INTERNATIONAL PACIFIC SALMON
FISHERIES COMMISSION

APPOINTED UNDER A CONVENTION
BETWEEN CANADA AND THE UNITED STATES FOR THE
PROTECTION, PRESERVATION AND EXTENSION OF
THE SOCKEYE AND PINK SALMON FISHERIES
IN THE FRASER RIVER SYSTEM

BULLETIN XIV

THE AGE, SEX RATIO AND SIZE OF FRASER RIVER SOCKEYE SALMON 1915 to 1960

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ABSTRACT

A total of 88,368 samples have been taken from the commercial catches to provide a continuous record of the annual age composition, sex ratio and size (weight and length) of Fraser River sockeye *(Oncorhynchus nerka)* from 1915 to 1960. Four *age classes,* 3_2, 4_2, 5_2, and 5_3, were found to be consistently present and represented by percentages of 2.20, 89.25, 6.94 and 1.61 respectively. The 4_2 fish constitute the dominant age class. The upper Fraser sockeye are largely four-year-old fish while five-year-old fish are relatively more numerous in the lower Fraser area. The management of the Fraser River sockeye fishery may be based almost entirely on the 4_2 age class. The *sex ratio* is slightly in favor of the females (47:53). The sex ratio of the 3_2 "jack" sockeye was greatly in favor of males (94:6); thus, this age class was not considered to be a self-perpetuating stock. The *size* of Fraser sockeye has varied considerably from a low of 5.05 pounds to a high of 7.21 pounds for four-year-old fish. Variations in annual sizes were attributed to basic differences in the genetic size characteristics of different races and to changes in growth conditions in the marine environment. The annual sockeye size variations greatly affected the size of the annual commercial packs. Selective fishing by gill nets was examined and no evidence was found to indicate that selection of either large or small sockeye had any permanent effects on the size of Fraser River sockeye. Predicting sockeye sizes in advance of each fishing season can be done with only limited accuracy until the first fish are caught in any season.

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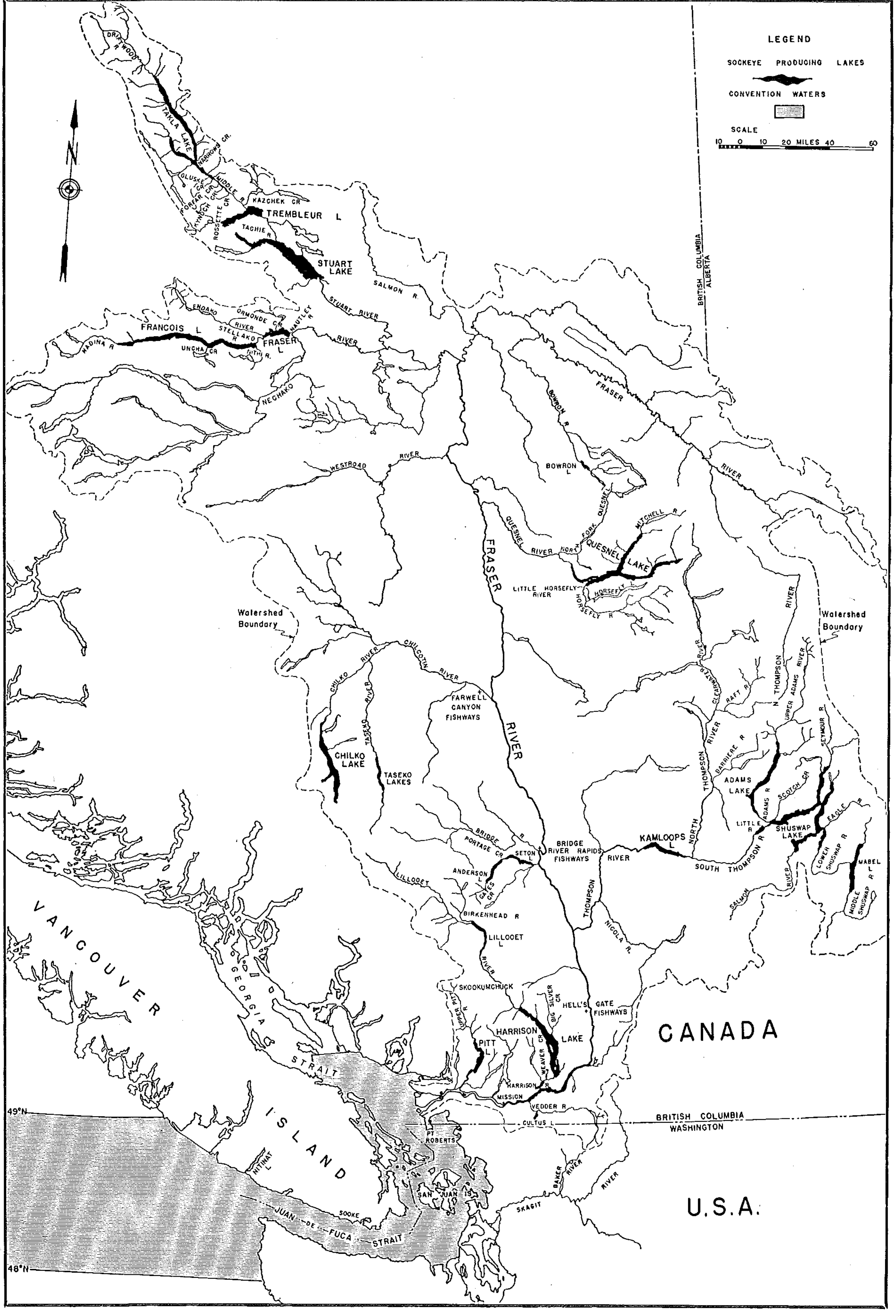

FRONTISPIECE—Fraser River Watershed showing areas utilized by major sockeye salmon spawning populations.

THE AGE, SEX RATIO AND SIZE OF FRASER RIVER SOCKEYE SALMON 1915 to 1960

INTRODUCTION

The runs of sockeye salmon (Oncorhynchus nerka) to the Fraser River, as they have entered the commercial fishery, have been sampled annually in respect to length, weight, sex and scales from 1915 to 1960 at Sooke or in the San Juan Island area. The period of sampling each year has ranged from late April to early October, while the total number of fish taken each year in random samples has ranged from 327 to 12,676. The analyses of these data have provided basic information as to the age-classes present, estimates of their numerical and percentage variation from year to year, and the average length, weight and ratio of the sexes in each year-class. The present review of the data has been made to determine if there were indications of basic patterns or trends in the different categories during the forty-six year period and, if such were present, to consider whether they might be correlated with factors in the fishery or in the environment.

THE FRASER RIVER

The Fraser River is a large stream, nearly 1,000 miles in length, arising in the central plateau region of British Columbia and draining a watershed of over 90,000 square miles. In its descent to the sea it cuts through the coastal range of mountains in a narrow canyon called Hell's Gate, then continues for 130 miles to empty into the Strait of Georgia. Thus the river consists of two portions; an extensive area above Hell's Gate referred to as the Upper Fraser, and an area of much lesser extent below Hell's Gate known as the Lower Fraser. Frequent reference will be made to these two areas.

GENERAL CONSIDERATIONS

In analyzing and evaluating the age, sex and size data on the sockeye salmon populations of the Fraser River, three important factors need to be taken into consideration: the life history of the species, the existence of races, and the phenomenon of quadrennial dominance. Information on these factors is obtained in part from unpublished data of the Commission.

Life History

The adult sockeye salmon proceed upstream from late June to the end of October and spawn in tributary streams having lakes within their watershed. In most cases, spawning takes place in streams above a lake and the young fish upon emerging from the gravel in the following spring are carried downstream into the lake. In a few regions, spawning takes place on gravelly beaches of lakes so that the emerging fry are immediately located in their lacustrine environments. In some cases, the adults spawn in the outlet streams of lakes and the young of these spawnings are carried downstream to the quiet waters of a stream expansion or a small lake and subsequently swim upstream into the large lake. The young sockeye remain in the lake for a year except for a small percentage which remain for two years. They then leave the lake, proceed to the ocean, feed, grow, commence sexual development in their third, fourth or fifth years and return to their natal spawning stream.

Some sockeye proceeding to the lower Harrison River have scales which fail to show a winter check at the end of the first year. Gilbert (1919) interpreted these scales to mean that the young fish did not move upstream into Harrison Lake but went to sea as fry in their first year. Valid proof of the existence of Fraser sockeye which do not spend one year in fresh water remains to be established.

There are variations in the basic life history of the sockeye salmon as a result of extensions or curtailments of the fresh and saltwater periods. These variations give rise to age-classes which for convenience are designated by numbers. For example, a fish which has spent one year in fresh water and matures in its fourth year is indicated by the symbol 4_2, the first figure indicating the age at maturity and the subscript indicating the year in which the fish went to sea (Clemens, 1935).

Year classes making up the Fraser River sockeye, as defined by Gilbert and Clemens, are as follows:

Age at Maturity	Years in Lake	Year of Migration to Sea	Designation of Year-Class
3	0	1	3_1 (sea type)
3	1	2	3_2 (jack)
4	0	1	4_1 (sea type)
4	1	2	4_2
4	2	3	4_3 (jack)
5	1	2	5_2
5	2	3	5_3
6	1	2	6_2
6	2	3	6_3

Only four age-classes commonly occur in the Fraser River populations: 3_2, 4_2, 5_2 and 5_3, and only these will be dealt with in the present paper.

Races

The sockeye population of the Fraser River consists of a large number of discrete units which are usually referred to as races. Each race is usually specific in its time of appearance at Sooke, migration period up the Fraser River, occupation of a particular spawning ground, average size of individuals, scale characteristics and probably in a number of other features. For example, Forfar Creek sockeye of the Early Stuart run appear at Sooke in late June and reach their peak numbers about July 4. They enter the Fraser River three days after their appearance at Sooke, proceed upstream for 670 miles at an average rate of about 30 miles per day, enter Forfar Creek and spawn, for the most part, from August 1 to 10. The 4_2 fish have an average length of 23.17 inches and average weight of 5.45 pounds. On the other hand, the Adams River sockeye usually reach their peak numbers at Sooke about August 20. They delay in the Strait of Georgia for 15 to 20 days and then enter the Fraser River about September 15. The fish travel for 300 miles at a rate of approximately 17 miles per day and the peak of spawning occurs from October 15 to 20 (Killick, 1955). The 4_2 fish have an average length of 24.52 inches and an average weight of 6.70 pounds.

In each year there is a procession of racial populations appearing in the traps at Sooke in an order which is maintained consistently year after year, although the annual numbers of fish of each race may vary widely. TABLE 1 provides the average expected duration and peak dates of passage of the most important races of Fraser sockeye at the Sooke traps. These dates are two days previous to the times of passage at the San Juan Islands based on the scale identification analyses and speeds of migration by Henry (1961). Except at the beginning of the season, there is considerable overlapping of the races; that is, there may be representatives of two or more races at any one time in the fishing area. With the exception of the Adams River run, the fish proceeding to the areas above Hell's Gate appear earliest in the sequence while those proceeding to the areas below Hell's Gate appear latest with the exception of the Pitt River fish. In seeking to interpret the sampling data on either an annual or weekly basis, it is essential to realize the existence of these races and to appreciate the relation of the time of their migration to the sampling data.

TABLE 1—The average expected duration and peak dates of passage of various Fraser River sockeye raes at the Sooke traps, based on scale analysis by Henry, (1961).

RACE	DURATION	PEAK OF ABUNDANCE
Early Stuart	June 18 to July 22	July 4
Bowron	July 2 to August 3	July 18
Pitt	July 5 to August 5	July 20
Quesnel (Horsefly)	July 15 to August 4	July 26
Chilko	July 8 to August 29	July 31
Late Stuart	July 16 to August 19	August 1
Stellako	July 16 to August 29	August 2
Birkenhead	July 18 to September 2	August 8
Harrison Rapids*	July 20 to August 31	August 11
Weaver	July 23 to September 3	August 14
Cultus	July 29 to September 10	August 19
Adams River	August 3 to September 10	August 20

* Limited information.

Quadrennial Dominance

The majority of the racial populations have four essentially distinct cycle-years due to the preponderance of four-year-old fish and each cycle-year tends to have a consistently different level of productivity. In the large reproductive areas, such as the Stuart, Quesnel and Shuswap Lakes, one cycle-year is much more productive than the other three and is known as the dominant year (TABLE 2). Up to the year 1913, the major up-river races had their dominant cycle-years in unison on the 1893-1913 cycle. The rock slide in 1913 at Hell's Gate almost annihilated this dominant cycle (Thompson, 1945). In recent years, the Stuart and Quesnel races have re-established dominance in the original cycle-years, 1913-1957, while that of Shuswap (Adams River) has developed dominance in the 1910-1958 cycle and that of Chilko chiefly in the 1912-1960 cycle. Dominance has not developed for any race in the 1911-1959 cycle (Internat. Pacific Salmon Fish. Comm., Ann. Rept. 1955).

TABLE 2—Escapements to various spawning areas illustrating the feature of one dominant cycle year.

YEARS	SPAWNING AREAS				
	Adams	Chilko	Quesnel	Early Stuart	Late Stuart
1941	50	280,000*	1,090*	6,216	5,425*
1942	2,568,000*	34,100	0	8,006	Present
1943	10,000+	13,546	0	3,005	2
1944	1,567	328,655*	3	398	25
1945	67,475	192,884	3,000*	26,341*	24,507*
1946	2,352,000*	58,950	60	9,554	562
1947	200,100	55,000	6	14,200	60
1948	15,100	670,000*	50	12,000	300
1949	21,320	59,000	20,350*	564,212*	147,900*
1950	1,268,000*	29,800	400	60,000	3,043
1951	145,190	118,110	51	61,023	2,300
1952	10,856	489,473*	7,013	33,580	1,135
1953	221,732	197,660	107,562*	154,122*	354,843*
1954	2,065,743*	36,534	297	35,286	5,544
1955	63,500	128,081	62	2,170	7,614
1956	8,173	647,479*	2,958	25,157	1,454
1957	307,223	140,765	229,055*	235,033*	526,920*
1958	3,280,016*	137,081	1,849	34,633	22,719
1959	134,782	470,621	Present	2,663	6,007
1960	2,218	420,746*	3,092	14,572	2,748

* Dominant years.

From the preceding, it is evident that a random sample of fish taken at Sooke or in the San Juan Island area on any one day may be drawn from one or more races, each having its own cycle of variable abundance; from a particular section of the individual migration pattern of each race; from the year-classes constituting each race; and from the varying proportions of the sexes within each age-class of each race. Each sample will be of a rather composite character. The analyses of the present data must of necessity involve the population of the Fraser River as a whole and the results must be interpreted as far as possible on the basis of such information as may be available on the occurrence of races and cycle years.

MATERIALS AND DATA

The analyses are based on data obtained in random samples of fish taken by the commercial traps at Sooke at the southern end of Vancouver Island and by purse seines operated in the San Juan Island area supplemented by other records where applicable. The material from 1915 to 1937 consists of scales, sex records and physical measurement data deposited with the International Pacific Salmon Fisheries Commission by the Fisheries Department of British Columbia under whose auspices a program of annual sampling and analysis was initiated and carried out throughout the above period. Subsequent to 1937, the material has been obtained by the Commission.

The samples at Sooke were taken only on the days of trap lifts and varied in both their frequency and numbers of fish sampled. The material has shortcomings in that the number of fish sampled per day does not bear either a constant relation to the total number caught on the sample day nor to the total number of fish passing the trap location. The trap-samplings were advantageous because the traps were non-selective as to size and sex of the fish, except possibly in the case of the small three-year-old fish, and the location of the traps well to seaward provided fish with minimum development of secondary sexual features, such as elongated snout in the male, and minimum amount of scale resorption. The samples throughout the period from 1915 to 1937 were taken almost without exception by the same individual.

The fish sampled from the San Juan Island area were caught in purse seines. Again, the number of fish sampled was not related to the total catch and the number of samplings during each year varied considerably. The purse seines, like the traps, should be non-selective except possibly in respect to the small three-year-old fish.

Since the results of tagging sockeye salmon at the traps by the Commission have shown that fish caught there prior to July 1 were largely from runs proceeding to streams other than the Fraser (MacKay, *et al.*, 1944, Verhoeven and Davidoff, 1962), and since the catches after September 15 were usually small, the materials used in the present analysis are those obtained from July 1 to September 15. To facilitate processing the large volume of data involved, each day's sample was averaged and then grouped by seven-day periods (also referred to as weekly periods) commencing July 1. The total numbers in each age class by time intervals are shown in TABLE 3. Sex ratios, weights and lengths were also grouped by these same time periods for each year. A summary of the data involving 88,368 fish is given in TABLE 4. The ages of the fish in TABLES 3 and 4 were determined by examination of the scales, those from 1915 to 1924 by Dr. C. H. Gilbert (1916-1925), those from 1925 to 1938 by Drs. W. A. Clemens and L. S. Clemens (1926-1930) and those of recent years by members of the Salmon Commission staff.

TABLE 3—Numbers of sockeye in four age-classes in seven-day periods, July 1 to September 15, 1915 - 1960. Samplings obtained at Sooke and in the San Juan Island area.

YEAR	JULY 1 - 7				JULY 8 - 14				JULY 15 - 21				JULY 22 - 28			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
1915	0	120	69	11	—	—	—	—	0	145	59	1	0	49	41	3
1916	—	—	—	—	2	241	28	2	0	187	18	1	24	143	42	3
1917	0	94	4	3	0	193	10	2	0	213	3	0	0	450	4	2
1918	0	29	13	5	0	76	22	7	0	69	23	8	0	36	8	6
1919	0	45	17	8	—	—	—	—	0	54	32	2	0	26	17	1
1920	0	105	41	11	0	180	13	5	0	171	18	1	0	112	33	3
1921	0	41	7	1	0	80	9	2	0	130	11	1	1	83	11	0
1922																
1923	0	21	1	0	0	29	6	2	0	47	13	4	0	54	4	7
1924																
1925	0	71	5	1	0	130	12	3	0	98	11	2	0	80	10	3
1926	0	64	31	5	0	57	31	4	0	78	25	6	0	56	15	2
1927	0	19	2	0	0	39	6	3	0	54	0	2	1	68	5	1
1928	1	31	3	2	0	30	10	0	0	33	3	4	1	72	8	2
1929	2	239	4	3	0	115	0	0	0	58	2	4	2	80	6	6
1930	0	13	3	0	0	29	13	1	0	19	10	0	0	68	16	4
1931	0	33	4	1	0	56	3	0	0	90	14	2	0	90	22	0
1932	0	7	3	0	0	14	1	0	0	19	2	1	1	98	15	0
1933	2	548	5	1	0	103	3	0	0	148	6	3	2	110	8	1
1934	0	4	3	0	0	37	5	4	0	45	10	0	0	48	6	3
1935	—	—	—	—	0	36	10	1	1	60	13	2	0	63	51	2
1936	0	28	4	2	0	27	6	0	0	27	4	0	1	78	5	0
1937	—	—	—	—	0	14	1	0	0	60	0	0	9	74	1	1
1938	0	6	0	0	—	—	—	—	—	—	—	—	2	80	10	1
1939	1	11	5	1	1	19	1	0	0	9	1	0	0	29	13	1
1940	0	6	2	0	0	14	4	0	0	24	4	0	0	15	4	0
1941	—	—	—	—	—	—	—	—	—	—	—	—	0	391	6	4
1942	3	33	4	0	1	58	1	0	—	—	—	—	0	85	15	0
1943	—	—	—	—	—	—	—	—	—	—	—	—	—	21	12	—
1944	—	—	—	—	—	9	12	—	—	161	43	—	—	91	10	—
1945	—	—	—	—	—	132	12	—	—	204	29	—	—	202	27	3
1946	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1947	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1948	—	—	—	—	—	—	—	—	1	139	45	2	0	189	53	0
1949																
1950																
1951	2	800	12	1	14	960	13	1	6	984	60	2	11	984	97	13
1952	—	376	15	4	—	405	76	1	—	1022	290	14	—	1130	140	27
1953	1	458	8	0	4	1778	34	4	4	1337	34	36	12	1572	42	134
1954	—	—	—	—	—	595	10	7	4	745	25	18	4	781	12	18
1955	—	—	—	—	—	300	19	1	1	564	60	4	1	661	74	8
1956	—	13	3	—	—	174	21	—	—	237	41	2	—	241	47	9
1957	—	30	—	—	—	307	2	—	—	303	6	1	10	299	13	1
1958	2	129	6	11	1	183	9	7	3	40	6	3	5	278	31	13
1959	—	—	—	—	—	—	—	—	4	181	11	7	6	230	16	4
1960	—	—	—	—	—	—	—	—	0	88	11	3	4	259	36	9
Totals	14	3374	274	71	22	6420	403	57	24	7843	943	136	97	9476	986	295

TABLE 3—(Continued)

JULY 29 - AUG. 4				AUG. 5 - 11				AUG. 12 - 18				AUG. 19 - 25			
3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40	132	42	4	89	271	87	20	—	—	—	—	—	—	—	—
0	243	1	2	0	221	12	1	0	134	13	3	0	180	19	0
0	103	17	11	0	84	12	3	1	66	6	0	0	4	3	1
0	63	25	2	0	55	12	1	0	162	19	1	1	73	4	0
0	147	57	6	0	148	55	12	1	108	32	16	0	98	21	42
0	122	19	6	2	162	22	9	2	84	20	11	0	56	10	1
0	53	14	5	0	80	17	0	0	78	6	4	0	134	18	3
0	135	24	4	1	76	37	5	0	48	48	7	4	47	37	4
0	57	5	5	0	66	4	6	0	24	0	2	0	17	0	2
0	65	15	0	0	89	13	1	0	91	12	6	0	207	15	8
4	65	10	3	1	56	16	2	0	60	12	11	1	92	14	5
41	65	7	8	35	49	11	6	28	78	21	13	108	47	18	16
0	60	36	0	0	36	21	4	1	161	34	16	2	160	15	3
6	43	12	1	7	89	24	4	2	83	5	2	2	126	11	5
0	161	23	4	7	235	38	14	3	123	10	3	0	17	2	0
15	349	33	9	26	132	30	8	60	179	45	6	27	48	18	6
0	21	4	0	0	133	8	4	10	310	41	6	4	156	3	0
0	29	36	2	1	94	49	8	2	124	33	5	5	155	22	0
3	51	4	2	0	137	18	6	0	67	10	1	1	61	11	1
6	201	7	5	22	283	11	26	38	269	26	19	23	156	32	21
3	54	8	0	3	63	7	0	3	114	16	0	1	124	8	0
2	36	12	0	0	40	21	0	1	54	23	0	1	88	9	2
0	89	3	1	0	49	11	0	0	21	0	0	4	46	5	2
2	301	5	6	13	326	20	2	39	383	78	24	14	157	37	9
0	32	7	0	0	78	8	1	0	69	6	1	0	82	4	0
1	140	113	1	—	108	53	—	—	158	79	2	2	132	62	—
—	227	21	—	2	104	31	1	—	—	—	—	—	—	—	—
2	246	37	6	13	182	62	—	20	62	21	—	—	—	—	—
—	126	17	—	—	220	17	3	—	260	9	1	—	282	9	—
—	—	—	—	—	—	—	—	1	35	11	2	22	184	58	10
0	559	60	6	4	527	43	4	—	—	—	—	—	—	—	—
16	789	61	12	24	832	77	14	24	1032	51	3	18	609	32	3
—	1012	55	19	—	528	72	37	—	—	—	—	—	—	—	—
23	824	21	59	176	404	26	41	2308	1328	126	112	1058	401	30	30
12	1386	28	54	23	1638	16	43	20	1485	6	6	9	1346	17	10
4	932	57	14	—	1377	145	28	—	1594	84	58	1	568	29	27
—	448	42	15	—	172	17	2	—	50	2	2	—	—	—	—
13	196	10	0	24	189	15	1	91	299	9	2	140	133	11	2
3	273	10	5	2	282	13	8	0	121	5	2	0	103	0	1
4	401	12	11	4	559	34	17	3	402	13	13	2	272	18	10
4	415	43	9	0	487	14	6	0	93	1	2	—	—	—	—
204	10651	1013	297	479	10671	1199	348	2658	9809	933	362	1450	6361	602	224

TABLE 3—(Continued)

YEAR	AUG. 26 - SEPT. 1				SEPT. 2 - 8				SEPT. 9 - 15				TOTAL
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3	
1915	—	—	—	—	—	—	—	—	—	—	—	—	498
1916	23	61	8	3	—	—	—	—	—	—	—	—	1,471
1917	0	61	5	0	—	—	—	—	—	—	—	—	1,873
1918	0	11	3	0	0	1	0	0	—	—	—	—	628
1919	0	84	2	0	0	31	2	0	—	—	—	—	739
1920	0	12	8	14	0	2	0	1	—	—	—	—	1,473
1921	0	5	1	0	—	—	—	—	—	—	—	—	909
1922													605
1923	0	54	7	1	0	32	2	2	0	1	0	0	699
1924													1,514
1925	1	37	14	3	0	6	4	0	—	—	—	—	968
1926	0	14	2	3	—	—	—	—	—	—	—	—	581
1927	0	170	6	0	0	164	1	0	0	58	1	3	1,125
1928	1	58	14	9	1	56	16	5	0	34	11	1	758
1929	116	19	7	12	32	6	0	2	25	3	3	4	1,301
1930	0	184	2	3	0	111	0	2	2	120	3	3	1,155
1931	10	180	20	3	7	113	8	0	3	106	5	1	1,193
1932	0	36	1	3	2	93	7	4	0	13	5	3	968
1933	4	52	8	2	0	51	1	0	0	43	0	0	2,092
1934	3	58	1	6	0	12	2	0	0	13	0	0	960
1935	2	87	6	3	3	75	4	2	2	36	1	0	1,025
1936	0	47	3	3	0	9	3	3	0	4	2	1	630
1937	9	59	28	10	12	58	31	15	4	14	5	6	1,566
1938	4	248	4	0	0	53	4	0	0	29	2	0	847
1939	0	86	7	1	0	88	11	1	3	29	2	0	608
1940	0	22	1	0	—	—	—	—	—	—	—	—	327
1941					—	—	—	—	—	—	—	—	1,817
1942	0	75	10	3	0	52	2	0	0	50	2	0	682
1943	2	187	47	—	0	65	30	0		26	10		1,251
1944	—	—	—	—									712
1945	14	63	17	1									1,355
1946	—	241	1	1									1,187
1947	27	201	51	4	12	171	34	4	1	12	6	0	846
1948	—	—	—	—									1,632
1949													—
1950													—
1951	5	76	2	—									7,640
1952	—	—	—	—									5,223
1953	140	102	2	7									12,676
1954	6	377	1	—									8,702
1955	—	248	13	13									6,885
1956	—	—	—	—									1,538
1957	201	165	15	4									2,492
1958	0	221	0	0	0	344	2	0	0	503	1	0	2,626
1959	6	341	18	16	3	275	11	10	2	176	4	11	3,107
1960	—	—	—	—	—	—	—	—	—	—	—	—	1,484
Totals	574	3942	335	128	72	1868	175	51	42	1270	63	33	88,368

TABLE 4—Numbers of sockeye salmon in the samplings, 1915 - 1960, by age classes.

YEAR	NUMBERS					
	Total Number	Number of Samplings	3_2	4_2	5_2	5_3
1915	498	3	0	314	169	15
1916	1,471	7	178	1,035	225	33
1917	1,873	18	0	1,789	71	13
1918	628	16	1	479	107	41
1919	739	16	1	593	130	15
1920	1,473	24	1	1,083	278	111
1921	909	20	5	763	110	31
1922	605	24	8	521	51	25
1923	699	29	0	583	88	28
1924	1,514	42	13	1,065	292	144
1925	968	28	6	728	202	32
1926	581	21	0	433	113	35
1927	1,125	28	1	1,024	76	24
1928	758	30	10	587	117	44
1929	1,301	33	389	759	79	74
1930	1,155	32	5	961	153	36
1931	1,193	33	37	1,009	128	19
1932	968	20	13	816	107	32
1933	2,092	31	136	1,763	157	36
1934	960	23	17	837	83	23
1935	1,025	27	16	759	225	25
1936	630	16	5	536	70	19
1937	1,566	27	123	1,198	142	103
1938	847	18	16	771	59	1
1939	608	26	8	489	105	6
1940	327	14	4	286	34	3
1941	1,817	16	68	1,558	146	45
1942	682	17	4	614	59	5
1943	1,251	25	5	837	406	3
1944	712	17	2	592	117	1
1945	1,355	28	49	1,091	205	10
1946	1,187	24	0	1,129	53	5
1947	846	20	63	603	160	20
1948	1,632	19	5	1,414	201	12
1949	—	—	—	—	—	—
1950	—	—	—	—	—	—
1951	7,640	40	120	7,066	405	49
1952	5,223	24	0	4,473	648	102
1953	12,676	31	3,726	8,204	323	423
1954	8,702	37	78	8,353	115	156
1955	6,885	29	7	6,244	481	153
1956	1,538	16	0	1,335	173	30
1957	2,492	23	479	1,921	81	11
1958	2,626	28	16	2,477	83	50
1959	3,107	26	34	2,837	137	99
1960	1,484	15	8	1,342	105	29
Totals	88,368		5,657	73,271	7,269	2,171

ANALYSES OF THE SAMPLING DATA

During the preliminary analysis of the sampling data for age, size and sex, it became apparent that certain limitations in precision of the results were inevitable. Small numbers in the samples represented the principal problem. Accuracy of age determinations, selectivity of the sampling gear, changes in age, size and sex characteristics by time and abundance were other features requiring special attention. Also, because the samples were obtained from traps as well as purse seines, it was necessary to know whether the samplings from the two types of gear were equivalent. Each of these factors has been examined to provide measures of confidence relative to the final conclusions to be reached.

Comparisons of Age Compositions from the Sooke Traps and San Juan Island Purse Seines

The data from 1915 to 1942 are those obtained from the samplings at the Sooke traps, while those from 1943 to 1960 are from the purse seine catches in the San Juan Island area. Fortunately, samplings were carried out in both areas from 1938 to 1942 inclusive and these data are given in TABLE 5. It was evident that the percentages among the year-classes as sampled in the five years in the two regions were very similar for the 3_2 and 5_3 ages, whereas there were considerable differences in the respective percentages of the 4_2 and 5_2 groups. The differences in percentages of 4_2 sockeye resulted from variations in numbers of the 5_2 age group. While the 5_2 age group was not precisely equivalent in the two areas, its annual abundance fluctuations were of approximately the same order through the series of years examined.

TABLE 5—A comparison of numbers and percentages of sockeye salmon, 1938 - 1942 in the samplings (July 1 - Sept. 1) obtained from the Sooke Traps and the San Juan Island purse seines.

YEAR	SOOKE NUMBERS					SAN JUAN NUMBERS				
	Total	3_2	4_2	5_2	5_3	Total	3_2	4_2	5_2	5_3
1938	759	16	689	53	1	3,476	40	3,198	197	41
1939	474	5	372	92	5	4,200	39	3,480	634	47
1940	327	4	286	34	3	1,360	11	1,240	108	1
1941	1,817	38	1,582	150	47	1286	54	1,163	56	13
1942	576	4	512	55	5	876	0	817	48	11

YEAR	SOOKE PERCENTAGES				SAN JUAN PERCENTAGES			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
1938	2.1	90.8	6.9	.2	1.1	92.0	5.7	1.2
1939	1.1	78.5	19.4	1.0	.9	82.9	15.1	1.1
1940	1.2	87.5	10.4	.9	.8	91.2	7.9	.1
1941	2.0	87.1	8.3	2.6	4.2	90.4	4.4	1.0
1942	.7	88.9	9.5	.9	0	93.3	5.5	1.2
Total Averages	1.4	86.6	10.9	1.1	1.4	89.9	7.7	.9

The Validity and Interpretation of Scale Readings for Age Determinations

The validity of age interpretations of sockeye salmon scales has been thoroughly investigated by Clutter and Whitesel (1956) and no doubt exists as to the correct determinations of the 3_2 and 4_2 age-classes for scales taken in the commercial fishing areas. It was found, however, that some difficulty could occur in classifying all members of the 5_2 and 5_3 ages. For instance, in seeking out the 5_2 sockeye there was occasional difficulty in deciding whether or not the marginal winter-check region of the scale had been resorbed. This problem was partly resolved in the present analysis by referring to the weight and length of the fish in question. An examination of the lengths of a mixed sample of 4_2 and 5_2 sockeye taken from the San Juan fishery showed that 80.7 per cent (77.3 for males and 84.2 for females) of the 5_2 sockeye were totally distinct from the 4_2 age class. The degree of segregation of these two ages depends considerably upon the races that might be concurrently present, however, in most cases 5_2 sockeye were consistently larger than the 4_2 age irrespective of racial composition. This size differential, plus the fact that only occasionally were scales from the Sooke or San Juan areas resorbed, indicated that few errors should occur in the identification of the 5_2 age class.

With the 5_3 age-group, some difficulty occurred in deciding whether or not there were two winter-checks in the freshwater region of the scales. For example, in 1943 when scale samples of the Chilko sockeye were taken upstream from the commercial fishery both at Hell's Gate and on the Chilko spawning grounds, large percentages of high ring count scales were found but these did not show a clear two-year-in-lake residence growth pattern. Clutter and Whitesel (1956) concluded that these counts, averaging 18 to 19 circuli could only represent the two-year-in-lake type (5_3) because in seventeen years of sampling Chilko sockeye scales, the mean one-year-in-lake type nuclear circulus count has never exceeded 14.8. Thus, according to the above authors, the 5_3 age can always be identified on the Chilko spawning grounds even though the first lacustrine winter check may be indistinct; however, when the 5_3 sockeye were sought in mixed commercial samples, they were unrecognizable unless the freshwater winter-checks were well defined. Fortunately, extensive spawning ground scale analyses have shown that indistinguishable 5_3 sockeye occur very seldom.

In addition to the aforementioned difficulties in the interpretation of 5_2 and 5_3 ages from scale readings, there existed an element of human error in the visual recognition and recording of ages by various observers. Clear and indisputable age patterns are not expressed on all sockeye scales and where patterns were indistinct, the best judgment of the reader was accepted. All damaged or regenerated scales were rejected. Accuracy eventually depended upon the careful consideration of each scale by a trained observer. The degree of reader variation is illustrated by comparative readings of over 3,000 scales by Clemens and another qualified scale reader of the Commission staff. The age composition percentages of these scales by the two independent readers are presented in TABLE 6.

TABLE 6—A comparison of the percentage age composition of two sets of scales taken from the commercial fisheries in 1956 and 1958 and independently interpreted by a Commission staff member and by Clemens.

WEEKLY PERIODS	YEAR - 1956							
	3_2*		4_2		5_2		5_3	
	Staff	Clemens	Staff	Clemens	Staff	Clemens	Staff	Clemens
July—								
1 - 7	—	—	—	—	—	—	—	—
8 - 14	—	—	89.23	87.76	10.77	11.22	0	1.02
15 - 21	—	—	84.64	81.57	14.64	17.41	.70	1.02
22 - 28	—	—	81.14	79.19	15.82	19.13	2.34	1.68
29 - Aug. 4	—	—	88.71	88.98	8.32	9.45	2.97	1.57
August—								
5 - 11	—	—	90.05	87.13	8.90	11.88	1.05	.99
12 - 18	—	—	92.59	94.34	3.70	5.66	3.71	0
19 - 25	—	—	—	—	—	—	—	—
26 - Sept. 1	—	—	—	—	—	—	—	—
Weighted Season Averages	—	—	86.80	85.39	11.25	13.34	1.95	1.27

* 1956 Jacks eliminated in routine sampling.

WEEKLY PERIODS	YEAR - 1958							
	3_2		4_2		5_2		5_3	
	Staff	Clemens	Staff	Clemens	Staff	Clemens	Staff	Clemens
July—								
1 - 7	1.36	0	87.16	90.98	4.05	4.51	7.43	4.51
8 - 14	.50	.54	91.50	93.48	4.50	5.98	3.50	0
15 - 21	5.77	3.92	76.92	78.43	11.54	15.69	5.77	1.96
22 - 28	1.72	1.22	82.33	86.07	10.78	9.84	5.17	2.87
29 - Aug. 4	1.58	1.51	91.62	90.95	4.71	6.53	2.09	1.01
August—								
5 - 11	.66	0	92.46	93.46	4.26	4.90	2.62	1.64
12 - 18	0	0	93.81	98.02	4.42	.99	1.77	.99
19 - 25	0	0	99.04	99.05	0	0	.96	.95
26 - Sept. 1	0	0	100.00	99.55	0	.45	0	0
Weighted Season Averages	.95	.58	91.32	92.82	4.66	5.11	3.07	1.49

In TABLE 6, the age analyses by the two readers were grouped into seven-day periods to provide for seasonal differences in the relative proportions of 3_2, 4_2, 5_2 and 5_3 sockeye. The scales were taken from fish caught by seines fishing in the San Juan Island area in 1956 and 1958. In 1956, the comparative readings for the season totals were 86.80 and 85.39, 11.25 and 13.34, 1.95 and 1.27 per cent respectively for the 4_2, 5_2 and 5_3 ages. In 1958, the comparative readings for the season totals were .95 and .58, 91.32 and 92.82, 4.66 and 5.11, 3.07 and 1.49 per cent for the 3_2, 4_2, 5_2 and 5_3 ages. These data indicated that the readings were in reasonable agreement; that is, within 1.5 to 2.0 per cent variation on the basis of the total 1956 and 1958 seasons. Differences between readings by seven-day periods were greater and ranged as high as 4.1 per cent.

Clemens consistently recorded more 5_2 sockeye because he was able to verify this age by size measurements which were not available to the other reader. Contrarywise, Clemens' counts of 5_3 sockeye were usually less than those of the second reader because he was less familiar with the spawning ground scales where the basic 5_3 pattern is most readily identified. In any event, it was apparent that some discrepancies in age interpretation from scales did exist and these would occur between any two readers and even between successive readings by a single individual. The degree of reader variation was not significant when an age class occurred in substantial numbers, but whenever an age class represented only 1 or 2 per cent of the total sample, a variation of 1 per cent was significant and could result in errors of 50 to 100 per cent in the eventual calculation of this particular age. It was therefore concluded that any year to year changes in the numbers of sockeye in minor age classes would have to be considered with caution; however, any trends in their occurrence through the 46 years of data would be reliable provided that the methods of analysis remained standard.

Sample Sizes

In any sampling procedure, assuming randomness, it is essential to know the reliability of the sample sizes since there exists a range of estimates which is usually reduced with increasing numbers. The range of estimates established for age determinations is not expected to be extensive since all age classifications from commercial catches are precise for each individual fish and only four ages are involved: 3_2, 4_2, 5_2 and 5_3. However, some numerical level of sample size must be established if the estimates of age proportions are to be accurate within reasonable limits. This problem of sample size in age determination has been previously investigated by Clutter and Whitesel (1956) wherein large samples of sockeye scales were divided into smaller subsamples of various magnitudes to show how the estimates of age composition became more exact as the sample sizes were increased. In one case a total sample of 1,200 sockeye scales was divided into twenty-four systematic subsamples of 50 fish each and the percentage ranges of 3_2 sockeye were measured at sample levels of 50, 100, 200, 300, 400 and 600 as follows:

Sample Size	Range of Estimates of 3_2	Variation
50	0.00 - 10.00 per cent	10.00 per cent
100	2.00 - 7.00 per cent	5.00 per cent
200	3.50 - 6.50 per cent	3.00 per cent
300	3.67 - 6.00 per cent	2.33 per cent
400	4.75 - 5.25 per cent	.50 per cent
600	4.50 - 5.33 per cent	.83 per cent
1200	Average 4.92 per cent	

Another mixed age sample of 1,400 sockeye scales taken for this present analysis on August 14 to 18, 1955 was subdivided as follows:

Sample Size	Range of Estimates of 4_2	Variation
50	84.0 - 96.0 per cent	12.0 per cent
100	89.0 - 94.0 per cent	5.0 per cent
150	89.4 - 94.0 per cent	4.6 per cent
200	89.5 - 93.5 per cent	4.0 per cent
250	90.8 - 94.0 per cent	3.2 per cent
300	91.4 - 93.0 per cent	1.6 per cent
350	90.9 - 93.4 per cent	2.5 per cent
400	91.0 - 93.3 per cent	2.3 per cent
500	91.0 - 92.8 per cent	1.8 per cent
1400	Average 91.71 per cent	

In the above case dealing with a high percentage of 4_2 sockeye, a sample size of 300 would be quite adequate, having a range of estimate variation of only 1.6 per cent. As a matter of fact, larger samples up to 500 did not reduce the degree of sample variation but fluctuations occurred randomly around the 2.0 per cent level.

The range variations of 5_3 and 5_2 sockeye in subdivisions of the same 1,400 samples were as follows:

Sample Size	Range of Estimates of 5_3	Variation
50	0.0 - 8.0 per cent	8.0 per cent
100	1.0 - 6.0 per cent	5.0 per cent
150	1.3 - 4.6 per cent	3.3 per cent
200	2.0 - 4.0 per cent	2.0 per cent
250	2.4 - 3.2 per cent	0.8 per cent
300	2.3 - 3.6 per cent	1.3 per cent
350	2.0 - 3.4 per cent	1.4 per cent
400	2.5 - 3.8 per cent	1.3 per cent
1400	Average 3.15 per cent	

Sample Size	Range of Estimates of 5_2	Variation
50	0.00 - 10.00 per cent	10.00 per cent
100	2.00 - 8.00 per cent	6.00 per cent
150	2.00 - 7.30 per cent	5.30 per cent
200	2.50 - 7.00 per cent	4.50 per cent
250	2.80 - 6.40 per cent	3.60 per cent
300	3.30 - 6.30 per cent	3.00 per cent
350	3.14 - 6.57 per cent	3.43 per cent
400	3.00 - 6.00 per cent	3.00 per cent
1400	Average 4.57 per cent	

For the 5_3 sockeye which averaged 3.15 per cent of the total 1,400 sample, it was found that subsamples of 200 confined the range to 2.0 per cent. For the 5_2 age, the variation was 4.5 per cent for samples of 200.

The 3_2 sockeye in the total sample of 1,400 fish equalled only .57 per cent, so their range of variation in different sized subsamples was not considered.

The significance of the range variations between subsamples is finally dependent upon the actual proportions of the sought for age group. For instance, when an age group such as the 4_2 is represented in substantial abundance (80 to 90 per cent) then a range of estimates in the order of 3 to 4 per cent does not constitute a serious problem. But when an age class such as 5_2 or 5_3 represents only 4 per cent of the total sample then a range variation of 3 or 4 per cent is significant and any numbers calculated from these percentages could fall below or above the actual by as much as fifty per cent.

In the presentation of *size data*, the mean or average weights and lengths will be given without repeated reference to standard deviations; however, examinations of randomly selected size frequency distributions have been made to illustrate the degree of variation that may occur by chance with different sample sizes. For instance, a sample of 375 weight measurements of 4_2 sockeye taken at Sooke in the period July 22-28, 1941 was subdivided into groups of 25, 50, 75 and 100 and the following ranges in average weights of the subsamples were found:

Sample Size	Range of Estimates	Variation
25	81.16 - 88.44 ounces	7.28 ounces
50	84.20 - 86.78 ounces	2.58 ounces
75	85.36 - 86.21 ounces	.85 ounces
100	85.46 - 86.13 ounces	.67 ounces
375	Average 85.66 ounces	

Another sample of 400 sockeye taken at Sooke from August 12-18, 1941 was subdivided as follows:

Sample Size	Range of Estimates	Variation
25	79.76 - 90.08 ounces	10.32 ounces
50	81.90 - 87.68 ounces	5.78 ounces
75	81.70 - 86.22 ounces	4.52 ounces
100	82.95 - 85.42 ounces	2.47 ounces
200	83.00 - 84.40 ounces	1.40 ounces
400	Average 83.66 ounces	

An almost pure racial sample of Early Stuart sockeye was taken at Sooke on July 7, 1955 and these 475 sockeye were examined for range of estimates at various sample levels:

Sample Size	Range of Estimates	Variation
25	80.78 - 90.05 ounces	9.27 ounces
50	82.49 - 88.88 ounces	6.39 ounces
75	82.55 - 86.99 ounces	4.44 ounces
100	83.01 - 86.64 ounces	3.63 ounces
125	83.65 - 84.66 ounces	1.01 ounces
150	83.78 - 85.11 ounces	1.33 ounces
175	83.96 - 85.09 ounces	1.13 ounces
200	83.68 - 84.94 ounces	1.26 ounces
225	84.02 - 84.82 ounces	.80 ounces
475	Average 84.36 ounces	

The weight variations for a pure race sample were actually more extensive than for the sample from mixed races taken later in the season. In all cases it was apparent that minimum samples of 125 to 200 were required to provide average estimates of weight below a range variation of 2 ounces, although a sample of 75 confined the range to .85 ounces in the first example. At the levels of 200 to 250, as required to provide reasonable age data, weight averages would fall within a range of .67 to 1.40 ounces according to the above examinations. Thus, on the average, where weights were determined on the basis of samples of 200 to 250 sockeye, the values obtained would be accurate within about 1.0 ounce. Only the 4_2 sockeye were sampled in sufficient abundance to provide accuracy to this degree; therefore, it would be necessary that any examinations of annual differences and possible long term fluctuations in sockeye sizes be restricted to the 4_2 age.

Selectivity of the Sampling Gear for 3_2 Sockeye

In obtaining annual samples of sockeye from the Sooke traps and United States purse seines, it was recognized that the small 3_2 (jack) sockeye may have escaped through these particular gears at a rate disproportionate to that of the larger sockeye. Clutter and Whitesel (1956) found that upon close examination of pure purse seine samples, some net-marked fish were present even among the size group of jacks which were actually caught, thereby indicating that at least some of the smaller sizes could have passed through the purse seine web, thus contributing to the differential selection of various age groups. Whether these net-marked jacks had escaped through seine meshes only or whether some were marked because of prior entanglements in gill nets was not established. However, other investigations being conducted by the Commission have revealed that different percentages of jacks occur in the spawning ground escapements compared with those which occur in the commercial fishery. This proved conclusively that selectivity did exist somewhere in the fishery. Evidence for the differential capture of small and large-sized sockeye within the commercial fishery is provided in the following table:

YEAR	COMMERCIAL FISHING MORTALITIES BY ALL GEAR	
	Small sockeye (3_2)	Large sockeye (4_2, 5_2, 5_3)
1953	59.05 per cent	78.00 per cent
1954	30.97 per cent	75.37 per cent
1955	49.17 per cent	85.40 per cent
1956	29.55 per cent	67.54 per cent
1957	55.11 per cent	66.35 per cent
1958	34.82 per cent	72.72 per cent
1959	45.43 per cent	78.35 per cent

Obviously a considerable portion of the 3_2 sockeye passed through or eluded the commercial fishery but it remained to be established which types of gear were responsible. Fortunately, the Commission, in recent years, has maintained separate estimates of the number of 3_2 and large sockeye by each type of gear in each major fishing area making it possible to calculate gear efficiencies for the respective capture of small and large-sized fish. Data for the period 1953 to 1959 were analyzed.

The analysis consisted of passing the total number of 3_2 and large sockeye (catch plus escapement) through consecutive commercial gears commencing with the first chronological fishery. For example, in 1959 there were 4,271,688 large sockeye and 40,339 small jack sockeye present as the total run arrived at the Canadian purse seine fishery off Port San Juan. (This does not provide for a partial migration of Fraser sockeye through Johnstone Strait; however, even though a portion of the run may have diverted through the northern route, the ratio of jacks to large sockeye has been found, from a limited amount of data, to be equivalent in both areas.) In a catch of 511,059 large sockeye by the Canadian seines at San Juan, there should also have been 4,826 jacks taken if no selectivity for size occurred. The actual catch of jacks was 4,830 for an efficiency rating of 100.8 per cent (non-selective). Marine gill nets, operating in both United States and Canadian waters, took so few jacks (as reported by Henry, 1961) that their jack efficiency was rated as zero. The United States purse seines, fishing after the Canadian purse seine and gill net fisheries at Port San Juan, and amidst the United States gill nets, captured 1,395,419 large sockeye and 9,014 jacks. After allowing for the extra jacks that passed unimpeded through the various gill nets, the United States seines should have taken 14,737 jacks; thus their efficiency in capturing only 9,014 was 61.18 per cent in 1959.

When the seven years of data from 1953 to 1959 were combined, it was found that, on the average, *Canadian purse seines* were 100 per cent effective in capturing jacks in proportion to the larger sockeye although in 1954 and 1958, when jacks represented only 1.01 and .08 per cent of all ages, their capture by Canadian seines was down to 40.2 and 45.1 per cent. The United States purse seines had an average efficiency of 73.7 per cent for the seven years but there was a distinct difference in results for years of small and large jack abundance. For example, in 1953 and 1957 when substantial percentages of jacks were present (10.05 and 16.39 per cent) the efficiency of catching jacks by United States seines was 107 and 108 per cent respectively; whereas, in the remaining five years when jacks occurred in small percentages of .08 to 1.01, the United States seines caught only 60 per cent of the numbers of jacks expected. This difference in the successful capture of jacks in some years while not in others occurred irrespective of the individual size of the sockeye involved, since in 1953 Fraser River sockeye were noticeably large, while in 1957 they were unusually small yet in both of these years the jacks were captured to an equal extent by the United States seines.

The disparity in the capture of jack and large sockeye between years of 3_2 scarcity and abundance is probably associated with the large sampling error that is inherent in the sampling procedure, especially when the 3_2's are present in very small numbers. Henry (ibid.) illustrated this point quite adequately wherein he notes on page 21 that:

> "The theoretical relative sampling error increases quite rapidly with smaller sample sizes. Even with a sample of 10,000 (for racial scale analysis), the relative error for a race comprising 1.0 per cent of the catch would be 20 per cent."

The degree of possible 3_2 selection at the Sooke traps was also considered. Unfortunately, while improved samples of large and small sockeye have been taken from purse seines and gill nets in recent years, these were not available from the Sooke traps which operated only in two years since 1955. However, it has been shown previously in TABLE 5 that the average percentage of the 3_2 age class in the Sooke trap samples was the same as that from the San Juan Island seines, that is 1.4 per cent. Therefore, since the traps and seine gears both provided equivalent 3_2 age samples for the same group of years, it was concluded that the numbers of jacks in both the purse seine and the trap catch samples were probably slightly less than the actual numbers present. The range of estimates for small numbers of 3_2's in most years were sufficiently broad that no attempt was made to revise the total 3_2 numbers.

Weighting the Samples by Time and Abundance

Inasmuch as the sample sizes were not taken in proportion to the numbers of fish present from either the traps or purse seines, it was necessary to weight the data according to the varying abundance. Also, it was found advisable to calculate the whole numbers of each age class rather than work with percentages since the reciprocal effect that percentages of one age class had upon another was often grossly misleading. This was most evident in the case of 5_2 sockeye which appeared least abundant in years when large upriver runs of 4_2 sockeye occurred and; conversely, most abundant when the upriver runs were small. Significant percentage changes of the 5_2 sockeye were often recorded even though there may have been no change in their actual numbers.

To obtain whole numbers of each age class, the total annual sockeye production including both the commercial and Indian catches and the spawning ground escapements had to be known. Data on the commercial fishery in Convention waters were available from Rounsefell and Kelez (1938); Washington State and Canadian departments of Fisheries and the Annual Reports of the Salmon Commission for both United States and Canadian fleets for all years from 1915 to 1960. These commercial catch numbers included small numbers of non-Fraser sockeye taken early in the season in Convention waters. Indian catches and spawning escapements since 1941 and 1940 respectively are from the Commission's Annual Reports. However, these same data for earlier years were not available and it was necessary that the early statistics for Indian catches and spawning escapements be estimated as accurately as possible. The ultimate data recorded in TABLE 7 were developed as follows:

Indian catches of sockeye for the years 1915 to 1940 were estimated in thousands relative to the average Indian catches of 1941 to 1960 and varied according to the general numbers of fish available each year. Zero catches were recorded for 1919, 1920, 1921 and 1922 when all Indian fishing was prohibited by the Canadian Department of Fisheries. The estimates of the early Indian catches could be in error by ten or even twenty thousand sockeye; however, such discrepancies were negligible considering the large numbers of fish involved in the total production.

Sockeye escapements on the other hand represented about twenty per cent of the total runs and required more specific consideration. Two methods were used to calculate escapements for the years prior to 1940. First, cycle average percentage escapements were calculated from the Salmon Commission's records of 1941 to 1960 (Internat. Pacific Salmon Fish. Comm., Ann. Repts., 1942 to 1961). In deriving these averages, years of extended closures were omitted, allowances were made for losses at river obstructions, and extra escapements

TABLE 7—Summation of the annual United States, Canadian and total Convention water catches, Indian catches, spawning grounds escapements and total production of Fraser River sockeye from 1915 to 1960.

Year	United States Catch	% of Total Run	Canadian Catch	% of Total Run	Total Catch	% of Total Run	Indian Catch	Spawning Ground Escapement	% Escapement	Total Run
1915	736,939	33.60	1,088,524	49.63	1,825,463	83.24	40,000e	327,679c	14.94	2,193,142c**
1916	909,425	58.46	376,891	24.23	1,286,316	82.73	40,000e	229,206c	14.73	1,555,522c
1917	5,005,609	60.00	1,877,792	22.51	6,883,401	82.51	150,000e	1,308,761c	15.69	8,342,162c
1918	569,094	57.13	242,275	24.32	811,369	81.45	30,000e	154,824c	15.54	996,193c
1919	778,669	53.88	470,199	32.54	1,248,868	86.42	0	196,296c	13.58	1,445,164c
1920	677,690	46.58	532,039	36.57	1,209,729	83.16	0	245,038c	16.84	1,454,767c
1921	1,199,929	59.26	486,312	24.02	1,686,241	83.27	0	338,776c	16.73	2,025,017c
1922	513,848	37.06	580,144	41.84	1,093,992	78.90	0	292,628c	21.10	1,386,620c
1923	495,490	48.65	361,463	35.49	856,953	84.14	20,000e	141,519c	13.90	1,018,472c
1924	772,056	52.42	442,250	30.02	1,214,306	82.44	40,000e	218,639c	14.84	1,472,945c
1925	1,375,012	61.92	453,704	20.43	1,828,716	82.34	60,000e	331,759c	14.94	2,220,475c
1926	469,900	26.50	912,566	51.46	1,382,466	77.96	40,000e	350,942c	19.79	1,773,408c**
1927	1,069,557	49.35	713,930	32.94	1,783,487	82.29	50,000e	333,819c	15.40	2,167,306c
1928	630,457	53.90	311,226	26.61	941,683	80.51	35,000e	192,985c	16.50	1,169,668c
1929	1,334,141	51.49	725,037	27.98	2,059,178	79.47	60,000e	472,120c	18.22	2,591,298c
1930	3,544,714	63.07	1,043,318	18.56	4,588,032	81.63	70,000e	962,536c	17.13	5,620,568c
1931	975,591	56.79	458,048	26.66	1,433,639	83.46	45,000e	239,178c	13.92	1,717,817c
1932	853,406	41.84	733,735	35.97	1,587,141	77.81	50,000e	402,616c	19.74	2,039,757c
1933	1,724,127	57.40	726,309	24.18	2,450,436	81.57	55,000e	498,514c	16.60	3,003,950c
1934	3,590,058	58.66	1,430,300	23.34	5,020,358	82.03	65,000e	1,034,968c	16.91	6,120,326c
1935	615,502	34.30	825,508	46.00	1,441,010	80.30	30,000e	323,548c	18.03	1,794,558c
1936	453,025	12.75	2,126,074	59.85	2,579,099	72.60	60,000e	913,284c	25.71	3,552,383c**
1937	897,022	35.17	1,075,986	42.19	1,973,008	77.35	60,000e	517,610c	20.29	2,550,618c
1938	1,408,361	32.22	1,900,220	43.47	3,308,581	75.68	65,000e	998,126c	22.83	4,371,707c
1939	555,233	39.85	568,943	40.84	1,124,176	80.69	40,000e	228,977c	16.44	1,393,153c
1940	654,091	29.74	1,033,000	46.96	1,687,091	76.70	45,000e	467,614	21.26	2,199,705
1941	1,558,554	32.42	2,116,723	44.02	3,675,277	76.44	52,920	1,079,898[1]	22.46	4,808,095

1942	2,935,192	27.08	5,047,599	46.58	7,982,791	73.66	46,708	2,807,718	25.91	10,837,217
1943	242,077	33.10	349,011	47.73	591,088	80.83	27,042	113,120	15.47	731,250
1944	435,443	22.75	1,003,826	52.45	1,439,269	75.20	42,820	431,769	22.56	1,913,858
1945	706,464	32.08	969,444	44.02	1,675,908	76.11	43,959	482,230	21.90	2,202,097
1946	3,551,306	33.08	4,240,198	39.50	7,791,504	72.58	50,127	2,893,027	26.95	10,734,658
1947	88,220	8.62	355,035	34.68	443,255	43.30	42,275	538,171	52.57	1,023,701**
1948	1,089,091	39.17	752,691	27.07	1,841,782	66.24	86,437	852,084	30.65	2,780,303
1949	1,056,792	32.39	1,020,799	31.28	2,077,591	63.67	69,426	1,116,118	34.20	3,263,135
1950	1,220,893	30.73	894,469	22.51	2,115,362	53.24	70,795	1,786,819	44.97	3,972,976
1951	1,136,795	36.66	1,288,162	41.54	2,424,957	78.20	78,305	597,576	19.27	3,100,838
1952	1,113,475	34.75	1,154,383	36.02	2,267,858	70.77	84,503	852,084	26.59	3,204,445
1953	2,032,437	37.59	1,992,343	36.84	4,024,780	74.43	108,140	1,274,346	23.57	5,407,266
1954	4,806,258	39.69	4,722,463	39.00	9,528,721	78.69	94,534	2,485,480	20.52	12,108,735
1955	1,006,610	38.80	1,108,081	38.96	2,114,691	81.51	65,630	414,185[2]	15.96	2,594,506
1956	906,872	33.06	894,836	32.62	1,801,708	65.69	62,188	878,988	32.05	2,742,884
1957	1,689,265	35.12	1,360,760	28.29	3,050,025	63.41	96,497	1,663,320	34.58	4,809,842
1958	5,257,316	27.67	5,241,617	27.59	10,498,933	55.26	82,365	4,138,702[3]	21.78	19,000,000[4]
1959	1,810,738	41.11	1,581,883	35.91	3,392,621	77.03	65,049	946,882	21.50	4,404,552
1960	1,198,969	37.69	1,255,195	39.46	2,454,164	77.15	86,456	640,535[5]	20.14	3,181,155
Totals	65,651,713		58,845,311		124,497,024		2,506,176	37,715,014		168,998,214[4]
Percentages		38.84		34.82		73.66			22.31	

Footnotes:
1. Includes 652,024 est. loss at Hell's Gate block.
2. Includes 35,000 est. loss at Yale block.
3. Includes 322,588 est. loss during spawning migration.
4. Includes est. catch of Fraser River sockeye in Johnstone Strait (4,280,000).
5. Includes 20,565 est. loss at Yale block.

e. Estimated numbers.

c. Calculated numbers.

** Min. number because substantial catch of Fraser River sockeye in Johnstone Strait <u>not</u> included.

from commercial fishing strikes were subtracted. Final percentage escapements thus obtained were 21.94, 22.46, 23.53 and 17.23 for the respective cycle years of 1940-1960, 1941-1957, 1942-1958 and 1943-1959. These percentages were applied to the sum of the commercial and Indian catches of the appropriate cycle years between 1915 and 1939 to produce a complete listing of early escapement data. A second method for calculating spawning escapements for years prior to 1940 is currently (1963) being developed by Gilhousen of the Salmon Commission staff; wherein he establishes the Fraser River gill net catch as a percentage of the total run available after the sockeye have passed through United States waters and then relates this percentage to the length of the Fraser River weekend closures. Thus, the shorter the weekend closure, the larger will be the river catch and the smaller will be the spawning ground escapement. Since both the Fraser River catch and the hours of closure per week are known for all years, it is possible to calculate the annual escapement numbers.

Preliminary calculations by Gilhousen indicate that escapements for the early years (1915 to 1939) would average about 13 per cent; whereas, if escapement percentage averages of recent years were used, they would range from 17.23 to 23.53 per cent. At present, it cannot be determined which of the two levels of escapements is more correct but this will be known when Gilhousen completes a full investigation of all relative historical data. In the meanwhile, it is believed that the most probable escapement percentages will lie between the two estimates. Averages of the two sets of percentage escapements were chosen and these values provided as the best present estimates in TABLE 7. No attempt should be made to calculate returns per spawner from the escapement numbers given until such time as these numbers have been more fully defined and proper cognizance is taken of all possible losses that may have been suffered by the escapements either en route to or within the spawning grounds.

Once the complete listing of total annual production figures from 1915 to 1960 were calculated, it was possible to proceed with the numerical segregation of the 3_2, 4_2, 5_2 and 5_3 age classes. Since the age proportions of the samples changed considerably for different weeks of the season, as did the numbers of sockeye from which the samples were taken; the samples had to be weighted by the numbers of sockeye present each week. Abundance weighting of the age samplings by weeks was accomplished after the annual production totals were converted to seasonal abundance curves by seven-day intervals commencing July 1 and ending September 15. Since the actual numbers of sockeye present at any one time along the migration path could not be measured directly, it was assumed that the United States commercial fishery, which until recently operated first on the incoming run, (except for the Sooke traps which took only a minor percentage of the total run) would vary in direct proportion to the total numbers of sockeye available. On the basis of this assumption, the United States daily catches were grouped into weekly segments; these converted to percentages and the percentage distributions applied to the total production numbers. Complete data were available for this procedure from 1935 to 1960 when total *daily* United States catch records were maintained.

Only *annual* catch totals were published prior to 1935, but it was possible to calculate weekly percentage distributions for the 1915 to 1934 period according to the landings of certain United States traps which fished uniformly throughout the season. The particular traps selected took an average of 48.47 per cent of the annual United States catches.

Once the total production numbers were divided into weekly periods for each year, the sample numbers from TABLE 3 were converted to age composition percentages and these applied to the weekly total production numbers. The complete application procedure is illustrated by an example using the actual statistics of 1931 shown in TABLE 8.

The weekly numbers of 3_2, 4_2, 5_2 and 5_3 age classes of Fraser sockeye for each year from 1915 to 1960 are given in Appendix TABLE A. In presenting such a record, a number of features require explanation since certain weeks and even some years were not sampled for age; yet, a complete sub-division of ages into weekly periods was given for all years. In the 46 years of age analysis, there were only two years in which sampling was omitted completely, 1949 and 1950. With no scale samples taken in 1949, the age analyses of the brood year 1945 were applied. The run of 1949 consisted of 3,263,135 sockeye compared with 2,207,097 in 1945; therefore, it had to be assumed that the 1949 increase was uniformly distributed by time and race to all weeks of the season. For 1950, the age composition percentages of 1938 were applied since the general racial abundance and timing of these two cycle years were quite similar. In the remaining 44 years the samplings could be divided into weekly periods in all but 1924 when only a season age classification was given. The difficulty of 1924 was overcome by using the weekly age composition data of the cycle year 1920. Total production in these two years was similar, 1,472,945 and 1,454,767 and their racial composition believed to have been nearly identical according to the seasonal percentages of the four and five-year age groups. These were 77 per cent four-year fish and 23 per cent fives in 1920 and 78 and 22 per cent in 1924.

While there were only two years totally lacking in age sampling, there were a considerable number of years during which samples were not complete for the eleven weekly periods from July 1 to September 15. However, the numbers of sockeye present were usually small when samplings were missed and as a consequence the total age production numbers were hardly affected. For those weeks when actual sampling data were lacking, an average age composition of the respective cycle-week was used.

Verification of Sample Age Analysis

Before discussing the status of the various age classes of Fraser sockeye, the accuracy of the numbers can be verified by a second technique for the years 1953 to 1960. During this period, Henry (1961) has developed a complete catalogue not only of the age structure of the total Fraser run but also of the number and age components of each of the unit races.

TABLE 8—The seasonal distribution of the 1931 Fraser River sockeye run into 3_2, 4_2, 5_2 and 5_3 age classes.

Weekly Periods	United States Trap Catches	Per Cent of Total Trap Catches	Trap Catch Percentages Applied to Total Run	Per Cent Age Composition of Samplings				Sample Percentages Applied to the Weekly Distribution of the Total Run			
				3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - 7	1,432	.450	7,730	0	86.842	10.526	2.632	0	6,713	814	203
8 - 14	6,627	2.081	35,748	0	94.915	5.085	0	0	33,930	1,818	0
15 - 21	18,465	5.797	99,582	0	84.906	13.208	1.886	0	84,551	13,153	1,878
22 - 28	40,017	12.563	215,809	0	80.357	19.643	0	0	173,418	42,391	0
29 - Aug. 4	65,312	20.504	352,221	9.677	69.355	19.355	1.613	34,084	244,283	68,173	5,681
Aug. 5 - 11	66,407	20.848	358,131	5.645	71.774	19.355	3.226	20,216	257,045	69,316	11,553
12 - 18	57,477	18.044	309,963	2.174	90.217	5.435	2.174	6,739	279,639	16,847	6,739
19 - 25	38,260	12.011	206,327	1.389	87.500	7.639	3.472	2,866	180,536	15,761	7,164
26 - Sept. 1	17,500	5.494	94,377	4.695	84.507	9.390	1.408	4,431	79,755	8,862	1,329
Sept. 2 - 8	7,033	2.208	37,929	5.469	88.281	6.250	0	2,074	33,484	2,371	0
9 - 15	0	0	0	—	—	—	—	—	—	—	—
Totals	318,530		1,717,817					70,410	1,373,354	239,506	34,547

Comparative data, as calculated by Killick and Clemens and by Henry, are shown in TABLE 9 where they have been expressed both as percentages and as whole numbers. In comparing the percentage age compositions, it was found that the two sets of values were remarkably alike and with few exceptions the results agreed within one per cent. Thus, if the differences between age classes within a year or the differences for the same age class through a series of years were greater than one per cent, then these differences could be accepted as being real and not occurring as a function of sampling error. This range of possible sampling error, as indicated by comparing two independent sets of data, was in close agreement with that shown in the sample size analysis previously discussed.

The calculated numbers of the various age classes illustrates the importance of minor differences in percentage accuracy, although in most cases there was good agreement between the two sets of data. Obviously, when an age class is so scarce as to represent only one or two per cent of a total population, its numerical segregation becomes difficult since only very large samples would establish its absolute proportions. With respect to the final accuracy of the age classification through the past 46 years, it is not contended that the numbers are without some element of discrepancy. The original samples were not large and the necessary calculations of early escapements and Indian catches and the weighting of the United States catch data into weekly periods all contribute to chance variations; however, the consistency in the numbers of the various ages and the close agreement of the age classification by two separate methods from 1953 to 1960 are considered amply sufficient to warrant their acceptance.

AGE CLASSES

The total calculated numbers of Fraser River sockeye by age classes for each year from 1915 to 1960 are given in TABLE 10. The percentages of the salmon in the age-classes as calculated from the total numbers are shown in TABLE 11. The 4_2 age class, with an average annual production of 3,279,018 over the past 46 years, has been overwhelmingly dominant with a percentage of 89.25. The 5_2 age class was second in abundance with an average production of 254,847 sockeye each year or a percentage of 6.94. The 3_2 and 5_3 age groups were of minor numerical importance, being represented by annual averages of 80,738 (2.20 per cent) and 59,271 (1.61 per cent) respectively. Numerical trends and possible relationships between the four age classes are described in the following discussion.

The 4_2 Age Class

The distribution of the annual numbers of 4_2 sockeye is shown in FIGURE 1. In presenting these data it should be appreciated that these production figures commenced in 1915 immediately following the disastrous 1913 rock slide at Hell's Gate, thus the annual numbers of 4_2 sockeye during the period 1915 to 1929 averaged only one and one half million excluding 1917. The eight million run of 1917 represented the last major remnant of the historically great runs of 1905-09-13. The year 1930 showed the first signs of recovery in the numbers of

TABLE 9—The percentages and total numbers of 3_2, 4_2, 5_2, 5_3 age classes of sockeye calculated by Killick and Clemens (1) compared to those calculated by Henry (2).

AGES		PERCENTAGES OF EACH AGE CLASS							
		1953	1954	1955	1956	1957	1958	1959	1960
3_2	(1)	10.054*	1.005	.319	.477*	16.388*	.077	.817	.368
	(2)	10.726	.375	1.580	.709	14.909	.467	.889	.413
4_2**	(1)	83.017	96.938	89.902	87.078	79.389	99.118	91.558	92.196
	(2)	81.049	97.911	89.094	84.309	80.605	98.358	91.651	93.148
5_2	(1)	2.405	1.463	7.666	10.069	3.778	.561	4.650	5.788
	(2)	3.491	.989	7.051	11.996	3.491	.551	4.411	4.770
5_3	(1)	4.524	.594	2.113	2.376	.443	.244	2.975	1.648
	(2)	4.734	.725	2.275	2.986	.995	.624	3.049	1.669

AGES		TOTAL NUMBERS OF EACH AGE CLASS							
		1953	1954	1955	1956	1957	1958	1959	1960
3_2	(1)	543,668*	121,643	8,273	13,074*	788,239*	14,527	35,980	11,700
	(2)	579,983	45,408	40,993	19,447	717,099	88,730	39,156	13,153
4_2**	(1)	4,488,945	11,737,996	2,332,511	2,388,459	3,818,529	18,832,413	4,032,718	2,932,896
	(2)	4,382,535	11,855,784	2,311,549	2,312,498	3,876,973	18,688,020	4,036,816	2,963,175
5_2	(1)	130,022	177,183	198,884	276,172	181,699	106,636	204,825	184,121
	(2)	188,768	119,755	182,939	329,036	167,912	104,690	194,285	151,736
5_3	(1)	244,631	71,913	54,838	65,179	21,375	46,424	131,029	52,438
	(2)	255,980	87,788	59,025	81,903	47,858	118,560	134,295	53,093

* 3_2 age established from special large samples.
** includes small numbers of 4_3 and 6_3 ages.

TABLE 10—The total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye present in the years of return to the Fraser River, 1915 - 1960.

YEARS OF RETURN	NUMBERS IN VARIOUS AGE CLASSES				TOTAL
	3_2	4_2	5_2	5_3	
1915	21,231	1,574,429	550,945	46,537	2,193,142
1916	216,014	1,069,261	239,360	30,887	1,555,522
1917	0	8,112,414	178,237	51,511	8,342,162
1918	0	819,374	131,630	45,189	996,193
1919	4,115	1,249,186	180,815	11,048	1,445,164
1920	729	1,095,921	304,847	53,270	1,454,767
1921	9,106	1,749,654	224,154	42,103	2,025,017
1922	19,378	1,242,259	90,399	34,584	1,386,620
1923	0	848,816	133,453	36,203	1,018,472
1924	1,044	1,052,554	344,055	75,292	1,472,945
1925	3,527	1,798,208	353,713	65,027	2,220,475
1926	0	1,515,785	127,360	130,263	1,773,408
1927	998	1,967,848	157,023	41,437	2,167,306
1928	20,419	936,468	150,210	62,571	1,169,668
1929	519,581	1,749,266	176,684	145,767	2,591,298
1930	16,841	4,850,892	596,790	156,045	5,620,568
1931	70,410	1,373,354	239,506	34,547	1,717,817
1932	21,540	1,740,856	221,142	56,219	2,039,757
1933	223,425	2,449,873	269,412	61,240	3,003,950
1934	126,833	5,541,552	356,382	95,559	6,120,326
1935	30,141	1,340,455	377,142	46,820	1,794,558
1936	97,448	3,081,998	291,876	81,061	3,552,383
1937	194,747	1,994,063	211,529	150,279	2,550,618
1938	78,390	3,989,464	302,260	1,593	4,371,707
1939	11,714	1,138,024	227,922	15,493	1,393,153
1940	1,283	1,919,998	269,717	8,707	2,199,705
1941	68,267	4,457,650	198,801	83,377	4,808,095
1942	1,600	10,270,482	452,489	112,646	10,837,217
1943	2,261	476,010	250,273	2,706	731,250
1944	2,438	1,694,716	215,159	1,545	1,913,858
1945	56,336	1,808,757	310,470	26,534	2,202,097
1946	20,197	10,435,169	217,394	61,898	10,734,658
1947	29,308	686,068	290,235	18,090	1,023,701
1948	7,536	2,351,310	387,680	33,777	2,780,303
1949	86,609	2,724,032	430,278	22,216	3,263,135
1950	71,241	3,625,597	274,690	1,448	3,972,976
1951	52,849	2,819,609	200,322	28,058	3,100,838
1952	89,287	2,718,987	329,068	67,103	3,204,445
1953	543,668	4,488,945	130,022	244,631	5,407,266
1954	121,643	11,737,996	177,183	71,913	12,108,735
1955	8,273	2,332,511	198,884	54,838	2,594,506
1956	13,074	2,388,459	276,172	65,179	2,742,884
1957	788,239	3,818,529	181,699	21,375	4,809,842
1958	14,527	18,832,413	106,636	46,424	19,000,000
1959	35,980	4,032,718	204,825	131,029	4,404,552
1960	11,700	2,932,896	184,121	52,438	3,181,155
Totals	3,713,947	150,834,826	11,722,964	2,726,477	168,998,214
Annual Average	80,738	3,279,018	254,847	59,271	3,673,874

TABLE 11—Percentages of 3_2, 4_2, 5_2 and 5_3 sockeye present in the years of return to the Fraser River, 1915 - 1960.

YEAR	3_2	4_2	5_2	5_3
1915	.97	71.79	25.12	2.12
1916	13.89	68.74	15.39	1.98
1917	.00	97.24	2.14	.62
1918	.00	82.25	13.21	4.54
1919	.29	86.44	12.51	.76
1920	.05	75.33	20.96	3.66
1921	.45	86.40	11.07	2.08
1922	2.54	88.54	6.46	2.46
1923	.00	83.34	13.10	3.56
1924	.07	71.46	23.36	5.11
1925	.16	80.98	15.93	2.93
1926	.00	85.47	7.18	7.35
1927	.05	90.80	7.24	1.91
1928	1.75	80.06	12.84	5.35
1929	22.00	65.17	7.03	5.80
1930	.30	86.31	10.62	2.79
1931	4.10	79.95	13.94	2.01
1932	1.06	85.35	10.84	2.75
1933	7.44	81.55	8.97	2.04
1934	2.07	90.55	5.82	1.56
1935	1.68	74.70	21.01	2.61
1936	2.74	86.76	8.22	2.28
1937	7.64	78.18	8.29	5.89
1938	1.79	91.26	6.91	.04
1939	.84	81.69	16.36	1.11
1940	.06	87.28	12.26	.40
1941	1.51	92.59	4.16	1.74
1942	.02	94.77	4.17	1.04
1943	.31	65.10	34.22	.37
1944	.13	88.55	11.24	.08
1945	2.56	82.14	14.10	1.20
1946	.19	97.21	2.02	.58
1947	2.86	67.02	28.35	1.77
1948	.27	84.57	13.94	1.22
1949	2.65	83.48	15.19	.68
1950	1.79	91.26	6.91	.04
1951	1.70	90.93	6.46	.91
1952	2.79	84.85	10.27	2.09
1953	10.05	83.02	2.41	4.52
1954	1.01	96.94	1.46	.59
1955	.32	89.90	7.67	2.11
1956	.48	87.08	10.07	2.37
1957	16.39	79.39	3.78	.44
1958	.08	99.12	.56	.24
1959	.82	91.56	4.65	2.97
1960	.37	92.19	5.79	1.65
Weighted Average	2.20	89.25	6.94	1.61

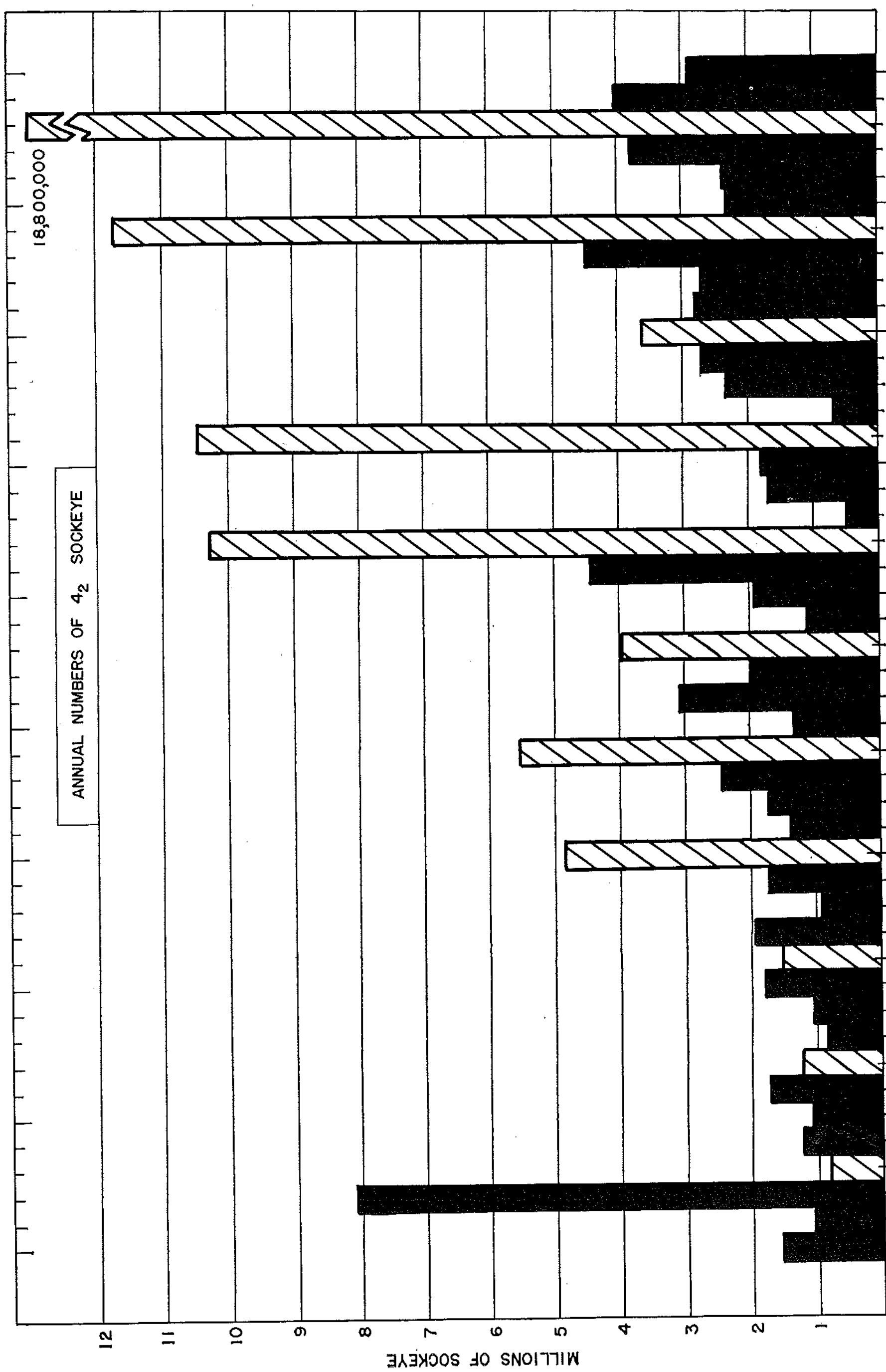

FIGURE 1.—The total annual numbers of 4_2 sockeye returns to the Fraser River for the period 1915 to 1960. The four year returns of the 1918-1958 cycle are cross-hatched for ease of reference.

Fraser sockeye with the Adams River run accounting for most of the five million production. From 1930 to 1958, the Adams run (in the dominant cycle only — 1934, 38, 42, 46, 50, 54, 58) increased substantially with large returns of over 10,000,000 sockeye occurring in 1942, 1946 and 1954. The exceptionally large run of 18,832,413 four-year-old sockeye in 1958 was mainly composed of Adams fish. At the same time, the Chilko run was also gaining numerical strength in two cycle years. The 1936 run of 3,081,998 four-year-old sockeye and the 1941 return of 4,457,650 four-year-olds originated principally from the Chilko spawning grounds. Beginning in 1949, the sockeye production of every cycle has increased well above the depressed state that existed for 35 years following the Hell's Gate obstruction. Construction of fish passage facilities at Hell's Gate and Bridge River Rapids on the main Fraser have assured access to all of the upper Fraser spawning grounds since 1945, in addition to which stringent closures of commercial fishing periods from 1946 to 1950 have rapidly increased the numbers of spawners in previously decimated areas. Since 1950, specially designed fishing regulations also have provided properly timed escapements to assure a high rate of freshwater production (Royal, 1953).

Since the numerical strength of each of the four cycles of 4_2 Fraser sockeye occurs relatively independently, these have been graphed separately in FIGURE 2 and their respective trends through eleven or twelve generations illustrated. Knowledge of the major races involved in the four cycles has been obtained from catch and escapement statistics and detailed racial scale analyses. In certain cases, numerical dominance has shifted from one cycle to another within the past 50 years. The status of the Chilko run in all cycles might well be emphasized since its change of dominance from one cycle to another has had much to do with the numerical trends of each of the four cycles. The records of spawning escapements to Chilko are somewhat fragmentary for the earlier years but they do indicate that the original dominant Chilko run was on the 1913-41-61 cycle in unison with all of the other large Fraser sockeye races. The second largest Chilko run was in the year preceding the dominant run, while the two remaining cycle years were relatively unimportant. This order was retained up to 1941. In 1941, Chilko had an exceptionally large production as evidenced by a large commercial catch. Unfortunately the escapement of 1941 was so seriously blocked at Hell's Gate that only a small run returned in 1945 and dominance shifted to the cycle one year earlier (1912-35-40-44 cycle). Subsequently, the former off-year cycle (1911-35-39-43) rapidly increased beginning in 1951 until, in 1959, the total production exceeded 4,000,000 sockeye and the contribution of the Chilko run was greater than that of any other race.

THE 1915-59 CYCLE RETURNS OF 4_2 SOCKEYE

It is apparent from FIGURE 2 that the sockeye production of the 1915-59 cycle has been the poorest of the four cycle groups up to the year 1951. No dominant runs to any particular spawning areas were evident and it is probable that sockeye of the Lower Fraser area contributed most of the production. The appearance of significant numbers of sockeye late in the season of 1927 suggests that the Adams

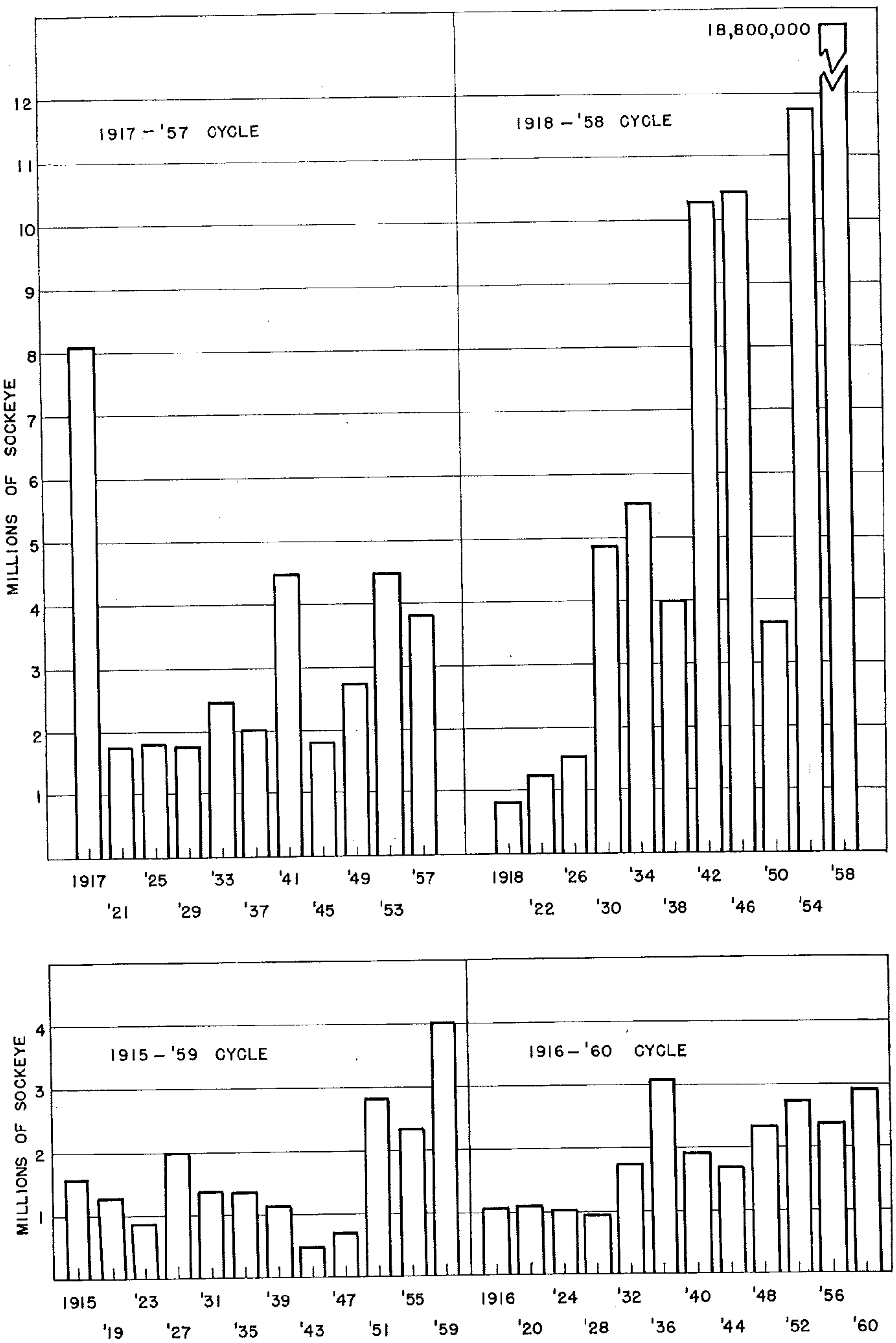

FIGURE 2—Total numbers of 4_2 sockeye returns in the 1915-59, 1916-60, 1917-57 and 1918-58 cycles.

run made up a substantial portion of the nearly 2,000,000 four-year-old fish returning in 1927. (Appendix Table A). No large runs occurred at any other times in that season to indicate significant numbers of other races; however, since 1951, the Commission has firmly established by scale analyses that a sub-dominant run to Chilko, as well as Adams, has produced the major share of sockeye in this cycle.

THE 1916-60 CYCLE RETURNS OF 4_2 SOCKEYE

The 1916-60 cycle ranks third in size of the four cycle groups. In the early years of 1916-20-24 and 1928, the annual runs were sustained at a stable low level of less than 1,000,000 four-year-old sockeye and the lower Fraser undoubtedly accounted for a high percentage of the production. Through the twelve generations shown in FIGURE 2, there has been a distinct upward numerical trend since 1928. In 1932, a substantial return of 1,740,856 sockeye was followed by an especially large run for this cycle of 3,081,998 sockeye in 1936. The return of 1940 reverted to the level of 1932 but a gradual increase in numbers has occurred in subsequent years. The most recent run of 2,932,896 in 1960 exceeded all previous productions for this cycle back to at least 1912 with the one exception of 1936. Since 1932, the Chilko run has become progressively larger and for the cycle years 1940 to 1960, this race has provided the major share of the sockeye.

THE 1917-57 CYCLE RETURNS OF 4_2 SOCKEYE

As previously noted, the 1917 run of over 8,000,000 sockeye was the last large adult return immediately following the Hell's Gate blockage. Subsequent cycle runs from 1921 to 1937 remained below 2,000,000 sockeye except for a slight increase to 2,449,873 in 1933. The 1937 return dropped to 1,994,063 whereas the progeny run of 1941 totalled 4,457,650. Unfortunately, prolonged low water levels at Hell's Gate obstructed much of the 1941 spawning escapement resulting in a reduced cycle return of 1,808,757 in 1945. One fishway was completed at Hell's Gate in time for the 1945 escapement. Unobstructed paths of migration and special management closures led to progressive increases to 2,724,032 sockeye in 1949 and 4,488,945 in 1953. The 1957 adult abundance suffered a decline to 3,818,529 due to a poor marine survival.

As far as the races involved in this cycle are concerned, Chilko was the main contributor in 1941 but since the construction of fishways in 1945, the upper Fraser races to Stuart and Quesnel increased rapidly and, in the cycle years 1953-57-61, these runs have become the major producers.

THE 1918-58 CYCLE RETURNS OF 4_2 SOCKEYE

The early cycle runs of 1918-22-26 of 4_2 sockeye showed no significant numerical strength but were improving very gradually until 1930 when there was a rather sudden three-fold increase to 4,850,892 Fraser sockeye. This run, destined mainly for the South Thompson watershed, was the nucleus of the now "famous" Adams River run. Apart from set-backs in 1938 and 1950, the Adams run developed at a very rapid rate and by 1958 it produced 15,000,000 sockeye while an additional 4,000,000 were credited to all other races of the watershed in that year. Without the Adams run, the annual production of this cycle in recent years would probably range from one to four million.

The 5_2 Age Class

During the 46 years of record, the average number of 5_2 sockeye of the Fraser watershed has been approximately 250,000 annually (TABLE 10). Between 1917 and 1929 the numbers were relatively low, reaching a minimum of 90,399 fish and an average number of 196,352. From 1930 to 1952 there was a higher average annual production of 300,000. Since 1952, the average annual run has been only 182,000. Upon examining the annual abundance fluctuations of the 5_2's in FIGURE 3, it was found that peaks occurred consistently at five year intervals through 1915, 1920, 1925, 1930 and 1935 after which the five year cycle disappeared.

Thompson (1945) studied 5_2 abundance peaks of the Fraser system in an attempt to determine whether five-year-old sockeye were merely carry-overs from the large runs of 4_2's, in which case the 5_2 abundance peaks would occur on a four year cycle but one year later. Instead of this, his data showed a tendency for the peaks of 5_2 and 4_2 abundance to occur in unison; that is, the 5_2's peaked on a four-year cycle in the same years that 4_2's were most abundant. However, Thompson derived the annual numbers of 5_2 sockeye by applying the seasonal percentages of 5_2's in the Sooke samples to the total annual catches but did not weight the samplings for weekly variations in the occurrence of the 5_2 age class. This procedure inadvertently led to the conclusion that large numbers of 5_2 sockeye were always present in the years of large runs of 4_2's. Such was not the case, for when the numbers of 5_2's were calculated from samples weighted by variations in seasonal age class composition and abundance there was no evidence (as demonstrated in FIGURE 4) that large numbers of 5_2 Fraser sockeye coincided with large runs of 4_2's in the same years nor were there large numbers in the years following the abundant 4_2 runs.

Possibly there was a particular race of Fraser sockeye composed mainly of 5_2 fish which was sufficiently large in the 1915-35 cycle years to produce peaks of abundance; or alternately, groups of races, each of which contained sizeable proportions of 5_2 sockeye, were dominant in unison in the 1915-1935 cycles in the same way that larger races of 4_2 sockeye were formerly dominant in the 1905-09-13 cycle. After 1935, peaks of 5_2's no longer occurred at five year intervals but, for some as yet unexplainable reason, peaks of abundance occurred in 1942, 1949 and 1956 at intervals of seven years. If this trend continues, the next abundance peak of 5_2's will return in 1963.

A full understanding of the annual numbers of 5_2 sockeye requires accurate knowledge of the numbers of this age class in each racial stock over an extended series of years. This need is recognized by the Commission and already the annual numbers of 5_2's by race have been derived for each year since 1952. Data for the major races are shown in TABLE 12. Nine years of records are insufficient to explain the annual variations in numbers of 5_2 sockeye but they do establish that this age class is not uniformly distributed among the various races of the Fraser but instead 5_2's are prevalent in some and scarce or absent in others. The 5_2's

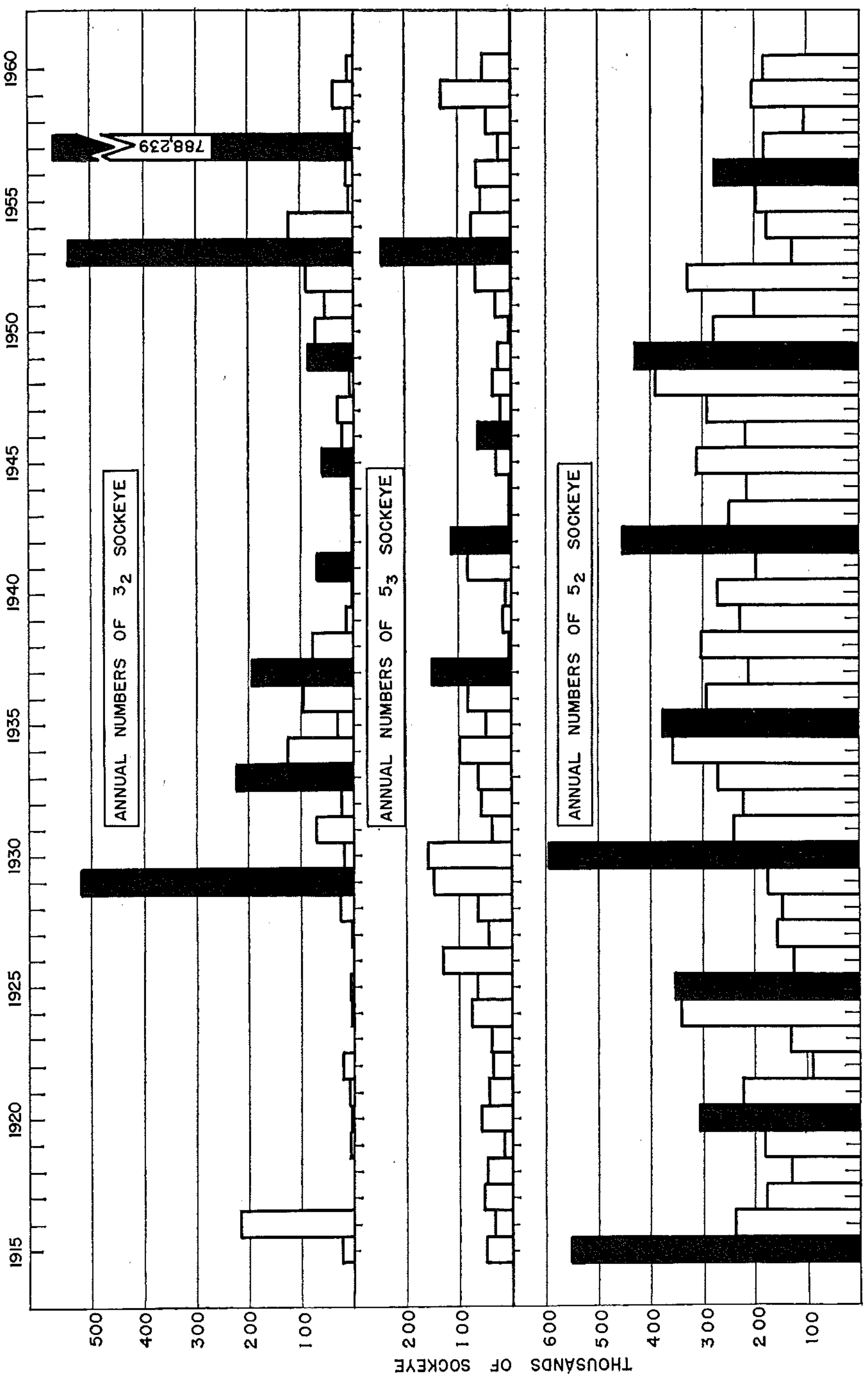

FIGURE 3—The total annual numbers of 5_2, 5_3 and 3_2 sockeye returns to the Fraser River for the period 1915 to 1960. Years of peak abundance are shaded in.

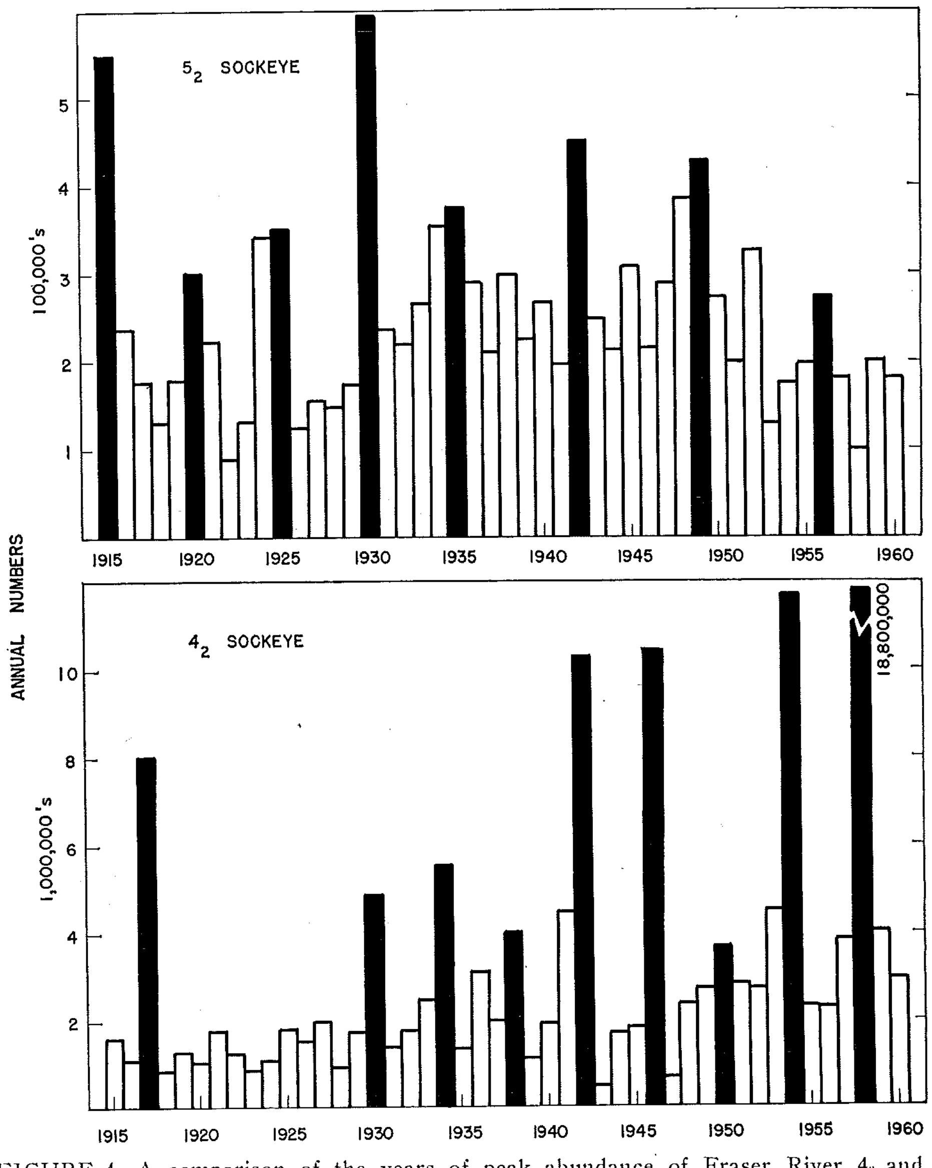

FIGURE 4—A comparison of the years of peak abundance of Fraser River 4_2 and 5_2 sockeye showing that peaks of 5_2 fish do not necessarily occur in the same years as 4_2 fish nor in the years following.

are consistently abundant in the Lower Fraser races to Pitt, Harrison, Birkenhead and present to a considerable degree in Weaver-Widgeon and Cultus. Probably it was the 5_2 sockeye of these races that created the five year peaks from 1915 to 1935 and sustained the levels of 5_2 production from 1917 to 1929 when the Upper Fraser races were at a low ebb. Since 1935, the Upper Fraser races have gradually recovered and with their somewhat erratic numbers of 5_2's have obscured the five year cycles and in fact may have produced sufficient 5_2's to have created the cycles at seven year intervals.

TABLE 12—The annual numbers of 5_2 sockeye in major races of Fraser sockeye situated above and below Hell's Gate, 1952 to 1960.

YEARS OF RETURN	SOCKEYE RACES ABOVE HELL'S GATE									
	Horsefly	Seymour	Adams	Gates-Nadina	Bowron	Late Stuart	Early Stuart	Raft	Chilko-Taseko	Stellako
1952	0	0	1,187	0	5,508	0	5,872	5,033	3,089	8,056
1953	0	0	0	0	0	0	17,130	669	10,935	21,364
1954	0	0	0	0	0	0	1,173	2,833	11,134	6,289
1955	0	0	12,175	50	8,620	2,157	571	5,675	6,510	31,169
1956	0	442	2,522	0	0	7,290	14,237	12,632	19,647	96,855
1957	0	0	1,725	131	5,610	25	10,324	4,297	33,307	14,185
1958	1,012	0	0	354	4,001	501	1,581	1,187	8,657	13,087
1959	0	3,306	10,920	403	2,712	2,204	200	10,469	5,340	63,071
1960	0	987	675	520	3,852	1,745	1,397	13,067	48,975	41,804

YEARS OF RETURN	SOCKEYE RACES BELOW HELL'S GATE				
	Cultus	Weaver Widgeon	Birkenhead	Harrison	Pitt
1952	455	6,274	18,317	55,176	178,229
1953	2,942	6,278	11,352	26,279	91,909
1954	0	9,551	8,681	67,548	12,550
1955	0	10,476	29,407	25,131	51,446
1956	5,847	19,383	63,406	10,888	75,808
1957	16,560	5,082	27,761	12,107	28,830
1958	1,037	17,962	9,746	11,400	9,458
1959	2,413	1,418	16,554	63,337	11,945
1960	1,090	2,550	9,808	7,076	18,196

The 5_3 Age Class

The 5_3 fish are those sockeye which mature at the end of their fifth year but have had two years of lake residence instead of the usual one. They spend the same period of time in the ocean as the 4_2 age class and are almost identical in size, having an average weight over a 46 year period of 6.14 pounds compared to 6.00 for 4_2's. While the numbers of 5_3's are relatively small, averaging only 59,271 or 1.61 per cent annually, their occurrence within the stock of Fraser sockeye is of considerable biological interest. For instance, it has been reported by Henry (1961) that 99 per cent of the Fraser 5_3 age class belonged to only three races in 1956 and these were Birkenhead, Taseko and Chilko. A further examination of age by racial stocks reveals that these same races accounted for 85.31 per cent of all 5_3's occurring throughout the watershed within a 9 year period from 1952 to 1960.

Closely associated with the more prevalent occurrence of 5_3 sockeye in the Birkenhead, Chilko and Taseko areas was evidence of restricted growth of the young sockeye during their freshwater rearing period. This was reflected both in the lesser length and weight (size) of the smolts and by low lacustrine circuli counts on the scales. Since size of smolts has been found by Clutter and Whitesel (1956) to be closely correlated with circuli counts, only the latter need be used to illustrate various levels of smolt growth in different rearing environments. In TABLE 13 are listed the numbers of circuli contained in the first year of growth of 4_2 adult scales for the three races known to possess most of the 5_3 age class as compared with races possessing few or no 5_3's. The number of years of sampling supporting these averages is given in brackets.

The smallest migrants of the Fraser watershed are those from Taseko, Chilko and Birkenhead, disregarding Adams for the moment. The fact that 5_3's occur in races having the smallest migrants, strongly suggests that two-year-old seaward migrating smolts (which give rise to 5_3 adults) occur because they are not sufficiently developed to migrate after one year in fresh water. In other words, it would appear that they are the extremely small sockeye of a potential migrating group that is already of minimal migration size. Data supporting this contention are obtained from Clutter and Whitesel (ibid.) who made comparative scale circuli counts of one and two-year-old smolts of concurrent first year residence in Chilko Lake (1950-54) and found that the average circuli number of one-year-old migrants was 11.9 whereas the average circuli counts was only 9.1 during the first year of lacustrine growth on two-year-old migrant scales. A similar examination was made of the lacustrine growth period of 4_2 and 5_3 Chilko adults (1948-52) where the circuli count of one-year-old migrating smolts averaged 12.9 compared to an average count of 9.1 in the first year of non-migrating sockeye of the same brood. Smolt sizes were also examined at Taseko and Birkenhead and in each case it was found that 5_3 sockeye arose from two-year-old smolts whose average first year freshwater growth was less than that of one-year-old migrating smolts reared at the same time. Thus, 5_3 sockeye occur as a result of retarded growth within the freshwater environment and they may be expected to be most common in those rearing areas

TABLE 13—The average number of scale circuli in the first year of freshwater growth of 4_2 sockeye in various races within the Fraser River watershed.

RACE	LAKE RESIDENCE	YEARS OF SAMPLING	AVERAGE FIRST YEAR CIRCULI COUNT
Rearing Lakes containing 5_3 sockeye			
Taseko	Taseko	(7)	11.25
Chilko	Chilko	(23)	13.01
Birkenhead	Lillooet	(5)	13.36
Rearing Lakes containing few or no 5_3 sockeye			
Adams (Big Runs)	Shuswap	(6)	10.92
Adams (Moderate Runs)	Shuswap	(13)	14.54
Harrison	Harrison	(9)	16.18
Pitt	Pitt	(9)	16.44
Horsefly	Quesnel	(6)	17.21
Stellako	Fraser	(21)	17.24
Early Stuart	Takla-Trembleur	(21)	17.78
Weaver	Harrison	(20)	19.22
Big Silver	Harrison	(6)	24.53

where the size of yearling smolts is of a minimal level. It is significant that the three lake systems of Taseko, Chilko and Birkenhead, known to support substantial numbers of 5_3's, are highly glaciated.

While it is evident that most Fraser River 5_3's occur in rearing areas which produce small sized migrants, the degree of size variation and the percentage of smolts that "carry-over" to a second year in fresh water may be the result of a very complex ecological situation. Most often it is found that smaller than average sized migrants occur when their numbers are large and; conversely, migrants are larger when their numbers are few but this does not always happen. There are other imposing factors, particularly environmental, which may have independent effects on migrant size. A few of these are variable plankton production, water turbidity, water temperatures, periods of ice cover and related times of fry and smolt migrations. Each of these may act favorably to give good growth or each may act unfavorably resulting in poor growth. Also, there are physical features of the rearing area such as size and depth of the lake, inlet and outlet flows, flushing rates and thermal stratifications that may influence the release of smolts as yearlings or their retention as two-year-olds. Which environmental factors are most important and how they function in effecting lacustrine growth and migratory behaviour is not yet fully established.

The Adams run and its lack of 5_3's requires special consideration since the migrants of big runs of this race are the smallest on record (10.92 circuli). Even in years when the Adams run is not large, the migrants are smaller (14.54 circuli) than in most other rearing areas, yet 5_3's seldom occur. Thus, the general relationship between the occurrence of 5_3 sockeye and restricted growth of the fresh-water smolts does not apply to this race. It is known, however, that Adams migrants proceed seaward over a much longer period than they do at Chilko, suggesting that there may be no physical barriers to impede their movements from Shuswap Lake, which, incidentally, is almost free of glacial silt. In summary, it is expected that the numbers of 5_3's will generally increase or decrease in proportion to the numbers of sockeye bound for Chilko, Taseko and Birkenhead with peaks occurring one year after the peak abundances of 4_2's of these three races. This was true in 1937, 1942, 1946 and 1953 but not in other years such as 1957 and 1960 following the large runs to Chilko in 1956 and 1959. The migrants which gave rise to the 1956 adults had a first year circuli count of 12.99, slightly less than the twenty-three year average of 13.01, and a normal percentage of 5_3's would have been expected in 1957 but they did not appear. Migrant growth of the 1959 adults was 15.21, or considerably above average, and this could have resulted in fewer two-year-old smolts and the subsequent small number of 5_3's in 1960. However, since the origin of 5_3's is concluded to be principally under environmental control, their occurrence relative to the abundance of 4_2's in the previous year could fluctuate randomly to a considerable degree.

The 3_2 Age Class

In the period 1915 to 1960, the 3_2 or "jack" sockeye of the Fraser have varied in annual number from 0 to 788,239 with an average of 80,738. It is improbable that this age class was ever totally absent in any one year, but rather, the value of 0 indicates that 3_2's were so few that none entered into the routine sampling. Annual percentages ranged from 0 to 22 per cent with an average of 2.20. No consistent trends of increase or decrease were evident during the 46 years but jacks were almost non-existent from 1916 to 1928 immediately following the Hell's Gate disaster. After 1928, the 3_2 sockeye began to reappear and unquestionably this was associated with the increased numbers of sockeye to the Upper Fraser races of Lower Adams and Chilko. In 1929 and on each following fourth year, the numbers of 3_2's peaked in abundance one year prior to large returns of 4_2 Adams River Sockeye. Since the 3_2's returned one year before the main body of its brood year, that is the four-year-old fish, their numbers might serve as an indication of the numbers of 4_2 fish expected in the following year. (The Salmon Commission is currently making a detailed study of the numerical relationship of 3_2 to 4_2 sockeye for each race. Preliminary results reveal that the growth rate of fingerling sockeye during their first year of marine residence has considerable bearing on the percentage of 3_2 sockeye relative to the numbers of the following 4_2 population (Internat. Pacific Salmon Fish. Comm., Ann. Rpt. 1962, Fig. 2B).)

The fact that the 3_2 fish are preponderantly males means that the escapements of these fish are almost a total loss to production because of the small numbers of 3_2 females present on the spawning grounds. For example, in 1957 there were

300,771 male 3_2's and only 2,479 female 3_2's in the Adams escapement. This does not apply in other areas to such an extreme extent except in the developing situation at Quesnel.

The Returns of All Age Classes in Relation to the Brood Years

FIGURE 5 shows the returns of all age classes in relation to the brood years; that is, the production from a given brood year is distributed over three subsequent years of return according to the numbers of three, four and five-year-old fish produced. The yearly totals of these numbers thus distributed result in little change from the actual numbers returning in any given year regardless of their brood year. The similarity of the two sets of annual numbers results from the fact that there are so few three and five-year-old sockeye in relation to the numbers of four-year-old fish. Other than for possible specific concern for the maintenance of certain stocks having a high percentage of 5_2's, the regulations for the taking of Fraser River sockeye may be based entirely on the four-year-age class.

Seasonal Distribution of the Annual Numbers of Sockeye

Segregation of the annual abundance of Fraser sockeye into *weekly periods,* (shown in FIGURES 6 to 9 and tabulated in Appendix Table A), made it possible to trace important changes in seasonal numbers as they have occurred throughout the past 46 years. Only 4_2 sockeye were considered as this group represented nearly ninety per cent of all ages. Also, in the interpretation of changes through successive generations, it was necessary to recognize that significant variations in times of migration have, on occasion, resulted from vagaries in migratory behaviour; thus a lack of sockeye abundance in a certain week may not necessarily indicate failure of return but rather a change of timing in that particular year. Fortunately this is usually quite obvious for when earliness or lateness occurs it generally applies to all weeks such that the timing of the entire abundance curve is shifted. A detailed examination of minor migration time changes was not pursued since the abundance data were grouped into weekly intervals making it impossible to detect any changes of less than one week's duration.

The more critical abundance changes sought were those associated with marked failure or extreme success of part or all of the Fraser run. When *part* of an abundance curve was diminished, it was probable that certain races were obstructed by river blockades such as at Yale, Hell's Gate or Bridge River Rapids. Low fresh-water survival of specific races might also have been a contributing factor or even totally responsible. When the *whole* of an abundance curve was less or greater than "normal", it was most probably because variations in the marine survival had a common effect on all races. The particular situations as they have occurred in each separate cycle will be discussed but for the most part only the extreme losses or gains in numbers will be considered.

THE 1915-59 CYCLE

The shape of the weekly abundance curve of 4_2 sockeye in the year 1915 was quite symmetrical and showed peak numbers during the two-week period from July 29 to August 11; however, the run returning four years later in 1919 showed very

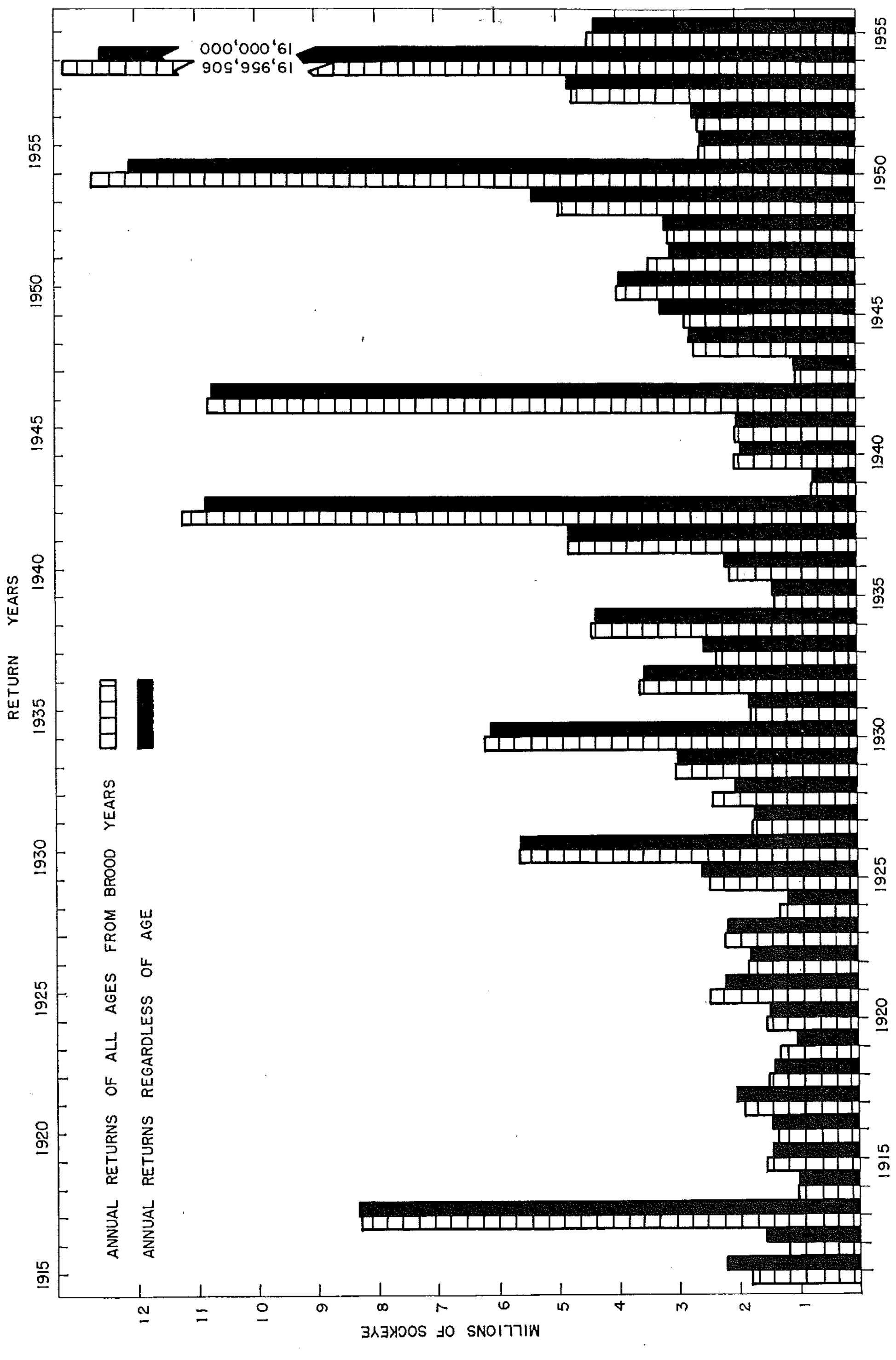

FIGURE 5—A comparison of the annual numbers of sockeye produced from brood years and the annual numbers of sockeye regardless of their year of egg deposition.

small numbers until the week of August 5 to 11, with the peak abundance occurring from August 12 to 18 (FIGURE 6). Possibly there was a shift in timing with the 1919 sockeye coming back a week late but it was more probable that a considerable portion of the late July run of 1915 was lost somewhere enroute to the spawning grounds. Significant numbers of July sockeye did not reappear until 1931 following which they again disappeared until 1951 when the largest run, July 22 - August 4, of this cycle was recorded. The disappearance of sockeye following 1915 and 1931 was believed to have been caused by conditions of difficult passage at Hell's Gate.

In general, the mid-season races of this cycle have shown a great range of successes and failures with no substantial production until 1951. The exceptional large catches of 1951, together with their above average weights, provided an impressive pack for this cycle. The degree of success was directly attributed to an increased escapement (52.57 per cent) obtained by extensive closures in 1947, undelayed passage of all adult migrants past Hell's Gate and Bridge River Rapids and an above average marine survival. The reduced returns of 1955 were attributed to a lesser sea survival. A record large run composed mainly of Chilko and Adams sockeye occurred in 1959, irrespective of a low escapement of only 15.96 per cent in 1955. A record high sea survival was actually measured in the case of Chilko and the same circumstance undoubtedly applied to Adams.

A large, late run of Adams sockeye occurred in 1927 but few Adams fish returned in 1931. An examination of water levels at Hell's Gate in 1927 showed severe block conditions extending all through September and into early October and there is little doubt that the Adams run was seriously decimated during that period. In no subsequent year of this cycle have the numbers of sockeye from August 26 to September 8 reached the abundance level of 1927. It is obvious that the Adams River run of that year was extremely late since the sub-dominant Adams runs of more recent years are known to have peaked in abundance prior to August 18.

THE 1916-60 CYCLE

From 1916 to 1932, the sockeye of this cycle maintained a low but fairly stable level of production and it was not until 1936 that a sizeable run of 3,081,998 four-year-sockeye occurred (FIGURE 7). Peak numbers in that year were present from July 29 to August 4 and were destined principally for Chilko. Following 1936, the sockeye abundance remained reasonably consistent. Annual productions averaged 2,215,000 and Chilko provided the main support of the total runs. No drastic declines occurred, suggesting that Chilko sockeye were more capable of withstanding delay at points of difficult passage during migration than were some of the other mid-season races. In addition to the numerical considerations, it may be noted that a fairly marked difference occurred between the timings of the 1952 and 1956 sockeye. The 1960 sockeye timing was even later than that of 1956, with the greatest numbers occurring during the week of August 5 to 11, yet it is known that Chilko provided the bulk of the catch in both years. This was the latest date for peak abundance recorded on this cycle since and including 1916.

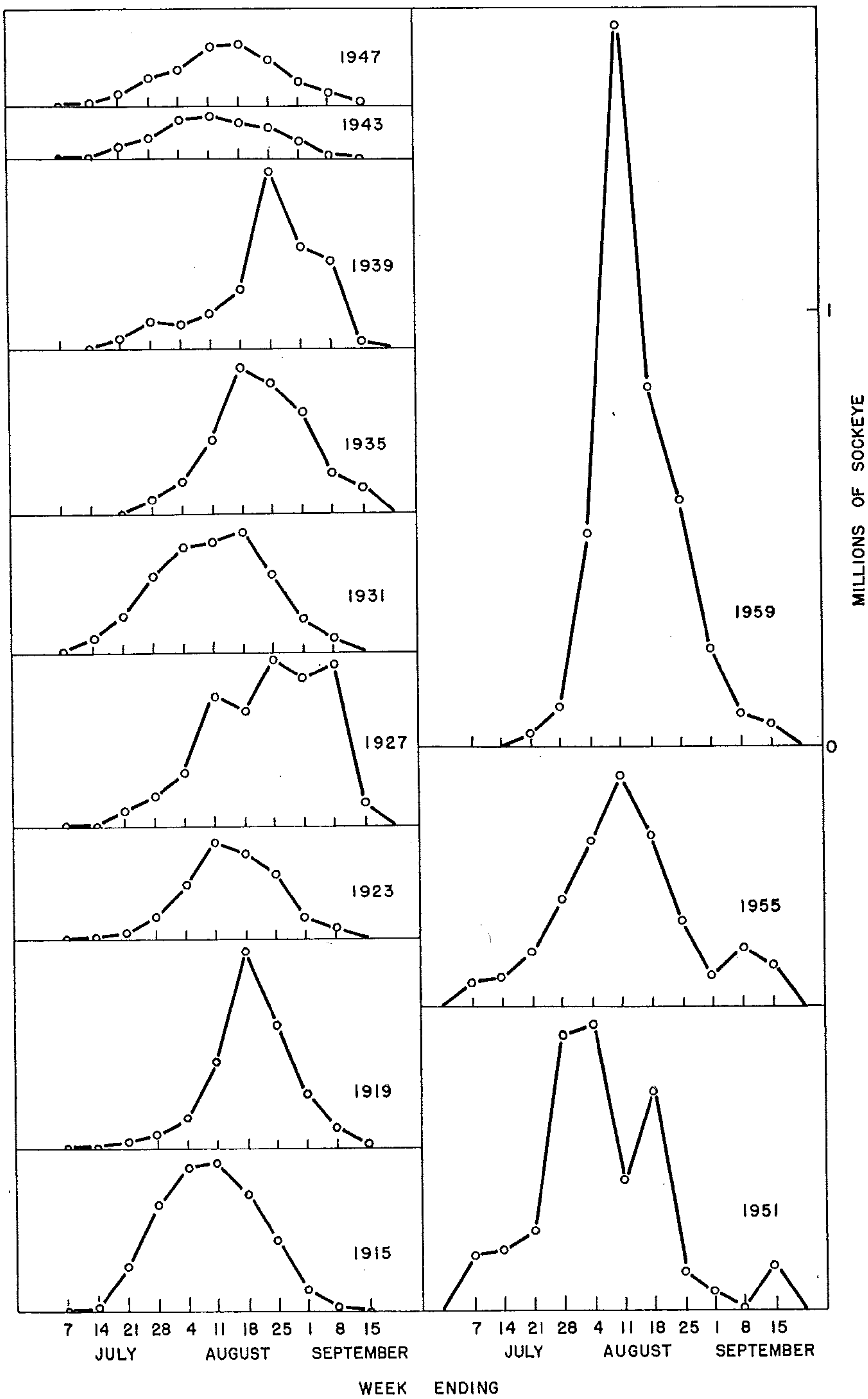

FIGURE 6—Changes in abundance of 4_2 sockeye by weekly periods in the 1915-59 cycle.

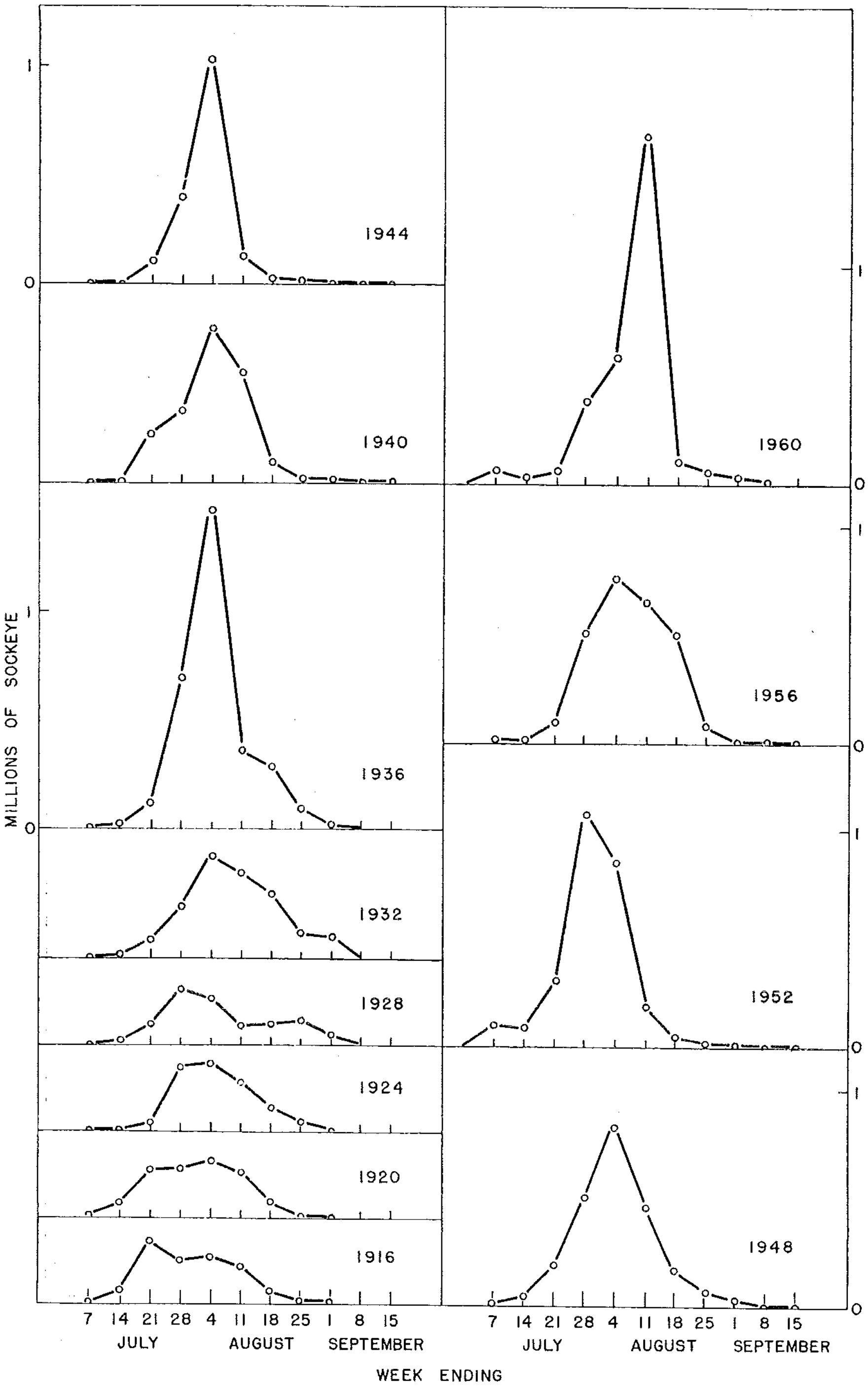

FIGURE 7.—Changes in abundance of 4_2 sockeye by weekly periods in the 1916-1960 cycle.

THE 1917-57 CYCLE

This cycle was formerly the most important of the four cycles, for it was the large runs of 1905-09-13 that made the Fraser famous and much of the potential of these historical runs still remains. If 1913 were illustrated in FIGURE 8, the total abundance probably would have exceeded 35,000,000 sockeye.

In tracing the numerical changes through eleven generations, the most critical feature was the drastic decline from 1917 to 1921 caused by the Hell's Gate obstruction. The greatest losses occurred from July 29 to August 4 and present knowledge of the runs passing between these dates indicates that the Horsefly (Quesnel), Late Stuart and Chilko runs were most seriously affected.

Up to 1941 there was no significant recovery in the cycle except for a substantial return of Early Stuart sockeye in 1929. Even larger numbers of this same race appeared in 1933 but the spawning escapement in that year must have suffered near extinction since practically no early sockeye could be found in 1937. Critical examination of the 1933 Fraser River water levels showed them to be nearly identical to those of 1955 when an almost total blockade of Stuart sockeye occurred in the lower Fraser Canyon near Yale (Internat. Pacific Salmon Fish. Comm., Ann. Rept. 1962). Unquestionably the 1933 Early Stuart run was lost at this same location.

Following 1937, a very significant increase in sockeye numbers occurred in 1941 and these were mostly of the Chilko race. This substantial return to Chilko was the largest run to this area in this cycle during the period 1917 to 1957. Because of a serious blockade at Hell's Gate in 1941 (Thompson, 1945), only moderate numbers of Chilko sockeye returned in 1945. In the more recent cycle years of 1949, 1953 and 1957, the abundance curves show a changing character because the Early Stuart, Late Stuart and Horsefly races are becoming more abundant and overlap Chilko in their times of passage.

THE 1918-58 CYCLE

An impressive record of sockeye rehabilitation in the Fraser River watershed is exhibited by the extreme numerical changes which have occurred in the 1918-58 cycle, the major racial component being that to Adams River (FIGURE 9). In 1918, the total sockeye production of 4_2 sockeye was 819,374 whereas only ten generations later the total was 18,832,413. This remarkable development of the Adams run is credited to a variety of circumstances. Beginning in 1922, a splash dam at the head of the Adams River spawning grounds ceased operation and alternate flooding and drying of the spawning grounds was avoided thereafter. The four-year-old sockeye numbered 1,242,259 in 1922 and with no adverse flows in Adams River a return of 1,515,785 occurred in 1926. The 1926 production was actually greater than shown for it has been noted by Gilhousen (1960) that substantial numbers of Fraser sockeye diverted through Johnstone Strait in that year but these sockeye were not included in the 1926 total. In 1930, production showed a marked rise to 4,850,892 sockeye. The subsequent cycle years continued to increase up to the record year of 1958 except for a moderate setback in 1938 and a more serious one in 1950.

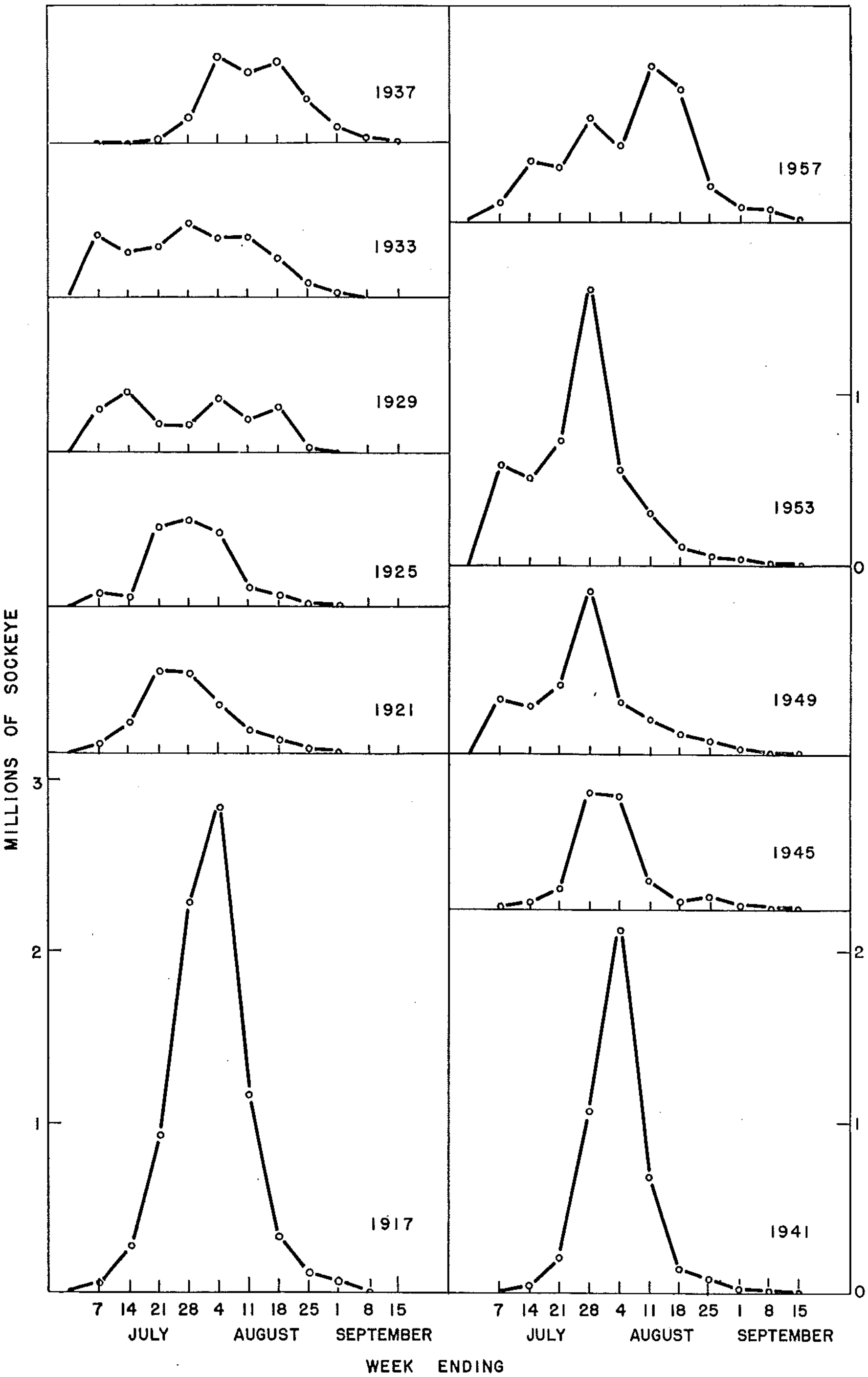

FIGURE 8—Changes in abundance of 4_2 sockeye by weekly periods in the 1917-1957 cycle.

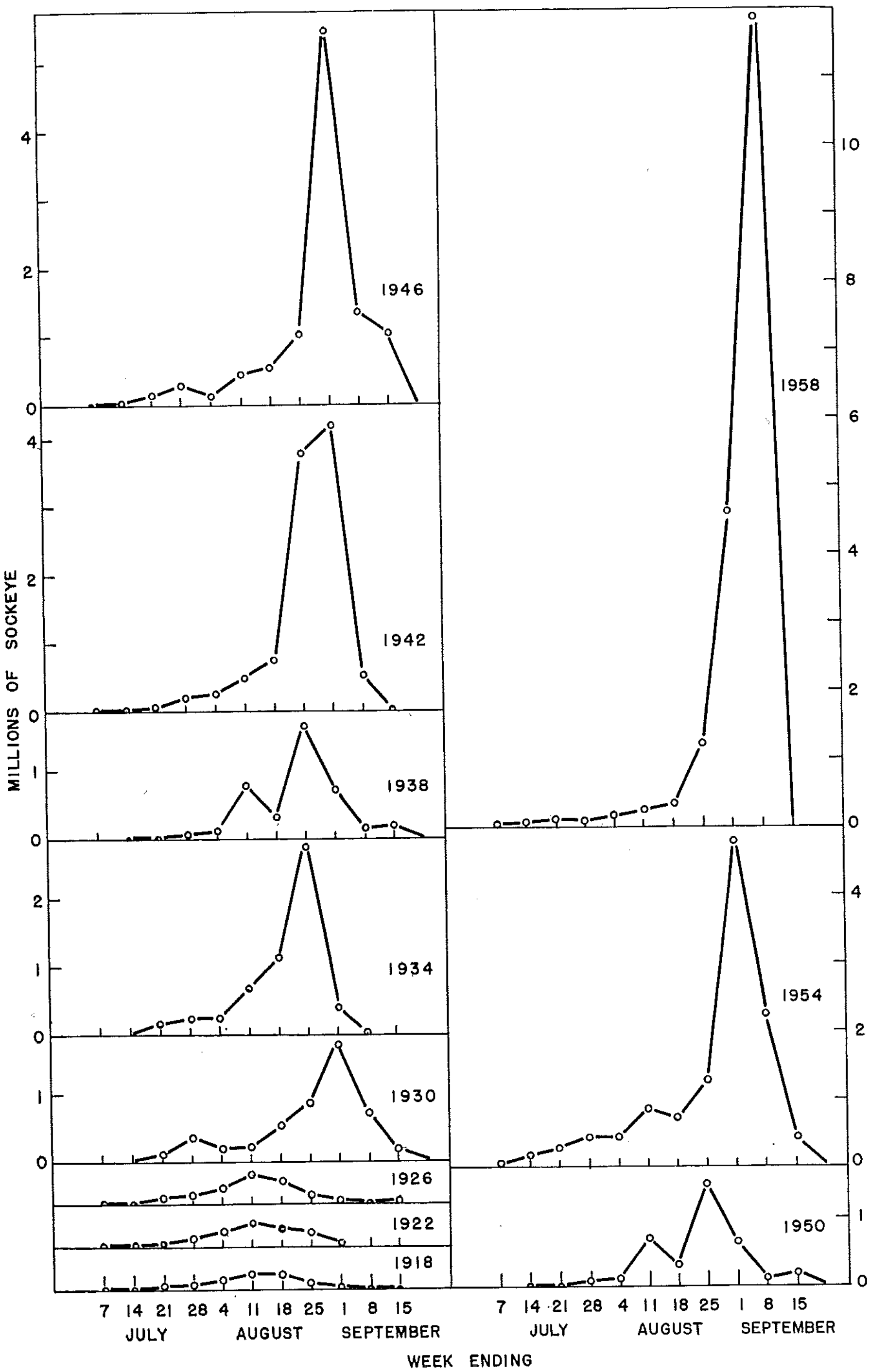

FIGURE 9—Changes in abundance of 4_2 sockeye by weekly periods in the 1918-1958 cycle.

Another reason for the success of the Adams run was the fact that Hell's Gate was seldom blocked during the periods of the Adams spawning migration, although the Adams sockeye of 1954 and 1958 would have been seriously delayed had the Hell's Gate fishways not been available for passage in those two important years. Also contributing to the development of the Adams run was the restricted fishing effort on this run in the early years. The success of recent large returns was credited, in part, to special fishing regulations whereby the spawning escapements have been obtained from the first and peak segments of the run, as far as was practical, so that their arrival on the spawning grounds was best suited to favorable environmental conditions for effective reproduction (Royal, 1953). A detailed analysis of the nature of the migratory habits of Adams River sockeye is discussed by Gilhousen (ibid.) and will not be further elaborated upon here.

SEX PROPORTIONS

For many fish populations, a 50:50 ratio between the sexes is known to exist. Published data in the annual reports of the Provincial Department of Fisheries on sockeye salmon of the Fraser River, as sampled at Sooke from May to September 1915 to 1937 inclusive, show equal numbers of the sexes in the combined 4_2, 5_2 and 5_3 age-groups (Gilbert, 1916-25; Clemens, 1926-39). The 3_2 fish were not included in these calculations. Further, sampling of sockeye smolts leaving Cultus and Chilko Lakes shows an equivalence of the sexes (Foerster, 1954; Clutter and Whitesel, 1956).

The information on sex proportions in this present text is based upon the original sampling data from 1915 to 1960. No figures are available for the years 1949, 1950 and 1953. The ratio of males to females in the combined 3_2, 4_2, 5_2 and 5_3 age groups in the above period is 47:53. The actual numbers are 35,855 males and 39,837 females. Throughout the period of record, the annual proportions of males to females have varied from 60 per cent males to 41 per cent males. Over the forty-three years, the males have exceeded the females in thirteen years, have equalled the females in three years and have been in the minority in twenty-seven years. No trends in the proportions of males to females are evident in Tables 14 and 15. Even in the case of the Adams River population (which is overwhelmingly abundant in the years 1930, 1934, 1938, 1942, 1946, 1954, 1958) the percentages of males are respectively 42, 54, 44, 47, 50, 44, 43. For the Fraser River population as a whole, the variations in the sex proportions are evidently random.

The data indicate that there has been a definite tendency for the females to exceed the males in numbers since the samples were obtained by gear which is considered to be non-selective for sex.

The sex proportions in the individual age-classes were as follows:

3_2	4_2	5_2	5_3	All
94:6	46:54	48:52	45:55	47:53

TABLE 14—The numbers of male and female sockeye salmon, 1915 - 1960, by age classes.

YEAR	3_2		4_2		5_2		5_3	
	Male	Female	Male	Female	Male	Female	Male	Female
1915	0	0	183	131	93	76	9	6
1916	176	2	486	549	110	115	14	19
1917	0	0	907	882	35	36	9	4
1918	1	0	252	227	60	47	24	17
1919	1	0	322	271	67	63	7	8
1920	1	0	540	543	128	150	50	61
1921	5	0	366	397	41	69	15	16
1922	8	0	248	273	27	24	12	13
1923	0	0	294	289	45	43	12	16
1924	12	1	544	521	147	145	67	77
1925	6	0	343	385	101	101	15	17
1926	0	0	209	224	52	61	18	17
1927	1	0	496	528	43	33	8	16
1928	5	5	287	300	72	45	27	17
1929	344	45	359	400	39	40	34	40
1930	5	0	384	577	78	75	15	21
1931	21	16	461	548	67	61	8	11
1932	11	2	350	466	56	51	10	22
1933	132	4	864	899	75	82	15	21
1934	17	0	446	391	42	41	11	12
1935	9	7	354	405	116	109	7	18
1936	5	0	216	320	33	37	6	13
1937	121	2	572	626	57	85	42	61
1938	12	4	338	433	21	38	0	1
1939	5	3	216	273	56	49	3	3
1940	4	0	130	156	19	15	3	0
1941	65	3	732	826	51	95	21	24
1942	0	4	290	324	32	27	1	4
1943	5	0	364	473	181	225	1	2
1944	2	0	277	315	45	72	0	1
1945	49	0	567	524	90	115	5	5
1946	0	0	569	560	16	37	4	1
1947	58	5	225	378	71	89	7	13
1948	4	1	695	719	108	93	8	4
1949								
1950								
1951	108	12	3,291	3,775	187	218	24	25
1952	0	0	2,046	2,427	313	335	37	65
1953								
1954	72	6	3,615	4,738	59	56	71	85
1955	4	3	2,678	3,566	220	261	65	88
1956	0	0	614	721	81	92	15	15
1957	479	0	884	1,037	44	37	4	7
1958	16	0	1,045	1,432	40	43	23	27
1959	34	0	1,246	1,591	63	74	49	50
1960	8	0	630	712	42	63	15	14
Totals	1,806	125	29,935	35,132	3,323	3,623	791	957

Total Males — 35,855
Total Females — 39,837

TABLE 15—The percentages of male and female sockeye salmon, 1915 - 1960, by age classes.

YEAR	3_2		4_2		5_2		5_3		ALL AGES	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
1915	0	0	58	42	55	45	60	40	57	43
1916	99	1	47	53	49	51	42	58	53	47
1917	0	0	51	49	49	51	69	31	51	49
1918	100	0	53	47	56	44	59	41	54	46
1919	100	0	54	46	52	48	47	53	54	46
1920	100	0	50	50	46	54	45	55	49	51
1921	100	0	48	52	37	63	48	52	47	53
1922	100	0	48	52	53	47	48	52	49	51
1923	0	0	50	50	51	49	43	57	50	50
1924	92	8	51	49	50	50	47	53	51	49
1925	100	0	47	53	50	50	47	53	48	52
1926	0	0	48	52	46	54	51	49	48	52
1927	100	0	48	52	57	43	33	67	49	51
1928	50	50	49	51	62	38	61	39	52	48
1929	88	12	47	53	49	51	46	54	60	40
1930	100	0	40	60	51	49	42	58	42	58
1931	57	43	46	54	52	48	42	58	47	53
1932	85	15	43	57	52	48	31	69	44	56
1933	97	3	49	51	48	52	42	58	52	48
1934	100	0	53	47	51	49	48	52	54	46
1935	56	44	47	53	52	48	28	72	47	53
1936	100	0	40	60	47	53	32	68	41	59
1937	98	2	48	52	40	60	41	59	51	49
1938	75	25	44	56	36	64	0	100	44	56
1939	63	37	44	56	53	47	50	50	46	54
1940	100	0	45	55	56	44	100	0	48	52
1941	96	4	47	53	35	65	47	53	48	52
1942	0	100	47	53	54	46	20	80	47	53
1943	100	0	43	57	45	55	33	67	44	56
1944	100	0	47	53	38	62	0	100	46	54
1945	100	0	52	48	44	56	50	50	52	48
1946	0	0	50	50	30	70	80	20	50	50
1947	92	8	37	63	44	56	35	65	43	57
1948	80	20	49	51	54	46	67	33	50	50
1949										
1950										
1951	90	10	47	53	46	54	49	50	47	53
1952	0	0	46	54	48	52	36	64	46	54
1953										
1954	93	7	43	57	51	49	46	54	44	56
1955	57	43	43	57	46	54	42	58	43	57
1956	0	0	46	54	47	53	50	50	46	54
1957	100	0	46	54	54	46	36	64	57	43
1958	100	0	42	58	48	52	46	54	43	57
1959	100	0	44	56	46	54	50	50	45	55
1960	100	0	47	53	40	60	52	48	47	53
Weighted Percentages All Years	94	6	46	54	48	52	45	55	47	53

Thus, the males are in the minority in all the age classes except in the 3_2's. Samplings were lacking in three years and in two of these, 1949 and 1953, very large numbers of three-year-old fish are known to have been present in the runs. Had samplings been available for these years, the percentage of males would have been increased slightly. On the basis of information available, it seems reasonable to conclude that the males suffer a slightly higher natural mortality than do the females.

The occurrence of the sexes in the ratio of 47:53 is probably not significant from the point of view of effective reproduction provided that the ratio is more or less retained on the spawning grounds. However, the ratio between the sexes may be changed by the selective action of gill nets as shown by Peterson (1954). The percentages of males on the spawning grounds in the early runs, such as Stuart and Bowron in the years 1945 to 1952 inclusive, averaged 48 per cent; for the mid-season runs such as those of Chilko, Stellako and Raft the percentages ranged from 43 to 46; while for the late runs to Adams, Cultus and Weaver the average percentages were 33 to 34. In the last situation each male would need to mate with two females in order to provide for the fertilization of the available eggs. In this regard, it has been amply demonstrated by Peterson (1951, unpub.) and Mathisen (1962) that a ratio of one male to two females has not interfered with total productivity.

The percentage of males of all age-classes changed very little throughout the season as shown in TABLE 16. This limited variability is undoubtedly the result of overlapping of races because data obtained on the spawning grounds shows that the males predominate in the early period of the racial migration and the females in the late period. This is illustrated by the data obtained at Adams River and Little River in 1950 (TABLE 17). In that year, the total numbers of the two sexes on the spawning grounds were essentially equal, Adams River, 108,765 males and 100,867 females; Little River, 24,031 males and 24,075 females.

TABLE 16—The percentages of males during the eleven weeks of sampling, all years combined, 1915 - 1960.

Weeks	3_2	4_2	5_2	5_3
July 1 - 7	55	47	57	56
July 8 - 14	94	50	49	42
July 15 - 21	100	47	47	52
July 22 - 28	94	47	55	45
July 29 - Aug. 4	87	46	46	51
Aug. 5 - 11	93	46	48	41
Aug. 12 - 18	96	46	44	41
Aug. 19 - 25	95	45	45	43
Aug. 25 - Sept. 1	95	44	43	46
Sept. 2 - 8	76	42	42	67
Sept. 9 - 15	87	42	48	45

TABLE 17—Proportions of dead male and female sockeye recovered from the spawning grounds of Adams and Little Rivers on succeeding days throughout the spawning season of 1950.

DATE	ADAMS RIVER		LITTLE RIVER	
	Male	Female	Male	Female
1950				
October 17	63	37	—	—
October 18	67	33	—	—
October 19	61	39	71	29
October 20	59	41	61	39
October 21	59	41	64	36
October 23	53	47	54	46
October 24	55	45	—	—
October 25	54	46	65	35
October 26	53	47	57	43
October 27	61	39	50	50
October 28	55	45	44	56
October 29	—	—	42	58
October 30	50	50	—	—
October 31	49	51	62	38
November 1	49	51	46	54
November 2	51	49	39	61
November 3	48	52	44	56
November 4	45	55	43	57
November 6	44	56	—	—
November 7	47	53	—	—
November 8	52	48	53	47
November 9	45	55	48	52
November 10	—	—	37	63
November 12	44	56	50	50
November 13	48	52	—	—

Sex Ratios by Separate Age-Class

In the forty-three years of record, the 4_2 males were in the minority in thirty-three years, in the majority in seven and equivalent in three (TABLE 14). The 65,067 individuals of the 4_2 age-class sampled consisted of 29,935 males and 35,132 females. The yearly percentages of males ranged from 37 to 58 (TABLE 15). The difference in the proportions of the sexes in the 4_2 age-group was undoubtedly partly the result of a large number of males maturing at three years of age. The percentage of males in the weeks from July 1 to September 15 did not vary significantly although there was a very slight suggestion of more males in July than in August and September (TABLE 16). The composite nature of the fish samples in respect to races did not permit drawing conclusions on relatively minor variations.

The individuals of the 5_2 age-group totalled 6,946. Of these, 3,323 were males and 3,623 females or percentages of 48 and 52 respectively. The males outnumbered the females in eighteen of the forty-three years of record, were equal in two and fewer in twenty-three. Again, it was impossible to determine definitely if the males tended to precede the females in the migration from the sea because of the difficulty in segregating the races. The numbers of individuals in the 5_3 age-group totalled 1,748 of which 791 were males (45 per cent) and 957 females (55 per cent). The 3_2 age-group was represented by 1,931 individuals; 1,806 were males and 125 females and percentages were 94 and 6 respectively (TABLES 14 and 15). The factors involved in the production of this extremely unbalanced proportion of the sexes are still unknown.

SIZE OF FRASER RIVER SOCKEYE

In view of the known selectivity of gill nets for larger sizes of sockeye, as established by Peterson (1954), the average size of Fraser River sockeye measured over a long period of years takes on added significance, for it then becomes possible to determine whether or not continuous gear selectivity has created an inherently smaller sized fish. If the sockeye have become smaller as a result of gear selectivity, a marked reduction in numbers of eggs deposited by the escapements should have occurred. Also pertinent would be the continuous poundage loss of sockeye taken by the commercial fishing gear. The importance of size relative to the commercial catch is documented by the fact that a reduction in the average weights of 4_2 sockeye from 7.2 pounds in 1951 to 5.12 pounds in 1959 represented a loss in the 1959 pack value of $4,800,000 (Internat. Pacific Salmon Fish. Comm., Ann. Rept. 1960).

Apart from measuring the possible long-term effects of gear selectivity, it was also hoped that a historical record of average sizes might lead to a means of predicting annual average weights prior to each fishing season. Such information would be most useful to the industry, especially in their pre-season choice of gill net mesh sizes. Ramifications such as size relative to numbers, smolt growth, ocean temperature, times of migration and racial differences can all be investigated to varying degrees. Further relationships may be examined in future years once the size data are placed on record.

The present analysis of size data was designed to:

1. Establish the annual size and size variations of Fraser sockeye through the past forty-six years from 1915 to 1960.
2. Establish the average weights of the various age classes involved and determine their effects on the annual average weights of the fish in the commercial catch.
3. Record any seasonal or cyclical size changes that may have occurred.

4. Examine factors related to size and size variations such as hereditary characteristics, length and condition, population sizes, the possible influence of varying conditions in the freshwater and marine environments and long-term selection by fishing gear.
5. Examine the possibilities of predicting sockeye sizes in advance of the commercial fishing season.

Three sources of size data for Fraser sockeye were available: (1) the 46 years of individual sampling records specifically analyzed in this present text; (2) 26 years of fish-per-case records from 1935 to 1960; and, (3) 17 years of daily catches and poundages of sockeye from the United States purse seine fishery from 1944 to 1960. Measurements of sockeye sizes from the latter two sources were advantageous in that large numbers of sockeye were involved; however, certain features of these particular data required cautious interpretation. For instance, with regard to the numbers of fish-per-case, there have been measurable improvements in the efficiency of canning since 69 to 70 pounds of sockeye now yield a 48 pound case whereas 80 to 82 pounds were used in some earlier years. There are also differences in the numbers of sockeye-per-case depending upon the size of sockeye being canned, with more pounds of fish being required when the sockeye are small. The size of cans as quarters, halves or one pound also affects the numbers of fish-per-case values. When data on catches and poundages of purse seine catches were used to reflect annual sockeye sizes, the only apparent limitation was the presence of varying proportions of small 3_2 sockeye or large 5_2's from year to year. The average annual size might be measurably distorted if the abundance of either of these age classes were substantial. Size measurements from individual sampling records were necessarily restricted to much smaller numbers of fish; however, these data were of particular value in that there were no problems because of changes in canning efficiencies and, more important, the annual sockeye sizes could be treated by separate age class.

Sockeye Sizes Established by Annual Samples of the Commercial Catches 1915 to 1960

There are 46 years of size records for Fraser sockeye measured at the Canadian Sooke traps or from landings of the United States purse seine fishery through the years 1915 to 1960; however, in the years 1946 to 1955, weights were omitted from the individual sampling procedure. Fortunately, adequate records of total daily poundages of all commercially caught sockeye by place, date and type of gear are available since 1944. These records, together with detailed scale samplings for age composition, permitted the separate weights of the important 4_2 sockeye to be calculated by weeks as in the following example:

United States Purse Seine Catch July 22 - 28, 1952

Total catch	87,851
Total pounds	617,928
Average sockeye weight (all ages)	7.04 pounds

From the seine catch of 87,851, a sample of 1,297 scales had been taken for age analysis with no lengths or weights recorded. The total weight of the sample would have been 9,131 pounds using the average of 7.04 pounds. The age proportions in the samples were 3_2 - 0, 4_2 - 1,130, 5_2 - 140 and 5_3 - 27. Since there were no 3_2 sockeye in the sample, this age class had no effect on the 7.04 pound total average. The average weight of the 5_3 age class was so similar to that of 4_2 sockeye (6.14 and 6.00 pounds) that no adjustment for the weight of these 27 sockeye was made. The 5_2 sockeye, being considerably larger than the 4_2, had to be considered. The average weight of 5_2 sockeye for the week of July 22-28 for all cycle years back to 1916 was 8.942 pounds. Thus, the 140 sockeye of age 5_2 were calculated to have weighed 1,252 pounds and this weight was subtracted from the 9,131 pounds in the total sample. The remaining weight of 7,879 pounds divided by the remaining 1,157 sockeye in the sample provided an average of 6.810 pounds for 4_2 sockeye in the period and year concerned. This procedure was applied whenever sampling weights were not available from 1946 to 1955. The validity of such calculations was checked in earlier and later years during which both sample and commercial weights had been recorded. Weekly average weights of 4_2 sockeye from both sources were found to agree very closely. For instance, a comparison of the sampled weights to those calculated from the total commercial weights was illustrated by the data of 1956. In that year, the season average weight of all commercially caught sockeye was 6.296 pounds while the average weight of the total sample group was 6.239 pounds (all ages included). Further, the actual sample average of 4_2 sockeye for July 22-28, 1956 was 5.960 pounds; whereas the calculated average from the total commercial catch for the same week was 5.852 pounds, a difference of only one-tenth of a pound.

WEIGHTS AND LENGTHS BY SEX AND AGE

Using 38,616 individual weight measurements obtained from 1915 to 1945 and 1956 to 1960, plus the weight averages for each age class calculated for combined sexes from 1946 to 1955 by the method just described, the respective average weights for male and female sockeye of the 3_2, 4_2, 5_3 and 5_2 age classes were summarized and are shown in TABLE 18.

TABLE 18—The weights and lengths of Fraser River male and female sockeye as averaged through 46 years from 1915 to 1960 by age classes.

AGE CLASSES	WEIGHTS (pounds)			* LENGTHS (inches)		
	Males	Females	Averages	Males	Females	Averages
3_2	3.117	—	3.117	19.00	—	19.00
4_2	6.342	5.666	6.004	24.05	23.26	23.66
5_3	6.570	5.703	6.137	24.40	23.35	23.87
5_2	8.056	7.139	7.598	26.12	24.99	25.56

* Total lengths - measured from tip of snout to fork of tail.

The average weights given in TABLE 18 illustrate the average growth schedule of sockeye from date of hatch to five years of age as plotted in FIGURE 10. For a period of nine months, following the deposition of the eggs in the spawning grounds, there is no appreciable weight increase. This time interval allows for the eyeing, hatching, absorption of the egg yolk and emergence of the small fry from the gravel. The average weight of the egg and the newly emerged fry at Chilko is .14 grams or .0003 pounds and this average would represent sockeye fry generally throughout the Fraser watershed. For the next year, the young sockeye fry remain in the freshwater rearing lake where growth is relatively slow and an average size at Chilko (1951-1955) is only .01 pounds. While .01 pounds may be slightly less than the average for all Fraser River rearing areas, it is at approximately this size that seaward migrants (smolts) enter the marine environment. Here, growth is greatly accelerated and at the end of one year and three months of marine residence sockeye average 3.12 pounds. (The actual total age is three years at this time.) Growth in the fourth year is also rapid with 4_2 sockeye averaging 6.00 pounds. Sockeye which do not mature in their fourth year but extend their marine residence into the fifth year weigh 7.60 pounds, a one year gain of only 1.60 pounds compared with annual gains of 3.11 and 2.88 pounds to the third and fourth years.

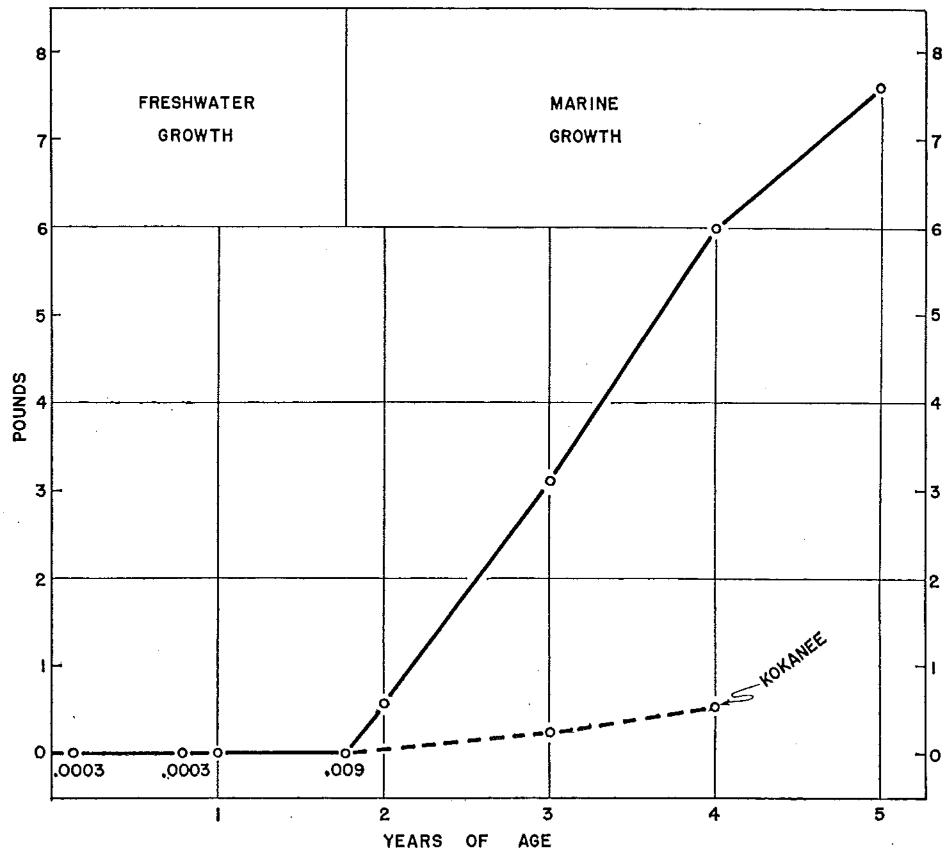

FIGURE 10—Annual growth rate of sockeye in their freshwater and marine environments. The comparative size of kokanee of equivalent age is shown.

The 5_3 sockeye, that remain two years rather than the usual one in fresh water, have a marine growth almost identical to that of the 4_2 group - 6.12 pounds increase from smolts to mature adults compared with 5.99 pounds. An interesting point is that the rate of sockeye growth is maintained at nearly a constant rate of 3 pounds per year from the time the smolts enter salt water through to their third and fourth years but this rapid growth is followed by a reduced rate of 1.6 pounds for 5_2 sockeye which remain an extra year in the ocean.

The average weights of kokanee *(Oncorhynchus nerka kennerlyi)* were available in the Commission files and are included in FIGURE 10 to demonstrate the vast difference between freshwater and marine growth rates. Kokanee (often called landlocked sockeye) do not migrate to sea but complete their life cycle entirely in fresh water. By doing so they weigh, in the Shuswap Lake, only one-quarter of a pound at the end of their third year and just over one-half of a pound upon maturity at four years of age. The five and a half pound growth advantage of anadromous 4_2 sockeye is well illustrated by this comparison. Despite the much lesser growth attained by kokanee the annual rates of growth to the third and fourth years were constant at .25 pounds annually.

THE WEIGHT-LENGTH RELATIONSHIP AND CONDITION OF FRASER SOCKEYE

The respective influences of length and condition on the weights of sockeye were measured in the following manner:

Annual average weights and lengths were related as shown in FIGURE 11 and through the array of points a line of best fit was plotted. It was then possible to calculate the expected average that the sockeye of each year should weigh according to its actual length. The differences between the actual weights and the expected weights provided *measures of condition,* which were expressed as plus or minus values in TABLE 19. For instance, the actual weight of the 1957 sockeye was 5.27 pounds and the length was 58.5 centimeters. But the expected weight for a 58.5 centimeter sockeye, according to the straight line relationship was 5.41 pounds or .14 pounds more than the actual weight. That is, the condition value was —.14 and the fish were slightly thin. In 1958, the actual sockeye weight average was 5.93 and the length 59.17 but the expected weight for a 59.17 centimeter sockeye was 5.69 pounds or .24 pounds less than the actual weight. The condition value in this year was +.24, thus the fish were heavy for their length. Condition values for all years ranged from minus .41 pounds in 1940 to plus .36 pounds in 1944.

Considerable effort was expended in attempts to use the condition formula:

$$K = \frac{100\ (\text{Weight})}{\text{Length}^3}$$

However, there appeared no satisfactory method for resolving the fact that K values varied almost directly with length such that larger sockeye had a larger K value and were heavier for their length than were shorter sockeye. For instance, K values derived from the average weight-length relationship over thirty-six years were 1.2096, 1.2657 and 1.3173 for lengths of 58, 60 and 63 centimeters. Such being the case, it was difficult to compare consecutive annual values of condition developed for annual groups of sockeye which differed considerably in length. Averaging all years, it was apparent that the sockeye were uniform in condition

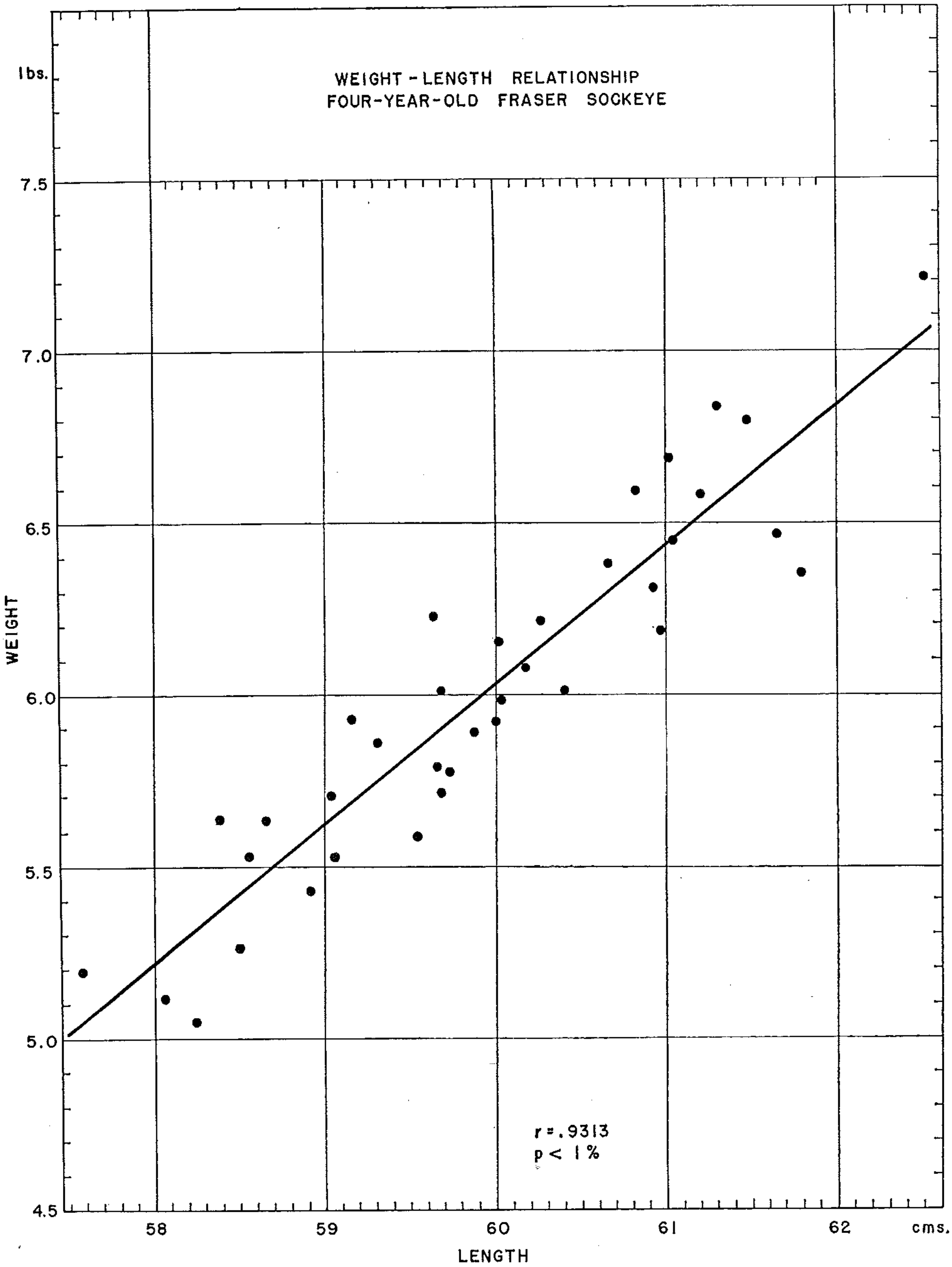

FIGURE 11—The weight-length relationship of four-year-old Fraser River sockeye (4_2), calculated from season averages—1919 to 1960.

TABLE 19—Annual variations in the condition (fatness) of Fraser River sockeye (4_2) as measured by deviations from a constant weight-length relationship.

YEAR	Actual Av. Lengths (cms.)	Actual Av. Weights (lbs.)	Expected Av. Weights (lbs.)	Difference Between Actual and Expected	
				Plus (lbs.)	Minus (lbs.)
1919	59.54	5.59	5.83		.24
1920	60.41	6.02	6.20		.18
1921	59.88	5.89	5.98		.09
1922	—	6.05	—		
1923	60.27	6.22	6.13	.14	
1924	—	5.60	—		
1925	59.74	5.76	5.93		.19
1926	60.93	6.31	6.42		.11
1927	60.19	6.08	6.11		.03
1928	60.67	6.38	6.30	.08	
1929	60.00	5.92	6.03		.11
1930	60.82	6.57	6.46	.11	
1931	60.03	5.98	6.05		.07
1932	61.05	6.45	6.46		.01
1933	58.92	5.43	5.58		.15
1934	60.98	6.19	6.43		.24
1935	59.66	5.79	5.88		.09
1936	61.66	6.47	6.72		.25
1937	58.24	5.05	5.30		.25
1938	61.02	6.69	6.45	.24	
1939	59.69	5.72	5.90		.18
1940	61.79	6.35	6.77		.42
1941	59.07	5.53	5.64		.11
1942	61.22	6.58	6.53	.05	
1943	58.39	5.64	5.36	.28	
1944	59.64	6.23	5.87	.36	
1945	59.03	5.71	5.53	.18	
1946	59.32	5.86	5.71	.15	
1947	60.02	6.16	6.03	.13	
1948	58.57	5.53	5.44	.09	
1949	—	5.85	—		
1950	—	6.96	—		
1951	62.51	7.21	7.06	.15	
1952	61.49	6.80	6.64	.16	
1953	—	6.08	—		
1954	61.31	6.84	6.57	.27	
1955	58.67	5.64	5.48	.16	
1956	59.68	6.02	5.90	.12	
1957	58.50	5.27	5.41		.14
1958	59.17	5.93	5.69	.24	
1959	58.07	5.12	5.23		.11
1960	57.51	5.19	5.00	.19	

within plus or minus two-tenths of a pound. A long period of slightly below average conditions was evident from 1919 to 1941 with few exceptions; then followed a series of above average conditions from 1942 to 1960 with only two exceptions occurring in 1957 and 1959. *These data indicated that variations in condition were of secondary importance in their effect on the annual sockeye sizes and that changes in length were mostly responsible.*

Weights increased very rapidly with only slight changes in length, so much so, that each centimeter was equivalent to nearly half a pound of weight or an inch would be equal to one and a quarter pounds. The mechanism whereby length could vary from one generation to another involves a complex growth interrelationship between the functions of genetic inheritance and the physicochemical environment. The principles of genetic inheritance provides for the similarity of length characteristics through successive generations which explains the persistence of different basic sizes for various racial groups within a given watershed area or between sockeye stocks of different watersheds. At the same time, variations also occur as a result of changes in environmental factors such as temperature, light, food and other physical or chemical properties. General considerations of certain environmental factors will be investigated later in the text with the express purpose of learning what size changes may have occurred in the past because of the environment and what may be anticipated in future years.

THE EFFECT OF AGE COMPOSITION ON COMMERCIAL LANDING WEIGHTS

Since the commercial fishery includes sockeye of all ages, the average weights of landings are affected by the varying proportions and sizes of different age classes occurring each year. The four important ages were 3_2, 4_2, 5_3 and 5_2 and their respective average weights 3.12, 6.00, 6.14 and 7.60 pounds.

The small 3_2 sockeye seldom exceeded a few thousand fish annually during the early period of the past 46 years and were of minor concern in affecting commercial weights; however, since 1930, the Adams River run of the 1930-58 cycle has come into prominence, and with it the numbers of 3_2 jacks in the preceding cycle years have increased considerably. Jack populations belonging mostly to Adams were:

1929 — 519,581	1945 — 56,336
1933 — 223,425	1949 — 86,609
1937 — 194,747	1953 — 543,668
1941 — 68,267	1957 — 788,239

Whenever the 3_2 population becomes a significant share of the total run, the average weight of the commercial catch decreases. It will be noted specifically later in the text that the average weights of United States purse seine catches were depressed in 1945, 1949, 1953 and 1957 from mid-August to early September when the Adams River jacks were at peak abundance.

The 4_2 sockeye constituted 89.25 per cent of the Fraser River age classes and their annual sizes principally controlled the commercial landing weights. This is demonstrated in FIGURE 12 where 4_2 average weights are compared to commercial weights for the years 1944 to 1960. In general, the weights of 4_2 sockeye, as measured from daily samples of the catch, were nearly identical to the average weights of the total commercial landings which were comprised of all age classes. The greatest differences occurred in the years of 3_2 abundance when the jacks reduced the landing averages below that of the 4_2 sample weights to a minor degree in 1945 and 1949 and to a significant degree in 1953 and 1957.

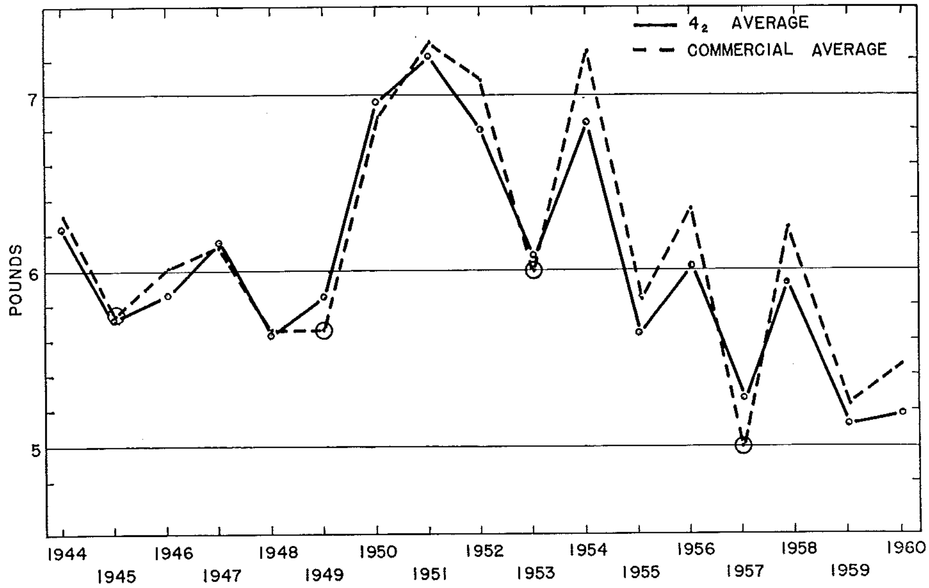

FIGURE 12—A comparison of the average annual weights of 4_2 sockeye from sampling and the average weight of commercial landings which are comprised of all age classes. The years of 3_2 abundance are specially marked⊙.

The numbers of 5_2 sockeye ranged from 90,399 to 596,790 annually and averaged 6.94 per cent of all Fraser sockeye produced in the past 46 years. Since these sockeye weighed 1.6 pounds heavier than four year fish, they could have a measurable effect on the commercial catch average weights in years of abundance. The previous analysis of the numerical occurrence of the 5_2 age class (FIGURE 3) revealed certain years of peak abundance but generally the annual numbers were relatively stable, thus their presence in the commercial catch has resulted in an average weight approximately .124 pounds above that of the predominating 4_2 age class.

ANNUAL, SEASONAL AND CYCLE SIZE VARIATIONS OF 4_2 SOCKEYE

This section of the report deals exclusively with one particular age class — the predominant 4_2's — and because of this, the annual, seasonal and cyclical differences are not complicated by the presence of varying numbers of small 3_2 jacks or large 5_2 fish, nor are there any intangible errors in dealing with size as measured by the numbers of sockeye-per-case.

Annual Size Variation

The annual weights and lengths of 4_2 sockeye are shown in TABLE 20 and FIGURE 13. These annual weight and length values are averages of nine weekly averages as they occurred between July 1 and September 1. In this way, the samples from each week are given equal status and the large runs do not overly influence the weights of lesser runs occurring in other parts of the season. The weights then represent an index of size uniformly developed from all races present irrespective of their varying abundance. This procedure did not entirely eliminate the effects of fluctuating numbers in the races from one cycle to the next but reduced the effect to a minimum.

TABLE 20—The annual average weights and lengths of Fraser River sockeye of the **four-year age class** (4_2) measured in the Sooke traps and United States purse seine fisheries, 1915 to 1960.

YEAR	WEIGHT (Pounds)	LENGTH (Centimeters)	YEAR	WEIGHT (Pounds)	LENGTH (Centimeters)
1915	5.91	61.90	1938	6.69	61.02
1916	5.86	62.05	1939	5.72	59.69
1917	5.47	60.17	1940	6.35	61.79
1918	6.30	62.04	1941	5.53	59.07
1919	5.59	59.54	1942	6.58	61.22
1920	6.02	60.41	1943	5.64	58.39
1921	5.89	59.88	1944	6.23	59.64
1922	6.05	—	1945	5.71	59.03
1923	6.22	60.27	1946	5.86*	59.32
1924	5.60	—	1947	6.16*	60.02
1925	5.76	59.74	1948	5.53*	58.57
1926	6.31	60.93	1949	5.85*	—
1927	6.08	60.19	1950	6.96*	—
1928	6.38	60.67	1951	7.21*	62.51
1929	5.92	60.00	1952	6.80*	61.49
1930	6.57	60.82	1953	6.08*	—
1931	5.98	60.03	1954	6.84*	61.31
1932	6.45	61.05	1955	5.64*	58.67
1933	5.43	58.92	1956	6.02	59.68
1934	6.19	60.98	1957	5.27	58.50
1935	5.79	59.66	1958	5.93	59.17
1936	6.47	61.66	1959	5.12	58.07
1937	5.05	58.24	1960	5.19	57.51
			1915 - 1960 Average	6.004 lbs.	60.09 cms.

* 1946 - 1955 weights calculated from daily commercial weight averages.

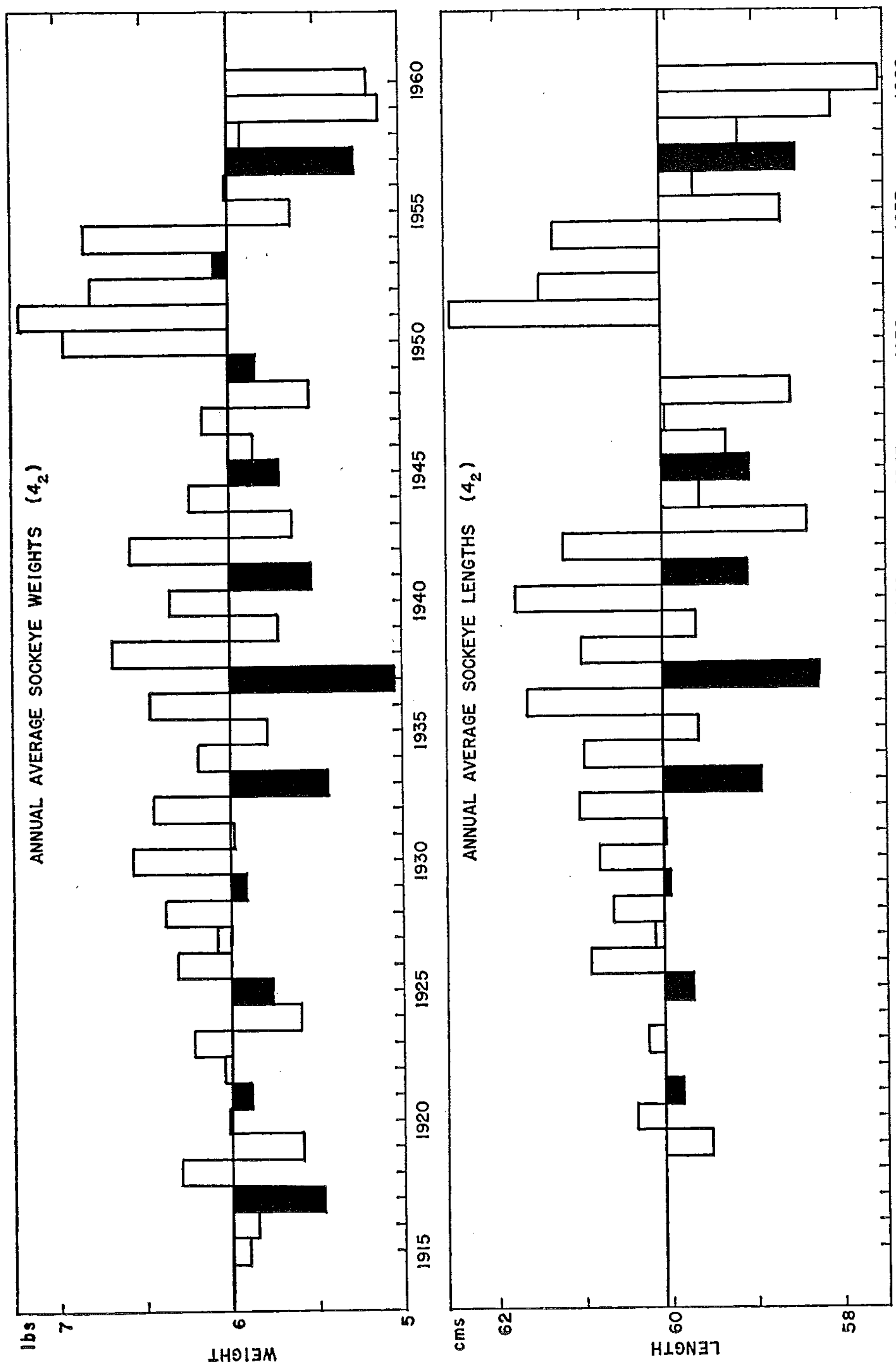

FIGURE 13—The annual average weights and lengths of four-year-old Fraser River sockeye measured from samples at the Sooke traps and the United States purse seines. (Note the small size of the 1917-57 cycle sockeye).

Although both weights and lengths are given to illustrate the close relationship between the two size measurements; weights will be used rather than lengths in further discussions of size. The 46-year average weight of 4_2 sockeye was 6.00 pounds and the average length for the same period was 60.09 centimeters (23.66 inches). Around these values there were extreme weights ranging from a minimum of 5.05 pounds in 1937 to a maximum of 7.21 pounds in 1951 and the lengths for these same years were 58.24 to 62.51 centimeters. A definite alternation of larger sockeye (6.23 lbs.) in the "even" years and smaller sockeye (5.78 lbs.) in the "odd" years occurred with very few exceptions. This alternation of sizes indicated considerable independence in the size of sockeye in each annual population.

The persistent alternation of small and large sockeye in the "odd" and "even" years must have some underlying cause. It was possible that the occurrence of large numbers of pink salmon *(Oncorhynchus gorbuscha)* in the "odd" years and their almost complete absence during "even" years in the Fraser watershed might provide a plausible explanation. If these two species were reared in the same marine habitat and depended on the same foods, then it is conceivable that they could be competing for the available food supply. This hypothesis had to be examined by employing indirect evidence for, as yet, no one has accurately defined the marine residence of Fraser River sockeye and pink salmon nor is it precisely known what foods make up their respective diets.

As a first step, an analysis was made of the relationship between the annual sizes of pink salmon (measured by the numbers of fish-per-case) and their own numerical abundance for the period 1935 to 1961 (FIGURE 14). Here, it was evident that there was a tendency for Fraser River pinks to be larger when their numbers were few; and conversely, pinks tended to be smaller when their numbers were large. The statistical correlation, excluding 1943, was very close to being significant at the five per cent level. Such a relationship between the numbers and size of pink salmon agrees with the conclusions of Davidson and Vaughan (1941) in their studies of pink salmon of southeastern Alaska; however, for both areas, important exceptions have occurred. On the Fraser in 1943, when the pink run was very small, the size was a record low for the 14 years of data. While the evidence does suggest that numerical competition for food exists within a single species, it still does not indicate any growth relationship that might exist between species. The next step was to compare size *fluctuations* of pinks and sockeye in the same years.

Comparative size fluctuations of Fraser sockeye and pink salmon in "odd" years are shown in FIGURE 15. Here, it was found that there was no consistent agreement in annual size variation between the two species. In nine of the sixteen years, sockeye and pinks were simultaneously larger or smaller than average; in the remaining seven years, the size deviations were opposed. Even in those years of agreement, the degree of size variation was markedly different, as for example in 1961 the sockeye were only slightly above the expected weight whereas the pinks were unusually large. These data indicated one of two possibilities; first, that the two species are not reared in the same ocean environment; or secondly, that they may be reared in the same or similar environment but do not respond in the same

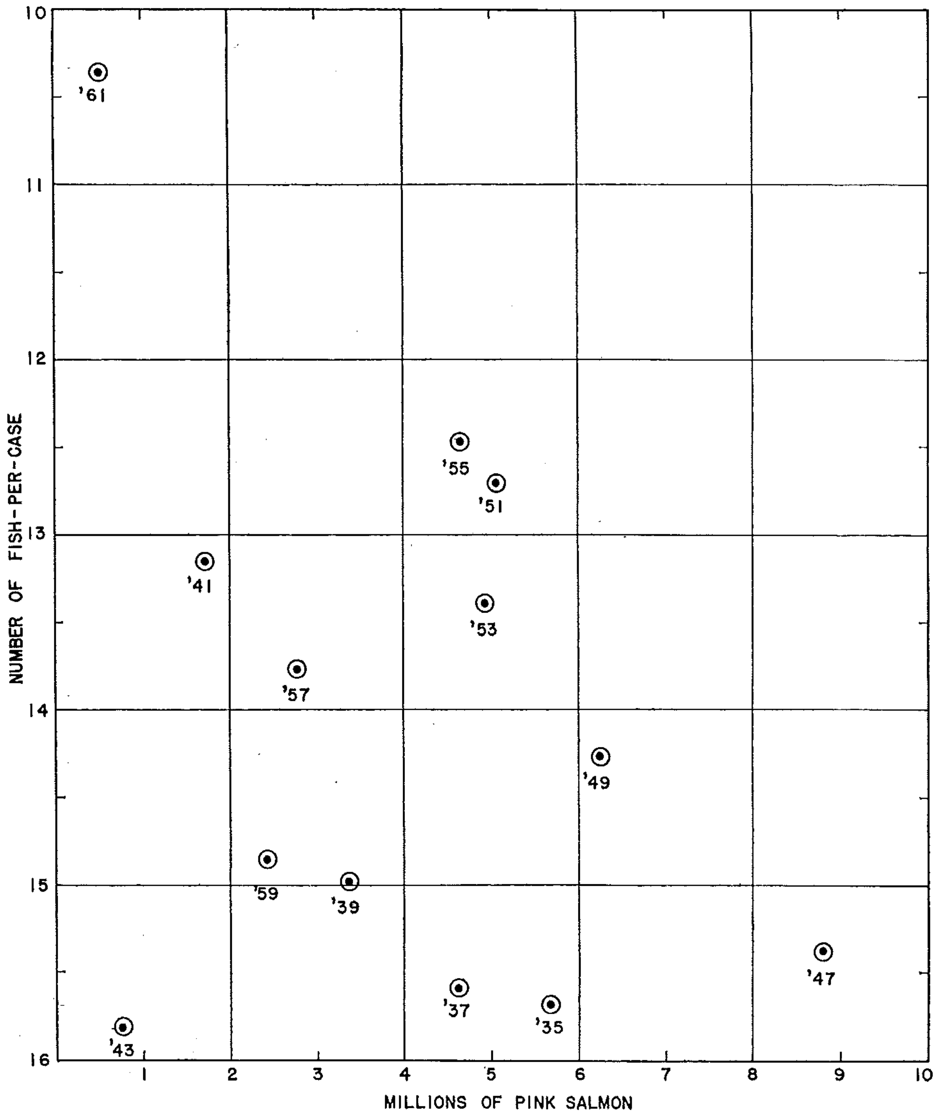

FIGURE 14—The relationship between the numbers of fish-per-case (size) of pink salmon and their numbers as recorded for the United States fishery, 1935 to 1961.

way in their rates of growth. There was no obvious evidence to indicate that sockeye sizes were reduced because of the presence of pink salmon in the "odd" years. Other concurring information was the fact that both sockeye and pinks returned in very small numbers in 1943 although the size of both species was well below average; by contrast, a very large pink salmon run of below average size occurred in 1947 but the sockeye of that year were larger than usual.

The most conclusive evidence as to whether or not an annual weight relationship existed between pinks and sockeye was provided by a series of annual average length measurements of a pure race of Chilko sockeye through 24 consecutive years.

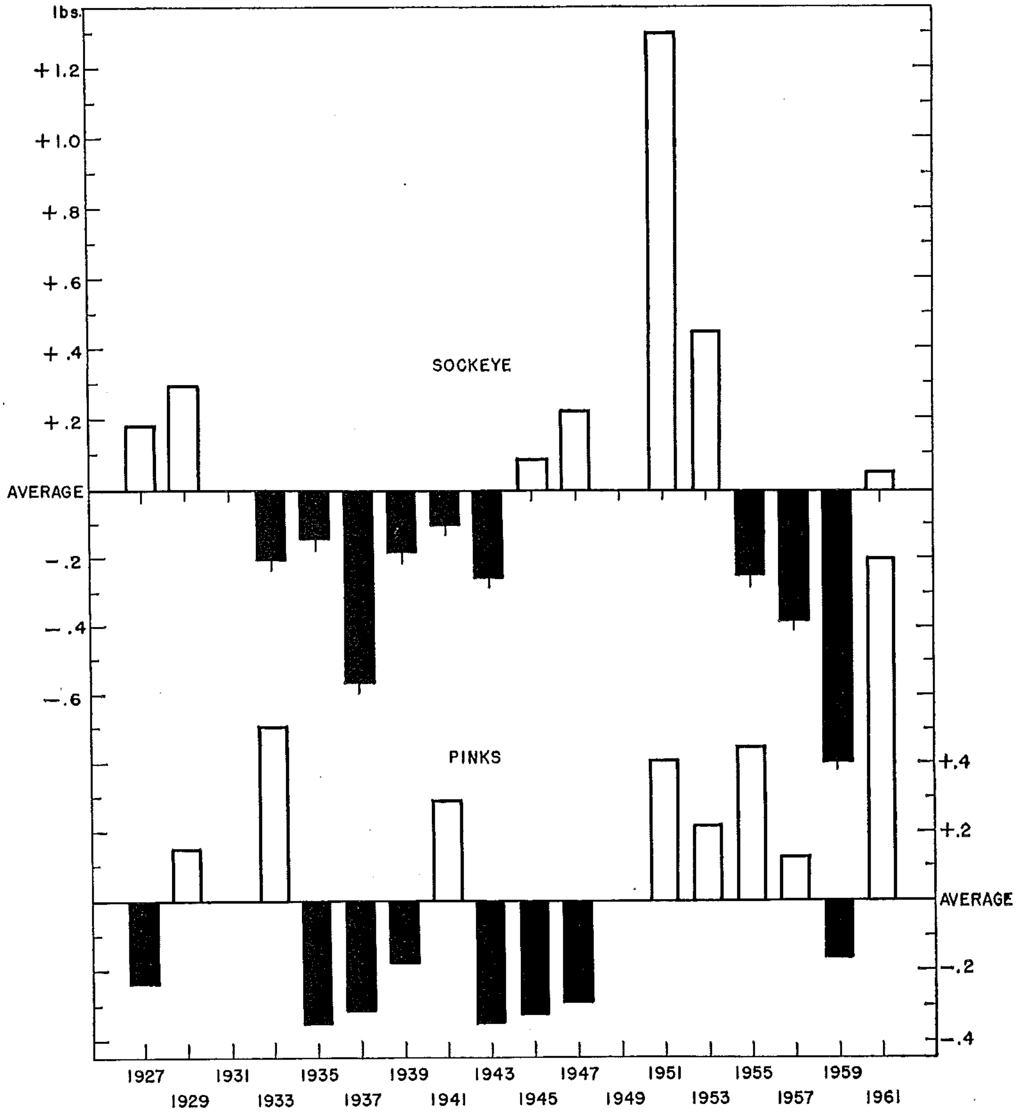

FIGURE 15—The annual size deviations above and below average for pinks and sockeye for the years 1927 to 1961. Shaded areas denote years of smaller sizes.

These data were plotted in FIGURE 16 to discover whether the Chilko sockeye were consistently smaller in the "odd" years. Here it was found that the sockeye *were not* necessarily small in the "odd" or "pink salmon" years. In fact, there were 7 "odd" years when the Chilko sockeye were above average compared with 5 "odd" years when this race of sockeye was below average size. The largest Chilko sockeye occurred in 1951 which was also a year of high production for Fraser River pinks. Because sockeye and pink salmon showed no consistent agreement in their annual size variations and because sockeye of a single race showed no tendency to be smaller in the "odd" numbered years, it was concluded that pinks and sockeye of the Fraser River system were not competitive for food during their marine existence, at least for the years of data examined. The occurrence of lower annual average weights in "odd" years for all races of sockeye as previously illustrated must stem from some other reason than the suspected influence of "odd" year pink salmon populations.

A close examination of the seasonal and cyclical size variations will be analyzed next to reveal not only the reason for the "odd" and "even" year size differences but also the basic size characteristics for each of the 4_2 cycle groups.

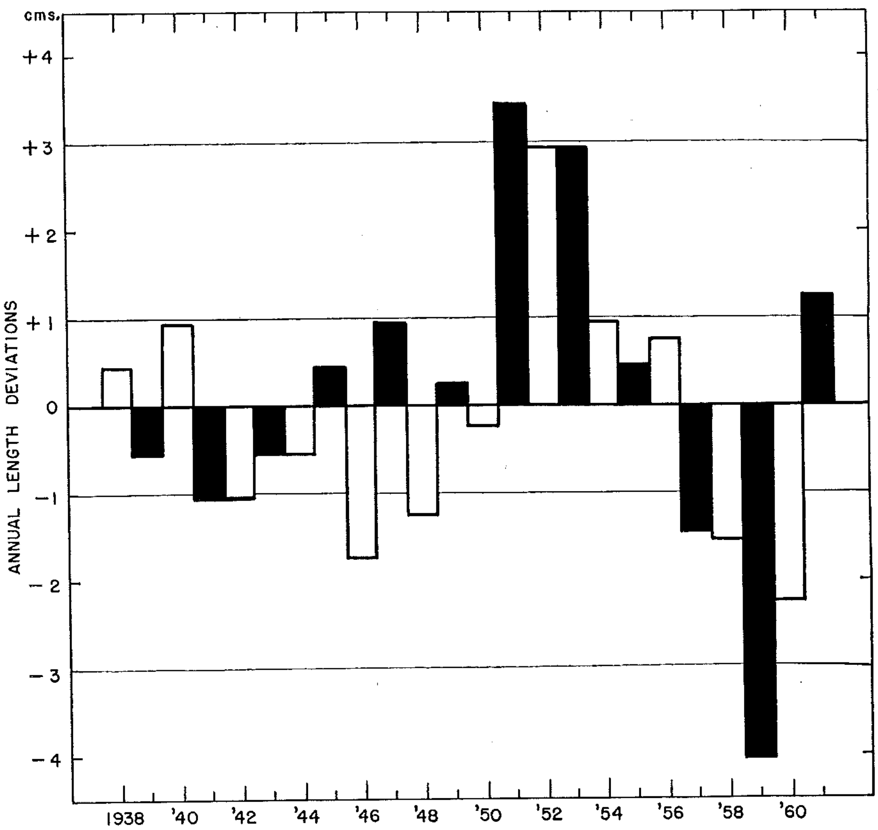

FIGURE 16—The annual deviations from the average standard length of Chilko sockeye (1938-61) illustrating that smaller sockeye of a given race do not occur regularly on the "odd" years shown as shaded areas.

Seasonal Size Variations

The seasonal weight changes of 4_2 sockeye by weekly periods are given for all years and for the four separate cycles in TABLE 21 and FIGURES 17 and 18. Lengths by weeks are shown only in the illustration of all years combined in FIGURE 17. Here, a smooth progression was noted from small sockeye in early July to a peak size in mid-August followed by a slight decline in both weight and length in late August and early September. Generally, the weights and lengths changed together except after August 19 to 25 when the weight declined but the length continued to increase. Consequently August sockeye tended to be slimmer than sockeye caught earlier in the season.

TABLE 21—Comparison of weekly average weights of four-year-old sockeye of each cycle: 1915 - 59, 1916 - 60, 1917 - 57, 1918 - 58 and all cycles combined.

CYCLE	WEEKLY SAMPLE PERIODS								
	July 1 - 7	July 8 - 14	July 15 - 21	July 22 - 28	July 29 - Aug. 4	Aug. 5 - 11	Aug. 12 - 18	Aug. 19 - 25	Aug. 26 - Sept. 1
1915-59	5.304	5.586	5.719	5.943	6.051	6.346	6.274	6.105	5.861
1916-60	5.945	6.028	6.135	6.132	6.219	6.308	6.522	6.320	6.222
1917-57	5.610	5.607	5.527	5.545	5.599	5.621	5.657	5.738	5.739
1918-58	5.619	5.994	6.070	6.208	6.512	6.543	6.742	6.758	6.721
All Years 1915-1960	5.620	5.804	5.863	5.957	6.095	6.205	6.299	6.230	6.136

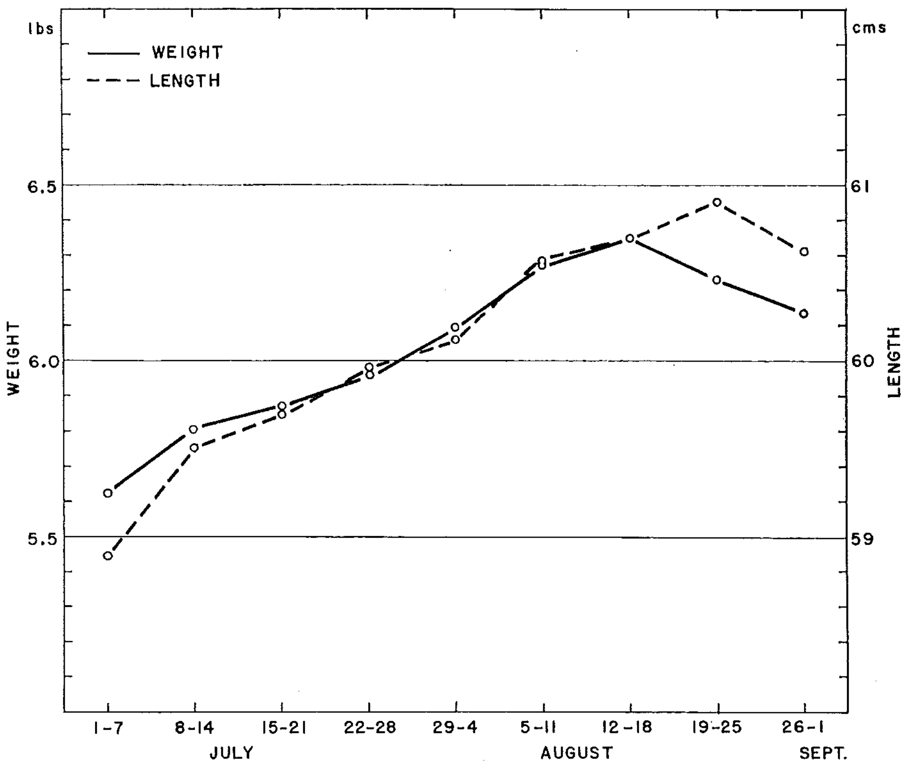

FIGURE 17—Season size trend of Fraser River sockeye in the Sooke and United States commercial fisheries calculated from all years of sampling, 1915-1960.

The fact that sockeye sizes became progressively larger throughout the fishing season at first suggested that the longer a sockeye remained in the ocean, the larger it would grow; however, when each of the four cycles was considered separately, a different conclusion became evident (FIGURE 18). In the particular cycle of 1917-57, there were essentially no size increases throughout the full season from July 1 to September 1. In each of the three remaining cycles, the last sockeye to enter the fishery were smaller than those of early or mid-August. This evidence indicated that, while there is undoubtedly some growth progression with time spent in the ocean, the seasonal sockeye size differences are mostly governed by the different genetic size characteristics peculiar to the various races present. As each race passes through the fishery, the average weight of the sockeye being caught changes in proportion to the characteristic average weight of the most abundant race or races present. Such seasonal size variations were first reported by Dr. C. H. Gilbert in 1916, when he said of the Fraser River runs:

> "Changes of great magnitude may occur suddenly from one week to another, changes which include more than one factor and in which several characteristics are correlated. Suddenly, the average size of individuals may change in both males and females, the relative sizes of the age groups may shift intensively and the characteristics of the nuclear area of the scales may present a sudden transformation. Small early running sockeye are replaced by a much larger type which increase progressively with the season until towards the end of the run they are followed by slightly but unmistakably smaller size."

Gilbert concluded that the average size changes through the fishing season would result from the appearance of various racial strains, some being characterized by individuals of large size and others of small size. Rounsefell and Kelez (1938) also found different sizes of sockeye in different cycles during their examination of fish-per-case records. They reported that the numbers of sockeye required to fill a 48-pound case varied from year to year from about 10 to 13 fish-per-case, tending to be higher in the earlier years, especially during years of the "big run". They also noted that the size tended to be the same from one cycle to the next and that this was probably because of the differences in size of the sockeye spawning in the different lake systems, since the various lakes did not contribute equally to the runs of each cycle.

These two independent observations are wholly supported by the analysis of 46 years of sampling data recorded in this present text in addition to which 11 years of recent Fraser River spawning ground samples show a rather extensive range of racial length differences as follows:

Harrison	51.82 centimeters	Cultus	54.70 centimeters
Late Stuart	53.14 centimeters	Bowron	55.21 centimeters
Stellako	53.53 centimeters	Horsefly	55.74 centimeters
Chilko	54.30 centimeters	Adams	57.11 centimeters
Early Stuart	54.70 centimeters	Weaver	58.29 centimeters

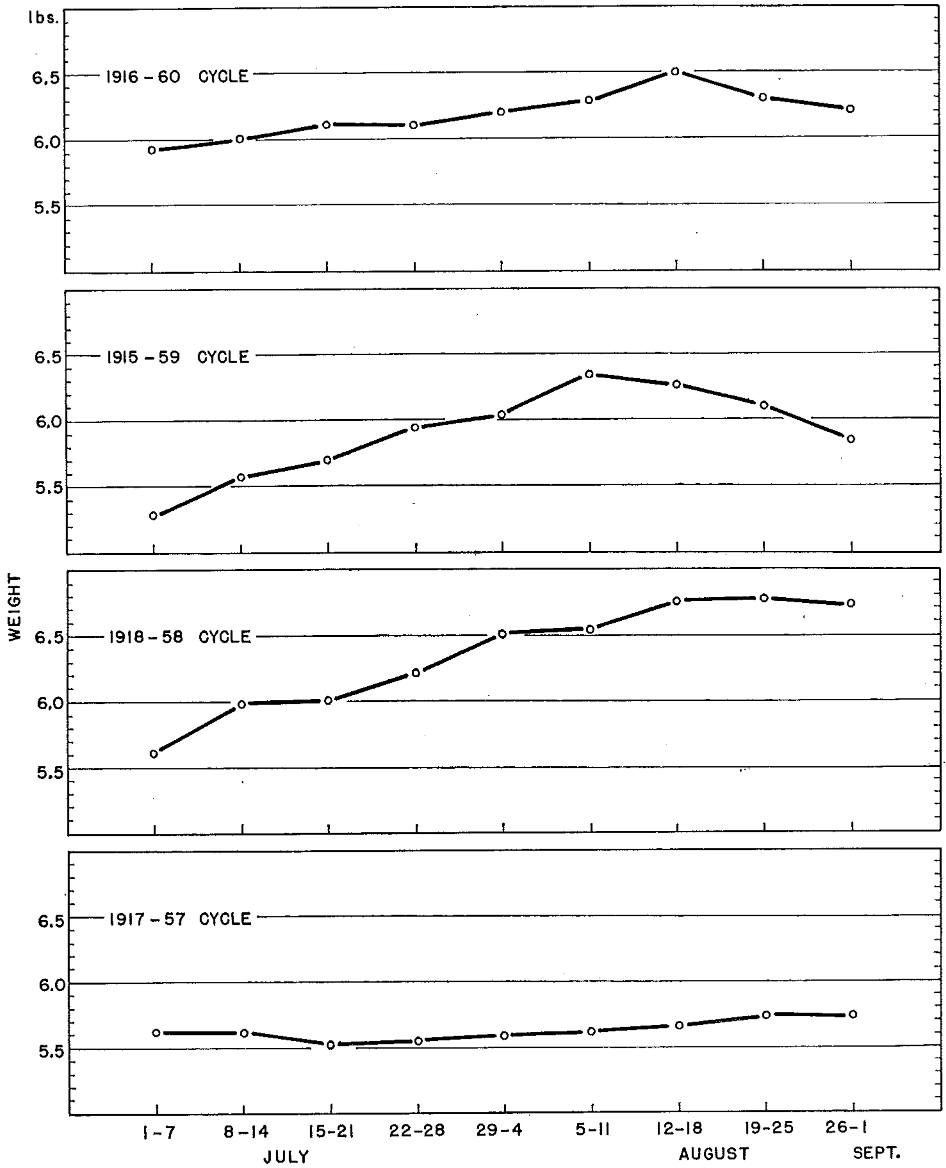

FIGURE 18—Seasonal weight changes of Fraser River sockeye as they occurred for the four cycles of 1917-57, 1918-58, 1915-59, 1916-60.

These are standard lengths measured from the tip of the snout to the end of the vertebral column for the 4_2 age class of sockeye. Weights of sockeye on the spawning grounds are not taken because of the substantial poundage losses which occur during migration.

To establish what lengths of sockeye might be expected within a given fishing season, with each race being of equal number, a hypothetical length was calculated for each week after the abundance curves of the races were placed in their proper time sequence. This is shown in FIGURE 19, using abundance curves and peak dates of passage established by Henry (1961). No significant changes in the sockeye size would occur from one week to the next and the pattern would be much like that of the 1917-57 cycle. This is the only cycle having a number of near equal races occurring in the same fishing season. In each of the other three cycles only one or sometimes two races are numerically dominant and the particular size of the one or two races will govern the seasonal size pattern. The distinct change in the dates of the greatest abundance, as created by variations in racial dominance, is shown graphically in FIGURE 20 for the cycle years 1954, 1955, 1956 and 1957. This phenomenon of average sizes being governed to a major extent by varying numbers of the different races in each of the four cycles is most important and should be thoroughly appreciated before attempts are made to explain the external or environmental factors which have additional effects on sockeye sizes each year.

To illustrate the actual mechanics whereby variations in racial sizes and numbers affect the seasonal and annual sockeye weights, the numbers and average weights of all major races by weekly periods as they appeared in the San Juan Island fishery in 1954 and 1957 are listed in TABLES 22 and 23. The numbers of each race by date of passage are obtained from the scale analysis of Henry *(ibid.)*, while the weights are calculated from spawning ground length measurements. In 1954, the average weights for the Early Stuart, Bowron, Chilko, Stellako and Adams races were 6.5, 6.3, 6.4, 6.4 and 7.4, respectively (TABLE 22). Tracing the seasonal size trend, the first sockeye taken from July 1-7 were all Stuart fish averaging 6.5 pounds, following which the appearance of slightly smaller sized Bowron and Chilko sockeye reduced the commercial landing weights to 6.47 and 6.4 pounds as of July 21. By July 22-28, Stuart sockeye were nearly gone and Stellako (6.4 pounds) showed strength and Adams (7.4 pounds) provided a few early arrivals. These latter races increased the landed pound average to 6.5. As of August 5 to 11, the Adams race began to dominate the commercial catch and the weekly average weights rose sharply to 6.94 pounds. By September 1, when the catch was nearly 100 per cent Adams, the peak size of 7.39 pounds was reached.

For contrast, the same analysis was done for the sockeye catches of 1957 (TABLE 23). Inasmuch as different races were numerically abundant in this cycle year, compared to 1954, it could well be expected that the size pattern would be completely different. The extent of the size difference between 1954 and 1957 was exaggerated to some degree by the fact that all sockeye of 1954 were above average while those of 1957 were particularly small; however, the contrast in the week-to-week pattern between the two cycle years would always prevail because of the fundamental differences in racial composition. The eventual patterns of weekly size changes in 1954 and 1957 are shown in FIGURE 21 as a composite of all races involved.

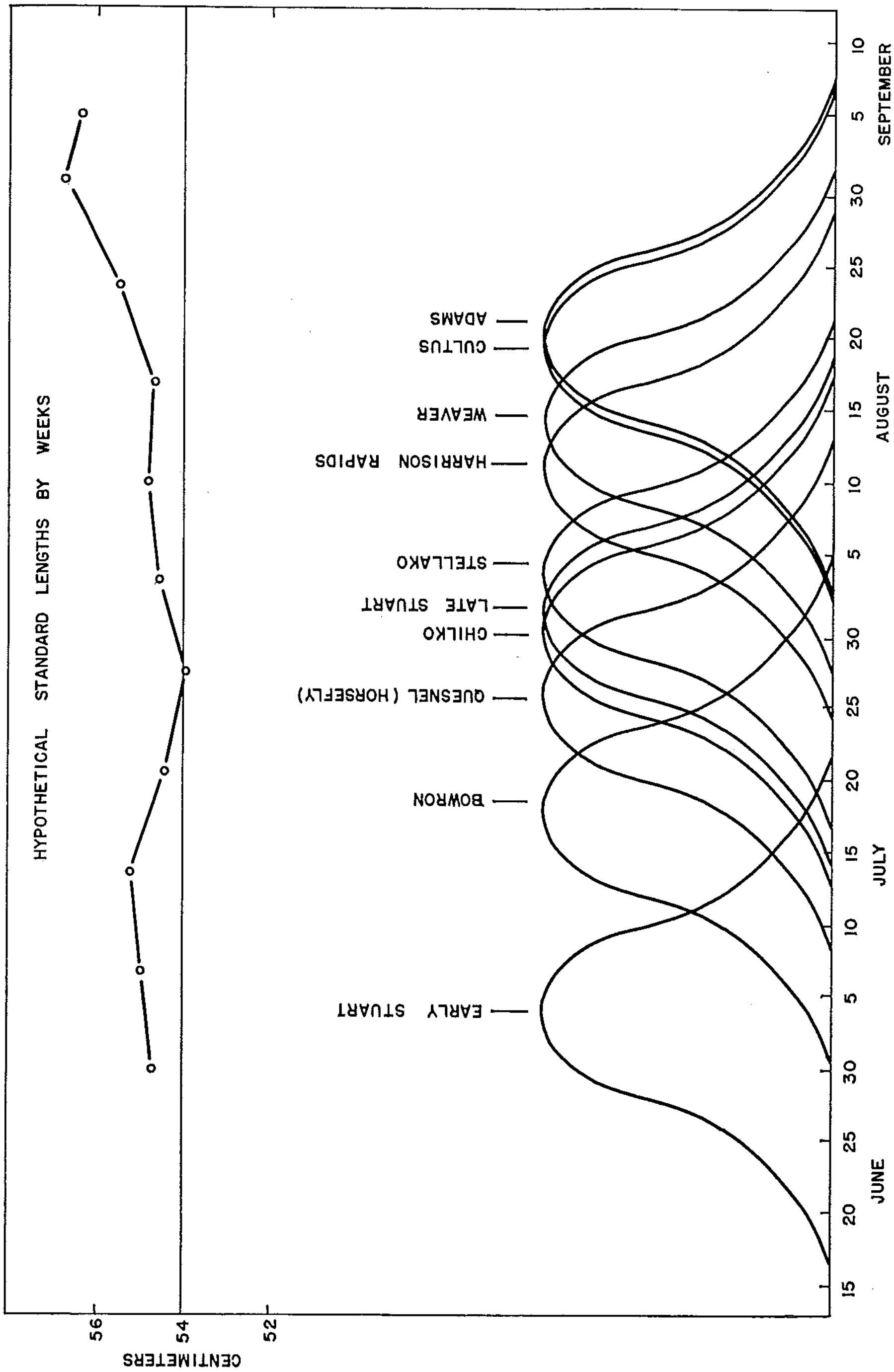

FIGURE 19—Best estimates of the average dates of passage at Sooke and the abundance curves of major Fraser River sockeye races showing the hypothetical weekly length measurement that would occur if each race were of equal numbers.

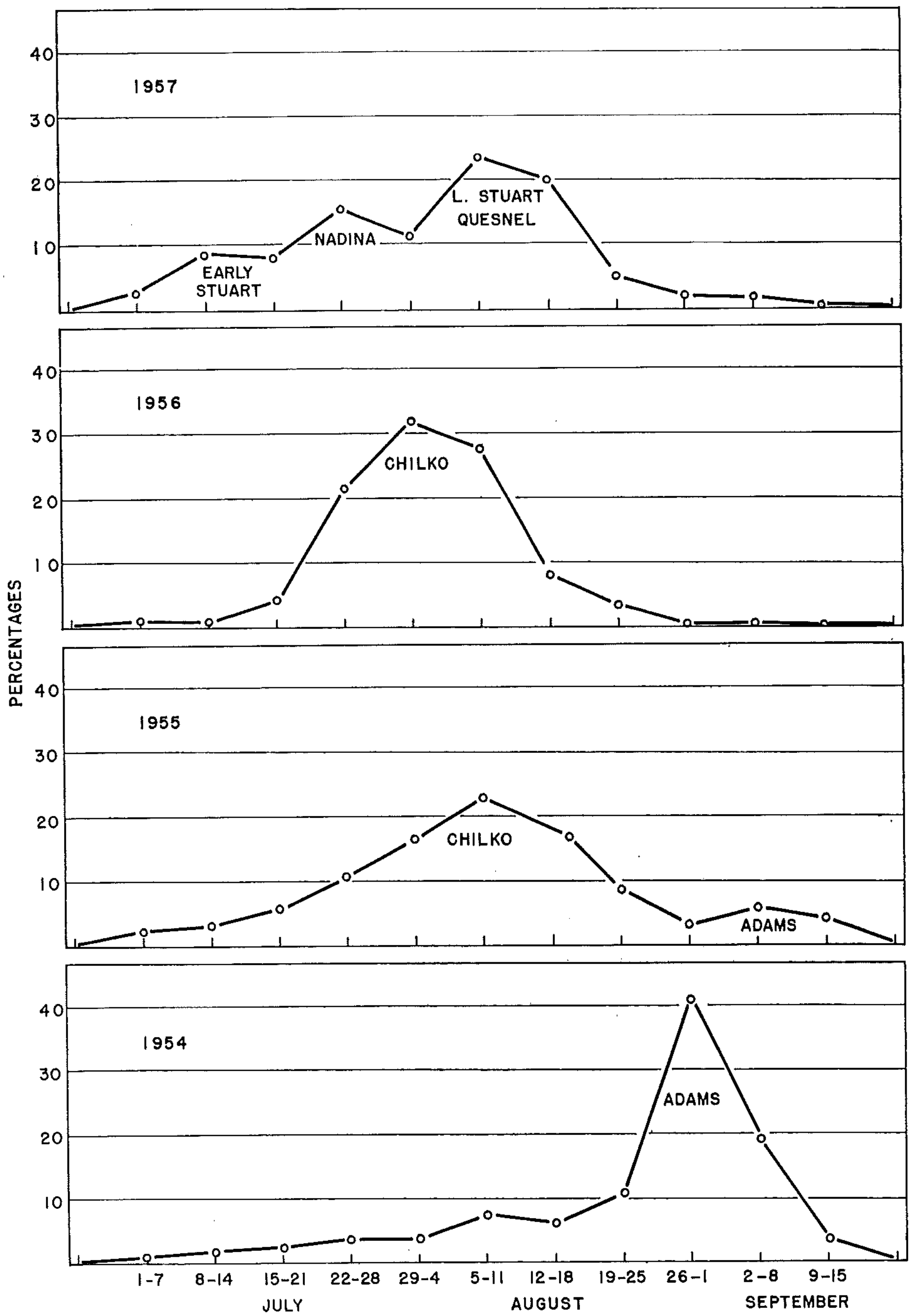

FIGURE 20—The percentage distribution of 4_2 sockeye in the United States commercial catch by weekly periods during 1954, 1955, 1956 and 1957.

TABLE 22—The weekly average weights of 4_2 sockeye in the United States San Juan Island commercial fishery as governed by the times of passage, numbers and size (weight) of the Early Stuart, Bowron, Chilko, Stellako and Adams races in 1954.

WEEKLY PERIODS	RACES AND SIZE					NUMBER SOCKEYE	POUNDS SOCKEYE	AVERAGE WEIGHT
	Early Stuart @ 6.5 lbs.	Bowron @ 6.3 lbs.	Chilko @ 6.4 lbs.	Stellako @ 6.4 lbs.	Adams @ 7.4 lbs.			
July 1 - 7	17,650					17,650	114,725	6.50 pounds
July 8 - 14	23,840	2,910	4,998			31,748	205,280	6.47 pounds
July 15 - 21	10,252	11,446	5,523	17,924		45,145	288,809	6.40 pounds
July 22 - 28	262	2,442	5,560	41,733	5,823	55,820	362,853	6.50 pounds
July 29 - Aug. 4		100	7,919	37,552	12,977	58,548	387,675	6.62 pounds
Aug. 5 - 11			18,291	50,912	82,199	151,402	1,051,172	6.94 pounds
Aug. 12 - 18			5,423	10,507	109,667	125,597	913,488	7.27 pounds
Aug. 19 - 25				19,308	188,056	207,364	1,515,185	7.31 pounds
Aug. 26 - Sept. 1				15,230	1,224,016	1,239,246	9,155,190	7.39 pounds

TABLE 23—The weekly average weights of 4_2 sockeye in the United States San Juan Island commercial fishery as governed by the times of passage, numbers and size (weight) of the Early Stuart, Nadina, Chilko, Horsefly, Late Stuart and Adams races in 1957.

WEEKLY PERIODS	RACES AND SIZE						NUMBER SOCKEYE	POUNDS SOCKEYE	AVERAGE WEIGHT
	Early Stuart @ 5.3 lbs.	Nadina @ 5.2 lbs.	Chilko @ 5.4 lbs.	Horsefly @ 5.1 lbs.	Late Stuart @ 5.1 lbs.	Adams @ 6.4 lbs.			
July 1 - 7	25,125	603					25,728	136,299	5.29 pounds
July 8 - 14	59,514	3,263					62,777	332,392	5.29 pounds
July 15 - 21	29,975	29,192	3,338				62,505	327,690	5.24 pounds
July 22 - 28		53,233	15,832	22,562	29,980		121,607	632,288	5.20 pounds
July 29 - Aug. 4		3,488	12,826	29,656	39,284		85,254	444,041	5.21 pounds
Aug. 5 - 11			25,022	40,701	103,778	279	169,780	878,451	5.17 pounds
Aug. 12 - 18			24,436	6,176	73,157	1,199	104,968	538,749	5.13 pounds
Aug. 19 - 25			9,272		4,270	1,812	15,354	80,661	5.25 pounds
Aug. 26 - Sept. 1			1,873			1,049	2,922	16,266	5.57 pounds

Racial size differences thus account for the changes in the average weights of sockeye caught during different parts of the fishing season in any given year. They also account for the specific average sizes being different for each of the four cycle years, as follows:

1915 - 1959 cycle — 5.922 pounds
1916 - 1960 cycle — 6.074 pounds
1917 - 1957 cycle — 5.632 pounds
1918 - 1958 cycle — 6.388 pounds

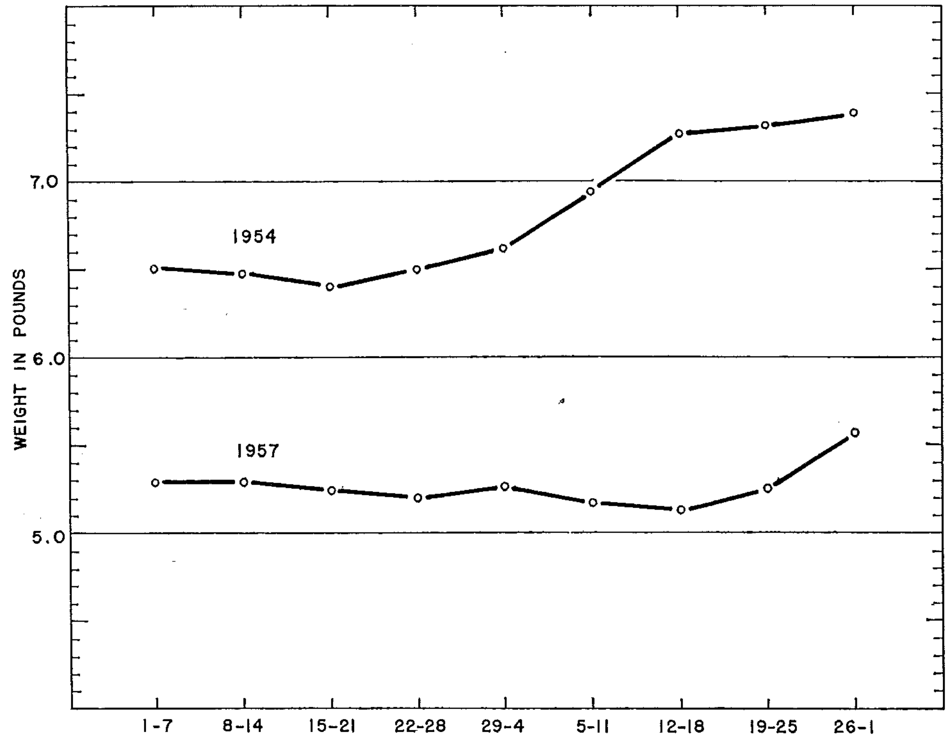

FIGURE 21—Comparison of the weekly average weights of 4_2 sockeye taken in the San Juan Island commercial fishery in 1954 and 1957. The differences in seasonal size trends between the two years is the result of variations in racial composition as demonstrated in Tables 22 and 23.

Two major points are drawn from the above discussion: First, that the numerically dominant races of genetically small sized sockeye occur, presumably by chance, in the "odd" numbered years whereas races of genetically large size are most abundant in the "even" years. This circumstance results in an expected alternation of annual sizes independent of any plus or minus growth attributes of the external environment. Second, since each of the four cycle groups has its own characteristic genetic size, it becomes necessary to compare each annual size to an average of the particular cycle average and not to the previous year nor to an average of all years combined.

With these pertinent size characteristics established, it is then appropriate to examine more closely the pattern of size fluctuations as they have occurred through a series of generations for each of the four independent cycle groups.

Cycle Size Variations

While characteristic sizes of sockeye for each of the four cycle years were basically governed by *genetic* differences in the particular races making up the time structure of the annual populations, genetic differences did not explain the variations that have occurred through successive generations of each cycle group where the racial composition was, for all practical purposes, relatively constant. Instead, it is believed that variations occurring within cycle groups were mostly caused by *environmental* factors and the nature of these cyclic size changes are shown in TABLE 24 and FIGURE 22 which illustrate the extent of the size variations of 4_2 sockeye for the respective cycle groups.

The erratic and abrupt weight changes have been an anomalous feature since the variations were often extreme, even though these were all parent-progeny relationships. Through each of the four cycle groups there were no consistent patterns which might allow a prediction or even a suggestion as to what a future generation weight might be; for example, the rather spectacular large size of the 1951 sockeye occurred without precedent, followed by a marked size decline in 1955. The most consistent feature established was that the expected mean weights of the four cycle groups would be different.

The next step was to develop a standardized set of annual size measurements that were comparable through the 46 years of consecutive data. These values, shown in FIGURE 23, are the annual deviations from the four cycle means as obtained from TABLE 24. Still, there were no rythmic fluctuations in size. Year to year weight changes seemed to have been mostly random in both direction and extent and at times, completely opposite size characteristics occurred in adjacent years, while at other times the sizes remained consistently above or below average for a number of years.

TRENDS OF ANNUAL WEIGHT DEVIATIONS FROM CYCLE AVERAGES

While the distinct year-to-year size variations were clearly evident in FIGURE 23, it was difficult to recognize any trend in the size of Fraser sockeye through the past 46 years so the data were smoothed by fours and plotted in FIGURE 24. In addition to smoothing, correlation and regression coefficients of weight versus time were calculated for the 46 years of annual deviations and also for each of the four separate cycles. These analyses showed *no* significant correlations between size changes and time and *no* significant regression slopes towards larger or smaller sockeye either through the 46 years, or through eleven or twelve generations of the four cycle groups. Thus, both the smoothed data and the statistical tests showed no tendency for Fraser sockeye to change their average size on a long-term basis even though radical annual deviations from the average have occurred. In general, the sizes (averaged over four year periods) were noticeably stable in the early years with only a slight tendency towards larger sizes from 1927 to 1932. The major distortion of the size pattern has occurred in the last decade with extremely large sockeye occurring from 1950 to 1954, followed by extremely small sockeye from 1955 to 1960. These recent departures from normal size indicate the possibility of rather severe changes in the marine growth environment.

Before exploring possible causes for the size changes, records of the *daily average weights from the commercial fishery* and numbers of *fish-per-case* will be examined. If the weights derived from sampling are reliable, they should agree well with the average weights of the total commercial catch and an analysis of these two sets of data thus can serve as an accuracy check on the sample weight information. Likewise, the average weights of the commercial catches should be reflected in the numbers of fish-per-case data. If such is found to be true, the numbers of fish-per-case can represent a third measure of Fraser sockeye sizes dating back to at least 1913.

TABLE 24—The annual average weights of successive generations of 4_2 sockeye in each of the four cycles: 1915 - 1959, 1916 - 1960, 1917 - 1957 and 1918 - 1958 and the plus or minus deviations from cycle averages.

CYCLE 1915 - 1959		
Year	Annual Average Weight	Deviations
1915	5.912	—.010
1919	5.589	—.333
1923	6.216	+.294
1927	6.079	+.157
1931	5.983	+.061
1935	5.792	—.130
1939	5.723	—.199
1943	5.639	—.283
1947	6.163	+.241
1951	7.208	+1.286
1955	5.641	—.281
1959	5.124	—.798
Cycle Average	5.922 pounds	

CYCLE 1916 - 1960		
Year	Annual Average Weight	Deviations
1916	5.856	—.218
1920	6.020	—.054
1924	5.600	—.474
1928	6.377	+.303
1932	6.445	+.371
1936	6.471	+.397
1940	6.351	+.277
1944	6.227	+.153
1948	5.527	—.547
1952	6.801	+.727
1956	6.024	—.050
1960	5.185	—.889
Cycle Average	6.074 pounds	

CYCLE 1917 - 1957		
Year	Annual Average Weight	Deviations
1917	5.470	—.162
1921	5.888	+.256
1925	5.755	+.123
1929	5.918	+.286
1933	5.431	—.201
1937	5.054	—.578
1941	5.525	—.107
1945	5.707	+.075
1949	5.853	+.221
1953	6.081	+.449
1957	5.272	—.360
Cycle Average	5.632 pounds	

CYCLE 1918 - 1958		
Year	Annual Average Weight	Deviations
1918	6.303	—.085
1922	6.050	—.338
1926	6.308	—.080
1930	6.568	+.180
1934	6.185	—.203
1938	6.688	+.300
1942	6.579	+.191
1946	5.860	—.528
1950	6.956	+.568
1954	6.841	+.453
1958	5.928	—.460
Cycle Average	6.388 pounds	

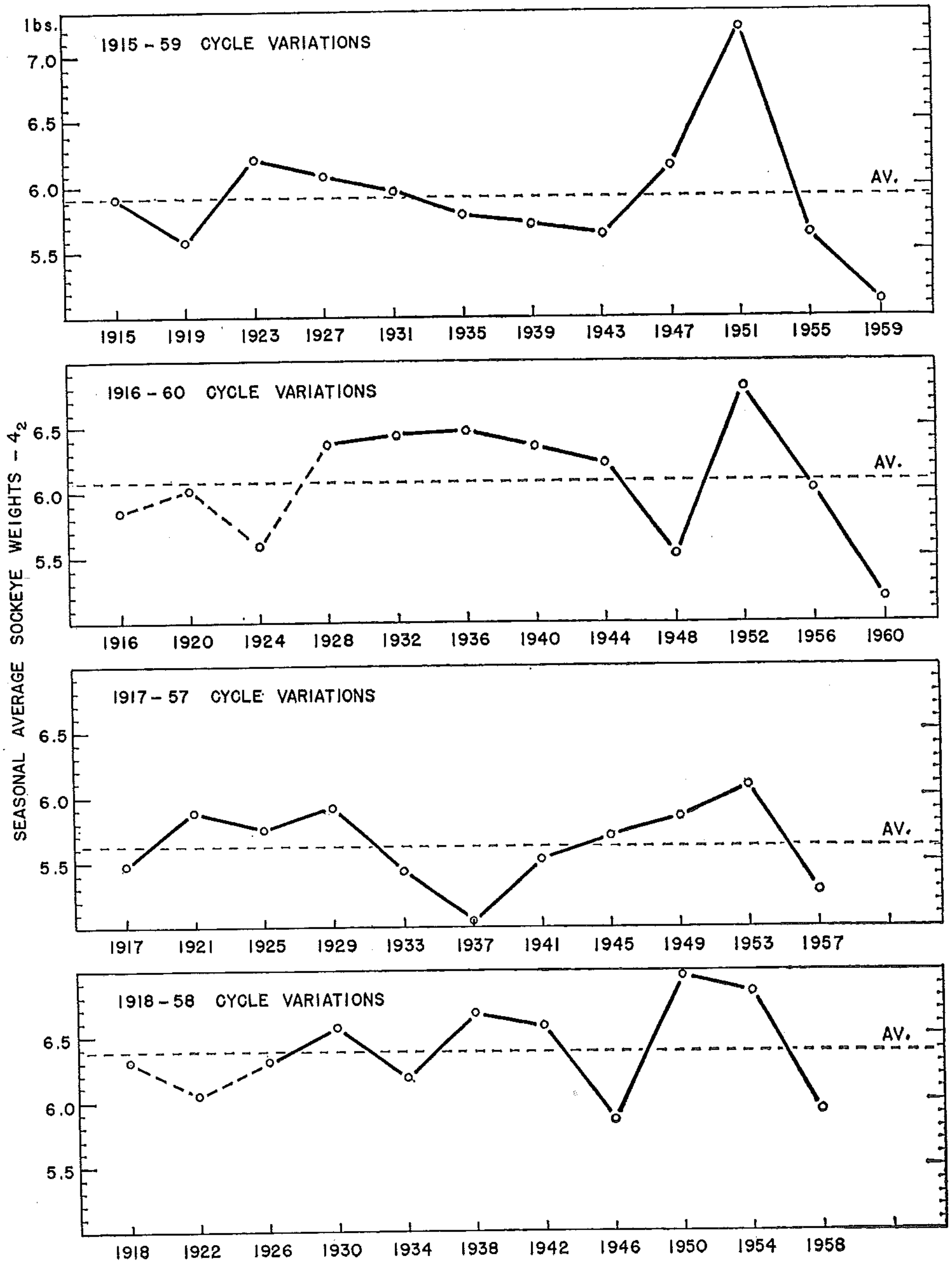

FIGURE 22—Variations in weights of four-year-old sockeye through successive generations in each of the four cycle groups: 1915-1959, 1916-1960, 1917-1957, and 1918-1958.

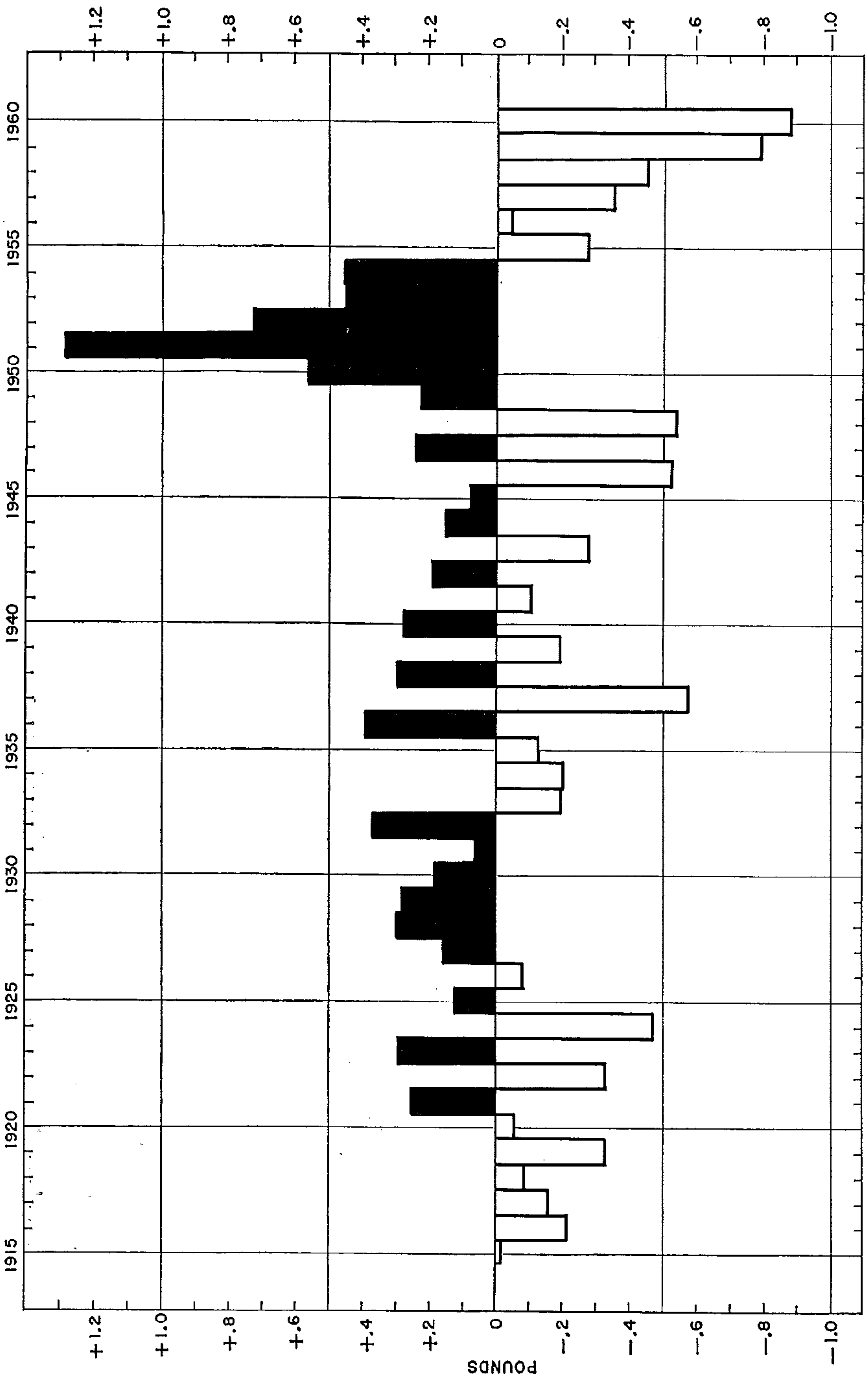

FIGURE 23—Annual weight deviations of four-year-old Fraser River sockeye from their respective cycle average weights for the years 1915 to 1960.

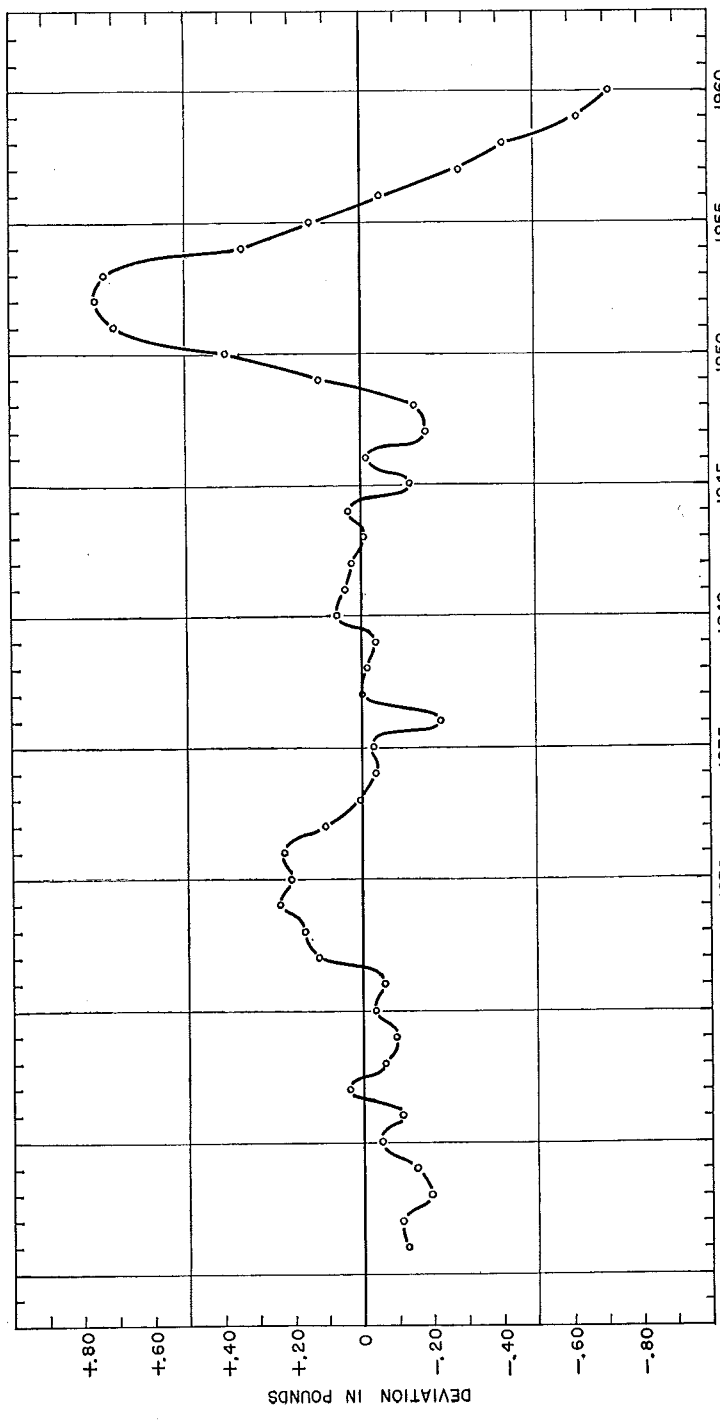

FIGURE 24—The size trend of the 4_2 sockeye of the Fraser River as measured by the annual weight deviations from cycle averages (smoothed by 4's) through the period of 1915 to 1960.

Weekly and Annual Average Weights of Commercial Catches 1944 to 1960

Records of the weekly and annual average weights of United States sockeye catches for the years 1944 to 1960 are given in TABLE 25. In years prior to 1944, sockeye were purchased by the piece and not by the pound thus average weight data of commercial landings are not available for earlier years. Only sockeye taken by purse seines were considered since these gears are considered non-selective as to size. Both weighted and unweighted annual means were derived. The *unweighted* annual means are averages of the nine weekly mean weights and are equivalent to values obtained from sampling. The *weighted* means were averages derived from the total numbers and pounds caught each year and as such tended to represent the average weight of the most abundant race rather than an average size characteristic of all races present in any particular year. The close agreement between the two sets of data indicated that any averages derived from individual samples would be quite representative of the actual weight of the total catches in most years.

The *weekly* average weights, shown in TABLE 25, were examined and these showed considerable differences in sockeye sizes within each fishing season. The years of 1945, 1949, 1953 and 1957 were deleted from the weekly summary calculations to avoid the influence of small 3_2 jack sockeye. Sockeye caught early in July weighed 6.21 pounds but as the season progressed the sizes became larger and reached a peak of 6.54 pounds from August 12-18, after which there was a slight decline in weight to 6.43 pounds by September 1. Each of these summary averages is larger than might normally be expected, especially for the early July period, because early season commercial closures in the years 1944 to 1949 and 1958 to 1960 precluded the obtaining of July weight data in these years when the sockeye were smaller than average. Contrarywise, early closures were not in effect in the five intervening years of large sockeye except for 1950. Irrespective of the fact that the average weights were somewhat above average (especially to mid-July), the pattern of the seasonal size trend of the commercially caught sockeye agrees closely with the seasonal trend of 4_2 sample weights.

With regard to the *annual* weight changes, it was found that marked year to year differences occurred in the size of sockeye captured by the commercial fishery. Sizes were nearly always smaller in the "odd" years. The average weights of sockeye in the 1913 cycle years (1945, 1949, 1953 and 1957) were noticeably low but this was due in part to the presence of large numbers of small 3_2 jacks, except for 1949.

When the commercial weight averages were compared with the 4_2 sample weights (FIGURE 25), they agreed within plus or minus two-tenths of a pound with the exception of 1953. The regression coefficient (r) value was highly significant (.9493) in this case. The close relationship occurred despite the varying annual proportions of small 3_2 and large 5_2 sockeye in the commercial landings. This finding clearly demonstrated that the sampling weights were sound measures of Fraser sockeye size and that the dominant 4_2 age group mostly controlled the commercial average weights.

TABLE 25—Weekly and annual average weights of sockeye landed by United States purse seine boats compared with annual average weights of sampled 4_2 sockeye.

YEARS	SOCKEYE FROM UNITED STATES PURSE SEINES									UNWEIGHTED AVERAGE	WEIGHTED AVERAGE	SAMPLED 4_2 WEIGHTS
	July 1 - 7	July 8 - 14	July 15 - 21	July 22 - 28	July 29 - Aug. 4	Aug. 5 - 11	Aug. 12 - 18	Aug. 19 - 25	Aug. 26 - Sept. 1	July 1 - Sept. 1	July 1 - Sept. 1	July 1 - Sept. 1
1944	—	—	6.35	6.15	6.28	6.70	—	—	—	6.370	6.306	6.23
1945	—	5.71	5.63	5.78	5.74	5.66*	5.60*	—	—	5.686*	5.743*	5.71
1946	—	—	—	—	5.80	5.88	5.92	6.13	5.99	6.015	6.014	5.86
1947	—	—	—	—	—	—	6.56	6.25	5.98	6.263	6.144	6.16
1948	—	—	6.21	6.03	5.65	5.53	—	—	—	5.855	5.638	5.53
1949	—	—	—	—	5.70	5.62*	5.70*	5.71*	5.77*	5.700*	5.656*	5.85
1950	—	—	—	—	6.82	6.84	6.94	6.87	6.75	6.844	6.861	6.96
1951	6.79	6.93	7.00	7.08	7.38	7.63	7.51	7.26	7.32	7.211	7.295	7.21
1952	6.34	6.43	7.01	7.04	7.19	7.29	7.14	7.31	7.56	7.034	7.070	6.80
1953	6.27	6.19	6.08	6.26	6.09	5.45*	4.79*	4.63*	4.85*	5.623*	5.995*	6.08
1954	6.59	6.44	6.32	6.48	6.68	6.94	7.23	7.33	7.36	6.819	7.218	6.84
1955	5.30	5.49	5.59	5.92	5.74	5.82	5.92	5.91	5.80	5.721	5.852	5.64
1956	6.05	6.09	6.29	6.23	6.39	6.44	6.45	6.40	6.33	6.296	6.354	6.02
1957	5.50	5.39	5.25	5.20	5.17	5.08*	4.78*	4.42*	4.46*	5.028*	4.997*	5.27
1958**	—	—	5.79	5.98	6.10	6.09	6.32	6.37	6.13	6.111	6.221	5.93
1959	—	—	4.99	5.12	5.19	5.24	5.36	5.28	5.08	5.180	5.250	5.12
1960	—	—	5.49	5.51	5.53	5.44	5.16	—	5.19	5.387	5.457	5.19
Weekly Averages***	6.21	6.28	6.17	6.23	6.29	6.40	6.54	6.51	6.43			
4_2 Sample Averages	5.62	5.80	5.86	5.96	6.10	6.21	6.30	6.23	6.14			

* Average weights reduced by presence of small 3-year-old Adams River jacks.

** Weekly average weights shifted one week early to adjust for late timing of all 1958 sockeye runs.

*** Cycle years 1945, 49, 53 and 57 omitted.

Having established that the sample weights were in close accord with commercial weights, the next step was to examine the relationship between the commercial weights and the numbers of fish-per-case.

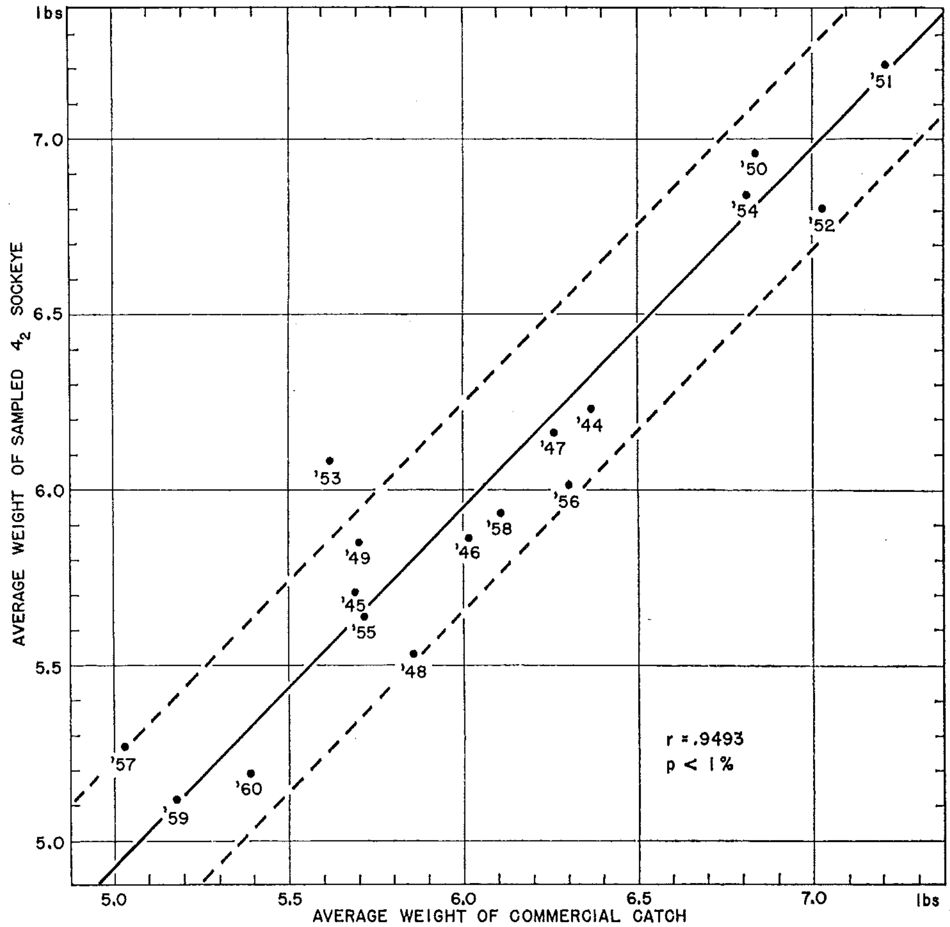

FIGURE 25—The relationship between the average annual weights of 4_2 sampled sockeye and the averages of the total commercial catches of United States purse seines.

The Numbers of Fish-Per-Case Related to Size of Sockeye 1935 to 1960

Prior to considering a relationship between sampled weights of 4_2 sockeye and fish-per-case, it was first necessary to establish whether or not the average weights of commercial catches were correlated with fish-per-case numbers. If these two measures of size did not agree, there would be no merit in proceeding further into comparisons with 4_2 sample sizes. The data relating average weights of commercial catches to numbers of fish-per-case are listed in TABLE 26. The source and nature of the information is as follows:

(a) *Catch* and *pack* numbers, available since 1935, were obtained from the Washington State Department of Fisheries Annual Report (1961) for the period 1935 to 1938; data from 1939 to 1960 were from the Annual Reports of the International Pacific Salmon Fisheries Commission (1940-1961).

(b) *Fish-per-case* numbers were obtained directly from the annual catch and pack numbers.

(c) *Average weights* were available from fish tickets for the years 1944 to 1960 when sockeye were bought by the pound. For the earlier years, 1935 to 1943, when sockeye were purchased by the piece, the average weights were calculated from the sampled 4_2 weights adjusted for varying percentages of 3_2 and 5_2 sockeye each year.

(d) *Total pounds* represent the annual catches times the average weights.

(e) *Pounds-per-case* were obtained directly from the total pounds divided by the numbers of cases packed.

TABLE 26—The commercial catch, pack, pounds, average weight, pounds and fish-per-case (48 pound) for the United States fishery of Fraser River sockeye, 1935 to 1960.

Year	Catch[1]	Pack[1] (48 pound cases)	Pounds	Pounds Per Case	Average[2] Weight	Fish Per Case
1935	615,848	54,677	3,756,673	68.707	(6.10)	11.263
1936	454,085	42,894	3,021,677	70.445	(6.67)	10.562
1937	898,311	60,259	4,491,555	74.537*	(5.00)	14.907*
1938	1,409,331	135,550	9,583,451	70.700	(6.80)	10.397
1939	555,233	43,511	3,220,351	74.012*	(5.80)	12.761*
1940	654,091	59,354	4,251,592	71.631	(6.50)	11.020
1941	1,558,554	110,605	8,416,192	76.092*	(5.40)	14.091*
1942	2,935,192	263,458	19,372,267	73.531*	(6.60)	11.141*
1943	242,077	19,060	1,452,462	76.205*	(6.00)	12.701*
1944	435,443	37,379	2,745,904	73.461*	6.306	11.649*
1945	706,464	53,054	4,057,223	76.473*	5.743	13.316*
1946	3,551,306	280,018	21,357,554	76.272*	6.014	12.682*
1947	88,220	6,760	542,024	80.181*	6.144	13.050*
1948	1,089,091	90,441	6,140,295	67.893	5.638	12.042
1949	1,056,792	80,547	5,977,216	74.208*	5.656	13.120*
1950	1,220,893	116,458	8,376,547	71.928	6.861	10.484
1951	1,136,795	118,151	8,292,920	70.189	7.295	9.622
1952	1,113,475	114,638	7,872,268	68.671	7.070	9.713
1953	2,032,437	178,323	12,184,460	68.328	5.995	11.398
1954	4,806,258	501,496	34,691,570	69.176	7.218	9.584
1955	1,006,610	85,136	5,890,682	69.191	5.852	11.824
1956	906,872	84,052	5,762,265	68.556	6.354	10.789
1957	1,689,265	119,985	8,441,257	70.353	4.997	14.077
1958	5,257,316	450,066	32,705,763	72.669	6.221	11.681
1959	1,810,738	135,489	9,506,375	70.163	5.250	13.364
1960	1,198,969	96,627	6,542,774	67.712	5.457	12.408

[1] Catch and Pack numbers from Washington State Dept. of Fisheries 1935 to 1938 and from Annual Report Int. Pac. Salmon Comm. 1939 to 1960.

[2] Average weights calculated from sampled weight averages and age compositions from 1935 to 1943 and from commercial poundage records of United States purse seine gear from 1944 to 1960.

* Years when average sockeye size and fish-per-case did not correspond.

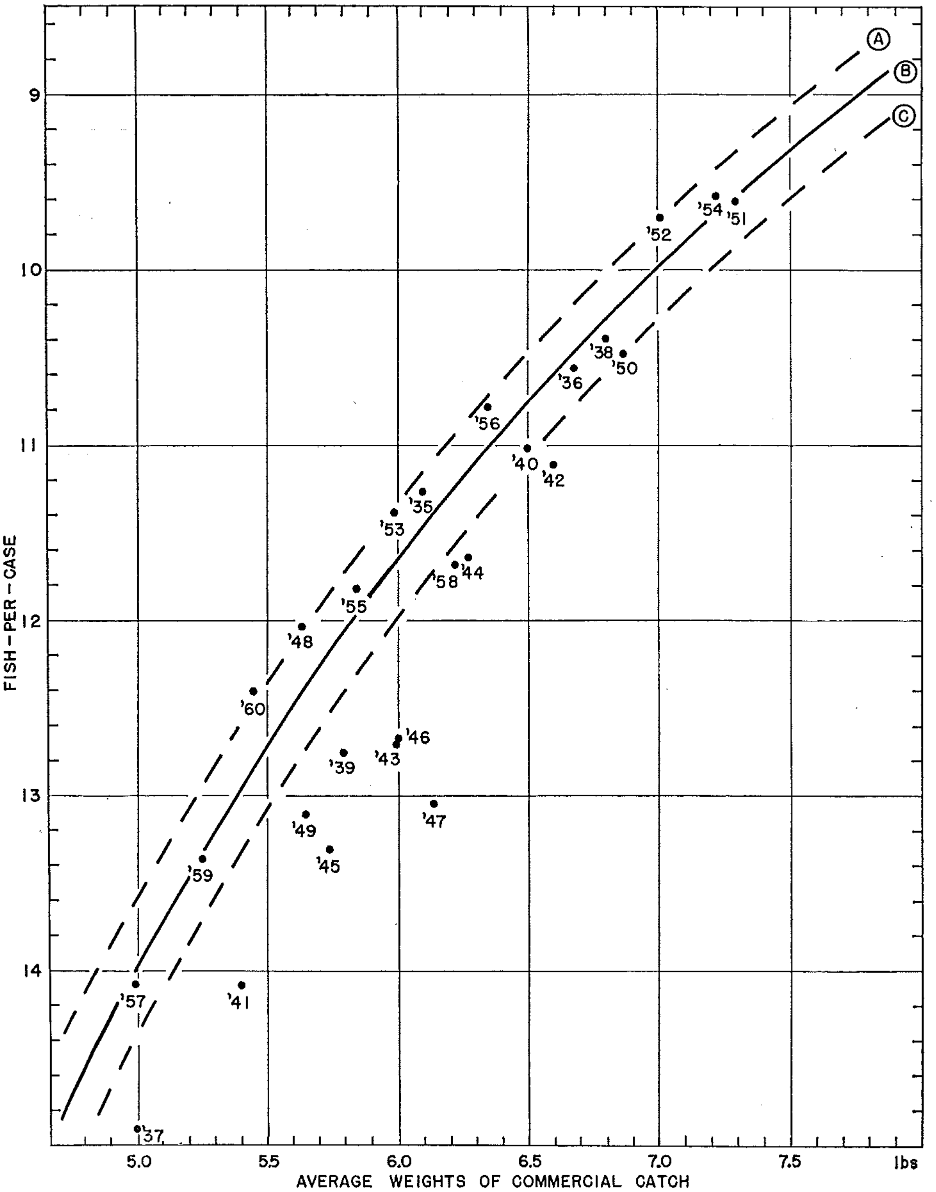

FIGURE 26—The relationship between the numbers of sockeye-per-case and the annual average sockeye weights of commercial landings. Line B is based on 70 pounds of caught sockeye to the 48 pound case while Lines A and C represent efficiency ranges of 68 and 72 pounds to the case respectively. (See text for more complete description of these lines.)

Using these data, the annual average commercial weights were plotted against the numbers of fish-per-case in FIGURE 26. Each point was identified by year. Reference or standard lines were drawn to describe the expected numbers of fish-per-case each year for different sized sockeye. Line B represents the numbers of sockeye required to produce a 48 pound pack from 70 pounds of whole or round sockeye of various sizes from 5 to 7.5 pounds. The level of 70 was determined from average canning recoveries for the recent years 1950 to 1960 when catch and pack statistics were known to be accurate and cannery operations carefully controlled. Line A represents a more efficient canning operation requiring only 68 pounds to the case and Line C a less efficient operation of 72 pounds to the case. The range of 68 to 72 could easily occur between canneries or for the same cannery in different years and would depend to a considerable degree on the relative numbers of quarter, half or one pound tins being produced.

It is interesting to note that the fish-per-case lines followed a declining curvilinear relationship rather than a straight line as the sockeye sizes progress into the larger categories. This happens because the weight increment becomes proportionately less per fish as the weights increase. For example, a 2 pound fish is twice as heavy as a 1 pound fish whereas a 3 pound fish is only one and one half times heavier than a 2 pound fish.

Having plotted the point relationships between the sockeye size and numbers of sockeye used per case and also the expected numbers of fish-per-case for normal canning efficiencies in FIGURE 26, it was immediately apparent that the years 1937, 1939, 1941 to 1947 inclusive and 1949 all fell below the range of even a poor canning operation. Such a wide divergence was ample evidence that fish-per-case records could *not* be used as a reliable measure of Fraser River sockeye sizes. For instance, a fish-per-case value of 14.08 in 1957 showed the sockeye to weigh 5 pounds; whereas, the same case value in 1941 occurred when the sockeye were 5.4 pounds. In 1947 the fish-per-case value was 13.05 and the expected size should have been 5.35 pounds whereas they actually averaged 6.15 pounds.

Efforts were made to determine why the size and fish-per-case data did not correspond more closely, especially through the period of 1941 to 1949 when the fish-per-case records indicated sockeye sizes much smaller than actually occurred. Either the catch and/or pack numbers were wrong or canning operations were notably inefficient during this period. A careful analysis of selected cannery records was made, even to the extent of tracing daily operations, and here it was discovered that as high as 82.57 pounds of sockeye were utilized to produce a 48 pound case in certain years. No complete explanation for the wide range in the annual canning efficiencies could be found but there was no good reason to believe the catch and pack statistics were seriously in error. Since the fish-per-case numbers did not accurately reflect the average weights of the commercially caught sockeye, no further attempt was made to associate fish-per-case record with the sampled 4_2 sockeye weights. This left sampling weights as the only adequate measure of Fraser River sockeye sizes between 1915 and 1943 after which commercial weights were also available.

Being satisfied that sampled weights were an accurate measure of annual sockeye sizes, as shown by their close agreement with total commercial landed weights in FIGURE 25, the next step was to examine closely the physical and biological environments to ascertain, if possible, the factor or factors responsible for the diverse annual sockeye size variations. First, the major procedures used in developing the annual size deviations shown previously in FIGURE 23 were reviewed:

(1) Since the size analysis from sampling has been confined to one age class (4_2) and to equal numbers of males and females, the weight changes were not complicated by varying numbers of small 3_2 or large 5_2 sockeye. Neither was there any possible bias caused by unbalanced proportions of large males or small females.

(2) The effects of different racial-genetic sizes (which in turn results in four different cycle averages) is minimized by using the annual weight deviations from the respective cycle averages and not from the average of all years combined.

(3) Since the annual averages were calculated from the sum of nine weekly averages of equal status, the weights of large numbers of one or more races occurring at a particular period of the fishing season did not unduly influence the weights of lesser races occurring at other times.

(4) The weight deviations calculated in the above manner provided indices of size changes that were fundamentally the result of changes in growth conditions of either the freshwater or marine environments.

The Relationship of Annual Size Variations to Time and Place

The next step was to ascertain where and when growth variations became most evident in the life cycle of the sockeye. In this regard, two major areas and time sequences were considered. These were: (1) the *freshwater* hatching and rearing phase involving an approximate period of one year and nine months from the date of egg deposition to the time of seaward migration of the young sockeye smolts; and (2) the *marine* rearing phase involving an approximate period of two years and three months from the date that the smolts entered the marine area until the four-year-old adults returned to their freshwater spawning stream.

If adult sockeye sizes were governed by growth conditions in the freshwater environment, then the size of adults should be correlated with their size as seaward smolts. To test this relationship, comparisons of smolt and adult sizes were made between races and within races for different years. Measurements of smolts and adults of the Stuart and Adams River races were examined. Early Stuart adult sockeye were the smallest in the Fraser watershed, averaging 5.6 pounds; yet, the yearling smolts of this race were among the largest, having an average length of 100 millimeters and a high first year scale circuli count of 18. (Clutter and Whitesel, 1956, showed a highly significant correlation between scale circuli counts and smolt size.) In contrast to the Stuart race, the Adams adult sockeye were the largest of the Fraser sockeye, weighing 6.7 pounds; yet, the smolts of this race were only 85.4 millimeters in length and the scales averaged 14.1 circuli. Thus the Adams sockeye, commencing their marine life as one of the smallest migrants, returned as adults one pound heavier than the Early Stuart adults even though the smolts of Stuart were much larger than those of Adams upon entry into their marine phase.

Comparative data between the smolt and adult sizes of the Chilko and Adams races in different years were also investigated (TABLE 27). Adult sizes were measured by their standard length from the snout to the end of the vertebral column, while the smolt sizes (of the same adults) were measured by the numbers of circuli on the scales during the first year of freshwater growth.

TABLE 27—The relationship between smolt and adult sockeye sizes for the Chilko and Adams River runs, 1950 to 1957.

	YEAR	SMOLT CIRCULI COUNT	ADULT STANDARD LENGTH (cm.)
CHILKO	1950	11.8	57.0
	1951	13.0	57.0
	1952	11.8	57.2
	1953	12.5	56.5
	1954	14.0	55.1
	1955	13.3	54.0
	1956	13.1	54.8
	1957	11.6	51.9
Average		12.6	55.4
ADAMS	1950	11.1	57.6
	1951	12.1	59.8
	1952	17.1	—
	1953	15.5	59.0
	1954	11.0	58.7
	1955	13.7	55.4
	1956	14.9	56.3
	1957	17.7	56.7
Average		14.1	57.6

The lengths of the Chilko adults (4_2) showed considerable size range from a minimum of 51.9 to a maximum of 57.2 centimeters while only slight variation occurred in the smolt sizes as indicated by the limited range in scale circuli counts from 11.6 to 14.0. By contrast, Adams adults showed less range in adult sizes (55.4 to 59.8 cms.) while smolt sizes varied extensively from 11.0 to 17.7 circuli. In neither case was there a significant correlation between the smolt and subsequent adult size variations. The r values were —.0360 for Chilko and —.3817 for Adams denoting an inverse relationship even though statistical significance was not reached. On this basis it was concluded that adult sockeye sizes were not predetermined by sizes attained in the freshwater environment.

Circumstantial evidence indicating a marine origin of size variations was provided by comparisons of weekly and annual average weights of sockeye as shown in Appendix Table B. For instance, if the annual average weight denoted extra large sockeye for a particular year, the large size was apparent for early, central and late migrating sockeye even though different races were involved. The only time and place that such a size control could act uniformly on all races was during the sockeye's two and one-quarter years of ocean residence; therefore, fluctuations in the marine environment were considered primarily responsible for annual sockeye size variations. This was most logical since it was earlier demonstrated that 99 per cent of the sockeye's growth is attained in the marine area.

It was also reasonable to believe that most of the size variations occurred in the final year of growth, since in many cases the patterns of *annual* size changes appeared to be independent of each other. For instance, the sockeye of 1947 increased by .524 pounds; whereas, in the year 1948 the size declined by .700 pounds. What occurred in one year did not necessarily indicate what would happen

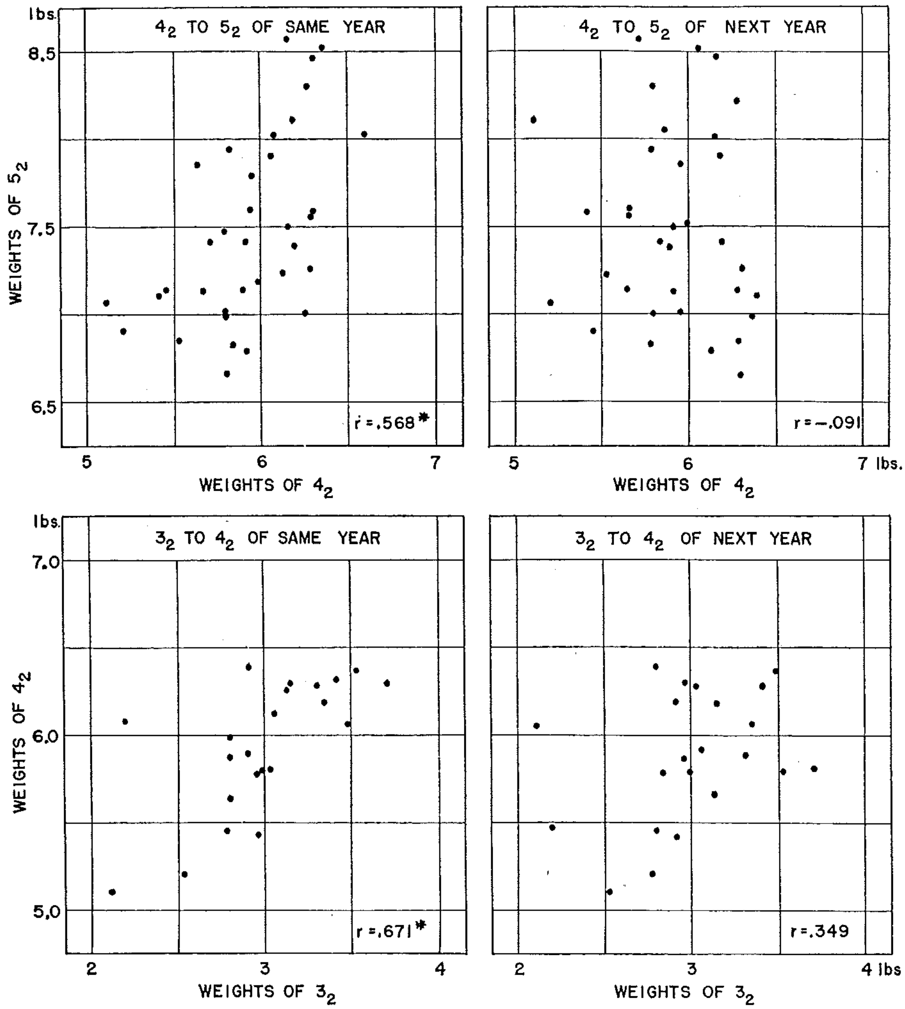

FIGURE 27—The relationship of the weights of 3_2's to 4_2 sockeye of the same year and 4_2 sockeye of the following year; and likewise, the weights of 4_2's to 5_2 sockeye of the same and the following years.

in the following year, despite the fact that the marine periods of residence of adjacent annual populations overlapped; the 1947 sockeye being present in the ocean as four-year-old fish at the same time as the 1948 sockeye were present as three-year-old fish yet the final fourth year adult sizes of each were exactly opposite in the amount of growth attained. Thus, it seemed apparent that variations in growth occurring in the fourth year mostly governed the final adult sizes and that these were relatively independent of the sizes reached at three years of age.

The contention that sockeye size variations are mostly established in the final year of maturity was further evidenced by the simultaneous weight changes of 3_2, 4_2 and 5_2 sockeye in the same year, as shown in FIGURE 27. Here it was found that weights of 3_2 and 4_2 sockeye of the same year were significantly correlated ($r = .617$); but 3_2 sockeye related to 4_2's of the following year had a non-significant correlation ($r = .349$). Likewise, 4_2 and 5_2 sockeye of the same year corresponded in their weights ($r = .568$) while 4_2's related to 5_2's of the next year were not significantly related ($r = -.091$). The similarity of annual size variations of different aged sockeye occurred despite the fact that they arose from different brood stocks. Conversely, sockeye arising from the same brood stocks but maturing in different years were dissimilar in their size attributes. These relationships for Fraser River sockeye concur with Godfrey's (1958) observations on year-to-year changes in average weights of Skeena and Rivers Inlet sockeye. Thus, for three separate river systems in British Columbia, it has been concluded that the final size of sockeye salmon at the time of maturity was determined mainly by the environmental conditions during the last year of ocean residence, not by the environmental conditions during early freshwater life and/or the early ocean phase.

Consideration of Various Factors in Relation to the Annual Size Variations

It seemed reasonable that the fluctuations in annual sockeye sizes could be significantly correlated with certain environmental factors. The following features were examined:

1. The effect on size of population abundance.
2. The effect on size of ocean water temperatures.

THE EFFECT ON SIZE OF POPULATION ABUNDANCE

Various studies of population dynamics have indicated that when the numbers of fish become large the size of the individuals becomes small. Foerster (1944) recorded this type of relationship for sockeye smolts at Cultus Lake. Birman (1951), working on the Amur River in Russia, concluded that an increase in the abundance of fall chum salmon *(Oncorhynchus keta)* caused a deceleration of growth and a later age of maturation of the stocks while, with a decreased abundance, these characteristics were reversed. Changes in growth were believed to be controlled by the numerical abundance and the "tightness" of the food situation on the marine foraging grounds.

Davidson and Vaughan (1941) examined the size, numbers and dates of migration of pink salmon in Southeastern Alaska through a period of 46 years from 1895 to 1940 and concluded that when the populations were large in numbers the individuals composing them were usually small and the majority of the fish migrated to the streams late in the season. On the other hand, when the populations were small in numbers the individuals composing them were usually large and the majority of the fish migrated to the streams early in the season. These authors attributed the variations in growth to variable competition among the individual salmon for food in the ocean as their numbers increased or decreased. At the same time they recognized that the annual abundance of food organisms in the ocean could vary as an independent factor such that the relationship between size, numbers and time of the spawning migration of pink salmon in Alaska was a general one applying only on a long term average basis. Yearly deviations could occur as complete exceptions to the general relationship.

With size data and numbers of Fraser River sockeye now available, their possible inter-relationships may be examined. Total commercial catches and annual average weights of four-year-old sockeye from 1915 to 1960 were listed by separate cycle in TABLE 28. These data showed that the cycle having the greatest abundance also had the largest sockeye: the annual average catch of the 1918-58 cycle was two to three times as great as the other three cycles and the weight 6.39 pounds compared with 5.63, 5.92 and 6.08 pounds. This information taken alone contradicts the suggestion that larger populations would result in smaller sized individual sockeye. However, such a conclusion is not entirely valid since, as was demonstrated earlier, the dominant races involved in the 1918-58 cycle are inherently larger than those of the other three cycles irrespective of population densities. Thus, it was necessary to consider the average weights and abundances of sockeye separately for each of the four cycle groups. By so doing, it was assumed that the racial composition of each cycle was reasonably proportional from one generation to the next.

To measure the possible relationship between the numbers and size of sockeye within cycle groups, correlation coefficients were calculated and the pertinent features of each group briefly described. In the 1915-59 cycle, the catches ranged from a minimum of 443,255 in 1947 to a maximum of 3,392,621 in 1959 and weights ranged from 5.12 pounds in 1959 to 7.21 in 1951. The largest sockeye occurred in the year of the second greatest catch. In other years of this cycle, the weights showed no relationship to increased numbers except that the smallest sockeye coincided with the largest catch of 1959. The absence of any definite relationship for this cycle is shown by the low correlation coefficient of $r = -.054$. In the 1916-60 cycle there was a tendency for the fish to be larger in the years of greatest catch but the relationship was not significant ($r = .004$). The sockeye of the 1917-57 cycle were consistently small even though the commercial catch ranged from 1,686,241 to 6,883,401. Here again no significant correlation was evident with the $r = -.020$. Sockeye of the 1918-58 cycle were usually large irrespective of ten-fold differences in numerical abundance. In 1958 it was possible that the very large Fraser run of approximately 19,000,000 sockeye (including non-Convention waters) may have contributed to the small sockeye size in that year (5.93 pounds); however,

TABLE 28—The annual average weights of four-year-old sockeye related to their abundance as represented by the Convention waters commercial catches recorded separately for each cycle for the period 1915 to 1960.

1915 - 1959 CYCLE		
Year	Weights (4_2)	Commercial Catch
1915	5.91	1,825,463
1919	5.59	1,248,868
1923	6.22	856,953
1927	6.08	1,783,487
1931	5.98	1,433,639
1935	5.79	1,441,010
1939	5.72	1,124,176
1943	5.64	591,088
1947	6.16	443,255
1951	7.21	2,424,957
1955	5.64	2,114,691
1959	5.12	3,392,621
Average	5.92 lbs.	1,556,680

1916 - 1960 CYCLE		
Year	Weights (4_2)	Commercial Catch
1916	5.86	1,286,316
1920	(6.02)	1,209,729
1924	(5.60)	1,214,306
1928	6.38	941,683
1932	6.45	1,587,141
1936	6.47	2,579,099
1940	6.35	1,687,091
1944	6.23	1,439,269
1948	5.53	1,841,782
1952	6.80	2,267,858
1956	6.02	1,801,708
1960	5.19	2,454,164
Average	6.08 lbs.	1,692,512

1917 - 1957 CYCLE		
Year	Weights (4_2)	Commercial Catch
1917	5.47	6,883,401
1921	5.89	1,686,241
1925	5.76	1,828,716
1929	5.92	2,059,178
1933	5.43	2,450,436
1937	5.05	1,973,008
1941	5.53	3,675,277
1945	5.71	1,675,908
1949	5.85	2,077,591
1953	6.08	4,024,780
1957	5.27	3,050,025
Average	5.63 lbs.	2,853,419

1918 - 1958 CYCLE		
Year	Weights (4_2)	Commercial Catch
1918	6.30	811,369
1922	(6.05)	1,093,992
1926	6.31	1,382,466
1930	6.57	4,588,032
1934	6.19	5,020,358
1938	6.69	3,308,581
1942	6.58	7,982,791
1946	5.86	7,791,504
1950	6.96	2,115,362
1954	6.84	9,528,721
1958	5.93	10,498,933
Average	6.39 lbs.	4,920,191

other years of relatively large catches such as 9,528,721 sockeye in 1954 did not show a sockeye size decline; instead, the 1954 sockeye at 6.84 pounds were the second heaviest in this cycle since 1918. Within the various populations of the 1918-58 cycle there was a complete lack of correlation between numbers and the size of sockeye as shown by an r value of —.087. Considering all of the cycles, it was concluded that variations in sockeye sizes were not governed by greater or lesser numbers in the annual populations. This does not preclude the possibility that adult sockeye sizes might become restricted if their numbers greatly exceed the population levels considered in this report.

THE EFFECT ON SIZE OF OCEAN WATER TEMPERATURES

Since it has already been demonstrated that size variations of Fraser River sockeye are mainly governed by environmental conditions within the ocean habitat, a search was made for long term oceanographic data which might be correlated with the sockeye size variations. The first step in this regard was to determine the most likely location of the Fraser sockeye rearing areas within the Pacific Ocean.

According to Davidson and Hutchinson (1938), the distribution of all species of salmon in the Pacific Ocean appears to be governed by ocean currents and associated temperatures and salinities (Figure 28). The northern distribution is bounded by the mean 5°C (41°F) isotherm and a mean surface salinity not less than 30 parts per thousand. However, these authors point out that salmon migrating to and from streams tributary to the Arctic Ocean must at times be subjected to surface temperatures only a few degrees above freezing. The southern distribution of salmon along the North American continent falls well within the region bounded by the mean 8°C (46.4°F) subsurface isotherm and salinities of 33 and 34 parts per thousand, although surface salinities may be as high as 35 parts per thousand.

Tully and Dodimead (1956) examined data collected by twelve oceanographic agencies during a synoptic survey of the northern Pacific Ocean and from the overall picture they were able to speculate on what might be classed as "Pacific Salmon Waters". The principal oceanographic features were such that two distinct regions of the Pacific Ocean could be distinguished. One was a sub-Tropic region south of latitude 38°N where the surface waters were of relatively high temperature and high salinity in all seasons. No salmon are known to frequent the waters of this southern region. The second region was identified as the sub-Arctic area north of latitude 48°N, extending into the Gulf of Alaska and along the Aleutian Islands. Here the waters are of relatively low temperature and low salinity and the surface waters are warmed in summer and cooled in winter. It is in these northern waters above latitude 48° that salmon are known to occur and this has been substantiated by exploratory fishing by United States, Canadian and Japanese government agencies. In what *part* of the northern salmon-type waters Fraser River sockeye take residence is the present matter of concern.

Concurrent with the writing of this report, an extensive program of research is being conducted in the northeast Pacific Ocean to define the marine distribution of Asian and North American salmon stocks in accordance with the terms of

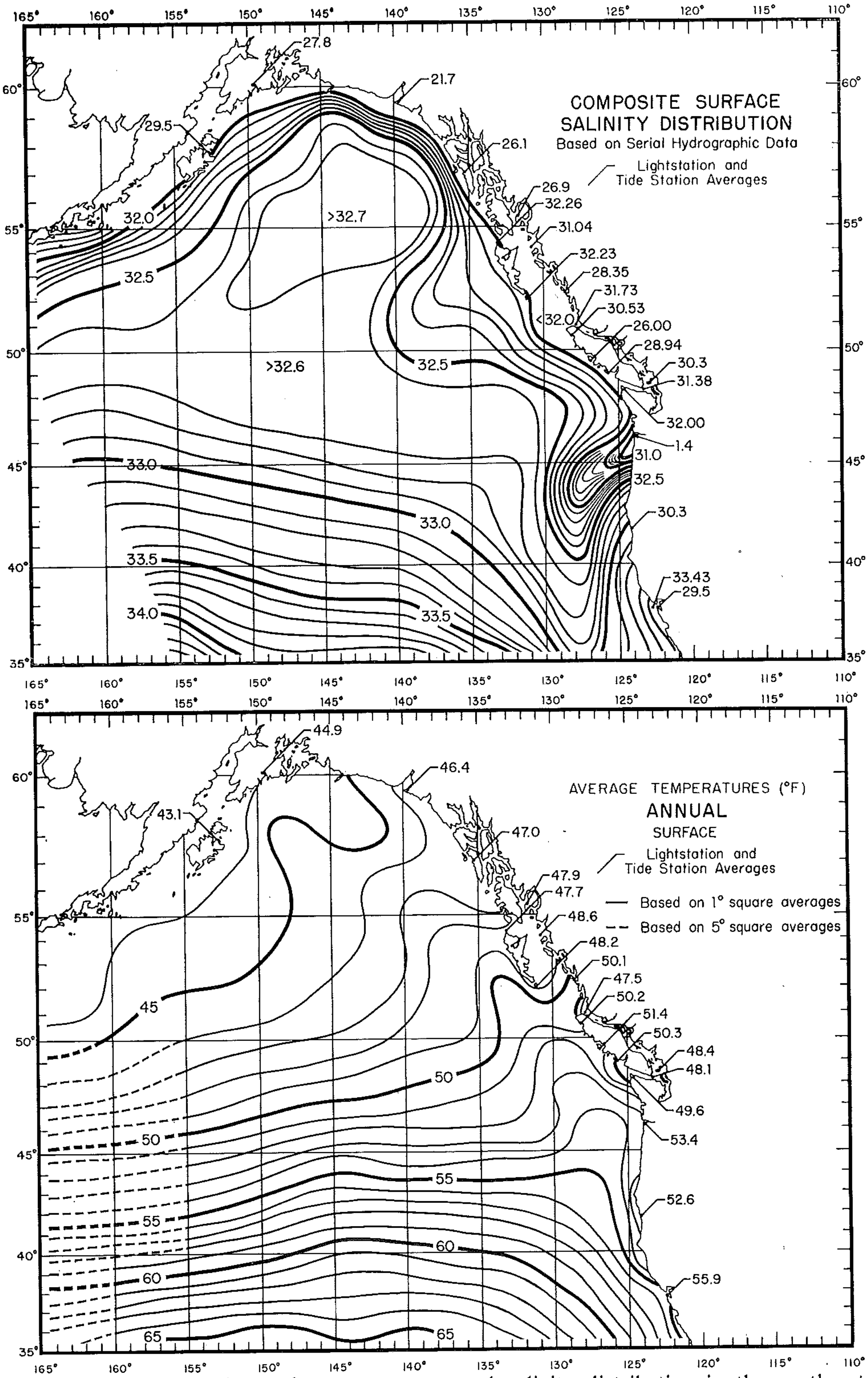

FIGURE 28—Composite surface temperature and salinity distribution in the northeast Pacific Ocean. (Figures reproduced by permission from Robinson (1957).

reference of the International North Pacific Fisheries Commission. As yet, the location of Fraser River sockeye has not been fully established. The most pertinent questions here would seem to be how far north do the Fraser sockeye range and are they randomly distributed among other sockeye populations, such as those to Rivers Inlet, Skeena and the Nass of northern British Columbia? A comparison of the annual size fluctuations of the Fraser and these northern sockeye runs could well provide tentative evidence in this regard. Presumably, the sockeye of the northern rivers are reared in or adjacent to the Gulf of Alaska and, if Fraser River sockeye were also reared in these same waters, they should exhibit similar size fluctuations. If the Fraser sockeye do not vary in size consistent with the northern sockeye, it would seem reasonable to conclude that they are reared in a separate and more southerly oceanographic environment. Weight data by separate age and sex annually from 1915 to 1956 for the three northern runs were obtained from the annual reports of the Provincial Fisheries Department (Foskett and Jenkinson, 1957) while those for the Fraser sockeye are recorded in this present analysis. Four-year sockeye (4_2) represent a substantial portion of the age groups of each area and these were used as a basis for correlating size fluctuations. The annual sockeye weights for each river system are presented in TABLE 29.

Obvious differences in the average sockeye weights for each area were found: Fraser sockeye averaged 6.08 pounds, Rivers Inlet 4.71, Skeena 5.10 and Nass 5.63. While these differences might indicate separate ocean rearing environments for each of the runs, comparisons of races within the Fraser River system have shown inherent differences and therefore the differences in the average sizes of the four separate populations could result for the same reason. Timing of the various runs could also contribute to the different average sizes since there is a tendency for early runs to the Fraser to be smaller than later runs. Rivers Inlet sockeye at 4.71 pounds are the smallest of the four runs and these sockeye are caught in late June and all of July. Skeena sockeye, averaging 5.10 pounds, provide moderate catches in June, a relatively large catch in July and substantial catches to mid-August. Nass sockeye, at 5.63 pounds, provide practically no June fishery, nearly a total catch in July and a small catch in August. Fraser sockeye, averaging 6.08 pounds, are the latest of the four runs having practically no June fishery, only light catches up to late July, large catches from late July through August and highly variable catches during the month of September.

The fact that Fraser, Rivers Inlet, Skeena and Nass sockeye were quite different in average size was not adequate proof of their being reared in different regions of the Pacific for the reasons just given; however, if it could be established that they were each significantly different in their *size fluctuations* above and below average then it would be reasonable to assign them into separate ocean rearing areas. This line of reasoning was pursued by examining correlations of the annual weight deviations from the respective four-year cycle means of each of the four watersheds as shown in TABLE 30 and FIGURE 29. The correlation values of these relationships may be subject to minor correction because the weight samples from the three northern areas were mostly obtained from gill net catches and changes in mesh sizes through the 42 years could have contributed somewhat to annual size fluctuations and apparent size declines. Godfrey (1958) recognized that the age

TABLE 29—Average annual weights of Fraser, Rivers Inlet, Skeena and Nass sockeye — four-years-old (4_2) and 50:50 sex ratio.

YEAR	FRASER	RIVERS INLET	SKEENA	NASS
1915	5.91	5.20	5.55	5.40
1916	5.86	5.25	5.25	5.65
1917	5.47	4.95	5.25	5.30
1918	6.30	5.00	5.55	6.05
1919	5.59	4.85	5.80	5.75
1920	—	—	5.35	5.40
1921	5.89	5.05	5.40	5.70
1922	—	5.95	5.25	5.65
1923	6.22	4.90	5.10	5.50
1924	—	4.85	5.30	5.65
1925	5.76	4.50	4.90	5.65
1926	6.31	5.20	5.20	5.70
1927	6.08	5.55	5.25	6.00
1928	6.38	4.90	4.80	5.30
1929	5.92	4.90	4.80	5.45
1930	6.57	4.85	5.25	5.55
1931	5.98	4.55	5.25	5.75
1932	6.45	4.70	5.15	5.95
1933	5.43	4.70	4.80	5.80
1934	6.19	4.75	5.35	6.30
1935	5.79	4.40	5.00	5.65
1936	6.47	4.50	5.40	6.20
1937	5.05	4.50	4.75	5.35
1938	6.69	4.60	4.90	5.85
1939	5.72	4.30	4.80	5.15
1940	6.35	4.60	5.25	6.45
1941	5.53	4.15	4.95	5.85
1942	6.58	4.85	4.90	5.45
1943	5.64	4.25	4.65	4.95
1944	6.23	4.50	4.85	5.35
1945	5.71	4.35	5.05	5.50
1946	5.86	3.90	4.45	5.25
1947	6.16	4.00	4.80	5.55
1948	5.53	4.65	5.20	5.55
1949	5.85	4.35	4.85	5.50
1950	6.96	4.05	4.55	5.55
1951	7.21	5.10	5.05	5.60
1952	6.80	4.80	5.30	5.60
1953	6.08	4.70	5.65	5.80
1954	6.84	5.00	4.90	5.95
1955	5.64	4.35	4.85	5.25
1956	6.02	4.70	5.65	5.40
All years	6.08 pounds	4.71 pounds	5.10 pounds	5.63 pounds

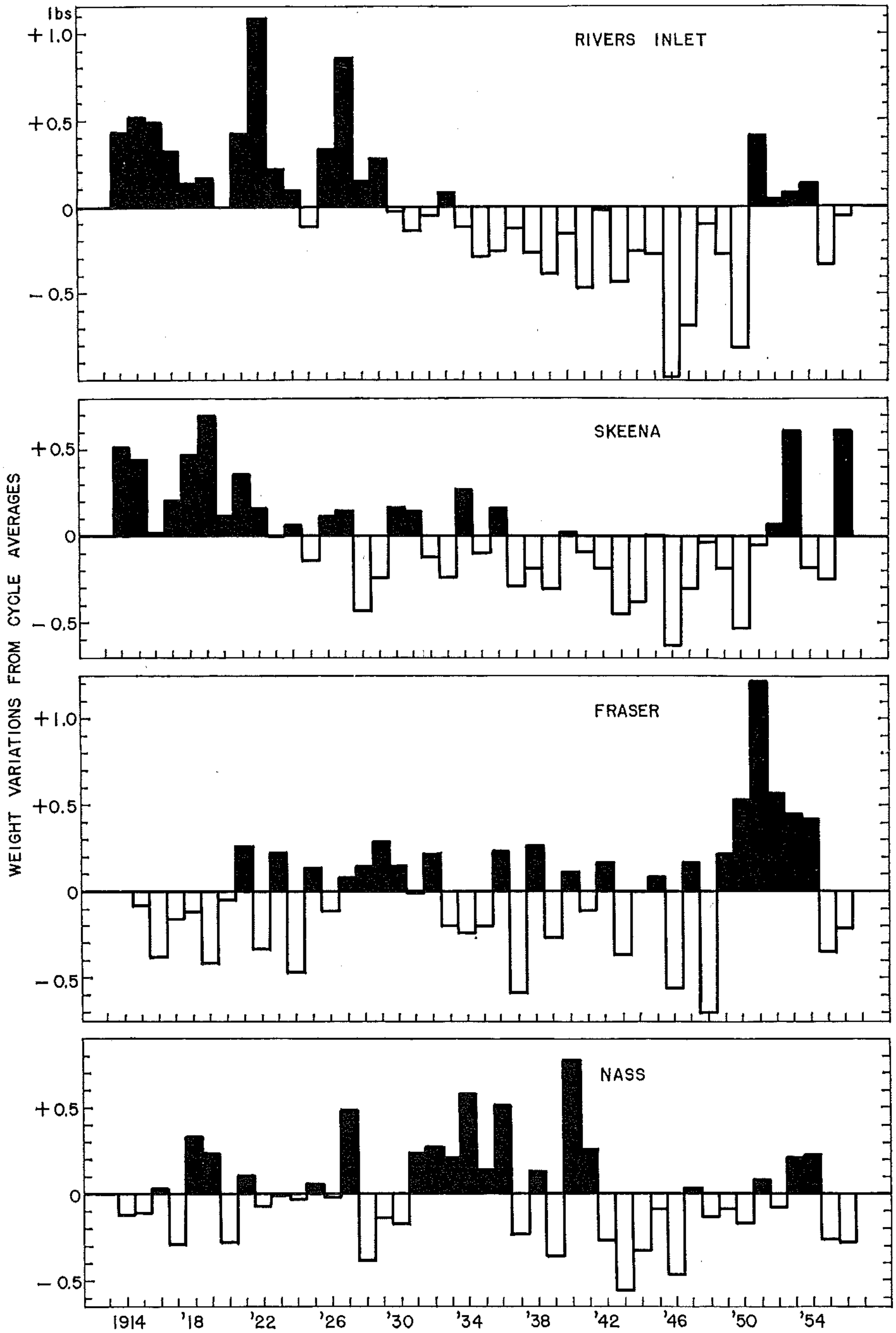

FIGURE 29—A comparison of the annual weight variations from cycle averages of 4_2 sockeye — Nass, Fraser, Skeena and Rivers Inlet.

TABLE 30—Correlation between the annual weight fluctuations of Fraser, Rivers Inlet, Skeena and Nass sockeye of age 4_2 through thirty-nine years, 1915 and 1956.

SOCKEYE POPULATIONS	NUMBER OF YEARS	r VALUES	5% LEVEL	SIGNIFICANT	1% LEVEL	SIGNIFICANT
Fraser - Rivers Inlet	39	.192	.317	No	.408	No
Fraser - Skeena	39	.026	.317	No	.408	No
Fraser - Nass	39	.232	.317	No	.408	No
Rivers Inlet - Skeena	39	.567	.317	Yes	.408	Yes
Rivers Inlet - Nass	39	.261	.317	No	.408	No
Skeena - Nass	39	.487	.317	Yes	.408	Yes

and sex composition of the gill net samplings could be biased by disproportionate selection of certain sizes, yet he suggested that the effect was not great enough to mask obvious trends in the data. *No significant correlations were found between the size fluctuations of Fraser sockeye and those of Rivers Inlet, Skeena and Nass Rivers. This strongly suggested that Fraser River sockeye were not reared in the same ocean environment as the northern runs and that presumably the Fraser sockeye would be located in a more southerly zone.*

Therefore, in view of the differences in the temperature and salinity properties of sub-Tropic and sub-Arctic waters, the southern migrational boundary for Fraser River sockeye in the Pacific Ocean is proposed as being 48°N and because of their independent size variance from northern British Columbia sockeye populations, the northern boundary is estimated to be about 55°N. With this general area in mind, a search was made for long term physical or chemical records measuring changes in the annual ocean environment that might be related to the annual sockeye size variations.

Surface water temperatures were available since 1943 (data incomplete in some years) at Station "Papa" (50°N, 145°W), whose location provided the longest series of information for the region believed to be most closely associated with the ocean rearing zone of the Fraser sockeye. Through the courtesy of G. Brooke, of the Meteorological Division of the Department of Transport in Vancouver, the International Pacific Salmon Fisheries Commission has received a complete series of surface water temperature of the Pacific Ocean at Station "Papa" since 1950. Earlier records back to 1943 were obtained from the Toronto headquarters of this same agency. In all, 21,900 readings were analysed. For each day, a mean temperature was calculated from four readings taken at 6 hour intervals. The monthly means, illustrating the relative annual temperature conditions are given in TABLE 31. Instead of calendar years, 12 monthly periods were arranged from August of one year to July of the next to correspond with the yearly growth period of the sockeye salmon.

TABLE 31—Monthly mean surface water temperatures of the Pacific Ocean at the weathership "Papa" (50°N, 145°W).

BEGINNING OF 4th YEAR	MONTHLY MEANS												END OF 4th YEAR	12 MONTH MEAN
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July		
1943	56.0*	55.7*	51.6*	45.9	44.7	42.3	42.3	42.1	42.0	44.1*	49.2	54.0*	1944	47.49
1944	58.5	56.5	52.0*	47.3	44.9	43.5	42.8	43.0	43.6	45.3	47.7	51.9	1945	48.08
1945	56.8	57.8	54.7	49.4	45.3	43.9	42.0	42.0	44.0*	45.0*	48.0*	53.6*	1946	48.54
1946	57.5*	58.0	52.8	51.8	47.8	46.2	45.9	42.6	42.9	44.8	47.2*	52.0*	1947	49.13
1947	—	—	—	—	—	—	—	—	—	—	—	—	1948	—
1948	56.0*	55.7*	49.3	46.5	43.8	42.1	42.2	42.4	43.2	45.1	49.1	54.7	1949	47.51
1949	55.4	56.2	51.5	48.2	45.3	43.1	41.2	41.4	40.9	41.8	45.3	48.9	1950	46.60
1950	52.8	52.1	50.0	45.8	43.8	41.8	41.2	42.0	40.9	43.1	47.3	53.2	1951	46.17
1951	56.7	57.6	53.5	47.8	44.2	41.9	40.2	40.1	39.8	41.9	44.1	49.9	1952	46.48
1952	56.7	54.0	53.3	48.6	44.1	41.4	40.1	39.8	40.7	42.4	46.1	51.6	1953	46.62
1953	57.2	55.7	49.5	46.3	43.9	43.4	41.7	41.2	42.3	44.1	46.6	51.6	1954	46.96
1954	58.3	58.2	53.2	48.4	44.9	43.3	42.1	42.6	41.6	43.3	45.3	49.8	1955	47.58
1955	52.9	52.8	48.1	46.4	44.2	41.8	42.3	40.5	41.0	44.1	46.1	51.9	1956	46.01
1956	56.7	55.9	49.7	45.3	44.2	43.1	42.7	42.8	43.8	45.9	49.3	52.5	1957	47.66
1957	56.4	57.1	55.6	51.5	47.4	44.5	43.4	43.5	43.4	45.8	49.5	55.2	1958	49.44
1958	55.1	54.2	51.5	46.2	44.0	42.8	41.8	43.5	42.6	45.3	49.1	52.0	1959	47.34
1959	54.2	54.5	53.8	50.9	46.8	44.2	42.9	42.4	42.1	43.8	46.4	50.8	1960	47.73
Monthly Means 1944 - 1959	56.1	55.8	51.9	47.9	45.0	43.1	42.2	42.0	42.2	44.1	47.3	52.1		47.48
1855 - 1935*	56.3	54.8	51.5	47.2	45.0	42.2	42.2	42.2	42.8	43.5	48.6	53.5		47.48

* Interpolated values.

Averages of the monthly means for the period 1943 to 1960 were compared with long term means derived by H. J. Hollister (1956) for the period of 1935-1955. These latter data were obtained from interpolations between the isotherms drawn on the surface temperature charts in United States Navy Hydrographic Office special publication No. 570 (1947). Averages of monthly temperatures for the period 1943 to 1960 were found to be identical to those of 1855 to 1935; this is 47.48°F. Thus, the records of the past 17 years provided an adequate average of surface water temperatures for the Pacific Ocean in the vicinity of the weathership "Papa" (50°N, 145°W).

Having postulated the most probable ocean rearing area for Fraser sockeye and having obtained a series of surface water temperatures from this general zone, it was then feasible to examine the relationship of these temperatures to recorded annual sockeye size variations. The first test was to correlate sizes with the 12 month temperature average for the maturing year as shown in FIGURE 30. The "r" value of —.5334 in this case was significant at the 95 per cent level but not at the 99 per cent. Were it not for the three years of marked exception (1947, 1956 and 1958), the relationship would have been highly significant. A second correlation was made with Station "Papa" temperatures using only the late spring months of May, June and July of the final ocean year when rapid gains in growth might be most expected. The "r" value of —.4087 in this test was less than that reached using the 12 month period.

Annual size fluctuations of Fraser sockeye also were correlated with surface water temperatures recorded at lighthouses along the British Columbia coastline (Anonymous, 1938 to 1958). Annual average temperatures from July 1 to June 30 of the maturing year of 4_2 sockeye were obtained from the combined records of Kains Island, Amphitrite Point, Cape St. James and Langara for the years 1935 to 1957. The correlation of these temperatures with the annual weight deviations was —.178. The relationship, although not statistically significant, was again inverse, indicating that whatever association there may be between sockeye size and ocean water temperatures (offshore or inshore), the sockeye tend to return as smaller than average adults in years of warmer water temperatures and larger than average in years of colder temperatures.

This inverse relationship between ocean temperatures at station "Papa" and sockeye size appeared contrary to the common belief that salmon reared in warmer water would grow more rapidly than those reared in colder waters. The explanation could be that the sockeye do not remain in the area of "Papa" when the temperatures are warm; instead, they seek a cold temperature which would place them in waters farther to the north. Thus, when the warm component of the North Pacific drift is dominant, the sockeye would be distributed to the northward where conditions for growth may not be of the best. Conversely, when the cold component of the drift is dominant, the sockeye would occupy more southern latitudes where conditions for growth apparently are more favorable. That temperature may greatly affect the geographic location and migratory behavior of sockeye is documented by conditions prevailing in 1958. Royal and Tully (1960) observed that ocean temperatures in 1958 were exceptionally high in much of the eastern portion of the

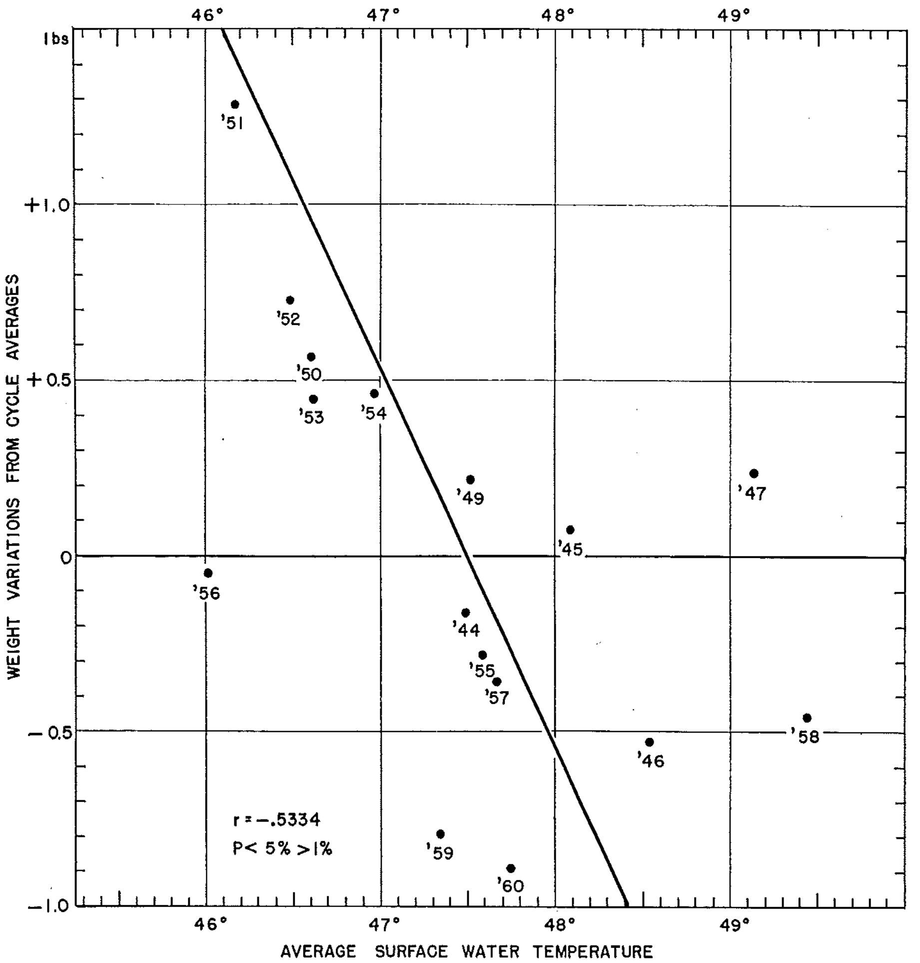

FIGURE 30—The relationship between the surface water temperatures of the Pacific Ocean at Station "Papa" (50°N, 145°W) and the annual sockeye weight variations. The water temperatures are an average of a period of 12 months prior to maturity; i.e. August to July of the fourth year of growth.

North Pacific because of a pronounced warm water intrusion from the sub-tropic region and that Fraser River sockeye were distributed farther northwestward than usual. Subsequently, a substantial portion of the Fraser River run migrated through Johnstone Strait rather than along the west coast of Vancouver Island to Juan de Fuca Strait. This phenomenon led to a careful scrutiny of the temperature distribution data and to the conclusion that Fraser River sockeye were not only distributed far northwestward but they were one-half pound smaller in average size and ten days late in their spawning migration.

Based on the above information, it was generally indicated that in years of low temperatures in the region of station "Papa", sockeye will be of large size and migrate early; in years of average temperatures, they will be of average size and migrate at what might be termed the "normal" time; and in years of higher temperatures they will be of small size and migrate late. However, in the present state of knowledge it is impossible to make a complete assessment of changes in the growth rates of sockeye in relation to variations in temperature. Salinities, currents, food supply, competition and any number of other factors also influence the rates of ocean growth to varying and possibly conflicting degrees.

The Effect of Size Selection by Commercial Fishing Gear

One of the principal objectives of this investigation was to determine whether selective action of the commercial fishing gear had created permanent changes in the sizes of Fraser River sockeye. In this regard, it was first necessary to establish that selective action had taken place within the fishery and which gear or gears were responsible. The gears employed to catch sockeye salmon consist of four types: purse seines, traps, reef nets and gill nets. The seines, traps and reef nets, made with heavy web and small mesh-openings, were considered non-selective for sockeye size except for some loss of the small 3_2 age. The only commercial gear believed to be selective was the gill net.

Peterson's extensive study (1954) of the size of gill net meshes and the size of sockeye caught in the Lower Fraser River showed an approximately straight-line relationship between mesh size and the fish's length; that is, small meshes caught mainly small fish and large meshes took predominantly large fish. As an example, it was indicated in 1946 that selectivity occurred when the gill net meshes were too large for maximum efficiency and mostly large sockeye were caught and any escapement through the gill nets was composed mainly of the smaller fish. The sockeye in 1946 were the smallest recorded in this cycle since 1918 and the gill net fishermen were unfortunate in using nets of too large mesh which allowed more of the smaller fish to escape. Selectivity for larger sockeye by gill nets also was clearly demonstrated for the Chilko run of 1948. In that year, the average weights of purse seine catches at Point Roberts were 5.61 and 5.52 pounds during the peak of the Chilko run in the fishing periods August 1-6 and August 8-12; while average weights from Fraser River gill nets were noticeably larger at 5.83 and 5.76 pounds. As a result, the sockeye escaping to Chilko averaged only 5.24 pounds after passing through the Fraser River gill net fishery.

Apart from the above specific examples of size selectivity, it was possible to measure the gross effect of net selectivity by comparing the average weights of all sockeye taken by purse seines and gill nets in both the United States and Canadian fisheries. This was done for the years 1951 to 1960 when the statistics of catch and poundages were accurately recorded. TABLE 32 shows the annual average weights for the two types of gear first in the Canadian San Juan Area 20, then in the United States San Juan Island area and finally in the Fraser River gill net fisheries below and above Pattullo Bridge at New Westminster, B. C. It is recognized that the derived weight averages are not always exactly comparable since the two types of gear may have fished disproportionately on different parts of the annual runs; however, in general the size differences adequately describe the average direction and degree of selectivity.

TABLE 32—Comparisons of the average weights of all commercially caught sockeye by purse seines and gill nets in the Canadian San Juan Area 20, United States San Juan Island and Fraser River fishing areas, 1951 to 1960.

YEAR	AREAS					
	Canadian San Juan Area 20		United States San Juan Island Area		Fraser River Below Bridge	Fraser River Above Bridge
	Gill Nets	Purse Seines	Gill Nets	Purse Seines	Gill Nets	Gill Nets
1951	7.48	7.49	7.08	7.30	7.29	7.21
1952	6.76	7.17	7.12	7.07	7.09	6.94
1953*	6.27	5.69	6.57	6.00	6.27	6.29
1954	7.21	7.26	7.10	7.22	7.26	6.60
1955	6.35	5.89	6.41	5.85	5.99	5.85
1956	6.24	6.48	6.60	6.35	6.42	6.35
1957*	5.65	4.67	5.91	5.00	5.25	5.30
1958	6.38	6.14	6.32	6.22	6.21	5.76
1959	5.65	5.31	5.82	5.25	5.45	5.15
1960	5.72	5.43	5.87	5.46	5.42	5.34
8 Year Average*	6.47	6.40	6.54	6.34	6.39	6.15 pounds

* 1953 and 1957 were omitted from the combined average because large numbers of small 3_2 jacks in these years were almost totally missed by the gill net gears.

Considering first the 8 year averages (1953, 1957 omitted), it was believed that a 6.40 pound average for the Canadian Area 20 purse seines was closest to the true unselected sockeye size. Following further along the migration path, the United States San Juan Island gill nets captured above average sockeye of 6.54 pounds while the United States purse seine average dropped to 6.34 pounds, apparently because both the Canadian and United States "outside" gill nets have taken an increasing percentage of the sockeye catch in recent years. Thus, even before the sockeye had reached the Fraser River, selection by gill nets had reduced the weight average from 6.40 to 6.34 pounds. The next major fishery was the Below Bridge gill nets which again took more of the larger sockeye for an average of 6.39 pounds, leaving the Above Bridge gill nets even smaller sockeye to capture such that their average was down to 6.15 pounds. No measures of the final escapement weights were available but it could be concluded that sockeye escaping to the spawning grounds would average less than 6.15 pounds.

Although the analysis of the 8 year averages showed definite evidence that gill nets were generally selective towards taking more of the larger sockeye, it was also noted in an examination of the individual years that gill nets were also *selective toward taking more of the smaller sized sockeye* whenever the available fish were particularly large. This feature is described for the Canadian San Juan Area 20, prior to the compounding effects of the selectivity which occur as the sockeye progress through a gauntlet of purse seine and gill net fisheries. In the years 1951, 1952, 1954 and 1956 when the sockeye were especially large at 7.49, 7.17, 7.26 and 6.48 pounds (purse seine averages), the size of sockeye taken by gill nets was less than that of the seines; that is, 7.48, 6.76, 7.21 and 6.24 pounds. However, because the exceptionally large sockeye occur infrequently, the usual circumstance is for gill net to take more of the larger sockeye.

More detailed evidence of gill net selectivity is illustrated in FIGURE 31 which compares the average weights of purse seine and gill net caught sockeye by weekly periods during 1952, 1955 and 1957. Commencing with 1952, the incoming stocks of sockeye were exceptionally large, and, as a result, the fish taken by gill nets were consistently smaller than those captured by the purse seines. Selection in this case allowed more of the larger fish to escape. By contrast when smaller sockeye appeared in 1955, gill nets took more of the larger fish and the smaller sizes escaped. The year 1957 represented an extreme case since the sockeye of all ages were especially small and large numbers of 3_2 jacks were present from mid-August into September. While seines caught all sizes without selection, gill nets caught none of the small jacks and few of the smaller fish of the older age classes. This resulted in extreme selection as evidenced by the major difference in average weights taken by the purse seine and gill net gears.

The failure of the gill nets to capture all sizes of sockeye is simply a matter of having insufficient small and large mesh sizes to efficiently cover the range of sockeye sizes available in different years. The problem is mostly economic, for the fishermen cannot afford to have a full range of all mesh sizes in stock. Also there appears to be a personal preference by the fishermen to employ a "standard" net of about 5⅞ inch stretched mesh that captures average or slightly above average sized sockeye. It is the persistent use of "standard-sized" nets that results in the selective capture of smaller fish when the available fish are large and of larger fish when the available fish are small.

Although gill nets have been shown to catch sockeye of a size different from that of the annual population, there is no evidence to show that this selectivity has had any permanent effect on the progeny sizes. As noted on page 77, the sockeye of cycle years of characteristically small fish have *not* became smaller *nor* have the larger groups become larger. Through the eleven to twelve generations of each of the four cycles, the component races have maintained their own genetic mean sizes. Only random variations have occurred from generation to generation without any persistent trend towards smaller or larger sockeye. Size variations have been governed principally by changes in the growth conditions in the marine environment, although minor size variations undoubtedly would have occurred even under constant environmental conditions depending upon the parcelling out of genetic size factors according to definite laws of inheritance.

It is most improbable that gill net selectivity for either large or small sockeye could ever permanently alter the size of the fish constituting the various races because the selection is neither complete nor continuous in any one direction. Only by rigidly selecting certain characteristics and continuously eliminating others

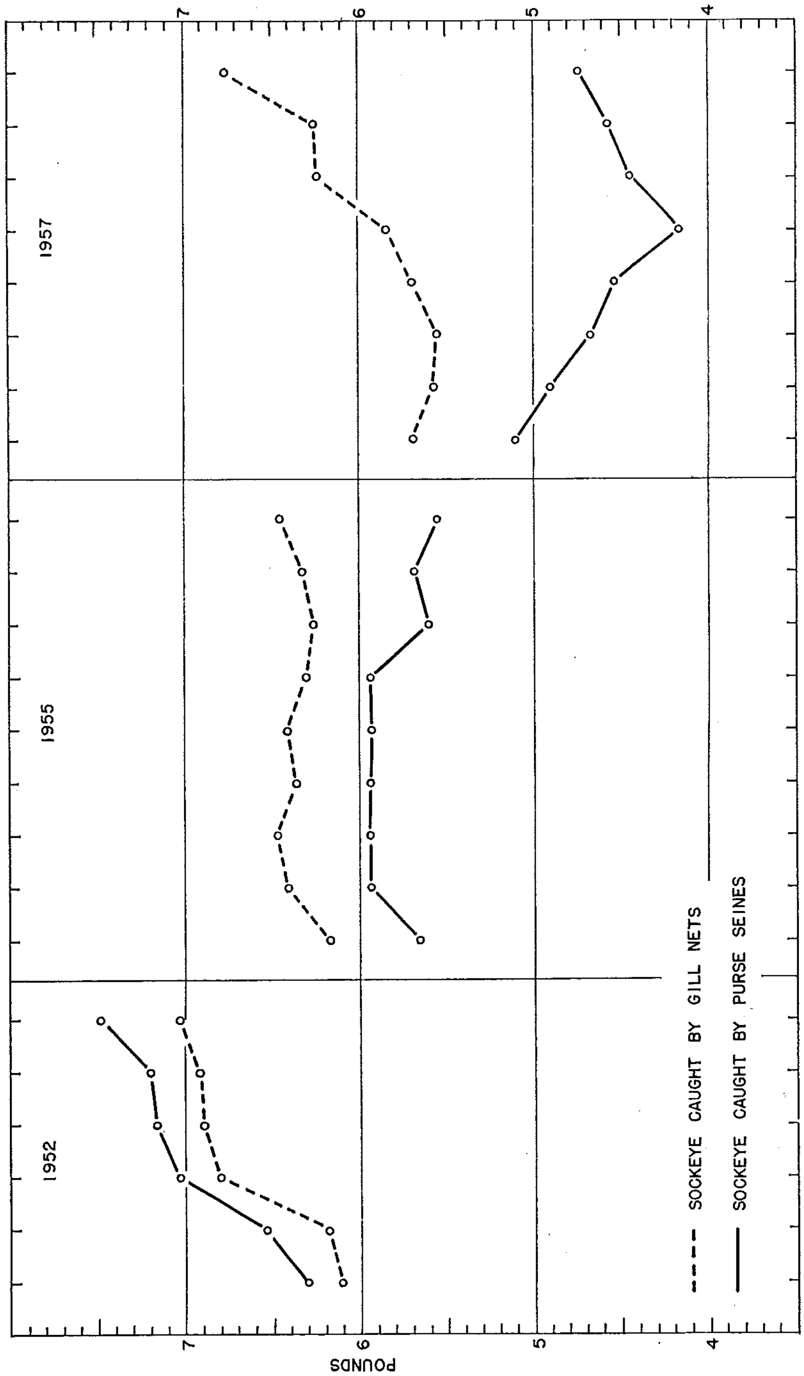

FIGURE 31—Comparisons of weekly average weights of sockeye catches by purse seines and gill nets fishing in the Canadian San Juan Area 20.

through many generations would it ever be possible to create inherent variations of a particular kind; even then, the changes could be reversed whenever the selected stocks were allowed to mate indiscriminately with unselected stocks.

Prediction of Sockeye Sizes

It was evident from the above discussion of size selectivity that gill net mesh sizes were sometimes either too large or too small to capture *efficiently* all available sizes of sockeye. This could well have been avoided if the size of the fish had been *predicted* at the start of the fishing season when gill nets were being ordered. Because considerable benefit could be derived from advance knowledge of sockeye sizes, especially if very large or very small sockeye are expected, a review has been made of all of the presently known governing factors and these are recapitulated below.

One of the first things learned from 46 years of size data analysis was that each race of sockeye had its own genetic size characteristic which resulted in a variation of sizes occurring throughout each fishing season. Also, because the numbers of sockeye involved in the individual races differed greatly each year, there would be different seasonal size characteristics for each of the four cycle groups (4_2 fish). Since the racial proportions in each of the four cycles appeared to be quite stable, one could predict the average size trend from week to week for each cycle. For instance, no significant differences should occur from week to week in the 1917-57 cycle; whereas, in each of the other three cycles, the mid-season average weights should be larger than those appearing earlier and later in the season. These time-size sequences for each cycle were shown in FIGURE 18. It should be noted that the date-line given would not apply to sockeye migrating up the Fraser after mid-August when certain races delay various lengths of time in the estuary off the Fraser River mouth.

Prediction of sockeye sizes can be taken a step further than shown in FIGURE 18 by obtaining a prompt size measure of the first sockeye entering the commercial fishery each year. Based on past experience, whatever the size of the early fish may be, the later sockeye will follow suit. If the first fish show up much smaller or larger than the weekly average for the cycle concerned, then the fishermen and cannery operators can be more accurately advised on the sizes expected through the remaining weeks of that fishing season. Granted, such information would come well after the main supply of nets had been ordered, but it is not improbable that significant numbers of the most efficient meshes could still be obtained.

In addition to describing the expected weekly size trends, the historical data also provide an expected mean weight for each of the four cycle groups. Commencing with the 1917-57 cycle, the mean weights were 5.63, 6.39, 5.92 and 6.07 pounds; however, some major departures from each of these cycle means are shown in FIGURES 22 to 24. Tracing size fluctuations through 11 or 12 generations of each cycle gave no indication of reoccurring size changes that might be predictable in future years for the cyclical weights were extremely random in both direction and degree. No sound predictions could be based on the nature of prior cycle size fluctuations.

It also has been shown that sockeye size variations within cycle groups were governed mainly by growth conditions in the marine environment and that the final adult sizes were determined principally during the last year of ocean residence. Thus, the size changes of 4_2 sockeye were similar to those of 3_2 and 5_2 sockeye of the same year but unlike the 3_2's of the previous year or 5_2's of the following year. This circumstance precluded the possibility of predicting sockeye sizes one year in advance on the basis of a younger age group.

The next step was to establish whether or not sockeye sizes were related to their numbers, inasmuch as smaller sizes may have occurred when the numbers were very large or, inversely, the sockeye might be large when their numbers are few. This appeared to be the general pattern for Alaska pink salmon on a long term basis but it did not follow for Fraser River sockeye. Correlations between the size fluctuations of Fraser sockeye and those of the Skeena, Nass and Rivers Inlet also were made and still no significant relationships were established whereby Fraser sockeye sizes might be predicted either by their own numerical abundance or the size of sockeye in some other river system.

Eventually it was apparent that the only prospect for explaining past size changes within cycle groups and predicting future ones would depend upon the possible correlation of size with varying conditions of the ocean environment. Limited data were available in this regard but it was found that an inverse correlation did exist between sockeye size changes and surface seawater temperatures at Station "Papa" (50°N, 145°W) (see FIGURE 30). Significance was only to the 95 per cent level because of some rather extreme exceptions; but, in general it was evident that when "Papa" surface temperatures were below 47.5°F (averaged over 12 months of the final year of maturation) the sockeye were above average in size, whereas when the temperatures were above 47.5°F the sockeye were smaller than average. The degree of size departure below and above average was relative to the degree of coolness or warmness of the water temperatures.

In summarizing all of the possible means of predicting sizes of Fraser River sockeye, it was concluded that, in the present state of knowledge, prediction of size could be made only to the extent of defining weekly and cycle averages; however, once the first sockeye were caught and measured in any particular year, the sizes for the balance of the season could be defined quite closely. More extensive information on the location and migratory habits of the sockeye during all stages of their marine life is required, together with more complete records of innumerable environmental factors, before more precise size predictions can be made.

SUMMARY

1. The data on 88,368 individual sockeye salmon obtained from the Fraser River run by sampling trap and purse seine catches from 1915 to 1960 inclusive were analyzed in regard to age, sex ratio and size. Sampling data and the records of catches and escapements were used to calculate the total annual numbers and percentages of sockeye in each age class.

2. Four *age classes*; namely, 3_2, 4_2, 5_2 and 5_3 were dealt with and these occurred in the following percentages respectively: 2.20; 89.25; 6.94 and 1.61.

3. The 5_2 sockeye are produced for the most part in that portion of the Fraser River drainage system below Hell's Gate. Their percentage occurrence is chiefly a reflection of the numbers of 4_2 salmon proceeding to the upper portion of the river; that is, when the number of upriver fish is large, the percentage of 5_2 fish is relatively small.

4. The fish of the 5_3 age class spend an extra year in fresh water. Their numbers are relatively small and their origin appears to be closely associated with retarded growth conditions in the freshwater environments.

5. The 4_2 sockeye represent nearly 90 per cent of all age classes; therefore, regulations for the taking of Fraser sockeye may be based almost entirely on this age group.

6. The 3_2 or jack sockeye have averaged 80,738 fish or 2.20 per cent of the annual total production.

7. The proportions of the *sexes* in the samples of all ages combined from 1915 to 1960, inclusive, were 35,855 males to 39,837 females; a ratio of 47 males to 53 females. The ratios of males to females in the four separate age classes were: 3_2 — 94:6; 4_2 — 46:54; 5_2 — 48:52; 5_3 — 45:55.

8. While there was usually a slightly smaller number of males than females, and while the difference may have been accentuated in some instances by the selective action of gill nets, the data of other investigators do not indicate a lowered production because of the discrepancy.

9. An extreme departure from a 50:50 sex ratio occurs in the 3_2 age-group where the males constitute an average of 94 per cent; however, since the 3_2 fish average only 2.20 per cent of the total number of Fraser sockeye, the lack of females does not affect production to a significant degree.

10. Variation in the *size* of sockeye involved both biological and economic aspects. Biological aspects were concerned with both genetic and environmental factors and their respective influences on sizes attained at maturity. Economic aspects were less complex and of immediate concern to the fishing industry. For instance, the reduction in sockeye sizes from a 7.2 pound average in 1951 to 5.12 pounds in 1959 represented a loss in potential pack of $4,800,000 to the salmon canning industry.

11. In the analysis of the sampling data, the size of each age class was considered separately with sexes combined on a 50:50 basis.

12. The combined *weights* of male and female sockeye by age class were: 3.12 pounds for 3_2 (females omitted), 6.00 pounds for 4_2, 6.14 pounds for 5_3 and 7.60 pounds for 5_2 sockeye.

13. The combined *lengths* of male and female sockeye by age class were: 48.25 centimeters (19.00 inches) for 3_2 (females omitted); 60.09 centimeters (23.66 inches) for 4_2; 60.64 centimeters (23.87 inches) for 5_3; 64.91 centimeters (25.56 inches) for 5_2 sockeye.

14. Over 99 per cent of the sockeye's growth occurred in the ocean. Seaward migrants (smolts) weighed only .014 pounds after one year in fresh water; whereas, in salt water, the gain in weight was 3 pounds in the first year, 2.9 pounds in the second year and 1.60 pounds in the third year. Kokanee (landlocked sockeye) complete their life cycle entirely in fresh water and weigh .5 pounds; that is, 5.5 pounds *less* at maturity than anadromous four-year-old sockeye.

15. The influence of changes in length and condition (fatness) on the weights of sockeye revealed that length accounted for most of the annual weight variations.

16. Considerable year-to-year differences in the sizes of 4_2 sockeye were found. Weights ranged from a minimum of 5.05 pounds to a maximum of 7.21 pounds and lengths from 58.24 to 62.51 centimeters. A definite alternation of larger sockeye (av. 6.23 lbs.) in the "even" years and smaller sockeye (av. 5.78 lbs.) in the "odd" years occurred with few exceptions. This is the result of races of genetically large size being most abundant in the "even" years and races of genetically small size being most abundant in the "odd" years.

17. Sizes of the 4_2 sockeye changed throughout each fishing season in three of the four cycles. Sockeye were small in early July, reached peak sizes in mid-August and were of lesser weight and length in late August and early September. Practically no seasonal size changes occurred in the years of the 1913-57 cycle.

18. Consideration of: the racial composition of each season's catch; the variations in numerical dominance of particular races each year, and the resultant changes in the dates of the largest commercial catches revealed that differences in racial genetic sizes not only caused size changes within seasons but they also resulted in different sizes being characteristic of each of the four cycles. Cycle size averages were: 1915-59 cycle — 5.922 pounds; 1916-60 cycle — 6.074 pounds; 1917-57 cycle — 5.632 pounds; 1918-58 cycle — 6.388 pounds.

19. In addition to the differences in sizes within seasons and between cycles, there were variations within cycles from one generation to the next. These deviations from the four cycle means were recorded for each of the 46 years under study.

20. Correlation and regression coefficients were calculated to establish whether or not the sockeye had become progressively smaller or larger through the 46 years. These analyses showed no significant size trends either through the 46 years or through any of the four separate cycle groups.

21. Analysis of the average weights of *all* sockeye caught commercially by United States purse seines from 1944 to 1960 confirmed that Fraser sockeye were usually smaller in the "odd" years than in "even" years. Changes in weekly weights of commercial landings also agreed with those shown by the sampling data.

22. Comparisons of the commercial catch weights and sampled 4_2 weights showed them to be significantly correlated.

23. Variations in the numbers of fish-per-case were found to be *unreliable* as a measure of annual sockeye sizes because of inconsistent differences in the numbers of pounds of fish used to pack a 48 pound case from one year to the next.

24. Upon establishing that sample weights were a dependable measure of sockeye size and the only reliable source of data prior to 1944, it was then possible to determine what factor or factors might have been responsible for the diverse annual size variations recorded as shown in the following items.

25. Changes to larger or smaller than average sized sockeye were consistent throughout all parts of each fishing season (all races affected alike). This indicated that growth conditions within the *marine* rather than the *freshwater* environment were principally responsible for variations in sockeye sizes within the four cycle groups. The indication that adult size was not determined by size attained in fresh water was confirmed by the lack of any consistent relationship between smolt (seaward migrants) and adult sizes of different races and of the same race in different years.

26. Because of the independent size variations between adjacent years, it seemed probable that growth variations in the fourth year (of 4_2 sockeye) were most important and that these would be relatively independent of the sizes reached at three and five years of age. This was verified by statistical tests showing that size changes of 4_2 sockeye were very similar to those of 3_2 and 5_2 sockeye of the same year but unlike the 3_2's of the previous year or 5_2's of the following year.

27. Examination of the size of Fraser sockeye in relation to their abundance showed no significant relationship either annually or through a series of years.

28. In examining possible relationships between sockeye size changes and varying marine conditions, an attempt was made to deduce the distribution of Fraser sockeye in the northeastern Pacific Ocean. In the present analysis, comparisons of the size fluctuations of Fraser sockeye with northern British Columbia runs to Rivers Inlet, Skeena and Nass Rivers showed independent size variations suggesting that Fraser sockeye inhabit a more southerly area than the three northern runs. The northern boundary for Fraser River sockeye was estimated to be about 55°N.

29. A significant inverse relationship ("r" value —.5334) was found between Fraser River sockeye size variations and Pacific Ocean surface water temperatures at the weather station "Papa" (50°N, 145°W). Sockeye were larger when temperatures were cold and smaller in years of warmer temperatures. The theory is proposed that sockeye have a temperature preference and seek out waters which are within their preferred temperature range. Thus, when the waters in the region of station "Papa" are warmer, the sockeye move northward where conditions for growth may not be of the best and small sized sockeye result; whereas, when temperatures at "Papa" are colder than usual, the sockeye move southward where apparently conditions for growth are more favorable and larger than average sockeye result. Sockeye which progress farthest into northern waters appear to take longer to return to the Fraser as indicated by their ten day lateness in 1958. On the basis of the above reasoning, it was tentatively concluded that in years of low temperatures in the region of station "Papa", sockeye will be of large size and migrate early; in years of average temperatures, they will be of average size and migrate at the "normal" time; and in years of higher temperatures they will be of small size and migrate late.

30. An examination of size selectivity by gill nets on Fraser sockeye revealed that in years when sockeye were unusually large the smaller fish tended to be caught and larger sockeye escaped. The reverse situation was true in years when sockeye were unusually small. There was no evidence to indicate that size selection had any permanent effects on the size of Fraser sockeye as a whole or in any one of the four cycle years.

31. Prediction of sockeye sizes could be provided well in advance of each season to the extent of defining weekly and cycle averages. However, the deviations from the weekly and cycle averages could not be accurately predicted until more precise information on the marine location and migratory habits of the sockeye becomes available together with more complete records of innumerable environmental factors. After the first sockeye are caught in any particular year, the sizes of sockeye for the balance of that year can be defined quite closely.

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APPENDIX TABLE A

Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1915				1916			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	3,909	2,247	358	68	7,676	1,711	267
July 8 - July 14	—	11,961	5,520	920	567	75,379	8,721	624
July 15 - July 21	—	109,470	44,543	757	—	294,142	28,314	1,575
July 22 - July 28	—	253,984	212,518	15,551	34,458	204,358	59,551	4,058
July 29 - Aug. 4	8,460	335,917	114,242	8,783	68,632	226,451	72,340	6,290
Aug. 5 - Aug. 11	4,442	348,179	92,593	7,143	56,862	173,328	55,998	12,566
Aug. 12 - Aug. 18	2,982	274,907	49,791	8,178	38,022	58,478	8,100	3,431
Aug. 19 - Aug. 25	3,595	166,150	22,387	3,781	13,163	18,296	3,224	1,405
Aug. 26 - Sept. 1	1,400	53,136	5,146	805	4,244	11,153	1,401	671
Sept. 2 - Sept. 8	334	16,010	1,874	248	—	—	—	—
Sept. 9 - Sept. 15	18	806	84	13	—	—	—	—
Totals	21,231	1,574,429	550,945	46,537	216,014	1,069,261	239,360	30,887
Percentages	.968	71.789	25.121	2.122	13.887	68.740	15.388	1.985
SEASON TOTAL	2,193,142				1,555,522			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1917				1918			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	66,149	2,815	2,111	—	750	336	129
July 8 - July 14	—	273,312	14,162	2,833	—	3,418	989	315
July 15 - July 21	—	924,665	13,024	—	—	40,768	13,589	4,727
July 22 - July 28	—	2,296,505	20,409	10,216	—	71,991	15,998	11,999
July 29 - Aug. 4	—	2,845,077	11,722	23,416	—	138,670	22,887	14,809
Aug. 5 - Aug. 11	—	1,156,207	62,778	5,227	—	237,888	33,986	8,495
Aug. 12 - Aug. 18	—	344,297	33,403	7,708	—	190,401	17,309	2,885
Aug. 19 - Aug. 25	—	127,974	13,509	—	—	102,423	18,289	1,830
Aug. 26 - Sept. 1	—	77,333	6,339	—	—	21,720	5,924	—
Sept. 2 - Sept. 8	—	925	76	—	—	3,936	806	—
Sept. 9 - Sept. 15	—	—	—	—	—	7,409	1,517	—
Totals	—	8,112,414	178,237	51,511	—	819,374	131,630	45,189
Percentages	0	97.246	2.137	.617	0	82.251	13.213	4.536
SEASON TOTAL	8,342,162				996,193			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1919				1920			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	1,375	520	244	—	9,321	3,640	976
July 8 - July 14	—	3,575	2,076	115	—	73,400	5,301	2,039
July 15 - July 21	—	17,443	10,337	646	—	222,187	23,440	1,247
July 22 - July 28	—	29,701	19,420	1,142	—	233,395	68,763	6,252
July 29 - Aug. 4	—	70,499	27,976	2,238	—	264,605	102,602	10,800
Aug. 5 - Aug. 11	—	201,304	43,921	3,661	—	204,149	75,868	16,551
Aug. 12 - Aug. 18	—	458,941	53,829	2,836	722	77,917	23,086	11,543
Aug. 19 - Aug. 25	3,890	284,004	15,562	—	—	8,714	1,867	3,734
Aug. 26 - Sept. 1	—	122,607	2,920	—	7	2,233	280	128
Sept. 2 - Sept. 8	—	49,538	3,196	—	—	—	—	—
Sept. 9 - Sept. 15	225	10,199	1,058	166	—	—	—	—
Totals	4,115	1,249,186	180,815	11,048	729	1,095,921	304,847	53,270
Percentages	.285	86.439	12.512	.764	.050	75.333	20.955	3.662
SEASON TOTAL	1,445,164				1,454,767			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1921				1922			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	63,811	10,895	1,556	—	2,992	212	193
July 8 - July 14	—	191,980	21,598	4,800	657	9,848	1,313	1,313
July 15 - July 21	—	477,838	40,434	3,675	541	40,571	3,787	2,884
July 22 - July 28	5,662	469,745	62,256	—	—	118,220	13,858	3,464
July 29 - Aug. 4	—	292,462	45,547	14,384	4,193	226,442	23,063	8,387
Aug. 5 - Aug. 11	1,795	145,370	19,741	8,076	3,133	335,143	32,890	10,959
Aug. 12 - Aug. 18	1,649	69,291	16,498	9,074	6,327	267,881	3,164	7,384
Aug. 19 - Aug. 25	—	30,145	5,383	538	4,527	208,225	9,052	—
Aug. 26 - Sept. 1	—	9,012	1,802	—	—	32,937	3,060	—
Sept. 2 - Sept. 8	—	—	—	—	—	—	—	—
Sept. 9 - Sept. 15	—	—	—	—	—	—	—	—
Totals	9,106	1,749,654	224,154	42,103	19,378	1,242,259	90,399	34,584
Percentages	.450	86.402	11.069	2.079	1.398	89.589	6.519	2.494
SEASON TOTAL	2,025,017				1,386,620			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1923				1924			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	1,624	77	—	—	1,842	719	193
July 8 - July 14	—	4,798	993	330	—	6,708	485	186
July 15 - July 21	—	14,106	3,902	1,200	—	40,923	4,308	230
July 22 - July 28	—	52,772	3,909	6,841	—	292,002	86,304	7,821
July 29 - Aug. 4	—	124,707	32,941	11,765	—	317,670	123,179	12,966
Aug. 5 - Aug. 11	—	225,903	48,005	—	—	232,931	86,567	18,885
Aug. 12 - Aug. 18	—	198,358	15,260	10,171	1,022	110,342	32,694	16,347
Aug. 19 - Aug. 25	—	150,520	20,219	3,369	—	42,534	9,114	18,229
Aug. 26 - Sept. 1	—	50,580	6,556	937	22	7,602	955	435
Sept. 2 - Sept. 8	—	25,448	1,591	1,590	—	—	—	—
Sept. 9 - Sept. 15	—	—	—	—	—	—	—	—
Totals	—	848,816	133,453	36,203	1,044	1,052,554	344,055	75,292
Percentages	0	83.342	13.103	3.555	.071	71.459	23.358	5.112
SEASON TOTAL	1,018,472				1,472,945			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1925				1926			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	94,059	6,625	1,325	—	1,385	671	108
July 8 - July 14	—	61,236	5,653	1,413	—	2,912	1,584	204
July 15 - July 21	—	470,911	52,858	9,612	—	101,879	32,654	7,837
July 22 - July 28	—	517,501	64,689	19,401	—	140,109	37,530	5,004
July 29 - Aug. 4	—	442,713	78,705	13,117	—	249,045	21,847	21,844
Aug. 5 - Aug. 11	1,460	110,997	54,037	7,303	—	442,460	26,815	40,225
Aug. 12 - Aug. 18	—	70,986	70,987	10,352	—	355,932	—	29,660
Aug. 19 - Aug. 25	1,849	21,723	17,101	1,849	—	136,554	—	16,065
Aug. 26 - Sept. 1	218	8,082	3,058	655	—	38,601	5,514	8,272
Sept. 2 - Sept. 8	—	—	—	—	—	16,601	—	299
Sept. 9 - Sept. 15	—	—	—	—	—	30,307	745	745
Totals	3,527	1,798,208	353,713	65,027	—	1,515,785	127,360	130,263
Percentages	.158	80.983	15.930	2.929	0	85.473	7.182	7.345
SEASON TOTAL	2,220,475				1,773,408			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1927				1928			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	1,961	206	—	27	843	82	54
July 8 - July 14	—	4,948	761	381	—	20,756	6,918	—
July 15 - July 21	—	34,755	0	1,287	—	100,541	9,140	12,187
July 22 - July 28	998	67,911	4,994	998	3,592	258,828	28,760	7,191
July 29 - Aug. 4	—	124,938	28,832	—	13,126	213,306	32,816	9,846
Aug. 5 - Aug. 11	—	300,029	43,823	3,372	1,588	88,960	25,416	3,178
Aug. 12 - Aug. 18	—	266,380	35,127	17,565	—	89,374	17,875	16,385
Aug. 19 - Aug. 25	—	382,604	27,730	14,788	1,261	116,008	17,653	6,304
Aug. 26 - Sept. 1	—	346,358	12,224	—	825	47,852	11,550	7,425
Sept. 2 - Sept. 8	—	379,026	2,311	—	—	—	—	—
Sept. 9 - Sept. 15	—	58,878	1,015	3,046	—	—	—	—
Totals	998	1,967,848	157,023	41,437	20,419	936,468	150,210	62,571
Percentages	.046	90.797	7.245	1.912	1.746	80.063	12.842	5.349
SEASON TOTAL	2,167,306				1,169,668			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1929				1930			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	2,225	251,333	4,190	3,144	—	—	—	—
July 8 - July 14	0	355,293	0	0	—	—	—	—
July 15 - July 21	0	174,624	6,022	12,043	—	122,882	64,676	—
July 22 - July 28	4,166	164,649	12,197	12,195	—	353,578	83,195	20,797
July 29 - Aug. 4	197,036	316,528	32,055	40,066	—	197,247	118,348	—
Aug. 5 - Aug. 11	142,830	199,167	43,150	23,241	—	200,349	116,870	22,263
Aug. 12 - Aug. 18	92,051	260,569	68,887	44,927	3,241	521,517	110,136	51,827
Aug. 19 - Aug. 25	50,789	22,144	8,263	7,271	10,757	860,622	80,680	16,140
Aug. 26 - Sept. 1	30,484	4,959	1,920	2,880	—	1,713,509	18,622	27,950
Sept. 2 - Sept. 8	—	—	—	—	—	710,674	—	12,806
Sept. 9 - Sept. 15	—	—	—	—	2,843	170,514	4,263	4,262
Totals	519,581	1,749,266	176,684	145,767	16,841	4,850,892	596,790	156,045
Percentages	20.051	67.505	6.818	5.626	.300	86.306	10.618	2.776
SEASON TOTAL	2,591,298				5,620,568			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1931				1932			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	6,713	814	203	18	3,651	814	127
July 8 - July 14	—	33,930	1,818	—	—	14,164	1,012	—
July 15 - July 21	—	84,551	13,153	1,878	—	85,227	8,971	4,485
July 22 - July 28	—	173,418	42,391	—	2,409	236,124	36,142	—
July 29 - Aug. 4	34,084	244,283	68,173	5,681	—	477,997	68,285	11,878
Aug. 5 - Aug. 11	20,216	257,045	69,316	11,553	11,850	397,806	64,325	23,700
Aug. 12 - Aug. 18	6,739	279,639	16,847	6,739	7,263	297,835	24,217	7,263
Aug. 19 - Aug. 25	2,866	180,536	15,761	7,164	—	122,862	14,454	—
Aug. 26 - Sept. 1	4,431	79,755	8,862	1,329	—	105,190	2,922	8,766
Sept. 2 - Sept. 8	2,074	33,484	2,371	—	—	—	—	—
Sept. 9 - Sept. 15	—	—	—	—	—	—	—	—
Totals	70,410	1,373,354	239,506	34,547	21,540	1,740,856	221,142	56,219
Percentages	4.099	79.948	13.942	2.011	1.056	85.346	10.842	2.756
SEASON TOTAL	1,717,817				2,039,757			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1933				1934			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	1,269	369,536	3,364	674	—	—	—	—
July 8 - July 14	—	260,607	7,590	—	—	—	—	—
July 15 - July 21	—	300,678	12,191	6,092	—	154,432	34,319	—
July 22 - July 28	7,538	444,356	32,028	4,001	—	217,241	27,154	13,577
July 29 - Aug. 4	15,202	358,136	34,303	9,081	—	227,081	43,254	—
Aug. 5 - Aug. 11	71,392	356,219	80,842	20,213	—	658,443	39,604	19,806
Aug. 12 - Aug. 18	75,213	225,849	57,032	7,985	36,159	1,120,859	148,247	21,682
Aug. 19 - Aug. 25	49,696	90,678	34,622	11,540	70,424	2,746,532	52,804	—
Aug. 26 - Sept. 1	3,115	43,814	7,440	1,654	20,250	391,468	6,751	40,494
Sept. 2 - Sept. 8	—	—	—	—	—	25,496	4,249	—
Sept. 9 - Sept. 15	—	—	—	—	—	—	—	—
Totals	223,425	2,449,873	269,412	61,240	126,833	5,541,552	356,382	95,559
Percentages	7.438	81.555	8.969	2.038	2.072	90.543	5.823	1.562
SEASON TOTAL	3,003,950				6,120,326			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1935				1936			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	0	—	—	—	790	113	56
July 8 - July 14	—	0	—	—	—	19,793	4,399	—
July 15 - July 21	23	1,403	304	47	—	123,204	18,252	—
July 22 - July 28	—	33,644	27,236	1,068	8,931	696,342	44,635	—
July 29 - Aug. 4	—	75,408	93,608	5,200	87,026	1,479,447	116,041	58,012
Aug. 5 - Aug. 11	2,017	189,708	98,891	16,145	—	364,553	47,897	15,967
Aug. 12 - Aug. 18	5,485	340,220	90,542	13,720	—	287,383	42,891	4,289
Aug. 19 - Aug. 25	9,891	306,645	43,524	—	1,491	90,954	16,401	1,491
Aug. 26 - Sept. 1	5,401	234,908	16,199	8,100	—	19,532	1,247	1,246
Sept. 2 - Sept. 8	3,809	95,240	5,080	2,540	—	—	—	—
Sept. 9 - Sept. 15	3,515	63,279	1,758	—	—	—	—	—
Totals	30,141	1,340,455	377,142	46,820	97,448	3,031,948	291,876	81,061
Percentages	1.680	74.696	21.015	2.609	2.743	86.759	8.216	2.282
SEASON TOTAL	1,794,558				3,552,383			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1937				1938			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	1,767	126	—	—	0	0	—
July 8 - July 14	—	5,072	363	—	13	1,159	205	66
July 15 - July 21	—	33,296	—	—	184	13,483	3,006	684
July 22 - July 28	18,273	151,173	1,937	1,937	1,686	67,428	8,429	843
July 29 - Aug. 4	13,908	501,460	17,205	12,290	6,345	114,221	16,924	—
Aug. 5 - Aug. 11	31,042	414,268	15,089	37,034	36,839	773,543	85,949	—
Aug. 12 - Aug. 18	65,500	468,062	46,306	33,078	8,614	327,431	45,955	—
Aug. 19 - Aug. 25	39,873	266,753	55,300	34,158	13,284	1,646,978	106,256	—
Aug. 26 - Sept. 1	16,218	104,920	51,601	17,200	11,425	708,149	11,418	—
Sept. 2 - Sept. 8	7,464	34,634	18,801	8,906	—	133,694	10,091	—
Sept. 9 - Sept. 15	2,469	12,658	4,801	5,674	—	203,378	14,027	—
Totals	194,747	1,994,063	211,529	150,279	78,390	3,989,464	302,260	1,593
Percentages	7.635	78.180	8.293	5.892	1.793	91.256	6.914	.037
SEASON TOTAL	2,550,618				4,317,707			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1939				1940			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	0	0	—	—	198	66	—
July 8 - July 14	—	424	22	—	—	6,193	1,770	—
July 15 - July 21	—	25,026	2,781	—	—	224,030	37,339	—
July 22 - July 28	—	64,943	29,112	2,240	—	334,628	89,231	—
July 29 - Aug. 4	3,184	57,306	19,102	—	—	718,029	24,205	8,066
Aug. 5 - Aug. 11	—	81,908	43,002	—	—	509,468	114,367	—
Aug. 12 - Aug. 18	2,565	138,629	59,044	—	—	87,724	0	—
Aug. 19 - Aug. 25	4,653	409,476	41,878	9,306	1,283	14,752	1,604	641
Aug. 26 - Sept. 1	—	237,161	19,304	2,758	—	9,300	423	—
Sept. 2 - Sept. 8	—	104,600	13,075	1,189	—	7,575	344	—
Sept. 9 - Sept. 15	1,312	18,551	602	—	—	8,101	368	—
Totals	11,714	1,138,024	227,922	15,493	1,283	1,919,998	269,717	8,707
Percentages	.842	81.686	16.360	1.112	.058	87.284	12.262	.396
SEASON TOTAL	1,393,153				2,199,705			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1941				1942			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	0	7,963	692	0	390	4,292	520	—
July 8 - July 14	0	56,574	5,595	0	527	30,590	528	—
July 15 - July 21	0	214,568	21,221	0	683	74,419	6,827	—
July 22 - July 28	0	1,060,044	16,264	10,850	—	194,642	34,349	—
July 29 - Aug. 4	12,898	2,125,770	35,192	42,239	—	244,531	53,489	—
Aug. 5 - Aug. 11	27,028	698,216	42,186	6,337	—	472,203	48,434	6,052
Aug. 12 - Aug. 18	15,235	149,823	30,645	9,458	—	755,144	65,667	10,946
Aug. 19 - Aug. 25	8,730	96,541	22,647	5,362	—	3,759,625	183,390	—
Aug. 26 - Sept. 1	2,858	34,863	17,146	5,715	—	4,190,134	38,268	95,648
Sept. 2 - Sept. 8	1,478	12,936	7,022	3,326	—	507,910	19,537	—
Sept. 9 - Sept. 15	40	352	191	90	—	36,992	1,480	—
Totals	68,267	4,457,650	198,801	83,377	1,600	10,270,482	452,489	112,646
Percentages	1.420	92.711	4.135	1.734	.016	94.770	4.175	1.039
SEASON TOTAL	4,808,095				10,837,217			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1943				1944			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	1	64	12	3	—	457	101	16
July 8 - July 14	5	1,802	344	43	—	3,373	572	17
July 15 - July 21	100	29,443	9,872	965	—	96,957	25,895	—
July 22 - July 28	—	47,711	27,264	—	—	394,000	43,297	—
July 29 - Aug. 4	656	91,820	74,112	656	—	1,034,293	95,687	—
Aug. 5 - Aug. 11	—	99,931	49,039	—	2,438	126,823	37,803	1,220
Aug. 12 - Aug. 18	—	82,080	41,040	1,039	—	23,936	7,006	292
Aug. 19 - Aug. 25	1,066	70,365	33,050	—	—	11,202	3,669	—
Aug. 26 - Sept. 1	433	40,420	10,159	—	—	2,286	699	—
Sept. 2 - Sept. 8	—	8,096	3,736	—	—	804	249	—
Sept. 9 - Sept. 15	—	4,278	1,645	—	—	585	181	—
Totals	2,261	476,010	250,273	2,706	2,438	1,694,716	215,159	1,545
Percentages	.310	65.095	34.225	.370	.127	88.550	11.242	.081
SEASON TOTAL	731,250				1,913,858			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1945				1946			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	2,162	188	—	166	9,763	2,630	538
July 8 - July 14	—	42,853	3,896	—	255	22,850	4,038	1,304
July 15 - July 21	—	113,264	16,101	—	1,634	120,000	26,750	6,088
July 22 - July 28	—	683,093	91,305	10,144	1,429	257,029	38,483	11,787
July 29 - Aug. 4	4,873	655,427	98,183	15,922	—	117,948	15,913	—
Aug. 5 - Aug. 11	11,084	160,079	55,082	—	—	446,053	34,466	6,083
Aug. 12 - Aug. 18	15,235	46,928	15,872	—	—	538,352	18,634	2,074
Aug. 19 - Aug. 25	18,283	73,233	21,447	—	—	1,034,750	33,026	—
Aug. 26 - Sept. 1	4,274	19,754	5,229	291	—	5,482,425	22,775	22,720
Sept. 2 - Sept. 8	1,387	6,418	1,699	95	7,457	1,358,508	7,471	7,471
Sept. 9 - Sept. 15	1,200	5,546	1,468	82	9,256	1,047,491	13,208	3,833
Totals	56,336	1,808,757	310,470	26,534	20,197	10,435,169	217,394	61,898
Percentages	2.558	82.138	14.099	1.205	.188	97.210	2.025	.577
SEASON TOTAL	2,202,097				10,734,658			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1947				1948			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	62	5,964	1,207	271	76	15,592	3,474	543
July 8 - July 14	26	9,239	1,763	224	26	47,671	8,084	243
July 15 - July 21	89	26,349	8,834	864	1,425	198,047	64,115	2,848
July 22 - July 28	—	61,887	35,364	—	—	503,480	141,189	—
July 29 - Aug. 4	593	83,074	67,054	593	—	831,578	89,257	8,926
Aug. 5 - Aug. 11	—	139,874	68,642	—	3,479	458,353	37,395	3,479
Aug. 12 - Aug. 18	4,114	143,982	45,252	8,228	855	178,913	24,782	9,645
Aug. 19 - Aug. 25	12,888	107,791	33,978	5,859	1,526	77,559	13,896	5,832
Aug. 26 - Sept. 1	7,985	59,439	15,081	1,183	105	36,155	4,543	2,069
Sept. 2 - Sept. 8	2,604	37,102	7,377	868	44	2,195	373	140
Sept. 9 - Sept. 15	947	11,367	5,683	—	—	1,767	572	52
Totals	29,308	636,068	290,235	18,090	7,536	2,351,310	387,680	33,777
Percentages	2.863	67.018	28.352	1.767	.271	84.570	13.944	1.215
SEASON TOTAL	1,023,701				2,780,303			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1949				1950			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	330,589	28,747	—	—	—	—	—
July 8 - July 14	—	285,482	25,952	—	12	1,053	186	60
July 15 - July 21	—	407,380	57,910	—	167	12,253	2,731	622
July 22 - July 28	—	947,761	126,682	14,074	1,532	61,277	7,660	766
July 29 - Aug. 4	2,349	307,084	46,001	7,461	5,767	103,803	15,380	—
Aug. 5 - Aug. 11	14,478	203,234	69,930	—	33,479	702,990	78,110	—
Aug. 12 - Aug. 18	39,315	117,718	39,816	—	7,828	297,568	41,763	—
Aug. 19 - Aug. 25	20,166	78,515	22,993	—	12,073	1,496,763	96,565	—
Aug. 26 - Sept. 1	7,284	32,716	8,660	481	10,383	643,561	10,377	—
Sept. 2 - Sept. 8	1,973	8,863	2,346	131	—	121,501	9,170	—
Sept. 9 - Sept. 15	1,044	4,690	1,241	69	—	184,828	12,748	—
Totals	86,609	2,724,032	430,278	22,216	71,241	3,625,597	274,690	1,448
Percentages	2.654	83.479	13.186	.681	1.793	91.256	6.914	.037
SEASON TOTAL	3,263,135				3,972,976			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1951				1952			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	319	127,808	1,917	160	2,317	108,887	4,344	1,159
July 8 - July 14	2,085	142,935	1,936	149	4,735	87,163	16,356	216
July 15 - July 21	1,142	187,337	11,424	380	13,924	309,330	87,774	4,236
July 22 - July 28	7,121	635,430	62,622	8,392	29,182	1,079,273	33,713	27,177
July 29 - Aug. 4	13,433	662,519	51,224	10,078	25,401	856,927	46,569	16,093
Aug. 5 - Aug. 11	8,837	306,375	28,354	5,154	13,008	185,612	25,309	13,008
Aug. 12 - Aug. 18	11,824	508,465	25,130	1,477	223	46,706	6,470	2,518
Aug. 19 - Aug. 25	2,783	94,164	4,948	464	342	17,405	3,118	1,309
Aug. 26 - Sept. 1	2,862	43,498	1,145	—	39	13,377	1,681	766
Sept. 2 - Sept. 8	169	8,118	950	126	116	5,828	991	372
Sept. 9 - Sept. 15	2,274	102,960	10,672	1,678	—	8,479	2,743	249
Totals	52,849	2,819,609	200,322	28,058	89,287	2,718,987	329,068	67,103
Percentages	1.704	90.931	6.460	.905	2.786	84.850	10.269	2.095
SEASON TOTAL	3,100,838				3,204,445			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1953				1954			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	1,274	583,974	10,200	—	7,329	80,617	9,772	—
July 8 - July 14	1,135	504,159	9,640	1,135	—	179,764	3,021	2,115
July 15 - July 21	2,182	730,590	18,582	19,669	1,523	284,300	9,542	6,870
July 22 - July 28	12,302	1,611,079	43,038	137,338	2,304	449,638	6,907	10,365
July 29 - Aug. 4	15,483	554,714	14,135	39,721	3,914	451,994	9,132	17,612
Aug. 5 - Aug. 11	131,762	302,458	19,467	30,695	12,069	859,674	8,395	22,568
Aug. 12 - Aug. 18	183,238	105,433	10,002	8,892	9,847	731,346	2,959	2,959
Aug. 19 - Aug. 25	134,755	51,075	3,821	3,821	8,450	1,264,216	15,966	9,424
Aug. 26 - Sept. 1	43,973	32,037	628	2,199	76,207	4,786,819	12,677	—
Sept. 2 - Sept. 8	11,913	8,680	170	596	—	2,237,597	86,069	—
Sept. 9 - Sept. 15	5,651	4,746	339	565	—	412,031	12,743	—
Totals	543,668	4,488,945	130,022	244,631	121,643	11,737,996	177,183	71,913
Percentages	10.054	83.017	2.405	4.524	1.005	96.938	1.463	.594
SEASON TOTAL	5,407,266				12,108,735			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1955				1956			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	578	55,427	11,221	2,514	—	28,659	6,614	—
July 8 - July 14	—	68,325	4,328	227	243	21,126	2,550	—
July 15 - July 21	233	131,510	13,991	933	1,292	102,058	17,656	860
July 22 - July 28	380	249,823	27,967	3,023	4,260	513,308	100,105	19,169
July 29 - Aug. 4	1,654	385,499	23,579	5,780	3,413	765,524	71,768	25,635
Aug. 5 - Aug. 11	—	536,316	56,475	10,903	3,866	664,661	65,692	7,731
Aug. 12 - Aug. 18	—	396,248	20,882	14,418	—	192,429	7,682	7,680
Aug. 19 - Aug. 25	351	199,100	10,165	9,464	—	83,455	3,338	3,338
Aug. 26 - Sept. 1	—	72,822	3,818	3,817	—	6,864	298	298
Sept. 2 - Sept. 8	2,871	137,572	16,106	2,131	—	8,807	383	383
Sept. 9 - Sept. 15	2,206	99,869	10,352	1,628	—	1,968	86	85
Totals	8,273	2,332,511	198,884	54,838	13,074	2,388,459	276,172	65,179
Percentages	.319	89.902	7.666	2.113	.477	87.078	10.069	2.376
SEASON TOTAL	2,594,506				2,742,884			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1957				1958			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	102,546	—	—	478	30,803	1,433	2,626
July 8 - July 14	—	350,854	2,285	—	473	86,577	4,258	3,312
July 15 - July 21	—	307,790	6,096	1,014	8,374	111,661	16,750	8,374
July 22 - July 28	19,996	597,878	25,996	1,996	1,688	93,848	10,465	4,389
July 29 - Aug. 4	28,868	435,249	22,206	—	1,740	158,235	5,797	2,899
Aug. 5 - Aug. 11	114,328	900,369	71,455	4,767	1,774	249,981	11,523	7,092
Aug. 12 - Aug. 18	234,530	770,612	23,192	5,157	—	345,927	14,294	5,720
Aug. 19 - Aug. 25	210,842	200,298	16,566	3,015	—	1,236,667	—	12,012
Aug. 26 - Sept. 1	87,663	71,962	6,542	1,745	—	4,629,920	—	—
Sept. 2 - Sept. 8	74,745	65,776	5,980	2,990	—	11,888,744	42,116	—
Sept. 9 - Sept. 15	17,267	15,195	1,381	691	—	—	—	—
Totals	788,239	3,818,529	181,699	21,375	14,527	18,832,413	106,636	46,424
Percentages	16.388	79.389	3.778	.445	.077	99.118	.561	.244
SEASON TOTAL	4,809,842				19,000,000			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1959				1960			
	3_2	4_2	5_2	5_3	3_2	4_2	5_2	5_3
July 1 - July 7	—	—	—	—	—	53,672	10,016	—
July 8 - July 14	—	—	—	—	—	35,195	3,001	—
July 15 - July 21	630	28,512	1,733	1,102	—	59,831	7,475	2,040
July 22 - July 28	2,380	91,254	6,348	1,587	6,020	390,075	54,205	13,560
July 29 - Aug. 4	4,918	493,306	14,764	13,532	5,680	589,805	61,110	12,784
Aug. 5 - Aug. 11	11,918	1,664,187	101,213	50,615	—	1,607,227	46,196	19,811
Aug. 12 - Aug. 18	6,196	829,070	26,809	26,808	—	104,411	1,123	2,244
Aug. 19 - Aug. 25	4,186	568,710	37,634	20,907	—	49,273	534	1,059
Aug. 26 - Sept. 1	4,018	228,169	12,043	10,705	—	30,795	331	662
Sept. 2 - Sept. 8	846	77,455	3,098	2,816	—	12,612	130	278
Sept. 9 - Sept. 15	888	52,055	1,183	2,957	—	—	—	—
Totals	35,980	4,032,718	204,825	131,029	11,700	2,932,896	184,121	52,438
Percentages	.817	91.558	4.650	2.975	.368	92.196	5.788	1.648
SEASON TOTAL	4,404,552				3,181,155			

TABLE A (Continued)—Calculations of the total numbers of 3_2, 4_2, 5_2 and 5_3 sockeye as they occurred by seven-day intervals in United States Convention waters, 1915 - 1960.

WEEKLY PERIODS	1915 to 1960 TOTAL PRODUCTION NUMBERS				
	3_2	4_2	5_2	5_3	Totals
July 1 - July 7	16,597	2,440,924	133,331	19,548	2,610,400
July 8 - July 14	10,759	3,418,451	191,586	24,584	3,645,380
July 15 - July 21	34,146	7,778,604	912,623	129,958	8,855,331
July 22 - July 28	176,307	17,867,076	2,165,869	431,213	20,640,465
July 29 - Aug. 4	582,836	21,588,795	2,300,484	528,851	25,000,966
Aug. 5 - Aug. 11	775,013	19,389,941	2,476,906	531,079	23,172,939
Aug. 12 - Aug. 18	881,993	13,553,893	1,556,247	464,584	16,456,717
Aug. 19 - Aug. 25	719,733	19,125,573	1,213,388	241,469	21,300,163
Aug. 26 - Sept. 1	346,124	24,939,887	385,538	280,005	25,951,554
Sept. 2 - Sept. 8	119,284	18,152,403	278,838	49,301	18,599,826
Sept. 9 - Sept. 15	51,155	2,579,279	108,154	25,885	2,764,473
TOTALS	3,713,947	150,834,826	11,722,964	2,726,477	168,998,214
WEIGHTED AVERAGES	2.20	89.25	6.94	1.61	

APPENDIX TABLE B

Fraser River sockeye salmon weekly average weights by cycles, four-year-old sockeye only (4_2).

YEAR	AREA	1915 - 1959 CYCLE									
		July 1 - 7	July 8 - 14	July 15 - 21	July 22 - 28	July 29 - Aug. 4	Aug. 5 - 11	Aug. 12 - 18	Aug. 19 - 25	Aug. 26 - Sept. 1	Season July 1 - Sept. 1
1915	Sooke Traps	5.755	—	5.745	6.235	—	—	—	—	—	5.912
1919	Sooke Traps	4.760	—	5.008	5.653	5.685	6.240	5.935	5.853	5.575	5.589
1923	Sooke Traps	4.473	5.785	6.120	5.965	6.635	6.935	6.837	6.574	6.622	6.216
1927	Sooke Traps	5.198	5.167	5.805	6.015	6.333	6.687	6.813	6.617	—	6.079
1931	Sooke Traps	5.508	5.547	5.912	6.445	6.100	6.333	6.097	6.129	5.773	5.983
1935	Sooke Traps	—	5.000	5.255	5.820	5.943	6.653	6.151	5.962	5.553	5.792
1939	Sooke Traps	4.690	5.245	5.960	5.658	6.060	6.210	6.333	5.957	5.396	5.723
1943	U.S. Purse Seine	—	—	—	—	5.590	5.800	5.849	5.423	5.535	5.639
1947	U.S. Purse Seine	—	—	—	—	—	—	6.270	6.191	6.029	6.163
1951	U.S. Purse Seine	6.752	6.968	6.937	6.852	7.357	7.692	7.575	7.356	7.381	7.208
1955	U.S. Purse Seine	5.299	5.392	5.592	5.755	5.698	5.623	5.823	5.842	5.747	5.641
1959	U.S. Purse Seine	—	—	4.858	5.028	5.109	5.282	5.335	5.253	5.003	5.124
Averages		5.304	5.586	5.719	5.943	6.051	6.346	6.274	6.105	5.861	5.922

YEAR	AREA	1916 - 1960 CYCLE									
		July 1 - 7	July 8 - 14	July 15 - 21	July 22 - 28	July 29 - Aug. 4	Aug. 5 - 11	Aug. 12 - 18	Aug. 19 - 25	Aug. 26 - Sept. 1	Season July 1 - Sept. 1
1916	Sooke Traps	—	5.865	5.810	5.735	6.060	5.928	—	—	5.740	5.856
1920	Sooke Traps	—	—	—	—	—	—	—	—	—	(6.020)
1924	Sooke Traps	—	—	—	—	—	—	—	—	—	(5.600)
1928	Sooke Traps	6.058	6.445	6.970	6.853	6.340	6.478	6.283	6.013	5.955	6.377
1932	Sooke Traps	—	5.910	5.860	6.240	6.240	6.615	6.873	6.550	7.273	6.445
1936	Sooke Traps	5.780	5.710	6.275	6.425	7.050	6.865	7.010	6.705	6.420	6.471
1940	Sooke Traps	5.845	—	6.685	6.658	6.350	6.598	6.945	6.010	5.720	6.351
1944	U.S. Purse Seine	—	—	6.019	6.215	6.079	6.595	—	—	—	6.227
1948	U.S. Purse Seine	—	—	5.837	5.519	5.414	5.339	—	—	—	5.527
1952	U.S. Purse Seine	6.271	6.347	6.837	6.810	7.075	7.150	7.120	—	—	6.801
1956	U.S. Purse Seine	5.770	5.890	5.840	5.960	6.270	6.260	6.180	—	—	6.024
1960	U.S. Purse Seine	—	—	5.221	4.902	5.311	5.251	5.241	—	—	5.185
Averages		5.945	6.028	6.135	6.132	6.219	6.308	6.522	6.320	6.222	6.074

TABLE B (Continued)—Fraser River sockeye salmon weekly average weights by cycles, four-year-old sockeye only (4_2).

1917 - 1957 CYCLE

YEAR	AREA	July 1 - 7	July 8 - 14	July 15 - 21	July 22 - 28	July 29 - Aug. 4	Aug. 5 - 11	Aug. 12 - 18	Aug. 19 - 25	Aug. 26 - Sept. 1	Season July 1 - Sept. 1
1917	Sooke Traps	5.055	5.480	5.615	5.500	5.488	5.843	5.308	5.495	5.445	5.470
1921	Sooke Traps	5.870	5.773	5.927	5.613	5.908	5.838	5.948	5.960	6.155	5.888
1925	Sooke Traps	5.768	5.518	5.307	5.738	5.882	5.518	6.062	5.970	6.035	5.755
1929	Sooke Traps	5.678	5.800	5.448	5.747	6.049	6.383	6.206	6.384	5.566	5.918
1933	Sooke Traps	5.306	5.323	5.245	5.113	5.316	5.599	5.544	5.682	5.755	5.431
1937	Sooke Traps	—	5.325	5.395	5.145	5.122	4.925	4.781	4.919	4.820	5.055
1941	U.S. Purse Seine	—	5.560	5.510	5.480	5.400	5.410	5.520	5.520	5.800	5.525
1945	U.S. Purse Seine	—	5.692	5.611	5.804	5.716	5.609	5.810	—	—	5.707
1949	U.S. Purse Seine	—	—	—	—	5.682	5.502	5.887	5.950	6.244	5.853
1953	U.S. Purse Seine	6.348	6.205	6.020	6.166	5.838	6.038	6.038	6.038	6.038	6.081
1957	U.S. Purse Seine	5.245	5.391	5.196	5.148	5.190	5.170	5.125	5.457	5.528	5.272
Averages		5.610	5.607	5.527	5.545	5.599	5.621	5.657	5.738	5.739	5.632

1918 - 1958 CYCLE

YEAR	AREA	July 1 - 7	July 8 - 14	July 15 - 21	July 22 - 28	July 29 - Aug. 4	Aug. 5 - 11	Aug. 12 - 18	Aug. 19 - 25	Aug. 26 - Sept. 1	Season July 1 - Sept. 1
1918	Sooke Traps	5.765	6.578	5.985	6.130	6.420	6.450	6.538	6.585	6.280	6.303
1922	—	—	—	—	—	—	—	—	—	—	(6.050)
1926	Sooke Traps	4.920	5.605	5.918	6.623	6.825	6.732	6.970	6.635	6.545	6.308
1930	Sooke Traps	5.163	5.988	6.278	6.345	6.968	6.925	7.190	7.025	7.232	6.568
1934	Sooke Traps	6.125		6.233	5.963		6.535	6.333	6.095	6.013	6.185
1938	Sooke Traps	5.410	—	—	6.420	6.555	7.205	7.108	7.013	7.102	6.688
1942	Sooke Traps	5.780	5.920	—	6.158	6.410	6.790	6.650	7.665	7.260	6.579
1946	U.S. Purse Seine	—	—	—	—	5.587	5.758	5.858	6.060	6.037	5.860
1950	U.S. Purse Seine	—	—	—	—	7.124	6.970	6.985	6.875	6.825	6.956
1954	U.S. Purse Seine	6.520	6.432	6.318	6.503	6.692	7.053	7.270	7.368	7.414	6.841
1958	Sooke & U.S. Purse Seine	5.270	5.440	5.685	5.525	6.025	6.125	6.515	6.260	6.505	5.928
Averages		5.619	5.994	6.070	6.208	6.512	6.543	6.742	6.758	6.721	6.388