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ABSTRACT

THE chum and pink salmon fisheries of British Columbia assumed commercial importance during the war of 1914-18. Catch statistics for a 31-year period, 1917 to 1947, have been summarized graphically to show variations in the catches from the major fishing areas and to show the manner in which the catches have been utilized. The availability of these salmon has shown marked changes. Although the total pack of British Columbia pink salmon has not varied greatly, the catches in the northern areas of the province have declined steadily. In contrast, chum salmon show no such definite trend but the catch has fluctuated considerably with three regularly occurring periods of low production. Approximately 95% of the pink salmon catch is canned, while only about 60% of the chums are used in this way. At present the remainder of the chum salmon are used fresh and frozen, though smaller amounts have from time to time been processed in other ways. Annual variations in size of both pinks and chums may be great enough to introduce serious errors in estimations of abundance based on weight of fish taken.

INTRODUCTION

CHUM (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) have now been fished intensively on the west coast of Canada for just over 30 years. Although "fall salmon", as these species were referred to in the early days of the salmon industry, were beginning to assume a place of commercial importance prior to the war of 1914-18 the catches suddenly became prominent during this period. Fig. 1 shows how the war-time demand, associated with decreased sockeye salmon (*Oncorhynchus nerka*) packs, resulted in a sharp increase in production

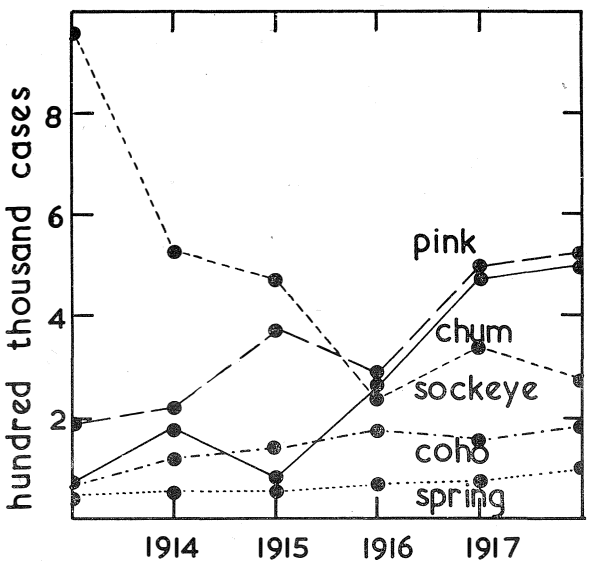

FIGURE 1. Changes in quantities of different species of canned salmon packed 1913-18.

of chums and pinks. During the same period coho (*Oncorhynchus kisutch*) and spring salmon (*Oncorhynchus tshawytscha*), already quite extensively exploited, show little change in the volume of pack. Table I emphasizes the fact that the pink and chum industry developed suddenly during World War I. The table shows that the canned packs of these species in 1917 and 1918 were above the average packs of the 31 years under consideration. For chums, the 1917 pack was almost twice as high as any previously recorded pack; for pinks more than one and one-half times as great as any pre-war pack.

The annual reports of the Departments of Fisheries describe the development of these industries. The British Columbia Commissioner of Fisheries in his annual report for 1911 states (p. 5, 1912) "A feature of the season's operations was that all five varieties of salmon were utilized for canning to a great degree. Owing to the increased demand for the product, the cheaper varieties of fish which only latterly have been used even sparingly were canned in all districts, and it was largely owing to this fact that the proportions of the pack have assumed such a noteworthy feature". In the Annual Report of the Commissioner for 1912 (p. 5, 1913) we find that "For the first time in any of the 'off-years' (for sockeye) on the Fraser has this Province led its Atlantic fishery rival, Nova Scotia . . . the phenomenal increase . . . was due almost entirely to the increased demand and value of the cheaper varieties of salmon".

TABLE I. Chum and pink salmon packed 1914-19 compared with the largest previous pack (1911) and the average pack for the 31 year period, 1917-47, in 48-lb. cases.

Year	Chums	Pinks
	Cases	*Cases*
1911	91,951	305,247
1914	184,474	220,340
1915	82,000	367,352
1916	240,201	280,644
1917	475,273	496,759
1918	497,615	527,745
1919	372,035	346,639
1917-47 (31 year average)	454,039	487,435

The annual reports of the Department of Fisheries (Ottawa) are in agreement. Thus, we find in the fiftieth annual report of the Fisheries Branch for 1916-17 (p. 250, 1917), ". . . dry-salting fell off . . . on account of the high prices paid for fresh chum salmon . . . It is very unlikely that this branch of the salmon industry will ever be revived, as the fall fish will find as ready a market and as great a demand as was found in former years by the higher grades of salmon". It is recorded in the report of the following year (p. 32) that "Notwithstanding this failure [of sockeye salmon in the Fraser due to the rock slide at Hell's Gate] . . . the total pack of salmon throughout the Province was a record one. Other grades, which prior to the outbreak of the war, were practically neglected by packers, are now keenly sought after and packed in ever greater quantities". Thirty years have now elapsed since this report was written.

There is perhaps a particular reason for reviewing the statistics of these two species at this time. When the importance of the "fall salmon" became evident in the later years of World War I the Dominion and Provincial Departments of Fisheries for the first time gave separate figures for the Vancouver island and Central areas of the Province. Previously, figures for these areas were combined and reported under "Outlying Districts". In fact, all areas

except the Fraser, Skeena, Rivers inlet and Nass areas were so reported. Since the revisions instituted at that time there has been little or no change in type of information published. Recent emphasis on the importance of statistical data has, however, had an effect and changes have been initiated which will eventually give a more complete picture of the quantities of chums and pinks marketed. It is understood that the quantities of chums marketed "fresh" and "frozen" will henceforth be reported separately, whereas previously all fresh and frozen salmon were lumped together in the published statistics. Moreover, in 1949 an inquiry made by Dr. G. L. Burton, Department of Fisheries and Bureau of Statistics, Ottawa, led to recommendations which should result in a much more valuable record of fish catches. Thus, the statistical literature of the 1917-47 period is less complete than subsequent statistics will be and requires its own treatment.

Factors Affecting the Fishery

It is impossible to establish accurately the annual catches of past years for many of the areas of British Columbia's extensive coast line. One can probably get a reasonably accurate estimate of the total annual catches and the catches for certain major areas. To decide whether there has been overfishing or depletion of the stocks of fish is a still more difficult task and requires a careful study of social, economic, psychological and environmental factors. The situation is extremely complex and none of these many factors can be ignored in estimating the true abundance of fish.

Although salmon is highly esteemed and usually in great demand, it is not free from the market fluctuations brought about by major economic upheavals. The less expensive varieties—chum and pink—will be first to feel these changes in economic conditions. Thus, the post-war recession of the 1920's and the depression of the 1930's are clearly reflected in the total catch figures. In considering economic factors it must be remembered that the cost of production of canned salmon is such that prices must remain high. Further, the industry is so highly mechanized that a strike or shortage in an industry seemingly quite remote from fishing may affect production considerably. On the other hand a boom in another fishery, as the spectacular dogfish fishery of the recent war years, may also have a definite effect. Likewise, the less expensive varieties are sometimes not fished as intensively when sockeye, which command higher prices, are abundant.

In appraising psychological factors, one must reckon not only with the minds and skill of many fishermen but also with the minds of administrative officials. The amount of fishing permitted in different areas has too often been dependent upon the "hunch" or opinion of certain individuals rather than on scientific knowledge. It is impossible to evaluate many of these factors in a quantitative manner, but their possible effect on estimation of true abundance should not be lost sight of. Another factor which might be added is "food preferences".

These may, from time to time, change the amounts of fish processed in one way or another and will affect existing catch statistics.

The two major wars of the thirty-year period have affected the chum and pink fisheries in a great many different ways. Increased demand and the development of the dogfish fishery have been mentioned. The relation of the recent war to the Indian fishery and to the loss of markets for certain salmon products will be discussed later. Fishing pressure on Pacific salmon may have been altered markedly by the exodus of the Japanese fishermen during World War II. In addition, there are the effects of war-time psychology, difficulties and shortages, which are impossible to evaluate quantitatively and are likely to be quickly forgotten. The influenza epidemic of 1918 which greatly affected the west-coast fishing effort (Pacific Fisherman Yearbook, 1919) may be cited as an example of the complicating factors in the situation.

Knowledge of the relation of environmental factors to the abundance of fish is now sufficient to suggest that environment may be quite as important as, or more important than, human activities. The river discharge may affect, not only the spawning grounds and conditions for fry production, but also the time of entrance of fish into the river and hence their vulnerability. Conditions in the ocean doubtless affect numbers and size of fish. These ocean conditions certainly influence fishing operations greatly, and thus the total catch, if not the true abundance. It is not wise to attribute decreased catches, or even decreased catches per unit effort, to overfishing until all the contributing factors have been evaluated.

Measuring the Abundance of Chum and Pink Salmon

Both the biologist and the business man are interested in the changes in true abundance of any particular species of fish. Any evidence which can be brought forward regarding depletion of these resources or about the general state of health in the fishery will be valuable. It is not an easy matter to measure this true abundance. If the fishing intensity were uniform from year to year, *total catch* could be used as a measure. It is, however, not at all uniform, but may be affected by any or all of the factors mentioned above. If the intensity changed gradually and not very greatly from one fish generation to the next, one could compare parent and offspring generations and use an *"index of return"* as a measure of relative abundance. But the use of such an index, too, is dangerous with a species such as pinks or chums where demand and consequent fishing intensity may vary greatly from time to time. The value of a *catch per unit effort* as a measure of abundance will depend on the degree of competition between units of gear. This competition factor is often so great and so variable in salmon fisheries that there is no adequate method of compensating for it. Catch per unit has been used to measure the relative abundance of salmon (Rounsefell and Kelez, 1938) but the results are not beyond criticism (Thompson, 1945). To apply such a measure to the fishery of past years requires numerous adjustments

and assumptions, and to collect reliable data on effort in the future will require much organization and time.

In certain respects management of salmon fisheries is simpler than that of some of the other important commercial fisheries. The "crop" is not one that may be harvested at various stages in growth. It reaches maturity and is available in rather limited areas at one time only in its life cycle. The relation between growth rate, stage of maturity, and mortality rates of adult fish does not enter into the consideration as it does in other fisheries. It is not a problem of using the "crop" or leaving it to grow, but a choice between using the crop and losing it. This means that conditions do not build up from year to year and from generation to generation for salmon as they do for—let us say—halibut. For salmon, it seems more logical to follow the history by direct comparisons of parent and offspring generations. Such direct comparisons should indicate whether the escapement was sufficient to maintain the population *at its then present level*—assuming the conditions in the nursery grounds do not change greatly. It will *not* show the true potentialities of the nursery ground. These must be demonstrated in other ways.

Several workers have followed changes in the abundance of salmon by a direct comparison of the catch in any year with that of the parent generation (Barnaby, 1944; Clemens and Clemens, 1926-37; Gilbert, 1922-5). Thompson (1945) expressed the salmon catch in any one year as a percentage of the parent catch ("index to the success of return"). Such comparisons will form valid estimates of the relative population in so far as the age composition of the stock is known and in so far as the rate of exploitation is constant. In direct comparisons of the offspring with parent generation, such as presented by Barnaby (1944), the complete and continuous trend of catch in the different generations may be seen at a glance. The "index to the success of return", on the other hand, will not reveal such trends. It does show, however, whether the catch is being maintained at the level of the parent generation. The picture developed by the first workers mentioned is more likely to be influenced by changes in effort. Long term, gradual changes in fishing intensity will not greatly affect the "index of success of return". However, if fishing intensity in parent and offspring years varied greatly, the index would not be valid.

In this report no attempt is made to calculate a catch per unit effort. The fishery does not lend itself readily to such a study. Licences are issued for salmon and not for any particular species. Boats may take several varieties at one time or shift from one species to another during the season. These considerations, in connection with the competition factor already mentioned, have made it impracticable to use such a measure. We have attempted, rather, to estimate the total catch of chum and pink salmon and to interpret this with reference to a measure of relative effort based on historical statements and general economic trends. The "index of return" has been calculated since it will compensate for gradual changes in effort and gradual changes in amounts of fish which might

result from diversion to channels where their numbers would not be recorded and therefore would not appear in published statistics (Indian fishery, for example). This index too is interpreted in relation to the recorded history.

It seems that "abundance" will eventually have to be measured by getting reasonably good figures for *escapement* as well as *catch*. Theoretically, escapement figures are available in the report of the inspectors of the various areas. At the present time these figures are based on rough estimates or guesses and cannot be considered sufficiently reliable for statistical analysis. With improvements in the inspection service it may be possible to increase the value of these estimates. Indications from tagging experiments are that the escapement tends to fluctuate with the catch.

SOURCES OF DATA

THE Dominion and Provincial Departments of Fisheries have published figures on source and quantity of salmon canned since the early days of the industry. For pinks, the canned salmon pack accounts for the greatest part of the catch. Chums, however, are frequently used in other ways. Dry salting, brine curing and freezing together have, at times, accounted for 30% to 50% of the catch. Smaller quantities of both pink and chum salmon are used by the Indians or by halibut and other fishermen for bait. For chums, in particular, it is necessary to make a number of adjustments in the published statistics. In addition to the figures compiled by the Dominion and Provincial Departments of Fisheries, the Inspectors in some areas have records of catch which they believe represent the situation for their areas more precisely than do the published data. These records have been summarized and considered in connection with other data for the years 1930-47. Unless otherwise stated, however, the figures used are from the published statistics—mostly those issued by the British Columbia Commissioner of Fisheries.

Published statistics give weight and not numbers of fish. If the fish vary greatly in size from year to year the actual numbers (hence abundance of fish) may not be truly represented by the pounds processed. This size variation may be sufficiently important to affect the picture and must be evaluated. For this, valuable data were obtained from the Salmon Canners' Operating Committee. Prior to 1945 seine-caught pinks and chums were sold by the piece. In 1944 a preliminary survey was made to learn of differences in weight which may occur. In that year 11,506 pinks and 15,319 chums were weighed in lots of definite size (25, 30 or 50 fish, depending on the area). Since 1944, numbers of pinks and chums with total and average weights have been reported by the industry to the Salmon Canners' Operating Committee weekly and used as a basis in paying the fishermen of the various areas. The data have been used in this bulletin to study the effect of size variations on existing catch statistics. In addition, figures on numbers of salmon per case canned were made available by some of the fishing companies.

The reliability of the published statistics may be questioned. It is obvious that their validity will depend on the good will, intelligence and interest of the fishermen and fishing companies. Consequently, their accuracy will vary from time to time and from fisherman to fisherman. Burton (1949) concludes that:

> In general the statistics on output of products, in terms of product weight, are accurate. . . . The data on landings, irrespective of where these fish were caught, are less accurate than estimates of output, but still reasonably satisfactory. The statistics on the catch of most species of salmon, by area of capture, are not sufficiently accurate to be used for biological research, which is presumably the primary purpose of collecting them.

This conclusion is most pertinent to the analysis attempted in this bulletin. It certainly substantiates the view that the calculation of catch per unit effort would be worthless. On the other hand, the report does suggest that the statistics for the landings from the major districts of the province will show the trend in number of fish caught and, when properly interpreted, should give a reasonably reliable picture of the general health of the fishery.

DISPOSITION OF THE CATCH

Pink and Chum Salmon Canned

The salmon industry of British Columbia has, since its beginning, been based on canned salmon. Today more and more salmon are being marketed fresh or frozen, but canning is still the most popular method of marketing. The history of this industry has been recorded by Cobb (1921) and Wallace (1945). The first successful canning of British Columbia salmon was done in a small cannery which started operations at Annieville, near New Westminster, in 1870. The number of canneries multiplied rapidly. By 1878 there were ten canneries, eight on the Fraser and two on the Skeena. By 1917 there were 94 canneries operating, and it became apparent that this was more than the industry could support. Since that time the number of canneries has been reduced to about one-third, whereas total canned salmon production has shown little change (Annual reports, Ottawa, 1929, 1949). It is more efficient and economical to centralize operations. There have likewise been vast changes in the cannery operations—from primitive establishments where salmon were packed by hand and processed in vats of boiling water to the present day highly mechanized factories.

The data for canned salmon pack are summarized in tables II and III. In these tables (also tables V, VII and IX) the symbols for the regression equation $\hat{Y} = a + bX$ (Snedecor, 1946) are as follows: $\hat{Y}$ is the calculated pack (size in table V, catch in tables VII and IX) at time X, "*a*" is the calculated pack for the initial period considered (1917 for chums, 1916 and 1917 for pinks) or the ordinate of the point where the regression line crosses the Y axis, and "*b*" is the rate of change in pack per unit time or the slope of the regression line. The positive or negative sign shows whether this trend is an increase or decrease. The fiducial limit value "$t_{.05}s_b$" shows by how much "*b*" may be expected to vary (95% level of confidence) in a positive or negative direction. P values of

less than 0.05, obtained from the calculated "t" values, indicate that the trend is statistically reliable at the 95% level of confidence.

The canned salmon pack will be discussed in detail when adjustments are considered for quantities marketed fresh and frozen and for size differences. It may be noted that, for the 31-year period, the average recorded pack of chums is 454,039 cases with a range of 55,997 (1931) to 926,801 (1941) and the

TABLE II. British Columbia pink salmon packed biennially from 1916-17 to 1946-47, calculations to nearest 100 cases, symbols explained in text.

Area	Quantity packed in		Regression equation $\hat{Y} = a + bX$				
	1916 and 1917	1946 and 1947	a	b	Limits of b		P
					$t_{.05}s_b$	t	
	Cases	*Cases*	*Cases*	*Cases/ 2 yrs.*	*Cases/ 2 yrs.*		
Total for B.C.	777,403	717,394	953,695	− 258	29,884	.019	>0.5
District 1 (Fraser river)	135,282	113,565	97,330	− 298	4,749	.134	>0.5
District 2 (North)	557,972	240,123	808,795	−16,270	24,914	1.401	0.18
District 3 (Vancouver island)	84,149	362,801	32,214	+18,175	8,048	4.844	<0.01*
Districts 1 and 3 (South)	219,431	467,366	121,080	+18,520	10,761	3.691	<0.01*
Rivers and Smith Inlet	11,632	11,955	29,677	− 974	931	2.244	0.04*
Skeena river	221,348	23,927	370,181	−18,104	7,960	4.878	<0.01*
Nass river	104,161	12,194	109,791	− 3,670	2,239	3.515	<0.01*
Central area[1]	431,909	182,826	295,100	+ 500	42,693	.028	>0.5
Queen Charlottes[2]	154,316	9,224	185,963	−13,364	10,632	2.800	0.02*

[1]Commences with packs of 1930 and 31. [2]Commences with packs of 1924 and 25. *Statistically reliable trend (95% level).

TABLE III. British Columbia chum salmon pack, 1917-47, calculations to nearest 100 cases, symbols explained in text.

Area	Quantity packed in		Regression equation $\hat{Y} = a + bX$				
	1917	1947	a	b	Limits of b		P
					$t_{.05}s_b$	t	
	Cases	*Cases*	*Cases*	*Cases/yr.*	*Cases/yr.*		
Total for B.C.[1]	494,080	486,615	552,285	+1,026	9,260	.227	>0.5
District 1 (Fraser river)	59,973	16,475	69,968	− 848	1,826	.950	0.35
District 2 (North)	174,919	345,644	181,237	+2,085	4,098	1.040	0.36
District 3 (Vancouver island)	240,381	99,680	131,194	+3,225	4,802	1.374	0.18
Districts 1 and 3 (South)	300,354	116,155	201,178	+2,376	5,978	.813	0.43
Rivers and Smith inlet	16,101	21,783	141	+ 691	319	4.431	<0.01*
Skeena river	21,516	8,236	29,642	− 721	644	1.119	0.23
Nass river	24,938	8,925	19,383	− 455	373	2.494	0.02*
Central Area[2]	128,602	292,604	82,080	+6,065	6,653	1.969	0.06
Queen Charlottes[2]	6,988	14,096	67,111	−1,551	5,253	.638	>0.5

[1]Includes dry salt salmon. [2]Commences with the pack of 1933. *Statistically reliable trend (95% level).

average recorded pack of pinks is 487,435 cases with a range of 116,607 (1946) to 1,111,937 (1930).

Quantities Marketed Fresh and Frozen

There are two sources of published statistics on the quantities of salmon utilized fresh and frozen. The Fisheries Statistics published by the Canadian Department of Trade and Commerce give the total quantity of salmon marketed in this way but provide no breakdown as to the different species. This same department issues monthly bulletins on food stocks in Canada. Since January, 1943, there has been a separate mimeographed report on cold storage holdings of fish and this has shown a breakdown as to quantities of the different salmon species since August, 1944. From neither of these sources are the data sufficiently complete to provide the necessary information on quantities frozen during the period under survey. For the past 3 years only have we been able to procure, through the Chief Supervisor of Fisheries in Vancouver, reasonably accurate estimates of fresh and frozen chum and pink production.

To supplement these data an attempt was made to obtain information directly from the producers. Thirty-three producers, dealers and packers were contacted and a number of these provided useful information. However, several were reluctant to release figures and consequently a complete picture was not obtained.

In lieu of complete production figures and satisfactory published statistics, certain estimates have been made as follows:

(*a*) Proportion of pinks and chums in the total of marketed fresh and frozen Canadian salmon (from monthly cold storage holdings 1944-7 and known production of 1945-7).

(*b*) Annual changes in the quantities of fresh and frozen pinks and chums marketed 1917-47 (from production figures of certain companies operating for that period).

(*c*) Quantities of pinks and chums marketed fresh or frozen (estimated from (*a*) and (*b*) using percentages obtained in (*a*) for three years and index numbers used from (*b*)).

It is evident (table IV) that very considerable quantities of chum and pink salmon are being marketed fresh and frozen. For the past three years about 50% of all fresh and frozen British Columbia salmon was chum and 5% pink. Moreover, at present about 40% of all chum salmon taken are marketed in fresh or frozen form and about 5% of all the pinks are used in this way.

Monthly cold storage holdings of frozen fish (Canada, Dept. Trade & Commerce) show the monthly consumption of these species. In fig. 2 we have summarized data for 3 years. A seasonal trend is evident and the graphs emphasize the large amounts of chum used in this way.

It sometimes happens that quantities of salmon are held in cold storage for a time and canned at a later date. It is important to know whether this is true for

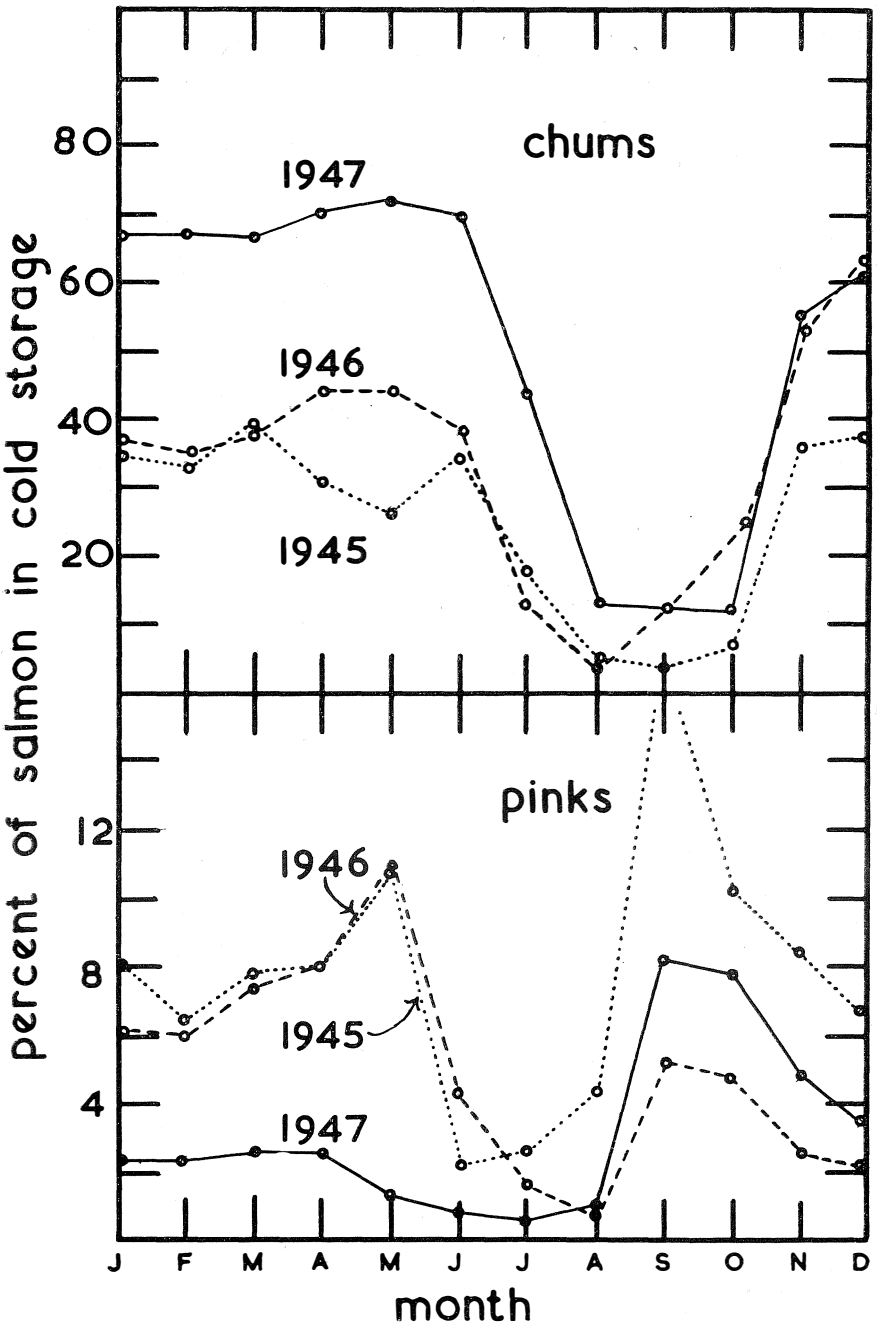

FIGURE 2. Per cent chums and pinks in the total Canadian frozen salmon holdings.

the pink and chum holdings. A representative of one of the large fish companies in Vancouver expressed the opinion that the amounts frozen were a good indication of the amount marketed fresh or frozen. Any large quantity of salmon canned from cold storage holdings will appear in the statistics. It is interesting to study the holdings of pink and chum in provinces outside of British Columbia.

TABLE IV. Quantities of chums and pinks used fresh and frozen, 1945-47.

Year	Total catch	Used fresh or frozen		Percentage of total fresh and frozen salmon
CHUMS	*cwt.*	*cwt.*	%	%
1945	362,482	99,841	27.5	27.9
1946	775,815	314,909	40.6	68.4
1947	608,371	238,932	39.3	53.7
PINKS				
1945	655,049	35,915	5.5	10.1
1946	106,966	13,681	12.8	3.0
1947	506,816	26,911	5.3	6.1

We may safely assume that the month-to-month holdings indicate in a general way the quantities used there. Outside of the Maritime provinces (where Atlantic salmon production is evident) 35% to 50% of all the frozen salmon used is British Columbia chum. The percentages for chums vary only slightly from British Columbia to Quebec. The quantities of pink salmon, on the other hand, are erratic, ranging from 0% to 18%.

In fig. 3 the total British Columbia fresh and frozen salmon (5 species combined) production has been graphed for the 31 year period. Quantities utilized in this way are surprisingly constant (175-275 thousand cwt. per annum) until 1945-6, when production is almost doubled. If the relative amounts of the different species remain the same over the period, then fresh and frozen figures will not affect the index of return or regressions of the catch greatly. It is essential, however, to know whether this has been the case before making such assumptions for chums and pinks. To establish this the production of one of the larger British Columbia cold-storage companies (handling from one to two million pounds of pinks and chums per annum) has been studied in relation to the total production. The data, summarized in fig. 3, show clearly that the quantities of chum marketed in this way have doubled during the past 10 years. Pinks have shown about the same relative increase although the amounts are still small. A more interesting feature of the pink production is the great decrease after 1925. Figure 3 suggests that increasing quantities of salmon frozen in British Columbia are made up of chums.

It was hoped to use data such as that summarized in figure 3 to estimate total fresh and frozen pink and chum production over the years. Thus, with a fairly precise knowledge of the production of the past 3 years, and given ratios

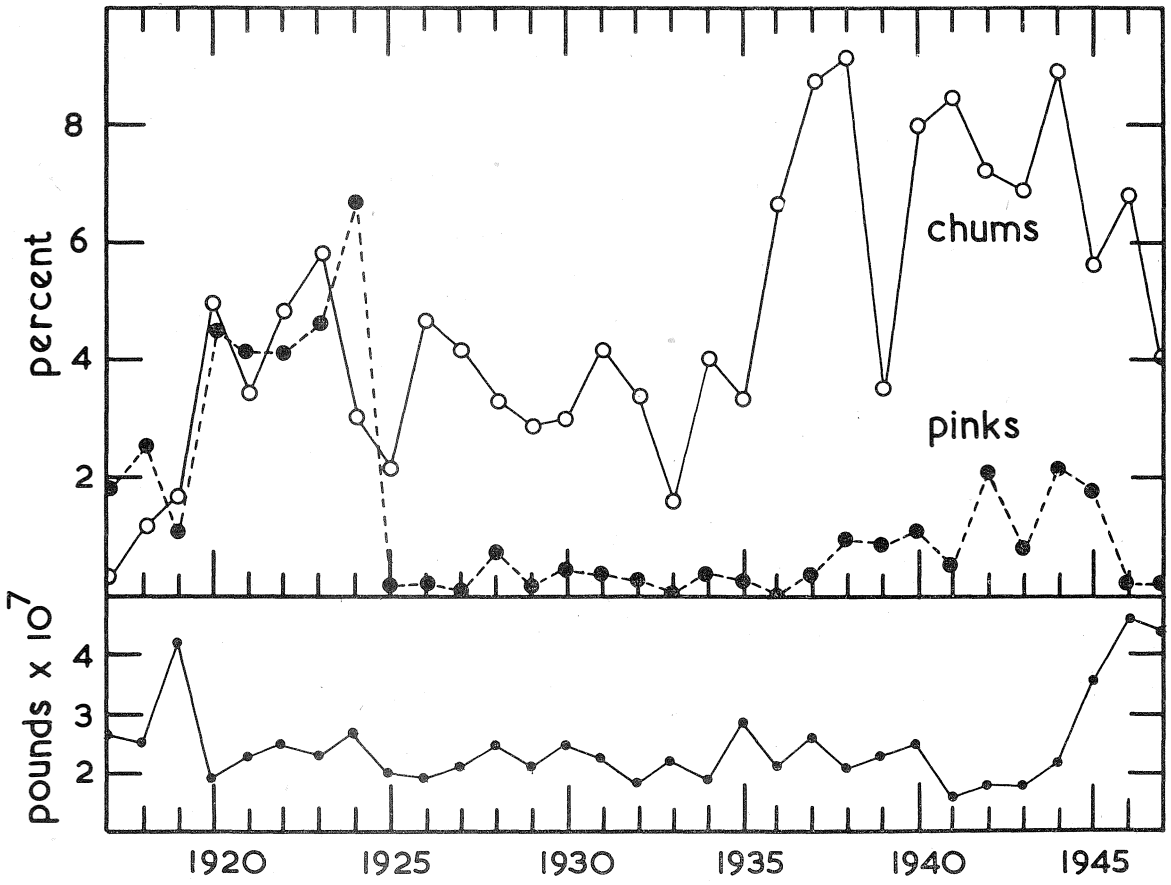

FIGURE 3. Quantities of British Columbia salmon marketed fresh and frozen, 1917-47. Lower graph, total salmon marketed fresh and frozen; upper graphs, chums and pinks frozen by one company, expressed as percentages of its total production of fresh and frozen salmon.

of year to year production for the 30-year period, it would be possible to estimate the annual production. To do this it would be necessary to assume that fig. 3 represented the overall picture for British Columbia. It has not been possible to obtain complete production figures from all companies, but data supplied by two other firms in a different area suggest that the above assumption would not be justified. In this particular region the sharp increase in production occurred between 1940 and 1944, with little change in quantities frozen prior to 1940. Further, the ratios of year to year production for the past 10 years are somewhat different.

Estimates for actual total quantities have not been attempted because of the uncertainties involved in using the above ratios. The most reliable figures available (fig. 3) account for only about 12% of the total production. The findings, however, can be used in interpreting the index of return and regressions of change in catch. In general, it is apparent that there have been three periods in growth of the frozen chum industry, namely, prior to 1920, 1920-35 inclusive and 1935-47 inclusive. The ratio of production during these periods was about 1:3.5:7. Likewise, pink production can be considered in 4 periods: 1917-19 inclusive, 1920-4 inclusive, 1925-37 and 1938 to present, with ratios of 2:4:0.5:1. These are admittedly only rough estimates. The suggestion, however, is that, for chums, 5% of the catch was used fresh or frozen prior to 1920, 20% between 1920 and 1935 and 40% since 1935; while for pinks percentages utilized fresh or frozen have been approximately 10% for 1917-19, 20% for 1920-4; 2.5% for 1925-37 and 5% since 1938.

Other Methods of Utilization

(i) DRY SALTING OF SALMON—This process has, in the past, accounted for more of the chum salmon than any of the other pickling or curing processes.

In this method the fish, after being dressed, are placed in layers in pickling butts or vats with about 15 pounds of half-ground salt for every 100 pounds of fish. A week or 10 days later the fish are removed, rubbed clean and repacked in 200-pound barrels, using 100 pounds of salt to every 600 pounds of fish.

This industry first became important on the Pacific coast during the Russo-Japanese War (1904-5), and the shipments to the Orient maintained the industry, with various ups and downs, until the recent war (Cobb, 1921; Wallace, 1945). The Provincial Government has not issued dry-saltery licences since 1939 and there has been no production of this commodity since 1938.

Figures for the production of chum and pink dry salted were summarized for the years 1925-38 inclusive in the 9th Annual Report of the Department of Fisheries, Ottawa (1939). For years previous to this we have figures for the total amounts of salmon dry salted. The 1925-38 data show that 95.4% of all the salmon dry salted were chum and 3% pinks. On the basis of these figures we have estimated production for the years 1916-24 inclusive (fig. 4). Equivalent numbers of cases may be estimated from the ratios of 80 pounds of fresh

Pacific salmon to the case and 125 pounds of fresh salmon to make a hundredweight of dry salted fish. The development of the industry in the early 20's is evident. A relatively steady period followed with production fluctuating around 100,000 cwt.

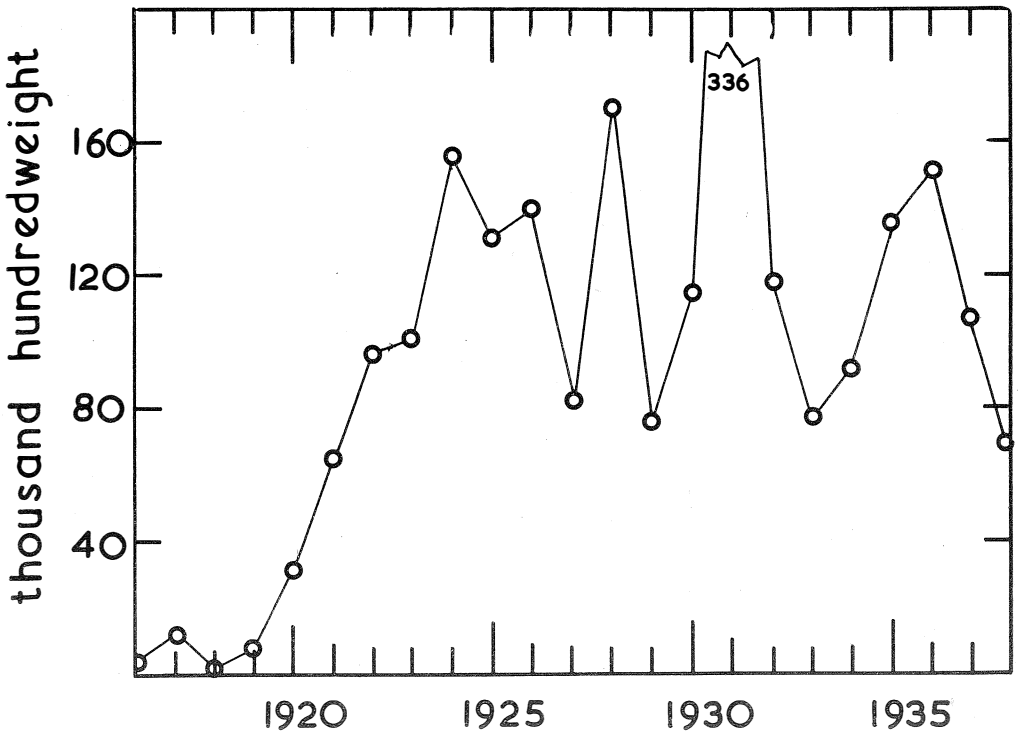

FIGURE 4. Chums dry-salted, 1916-38.

(ii) BRINE CURING—The Provincial Fisheries Report for 1938 states that 68,949 chums were brine cured at a plant in Barkley sound. These were shipped in barrels (900 lb. each) to Japan. This was a new development and the operation was not repeated because of the outbreak of war in September, 1939.

(iii) MILD CURING—Quantities of Pacific salmon are mild cured (brine cure) for subsequent smoking. Spring salmon are almost invariably used for this purpose. Chums and pinks have been tried (Cobb, 1921) but the small quantities used in this way can be neglected.

(iv) PICKLING—Pickling in brine was the earliest method used for preserving salmon on the coast. In Canada pickling was discontinued in 1939, but prior to that year small quantities were so cured. In the early days of the

industry the sockeye was favored but in the last 15 or 20 years springs have been most popular. Any of the Pacific salmon may be used for salting and the chum and pink production may be influenced slightly by this.

(v) SMOKING AND KIPPERING—These processes may be regarded as continuations of the pickling. In the first process the fish, after having the salt soaked out, is cured with heat and smoke. In the kippering process the fish is dried in a hot fire and then smoked over a hot fire. Chum salmon and, to a lesser extent, pinks have been used but the consensus of producers is that the quantities processed in this way are only a fraction of one per cent of the total. It appears further that chums and pinks pickled, smoked and kippered were frozen first and will consequently show up in the production figures for frozen salmon.

(vi) SALMON USED AS BAIT—Salmon are occasionally used as bait for halibut and other fish. The quantities, however, are small in comparison with the total production. Any of the salmon which have been held too long may be discarded as bait, but chum is probably the species most frequently disposed of in this manner. The total quantity of all salmon used as bait has never exceeded the equivalent of 2,000 cases annually and is usually of the order of the equivalent of 500 cases or less. It probably does not affect the overall production figures greatly, but may introduce considerable errors in certain localities.

INDIAN FISHERY

It is impossible to estimate with any degree of accuracy the numbers of chum and pink salmon taken by the Indians during the period under consideration. Since 1937 the Dominion Fisheries Department has published figures for the three fishing districts of British Columbia. These figures are estimates made by fisheries' officers and admittedly useful in a general way only. Fig. 5 summarizes these data. This figure emphasizes the fact that considerable numbers of fish (in 1939 about two million pounds of chums and three-quarters of a million pounds of pink) are used by the Indians, that the numbers are variable and that a regular decline in the Indian fishery is evident since 1939. This decline is, no doubt, related to the greater opportunity for work and higher wages paid during the war and post-war period. It is highly probable that the Indian fishery will vary with economic conditions. When there is ample employment and wages are high the men will leave the fishing to the women and the women will not fish as intensively if food can be procured at the local store.

Again the quantities of salmon eaten by Indians will vary with the supply of big game. It is, for example, noted in the Annual Report for 1934, Department of Fisheries, Ottawa (p. 76, 1935) that the Indians at the outlet of Stuart lake have not depended so much on sockeye owing to the increase in quantities of moose in the northern section of the Fraser river watershed. Although chum would not be affected in this particular instance, the same sort of thing may

be expected to occur in other areas. It is impossible to evaluate this factor in a precise quantitative manner over the years.

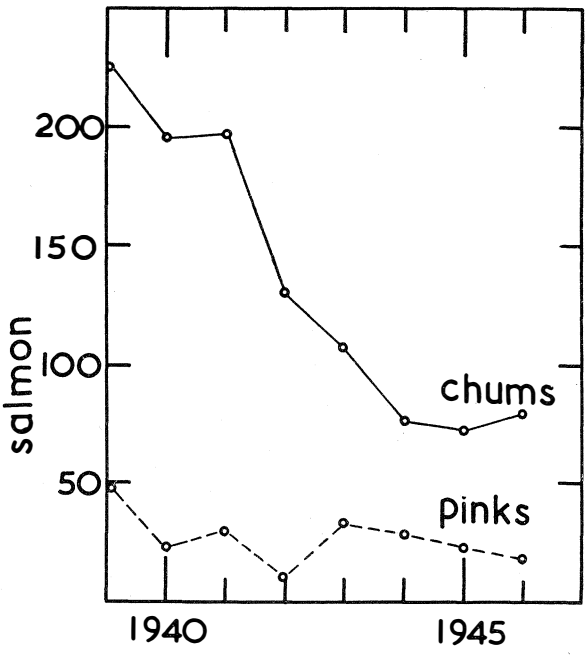

FIGURE 5. Numbers of salmon taken by Indians under free permit, 1939-47, in thousands.

VARIATION IN SIZE OF FISH

AN analysis of the available data indicates three sources of size variability in pink and chum salmon. Average sizes vary within the season, between localities and between years.

SIZE VARIATIONS WITHIN THE SEASON

In table V the "*b*" values of the regression equation $\hat{Y} = a + bX$ (Snedecor, 1946), show the weekly change in average size (pounds) for salmon weighed in the various areas. In the Port McNeill to Seymour Narrows region the average weekly size of pink salmon shows a small improvement in each of the three years considered. The reverse was true for pinks in all other areas, and for chums in all areas considered. In addition to the data summarized in this table, five regressions were calculated for pinks landed at Klemtu, Namu and Kildonan, four of which indicate significant decreases in size ($P < 0.05$). Eight other negative regressions were calculated for chums, four of them significant.

It would thus seem that, in most localities, the weights of chum and pink salmon decline during the fishing season. Apparently the larger fish come

earlier into the fishery. It seems probable that there is a relation between rate of growth, onset of sexual maturity, and availability to the fishery. However, since these seasonal variations follow a general pattern from year to year, they will not affect the overall production figures greatly and need not concern us further here.

TABLE V. Changes in weekly average size, in pounds, of salmon weighed in different areas.

Area	Period	Regression equation $\hat{Y} = a + bX$				
				Limits of b		
		a	b	$t_{.05}s_b$	t	P
		lb.	*lb./week*	*lb./week*		
PINK SALMON						
Port McNeill	Aug. 11 - Oct. 6, '45	4.45	+.06	.04	3.22	<.02
to Seymour	Aug. 10 - Oct. 19, '46	2.80	+.09	.07	3.06	<.02
Narrows	Aug. 9 - Nov. 1, '47	4.25	+.01	.02	2.00	>.05
Butedale	July 14 - Sept. 22, '45	5.19	−.21	.05	11.05	<.01
	July 13 - Sept. 7, '46	3.65	−.07	.03	6.08	<.01
	July 12 - Sept. 27, '47	4.74	−.12	.06	4.47	<.01
CHUM SALMON						
Port McNeill	Aug. 11 - Nov. 3, '45	10.79	−.12	.05	4.92	<.01
to Seymour	Aug. 10 - Nov. 16, '46	11.68	−.23	.35	1.44	.22
Narrows	Aug. 9 - Nov. 15, '47	10.98	−.12	.05	4.86	<.01
Butedale	July 14 - Sept. 22, '45	15.22	−.68	.18	8.71	<.01
	July 13 - Sept. 7, '46	16.14	−.83	.23	8.36	<.01
	July 12 - Sept. 27, '47	11.40	−.26	.18	3.16	<.02
Klemtu	July 21 - Sept. 24, '45	12.43	−.41	1.33	.86	.45
	Aug. 2 - Sept. 27, '47	10.96	−.34	.21	4.13	<.01
Namu	Aug. 3 - Sept. 28, '46	12.16	−.73	.39	4.87	<.01
Ceepeecee	Sept. 21 - Nov. 9, '46	10.43	−.30	.07	9.68	<.01
	Sept. 20 - Oct. 25, '47	10.11	−.23	.15	4.30	<.02
Kildonan	Sept. 28 - Nov. 9, '46	10.44	−.35	.11	8.24	<.01
	Sept. 22 - Oct. 20, '45	10.34	−.39	.18	6.09	<.01

VARIATIONS IN SIZE BETWEEN LOCALITIES

The best available data on local variations are those provided by the Salmon Canners' weighings of 1944. These, summarized in table VI, suggest that, for chums, size variations may produce inaccuracies in interpretations of abundance based on weight of fish. Here the variation from place to place may amount to 3 pounds or more. The pinks, with their more precise 2-year cycle, show less local size variation and this factor can hardly affect the production picture for pinks. At the present time there is no way of compensating for these place-to-place variations of chums in an analysis of the catch statistics. With

the improved collection of fish statistics, and additional weighings in the areas over a period of years, adjustments for this factor could be made.

TABLE VI. Average sizes of seine-caught pinks and chums, 1944.

Place and date	Number of samples	Size of samples	Mean weight	Standard deviation	Fiducial limits 95%
			lb.	*lb.*	*lb.*
PINK SALMON					
Koeye—Aug. 4	19	100	4.44	.16	±.08
Nass Steamboat channel—Aug. 8, 9 and 10	58	50	4.48	.16	±.04
Massett—Aug. 21	31	60	4.57	.17	±.06
Skidegate—Aug. 21	20	75	4.58	.29	±.13
Whale channel—Aug. 17	43	75	4.46	.12	±.04
Fin island—Aug. 16	21	75	4.49	.16	±.07
CHUM SALMON					
Nass Steamboat channel—Aug. 8-9	21	20	11.56	.59	±.27
Fin island and Whale channel—Aug. 16-17	25	25	10.59	.70	±.29
Selwyn and Cumshewa—Sept. 12-13	178	25	9.35	.43	±.06
Deena river—Sept. 15	70	30	8.26	.40	±.09
Growler cove—Sept. 20-21	57	25	11.22	.91	±.24
Alert bay—Sept. 21	37	25	11.25	.59	±.20
Bear river—Sept. 26	49	25	10.46	.82	±.23
Sewell—Sept. 12	18	30	9.53	.35	±.15

ANNUAL VARIATIONS IN SIZE

Errors from annual variations in size are liable to be more serious than the seasonal or local variations. It is evident from table V that the pinks and chums may run consistently heavier or lighter from year to year. The pinks with their precise 2-year cycle show these differences more clearly, but they are obvious for both species.

Table V shows that the pinks average more than 1 pound lighter in 1946 than in 1945. The 1947 figures are intermediate. The trend seemed to be in the same direction at all points on the coast. The histograms of fig. 6 for the Butedale and Koeye areas where there are figures for 4 years on the same date, again show yearly differences.

It would be interesting to follow such changes through several seasons to see whether there is a regular variation. Average weights are available only for the 4 years indicated. However, a large packing company has supplied the average numbers of pink salmon used per 48-lb. case for the years 1927-43. These data are graphed in fig. 7. The variation is seen to be of considerable magnitude (as much as 8-10 fish per case). Further, whatever factor is responsible for this variation seems to operate generally on the British Columbia coast. Five areas for which the series of figures is fairly complete are plotted. In only 3 instances are there inconsistencies in the annual trend at any one time.

Such variations in size of fish might be due to variations in the size of the brood year or related to feeding conditions and competition in the ocean. If an extremely successful spawning produced so many fish that the available food was limited and with it the fish's growth, then the size of fish should be less in the years when the numbers are relatively greater and vice versa. Davidson and Vaughan (1941) have studied variations in the size of pink

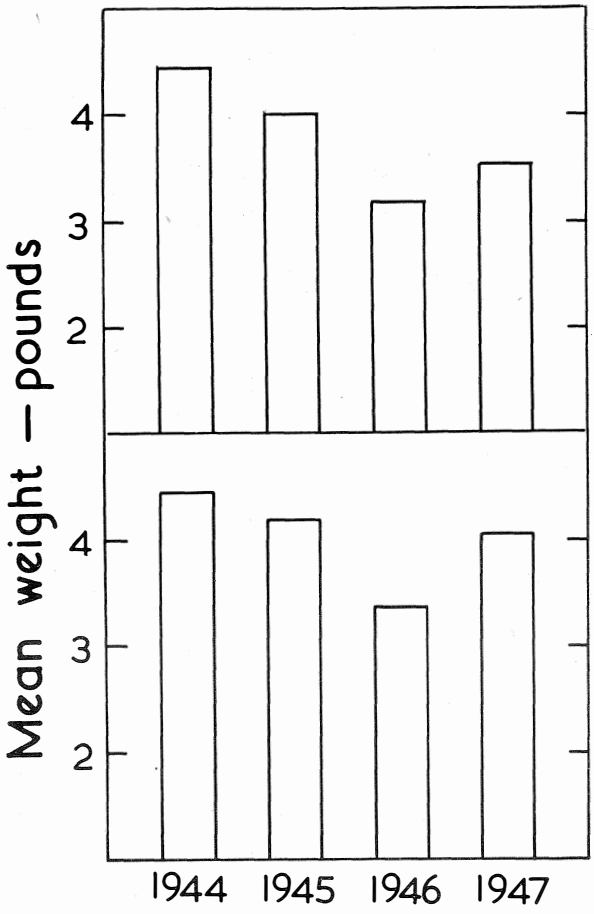

FIGURE 6. Annual changes in mean weight of pink salmon. Upper, Butedale Area, August 17; lower, Koeye inlet, August 3-4.

salmon taken in southeastern Alaska from 1895 to 1940. Their graph shows the same general oscillation in size as is evident in fig. 7, with largest fish appearing in the "odd" years in southeastern Alaska as in British Columbia. These writers have not concerned themselves with such minor fluctuations but have empha-

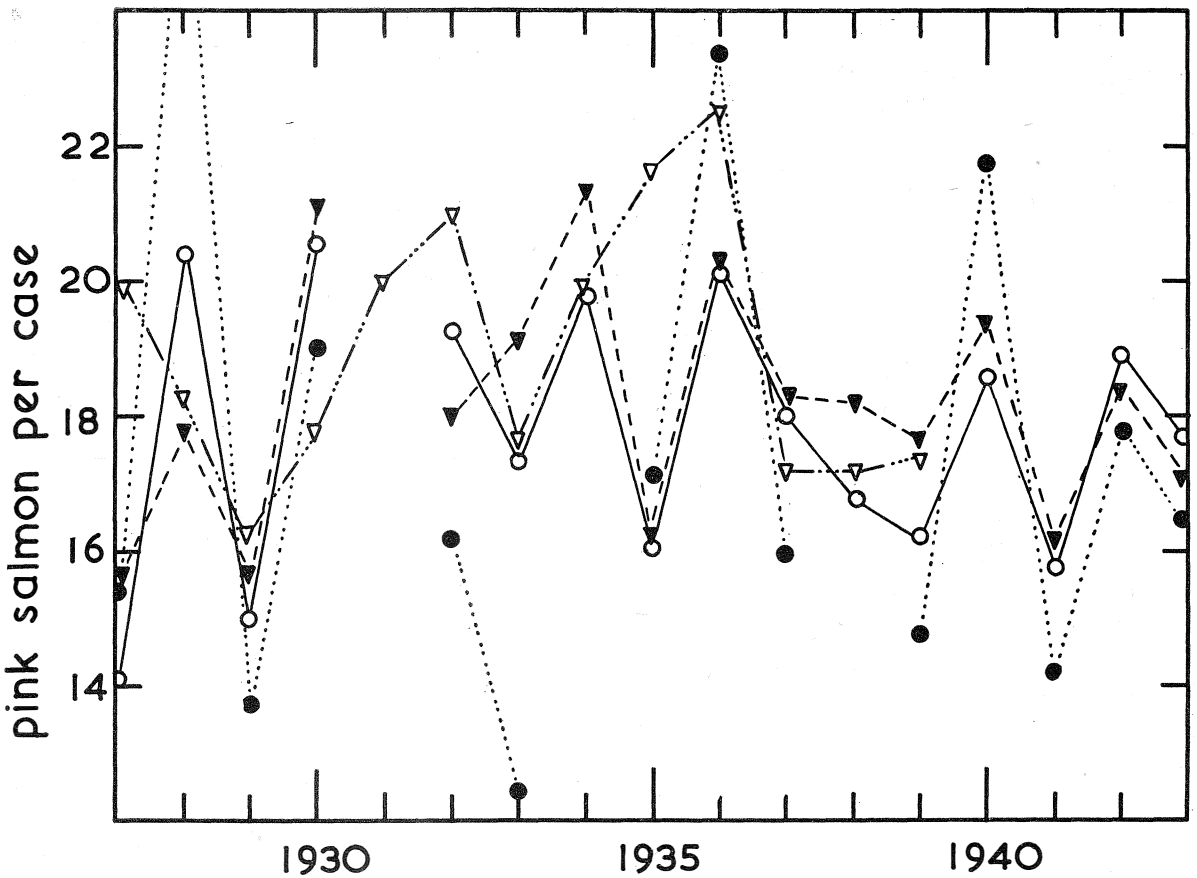

FIGURE 7. Number of pink salmon per 48-lb. case at four different canneries. Solid circles, near Vancouver (27.1 in 1928); solid triangles, near Prince Rupert; open circles, Central area; open triangles; Rivers and Smiths inlets.

sized the fact that the average size of pink salmon in this area increased from 1911 to 1921 while the stocks declined. A relationship between density of pink salmon population and rate of growth is strongly indicated. Other workers have been impressed by marked fluctuations in size of mature salmon. Gilbert (1923) suggested that the small size of the 1922 sockeye was related to unfavourable conditions in the year of maturity. Dannevig (1949), on the other hand, shows an annual fluctuation in size of Atlantic salmon (*Salmo salar*) very similar to that described for pinks and provides a suggestive correlation for a relation between size of fish and the water temperature during the first year of sea life.

The British Columbia data offer interesting material for a study of these annual fluctuations in size of pink salmon. Fig. 7 shows that the same general trend in size occurs on the Fraser, Skeena, Rivers and Smiths inlets and in the Central area. Since pink salmon show such different and marked cycles of abundance in these areas it is difficult to relate these size variations to the density of population. Thus, on the Fraser the maximum stocks of pink salmon have appeared, at least since 1907, in the "odd" years whereas in the Queen Charlotte islands, on the Nass and Skeena rivers the "even" years have produced maximum stocks. In the Rivers and Smiths inlets and Vancouver island areas the "odd" years have shown a well-marked cycle of abundance since 1933 while prior to that time there was either no well-marked cycle (Vancouver island area) or this occurred in the "even" years (Rivers and Smiths inlets). Considering the total production of British Columbia pink salmon, the "big" years for pinks were the "even" years from 1918 to 1930 but have been the "odd" years from 1933 to 1947. In spite of these variable cycles the largest pink salmon seem to have appeared consistently in the "odd" years. For these annual fluctuations in size, such considerations make it difficult to associate size of fish with density of population. It is felt that these annual variations in size of pink salmon are likely to be related to feeding conditions in the ocean but, at the moment, no explanation of the mechanism is offered.

One other observation may be made in connection with fig. 7. For the Fraser river (solid circles), a 4-year cycle in pink salmon size is also suggested. Thus in 1928, 1936 and 1940 the fish were particularly small, compared to other even-numbered years. On the other hand, in 1929, 1933, and 1941 the pinks in the Fraser river area were exceptionally large. It is possible that the dominant 4-year cycle of abundance in Fraser river sockeye is related to this size variation and that the pink salmon of the Fraser compete with the sockeye. During this period the years of abundance for mature sockeye on the Fraser river were 1930, 1934, 1938 etc. Thus the exceptionally small pink salmon live their second year of life in the ocean in the same year as the superabundant sockeye population spends its first year of sea life (second year of life) there; on the other hand, the exceptionally large pink salmon are in their second year of life during the only growing season in which no

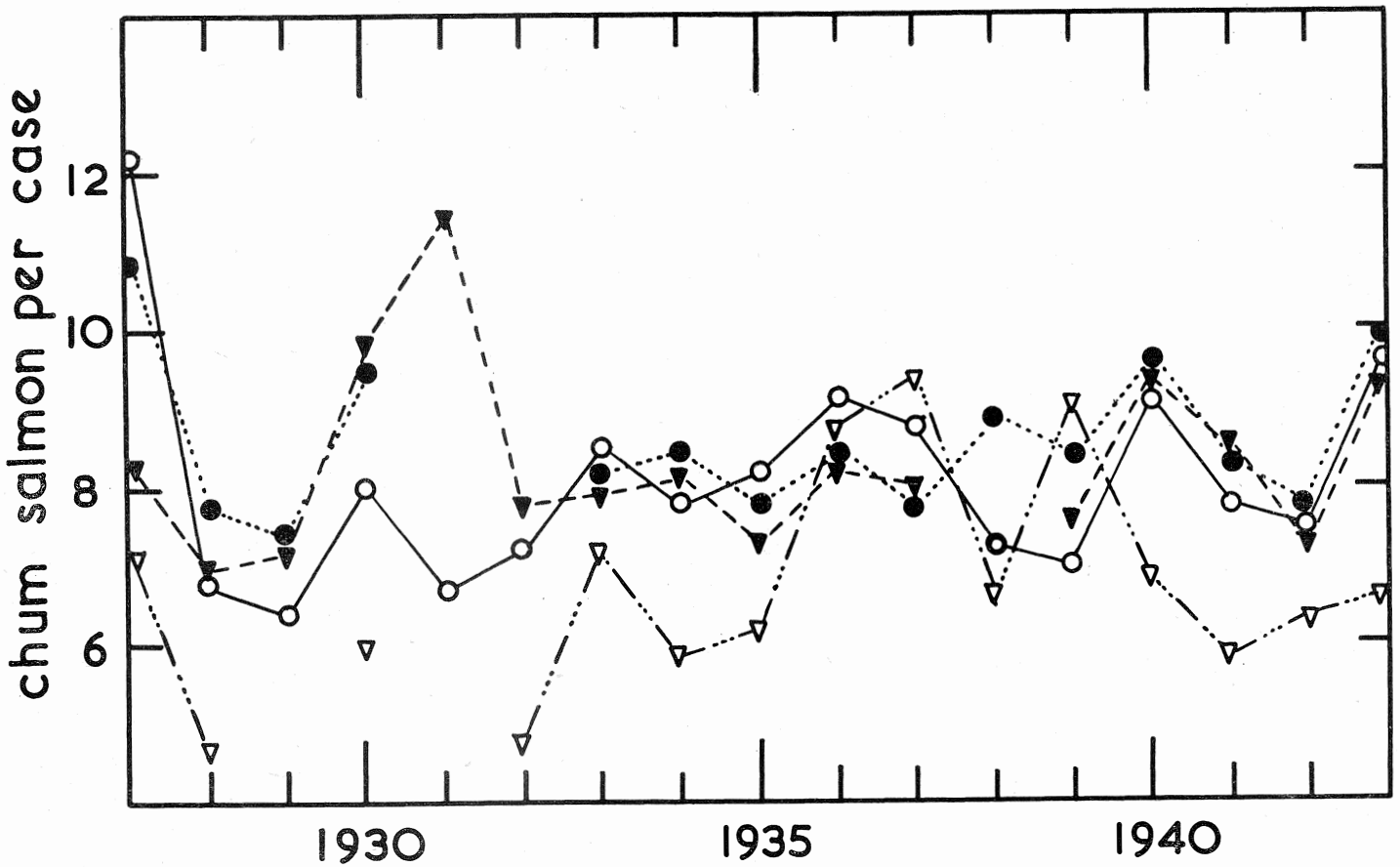

FIGURE 8. Number of chum salmon per 48-lb. case at four different canneries. Solid circles, West coast Vancouver island; open circles, Central area; open triangles, near Prince Rupert; solid triangles, near Vancouver.

4-year sockeye of any age from the superabundant population are present in the ocean. These coincidences can at most suggest a line of investigation into possible food competition, which could be studied directly from the stomachs of ocean-caught fish if these can be obtained, or indirectly by comparing relative first-year and second-year growth on the scales of the pinks in different years.

Table V shows that for chums, also, there are seasonal differences in size. It appears that chum salmon were, on the whole, heavier in 1946 than in 1945 or 1947 and that the fish weighed somewhat less in 1947 than in 1945. The figures for average number of fish per 48-lb. case have been graphed in fig. 8. Considerable variation is apparent (up to 3-5 fish per case) and the peaks and depressions are quite general for the coast. Further, it is evident from a comparison of figs. 7 and 8 that the variability in number of fish per 48-lb. case is of the same order for both pinks and chums. In making these comparisons it must be remembered that the chums weigh at least twice as much as the pinks (table V). One contrast between the two species is, however, obvious. The size variation does not oscillate as regularly for chums as for pinks. Since the chum samples will contain two or three different year classes this irregularity is not unexpected. A rhythm, nevertheless is still apparent. In the 17 years under consideration chums have shown 6 definite peaks and 5 depressions. This gives, in a very rough way, a 3-year cycle for large chum salmon.

DISCUSSION OF CATCH STATISTICS

THE foregoing survey shows how difficult it is to obtain precise figures for the total catches of pink and chum salmon. If the canned salmon pack is used as a basis for calculations, it is necessary to add to it the amounts marketed fresh, frozen, salted or otherwise processed. The amounts used by the Indians will be important when it comes to estimating the total drain on the stocks. Variation in size of fish may also affect the picture. For pinks, this size difference may amount to from 8 to 10 fish per case; for chums, from 2 to 5 fish per case. The fisheries biologist should have an understanding of the annual changes in numbers as well as weight. It may not be legitimate to conclude, on the basis of weight of fish processed, that the population had been reduced, since such apparent reduction might be caused by size variation only.

ABUNDANCE OF PINK SALMON

It has been stated that the bulk of British Columbia pink salmon are canned. Amounts frozen and otherwise processed will not greatly affect the picture for pinks. In the first place it is estimated that less than 10% (probably less than 5%) of the catch is used in this way and with packs of 50,000 cases and more an

increase of 10% will cause only minor changes in the overall picture. With such quantities "the index of return" (figs. 9-13) would be changed by 1% at the 100% line. Most of the variations are of a much greater order. Secondly, the only abrupt changes in quantities of frozen pinks (freezing is the only important processing method other than canning) occur in 1925 and 1942. De-

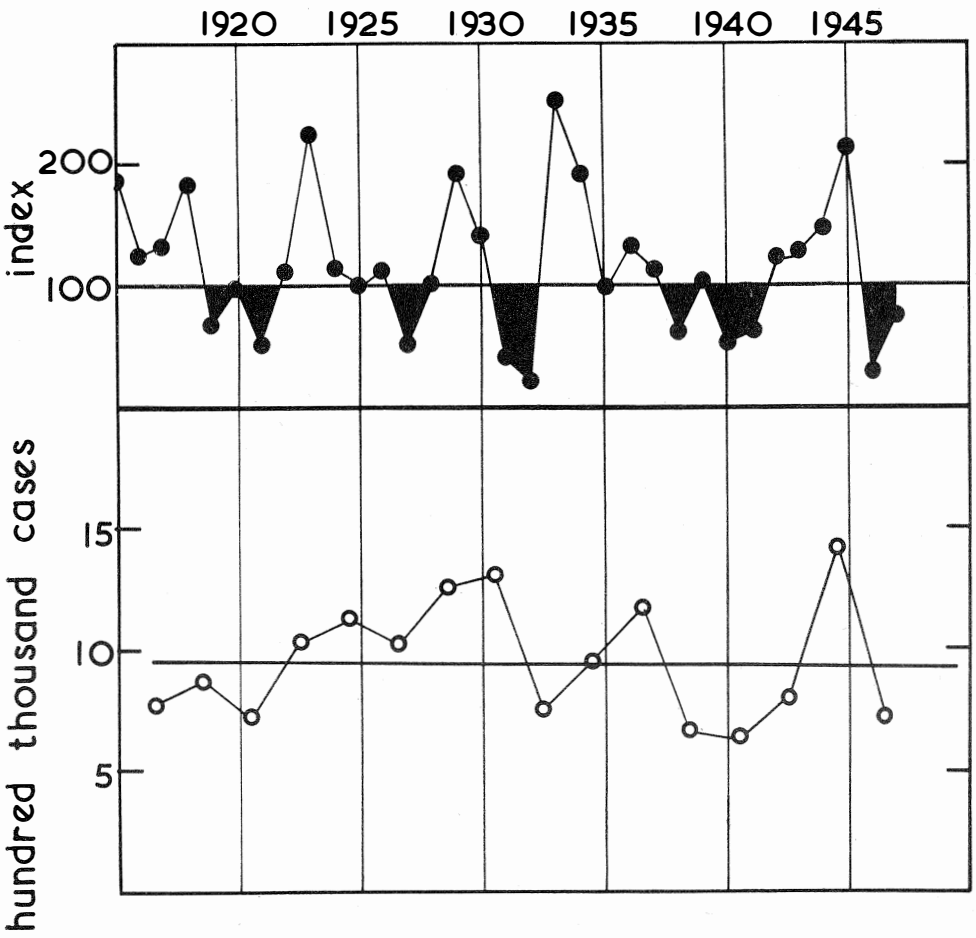

FIGURE 9. Canned pink salmon packed in British Columbia. Open circles, cases packed in biennia of 1916-17 to 1946-47; solid circles, indices of return calculated annually; regression line cuts across the graph for cases packed.

creasing amounts frozen in 1925 would have caused an increased "index of return" in that year. The reverse is the case. On the other hand, increased freezing in 1942 should cause a decreased "index of return". This does not appear in the overall picture (fig. 9). In localities (fig. 10) where the index

is below 100% in 1942, it is too far down to be caused by the small increase in frozen pinks indicated by the data (0.5% of catch). Since the size variation in pinks is of a 2-year cyclical nature, it cannot greatly affect the regression

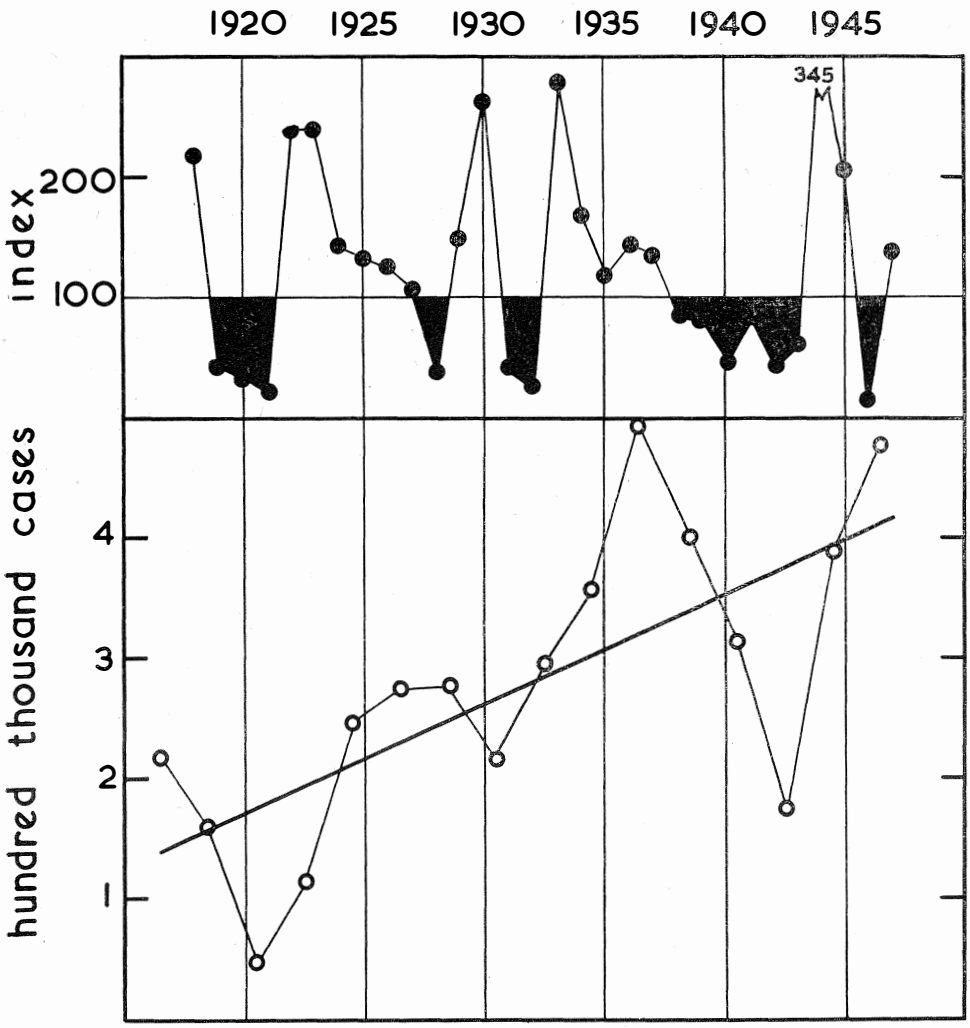

FIGURE 10. Canned pink salmon packed in southern British Columbia, districts 1 and 3. Open circles, cases packed in biennia of 1916-17 to 1946-47; solid circles, indices of return calculated annually; regression line cuts across graph for cases packed.

lines or "index of return". The regression lines were calculated from the biennial totals of the pink life cycle; the "index of return" is calculated from parent and offspring generation figures (that is, figures of alternate years).

Figures for the pink salmon packed should, then, serve adequately to show general trends in catch.

Figs. 9-14 summarize graphically the statistics for pink salmon from several of the larger regions. The "index of return", as well as the trend lines for total

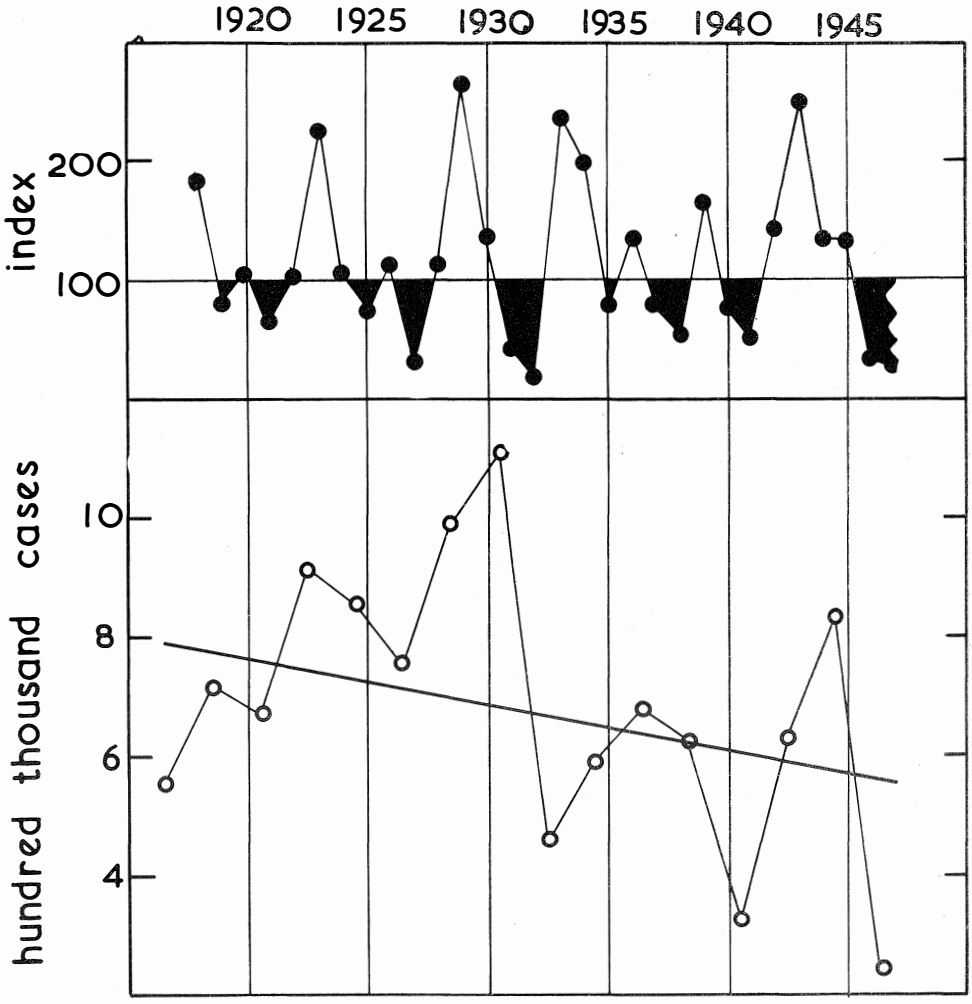

FIGURE 11. Canned pink salmon packed in northern British Columbia, district 2. Open circles, cases packed in biennia of 1916-17 to 1946-47; solid circles, indices of return calculated annually; regression line cuts across graph for cases packed.

pack, are shown. For pink salmon, with their precise life cycle, this index can be calculated accurately if the catch figures are reliable. The black areas below the 100% line emphasize periods of low production. Because of the nature of

the data, small variations in this index cannot be considered particularly significant, but when the index falls for several consecutive years below 75% (figs. 10, 12, 13) it must indicate an unhealthy condition. These graphs, in

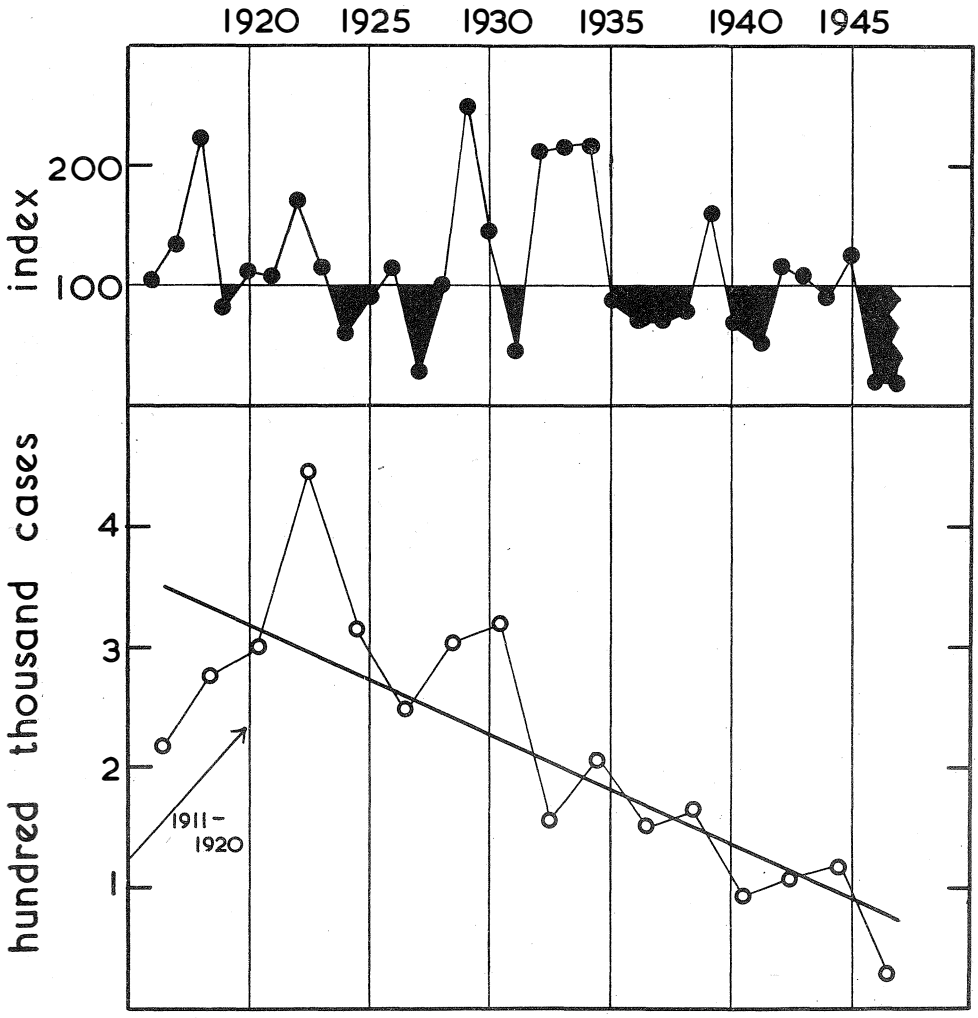

FIGURE 12. Canned pink salmon packed in the Skeena river area. Open circles, cases packed in biennia of 1916-17 to 1946-47; solid circles, indices of return calculated annually; regression line cuts across graph for cases packed; arrow at lower left is the regression for the period 1911 to 1920.

conjunction with table II, suggest three points for consideration. In the first place it is evident (fig. 9) that the total production of pink salmon in British Columbia has not changed greatly during the past 31 years. The pack has

fluctuated but the packs of today are of the same order as those of thirty years ago. In the second place, there have apparently been three (fig. 10) or four (figs. 11-13) periods when pink salmon production was particularly low in

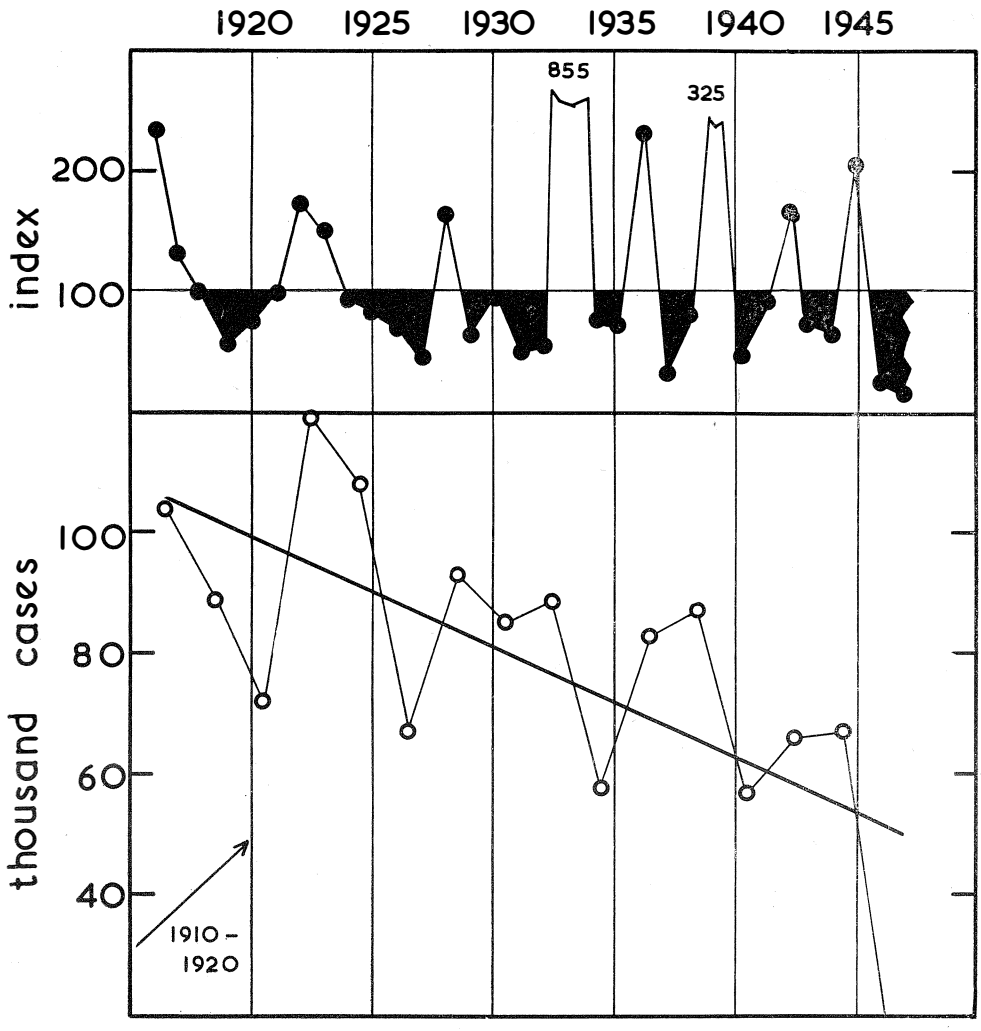

FIGURE 13. Canned pink salmon packed in the Nass river area. Open circles, cases packed in biennia of 1916-17 to 1946-47; solid circles, indices of return calculated annually; regression line cuts across graph for cases packed; arrow at lower left is the regression for the period 1911 to 1920.

British Columbia. This condition is most marked in the southern areas during the early '20's, '30's and '40's (figs. 10, 14). In the third place, there is an evident downward trend in the packs of the northern areas of the province (figs. 11-14)

and an upward trend in the southern regions (figs. 10, 14). Table II indicates for the Queen Charlottes, Rivers and Smiths inlets, a situation similar to that depicted for the Nass and Skeena in fig. 12 and fig. 13. Before considering the significance of these three points it is necessary to summarize the available information on fishing effort for pink salmon.

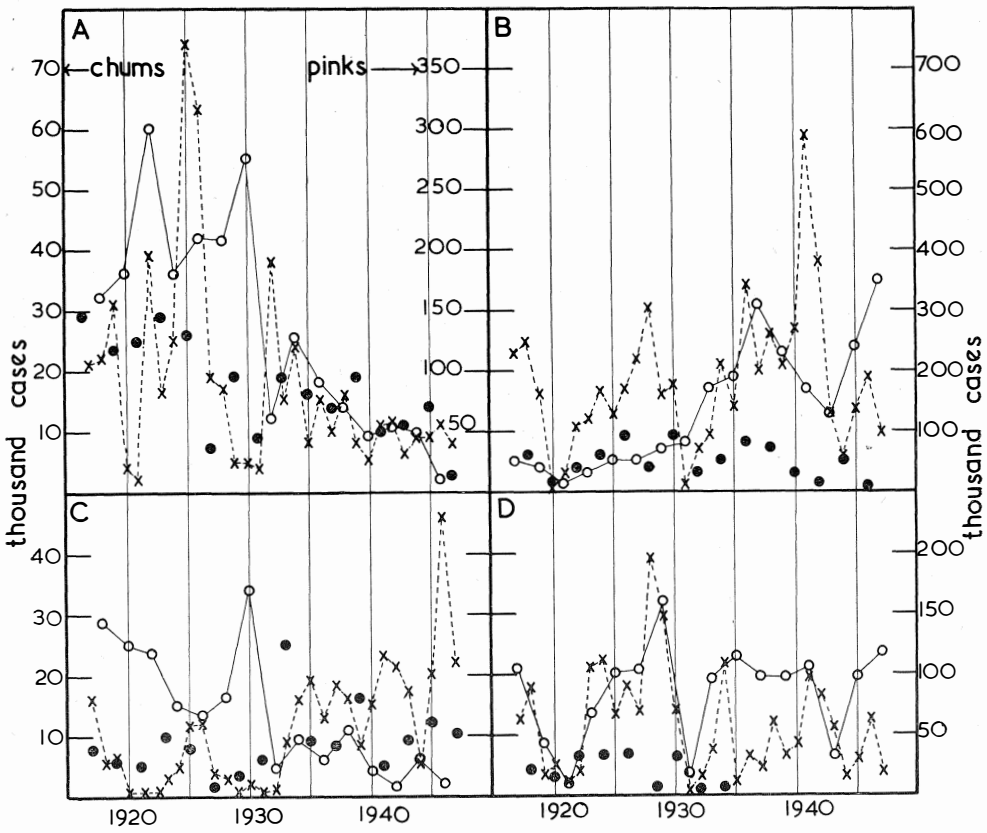

FIGURE 14. Comparisons of the pink and chum canned salmon packs in different areas. A, Skeena; B, Vancouver island; C, Rivers and Smiths inlets; D, Fraser. Crosses, annual pack of chums; open circles, pack of pinks in years of the more abundant cycle; closed circles, pack of pinks in years of the less abundant cycle.

VARIATION IN FISHING EFFORT FOR PINK SALMON

The Annual Reports of the Department of Fisheries (Ottawa) show that 90% of all the pink salmon caught in British Columbia are taken in either gill nets or purse seines. Although the quantities taken by purse seine have increased gradually (by about 0.89% per year since 1925) there has been no marked change at any one time. Such gradual changes will not affect the "index of return"

at any rate. No suggestion could be found in the literature that there has been any relative change in the fishing effort expended in the different regions. There is, however, very definite evidence that fishing intensity has varied during certain periods and these variations are most pertinent to an interpretation of the data. The Pacific Fisherman Yearbook and Reports of the Departments of Fisheries are the most helpful sources although no quantitative data on fishing effort are provided.

Except for two periods, the effort to obtain pink (and chum) salmon seems to have been consistently high. For 1921 the British Columbia Commissioner of Fisheries reports decreased packs of pinks (and chums) due to small demand. The Pacific Fisherman Yearbook (1921) reports the lowest salmon packs since 1910 for this year and says that it was due to restrictions of outfitting in certain areas but *also largely to shortages of fish.* The catch was, in many places, not commensurate with the gear employed and "it is doubtful if the output would have been materially larger if twice the quantity of gear had been used". Thus, although the effort was less in 1921, there is some evidence of a real shortage during this period. This is further suggested by the fact that the lower "index of return" so general at this time first appeared prior to 1921—in northern areas as early as 1918. The Annual Report of the Department of Fisheries, Ottawa, (p. 42, 1920) mentions decreased runs of pinks in 1919 due to the disastrous freshets of 1917.

Davidson and Vaughan (1941) found that the populations of pink salmon in southeastern Alaska declined from 1911 to 1921, with the greatest rate of decline occurring just prior to 1921. Their conclusion, based on the yearly catches of traps operated in the area, is that this decline in abundance "was due primarily to the unlimited exploitation of the resources by the commercial fishery".

The second period of decreased fishery effort was in 1931-2. For these years the British Columbia Commissioner (1932, 1933) records low packs due entirely to lack of demand, although Queen Charlotte pinks were a real failure in 1932. The Pacific Fisherman Yearbook records satisfactory runs of pinks but packs reduced materially owing to lack of demand. However, the spawning ground reports (Annual Reports, Ottawa, 1932, 1933) emphasize escapements below normal for many of the central and northern areas of the province in 1931 and 1932. The suggestion is that although demand was slight in these years, escapement was not above average and the low pack figures may not represent the true situation too inadequately. Numbers of purse seine licences issued tell the same story. There was a definite reduction in number of licences issued in 1921, 1931 and 1932. Effort to obtain pink salmon has been consistently high except for these three years.

Periods of Particularly Low Pink Production

The periods of particularly low pink production may now be considered in connection with what has been said regarding variations in fishing effort. Four

periods of low return are evident in the overall picture of pink salmon (fig. 9). As previously indicated, the low of the '20's was in part due to increased demand but probably in part, also, to scarcity of fish. The low production of 1927, particularly in district 2, was due entirely to low availibility. This is emphasized in all official reports. The low of the '30's may have been due entirely to decreased effort, but there are suggestions of a reduction in supply also. The low of '38-'42 was certainly due to a scarcity of fish. The same picture is evident in many of the individual areas. Except for the excessively low period in the early '30's it seems probable that the graphs developed from the canned pack represent the major fluctuations in the available stocks of pink salmon.

Thus it is suggested that, in addition to the well-recognized annual alternation in particularly successful generations of pink salmon, there are longer cycles in abundance affecting both "odd" and "even" years (fig. 14). Such fluctuations are not uncommon in marine fisheries. This variation in abundance is probably not as serious as the progressive declines in production to be discussed in the next section. There is ample evidence to show that the "index of return" may swing from an extremely low value one year to an extremely high value the next, and that the catch may show a 100% increase or decrease between generations. However, an understanding of the causes of these cycles of abundance is vital to prediction of events and scientific management of the fishery. It is probable that environmental conditions are ultimately responsible for these cyclical variations in abundance; however, an analysis of the relationship between variations and environment is beyond the scope of the present bulletin. In this connection, fig. 14 suggests an interrelation between the cycles of abundance of pink and chum salmon. There seems to be an inverse relationship between chums and the abundant pink generation for Rivers and Smiths inlets and the Skeena—before the stocks there declined. This is suggested also for the southern areas plotted in fig. 14 although the condition is less marked. This inverse relationship may be, partly or wholly, due to relative strength of market demand, rather than intercompetition between species.

Decline in the Catches of Northern Pinks

This decline is the most striking feature of the statistics presented for pink salmon and one which should, perhaps, give rise to some concern. Four possible explanations of the decline are suggested: changes in relative fishing effort in different areas; transport of more and more of northern British Columbia pinks to canneries in other areas; a real decline in the northern stocks of pink salmon; increasing stocks of predators or competitors. The first possibility is remote and has been mentioned in the previous section; consideration of the last possibility will not be attempted with the data presently available.

The canning of increasing quantities of northern pinks in southern British Columbia would account for the increased packs evident in the latter region. However, although the evidence is indirect, there is very little to support the

theory that more northern pinks are being canned in the southern area. The statistics used are said to be for quantities of fish caught in the area regardless of where canned or marketed. It is commonly admitted that inaccuracies in these statistics are likely to occur. There is a feeling that figures compiled by the inspectors in certain areas may be more accurate in detail. These are available from some districts for the years since 1930 and have been summarized in table VII. The decline in catches is still evident although the probability values are not as low for the shorter period. The inspectors' figures confirm the finding for declining pink catches in northern British Columbia.

TABLE VII. Biennial catches of British Columbia pink salmon, 1930-47, calculations to nearest cwt., data compiled from inspectors' reports.

Area	Catch in		Regression equation $\hat{Y} = a + bX$				
	1930 and 1931	1946 and 1947	a	b	Limits of b		P
					$t_{.05}s_b$	t	
	cwt.	*cwt.*	*cwt.*	*cwt./ 2 yrs.*	*cwt./ 2 yrs.*		
Nass river	84,308	12,326	96,650	− 6,930	5,132	3.193	0.02*
Skeena river	205,072	20,359	168,549	−13,258	10,862	2.886	0.02*
Queen Charlottes	179,945	10,099	95,250	− 6,630	15,732	0.997	0.35
Bella Bella and Bella Coola	166,396	56,563	99,295	+ 3,000	16,425	0.432	>0.5
Central Area	467,899	158,134	299,865	− 8,633	39,980	0.511	>0.5
Rivers and Smith inlet	15,196	9,752	13,915	− 203	1,341	0.359	>0.5
Victoria (Sooke traps)	18,638	30,409	17,583	− 516	3,112	0.393	>0.5
Alert Bay[1]	164,347	197,273	171,714	− 1,204	22,650	0.137	>0.5
Alberni[2]	189	792	76	+ 74	86	1.337	0.2

*Significant trend. [1]Cycle years of 1934-5 to 1946-7. [2]Cycle years of 1936-7 to 1946-7.

In addition, it is perhaps worth mentioning that only in district 3 (Vancouver island and adjacent mainland) have the catches increased and it is quite unlikely that fish have been transported into this district for canning. For district 1 (Fraser river), which is the centre of southern canning operations, the pack shows a small decline for the period considered. However, the packs here are quite variable–possibly owing to competition between American and Canadian fishermen. This same irregularity is evident to a lesser degree at the northern limit where the "index of return" for the Nass river shows such extreme variation (fig. 13). Lastly, it may be mentioned that the orderly decline in northern pink salmon packed appears to be continuing (figs. 12, 13) while the increasing packs elsewhere have levelled off or are showing declines (fig. 10).

It might be suggested that increasing quantities of northern British Columbia pinks are being taken in the Alaska fishery. The data, however, do not support the idea. The regression of southeastern Alaska pink salmon pack (data from the Pacific Fisherman Yearbook, 1950) upon time is negative for this period. The

fishery in southeastern Alaska is evidently following a course somewhat similar to that in northern British Columbia. The present evidence indicates that northern pink salmon have experienced a real decline during this period. The trend should be followed closely in the next few years.

Abundance of Chum Salmon

Again, it is necessary to base the discussion on the canned pack, since the greater part of the catch is disposed of in this way and since, for the 31-year period, only the canned pack figures are broken down as to area.

Table VIII. British Columbia chum salmon catches, 1930-47, calculated to nearest cwt., data compiled from inspectors' reports.

Area	Catch of		Regression equation $\hat{Y} = a + bX$				
					Limits of b		P
	1930	1947	a	b	$t_{.05}s_b$	t	
	cwt.	*cwt.*	*cwt.*	*cwt./yr.*	*cwt./yr.*		
Nass river	3,721	8,764	6,735	+ 137	498	.584	>0.5
Skeena river	3,364	8,111	10,012	− 107	498	.453	>0.5
Queen Charlottes	78,513	14,711	60,365	− 838	3,350	.531	>0.5
Bella Bella and Bella Coola	73,990	142,390	44,748	+2,037	3,651	1.182	0.26
Central Area	82,750	226,882	64,300	+3,536	4,064	1.845	0.06
Rivers and Smith inlet	11,420	21,826	5,300	+ 843	854	2.090	0.06
Victoria (Sooke traps)	992	3,146	633	+ 12	69	.037	>0.5
Alert Bay[1]	41,571	148,227	40,146	+5,907	4,584	2.784	0.02*
Alberni	82,560	4,460	89,895	−3,789	2,739	2.933	<0.01*

*Significant trend. [1]1934-48 inclusive.

The data for chums are summarized in table III. The most striking feature of this summary is absence of statistically significant trends in the fishery in different areas. Only two of the 10 regression coefficients calculated have probabilities of less than 0.05. Two possible explanations were considered. Either (*a*) the pack figures are not sufficiently accurate to reveal an existing trend, or (*b*) fluctuations in the availability and/or fishing effort are so great that there can be no orderly change during the period under discussion.

It is certainly true that the pack figures represent only a part of the salmon taken. They may not reveal trends which actually exist. The most reliable figures for quantities of fish captured in the various areas are perhaps those compiled by the inspectors. These are available from certain areas for the years 1930-47 inclusive and have been summarized in table VIII. On the whole the trends are just as variable as those of table III and the probability values do not suggest any greater reliability. In addition, figs. 19 and 20 show that the canned pack figures parallel the inspectors' figures, at least in a general way, for the period in which both sets of values are available.

If radical changes in availability have occurred during one or two periods, the fishery may have undergone changes which would be revealed if the data were

considered for shorter periods. Three 10-year periods were, therefore, considered separately and the data calculated for each of the areas shown in table III. The picture was not clarified. Only one significant value appeared in 24 regressions calculated.

On the whole it seems that the fluctuations in availability (possibly fishing effort) of chums must be very great and that no significant trend in quantities taken has occurred. A study of the "index of return" emphasizes this variability and suggests some additional features in the chum statistics.

Index to the Success of Return for Chum Salmon

It has been pointed out that the validity of this index depends upon a constancy in fishing effort between parent and offspring generations and upon a knowledge of the age composition of the stock. Probable changes in fishing intensity are discussed in more detail below. At the moment it can be stated that although such changes are evident they have probably not been radical enough to alter the major fluctuations of the "index of return". The age composition of chum salmon varies greatly from place to place and for many areas there is no precise information (Pritchard, 1943). Considering the uncertainties involved the wisdom of making index calculations might be questioned. However, it will be shown that major variations in the fishery have been so great that the index picture is the same within the extreme limits of possible age composition; further, that these variations in index do not seem to be associated entirely with changes in effort.

In addition to the data summarized by Pritchard (1943) age determinations for over 2,000 Johnstone strait, 2,000 Central area and 1,000 West Coast, Vancouver island chums were available for this study. Since the precise age composition is so variable (Pritchard, 1943; upub. data Pacific Biological Station) and since there is no information for some of the fishing areas and since small differences in age composition do not change the important major fluctuations found in the "index of return", we have used an overall approximate figure of 35% 3-year and 65% 4-year fish in calculating the indices of return for the chums. This is an approximation to the percentage of 33% 3-year, 65% 4-year and 2% 5-year, obtained from a compilation of ages of 7,792 chum salmon available in 1946. The following considerations would seem to justify the use of this approximate ratio.

Theoretically it should be possible to decide which of the ratios most nearly represents the true age composition by comparing the correlation coefficients of offspring and the different theoretical parent generations. This has been attempted but table IX shows that there is no significant correlation between parent and offspring using any of the ratios. The chum fishery does not show the direct correlation between generations which is evident for pinks (table X) or which Barnaby (1944) demonstrated for the Karluk river sockeye in Alaska.

In fig. 15 the index for Vancouver island is shown as calculated from the

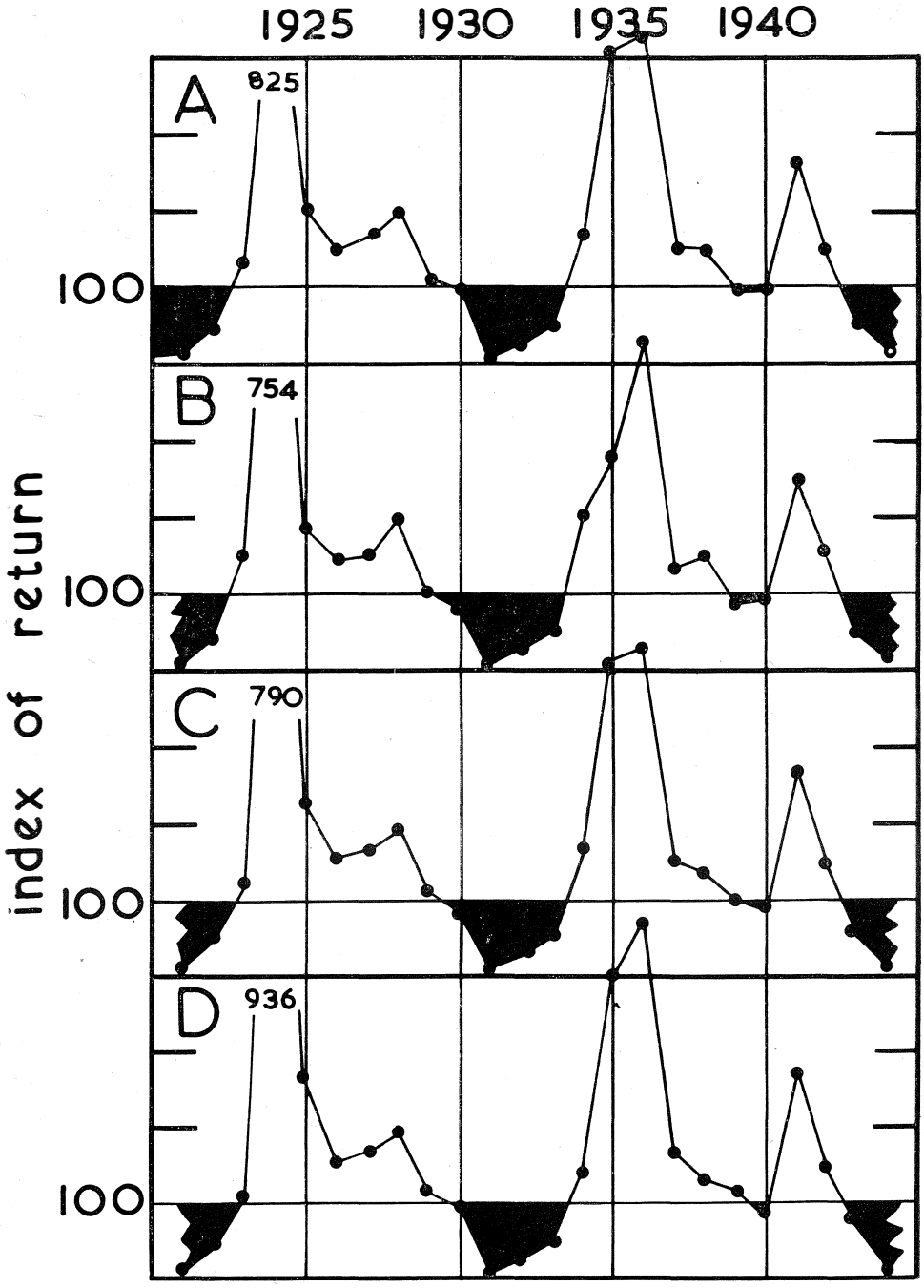

FIGURE 15. Vancouver island chum salmon. Indices of return calculated from different theoretical parent generations. A, average ratio of 35% 3-year and 65% 4-year fish; B, ratio 44.7: 54.3: 1.0 (Fraser); C, ratio 30.6: 67.7: 1.6 (Pritchard); D, ratio 17.4: 81.5: 1.2 (Neave). (Each ordinate division represents 100 units.)

average age composition (35% of 3-year fish and 65% of 4-year fish) and from the more precise ratios of the 3 different workers. Although the composition varies from 54% of 4-year fish to 82% of 4-year fish, the picture is essentially the same because the major variations in catch are of such an extreme order. The graphs are not identical but 3 periods of very low return are evident in each case.

TABLE IX. Correlation (r) between chum salmon pack (1921 to 1944) and catch of previous year, or parent generation; calculations to nearest 100 cases, symbols from Snedecor (1946).

Area	Previous year			Parent year			Age composition of theoretical parent generation
	r	z	P	r	z	P	3: 4: 5: 6 year ratios
Fraser river—District 1	.488	.533	.02	−.073	.074	>.1	35: 65: 0: 0
Vancouver island—District 3	.507	.56	.01	−.168	.17	>.1	
				.003	.003	>.1	44.7: 54.3: 1.0: 0[1]
				−.045	.045	>.1	30.6: 67.7: 1.6: 0[2]
				.054	.054	>.1	17.4: 81.5: 1.2: 0[3]
Northern Areas—District 2	.471	.512	.02	−.291	.30	>.1	
Skeena river	.390	.413	.05	−.060	.061	>.1	35: 65: 0: 0
Nass river	.458	.495	.01	−.180	.182	>.1	
				+.081	.081	>.1	0: 20: 70: 10[2]

[1]Fraser (summarized by Pritchard (1943)). [2]Pritchard (1943). [3]Neave, Ferris. Unpublished data.

TABLE X. Correlation (r) of pink salmon pack with pack for the previous year and for the parent year; data calculated to the nearest 100 cases for 1921 to 1944 inclusive, symbols and methods from Snedecor (1946).

Area	Previous year			Parent year		
	r	z	P	r	z	P
Fraser river—District 1	−.623	.73	<.01	+.611	.716	<.01
Vancouver island—District 3	−.193	.195	>.1	+.807	1.119	<.01
District 2	−.407	.432	.05	+.474	.516	.02
Skeena river	+.075	.053	>.1	+.559	.632	<.01

Again, in fig. 20 the index for the Nass river is shown as calculated from the same 35%-65% ratio of 3- and 4-year fish, and as calculated from the figures given for the Queen Charlotte Islands where Pritchard found approximately 20% 4-year olds, 70% 5-year olds, and 10% 6-year olds. Although the numerical value of the Nass river index is greatly changed by the two calculations, the years of failure are so spectacular that the period of low index appears in each case. It may be noted that later studies (Unpublished data, Pacific Biological Station) indicate that the northern chums are not generally as old as indicated in Pritchard's (1943) report.

The use of any index in which a similar picture is obtained for such great variations in age composition may be questioned. This is only justifiable in a case of such extreme variability as seen in the chum fishery and useful only for broad generalizations. For the chum figures under consideration it is obvious

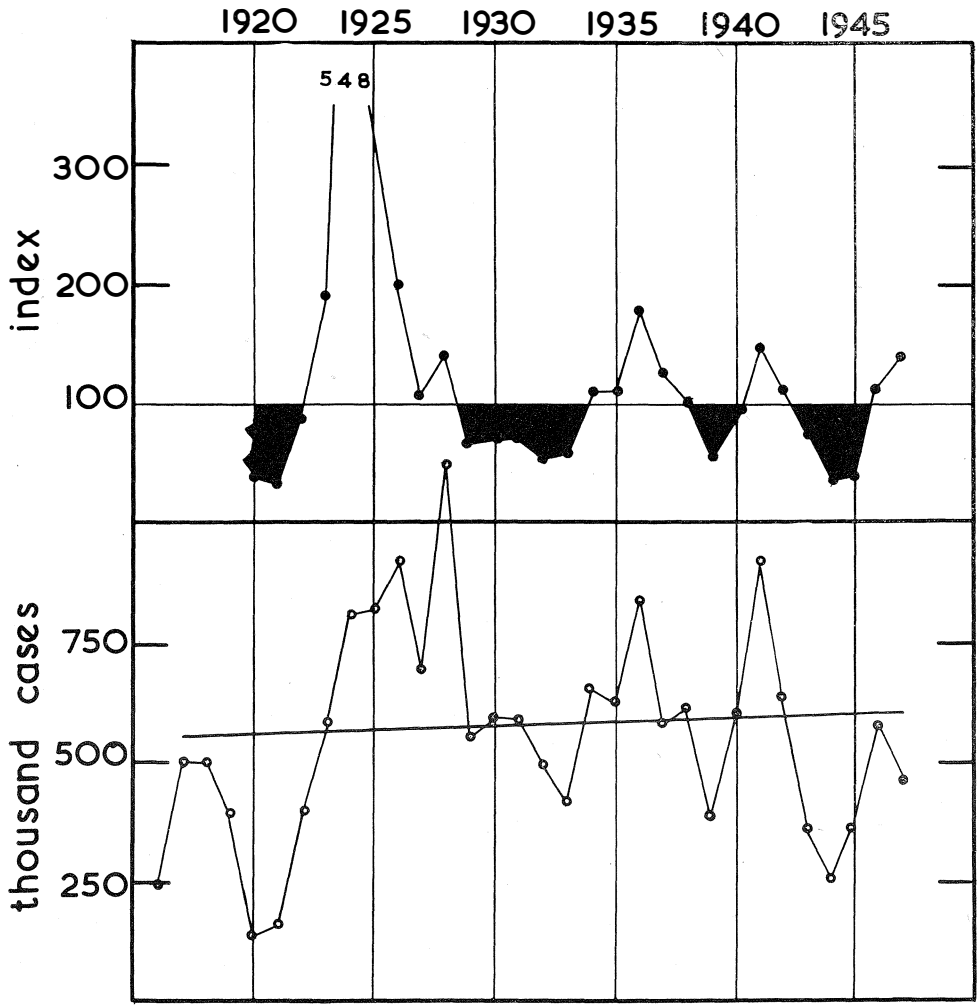

FIGURE 16. Total production of British Columbia chum salmon canned, dry-salted and brine cured (lower graph) and index of success of return (upper graph). The regression line cuts across the production graph in the lower figure.

that with the catches of certain years reduced to 10% of the previous years any of the theoretical age compositions will give a strikingly low index for that year. The calculated parent generation will be of the same order with respect to the

fat and lean years. Certainly we cannot attach much significance to small differences (say 10%) in index. The change in index parallels the change in total pack, as can be seen from any of the graphs, but the index has the *advantage of emphasizing the change in the fishing return.*

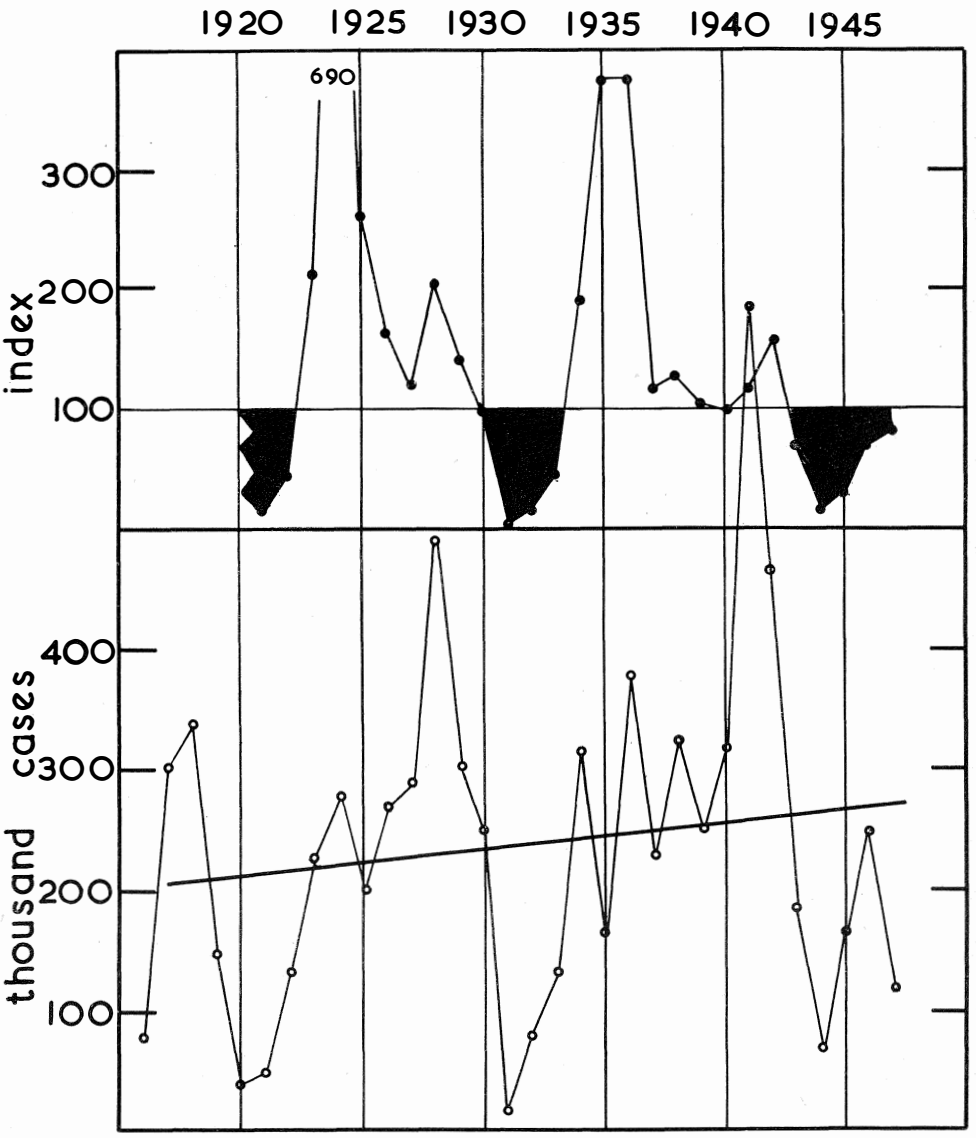

FIGURE 17. Chum salmon pack, southern British Columbia, districts 1 and 3. Open circles, salmon packed 1917 to 1947; closed circles, indices of return; regression line cuts across pack figures.

Changes in Availability of Chum Salmon

The prominent feature in all the calculations for chum salmon is the presence of 3 periods in which the index is well below 100 for several consecutive years (figs. 15-21). This applies to the United States (fig. 21) and Siberian fisheries

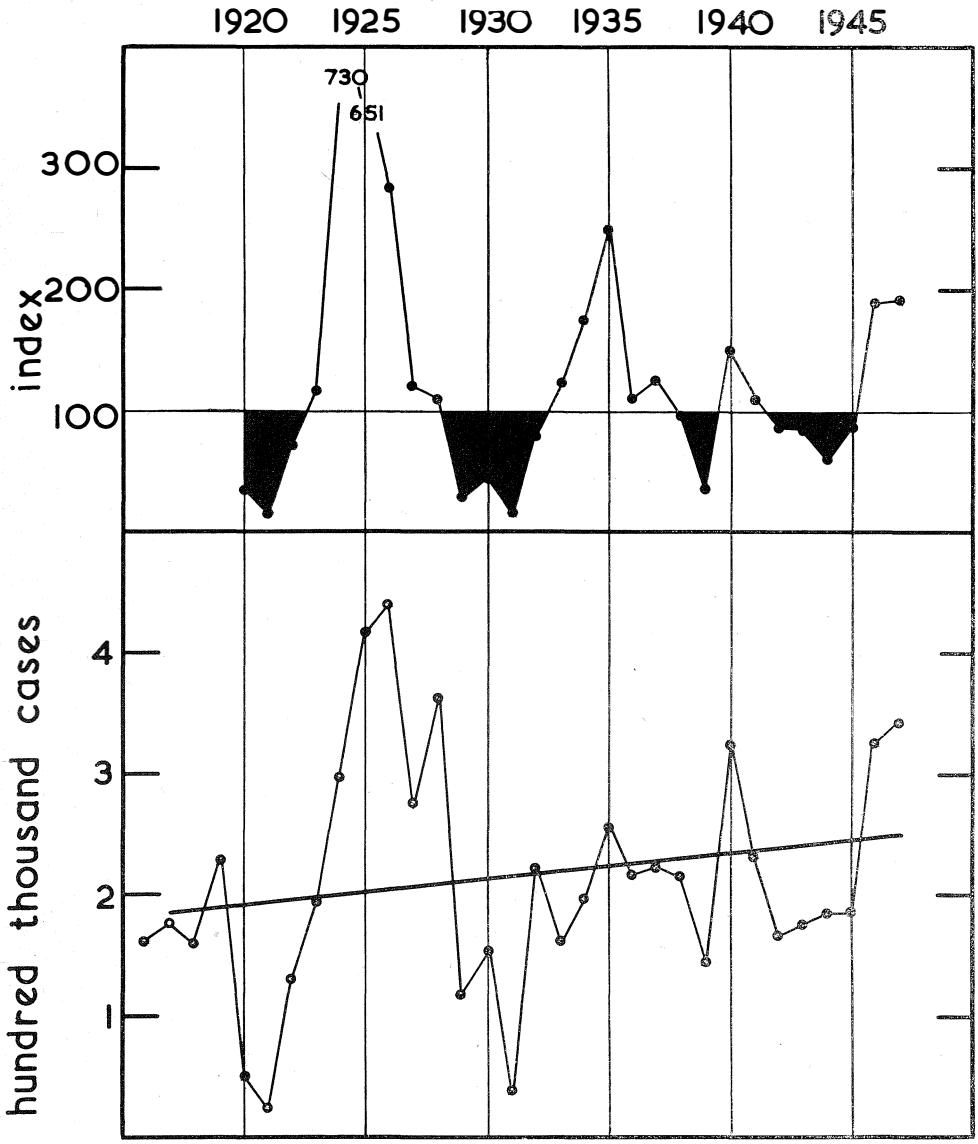

FIGURE 18. Chum salmon pack, northern British Columbia, district 2. Open circles, salmon packed 1917 to 1947; closed circles, indices of return; regression line cuts across pack figures.

(Pacific Fisherman Yearbook, 1940) as well as the Canadian fisheries. It is a feature common to the Pacific chum. These low periods of production, appearing in the early '20's, early '30's and early '40's, are variable from place to place and particularly irregular in the last period. It might seem reasonable to explain them on economic grounds alone. The post-war recession of the early '20's, the depression of the early '30's and the adverse fishing and changed market conditions of the wartime period in the early '40's could have produced such variations.

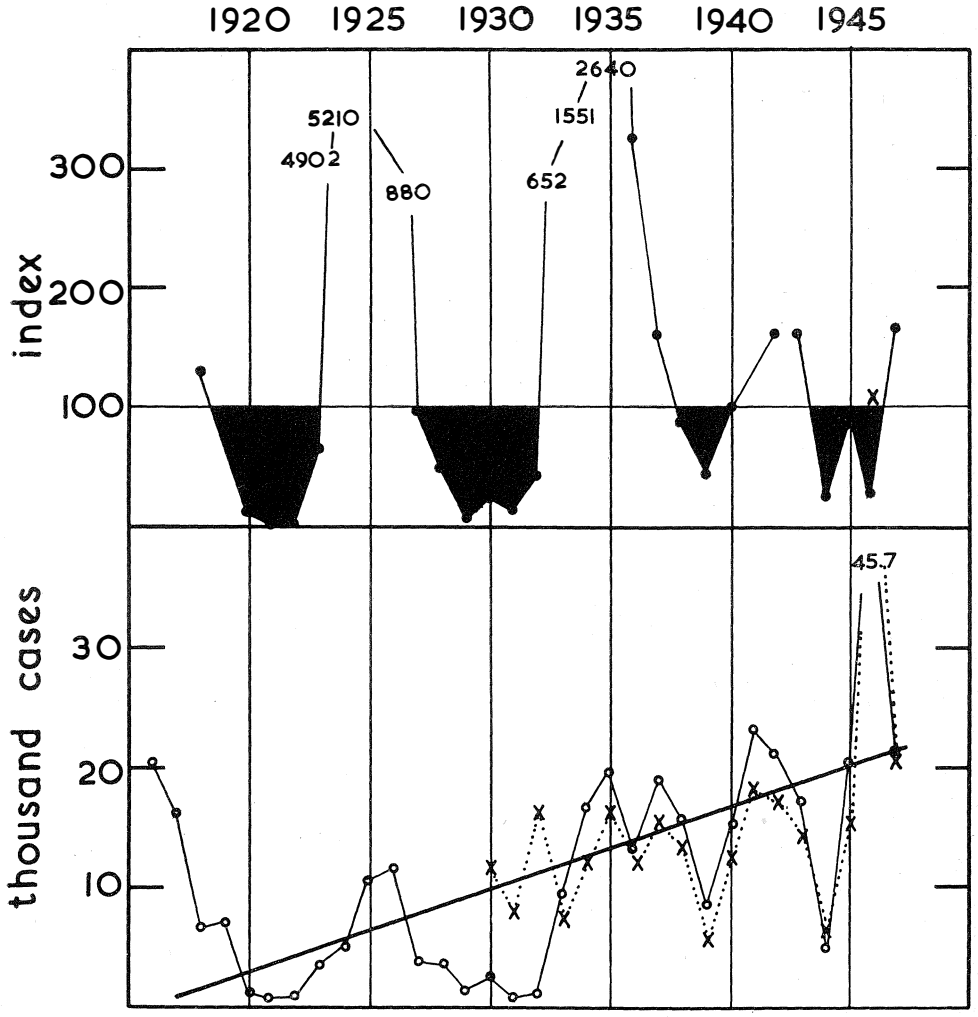

FIGURE 19. Chum salmon production for Rivers and Smiths inlets. Open circles, canned salmon packed 1917 to 1947; closed circles, indices of return; dotted line, inspector's estimate in thousand cwt. of salmon taken in area; regression line cuts across pack figures in lower graph.

The annual reports of the Department of Fisheries (Ottawa) seem to show quite conclusively that the reduced catches of the early '20's and '30's were due to decreased fishing effort. For the year 1918 limitations in pack of Canadian chums and increased shipments of fresh chum to the United States are mentioned. Again in 1920 and 1921 packs of chums were said to be curtailed with adverse market conditions and large carry-overs. In 1929 fishing was curtailed not because of market conditions but because the "numbers seemed smaller" to the Fisheries Department (probably in contrast to the record packs of previous years). In 1930, 1931 and 1932 these reports state that the packs could have been greatly

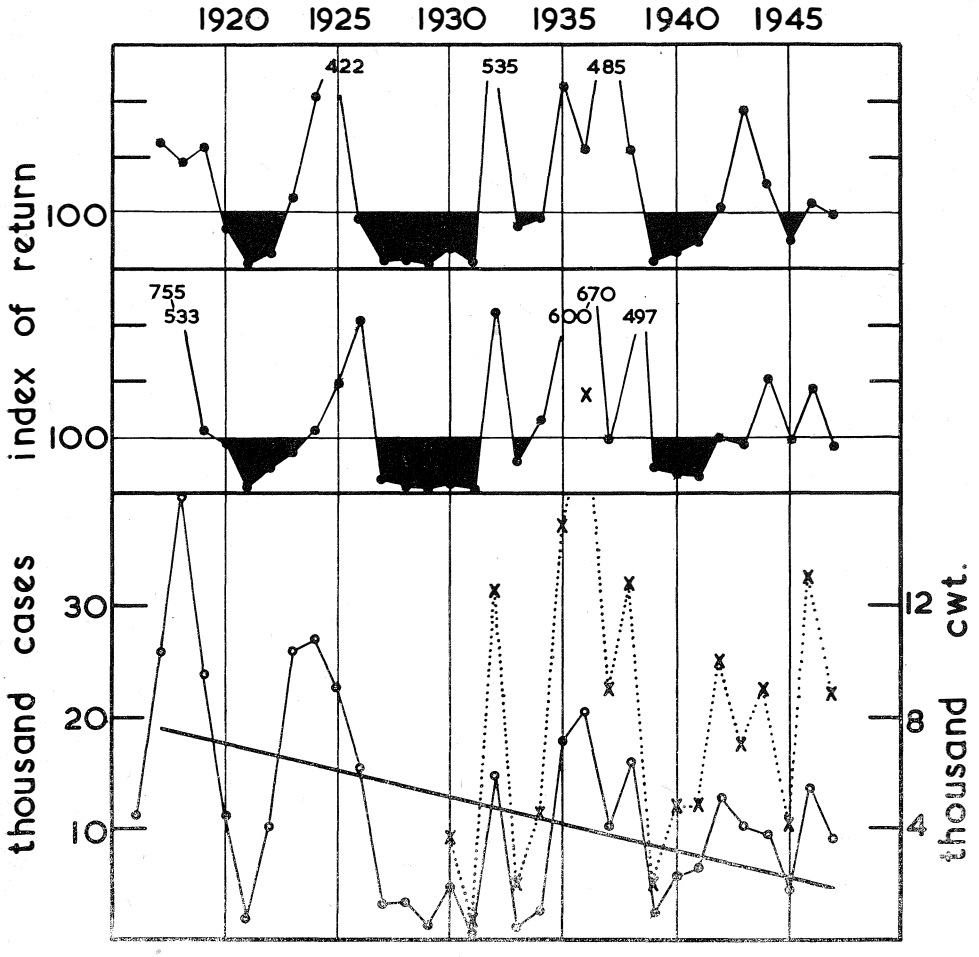

FIGURE 20. Chum salmon production for the Nass river. Open circles, canned salmon packed 1917 to 1947; dotted line, inspectors' figures in cwt. for salmon production in the area. Closed circles, indices of return calculated from ratio of 35% 3-year and 65% 4-year chums (upper graph) and from ratio 20% 3-year, 70% 4-year and 10% 5-year fish (middle graph); regression line cuts across pack figures in lower graph.

increased if market conditions had warranted it. In 1943 the chum pack was said to be affected by the demands of cold storage plants and for only 3 years is there a real scarcity of chums recorded (1939, 1944 and 1945).

From these reports it would be concluded that with the exception of very recent years (1939, 1944 and 1945) there had never been a scarcity of chums on this coast and that fluctuations in catch were due entirely to market conditions. This may be the simple explanation of the facts, but there is some evidence to suggest that the periods of adverse market conditions in the early 1920's and 1930's coincided with scant supplies of chums.

The first pertinent feature seems to be that the decline in catches of the '20's and '30's started in some areas prior to the periods of reduced fishing. For the first period, catches in several places declined as early as 1918 (figs. 19, 21)

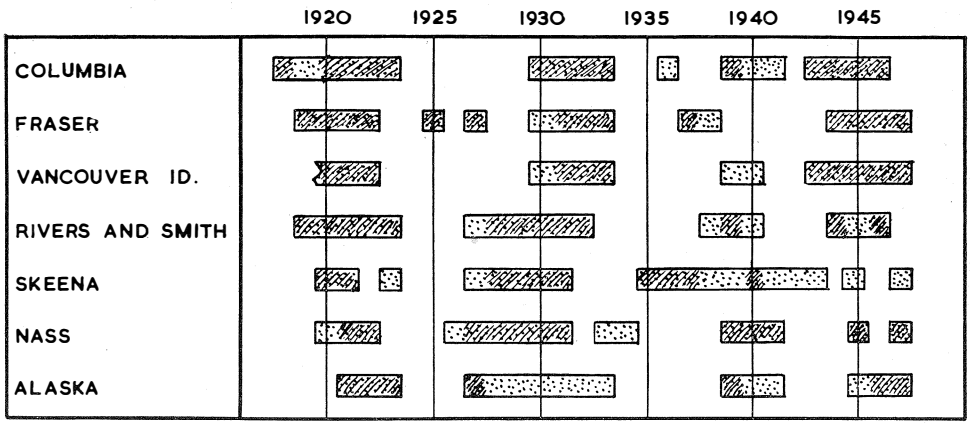

FIGURE 21. Index of success of return for chum salmon of different areas. Stippling, 75-99; stippling and cross-hatching, below 75; clear, above 100.

and for the second period the sharp decrease in catches occurred quite generally in 1926-7, (figs. 16, 19, 20). There was evidently some official concern over the stocks of pink and chum in 1927 as the season was closed early. This may have affected our picture but indicates that a reduction in stocks occurred at this time. In the second place, the low production periods occur at slightly different times on the coast (fig. 21). This is most marked for the "lows of the '30's" where the low "index of return" comes progressively later along the coast from Alaska to the Columbia river. Prices at this time declined sharply and suddenly and the records indicate that the decreased fishing effort occurred in all places at the same time. The Pacific Fisherman Yearbook (1932) records definite shortages of chums in 1931 and unsatisfactory stocks to meet even a reduced demand. In the third place, it is evident that doubling or even quadrupling the catches of the leanest years in the '20's and '30's would not produce an average catch.

The effect of methods of processing other than canning and of size vari-

ations on the canned chum pack should also be considered. The sharply increased production of frozen chum in 1920 and again between 1935 and 1940 could contribute to the picture of low production as obtained from the canned pack for the early '20's and '40's. It alone could not, however, account for the extremely low indices of return so evident at these times. A rough calculation will make this evident. In the general picture (fig. 16) production around 1920 is approximately 250,000 cases. Between 1917 and 1921 production dropped from about 500,000 to about 125,000 cases. Total amounts frozen in 1921 could not have exceeded the equivalent of 20,000 cases, which leaves the offspring pack still far below that of the parent year. Quantities frozen did not influence the picture as shown by our graphs until the latter part of the '30's. Increased amounts frozen in recent years are probably responsible for some of the irregularities seen in the latter part of the curves.

Size variation of chums is not as great as it is in pinks, but could still influence the production graphs to a certain extent. It is impossible to evaluate this precisely. Adjustments which could be made would be approximate only. It is evident, however, that a 30% variation, such as occurs frequently, in average size (or even a 75% difference if frozen production is considered also) could not produce such violent fluctuations as were just mentioned.

Fishing effort was greatly reduced in the early '20's and '30's, but since the fluctuations in catches are so great and since they do not coincide in a very precise way with the years of poor market conditions, it is possible that these years were also years of small numbers of chum salmon.

All the data emphasize the extreme variability of chum catches and the presence of very "fat and lean years" rather than long term trends in fishing return. Table IX is perhaps pertinent. As previously stated there is apparently no significant correlation between parent and offspring chum generations. The correlation with the catch of the previous year is, however, definite. Whatever the cause or causes may be—environmental or economic—this is to be expected with a cyclic decrease of such magnitude appearing at approximately 10-year intervals in a fish of 4-6 years of age.

Finally, it should be pointed out that the chums in the far north, like the pinks, have evidently declined in abundance. The trend is less marked for chums but obvious for the Nass (fig. 20), the Skeena (fig. 14) and the Queen Charlottes (table III). Factors governing the production of the two species are, no doubt, closely related. An understanding of these factors is urgent.

SUMMARY AND CONCLUSIONS

THE chum and pink salmon fisheries first became important during the latter part of the first world war. In 1917 and 1918 the canned packs of these species were above the average for the 31-year period, 1917-47.

Although the greater portion of chum and pink salmon is canned, smaller

quantities are disposed of in other ways and size variations are great enough to cause serious errors in estimates of abundance based on canned pack alone.

For pink salmon it is estimated that about 5% are at present being marketed fresh or frozen. This percentage has varied during the past 30 years. On an average, it is judged, that 10% of the pinks were used in this way in the period from 1917-19; 20% in 1920-4; 2.5% in 1925-37 and 5% since 1938. Other methods of curing have not been used for any considerable number of pinks.

For chum salmon it is estimated that, at present, about 40% of all the chum salmon caught are being marketed fresh or frozen. This percentage also has varied and, in round numbers, amounted to 5% of the catch prior to 1920, 20% between 1920 and 1935, and 40% since 1935. Significant quantities of chum salmon (fluctuating around 100,000 cwt.) were dry salted until the beginning of war in 1939. Smaller quantities have, from time to time, been used in other ways.

Quantities of both chum and pink salmon used by the Indians have declined in recent years.

Size variations of pink and chum salmon are considerable. For pinks this amounts to as much as 5 or 7 fish in a 48-lb. case, for chums 2 to 3 fish. The fish for any season are usually large, average or small over the entire region. Whatever it is that influences size seems to operate over a wide area. A comparison of average sizes for a 20-year period shows a cyclical change. For pinks, fish of large and small size alternate from year to year. For chums, the cycle is irregular but approximates 3 years.

For pinks, the condition of the fishery may be judged from the canned pack. Amounts of pinks used in other ways are small and the size variation is compensated for by the use of an "index of return" and cycle totals for plotting the trend lines. A low period in pink production appeared about 1920 and was caused by a scarcity of fish associated with decreased fishing effort; a second low period in 1927 was associated with small stocks of fish; the decreased production of the early '30's may have been due entirely to adverse market conditions, but there is some indication of a scarcity of fish; pinks were scarce and demand high in the low period of pink production 1938-42.

Some concern should be shown for the declining pink (and chum) catches of northern rivers—Nass and Skeena. The analysis suggests that either the environmental conditions are becoming progressively less favourable or the fishing pressure is too great.

For chum salmon the canned pack alone will give only a general picture of the history of the fishery. Freezing, dry-salting, and size variation are significant and must be considered. The outstanding feature of the graphs for chum salmon is the three periods of very low production coming near 1920, 1930 and 1940. Market conditions have contributed largely to these low production figures. The post-war recession of the early '20's was coupled with increased freezing of chums, the depression of the '30's affected industry in every way and the early war years of 1940 saw great changes in marketing conditions, particularly in sharply

increased quantities of salmon frozen. It is evident, however, that a real scarcity of chums was experienced in the early '40's and it seems highly probable that the stocks were low in the early '20's and '30's. The main evidence for this lies in the fact that the declines commenced in some areas prior to the economic depressions, that they did not appear at the same time in all places and that the fluctuations are of such a violent nature. The extreme variability of chum catches is emphasized.

In conclusion it is felt that there should be an effort made to discover the basis for the declining pink and chum catches in the north. This decline is sufficiently marked to be subject for economic concern. In addition research programs should be intensified to eliminate the extreme variability demonstrated, particularly for chums, and provide a sustained yield.

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