THE USE OF PROBABILITY PAPER FOR THE GRAPHICAL ANALYSIS OF PERCENTAGE COMPOSITIONS OF CHUM SALMON WITH DIFFERENT SCALE CHARACTERISTICS

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By

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Introduction

It is known that the characteristics of the chum salmon scale pattern differ among their river stocks (6). The difference of the scale characteristics is more prominent in the districts such as America-Canada-Southeastern Alaska, Central-Western-Northern Alaska, and Asia, along the northern Pacific. The majority of the chum salmon hatched out in a river are considered to return to the area including their mother stream after growing in the off seas. Therefore, the geographical origin of the chum salmon caught in the high sea areas of the northern Pacific can be distinguished by the difference in their scale characteristics.

The present paper is an attempt to estimate the percentage compositions of the chum salmon with different scale characteristics in the high sea areas of the northern Pacific. The work was carried out at the Pacifie Biological Station, Nanaimo, B. C., Canada and in the Tohoku University, Sendai, Japan.

The writer is indebted to Dr. A. W. H. Needler, Director of the Pacific Biological Station, Nanaimo, B. C., Canada for providing the opportunity of the study. To Drs. R. E. Foerster, M.P. Shepard, W. E. Jhonson, and W. E. Ricker of the Station the writer is grateful for their kind advice. The writer also expresses his sincere thanks to Dr. Ted S. Y. Koo of the Fisheries Research Institute, University of Washington, U. S. A. for his suggestions concerning the problem. To Dr. T. Imai of the Tohoku University, Sendai, Japan the writer express his sincere thanks for his kind suggestions and encouragement. The writer also extends his thanks to Dr. M. Fujinaga, Mr. T. Sone, Mr. K. Yamahira, and Mr. T. Matsushita of the Japanese Fisheries Agency for the necessary arrangements made to complete this work.

Materials and Methods

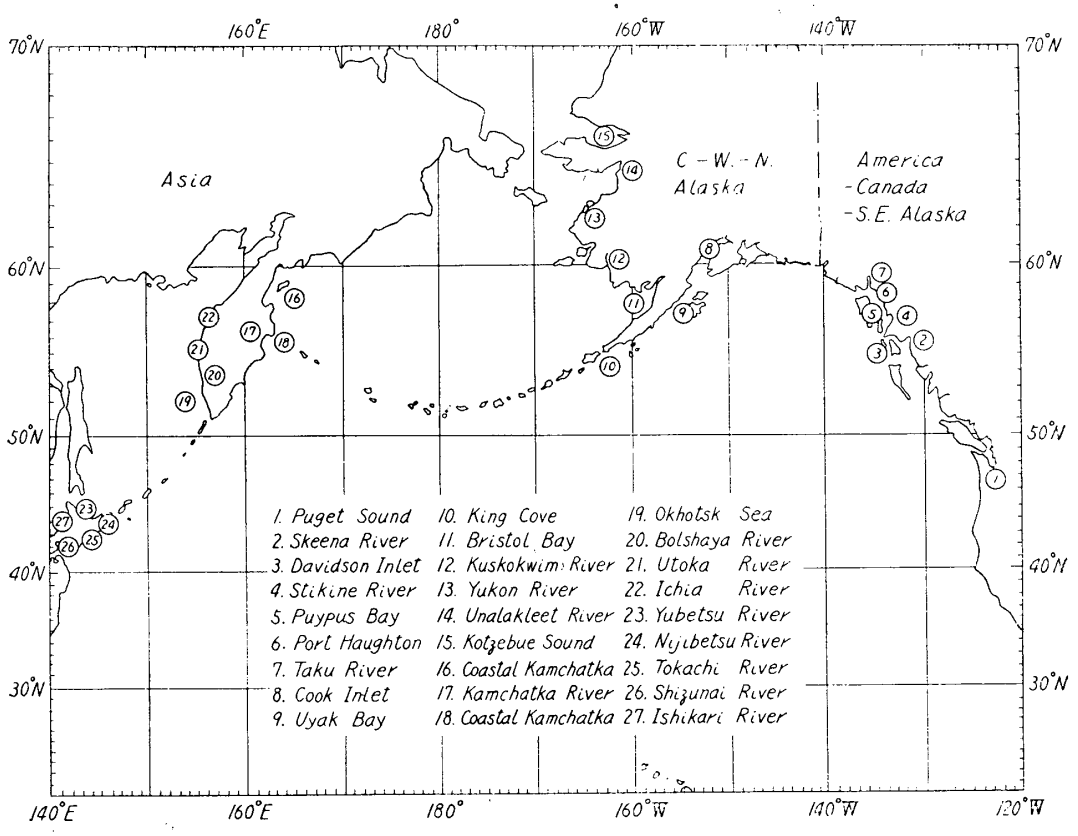
Materials used in the present work were collected by the members of the research groups of the United States of America, Canada, and Japan as a part of the project of the International North Pacific Fisheries Commission. Besides these materials, some samples collected by research workers of the Union of Soviet Socialist Republics were also used in the study.

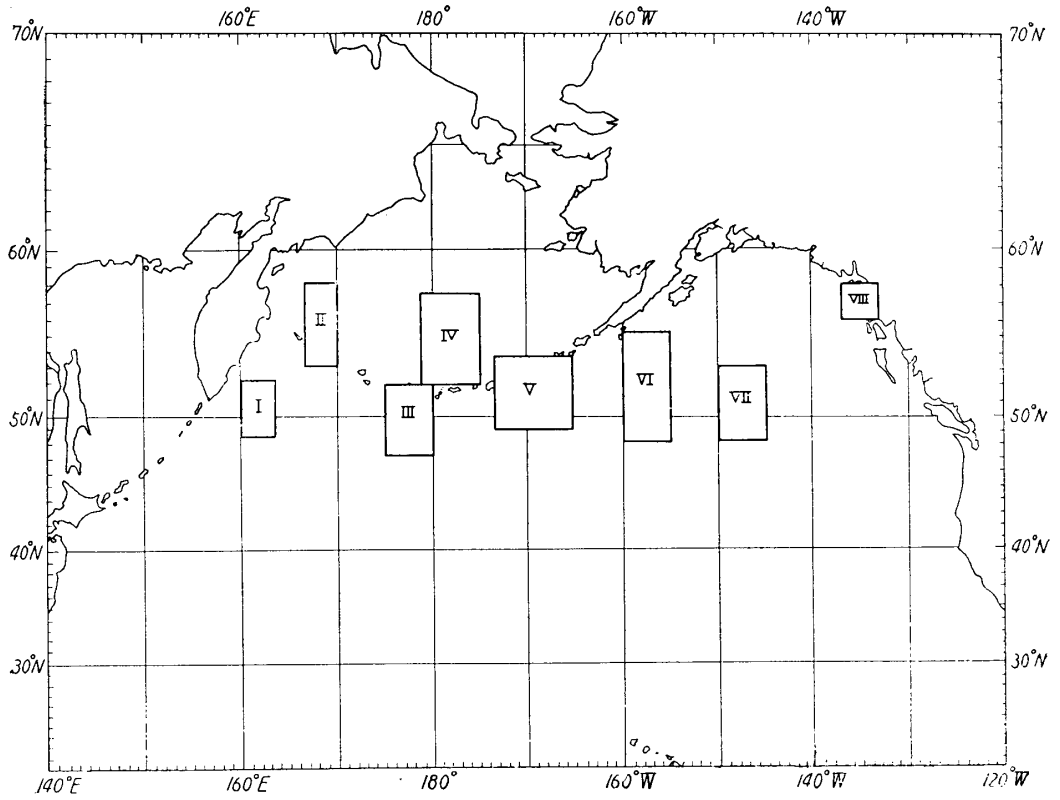
Scales of adult migrants of the chum salmon collected in 23 rivers and inshores along the coasts of the northern Pacific during the season of 1956 were examined. Scales of the fish collected in four rivers of Kamchatka Peninsula in 1957 were also used. Locations of these rivers and inshores and number of fish collected there are shown in the following Map and Table.

Rivers and inshores	No. of fish	Year
1 Puget Sound	68	1956
2 Skeena River	100	1956
3 Davidson Inlet	72	1956
4 Stikine River	100	1956
5 Puypus Bay	85	1956
6 Port Haughton	44	1956
7 Taku River	100	1956
8 Cook Inlet	90	1956
9 Uyak Bay	100	1956
10 King Cove	100	1956
11 Bristol Bay	66	1956
12 Kuskokwin River	17	1956
13 Yukon River	98	1956
14 Unalakleet River	93	1956
15 Kotzebue Sound	100	1956
16 Coastal Kamchatka	50	1956
17 Kamchatka River	56	1957
18 Coastal Kamchatka	86	1956
19 Okhotsk Sea	81	1956
20 Bolshaya River	50	1957
21 Utoka River	50	1957
22 Ichia River	23	1957
23 Yubetsu River	46	1956
24 Nijibetsu River	92	1956
25 Tokachi River	84	1956
26 Sizunai River	100	1956
27 Ishikari River	100	1956

Scales of the chum salmon collected in the high sea areas of the northern Pacific during 1956 were also used. These eight high sea areas where the chum salmon were caught are shown in the following Map.

A scale was obtained from the body section near the lateral line between the dorsal and adipose fins. After being removed from the fish body, the scale was adhered with the sculptured surface upwards to a gummed card and impressed on a cellulose acetate card. The impression was projected on a mm graph paper and the outer contour of each circulus was marked off along the longest antero-lateral axis of the scale. The magnification adopted was 100 times in length.


160°E
180°
160°W
140°W
70°N
60°N
50°N
40°N
30°N
140°E
120°W
Asia
C – W. – N.
Alaska
America
-Canada
-S.E. Alaska
1. Puget Sound
2. Skeena River
3. Davidson Inlet
4. Stikine River
5. Puypus Bay
6. Port Haughton
7. Taku River
8. Cook Inlet
9. Uyak Bay
10. King Cove
11. Bristol Bay
12. Kuskokwim River
13. Yukon River
14. Unalakleet River
15. Kotzebue Sound
16. Coastal Kamchatka
17. Kamchatka River
18. Coastal Kamchatka
19. Okhotsk Sea
20. Bolshaya River
21. Utoka River
22. Ichia River
23. Yubetsu River
24. Nyibetsu River
25. Tokachi River
26. Shizunai River
27. Ishikari River


160°E
180°
160°W
140°W
70°N
60°N
50°N
40°N
30°N
140°E
120°W
I
II
III
IV
V
VI
VII
VIII

In the present work, an average spacing between circuli on the latter half of the first year growth was adopted as a scale characteristic. In the first place, the scales of the adult chum salmon migrants cellected in rivers and inshores were measured and their statistical constants were calculated. Then, the frequency distributions of the scale character of the adult chum salmon caught in the high sea areas were divided into component unimodal frequency distributions by means of Hazen's probability graph paper as suggested by Harding (1) with an aim to find the origins of the fishes.

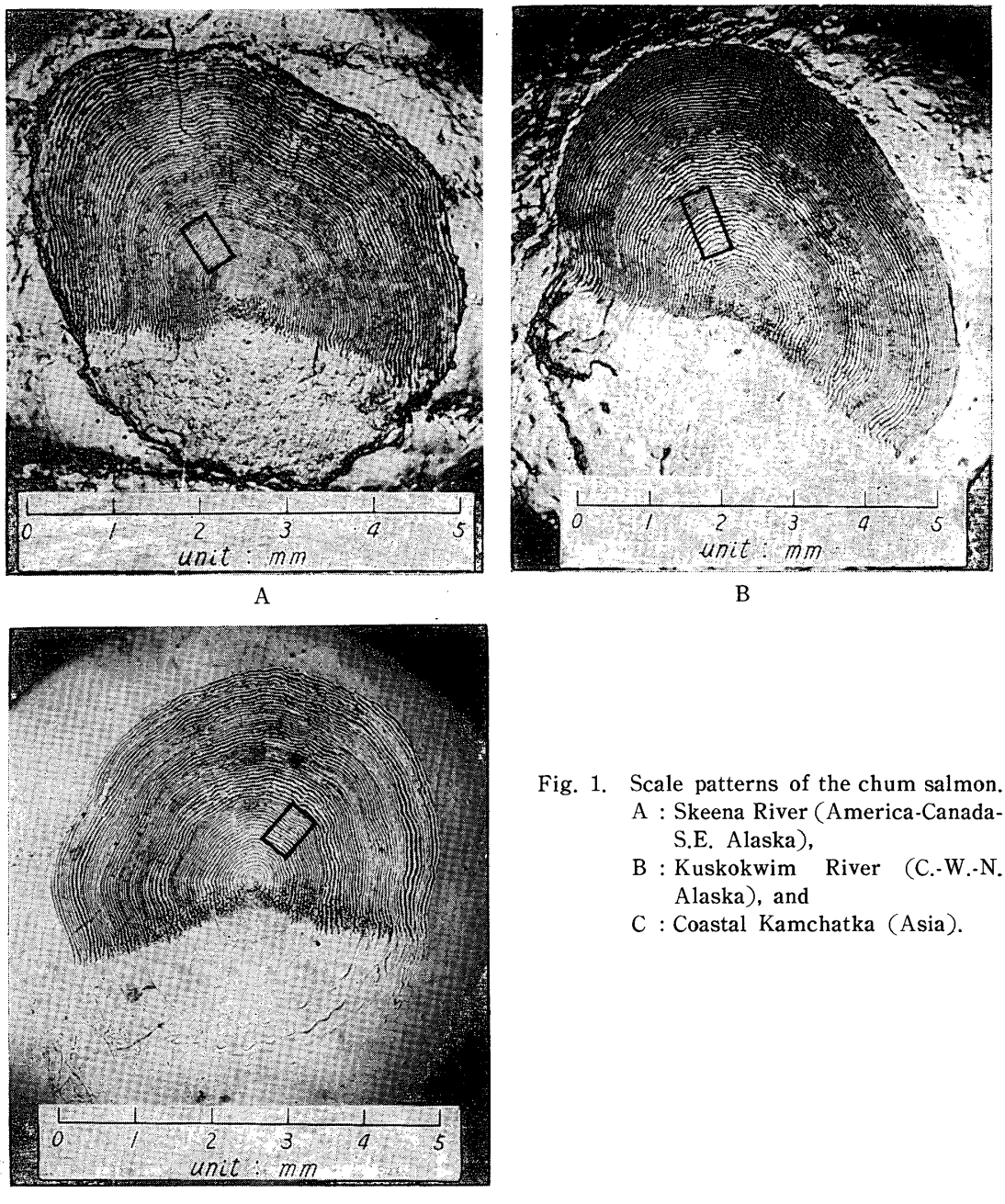


Fig. 1. Scale patterns of the chum salmon.
A : Skeena River (America-Canada-S.E. Alaska),
B : Kuskokwim River (C.-W.-N. Alaska), and
C : Coastal Kamchatka (Asia).

Results

1. Difference of the spacing between circuli of scales among the adult chum salmon migrants of different districts.

Comparisons of the spacing between circuli of scales have been made among adult migrants of different geographical districts.

There are recognizable differences among the average spacing between circuli of scales of adult migrants of different districts (Fig. 1 and Table 1).

Table 1. Frequency distribution of the spacing between circuli of scales of the adult chum salmon migrants collected in rivers and inshores.

	1. Puget Sound	2. Skeena River	3. Davidson Inlet	4. Stikine River	5. Puypus Bay	6. Port Haughton	7. Taku River	8. Cook Inlet	9. Uyak Bay	10. King Cove	11. Bristol Bay	12. Kuskokwim River	13. Yukon River	14. Unalakleet River	15. Kotzebue Sound	16. Coastal Kamchatka	17. Kamchatka River	18. Coastal Kamchatka	19. Okhotsk Sea	20. Bolshaya River	21. Utoka River	22. Iichia River	23. Yûbetsu River	24. Nijibetsu River	25. Tokachi River	26. Shizunai River	27. Ishikari River
2.5(mm)			1		1															1							
2.6				1	1		1																				
2.7	4	3			1		2																				
2.8	2	10	2	1	2	3	3																				
2.9	11	12	4	2	2	6	2																	1			1
3.0	7	6	5	4	5	6	5													2							
3.1	6	16	9	4	10	1	9								2		1								1		
3.2	12	10	8	5	4	6	6										1	2		1	1				1	1	2
3.3	8	8	13	5	13	5	12			1						1	2	1		2		2	1	2	1	1	1
3.4	6	7	8	10	11	4	7						2		1	1		1					3	1	3	6	3
3.5	8	5	5	7	7	7	13						3	1	1	3	7		1	2	2	2	2	4	3	5	3
3.6	2	11	9	12	8	1	9		1	1			1		1	2	4	4		1		1	2	4	10	10	3
3.7	1	3	5	14	6	1	8		3	1				1	3	1	2	5	1	2	2	3	4	5	6	2	4
3.8	1	3	2	22	2		10		5	3			4	2	3	6	5	7	9	2	1	1	11	4	9	13	16
3.9		2	1	8	5	3	3	2	9	1			5	4	6	6	6	9	7	5	7		12	5	8	9	9
4.0				5	1	1	5	2	2	3			5	3	5	3	5	9	4	4	4	1	2	7	5	8	7
4.1		1			5		3	10	8	11	4		8	10	6	5	3	13	22	6	6	3	13	6	16	11	12
4.2		2			1		1	5	8	6	2		4	4	10	2	1	7	10	1	4	2	9	7	6	8	7
4.3								10	5	11	2		7	7	13	3	6	9	5	4	3	2	7	8	2	5	12
4.4							1	10	14	9	4		4	11	8	5	3	7	9	4	6	1	14	7	4	7	7
4.5		1						10	13	13	2		7	5	9	2	2	1	5	3	2	1	6	15	1	3	4
4.6								10	9	11	1		10	13	10	3	2	1	6		3	1	3	4	2	3	5
4.7								7	3	5	6		9	3	1	3	1	4	3		4	3	3	4	1	3	1
4.8								6	7	7	3	1	4	7	6	2		3	3	4	1		2	1	1	1	
4.9								4	3	10	7	3	9	6	4	1	1	1	4	1	3		1	3	2	1	2
5.0								7	1		4		9	3	4	1	3	1	1	1				2	2	1	1
5.1								3	5	2	5	5		3	4		1	1	1					1		1	
5.2								2			4	1	2	5	3						1			1			
5.3									1	2	8	2	1	2									1	1			
5.4								2	2	1	1		3	2													
5.5											6	1												1			
5.6									1			1	1					1						1			
5.7										1	1	1		1													
5.8											1							1									
5.9										1																	
6.0												1															
6.1												1															
Total	68	100	72	100	85	44	100	90	100	100	66	17	98	93	100	50	56	86	81	50	50	23	46	92	84	100	100

The mean values of the scale character of the adult migrants collected in rivers and inshores are 3.2~3.6 mm in America-Canada-S. E. Alaska, 4.0~4.3 mm in Asia, and 4.3~5.3 mm in C.-W.-N. Alaska (Fig. 2). The differences among the fish groups ot the three districts are statistically significant.

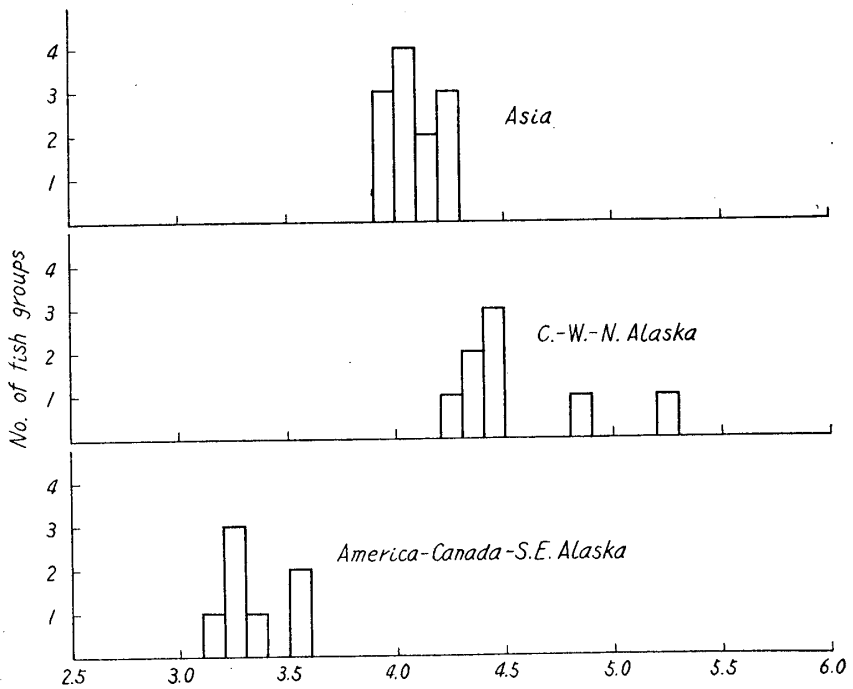


Fig. 2. Frequency distribution of means of the spacing between circuli of scales of the adult chum salmon migrants collected in rivers and inshores.

2. Analysis of frequency distributions of the spacing between circuli of scales of the high sea chum salmon.

Frequency distributions of the spacing between circuli of scales of the chum salmon caught in the high sea raeas, especially in the mid-ocean, have much broader range than those of fish collected in rivers and inshores (Table 2).

This seems to indicate the mixing of fishes of different geographical origins in the high sea areas. The frequency distributions of the spacing between circuli of each fish group caught in the high sea areas, I, II, III, and VIII, show straight lines when plotted on probability graph paper. Therefore, their distributions can be considered as normal (Figs. 3, 4, 5, and 10).

Whereas the frequency distributions of the spacing between circuli of scales of each fish group caught in the high sea areas, VI and VII, can be considered to be a summation of two normal distributions (Figs. 8 and 9).

Also the distributions of the chum salmon caught in the high sea areas, IV and V, are considered to be a summation of three normals (Figs. 6 and 7).

Table 2. Frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea areas.

	High sea area							
	I	II	III	IV	V	VI	VII	VIII
2.7 (mm)					1			
2.8				1		4		2
2.9				1	1	8		1
3.0		4	1	2	3	10	2	4
3.1	1	4	2	4	7	11	6	10
3.2	3	5	1	2	6	12	1	12
3.3	2	13	6	6	7	18	3	12
3.4	4	14	9	5	7	11	4	11
3.5	5	9	13	7		11	2	14
3.6	14	22	9	15	12	16	6	9
3.7	9	9	11	10	5	15	2	7
3.8	23	24	30	22	7	14	5	7
3.9	33	17	31	13	11	19	6	4
4.0	24	11	19	8	10	20	4	2
4.1	24	25	32	13	7	31	7	2
4.2	28	10	21	9	10	20	6	
4.3	36	13	28	17	6	22	13	2
4.4	21	12	29	13	8	17	5	1
4.5	20	7	15	12	4	20	13	
4.6	16	4	11	4	12	16	16	
4.7	15	2	6	8	5	8	7	
4.8	5		8	2	2	6	8	
4.9	3	2	8	1	3	10	9	
5.0	6		3	1	3	2	4	
5.1			5	2	1	3	6	
5.2	2		1	1		2	5	
5.3				1		2	4	
5.4	1					2	4	
5.5						2	2	
5.6								
5.7								
Total	295	207	299	181	138	332	150	100

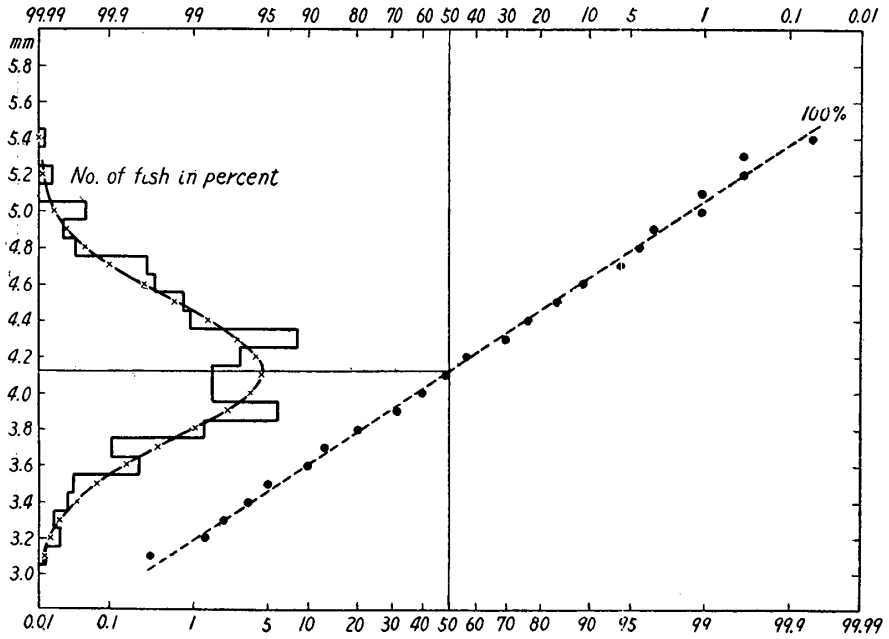


Fig. 3. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area I.

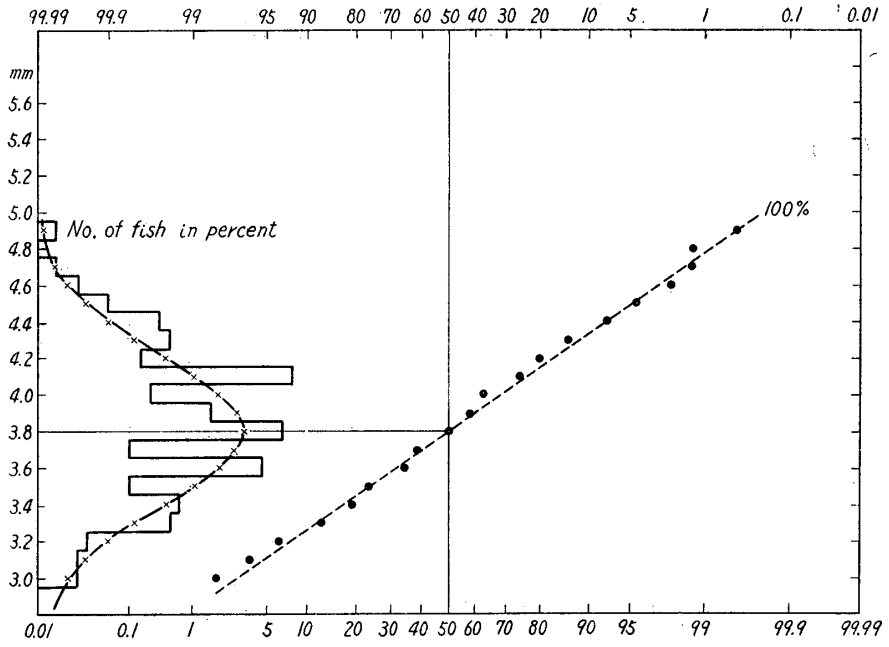


Fig. 4. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area II.

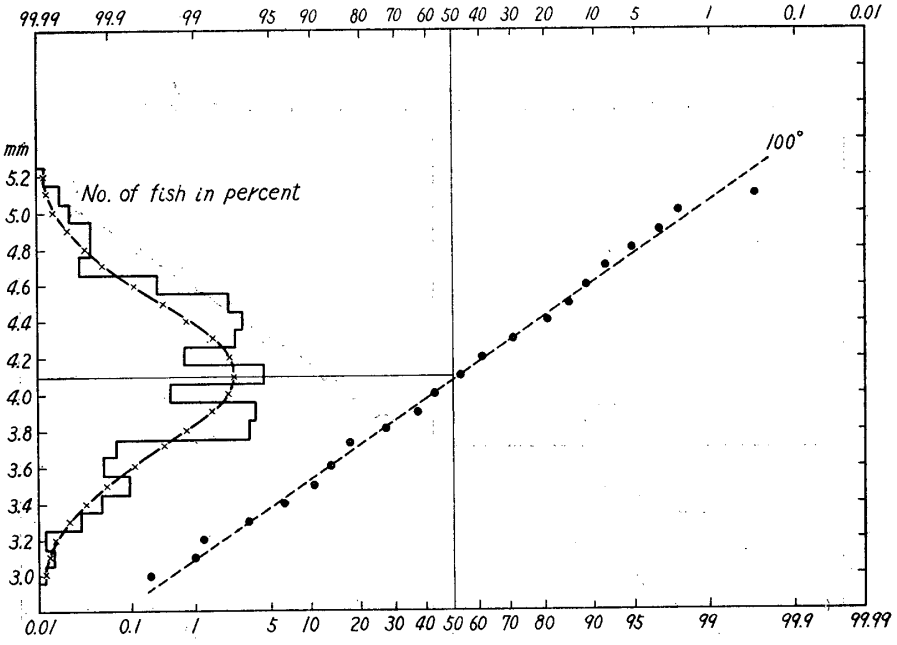


Fig. 5. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area III.

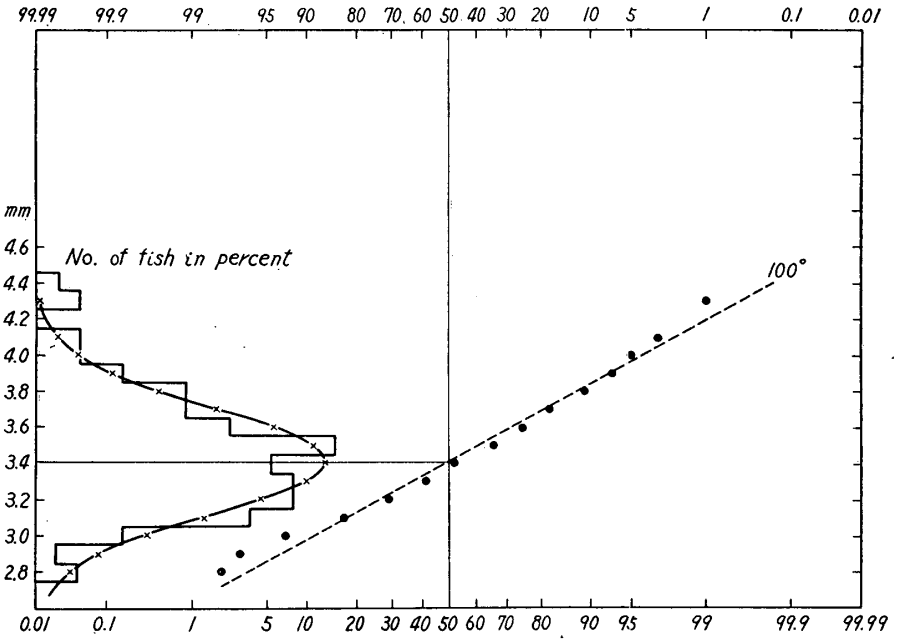


Fig. 10. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area VIII.

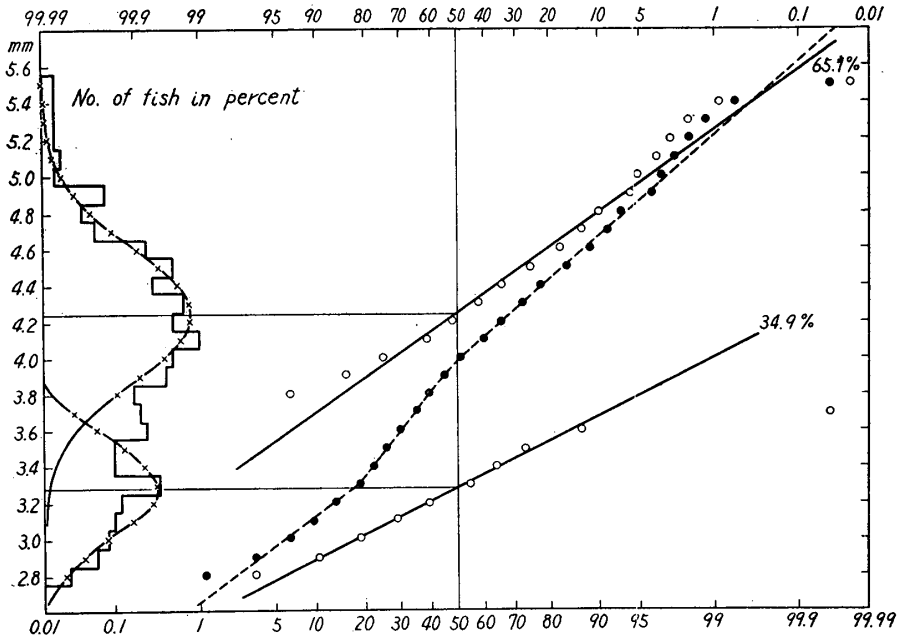


Fig. 8. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area VI.

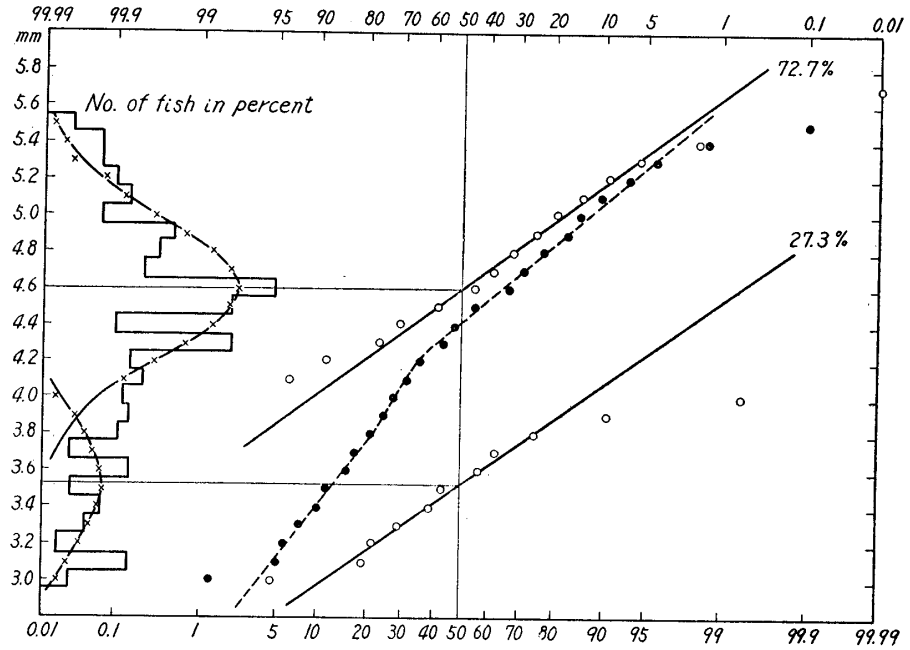


Fig. 9. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area VII.

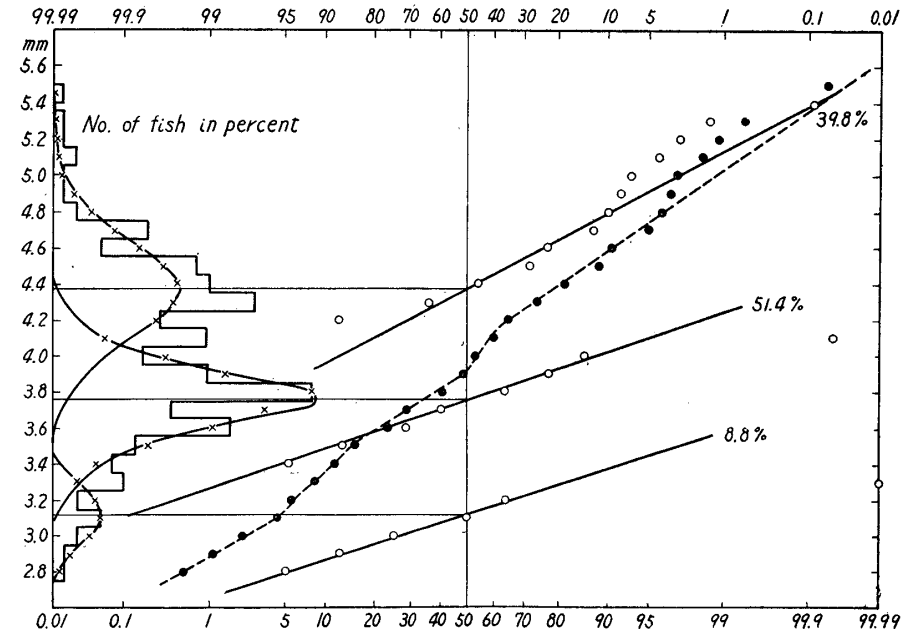


Fig. 6. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area IV.

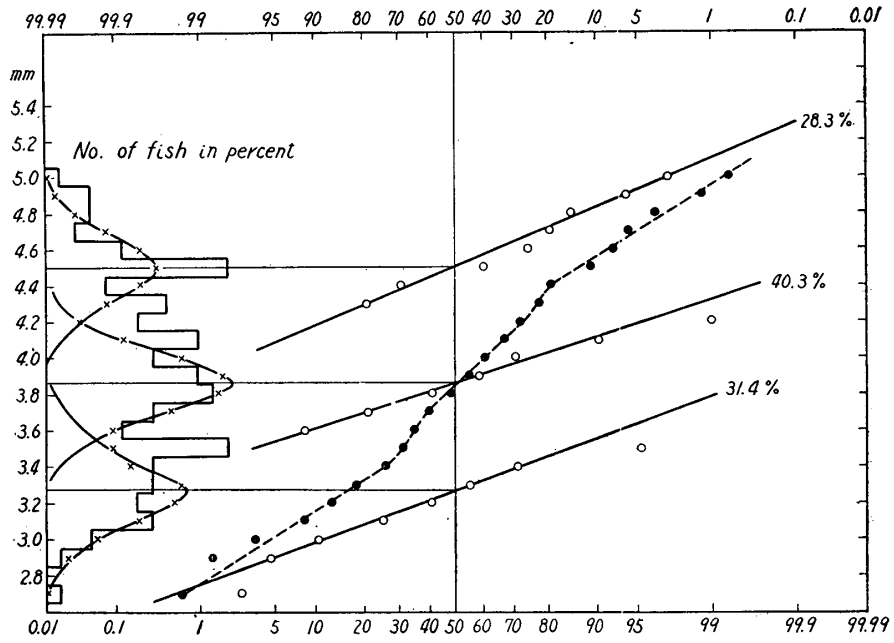


Fig. 7. Probability paper analysis of frequency distribution of the spacing between circuli of scales of the chum salmon caught in the high sea area V.

The mean value of each normal frequency distribution of the scale character of the high sea chum salmon (Table 3) has been compared with that of each fish group of different districts. As a result, it can be known that the chum salmon caught in the high sea areas of the Asiatic side, west of 180° longitude, are all of asiatic geographical origin. The fish caught in the high sea areas of the American side, east of 160° W longitude, are all of the America-Canada-S. E. Alaska geographical origin. The fish caught in high sea areas between 180° and 160° W longitude comprise a mixture of fishes of three different orgins, America-Canada-S. E. Alaska, C.-W.-N. Alaska, and Asia (Fig. 11).

Table 3. Means of the spacing between circuli in the chum salmon groups of the high sea areas, obtained as a result of analysis by probability paper method.

Area	Estimated fish group		
	America-Canada-S.E. Alaska	C.-W.-N. Alaska	Asia
I	— mm	— mm	4.1 mm
II	—	—	3.8
III	—	—	4.1
IV	3.1	4.4	3.8
V	3.3	4.5	3.9
VI	3.3	4.2	—
VII	3.5	4.6	—
VIII	3.4	—	—

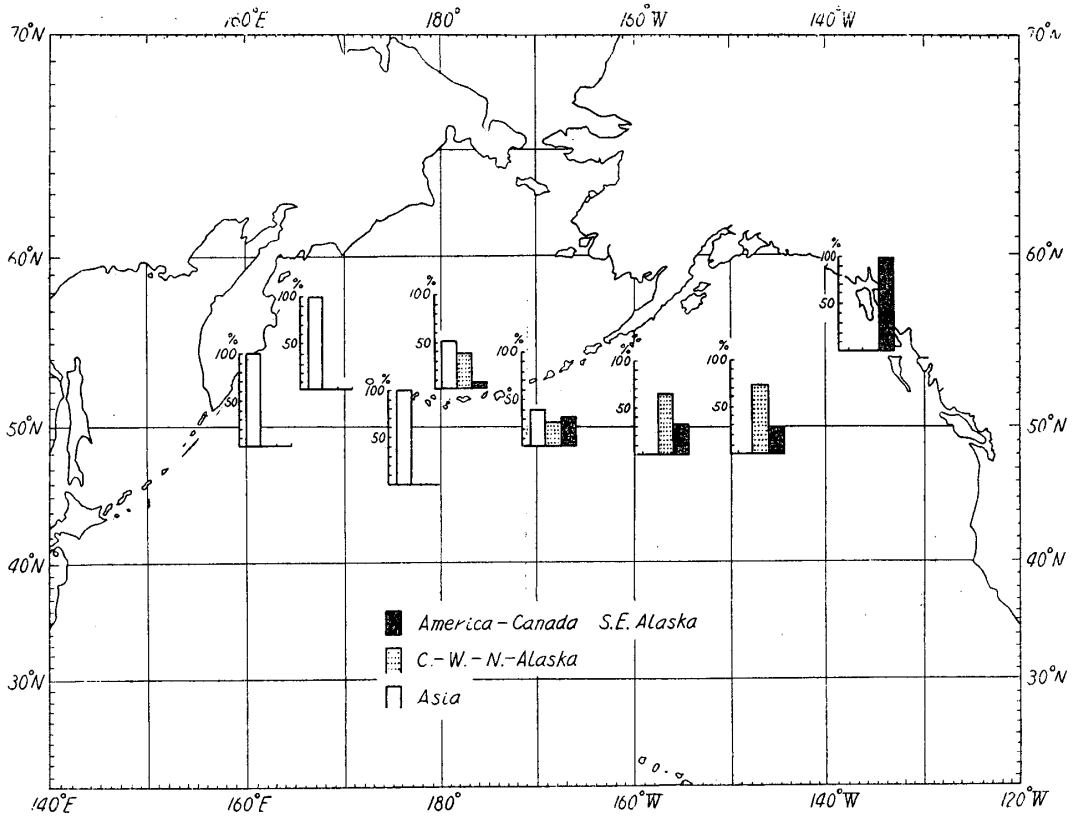


Fig. 11. Percentage compositions of the chum salmons of different geographical origins in the high sea areas.

Discussion

The geographical origins of the chum salmon has been studied by Kawakami and Tanaka (4), Hirano and Nakagawa (2), and Kobayashi and Abe (5). In their studies, the axis lengths and circulus numbers of the scale were used to distinguish the chum salmons of different origin. However, it seemed to be rather difficult to distinguish the fishes of different origin, because component groups showed overlapping in their frequency distributions of the scale characteristics and no adequate method was applied in analysis.

In the present study, probability graph paper was used to analyse overlap of frequency distributions of the scale character. As a result, it was possible to identify the geographical origins of fishes in the high sea areas. In a case of mixed population in the high sea areas, it was possible to elucidate the percentage compositions of the fish groups of different origin. The result of analysis of samples from the high sea areas between 160° W and 180° longitude showed good agreement with the result of marking experiments carried out by research workers of the United States of America as a part of the resaerch program of the International North Pacific Fisheris Commission in 1956 (3).

The conclusion of the present paper is based on the scale samples collect-

ed in the 1956 season almost exclusively. From the preceeding papers (6), it has been known that yearly differences of the scale character were small in the case of the chum salmon collected in the Skeena River, B. C., Canada in 1955, 1956, and 1957. However, it may be necessary to check the yearly difference of the scale character of the samples collected in several districts befor a general conclusion regarding the difference in scale character by geographical origins can be obtained.

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