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MORPHOLOGICAL STUDIES ON THE JACK MACKEREL POPULATIONS

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ABSTRACT

This work concerns morphological studies of the Japanese jack mackerel, *Trachurus japonicus* (Temminck & Schlegel). A total of 48 random samples consisting of 2669 fish is examined, representing three geographic regions, namely, *Kamakura, Nagasaki,* and *Tottori*. Preservation affects length and weight of fish considerably, but the variability after 10 days is shown to be negligible. The variability in measuring the morphometric characters due to different measurers and orders is found to be significant. They are relatively small, however, compared to the variability in mean length to be expected in samples drawn from the population. Two meristic characters, namely, anal and second dorsal fin rays and three morphometric characters, namely, head length, first and second dorsal insertion distances are chosen for the study. Results of the statistical analysis reveal that differences in the selected meristic characters among samples within and between regions are found to be significant. In general, it is reasonable to state that the jack mackerel collected in Nagasaki region, on the average, have greatest number of anal fin ray and second dorsal fin ray followed by Kamakura, and Tottori regions in that order. It is found that although no significant differences in the slope of regression line are noticed, the mean differences of the selected morphometric measurements in relation to fish length are found to be significant among samples within each region. Differences in the regression coefficients as well as the adjusted sample means are found to be significant between regions. The analysis suggests that samples from Nagasaki region, on the average, have longest head length and greatest distances from snout to the insertion of first dorsal and second dorsal fins followed by Kamakura, and Tottori regions in that order.

INTRODUCTION

The Japanese jack mackerel, *Trachurus japonicus* (Temminck & Schlegel) forms one of the most important commercial fisheries in Korea and Japan.

The problem of conservation and development of the jack mackerel resources has recently been emphasized by fisheries researchers and relatively extensive and diverse work which, however, is but a brief prologue to what research can bring to light, has been carried out on this species.

A knowledge on the race of the species concerned is of fundamental importance in designing a practical management program for the fisheries. Several methods have been employed in the racial study of fish such as use of meristic, morphometric, physiological, biochemical characters, and tagging or marking experiments. Earlier investigations dealing with the racial study in Japanese jack mackerel are reported by Yamada (1958 a, b) and Azeta and Ochiai (1962).

In the present study, an attempt is made to determine whether or not the jack mackerel taken from different regions along the coast of Japan formed physically unrecognizable homogeneous groups. A detailed study of the meristic and morphometric characters of jack mackerel samples collected from the different geographic regions was carried out to see whether significant differences in the meristic and morphometric characters can be recognized between the regions.

MATERIALS AND METHODS

Sources of Samples

The jack mackerel were obtained mainly from three sources, namely, from Sagami Bay, Kamakura during November, 1963 to October, 1965, from Nagasaki region during June, 1964 to October, 1965, and from Tottori region during November, 1964 to July, 1965. A total of 48 random samples consisting of 2669 fish was examined. All the samples have been preserved in 10% formalin.

Meristic Count

Meristic counts were centered on variations in the number of anal and second dorsal fin rays. All soft fin rays including rudimentary rays on the anal and second dorsal fins were counted. Within sample variability due to fish length was analyzed. Since no differences in the number of anal and second dorsal fin rays between different length groups were found, the latter were combined for further analyses.

Morphometric Measurement

The three characters selected on the merits of their uniformity, easiness in measuring, and also of promise in separating different groups are as follows:

1. Head length—the distance from the tip of snout to the most posterior edge of the subopercle.
2. First dorsal insertion—the distance from the tip of snout to the insertion of the first dorsal fin.
3. Second dorsal insertion—the tip of snout to the insertion of the second dorsal fin.

Poorly preserved samples in a bad condition were excluded from the measurement, and only fish belonging to size range of 100-200 mm in body length were used in the analyses. Effect of formalin preservation on length and weight of fish was examined and differences between measuring fish were analyzed.

Body length as measured from the tip of snout to the insertion of the lower lobe of the caudal fin was taken to the nearest millimeter with the fish lying flat on its right side on a measuring board. Measurements of the body part selected for morphometric characters were made with a divider and read to the nearest millimeter. All measurements were taken by the author himself and always on the left side of fish.

MORPHOLOGICAL STUDY

Effect of Preservation on Length and Weight of Fish

As has been mentioned earlier the fish were preserved in 10% formalin when collected. The effect of the preservation on subsequent measurement of length and weight was considered important at the begining of the study to determine the safe intervals of preservation, after which the variation would be negligible. Hence an inquiry to measure the effect of 10% formalin was made on 18 fresh jack mackerel, ranging from 145 mm to 176 mm in body length, obtained from fish market. Readings were taken after preservation for 1, 7, 10, 30, and 50 days. The results of the study are illustrated in Figure 1 in which mean length of several body parts and mean weight of the fish are plotted against time on a logarithmic scale. The variability was seen to be greatest during the first day after preservation, but after 10 days it was found to be negligible. During the course of present investigation, therefore, all the measurements were made roughly 20 days after preservation so that the variability is considerably reduced still, and can be considered to be insignificant compared to natural variations in fish population.

Size of Fish

As mentioned earlier, all length measurements are given as body length. To obtain the relationship of the body and fork lengths so that it may

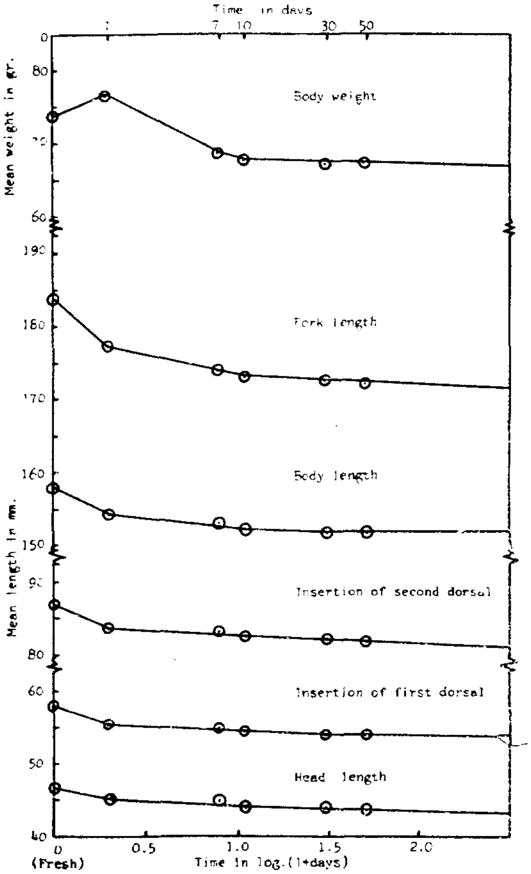

Fig. 1. Relationship between the measurement of body parts and time after preservation.

be useful for conversion, data based on 2348 fish were analyzed by the method of least squares, and the following equation for the relationship between the body length (BL in mm) and fork length (FL in mm) was derived.

$$FL = 2.9 + 1.115\,BL$$

To evaluate within sample variability in the meristic counts an morphometric measurements in relation to fish length, their correlation was examined. As such a correlation of the meristic counts with size of fish was found to be negligible, the distribution of the selected meristic characters was regarded as varying independently of fish length. The correlation of the selected morphometric characters with length of fish, on the other hand, was found to be significant. The fish smaller than approximately 100 mm in body length differed considerably from the fish larger than approximately 200 mm in body length. However, none of the selected morphometric characters varied significantly with length for the fish ranging from about 100 mm to 200 mm in body length. Consequently, the morphometric analysis was based on size categories ranging from 100 mm to 200 mm in body length, which approximately denote the length attained by age I group (Kim, 1969).

Effect of Measurers

Although all morphometric measurements, during the course of the study, were made by the author himself, the effect of different measurers in measuring body parts is of great concern. In the present study, morphometric measurements made by different measurers on 100 fish were examined for possible effect of measurers and orders in measuring body parts of fish. Two measurers including the author himself repeated measurements three times on the same fish and then differences were analyzed. The results of the analyses are presented in Tables 1 to 3 in which significant differences between measurers and orders are declared. The average difference in mean length obtained by the two measurers was about 0.5 mm, while the average difference in mean length recorded for different orders was about 0.1 mm, which is relatively small compared to the variability in mean length to be expected in samples drawn from the population.

Analyses of Meristic and Morphometric Data

The meristic characters chosen for the study are anal fin ray and second dorsal fin ray counts. The most extensive meristic counts made during the course of the study was on the total number of anal fin rays. A total of 2669 fish comprising of 1140 fish from Kamakura region, 1082 fish from Nagasaki region, and 447 fish from Tottori was examined for anal fin ray counts.

To determine whether there were significant

Table 1. Analysis of differences in head length measurement between measurers and orders.

Source	S.S.	d.f.	M.S.	F-ratio	E (MS)
Fish	2433.59	99	24.58		$\sigma^2e+6\,\sigma^2F$
Measurer	51.63	1	51.63	147.51*S	$\sigma^2e+3\,\sigma^2FM+300\sigma^2M$
Order	2.37	2	1.18	8.43*S	$\sigma^2e+2\,\sigma^2FO+200\sigma^2O$
FM	35.04	99	0.35		$\sigma^2e+3\,\sigma^2FM$
FO	28.30	198	0.14		$\sigma^2e+2\,\sigma^2FO$
MO	1.74	2	0.87	7.25*S	$\sigma^2e+\sigma^2FMO+100\,\sigma^2MO$
FMO	23.59	198	0.12		$\sigma^2e+\sigma^2FMO$
Total	2576.26	599			

Table 2. Analysis of difference in insertion of first dorsal length measurement between measurers and orders.

Source	S.S.	d.f.	M.S.	F-ratio	E (MS)
Fish	4003.70	99	40.44		$\sigma^2e+6\,\sigma^2F$
Measurer	98.42	1	98.42	209.40*S	$\sigma^2e+3\,\sigma^2FM+300\,\sigma^2M$
Order	4.40	2	2.20	5.95*S	$\sigma^2e+2\,\sigma^2FO+200\,\sigma^2O$
FM	46.41	99	0.47		$\sigma^2e+3\,\sigma^2FM$
FO	461.41	198	0.37		$\sigma^2e+2\,\sigma^2FO$
MO	0.63	2	0.31	1.11 N.S.	$\sigma^2e+\sigma^2FMO+100\,\sigma^2MO$
FMO	56.04	198	0.28		$\sigma^2e+\sigma^2FMO$
Total	4283.20	599			

Table 3. Analysis of difference in insertion of second dorsal length measurement between measurers and orders.

Source	S.S.	d.f.	M.S.	F-ratio	E (MS)
Fish	9536.52	99	96.33		$\sigma^2e+6\,\sigma^2F$
Measurer	35.52	1	35.52	39.91*S	$\sigma^2e+3\,\sigma^2FM+300\,\sigma^2M$
Order	1.22	2	0.61	1.97 N.S.	$\sigma^2e+2\,\sigma^2FO+200\,\sigma^2O$
FM	88.48	99	0.89		$\sigma^2e+3\,\sigma^2FM$
FO	60.45	198	0.31		$\sigma^2e+2\,\sigma^2FO$
MO	2.41	2	1.20	4.29*S	$\sigma^2e+\sigma^2FMO+100\,\sigma^2MO$
FMO	54.59	198	0.28		$\sigma^2e+\sigma^2FMO$
Total	9779.19	599			

differences in variances between samples for each region, Bartlett's test for homogeneity of variance was employed, and the results are summarized in Tables 4 and 5. For both anal and second dorsal fin ray data, the differences among sample mean squares are found to be only sampling phenomena, and the assumption underlying the subsequent analysis of variance test was varified.

To determine whether there were significant differences in the distribution of the selected meristic counts among samples within and between regions, analyses of variance of the anal and second dorsal fin counts were carried out. Theses analyses are summarized in Tables 6 and 7. Both anal and second dorsal fin ray counts showed a difference among samples within and between regions at 5% level of significance. The 95% confidence interval for each sample mean using the estimated within region common variance are presented in Tables 8 and 9, and also illustrated in Figure 2.

Table 4. Results of Bartlett's tests for homogeneity of variance number of anal fin ray.

Comparison	Number of Samples, k	B*	C**	Corrected chi-square	$x^2(0.05)(k\text{-}1\ \text{d.f})$
Kamakura Samples	16	20.46378	1.00577	20.35	25.00
Nagasaki Samples	27	15.89644	1.01033	15.73	38.89
Tottori Samples	5	1.70105	1.00459	1.69	9.49
Kamakura-Nagasaki-Tottori Samples	48	44.45908	1.01506	43.80	63.98

* Computed from $-\Sigma f_i \log_e (s^2_i/s^2)$
** Computed from $1+1/3(k-1)\Sigma(1/f_i-1/f)$

Table 5. Results of Bartlett's tests for homogeneity of variance number of second dorsal fin ray.

Comparison	Number of Samples, k	B*	C**	Corrected chi-square	$x^2(0.05)(k\text{-}1\ \text{d.f})$
Kamakura Samples	9	13.30755	1.00750	13.21	15.51
Nagasaki Samples	18	7.41921	1.00112	7.41	27.59
Tottori Samples	4	6.23102	1.00493	6.20	7.81
Kamakura-Nagasaki-Tottori Samples	31	31.44300	1.02002	27.88	43.77

* Computed from $-\Sigma f_i \log_e (s^2_i/s^2)$
** Computed from $1+1/3(k-1)\Sigma(1/f_i-1/f)$

Table 6. Analyses of differences in number of anal fin ray for each region.

Kamakura Region	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*F*(0.05)
Between Samples	83.41	15	5.56	5.79*S	1.67
Within Samples	1082.48	1124	0.96		
Total	1165.89	1139			

Nagasaki Region	Sum of squares	Degrees of Freedom	Mean Square	*F*	*F*(0.05)
Between Samples	40.14	26	1.54	1.50*S	1.50
Within Samples	1086.77	1055	1.03		
Total	1126.91	1081			

Tottori Region	Sum of squares	Degrees of Freedom	Mean Square	*F*	*F*(0.05)
Between Samples	8.56	4	2.14	2.55*S	2.38
Within Samples	370.29	442	0.84		
Total	378.85	446			

All Regions	Sum of Squares	Degrees of Freedom	Mean Square	F	$F(0.05)$
Between Samples	222.82	47	4.74	4.89*S	1.37
Within Samples	2539.54	2621	0.97		
Total	2762.36	2668			

Table 7. Analyses of differences in number of second dorsal fin ray for each region.

Kamakura Region	Sum of Squares	Degrees of Freedom	Mean Square	F	$F(0.05)$
Between Samples	54.55	8	6.82	6.04*S	1.95
Within Samples	517.75	459	1.13		
Totatal	572.30	467			

Nagasaki Region	Sum of Squares	Degrees of Freedom	Mean Square	F	$F(0.05)$
Between Samples	57.31	17	3.37	2.93*S	1.64
Within Samples	684.59	597	1.15		
Total	741.90	614			

Tottori Region	Sum of Squares	Degrees of Freedom	Mean Squar	F	$F(0.05)$
Between Samples	19.52	3	6.51	7.94*S	2.62
Within Samples	351.33	343	0.82		
Total	370.85	346			

All Regions	Sum of Squares	Degrees of Freedom	Mean Square	F	$F(0.05)$
Between Samples	200.12	30	6.67	6.01*S	1.46
Within Samples	1553.67	1399	1.11		
Total	1753.79	1429			

Table 8. Interval estimate for the means number of anal fin ray.

Region	Sample No.	N	Mean (x)	95% Conf. Interval[1]
Kamakura	9	110	28.5	28.3-28.7
	10	130	28.7	28.5-28.9
	11	109	28.1	27.9-28.3
	12	103	28.5	28.3-28.7
	13	65	28.7	28.5-28.9
	14	89	28.3	28.1-28.5
	15	66	28.4	28.2-28.6
	16	47	28.1	27.8-28.4

	17	38	28. 2	27. 9–28. 5
	19	54	28. 5	28. 2–28. 8
	21	47	28. 1	27. 8–28. 4
	22	47	28. 5	28. 2–28. 8
	23	51	28. 7	28. 4–29. 0
	24	59	28. 8	28. 5–29. 1
	25	50	27. 7	27. 4–28. 0
	26	75	28. 6	28. 4–28. 8
Region Average			28. 4	28. 3–28. 5
Nagasaki	3	55	28. 8	28. 5–29. 1
	4	33	28. 7	28. 4–29. 0
	5	60	28. 6	28. 4–28. 8
	7	20	28. 9	28. 5–29. 3
	8	60	28. 4	28. 2–28. 6
	9	30	28. 7	28. 3–29. 1
	10	30	28. 4	28. 0–28. 8
	12	90	28. 8	28. 6–29. 0
	13	90	28. 7	28. 5–28. 9
	14	30	28. 4	28. 0–28. 8
	15	30	28. 8	28. 4–29. 2
	16	31	28. 4	28. 1–28. 7
	17	30	28. 3	27. 9–28. 7
	18	61	28. 9	28. 7–29. 1
	19	30	28. 5	28. 1–28. 9
	20	30	28. 2	27. 8–28. 6
	21	27	28. 6	28. 2–29. 0
	22	31	28. 5	28. 2–28. 8
	24	30	28. 9	28. 5–29. 3
	25	34	28. 3	28. 0–28. 6
	26	30	28. 8	28. 4–29. 2
	27	30	28. 5	28. 1–28. 9
	30	35	28. 5	28. 2–28. 8
	31	30	28. 5	28. 1–28. 9
	33	61	28. 5	28. 3–28. 7
	34	32	28. 8	28. 5–29. 1
	35	32	28. 3	28. 0–28. 6
Region Average			28. 6	28. 5–28. 7
Tottori	1	100	28. 1	27. 9–28. 3
	2	94	28. 0	27. 8–28. 2
	3	96	27. 8	27. 6–28. 0
	4	85	28. 2	28. 0–28. 4
	5	72	28. 2	28. 0–28. 4
Region Average			28. 1	28. 0–28. 2

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1. Computed from $x \pm t(0.05)\sigma/\sqrt{n}$

Table 9. Interval estimate for the means number of second dorsal fin ray.

Region	Sample No.	N	Mean (x)	95% Conf. Interval[1]
Kamakura	16	47	31.3	31.0-31.6
	17	38	31.1	30.8-31.4
	19	54	31.5	31.2-31.8
	21	47	31.0	30.7-31.3
	22	47	31.7	31.4-32.0
	23	51	31.8	31.5-32.1
	24	59	31.7	31.4-32.0
	25	50	30.7	30.4-31.0
	26	75	31.4	31.2-31.6
Region Average			31.4	31.3-31.5
Nagasaki	14	30	31.5	31.1-31.9
	15	30	31.9	31.5-32.3
	16	31	31.7	31.3-32.1
	17	30	31.5	31.1-31.9
	18	61	32.1	31.8-32.4
	19	30	31.4	31.0-31.8
	20	30	31.0	30.6-31.4
	21	27	31.4	31.0-31.8
	22	31	31.4	31.0-31.8
	24	30	31.8	31.4-32.2
	25	34	31.4	31.0-31.8
	26	30	32.0	31.6-32.4
	27	30	31.2	30.8-31.6
	30	35	31.6	31.3-31.9
	31	30	32.2	31.8-32.6
	33	62	31.6	31.3-31.9
	34	32	31.6	31.2-32.0
	35	32	31.4	31.0-31.8
Region Average			31.6	31.5-31.7
Tottori	2	94	31.0	30.8-31.2
	3	95	30.7	30.5-30.9
	4	85	31.3	31.1-31.5
	5	72	31.3	31.1-31.5
Region Average			31.1	31.0-31.2

1. Computed from $x \pm t\ (0.05)\sigma/\sqrt{n}$

Although there was a significant intra-region variation between samples, in general, it is reasonable to state that the number of anal and second dorsal fin rays, on the average, is shown to be greatest in the samples from Nagasaki region followed by Kamakura region, and Tottori region in that order. The data, when further subjected to a series of t-test to compare regional differences,

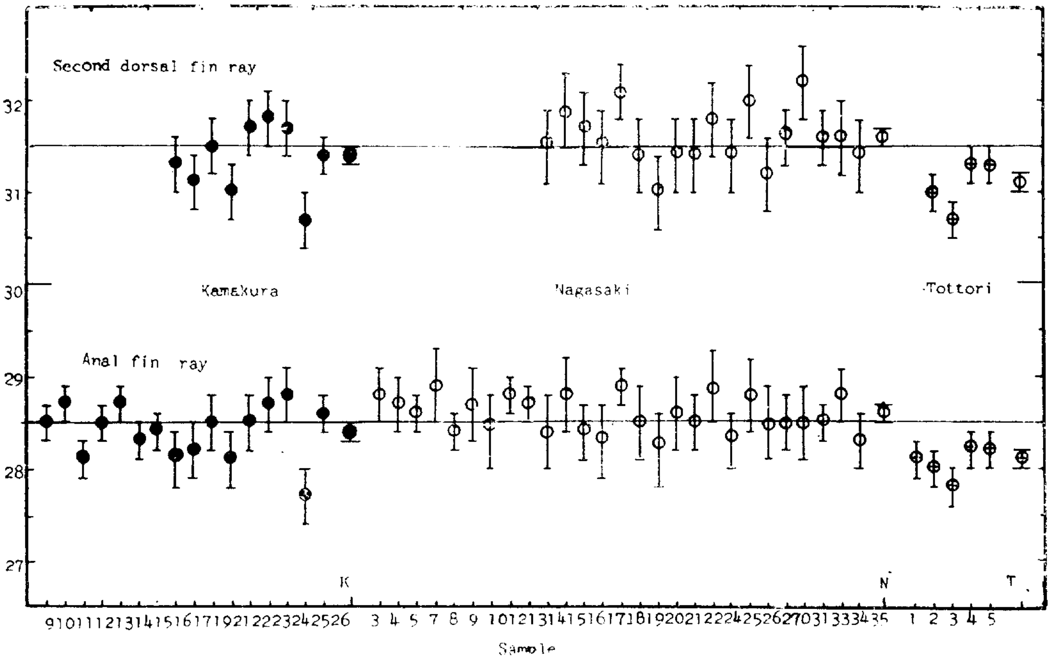

Fig. 2. Variation in the number of anal and second dorsal fin rays: the vertical line indicates the 95% confidence interval for each sample mean. The letters K, N, and T refer to the region averages for Kamakura, Nagasaki, and Tottori, respectively.

it was found to be significant at 5% level.

The morphometric characters chosen are head length, distances from the tip of snout to the insertion of first and second dorsal fins. Analyses of these three selected morphometric measurements are based on a total of 1647 fish, in which 734 fish represent Kamakura, 542 fish Nagasaki, and 371 fish Tottori samples.

To determine whether there were differences in the selected morphometric characters among samples within and between regions, the data were analyzed by analysis of covariance method to determine if the linear regressions of the three selected morphometric characters are same in different regions.

In treating the morphometric data, the tests for the significance of differences in slopes of sample regression lines within and between regions were first made. If the differences among the sample regression coefficients are significant, second test for the significance of differences in adjusted means were not made because the test of the elevation becomes inappropriate if the slopes are different. The statistics describing the regression for each region are summarized in Tables 10, 11, and 12 and also shown graphically in Figures 3, 4, and 5.

The analyses of the significance of differences in the three selected morphometric features for each region are presented in Tables 13, 14, and 15, while the results have been summerized, in more convenient form, in Tables 16, 17, and 18, which reveal several interesting points.

1. Head length data showed no differences among sample regression coefficients within each region at 5% level of significance. However, when the various pairs of regions are compared, two of the four possible comparisons showed differences at 5% level of significance although none showed a difference at 1% level of significance. The differences in the adjusted means among samples both within and between regions were declared significant at 5% level.

2. Analyses of the first dorsal fin insertion data showed no significant differences among sample regression coefficients for each region except for

Kamakura region. However, when the two of the eleven samples in Kamakura region were deleted from the analyses, no significant differences in slopes was observed. The differences among the adjusted means were also declared significant.

3. Essentially similar results were obtained for the second dorsal fin insertion data as the first dorsal fin case.

The adjusted sample means with 95% confidence intervals were computed by employing within region common slope to observe sample differences in elevation. These are presented in Tables 19, 20, and 21, and also shown graphically in Figures 6, 7, and 8. A perusal of the figures reveals that the samples from Nagasaki region, on the average, have largest head length and longest distance from snout to the insertion of first dorsal and second dorsal fins followed by Kamakura region, and Tottori region in that order.

Table 10. Results of computations of the regression of head length (Y) on body length (X) for each region.

Region	Number of Samples	N	Size Range, B.L(mm)	$\bar{x}$ (mm)	$\bar{y}$ (mm)	Reg. Coef.	Y	Y for X=150	$\sigma y \cdot x$	95% Conf. Interval
Kamakura	11	734	104-202	156.7	45.8	0.2557	5.7+0.2557X	44.1	0.7349	44.0-44.2
Nagasaki	14	542	114-214	166.5	48.8	0.2514	6.9+0.2514X	44.6	0.6853	44.5-44.7
Tottori	4	371	99-150	129.8	38.5	0.2634	4.3+0.2634X	43.8	0.6325	43.6-44.0

Table 11. Results of computations of the regression of distance from tip of snout to insertion of first dorsal fin (*Y*) on body length (*X*) for each region.

Region	Number of Samples	N	Size Range, B.L.(mm)	$\bar{x}$ (mm)	$\bar{y}$ (mm)	Reg. Coef.	Y	Y for X=150	$\sigma y \cdot x$	95% Conf. Interval
Kamakura	11	734	104-202	156.7	55.4	0.3119	6.5+0.3119X	53.3	1.0050	53.2-53.4
Nagasaki	14	542	114-214	166.5	58.8	0.3251	4.7+0.3251X	53.5	1.0100	53.4-53.6
Tottori	4	371	99-150	129.8	46.3	0.3253	4.1+0.3253X	52.9	0.8246	52.7-53.1
Kamakura[1] (excluding sample No. 15 and No. 19)	9	623	105-201	156.6	55.3	0.3044	7.6+0.3044X	53.3	0.9899	53.2-53.4

[1] Based on 9 samples.

Table 12. Results of computations of the regression of distance from tip of snout to insertion of second dorsal fin (Y) on body length (X) for each region.

Region	Number of Samples	N	Size Range, B.L.(mm)	$\bar{x}$ (mm)	$\bar{y}$ (mm)	Reg. Coef.	Y	Y for X=150	$\sigma y \cdot x$	95% Conf. Interval
Kamakura	11	734	104-202	156.7	84.3	0.5074	4.8+0.5074X	80.9	1.3675	80.8-81.0
Nagasaki	14	542	114-214	166.5	89.7	0.5143	4.1+0.5143X	81.2	1.2845	81.0-81.4
Tottori	4	371	99-150	129.8	70.3	0.5221	2.5+0.5221X	80.8	0.9434	80.5-81.1
Kamakura[1] (excluding sample No. 19)	10	683	105-202	156.6	84.3	0.5011	5.8+0.5011X	81.0	1.3379	80.9-81.1

[1] Based on 10 samples.

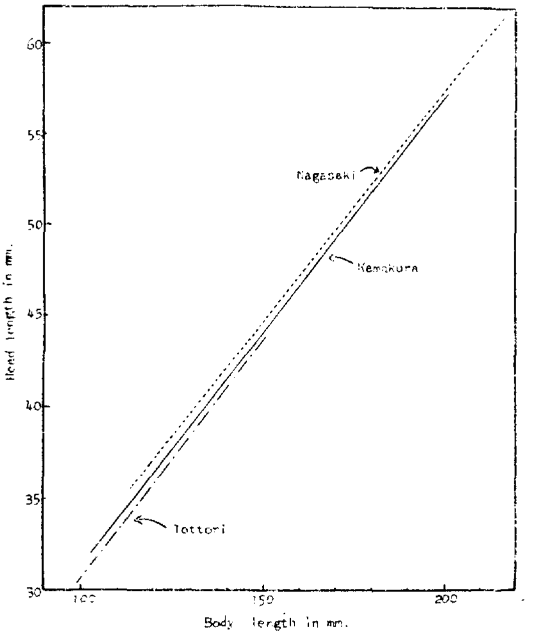

Fig. 3. The regression of head length on body length for each region.

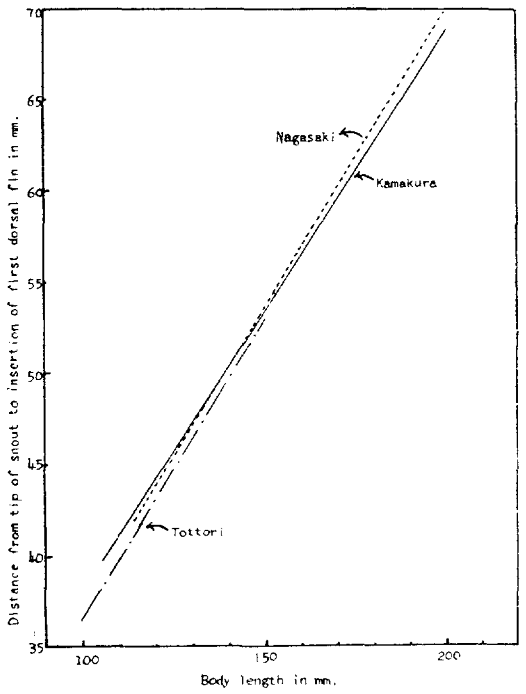

Fig. 4. The regression of insertion of first dorsal on body length for each region.

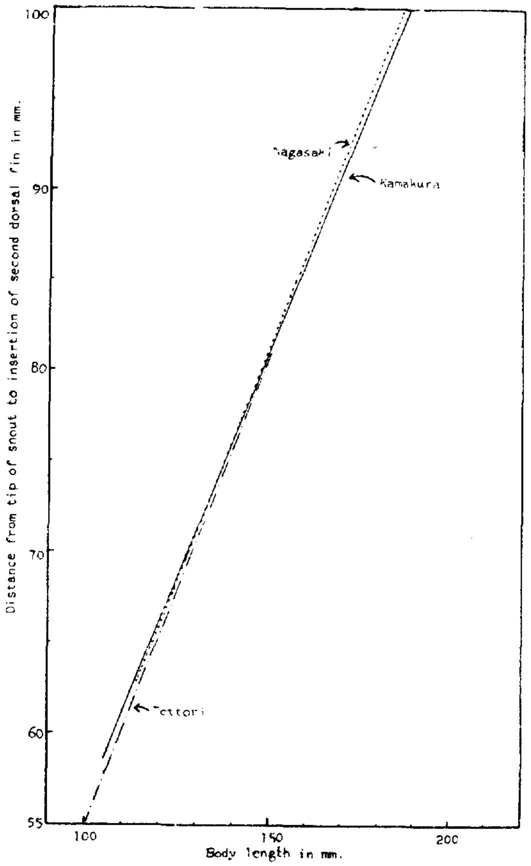

Fig. 5. The regression of insertion of second dorsal on body length for each region.

Table 13. Analyses of differences in head length for each region.

Kamakura Region	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*F* (0.05)
Individual Reg. (Within)	379.32	712	0.53		
Reg. Coefficients	9.63	10	0.96	1.81	1.84
Parallel Reg. (Common)	388.95	722	0.54		
Adjusted Means	203.09	10	20.31	37.61*S	1.84
Region Reg. Line (Total)	592.04	732			

Nagasaki Region	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*F* (0.05)
Individual Reg. (Within)	237.28	514	0.46		
Reg. Coefficients	7.95	13	0.61	1.33	1.75
Parallel Reg. (Common)	245.23	527	0.47		
Adjusted Means	159.84	13	12.30	26.17*S	1.75
Region Reg. Line (Total)	405.07	540			

Tottori Region	Sum of Squares	Degress of Freedom	Mean Square	*F*	*F* (0.05)
Individual Reg. (Within)	144.98	363	0.40		
Reg. Coefficients	0.41	3	0.14	<1	
Parallel Reg. (Common)	145.39	366	0.40		
Adjusted Means	19.38	3	6.46	16.15*S	2.62
Region Reg. Line (Total)	164.77	369			

Table14. Analyses of differences in distance from tip of snout to insertion of first dorsal fin for each region.

Kamakura Region	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*F* (0.05)
Individual Reg. (Within)	701.09	712	0.98		
Reg. Coefficients	28.54	10	2.85	2.91*S	1.84
Parallel Reg. (Common)	729.63	722	1.01		
Adjusted Means	47.01	10	4.70	4.65*S	1.84
Region Reg. Line (Total)	776.64	732			

Nagasaki Region	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*F* (0.05)
Individual Reg. (Within)	517.13	514	1.01		
Reg. Coefficients	21.88	13	1.68	1.66	1.75
Parallel Reg. (Common)	539.01	527	1.02		
Adjusted Means	40.50	13	3.12	3.06*S	1.75
Region Reg. Line (Total)	579.51	540			

Tottori Region	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*F* (0.05)
Individual Reg. (Within)	248.17	363	0.68		
Reg. Coefficients	1.14	3	0.38	<1	
Parallel Reg. (Common)	249.31	366	0.68		
Adjusted Means	87.47	3	29.16	42.88*S	2.62
Region Reg. Line (Total)	336.78	369			

Table 15. Analyses of differences in distance from tip of snout to insertion of second dorsal fin for each region.

Kamakura Region	Sum of Squares	Degrees of Freedom	Mean Square	*F*	*F* (0.05)
Individual Reg. (Within)	1298.54	712	1.82		
Reg. Coefficients	53.43	10	5.34	2.93*S	1.84
Parallel Reg. (Common)	1351.97	722	1.87		
Adjusted Means	138.02	10	13.80	7.38*S	1.84
Region Reg. Line (Total)	1489.99	732			
Nagasaki Region	**Sum of Squares**	**Degrees of Freedom**	**Mean Square**	***F***	***F* (0.05)**
Individual Reg. (Within)	839.03	514	1.63		
Reg. Coefficients	30.37	13	2.34	1.44	1.75
Parallel Reg. (Common)	869.40	527	1.65		
Adjusted Means	96.75	540	7.44	4.51*S	1.75
Region Reg. Line (Total)	966.15				
Tottori Region	**Sum of Squares**	**Degrees of Freedom**	**Mean Square**	***F***	***F* (0.05)**
Individual Reg. (Within)	323.48	363	0.89		
Reg. Coefficients	1.71	3	0.57	<1	
Parallel Reg. (Common)	325.19	366	0.89		
Adjusted Means	141.11	3	47.04	52.85*S	2.62
Region Reg. Line (Total)	466.25	369			

Table 16. Results of analyses of differences in head length, within and between regions.

	Difference in Regression Slope			Difference in Adjusted Means		
Comparison	Degrees of Freedom	*F*	*F* (0.05)	Degrees of Freedom	*F*	*F*(0.05)
Kamakura Samples	10, 712	1.81	1.84 N.S.	10, 722	37.61	1.84 S.
Nagasaki Samples	13, 514	1.33	1.75 N.S.	13, 527	26.17	1.75 S.
Tottori Samples	3, 363	<1	— N.S.	3, 366	16.15	2.62 S.
Kamakura-Nagasaki Samples	24, 1226	1.56	1.52 S.	— —	—	—
Kamakura-Tottori Samples	14, 1075	1.65	1.69 N.S.	14, 1089	32.53	1.69 S.
Nagasaki-Tottori Samples	17, 877	1.48	1.64 N.S.	17, 894	40.07	1.64 S.
Kamakura-Nagasaki-Tottori Samples	28, 1589	1.54	1.48 S.	— —	—	—

Table 17. Results of analyses of differences in distance from tip of snout to insertion of first dorsal fin, within and between regions.

Comparison	Difference in Regression Slope			Difference in Adjusted Means		
	Degrees of Freedom	F	F (0.05)	Degrees of Freedom	F	F (0.05)
Kamakura Samples	10, 712	2.91	1.84 S.	10, 722	4.65	1.84 S.
Nagasaki Samples	13, 514	1.66	1.75 N.S.	13, 527	3.06	1.75 S.
Tottori Samples	3, 363	<1	— N.S.	3, 366	42.88	2.62 S.
Kamakura-Nagasaki Samples	24, 1226	2.54	1.52 S.	— —	—	—
Kamakura-Tottori Samples	14, 1075	2.72	1.69 S.	— —	—	—
Nagasaki-Tottori Samples	17, 877	1.55	1.64 N.S.	17, 894	12.07	1.64 S.
Kamakura-Nagasaki-Tottori Samples	28, 1589	2.46	1.48 S.	—	—	—
Kamakura Samples[1] (excluding sample No. 15 and No. 19)	8, 605	<1	— N.S.	8, 613	6.19	1.95 S.

[1] Based on 9 samples.

Table 18. Results of analyses of differences in distance from tip of snout to insertion of second dorsal fin, within and between regions.

Comparison	Difference in Regression Slope			Difference in Adjusted Means		
	Degrees of Freedom	F	F (0.05)	Degrees of Freedom	F	F (0.05)
Kamakura Samples	10, 712	2.93	1.84 S.	10, 722	7.38	1.84 S.
Nagasaki Samples	13, 514	1.44	1.75 N.S.	13, 527	4.51	1.75 S.
Tottori Samples	3, 363	<1	— N.S.	3, 366	52.85	2.62 S.
Kamakura-Nagasaki Samples	24, 1226	2.07	1.52 S.	— —	—	—
Kamakura-Tottori Samples	14, 1075	2.82	1.69 S.	— —	—	—
Nagasaki-Tottori Samples	17, 877	1.47	1.64 N.S.	17, 894	11.13	1.64 S.
Kamakura-Nagasaki-Tottori Samples	28, 1589	2.11	1.48 S.			
Kamakura Samples[1] (excluding sample No. 19)	9, 663	<1	N.S.	9, 672	6.78	1.95 S.

[1] Based on 10 samples.

Table 19. Interval estimate of the adjusted means, head length (Y).

Sample No.	N	Size Range B.L.(mm)	Mean Body Length $\bar{x}$ (mm)	Mean Body Length $\bar{y}$ (mm)	b	$\hat{Y}$ * for X=150	95% ** Confidence Interval
			Kamakura Region				
9	73	137-191	149.2	42.9	0.2555	43.1	42.9-43.3
10	130	105-175	131.6	38.7	0.2545	43.4	43.3-43.5
12	75	136-196	160.2	46.8	0.2438	44.2	44.0-44.4
13	66	126-185	153.0	45.6	0.2436	44.8	44.6-45.0
14	89	138-196	168.9	49.5	0.2423	44.7	44.5-44.9
15	60	125-202	157.5	46.7	0.2617	44.8	44.6-45.0
17	42	131-199	179.5	51.9	0.2483	44.4	44.2-44.6

19	51	104-202	156.9	45.8	0.2636	44.0	43.8-44.2
21	45	155-201	181.4	52.2	0.2555	44.2	44.0-44.4
22	53	123-177	158.9	46.2	0.2599	43.9	43.7-44.1
25	50	150-185	165.4	48.3	0.2654	44.4	44.2-44.6
$\hat{\beta}=0.2557$		$\hat{\sigma}=0.7349$		$sx^2=208983.49$		$t(0.05)\hat{\sigma}=1.4404$	
			Nagasaki Region				
4	33	138-172	147.4	45.0	0.2451	43.7	43.5-43.9
5	60	150-214	183.4	52.1	0.2582	43.7	43.5-43.9
8	43	163-202	182.9	52.8	0.2543	44.5	44.2-44.8
12	59	142-186	160.2	47.5	0.2566	44.9	44.7-45.1
13	69	133-195	158.8	47.5	0.2396	45.3	45.1-45.5
15	30	148-187	167.6	49.3	0.2440	45.0	44.7-45.3
16	31	152-178	166.6	49.1	0.2770	44.9	44.6-45.2
18	34	167-187	175.1	51.6	0.2453	45.3	45.0-45.6
20	30	148-170	159.6	46.6	0.2575	44.2	44.0-44.4
24	30	175-195	184.5	53.5	0.2755	44.8	44.5-45.1
26	29	172-197	180.4	52.7	0.2440	45.1	44.8-45.4
27	30	147-182	161.7	47.7	0.2778	44.8	44.5-45.1
34	32	158-191	177.4	52.1	0.2394	45.2	44.9-45.5
35	32	114-132	120.5	37.4	0.2669	44.8	44.5-45.1
$\hat{\beta}=0.2514$		$\hat{\sigma}=0.6856$		$sx^2=75302.17$		$t(0.05)\hat{\sigma}=1.3458$	
			Tottori Region				
1	100	109-150	124.8	37.3	0.2594	43.9	43.7-44.1
2	95	113-148	134.8	40.1	0.2560	44.1	43.9-44.3
3	89	99-149	126.3	37.2	0.2670	43.4	43.2-43.6
4	87	110-149	133.7	39.7	0.2634	44.0	43.8-44.2
$\hat{\beta}=0.2634$		$\hat{\sigma}=0.6325$		$sx^2=23917.66$		$t(0.05)\hat{\sigma}=1.2497$	

* Computed from $y+\hat{\beta}(X-x)$ ** Computed from $\hat{Y}\pm t(0.05)\hat{\sigma}\sqrt{1/N+\frac{((X-x)^2}{sx^2}}$

Table 20. Interval estimate of the means, distance from tip of snout to insertion of first dorsal fin (Y)

Sample		Size Range B.L.(mm)	Mean Body Length x (mm)	y (mm)	b	$\hat{Y}$ for X=150	95% Confidence Interval
			Kamakura Region				
9	73	137-191	149.2	53.1	0.2940	53.3	53.1-53.5
10	130	105-175	131.6	47.3	0.3058	52.9	52.7-53.1
12	75	136-196	160.2	56.6	0.3154	53.5	53.3-53.7
13	66	126-185	153.0	54.5	0.2896	53.6	53.4-53.8
14	89	138-195	168.9	59.5	0.3112	53.7	53.5-53.9
15	60	125-202	157.5	55.9	0.3250	53.5	—
17	42	131-199	179.5	62.5	0.3018	53.5	53.2-53.8
19	51	104-202	156.9	55.2	0.3276	52.9	—

21	45	155-201	181.4	62.8	0.2931	53.2	52.9-53.5
22	53	123-177	158.9	55.5	0.3007	52.8	52.5-53.1
25	50	150-185	165.4	57.9	0.3044	53.2	52.9-53.5
$\hat{\beta}=0.3044$		$\hat{\sigma}=0.9899$		$sx^2=137271.80$		$t(0.05)\hat{\sigma}=1.9402$	
			Nagasaki Region				
4	33	138-172	147.4	52.3	0.3256	53.1	52.8-53.4
5	60	150-214	183.4	64.0	0.3266	53.1	52.7-53.5
8	43	163-202	182.9	64.0	0.3004	53.3	52.9-53.7
12	59	142-186	160.2	56.8	0.3381	53.5	53.2-53.8
13	69	133-195	158.8	56.5	0.3351	53.6	53.4-53.8
15	30	148-187	167.3	59.1	0.3201	53.5	53.1-53.9
16	31	152-178	166.6	58.9	0.3528	53.5	53.1-53.9
18	34	167-187	175.1	61.8	0.2934	53.6	53.2-54.0
20	30	148-170	159.6	56.0	0.2766	52.9	52.5-53.3
24	30	175-195	184.5	64.4	0.3010	53.2	52.8-53.6
26	29	172-197	180.4	63.7	0.2755	53.8	53.4-54.2
27	30	147-182	161.7	56.9	0.3557	53.1	52.7-53.5
34	32	158-191	177.4	62.2	0.2935	53.3	52.9-53.7
35	32	114-132	120.5	44.5	0.2638	54.1	53.7-54.5
$\hat{\beta}=0.3251$		$\hat{\sigma}=1.0100$		$sx^2=75302.17$		$(0.05)\hat{\sigma}=1.9796$	
			Tottori Region				
1	100	109-150	124.8	45.2	0.3311	53.4	53.1-53.7
2	95	113-148	134.8	48.2	0.3099	53.1	52.9-53.3
3	89	99-149	126.3	44.4	0.3285	52.1	51.8-52.4
4	87	110-149	133.7	47.4	0.3203	52.7	52.5-52.9
$\hat{\beta}=0.3253$		$\hat{\sigma}=0.8246$		$sx^2=2391.66$		$t(0.05)\hat{\sigma}=1.6162$	

Table 21. Interval estimate of the means, distance from tip of snout to insertion of second dorsal fin(Y).

Sample No.	N	Size Range B.L.(mm)	Mean Body Length $\bar{x}$ (mm)	Mean Body Length $\bar{y}$ (mm)	b	$\hat{Y}$ for X=150	95% Confidence Interval
			Kamakura Region				
9	73	137-191	149.2	80.8	0.4822	81.2	80.9-81.5
10	130	105-175	131.6	71.7	0.5030	80.9	80.6-81.2
12	75	136-196	160.2	85.1	0.4810	81.0	80.7-81.3
13	66	126-185	153.0	82.7	0.4972	81.2	80.9-81.5
14	89	138-195	168.9	91.2	0.4974	81.7	81.4-82.0
15	60	125-202	157.5	84.7	0.5124	80.9	80.6-81.2
17	42	131-199	179.5	95.8	0.4967	81.0	80.6-81.4
19	51	104-202	156.9	83.8	0.5380	80.1	—
21	45	155-201	181.4	95.8	0.5020	80.1	79.7-80.5
22	53	123-177	158.9	85.0	0.4936	80.5	80.1-80.9
25	50	150-185	165.4	88.4	0.4947	80.7	80.3-81.1

$\hat{\beta}=0.5011$		$\hat{\sigma}=1.3379$		$sx^2=173240.80$		$t(0.05)\hat{\sigma}=2.6233$	
Nagaski Region							
4	33	138-172	147.4	80.1	0.4833	81.4	81.0-81.8
5	60	150-214	183.4	98.6	0.5171	81.4	81.0-81.8
8	43	163-202	182.9	98.4	0.5113	81.5	31.0-82.0
12	59	142-186	160.2	86.6	0.5437	81.4	81.1-81.7
13	69	133-195	158.8	85.1	0.5094	80.6	80.3-80.9
15	30	148-187	167.3	89.6	0.5298	80.7	80.2-81.2
16	31	152-178	166.6	89.3	0.5126	80.8	80.3-81.3
18	34	167-187	175.1	94.1	0.5599	81.2	80.7-81.7
20	30	148-170	159.6	85.7	0.4357	80.8	80.3-81.3
24	30	175-195	184.5	99.9	0.4640	82.2	81.6-82.8
26	29	172-197	180.4	96.7	0.4774	81.1	80.6-81.6
27	30	147-182	161.7	87.0	0.5527	81.0	80.5-81.5
34	32	158-191	177.4	95.7	0.4634	81.6	81.1-82.1
35	32	114-132	120.5	66.5	0.5376	81.7	81.2-82.2
$\hat{\beta}=0.5143$		$\hat{\sigma}=1.2845$		$sx^2=75302.17$		$t(0.05)\hat{\sigma}=2.5176$	
Tottori Region							
1	100	109-150	124.8	68.5	0.5155	81.7	81.3-82.1
2	95	113-148	134.8	73.3	0.5190	81.2	80.9-81.5
3	89	99-149	126.3	67.8	0.5298	80.2	79.9-80.5
4	87	110-149	133.7	71.8	0.5090	80.3	80.0-80.6
$\hat{\beta}=0.5221$		$\hat{\sigma}=0.9434$		$sx^2=23917.66$		$t(0.05)\hat{\sigma}=1.8491$	

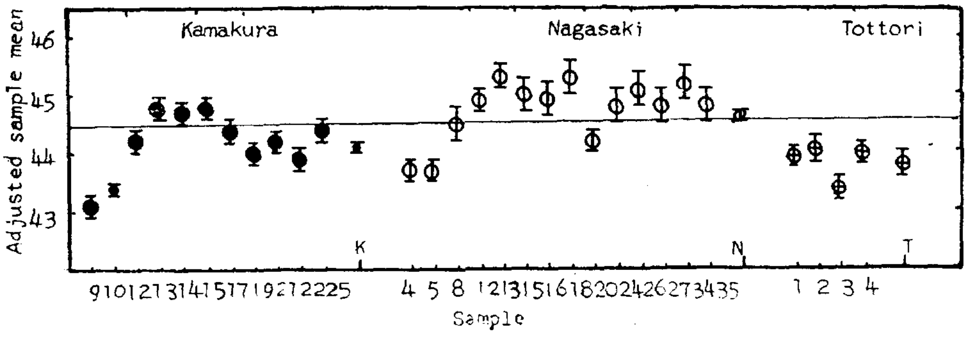

Fig. 6. Variation in the head length estimated from the regression: the vertical line indicates the 95% confidence interval for each sample mean. The letters K, N, and T refer to region averages for Kamakura, Nagasaki, and Tottori, respectively.

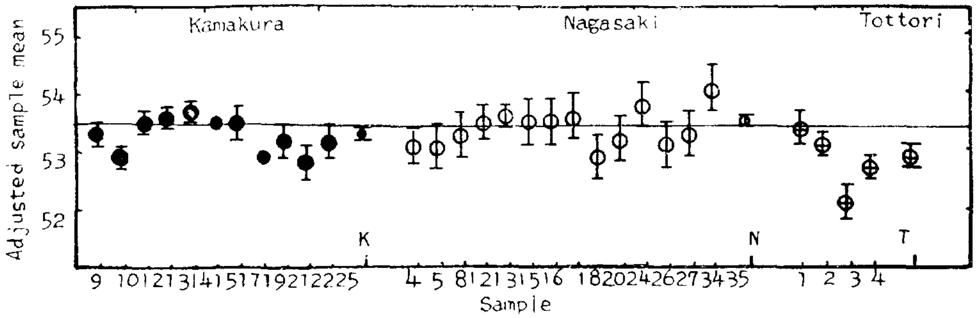

Fig. 7. Variation in the insertion of first dorsal estimated from the regression: the vertical line indicates the 95% confidence interval for each sample mean.

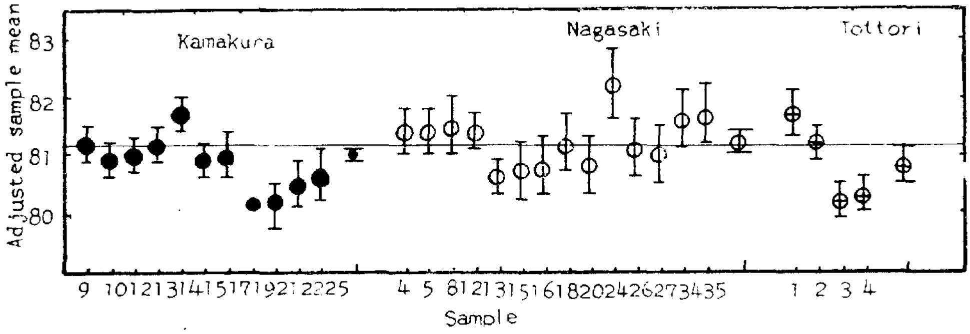

Fig. 8. Variation in the insertion of second dorsal estimated from the regression: the vertical line indicates the 95% confidence interval for each sample mean.

CONCLUSION

It has been shown conclusively that;

1. Preservation affects length and weight of fish and it is preferable to measure fresh fish for morphometric study. If preservation is necessary, a minimum period of about 10 days should elapse prior to measurement.

2. Variabilities in measuring body parts of fish due to different measurers and orders are found to be significant. If morphometric comparisons are to be made, the measurements should be made by a trained person or persons on clearly defined body parts.

3. The jack mackerel collected in Nagasaki region, on the average, have greatest anal fin ray and second dorsal fin ray counts, largest head length, and greatest distances from snout to the insertion of first dorsal and second dorsal fins followed by Kamakura and Tottori regions in that order.

4. At present it is not possible to explain whether the differences in the selected mristic and morphometric features discussed in the present study are genotypic, but it is likely that they are phenotypic and associated with differences in environmental conditions during early stage of their life.

SUMMARY

The purpose of the present study is to analyze differences, if any, in meristic and morphometric features for racial study.

A total of 46 random samples consisting of 2669 fish is examined,, representing three geographic