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R. F. SHUMAN

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary

FISH AND WILDLIFE SERVICE
Albert M. Day, Director

Special Scientific Report No. 50

ESTIMATION OF THE TROLL CATCH OF COLUMBIA RIVER CHINOOK SALMON, *ONCORHYNCHUS TSCHAWYTSCHA*

by

Ralph P. Silliman

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Explanatory Note

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Ralph P. Silliman
Aquatic Biologist

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INTRODUCTION

Statistics of the total catch of Columbia River chinook salmon are obviously essential to proper evaluation of the economic worth of the resource and to intelligent regulation of the fishery. In order to obtain such total catch statistics it is necessary to add to the river catch an estimate of the high seas troll catch, and this need has given rise during the past few years to several different estimates. The wide divergence of these, and the considerable circulation given some of them indicate a need for assembling the available data on the subject and obtaining the best estimate which it is possible to make from them. This should give a figure which will be as good as can be had short of gathering new direct evidence such as might be obtained from tagging experiments. In addition, it is felt desirable to have estimates referable to specific fishing seasons; those made previously are not clearly defined chronologically, although it is inferred that they apply to fishing conditions during recent years. Sufficiently detailed data upon which to base approximations are not available for seasons prior to 1926, so that the analysis to follow will cover the 20 years 1926 through 1945. It is proposed to review critically each step of the analysis as it is developed, paying particular attention to sources of possible error.

BRITISH COLUMBIA AND ALASKA ESTIMATES

Tagging Experiments

The troll fishery of British Columbia has available the largest body of direct evidence on proportion of Columbia River chinooks of any fishing region along the Pacific Coast, consisting of the results of several tagging experiments made during the years 1925-30 by the Biological Board of Canada (Williamson, 1927, 1929; Williamson and Clemens, 1932; Clemens, 1932; Pritchard, 1934). In addition, one experiment was carried out off the west coast of Baranof Island in Alaska by the United States Bureau of Fisheries (1928). In Table I, which summarizes the results of all experiments, attention is directed to the column "Local or Indefinite" under "Number of Recoveries." This includes tags recovered in waters adjacent to the tagging locality and those for which the locality of recovery is uncertain. Because there is no way of knowing the origin of these fish, they were deducted from the total before calculating the percentage of Columbia River fish.

Before proceeding further with the application of the tagging results to the determination of the percentage of Columbia River fish in the British Columbia and Alaska troll catches, it is well to recognize that their suitability for this purpose is entirely dependent upon the fishing intensiry and recovery effort in the various regions. For instance, we assume a stock of 1500 tagged salmon, composed of 1000 British Columbia and 500 Columbia River fish. Disregarding other mortality, and assuming 100 percent recovery of tagged fish caught, a fishing intensity of 25 percent in British Columbia and 50 percent in the Columbia River would result in 250 recoveries of tags in each region, and evidence from recoveries alone would point to 50 percent Columbia River fish instead of the true 33-1/3 percent. When efficiency in recovering the caught fish, as well as fishing intensity itself, varies, the situation is further complicated. However, beyond recognizing this source of possible error, there is little that can be done with the available data in regard to variability arising from these causes. Without knowledge of fishing intensity in British Columbia River waters, we can only say that both fisheries were well developed by 1925, and perhaps had become stabilized at somewhat similar levels of intensity. No statements were noted in the references cited above regarding the relative amount of effort directed toward recovering tags in the various regions. Since all but one of the experiments were carried on

in Canada by Canadians, it might be supposed that a little more effort toward the recovery of tags was put forth in British Columbia than in the United States.

Having recognized the possibility of error due to differences in fishing intensity or recovery effort we are compelled because of the lack of data to accept the tagging results at their face value, considering that the proportion of tagged fish recovered in the Columbia River represents the proportion in the troll catch. We turn to the consideration of another source of error--the application of the tagging results to years other than those during which the experiments were performed. It is necessary here to realize that the percentage of Columbia River fish on the British Columbia trolling grounds depends upon the abundance of other fish as well as those from the Columbia. If other fish increase in numbers the percentage of Columbia River fish will decrease, even though their absolute number remains the same. Only if the two stocks bear a constant relation to each other will the percentage of Columbia River fish on the trolling grounds be constant. We may perhaps gain some idea of the relative abundance of Columbia River and British Columbia-Alaska stocks by examination of case packs, which are practically all derived from "inside" fish. In Table 2 and Figure I are given the case packs for the Columbia River, and for Alaska and British Columbia, covering the period 1926-45. It will be noted that during this period the packs of both regions has a similar downward trend; although the correspondence is rough, and the percentage decrease is somewhat greater for the more northern region, the comparison at least gives some indication of an approximately constant ratio between the two stocks of chinook salmon. To this extent, then, percentages of Columbia River fish in the British Columbia and Alaska trolling grounds as determined for the period 1925-30 may be justifiably applied over the longer period 1926-45.

In Table I the various tagging experiments are listed roughly from South to North, with the exception of the first three, which were located inside Vancouver Island. Eliminating these three experiments because of their enclosed location, a general tendency is apparent for the percentage of Columbia River fish to decrease as one proceeds northward. This is brought out more clearly if the experiments are summed by larger areas and compared with their north latitude, which is done in Table 3 and Figure 2. Because of the large dispersion of the percentages and the great variation in numbers of recoveries

TABLE I. Results of chinook salmon tagging experiments by the Biological Board of Canada and the United States Bureau of Fisheries. Data are from Williamson (1927, 1929), Williamson and Clemens (1932), Clemens (1932), Pritchard (1934), United States Bureau of Fisheries (1928).

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Year tagged	Tagging Locality	Number tagged	Number of Recoveries				
			Total	Local or Indefinite	All Other	Columbia River	% Columbia River
1928	Nanaimo Area	267	20	1	19	1	5.3
1927	Deep Bay	168	16	1	15	0	.0
1928	Queen Charlotte Strait	117	10	1	9	0	.0
1925	Barkley Sound	1,125	123	12	111	74	66.7
1926	Barkley Sound	1,353	183	13	170	109	64.1
1927	Kyuquot Sound	517	80	6	74	48	64.9
1927	Quatsino Sound	54	8	1	7	4	57.1
1930	N.E. Coast Vancouver Island	436	28	3	25	4	16.0
1930	Milbank and Fitzhugh Sounds	302	16	2	14	2	14.3
1930	Hecate Strait	182	15	0	15	6	40.0
1925	W.Coast Queen Charlotte Isl.	274	37	3	34	10	29.4
1929	W.Coast Queen Charlotte Isl.	375	41	2	39	7	17.9
1930	W.Coast Queen Charlotte Isl.	179	24	0	24	10	41.7
1929	N.Coast Queen Charlotte Isl.	445	63	3	60	15	25.0
1930	N.Coast Queen Charlotte Isl.	662	97	7	90	27	30.0
1926-27	W.Coast Baranof Island	480 1/	38	(2/)	38	22	57.9

1/ 480 in 1927 plus an unknown number in 1926.

2/ No information.

TABLE 2. Pack of chinook salmon, thousands of cases, for certain Pacific Coast regions (data are from Pacific Fisherman Yearbook, 1946).

Year	Columbia River	S.E. Alaska and British Columbia
1926	295	80
1927	339	68
1928	251	25
1929	243	26
1930	281	50
1931	295	42
1932	217	100
1933	251	28
1934	251	46
1935	206	33
1936	220	52
1937	291	47
1938	174	32
1939	208	18
1940	245	20
1941	329	52
1942	275	27
1943	130	13
1944	163	21
1945	132	16

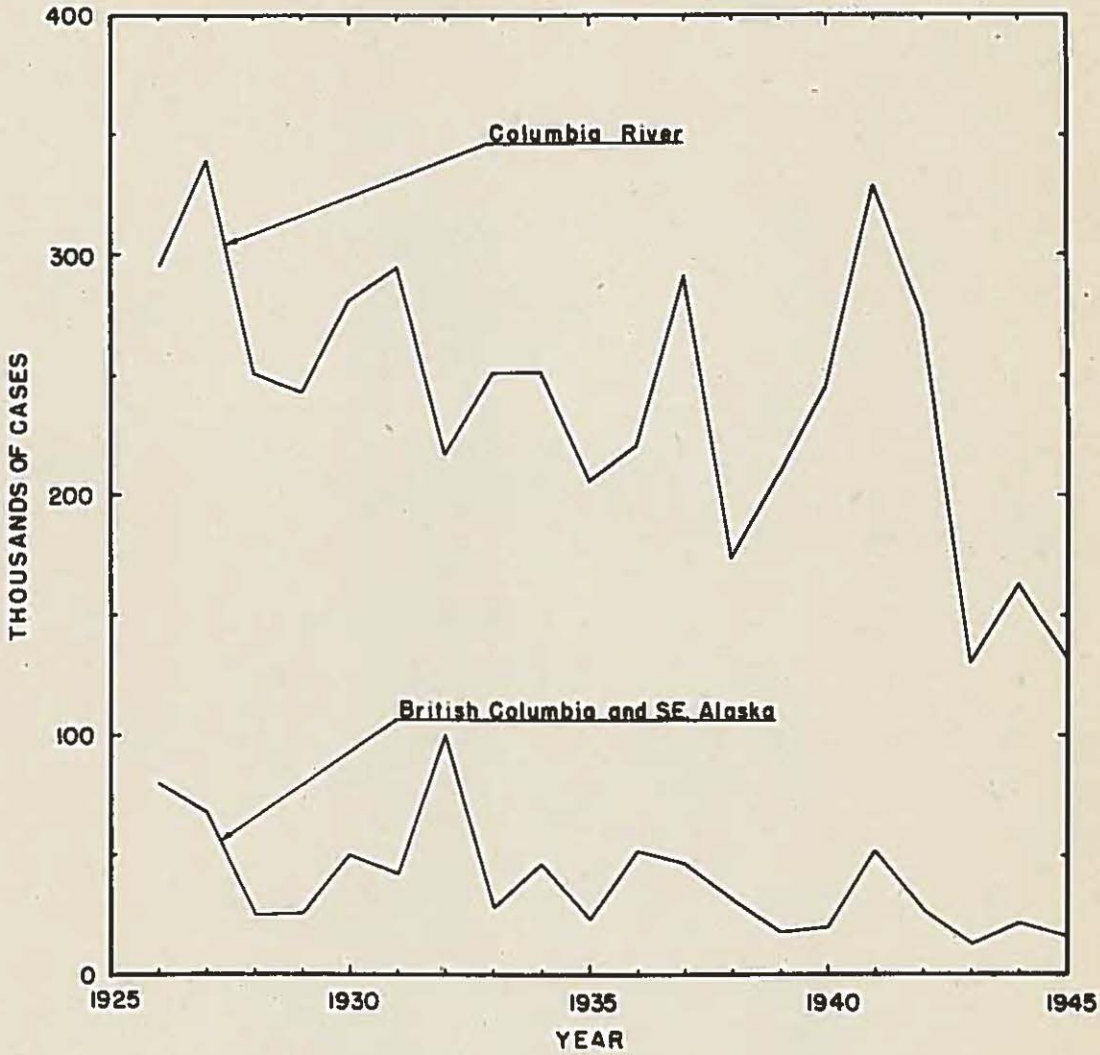

Figure 1. Pack of chinook salmon, regions compared. (Data from Pacific Fisherman Yearbook, 1946)

TABLE 3. Summary of chinook salmon tagging experiments. British Columbia and Alaska, by larger regions according to latitude.

Region	North Lat.	Number Tagged	Number of Recoveries				
			Total	Local or Indefinite	All Other	Columbia River	% Columbia River
Barkley Sound	48° 55'	2,478	306	25	281	183	65.1
Kyuquot	50° 00'	517	80	6	74	48	64.9
Quatsino Sd.and N.E. Coast Vanc. Isl.	50° 40'	490	36	4	32	8	25.0
Milbank and Fitzhugh Sounds	52° 00'	302	16	2	14	2	14.3
Hecate Str. and W. Coast Q.Charl.Isl.	53° 50'	1,010	117	5	112	33	29.5
North Coast Queen Charlotte Isl.	54° 15'	1,107	160	10	150	42	28.0
West Coast Barnaof Island	57° 00'	480	38	-	38	22	57.9

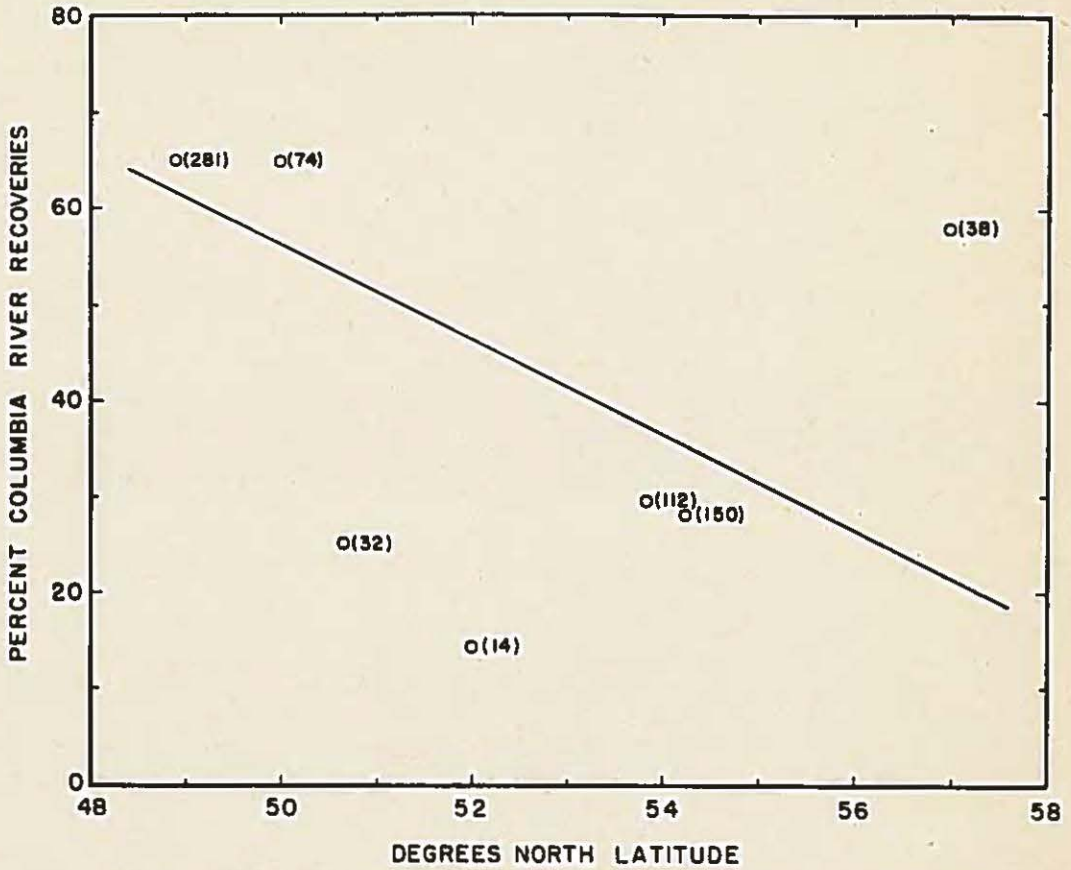

Figure 2. Tagging experiments in British Columbia and Alaska, regression of percentage of Columbia River recoveries on north latitude. Regression line was fitted by least squares, weighted according to number of recoveries (indicated on graph by figures in parentheses).

the data were graduated by fitting to them a regression line weighted according to numbers of recoveries (Figure 2). The regression equation was R==65.9 - .413L, where R is the percentage of Columbia River recoveries and L is the north latitude less 48 degrees, expressed in minutes and divided by five. Correlation of percentage with latitude proved significant, with a P value of approximately .03 (entering the correlation coefficient of - .731 in Table V.A. of Fisher, 1941).

Estimation of Total and Columbia River Troll Catch

In Southeastern Alaska there are six major landing points for troll-caught salmon: Ketchikan, Sitka, Pelican City, Wrangell, Petersburg and Juneau. Of these the last three are in enclosed waters, and may be considered separately in this connection. In Table I it was shown that the tagging experiments inside Vancouver Island yielded only one Columbia River recovery from an experiment carried on at the south end of the island. This would indicate that, in the far north at least, practically no Columbia River fish migrate into enclosed waters. For this reason the catch landed at Wrangell, Petersburg, Juneau and adjacent points was excluded in estimating the Southeastern Alaska troll catch of chinook salmon. This left three ports accessible to the open ocean, which with some adjacent points, consittute the Ketchikan, Sitka and Pelican City areas referred to herein. The north latitudes of these three areas are 55° 20', 57° 00' and 58° 00' respectively, and use of the regression equation given above yields Columbia River percentages of 30, 21 and 16.

Before applying the percentages it is necessary to have the annual troll catch in pounds for each of the areas referred to. No direct data of the type are available prior to 1943, but the total troll catch in Southeastern Alaska may be estimated from the mild cured, fresh, and frozen poundages, since these three outlets account for practically all Alaska troll caught chinook salmon. The necessary data up to 1942 were secured from the annual reports on "Alaska Fishery and Fur Seal Industries" issued by the United States Bureau of Fisheries and Fish and Wildlife Service. The poundages given were converted to pounds of round fish by application of the factors 1100 to tieres mild cured (Craig and Hacker, 1940, p. 196) and 1.17 to pounds fresh and frozen. This latter factor of 1.17 was applied

TABLE 4. Troll catch of chinook salmon in Southeastern Alaska, and estimated catch of Columbia River fish, thousands of pounds.

Year	Total Catch[1]	Prorated catch[2]			Catch of Columbia River Fish[3]			
		Ketchikan Area	Sitka Area	Pelican City Area	Ketchikan Area	Sitka Area	Pelican City Area	Total
1926	8,881	5,062	2,575	-	1,519	541	-	2,060
1927	11,735	5,163	4,929	117	1,549	1,035	19	2,603
1928	7,019	3,860	1,474	70	1,158	310	11	1,479
1929	7,976	3,270	1,675	160	981	352	26	1,359
1930	9,897	4,157	2,672	100	1,247	561	16	1,824
1931	8,009	3,444	2,162	160	1,033	454	26	1,513
1932	9,025	2,798	2,708	90	839	569	14	1,422
1933	7,028	2,179	2,600	70	654	546	11	1,211
1934	5,460	1,911	2,293	55	573	482	9	1,064
1935	10,356	4,971	3,935	104	1,491	826	17	2,334
1936	10,623	5,843	3,293	--	1,753	692	--	2,445
1937	12,785	5,881	4,347	--	1,764	913	--	2,677
1938	11,401	3,648	5,586	--	1,094	1,173	--	2,267
1939	11,613	4,065	4,877	--	1,220	1,024	--	2,244
1940	7,452	2,161	5,440	--	648	1,142	--	1,790
1941	13,281	2,125	8,101	--	640	1,701	--	2,341
1942	10,835	1,409	5,959	108	423	1,251	17	1,691
1943	3,285	891	1,126	--	267	236	--	503
1944	2,452	754	815	86	226	171	14	411
1945	3,708	789	944	730	237	198	117	552

TABLE 4. Continued - 1926-1942 data

1/ 1926-1942 data obtained from "Alaska Fishery and Fur Seal Industries" by application of factors of 1100 to tierces mild cured, and 1.17 to pounds fresh and frozen. 1943-1945 data from Pacific Fisherman Yearbooks.

2/ Prorated according to tierces mild cured in each area, as reported in Pacific Fisherman Yearbooks. Part of catch landed in inside areas not shown here. 1943-1945 data secured directly from Pacific Fisherman Yearbooks, without proration.

3/ Computed by application of following percentages (derived as explained in text): Ketchikan, 30%; Sitka, 21%; Pelican City, 16%.

and Clayoquot Sounds; (4) Barkley Sound. The north latitudes are 54° 00'; 50° 15', 49° 20' and 48°50' respectively, yielding (by use of the aforementioned regression equation) percentages of Columbia River fish as follows: Queen Charlotte Islands, 36 percent; Quatsino and Kyuquot, 55 percent; Nootka and Clayoquot, 59 percent; Barkley 62 percent. Total troll catches, and catches of Columbia River fish estimated by the application of the foregoing percentages, are given in Table 5.

WASHINGTON ESTIMATES

Estimation of Percentage Columbia River Fish

There are no direct data, such as those available for British Columbia and Alaska, on the percentage of Washington troll-caught fish which originate in the Columbia River. In the absence of such data, about the best that can be done is to extrapolate the regression, found for the northern areas, southward to the Columbia River. Along the coast of Washington there are three main trolling regions: (1) Swiftsure Bank, at the entrance of the Strait of Juan de Fuca, (2) the coastal district off Grays Harbor and Willapa Bay and (3) the area adjacent to the mouth of the Columbia itself. Extrapolation of the regression described under "British Columbia and Alaska Estimates: Regression Analysis" gives 63 percent Columbia River fish for Swiftsure Bank, 71 percent for the coastal district, and 75 percent for the Columbia River district.

The method of extrapolation is indeed an uncertain one, to be avoided wherever possible. However, in the present instance the only alternative is the use of pure guesswork, which seems even less desirable. Under these circumstances extrapolation has been used, with full realization of the errors inherent in the method.

Estimation of Total and Columbia River Troll Catch

Direct poundage figures are available in most instances for Washington trolling areas, but a word of explanation is necessary in regard to the data for Swiftsure Bank. In the Fisheries Industries and Fishery Statistics bulletins of the United States Fish and Wildlife Service, catches in this region are included in the data for the "Puget Sound District," which includes some fish caught inside Puget Sound. Rounsefell and Kelez (1938), however, state that "For the 8-year period from 1927-34, Puget Sound trollers took... 18,285 kings. During the same period the cape fleet

took... 1,545,178 kings." Thus 99 percent of the "Puget Sound District" troll catch is composed of fish taken by cape trollers at Swiftsure Bank and in its vicinity: the "Puget Sound District" troll catch is practically equivalent to the ocean catch in the Swiftsure Bank region, and is so used in the accompanying calculations. All data on Washington troll catches for the period 1926-42 were derived from the annual reports "Fishery Industries of the United States" and "fishery Statistics of the United States" published by the United States Fish and Wildlife Service and the United States Bureau of Fisheries. The data for 1943-45 were secured directly from the State of Washington Department of Fisheries. A summary of the source data and estimates of Columbia River troll catch are given in Table 6.

OREGON ESTIMATES

Estimation of Percentage Columbia River Fish

As in Washington and California, there are no direct data on the proportion of Columbia River fish in the Oregon troll catch of chinook salmon. For the area adjacent to the mouth of the Columbia River, the same percentage was used as was applied to the similar Washington area, namely, 75 percent. For the Oregon coastal region the percentage was obtained by considering the Columbia River region the area of maximum occurrenceof Columbia River fish. The percentage of these fish was considered to decline from the Columbia River region to the coastal region at the same rate as indicated by the regression line from the Columbia River northward. It is recognized that this method of estimation is fully as dubious as the extrapolation employed in Washington, but again there is no alternative, since no other data are available. The proportion of Columbia River fish in the Oregon coastal district troll catch so estimated was 64 percent.

Estimation of Total and Columbia River Troll Catch

Derivation of total poundage figures for the Oregon chinook troll catch presented no particular problem, the 1926-42 data being found in the United States Fishery Industries and Fishery Statistics series while the 1943-45 data were in the Pacific Fisherman yearbooks. Application of the above-mentioned factors of 75 percent and 64 percent gave estimates of the Columbia River and coastal districts, respectively, as indicated in Table 7.

TABLE 5. British Columbia troll catch of chinook salmon and estimated catch of Columbia River fish, thousands of pounds.

Year	Total troll catch[1]				Estimated catch of Columbia River fish[2]				
	Q.Charl. Islands	Quatsino & Kyuquot	Nootka & Clayoquot	Barkley Sound	Q.Charl. Islands	Quatsino & Kyuquot	Nootka & Clayoquot	Bark. Sound	Total
1926	(3/)	(3/)	(3/)	(3/)	-	-	-	-	5/2,645
1927	(3/)	(3/)	(3/)	(3/)	-	-	-	-	5/3,302
1928	(3/)	(3/)	(3/)	(3/)	-	-	-	-	5/4,625
1929	4/ 1,481	581	711	1,525	533	320	419	946	2,218
1930	4/ 1,615	591	415	2,064	581	325	245	1,280	2,431
1931	4/ 1,355	634	737	1,204	488	349	435	746	2,018
1932	1,337	686	668	1,206	481	377	394	748	2,000
1933	2,224	670	478	1,689	801	368	282	1,047	2,498
1934	2,142	835	483	2,141	771	459	285	1,327	2,842
1935	1,252	659	623	2,076	451	362	368	1,287	2,468
1936	1,085	681	610	1,778	391	375	360	1,102	2,228
1937	1,854	625	258	864	667	344	152	536	1,699
1938	957	561	634	1,266	345	309	374	785	1,813
1939	849	813	658	1,446	306	447	388	897	2,038
1940	457	567	520	1,114	165	312	307	691	1,475
1941	948	1,113	405	1,332	341	612	239	826	2,018
1942	1,002	1,098	145	1,412	361	604	86	875	1,926
1943	904	806	159	1,210	325	443	94	750	1,612
1944	501	1,417	212	1,589	180	779	125	985	2,069
1945	676	714	732	1,358	243	393	432	842	1,910

TABLE 5. Continued

1/ Data from B. C. Provincial Fisheries Department, through J. L. Hart. Catches are referable to point of landing rather than region of capture, although in general the former may be considered to correspond closely with the latter.

2/ Computed by use of following percentages (derived as explained in text):
Queen Charlotte Islands, 36%; Quatsino and Kyuquot, 55%; Nootka and Clayoquot, 59%; Barkley Sound 62%.

3/ No data available.

4/ Estimated from ratio of Queen Charlotte to Vancouver Island catches for period 1932-36.

5/ 52% (weighted mean % of four regions) of total troll catch as estimated from ratio between total troll chinook catch and Vancouver Island salmon catch (as given in "Fisheries Statistics of Canada") for period 1929-33.

TABLE 6. Troll catch of chinook salmon in ocean off coast of Washington, and estimated catch of Columbia River fish, thousands of pounds.

Year	Total troll catch 1/			Estimated catch of Col.R.Fish 2/			
	Puget Sound (Swiftsure)	Coastal Dist.	Columbia River Dist.	Puget Sound (Swiftsure)	Coastal Dist.	Columbia River Dist.	Total
1926	4,110	-	394	2,589	-	296	2,885
1927	5,241	-	269	3,302	-	202	3,504
1928	4,744	-	232	2,989	-	174	3,163
1929	4,564	580	310	2,875	412	232	3,519
1930	5,238	841	385	3,300	597	289	4,186
1931	5,429	1,633	61	3,420	1,159	46	4,625
1932	3,734	1,785	21	2,352	1,267	16	3,635
1933	2,499	964	27	1,574	684	20	2,278
1934	2,964	723	30	1,867	513	22	2,402
1935	2,717	1,308	42	1,712	929	32	2,673
1936	5,110	1,096	332	3,219	778	249	4,246
1937	3,648	1,263	198	2,298	897	148	3,343
1938	2,896	1,015	117	1,824	721	88	2,633
1939	2,308	664	180	1,454	471	135	2,060
1940	4,295	1,237	277	2,706	878	208	3,792
1941	2,976	1,111	394	1,875	789	296	2,960
1942	3,725	1,681	389	2,347	1,194	292	3,833
1943	2,549	1,216	124	1,606	863	93	2,562
1944	1,606	1,109	286	1,012	787	214	2,013
1945	1,948	1,425	330	1,227	1,012	248	2,487

1/ Data for 1926-1942 from "Fishery Industries of the United States" and "Fishery Statistics of the United States". Data for 1943-1945 secured directly from State of Washington Department of Fisheries.

2/ Computed by use of following percentages (derived as explained in text): Swiftsure, 63%; Coastal Dist., 71%; Columbia River Dist., 75%.

TABLE 7. Troll catch of chinook salmon in Oregon, and estimated catch of Columbia River fish, thousands of pounds.

Year	Total catch 1/		Est. Catch of Col. R. Fish 2/		
	Columbia River Dist.	Coastal District	Columbia R. District	Coastal District	Total
1926	769	127	577	81	658
1927	1,127	561	845	359	1,204
1928	727	236	545	151	696
1929	908	515	681	330	1,011
1930	624	280	468	179	647
1931	142	95	106	61	167
1932	188	76	141	49	190
1933	1,329	379	997	243	1,240
1934	504	213	378	136	514
1935	233	284	175	182	357
1936	644	792	483	507	990
1937	357	1,035	268	662	930
1938	187	551	140	353	493
1939	183	429	137	275	412
1940	413	620	310	397	707
1941	748	682	561	436	997
1942	438	322	328	206	534
1943	158	247	118	158	276
1944	458	815	344	522	866
1945	1,013	979	760	627	1,387

1/ Data for 1926-42 from "Fishery Industries of the United States" and "Fishery Statistics of the United States". Data for 1943-45 from Pacific Fisherman Yearbook, 1946.

2/ Derived by application of following percentages (as explained in text): Columbia River District, 75%; Coastal District, 64%.

STUDY OF EVIDENCE RELATING TO CALIFORNIA TROLL CATCH

Introduction

Although no estimate of a California troll catch of Columbia River chinocks has been included with the estimates for the areas given herein, various amounts of California troll fish have in the past been attributed to the Columbia River and it is therefore deemed necessary to consider rather fully the evidence relating to the subject. Information pertinent to the matter is of three general types: (1) a regression analysis involving California troll catch and Columbia and Sacramento River catches, (2) a comparison of egg numbers of Columbia River and California chinook salmon and (3) tagging experiments performed by the California Bureau of Marine Fisheries in 1939-1942. An analysis of each of these is presented below.

Regression Analysis

Opportunity is here taken to bring up to date and further study a multiple correlation analysis originally made by Rich (1940b). Briefly stated the analysis consists of a multiple correlation of the California troll catch as the dependent variable with the Columbia and Sacramento River catches as the independent variables. The basic data for the analysis covering period 1916-45 are given in Table 8 and shown graphically in Figure 3. Because it was not possible for years prior to 1926 to split off the small amount of fish caught by trollers near the mouth of the Columbia, this amount has for the sake of consistency been included with the Columbia River catch throughout the entire period of the analysis.

The regression as presented by Rich utilized year-for-year comparisons, the triplets of values for each year consisting of the troll and the two river catches for that year. It is known, however, that not all of the salmon caught by the troll fishermen are fish which would have matured and ascended the streams during the year caught; many would not have matured until one or two years hence. Therefore, it is appropriate in comparing troll and river caught fish to take into account the percentage maturity of the troll fish. A large amount of information on this subject is given by Rich (1926), whose Table 6 indicates that about 41 percent of troll-caught fish would have matured the year caught, 45 percent one year later, and 14 percent two years later.

To account for the variation in maturity of the troll fish, a weighting system was set up whereby the river catches were weighted in accordance with the maturity percentages. That is, the river catch to compare with the troll catch of year n consisted of 41 percent of the river catch of year n, 45 percent of the catch of year n + 1, and 14 percent of the catch of year n + 2. For purposes of comparison, regressions were made for the period 1916-43 of the California troll catch on both the weighted and unweighted river catches. Beta coefficients (B) and coefficients of multiple correlation (R) are as follows:

Regression of troll catch on:	Sacramento R. B.	Columbia R. B.	R
Unweighted river catches	.46	.36	.76
Weighted river catches	.46	.37	.78

Despite the theoretical justification for using the weighted river catches, it is seen above that results from the two regressions are practically identical. Apparently other sources of variation are so great as to mask any effect of varying maturity of the troll-caught fish. Since use of the unweighted values permits the addition to the series of the years 1944 and 1945, these values will be used in all regressions subsequently referred to.

In studying the catch regressions it is pertinent to analyze any changes in the relationships during the period being investigated. To do so separate regressions were calculated for three 10-year periods, with the following results:

Period	Sacramento R.		Columbia R.		R.
	B	P_B	B	P_B	
1916-25	.25	.4	.63	.09	.84
1926-35	- .20	.6	.38	.3	.41
1936-45	.72	.04	.03	.9	.72

The values of P_B given have been derived by calculating $_B$ and then making use of Student's t distribution (Fisher, 1941). Since only values of P equal to or small than .05 are conventionally considered significant, it is seen that only one of the Sacramento B's and noe of the Columbia B's can be considered significant. In this study it is the Columbia River that is important, and lack of significance of its component of the regressions precludes their use in estimating the proportionate contribution of the Columbia

TABLE 8. Catches of chinook salmon taken in California troll fishery, Sacramento River Fishery, and Columbia River Fishery, thousands of pounds, as used in multiple correlation analysis.

Year	California Troll				
	Northern Dist. 1/	Monterey Dist. 2/	Total	Sacramento River 3/	Columbia River 4/
1916	272	4,708	4,980	3,451	31,993
1917	1,653	3,491	5,144	3,975	29,522
1918	2,280	2,604	4,884	5,938	29,249
1919	3,295	2,534	5,829	4,529	30,325
1920	3,431	1,342	4,773	3,860	31,094
1921	2,429	1,120	3,549	2,511	21,552
1922	2,594	792	3,386	1,765	11,947
1923	2,256	654	2,910	2,244	17,617
1924	4,123	789	4,912	2,640	22,641
1925	3,287	989	4,276	2,779	26,737
1926	2,858	47	2,905	1,262	21,818
1927	3,154	645	3,799	921	23,206
1928	2,332	302	2,634	554	16,931
1929	2,235	949	3,184	521	15,662
1930	2,854	251	3,105	1,214	17,629
1931	2,762	82	2,844	950	20,329
1932	2,086	73	2,159	1,265	16,042
1933	2,326	513	2,839	448	19,716
1934	2,733	257	2,990	402	18,657
1935	3,097	198	3,295	889	15,417
1936	2,942	130	3,072	954	16,514
1937	3,753	802	4,555	973	19,006
1938	1,472	179	1,651	1,668	12,789
1939	1,580	112	1,692	497	13,951
1940	3,410	552	3,962	1,516	14,481

TABLE 8. Continued.

Year	California Troll			Sacramento	Columbia
	Northern Dist. 1/	Monterey Dist. 2/	Total	River 3/	River 4/
1941	2,092	141	2,233	845	20,547
1942	2,924	148	3,072	2,553	19,317
1943	3,137	992	4,129	1,295	11,850
1944	4,828	525	5,353	3,265	15,851
1945	5,295	766	6,061	5,468	13,550

1/ 75% of combined catch of chinooks and silvers as given in Clark (1940) for 1916-1939, and in California Bureau of Marine Fisheries (1942,1944,1946a,1946b) for 1940-1945. Factor of 75% based on Clark's (1940,p.53) statement that "...between 20 and 30 per cent of the catch loaded at points north of Point Arena are silver salmon..."

2/ 90% of combined catch of chinook and silver salmon as given in sources listed in footnote I. Factor of 90% based on Clark's (1940, p.53) statement that "... less than 10 per cent of the salmon catch south of Point Arena is composed of silvers."

3/ Derived from sources listed in footnote I.

4/ Includes small amounts of troll fish caught near the mouth of the Columbia. Data for 1916-1921 are from Craig and Hacker (1940); for 1922-1942, from "Fishery Industries of the United States" and Fishery Statistics of the United States"; for 1943-1945 from Annual Bulletin, 1944 of Washington State Fisheries Department, from Pacific Fisherman Yearbook, 1946 and directly from Oregon and Washington State Fisheries Departments.

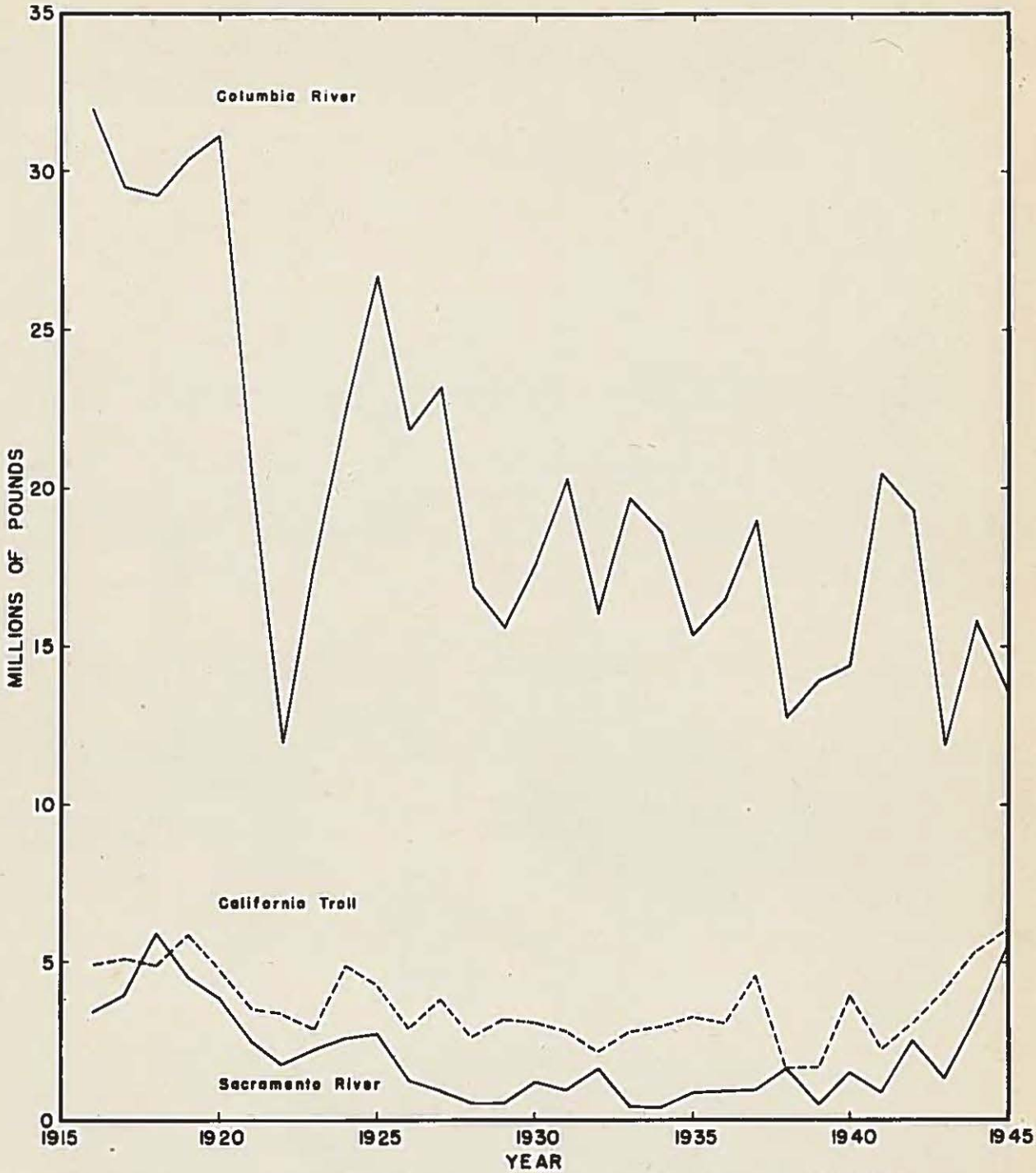

Figure 3. Catch of chinook salmon, Columbia River and California, as used in multiple regression analysis.

River stocks to the California chinook troll catch. It is worthy of note, however, that the value of B associated with the Columbia River declined at almost a constant rate during the three periods.

Increasing the number of items in a regression ordinarily increases its chances of showing significance, and two longer periods were therefore tried. The results for these were:

Period	Sacramento R.		Columbia R.		R.
	B	P_B	B	P_B	
1916-30	.44	.07	.50	.04	.88
1931-45	.73	.01	.04	.09	.72

In these regressions the Columbia River B was significant for one of the periods, 1916-30, making it desirable to consider the causes for this significant association of Columbia River and California troll catches with a view to determining whether or not it actually reflects a contribution of Columbia River stocks to the California troll catch. Inspection of Figure 3 indicates that both the Columbia River and California troll catches dropped sharply during the economic depression of the early twenties, suggesting common response to economic conditions as one reason for the correlation.

Another phenomenon common to both Columbia River and California troll catches is a general downward trend during the period 1916-30, also contributing to the correspondence noted above. Obviously neither the common response to economic conditions nor the common downward trend need have anything to do with the contribution of Columbia River stocks to the California troll catch. The effects of these influences can be eliminated by omitting the years 1921-23 from the analysis and by dealing with deviations from the trends rather than the actual catches. Deviations from simple rectilinear least-squares trends of catch on time were used and the simple correlation between the Columbia River deviations and the California troll deviations was calculated. The resulting correlation coefficient (.397) proved not to be significant when entered in Fisher's (1941) Table V.A. with 10 degrees of freedom.

Recapitulating, a multiple regression analysis with the California troll catch as the dependent variable and Columbia and Sacramento River catches as independent variables has been made.

The beta coefficients measuring degree of association of California troll catch with Columbia River catch were not significant, with the single exception of that for the period 1916-30. The correlation in this instance appeared to be mainly the result of common response to economic factors, and a common downward trend. The results in general indicate that the regression analysis approach is not suitable for estimating the proportionate contribution of Columbia River stocks to the California troll catch.

Egg Number Comparisons

The data under this heading were adduced by Rich (1940b) in a general discussion of the California troll fishery in relationship to Columbia River fish. The mean number of eggs per chinook female at various points in Oregon, Washington, and California is given, as derived from published works and other sources. The salient mean counts given are as follows, proceeding from North to South: Rock Island (Columbia River) Washington, 4,885; Columbia River tributaries in Oregon, 4,800; Klamath River (California), 3,760; Fort Bragg (California) troll fishery, 4,910; Sacramento River (California), 7,453. Since the Columbia River counts are closer to the Fort Bragg count than either the Klamath or Sacramento River counts, the conclusion was drawn that this showed that a large part of the California troll fish originated in the Columbia River.

Consultation of the paper (McGregor, 1923) containing the egg counts, however, leads to a somewhat different conclusion. Figure 32 of that report shows that the range of the Fort Bragg series of counts nearly brackets the combined ranges of the Sacramento and Klamath River series. Thus the Fort Bragg fish could well have been composed of a combination of Sacramento and Klamath stocks, and this is the interpretation which McGregor himself makes. When the ranges are thus examined the fact that both the Columbia River and the Fort Bragg counts lie midway between the Klamath and Sacramento counts seems of considerably less significance than when the means alone are considered. This is recognized by Rich in his statement: "It is true that a proper combination of Klamath River and Sacramento River fish would give a similar mean..." In view of the doubt now cast upon the regression analysis, this seems a reasonable conclusion.

Tagging Experiments

The most direct evidence yet obtained as to the origin of the chinook salmon caught in the California troll fishery is embodied in the results of tagging experiments carried out by the California Bureau of Marine Fisheries in 1939-1942 (McCully, 1948). In these experiments numbers of chinook salmon from the troll fishery were tagged off the Coast of California as follows: 1939, 694; 1940, 944; 1941, 1348; 1942, 1663; total, 4649. Of these tagged fish 296 were recovered during the period 1939-1946. In addition there was one recovery in the Columbia River for which the species was unknown, but it seems likely that this fish was a chinook, since the silver salmon (the only other species tagged) is not as strongly migratory as the chinook.

Thus of a total of 297 recoveries from 4649 tagged chinook salmon, only 1, or about .3 percent was recovered in the Columbia River. It seems reasonable to assume that there would have been a greater recovery than this had the California troll catch contained any significant proportion of Columbia River chinooks. This is particularly true when it is considered that the tags used were celluloid discs which could easily be seen by cannery butchers, and that a reward of $5.00 was offered for the return of any California tag from the Columbia River during the summer of 1942, when the greatest number of California recoveries was made.

Conclusion from Evidence Presented

It has been shown above in relation to evidence on the proportion of Columbia River chinooks in the California troll catch that: (1) the multiple correlation analysis indicated no significant association of Columbia River catch with California troll catch except during one period when the correspondence could be explained on the basis of common response to economic conditions and a common downward trend, (2) the data on egg numbers could as well be explained on the basis of the California troll fish consisting of a combination of California stocks as on the basis of these fish consisting largely of Columbia River stocks and (3) tagging results indicated no significant proportion of Columbia River chinooks in the California troll catch. Taking this evidence into account it seems reasonable to conclude that the majority of the chinook salmon caught in the troll fishery off California consist of other than Columbia River stocks. This does not mean of course that no Columbia River fish are caught by

California trollers, but only that the proportion is too small to be significant in rough estimates such as those presented in this report. No estimate for California troll fish, therefore, will be included in the estimate for total troll catch of Columbia River chinook salmon.

SUMMARY AND DISCUSSION

Estimates for the troll catch of Columbia River chinook salmon in the various areas covering the period 1926-1945 have now been presented, and it remains to bring these together into a single estimate for the entire troll catch of Columbia River chinooks. This is done in Table 9, which shows the estimates for individual areas and the annual totals. The total estimated troll catch varies from 4,953,000 pounds in 1943 to 10,613,000 pounds in 1927; the mean for the period 1926-1945 being 7,835,000 pounds. It is recognized that these estimates, even though derived with a considerable amount of elaboration, are still subject to considerable error; not until more observational data are available can fully accurate determinations be made. Nevertheless, it is of interest to add the estimated annual troll catches to the river catches in order to obtain an idea of the changes in total commercial catch. The available data are brought together in Table 10 and shown graphically in Figure 4.

Inspection of Figure 4 indicates that, if the estimated troll catch be considered reasonably correct, its addition to the "inside" catch materially changes the interpretation of the course of the commercial chinook salmon production. The new total catch has a current level of around 19,000,000 pounds per year, as compared with around 13,000,000 pounds for the "inside" catch alone. These levels may be compared with the "inside" catches prior to 1910, which, since there was practically no trolling then, probably approximate closely the total catches. On this basis the present level of the new total catch is somewhat less than half the peak level attained in 1883, and is about two-thirds of the average level for the period 1875-1909; comparable fractions for the "inside" catch are roughly one-third and one-half, respectively. In other words inclusion of the estimated troll catch makes the situation with respect to the commercial catch appear less serious than would be the case if the "inside" catch alone were considered, although in both instances the indication of a marked decline in recent years is unmistakable.

TABLE 9. Summary of the estimated troll catch of Columbia River Chinook salmon along the Pacific Coast of North America, thousand of pounds. 1/

Year	Alaska	British Columbia	Washington	Oregon	Total
1926	2,060	2,645	2,885	658	8,248
1927	2,603	3,302	3,504	1,204	10,613
1928	1,479	4,625	3,163	696	9,963
1929	1,359	2,218	3,519	1,011	8,107
1930	1,824	2,431	4,186	647	9,088
1931	1,513	2,018	4,625	167	8,323
1932	1,422	2,000	3,635	190	7,247
1933	1,211	2,498	2,278	1,240	7,227
1934	1,064	2,842	2,402	514	6,822
1935	2,334	2,468	2,673	357	7,832
1936	2,445	2,228	4,246	990	9,909
1937	2,677	1,699	3,343	930	8,649
1938	2,267	1,813	2,633	493	7,206
1939	2,244	2,038	2,060	412	6,754
1940	1,790	1,475	3,792	707	7,764
1941	2,341	2,018	2,960	997	8,316
1942	1,691	1,926	3,833	534	7,984
1943	503	1,612	2,562	276	4,953
1944	411	2,069	2,013	866	5,359
1945	552	1,910	2,487	1,387	6,336

1/ Estimates for the individual regions are from Tables 4,5,6, and 7; sources of data are given in footnotes to these tables.

TABLE 10. Estimated inside, troll, and total, commercial catches of Columbia River Chinook salmon, thousand of pounds.

Year	Inside 1/	Troll 2/	Total	Year	Inside 1/	Troll 2/	Total
1866	272	-	272	1894	23,875	-	23,875
1867	1,224	-	1,224	1895	30,254	-	30,254
1868	1,904	-	1,904	1896	25,224	-	25,224
1869	6,800	-	6,800	1897	29,427	-	29,427
1870	10,200	-	10,200	1898	22,410	-	22,410
1871	13,600	-	13,600	1899	17,396	-	17,396
1872	17,000	-	17,000	1900	17,843	-	17,843
1873	17,000	-	17,000	1901	(3/)	-	(3/)
1874	23,800	-	23,800	1902	23,034	-	23,034
1875	25,500	-	25,500	1903	27,917	-	27,917
1876	30,600	-	30,600	1904	31,783	-	31,783
1877	25,840	-	25,840	1905	33,029	-	33,029
1878	31,280	-	31,280	1906	29,971	-	29,971
1879	32,640	-	32,640	1907	24,250	-	24,250
1880	36,040	-	36,040	1908	19,743	-	19,743
1881	37,400	-	37,400	1909	17,119	-	17,119
1882	36,808	-	36,808	1910	25,326	(4/)	-
1883	42,799	-	42,799	1911	36,602	(4/)	-
1884	42,160	-	42,160	1912	21,388	(4/)	-
1885	37,658	-	37,658	1913	19,384	(4/)	-
1886	30,498	-	30,498	1914	25,409	(4/)	-
1887	24,208	-	24,208	1915	32,127	(4/)	-
1888	25,328	-	25,328	1916	31,993	(4/)	-
1889	18,135	-	18,135	1917	29,522	(4/)	-
1890	22,821	-	22,821	1918	29,249	(4/)	-
1891	24,066	-	24,066	1919	30,325	(4/)	-
1892	23,410	-	23,410	1920	31,094	(4/)	-
1893	19,637	-	19,637	1921	21,552	(4/)	-

TABLE 10. Continued.

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Year	Inside 1/	Troll 2/	Total	Year	Inside 1/	Troll 2/	Total
1922	11,947	(4/)	-	1934	18,123	6,822	24,945
1923	17,617	(4/)	-	1935	15,141	7,832	22,973
1924	22,641	(4/)	-	1936	15,538	9,909	25,447
1925	26,737	(4/)	-	1937	18,450	8,649	27,099
1926	20,654	8,248	28,902	1938	12,486	7,206	19,692
1927	21,810	10,613	32,423	1939	13,588	6,754	20,342
1928	15,973	9,963	25,936	1940	13,792	7,764	21,556
1929	14,444	8,107	22,551	1941	19,405	8,316	27,721
1930	16,619	9,088	25,707	1942	18,490	7,984	26,474
1931	20,127	8,323	28,450	1943	11,568	4,953	16,521
1932	15,833	7,247	23,080	1944	14,317	5,359	19,676
1933	18,360	7,227	25,587	1945	12,384	6,336	18,720

1/ Data for 1866-1921 from Craig and Hacker (1940); for 1922-1942 from Fishery Industries of the U. S. and Fishery Statistics of the U. S.; for 1943-1945 from Annual Bulletin of Washington State Department of Fisheries, 1945. May include small amounts of troll fish from 1912 to 1925.

2/ From Table 9 of this report.

3/ No data available.

4/ Trolling carried on, but no catch data available. Based on information from Rounsefell and Kelez (1938).

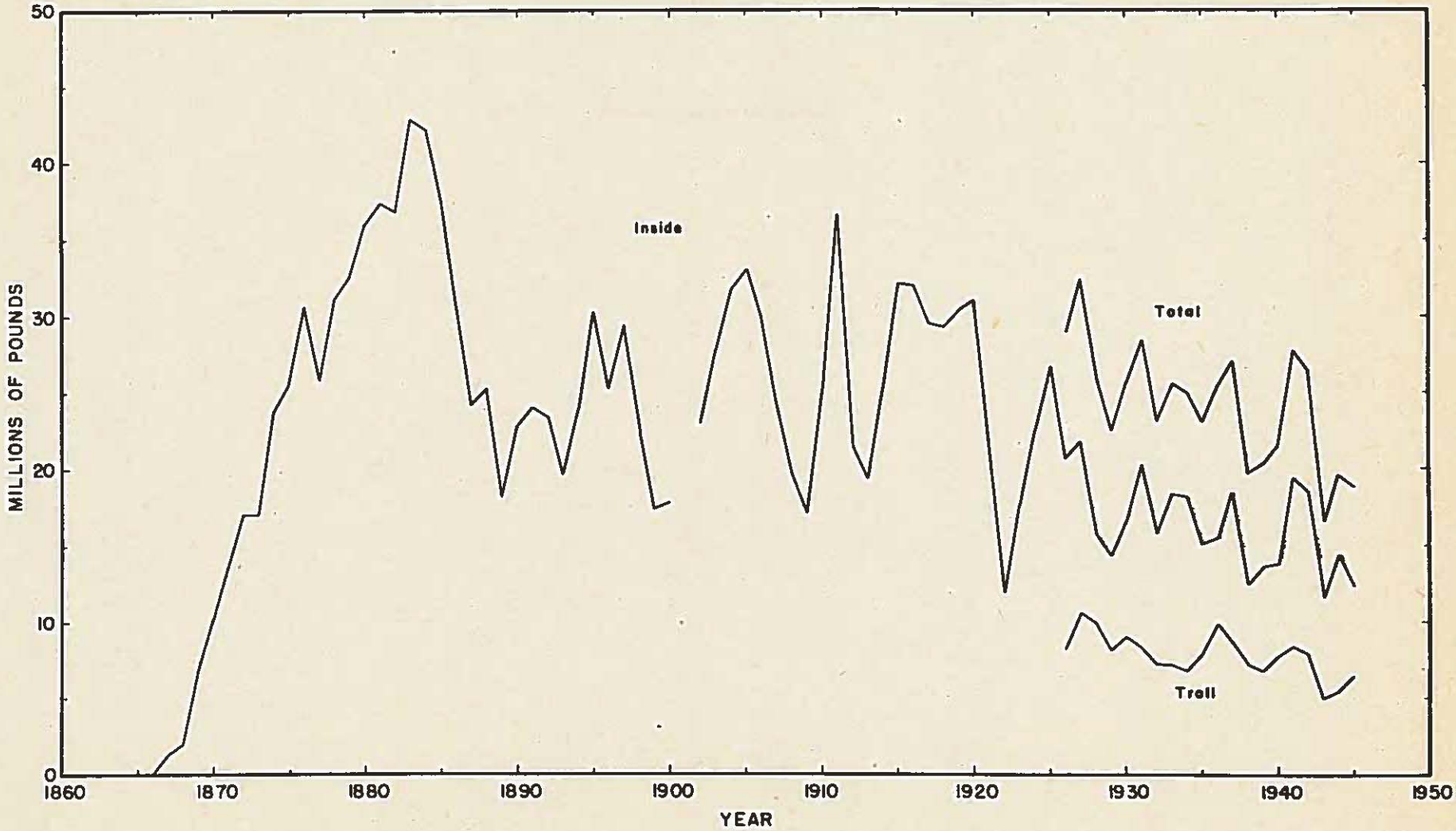

Figure 4. Estimated inside, troll and total commercial catches of Columbia River chinook salmon. The inside catch may be considered the total catch, prior to 1910.

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