太平洋水域と大西洋水域のキハダの年令及び成長の比較に関する研究

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太平洋水域及び大西洋水域のキハダについて，第6背離鰭（後方より数える）の付け根附近から採集した鱗を用いて，年令と成長を比較した。

大西洋水域のキハダの鱗の大きさは同じ体長（尾叉長）の太平洋水域のものに比して小さく体長と鱗径との関係は，両大洋間において著しく異なっている。輪紋は，両大洋のキハダとも，鱗の被覆部においては普通成長線（circuli）の疎密として，露出部に近い所では成長線の不連続によって識別できる。輪紋の測定値（r_i）は鱗の大きさに差があるのにもかゝわらず，両大洋間において殆んど差がない値を示している。したがって輪紋形成時の逆算体長（l_i）及び極限体長（l_∞）は，両大洋間において異なり，いずれも大西洋水域のものの値が大きい。

輪紋形成は太平洋水域の場合と同様，大西洋水域においても 3・4 月と 9・10月の間に1回ずつ，年2回形成されるものと見られる。両大洋におけるキハダの孵化から第1輪の形成までの時間の長さが等しいものであるとすれば，そして読み取った l_1 が両大洋間において対応するものであるとすれば l_1 以前においては大西洋水域における成長は太平洋水域に比して速く，l_1 以降においては同輪紋数（または同年令）のものでは大西洋水域のキハダの体長が太平洋水域に比して大きいということになる。

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MORPHOMETRIC STUDIES ON THE ATLANTIC ALBACORE AND YELLOWFIN TUNA*

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ABSTRACT

12 samples of albacore (*Thunnus alalunga*) and 10 samples of yellowfin tuna (*T. albacares*) from the Atlantic Ocean, each consisting of 20 to 55 specimens, were compared in morphometric measurements. The measurements used were head length and distances from the tip of snout to insertion of pectoral, first and second dorsal, ventral and anal fin. Comparisons were made first by covariance analysis on each character individually ; then, generalized distance function analysis were employed for multiple character comparison. Before applying the method of generalized distance function analysis, morphometric measurements were adjusted for the values of equal fork length for diminishing the correlations among characters and the effects of fork length on characters. The results obtained by the multiple character comparison were investigated thoroughly, considering the distributions of fishing grounds and currents in the Atlantic, for albacore and yellowfin respectively.

It seems that albacores in the Atlantic belong to at least two different "stocks", viz., the northern and southern Atlantic "stocks", showing a time lag of about half of a calender year in life cycle. Albacore samples from southern Atlantic seem to be larger in values of each character than do the northern Atlantic samples and the sample taken from the waters off northeast of Canaries Islands seems to belong to neither of the two "stocks".

A so-called "progressive differences in morphometric characters" in the north-south direction appears to exist among yellowfin samples from the Equatorial waters of Atlantic. The morphometric differences among yellowfin samples lined in an east-west direction are not as remarkable as that among samples lined in north-south direction.

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I. INTRODUCTION

On the albacore and yellowfin tuna widely distributed in the oceans of the world, it is almost admitted today, through intensive works on the morphometric, serological and biochemical studies and analysis of catch statistics by various scientists (e.g., GODSIL, 1948; SCHAEFER, 1948, 1952 and 1955; GODSIL and GREENHOOD, 1951; ROYCE, 1953 and 1961; TSURUTA, 1954; KUROGANE and HIYAMA, 1957, 1958 and 1959; SUZUKI et al, 1959; SUZUKI, 1963; SUDA, 1962 and 1966; MARR and SPRAGUE, 1963; OTSU, 1960; OTSU and UCHIDA, 1961 and 1963; OTSU and HANSEN, 1962; CLEMENS, 1961; KAMIMURA and HONMA, 1963; and UEYANAGI, 1966), that the albacores from the waters of northern Pacific belong to a unit stock; and that the yellowfin tuna distributed along the Equator in Pacific consists neither of a single homogeneous population nor of two or more highly independent groups, but is represented by a state intermediate between both (KAMIMURA and HONMA, 1963). Hence studies on the dynamics and managements of both the species in these regions have been proceeding on these lines.

On the Atlantic albacore and yellowfin tuna also, some morphometric studies have been carried out already. SCHAEFER and WALFORD (1950) pointed out that the yellowfin from Angola closely resembles that taken from between Costa Rica and the Line Islands. Based on the catch statistics of the Japanese long-line fishery issued by SHIOHAMA et al (1965), WISE et al (1966) presented the results of analysis and suggested that the eastern tropical Atlantic yellowfin is separated from the western one. On the Atlantic albacore, ISHII (1965) stated that the morphometric differences between samples from the northeastern and southeastern Atlantic is significant, i.e., the northeastern fish has shorter head, and the first and second dorsals, ventrals and anal fins more anterior in position than does the southeastern one.

Today, among the tuna fisheries of the Atlantic Ocean, those for albacore and yellowfin are the most important. Prior to 1956, with the exception of a small quantity from Angola, all of the landings of tunas in the Atlantic came from the albacore fishery in the Bay of Biscay (SHOMURA, 1966). In 1955, the Japanese long-line fishery started in the Atlantic, with an exploratory cruise (NAKAGOME and SUZUKI, 1963). In the beginning, fishing was restricted to the western Atlantic off South America, and by 1958 it had extended throughout the tropical Atlantic from South America to Africa, and then, by 1962, the area of operation had expanded both northward and southward as far as latitude 30°N and 30°S (SHIOHAMA et al, 1965). And now, for albacore the operation area in the Atlantic has been expanded so far and wide as to the Indian Ocean in the southern hemisphere, and to the Bay of Biscay in the northern hemisphere. As for yellowfin, just as that in the Pacific, fishing was concentrated in the Equatorial waters; but somewhat northwardly.

As tuna fishing grounds in the Atlantic have been expanding throughout, it is our interest that whether there exist subpopulations or stocks in the albacore and yellowfin of the Atlantic. And our first approach to this problem has been made through morphmoetric study.

Table 1. The Atlantic albacore samples used in the morphometric studies.

Sample number	Fishing date	Fishing gronnd	Sample size	Range of fork length	Average of fork length
0	July, 1964	27°—34°N, 61°—75°W	20	887-1014mm	943mm
1	July, 1964	10°—13°N, 75°—78°W	33	880-1080	1002
2	Aug.-Sept., 1964	14°—15°N, 77°—79°W	30	880-1006	943
3	Eeb.-Apr., 1965	9°N, 23°W	30	936-1122	1028
4	Mar., 1965	35°N, 15°W	28	562-1140	903
5	Mar., 1965	10°N, 20°W	20	948-1107	1012
6	Nov.-Dec., 1965	30°N, 61°W	24	820- 974	892
7	Sept., 1965	15°S, 11°E	25	814-1002	877
8	Sept.,-Oct., 1965	1°—10°N, 47°—57°W	20	942-1144	1006
9	Sept., 1965	29°—30°S, 25°—35°W	25	930-1110	1013
10	Nov., 1965	5°—6°S, 33°—34°W	24	983-1154	1048
11	Dec., 1965•Jan., 1966	17°—20S, 35°—38°W	30	952-1155	1037

Samples for morphometric study were taken from the Atlantic albacore and yellowfin landed in Japan, from July, 1964 through January, 1966. Morphometric data were first compared between samples by covariance analysis, for each character individually. And then the method of generalized distance function analysis, proposed by MAHALANOBIS (1936), was applied, dealing the characters in all between samples. Finally, the results obtained by the multiple characters comparison were investigated as a whole, considering the distributions of fishing grounds and currents in the Atlantic; for albacore and yellowfin respectively.

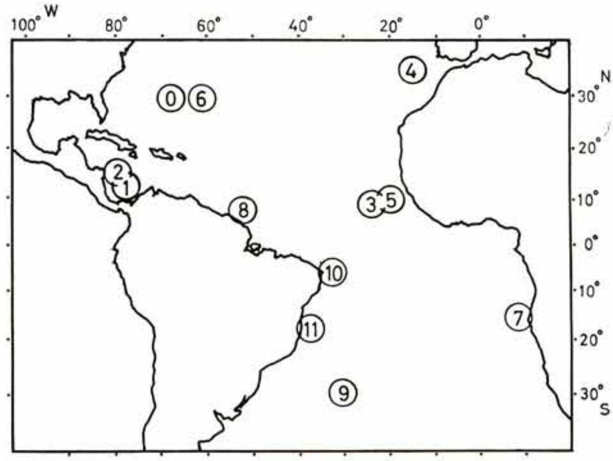

Fig. 1. Geographic distribution of the albacore samples. Figures in the circle indicate sample number.

All of the computations in this study were made on the OKITAC 5090 electronic computers of the Data Processing Center of the University of Tokyo and of the Ocean Research Institute, University of Tokyo.

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Table 2. The Atlantic yellowfin tuna samples used in the morphometric studies.

Sample number	Fishing date	Fishing ground	Sample size	Range of fork length	Average of fork length
0	Aug., 1964	39.5°N, 61.0°W	32	1294-1513mm	1378 mm
1	Aug., 1964	17.0°N, 83.0°W	23	826-1513	1278
2	Dec., 1964•Jan., 1965	2°—3°S 3°—6°E	41	870-1450	991
3	Apr., 1965	9°N, 23°W	55	700-1485	1189
4	Mar.,-May, 1965	11°—12°N, 51°—52°W	30	980-1510	1273
5	Mar., 1965	0°—5°N, 38°—44°W	22	727-1520	1195
6	Sep., 1965	6°S, 4°E	18	1150-1493	1325
7	Sept.-Oct., 1965	7°—8°N, 14°—15°W	25	950-1490	1135
8	Nov., 1965	5°—6°S, 33°—34°W	20	1108-1550	1304
9	Aug.-Sept., 1965	10°—20°N, 20°—30°W	30	1040-1495	1205

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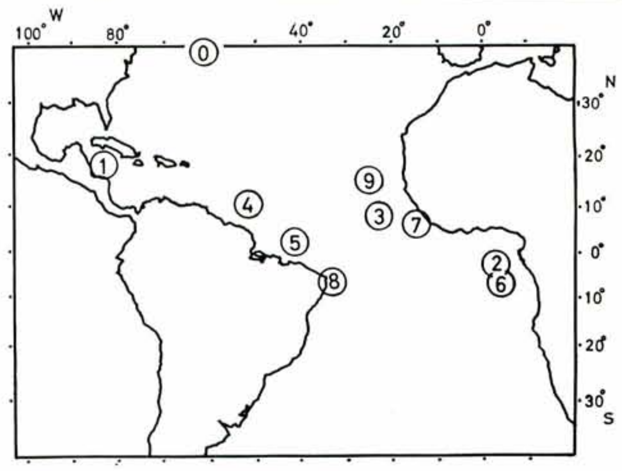

Fig. 2. Geographic distribution of the yellowfin tuna samples. Figures in the circle indicate sample number.

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III. SOURCE OF DATA

12 samples of Atlantic albacore and 10 samples of Atlantic yellowfin tuna, each consisting of 20 to 55 specimens, were drawn from the frozen fish landed at the ports or markets in Japan. For the details about samples refer to Tables 1 and 2 and, also, to Figures 1 and 2.

IV. METHODS OF MEASUREMENT

6 morphometric characters together with the fork length of each specimen of the samples were measured i.e., head length and distances from the tip of snout to insertion of pectoral, first and second dorsal, ventral and anal fin; with a slide caliper by one of the authors, YANG.

Since the measurements were taken on those specimens just after landed at ports or markets in Japan, they were all rigidly frozen; and so the fins could not be held erect for determining the intersection of the anterior margin of the fin with the contour of the body, as for the insertions of fins. Consequently, the measurements were made somewhat in different ways with the specifications given by MARR and SCHAEFER (1949) and also with those measurements by KUROGANE and HIYAMA (1958, 1959) and ISHII (1965), who had followed the specifications by the former authors. The measurements employed in this study are as follows:

(1). Fork length: the distance from the tip of the snout to the cartilaginous median part of the caudal fork, with jaw closed; as done by other authors.

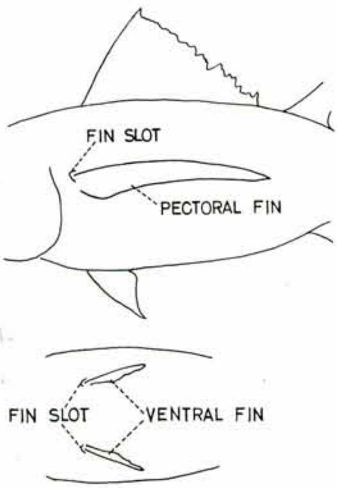


Fig. 3. Diagrams showing the pectoral and ventral fins with fin slot.

(2). Head length: the distance from the tip of the snout to the most posterior point on the margin of the subopercle; as done by other authors.

(3). Snout to the insertion of the pectoral: the distance from the tip of the snout to insertion of the pectoral fin. A curved short slot around the front-dorsal margin of pectoral can be seen as shown in Figure 3, and this slot seems to be identical with the most anterior point when the fin is held erect, if the fish is not frozen. The anterior end of slot has been determined as the insertion of pectoral.

(4). Snout to the insertion of the first dorsal: the distance from the tip of the snout to the insertion of the first dorsal. The anterior most point of the first dorsal fin slot is taken as the insertion of the first dorsal. According to MARR and SCHAEFER (1949), this point is identical with the insertion of the anterior margin of the first dorsal spine, when the fin is held erect, with the contour of the back.

(5). Snout to the insertion of the second dorsal: the distance from the tip of the snout to the insertion of the second dorsal. The point where the first soft ray fits into the back has been taken as the insertion of the second dorsal, examined with the back of a knife or the thumbnail.

(6). Snout to the insertion of the ventral: the distance from the tip of the snout to the insertion of the ventral. Just as that of the pectoral, a curved short slot presents in front of the ventral (Figure 3), and the anterior most end of this slot has been taken as the insertion.

(7). Snout to the insertion of the anal: the distance from the tip of the snout to the insertion of the anal. The insertion of the anal was determined in the same manner as that of the second dorsal.

Abbreviations **H. L.**, **S.-P.**, **S.-I.**, **S.-II.**, **S.-V.**, and **S.-A.** are used in this report referring to the characters, viz., head length, snout to insertion pectoral, snout to insertion first dorsal, snout to insertion second dorsal, snout to insertion ventral and snout to insertion anal, respectively.

V. METHODS OF ANALYSIS

(1). Regressions of Characters on Fork Length

In case of albacore and yellowfin, it is well known that there exist straight line relations between fork length and morphometric characters, if the range of fork length is adequate. Each measurement was related to fork length by regression analysis, for examining the linear relations of measurements with fork length. And then, the reliability of measurements was examined on the coefficient of variation, C, calculated by the formula of ROYCE (1961):

$$C=\frac{\sqrt{V_{y\cdot x}}}{\overline{X}}\times 100$$

where $\sqrt{V_{y\cdot x}}$ is the standard deviation from regression and $\overline{X}$ is the mean value for characters in a sample.

The values of coefficient of variations were compared between the samples for identical characters as well as between characters within sample.

For the details of regression analysis of characters on fork length refer to ROYCE (1961).

(2). Character-by-Character Comparison of Samples—Covariance Analysis

After the reliability of measurements was investigated, the regression statistics obtained were turned to the test by covariance analysis, for each character individually.

First, the test was done for all the samples with a view to finding whether these samples belonged to the same population. After testing for the sample in all, tests for pairs of samples were made on every pairs of samples.

Following the tests mentioned above, the adjusted means with its 95% confidence interval were deduced for individual characters of each sample; based on the common regression coefficient estimated from the whole samples in case of the results of test on regression coefficients for the character is not significant among samples, and on the individual regression coefficient in case of the test for the character is significant.

The values of adjusted means of each character were tabulated with their 95% confidence interval, and were given in Figures 4 and 8 for comparison.

For the details of the processes of analysis see KUROGANE and HIYAMA (1957, 1958 and 1959) and ISHII (1965).

(3). Multiple Character Comparison of Samples—Generalized Distance Function Analysis

The generalized distance function was first proposed by MAHALANOBIS in 1936 and described in mathematical terms by RAO in 1952. According to this method, the differences between pairs of measurements from two or more sources are pooled to form an index of dissimilarity, D^2, called the generalized distance function (FUKUHARA et al 1962). According to AMOS et al (1963), using of this method statistical assumptions required the data to have jointly normal distributions with a common dispersion (variance-covariance) matrix in the populations selected; and those conditions, including common variance, normality of distributions and common correlation, are required to be satisfied simultaneously.

Besides, it is desirable that there is no carrelation among characters, as the efficiency of the test on the variance-ratio of D^2 would be reduced if there was any (RAO, 1952).

Adjustment of Data:

In the present study, all the characters used are morphological and with linear relations on the fork length. The existence of correlations among characters is apparent. In order to remove the correlations among characters and, on the other hand, to diminish the effect of fork length on characters, the measurements of each character were adjusted for the same fork length before analysis. In this case, the values of coefficient of regressions employed for individual character in each sample were computed in the same manner as that for the estimations of adjusted means (see Section V (2)).

Normality of Distributions:

As listed in Tables 1 and 2, the number of specimens in each sample in the present study varies from 20 to 55. There is no adequate test for normality for small samples. So, no statistical procedure is applied to the adjusted measurements for the test of the normality of distributions. Yet, from the frequency distributions of adjusted measurements (shown in Figures 5 and 9), no radical departure from normality are evident.

Common Variance:

Common variance is required between each identical character of the samples in comparison. Variance-ratio test was used in this study.

Correlations Between Characters and Common Correlation Tests for All Samples:

Table 3. Regression statistics of various characters on fork length of the Atlantic albacore. M. F. L.: mean value of fork length; M. CHA.: mean value of character; *b*: regression coefficient; *a*: intercept; *r*: correlation coefficient; $\sqrt{V_{y \cdot x}}$: standard deviation from regression; *C. V.*: coefficient of variation.

Head length

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	943mm	275mm	0.2834	8.3 mm	0.9537	3.8384	1.39%
1	1002	292	0.2923	−0.7	0.9604	4.5942	1.57
2	943	277	0.2988	−4.7	0.9261	5.0281	1.81
3	1028	300	0.2662	2.7	0.9468	4.5599	1.52
4	903	262	0.2738	14.4	0.9834	7.3527	2.81
5	1012	294	0.2519	39.4	0.9209	4.3031	1.46
6	892	264	0.2911	4.7	0.9796	2.8833	1.09
7	877	261	0.2811	15.1	0.9093	4.9987	1.91
8	1006	294	0.2418	51.0	0.9400	3.8246	1.30
9	1013	296	0.2777	14.4	0.9179	4.9568	1.68
10	1048	302	0.2547	34.6	0.9490	3.9306	1.30
11	1037	306	0.2528	43.3	0.9361	4.5943	1.50

Snout to pectoral

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	943	284	0.3003	1.4	0.9118	5.8143	2.04
1	1002	298	0.2811	15.9	0.9374	5.6614	1.90
2	943	280	0.3066	-9.1	0.9161	5.5453	1.98
3	1028	302	0.2580	37.2	0.9667	3.4419	1.14
4	903	265	0.2709	20.3	0.9774	8.5379	3.22
5	1012	298	0.2709	24.1	0.9253	4.4821	1.50
6	892	270	0.2930	8.5	0.9492	4.6919	1.74
7	877	269	0.2905	13.9	0.9097	5.1516	1.92
8	1006	298	0.2276	69.2	0.8765	5.4518	1.83
9	1013	299	0.2782	17.5	0.8994	5.5818	1.86
10	1048	306	0.2391	55.1	0.9148	4.8999	1.60
11	1037	309	0.2462	53.7	0.9341	4.5529	1.47

Correlation coefficients between all possible pairs of characters were calculated for each sample. Then, the values of correlation coefficients, r, were converted by published tables to FISHER's "Z" values; and finally, the differences among the "Z" values of all samples for the identical combinations of characters were tested by χ^2.

Calculations of D^2 Values and Tests for Variance-Ratio:

After the assumptions had been examined, D^2 values were calculated for all possible pairs of samples, with the characters arranged in the order of its contribution to the value of D^2. (See APPENDICES A and B). Using this D^2 value,

Table 3. …continued.

Snout to first dorsal

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	943	300	0.3194	-1.1	0.9209	5.8090	1.94
1	1002	318	0.2803	36.9	0.9149	6.7020	2.11
2	943	303	0.2957	23.9	0.8524	7.4950	2.48
3	1028	326	0.2896	27.9	0.8590	8.6991	2.67
4	903	286	0.2941	20.9	0.9889	6.4334	2.25
5	1012	319	0.1912	125.6	0.6934	8.0215	2.51
6	892	289	0.2771	42.0	0.8761	7.3652	2.55
7	877	283	0.2851	33.4	0.8743	6.1506	2.17
8	1006	320	0.3247	-6.2	0.9041	6.6912	2.09
9	1013	324	0.2830	37.1	0.8626	6.8477	2.11
10	1048	331	0.2452	74.0	0.8436	7.2469	2.19
11	1037	334	0.2389	85.6	0.8924	5.8444	1.75

Snout to second dorsal

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	943	548	0.5810	0.7	0.9746	5.7334	1.05
1	1002	582	0.5291	52.1	0.9593	8.4351	1.45
2	943	553	0.5527	31.4	0.9587	6.7715	1.23
3	1028	596	0.5540	26.9	0.9508	9.0918	1.52
4	909	531	0.5629	19.1	0.9934	9.3836	1.77
5	1015	587	0.5042	75.1	0.9253	7.9258	1.35
6	894	522	0.5598	22.2	0.9533	8.5777	1.64
7	878	516	0.5762	10.1	0.9483	7.5120	1.46
8	1006	587	0.6570	-74.1	0.9545	8.9497	1.52
9	1013	591	0.6056	-22.7	0.9646	6.8385	1.16
10	1048	606	0.5086	72.8	0.9431	8.3260	1.37
11	1037	604	0.5022	82.9	0.9537	7.6646	1.27

the variance-ratio of D^2 was calculated, following the formula by FISHER, 1936 (RAO, 1952). The significance of variance-ratio is then determined from the tables of "F".

The results obtained during the course of analysis described above were examined thoroughly considering the probable relations on the distributions and conditions of fishing grounds and currents in the Atlantic.

VI. RESULTS OF ANALYSIS FOR ALBACORE

(1). Regressions of Characters on Fork Length

As shown in Table 3, the results of tests for the linear relations between character and fork length are all highly significant, and most of the values of coefficient of variations are in the range of from 1.0 to 3.0%. The coefficient of variation of characters concerned seems to be rather small and the reliability of measurements is regarded as acceptable.

Table 3. …continued.

Snout to ventral

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	943	318	0.2441	88.4	0.7980	7.9232	2.49
1	1002	335	0.3405	-6.5	0.8855	9.6822	2.89
2	943	317	0.3115	22.9	0.9293	5.1130	1.61
3	1028	344	0.2985	37.1	0.8902	7.6979	2.24
4	883	292	0.3030	22.8	0.9814	8.7101	2.98
5	1012	341	0.4284	-92.5	0.9350	6.5612	1.92
6	892	300	0.3352	1.3	0.9511	5.2557	1.75
7	877	302	0.3542	-8.8	0.8465	8.6545	2.87
8	1006	336	0.2910	43.2	0.9084	5.8405	1.74
9	1013	337	0.3719	-39.3	0.9197	6.5468	1.94
10	1048	351	0.2808	56.3	0.8561	7.8703	2.24
11	1037	349	0.2848	53.4	0.8336	9.1292	2.62

Snout to anal

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	943	601	0.5789	55.0	0.9835	4.5692	0.76
1	1009	637	0.6218	13.6	0.9760	7.5054	1.18
2	943	602	0.6158	21.2	0.9763	5.6350	0.94
3	1031	653	0.6290	4.9	0.9765	6.8182	1.04
4	903	571	0.6125	17.8	0.9961	7.9142	1.39
5	1012	640	0.6497	-17.3	0.9776	5.6416	0.88
6	894	568	0.5950	35.9	0.9569	8.7331	1.54
7	877	562	0.6736	-28.8	0.9564	7.9954	1.42
8	1006	643	0.6343	4.7	0.9584	8.2364	1.28
9	1013	647	0.6460	-7.3	0.9509	8.6791	1.34
10	1048	664	0.5310	108.4	0.9572	7.4556	1.12
11	1037	663	0.5661	75.3	0.9694	6.9313	1.05

(2). Character-by-Character Comparison of Samples—Covariance Analysis

Covariance analysis was, first, applied for 12 samples in all. The results are shown in Table 4. The values of variance-ratio F_b show no significant difference in the regression coefficients among samples; but the values of variance-ratio F_a show significant difference in the adjusted means among samples, excepting the character **S.-II.** Since 5 out of 6 characters are showing highly significant differences in the adjusted means, it is hard to consider that the 12 samples concerned are all from a common origin. And we turn to test the differences in pairs of samples.

Table 4. Covariance analysis for albacore samples from the Atlantic Ocean. F_r, F_b and F_a are the variance-ratios to test the significance of the differences of regression line, regression coefficient and adjusted mean respectively.

*: significant at 5% level; **: significant at 1% level.

	H. L.	S.-P.	S. -I.	S.-II.	S.-V.	S.-A.
F_r	3. 30**	4. 39**	1. 96*	1. 31	2. 86**	2. 48**
F_b	0. 73	0. 92	1. 16	1. 31	1. 58	1. 30
F_a	5. 92**	7. 88**	2. 74**	1. 29	4. 06**	3. 63**

Table 5 shows the results of tests for samples. The figures in Table 5 are the number of sample. As shown by the results, there are only a few pairs of samples without any significant difference in all of the 6 characters.

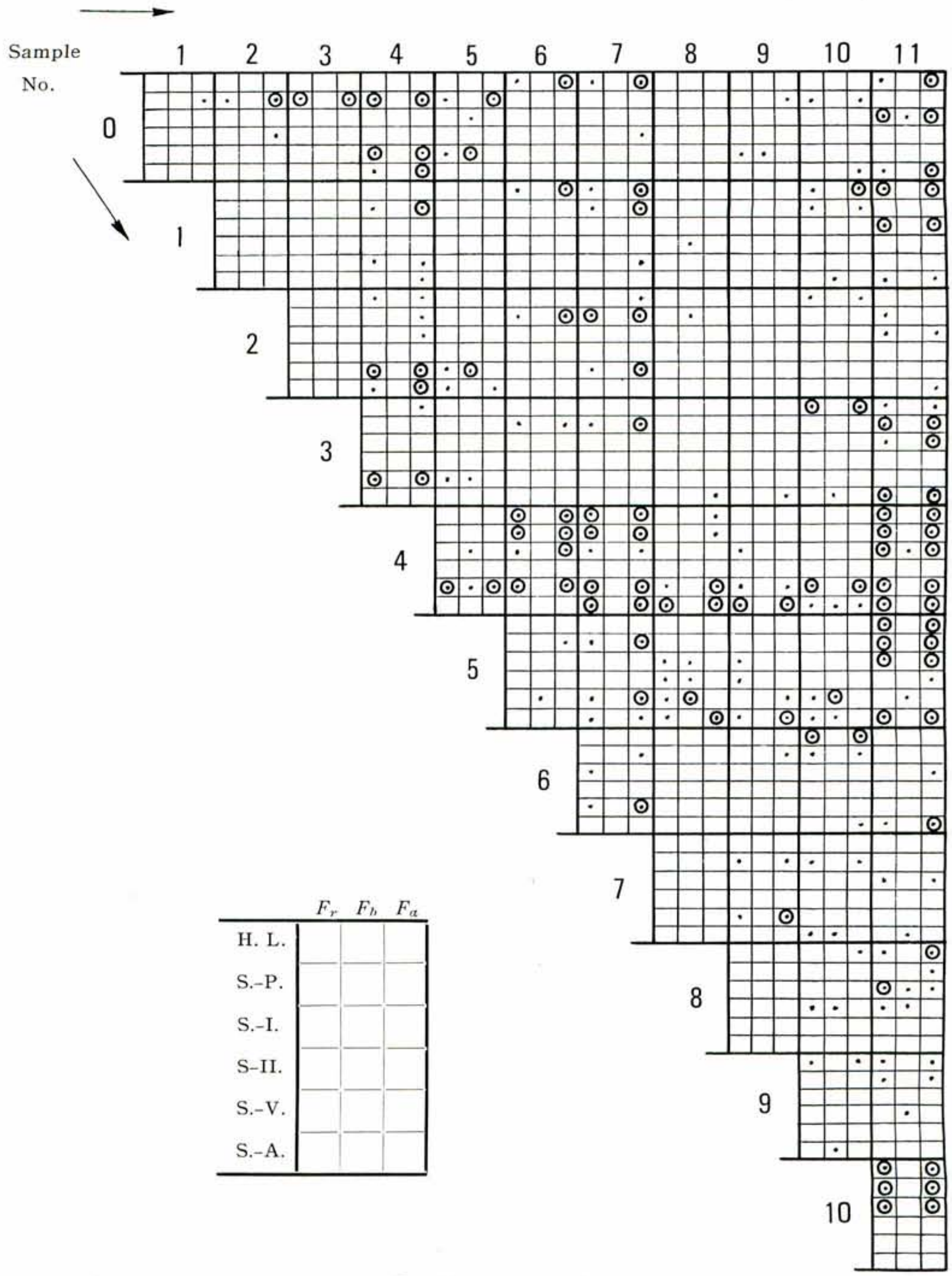
Among the pairs of samples showing significant difference, the most remarkable ones are those paired with Sample 4. Sample 4, from the waters northeast off Canarries Islands, shows significant differences with all of the other samples in at least 2 characters. Further, Sample 4 shows significant differences in 5 characters on comparison with the samples from the southern hemisphere (i. e., Samples 7 and 11), and significant differences in 3 to 5 characters with the two samples from the waters off Washington and Bermudas Islands (i. e., samples 0 and 6) and also with the two samples from the Caribbean Sea (i. e., Samples 1 and 2).

In the case of the pairs of samples besides those mentioned above, the relations among them are rather complicated, but the numbers of significantly different character are small or none.

On the 6 characters compared, the character **S.-P.** shows the maximum difference between samples, followed by the other characters in order of **S.-A.**, **S.-V.**, and **H. L.**

For further consideration of the relations among the differences in characters between samples, the adjusted means with its 95% confidence interval of each individual character of samples are calculated as described in Section, V (2), i. e., using the common regression coefficients estimated on the whole samples, as none of the tests for the difference in regression coefficients of characters on fork length has been significant among samples (see Table 4). The adjusted means of characters are calculated on the fork length of 976. 4 mm., which is the grand mean value of fork length for all albacore specimens used

Table 5. Covariance analysis for pairs of albacore samples. F_r, F_b and F_a are the variance ratios to test the significance of the differences of regression line, regression coefficient and adjusted mean respectively.



· : Significant at 5% level

⊙ : Significant at 1% level

in this study. The values calculated, with their 95% confidence interval, are tabulated in Table 6 and shown also in Figure 4 in an arrangement of samples with regard to the results of covariance analysis test.

Table 6. Adjusted mean values of various characters of the Atlantic albacore samples, with 95% confidence limits in the parentheses, adjusted for the fork length of 976.4 mm.

Sample No.	H. L.	S.-P.	S.-I.	S.-II.	S.-V.	S.-A.
0	284.7 (2.10)	293.7 (2.42)	309.6 (3.11)	567.2 (3.57)	329.0 (3.44)	621.4 (3.25)
1	285.2 (1.64)	290.7 (1.88)	310.5 (2.42)	568.0 (2.87)	326.7 (2.67)	621.0 (2.61)
2	286.2 (1.73)	289.0 (1.98)	312.3 (2.56)	571.2 (2.93)	327.1 (2.81)	622.3 (2.66)
3	286.0 (1.76)	288.5 (2.02)	311.0 (2.60)	567.7 (3.00)	327.9 (2.88)	620.0 (2.82)
4	281.8 (1.87)	284.9 (2.16)	307.4 (2.78)	568.4 (3.22)	319.5 (3.32)	615.8 (2.90)
5	284.5 (2.10)	288.6 (2.42)	309.0 (3.12)	565.4 (3.68)	329.9 (3.43)	618.4 (3.25)
6	287.5 (2.04)	292.8 (2.35)	313.2 (3.03)	568.6 (3.54)	326.6 (3.34)	618.2 (3.21)
7	288.9 (2.06)	295.7 (2.37)	311.8 (3.05)	571.3 (3.52)	332.7 (3.38)	622.7 (3.18)
8	286.1 (2.09)	290.2 (2.41)	312.0 (3.10)	570.4 (3.57)	326.8 (3.43)	624.8 (3.24)
9	285.8 (1.89)	289.5 (2.18)	313.4 (2.79)	570.3 (3.22)	326.0 (3.08)	624.6 (2.92)
10	281.9 (2.00)	286.3 (2.30)	310.6 (2.96)	566.0 (3.41)	328.3 (3.28)	621.2 (3.10)
11	288.9 (1.78)	292.7 (2.06)	316.1 (2.64)	569.9 (3.04)	329.9 (2.92)	625.3 (2.76)

Among the four samples from along the coast of Africa, viz., Samples 4, 5, 3 and 7, an apparent character gradient can be seen on most of the characters. Sample 4 from the northern hemisphere has the smallest values in 5 characters, while Sample 7 from the southern hemisphere has the highest values in all characters. On the three samples from along the coast of South America, i. e., Samples 10, 11 and 9, the values of Samples 10 are all smaller than of Samples 11 and 9 from the southern hemisphere.

The values of characters of those samples from the northwest Atlantic, i. e., Samples 0, 6, 1, and 2, do not have much difference between each others. Sample 8, from North Equatorial Current off Guiana, appears to be similar to the Samples 1 and 2, from the Caribbean Sea, in most of the characters. Besides, Sample 8 seems to be close with Samples 3 and 5, both from the waters off south of Cape Verde Islands and having almost the same values in all characters.

As a whole, samples from southern hemisphere, i. e., Samles 7, 11 and 9, seem to be higher in values of each character than do the samples from northern hemisphere; especially the Samples 7 and 11. Sample 4 from the waters off northeast of Canaries Islands in northern hemisphere is remarkable in that it shows the lowest value in all characters.

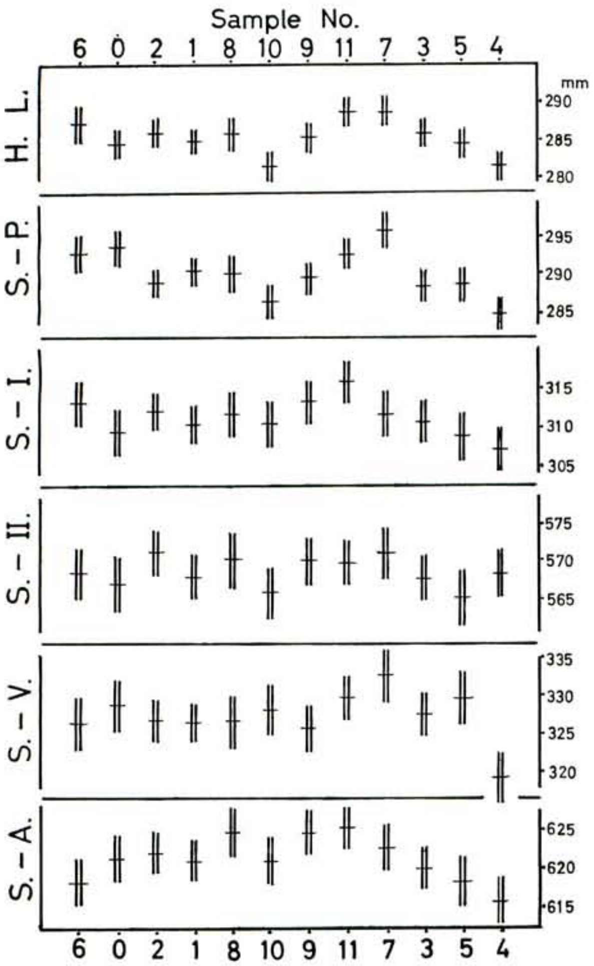


Fig. 4. Adjusted mean values of various characters of the Altantic albacore samples, with 95% confidence limits, adjusted for the fork length of 976.4 mm.

(3). Multiple Character Comparison of Samples—Generalized Distance Function Analysis

As mentioned in Section V (3), for applying the method of generalized distance function analysis, some statistical assumptions are required to be satisfied (AMOS et al, 1963), and no correlation among the characters is desirable, in this case.

First, the individual measurement of characters of each sample are adjusted forthe fork length of 976.4 mm., using the common regression coefficients that are used for the estimation of adjusted means in the previous section. The frequency distributions of adjusted measurements of each sample are shown in Figure 5. No radical daparture from normality is evident and no statistical tests are applied to the normality of distributions for reasons that there is no adequate test for the normality of small samples.

The second assumption required is the existence of common variance between identical characters of the samples compared. "F" tests for the values of variance-ratio are applied to all the possible pairs of samples. The results obtained are shown in Table 7. Out of the 396 values of variance-ratio (i.e., the number of combinations of samples times the number of characters, ${}_{12}C_2 \times 6$), 58 values show significant differences. The items of the 58 variance-ratios showing significanc difference are: **H.L.**, 14; **S.-P.**, 15; **S.-I.**, 0; **S.-II.**, 3; **S.-V.**, 15; and **S.-A.**, 11.

The final assumption examined is the existence of common correlations between samples. Firstly the values of correlation coefficients of all posible pairs of characters within sample are calculated and tested on the significance. The results of tests are presented in Table 8. Then, the values of correlation coefficients obtained were converted to FISHER's "Z" values, by tables, and χ^2 test was applied to the difference of "Z" values among samples, on each combinations of characters. The results of χ^2 test are also listed in Table 8. 66 values of correlation coefficient, out of a total of 180 values (i. e., the number of combinations of characters times the number of samples, ${}_6C_2 \times 12$) are significant; in spite of the procedure having been applied for diminishing the correlations between the measurements of characters (Section V(3)). On the combinations of characters significant in correlation, those for **H. L.** and **S.-P.** are the maximum in number followed by: **H. L.** and **S.-V.**; **S.-P.** and **S.-V.**; **S.-I.** and **S.-II**,; and **S.-V.** and **S.-A.**

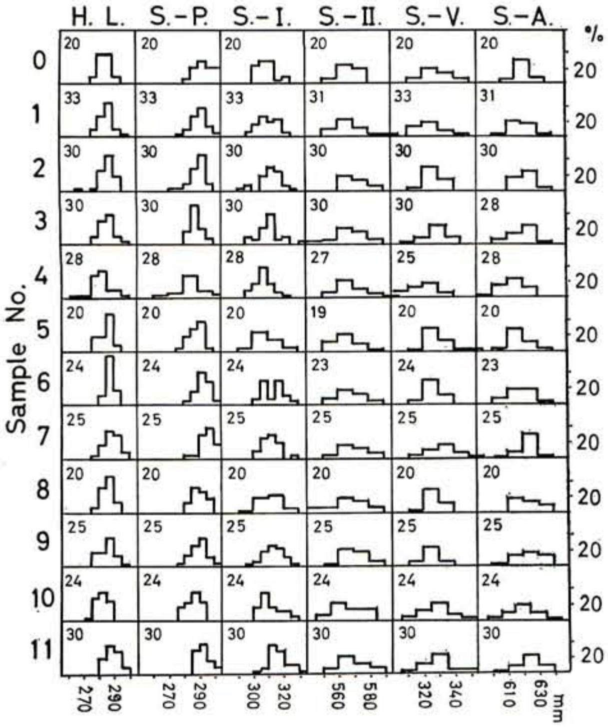


Fig. 5. Frequency distributions of characters of albacore adjusted for the same fork length (976.4 mm). Figures in the body of graph indicate sample size.

The results of χ^2 test on the common correlation are significant in the pairs: **H. L.** a nd **S.-P.**; **H. L.** and **S.-V.**; and **S.-P.** and **S.-A.**

Though the required assumption has not been verified perfectly, as described above, we take it as a result that the assumptions are provisionally verified for the most pairs of samples; in order to proceed with the further steps of analysis. The D^2 values for all possible pairs of samples are calculated and tested on the significance of variance-ratio, as shown in Table 9. A detailed description of the method of generalized distance function analysis (including the test on the variance-ratio of D^2 values) is available from RAO (1952), and an outline of it can be found in FUKUHARA et al (1962). In the present study, the D^2 values have been calculated by using the 6 characters according to the

Table 7. Results of tests for variance ratio between identical characters of the albacore samples.

Sample No.		1	2	3	4	5	6	7	8	9	10	11
0	1				**							
	2			*								
	3											
	4			*	*				*			
	5		*				*					
	6	*			*		*	*	*	**	*	
1	1				*		*					
	2			*	*							
	3											
	4											
	5		**				**		*			
	6											
2	1						*					
	2			*	*							
	3											
	4											
	5			*	**	*		**			*	**
	6						*	*		*		
3	1				*		*					
	2				**			*	*	*		
	3											
	4											
	5											
	6											
4	1					*	**		*		*	*
	2					**	**	*		*	*	**
	3											
	4											
	5						*					
	6											
5	1											
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	3											
	4											
	5											*
	6											
9	1											
	2											
	3											
	4											
	5											
	6											
10	1											
	2											
	3											
	4											
	5											
	6											

H. L.
S. - P.
S. - I.
S. - II.
S. - V.
S. - V.
S. - A.

*: Significant at 5% level
**: Significant at 1% level

contributions of characters to the D^2 value (see APPENDIX A), as mentioned in Section V (3).

The results of tests on the variance-ratio of D^2 value are also tabulated in Table 10, showing the relations between samples. Again on investigating the

Tabel 8. Results of common correlation tests for the albacore samples.
*: significant at 5% level; **: significant at 1% level.

Sample No.	0	1	2	3	4	5	6	7	8	9	10	11	χ^2 Test
H. L. S.-P.		**	**	**	**	**	*	**	**	**	**	**	**
H. L. S.-I.		**			**		**	*		*		**	
H. L. S.-II.		**					*					*	
H. L. S.-V.	*	*		*	**		*	**		**		**	**
H. L. S.-A.		**			*		**						
S.-P. S.-I.			*		**		**	*		**			
S.-P. S.-II.		*					*				*		
S.-P. S.-V.		*		*	**		*	**		**	**	**	
S.-P. S.-A.		**					*				**		*
S.-I. S.-II.		**	**		*	**	**				*	**	
S.-I. S.-V.													
S.-I. S.-A.					**								
S.-II. S.-V.													
S.-II. S.-A.				*			*	**		**		**	
S.-V. S.-A.		**	**			*		**	*	**	*		

results as shown in Table 10, we begin with the 4 samples (i. e., Samples 4, 3, 5 and 7) that show an apparent character gradient from north to south (i. e., smaller in the north and larger in the south) along the coast of Africa (see Section V (2)). First, there is no significant difference between Samples 3 and 5; both from the waters off south of Cape Verde Islands and having not much difference in the adjusted means with each others; as shown in Figure 4. Both Samples 3 and 5 differ significantly from Sample 4 in the north and from Sample 7 in the south. Samples 4 and 7 are highly significant in difference.

Among Samples 10, 11 and 9, there is no significant difference between Samples 9 and 11 (both from the waters of Brazil Current); but both show significant difference from the Sample 10, from the waters where the South Equatorial Current partly turn to south and partly crosses the Equator and flows westward to Caribbean Sea.

Besides, the 2 samples from Caribbean Sea (i. e., Samples 1 and 2) have no difference between each other, and also from Sample 8. Sample 4 having the smallest values in adjusted means in almost all of the characters, shows significant difference with all of the other samples.

Further considerations on the results of tests, among samples, are given in next section.

Table 9. D^2 and the results of tests for the variance ratio between albacore samples, using characters arranged in the order of its contribution to the value of D^2. *: significant at 5% level; **: significant at 1% level; # 0, 1, 2, 3, 4 and 5 stand for character H. L., S.-P., S.-I., S.-II., S.-V·, and S.-A., respectively.

Combination of Samples	Characters						D^2	Variance Ratio
0 − 1	1#	4	0	2	3	5	0.8171	1.5296
0 − 2	1	3	2	0	4	5	2.9559	5.2961**
0 − 3	1	0	5	2	4	3	2.5263	4.5264**
0 − 4	1	4	5	0	2	3	3.6032	6.2591**
0 − 5	1	5	3	2	4	0	1.6460	2.3824
0 − 6	0	2	5	4	3	1	2.6309	4.2139**
0 − 7	0	3	4	1	2	5	1.5052	2.4633
0 − 8	1	5	3	0	2	4	2.1699	3.1407*
0 − 9	1	2	3	5	4	0	3.0328	4.9632**
0 −10	1	0	3	2	4	5	2.9470	4.7202**
0 −11	2	0	5	3	1	4	2.9455	5.2775**
1 − 2	3	1	2	0	5	4	0.9392	2.2582
1 − 3	1	0	4	5	2	3	0.8526	2.0500
1 − 4	1	4	5	0	2	3	1.6252	3.7552**
1 − 5	1	5	4	3	2	0	0.8387	1.5700
1 − 6	0	1	2	5	3	4	1.0139	2.1346
1 − 7	1	0	4	3	5	2	1.3035	2.8143*
1 − 8	5	3	2	0	1	4	0.5883	1.1013
1 − 9	5	2	3	1	0	4	0.9563	2.0647
1 −10	1	0	3	4	2	5	1.6348	3.4417*
1 −11	2	0	5	1	4	3	1.4633	3.5184*
2 − 3	3	5	2	4	1	0	0.3840	0.8772
2 − 4	4	5	0	2	1	3	1.8262	4.0145**
2 − 5	3	5	4	2	0	1	2.1152	3.7898**
2 − 6	1	5	3	0	2	4	1.5809	3.1752*
2 − 7	1	4	0	2	5	3	3.2354	6.6594**
2 − 8	5	1	3	4	2	0	0.3636	0.6515
2 − 9	5	4	2	3	0	1	0.4313	0.8877
2 −10	0	3	1	2	4	5	1.4331	2.8784*
2 −11	1	2	0	5	4	3	1.4659	3.3488*
3 − 4	4	0	5	1	2	3	1.5137	3.3276*
3 − 5	0	3	5	4	2	1	0.4498	0.8059
3 − 6	1	0	2	5	4	3	1.8403	3.6962**
3 − 7	1	0	4	3	5	2	4.4144	9.0862**
3 − 8	5	1	3	4	2	0	1.1787	2.1119

(4). Discussion

The results obtained in the previous section reveal that: (1) the values for each character are larger in the case of southern Atlantic samples, as a whole; (2) the heterogeneity among northern samples and that among southern samples does not appear to be as remarkable as the difference between the northern and southern samples; and (3) Sample 4 from the waters off northeast of Canaries Islands are different from the other samples; including both from the northern and southern Atlantic.

Table 9. …continued.

Combination of Samples	Characters						D^2	Variance Ratio
3—9	5	3	2	4	1	0	1.0085	2.0758
3—10	0	1	3	5	4	2	1.2217	2.4538
3—11	1	5	2	0	3	4	2.6389	6.0286**
4—5	4	1	0	5	3	2	2.7937	4.8418**
4—6	1	0	4	2	5	3	1.8421	3.5709*
4—7	1	4	0	5	2	3	4.0198	7.9809**
4—8	5	4	1	0	2	3	1.8385	3.1863*
4—9	5	2	4	0	1	3	1.7077	3.3905*
4—10	4	5	2	3	1	0	2.6609	5.1582**
4—11	2	5	4	0	1	3	4.2063	9.2467**
5—6	1	0	2	4	3	5	2.1305	3.4124*
5—7	1	0	3	5	2	4	3.5043	5.7348**
5—8	5	3	4	2	0	1	2.3061	3.3378*
5—9	5	3	2	4	0	1	2.1757	3.5605*
5—10	0	1	5	2	4	3	1.0767	1.7246
5—11	5	2	0	1	3	4	2.9100	5.2138**
6—7	4	1	5	3	0	2	1.1675	2.1292
6—8	5	1	0	3	2	4	1.1928	1.9105
6—9	5	1	0	3	4	2	1.8819	3.4318*
6—10	0	1	2	5	3	4	6.4461	11.4908**
6—11	5	4	2	0	3	1	1.7400	3.4948*
7—8	1	4	0	5	3	2	2.1367	3.4967*
7—9	1	4	0	2	5	3	4.0496	7.5578**
7—10	1	0	3	4	5	2	5.4075	9.8617**
7—11	2	1	5	4	3	0	3.0045	6.1842**
8—9	2	1	4	0	3	5	0.1034	0.1692
8—10	0	1	3	5	4	2	2.0892	3.3463*
8—11	2	0	1	4	5	3	0.8761	1.5697
9—10	0	1	3	5	2	4	1.9071	3.4780*
9—11	0	1	4	2	5	3	0.5626	1.1580
10—11	0	1	2	5	3	4	3.9647	7.9631**

SHIOHAMA et al (1965) stated that the distribution density of long-line operations for albacore in the Atlantic is rather low in the Equator region

Table 10. Results of tests for the variance-ratio of D^2 value between albacore samples.
★ significant at 5% level; ★★ significant at 1% level,

Sample number

	1	2	3	4	5	6	7	8	9	10	11
0		★★	★★	★★		★★		★	★★	★★	★★
1				★★			★★			★	★
2				★★	★★	★	★★			★	★
3				★		★★	★★				★★
4					★★	★	★★	★	★	★★	★★
5						★	★★	★	★		★★
6									★	★★	★
7								★	★★	★★	★★
8										★	
9										★	
10											★★

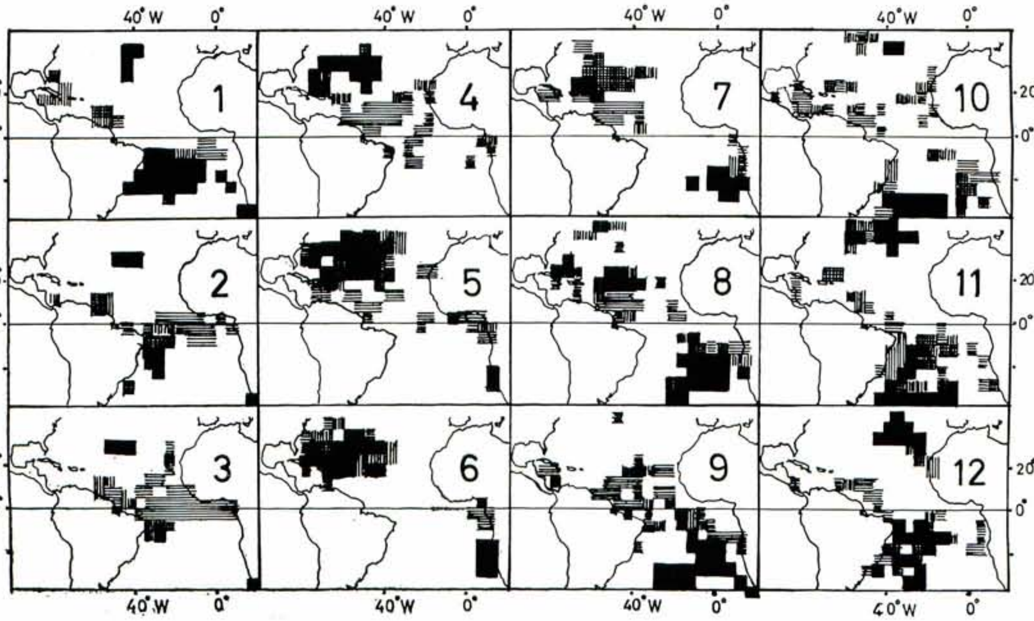


Fig. 6. Monthly distribution of hook-rates for the Atlantic albacore, 1965. Data of hook-rates taken from "Tuna Fishing, No. 39～50; Oct., 1965 ～Sept., 1966." Note: ≣ 0.1～0.9%; ||||| 1.0～1.9%; ▦ 2.0～2.9%; ■ 3.0%～.

throughout the year and that the concentrated operation area in the Atlantic could be divided into two major parts; nemely, the northern and southern Atlantic. In the southern Atlantic, the major fishing seasons are from November to January, and in the Northern Atlantic from May to August with the exception of Caribbean Sea where the hook-rates are rather higher from November to January. As mentioned in Section I, the albacore fishing grounds in the Atlantic extends so far and wide as latitude 40° N and 40° S, and the seasonal changes in distributions of operation area are much complicated. As shown in Figure 6, there is remarkable difference between the monthly distribution of hook-rates of albacore in the northern Atlantic and that in the southern Atlantic. In the northern Atlantic, the higher hook-rates are concentrated in area (A), as shown in the schematic diagram in Figure 7, in the so-called northern summer (i. e., from April to August); and in area (B) in the northern winter (i. e., from November to January). In the southern Atlantic, on the contrary, the higher hook-rates are concentrated in area (D) during southern winter (i. e., from May to September), and in area (C) in southern summer (i. e., from October to January).

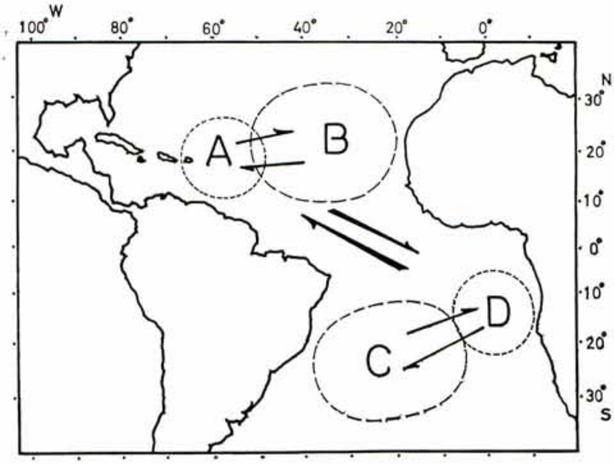


Fig. 7. Schematic diagram showing the areas where the higher hook-rates are concentrated along with the fishing seasons. See text for the details. (schematic diagram after KOTO and SUDA, 1967)

Based on the analysis of the length composition and hook-rates data of Atlantic albacore by Japanese long-line fishry, KOTO and SUDA (1967) suggested that there is difference in the "ecological status" between the albacores from areas (A) and (B); and also between that from areas (C) and (D). The difference in "ecological status" as suggested by them are: albacores from areas (B) and (D), in northern winter and southern winter respectively, belong to the feeding groups or the immature groups; while that from areas (A) and (C), in northern summer and southern summer respectively, belongs to the matured or the spawning groups. On supporting the views of KOTO and SUDA, we cannot ignore the report by UEYANAGI (1967) that larvae as well as matured albacores have been observed in area (A) in northern summer and area (C) in southern summer.

Summarizing the information mentioned above, it seems that albacores in the Atlantic belong to at least two different "stocks", viz., the northern and southern Atlantic "stocks", that show a time lag of about half of a calender year in life cycle. "At least two different stocks" here we stated, means that some others also may be existing. As described by SHOMURA (1966), the season for the Bay of Biscay Albacore Fishery, by trolling prior to 1946 and then by pole and line, extends from June to November; and the largest of three size groups in the catch is less than 25 pounds (i.e., about 11.4 kg in weight and 83*cm. in length, estimated by the authors following the formula of SUDA, 1961). Moreover, WATSON et al (1961) reported that juvenile of albacore have been collected during the summer months of 1958, 1959 and 1960 from the Straits of Messina in Mediterranean Sea. Sample 4 in the present study, having the smallest values in all characters and showing significant differences with all of the other samples (refer to Sections VI (2) and (3) for details) was taken from the waters off northeast of Canaries Islands and closing to both Bay of Biscay and Straits of Gilbraltar connecting Mediterranean Sea with the Northern Atlantic. Though we are having evidences neither for explaining the relation of Sample 4 with the albacores caught by pole and line in Bay of Biscay nor that with the albacore juvenile in Mediterranean Sea, we are inclined to think that Sample 4 is separated from thoes "stocks" to which others belonged. In other words, Sample 4 belongs neither to the northern Atlantic "stock" nor to the Southern Atlantic "stock"; assuming that there do exist two different "stocks", one in the northern Atlantic and another in the Southern Atlantic possessing separate life cycle as mentioned before.

Considering the possible existence of the northern and southern Atlantic "stocks" that differ in life cycle, we review on the results obtained in the Section VI. Among the 4 samples from the southern Atlantic (i.e., Samples 7, 9, 10 and 11), there is no difference between Samples 9 and 11; but both differ from Sample 10; and Sample 7 is different from the other three samples (see Table 10). Sample 7, taken in September, 1965 (Figure 1) with an average fork length of 877 mm. seems to correspond to the "feeding groups" in the area in southern winter as proposed by KOTO and SUDA, or to the "immatured groups" suggested By UEYANAGI. Samples 9, 10 and 11, possessing 1013, 1048 and 1037 mm. of average fork length respectively and taken in southern summer, correspond to the "matured" or "spawning" groups. Accordingly, the differences disclosed among Samples 7, 9, 10 and 11 seem to be attributed to the differences in ecological status of the samples; supposing that all of them belonged to a common stock, i.e., southern Atlantic stock.

Sample 10 shows smaller values in adjusted means, in all characters, than that for Samples 9 and 11 (see Figures 1 and 4) and is different from the

* Note: according to UEYANAGI (1955) and OTSU et al (1959), 90 cm. is the size at which albacore are believed to reach sexual maturity.

latter two samples. Excepting Sample 10 which is from the South Equator Current, Samples 7, 9 and 11 show relatively larger values in adjusted means in every characters than do the northern Atlantic samples.

Among the 7 samples from the northern Atlantic (i. e., Samples 0, 1, 2, 3, 5, 6 and 8; putting Sample 4 aside), as shown in Figure 4, no serious differences in the adjusted means of the 6 characters are noted. Yet, the results of tests on the values of generalized distance function showing the dissimilarity among samples are rather complicated, as shown in Table 10. Being taken from the same waters in the same season and having no significant difference among them, it appears that Samples 1 and 2 and Samples 3 and 5 display high-reproducibility in morphometirc measurements. On the pairs of samples taken from different waters (both in the same and different seasons) and showing no significant difference between them (i. e., Samples 0 and 1; 2 and 8; 0 and 5; 1 and 3; 1 and 5; 1 and 6; 2 and 3; 3 and 8; 6 and 8; and 1 and 8), it seems that the results of tests imply that they belong to a common "stock" distributed or migrating in an wild range of the north Atlantic. On the other hand, for the pairs of samples taken from different waters (both in the same and difierent seasons) and showing significant difference between them (i. e., Samples 0 and 2; 0 and 3; 0 and 6; 0 and 8; 2 and 5; 2 and 6; 3 and 6; 5 and 6; and 5 and 8), we are tempted to consider it as an evidence of heterogeneity among samples.

There are two possible explanations we can think about for the intricate relationship among the northern Atlantic samples. The first one is the same as that for explaining the relationship among the southern Atlantic samples, viz., the heterogeneity disclosed among the northern Atlantic samples is due to the different ecological status of samples, too; if the northern Atlantic samples do belong to a common "stock". And, the second explanation we are thinking about for the intricate relationship among the northern Atlantic samples is in the light of the views of KOTO and SUDA (1968). On the distributions of albacores in the Atlantic Ocean, KOTO and SUDA (1968) suggested, in addition to that referred to before, that there are possible migrations of feeding groups and spawning groups between the northern and southern Atlantic in the directions as shown by thick arrows in Figure 7. If the views of KOTO and SUDA (1968) are true here again, then the migrations of albacores between the northern and southern Atlantic can be considered as one of the factors making the relationship among the northern Atlantic samples rather complicated. Considering the oceanographic structure and currents in the Atlantic, the suggestions is not absolutely invalid. Benguela current, the most outstanding current of the southern Atlantic, which flows north along the coast of Africa, leaves the coast toward the Equator and continues as the northern of the northern portion of the South Equatorial Current. And part of the South Equatorial Current crosses the Equator continuing into the northern Atlantic, as far as into the Caribbean Sea, while the other part turns to the left and flows south. In fact, as shown in Table 10, the results we obtained reveal that there is no difference between Sample 9, from Brazil Current, and Samples 1 and 2, both from the Caribbean Sea.

Some discussion on statistical procedures used for the present study is needed. First, as shown in Figure 5, the numbers of measurements of individual character within sample are not the same in some cases: and in calculating the variance-ratio of D^2 value by FISHER's formula (see Section V (3) and APPENDIX A), we were obliged to take the largest number of measurements as for the sample size. Next, as described in Section VI (3), the assumptions required for applying the method of genrealized distance function analysis have not been verified thoroughly for all of the pairs of samples. However, further consideration on the possible effects of these problems on the results of tests are beyond us.

Following the discussions on statistical procedures, we have to take up the problems concerning the data used. The first problem is of the sampling procedure employed. As described in Sections III and IV, sampling has been carried out on the fish landed in ports or markets in Japan, and hence it was impossible to obtain the desired samples of fish caught in the desired waters and time. The sample sizes, varying from 20 to 55, are rather small for a morphometric sample; and so we have no confidence that the sample used in this study are indeed representative of the groups of fish from which they were drawn; although every possible means having been used for this purpose. Besides, the sex of specimens are all unknown. SCHAEFER (1948), KUROGANE (1960) and ISHII (1965) all reported that there is no sexual differences in morphometric measurements of albacore. But, SHOMURA et al (1955), SUDA (1956) and OTSU et al (1959) pointed out, that unbalanced sex-ratio has been noted among larger albacores. SUDA (1956) suggested that the unequal sex-ratio is due to the behavior of the males showing an inclination to gather in regions where and when the sexual activities are high; while OTSU et al (1959) stated the phenomenon of unequal sex-ratio is primarily due to the differential growth, with differential mortality or differential availability playing a possible secondary role. In either case, the unequal sex-ratio of larger albacore seems to be definite and its possible relations with the morphometric differences that exist between samples of different ecological status are worth reconsidering.

The final problem to be considered is the possible relation of the southern Atlantic "stock" with that of the Indian Ocean. If this point is made clear and at the same time if the problem of the relationship between the northern Atlantic long-line albacore fishery and the Bay of Biscay pole and line albacore fishery is solved, then the whole aspect about the Atlantic albacore stocks will be clarified. For this purpose, as a matter of course, the approach by those studies through various fields besides morphometric analysis, e. g., serological, biochemical or tagging experiments, are all indispensable for gathering fundamental biological information about albacores.

Table 11. Regression statistics of various characters on fork length of the Atlantic yellowfin. M. F. L.: mean value of fork length; M. CHA.: mean value of character: b: regression coefficient; a: intercept; r: correlation coefficient; $\sqrt{V_{y \cdot x}}$: standard deviation from regression; $C. V.$: coefficient of variation.

Head length

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C. V.$
0	1378 mm	342 mm	0. 2071	57. 4	0. 8851	5. 2488	1. 53%
1	1278	321	0. 2292	28. 4	0. 9925	5. 1847	1. 61
2	991	268	0. 2244	46. 5	0. 9838	5. 2628	1. 96
3	1189	306	0. 2074	60. 1	0. 9924	4. 6769	1. 52
4	1273	326	0. 2218	44. 0	0. 9868	4. 9903	1. 53
5	1195	307	0. 2044	63. 6	0. 9903	6. 6246	2. 15
6	1325	337	0. 2427	15. 4	0. 9364	6. 7129	1. 99
7	1135	297	0. 2222	45. 5	0. 9892	4. 7889	1. 61
8	1304	329	0. 2101	55. 6	0. 9823	5. 4238	1. 65
9	1205	307	0. 2115	52. 9	0. 9871	4. 3462	1. 41

Snout to pectoral

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C. V.$
0	1382	349	0. 1690	11. 6	0. 7913	6. 5085	1. 86
1	1224	311	0. 2317	27. 4	0. 9940	5. 2978	1. 70
2	991	269	0. 2188	53. 1	0. 9819	5. 4302	2. 01
3	1135	305	0. 2020	65. 6	0. 9908	4. 9821	1. 63
4	1273	326	0. 2133	54. 7	0. 9843	5. 2505	1. 61
5	1195	308	0. 2076	59. 9	0. 9823	9. 1682	2. 98
6	1325	336	0. 2330	27. 3	0. 9201	7. 3242	2. 18
7	1146	302	0. 2110	60. 9	0. 9757	6. 8766	2. 27
8	1304	331	0. 9060	62. 9	0. 9800	5. 6696	1. 71
9	1205	209	0. 2078	59. 4	0. 9768	5. 7691	1. 86

VII. RESULTS OF ANALYSIS FOR YELLOWFIN TUNA

The procedure of analysis employed for yellowfin samples are entirely the same as that for albacore samples. Here we just mention the results obtained.

(1). Regressions of Characters on Fork Length

The regression statistics of characters on fork length are listed in Table

11. The linear relations between character and fork length are all highly significant, and most of the values of coefficient of variation are in the range of from 1.0 to 2.0%. The reliability of measurements is regarded as acceptable.

Table 11. ...continued.

Snout to first dorsal

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	1379	368	0.2222	61.9	0.8043	8.1058	2.20
1	1278	346	0.2245	59.5	0.9809	8.1723	2.34
2	991	286	0.2282	60.0	0.9868	4.8228	1.69
3	1185	322	0.2427	34.6	0.9898	6.2955	1.95
4	1273	348	0.2485	35.2	0.9832	6.2769	1.80
5	1195	328	0.2315	52.2	0.9899	7.6580	2.33
6	1325	361	0.2211	68.7	0.8672	9.3706	2.59
7	1146	324	0.2281	62.8	0.9786	6.9614	2.15
8	1304	353	0.2266	58.0	0.9743	7.1028	2.01
9	1205	327	0.2402	37.8	0.9774	6.5805	2.01

Snout to second dorsal

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	1385	681	0.2958	271.9	0.8652	7.4599	1.09
1	1278	643	0.4479	71.1	0.9964	8.7804	1.36
2	996	517	0.4567	62.7	0.9876	8.3689	1.62
3	1202	603	0.4556	56.1	0.9963	7.3039	1.22
4	1273	643	0.4530	67.1	0.9913	8.2769	1.29
5	1151	583	0.4495	66.1	0.9962	9.3270	1.60
6	1316	665	0.4759	39.4	0.9756	9.2289	1.39
7	1149	591	0.4574	65.6	0.9905	9.3670	1.58
8	1304	654	0.4479	70.0	0.9934	6.8662	1.05
0	1205	602	0.4006	120.2	0.9896	7.3592	1.22

(2). **Character-by-Character Comparison of Samples—Covariance Analysis**

Listed in Table 12 are the results of tests of covariance analysis applied to the 10 samples in all. Significant differences in the regression coefficients among samples are displayed for those characters: **H. L.**, **S.-II.** and **S.-V.** And, all of the 6 characters have significant difference in the adjusted means among samples. The heterogeneity among yellowfin samples appears to be more remarkable than that among albacore samples.

The results of covariance analysis for pairs of samples are shown in Table 13. Samples 0, 9 and 1 from the waters off Washington, off Cape Verde Islands and the Caribbean Sea, respectively, are all showing significant differences in at least 2 characters with all the other samples which are mostly concentrated in the Equatorial waters (Figure 2). Among those samples from Equatorial waters, there is no significant difference on any character between Samples 4 and 5 and Samples 5 and 8, respectively (all in the west side); and the same can be found between Samples 2 and 6 (all in the east side). Samples 2 and 6

Table 11. ···continued.

Snout to ventral

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	1375	397	0.2651	32.8	0.6957	11.6434	2.93
1	1278	365	0.2794	8.0	0.9761	11.4239	3.13
2	991	306	0.2309	77.9	0.9719	7.1951	2.35
3	1185	349	0.2273	80.1	0.9790	8.5296	2.44
4	1273	367	0.2220	84.8	0.9649	8.2985	2.26
5	1196	352	0.2293	78.8	0.9839	9.6455	2.73
6	1325	381	0.2948	9.2	0.9174	9.4413	2.48
7	1146	343	0.2560	50.0	0.9467	12.6470	3.68
8	1304	377	0.2253	83.3	0.9706	7.6571	2.01
9	1205	350	0.2262	77.9	0.9774	6.1904	1.77

Snout to anal

Sample number	M. F. L.	M. CHA.	b	a	r	$\sqrt{V_{y \cdot x}}$	$C.V.$
0	1393	764	0.3729	245.1	0.7822	16.0348	2.10
1	1285	706	0.4796	90.5	0.9797	16.5447	2.34
2	992	572	0.4895	86.7	0.9866	9.2251	1.61
3	1194	666	0.5016	68.1	0.9958	8.5950	1.27
4	1273	710	0.4828	95.9	0.9877	10.4912	1.47
5	1187	665	0.4881	86.2	0.9948	12.6061	1.89
6	1325	730	0.4502	133.3	0.9175	14.4057	1.97
7	1146	650	0.4888	89.6	0.9916	9.2731	1.43
8	1304	719	0.4981	69.3	0.9967	5.4493	0.76
9	1205	669	0.4945	73.5	0.9920	7.9837	1.19

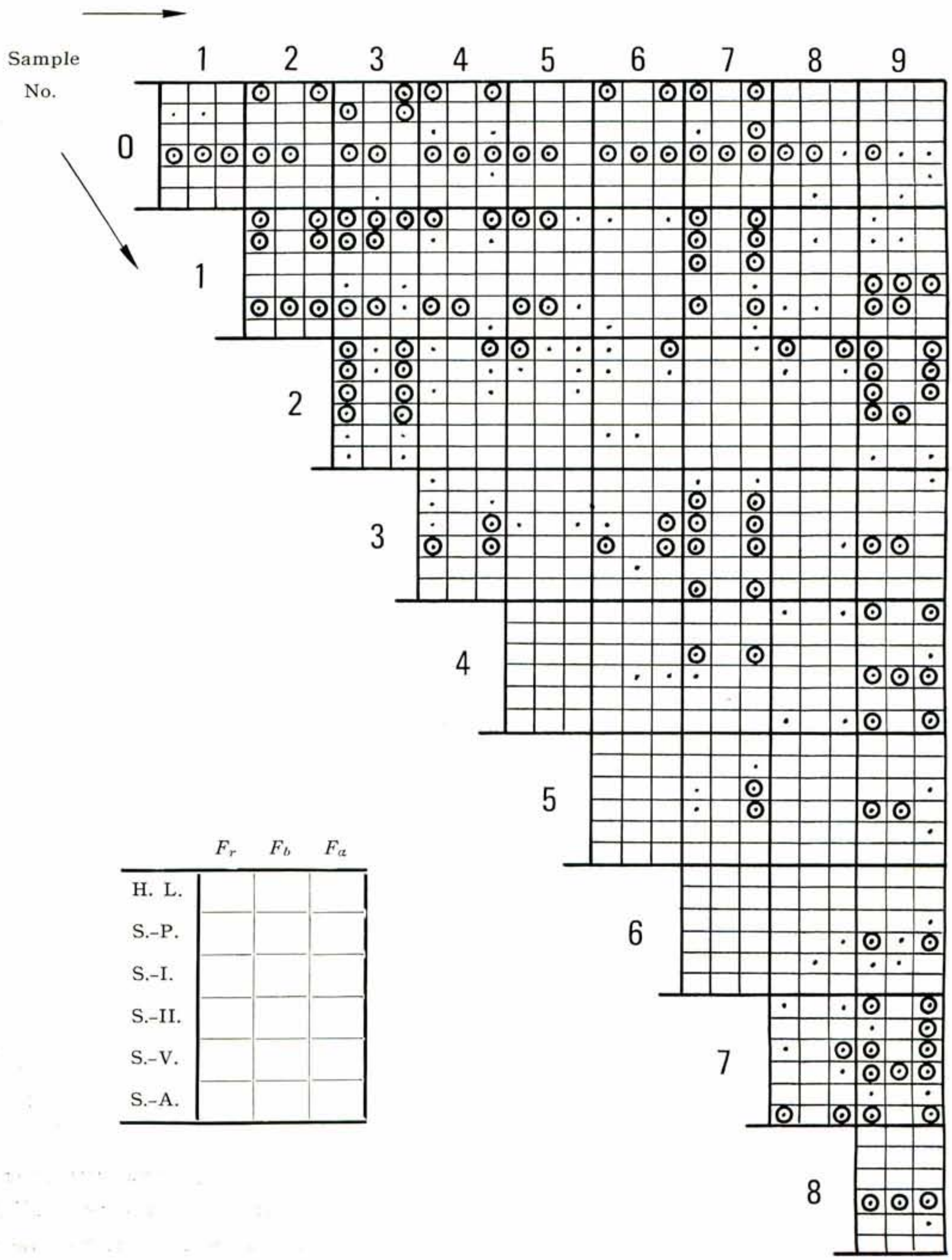
Table 12. Covariance analysis for yellowfin samples from the Atlantic Ocean· F_r, F_b and F_a are the variance-ratios to test the significance of the differences of regression line, regression coefficient and adjusted mean respectively.

* : significant at 5% level; **: significant at 1% level.

	H. L.	S.-P.	S.-I.	S.-II.	S.-V.	S.-A
F_r	4.95**	2.93**	4.85**	6.34**	3.03**	1.85*
F_b	2.26*	1.68	0.85	3.38**	2.93**	1.04
F_a	7.36**	4.06**	8.90**	8.52**	2.93**	2.65*

both from the Gulf of Guinea, but taken in different seasons, have significant differences in 3 characters between them. Sample 3 seems to be very similar to Samples 5 and 8; and Sample 5 in the west has no difference from Sample 6 in the east.

Table 13. Covariance analysis for pairs of yellowfin samples. F_r, F_b F_a are the variance ratios to test the significance of the differences of regression line, regression coefficient and adjusted mean respectively.



• : Significant at 5% level ⊙ : Significant at 1% level

The adjusted means with its 95% confidence interval of each character of the samples are estimated as shown in Table 14 and Figure 8. For the 3 characters that are significant in difference (i. e., **H. L.**, **S.-II**, and **S.-V.**) in the regres-

Table 14. Adjusted mean values of various characters of the Atlantic yellowfin tuna samples, with 95% confidence limits in the parentheses, adjusted for the fork length of 1211.4 mm.

Sample No.	H. L.	S.-P.	S.-I.	S.-II.	S.-V.	S.-A.
0	308.4 (7.01)	313.6 (2.57)	329.1 (2.64)	630.3 (15.1)	354.0 (19.04)	675.5 (5.35)
1	306.1 (2.41)	308.4 (3.24)	330.8 (2.85)	2613.6 (4.16)	346.5 (5.30)	670.6 (5.13)
2	318.4 (3.34)	316.2 (2.19)	337.9 (2.44)	616.0 (7.08)	357.6 (4.60)	680.0 (4.20)
3	311.4 (1.28)	310.6 (1.65)	328.6 (1.86)	608.0 (2.34)	355.5 (2.36)	675.6 (2.91)
4	312.8 (2.06)	313.3 (2.23)	333.7 (2.50)	615.9 (3.41)	353.8 (3.42)	680.3 (3.87)
5	311.3 (2.96)	311.5 (2.58)	332.8 (2.89)	610.7 (5.00)	356.6 (4.31)	677.6 (4.96)
6	309.4 (6.42)	312.2 (2.91)	335.1 (3.26)	616.0 (9.34)	347.9 (9.03)	674.1 (5.06)
7	314.8 (2.38)	316.5 (2.45)	339.6 (2.74)	619.7 (4.33)	360.2 (5.78)	682.0 (4.23)
8	310.1 (3.15)	312.1 (2.75)	331.8 (3.08)	612.8 (3.99)	356.3 (4.39)	673.4 (4.77)
9	309.2 (1.63)	311.2 (2.21)	328.8 (2.48)	605.5 (2.76)	352.0 (2.32)	672.5 (3.83)

sion coefficients among samples, the individual regression coefficient of each sample is used; and for the 3 characters that are not significant in difference in the regression coefficients among samples, the common regression coefficients are estimated and used.

On the 3 samples of west Equatorial waters (i. e., Samples 4, 5 and 8) and the 3 samples of east Equatorial watrs (i. e., Samples 7, 2 and 6), there is a common tendency to show greater values for the sample from the north and the smaller values for the sample in the south. Considering the tendency here observed with the relations recognized in covariance analysis for pairs of samples, a so-called "progressive difference in morphological characters" in the direction of north and south appears to be present among yellowfin samples from the Equatorial waters.

(3). Multiple Character Comparison of Samples — Generalized Distance Function Analysis

As it has been done in the case of the albacore samples, all of the measurements are adjuste for the values of same fork-length of 1211.4 mm. (i. e., the grand mean value of the fork length of yellowfin specimens in the present study), using the individual or common regression coefficients in a manner that was employed to the estimation of adjusted means of characters, in the previous section.

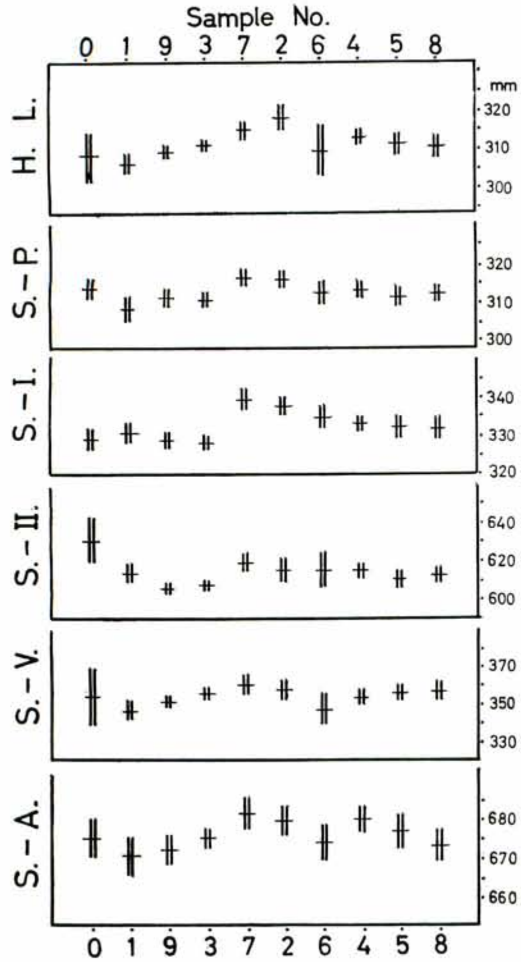


Fig. 8. Adjusted mean values of various characters of the Atlantic yellowfin tuna samples, with 95% confidence limits, adjusted for the fork length of 1211.4 mm.

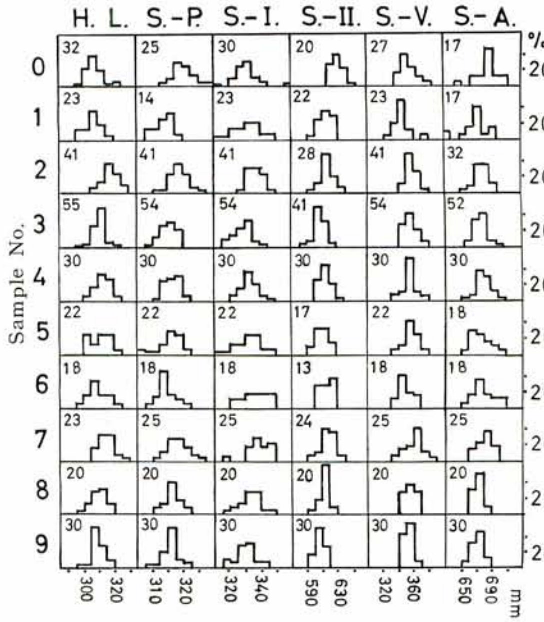


Fig. 9. Frequency distributions of characters of yellowfin adjusted for the same fork length (1211.4 mm.). Figures in the body of graph indicate sample size.

The frequency distributions of adjusted measurements of each sample are shown in Figure 9. As it has been the case for the albacore samples, no radical departure from normality is evident for the yellowfin samples, too.

Shown in Table 15 are the results of F-test for the values of variance-ratio of characters between samples. 48 values of variance-ratio, out of a total of 270 values (i. e., the number of combinations of samples times the number of characters, ${}_{10}C_2 \times 6$) are significant. The items of significant variance-ratios are: **H. L.**, 2; **S.-P.**, 6; **S.-I.**, 6; **S.-II.**, 0; **S.-V.**, 10; and **S.-A.**, 22.

The calculated correlation coefficients between all possible pairs of characters in each sample are tested on the significance and, then, converted to "Z" values for the χ^2 test on the common correlation among samples. As shown in

Table 15. Results of tests for variance ratio between identical characters of the yellowfin tuna samples.

Sample No.	Character	1	2	3	4	5	6	7	8	9
0	H. L.									
	S.-P.									
	S.-I.		**							
	S.-II.									
	S.-V.		**							**
	S.-A.		*	**				*	**	**
1	H. L.									
	S.-P.									
	S.-I.		**							
	S.-II.									
	S.-V.		*							**
	S.-A.		**	**	*			*	**	**
2	H. L.									
	S.-P.					**				
	S.-I.					*	**	*		
	S.-II.									
	S.-V.							**		
	S.-A.						*		*	
3	H. L.									
	S.-P.					**	*			
	S.-I.						*			
	S.-II.									
	S.-V.							*		
	S.-A.					*	*		*	
4	H. L.									
	S.-P.					**				
	S.-I.									
	S.-II.									
	S.-V.							*		
	S.-A.								**	
5	H. L.									*
	S.-P.								*	*
	S.-I.									
	S.-II.									
	S.-V.									*
	S.-A.								**	*
6	H. L.									*
	S.-P.									
	S.-I.									
	S.-II.									
	S.-V.									
	S.-A.								**	**
7	H. L.									
	S.-P.									
	S.-I.									
	S.-II.									
	S.-V.								*	**
	S.-A.								*	
8	H. L.									
	S.-P.									
	S.-I.									
	S.-II.									
	S.-V.									
	S.-A.									

H. L.
S.-P.
S.-I.
S.-II.
S.-V.
S.-A.

*: Significant at 5% level
**: Significant at 1% level

Table 16, out of the 150 values of correlation coefficients (i. e., the number of combinations of characters times the number of samples, ${}_6C_2 \times 10$) 61 values show seignificant differences. The results of χ^2 test on the common correlations are significant in the pairs: **H. L.** and **S.-P.**; **H. L.** and **S.-A.**; **S-P.** and **S.-I.**; **S.-P.** and **S.-A.**; and **S.-I.** and **S.-II.**; each at 5% level.

Table 16. Results of common correlation tests for the yellowfin tuna samples. *: significant at 5% level; **: significant at 1% level.

Sample No.		0	1	2	3	4	5	6	7	8	9	χ^2 Test
H. L.	S.-P.	**	**	**	**	**	**	**	**	**	**	*
H. L.	S.-I.	*			**	*	**			*		
H. L.	S-II.			*	*		*			*		
H. L.	S.-V.			**		*			**	*	**	
H. L.	S.-A.		*	**			**		**	*		*
S.-P.	S.-I.	*			*	**	**			**		*
S.-P.	S.-II.				*							
S.-P.	S.-V.		**	**		**	**		**		**	
S.-.P	S·-A.			**			**		*	*		*
S.-I,	S.-II.				**	**	**		**		*	*
S.-I.	S.-V.							**				
S.-I.	S.-A.				**							
S.-II.	S.-V.		*									
S.-II.	S.-A.			**		**					*	
S.-V.	S.-A.		*	**	**		*		*		*	

As described above, the assumptions required for applying the generalized distance function analysis have not been varified perfectly; as in the case of the albacore samples; yet, it is apparent that for the most pairt of samples the assumptions are provisionally acceptable. The D^2 values for all pairs of samples are calculated in a manner similar to that for the albacore samples, and tested on the significance of variance-ratio (see Appendix B). The results are listed in Tables 17 and 18.

Considering the information obtained in previous section by covariance analysis, first we investigated the relations among the samples from the Equatorial waters. No significant difference is found to exist in the pairs of Samples; 4 and 5; 5 and 8; 5 and 7; 3 and 5; 6 and 7; 6 and 4; 6 and 1, respectively; but some difference is observed between the following Samples: 4 and 8; 3 and 8; and 3 and 6. Thus, it is clear that there are no significant differences between some pairs of samples that are far apart from each other; whereas some other pairs of samples (e. g., Samples 2 and 6; 3 and 7; and 3 and 9) taken from near by areas in different seasons do show clear difference. Based on the fact that

Table 17. D^2 and the results of tests for the variance ratio between yellowfin tuna samples, using characters arranged in the order of its contribution to the value of D^2. *: significant at 5 % level; **: significant at 1% level; # 0, 1, 2, 3, 4 and 5 stand for character H. L., S.-P., S.-I., S.-II., S.-V., and S.-A., respectively.

Combination of Samples	Characters						D^2	Variance Ratio
0—1	1#	3	5	4	0	2	15.1470	30.5954**
0—2	0	3	5	2	1	4	31.8444	88.6707**
0—3	3	5	1	0	2	4	29.4763	93.5371**
0—4	3	1	5	0	2	4	18.4504	43.6463**
0—5	3	5	1	0	4	2	35.9273	70.5576**
0—6	3	1	5	2	4	0	17.2966	29.7502**
0—7	0	3	5	2	1	4	22.9475	48.7979**
0—8	3	5	1	0	4	2	25.5450	47.1612**
0—9	3	5	1	2	4	0	25.1308	59.4494**
1—2	0	1	4	2	5	3	7.5738	17.0994**
1—3	0	4	3	1	2	5	3.0282	7.6468**
1—4	0	1	4	5	3	2	1.9578	3.8316**
1—5	4	0	1	5	3	2	3.4672	5.7424**
1—6	2	0	5	3	1	4	1.2848	1.8851
1—7	0	1	4	2	5	3	4.6091	8.2019**
1—8	4	1	0	2	3	5	1.8295	2.8641*
1—9	3	0	4	1	2	5	1.7609	3.4463*
2—3	1	0	2	3	5	4	3.6171	13.4075**
2—4	0	1	2	4	5	3	2.0601	5.5172**
2—5	0	1	2	3	5	4	2.3550	5.1589**
2—6	0	1	4	5	2	3	3.7173	7.0699**
2—7	0	2	3	4	1	5	2.0195	4.8189**
2—8	0	1	5	2	3	4	4.0333	8.2707**
2—9	0	2	3	1	5	4	5.5397	14.8361**
3—4	3	2	5	1	0	4	1.5352	4.6676**
3—5	2	3	5	1	4	0	0.5926	1.4486
3—6	2	3	4	0	5	1	3.6082	7.5812**
3—7	2	3	1	0	5	4	3.4155	9.1570**
3—8	3	2	1	5	0	4	1.9914	4.5344**
3—9	0	4	5	3	1	2	1.4670	4.4603**
4—5	3	4	5	0	1	2	1.2878	2.4517
4—6	4	0	1	2	5	3	1.4765	2.4675
4—7	2	4	1	3	0	5	1.5472	3.1846*
4—8	5	0	3	4	1	2	1.6705	2.9929*

the fishing grounds of the Atlantic yellowfin are distributed widely along the Equatorial waters to the east and west of the Atlantic, we are convinced that the morphological differences among samples lined in an east-west direction are not as remarkable as that among samples lined in the north-south direction.

Table 17. …continued.

Combination of Samples	Characters						D^2	Variance Ratio
4—9	3	5	0	2	1	4	2.1404	4.8897**
5—6	4	3	2	0	1	5	2.2805	3.2677*
5—7	3	2	1	0	5	4	1.1368	1.9708
5—8	5	3	0	1	4	2	0.8673	1.3250
5—9	3	4	2	5	0	1	1.8637	3.5481*
6—7	4	1	0	3	2	5	1.5897	2.4346
6—8	4	5	2	1	3	0	3.0541	4.1524**
6—9	ε	2	5	4	1	0	4.1374	6.9144**
7—8	5	2	0	3	1	4	1.9272	3.1539*
7—9	3	2	0	5	1	4	4.9661	10.2217**
8—9	3	4	2	1	0	5	2.1392	3.8328**

Table 18. Results of tests for the variance-ratio of D^2 values between yellowfin samples.

★ significant at 5% level; ★★ significant at 1% level.

Sample number	1	2	3	4	5	6	7	8	9
0	★★	★★	★★	★★	★★	★★	★★	★★	★★
1		★★	★★	★★	★★		★★	★	★
2			★★	★★	★★	★★	★★	★★	★★
3				★★		★★	★★	★★	★★
4							★	★	★★
5						★			★
6								★★	★★
7								★	★★
8									★★

(4). Discussion

Following the opinion of NAKAMURA (1965), HAYASHI (1966) suggested that it is advisable to consider the yellowfins in the Equatorial Atlantic waters as belonging to a unit stock; for studying the dynamics of Atlantic yellowfins on which long-line fishery is operated. SHIOHAMA et al (1965) described that the major fishing grounds of Atlantic yellowfin long-line fishery are concentrated in the Ivory Coast, Gulf of Guinea and Benguela from February to April; and gradually shifts northward from May, extending to the west, throughout the Equatorial region from Africa to south America. Seasonal migrations of yellowfins in the north and south are apparent. UEYANAGI (1966) added that Gulf of Guinea seems to be abundant in younger yellowfins, on which African surface fishery is based (LEGUEN et al, 1965; HAYASHI, 1966).

Based on the results of analysis on the Japanese long-line catch statistics by SHIOHAMA et al (1965), WISE et al (1966) stated that (1): cycilc changes of monthly catch rates are apparent both in the eastern Atlantic (including Bunguela, Gulf of Guinea, Cape Verde and North Oceanic) and western Atlantic (including Bahia area, Guianas and Caribbean), respectively; and that (2): the western tropical Atlantic yellowfin is separated from the eastern Atlantic yellowfin.

So far as the fact (1) is concerned, there seems to be no inconsistency in itself with the facts we described in Sections VII (2) and (3), i. e., character gradients exist in every characters of samples that are lined in a north-south direction and dissimilarities among them are of significance; both for the three samples in the eastern Atlantic (i. e., Samples 7, 2 and 6) and the three samples in the western Atlantic (i. e., Samples 4, 5 and 8), respectively. The fact that WISE et al disclosed is of the phenomenon with regard to the fishing statistics, while that we pointed out is some reflections on the difference in morphometric measurements.

As to the point (2) suggested by WISE et al, we find that the morphometrical differences existing among samples in an east and west direction are not as remakable as that present among samples in a north-south direction as described in Section VII.

Detailed discussions on the data collected and the statistical procdure employed has been presented in Section VI (4) in connection with albacores and hence repetition is avoided.

VIII. SUMMARY AND CONCLUSIONS

1. Six morphometric characters (i. e., head length and distances from snout to insertion of pectoral, first and second dorsal, ventral and anal fin) are compared among 12 samples of Atlantic albacores and 10 samples of Atlantic yellowfins, respectively.
2. Linear relationships between characters and fork length are all significant, and most of the values of coefficient of variation are in the range of from 1.0 to 3.0%. The reliability of measurements is acceptable.

For albacores:

3. The result of covariance analysis applied to the 12 albacore samples in all shows no significant difference in the regression coefficients of every character. But, the adjusted means except for one character, i. e., snout to insertion second dorsal, show highly significant differences.

4. The results of covariance analysis for pairs of albacore samples show that Sample 4 from the waters off northeast of Canaries Islands, are different from the other samples; including both from the north and south Atlantic.
5. The adjusted means of each individual character of samples, with its 95% confidence interval, are calculated on the same fork length of 976.4 mm., using the common regression coefficients estimated on the whole samples.
6. Among the four samples from along the coast of Africa, i. e., Samples 4, 5, 3 and 7, an apparent character gradient can be seen on most of the characters.
7. Sample 4 in the northern hemisphere have the smallest values in 5 characters; Sample 7 in the southern hemisphere have the largest values in all characters.
8. A similar trend is present among the samples from the coast of south America, i. e., Samples 10, 11 and 9.
9. As a whole, Samples from southern Atlantic seem to be larger in values of each character than do the northern Atlantic samples.
10. For applying the method of generalized distance function analysis, all of the measurements are adjusted for the values of same fork length of 976.4 mm., using the common regression coefficients.
11. No radical departure from normality is evident among the frequency distributions of adjusted measurements of each sample.
12. Test on the common variance between identical character of the samples disclose that out of the 396 values of variance-ratio, 58 values show significant differences.
13. The values of correlation coefficients of all pairs of characters are calculated and tested on the significance. 66 values of correlation coefficients out of a total 180 values are significant.
14. The correlation coefficients are then converted to FISHER's "Z" values by tables, and χ^2 test is applied for the test on the common correlations among samples. The results are significant in the pairs: head length and snout to insertion ventral; head length and snout to insertion pectoral; and snout to insertion pectoral and snout to insertion anal.
15. The assumptions required for applying the technique of generalized distance function analysis are provisionally verified for most pairs of samples; and the D^2 values for all pairs of samples are calculated and tested on the significance of variance-ratio, by the formula of FISHER (1936).
16. The results of tests on the significance of variance-ratio of D^2 values reveal that Sample 4 is significantly different from all other samples.
17. Having no significant difference between them, Samples 1 and 2 (both from Caribbean Sea) and Samples 3 and 5 (both from the waters off south of Cape Verde Islands) display high-reproducibility in morphometric measurements.

18. On the pairs of samples taken from different waters in the northern Atlatinc and showing no significant difference between them, the results of tests imply that they belong to a common "stock" distributing or migrating in wide range of the northern Atlantic.
19. On the pairs of samples taken from different areas in the northern Atlantic and showing significant difference between them, the results of tests illustrate the heterogeneity of the samples.
20. The heterogeneity disclosed among the northern Atlantic samples as well as that among the southern Atlantic samples, seems to be attributed to the different ecological status of samples.
21. Summarizing the facts described above and considering the distribution of fishing grounds and currents in the Atlantic as well as the information on the sexual-activities and length composition of Atlantic albacores, it seems that albacores in the Atlantic belong to at least two different "stocks" showing a time lag of about half of a calender year in life cycle.
22. Two different "stocks" correspond with the Northern Atlantic and Southern Atlantic "stocks"; and Sample 4 does not seem to belog to either.

For yellowfins:

23. Covariance analysis applied to the 10 yellowfin samples in all reveals the existence of significant differences in the regression coefficients among samples for those characters: head length, snout to insertion second dorsal and snout to insertion ventral. And, all of the 6 characters have significant difference in the adjusted means among samples.
24. The heterogeneity among yellowfin samples appears to be more remarkable than that among albacore samples.
25. The adjusted means of each individual character, with its 95% confidence interval, are calculated on the same fork length of 1211.4 mm., using the common regression coefficients estimated on the whole samples for the three characters, viz., snout to insertion pectoral, snout to insertion first dorsal and snout to insertion anal; and using the individual regression coefficient for the other three characters.
26. A so-called "progressive difference in morphological characters" in the direction of north-south appears to exist among yellowfin samples from the Equatorial waters, based on the results of covariane analysis for pairs of samples and the character gradient displayed among the samples from the Equatorial waters.
27. For applying the method of generalized distance function analysis, all of the measurements are adjusted for the values of same fork length of 1211.4 mm. The regression coefficient used for each character is the same as that used for estimating its adjusted means.

28. No radical departure from normality are evident among the frequency distributions of adjusted measurements of each sample.
29. Test on the common variance between identical character of the samples disclose that out of the 270 values of variance-ratio 48 values show significantly differences.
30. The values of correlation coefficients of all pairs of characters are calculated and tested on the significance. Out of the 150 values of correlation coefficient, 61 values show significantly differences.
31. The correlation coefficients are then converted to FISHER's "Z" values by tables, and χ^2 test is applied for the test on the common correlations among samples. The results are significant in the case of following pairs of characters: head length and snout to insertion pectoral; head length and snout to insertion anal; snout to insertion pectoral and snout to insertion first dorsal; snout to insertion pectoral and snout to insertion anal; and snout to insertion first dorsal and snout to insertion second dorsal.
32. The assumptions required for applying the method of generalized distance function analysis are provisionally verified for the most pairs of samples; and the D^2 values for all pairs of samples are calculated and tested on the significance of variance-ratio, by the formula of FISHER (1936).
33. The morphological differences among samples lined in an east-west direction are not as remakable as that among samples lined in north-south direction.

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Appendix A. Successive D_i^2 values and the Variance-Ratios for Albacore Samples, with the Characters Arranged in the Order of its Contribution to the value of D_i^2

(Remark)

Tables from C-2 to C-66 omitted, due to space limitations

Procedure for Computation

1. D_i^2 values are given by $D_i^2 = \sum_{i=1}^{6} l_i d_i$, where d_i is the difference between sample means of the i^{th} character with corresponding coefficient l_i.

   The coefficients l_i are obtained by solving the following set of equations:

$$\begin{array}{l} l_1 w_{11} + l_2 w_{12} + l_3 w_{13} + l_4 w_{14} + l_5 w_{15} + l_6 w_{16} = d_1 \\ l_1 w_{21} + l_2 w_{22} + \cdot \quad \cdot \quad \cdot + l_6 w_{26} = d_2 \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ l_1 w_{61} + \cdot \quad \cdot \quad \cdot \quad \cdot + l_6 w_{66} = d_6 \end{array}$$

   w_{ij} is the pooled covariance between the i^{th} and j^{th} characters; estimated from the following equation:

$$(N_a + N_b - 2) w_{ij} = \sum_{k}^{Na} (X_{ika} - X_{ia})(X_{jak} - X_{ja}) + \sum_{b}^{Nk} (X_{ibk} - X_{ib})(X_{jbk} - X_{jb})$$

   where N_a and N_b are the sample sizes, X_{iak} is the value of the i^{th} character for the k^{th} fish from the Sample a, and X_{ia} is the mean value of the i^{th} character for the Sample a.

2. The variance-ratio, F, of D_i^2 value is calculated by FISHER's (1936) formula:

$$F = \frac{N_a N_b (N_a + N_b - C - 1)}{C (N_a + N_b)(N_a + N_b - 2)} D^2$$

   with C and $(N_a + N_b - C - 1)$ as the degrees of freedom; where C is the number of characters.

3. The significance of F value is then determined from the tables of "F"; *: significant at 5% level; **: significant at 1% level.

Table C-1. Successive D_i^2 values for the pair of Sample 0 and 1.

(A). D^2 values for individual character.

character	S.-P.	S.-V.	H. L.	S.-I.	S.-II.	S.-A.
D^2	0.2618	0.0618	0.0187	0.0103	0.0098	0.0023
d	2.9011	2.2731	-0.5910	-0.6420	-0.7437	0.3088
l	0.0902	0.0272	-0.0316	-0.0160	-0.0133	0.0074

(B). Successive D_i^2 values.

Number of characters	l_i						D_i^2
2	0.0851	0.0097					0.2688
3	0.1669	0.0417	-0.2101				0.7032
4	0.1653	0.0490	-0.2291	0.0203			0.7133
5	0.1674	0.0471	-0.2256	0.0247	-0.0113		0.7186
6	1.1935	0.0681	-0.2316	0.0152	0.0074	-0.0664	0.8171

F = 1.5296

Appendix .B Successive D_i^2 values and the Variance-Ratios for Yellowfin Tuna Samples, with the Characters Arranged in the order of its Contribution to the Value of D_i^2

(Remarks)

1. procedure for computation refer to Appendix A
2. tables from D-2 to D-45 omitted, due to space limitations

Table D-1. Successive D_i^2 values for the pair of Sample 0 and 1.

(A). D^2 values for individual character.

Character	S.-P.	S.-II.	S.-A.	S.-V.	H. L.	S.-I.
D^2	4.4554	4.3251	2.6043	0.4456	0.1925	0.0022
d	12.5647	16.5841	25.4567	7.5435	2.2482	-0.3798
l	0.3546	0.2607	0.1023	0.0590	0.0856	-0.0059

(B). Successive D_i^2 values.

Number of characters	l_i						D_i^2
2	0.3781	0.2785					9.3709
3	0.2836	0.3043	0.0837				10.7446
4	0.2840	0.3072	0.0782	0.0135			10.7597
5	0.5616	0.3563	0.1307	-0.0347	-0.5530		14.7894
6	0.5703	0.3630	0.1384	-0.0576	-0.5168	-0.0860	15.1470

F =30.5954**

大西洋水域のビンナガ及び キハダの形態測定学的研究

楊栄宗・能勢幸雄・檜山義夫

大西洋水域のビンナガ12標本及びキハダ10標本について，体長（尾叉長）の他，頭長及び，吻端から胸鰭，第1及び第2背鰭，腹鰭，臀鰭などの各鰭起部までの距離の7形質の測定資料を用い，標本間個々の形質の差異を統計的検定によって，解析するとともに，線型判別函数を用いて，標本間における汎距離（D^2）の計算を行ない，系統群の解析を試みた。

ビンナガ12標本については，解析の結果：(1). 全体として，南半球の各標本の各形質は北半球の標本のそれより大きい，(2). 北半球の標本間及び南半球の標本間にみられる違いは，南北半球間においてみられる違いに比して小さい，及び(3). カナリア諸島東北水域の1標本は，南北半球を含め，その他の各標本と異なった存在である，などのことを明らかにした。これらの結果を，大西洋におけるビンナガ漁場の地理的分布，釣獲率の季節的変化，及び稚仔魚・成熟魚の出現季節及び水域などに関する知見とつきあわせると，大西洋水域のビンナガは，その生活周期に約半年のずれを示す北半球の系統群と南半球の系統群に分けて考えられる。南半球における標本間の異同関係が比較的単純であるのに対し，北半球における標本間の関係が複雑であるのは，南半球の系統群との交流が影響しているのではないかと考える。

キハダについては，赤道水域の標本間にみられる形態の違いは東西方向における違いよりも南北方向にみられる違いの方がより顕著であり，各形質について南小北大の漸進的な傾斜が認められた。なお外部形態からみてビンナガの場合よりも，キハダの地域性が目立つ。