The Skeena River Salmon Fishery, with Special Reference to Sockeye Salmon[1]

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ABSTRACT

The general history of the Skeena River commercial salmon fishery is presented from 1877 to 1948. The changes in fishing areas, seasons and fishing methods are described, together with the trends in the catches obtained. The most accurate data pertain to the important sockeye salmon gill-net fishery. The sockeye catch attained a maximum of 187,000 cases in 1910 and since then has declined to a minimum of 28,000 cases in 1933 and 1943. In recent years the catches have tended to level off. The pink salmon catches declined markedly after 1930. The chum catches also appear to have declined in recent years. Whether or not the spring and coho salmon catches have declined is not known. The size of the sockeye catch appears to be the best available measure of the relative size of the population. An analysis of the age cycles in the catch of sockeye and pink salmon did not reveal a practical basis for prediction. Some possible changes in the fishing regulations are discussed and the need for more data on the fluctuations in the size of the stocks during the fresh water phase is stressed.

INTRODUCTION

THE SALMON of the genus *Oncorhynchus* have long been an important source of food around the shores of the North Pacific Ocean. Before white settlement, they were used for food and barter by the Indians. Recent advances in fishing and handling methods have made them the natural resource for an important and highly developed industry.

The sockeye salmon (*O. nerka*) is the most valuable of the five species of Pacific salmon. It is concentrated in the large rivers that have suitable nursery lakes at their headwaters. In British Columbia the Skeena River is of intermediate rank, with a production of raw fish for canning worth about $2,000,000 annually. In addition, the whole benefit includes the value of the salmon handled fresh and frozen. This is hard to determine. Some of the fish are caught so far from the river in which they spawn that it is difficult to credit them to their proper destination.

The sockeye salmon constitutes about 30 per cent of the number and 50 per cent of the value of the salmon canned from the Skeena River fishery. Pink salmon (*O. gorbuscha*) is also important, but in recent years the catch has been greatly reduced. Spring (*O. tshawytscha*) and coho (*O. kisutch*) are prominent in the fresh and frozen trade. The chum salmon (*O. keta*) catch is small and of little importance in the Skeena River.

The records of the commercial fishery on the Skeena River provide the only available data on the fluctuations in these salmon populations. Since the fish are exploited assiduously near the river mouth during almost the whole of the relatively short migration period, the size of the catch should in general indicate the size of the population. Therefore from a study of the fluctuations in the commercial catch and in the intensity of the fishing effort it was hoped that an indication of the change in the stock could be obtained. Since the catches of both sockeye and pink salmon have appeared to fluctuate, the long-term trends and short-term cycles were also analysed to determine what changes may have occurred in these populations and whether our present knowledge is exact enough to provide useful predictions of future catches. The catches of the other three species of salmon, spring, coho and chum, are given but, owing to the varied

nature of these fisheries, the present state of the population which spawn in the Skeena River can not be clearly established.

The work reported here was a part of the Fisheries Research Board's five-year Skeena River Salmon Investigation, conducted in 1944–48. Statistics available through 1948 were used for the analysis of trends in catch and fishing effort, and the computations made from them have not been altered. At time of publication five more years' data have become available. However, to incorporate this period into the analysis would involve complete reworking of most of the computations, so it has seemed best to present the material substantially as it was available in 1948. More recent years will be reported in detail by the investigators now concerned with the Skeena fishery. The present paper makes only a few brief references to recent trends, at places where they seem to support or modify the interpretation of earlier information.

ACKNOWLEDGMENTS

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The officers of the Federal Department of Fisheries and the managers of the canneries on the Skeena River, namely Sunnyside, Cassiar, Carlisle, North Pacific, Inverness and Port Edward, have been most cooperative and helpful in making available past records.

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HISTORY OF THE FISHERY

Development of Canneries and Fresh-Fish Establishments

The first cannery on the Skeena River, Inverness, was built in 1877, in which year 3,000 cases of salmon were canned. The number of canneries increased to a maximum of fifteen operating between 1917 and 1920 and in 1926. Since the latter date the number has decreased. From 1944 to 1948 there were seven.

The first fresh-fish establishment was issued a licence in 1910, but it was not until 1914 that the Canadian Fish and Cold Storage plant was completed and the first frozen fish shipped east by rail. Since then the number of fresh-fish establishments has increased until at the present time there are ten operating, of which three have freezing and cold-storage facilities.

The number of plant licences issued from 1877 to 1948 is given in Table I.

The reduction in the number of canneries operating since 1926 was accompanied by a concentration of equipment in certain canneries with a consequent increase in efficiency and capacity. A comparison between the capacities of the twelve canneries operating in 1910 and the seven canneries operating in 1945

TABLE I. Number of licences issued to canneries and fresh fish establishments, 1877–1948. (Records are not available for all years prior to 1905.)

Year	Canneries[a]	Fresh fish establishments[b]	Year	Canneries[a]	Fresh fish establishments[b]
1877	1	..	1921	13	3
1878	2	..	1922	13	3
			1923	13	3
1883	5	..	1924	13	3
			1925	13	3
1885	2	..	1926	15	7
			1927	13	7
1890	7	..	1928	11	7
			1929	11	7
1895	7	..	1930	11	7
			1931	8	7
1900	10	..	1932	10	7
			1933	10	7
1905	12	..	1934	9	7
1906	14	..	1935	9	7
1907	13	..	1936	8	7
1908	13	..	1937	7	7
1909	12	..	1938	6	7
1910	12	1	1939	6	7
1911	12	1	1940	7	8
1912	12	1	1941	7	9
1913	13	1	1942	6	9
1914	13	2	1943	8	9
1915	13	2	1944	7	9
1916	14	2	1945	7	9
1917	15	2	1946	7	10
1918	15	2	1947	7	10
1919	15	2	1948	7	10
1920	15	3			

[a]From Annual Reports of Federal Department of Fisheries.
[b]From files of Federal Department of Fisheries, Prince Rupert.

indicated that in the latter period more than twice as many fish were handled and that each cannery processed more than three times as many fish as in the earlier period. In the face of the decline in parts of the Skeena River salmon catches, the increased amount which is now canned is only possible by an increase in the number of fish brought in from other areas.

TREND IN FISHING EFFORT

REGULATIONS REGARDING AREA

The *Skeena gill-net area*, described in the Special Fishery Regulations of B.C. (1949), is shown in Figure 1 bounded by double lines. Formerly the area extended farther upriver and not as far seaward. Thus, in 1910 the river boundaries were about 20 miles up the Skeena and 8 miles up the Ecstall River, in 1925 about 12 miles up the Skeena and 8 miles up the Ecstall and in 1935 about 9 miles up the Skeena and 3 miles up the Ecstall. The 1935 limits are the present

river boundaries for spring and coho fishing, but during the sockeye season the boundary is lowered by about 5 miles to extend between Mowitch and Veitch points. This prohibits fishing for sockeye in the Ecstall River. With the reduction of the river area in 1935 the ocean area was extended from a line running west of Ryan Point to one west of Finlayson Island. Thus the present Skeena gill-net

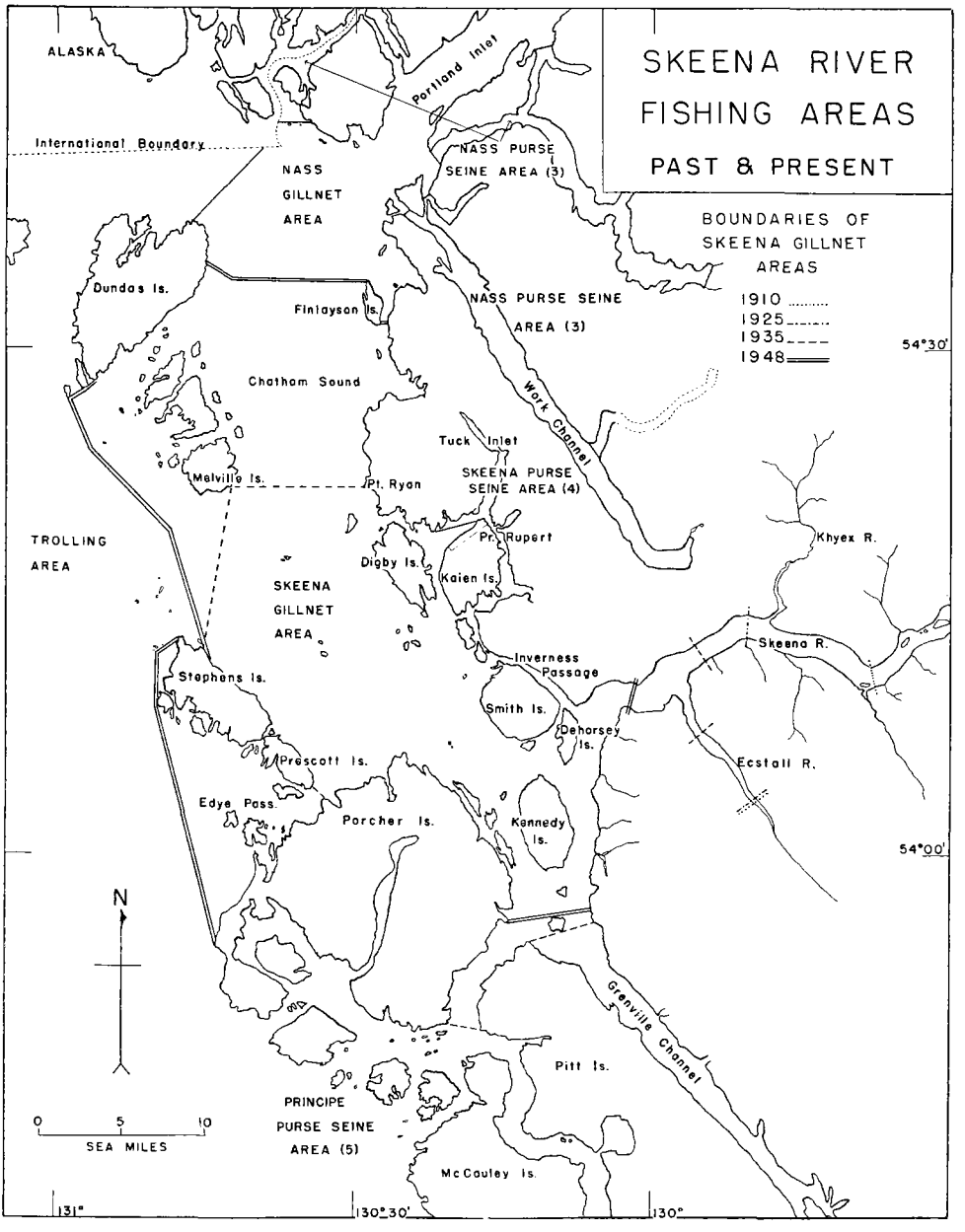

FIGURE 1. Map of Skeena River commercial salmon fishing areas—past and present.

area extends from the river boundaries to Porcher Island on the south, Finlayson and Dundas Islands on the north, and Stephens Island on the west. The above changes in fishing boundaries are also shown in Figure 1.

Within the Skeena gill-net area the majority of the sockeye fishing occurs in the river mouth, in Inverness Passage, west of Smith Island, in Edye Passage and off Finlayson Island. These fishing sites are of biological interest when related to the path of the freshwater runoff from the Skeena River (Cameron, 1948).

The neighbouring salmon fishing areas are also shown in Figure 1. The Nass gill-net area lies to the north. The closest purse-seine area to the Skeena River is Tuck Inlet, No. 4, which has not been fished in recent years. To the north, purse-seine area No. 3 is divided into five parts off the mouth of the Nass River. Area No. 5 lies to the south of the Skeena gill-net area. Trolling is permitted throughout the whole region but the major part is carried on outside Dundas, Stephens and Porcher Islands.

REGULATIONS REGARDING SEASON

Prior to 1935 the sockeye fishing season commenced on June 20. Since then the season has commenced on the last Sunday in June, which means that a variation of up to six days might exist in the actual starting date from year to year. The opening has been delayed in two instances owing to strikes. In 1932 fishing did not start until July 11 (Indian fishermen started July 3), a loss of fifteen days fishing, and in 1945 it did not start until July 1, a loss of seven days. The closing date is set each year by the Federal Department of Fisheries and has varied from August 13 to August 22. The opening and closing dates for sockeye salmon from 1931 to 1948 are listed in Table II.

TABLE II. Skeena sockeye fishing seasons, 1931–48.

Year	Opening date	Closing date	Year	Opening date	Closing date
1931	June 20	Aug. 21	1940	June 30	Aug. 16
1932	July 11	20	1941	29	22
1933	June 20	18	1942	28	21
1934	20	17	1943	27	20
1935	July 1	16	1944	25	18
1936	June 28	20	1945	July 1	17
1937	July 1	13	1946	June 30	16
1938	June 26	19	1947	29	15
1939	25	18	1948	27	20

No predetermined dates are set for the spring salmon gill-net fishery, which starts when the first spring net is used, usually in April, and ends when the migration is over in the latter part of July. The river boundary is moved downstream as soon as the sockeye season opens. The coho gill-net season opens 48 hours after the closing of the sockeye season and closes when the migration is over in the latter part of September. The river boundary is moved upriver for

the coho fishing one week after the closing of the sockeye season. The weekend closed period for gill-net fishing is from Friday at 6 p.m. to Sunday at 6 p.m.

REGULATIONS REGARDING GEAR

The regulations for gear require that a gill-net shall not exceed 200 fathoms in length and 50 meshes of uniform size in depth. There is no minimum limit for the mesh size of sockeye gill-nets. The mesh of other salmon gill-nets is not less than 6½ inches extension measure when in use. The nets must not be used so as to enclose any bay, cove, creek or inlet, and in all cases one-third of the width of any such channel shall remain open and unobstructed for the passage of fish. In commercial fishing no salmon weighing less than 3 pounds in the round (or 2½ pounds dressed) can be retained.

When the current regulations are compared with those laid down in 1894 only a few minor changes appear (Carrothers, 1941). For example, in 1894 the weekly closed period was from 6 a.m. Saturday to 6 p.m. Sunday, the spring salmon net mesh size was not less than 7¾ inches and the sockeye 5¾ inches, and the sockeye season was open from July 1 to August 25.

Operating Methods of the Gill-net Fishery

Salmon are caught by three types of gear, gill-net, purse-seine and troll. However for the Skeena salmon populations, particularly the sockeye salmon, the gill-net is the most important method and will now be treated in detail.

DESCRIPTION OF A GILL-NET

A gill-net is a long rectangular net of fine twine with a cork line along the upper edge and a lead line along the lower. The mesh sizes in use at present are 8½ to 9 inches for spring salmon, 6½ to 7 inches for coho salmon and 5½ to 5¾ inches for sockeye salmon. When set, the net forms a vertical barrier about 1,200 feet in length (200 fathoms) and 25 feet in depth in the path of the incoming fish, with only the cork line showing on the surface of the water. The size of mesh is large enough to allow a fish to thrust its head through but is small enough to prevent the body passing. When a fish hits the net, it either attempts to back up and so is caught by the gills, or it drives through and is firmly caught around the body ahead of the dorsal fin. The net is usually set at right angles to the direction of flow of the tide or current, and is allowed to drift with it. It is thus called a "drift-net".

CHANGES IN EFFICIENCY OF GEAR AND OF FISHERMEN

At the beginning of the century all gill-net boats on the Skeena River were equipped with sails and were towed to the fishing grounds by power-driven tugs. There were usually two men on each boat. Prior to 1924 it was unlawful to use boats other than those propelled by sails or oars for salmon gill-net fishing in the northern area of British Columbia. From 1924 to 1935 gasoline engines were installed in many of the old sail boats and new power-driven boats were built. Since 1942 no sail boats have operated on the Skeena River. The gill-net boats are about 30 feet long and powered by engines ranging from 10 to 110 h.p. In 1942 the power-driven "net-drum" came into general use for lifting

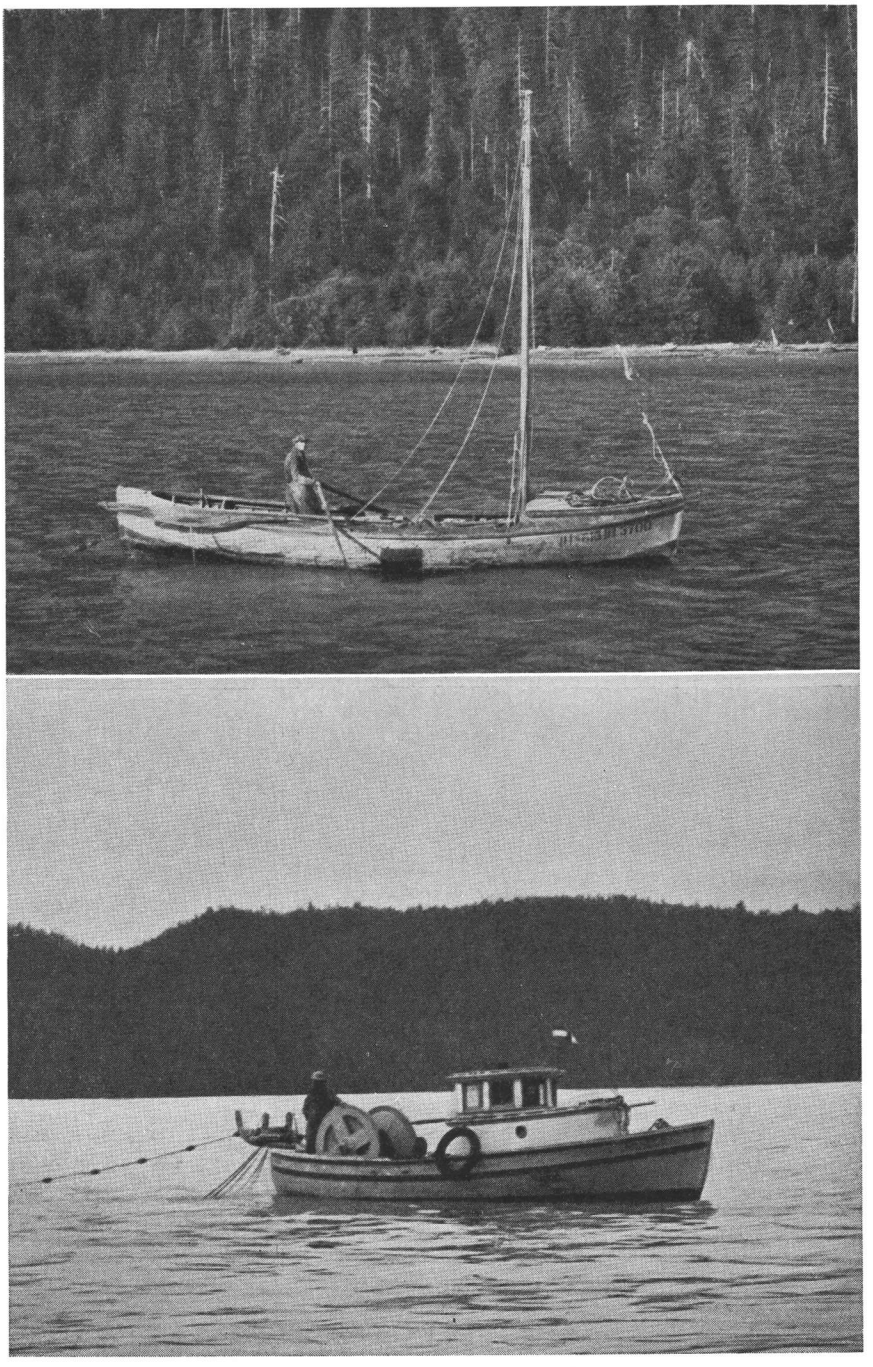

FIGURE 2. The old and new types of gill-net fishing boats. *Above*: sail boat; *below*: gasoline boat with drum.

the nets. The old and the new types of salmon gill-net boats are illustrated in Figure 2.

The number of gill-net boat licences issued each year for the Skeena area is given in Table III and presented in Figure 3. From the number of licences issued it appears that the effort increased up to 1919 and since 1933 has fallen off. The decline is probably associated with a reduction in the availability of fish and an increase in the efficiency of the gear.

The introduction of the gas boat in 1924 brought a change in fishing methods, in that the boats were able to move around faster and make more sets by doubling back and resetting in the most favourable locations. A comparison of the records available at one cannery shows a small increase in the catch of the gas boat over the sail boat. For example during the years 1930 to 1933 inclusive, 96 gas boats averaged 1,260 sockeye per boat per year while 41 sail boats averaged 1,163. The automatic "net-drum" speeded up the netting operations, with the result that as

TABLE III. Skeena gill-net boat licences issued from 1877 to 1948. (Figures are not available for all years prior to 1911.)

Year	Total[a]	Year	Total[a]	Japanese[b]	Gas boats[b]	Adjusted total[c]
1877	40	1922	1,091	642	...	1,321
1878	80	1923	900	578	...	1,101
...	...	1924	941	385	18	1,048
1883	160	1925	1,067	327	65	1,134
...	...	1926	1,129	295	75	1,184
1890	269	1927	1,195	295	162	1,253
...	...	1928	1,208	295	257	1,299
1900	448	1929	1,143	295	263	1,214
...	...	1930	1,202	295	637	1,301
1905	781	1931	1,076	295	607	1,184
1906	870	1932	1,119	295	760	1,237
1907	700	1933	1,218	295	669	1,318
1908	863	1934	1,164	295	740	1,276
...	...	1935	1,053	295	842	1,184
1911	850	1936	970	295	882	1,109
1912	850	1937	850	295	840	999
1913	850	1938	1,049	295	1,043	1,199
1914	850	1939	844	295	841	994
1915	962	1940	926	295	922	1,076
1916	868	1941	981	295	976	1,131
1917	788	1942	775	...	774	775
1918	889	1943	749	...	749	749
1919	1,153	1944	725	...	725	725
1920	954	1945	787	...	787	787
1921	1,109	1946	877	...	877	877
		1947	750	...	750	750
		1948	833	...	833	833

[a]From Annual Reports of Federal Department of Fisheries.
[b]From files of Federal Department of Fisheries, Prince Rupert.
[c]Total adjusted by rating gas boats 1.0, sail boats 0.9; and Japanese fishermen 1.5, Indian and White fishermen 1.0.

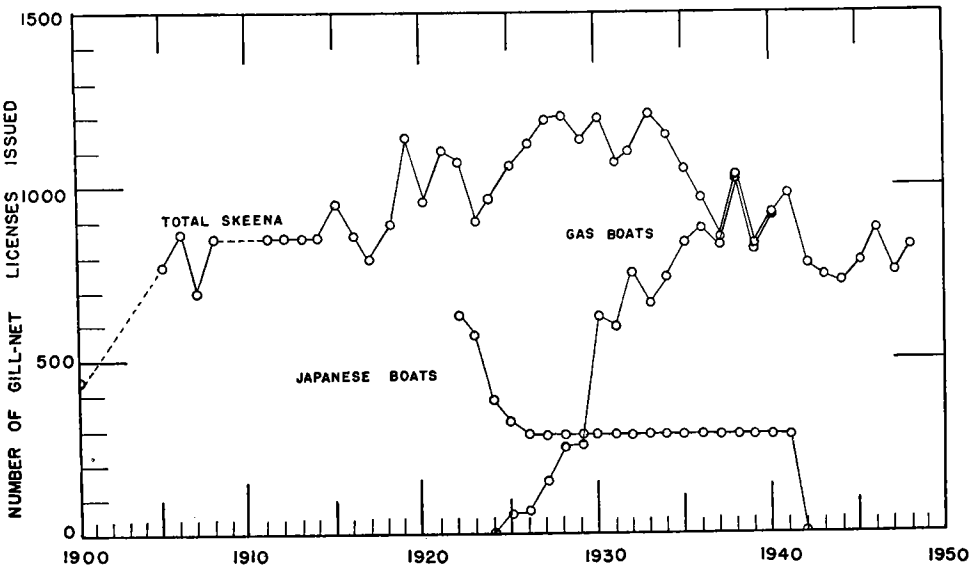

FIGURE 3. The total number of gill-net licences issued in the Skeena River area up to 1948, showing the introduction of the gasoline boats and the decrease in the Japanese boats.

many as four times the number of sets could be made in the same period of time. The result has been that more sets can now be made at each high and low tide with a great reduction in manual labour.

A comparison of the catches of the three groups of fishermen, namely, Japanese, Indian and White, indicates that during the period 1930–36 the Japanese, who comprised about one-third of the fishermen of a cannery fleet, caught about twice as many sockeye per boat per year as either the Whites or the Indians. This difference in efficiency was reduced when the latter two groups of fishermen acquired and learned to operate the new gasoline boats. Thus a similar comparison for the years 1937–41 shows that the Japanese caught only 1.4 times as many fish as the Whites or the Indians.

To accomplish this greater catch the Japanese fished from 2 to 10 days longer and caught from 300 to 900 more fish per season. Since their daily catch was 5 to 8 fish higher, they probably also fished longer each day. From 1922 to 1926 the number of Japanese licences gradually decreased from over 600 to less than 300. The emigration of the Japanese fishermen from coastal areas in 1941 lowered the fishing intensity during 1942 and 1943 while new Indian fishermen were being recruited. This partly accounts for the extremely low catches in these two years.

SELECTIVITY OF THE GILL-NET FISHERY

The gill-net fishery is selective for size of fish, both because of the uniformity of mesh size and because of the time of the fishing in relation to the progress of the run. This results in the commercial sockeye catch or any samples taken from

it being unrepresentative of either the total population or of the spawning escapement as regards size, age and sex.

A study of age and sex distribution of the sockeye salmon catch for the years 1926 to 1940 (Withler, 1945) has shown that the percentage of the 4_2 age-group[2] (particularly the females) increases throughout the fishing season while that of the 5_2's (particularly the males) decreases, with the result that the females comprise an increasing proportion of the catch. This is because the males of each group migrate earlier than the females, and the older age-groups precede the younger ones. In sockeye salmon the males tend to mature at a younger age than the females, with the result that there is a higher proportion of females in the older age-groups (5's and 4's), whereas the 3-year-olds are almost all males. These small precocious males, less than 19 inches in length, are usually called "jacks" and are not normally caught in the gill-nets, but show up on the spawning grounds as "runts".

In the Skeena fishery the commercial sockeye catch has always contained more females than males in the 5_2 age-group (Clemens, 1950). During the period from 1915 to 1935, when the season opened on June 20, the average percentage of females was 56. From 1936 to 1948, when the opening date was the last Sunday in June, the average percentage was 63. Apparently more males than females run prior to the opening of the fishing season. In the case of the 4_2 age-group, which runs later, the males averaged 53 per cent of the catch from 1915 to 1929, at which time the mesh size was reduced so that the smaller females might be caught. Since then, from 1930 to 1948, the average for males has dropped to 43 per cent. The jacks appear to run later in the season than the other groups.

The selective action of the fishery was most striking in 1947, when a large proportion of the spawning population was jacks. Scale samples taken from sockeye caught by the commercial fishery, using gill-nets with a mesh size of 5¾ inches, contained only 6 jacks in 1,365 fish, or 0.3 per cent. Females made up 66 per cent of these samples. The number of jacks caught by the tagging boat, up to July 27, using a purse-seine with a mesh size of 3½ inches, was 360 out of 2,328 or 15 per cent. Since the percentage of jacks was increasing as the season progressed, the tagging boat would probably have taken a greater number of jacks if fishing had continued until August 15. When the fish passed upriver the number of jacks in the escapement was high. At Moricetown Falls, where most of the jacks are in the 4_3 age-group, it was estimated that they comprised about one-quarter of the run and at the Babine River counting fence, where most of the jacks are of the 3_2 age-group, they made up 50 per cent of the total count.

To judge from smaller samples of pink and chum salmon taken from the gill-net fishery from 1946 to 1948, the effect of selection was apparently the reverse of that for sockeye. In pink salmon the selection of males was particularly high, probably because of their shape and large size. The maturing male develops a pronounced hump on the back and a long hooked nose, which are

[2]A fish of the 4_2 age-group is one that went to sea early in its second year and returned to spawn in its fourth year.

absent in the female. The samples in 1946 contained 90 per cent males; in 1947 it was 75 per cent and in 1948, 65 per cent. In the case of chum salmon the percentage of males ranged from 50 to 75. For both spring and coho salmon the sex ratio in these samples was approximately equal, but many jacks are observed in the spawning streams.

EFFECTS OF WEATHER

Fishermen believe that the weather affects sockeye salmon in the following manner: southeasterly winds, bringing rain and storms, drive the fish deeper, where they are either caught near the lead line or miss the net altogether. Westerly winds, bringing good weather, cause the fish to leap at the surface where they are caught near the cork line. In bright weather it was found advantageous to camouflage the nets, with the result that they are now all dyed green.

The records of one cannery for 1943–46 were examined to check the effect of weather on fishing. These records gave the average number of fish per boat per day and type of weather on the fishing grounds. It was noted that in general the best fishing was on bright days and that a continued period of rainy weather resulted in low catches. One week of bad weather at the peak of the season in 1945 was particularly striking in this regard. When the catch data are split into high, medium and low catches, and the weather records into rainy, dull and bright days it is evident that the bright and dull days yield about equal catches, which are higher than those of rainy days. This difference was statistically significant by the chi-square test and could be expected to occur only three times in 100 by chance alone. However, whether rainy days affect the movements of the fish or the effort of the fishermen is still an open question. That weather is only one of the factors affecting the catch is demonstrated by a comparison of the catches in 1943 and 1946. The 1946 season had about twice the rainfall of 1943, yet produced almost twice the catch.

INDEX OF EFFORT

In general, during the salmon migration every opportunity is taken to catch as many fish as possible while the season lasts and the fishing effort tends to fluctuate with the abundance of the population. The success of the sockeye catch largely determines the fishing effort directed toward the other species. For example, during the large sockeye run in 1945 the boats fished the Skeena River relentlessly; despite a strike of a week's duration at the start of the season, about 40 per cent more boat-days were fished than in 1947 when the run was small. In the latter year many boats moved off to fish other areas such as the Nass River and Rivers Inlet. In 1945 there was also a large run of pinks, but the effort directed to catch them was proportionately less than in 1947 when both the sockeye and pink salmon runs were small. Over longer periods such economic factors as the depression of the 1930's and the boom of two world wars have affected the fishing effort. Thus, it is impossible to obtain, on the basis of the data available, a true index for effort over the years. Such an index would have

to consider, among other factors, the number of boat-days of fishing, the changes in efficiency of gear and fishermen, and the changes in the fishing areas for each year. The total number of licences is the only information available which has some comparative value. In Table III adjusted totals are presented to indicate the changes due to differences in efficiency of gear and fishermen.

TRENDS IN TOTAL CATCH

Methods of Collecting and Validity of the Catch Data

The Federal Department of Fisheries has obtained catch statistics by various means. Prior to 1938 the Fisheries inspectors collected all the data. Since then each cannery has reported the catch to the Prince Rupert Fisheries office on both monthly and annual forms. All weekly pack figures were sent to the Chief Supervisor of Fisheries in Vancouver and the records of the combined Nass and Skeena pack appeared weekly in the British Columbia Canned Salmon Pack Bulletin. The monthly statistical report, showing a break-down of the catch from the Skeena River of both canned salmon and that marketed fresh, frozen or mild-cured, was the only form which gave complete data on the Skeena catch. Starting in 1947 this form was virtually abandoned and replaced by one from the Bureau of Statistics which records the total pack and by-products in hundredweights for each firm but in which the catch for the Skeena area is not separated out. The annual schedule, which was forwarded directly to the Vancouver office, was the basis for the Skeena catch figures published by the Federal Fisheries Department in their annual report. Unfortunately these forms do not cover the salmon which are handled fresh. The Provincial Fisheries Department also publishes an annual return of the salmon canned from each area. The multiple-sales slip method recommended by Dr. G. L. Burton (1949) was instituted on the Skeena River in 1950, so at the present time the total number of salmon of each species caught in each area is available regardless of how and where they are later processed.

The problem of allocating the salmon to the area in which they are caught rather than to the one where they are processed is a complicated one. Prior to 1924 the few salmon caught outside the Skeena area were not separated from the total Skeena pack. The Skeena-caught fish have always been packed on the Skeena, but since 1924 many fish have been brought in from other areas and packed in the Skeena River area. Thus the number of cases recorded as *packed* in this area prior to 1924 is considered to be more comparable to the number of cases of salmon recorded as *caught* since that date.

For sockeye salmon, care is taken to separate the catch from the pack as accurately as possible. For the other species of salmon, less care is taken and usually an approximate breakdown suffices. It is difficult to separate Skeena fish from those taken in the Nass River fishery. Fish tagged in each area have later been caught in the other. In the 1944–48 tagging experiments, only one per cent of the sockeye salmon tagged off the Skeena mouth were returned from the Nass area, but from 10 to 20 per cent of those tagged at Steamer Passage in the Nass area were taken at the mouth of the Skeena River.

Up to the early 1930's the Nass salmon catch was packed at four canneries on the river itself. With the gradual closing of these canneries from 1936 to 1945 an increased number of Nass fish have been canned on the Skeena, making it more difficult to keep the Nass and Skeena River catches separate. Many fishermen consider that sockeye salmon which are caught around Finlayson Island are bound for the Skeena River and the small amount of tagging in this area appears to bear this out, but there is no general agreement among the canneries on dividing of these fish between Nass and Skeena catches. Prior to 1935 when an eight-mile closed area from Point Ryan to Finlayson Island existed between the Nass and Skeena fishing areas, the catches could be kept separate. In recent years, fish allotted to the Nass catch are those caught in Portland Inlet or in the mouth of the Nass River itself. The Nass River catch of sockeye salmon is about one-third the size of the Skeena catch.

Age determinations of sockeye salmon recorded since 1912 (Clemens, 1950) indicate that the Nass and Skeena River catches differ in age composition. The Skeena fish are predominately of the two age-groups 4_2 (48 per cent) and 5_2 (40 per cent) whereas 65 per cent of the Nass fish are 5_3's. The Nass fish, besides differing in age, are also larger than Skeena fish. For example, the 5_3 fish from the Nass average two inches longer and one pound heavier than 5_3 fish from the Skeena. Although the fluctuations in the catches of the two river systems appear to have many features in common, marked exceptions occurred in 1940 and 1945 when the Skeena catches were high and the Nass catches were low. In 1940 the large Skeena catch was due to a large 4_2 age-class and in 1945 to a large 5_2 age-class while the failure in these years of the Nass catches was due to the small numbers in the dominant age-group, the 5_3's.

The catch figures published in the Annual Reports of the Federal Department of Fisheries will be used to evaluate the trend in the fishery, but it must be noted that they include canned salmon only, and even here there are uncertainties as to the true catch. The following two examples will suffice to indicate the difficulties involved.

(1) The sockeye catches published in the annual reports of the Federal and Provincial Fisheries Departments differ in certain years, particularly prior to 1933. In more recent years the low catch in 1942 is reported as 29,976 cases by the Federal Department and 34,544 cases by the Provincial Department. The reason appears to be in the distinction drawn between the Skeena catch and pack.

(2) A comparison of the total cases from the monthly records of the canneries and the annual Skeena catch figures for each species in 1946 follows:

	Sockeye	*Pink*	*Coho*	*Chum*	*Spring (red)*	*Spring (white)*
Monthly totals	52,650	10,614	16,093	18,859	1,122	462
Annual	52,928	10,737	26,281	11,161	2,029	410

The sockeye and pink salmon, which are largely canned, show smaller discrepancies than the other species. Many of the errors arise from the fact that the fish are transferred so often that the bookkeepers who compile the returns cannot always determine the area of capture from the cannery records.

Although a check was made on the accuracy of the catch figures during 1946–48, no successful attempt was made to collect entirely accurate figures for any one year. For our purpose, however, absolute accuracy is not required, and for sockeye and pinks at least the data give a useful picture of the relative Skeena catch from year to year.

FLUCTUATIONS IN THE CATCH FIGURES FOR EACH SPECIES, 1904–48.

The number of cases of each species of salmon *packed* on the Skeena from 1904 to 1948, and the number of cases *caught* from 1925 to 1948 as published in the annual reports of the Federal Department of Fisheries, are presented in Table IV. It should be recalled that the catch of the salmon populations spawning

TABLE IV. The pack and catch of canned salmon (in number of cases) for the Skeena river, 1904–1948, as published in the Annual Reports of the Federal Department of Fisheries. (C: *catch*—Pack of fish caught at Skeena regardless of where canned. P: *pack*—Pack at Skeena regardless of where caught.)

Year		Sockeye	Pink	Coho	Chum	Spring (white)	Spring (red)	Spring (pink & jack)
1904		93,404	30,529?	10,315	...	...	20,261	...
1905		84,717	7,523?	7,247	...	...	14,598	...
1906		86,394	...	16,867	...	...	20,138	...
1907		108,413	...	15,247	...	...	10,378	...
1908		139,846	...	10,075	...	...	13,374	...
1909		87,901	...	11,249	...	742	11,727	...
1910		187,246	13,423	11,531	...	239	9,546	...
1911		131,066	81,956	23,376	70	2,428	15,514	...
1912		92,498	97,588	39,835	504	4,501	19,322	...
1913		52,927	66,045	18,647	...	3,186	23,215	...
1914		130,166	71,021	16,378	8,329	211	11,529	...
1915		116,553	107,578	32,190	5,769	204	15,069	...
1916		60,923	73,029	47,409	17,721	2,561	18,272	...
1917		65,760	148,319	38,456	21,516	2,699	13,586	...
1918		123,322	161,727	38,759	22,573	6,828	16,013	...
1919		184,945	117,303	36,559	31,457	2,656	19,651	3,624
1920		90,869	177,679	18,068	3,834	3,123	37,403	2,198
1921		40,018	124,457	45,033	1,993	445	18,599	2,722
1922		100,615	203,555	24,673	17,668	1,805	7,080	5,591
1923		131,731	145,973	31,967	16,527	499	8,863	2,885
1924		144,732	181,338	26,907	25,603	1,301	9,511	1,361
1925	C	77,785	127,226	38,029	10,687	2,457	17,811	1,657
	P	81,149	130,083	39,168	74,308	2,603	19,185	1,657
1926	C	82,307	170,586	30,153	46,382	1,750	17,896	966
	P	82,337	210,064	30,209	63,527	1,750	17,896	966
1927	C	83,988	38,903	25,209	9,656	1,609	13,595	1,609
	P	83,984	38,761	25,623	18,659	1,609	14,856	3,567
1928	C	34,524	191,812	18,751	11,792	397	4,121	988
	P	34,559	209,579	30,194	17,751	354	5,043	988
1929	C	77,714	94,846	37,138	3,625	383	3,795	441
	P	78,014	95,305	37,456	4,835	383	3,795	441

TABLE IV (*cont'd.*)

Year		Sockeye	Pink	Coho	Chum	Spring (white)	Spring (red)	Spring (pink & jack)
1930	C	130,952	214,266	24,191	3,327	322	6,589	1,047
	P	132,372	275,642	29,203	5,057	324	6,674	1,047
1931	C	93,029	44,807	10,737	3,610	534	7,040	2,284
	P	107,936	41,264	20,146	3,893	534	7,040	2,284
1932	C	52,624	32,519	20,549	28,756	2,472	14,268	9,419
	P	59,916	58,261	48,312	38,549	2,472	16,378	9,419
1933	C	27,693	79,932	21,366	10,970	828	6,805	444
	P	30,506	95,783	39,896	15,714	227	2,626	444
1934	C	54,558	27,628	21,298	6,242	860	6,809	592
	P	70,654	125,163	54,470	24,388	860	6,844	492
1935	C	52,879	81,868	8,122	23,498	188	3,422	429
	P	64,140	99,412	45,512	31,807	188	3,443	429
1936	C	81,960	92,997	32,142	15,343	356	3,781	414
	P	97,823	178,299	55,198	36,892	435	4,883	455
1937	C	41,023	57,623	14,573	10,027	315	3,704	382
	P	55,811	72,455	34,502	37,431	315	3,788	382
1938	C	46,988	69,299	38,542	14,668	259	2,916	1,141
	P	73,580	146,676	100,658	34,785	259	3,361	1,165
1939	C	68,388	91,559	27,115	6,360	336	3,124	1,396
	P	96,358	127,521	48,973	15,666	348	3,277	1,488
1940	C	116,505	46,687	19,196	4,684	396	4,708	1,017
	P	133,854	91,612	62,516	62,114	571	5,884	1,113
1941	C	81,183	51,389	45,891	12,138	368	3,929	641
	P	110,544	73,896	126,557	54,357	448	4,695	703
1942	C	29,976	47,819	36,396	10,611	617	5,305	699
	P	57,539	146,322	70,385	31,481	832	5,850	874
1943	C	28,259	53,203	40,281	6,408	379	964	441
	P	51,476	122,040	63,639	57,580	623	1,443	839
1944	C	67,855	45,833	18,810	7,173	193	899	468
	P	92,203	190,872	38,160	87,072	289	1,176	664
1945	C	103,940	69,149	33,673	9,121	363	1,208	785
	P	117,860	211,140	51,905	44,104	389	1,324	827
1946	C	52,928	10,737	26,282	11,161	410	1,591	438
	P	72,319	50,799	38,534	81,633	551	1,864	579
1947	C	32,511	13,184	12,766	8,224	414	1,376	326
	P	65,429	47,831	35,522	87,476	531	1,688	398
1948	C	101,268	50,656	16,133	11,863	593	3,133	99
	P	121,699	153,213	41,146	108,622	764	3,824	143

in the Skeena is probably best represented by the *pack* figures up to 1924 and the *catch* figures after that date.

SOCKEYE SALMON

Since most sockeye are eventually canned the number of cases given in Table IV and Figure 4 represents the relative catch from year to year. In such a competitive fishery, where probably half of a limited population is caught within

a short period during the spawning run, the effort is markedly regulated by the size of the catch, both within and between seasons. Moreover, since a precise index of effort is not available, the commercial catch alone provides the most adequate index of relative population size. No doubt the magnitude of the fluctuations in the catch is less than in the total population but since accurate estimates of the escapements are not available the absolute sizes of the populations are unknown.

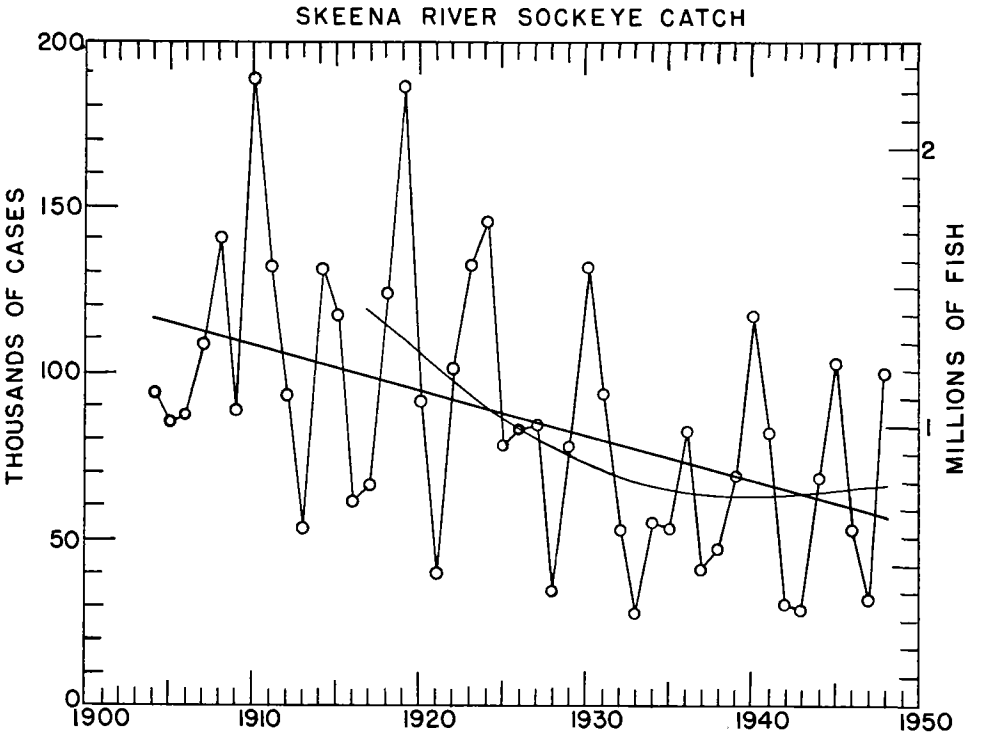

FIGURE 4. The catch of sockeye salmon from the Skeena River area, 1904–48. The heavy trend lines were fitted by a straight line (1904–48) and by a second degree polynomial, 1917–48.

Prior to the turn of the century the catches increased with the development of the fishery, until in 1910 a peak of over 185,000 cases was reached. The over-all trend line indicates a general decline of about 50 per cent or an average decrease of 1,300 cases per annum. The shorter trend line, computed since 1917 when detailed age determinations were started, indicates a period of gradual decline in the catches prior to about 1935 and a period of levelling off since then. It should be noted that it was during this period of decline that the number of Japanese licences decreased (1923–26) and the river boundaries were lowered (1925 and 1935). The concurrent trends in effort will be discussed in a later section.

Although the fluctuations of the Skeena sockeye catch are large and irregular, varying as much as fourfold from one year to another, with peaks from two to six years apart, it is apparent that there has been a marked decline since 1910, with a tendency to level off in recent years.

PINK SALMON

Over 90 per cent of the pink salmon in this area are canned; the few which are handled fresh are used either as fillets or bait. The effort devoted to the catch of Skeena pinks varies from year to year in that it is affected by the size of the sockeye catch made earlier in the same year. Because the majority of the pink salmon packed on the Skeena in recent years have been brought in from other areas, the figures for pink salmon caught on the Skeena are much less reliable than those for sockeye.

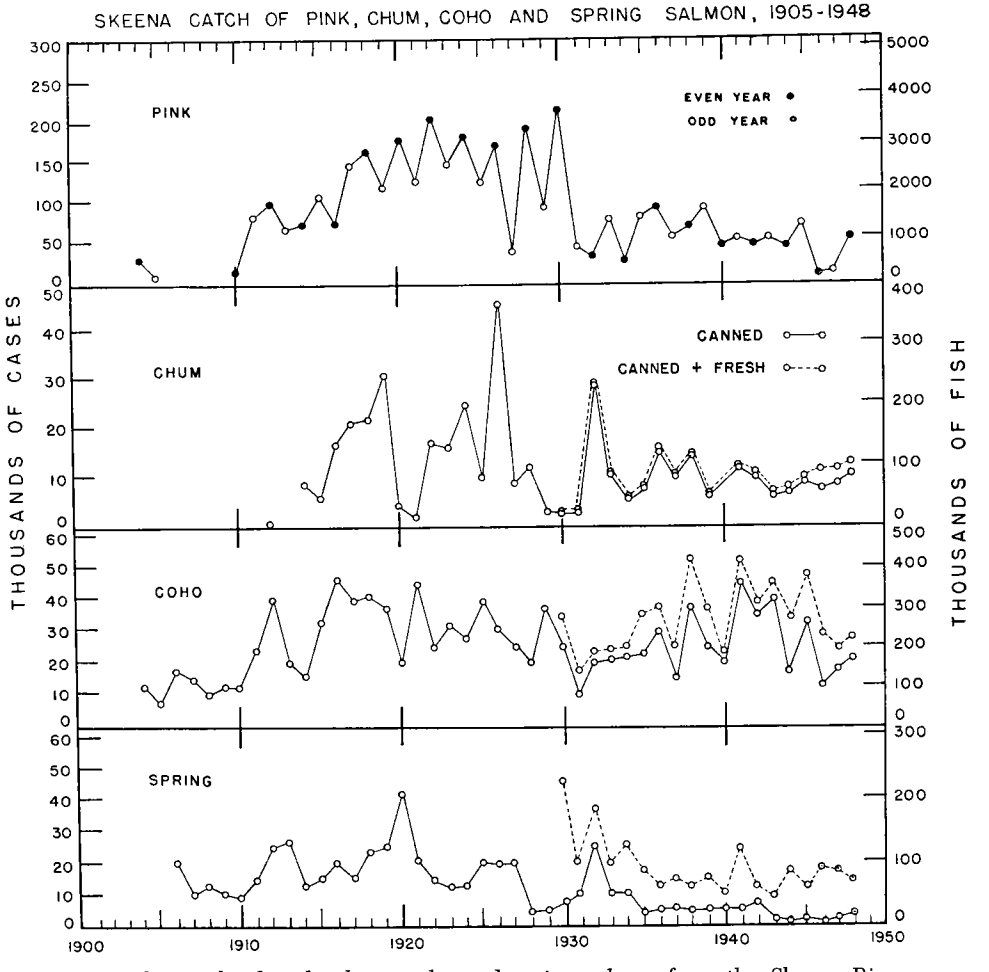

FIGURE 5. The catch of pink, chum, coho and spring salmon from the Skeena River area, indicating the proportion used by the fresh fish and canning industries.

With these reservations, the catch figures for Skeena pink salmon, presented in Table IV, are shown in Figure 5 in order to portray the general trend for this species. The pink salmon fishery commenced prior to 1910 and reached a peak catch from 1920 to 1930, during which period the even year population was the larger one. Since these fish all mature at two years of age, two separate populations are present in the odd and even years. The large even-year run of 1930 failed to repeat itself in 1932. The same thing happened in that year to catches from other northern British Columbia districts, and probably the cause was the same in all cases. Since 1930 the catch of this cycle has been greatly reduced, with the catch in the even years often smaller than that in the odd years. The catches made in 1946 and 1947 were record lows for both cycles.

CHUM, COHO AND SPRING SALMON

A large proportion of chum, coho and spring salmon is handled fresh, so it was necessary to determine these quantities and add them to the quantity canned. Data on fresh fish were supplied by the Prince Rupert office of the Federal Department of Fisheries. Care was taken to separate the Skeena catch from the Skeena pack as effectively as possible. To convert number of cases and hundredweights of salmon into numbers of fish, the values in Table V were used.

TABLE V. Average weight per fish and number of fish per case for Skeena river salmon. (Approximately 72 pounds of raw fish are required to make a 48-pound case of canned salmon.)

Species	Pounds per fish	Fish per case
Sockeye	6	12
Pink	4	18
Chum	9	8
Coho	9	8
Red spring	12	6
White spring	18	4
Jack spring	4	18

The best estimates of the number of Skeena-caught fish which are handled fresh are presented in Table VI. The total catches of chum, coho and spring salmon are shown in Figure 5, based on Table IV (the number of cases canned) and Table VI (the numbers of fish handled fresh).

Most of the *chum salmon* are canned. The chum salmon catch fluctuated greatly from the start of the fishery, about 1915, down to the year 1932. Since 1932 it has remained more uniform, but it has never been as important as that of any of the other species.

Since 1904 the *coho salmon* catch has increased steadily, with the largest catches recorded in 1938 and 1941. In recent years the fresh-fish houses have handled more of the fish, between 25 and 60 per cent of the catch. Because they are captured by trolling far out in the ocean, it is impossible to obtain a true picture of the Skeena coho population from the Skeena catch figures alone.

As in the case of coho salmon, it is difficult to obtain a true picture of the Skeena population of *spring salmon,* for in recent years the fresh-fish industry has

TABLE VI. Skeena catch handled fresh, 1930–1948, in thousands of fish. (The method of estimation was different for the years 1930–1940 and 1941–1948.)

Year	Sockeye	Pink	Coho	Chum	Spring
1930	...	...	87	5	150
1931	...	...	60	15	36
1932	...	12	22	15	34
1933	...	...	22	10	38
1934	...	12	22	5	64
1935	...	25	100	15	48
1936	...	...	55	...	23
1937	...	12	105	10	30
1938	...	25	120	5	30
1939	...	50	105	5	40
1940	...	35	28	5	16
1941	1	35	54	...	96
1942	...	37	23	2	23
1943	1	20	45	2	38
1944	3	68	134	7	76
1945	2	118	105	8	49
1946	4	21	106	26	78
1947	1	7	67	22	70
1948	...	70	92	13	57

handled from 60 to 90 per cent of the fish. The exceptional number handled fresh in 1930 was probably composed of a large number of spring salmon from rivers other than the Skeena. The percentage mild-cured varies from 1 to 25, while that canned varies from 5 to 30. From 5 to 30 per cent of the spring salmon caught have white flesh and are marketed at a reduced price.

DETAILED TRENDS IN THE CATCH AND EFFORT FOR SOCKEYE SALMON, 1935–48

Lacking detailed data for the total Skeena sockeye catch and effort, data were used from a group of fishermen for which daily records were available back to 1935. The catch and effort data of this sample (Fig. 6) when compared to that of the whole fishery (Fig. 3, 4) indicate that the sample, which comprises about one quarter of the total fishery, is fairly representative of the fishery.

In considering the data summarized in Figure 6 it should be noted that, up to 1941, about 50 per cent of the fishermen were Japanese. The Japanese fished a longer season (2 to 4 days more than the Indians and 2 to 9 days more than the Whites); they also must have fished longer hours or more effectively each day, since the average daily catch from 1935 to 1941 (Fig. 6C) is 37 for the Japanese and 29 for both the White and Indian fishermen. During this same period the Japanese caught an average of 1,378 sockeye per season, the Indians 1,023 and the Whites 922. Since the withdrawal of the Japanese in 1941 the intensity of the fishing effort (Fig. 6B) and the number of fish caught (Fig. 6A) have been lower. If the Japanese had continued fishing, the total catch and effort after 1941 would no doubt have been higher. The fact that the Indians and

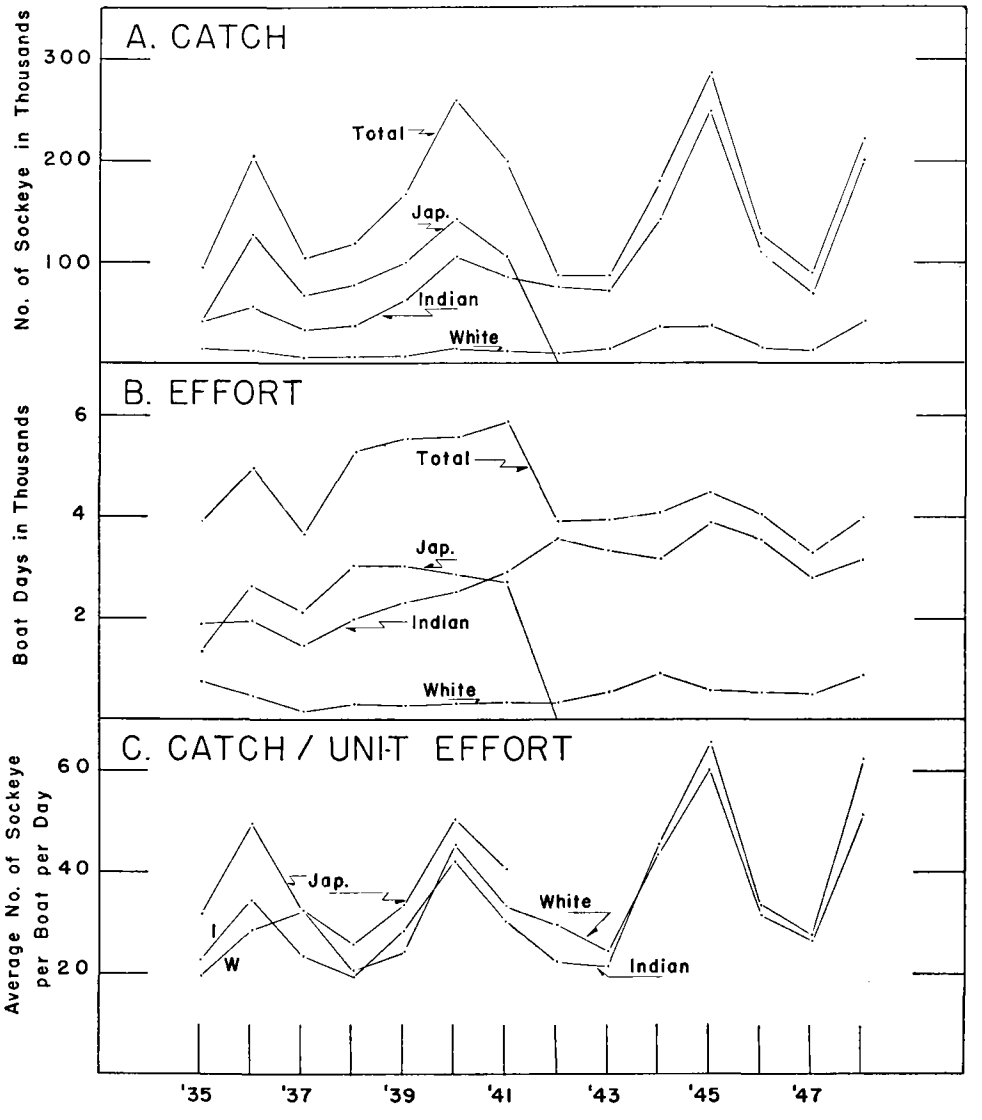

FIGURE 6. Catch (A), effort (B) and catch per unit effort (C) for a sample of the fishermen in the sockeye salmon fishery.

Whites only partially replaced the fishing effort of the Japanese after 1941 must account in part for the extremely low catches in 1942 and 1943.

Only power boats are involved in the sample. The net-drum, which was introduced in 1942 after the Japanese left, was in general use by 1944. When all factors which might affect the fishing are considered, it appears that the catches and catches per unit effort for the period were at least maintaining themselves with peaks four, five and three years apart. The catch in 1945 would have been

larger if there had not been a strike at the beginning of the season. Therefore we might infer from the sample data that the sockeye population, although fluctuating widely, has not been trending downward during the last 14 years.

The weekly number of fish caught by the sample group is shown cumulatively in Figure 7. These data indicate that the run is under way when the fishing season starts but is virtually over when the fishing season is closed around the middle of August. Prior to July 10 the fishing fleet is not at full strength and after August 10 the effort falls off rapidly. Over the years the heavier exploitation during the latter half of the season may have had some effect on the relative size of the runs to the various tributaries.

There is considerable variation in the catch from week to week (Fig. 7).

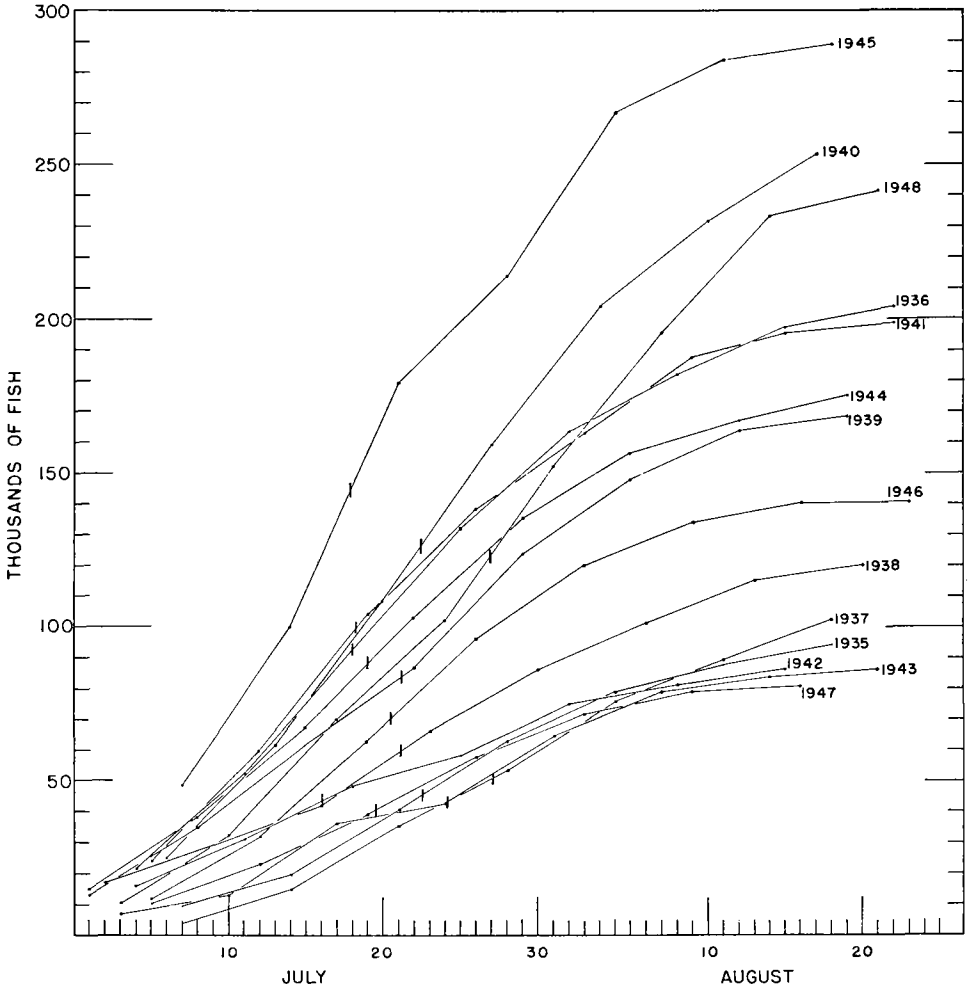

FIGURE 7. Seasonal occurrence of the Skeena sockeye run, 1935 to 1948, based on the cumulative weekly catches from a sample group. Vertical lines mark 50 percentile points.

This is sometimes due to weather conditions adversely affecting the fishing and at other times due to fluctuations in the size of the run. Thus, analysis of the first few weeks of fishing provides only a general prediction of the ultimate size of the run in progress. The catch during 1948 was most aberrant in this respect. The time at which 50 per cent of the catch in each year was taken (Fig. 7) has varied from July 16 to July 27. The exceptionally large catches toward the end of the season in 1948 were associated in part with the abnormal weather conditions, which caused great floods and hence poor fishing in the early part of the season, and in part to the occurrence of a large proportion of 4_2 fish, which tend to come later than the 5_2's.

General Trends in the Catch and Effort for Sockeye Salmon, 1904–48

The number of gill-net licences issued each year have been presented in Table III and Figure 3. It has been noted previously that these data do not represent the true fishing effort each year, but for the following discussion they should adequately represent the general trends in the effort.

The sockeye catch figures, Table IV and Figure 4, represent the commercial exploitation with reasonable accuracy. In general the size of the catch tends to regulate the intensity of the effort both within and between seasons, because it is economically unsound to continue operations unless a profitable catch per unit of effort is achieved. Thus, within limits, a balance between the catch and effort is maintained.

To consider the general history of the fishery, when fishery started in 1877 there existed a large population of sockeye salmon in a natural state. The rate of mortality through physical and biological causes would be in balance with the rate of increase through reproduction. With the fishery acting as a predator, the size of the population would drop, the survival rates would increase to counteract this new drain and the size of the population would tend to reach a balance at new levels. Prior to 1900 the total catch increased with the increase in fishing effort. Following this early period of exploitation and underfishing for which detailed records are not available, the catch reached a peak around 1910 and started to decrease gradually. The effort continued to increase until the period 1925–30 when it was maintained at an average level of over 1,100 gill-net boats. Much of this fleet operated in the river above the present fishing boundaries. During this period of high effort the total catch dropped off at a faster rate than formerly. If overfishing is defined as the condition of a fishery in which the more you fish the less you catch, then it was during this period that overfishing was occurring. Since about 1935 the effort has gradually decreased for economic reasons and as a result of restrictive regulations, and the catch has tended to level off. Recent catches from 1948 to 1952 suggest the commencement of a period of increase in catch. However, when the catches obtained by 800 gasoline boats in recent years are compared to the catches of twice the size made around 1910 by 800 sail boats, it is clear that a great change has taken place in the size of the sockeye population. It is difficult to determine the number of fishing units by which the maximum steady yield would be maintained, but it is at some intermediate level between these two periods.

In Figure 8 the data of catch and effort have been smoothed by a moving average of five years to indicate these general trends. The catch appears to fluctuate more than the effort. At present the keen competition in fishing a limited population with efficient gear is being restricted by law and for economic reasons. If the adverse factors which have been or are affecting the natural survival are alleviated as much as possible, the size of the population should increase somewhat from its present level.

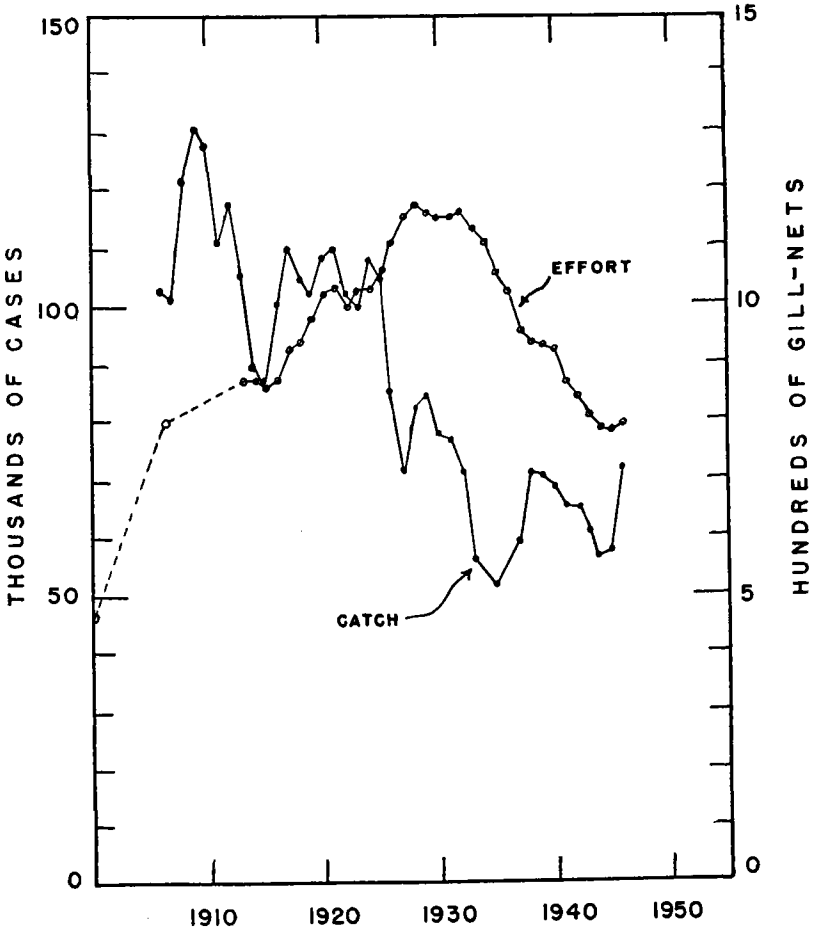

FIGURE 8. The catch and effort in the Skeena River sockeye salmon fishery based on data in Tables III and IV smoothed by a moving average of 5 years.

CYCLES IN THE CATCH AS A POSSIBLE BASIS FOR PREDICTION

SOCKEYE SALMON

The Skeena River sockeye catch (Fig. 4) has been shown to fluctuate about a gradually decreasing trend line with peaks 2 to 6 years apart. For successful prediction an understanding of these short-term cycles in the catch is essential.

The fluctuations are the result of many factors which affect the size and age composition of the spawning escapement and the subsequent survival of the young salmon in both the fresh and salt water stages. Precise data on these topics are not available. Fortunately the age composition of the sockeye catch has been obtained since 1912 (Clemens, 1950), and a study of the age-classes may throw some light on the fluctuations in the catch.

TABLE VII. The percentage of each age-group and the total number of cases (in thousands) of sockeye salmon caught in the Skeena River from 1917 to 1948.

Year	% 4_2	% 5_2	% 5_3	% 6_3	Total catch	Total catch index[a]	Predicted catch index[b]
1917	57	29	9	5	66	55	...
18	51	34	9	6	123	107	...
19	27	60	9	4	185	167	...
20	15	71	6	8	91	85	...
21	69	22	6	3	40	39	...
22	70	16	12	2	101	103	...
23	56	29	8	7	132	138	94
24	23	69	7	1	145	159	134
25	51	45	3	1	78	89	99
26	62	26	9	3	82	96	90
27	62	28	9	1	84	102	106
28	51	39	7	3	35	44	90
29	62	30	6	2	78	101	176
30	39	52	8	1	131	177	105
31	40	30	28	2	93	129	98
32	44	37	7	12	53	76	63
33	57	36	5	2	28	41	84
34	58	34	7	1	55	82	106
35	49	31	18	2	53	80	159
36	67	20	11	2	82	126	110
37	45	40	11	4	41	64	59
38	64	15	16	5	47	75	74
39	50	35	11	4	68	108	74
40	80	15	4	1	117	186	124
41	39	52	8	1	81	129	70
42	36	54	7	3	30	48	83
43	39	39	16	6	28	44	80
44	37	52	7	4	68	106	203
45	20	63	12	5	104	160	89
46	13	70	8	9	53	80	96
47	14	82	3	1	33	49	47
48	80	13	6	1	101	149	64
Av.	47.7	39.6	9.2	3.5			

[a]Indices were calculated as the ratio of each year's catch to the average catch determined from the curved trend line (Fig. 4) which was considered to equal 100.

[b]This index is the total of the individual catch indices for each age-class caught in the respective parent years.

The age data are based on random scale samples taken from two to three thousand fish in the commercial catch each year. The collections were made throughout the entire fishing season from the commercial sockeye catch at one of the larger canneries. For the first few seasons only two age-classes are recorded. On the basis that the sampling adequately represents the four age-classes in the Skeena River catch since 1917, the percentage of each age-class and the total number of cases of sockeye caught are shown in Table VII. The majority of the fish are 4 and 5 years of age, these being approximately equal in numbers when averaged over the whole period, but exhibiting large annual variations.

HEREDITARY AND ENVIRONMENTAL INFLUENCES UPON AGE AT MATURITY

An attempt was made to decide whether age at maturity is determined more by hereditary or by environmental influences, for the two major age-classes. To eliminate the trend in the catches a curved line (Fig. 4) was fitted by means of the equation $\hat{y} = 120.3 - 4.87x^2$, where $\hat{y}$ is the estimated "average" catch and x is the year (1917 = 0). The trend line was considered equal to 100 and the ratio calculated for each year's catch was expressed as a percentage of the calculated "average" for that year (Table VII). This index was then divided in proportion to the ages in the sample, giving indices for each age-class separately. In order that large fluctuations should not contribute unduly to the correlation values, the data were transposed to logarithms. The correlations obtained are shown in Table VIII.

TABLE VIII. Correlations (r) between parental and progeny age-class indices for Skeena River sockeye salmon from 1917 to 1948. An asterisk indicates a statistically significant relationship.

	Parents	Offspring	Number of years	r	P
A	4_2 in year n	4_2 in year $n+4$	28	0.44	$<.05$*
B	5_2 in year n	5_2 in year $n+5$	27	0.49	$<.01$*
C	5_2 in year n	4_2 in year $n+4$	28	0.21	$>.05$
D	4_2 in year n	5_2 in year $n+5$	27	0.39	$<.05$*
E	4_2 plus 5_2 plus 5_3 plus 6_3 in year n	4_2 in year $n+4$, plus 5_2 in year $n+5$, plus 5_3 in year $n+5$, plus 6_3 in year $n+6$	26	0.44	$<.05$*
F	4_2 year in $n-4$, plus 5_2 in year $n-5$, plus 5_3 in year $n-5$, plus 6_3 in year $n-6$	4_2 plus 5_2 plus 5_3 plus 6_3 in year n	26	0.35	$>.05$
G[a]	4_2 in year n	5_2 in year $n+1$	31	0.41	$<.05$*

[a]Here the correlation is between members of the same brood, rather than between parents and offspring.

If there were no *hereditary* influence in the determination of age at maturity, then the correlation values for A and C should be equal (apart from sampling variation), as should B and D. Actually A is greater than C and B is greater than D; and the combined probabilities of significance of the differences between the two pairs is about 80 per cent ($P = 0.2$). Hence there is some indication of an hereditary influence upon age at maturity, but it cannot be established from these data.

If there were no *environmental* influence in the determination of age at maturity, the correlation values for A and B should be positive and those for C and D should be zero. Actually the C and D correlations are both positive; the combined estimate is 0.30, which differs from zero with 90 per cent probability ($P = 0.1$). Hence there is some indication of environmental influence upon age at maturity, but it too cannot be proven.

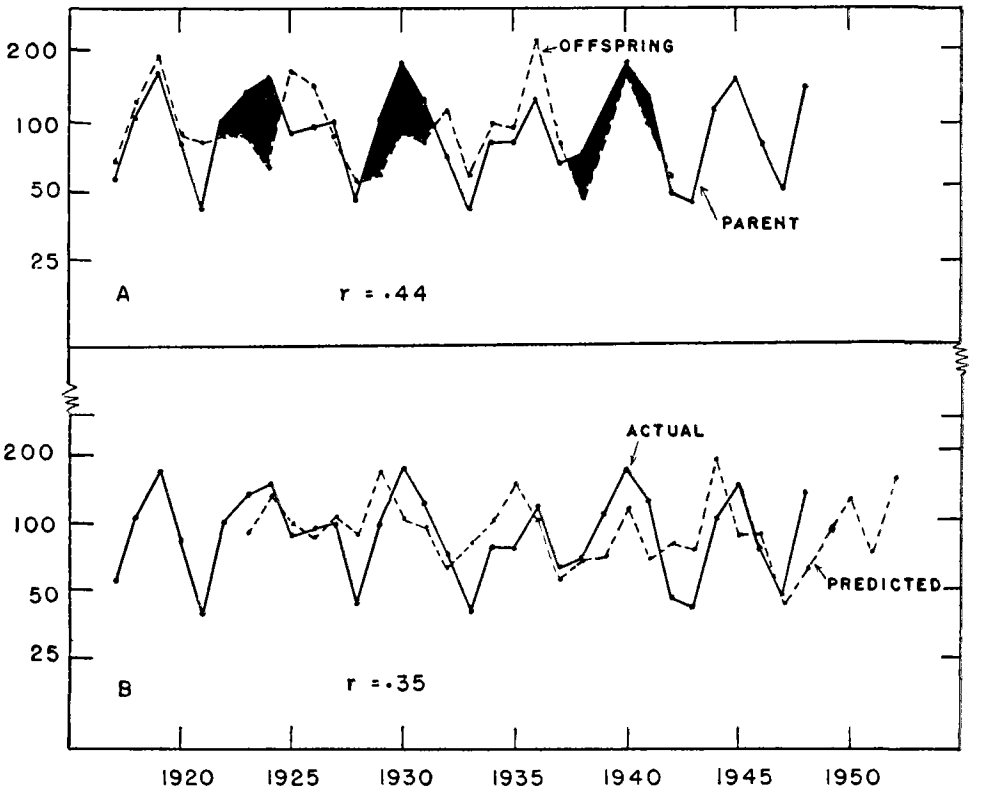

FIGURE 9. Reproduction indices for sockeye salmon, in terms of the "normal" catch indicated by the curved trend line of Figure 4. (A) "RETURN" INDEX: The catch in each parental year (as percentage of the "normal"—solid line) is compared with the sum of the observed progeny catches (as percentages of the "normal" for their respective years—dotted line). (B) PREDICTION INDEX: The actual catch in each year (as percentage of "normal"—solid line), is compared with a predicted catch (dotted line) obtained by summing the percentage contributions of the fish of appropriate ages in respective parental years. The catch indices (Table VII) are plotted on a logarithmic scale.

It can be argued that age at maturity could scarcely be determined by chance: it must be the result of either hereditary or environmental factors, or both. Hence the above P-values, which are of the same order of size for the two effects, may constitute evidence that both effects are in operation. The failure to obtain a more clear-cut picture springs from the inadequacies of the data. One source of variability is that, even if the samples used for age determination always adequately represent the catch (which is far from certain), they are not likely to be as good a representation of age composition of the spawning escapement, because of the selective action of the gill-net fishery. Also, variations in natural survival rate of the salmon, both in fresh and in salt water, result in a variable relationship between spawning escapement and ocean return. Finally, the ratio of catch to stock may vary between years, and also within a year.

PREDICTION OF CATCHES FROM INDICES OF PARENTAL YEARS

To obtain an over-all relationship between catches of parental and progeny years there are two possible procedures. First, the index of total catch for year n may be related to the sum of the indices for appropriate ages four, five and six years later. This correlation, shown in line E of Table VIII, is equal to 0.44, suggesting that only 19 per cent of the variation in the offspring catch is associated with variation in the parent catch. These data are presented in Figure 9A, and indicate three periods of failure of the offspring catches to maintain the parent catch of each brood year. This graph is similar to the "index to the success of return" used by Thompson (1945) in a percentage form. The periods of failure around 1923 and 1930 were most critical in producing the over-all decline in the sockeye catch shown in Figure 4.

The relationship just discussed cannot be used to predict catches in advance, because it becomes available only after all of the progeny generations have been taken. For purposes of prediction it is necessary to estimate the catch in year n from the catches of appropriately aged fish in years $n - 4$, $n - 5$ and $n - 6$ (Table VIII, line F). This correlation is only 0.35, which suggests that only 12 per cent of the offspring variation is dependent on the variation in parent catch. The data for this "index of prediction" are presented in Table VII and in Figure 9B to show that catches predicted on this basis have limited practical usefulness, since they may vary from one-half to twice the size of the actual catch index.

Both the E and the F correlations above presuppose an hereditary effect in determination of age at maturity, but they differ in respect to where environmental effects producing differences in survival are most active. With E, all the parents spawn in the same brood year and all the young are reared for a year under the same freshwater conditions but mature in different years in the ocean. With F, the parents spawn in different brood years; the young are reared under different freshwater influences, but they mature in the same year and all have had the same two final years of life in the ocean. Though the difference between the correlations 0.44 and 0.35 is not significant, the higher value for the E series may suggest a greater importance of the freshwater phase in determining over-all survival.

Recent catches indicate a high survival from the 1944 brood year. It was previously mentioned that in 1947 the sockeye escapement included a large number of three-year-old males. This was followed by a large number of 4_2 fish (80 per cent or 81,000 cases) in the catch of 1948, and of 5_2 fish (76 per cent or 50,000 cases) in 1949. Over past years the relationship between 4_2 fish in the catch and 5_2 fish in the catch the following year (G, Table VIII) is significant ($r = 0.41$), but the variation is sufficiently great to prevent useful predictions being made on this basis. However it does further substantiate the importance of the freshwater environmental influences on the survival of the young.

In summary, commercial catch data suggest influences of both hereditary and environment on age at maturity and rate of survival, but the relationships are not precise enough to provide a basis for useful prediction of the size of the sockeye population which will be available to the fishery. Before a reliable basis can be established, detailed information on the spawning escapement and subsequent survival of the offspring in both fresh and salt water must be obtained for a series of years. Such information is currently being accumulated.

Pink Salmon

Pink salmon invariably mature at two years of age. Thus the odd- and even-year catches are from two distinct populations and the offspring catch is associated solely with the parent catch two years earlier. The offspring and parent catches are shown in Figure 10, A and B, for both odd- and even-year cycles. In the odd-year population the drastic failures of the brood years 1925, 1929 and 1945, and in the even-year population the failure of the brood years 1930 and 1944, have had a marked effect on the trend in the catches. If predictions are based on a two-year cycle in the catches (Fig. 10C), it is apparent that they would have been useful only for the period 1919–31 and to a lesser extent for 1940–46. The numerous factors which affect the size of the catch, escapement and resulting return are apparently too variable to provide reliable predictions of the offspring catch on the basis of the catch in the parent year.

The periods of marked failure in the offspring catches cannot be attributed to abrupt changes in fishing effort and, since the escapements were apparently good, the conditions for survival must have been extremely adverse either in the streams or in the ocean. The water conditions in the streams during the years 1944 and 1945 will be discussed briefly. The rainfall data for the lower Skeena indicate that August and September of 1945 were exceptionally dry months, which corroborates the field observations that pink salmon had difficulty ascending from the main river into the tributary streams and that the areas available for spawning were reduced. Following this dry period, exceptionally heavy rainfall in October and November resulted in freshets which scoured the spawning beds thoroughly. In 1944 the conditions were reversed, as the rainfall was heavy during July, August and September and light during October, November and December. This would result in easy access to the spawning beds, but probably many eggs either dried out or were damaged by frost during the following winter. Consequently the failure of the 1946 and 1947 catches may have been due to different adverse conditions in the streams.

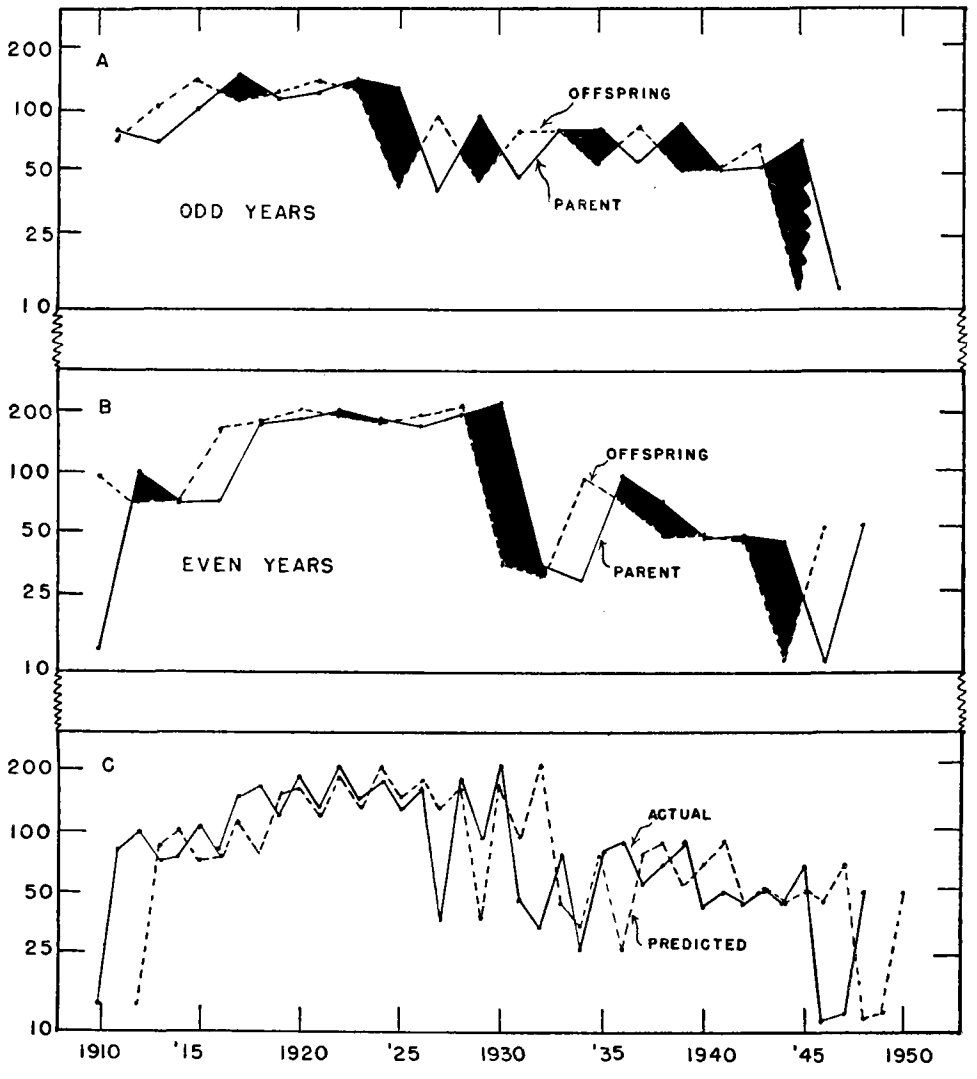

FIGURE 10. Reproduction indices for pink salmon, in terms of catches plotted in thousands of cases on a logarithmic scale. (A) "Return" index for the odd-year cycle. (B) "Return" index for the even-year cycle. (C) Prediction index.

If the Skeena River pink salmon catches were more representative of the total population and if survival records were available for the pink spawning areas for a number of years, a useful prediction of the catch should be feasible.

RELATIONSHIP OF CATCH AND ESCAPEMENT OF SOCKEYE SALMON, 1944–48

In any study of a commercial salmon fishery of the most important objectives is to determine the relationship between the catch and escapement for the watershed concerned, so that an optimum balance can be established and the

maximum safe exploitation can be obtained. The catch of the commercial fishery is probably recorded with an error of less than 10 per cent, and the much smaller catch by the Indian food fishery with an error of less than 50 per cent. Estimating the escapement to a large river system such as the Skeena River is much more difficult than determining the catch. The methods used and the results achieved for the period 1944 to 1948 have been summarized by Brett (1952), but there is still a need for improving the accuracy of present estimates. Each year the spawning grounds were closely inspected and counts were made of the fish in accordance with standard procedures. The construction and operation of a counting fence on the Babine River made possible a count of all the fish entering the most important sockeye spawning area in the system. A comparison between observer's estimates and the actual fence counts at Babine showed that the estimates were approximately one-half of the actual counts.

The returns from salmon taggings off the mouth of the Skeena River (Pritchard, 1945, 1946, 1947, 1948; Milne, 1949) provide another method for estimating the Indian catch and the spawning escapement. Each year approximately 2,000 sockeye salmon were caught in the commercial gill-net area by means of a chartered purse-seine boat, tagged with plastic discs and released. Many of these tagged fish were subsequently recovered from the gill-net fishery at the river mouth, from the Indian fishery at various locations on the river and from the spawning grounds. The high proportion of tags returned from the Indian fishery is difficult to explain. It is possible that the Indians returned a few tags upriver which were actually caught in the ocean and commercial fishery, or in certain places they may be able to fish selectively for tags. Only a few tags were recovered from the spawning grounds. The number of tags that cannot be accounted for, if used as an estimate of the escapement, after the commercial and Indian tag returns are deducted, is usually too high. It includes tags which have been lost from the fish and those recovered but not turned in, as well as those actually present on spawning fish. Thus, estimates of the escapement based on ocean tagging are high, while estimates based on observations are low.

For 1944–48 the best estimates for the escapement no doubt lie part way between these two extremes. From general observations, Indians catch only what they need for food, and tend to fish more heavily in a poor year and more lightly in a good year. Therefore the Indian catch probably remains at a more constant level than either the commercial catch or the escapement.

In Table IX estimates of the fraction of the stock taken commercially are large (50 to 75 per cent) when based on observations of the escapement but are small (19 to 41 per cent) when based on tag returns. The estimates of the Indian catch and spawning escapement are correspondingly small when based on direct observations, and are large when calculated from tag recoveries. The tagging estimates are more erratic, and are difficult to rationalize, unless it is borne in mind that the tags are not randomly distributed throughout the population but were placed on the fish during the first half of the run when the fish were part way through the fishery.

The true average situation is probably close to a spawning escapement of

TABLE IX. Estimates of Skeena sockeye population, 1944–48.

	1944		1945		1946		1947		1948	
	No. of fish	%	No. of fish	%	No. of fish	%	No. of fish	%	No. of fish	%
Observational estimates										
Commercial	807,000	70	1,227,000	71	621,000	62	385,000	50	1,200,000	75
Indian fishery	58,000	5	56,000	3	39,000	4	41,000	5	50,000	3
Escapement	285,000	25	447,000	26	341,000	34	345,000	45	350,000	22
	1,150,000	100	1,730,000	100	1,001,000	100	771,000	100	1,600,000	100
Tagging estimates										
Commercial	807,000	41	1,227,000	26	621,000	30	385,000	19	1,200,000	22
Indian fishery	138,000	7	425,000	9	207,000	10	243,000	12	600,000	11
Escapement	1,020,000	52	3,060,000	65	1,240,000	60	1,400,000	69	3,700,000	67
	1,965,000	100	4,712,000	100	2,068,000	100	2,028,000	100	5,500,000	100
Best estimates										
Commercial	807,000	53	1,227,000	45	621,000	45	385,000	34	1,200,000	48
Indian fishery	90,000	6	150,000	5	75,000	5	70,000	6	150,000	6
Escapement	620,000	41	1,360,000	50	680,000	50	690,000	60[a]	1,150,000	46
	1,517,000	100	2,737,000	100	1,376,000	100	1,145,000	100	2,500,000	100

[a]The escapement to Babine Lake in 1947 included 261,000 three-year-old males. Considering only the older fish, the 1947 escapement is only 50 per cent of the total stock. In other years the "jacks" were not numerous enough to distort the relationship appreciably.

50 per cent, a commercial catch of 45 per cent and Indian catch of 5 per cent. This approaches the requirements of the "White Act" in Alaska which provides for an escapement of 50 per cent of the population. Since the Skeena catches for recent years appears to be fluctuating in balance with the natural survival rates without producing a further decline, a catch of 50 per cent is probably approaching the optimum exploitation which the present Skeena sockeye salmon population can support.

DISCUSSION OF THE SOCKEYE SALMON FISHERY REGULATIONS

The Skeena sockeye salmon catches show a gradual decline followed by a recent levelling off. The pertinent problem is how to build up the population so the maximum surplus can be harvested without endangering future use. So many factors are involved that no single measure will probably suffice to improve the situation quickly and efficiently. During the survey from 1944 to 1948, no convincing evidence was found for any change in the freshwater environment of the sockeye salmon which would impose significant added hazards to the success of spawning in recent years, and the decline was attributed mainly to the commercial fishery (Pritchard, 1948–49). Since then, a natural rock slide has occurred which partially blocked the important Babine River in 1951 (Godfrey *et al.*, 1954). This slide has now been removed. It is possible that points of difficult passage, either here or elsewhere, have affected the salmon runs. The final solution will probably involve both changes in the fishing and implementation of proven methods to increase the natural survival rates.

A few possible changes in the fishing regulations will be discussed briefly. The effect of man's exploitation has been examined as a possible cause for the decline in the sockeye salmon population. The canners themselves fully realize that their present efficient methods, if unchecked, could almost eliminate the sockeye population. The fact that no decline has occurred in the catches in recent years would suggest that the effort may have been sufficiently restricted by regulations and by economic considerations for the present size of the population. Also there is no guarantee that a substantial restriction of present effort would be followed by a high catch, as might be anticipated, because unidentified factors of survival in the watershed or in the sea may be more important than the fishery. Nevertheless the following changes in the regulations appear warranted.

The start of the fishing season has been set each year in the latter part of June while the closing date around the middle of August has been dictated by the lack of fish to be caught. Thus over the years the later portion of the run appears to have been more heavily fished. Since this is composed largely of 4_2 females, it has been suggested that the season be terminated earlier. By opening the season earlier the older males, which precede the females, could be more heavily exploited. For the period 1936 to 1948 the annual samples of the catch have averaged 61 per cent females. Few small "jacks" are caught by the present commercial nets. The selective action of the gill-nets must also be considered in any attempt to produce a more evenly balanced sex ratio in the catch and the escapement.

The results of five years of ocean tagging, 1944–48, have shown that two-thirds of the sockeye require more than two days to move from the tagging area off the mouth of the river to the river boundary, and that a few fish spend as long as a month in this area. Hence the present 48-hour closed weekend period is only partially effective. In order to make the weekend closure more effective the period could be extended. Lowering the river boundary, or changing the ocean boundary back to Point Ryan where it was prior to 1935, would have similar effects. Such a change in the ocean limits would have the added advantage of leaving a gap between the Nass and Skeena areas. In this way a more accurate separation of the catches from the two rivers would be possible. In the past the lowering of the river boundary has been largely negated by the extension of the ocean fishery.

For any change in regulations, it is vital that the effect on catch and escapement be recorded by adequate data. Only in this way can the most effective combination of fishing regulations be used, to achieve the desired result of increasing the production of sockeye salmon in the Skeena River.

SUMMARY

The Skeena commercial salmon fishery commenced with the opening of the first cannery in 1877 and expanded greatly by exploiting a greater variety of species and stocks, until in 1948 it supported numerous modern canneries and fresh-fish establishments. The changes in fishing areas, seasons and methods of fishing, which have been described in detail for the important sockeye salmon gill-net fishery, make it difficult to determine an adequate index for effort over the years.

The methods and difficulties of obtaining catch and effort statistics for the Skeena River salmon populations in past years emphasizes the need for improving the accuracy of their collection in the future. The new multiple-sales slip system should satisfy this need.

On the basis of the catch data available for each species of salmon the probable trends in population sizes are indicated. For sockeye salmon the catch attained a maximum of 187,000 cases (about 2,250,000 fish) in 1910 and since then has declined to minima of 28,000 cases (about 335,000 fish) in 1933 and 1943. In recent years the catches have tended to level off. For pink salmon the catches declined drastically after 1930, especially in the even-year cycle. In 1946 and 1947 record lows were caught in both odd- and even-year cycles, but there was substantial recovery subsequently. The smaller chum salmon catches appear to have declined in recent years to provide a more uniform catch than in the earlier years. Owing to the difficulty of separating the spring and coho salmon catches into Skeena River fish, it is not possible to state whether or not the catches of these species have declined.

An analysis of the age-cycles in the annual catches of both sockeye and pink salmon indicates that these data alone do not provide a reliable basis for making useful predictions of future catches. Detailed information on the size of the

escapements and on the fluctuations in survival in both the freshwater and ocean environments is needed before a sound system of regulations can be established, and is now being obtained.

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