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SCALE CHARACTERISTICS OF SOCKEYE SALMON (Oncorhynchus nerka) ORIGINATING FROM SMALL NURSERY AREAS OF THE SKEENA RIVER SYSTEM

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INTRODUCTION

Scales of sockeye salmon begin to form soon after the young become free swimming, at an average length of about 38.0 mm (Foerster, 1929; Clutter and Whitesel, 1956). From that size onward, variation in growth rate of the body is accompanied by directly correlated variation in growth rate of the scale; however, the rate of formation of circuli does not necessarily change in correspondence. Thus, when growth of the fish slows, as in winter, circuli tend to be closer together, forming bands of closely spaced circuli. (In this report, these are called "annual rings"). The last circulus of the annual ring is defined here as the annulus (Fig. 1). During the following spring and summer the distance between circuli increases as rapid growth is renewed.

Environmental factors influencing growth of young salmon differ from lake to lake, and the scales of young salmon which have lived for a time in those lakes may be expected to reflect the differences in the way in which their scale circuli are laid down. Underlying the environmentally induced scale patterns there may well be patterns which are under genetic control.

The objective of this study has been to assemble the data available concerning the scale characteristics of sockeye salmon spawning in a series of isolated locations within the Skeena River system (1945-1966), with a view to their possible use in describing growth patterns which may be characteristic of individual stocks, useful for the identification of individual stocks as they pass through the commercial fishery. Certain counts and measurements from the scales have been arranged in a manner which may prove useful to studies of these populations. Some possible relationships between scale characters and types of freshwater environment are discussed.

For the purposes of this report, a stock is defined as a population unit in a specific Skeena tributary. Stocks discussed here seem likely to be genetically distinct because their spawning grounds are widely separated.

This study is limited to an assessment of the scale characteristics of stocks other than those of Babine-Nilkitkwa lake system. Extensive data concerning the latter stocks are available, but will be the subject of a separate manuscript.

The study area

The Skeena River enters the Pacific Ocean near Prince Rupert, British Columbia. It is a diversified system drawing water from a 19,000 sq mi drainage basin embracing more than 50 lakes in excess of 1,000 acres. At least 27 of these lakes, between a few feet and 5,000 ft above tide water and varying between a few miles and 400 river miles from the sea, support sockeye salmon (Smith and Lucop, 1966). Fourteen were sampled from time to time and are the basis of the data presented here (Fig. 1). All but one support small spawning escapements, numbering between a few hundred and 2-3,000 fish annually. Only the Babine-Nilkitkwa system has had annual escapements in excess of 50,000 fish in the past 20 years. Lakes supporting stocks used in this report are identified as solid dark areas in Fig. 1, and four regions are defined arbitrarily as an aid to identification. Table I names the lake or lakes believed to support the juveniles of each sampled population and gives the source of the samples, e.g., lake spawners, tributary stream spawners and outlet stream spawners. Abbreviations for each system are used and are listed in the table.

During the years 1944-1948 the Skeena River Salmon Investigation, as part of the program of salmon research under the direction of Dr. A. L. Pritchard, carried out an extensive study of the lakes in the Skeena River drainage. This study included assessment of the physical features of the various lakes. The results of physical studies were summarized by Dr. J. R. Brett in Appendix VIIa of the Interim Report of the Skeena River Salmon Investigation (Pritchard, 1948). We have extracted data from this report for use in the present study. These are shown in Table I.

METHODS

Dead (spawned out) sockeye were sampled on the grounds, usually when scheduled population estimates coincided with an accumulation of dead spawned-out fish.[1] In most systems access was by air, and sampling was therefore intermittent.

Whenever possible, scales were taken from the left side of the fish midway between the lateral line and the insertion of the dorsal fin. Scales were obtained from other body areas when the desired location could not be sampled.

Scale impressions were made in the laboratory and were examined under a microprojector at 100 x. Because mature salmon begin to resorb their scales after they reach fresh water, the majority of the scales in our samples had retained only the freshwater zones and that part laid down in the first summer and winter in the ocean. As a result, measurement of scale characters was confined to the first two year bands. The order of presentation of scale data and the characters used in this evaluation are presented in Table II.

All measurements and circulus counts were made on the longest axis from the centre of the scale focus to the scale margin. The distance to each "annulus" and the number of circuli in each year band were recorded for each scale.

[1]Spawning ground estimates were required by the Skeena River Management Committee and obtained as a part of the work done for that Committee by personnel of this Station, 1955 to 1965. In addition to scales, samples by sex for length and otoliths were frequently obtained in the course of this work.

Freshwater circuli were readily distinguished from ocean circuli. The former are more delicate in structure and more closely spaced than those formed in the ocean[2]. Sometimes there are varying numbers of widely spaced freshwater circuli following the freshwater annulus which in this report are referred to as "new" growth circuli (Fig. 2). The scale characteristics of 1. and 2. sockeye are considered separately.[3]

Samples were generally too small for statistical tests to verify observed differences in scale characteristics. The average number of scales per sample (total of scales in one system in one year) was only 16, and 25 of the 32 samples contained less than 15 scales. Nevertheless, the presence of characteristic patterns in the same populations in different years encouraged us to graph all data, no matter how small the sample.

There appeared to be consistencies in the relative magnitude of certain scale characters in stocks in separate years, and these were confirmed in tests by the Spearman rank correlation coefficient r_s (Siegel, 1956).

Figures 4 to 6 and 8 to 10 show the range, mean - and when 15 or more scales constitute the sample - the standard deviation. However, to aboid erroneous judgements based upon too few data, only samples of 5 or more scales are used as supporting evidence for the discussions which follow each section. Sample measurements and circulus counts of both sexes and total ages were combined. Total ages can be determined from examination of the otoliths.

The scale characters of samples of age 1. and 2. sockeye from each stock have been arranged in the graphs in two ways: (1) by stock within years (the stocks are displayed in descending order of magnitude of means of scale characters, and the years are considered in chronological order; see example A below); (2) by year within stock (the stocks are again displayed in descending order of magnitude of the grand average value of the scale character for all years combined. Within each stock the individual years are also arranged in descending order of magnitude of the average value of the scale characters for all years combined; see example B below).

Growth differences attributable to inheritance or environmental factors associated with specific stocks will most readily be seen in the first graphical

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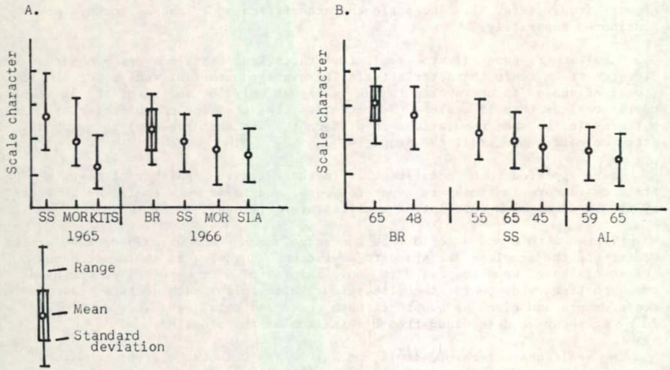
[2] Studies of scale characters by Bilton et al. (1964) indicated that for sockeye, coho, and for those chinooks believed to have spent one year in fresh water, the diameter (the distance measured along a line drawn through the focus at right angles to the longest axis of the scale) of the first-year band rarely exceeded 1.10 mm, whereas for pinks and chums, and for chinooks which spent their first year in the sea, diameters always exceeded 1.10 mm.

[3] The European system of age designation (Koo, 1962) is used in this report. The first digit indicates the number of annuli formed in fresh water, and the second digit indicates the number of annuli formed while the fish was in the ocean. (Scales referred to in this report were from spawned-out fish and were badly resorbed; therefore the number of ocean annuli could not be ascertained).

arrangements, while year-to-year differences such as may result from annual variations in climate will be most readily seen in the second arrangement.



Tables showing the values of the scale characters measured for sockeye from the various stocks are given in Appendices 1 and 2 at the end of the report.

RESULTS

Freshwater age composition

Samples for all available years were combined by stocks to provide the freshwater age composition as shown in Fig. 3 and Table III. In Fig. 3, stocks with 15 or more fish sampled in any one year are shown arranged in descending order according to the proportion of age 1. sockeye. The highest proportion of age 1. sockeye (98%) was in Bear Lake in the upper part of the system, closely followed by McDonell in the central region, Lakelse in the lower region and Slamgeesh and Sustut again in the upper region. The lowest (11%) was clearly in the Morice system in the southwest.

Scale characters of age 1. sockeye

The characters of those parts of the scale considered to represent freshwater growth and the first summer and winter ocean growth are compared as follows:

Number of circuli (C_1) and width of freshwater year band (A_1) to annulus

Combination of the data for all years (Fig. 4, A_1 and C_1) indicate that Kitwanga sockeye, located in the central region of the system, had the highest number of circuli (19.49) and the greatest year band width (49.39 mm). Sockeye from Asitka and Sustut lakes, located in the upper region, had the least number of circuli (6.8, 7.8) and the smallest year band width (19.7, 24.2 mm). Thus scales of sockeye from the two latter systems averaged about one-half the amount of freshwater growth observed on those of Kitwanga sockeye (also Fig. 5). Annual variability in these characters within stocks was relatively small (Fig. 6). For instance, Kitwanga circuli ranged from 19.3 to 19.8 and widths from 49.0 mm to 49.7 mm in 1945 and 1946 respectively. Sustut circuli ranged from 6.67 to 8.71 and widths from 20.6 to 27.2 mm in the years 1963, 1965 and 1966. Scale characters of adjacent stocks in the array from high to low differed little.

Number of circuli (C_2) and width of year band (A_2) to first ocean annulus

Combination of the data for all years (Fig. 4, A_2 and C_2) indicates that sockeye of the Kitsumgallum Lake, located in the lower region, and Kitwanga Lake, 40 miles away in the central region had, on the average, the highest number of circuli (33.2 and 30.9 respectively) and the greatest year band width (122.5 and 120.9 mm respectively). Sockeye from Asitka, Sustut and Onerka lakes of the upper region again had the lowest (26.2, 27.8, 26.1 circuli and 88.3, 91.1, 94.3 mm respectively). There was a difference of 3.1 circuli between the grand means of the lower region Kitwanga fish and the upper region Sustut fish, and a difference of 26.6 mm between the mean counts of the lower region Kitwanga fish and the upper region Onerka fish (also Fig. 5).

Annual variations within each stock were relatively small (Fig. 6). In the three years when Kitsumgallum fish were sampled, the average number of circuli ranged from 32.3 to 34.3 (a difference of 2.0 circuli) and widths from 119.4 to 127.0 mm (a difference of 7.6 mm). In three years of Sustut sampling average circuli ranged from 25.6 to 29.6 (a difference of 4.0 circuli) and widths from 80.6 to 98.0 mm (a difference of 17.4 mm). Scale characters of adjacent stocks in the array from high to low differed very little.

Scale characters varied in magnitude from year to year, as might be expected, but ranking of each in the array of all stocks in a particular year appeared consistent. For instance, in Fig. 7 freshwater circuli and first ocean circuli counts for 1965 have been arrayed in descending order as in Fig. 5. Counts for most of the same stocks in 1966 have been superimposed upon them. The nonparametric statistic r_s has values of 0.81 and 0.69 for freshwater and first ocean counts respectively ($P < 0.05$), indicating a high degree of consistency between relative values in the two years. Number of freshwater circuli were on the average slightly higher in 1965 than in 1966 (11.7 and 11.1 respectively). The number of first ocean circuli were consistently greater in 1965 than in 1966 (29.1 and 27.6 respectively).

New growth in fresh water

New growth was present on scales of only 9 of the 14 stocks studied (Fig. 5, NGW, NGC and 6, NGW, NGC). The average number of new growth circuli (NGC) ranged from 2 to 4 and the width (NGW) from 3 to 8 mm. Combination of the data for all years for these stocks indicates that scales of sockeye from McDonell have had the highest incidence of new growth (5 out of 28 fish, or 18%) followed by those from Stephens and Swan lakes also located in the central region, Alastair Lake of the lower region, and finally Sustut and Asitka lakes of the upper region in that order (per cent occurrence ranged from 14 down to 11). Sockeye from 3 of the 4 remaining lakes (Kitwanga, Lakelse and Bear) had 10, 3 and 2 per cent respectively. The sample of Sicintine sockeye was too small (3 fish) to contribute to the discussion. These data are incorporated in Appendix 1.

Scale characters of age 2. sockeye

The first and second year freshwater scale characters of age 2. sockeye from each stock are compared. The first ocean year band was not measured.

Number of circuli (C_1) and width of year band (A_1) to first fresnwater annulus

Combination of the data for all years (Fig. 8, A_1 and C_1) indicates that on the average sockeye of Kitwanga, Lakelse and Morice origin had the highest and similar numbers of circuli and the greatest year band widths. Sockeye from Johansen and Sustut lakes, located in close proximity in the upper region of the system, had the lowest. There was a difference of 2.0 circuli between the grand means of the southwestern-located Morice fish and the upper region Johansen fish, and a difference of 8.8 mm in the average year band width (also Fig. 9).

Annual variations within most stocks were not large with the exception of Alastair which will be discussed later (Fig. 10). For instance, Morice circuli averaged 8.2, 8.3 and 8.4, and widths 24.2, 25.8 and 26.0 mm in the years 1966, 1956 and 1955 respectively. Sustut circuli averaged 5.0, 5.5 and 7.0, and widths 13.0, 14.0 and 21.0 in the years 1965, 1966 and 1963 respectively. Adjacent scale characters in the array differed but little.

Number of circuli (C_2) and width of year band (A_2) from the first freshwater annulus to the second freshwater annulus

Combination of the data for all the years (Fig. 8, A_2 and C_2) indicates that on the average sockeye of Lakelse in the lower region had the highest average number of circuli and widths (11.8 circuli and 28.7 mm). Sockeye from

Sustut, Sicintine, Onerka and Johansen lakes of the upper region again had the least (from 7.8 to 9.2 circuli and 17.8 to 19.0 mm). There was a difference of 2.7 circuli between the grand means of the lower region Lakelse and the upper region Johansen fish, and a difference of 9.7 mm between the Lakelse fish and the upper region Sustut fish. The difference in second-year characters was not as great as for first-year characters.

Scale growth in the second year in fresh water was greater than in the first for all stocks represented by five or more scales, but the two years of growth were positively correlated (for circuli $r_s = 0.58$; for width 0.69; $P < 0.05$).

New growth in fresh water

New growth was present on scales of only 4 out of the 12 stocks studied (Figs. 9, NGW, NGC and 10, NGW, NGC). The average number of new growth circuli (NGC) ranged between 3 and 4 and the width (NGW) from 5 to 9 mm. Combination of the data for all years for these stocks indicate that scales from centrally located Stephens and Swan lakes had the highest incidence of new growth (3 out of 12 fish, or 25%), followed by those from Alastair (5 out of 56 fish, or 9%), Sustut (1 out of 13 fish, or 8%) and Kitwanga Lake (1 out of 19 fish, or 5%).

Scale characters of age 2. sockeye varied in magnitude from year to year as expected. In spite of this annual variation, the ranking of the characters of first year fresh water in the array of all stocks in a particular year appeared consistent. For instance, in Fig. 11, first year freshwater circuli counts for 1965 have been arrayed in descending order as in Fig. 9. Counts for most of the same stocks in 1966 have been superimposed upon them. The r_s value ot 0.90 indicates a high degree of consistency between relative values in the two years. Age 2., like age 1., sockeye had on the average about the same number of first year freshwater circuli in both years (7.0, 7.01 circuli in 1965 and 1966 respectively). Values in one year were not consistently greater than in the other year.

Rank of the characters of the second year fresh water in the array of all stocks in a particular year, unlike those of the first year, were not consistent from year to year. For instance, second year freshwater circuli counts for 1965 were arrayed in descending order as in Fig. 9. Counts in 1966 were compared with them. The r_s value of 0.32 indicated very little correlation between relative values in the two years.

DISCUSSION

Among both age groups differences in freshwater or first ocean sockeye scale characters might be sufficiently great to permit identification of some groups of stocks from scales sampled in commercial fishery catches. However, in practice such identification would be difficult, if not impossible, for several reasons, particularly for the age 1. sockeye. Each of these stocks contributes only a small fraction to the total run to the system. Over 85%

of all age 1. sockeye in the system consisting of about 1,000,000 fish annually originate from Babine Lake. The success of separation would depend to a great deal upon the time of occurrence of these populations in the fishery. For stocks passing through the fishery when Babine sockeye are present, separation might be impossible simply because of the magnitude of the Babine stock. The probability that a particular stock would be represented in a sample of fish taken under these circumstances would be extremely remote. The problem of separation is further compounded when there are appreciable numbers of Babine fish present with scale characters similar to one or more of the small stocks. We know that the freshwater scale character of age 1. Babine sockeye are similar to those from many of the minor stocks. For example, in 1962 the average number of freshwater circuli for stocks tributary to Babine Lake varied from 11 to 14 and would therefore overlap several stocks from the lower and central regions (see Fig. 4). Only the upper region stocks were different and could theoretically be separated).

It is possible that single or aggregates of several stocks of age 2. fish could be identified in the fishery. This is primarily because Babine fish of age 2. are uncommon. (Less than 2 per cent of the Babine run, or at most 25-35,000 sockeye in any year in a total of about 85,000[4] age 2. fish in the system). Moreover, Aro and McDonald (1968) have demonstrated that Morice and Alastair stocks (with a high proportion of 2. fish) probably pass through the area of the fishery long before the main Babine run does. (The earliest runs into the river are the Alastair and Lakelse fish (June and early July), followed a short while later by the Babine and Morice runs. The Morice run continues to the end of July and Babine fish into late August).

Measurement of the first freshwater year band width may be a means of separating the centrally located Kitwanga, Stephens-Swan and southwestern Morice fish from the upper region Johansen, Sicintine and Sustut fish. For the years sampled (Fig. 8), there was a minimum difference of 4.21 mm between means of centrally located Stephens-Swan fish and upper region Sicintine fish. Within a given year the difference was greater. In 1965 there was a difference of 8.50 mm between the means of centrally located Stephens-Swan fish and upper region Johansen fish. In 1966 there was a difference of 7.00 mm between means of centrally located Stephens-Swan fish and the upper region Sicintine fish.

The freshwater scale characteristics of sockeye of some of these stocks were compared with several environmental conditions of their nursery areas to see if scale characters might reflect physical conditions in a nursery area. Turbidity, mean depth and maximum surface temperatures (Table I) were compared with freshwater growth on the scales of age 1. and 2. fish found in each. For the conditions tested, scale growth (width of the year band) in the first freshwater year of age 1. and 2. sockeye appeared to be correlated only

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[4] The estimate of 85,000 age 2. fish is the average of the estimated number of age 2. fish in the Skeena catches and escapements for 5 years during the period from 1960 to 1967.

with the maximum surface temperature (example in Fig. 12). The r_s values for each age group are 0.82 and 0.64 respectively and are significant at $P < 0.05$). On the other hand, width of the second freshwater year on scales of age 2. fish did not appear to be correlated with surface temperature (r_s of 0.4). The report of the Skeena River Salmon Investigation cited above concluded that "in general, low temperature was also directly related to low production. It may be that the whole area is limited by a low heat income". If this is the case, scale examination could provide some assessment of the relative productivity of nursery areas.

The amount of scale growth during the first year in the ocean of various stocks of age 1. sockeye was compared with the distance of their nursery areas from the Skeena River estuary. An inverse relationship (Fig. 13) was indicated, with stocks closest to the estuary having the most ocean growth[5] and those from the upper reaches of the system the least (for width of first ocean year band, there is a r_s value of 0.67, $P < 0.05$). The amount of growth during the first year in the ocean will depend in part upon the locations of nursery areas. This is because climatological and perhaps other factors will bear upon the time of seaward migration of the young and directly influence the length of the first ocean growth period. For example, distance of the nursery areas from the estuary is associated with a rather rapid increase in elevation (Fig. 14). Upriver nursery areas such as Sustut, Asitka and Johansen are more than 4,000 ft above sea level; nursery areas near the coast such as Alastair and Kitsumgallum are only about 500 ft above sea level. Because of their greater elevation and inland positions, these upriver nursery areas are subjected to colder weather conditions, which retards the time of break-up of ice cover, the subsequent

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[5] There are several unique features of Alastair Lake sockeye which may bear some relation to the atypical ratio of circuli to distance from the sea noticeable in Fig. 13, and to the high variability in year-to-year measurements observed earlier in this report. Alastair Lake fish include some of the earliest spawners in the system (early August), yet fresh fish have been observed in the stream late in September, e.g. September 7, 1963. Clearly there is spawning during at least a 2-month period. We believe the bulk of this occurs in a single stream though some late spawning may occur in the lake. In addition, Alastair system sockeye bear unusual colour patterns. In contrast to the usual red body coloration in spawning males, those of Alastair are green in colour with a broad band of red along each side of their bodies, closely resembling that of spawning steelhead trout (S. gairdnerii). Apart from the colour characteristics, Alastair sockeye resemble pink salmon in general appearance. However, meristic and morphological measurements on two age 2.2 Alastair sockeye from the 1963 escapement revealed no unusual features. All counts and measurements fell within the range of values given for the species in Clemens and Wilby (1961).

The prolonged spawning time and atypical appearance of these sockeye may be linked with their diverse growth patterns.

warming of the lake in the spring, and the time when the sockeye smolts emigrate to the sea. This is reflected in the freshwater growth patterns of these stocks.

We conclude from these few data: (1) There is some possibility of providing a general separation of Skeena River stocks spawning at a low elevation, far inland. (2) There appears to be greater variability of scale characters among stocks in a given year than from year-to-year within any one stock. (3) Scale patterns presented here provide some insight into the productivity of the nursery areas where Skeena juveniles are reared. Some geographical anomalies exist. Sicintine Lake is high and fed by springs and run-off from snow fields and glaciers. Growth patterns there are most like those of the other northern lakes. Slamgeesh and Bear Lakes, on the other hand, are lower, tend to be more eutrophic, and growth patterns are more like those of the central lakes. Kitsumgallum Lake, although it is in the lower region, is cold, glaciated, and growth patterns are similar to those from the upper region of the system. (4) An additional year or two of representative sampling is required to permit statistical testing of differences discussed here, and such sampling appears warranted on both managerial and research grounds.

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Table I. Physical features of nursery areas, from Appendix VIIa of Skeena River Salmon Investigation.

Nursery area	Area (sq. mi)	Maximum length (miles)	Maximum width (miles)	Maximum depth (feet)	Mean depth (feet)	Volume (cu. yd) × 10^6	Shoreline develop-ment	Eleva-tion (feet)	Maximum surface temp. °C	Maximum bottom temp. °C	Mean trans-parency (feet)	Minimum summer bottom O_2 % conc.	General comment on water
Alastair	2.3	5.2	0.5	236	74.0	179	2.21	500	17.1	4.4	25.7	..	Mostly clear
Lakelse	5.5	5.4	1.5	98	24.0	141.3	1.83	220	20.2	13.8	10.0	45	Clear
McDonnel	..	..	..	..	..	..	..	..	..	..	..	..	Clear
Kitwanga	2.8	4.5	1.0	44	23.8	68	2.33	600	19.1	7.0	18.9	0	Clear
Stephens	3.1	3.5	1.0	85	34.0	112	2.10	1,500	20.3	5.0	..	72	Clear
Swan	10.8	7.0	2.0	210	74.7	832	3.47	1,500	16.8	4.3	..	90	Clear
Sicintine	..	..	..	..	..	..	..	..	..	..	..	..	Glaciated
Slamgeesh	..	0.25	0.25	26	..	..	..	..	12.3	11.4	12.0	..	Clear
Sustut	1.3	3.5	0.5	61	21.4	28	2.06	4,250	..	..	30.0	..	Clear
Bear	7.2	12.4	3.0	240	42.0	314	3.2	2,640	19.25	6.0	14.5	..	Clear
Onerka	..	..	..	..	..	..	..	..	..	..	..	..	Clear
Kitsumgallum	6.8	6.8	1.6	435	232.5	1,632	2.03	468	13.0	4.0	1.5	80	Highly glaciated most of year
Johanson	0.6	2.75	0.5	162	48.3	30	2.90	4,730	11.5	5.3	30.0	..	Clear
Asitka	..	0.75	0.5	26	..	..	..	4,250	13.5	11.7	18.0	..	Clear
Morice	40.0	25.9	2.8	775+	327.0	13,507	3.18	2,614	14.0	4.0	9.8	..	Highly glaciated most of year

Table II. Order of presentation and discussion of scale characters.

1. Freshwater age composition of each sub-stock (proportion of age 1. and 2. sockeye in the samples).

2. Scale characters of age 1. sockeye

   2a. Number of circuli (C_1) and width of freshwater year band (A_1) to annulus.

   2b. Number of circuli (C_2) and width of year band (A_2) to first ocean annulus.

   2c. New growth [number of freshwater circuli (NGC) and width of freshwater growth (NGW) after the annulus].

3. Scale characters of age 2. sockeye

   3a. Number of circuli (C_1) and width of year band (A_1) to first freshwater annulus.

   3b. Number of circuli (C_2) and width of year band (A_2) from the first freshwater annulus to the second freshwater annulus.

   3c. New growth [number of freshwater circuli (NGC) and width of freshwater growth (NGW) after the second freshwater annulus].

Table III. Percent representation of 1. and 2. freshwater sockeye in samples from various sub-stocks of the Skeena River system.

Sub-stock	Year	Number Age 1.0	Number Age 2.0	Percent Age 1.0	Percent Age 2.0	Total No. Samples
Alastair	1955	-	9	-	100	9
	1957	-	2	-	100	2
	1959	82	3	96	4	85
	1965	4	3	57	43	7
	1966	-	39	-	100	39
		86	56	60	40	142
Lakelse	1950	257	29	90	10	286
	1951	169	12	93	7	181
		426	41	91	9	467
Kitsumgallum	1955	3	1	75	25	4
	1965	6	-	100	-	6
	1966	10	-	100	-	10
		19	1	95	5	20
McDonnel	1965	13	1	93	7	14
	1966	15	1	94	6	16
		28	2	93	7	30
Kitwanga	1945-46	4	17	19	81	21
	1965	6	2	75	25	8
		10	19	34	66	29
Stephens-Swan	1945-46	8	7	53	47	15
	1955	8	2	80	20	10
	1965	1	1	50	50	2
	1966	11	2	85	15	13
		28	12	70	30	40
Sicintine	1964	-	2	-	100	2
	1965	2	4	33	67	6
	1966	1	2	33	67	3
		3	8	27	73	11
Slamgeesh	1964	2	1	67	33	3
	1965	15	1	94	6	16
	1966	6	1	86	4	7
		23	3	88	12	26
Sustut	1963	34	5	87	13	39
	1965	25	4	86	14	29
	1966	31	4	88	12	35
		90	13	87	13	103
Asitka	1964	9	-	100	-	9

cont'd.

Table III (cont'd.)

Sub-stock	Year	Number Age 1.0	Number Age 2.0	Percent Age 1.0	Percent Age 2.0	Total No. Samples
Azuklotz	1965	2	-	100	-	2
Bear	1948	52	2	96	4	54
	1963	6	-	100	-	6
	1965	16	-	100	-	16
	1966	16	-	100	-	16
		90	2	98	2	92
Onerka	1965	4	5	44	56	9
	1966	4	1	80	20	5
		8	6	57	43	14
Morice	1955	3	23	11	89	26
	1956	6	35	15	85	41
	1966	1	25	4	96	26
		10	83	11	89	93
Johansen	1963	1	12	8	92	13
	1965	-	6	-	100	6
		1	18	5	95	19
TOTAL		407	223			630

Appendix 1

Scale characters of age 1. sockeye by year from different sub-stocks in the Skeena River system.

Year	Sub stock	Width F.W. Year band (mm x 100)			Width new growth (mm x 100)		Width 1st ocean year band (mm x 100)			Number F.W. circuli			Number new growth circuli		Number 1st ocean circuli			Total No. samples with new growth	Total No. samples
		Mean	Range	S.D. ±	Mean	Range	Mean	Range	S.D. ±	Mean	Range	S.D. ±	Mean	Range	Mean	Range	S.D. ±		
1945-46	Kitwanga	49.00	43-54	-	-	-	126.25	116-138	-	19.75	18-23	-	-	-	33.75	32-35	-	-	4
	Stephens-Swan	36.50	26-45	-	8.00	-	96.25	76-110	-	15.37	11-19	-	4.00	-	27.87	23-32	-	1	8
1948	Bear	38.92	25-54	6.82	6.00	-	96.07	71-115	10.50	13.75	9-19	2.04	3.00	-	27.79	23-35	3.35	1	52
1950	Lakelse	39.26	27-55	5.93	7.00	-	101.72	74-132	12.83	14.10	10-19	1.92	4.00	-	29.08	22-37	3.37	1	50
1952	Lakelse	40.44	29-52	5.10	2.50	2-3	101.04	77-141	12.75	14.36	9-20	1.72	1.50	1-2	28.46	23-34	2.68	2	50
1955	Kitsum-gallum	19.66	18-21	-	-	-	123.66	119-131	-	8.00	8	-	-	-	34.33	31-41	-	-	3
	Stephens-Swan	39.25	31-50	-	6.00	4-8	110.00	91-140	-	14.62	12-19	-	2.50	2-3	29.25	26-33	-	2	8
	Nanika	31.00	28-35	-	-	-	94.33	86-100	-	11.00	10-12	-	-	-	26.67	25-28	-	-	3
1956	Morice	31.50	29-39	-	-	-	100.16	88-137	-	11.66	8-16	-	-	-	30.00	27-39	-	-	6
1959	Alastair	39.36	31-56	4.80	4.70	3-8	111.56	83-130	10.10	13.13	9-20	1.42	2.30	2-4	28.87	23-36	2.45	10	82
1963	Sustut	25.20	13-32	4.36	4.40	3-7	97.97	74-117	10.30	8.12	5-11	1.31	2.40	2-3	29.58	23-37	3.32	5	34
	Bear	37.33	29-41	-	-	-	99.33	92-108	-	13.16	11-16	-	-	-	30.00	28-33	-	-	6
	Johansen	32.00	32	-	-	-	117.00	117	-	12.00	12	-	-	-	30.00	30	-	-	1
1964	Slamgeesh	34.00	32-36	-	-	-	99.50	93-106	-	14.50	13-16	-	-	-	31.00	30-32	-	-	2
	Asitka	19.70	13-26	-	5.00	5	88.30	77-101	-	6.80	5-10	-	2.00	2	26.20	22-28	-	1	9

Appendix 1 continued.

Year	Sub stock	Width F.W. Year band (mm x 100)			Width new growth (mm x 100)		Width 1st ocean year band (mm x 100)			Number F.W. circuli			Number new growth circuli		Number 1st ocean circuli			Total No. samples with new growth	Total No. samples
		Mean	Range	S.D. ±	Mean	Range	Mean	Range	S.D. ±	Mean	Range	S.D. ±	Mean	Range	Mean	Range	S.D. ±		
1965	Alastair	27.25	20-36	-	3.00	3	126.00	113-143	-	9.75	7-11	-	2.00	2	34.00	31-39	-	1	4
	Kitsum-gallum	27.83	21-36	-	-	-	127.00	118-138	-	8.66	7-12	-	-	-	32.33	28-35	-	-	6
	McDonnel	34.77	27-49	-	4.66	3-6	101.23	80-123	-	13.38	11-18	-	2.00	1-3	28.76	24-34	-	3	13
	Kitwanga	49.66	46-55	-	5.00	5	117.33	109-129	-	19.33	17-23	-	2.00	2	29.00	28-31	-	1	6
	Stephens	44.00	44	-	-	-	116.00	116	-	16.00	16	-	-	-	30.00	30	-	1	2
	Sicintine	24.00	20-28	-	4.00	4	102.50	97-108	-	8.00	7-9	-	2.00	2	29.00	28-30	-	1	2
	Slamgeesh	34.27	19-48	7.91	-	-	102.26	85-113	9.20	12.33	7-16	2.33	-	-	29.33	25-36	2.99	-	15
	Sustut	27.19	18-41	6.25	5.60	5-7	94.72	77-108	9.00	8.71	6-12	1.73	3.00	3	28.23	22-33	2.65	5	25
	Bear	45.65	30-65	7.77	7.00	7	103.60	82-123	8.80	14.94	12-19	1.80	3.00	3	28.88	24-31	2.09	1	18
	Onerka	33.50	28-47	-	-	-	93.00	84-100	-	11.75	9-17	-	-	-	26.50	24-29	-	-	4
1966	Kitsum-gallum	30.09	19-36	-	-	-	119.40	102-134	-	9.89	8-12	-	-	-	33.29	31-37	-	-	10
	McDonnel	34.33	26-42	4.21	6.00	6	97.53	85-111	8.53	13.92	11-17	1.77	2.50	2-3	27.19	21-31	3.28	2	15
	Swan	38.27	34-43	-	-	-	107.27	85-125	-	13.72	12-15	-	-	-	27.81	22-32	-	-	11
	Sicintine	30.00	30	-	-	-	74.00	74	-	9.00	9	-	-	-	25.00	25	-	-	1
	Slamgeesh	34.67	30-46	-	-	-	103.33	95-113	-	12.33	9-16	-	-	-	29.16	25-34	-	-	6
	Sustut	20.57	11-40	5.48	-	-	80.64	57-103	11.92	6.67	4-14	1.74	-	-	25.55	20-32	3.17	-	31
	Bear	38.43	29-52	8.18	-	-	92.30	73-107	12.82	12.31	10-16	1.93	-	-	26.93	20-31	3.15	-	16
	Onerka	32.00	24-40	-	-	-	95.50	90-100	-	10.75	9-12	-	-	-	25.75	24-28	-	-	4
	Morice	35.00	35	-	-	-	102.00	102	-	12.00	12	-	-	-	30.00	30	-	-	1

Appendix 2

Scale characters of age 2. sockeye by year from different sub-stocks in the Skeena River system.

Year	Sub stock	Width 1st F.W. year band (mm x 100)			Width 2nd F.W. year band (mm x 100)			Width new growth (mm x 100)		Number 1st year F.W. circuli			Number 2nd year F.W. circuli			Number new growth circuli		Total No. samples with new growth	Total No. samples
		Mean	Range	S.D. ±	Mean	Range	S.D. ±	Mean	Range	Mean	Range	S.D. ±	Mean	Range	S.D. ±	Mean	Range		
1945-46	Kitwanga	26.47	18-37	5.83	20.70	12-28	3.88	-	-	9.00	6-12	2.14	10.05	7-14	1.72	-	-	-	17
	Stephens-Swan	21.00	16-33	-	22.42	10-30	-	7.0	-	7.57	5-12	-	10.85	5-15	-	3.00	-	1	7
1948	Bear	21.00	16-26	-	30.50	25-36	-	-	-	6.50	6-7	-	11.50	10-13	-	-	-	-	2
1950	Lakelse	27.92	20-35	-	29.07	16-41	-	-	-	8.71	7-11	-	12.00	8-15	-	-	-	-	14
1951		23.83	18-31	-	28.33	18-44	-	-	-	8.00	5-10	-	11.66	10-16	-	-	-	-	6
1955	Alastair	24.22	20-30	-	18.88	15-28	-	6.00	5-7	8.88	6-12	-	9.77	8-13	-	3.00	3	3	9
	Kalum	18.00	-	-	12.00	-	-	-	-	7.00	-	-	6.00	-	-	-	-	-	1
	Stephens-Swan	21.00	18-24	-	20.50	20-21	-	7.00	-	11.50	7-16	-	10.00	10	-	3.00	-	1	2
	Morice	26.00	14-40	5.74	24.13	13-30	4.26	-	-	8.39	5-12	1.87	10.39	7-13	1.74	-	-	-	23
1956	Morice	24.20	18-33	4.47	22.28	17-33	4.35	-	-	8.34	5-12	1.95	10.00	7-13	2.25	-	-	-	35
1957	Alastair	21.00	19-23	-	19.50	17-22	-	5.00	-	7.50	7-8	-	11.00	10-12	-	3.00	-	1	2
1959	Alastair	32.33	31-33	-	27.00	21-30	-	-	-	10.00	9-11	-	10.66	9-12	-	-	-	-	3
1963	Sustut	21.00	17-25	-	19.00	13-30	-	-	-	7.00	6-9	-	8.60	6-13	-	-	-	-	5
	Johansen	16.83	12-23	-	18.50	12-26	-	-	-	6.41	4-8	-	9.66	6-13	-	-	-	-	12
1964	Sicintine	22.50	15-30	-	21.00	18-24	-	-	-	7.50	6-9	-	9.50	9-10	-	-	-	-	2
	Slamgeesh	20.00	-	-	19.00	-	-	-	-	7.00	-	-	9.00	-	-	-	-	-	1

Appendix 2 continued.

Year	Sub stock	Width 1st F.W. year band (mm x 100)			Width 2nd F.W. year band (mm x 100)			Width new growth (mm x 100)		Number 1st year F.W. circuli			Number 2nd year F.W. circuli			Number new growth circuli		Total No. samples with new growth	Total No. samples
		Mean	Range	S.D. ±	Mean	Range	S.D. ±	Mean	Range	Mean	Range	S.D. ±	Mean	Range	S.D. ±	Mean	Range		
1965	Alastair	22.67	21-24	-	15.67	15-16	-	-	-	8.00	7-10	-	8.00	7-9	-	-	-	-	3
	McDonnel	25.00	-	-	16.00	-	-	-	-	8.00	-	-	7.00	-	-	-	-	-	1
	Kitwanga	26.50	23-30	-	20.00	19-21	-	7.00	-	8.50	7-10	-	10.00	-	-	3.00	-	1	2
	Stephens	24.00	-	-	20.00	-	-	6.00	-	9.00	-	-	9.00	-	-	3.00	-	1	1
	Sicintine	15.25	13-21	-	17.00	11-24	-	-	-	5.50	4-8	-	7.25	5-11	-	-	-	-	4
	Slamgeesh	21.00	-	-	25.00	-	-	-	-	6.00	-	-	11.00	-	-	-	-	-	1
	Sustut	13.00	8-18	-	22.25	21-25	-	9.00	-	5.00	5	-	8.50	8-9	-	4.00	-	1	4
	Onerka	19.00	16-24	-	18.00	12-30	-	-	-	7.19	7-8	-	7.60	5-11	-	-	-	-	5
	Johansen	15.50	12-19	-	16.33	12-26	-	-	-	6.00	4-9	-	8.16	6-12	-	-	-	-	6
1966	Alastair	18.40	13-23	2.78	20.02	15-26	2.88	5.00	-	7.07	4-9	1.21	9.58	7-12	1.28	3.00	-	1	39
	McDonnel	20.00	17-23	-	21.00	20-22	-	-	-	8.50	7-10	-	10.50	10-11	-	-	-	-	2
	Swan	24.50	20-29	-	19.00	18-20	-	-	-	8.00	6-10	-	9.00	9	-	-	-	-	2
	Sicintine	17.50	15-20	-	19.50	18-21	-	-	-	6.00	6	-	8.50	8-9	-	-	-	-	2
	Slamgeesh	20.00	-	-	38.00	-	-	-	-	7.00	-	-	15.00	-	-	-	-	-	1
	Sustut	14.00	12-17	-	15.75	7-22	-	-	-	5.50	5-6	-	8.75	5-11	-	-	-	-	4
	Onerka	20.00	-	-	20.00	-	-	-	-	7.00	-	-	9.00	-	-	-	-	-	1
	Morice	25.84	19-37	4.18	22.96	15-31	3.75	-	-	8.16	6-11	1.28	9.80	7-14	1.70	-	-	-	25

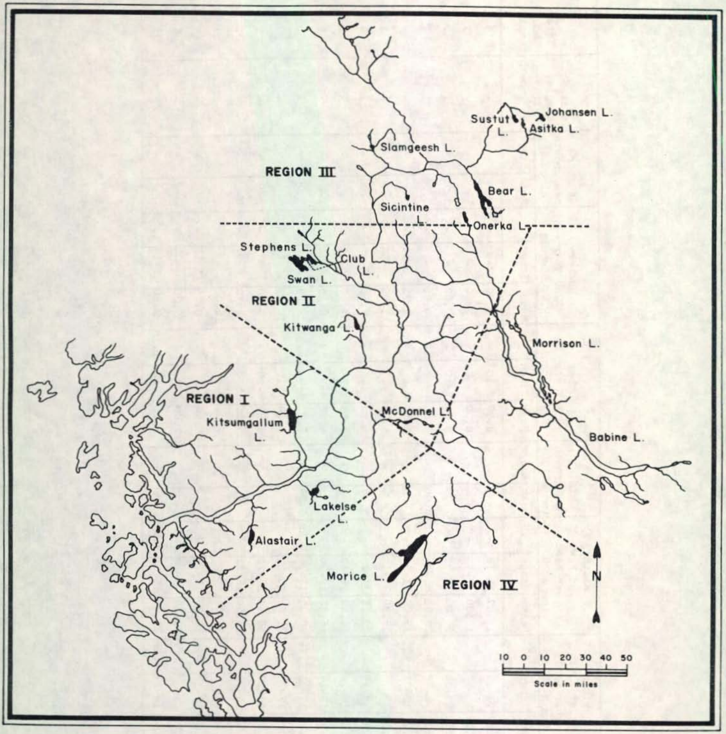

Fig. 1. Map of the Skeena River system, with 5 sample regions superimposed.

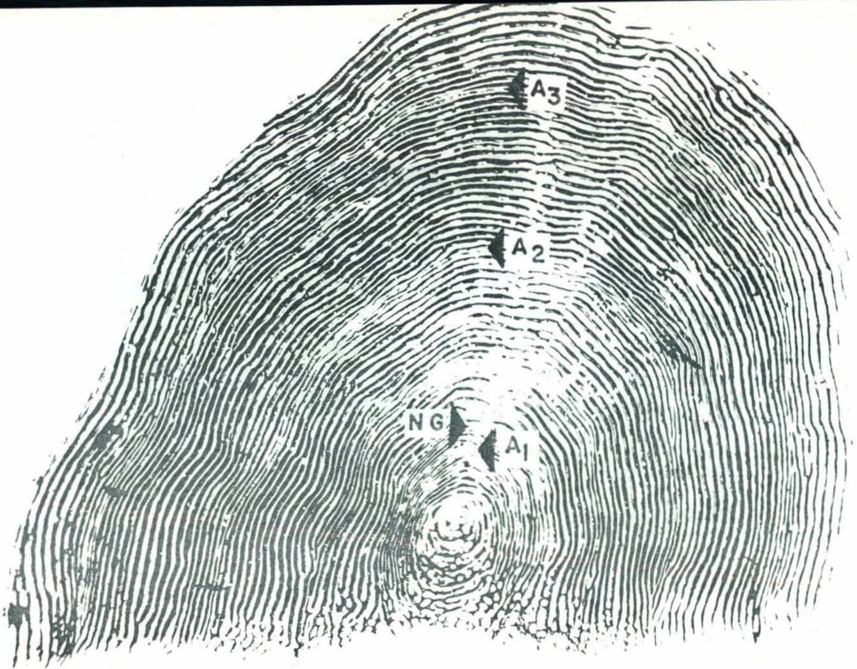

Fig. 2. Scale from an adult (age 1.2) sockeye salmon sampled from the Skeena River fishery showing the freshwater annulus (A_1); freshwater growth after the freshwater annulus (NG); and the first and second ocean annuli (A_2), (A_3).

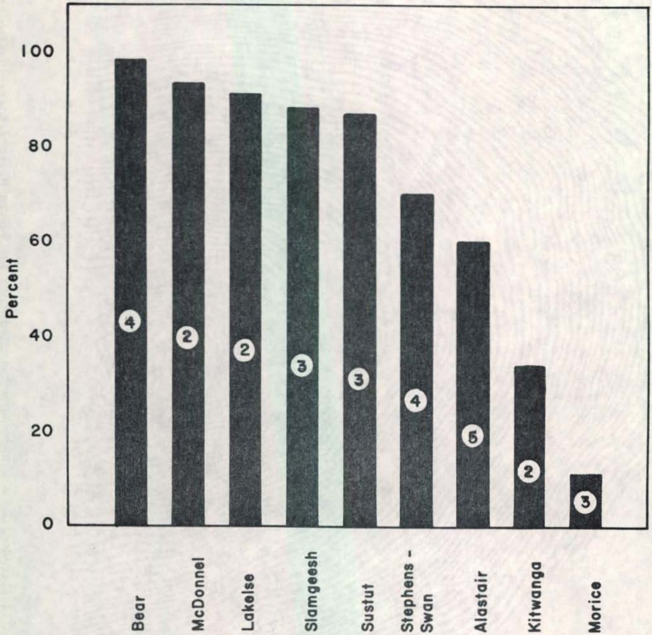

Fig. 3. The proportions (per cent) of age 1. sockeye in samples from various sub-stocks of the Skeena River system for all years combined. Number of years when samples were obtained is indicated in each bar.

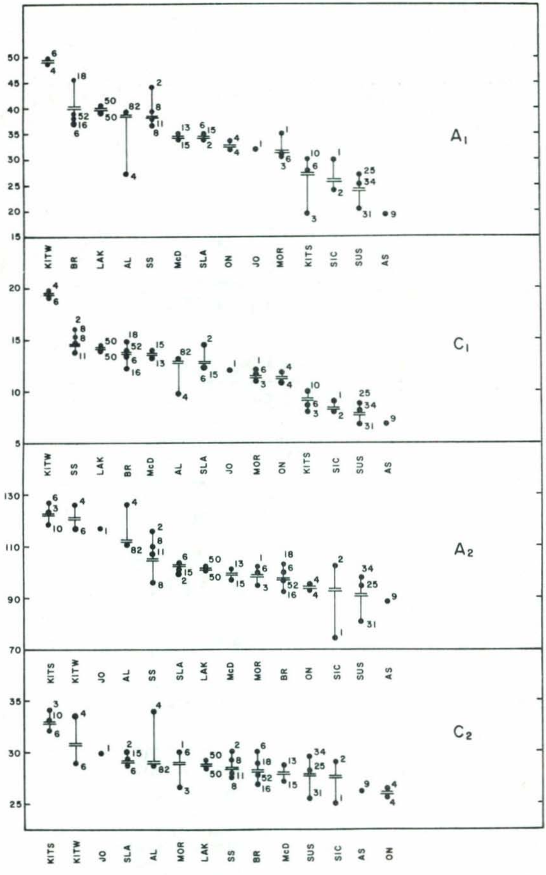

Fig. 4. Scale characters of age 1. sockeye from different Skeena River sub-stocks. Figure shows the grand mean for all years combined (=) and the mean for each year (•) for each character and sub-stock, arrayed in descending order of grand means. Numerals show sample sizes.

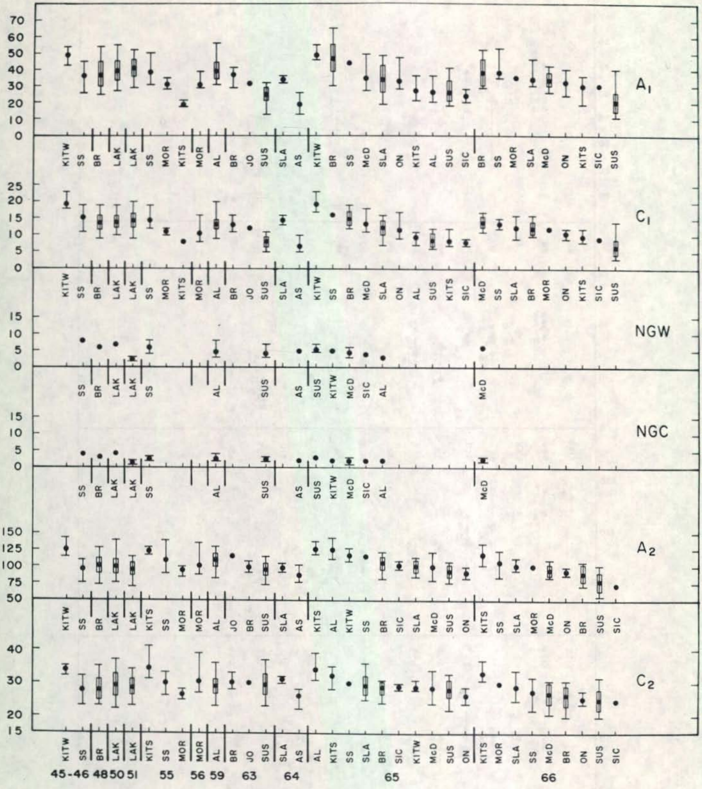

Fig. 5. Scale characters for age 1. sockeye from different Skeena River sub-stocks. Data are arrayed in descending order of means within sample years. Means and range of counts and measurements are shown for all sample years. Standard deviations are included for samples of 15 and more.

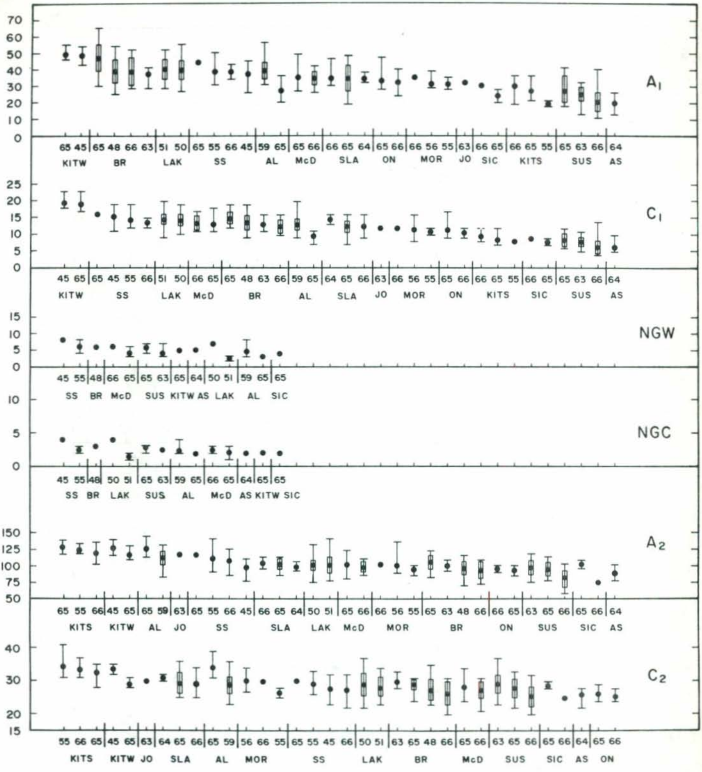

Fig. 6. Scale characters of age 1. sockeye from different Skeena River sub-stocks. Data arrayed by year within sub-stock in descending order of magnitude of the grand average value of the scale character in all years. Within each sub-stock the years are arrayed in descending order of magnitude of the average scale character value. Means and range of counts and measurements are shown for all sample years. Standard deviations are included for samples of 15 and more.

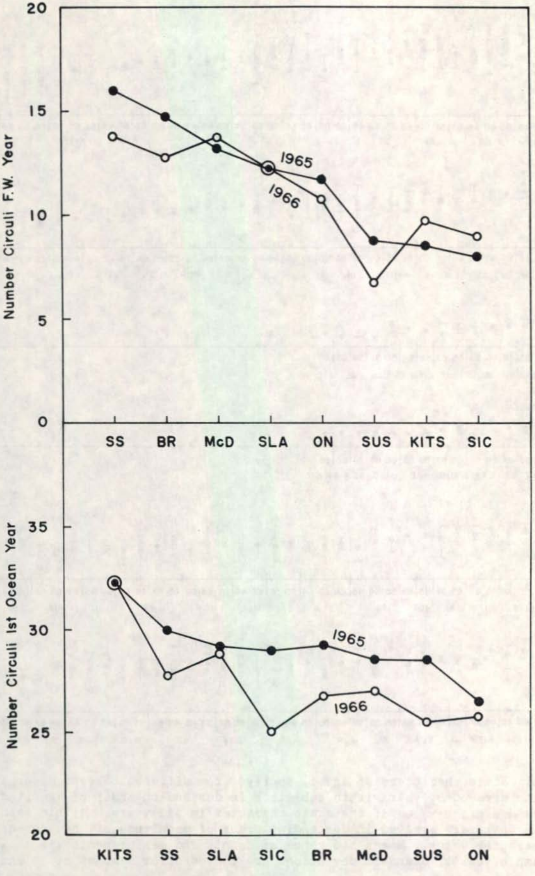

Fig. 7. Freshwater circuli and first ocean circuli counts of age 1. sockeye arrayed in descending order by sub-stock in 1965 and 1966.

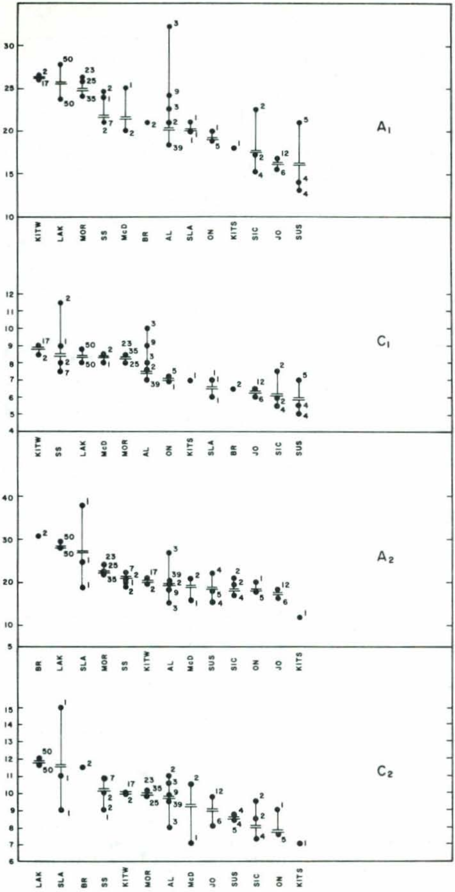

Fig. 8. Scale characters of age 2. sockeye from different Skeena River sub-stocks. Figure shows the grand mean for all years combined (=) and the mean for each year (•) for each character and sub-stock, arrayed in descending order of grand means. Numerals show sample sizes.

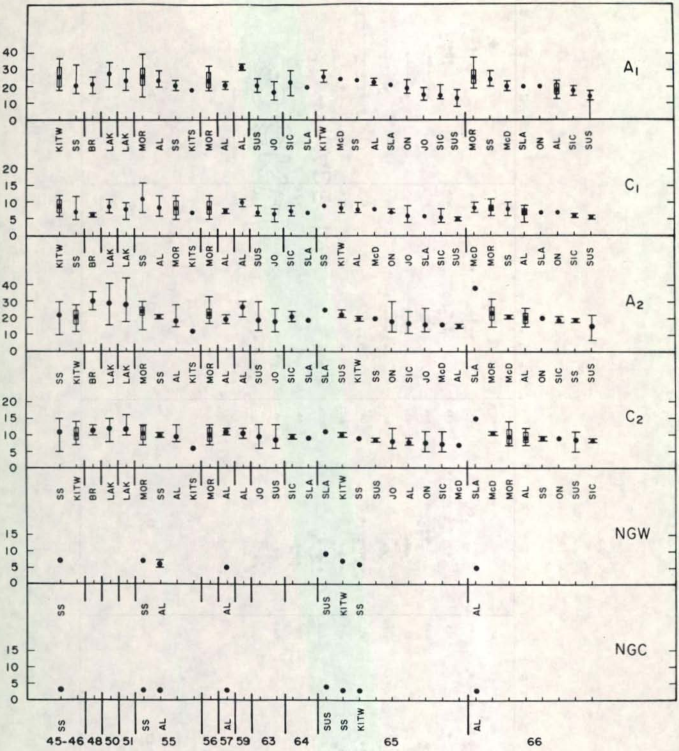

Fig. 9. Scale characters for age 2. sockeye from different Skeena River sub-stocks. Data are arrayed in descending order of means within sample years. Means and range of counts and measurements are shown for all sample years. Standard deviations are included for samples of 15 and more.

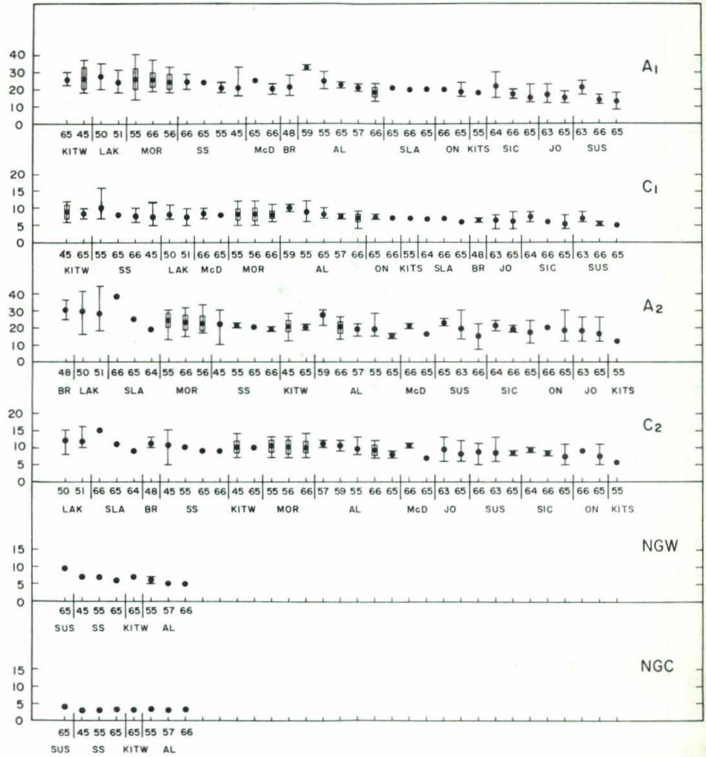

Fig. 10. Scale characters of age 2. sockeye from different Skeena River sub-stocks. Data arrayed by year within sub-stock in descending order of magnitude of the grand average value of the scale character in all years. Within each sub-stock the years are arrayed in descending order of magnitude of the average scale character value. Means and range of counts and measurements are shown for all sample years. Standard deviations are included for samples of 15 and more.

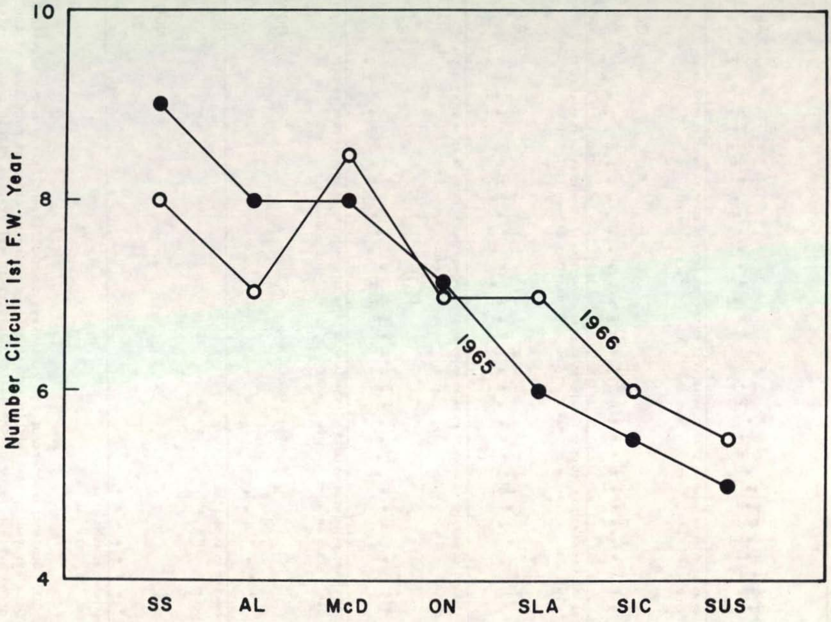

Fig. 11. First year freshwater circuli counts of age 2. sockeye arrayed in descending order by sub-stock in 1965 and 1966.

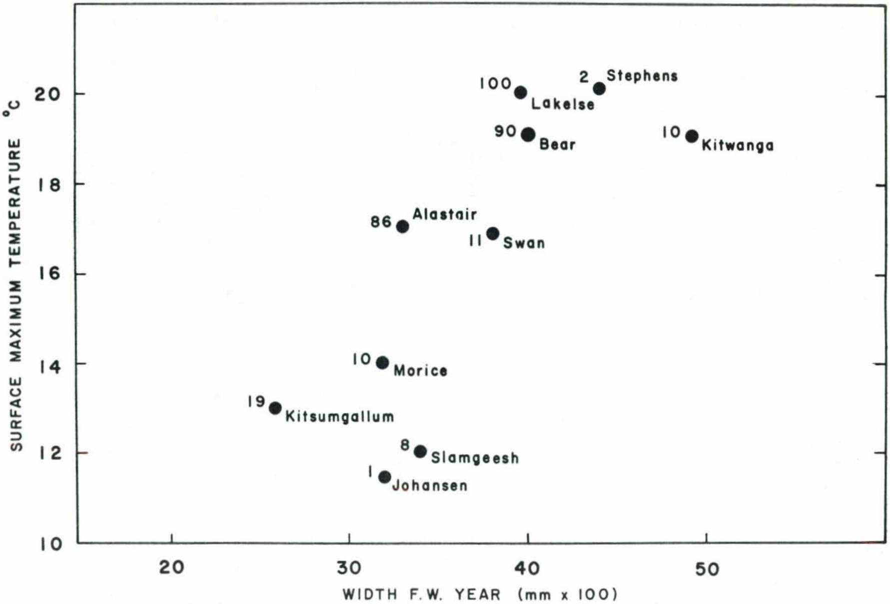

Fig. 12. Shows the relationship between freshwater growth of age 1. sockeye and the peak surface temperatures for various nursery areas.

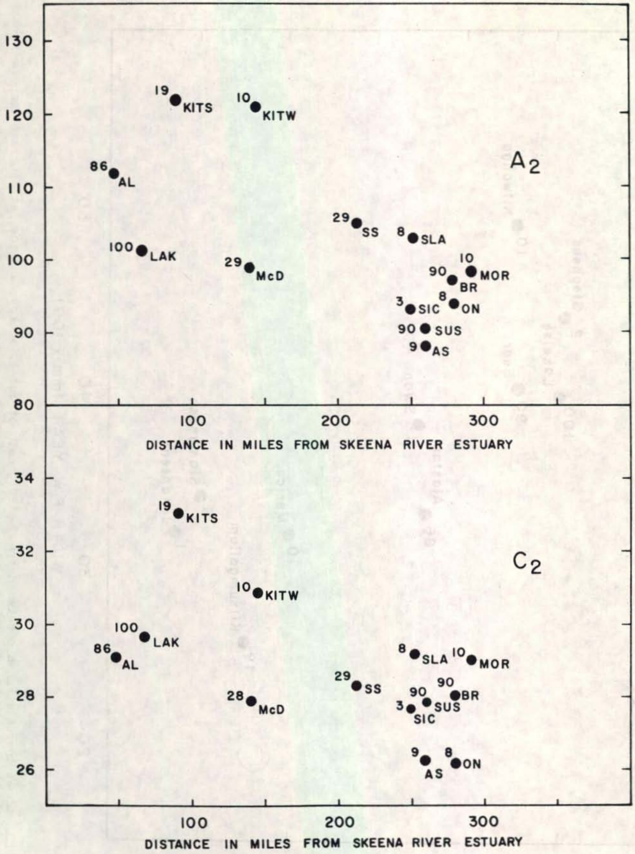

Fig. 13. Average number of circuli and average year band widths in the first ocean year for all years combined for age 1. sockeye from different sub-stocks located at various distances from the mouth of the Skeena River.

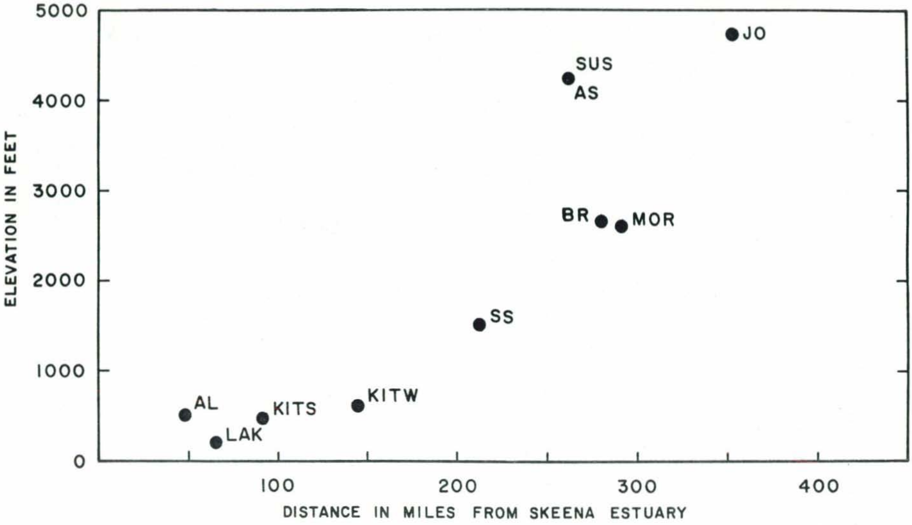

Fig. 14. Shows the relationship between distance of some of the nursery areas from the Skeena estuary and their elevation above sea level.