	210	<0.001	15.74	7	0.05–0.025	t'= 0.64	144	>0.50	7.39	6	0.30–0.20
St. 41–St. 46	8.709	216	<0.001	62.03	9	<0.001	t'=12.09	206	<0.001	84.60	7	<0.001
St. 41–St. 47	7.285	157	<0.001	45.86	7	<0.001	t'= 8.92	125	<0.001	71.56	8	<0.001
St. 43–St. 46	4.504	186	<0.001	19.36	8	0.025–0.01	9.087	200	<0.001	66.95	8	<0.001
St. 43–St. 47	4.156	127	<0.001	15.65	7	0.05–0.025	7.513	119	<0.001	50.61	8	<0.001
St. 46–St. 47	0.940	133	0.40–0.20	1.80	7	>0.50	0.563	181	>0.50	7.92	8	0.50–0.30

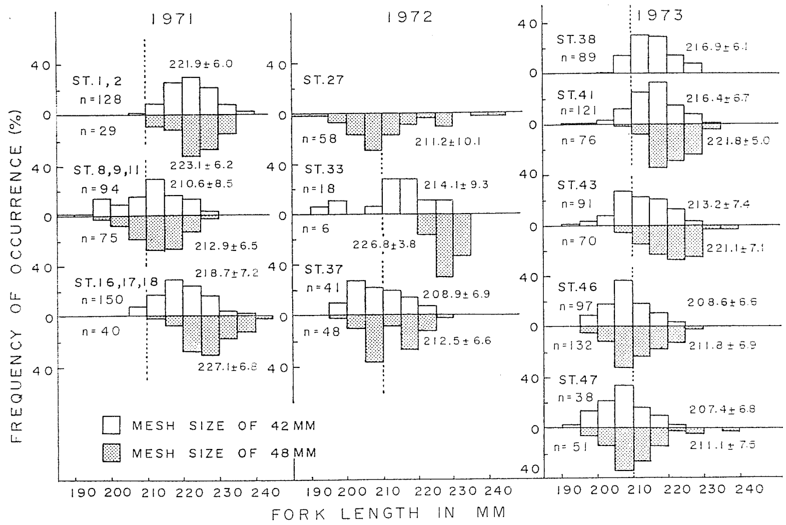

Fig. 4. Frequency distributions of fork length in 4 year-old herring from the different stations in the northern part of the Okhotsk Sea from August to September, 1971–1973. The figures show the mean and standard deviation of fork length. n: Number of fish.

at St. 27 in the area of the Ayan and St. 37 in the eastern area off the North Sakhalin. The samples from these two stations were considerably smaller in size than those of the 1971, with the mode of approximately 206–210 mm together. On the other hand, at St. 33 in the area of the Okhotsk, though the number of fish observed were minor, the proportion of larger fish was clearly high as compared with the other stations (Fig. 4).

And then, samples in 1973 also showed a similar tendency to above. Namely, the mean fork length of samples taken at St. 46 and St. 47 in the area of the Ayan is smaller than that of St. 38 and St. 41 in the area of the Tauisk, and this difference is statistically significant at the 0.1% level in any cases. The differences in means and frequency distributions of fork length between the different stations within area are not significant. The difference in length frequency distribution between meshes is larger in the fish of St. 43 in the area of the Okhotsk than that of other areas. This shows that the range of size of 4 year-old fish in this station was considerably larger. The mean fork length of St. 43 was smaller than that of Tauisk and larger than that of Ayan.

From the above results, it is confirmed that the mean fork length of 4 year-old fish found around the area of the Ayan was consistently about 1 cm

Table 3. Number of scale examined, mean ($\overline{R_i}$) and standard deviation (δ) of scale ratio R_i (i=1–3), and difference between $\overline{R_i}$ and $\overline{R_{i-1}}$ for the 4 year-old herring from the different stations, 1971 and 1973

Station	Mesh size (mm)	n	$\overline{R_1}\pm\delta$	$\overline{R_2}\pm\delta$	$\overline{R_3}\pm\delta$	$\overline{R_2}-\overline{R_1}$	$\overline{R_3}-\overline{R_2}$
ST. 1, 2	42	65	35.34±3.9	61.90±3.1	88.42±2.5	26.56	26.52
	48	19	35.78±3.6	61.21±3.5	86.87±1.8	25.43	25.66
ST. 8, 9, 11	42	50	33.40±4.8	57.34±5.4	87.01±4.0	23.94	29.67
	48	31	31.93±3.9	55.57±4.2	87.77±2.2	23.64	32.20
ST. 16, 17, 18	42	78	34.87±3.2	59.38±3.6	85.12±2.5	24.51	25.74
	48	23	33.55±3.3	59.64±4.6	85.92±3.2	26.09	26.28
ST. 38	42	56	37.96±3.5	66.11±2.8	91.70±2.2	28.15	25.59
ST. 41	42	75	36.56±3.9	64.46±3.5	89.03±1.8	27.90	24.57
	48	35	37.11±3.4	65.64±3.1	90.07±2.0	28.53	24.43
ST. 43	42	49	35.37±4.3	63.80±3.9	88.09±3.2	28.43	24.29
	48	39	37.13±4.7	67.37±6.2	90.41±3.6	30.24	23.04
ST. 46	42	57	39.61±5.2	71.67±6.4	94.22±3.2	32.06	22.55
	48	74	41.18±3.9	72.56±5.5	94.88±2.3	31.38	22.32
ST. 47	42	18	43.00±4.7	73.13±6.3	95.27±2.5	30.13	22.14
	48	29	40.19±4.1	72.57±5.1	94.96±1.8	32.38	22.39

smaller than that of the eastern area of the Okhotsk during 1971–1973. The differences among year-classes are also seen.

The R_i/Fork Length Relationship

Means of scale ratio R_i for the 4 year-old fish taken by the two meshes at the sixteen stations in the summers of 1971–1973 are given in Table 3. In general, it is well known that the growth of scale is related to that of body length, hence, the scale ratio R_i is used for analyzing the growth rate of body length in each year of life. Although the various allometric equations are usually used as a method of expressing the growth pattern of fish individuals, in the present study the R_i/fork length relationship was first analyzed. The plots of R_i on fork length for each sample in general show the elliptical distribution with a remarkably low correlation (correlation coeficient r for $R_1=-0.17 \sim 0.23$, r for $R_2=-0.08 \sim 0.46$, r for $R_3=-0.13$

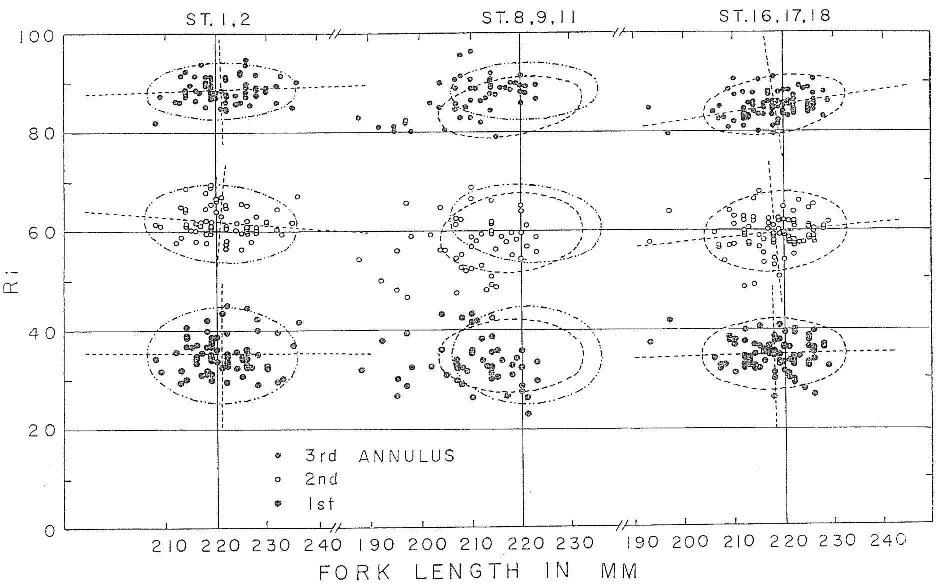

Fig. 5. Relationships between fork length and scale ratio R_i ($r_i \times 10^2/R$), where r_i (i=1–3) is scale radius to each annulus and R is scale radius to anterior margin, for the 4 year-old herring taken by the net of 42 mm mesh, 1971. For comparison rejection ellipses of the 5% level of significance for the samples of St. (1,2) and St. (16,17,18) are superimposed on the points plotted for St. (8, 9, 11).

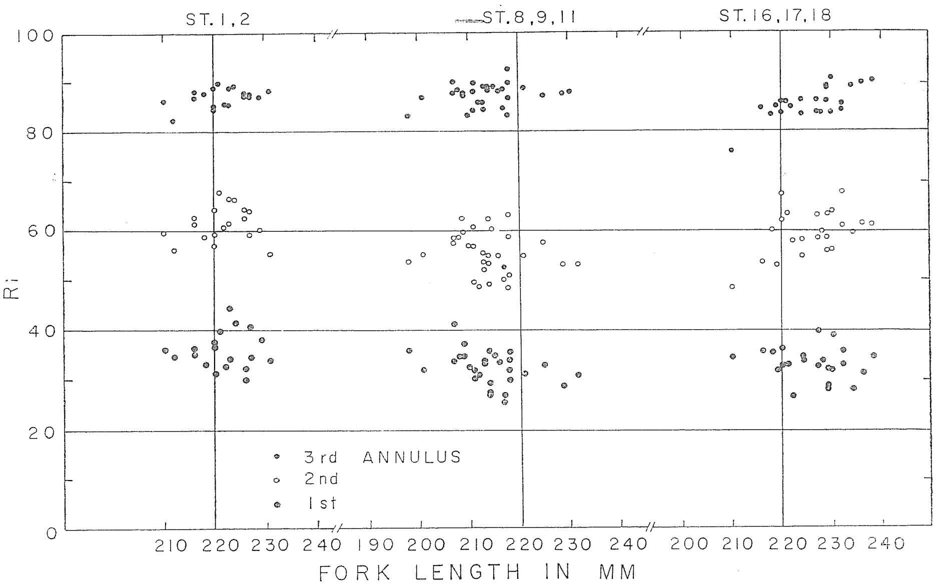

Fig. 6. Relationships between fork length and scale ratio R_i ($r_i \times 10^2/R$), where r_i (i=1–3) is scale radius to each annulus and R is scale radius to anterior margin, for the 4 year-old herring taken by the net of 48 mm mesh, 1971.

~0.72). For this reason, the method of rejection ellipse[9] was employed in place of the usual Analysis of covariance as a method for examining the homogeneity of growth pattern among samples. When it was found that the frequency distributions of fork length and R_i were normal using a normal probability paper method, rejection ellipse was calculated at the 5% level of significance. The R_2 for the St. 47 sample is not normal, however, the ellipse was calculated for reference. The rejection ellipses shown in figures is those obtained from the data except the points which were rejected at the 5% level of significance. The parameters for each ellipse are given in Table 4.

Figs. 5 and 6 show the plots of R_i on fork length for each sample in 1971 (1968 year-class). In general, the positions of the 3rd annulus for the scales from St. (1,2) where sampling was made in the earliest period were the outermost, and followed by St. (8,9,11) and St. (16,17,18) in the order, though the difference was not so large. In addition, the samples of St. (1,2) and St. (16,17,18) is those taken from the same Tauisk area. Therefore, thus the difference of positions of the 3rd annulus among samples almost seems to be due to the difference of sampling period. As shown in Table 3, the ratio of distance among the annuli (R_1: R_2-R_1: R_3-R_2) for the sample of St. (1,2) is similar to that of St. (16,17,18), and as mentioned before, no significant difference was found in length frequencies between these samples. Therefore, it seems likely that the fish of St. (1,2) had a similar growth pattern to those of St. (16,17,18) until they were caught.

If fish in the area of the Ayan have a similar growth pattern to those in the area of the Tauisk, one would expect that the points of R_i/fork length for the Ayan sample would be distributed in the middle position of the two rejection ellipses for St. (1,2) and St. (16,17,18). As shown in Fig. 5, the distribution of the points for each annulus is mostly within the two ellipses, with the exception of the smaller fish less than 205 mm being out from the ellipses. However, it is also seen that the points for the 1st and 2nd annulus lie chiefly within the lower part of the ellipses and those for the 3rd annulus lie chiefly within the upper part of them. This shows that in the fish of Ayan the scale growth in the second year is considerably small as compared with that in the third year, and this tendency is especially remarkable in fish below 205 mm long. On the other hand, in fish of Tauisk the scale growth in the second year and that in the third year are approximately equal. These results are also evident from Table 3. As to the samples from the 48 mm mesh, though the rejection ellipse was not obtained because of a small number of individuals, the data shows approximately a similar tendency to that from the 42 mm mesh (Fig. 6). Otherwise, it was attracted that fish of the Ayan type being smaller in size and in scale growth of the second year, though the number of

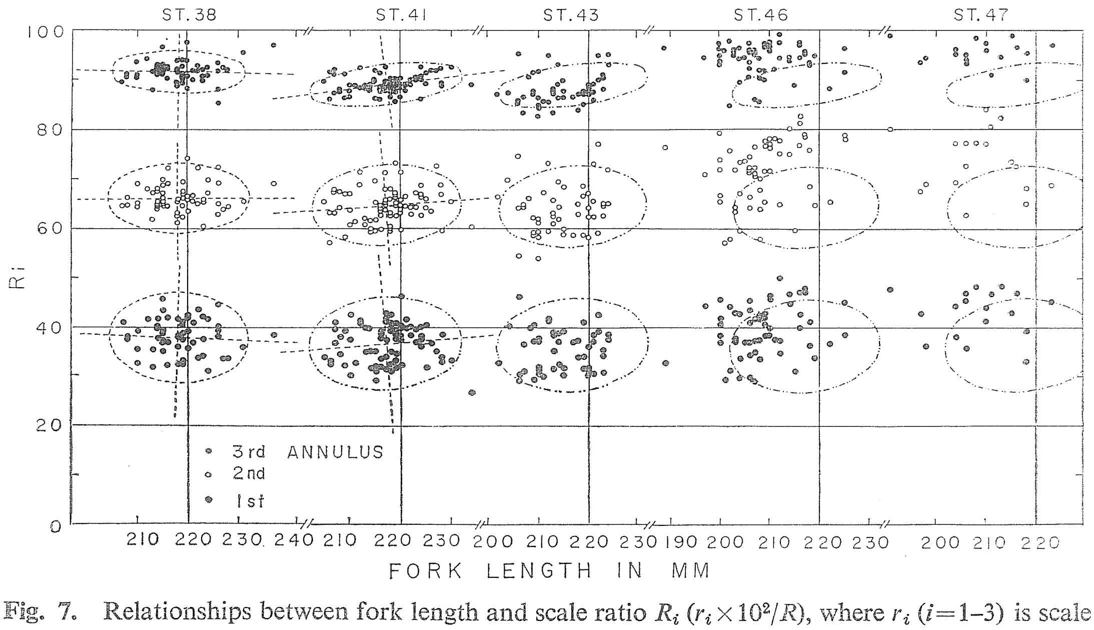

Fig. 7. Relationships between fork length and scale ratio R_i ($r_i \times 10^2/R$), where r_i (i=1–3) is scale radius to each annulus and R is scale radius to anterior margin, for the 4 year-old herring taken by the net of 42 mm mesh, 1973. For comparison rejection ellipse of the 5% level of significance for the sample of St. 41 is superimposed on the points plotted for St. 43, St. 46, and St. 47 respectively.

individuals were not so many, were included in the sample of St. (16,17,18).

In the same manner, the relationship between fork length and R_i for each sample in 1973 (1970 year-class) were compared (Figs. 7 and 8). In these figures, one are earlier sampling date in order from the left side. Although the samples of St. 38 and St. 41 were taken on the earlier dates, the positions of the 3rd annulus were remarkably inner as compared with those for St. 46 and St. 47 where were taken on the later dates. Namely, this shows that the scale growth after the formation of the 3rd annulus, i.e. marginal growth is remarkably smaller in the samples of Ayan (St. 46, St. 47) than those of Tauisk (St. 38, St. 41). And for this reason, the positions of each annulus for the Ayan samples are outer as compared with the other samples on the whole. Again, when comparing St. 38 with St. 41, though no available data was obtained from the 48 mm mesh at St. 38, some difference in positions of the 3rd annulus was seen, despite the fact that the samples of these two stations were taken within only three days. However, the ratio of scale growth among the annuli for the sample of St. 38 is similar to that of St. 41 (Table 3), and as before, no significant difference was shown in mean fork length between these samples. Therefore, it seems that fish of St. 38 had a similar growth pattern to those of St. 41 until the 3rd annulus was formed.

As in Fig. 7, result superimposed the rejection ellipse for St. 41 upon the points plotted for St. 46 and St. 47 respectively, shows that the points for the 1st annulus lie chiefly within the ellipse and about it, but those for the 2nd and 3rd annulus are chiefly far outside from it. This reason is that in fish of Ayan the scale growth in the third year is remarkably small as compared with that of Tauisk as a rule, in addition to the small marginal growth. And this tendency is also seen in the samples from the 48 mm mesh (Fig. 8). Result superimposed the rejection ellipses for St. 41 and St. 47 upon the points plotted for St. 43 and St. 46 respectively, shows that the sample of St. 43 is chiefly composed of fish with the same growth pattern as St. 41 and some fish with that of the same type as St. 47. On the contrary, the sample of St. 46 is almostly composed of fish with the same growth pattern as St. 47 and a few fish with that of the same type as St. 41. These results agree very well with those of fork length distributions as before.

However, it is seen that there is a remarkable variation in positions of the 2nd annulus for the Ayan samples (St. 46, St. 47). Namely, in general the scale growth in the third year at large lengths is remarkably small, while at small lengths there is not such a characteristic and their scale pattern is rather similar to that of the Tauisk sample. Therefore, if this phenomenon means a mixture of fish with the different scale patterns of Tauisk and Ayan types, the size at the time of mixing must be smaller

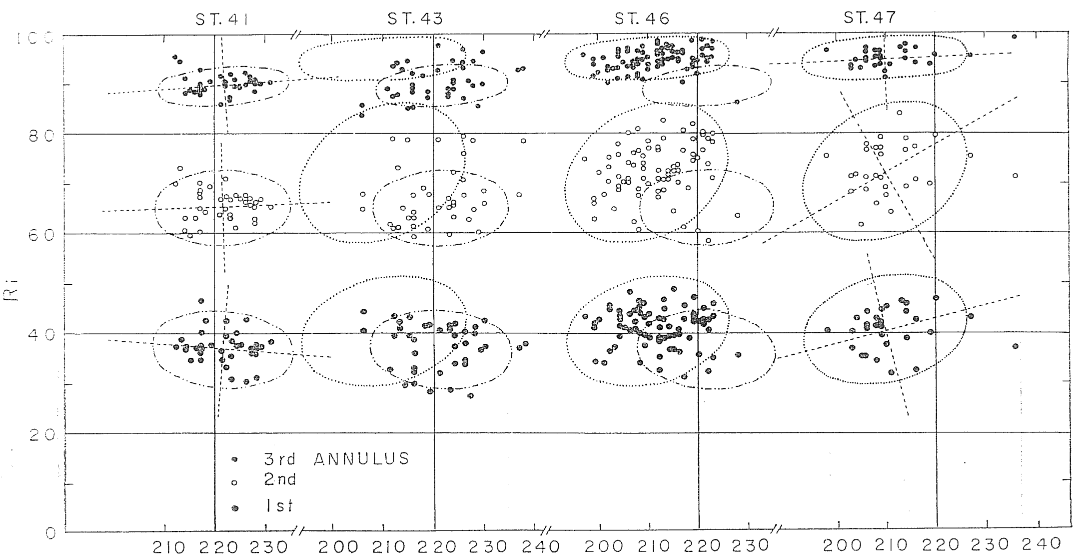

Fig. 8. Relationships between fork length and scale ratio R_i ($r_i \times 10^2/R$), where r_i ($i=1$–3) is scale radius to each annulus and R is scale radius to anterior margin, for the 4 year-old herring taken by the net of 48 mm mesh, 1973. For comparison rejection ellipses of 5% level of significance for the samples of St. 41 and St. 47 are superimposed on the points plotted for St. 43 and St. 46 respectively.

Table 4. The parameters of rejection ellipse equations ($\eta_1^2/a^2+\eta_2^2/b^2=1$, where η_1 and η_2 mean the co-ordinates generated by revolving angle θ, and a, b the constant) for the regression of scale ratio R_i on fork length L.

Station	Mesh size (mm)	No. of annulus (i)	n	$\overline{L}$ (mm)	$\overline{R_i}$	a	b	θ
ST. 1, 2	42	1	64	221.08	35.24	9.70	15.03	89°38′
		2	64	221.08	61.82	7.82	15.13	85°22′
		3	62	221.23	88.48	14.71	5.66	1°48′
ST. 16, 17, 18	42	1	74	218.07	34.96	14.53	7.29	1°14′
		2	74	218.31	59.62	14.51	8.07	5°11′
		3	75	218.28	85.13	14.46	5.83	8°40′
ST. 38	42	1	55	218.02	37.95	9.11	13.88	88°02′
		2	54	217.98	65.92	6.71	14.00	89°53′
		3	52	217.58	91.55	4.34	13.15	88°39′
ST. 41	42	1	74	217.18	36.69	15.07	9.33	4°38′
		2	72	217.19	64.51	14.61	8.18	4°20′
		3	73	217.32	88.99	14.93	4.11	7°07′
	48	1	34	221.59	36.83	7.85	13.98	85°27′
		2	34	221.71	65.42	13.54	7.61	2°02′
		3	33	222.00	89.77	13.01	3.99	4°09′
ST. 47	48	1	28	210.04	40.33	16.54	10.73	14°15′
		2	28	210.04	72.62	17.15	12.93	29°21′
		3	28	210.04	94.81	16.26	4.48	2°37′

Ellipses were calculated from the data except the points which were rejected at the 5% level of significance.

in the fish with the scale pattern of Tauisk type than that of Ayan type. However, because it was difficult to divide the Ayan sample into two, their size before the time of capture was examined based on the result of comparison between stations. Information about this is dealt in the following result section.

Fork Length at the Annulus Formation, L_i

To examine the differences of size at the time of each annulus formation between samples, values of $L_i(L\times r_i/R)$ were calculated according to the Dahl's equation[10]. No correction was made for the size of fish at the time the scale was first formed. Therefore, the back-calculated fork lengths will be slightly exaggerated.

As shown in Fig. 9, the means of fork length estimated at the time of the 1st annulus formation (L_1) for the 1968 year-class are remarkably smaller in the Ayan sample (St. 8,9,11) than that of the Tauisk sample (St. 1,2), and this difference is sustained until the 3rd annulus formation. The difference of means of L_1 between these two samples is highly significant (Sample from the 42 mm mesh: $t=4.342$, df. 113, $P<0.001$; Sample from the 48 mm mesh: $t=4.668$, df. 38, $P<0.001$). The difference in frequency distributions of L_1 (not shown in figure) was also significant ($\chi^2=27.50$, df. 10, $0.001<P<0.005$) between the samples from the 42 mm mesh, though not significant ($\chi^2=17.38$, df. 10, $0.05<P<0.10$) between those from the 48 mm mesh.

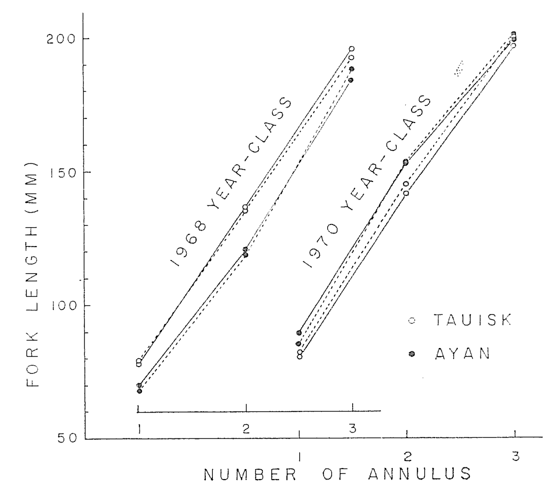

Fig. 9. Comparison of means of fork length estimated at the time of each annulus formation, calculated from the Dahl's equation, $L_i=L\times r_i/R$, for the 4 year-old herring of the 1968 and 1970 year-classes taken from the areas of the Tauisk and Ayan, 1971 and 1973. Solid line: Sample from the net of 42 mm mesh, Dotted line: Sample from the net of 48 mm mesh.

For the 1970 year-class the mean of L_1 is considerably larger in the Ayan sample (St. 47) than that of the Tauisk sample (St. 38 and St. 41), but at the 3rd annulus formation this difference is hardly disappeared. The differences of means

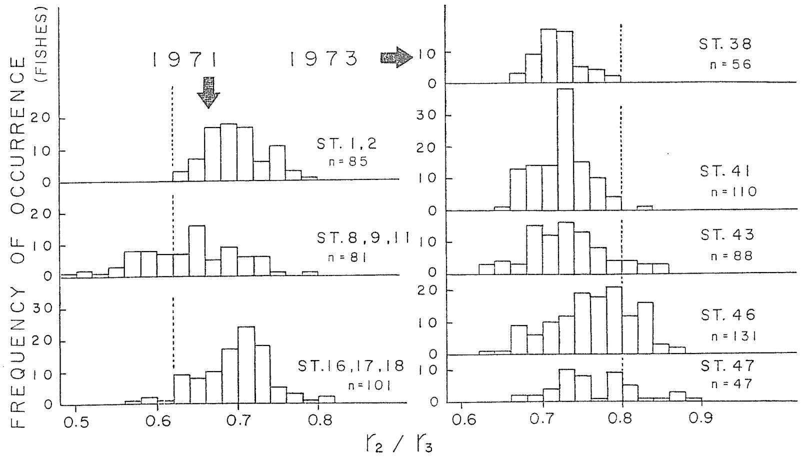

Fig. 10. Frequency distributions of r_2/r_3, where r_2 is scale radius to the 2nd annulus and r_3 is that to the 3rd annulus, in 4 year-old herring, 1971 and 1973. n: Number of fish.

and frequency distributions of L_1 were significant between the samples from the 42 mm mesh (t=3.981, df. 147, $P<0.001$, and $\chi^2=32.63$, df. 8, $P<0.001$), though not significant between those from the 48 mm mesh (t=1.238, df. 62, $0.20<P<0.40$, and $\chi^2=9.14$, df. 7, $0.20<P<0.30$).

From the above, it was confirmed that the size of fish found in the area of the Tauisk in 1973 was smaller than that of the area of the Ayan until the third year of life, though the size at the time of capture was rather larger in the former. This also suggests that the size of fish with the scale pattern of Tauisk type at St. 46 and St. 47 is smaller than that of Ayan type at the same stations throughout the period before they are caught. Therefore, the 4 year-old group in the area of the Ayan in 1973 seems to be a mixture of fish with the different scale patterns of Tauisk and Ayan types, and it can be considered that the mixing arose during the third year of their life. Furthermore, the difference of the size at the 1st annulus formation indicates that these two groups with the different scale patterns had lived under different circumstances after the first year of life.

As to the fish in 1971, the presence of such a mixing was not confirmed, because the variation in R_i/fork length relationship was not so appreciable in any samples. However, the result that the variations in the values of R_1 and R_2 are somewhat large in the Ayan sample as compared with others suggests a possibility of mixing of fish with the different scale pattern.

Scale Ratio r_2/r_3

Fig.10 shows the frequency distributions of the ratio of distance to the 2nd annulus to that to the 3rd annulus (r_2/r_3). No significant difference was found in the means of scale ratio r_2/r_3 between meshes, therefore, samples from the nets of 42 and 48 mm mesh were combined. As seen in Fig. 10, the distribution mode of r_2/r_3 for the Ayan samples differes clearly from that of the Tauisk samples in each year, however, there is considerable overlap in the distributions between these two areas. Therefore, one could not separates the sample derived from the mixed sample as in the case of St. 43 into the two components—fish of Tauisk and Ayan types—according to the ratio r_2/r_3.

However, in 1971 fish with the values of r_2/r_3 less than 0.62 is not included in the Tauisk samples, though 37% of the total observations on the Ayan sample were fish with these values. Similarly, in 1973 fish with the values of r_2/r_3 more than 0.80 is hardly included in the Tauisk samples, though 25% of the Ayan sample were fish with these values. Therefore, it may be possible that one confirms the later distribution areas of 4 year-old group found around the area of the Ayan in each year, in addition, pursuits the process of their disappearance, using the fish with these scale ratios as an indicator of presence of fish of Ayan type.

Discussion

It is known that the northern part of the Okhotsk Sea includes the several populations of Pacific herring. PRAVOTOROVA[4] reported that a part of the Okhotsk and the Gizhiga-Kamchatka Population mixed with each other between the Koni Peninsula and the northwest coast of the Kamchatka Peninsula in 1963 of great abundance. However, at present it seems likely that the latter is hardly caught by the commercial vessels, because the stock have been decreased. Furthermore, as descrived in the previous paper[7], the age compositions of fish group composed of fish older than 4 years old found in the present study periods were very similar to those of statistical data on the commercial catches which were made with the gill nets during the same periods of 1971–1973. Therefore, there is no doubt that this fish group belongs to the Okhotsk Population which is of the greatest commercial value of Pacific herring nowadays.

On the other hand, DORUGININ[11] studied the migration of herring around the area of the Sakhalin and noted that a part of the Hokkaido-Sakhalin Population migrated to the north along the east coast of the Sakhalin and arrived at the waters around the Ionui Island within the area of the Ayan from the late July to August. TAKAHASHI *et al.*[8] suggest that there is a possibility that the fish group in the area off the Ayan may not belongs to the Okhotsk Population, as the results of the investigating the biological characteristics of 4 year-old fish collected in 1971.

In the present study, the fork lengths and scale patterns of samples in 1971–1973 were examined. As the result, it was confirmed that the mean fork length of 4 year-old fish around the area of the Ayan was consistently about 1 cm smaller than that of the eastern area of the Okhotsk. Scale patterns also differes considerably among areas and they are divided roughly into the two types of Tauisk and Ayan; the former is very common one and the difference between the distance from the 1st to the 2nd annulus and that from the 2nd to the 3rd annulus is not so large, and fish in the area of the Tauisk have almostly the scale pattern of this type, and the latter is characterized by the large difference between them.

The results of analyzing the ratio of distance among the annuli and the fork length estimated at the 1st annulus formation indicate that these two 4 year-old group with the different scale pattern had lived under different circumstances after the first year of life. However, these fish group are not always isolated from each other through the stages in development. Namely, comparison of R_i/fork length relationships shows that fish group in the area of the Ayan in 1973 is mixture, which arose during the third year of life, of fish with the different scale pattern of Tauisk and Ayan types. In addition, it was found that these fish groups also mixed to some extent with each other chiefly in the western area of the Okhotsk during the fourth year, i.e. the year they were caught. Therefore, it can be considered that there is considerably closed relationship between these two groups with the different scale pattern.

In the present study, however, their relationship of origin was not solved. But, a clue to elucidate the stock system of fish group in the area of the Ayan can be found from the result of distribution pattern of herring in the present study area. Namely, that is the fact that the fish group chiefly composed of 4 years old appeared consistently around the area of the Ayan in the summers of 1971–1973. Naturally, this means that the 4 year-old fish being the main part of this group disappear from this area in the following summer. If they recruit to the fish group composed of fish older than 4 years old as 5 year-old fish, it may be concluded that they belong to the Okhotsk Population as well as 4 year-old fish in the area of the Tauisk. Otherwise, if the main part of them disappear from the northern part of the Okhotsk Sea, it can be considered that they are of other population, for instance, as the Hokkaido-Sakhalin Population as reported by DORUGININ. From this reason, it is considered that the tagging experiment is reliable method for elucidating the stock system of fish group around the area of the Ayan.

Fortunately, it was found that the fish with the specific values of scale ratio r_2/r_3 could be used as an indicator of presence of fish appeared around the area of the Ayan in each year. The results of the pursuit investigation of "the natural tagged fish" will be reported at a later date.

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