UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

THE SALMON RUNS OF THE COLUMBIA RIVER IN 1938

FISHERY BULLETIN 37

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Ichthyological Notes

ATLANTIC SALMON IN LAKE JESSE, NOVA SCOTIA[1].—In 1934 the fish population in Lake Jesse, Nova Scotia, was destroyed by treating the water with copper sulphate (Smith, 1935, Trans. Amer. Fish. Soc., 65: 101–114). The purpose was to make a lake habitat in which speckled trout fry or fingerlings could be planted with no predation or competition from other fish. In 1936 the lake was stocked with speckled trout fingerlings, and closed to angling until 1939. Fish were prevented from moving into or out of the lake by a barrier at the outlet. A creel census was taken during 1939, and this disclosed that an unknown number of Atlantic salmon (*Salmo salar* Linnaeus) had inadvertently been included with the trout introduced in 1936. In all, 49 salmon were taken by the anglers during April, May and June. These fish had an average total length of 32.6±0.27 cm., an average weight of 241±6.8 gm., and were in their fourth year of age.

The normal habitats of the Atlantic salmon during their life in fresh water are the coastal streams, not lakes; and in the streams they tend to occupy the rapids rather than the pools or still waters. Particular interest is therefore attached (1) to the ability of small salmon fingerlings to adjust themselves and survive in the relatively quiet waters of Lake Jesse, and (2) to the growth the fish made under such conditions.

The fingerlings were quickly transferred from the running water in the hatchery, where they had been feeding from two to eight weeks, to the still water of the lake. White (1933, Biol. Bd. Can. Atl. Prog. Rep., 7: 6–81) observed that salmon fry require a period of adjustment following a sudden change of this nature before their swimming movements become normal in still water. The adjustment appears contingent upon an enlargement of the lumen in the air bladder. Obviously such fish would be particularly vulnerable to predator action during this period, which is a matter of days, and it may be pertinent that the survival of considerable numbers of salmon in Lake Jesse was in a habitat that was free of predator fish. As the number planted is not known, the proportion surviving cannot be determined.

Most Atlantic salmon in Nova Scotia migrate to the sea as smolts at two (the majority) or three full years of age. The migration is usually in May. However, the salmon in Lake Jesse were prevented from migrating by the barrier at the outlet. If these fish would normally have gone to sea at two years of age, then it may be considered that when captured in 1939 they would have had a year of post-smolt growth. On May 8, 1938, a salmon smolt was taken by rod in Lake Jesse. This fish was two full years of age and had a total length of 11⅜ inches (28.9 cm.). On this evidence, the salmon in Lake Jesse would have gone to sea at two years of age, and the post-smolt growth was small compared to that which would have been made during the first year of sea-life. The same observation indicates that the salmon parr made rapid growth in Lake Jesse by comparison to that attained by two-year, or even three-year parr and smolts in Atlantic coastal streams (Belding, 1935, Trans. Amer. Fish. Soc., 65: 157–160; 1937, *ibid.*, 66: 211–224; Belding and Clark, 1937, *ibid.*, 67: 184–194; Kendall, 1935, Mem. Boston Soc. Nat. Hist., 9 (1): 1–166; Hoar, 1939, Journ. Fish Res. Bd. Canada, 4: 441–460). If some of the fish in Lake Jesse would not have migrated until three years of age, then the parr growth was more strikingly rapid. The rapid growth of the young salmon in Lake Jesse is in agreement with the statement of Belding (1935, *op. cit.*: 159) that "almost invariably the lake-fed rivers have more rapidly growing parr than the rivers without lakes." The moderately high temperature level of the unstratified waters of Lake Jesse doubtless had an important influence on the parr growth.

The results from Lake Jesse suggest the possibility of using lakes as rearing areas to secure rapidly growing salmon parr. There was evidence, however, that post-smolt growth was slower in the lake than in the sea, and this is substantiated by Menzies (1912, Fish. Scotland, Salmon Fish. 1911.1: 1–7) who recorded that Atlantic salmon, retained in fresh water in Scotland during post-smolt life, made much poorer growth than if they had normally migrated to sea, although the fish matured and spawned. Similarly, the adult size of the landlocked form of Atlantic salmon in American lakes is decidedly smaller than that attained by the sea-run variety.

Permission from the Fish Culture Branch of the Department of Fisheries of Canada, Ottawa, (Mr. J. A. Rodd, Director) to use the creel census data for for Lake Jesse is gratefully acknowledged.—M. W. SMITH, *Fisheries Research Board of Canada, Atlantic Biological Station, St. Andrews, New Brunswick.*

1 Published with permission of the Fisheries Research Board of Canada.

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
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THE SALMON RUNS OF THE COLUMBIA RIVER IN 1938

By WILLIS H. RICH

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ABSTRACT

EXCEPTIONAL DATA are available for the study of the salmon runs of the Columbia River in 1938. Detailed figures on catch were supplied by Oregon and Washington in such form that they could readily be combined with the counts at Bonneville Dam to provide a basis for estimating the escapement. Tables show the catch of each species for each week in each of six zones, and the counts at Bonneville and Rock Island dams. The general course of the run of each species is shown. The numbers of fish bound for the spawning grounds above Rock Island Dam are estimated as follows: Chinook salmon entering Columbia River before May 1, 4 percent; during May, 6 percent; June and July, 15 percent; and August to December, 1 percent. Blueback salmon entering the river during the above periods, 40 percent. Steelhead trout entering the river during June to September, 1 percent; during the rest of the year, 10 percent. Fishing intensities are shown by escapement to catch ratios. Percentages of chinook salmon escapement are less than 15 during May; 17 during June and July; and 33 during the remainder of the year. The June and July runs are now greatly depleted, and an important part of these runs spawns above Rock Island Dam. The blueback salmon escapement is about 20 percent, and of steelhead trout about 33 percent. Weekly and seasonal closed periods are shown to be almost entirely ineffective for increasing the spawning escapement. Exploitation is further increased by the intensive troll fishery conducted from Monterey Bay to southeastern Alaska. Chinook salmon are also subjected to a sport fishery of considerable importance. Main runs of salmon to the Columbia River are practically unprotected and are fished with destructive intensity.

THE SALMON RUNS OF THE COLUMBIA RIVER IN 1938[1]

By WILLIS H. RICH, *Professor of Biology, Stanford University and Director of Research, Fish Commission of Oregon; in cooperation with the Division of Fishery Biology, Fish and Wildlife Service*

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INTRODUCTION

With the announcement of plans for the construction of the Grand Coulee Dam on the Columbia River in eastern Washington, questions were raised as to the effect that this development would have on the salmon runs and as to the possible means for preserving those salmon populations that had formerly reproduced in the area above the site of the dam. Funds were provided by the United States Bureau of Reclamation to the Washington State Department of Fisheries for the purpose of making a preliminary study of possible means for preserving the runs. A report (Washington State Department of Fisheries 1938 [2]) was presented in January 1938, in which the chief recommendation was for an extensive system of artificial propagation. Later the Bureau of Reclamation appointed a board of consultants to review the proposed plan and to make recommendations. In their report (Calkins, Durand, and Rich 1939 [3]) these consultants recommended, substantially, the plan proposed by the Washington Department of Fisheries.

In the preparation of this report the writer made an analysis of the available data on the salmon runs of 1938 for the particular purpose of determining the relative importance of those fractions of the runs that would be affected by the construction of the Grand Coulee Dam. Various other facts bearing upon the state of the Columbia River salmon resources and the problems of their conservation were developed during the course of this analysis and it has seemed desirable to amplify the part of the

[1] Contribution No. 7, Department of Research, Fish Commission of Oregon.

[2] Report of the preliminary investigations into the possible methods of preserving the Columbia River salmon and steelhead at the Grand Coulee Dam. 121 pp. U. S. Bureau of Reclamation, Washington. (Processed.)

[3] Report of the board of consultants on the fish problems of the upper Columbia River. 83 pp. U. S. Bureau of Reclamation, Denver, Colo. (Processed.)

report that treats of the 1938 run and to present it as a separate publication. For this purpose the data presented in the original report of the board of consultants have been supplemented by data that have become available since the original report was prepared. At that time no catch data were available later than the close of the "spring" fishing season on August 25. In this revision the catch data for the "fall" season also have been included. Various omissions and minor changes have been made, and some additional analysis is given.

Acknowledgment is due the Bureau of Reclamation and the writer's associates on the board of consultants for permission to use here the material of the original report. Acknowledgment also is due the Washington Department of Fisheries, the Fish Commission of Oregon, the United States Army Engineers, and the Bureau of Reclamation for many data used in the original report and in this revision.

THE COLUMBIA RIVER SALMON FISHERY

Five species of salmon are taken in the commercial fishery on the Columbia River. These are (1) chinook salmon (*Oncorhynchus tschawytscha*), (2) silver salmon (*O. kisutch*), (3) blueback salmon (*O. nerka*), (4) chum salmon (*O. keta*), and (5) steelhead trout (*Salmo gairdnerii*).

Fishing is permitted throughout the year except during March and April, and during the period from August 25 to September 10. The open season from May 1 to August 25 is spoken of as the spring season, and that from September 10 to March 1 as the fall season. Comparatively few fish are taken during December, January, and February, however, so that the fall season is practically limited to the period from September 10 to about the end of November. In addition to these seasonal closed periods there is a weekly closed period extending from 6 o'clock Saturday evening until 6 o'clock Sunday evening, effective during the spring open season.

Because the estimate of the intensity of the fishery is based on the ratio of the commercial catch to the fish passing Bonneville Dam, it is important to consider the relative extent of spawning which, for each species, takes place above and below this point. Obviously, if a large proportion of the fish of any one species, population, or group of populations spawns below Bonneville Dam, estimates of relative spawning escapement based upon the number of fish passing Bonneville will be in error.

Practically all the bluebacks spawn above Bonneville. As is well known, their habit is to spawn only in lakes or the tributaries of lakes in which the young remain for 1 or more years before making the seaward migration, and no lakes typical of those in which bluebacks spawn are to be found in the tributaries of the lower Columbia.

The chinooks spawn in nearly all the accessible tributaries of the river, both above and below Bonneville; a fact certain to lead to some error. With one exception, however, this error is probably negligible during the main part of the run because it is chiefly the late fall fish that spawn in the lower tributaries. The exception is the considerable run of chinooks that ascends the Willamette River in April and early May. There are, unfortunately, no reliable estimates of the extent of this run, but it forms the basis for an extensive sport fishery in the Willamette River, especially just below the falls at Oregon City. No commercial fishing is permitted in the Willamette River itself and the peak of the run is ordinarily past Oregon City by the opening of the season on May 1. Although some of these Willamette River chinooks are undoubtedly taken in the commercial fishery in the Columbia below the mouth of the Willamette, it does not seem likely that these constitute a large percentage of the total

commercial catch. It is believed, therefore, that error in the estimates of fishing intensity of chinooks, due to spawning in the tributaries that enter the Columbia below Bonneville Dam, is relatively small, even during the first few weeks of the spring open season. After about the middle of May it seems reasonably certain that there is very little error due to this cause until at least the first of August, at which time some fish that will eventually spawn in the smaller tributaries below Bonneville Dam begin to enter the river.

In none of these lower tributaries is there a large run of spawning fish while the count of fish passing Bonneville is at its peak during August and September. These facts indicate clearly that, even during these months, the error in the estimate of fishing intensity based on a comparison of catch with the count at Bonneville will not be serious. As the season advances, however, progressively larger percentages of the fish entering the river are destined to spawn in the lower tributaries. Although the total number of fall fish spawning below Bonneville Dam is probably not large compared with the number spawning above the dam, the error will tend to increase, and great dependence cannot be placed on the results of the study of the late fall fish.

Steelhead trout spawn generally throughout the accessible tributaries, but apparently are more abundant in the upper than in the lower streams. In the case of silver and chum salmon, a very large proportion of the spawning occurs in the tributaries below Bonneville Dam, so that the ratio between the count at the dam and the catch gives no reliable indication of the intensity of the fishery.

This report deals primarily with the salmon runs of 1938 and it is to be hoped that similar studies, either by this writer or by others, will be made of future runs for which similar data will be available. As a part of the "frame of reference" into which are placed these studies of the runs of individual years, however, it is important to present something of the earlier history of these runs. This has been done in some detail elsewhere (Craig 1938 [4]; Oregon State Planning Board 1938 [5]; Craig and Hacker 1940; and Rich 1940b) and there is presented here only a graph showing the average annual catch of each species for each 5-year period. The data for this graph have been taken from Craig (1938), and recent numbers of the Pacific Fisherman Year Book. Previous to 1888 there was no segregation of the salmon catch by species, but there can be no doubt that chinooks formed the bulk of the catch. For the first 2 decades during which the pack was segregated the chinooks formed about 80 percent of the total, and it has been assumed that approximately the same percentage existed prior to 1888. No attempt has been made to estimate the catch of the other species previous to the period 1890–94. The catch in pounds has been estimated from the figures for the canned and mild-cured packs, which include a large part of the total. Further details may be found in the several references given.

Figure 1 shows the rapid growth of the industry during the first 2 decades after its inception, a period of 35 or 40 years in which the catch of chinook salmon fluctuated from about 20,000,000 to 30,000,000 pounds and a final period of some 20 years in which there has been a constant decline. In all probability this decline is an indication of true depletion; that is, a reduction in productivity below the point that can be maintained over a long period of time. The picture is complicated by the existence of an extensive oceanic fishery extending from Monterey Bay to southeastern Alaska, which draws heavily upon the supply of Columbia River chinooks (Rich 1941).

[4] Memorandum regarding fishing in the Columbia River above and below Bonneville Dam. 16 pp., U. S. Bureau of Fisheries, Washington. (Processed.)

[5] Commercial fishing operations on the Columbia River. 73 pp. Oregon State Planning Board, Portland, Oreg. (Processed.)

The catch within the river does not, therefore, represent the entire productivity of the runs of this species, but with available data it is not possible to determine with much accuracy what this total productivity actually is. The constant decline of the last 20 years, however, taken in connection with data presented in this report, certainly warrants the conclusion that the chinook runs are seriously depleted.[6] We shall show below that the present exploitation of these depleted runs is being conducted with an intensity so great that it can only lead to disaster in the not far distant future unless the present trends can be altered.

The blueback salmon catch for both of the first 2 periods shown in figure 1 is approximately twice that of the succeeding periods, and there is some reason to think that the abundance of blueback salmon previous to 1890 was at least the equal of that

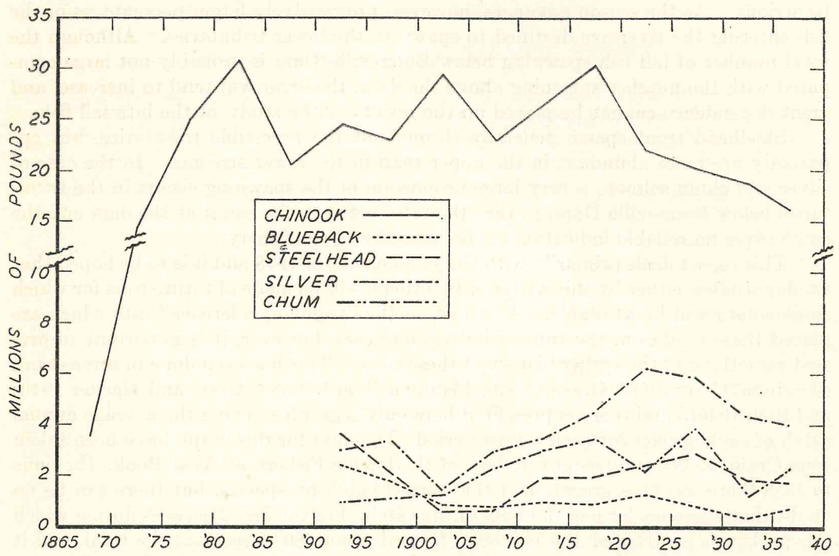

FIGURE 1.—Average annual catch by 5-year periods of chinook salmon, 1866–1938; and of blueback, silver, and chum salmon; and steelhead trout, 1891–1938.

which existed during the decade of the 90's. Since 1900, however, there has been little change—the trend is almost horizontal. These facts imply that this species originally was fairly abundant in the Columbia River, but that this early abundance was sharply reduced about 1900, and since that time there has been comparatively little change. This species almost universally spawns in or above lakes and it seems quite possible that the damming of lakes for use as reservoirs without providing adequate fishways, and the unrestricted use of unscreened irrigation ditches, were chiefly responsible for the depletion.

In figure 1 considerable fluctuation is shown in the estimated catch of steelhead trout, especially in the early years of the record, but there is little evidence of a marked

[6] Since this report was in page proof an additional study of these data has been made using the methods of the control chart as developed by Shewhart, Deming, and others, for the control of quality in manufactured products. The results show conclusively that the productivity of the chinook fishery since 1925 has been at a distinctly lower level than was maintained during the period 1876 to 1920. These will be published elsewhere.

trend. It suggests, however, that the slightly reduced averages for the past two 5-year periods may signify some real reduction in abundance.

The general trend for both silver and chum salmon is distinctly upward (fig. 1) despite rather wide fluctuations. This doubtless reflects an increased usage of these 2 less desirable species that has come with the reduced abundance of the other species, especially the chinook.

DATA FOR THE RUNS OF 1938

In this study of the 1938 salmon runs to the Columbia River, data have been available for the first time in the history of the fishery that have made it possible to evaluate the intensity of the fishery as a whole, the relative intensity at different times and in different parts of the river, and the proportion of the total that is formed by the run to the upper Columbia River (Clarks Fork). These data include the following series: (1) Daily commercial catch in pounds and by species in each of 6 districts corresponding to the 6 counties of the State of Washington that form the northern shore of the Columbia; (2) daily counts, by species, of the salmon passing Bonneville Dam beginning with May 7, and estimates for the period from February 15 to May 6; and (3) daily counts, by species, of the salmon passing Rock Island Dam across the upper Columbia near Wenatchee, Wash., about 100 miles below the site of the Grand Coulee Dam. The latter have been available since the season of 1933.

The importance of the data on the Bonneville count and the total daily catches to the proper development of a sound program for the conservation of the salmon of the Columbia River should be emphasized. Without them an intelligent consideration of the problems raised by the Grand Coulee Dam would have been impossible, and they will be of equal importance in the study of any other problems dealing with the maintenance of this valuable resource. For the previous three seasons the Washington Department of Fisheries had collected records of the daily deliveries of each species of salmon in each of the counties of the State bordering on the Columbia River. The Fish Commission of Oregon also had collected data on the daily deliveries of salmon, but not until 1938 were these presented in such form as to make it possible to combine them with the data from Washington so as to give a record of the total daily deliveries by species and by locality. For no other year are such data available, although figures for 1939 will be in suitable form for study when they are available. Now that a uniform system for presenting the catch data has been started by the two States, it probably will be continued so that in the future data will be available showing the total daily deliveries in each of the six districts.

Of equal importance has been the record of counts of fish passing the dams at Bonneville and Rock Island. Since 1933 there have been counts, more or less complete, at Rock Island, but the Bonneville Dam was not finally closed to the passage of fish previous to 1938, so that this year marks the beginning of the count at this point. The tremendous value in the conservation program of the count of salmon passing over the Bonneville Dam cannot well be overstated. This count should, by all means, be made a permanent feature and should be in the hands of competent men familiar with the fish and with the techniques of fishery research, and having a primary interest in the fishery problems upon which these data will bear.

In presenting these data it has been found expedient to sum them for the smallest practical time interval. The unit of 1 week was selected as the shortest period that would avoid insignificant fluctuations, particularly the disturbing effect of the Sunday closed period. For special purposes the data have also been arranged relative to

longer time intervals, but these have been selected carefully on the basis of facts apparent from the tabulations made on a weekly interval. The use of relatively short time intervals has been important because of the considerable fluctuation in the commercial value of the salmon, particularly chinooks, during the season. The spring fish, entering the river during the period from April to the early part of August are much more valuable than those running later in the season. Furthermore, the magnitude of the run varies greatly from week to week and some portions of the run are far more seriously depleted than others. The intensity of fishing also varies, and the closed seasons tend to favor certain portions of the run and leave others practically unprotected from intensive exploitation. The commercial and biological importance of the various portions of the run of each species must, therefore, be determined independently, and to do this a relatively short time interval is essential. Because the fishing season begins May 1, the first week in May has been taken as the point of departure, and the weekly intervals, both before and after, are arranged to conform to this.

TABLE 1.—*Catch of chinook salmon in the Columbia River, 1938*

Week ending	Outside [1]	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Apr. 2	2,393						
Apr. 9	38,292						
Apr. 16	8,193						
Apr. 23	11,123						
Apr. 30	11,309						
May 7		212,139	390,998	237,612	38,294	41,327	14,447
May 14	225	131,269	116,015	105,441	29,720	28,531	38,464
May 21		69,042	71,280	17,411	5,097	4,662	19,509
May 28		36,655	43,170	7,619	1,805	1,476	7,395
June 4	1,388	35,005	19,783	539	20	129	4,346
June 11	9,062	53,963	35,554	736	51	30	6,955
June 18	5,872	81,434	48,300	3,392	1,683	947	4,495
June 25	6,398	110,052	86,608	11,544	2,931	1,113	4,248
July 2	12,494	127,078	66,401	11,230	4,340	2,306	1,989
July 9	5,984	189,276	133,845	26,334	4,572	4,605	1,217
July 16	5,580	154,680	108,092	34,388	5,202	7,358	1,118
July 23	8,577	187,621	84,095	30,224	7,414	5,988	2,872
July 30	21,454	309,210	123,905	29,035	11,648	10,111	2,070
Aug. 6	40,596	658,106	127,847	16,158	7,733	6,899	6,157
Aug. 13	12,869	1,000,675	482,395	55,821	15,180	9,363	15,373
Aug. 20	9,911	1,121,367	617,998	84,876	7,755	17,030	40,676
Aug. 27	26,875	[2] 960,365	288,497	65,964	19,611	29,544	37,532
Sept. 3	18,896						
Sept. 10	7,573						
Sept. 17	12,648	188,933	142,308	83,724	[3] 94,942	45,331	[3] 772,785
Sept. 24	2,247	146,414	164,363	130,829	39,201	52,156	398,660
Oct. 1	2,037	30,414	30,701	8,264	14,075		117,743
Oct. 8	2,794	8,700	13,987	4,776	5,385	34	69,656
Oct. 15	502	14,481	15,990	6,303	1,371		23,199
Oct. 22	1,295	9,356	9,273	4,446	1,929	28	6,022
Oct. 29		2,635	6,592	2,852	671	63	5,507
Nov. 5	6	1,477	2,952	1,305	1,035		1,358
Nov. 12		547	812	701	151		
Nov. 19		83	167	177	142		
Nov. 26		65	141	30		26	11
Dec. 3			18				
Dec. 10			96				
Dec. 17			14				

[1] Outside may include some fish caught by troll inside the river and along the coast from Neah Bay to Coos Bay.
[2] The season on the river closed on August 25.
[3] The fall season opened at noon on September 10 and on that day 450 pounds were delivered in Zone 4 and 93,837 pounds in Zone 6. Since these catches represented a fishing period of only one-half day, they have been added to the catches of the following week.

TABLE 2.—*Catch of blueback salmon in the Columbia River, 1938*

Week ending	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Week ending	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
May 21	5						July 16	2,310	6,771	2,408	1,919	4,571	29,322
May 28							July 23	518	380	719	177	919	17,749
June 4	4						July 30	65	72	71	12	71	3,960
June 11	47	16				4	Aug. 6	7	8			6	1,125
June 18	2,282	8,138	905	468	834	203	Aug. 13						411
June 25	20,804	63,156	7,342	6,393	9,040	2,872	Aug. 20					48	57
July 2	18,326	59,368	13,534	7,325	10,579	15,312	Aug. 27 [1]						15
July 9	8,301	37,708	11,624	6,430	8,117	27,368							

[1] Season closed on August 25.

TABLE 3.—*Catch of steelhead trout in the Columbia River, 1938*

Week ending	Outside	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
May 7		1,833	5,347	1,174	169	449	1,298
May 14		1,166	4,366	851	75	184	3,253
May 21		722	2,465	243	41	56	2,212
May 28		447	1,703	144	56	74	1,203
June 4		566	627	28	5		737
June 11		898	890	39	7	10	503
June 18		3,448	5,070	171	113	57	255
June 25	667	17,724	20,566	1,247	371	327	416
July 2	358	20,449	38,342	2,929	1,008	503	451
July 9	38	59,666	94,512	10,610	2,142	1,701	829
July 16	22	50,226	76,705	23,060	3,224	3,821	1,029
July 23	46	36,944	56,598	24,920	4,686	3,409	6,204
July 30	72	37,928	58,537	11,797	2,225	2,210	3,524
Aug. 6	119	22,679	30,245	7,362	2,600	3,084	3,857
Aug. 13	50	45,215	94,016	11,274	2,908	2,204	15,784
Aug. 20	100	32,885	72,520	15,284	3,152	3,777	20,863
Aug. 27	66	[1] 21,852	40,807	11,017	3,524	3,293	11,566
Sept. 3	19						
Sept. 10	12						
Sept. 17		1,826	7,347	4,332	14,911	2,326	[2] 126,464
Sept. 24		11,583	30,153	10,036	5,600	3,008	99,731
Oct. 1		6,647	14,878	3,741	3,768		23,007
Oct. 8		2,258	5,025	2,021	1,007		10,723
Oct. 15		1,337	3,090	1,174	376		4,383
Oct. 22		1,730	2,585	982	104		1,456
Oct. 29		1,149	2,228	730	41	12	2,860
Nov. 5		1,130	2,503	993	59	14	1,250
Nov. 12		2,240	5,206	1,357		13	83
Nov. 19		2,810	5,497	1,520	91		
Nov. 26		2,127	8,459	2,694	177		
Dec. 3			930	7,180	2,433		
Dec. 10		2,757	18,101	1,852			
Dec. 17		1,094	8,800	1,203			
Dec. 24		774	6,955	1,996			
Dec. 31		427	9,660	1,741			

[1] Season closed on August 25.
[2] Includes 14,531 delivered on September 10 (see footnote 3, table 1).

TABLE 4.—*Catch of silver salmon in the Columbia River, 1938* [1]

Week ending	Outside [2]	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Week ending	Outside [2]	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
June 4	1,456						Sept. 24	43,757	122,075	108,240	22,933	1,497	275
June 11	3,850						Oct. 1	68,257	83,378	60,661	10,330	1,326	
June 18	34,196						Oct. 8	94,171	41,359	64,417	18,546	9,811	20
June 25	43,611						Oct. 15	57,338	141,280	182,825	50,453	9,029	27
July 2	17,464						Oct. 22	104,462	154,600	164,545	45,604	7,593	266
July 9	61,362						Oct. 29	24	68,087	134,595	44,495	6,415	245
July 16	30,888						Nov. 5	799	74,463	158,286	37,209	3,698	373
July 23	51,354						Nov. 12	3,466	46,270	87,188	18,721	1,054	17
July 30	90,517						Nov. 19		12,127	49,966	14,793	1,165	
Aug. 6	114,334	8		7			Nov. 26		3,374	19,376	8,165	149	
Aug. 13	153,856	478	69	19			Dec. 3		1,312	14,610	8,410	234	
Aug. 20	257,407	7,848	6,692	100	27		Dec. 10		4,699	52,925	5,470		
Aug. 27	238,679	19,457	6,904	2,327	49		Dec. 17		754	9,940	2,039		
Sept. 3	327,076						Dec. 24		285	1,573	882		
Sept. 10	258,672						Dec. 31		97	1,439	487		
Sept. 17	154,168	[3] 23,730	21,906	7,674	1,198	152							

[1] No catch reported from Zone 6.
[2] May include some fish caught by troll inside the river and along the coast from Neah Bay to Coos Bay.
[3] Includes 43 pounds delivered September 10 (seef ootnote3 - table 1)

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TABLE 5.—*Catch of chum salmon in the Columbia River, 1938*

Week ending	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Week ending	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Sept. 24	32	-------	-------	-------	-------	165	Nov. 19	29,877	130,691	43,299	5,589	1,950	-------
Oct. 1	473	699	-------	-------	-------	304	Nov. 26	7,658	53,078	24,680	3,476	2,965	-------
Oct. 8	1,732	1,606	265	2,577	-------	247	Dec. 3	808	10,021	11,407	695	-------	-------
Sept. 15	19,686	28,704	2,962	241	-------	693	Dec. 10	1,784	21,075	4,395	-------	-------	-------
Oct. 22	54,781	104,820	13,567	1,815	-------	69	Dec. 17	262	4,264	568	-------	-------	-------
Oct. 29	60,490	163,206	22,293	6,945	73	3,188	Dec. 24	-------	439	232	-------	-------	-------
Nov. 5	106,475	408,107	43,641	6,419	3,653	1,380	Dec. 31	-------	148	82	-------	-------	-------
Nov. 12	94,797	321,213	69,073	2,990	284	-------							

TABLE 6.—*Miscellaneous catches in the Columbia River, 1938*

Month	Chinook	Steelhead	Blueback	Silver	Chum	Month	Chinook	Steelhead	Blueback	Silver	Chum
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
April	59	-------	-------	-------	-------	October	9,753	1,186	-------	4,420	1,060
May	18,714	2,725	-------	-------	-------	November	-------	571	-------	3,164	5,551
June	1,170	178	2,219	166	-------	December	-------	423	-------	21	29
July	1,503	93	722	5	9						
August	8,057	311	27	152	-------	Total	86,355	7,561	2,968	8,146	6,649
September	47,099	2,074	-------	218	-------						

Tables 1 to 5 give the aggregate Washington and Oregon catches for 1938, by species, weeks, and zones. These figures include only those catches that were reported by locality and date. There is a relatively small portion of the total catch that is reported without these important data and these have been excluded from this analysis, although for completeness they are given in table 6. The catch of chinook and silver salmon made in the ocean outside the mouth of the river by troll fishermen was not given in the original report by the board of consultants, but is included here. Occasionally deliveries are reported during the spring season as of Sunday. Since the period from 6 p. m. Saturday to 6 p. m. Sunday is closed to fishing each week during the spring season, such catches have been added to those of the preceding week. Catches made on Saturday are not infrequently held over and delivered on Sunday, and it rarely happens that catches are made after 6 p.m. on Sunday and delivered that same evening.

The zones correspond to the Washington counties bordering the river, beginning at the mouth. Zone 1 is that part of the river that is bounded on the north by Pacific County, Zone 2 by Wahkiakum County, Zone 3 by Cowlitz County, Zone 4 by Clark County, Zone 5 by Skamania County, and Zone 6 by Klickitat County. The catch in Zone 5 has, on the advice of both the Washington and Oregon officials, been referred wholly to the area below Bonneville Dam. This zone extends above Bonneville for some distance, but for a part of this distance the river is closed to all fishing and the catch in the remaining portion is so small as to be negligible, either when omitted from the record of the catch above or added to the record of that below Bonneville.

In this analysis we have necessarily omitted consideration of three elements in the catch which are recognized as important but which cannot, with the data at hand, be evaluated. These are: (1) The catch in the ocean by the troll fishery; (2) the hook-and-line catch by sport fishermen; and (3) the catch made by Indians for their own use, especially at Celilo Falls.

The troll fishery is very important, and from southeastern Alaska to the mouth of the Columbia it draws largely upon the supply of Columbia River chinooks—as demonstrated by tagging experiments (Pritchard 1934, Fisheries Service Bulletin, Jan. 3, 1928). Fairly good data are available as to the aggregate troll catch of chinooks and silvers in Alaska, Oregon, and Washington. The percentage of Columbia River fish in this catch, however, undoubtedly varies greatly during the season. There are no satisfactory data on this latter point. Even though we knew the proportions of Columbia River fish in the catch at different times and in different localities, it would be impossible to allocate these to the seasonal runs of the Columbia and thus, eventually, to determine the element in the troll catch derived from the runs to the Columbia River above Rock Island Dam. Likewise, we have no data on the catch of the sport fishery or on that part of the Indian catch that is not sold. All of these elements increase to some unknown extent the economic importance of the salmon runs with which we are here concerned.

TABLE 7.—*Estimates and counts of fish passing Bonneville, 1938*

[The figures up to and including May 7 are estimates based on partial counts only. Differences between the figures given here and those in the report by Calkins, Durand, and Rich are due to the fact that this table includes the final figures as given by the Army Engineers, in which minor corrections were made of the figures submitted weekly.]

Week ending	Chinook	Grilse [1]	Steelhead	Blueback	Silver	Chum	Week ending	Chinook	Grilse [1]	Steelhead	Blueback	Silver	Chum
Feb. 19	-------	-------	55	-------	-------	-------	Aug. 6	1,327	329	4,886	1,125	-------	-------
Feb. 26	-------	-------	158	-------	-------	-------	Aug. 13	4,163	769	6,086	621	-------	-------
Mar. 5	4	-------	204	-------	-------	-------	Aug. 20	5,104	1,010	6,457	279	0	-------
Mar. 12	68	-------	980	-------	-------	-------	Aug. 27	10,112	2,166	6,908	209	115	-------
Mar. 19	84	-------	1,267	-------	-------	-------	Sept. 3	53,753	9,452	17,689	156	6,964	-------
Mar. 26	0	-------	84	-------	-------	-------	Sept. 10	80,693	8,913	15,814	76	4,766	-------
Apr. 2	14	-------	981	-------	-------	-------	Sept. 17	63,224	5,756	13,744	71	1,933	-------
Apr. 9	339	-------	7,319	-------	-------	-------	Sept. 24	12,258	1,581	3,935	10	239	-------
Apr. 16	402	-------	1,927	-------	-------	-------	Oct. 1	2,057	406	1,204	1	56	0
Apr. 23	484	-------	639	-------	-------	-------	Oct. 8	994	244	857	0	94	2
Apr. 30	1,545	-------	320	-------	-------	-------	Oct. 15	489	99	604	3	389	68
May 7	3,359	-------	133	-------	-------	-------	Oct. 22	161	34	230	1	240	179
May 14	12,936	1,357	3,217	131	-------	-------	Oct. 29	234	17	253	1	212	945
May 21	5,097	842	1,622	572	-------	-------	Nov. 5	208	40	152	0	138	174
May 28	3,827	871	1,644	318	-------	-------	Nov. 12	47	10	90	2	18	236
June 4	205	53	164	24	-------	-------	Nov. 19	29	5	60	0	9	225
June 11	1,981	710	632	153	-------	-------	Nov. 26	9	1	58	0	4	202
June 18	2,932	515	652	1,358	-------	-------	Dec. 3	5	1	30	0	1	45
June 25	2,230	334	520	5,719	-------	-------	Dec. 10	21	5	43	0	7	46
July 2	1,240	164	641	15,441	-------	-------	Dec. 17	2	0	18	0	0	13
July 9	884	102	800	16,491	-------	-------	Dec. 24	0	0	1	0	0	1
July 16	1,855	204	4,061	21,673	-------	-------	Dec. 31	2	0	13	0	0	0
July 23	1,534	337	7,161	7,835	-------	-------							
July 30	1,753	430	6,667	2,770	-------	-------	Total	277,665	36,757	120,985	75,040	15,185	2,136

[1] Grilse, locally designated as "jack" salmon, are precocious males. These are included in the preceding column headed "Chinooks," the figures in which are, therefore, the totals for this species.

In table 7 are given the counts and estimates of the number of salmon and steelhead passing Bonneville Dam during 1938. Actual counting did not begin until May 7, but estimates could be made from partial counts—the so-called "spot" counts—covering the period from the middle of February to and including May 6. These partial counts were made by observers stationed for portions of the day at the several fish ladders. The records consisted of (1) the length of time during which the observations were continued, and (2) the number of fish of each species observed. This is essentially a sampling method, and it is known that the fish do not run uniformly during the entire 24 hours, or even during the daylight hours. A fairly good estimate can be made from such records, however, if the hours during which the fish run are determined with care, and if the periods during which the counts are made are suitably distributed. The method adopted here for estimating the total number for the day from the partial counts is to multiply by 12 the average hourly count as determined from the records. This is the method recommended and used by Fred Morton, who

was actively in charge of the count. This method assumes that the fish are passing over the ladders for 12 hours per day at the same average rate as observed during the period of the count and has been applied to each ladder separately and the sum is the estimated total for the day. For periods during which no count was made a linear interpolation between the preceding and the following days' estimated counts was used. Although not comparable in accuracy to the actual count, these estimates appear to give a reasonable basis for further calculations.

A chief source of error in these counts and estimates is undoubtedly the identification of species as the fish were passing up the ladders. After May 7, when the actual count began, the fish were forced to pass through a small opening in a weir placed across each fish ladder and over a submerged platform painted white. Identification of species under these conditions can be made with some accuracy by careful observers and, in general, reasonable confidence can be placed in the identifications so made. Those made under less favorable conditions must, necessarily, be accepted as the best available. Circumstances may arise in which a particular misidentification is especially likely to occur, in which case it may be recognized and steps taken either to improve the identification or to determine its influence and allow for it in the estimates of the number of fish of the species confused.

It is apparent that one such particular case of misidentification might easily arise during the time when the blueback run is at its peak. Grilse, which are approximately the same size as the bluebacks, are among the chinooks and run at the same time, and it has seemed likely that bluebacks might be mistaken for grilse or grilse for bluebacks. An analysis has been made in which the correlation was determined between the percentage of grilse in the total count of chinooks and the number of bluebacks for the 10 weeks of the blueback run—June 11 to August 13.

The Pearsonian coefficient of correlation is -0.72. Using the standard procedure the probability of chance occurrence of a coefficient of correlation as high as this is only 0.03, so that the observed negative correlation between the percentage of grilse and the number of bluebacks can be accepted as significant. Furthermore, it seems likely that the relationship between these two variables is curvilinear rather than rectilinear, as assumed by the Pearsonian coefficient, and that a true measure of the correlation would be even higher than that calculated. Our measure is, therefore, conservative. It seems quite likely that this negative correlation can be ascribed to a tendency on the part of the observers to mistake grilse for bluebacks when the bluebacks are numerous.

This raises the question as to what other errors there may be in the counts. It is certainly difficult to distinguish species under the conditions of counting unless there is a fairly well marked difference in size, shape, or markings, especially if light conditions are not favorable. Observers should not be blamed for making errors under these conditions, but, in view of the evidence of error in identification just given, it would seem proper to investigate carefully to see how extensive these errors may be. The importance of having properly trained and experienced observers is obvious.

TABLE 8.—*Counts of chinook salmon at Rock Island Dam, 1933 to 1938*

Week ending	1933	1934	1935	1936	1937	1938	Week ending	1933	1934	1935	1936	1937	1938
Apr. 16	--------	2	--------	--------	--------	--------	Aug. 6	257	836	686	848	645	383
Apr. 23	--------	11	--------	--------	--------	--------	Aug. 13	253	741	689	275	42	419
Apr. 30	--------	9	--------	--------	--------	14	Aug. 20	2,600	3,047	2,187	139	241	196
May 7	--------	39	65	6	--------	28	Aug. 27	409	386	3,342	65	172	82
May 14	--------	87	117	13	2	70	Sept. 3	1,154	133	2,710	21	102	162
May 21	--------	137	509	84	7	78	Sept. 10	656	57	1,104	--------	61	171
May 28	--------	93	532	399	30	650	Sept. 17	210	113	437	--------	65	209
June 4	--------	47	462	727	63	235	Sept. 24	70	67	1,077	--------	371	515
June 11	--------	36	282	254	25	195	Oct. 1	--------	58	306	--------	239	344
June 18	--------	13	321	298	33	69	Oct. 8	--------	111	629	--------	65	344
June 25	--------	11	86	201	19	94	Oct. 15	--------	350	123	--------	55	111
July 2	--------	29	59	95	159	120	Oct. 22	--------	30	41	--------	9	8
July 9	--------	104	116	91	180	39	Oct. 29	--------	27	5	--------	--------	15
July 16	--------	126	38	183	148	77	Nov. 5	--------	3	--------	--------	--------	--------
July 23	8	129	90	1,245	608	450							
July 30	51	268	288	1,530	1,791	725	Total	5,668	7,100	16,301	6,475	5,132	5,803

TABLE 9.—*Counts of blueback salmon at Rock Island Dam, 1933 to 1938*

Week ending	1933	1934	1935	1936	1937	1938	Week ending	1933	1934	1935	1936	1937	1938
May 21	--------	--------	18	--------	--------	--------	Aug. 20	4,941	104	2,172	168	241	266
May 28	--------	--------	3	--------	--------	--------	Aug. 27	827	35	561	20	74	93
June 4	--------	--------	2	1	--------	--------	Sept. 3	125	30	180	14	128	43
June 11	--------	--------	3	4	--------	--------	Sept. 10	56	15	23	--------	45	35
June 18	--------	2	5	6	--------	--------	Sept. 17	42	13	4	--------	7	37
June 25	--------	--------	5	--------	--------	2	Sept. 24	26	4	3	--------	12	96
July 2	--------	22	5	9	4	80	Oct. 1	--------	1	1	--------	5	61
July 9	--------	93	9	313	7	139	Oct. 8	--------	--------	--------	--------	5	--------
July 16	--------	144	62	1,865	2,871	871	Oct. 15	--------	--------	--------	--------	8	--------
July 23	1,218	667	1,058	8,011	6,310	8,958	Oct. 22	--------	--------	--------	--------	--------	--------
July 30	8,066	561	3,856	4,474	4,077	4,530	Oct. 29	--------	--------	--------	--------	--------	1
Aug. 6	16,868	410	2,263	1,217	919	1,234							
Aug. 13	7,668	126	3,778	380	356	677	Total	40,737	2,227	14,011	16,482	15,069	17,123

TABLE 10.—*Counts of steelhead trout at Rock Island Dam, 1933 to 1938*

Week ending	1933	1934	1935	1936	1937	1938	Week ending	1933	1934	1935	1936	1937	1938
Apr. 9	--------	14	8	--------	--------	--------	Aug. 27	149	2	306	52	68	25
Apr. 16	--------	7	8	--------	--------	49	Sept. 3	189	2	336	21	60	33
Apr. 23	--------	71	29	--------	--------	222	Sept. 10	168	17	397	--------	89	56
Apr. 30	--------	62	191	--------	--------	143	Sept. 17	173	26	591	--------	109	97
May 7	--------	3	338	15	--------	243	Sept. 24	130	25	411	--------	312	200
May 14	--------	--------	146	35	9	67	Oct. 1	--------	13	699	--------	384	90
May 21	--------	6	89	135	55	55	Oct. 8	--------	30	677	--------	265	126
May 28	--------	1	132	304	211	395	Oct. 15	--------	51	215	--------	306	39
June 4	--------	4	37	618	67	100	Oct. 22	--------	31	306	--------	42	34
June 11	--------	--------	9	70	15	53	Oct. 29	--------	23	25	--------	--------	67
June 18	--------	3	12	32	18	28	Nov. 5	--------	16	5	--------	--------	--------
June 25	--------	1	2	9	9	29	Nov. 12	--------	20	--------	--------	--------	--------
July 2	--------	1	--------	11	26	8	Nov. 19	--------	8	--------	--------	--------	--------
July 9	--------	2	9	18	14	1	Nov. 26	--------	4	--------	--------	--------	--------
July 16	--------	4	1	10	10	4	Dec. 3	--------	3	--------	--------	--------	--------
July 23	--------	1	7	27	--------	12	Dec. 10	--------	11	--------	--------	--------	--------
July 30	38	2	14	70	--------	60	Dec. 17	--------	5	--------	--------	--------	--------
Aug. 6	131	3	46	77	12	62	Dec. 24	--------	2	--------	--------	--------	--------
Aug. 13	90	4	85	74	36	57							
Aug. 20	87	--------	260	59	97	45	Total	1,055	484	[1] 5,411	1,637	2,214	2,400

[1] Includes 20 counted previous to the week ending April 9.

Tables 8, 9, and 10 give the counts made at Rock Island Dam during the years 1933 to 1938, inclusive. These were all actual counts which are presumably accurate, both as to number and identification. In addition to the records given in these tables, 78 silver salmon were counted at Rock Island Dam late in September and early in October 1938.

MODIFIED TABLES

The data on the run of 1938 (tables 1 to 10) are presented below in such form as to bring out certain facts bearing upon the biological and economic importance of

different portions of the salmon runs and upon matters important to their conservation. This section deals with the methods used in forming these modified tables and the reasons for the various modifications that have been introduced. The chief purpose in the original report was to show the contribution that the Rock Island runs make to the commercial catch for different periods and also the intensity with which the run as a whole, and particularly the Rock Island component, is being exploited. In that report only the spring runs of chinook and blueback salmon and the steelhead trout were considered. In the present report all of the species of salmon found in commercial quantities in the Columbia River have been included and the data covering the fall season to the end of the year have been considered. Information not available at the time the original report was prepared has, we believe, made possible an improved analysis. Additional facts not pertinent to the original report but bearing on the more general problems of the depletion and conservation of these fishery resources have been introduced.

Primarily for the purpose of comparing commercial catch with escapement of fish to the spawning grounds, it has been necessary to convert the catch as given in pounds into numbers of fish. Entirely satisfactory conversion factors (average weights) are not available, so that the estimated numbers as given in the following tables cannot be considered as anything more than reasonable approximations. The terminal digits in the figures as given are not, therefore, to be taken as significant.

In the original report the following conversion factors were used in converting the catch, given as poundage landed, into numbers of fish: For chinook salmon 2 systems were used; (1) an average weight throughout the season of 22 pounds, and (2) an average of 15 pounds during May, 20 pounds during June, and 25 pounds during July and August. For bluebacks also 2 systems were used; (1) an average of 3 pounds throughout the season in all zones, and (2) an average of 3 pounds throughout the season below Bonneville (Zones 1 to 5) and 2½ pounds above Bonneville (Zone 6). For steelhead trout an average weight of 10 pounds throughout the season in all zones was assumed. In general these were in accord with accepted figures. In the present report we introduce no change in respect to the figures used for bluebacks and steelheads, but have considerably modified our treatment of the chinooks.

In another paper (Rich 1940a) the writer has described the seasonal changes in weight of chinook salmon in the commercial catch on the Columbia River during the season of 1939, and the estimated weekly average weights given in that paper have been used in this report to convert poundage to number of fish. The validity of applying the 1939 averages to the 1938 run is perhaps questionable, but appears to us to be by far the most acceptable procedure available.

It was shown in the paper just mentioned that a satisfactory empirical graduation of the observed weekly mean weights in 1939 is given by the use of two linear equations. Letting y=weekly mean weight, x=the week, with origin at the week of July 9, the data for the first part of the season, up to and including the week ending July 9, are fitted by the equation $y=30+1.78x$, and those for the last part of the season, including again the week of July 9, are fitted by the equation $y=30-0.55x$. Table 11, gives the estimated weights for each week of the spring season as determined from these equations. For this present report, estimated average weights for the weeks previous to the opening of the fishing season on May 1 and for the fall season have also been determined by the dubious method of extrapolation. We fully recognize the dangers of this procedure but, in the absence of any better objective basis for estimate, believe

it to be justified here. This gives the following estimated weights: For the week ending April 30, 12.20 pounds; April 23, 10.42; September 3, 25.60; September 10, 25.05; September 17, 24.50; September 24, 23.95; October 1, 23.40; October 8, 22.85; October 15, 22.30; October 22, 21.75; October 29, 21.20; and for the week ending November 5, 20.65. After this date so few fish were taken in the fishery that an approximation on the basis of about 20 pounds is adequate for all purposes.

TABLE 11.—*Estimated weights of chinook salmon in the commercial catch in Zones 1 and 2 for the spring season of 1939. Figures for the first 3 weeks were extrapolated*

Week ending	Estimated mean weight	Week ending	Estimated mean weight	Week ending	Estimated mean weight	Week ending	Estimated mean weight
May 7	(13.98)	June 4	21.10	July 2	28.22	Aug. 6	27.80
May 14	(15.76)	June 11	22.88	July 9	30.00	Aug. 13	27.25
May 21	(17.54)	June 18	24.66	July 16	29.45	Aug. 20	26.70
May 28	19.32	June 25	26.44	July 23	28.90	Aug. 27	26.15
				July 30	28.35		

In converting poundage of silver and chum salmon to numbers of fish we here adopt an average weight of 10 pounds for both species—the same as that adopted for steelhead trout. This is not in accord with the figures commonly given, viz, 7–9 pounds for silvers and 8–10 pounds for chums. Some years ago, however, the writer measured and weighed several hundred silver and chum salmon taken on the lower Columbia River, and these gave averages for both species that were considerably over 10 pounds—240 chums averaged 10.3 pounds with a standard deviation of 2.0, and 133 silver salmon averaged 10.9 pounds with a standard deviation of 2.6. This average does not include 16 silver salmon grilse which were in the same collections. The samples came from fish caught in traps and the small grilse are seldom taken by gill nets although, as stated above, this form of gear is of primary importance in the Columbia River fishery. In view of these figures, and the purpose to which the estimates are to be put, it seems reasonable to use a conversion factor of 10 pounds for both of these species.[7]

Some time is required for the journey of the fish up the river, so that on a given day the fish in the upper river may be expected to represent an entirely different stock from that to be found simultaneously in the lower river, although it is the same stock as was to be found in the lower river during an earlier period. Therefore, in order to aid interpretation of some of the more important data, these have been presented so that as nearly as possible those referring to the same stocks of fish are placed on the same lines in the table. In other words, the several series of data have been so "lagged" that comparable portions are related to the same marginal date—which date is the end of the week in which the fish may reasonably be expected to have entered the river from the ocean. From a careful examination of tables 1 to 5 it appears that a given group of fish that entered the river and were to be found in Zones 1 and 2 in a given week (the week of the marginal date in the table) would be in Zones 3 to 5 the next week, at Bonneville and in Zone 6 during the second week, and at Rock Island the fourth week after their appearance in Zones 1 and 2.

In table 12 the dates given in the left-hand margin are those ending the weeks during which the fish were in Zones 1 and 2, the estimated catches made in Zones 3 to 5

[7] Since this report went to press a paper by Wilbert Chapman, of the Washington State Department of Fisheries, dealing with the weights of fish taken in the Columbia River fisheries has appeared. His figures are somewhat different from ours but it is not possible to give a critical discussion of them here.

were made 1 week later than that indicated by the marginal date, the Bonneville count and the estimated catch above Bonneville were made 2 weeks later than that indicated by the marginal date, and the Rock Island count 4 weeks later. For convenience we shall refer below to the assumed position of the fish during their upward migration as in Zones 1 and 2 the first week, in Zones 3 to 5 the second week, at Bonneville and in Zone 6 the third week, and at Rock Island the fifth week of their freshwater migration. The same system was followed in preparing the similar tables for the other species.

Thus, reading across any one line, say the line for May 7 in table 12, the first column gives the estimated catch made in Zones 1 and 2 during the week ending May 7, the second column the estimated catch made in Zones 3 to 5 during the week ending May 14, the fourth column the count at Bonneville during the week ending May 21, the fifth column the estimated catch above Bonneville during the week ending May 21, and the seventh column the count at Rock Island during the week ending June 4. Columns 3 and 6 are derived by summing across the rows in the appropriate columns and therefore show totals for the run as a whole—all referred back to the week that the fish were presumably in the extreme lower part of the river and, therefore, approximately to the time that they entered the river.

Individual fish undoubtedly vary greatly in respect of their rate of travel upstream, but the obvious similarity in the trends of all the columns in this table is evidence that, on the average, these assumptions are well founded.

NATURE OF THE ANALYSIS OF RUNS

From the tables of this structure it is possible, for those species that largely spawn above the site of the Bonneville Dam, to estimate the number of fish of each species that escaped the intensive fishery below Celilo Falls (the upper limit of commercial fishing) in 1938 and were available for reproduction above Bonneville Dam. This is readily done for any desired portion of the season by subtracting the catch above Bonneville from the Bonneville count. Such an estimate of the escapement is subject to error from several causes, of which the following may be mentioned: (1) Error in the count of fish of the different species at Bonneville, (2) error in the catch figures due to the fact that a considerable catch that does not appear in the record is made by Indians, and to some extent by Whites for home use, and (3) error in converting pounds to number of fish. While these sources of error are present, it is believed that their total effect is relatively small and will not affect the general conclusions that may logically be drawn. Furthermore, in making these estimates no attempt has been made to correct for the spawning that takes place in the tributaries below Bonneville Dam. In the case of the silver and chum salmon such a large percentage of the spawning takes place below Bonneville that a similar analysis has not been made. Also, as mentioned above, there is a considerable part of the fall run of chinooks that spawns below Bonneville so that our study of the fall run is probably less reliable than that for the spring season. Since our estimate of the escapement is based primarily upon the count at Bonneville (from which is subtracted only the estimate of the number of fish in the recorded commercial catch above Bonneville) the spawning in the tributaries between Bonneville and the upper end of the commercial fishing district at Celilo Falls will not affect the results. If any considerable portion of the run that is actually derived from the tributaries below Bonneville be ascribed to the river above Bonneville, this will tend to magnify the importance of the spawning in the river above Bonneville, including that above Rock Island. Undoubtedly a part of the commercial catch of all species except the blueback is composed of fish derived from the tributaries below Bonneville, but it seems probable that this forms a relatively small part of the total catch of chinook salmon, at least until after the peak of the fall run. There is a very large count of chinooks at Bonneville immediately after the beginning of the closed period in August—certain evidence that a large proportion of the fish that are in the river at that time are derived from populations spawning in the higher tributaries. On the whole we feel fairly confident that only a relatively small part of the commercial catch of this important species that is made before the first of October comes from the runs into tributaries below Bonneville.

An understanding of the analysis of these runs, particularly in relation to the fish destined to spawn in the upper Columbia River above Rock Island Dam, may be aided by the following discussion (see also fig. 2).[8] While this particular treatment is related specifically to the run to Rock Island, a similar treatment could be applied to any other tributary runs for which similar data were available.

Let us assume:

A. That the estimated escapement at Celilo is the total escapement for the total run of the period; and

B. That the ratio between the escapement at Rock Island Dam and the catch made from the same stocks of fish that furnished this escapement is the same as that between the escapement at Celilo and the total catch. This assumes that there is no appreciable loss between Celilo and Rock Island, and that, for each species, the proportion of Rock Island fish caught is the same as the average for all salmon of the species that are passing through the fishery at the same time.

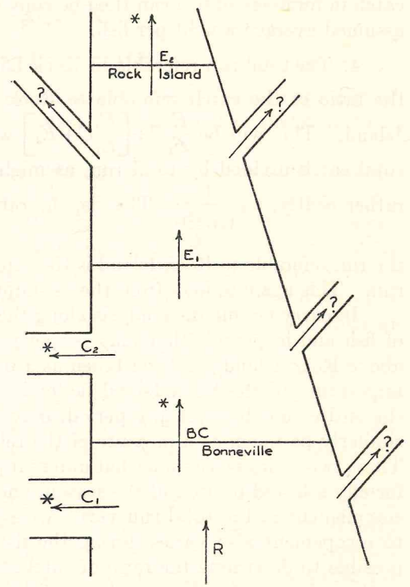

FIGURE 2.—Diagram of the ultimate subdivisions of the main run of chinook salmon entering the Columbia River, illustrating the various ratios. R denotes total run; C_1 denotes total catch below Bonneville Dam; BC denotes Bonneville count; C_2 denotes catch above Bonneville Dam; E_1 denotes escapement at upper limit of commercial fishing; E_2 denotes escapement at Rock Island Dam; ? denotes diversions of unknown amounts at various points in the river.

From this it would follow also that the relation between the escapement at Rock Island Dam and the run referable to this escapement will be the same as that between the escapement at Celilo and the total run.

Having then determined, for a selected time interval, the total catch, denoted by C, the escapement at Celilo, denoted by E_1, and the count at Rock Island, denoted by E_2, we are able to determine the following:

[8] This clarifying symbolic treatment was contributed to the original report of the Board of Consultants by Dr. Durand, who has kindly permitted slightly altered repetition here.

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1. The fraction of the total run (R) derived from that portion normally spawning above Rock Island. This will be $\frac{E_2}{E_1}$.

2. The fraction of the total catch (C) referable to the Rock Island escapement (Rock Island count). This also will be $\frac{E_2}{E_1}$.

3. The catch derived from the Rock Island contingent. This will be $\frac{E_2}{E_1}C$. This catch in numbers of fish can then be converted into pounds weight on the basis of the assumed average weight per fish.

4. The total run referable to Rock Island. This will be $\left[\frac{E_2}{E_1}C+E_2.\right]$ Likewise, the ratio of the catch referable to Rock Island to the total run referable to Rock Island. This will be $\frac{E_2}{E_1}C \div \left[\frac{E_2}{E_1}C+E_2\right]$ which reduces directly to $C \div (C+E_1)$ or to total catch divided by total run, as might be expected. This may also be written, rather neatly, as $\frac{1}{1+\frac{E_1}{C}}$. That is, the ratio of the catch referable to Rock Island to the run referable to Rock Island is the same as the ratio of the total catch to the total run. This again follows from the assumptions A and B.

In carrying out the analysis along the lines indicated above, the catch in number of fish and in pounds that may properly be ascribed to fish of the runs to the river above Rock Island has been taken as a measure of what may be termed the absolute importance of the Rock Island factor in the commercial fishery. The percentage of the entire run that, for any period, may be ascribed to these Rock Island fish, may similarly be taken as a measure of the relative importance of the Rock Island factor. These two series serve somewhat different purposes. These values may be determined for any selected portion of the season, and this is important because the Rock Island complement in the total run varies widely from time to time and the ratio of catch to escapement also varies during the fishing season. But for any one period it is possible to determine the ratio of catch to escapement—a ratio that may be applied to the entire run for the period or to fish bound for other tributaries above Bonneville Dam as well as to those destined to tributaries above Rock Island Dam. Given the ratio for any period, the catch ascribable to the upper Columbia may be determined by multiplying the Rock Island count, E_2, for the corresponding period, by this ratio, $\frac{C}{E_1}$, giving $\left(\frac{C}{E_1}\right)E_2$. Or, on the other hand, we may use the fraction of the entire run that may be attributed to the river above Rock Island, $\frac{E_2}{E_1}$, and multiply the total catch, C, by this fraction to get the number of fish derived from those spawning above Rock Island giving $\left(\frac{E_2}{E_1}\right)C$. Mathematically these two procedures are obviously identical and, where either may be applied, they will give identical results; but the latter procedure, making use of fractions of Rock Island fish in the run, may be applied when necessary to determine the part that the Rock Island fish play in producing the catch in any portion of the river, while the former can only be applied to the catch as a whole.

We will now consider, specifically, certain runs and portions of runs in respect of their importance to the general problems of the preservation of the salmon of the Columbia River, and in particular of those that have derived from the river above Grand Coulee Dam. Although the data have been studied and presented on the basis of time units of 1 week, it is convenient and even more illuminating to consider them also for longer intervals of time which have been selected for various reasons as being of special importance.

CHINOOK SALMON

HISTORY OF THE RUN OF 1938

On account of the dominating importance of this species in the fishing industry, particular attention has been paid to it. The data are presented in tables 12 to 14 and are shown graphically in fig. 3.

The earliest part of the run to the Columbia River above Bonneville does not enter into the commercial fishery—it is past the commercial fishing area before the opening of the season on May 1. The first of the run to contribute to the commercial catch is that which enters the mouth of the river during the week ending April 23. These fish, in general, may be expected to pass Bonneville and to be in Zone 6 during the first week in May—the first week of the spring open season. We have therefore considered as a separate period the weeks up to and including the week ending on April 16. The next period includes the part of the run that provides the peaks in catch and Bonneville count that occur in May. We consider that this period terminates with the week ending May 28. The next period includes the succeeding 9 weeks ending on July 30, during which the catch and the Bonneville count were both relatively low, while at corresponding weeks the Rock Island count attained the maximum for the year.

In the original report the last period treated covered only the 4 weeks ending August 27—the last 4 weeks of the spring fishing season. It was impossible to carry the study beyond this because at the time the report was prepared data were not available for the fall season. But, with the data now on hand, it is obvious that the portion of the run beginning with the week ending August 6 and extending to the end of the year should be considered as forming a single unit rather than two or more units. In table 12 it is apparent that the run from the week of August 6 to the end of the year contains the main mode which, for purposes of study, should certainly not be broken up without good reason. Furthermore, table 12 and fig. 3 show that there is a mode in the Rock Island count for this period. In the present report, therefore, we shall take for the final period to be studied the entire remainder of the year after the week ending July 30.

The data for these selected periods are given in table 13, which, for comparison, also includes the figures for the last period considered in the original report—July 31–August 27. Table 14 gives some of the more significant comparative figures that may be derived from table 13.

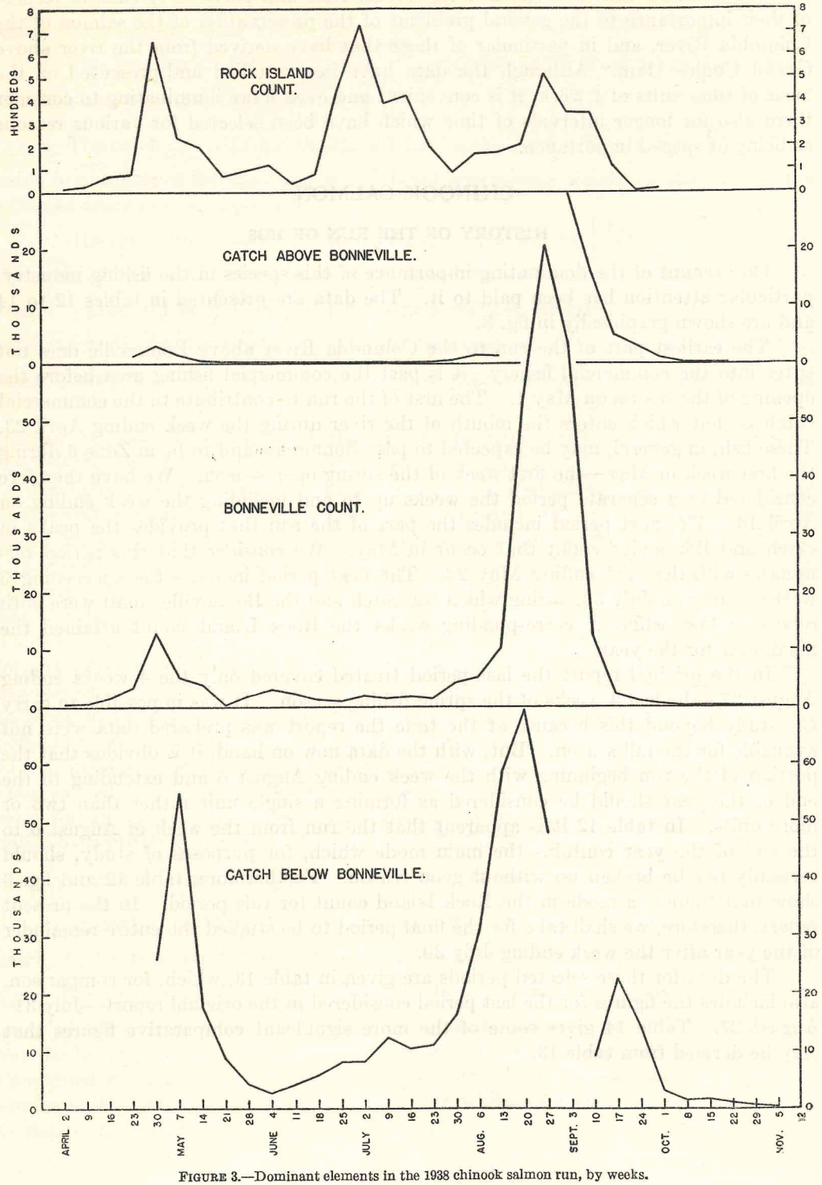

FIGURE 3.—Dominant elements in the 1938 chinook salmon run, by weeks.

TABLE 12.—*Chinook salmon run in the Columbia River, 1938*

[Catch in number of fish estimated from weekly average weights, as determined from the 1939 run. Data combined and arranged by corresponding weeks]

Week ending	Zones 1 and 2	Zones 3 to 5	Total catch below Bonneville	Bonneville estimate and count	Catch above Bonneville	Total catch	Rock Island count	Total run
Feb. 19				4				4
Feb. 26				68				68
Mar. 5				84				84
Mar. 12				0				0
Mar. 19				14				14
Mar. 26				339				339
Apr. 2				402			14	402
Apr. 9				484			28	484
Apr. 16				1,545			70	1,545
Apr. 23				3,359	1,386	1,386	78	3,359
Apr. 30		26,003	26,003	12,936	3,153	29,156	650	38,939
May 7	43,143	11,709	54,852	5,097	1,395	56,247	235	59,949
May 14	15,691	1,724	17,415	3,827	469	17,884	195	21,242
May 21	8,000	621	8,621	205	248	8,869	69	8,826
May 28	4,132	36	4,168	1,981	360	4,528	94	6,149
June 4	2,597	39	2,636	2,932	213	2,849	120	5,568
June 11	3,912	263	4,175	2,230	186	4,361	39	6,405
June 18	5,261	632	5,893	1,240	81	5,974	77	7,133
June 25	7,438	676	8,114	884	46	8,160	450	8,998
July 2	6,856	1,258	8,114	1,855	40	8,154	725	9,969
July 9	10,771	1,565	12,336	1,534	96	12,432	383	13,870
July 16	8,923	1,481	10,404	1,753	70	10,474	419	12,157
July 23	9,402	1,758	11,160	1,327	213	11,373	196	12,487
July 30	15,277	1,086	16,363	4,163	542	16,905	82	20,526
Aug. 6	28,272	2,891	31,163	5,104	1,463	32,626	162	36,267
Aug. 13	54,425	4,024	58,449	10,112	1,377	59,826	171	68,561
Aug. 20	65,145	4,312	69,457	53,753		69,457	209	123,210
Aug. 27	47,758		47,758	80,693		47,758	515	128,451
Sept. 3				63,224	30,109	30,109	344	63,224
Sept. 10		8,942	8,942	12,258	15,915	24,857	344	21,200
Sept. 17	13,520	9,069	22,589	2,057	4,806	27,395	111	24,646
Sept. 24	12,976	933	13,909	994	2,908	16,817	8	14,903
Oct. 1	2,612	436	3,048	489	991	4,039	15	3,537
Oct. 8	993	336	1,329	161	264	1,593		1,490
Oct. 15	1,366	287	1,653	234	247	1,900		1,887
Oct. 22	857	165	1,022	208	62	1,084		1,230
Oct. 29	435	110	545	47		545		592
Nov. 5	214	41	255	29		255		284
Nov. 12	68	16	84	9	1	85		93
Nov. 19	13	3	16	5		16		21
Nov. 26	11		11	21		11		32
Dec. 3	1		1	2		1		3
Dec. 10	4		4			4		4
Dec. 17	1		1	2		1		3
Total	370,074	80,416	450,490	277,665	66,641	517,131	5,803	728,155

TABLE 13.—*Catch and escapement of chinook salmon by selected and corresponding periods*

Period	Catch below Bonneville	Bonneville count	Catch above Bonneville	Total catch	Estimated escapement past Celilo	Rock Island count
To and including Apr. 16	None	2,940	None	None	2,940	112
Apr. 17–May 28	111,059	27,405	7,011	118,070	20,394	1,321
May 29–July 30	79,195	17,918	1,487	80,682	16,431	2,491
July 31–Aug. 27	206,827	149,662	2,840	209,667	146,822	1,057
July 31–Dec. 17	260,236	229,402	58,143	318,379	171,259	1,879
Total [1]	450,490	277,665	66,641	517,131	211,024	5,803

[1] Eliminating duplication in the last 2 periods.

TABLE 14.—*Significant ratios between elements of the chinook run*

Period	Total catch to escapement	Catch below Bonneville to—		Catch above Bonneville to—		Rock Island count to escapement
		Total catch	Bonneville count	Total catch	Bonneville count	
Apr. 17–May 28	5.79	0.941	4.06	0.059	0.256	0.065
May 29–July 30	4.91	.981	4.42	.018	.083	.152
July 31–Aug. 27	1.43	.986	1.38	.014	.019	.007
July 31–Dec. 17	1.86	.818	1.13	.182	.253	.011

For the season prior to April 16 there was, of course, no catch; the estimated escapement was 2,940, and the corresponding count at Rock Island was 112. The percentage of the run going to the upper Columbia River was, therefore, 3.8. (All of these statements and other similar ones to follow are approximations that are affected by errors in the data and in the various assumptions involved. We believe, however, that neither the data nor the assumptions are seriously in error so that these are valid approximations.)

During the period from April 17 to May 28, the period when the first conspicuous peak of the run occurred, the catch amounted to over 1,681,000 pounds (table 1), estimated as representing approximately 118,000 fish. The Bonneville count was 27,400, the catch above Bonneville 7,000, and the estimated escapement 20,400. The Rock Island count was 1,321. The ratio of catch to escapement (catch divided by escapement) is 5.8:1—in other words, it is estimated that 5.8 fish are caught for every one that escapes and is available for reproduction. The percentage of the entire escapement that went to Rock Island was 6.5. The catch that may be attributed to the Rock Island contingent in the run is, therefore, 6.5 percent of 118,000 fish, about 7,650. An estimate of the poundage derived from the Rock Island run during this period may also be had by taking 6.5 percent of the total weight of chinooks in the catch made in the corresponding periods on the lower river. (This includes the catch of the first 4 weeks in Zones 1 and 2, of the first 5 weeks in Zones 3 to 5, and of the first 6 weeks in Zone 6.) The estimate of the poundage derived from the Rock Island run is, therefore, 109,000 lbs. (6.5 percent of 1,681,000 pounds).

For the period from May 29 to July 30, the total catch was 2,242,000 pounds, representing an estimated 80,700 fish. The Bonneville count was only 17,900. The catch above Bonneville amounted to some 1,500 fish, leaving an estimated escapement of 16,400. The Rock Island count was 2,491. The ratio of catch to escapement is 4.9:1—approximately 5 fish are captured for every one that escapes. The Rock Island count was 15.2 percent of the estimated escapement. The catch that may be attributed to the Rock Island run, therefore, is 12,300 fish of an aggregate weight of 341,000 pounds.

It is to be noted especially that the Rock Island portion of the run during this period constitutes over 15 percent of the total and that this is the period during which the run is slack and the catch relatively poor. It is well known that this condition exists each year and it is the general opinion that the populations that characterize this period are the most seriously depleted of any. Certainly it is evident that they are without adequate protection at the present time. By far the greater part of the fish taken in the commercial fishery during these weeks is of high quality and produces the finest of the Columbia River pack. The preservation of so important a part of the run is obviously a matter of the highest importance. This part of the run will be considered in more detail below.

The run from July 31 to August 27 provides a large part of the total catch of the spring season, but the contribution made by the Rock Island runs is relatively small. The total catch for this period during 1938 was 5,640,000 pounds, representing about 207,000 fish. The Bonneville count was approximately 149,600, and the catch above Bonneville was 2,800, giving an estimated escapement of 147,000. The ratio of catch to escapement during this period was, therefore, only 1.4:1, which was undoubtedly reduced by the increased escapement during the last 2 days of the period after the fishing season closed on August 25. The Rock Island count was 1,057, which

is only 0.72 percent of the escapement. The catch that may be attributed to Rock Island is, therefore, 1,500 fish with an aggregate weight of 40,600 pounds.

The data last presented (for the period July 31 to August 27) are similar to those given in the original report and are presented here chiefly for comparison with those that follow. We have already stated that this is not a natural subdivision of the run and that, properly, the period from July 31 to the end of the year should be treated as a unit. This larger period takes in the major peak of abundance that occurs in late August and early September and includes completely the closed period, August 25 to September 10, and all catches that may be referred to the stocks of fish affected by the closed season. The total catch was recorded as 8,326,000 pounds, which we estimate included some 318,000 fish. In contrast to the other selected periods, the catch above Bonneville Dam forms a large part of the total and it is of interest to note (tables 1, 12, and 13) that the major part of this catch above Bonneville takes place after the closed period. The total catch during the fall season alone was 2,685,000 pounds (109,000 fish), of which over half, 1,395,000 pounds (55,000 fish) were taken above Bonneville. It is obvious that one important result of the closed period is to permit enough fish to escape the fishery on the lower river so that upwards of a million pounds may be taken above Bonneville Dam.

The Bonneville count during the period July 31 to the end of the year was 229,000 fish. The net escapement (Bonneville count less the catch above Bonneville) was, therefore, approximately 175,000 fish. The ratio of catch to escapement is 1.9:1, which, while still high, is much less than that during the earlier periods. It is to be noted, however, that this ratio is considerably higher than that for the month of August, when the ratio is 1.4:1. This was one of the results of treating the period from July 31 to August 27 as a unit. The facts that this period is not a natural subdivision of the run and that the count at Bonneville for the period is undoubtedly influenced by the incidence of the closed season on August 25 have resulted in this and other differences between the data for the month of August and those for the entire period of the fall run.

The Rock Island count for the period corresponding to that from July 31 to the end of the year was 1,879, or 1.1 percent of the estimated net escapement. Taking this as the percentage of Rock Island fish in the run as a whole, the catch that may be attributed to the Rock Island runs is estimated at 3,500 fish, or 91,500 pounds. This is to be compared with an estimate of 1,500 fish of an aggregate weight of 40,600 pounds for the month of August.

Table 15 presents the more significant figures bearing on the absolute and relative importance of the Rock Island runs of chinook salmon. There are given not only the figures obtained through the basis of estimate adopted in this report, but also, for comparison, those obtained through the two bases used in the original report by Calkins, Durand, and Rich. (The estimates given here for the full season on the bases used in the original report were not, of course, given in that report, which treated the catch only up to August 25.) It is apparent that, in general, the results of all three procedures are of the same order of magnitude so that one may assume with some confidence that no gross errors have been introduced. Although we believe that the estimates based on the average weights obtained in 1939 are the most accurate, and should certainly be used for detailed study of parts of the run, it is clear that simpler methods will give approximate results of real value.

TABLE 15.—*Chinook salmon—comparison of certain estimates as made on the following bases: (1) An average weight of 22 pounds throughout the season; (2) average weights of 15 pounds in May, 20 pounds in June, and 25 pounds for the remainder of the year; and (3) average weights for each week as calculated from the trend lines described in the text. The first two were used in the original report by Calkins, Durand, and Rich*

Basis of estimate	Ratio of catch to escapement	Percentage of Rock Island fish in total run	Catch attributed to Rock Island run—in fish	Catch attributed to Rock Island run—in pounds
April 17 to May 28				
(1)	3.3	5.67	4,300	95,300
(2)	5.2	6.19	6,900	104,000
(3)	5.8	6.50	7,650	109,000
May 29 to July 30				
(1)	6.3	15.46	15,800	346,900
(2)	5.8	15.38	15,700	379,000
(3)	4.9	15.20	12,300	341,000
July 31 to August 27				
(1)	1.8	0.72	1,860	40,900
(2)	1.5	.72	1,600	41,000
(3)	1.4	.72	1,500	40,600
July 31 to December 17				
(1)	2.3	1.16	4,400	96,600
(2)	2.0	1.11	3,700	92,500
(3)	1.9	1.10	3,500	91,500

On the basis of these figures the total catch that may reasonably be attributed to the Rock Island runs is between 500,000 and approximately 600,000 pounds, of which by far the larger proportion was of the valuable spring run. Furthermore, it is of especial importance to note that the Rock Island run forms a particularly large percentage of the seriously depleted and heavily fished June–July run.

RATE OF TRAVEL

These data provide additional information relative to the rate of migration up the river. We have given the reasons for thinking that the interval between the time that the fish appear in Zones 1 and 2 and at Bonneville is approximately 2 weeks. The peak of the run that occurs in late August and early September is obviously an important landmark and should, therefore, provide important evidence on this point—evidence that was not available at the time the original report was prepared.

From the figures of the numbers of fish caught (estimated on the basis of the trend lines of average weights obtained in 1939) it would seem that the peak of the catch in Zones 1 and 2 came 3 weeks before the peak of the count at Bonneville, instead of 2 weeks (fig. 3). The drop in the catch that occurs between the weeks ending August 20 and 27, however, is due, at least in large part, to the fact that there were only 4 days of fishing in the week ending August 27. The spring fishing season closed on August 25. An estimate may be made of what the catch would have been if the full 6 days of fishing had prevailed, instead of 4 days, by multiplying the estimate already presented by 1½. The result is over 71,000 fish; actually a few more than estimated for the week ending August 20. This result indicates strongly that the real peak of abundance in Zones 1 and 2 came not earlier than the week ending August 27—2 weeks earlier than the actual peak in the Bonneville count and quite in agreement

with the original assumption. Whether, without the closed period, the peak in the Bonneville count would have come in the week ending September 10 is perhaps somewhat doubtful, and no method has occurred to us whereby that can be independently determined. From the total run (table 12) this would seem to be a reasonable inference, but it has been based on the assumption that 2 weeks are required for the journey from the mouth of the river to Bonneville.

In passing, it should be emphasized for future use in similar situations that the effect of the closed period has been to so increase the Bonneville count immediately following the beginning of the closed period that it has the effect of shifting the peak of the count upward. This would be true even if the final week of the open period had consisted of 6 days instead of 4 days of fishing. In general, the incidence of a closed period will increase the escapement in the following weeks, but in this case the peak of the run happens to coincide so closely with the beginning of the closed period (probably actually preceding it on the lower river) that the effect is to shift the peak of the escapement upward. Also, in this particular case, the fact that the last week of the open season contained only 4 fishing days had the effect of apparently shifting the peak of the catch downward. The combined result was an apparent lag of 3 instead of 2 weeks between the peak of the catch in Zones 1 and 2 and the peak of the count at Bonneville. Similarly, at the beginning of an open period there will be the reverse tendency for the peak of the escapement to be shifted downward and the peak of the catch to be shifted upward. Doubtless the peak of the Bonneville count that occurs during the week corresponding to that of April 30 has been so modified. Actually this count was made during the week ending May 14, and the fish passing Bonneville during that week were doubtless partly through Zones 1 and 2 before the fishing season opened on May 1. These rather confusing effects are, of course, due to the complementary relationship existing between the catch and the count at Bonneville.

Related to these phenomena is the fact that there appears to have been some delay in the passage of fish through Zone 6 following the peak of the run and the closed season. This is shown particularly by the fact that during the weeks ending September 10 to October 15 (almost the entire effective fall season) the catch above Bonneville exceeded the Bonneville count. However, we believe that this does not indicate a general lower average rate of travel, but is due, rather, to the combined influence of individual variation in the rate of travel and a constant reduction in the number of fish passing Bonneville. The anomaly, then, of the existence over a number of weeks of a greater catch above Bonneville than count over the dam is closely related to the fact that the peak of the escapement curve is shifted to an earlier date by the incidence of an open season.

THE JUNE–JULY RUN

As previously mentioned, the June–July run of chinooks is poor compared with that in May or August, and it is rather generally thought that the populations forming this part of the run are the most seriously depleted of any. Some evidence of this was developed at the time the original study was made, but was not included in the original report. It has seemed worth while to pursue the investigation further.

As bearing on the extent to which the June–July run has been depleted, we have examined data secured through the cooperation of the Columbia River Packers Association. These data are in the form of reports of daily deliveries to this company

over the period from 1912 to 1937, with the exception of occasional years for which no figures were available. It is unfortunate that similar data are not available for the entire river.

During this long period the catch delivered to the association has averaged nearly 25 percent of the total deliveries on the Columbia River, and has ranged quite consistently between 20 and 30 percent. To test the reliability of these data as an index of changes in relative abundance during different periods, the Pearsonian coefficient of correlation, "*r*," has been calculated between the total annual deliveries to the company and the total deliveries for the entire fishery as given in the report by the Oregon State Planning Board (1938). Between 1912 and 1937 there were 20 years for which complete records were available, and for these the coefficient of correlation is 0.86. The records appear to show, however, that some change took place about 1934, so that the records for the last 3 or 4 years are not consistent with those for earlier years. We have, therefore, calculated "*r*" for the 16 years of record between 1912 and 1928. The value is practically 0.9. Both show such a high degree of correlation that reasonable confidence may be placed in the assumption that the deliveries to the Columbia River Packers Association will serve to indicate long-time (secular) changes in relative abundance of chinook salmon in different parts of the season.

TABLE 16.—*Monthly totals of deliveries of chinook salmon to the Columbia River Packers Association, 1912–37, in thousands of pounds, for the spring fishing season only*

Year	May	June	July	August	Total	Year	May	June	July	August	Total
1912	420	749	1,629	1,628	4,426	1924	609	992	1,270	1,296	4,167
1913	759	683	1,381	918	3,741	1925	703	996	1,100	1,747	4,546
1914	859	1,203	1,935	1,378	5,375	1926	169	732	934	1,680	3,516
1915	1,163	2,194	2,693	1,685	7,736	1927	638	704	794	1,695	3,830
1916	684	496	1,811	3,232	6,223	1928	440	503	702	1,590	3,235
1917	717	578	1,275	2,982	5,552	1931	296	502	680	2,781	4,260
1918	378	643	1,246	3,489	5,756	1932	428	688	714	2,457	4,286
1919	882	665	1,436	2,700	5,683	1933	93	843	456	2,044	3,435
1920	854	1,194	1,271	3,194	6,514	1934	329	616	886	2,783	4,614
1921	468	594	1,143	2,394	4,599	1936	608	701	605	1,970	3,884
1922	727	440	808	2,128	4,103	1937	584	445	676	2,559	4,265
1923	624	973	1,254	1,150	4,000						

NOTE.—The years 1929, 1930, and 1935 are omitted because of incomplete records.

From data given in table 16 we have calculated the trends by the method of averages, and these are shown in figure 4, which has been put on a semilogarithmic grid so that relative changes will be correctly shown and the several trends can be directly compared. It is apparent from this that while a general reduction has taken place, as is shown in each month and also in the total, the reduction in the July catch has been by far the greatest. From a value of nearly 2,000,000 pounds at the beginning of this period (1912), the line of trend of the July deliveries has dropped to only about 600,000 pounds in 1937. The present deliveries are, therefore, approximately one-third of what they were during July 25 years ago. At the same time the totals for the entire spring fishing season have dropped from about 6,000,000 pounds to about 3,500,000 pounds. This graph also shows that the deliveries during May have been seriously reduced. Curiously enough, the trend of the June deliveries is approximately the same as for the spring season as a whole, although those of May and July show evidence of much more serious depletion. Deliveries in August have not suffered nearly so much as those of the other months of the spring season—perhaps because of increased utilization of these later running fish which are not of so good a quality as those of May, June, and July.

Before adopting the policy of treating all of the data on the basis of time units of 1 week, the daily records were examined and it soon appeared that there was, especially in June and July 1938, a very definite weekly cycle of abundance as indicated by the catch in Zones 1 and 2. The Sunday closed season, of course, resulted in

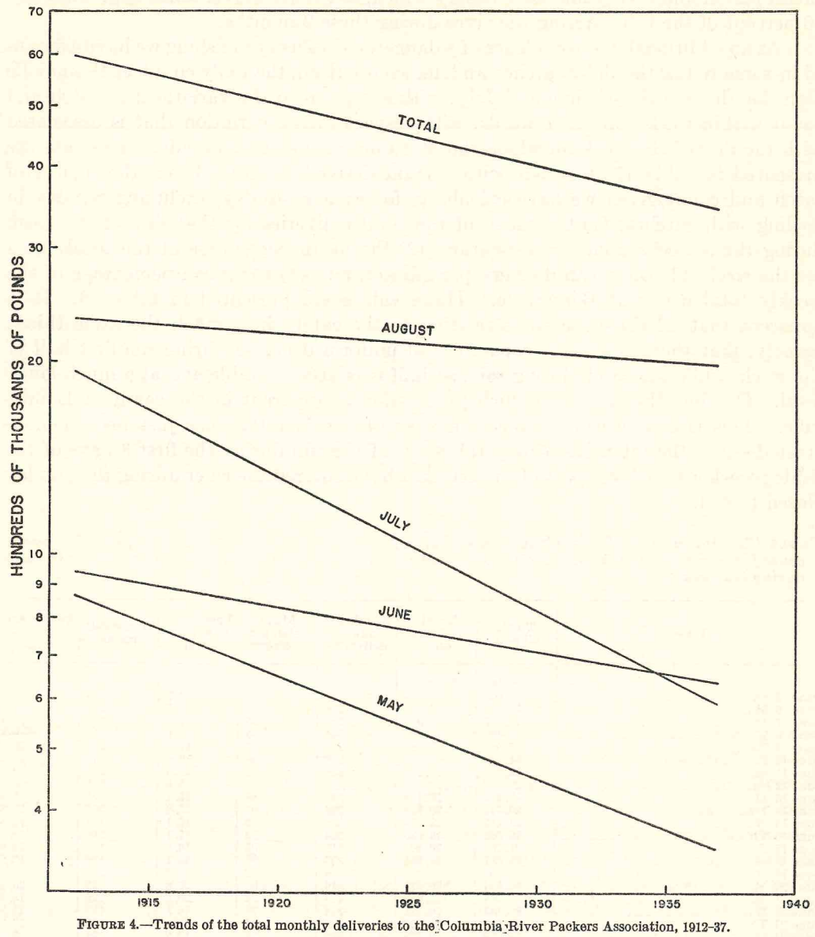

FIGURE 4.—Trends of the total monthly deliveries to the Columbia River Packers Association, 1912-37.

practically no catch on that day, but there was a distinct tendency for the catches to be highest early in the week and to drop gradually toward the end of the week. The natural interpretation was that during the Sunday closed period a body of fish entered the river and on Monday (actually beginning Sunday evening) there were available to the fishermen, in addition to those left at closing time on Saturday, all of the fish that had entered the river and that were free of all commercial fishing during an

entire day; 6 pm. Saturday to 6 pm. Sunday. The effect of this accumulation was to increase the catch during the following day or two, but it wore off until, by the end of the week, little if any effect of the closed period remained. The character of the cycle obviously has been determined by the combined influence of a Sunday closed period and a very intensive fishery which, as shown above, takes approximately 80 percent of the fish entering the river during these 2 months.

As an additional line of evidence of a dangerous intensity of fishing we have examined in some detail the daily catches and, for comparison, the daily count at Bonneville Dam for the months of June and July, with attention to the variations in catch and count within weeks; in other words, with respect to the variation that is associated with the day of the week on which the catch or the count was made. The data are presented in table 17, together with certain derived figures. From the figures of catch and count given we have calculated for each week day, excluding Sunday in dealing with catches, (1) the mean of the total deliveries for that day of the week during the 8 weeks under investigation, (2) the mean percentage of the total catch for the week, (3) the mean delivery per gill net, and (4) the mean percentage of the weekly total count at Bonneville. These values are presented in table 18. It is apparent that all three measures relating to the catch show much the same thing; namely, that there is a fairly constant and uniform decrease during the first half of the week, while the catch during the last half is relatively stable and at a much lower level. On the other hand, no such progression is apparent in the count at Bonneville. This is as one would expect in view of the fact that has just been demonstrated—that the intensive fishery takes out of the run during the first 3 days of the fishing week a very large part of the fish that have entered the river during the Sunday closed period.

TABLE 17.—*Daily catch of chinook salmon in Zones 1 and 2, June 5 to July 30, 1938, and Bonneville count for corresponding runs, June 19 to August 13, with derived figures showing fluctuations in catch during the week*

Date	Total, all gear	Total, gill nets only	Number of gill-net deliveries	Mean catch per delivery	Percentage of weekly total	Bonneville count	Percentage of weekly total
	Pounds	*Pounds*					
June 5 Su	605	605	7	86	0.7	260	11.7
June 6 M	17,612	17,612	288	61	19.5	283	12.7
June 7 Tu	16,047	16,047	291	55	17.8	318	14.3
June 8 W	13,499	13,499	244	55	15.0	422	18.9
June 9 Th	15,867	15,867	240	66	17.6	283	12.7
June 10 F	14,353	14,353	246	58	16.0	446	20.0
June 11 Sa	12,139	12,139	235	51	13.5	218	9.8
June 12 Su					0.0	191	15.4
June 13 M	19,462	19,462	335	58	15.1	191	15.4
June 14 Tu	20,542	20,519	336	61	15.8	167	13.5
June 15 W	23,412	23,134	353	65	18.1	159	12.8
June 16 Th	19,502	19,025	324	59	15.1	243	19.6
June 17 F	21,767	20,804	318	65	16.8	159	12.8
June 18 Sa	24,681	21,915	337	65	19.1	130	10.5
June 19 Su	368	368	4	92	0.2	231	24.1
June 20 M	40,894	35,627	416	86	20.8	243	25.4
June 21 Tu	39,249	35,039	429	82	20.0	128	13.4
June 22 W	32,141	26,481	374	71	16.3	113	11.8
June 23 Th	27,200	21,596	332	65	13.8	133	13.9
June 24 F	23,979	19,578	308	64	12.2	36	3.8
June 25 Sa	32,808	23,850	366	65	16.7	1 0	7.7
June 26 Su	389				0.2	149	4.2
June 27 M	42,683	37,596	421	89	22.2	79	4.4
June 28 Tu	38,411	34,501	419	82	20.0	1 0	17.3
June 29 W	33,043	31,638	391	81	17.2	618	17.3
June 30 Th	27,712	25,871	354	73	14.4	471	26.4
July 1 F	23,605	21,452	328	66	12.3	261	14.6

[1] The ladders were closed this day because of manipulation of the water levels. In calculating the percentage of the weekly total, the count of the following day was divided equally between the two days.

TABLE 17.—*Daily catch of chinook salmon in Zones 1 and 2, June 5 to July 30, 1938, and Bonneville count for corresponding runs, June 19 to August 13, with derived figures showing fluctuations in catch during the week*—Continued

Date	Total, all gear	Total, gill nets only	Number of gill-net deliveries	Mean catch per delivery	Percentage of weekly total	Bonneville count	Percentage of weekly total
	Pounds	*Pounds*					
July 2 Sa	26,612	23,951	370	65	13.8	277	15.6
July 3 Su	1,413	374	11	34	0.4	254	16.5
July 4 M	49,636	40,318	396	102	15.5	231	15.1
July 5 Tu	54,333	44,373	435	102	16.9	206	13.4
July 6 W	51,809	38,866	419	93	16.2	239	15.6
July 7 Th	59,254	42,447	461	92	18.5	231	15.1
July 8 F	54,530	36,775	474	78	17.0	201	13.1
July 9 Sa	49,862	34,826	496	70	15.5	172	11.2
July 10 Su	3,697	30	1	30	1.4	213	12.2
July 11 M	72,215	57,578	516	111	27.3	270	15.4
July 12 Tu	52,111	39,005	492	79	19.3	288	16.4
July 13 W	47,137	36,259	476	76	17.8	209	11.9
July 14 Th	36,822	27,852	440	63	13.9	212	12.1
July 15 F	29,553	22,352	394	57	11.2	297	16.9
July 16 Sa	22,313	15,561	328	48	8.5	264	15.1
July 17 Su	2,591	460	5	92	1.0	241	18.2
July 18 M	49,528	39,839	460	87	18.4	285	21.5
July 19 Tu	46,097	33,295	440	76	17.2	189	14.2
July 20 W	40,653	27,363	410	67	15.2	201	15.2
July 21 Th	32,998	22,681	364	62	12.3	163	12.3
July 22 F	40,156	29,917	367	82	15.0	160	12.1
July 23 Sa	56,263	36,345	378	96	21.0	88	6.6
July 24 Su	6,021	285	4	71	1.4	264	6.3
July 25 M	87,161	56,639	485	117	20.0	259	6.2
July 26 Tu	79,155	59,637	470	127	18.1	476	11.4
July 27 W	81,890	64,596	545	119	18.8	445	10.7
July 28 Th	60,369	51,119	494	103	13.8	1,102	26.4
July 29 F	63,156	53,332	485	110	14.5	870	20.4
July 30 Sa	57,918	52,139	530	98	13.3	747	18.0

TABLE 18.—*Variation in certain features of the chinook salmon catch in Zones 1 and 2 and of the Bonneville count during June and July, related to the days of the week*

Day of the week	Thousands mean total catch	Mean percentage of weekly total	Mean delivery per gill net	Mean percentage of weekly total of Bonneville count
Sunday				13.6
Monday	47.4	19.8	88.9	14.5
Tuesday	43.2	18.1	83.0	14.2
Wednesday	40.5	16.8	78.4	14.3
Thursday	35.0	14.9	72.9	17.4
Friday	34.9	14.4	72.5	14.2
Saturday	35.2	15.2	69.8	11.8

The intensity with which the June–July run is being exploited is shown in still another way by comparing the change in the weekly totals of the catch with the weekly totals of the Bonneville count for the corresponding weeks. These data are given in table 12, where the two series may be readily compared. It is seen that the catch below Bonneville during June and July constantly increased from 2,636 fish in the week of June 4, to 16,363 fish in the week ending July 30. At the same time the number of fish passing the Bonneville Dam remained, except for the last week, below the count for the first week of the period. It is obvious that the effect of an increased run entering the river is not felt at Bonneville—a result, without doubt, of a concurrent increase in the intensity of fishing. It is to be noted that the record of the catch above Bonneville Dam agrees with that of the Bonneville count, and thus supports this interpretation. As a measure of this intensity we may take the total number of

landings per week derived from the figures given in table 17, and shown in the following statement:

Total number of deliveries per week in Zones 1 and 2 during June and July

Week ending	*Deliveries*
June 11	1, 551
June 18	2, 008
June 25	2, 229
July 2	2, 283
July 9	2, 692
July 16	2, 647
July 23	2, 424
July 30	3, 013

It is shown by the preceding statement that the number of deliveries practically doubles during the months of June and July—an increase in fishing effort that could readily account for the fact that the count at Bonneville Dam does not increase, although there is better than a fourfold increase in the number of fish taken in the fishery in Zones 1 and 2.

In this connection it has been of interest to determine something of the relationship that exists between the abundance of fish as measured by the average poundage per delivery and the number of deliveries. The number of deliveries may be taken as a fair measure of the number of men fishing. We have, therefore, taken these two series of values from table 17 and calculated the coefficient of correlation. This proved to be +0.75. The interpretation is quite clear that the abundance of fish, as shown by the size of the individual catches, is an important factor in determining the number of fishermen that will fish.

INTENSITY OF FISHING IN GENERAL

The runs of chinook salmon considerably outweigh in importance and value the runs of all other species in the Columbia River fishery combined. Of the entire run the part that enters the river during spring and early summer, April to July inclusive, is the most valuable on account of the fine quality of the fish. This part of the run, perhaps more than any other, has been adversely affected by the reduction of spawning areas and localities suitable for the rearing of the young fish that has attended the utilization of the water resources in the headwaters, especially for power and irrigation. Since the salmon industry began on the Columbia River the chinook has been the mainstay of the fishery and the most relentless exploitation has fallen upon the spring run.

It has been shown above that the present intensity of fishing is such that, in 1938, over 80 percent of the spring run and between 60 and 70 percent of the main fall run of chinook salmon were taken in the commercial fishery. In this connection it is pertinent to recall that in the regulation of the Alaska salmon fisheries the Federal Government, acting through the Fish and Wildlife Service, has adopted the principle that the escapement should be not less than 50 percent of the entire run. There are sound theoretical grounds for thinking that the maximum sustained yield of the salmon fisheries can be maintained with an escapement of this order of magnitude, and the practical results obtained with the Alaska fisheries support this view. It seems

reasonably certain that, at least for the spring run of chinooks on the Columbia, the escapement is well below the level that would provide the maximum sustained yield.

Such regulations and restrictions as have been imposed upon the Columbia River salmon fisheries apparently have very little effect insofar as they may act to reduce the intensity of fishing and provide a greater escapement of breeding fish to the spawning grounds. It is to be noted that in the lower river the peaks of both spring and fall runs come within the spring open season so that, insofar as the fishery in the lower river is concerned, the main portions of both runs are exposed to the full force of the exploitation. There is the weekly closed period from 6 pm. Saturday to 6 pm. Sunday that is in force during the spring fishing season, May 1 to August 25, but it has already been shown that this has little value from the standpoint of conservation; its chief effect being to spread the fishery out over a longer stretch of the river. Again it has been shown that whatever effect the closed season, August 25 to September 10, may have in increasing the escapement through the lower river, it is largely offset by the intensive fishery that exists during September and October above Bonneville Dam. In a larger way this closed season acts much the same as does the weekly closed period, and chiefly tends to distribute the fishery over a wider area without materially increasing the breeding population. The effect of the closed season may be seen by examining table 19, which is a diagram representing the passage of a series of stocks of

TABLE 19.—*Effect of a two-week closed period on the stocks of fish passing up the river at the assumed rate*

[Letters represent stocks of fish]

Week	Position of stock		
	Zones 1 and 2	Zones 3 to 5	Bonneville and Zone 6
1	A		
2	B	A	
3	C	B	A
4	D	C	B
5	**E**	**D**	**C**
6	**F**	**E**	**D**
7	G	F	E
8	H	G	F
9		H	G
10			H

NOTE.—Bold-face letters represent closed period.

fish through the fishing district at the rate we have assumed to hold. It is obvious from this diagram that there is no stock of fish that is wholly protected from exploitation by the closed season. For example, stock C is only protected by the closed season from exploitation in Zone 6; stock D is protected in Zones 3 to 6; stock E in Zones 1 to 5; and stock F in Zones 1 and 2 only. But, on the other hand, stock C is open to the very intensive exploitation below Bonneville just before the closed season, and stock D to the fishery in Zones 1 and 2 where a very large part of the total catch is made during the week just before the closed season. Stock E, however, is completely protected from the fishery below Bonneville but is exposed immediately after the closed season to the much intensified fishery above Bonneville. Stock F is protected

from the fishery in Zones 1 and 2 only, and also feels the full force of the intensified fishery above Bonneville, while stock G, entering the river at the end of the closed season, is given no protection at all. The closed season undoubtedly does help to increase the escapement to some degree, but it seems very probable that the heavy, concentrated run that enters the river during August and September is actually less intensively fished than is the spring run. This lowered fishing intensity is perhaps due in part to reduced effort by the fishermen, brought about by the lower price received for the fish, and also to the fact that with constant effort the percentage of fish caught when the run is light is probably greater than when the run is heavy. The actual catch per unit of effort is, of course, greater with the heavier run, but the efficiency of the total effort, as measured by the ratio of catch to escapement, is probably inversely related to the intensity of the run.

Within the last few years the use of fish wheels has been entirely eliminated, and the use of traps greatly curtailed. Ostensibly these restrictions were imposed in the interest of conservation, but they could only be effective insofar as they increased the escapement of fish to the spawning grounds, and correspondingly decreased the commercial catch. It seems rather doubtful that these restrictions have actually had this result, although the available data are inadequate either to prove or disprove the point. It may well be, however, that the elimination of these two forms of gear has only resulted in increasing the catch of other forms, without materially increasing the breeding stock.

On the whole it would appear that the chinook salmon runs of the Columbia River are subjected to an exceedingly intensive fishery without any effective protection whatsoever, except such as has been afforded by the elimination of certain forms of gear and by artificial propagation.

PERCENTAGE OF GRILSE

Along with the larger fish that form the bulk of the chinook salmon run there are always some smaller fish, from 2 to 10 pounds in weight, that are commonly designated as "grilse," or, among the Columbia River fishermen, "jack salmon," or simply "jacks." These are practically all males that have become sexually mature 1 or 2 years younger than the average and have, perforce, joined the spawning migration. It has been shown by Gilbert, Rich, and others that most grilse are in their second and third years, while the larger fish are in their fourth, fifth, or sixth years. In counting the fish past Bonneville Dam an effort has been made to record these grilse separately, as shown in table 7, and a study of these records has shown some interesting and significant fluctuations in the percentages of these smaller fish (fig. 5).

It is apparent from this graph that, except for 2 periods during which the percentage of grilse is consistently low, the average is about 20 percent. The fluctuations that involve only individual weeks may be taken as due to "sampling error," but those that extend over several weeks and show consistent change challenge some other explanation.

The 2 periods that show consistently low percentages are those covering the weeks ending June 25 to July 16, and those ending September 10 to September 24. We have already explained the lower percentages of the first period as probably due to confusion of chinook grilse with blueback salmon during the peak of the run of this last species. The second period is that during which the Bonneville count is

greatly increased on account of the closed season from August 25 to September 10. The explanation is obvious. A very large part of the total catch of chinooks in the river below Bonneville is made by means of gill nets, and this type of gear is selective—taking more of the larger fish and permitting most of the smaller ones to pass through. During the closed period this selection is not operating, and both large

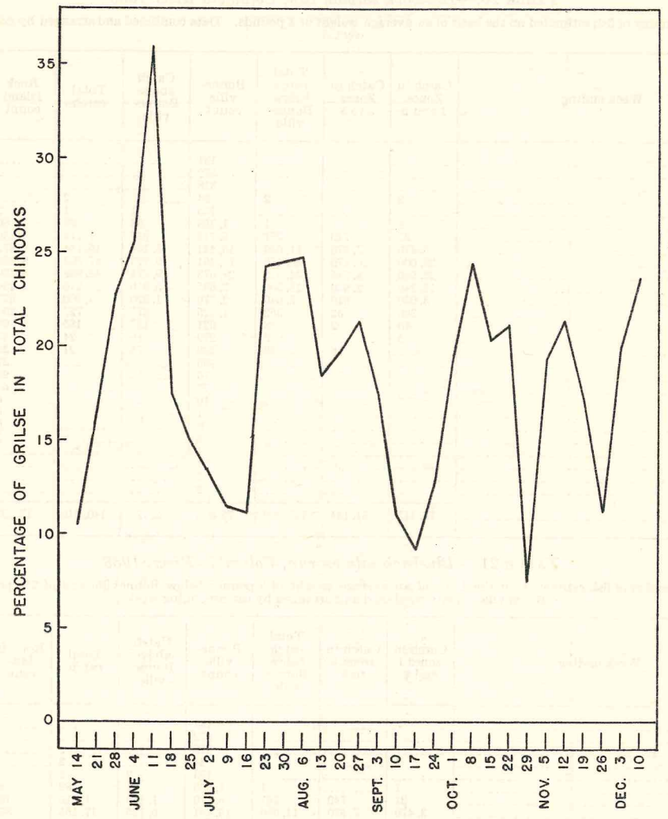

FIGURE 5.—Percentage of grilse in the Bonneville count for 1938, by weeks.

and small fish pass through the lower river and arrive at Bonneville with their proportions practically unmodified.

The grilse passing Bonneville during the 2 weeks ending September 10 and 17 (the weeks in which the run has been least affected by the intensive fishery in the lower river) form approximately 10 percent of the total count, so that it seems probable that this figure is not far from the correct one for the fall run as a whole. This is approximately half of the percentage of grilse found both earlier and later in the season—a fact which supports a previous conclusion based on quite different

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data, that well over half of the fish that enter the river after the first of August are captured before they can reach Bonneville. If a greater percentage of the larger fish are caught it naturally follows that the percentage of grilse at Bonneville would be approximately doubled.

BLUEBACK SALMON

TABLE 20.—*Blueback salmon run, Columbia River 1938*

[Catch in number of fish estimated on the basis of an average weight of 3 pounds. Data combined and arranged by corresponding weeks]

Week ending	Catch in Zones 1 and 2	Catch in Zones 3 to 5	Total catch below Bonneville	Bonneville count	Catch above Bonneville	Total catch	Rock Island count	Total run
Apr. 30				131				131
May 7				572				572
May 14				318				318
May 21	2		2	24	2	2		26
May 28				153	1	1	2	153
June 4	1		1	1,358	68	69	80	1,359
June 11	21	740	761	5,719	957	1,718	139	6,480
June 18	3,470	7,570	11,040	15,441	5,104	16,144	871	26,481
June 25	28,000	10,470	38,470	16,491	9,123	47,593	8,958	54,961
July 2	25,900	8,715	34,615	21,673	9,774	44,389	4,530	56,288
July 9	15,340	2,960	18,300	7,835	5,916	24,216	1,234	26,135
July 16	3,030	610	3,640	2,770	1,320	4,960	677	6,410
July 23	300	52	352	1,125	375	727	266	1,477
July 30	46	2	48	621	137	185	93	669
Aug. 6	5		5	279	19	24	43	284
Aug. 13		16	16	209	5	21	35	225
Aug. 20				156			37	156
Aug. 27				76			96	76
Sept. 3				71			61	71
Sept. 10				10			0	10
Sept. 17				1			0	1
Sept. 24				0			0	0
Oct. 1				3			1	3
Oct. 8				1				1
Oct. 15				1				1
Oct. 22				0				0
Oct. 29				2				2
Total	76,115	31,135	107,250	75,040	32,799	140,049	17,123	182,290

TABLE 21.—*Blueback salmon run, Columbia River, 1938*

[Catch in number of fish estimated on the basis of an average weight of 3 pounds below Bonneville and of 2½ pounds above Bonneville. Data combined and arranged by corresponding weeks]

Week ending	Catch in zones 1 and 2	Catch in zones 3 to 5	Total catch below Bonneville	Bonneville count	Catch above Bonneville	Total catch	Rock Island count	Total run
Apr. 30				131				131
May 7				572				572
May 14				318				318
May 21	2		2	24	2	2		26
May 28				153	2	2	2	153
June 4	1		1	1,358	81	82	80	1,359
June 11	21	740	761	5,719	1,149	1,910	139	6,480
June 18	3,470	7,570	11,040	15,441	6,125	17,165	871	26,481
June 25	28,000	10,470	38,470	16,491	10,950	49,420	8,958	54,961
July 2	25,900	8,715	34,615	21,673	11,730	46,345	4,530	56,288
July 9	15,340	2,960	18,300	7,835	7,100	25,400	1,234	26,135
July 16	3,030	610	3,640	2,770	1,580	5,220	677	6,410
July 23	300	52	352	1,125	450	802	266	1,477
July 30	46	2	48	621	164	212	93	669
Aug. 6	5		5	279	23	28	43	284
Aug. 13		16	16	209	6	22	35	225
Aug. 20				156			37	156
Aug. 27				76			96	76
Sept. 3				71			61	71
Sept. 10				10			0	10
Sept. 17				1			0	1
Sept. 24				0			0	0
Oct. 1				3			1	3
Oct. 8				1				1
Oct. 15				1				1
Oct. 22				0				0
Oct. 29				2				2
Total	76,115	31,135	107,250	75,040	39,360	146,610	17,123	182,290

Data on the blueback run are presented in modified form in tables 20 and 21. As previously stated (p. 114), two methods have been applied in changing the poundage records to numbers of fish; (1) assuming an average weight of 3 pounds throughout the season in all zones, and (2) assuming an average of 3 pounds throughout the

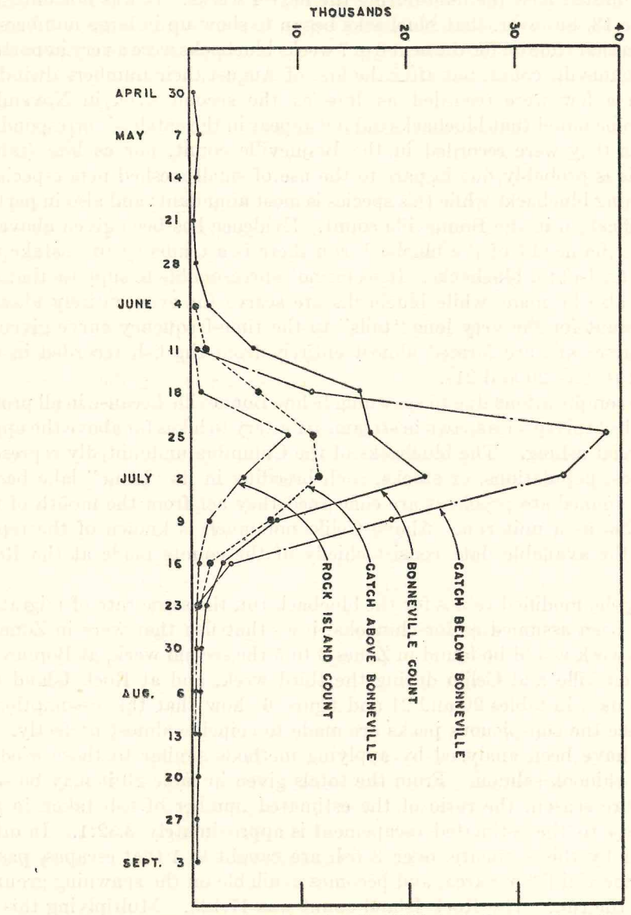

FIGURE 6.—Dominant elements in the 1938 blueback salmon run, by weeks.

season below Bonneville and of 2½ pounds throughout the season above Bonneville. The first method gives the figures of table 20 and the second those of table 21. It is known that the fish caught above Bonneville are smaller than those caught below on account of the selective effect of the gill nets which provide a large portion of the catch below Bonneville, while the catch above Bonneville is made largely by means of dip nets which are not selective. These conversion figures are based on data secured from Harlan B. Holmes, of the Fish and Wildlife Service.

The general features of the run are much simpler than in the case of the chinook salmon just considered. There is a single, well defined peak formed by fish that enter the lower part of the river late in June and early in July. The first fish of this species to appear in the records were in the Bonneville count for the second week in May, and a few were counted past the dam during the next 4 weeks. It was not until the week ending June 18, however, that bluebacks began to show up in large numbers at Bonneville. From that time on for the next 6 or 7 weeks bluebacks were a very important element in the Bonneville count, but after the first of August their numbers dwindled rapidly although a few were recorded as late as the second week in November (table 7). It is to be noted that bluebacks did not appear in the catch of corresponding weeks as early as they were recorded in the Bonneville count, nor as late (tables 20 and 21). This is probably due in part to the use of small-meshed nets especially adapted for catching bluebacks while this species is most abundant; and also in part to inaccurate identification in the Bonneville count. Evidence has been given above to show that during the height of the blueback run there is a tendency to mistake the smaller chinooks (grilse) for bluebacks. It seems not unreasonable to suppose that the same error may also be made while bluebacks are scarce (or even entirely absent) which would account for the very long "tails" to the time-frequency curve given in figure 6, since these tails are formed almost entirely from the fish recorded in the Bonneville count (tables 20 and 21).

There are no complications due to spawning below Bonneville because in all probability all of the fish of this species spawn in streams tributary to lakes far above the upper limits of commercial fishing. The bluebacks of the Columbia undoubtedly represent a number of races, populations, or stocks, each breeding in its "home" lake basin; but so far as the immediate problems are concerned they act from the mouth of the Columbia to Celilo as a unit run. Above Celilo not much is known of the representative races; the available data consist chiefly of the counts made at the Rock Island Dam.

In preparing the modified tables for the blueback run the same rate of migration up the river has been assumed as for chinooks; i. e., that fish that were in Zones 1 and 2 in the first week would be found in Zones 3 to 5 the second week, at Bonneville and between Bonneville and Celilo during the third week, and at Rock Island the fifth week. The data in tables 20 and 21 and figure 6 show that this assumption is well justified, since the conspicuous peaks are made to coincide almost perfectly.

These data have been analyzed by applying methods similar to those used in the study of the chinook salmon. From the totals given in table 20 it may be seen that, for the entire season, the ratio of the estimated number of fish taken in the commercial fishery to the estimated escapement is approximately 3.32:1. In other words, as shown by this estimate, over 3 fish are caught to 1 that escapes, passes through the commercial fishing area, and becomes available on the spawning grounds for perpetuating the run. The Rock Island count was 17,123. Multiplying this by the ratio of catch to escapement gives 56,800 as an estimate of the number of fish caught out of the populations normally spawning in the Columbia River above Rock Island. Reconverting this to pounds by multiplying by 3 gives a total of 170,000 pounds caught that may be attributed to the runs spawning above Rock Island.

These figures are based upon a consideration of the catch and escapement for the entire spring season up to and including August 25, and the total Rock Island count.

For the bluebacks this comprises practically the entire season. But there is evidence that the catch during the central portion of the season constitutes a higher percentage of the run than at the beginning and end of the run—in other words that the fishing is more intense while the fish are most abundant. For the period covered by the weeks ending June 11 to July 16 the estimated number of fish caught is 139,000, while the escapement is 37,600; giving a ratio of catch to escapement of 3.69:1. Applying this ratio to the Rock Island count for the period gives an estimate of 60,500 fish weighing 181,500 pounds that may be attributed to the Rock Island runs during this period only.

The percentage that the Rock Island count constitutes of the total estimated escapement of this species is a measure of the relative importance of the Rock Island runs in the total. On the basis of the entire season the percentage is 40.58, and on the basis of the central, more important period of 6 weeks, the percentage is 43.55. From these figures it appears that approximately four-tenths of the entire run of bluebacks on the Columbia River in 1938 was composed of fish derived from the runs to the upper Columbia River, and that the aggregate commercial catch was approximately 182,000 pounds.

The application of the second method for converting poundage figures into numbers of fish increases the estimate of the number of fish taken above Bonneville, and correspondingly decreases the estimated number in the escapement—since this is derived by subtracting the estimated catch above Bonneville from the Bonneville count. As shown in table 21, it gives an estimate of 39,400 bluebacks taken above Bonneville, instead of 32,800, on the assumption of an average weight of 3 pounds. The estimated escapement is reduced to 35,600 from 42,200; the ratio of catch to escapement is 4.11:1, and the percentage of the total escapement later counted at Rock Island is 48.05. The total catch and poundage attributable to the Rock Island runs can be determined by multiplying separately the catches made above and below Bonneville by the percentage of Rock Island fish in the whole run (48.05 percent). For the number of 3-pound fish caught below Bonneville this gives 51,500, and for the number of 2½-pound fish caught above Bonneville 18,900—a total of 70,400 fish with an aggregate weight of 202,000 pounds. A similar estimate for the period from June 5 to July 16 gives a ratio of catch to escapement of 4.66:1, and the percentage of Rock Island fish in the total run is 52.57. The total catch on the basis of these ratios is 76,500 fish of an aggregate weight of 219,300 pounds.

These estimates show quite conclusively that in 1938 about half of the blueback run was derived from the tributaries above Rock Island; that about four fish were caught in the commercial fishery for every one that was left to propagate, and that the total weight of the fish taken in the commercial fishery and derived from the Rock Island runs was of the order of 200,000 pounds.

STEELHEAD TROUT

TABLE 22.—*Steelhead trout run, Columbia River, 1938*

Catch in number of fish estimated on the basis of an average weight of 10 pounds. Data combined and arranged by corresponding weeks]

Week ending	Catch in Zones 1 and 2	Catch in Zones 3 to 5	Total catch below Bonneville	Bonneville estimate and count	Catch above Bonneville	Total catch	Rock Island count	Total run
Feb. 5				55				55
Feb. 12				158				158
Feb. 19				204				204
Feb. 26				980				980
Mar. 5				1,267				1,267
Mar. 12				84				84
Mar. 19				981			49	981
Mar. 26				7,319			222	7,319
Apr. 2				1,927			143	1,927
Apr. 9				639			243	639
Apr. 16				320			67	320
Apr. 23				138	130	130	55	138
Apr. 30		179	179	3,217	325	504	395	3,396
May 7	718	111	829	1,622	221	1,050	100	2,451
May 14	554	34	588	1,644	120	708	53	2,232
May 21	318	27	345	164	74	419	28	509
May 28	215	4	219	632	50	269	29	851
June 4	120	6	126	652	26	152	8	778
June 11	179	34	213	520	42	255	1	733
June 18	852	195	1,047	641	45	1,092	4	1,688
June 25	3,829	444	4,273	800	83	4,356	12	5,073
July 2	5,880	1,445	7,325	4,061	103	7,428	60	11,386
July 9	15,418	3,010	18,428	7,161	620	19,048	62	25,589
July 16	12,693	3,302	15,995	6,667	352	16,347	57	22,662
July 23	9,354	1,623	10,977	4,886	386	11,363	45	15,863
July 30	9,647	1,304	10,951	6,086	1,578	12,529	25	17,037
Aug. 6	5,292	1,638	6,930	6,457	2,086	9,016	33	13,387
Aug. 13	13,924	2,221	16,145	6,908	1,157	17,302	56	23,053
Aug. 20	10,540	1,783	12,323	17,689		12,323	97	30,012
Aug. 27	6,266		6,266	15,814		6,266	200	22,080
Sept. 3				13,744	12,640	12,640	90	13,744
Sept. 10		2,160	2,160	3,935	9,970	12,130	126	6,095
Sept. 17	920	1,860	2,780	1,204	2,300	5,080	39	3,984
Sept. 24	4,170	750	4,920	857	1,070	5,990	34	5,777
Oct. 1	2,150	300	2,450	604	490	2,940	67	3,054
Oct. 8	730	150	880	230	150	1,030		1,110
Oct. 15	440	110	550	253	290	840		803
Oct. 22	430	80	510	152	130	640		662
Oct. 29	340	110	450	90	8	458		540
Nov. 5	360	140	500	60		500		560
Nov. 12	740	160	900	58		900		958
Nov. 19	830	290	1,120	30		1,120		1,150
Nov. 26	1,060	240	1,300	43		1,300		1,343
Dec. 3	810	180	990	18		990		1,008
Dec. 10	2,090	120	2,210	1		2,210		2,211
Dec. 17	1,070	200	1,270	13		1,270		1,283
Dec. 24	770	170	940			940		940
Dec. 31	1,010		1,010			1,010		1,010
Total	113,719	24,380	138,099	120,985	34,446	172,545	2,400	259,084

TABLE 23.—*Catch and escapement of steelhead trout by selected and corresponding periods*

Period	Catch below Bonneville	Bonneville count	Catch above Bonneville	Total catch	Estimated escapement past Celilo	Rock Island count
Apr. 17–May 28	2,160	7,416	920	3,080	6,496	660
May 29–July 30	69,335	31,474	3,235	72,570	28,239	274
July 31–Sept. 24	51,524	66,608	29,223	80,747	37,385	675
Sept. 25–Dec. 31	15,080	1,552	1,068	16,148	484	[1] 67

[1] Incomplete.

TABLE 24.—*Steelhead trout, significant ratios between elements of the run*

Period	Total catch to escapement	Catch below Bonneville to—		Catch above Bonneville to—		Rock Island count to escapement
		Total catch	Bonneville count	Total catch	Bonneville count	
Apr. 17–May 28	0.48	0.702	0.291	0.298	0.124	0.101
May 29–July 30	2.57	.955	2.200	.045	.103	.010
July 31–Sept. 24	2.16	.638	.773	.362	.439	.017
Sept. 25–Dec. 31	33.35	.934	9.716	.066	.688	.139

Table 22 gives the data relative to steelhead trout in modified form. The catch figures have been converted to number of fish on the basis of an average weight of 10 pounds throughout the season and in all zones. Tables 23 and 24 present some of these data and certain derived figures for selected periods that have particular significance. In preparing these tables and the graph (fig. 7) the same rate of travel has been assumed as proved satisfactory for the study of the chinooks and bluebacks, and the results appear to justify this assumption.

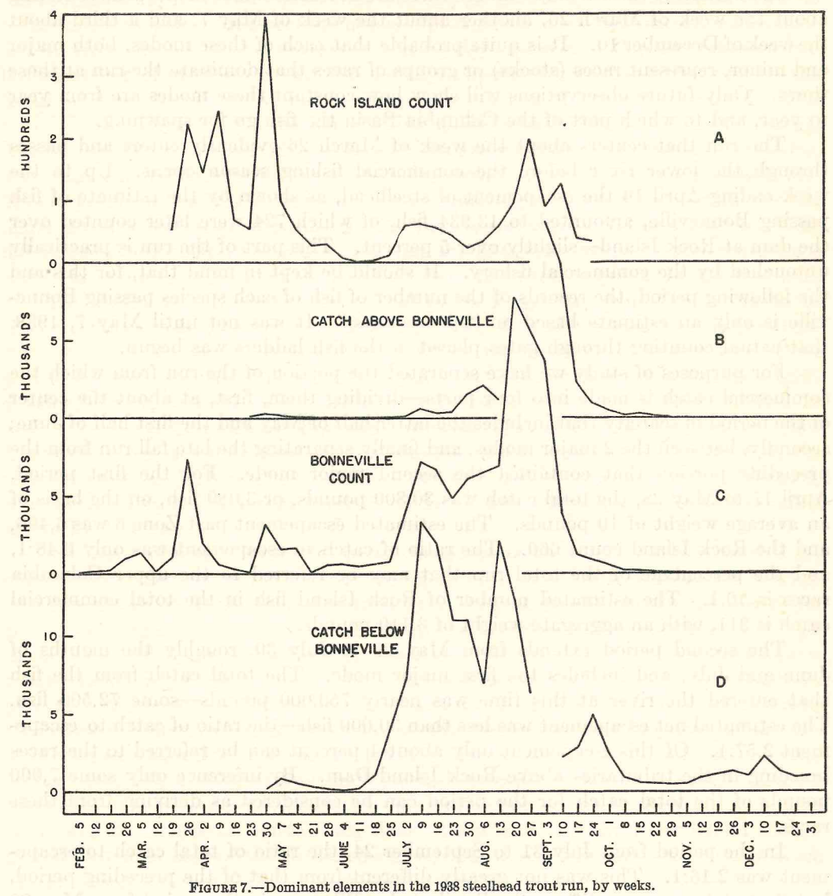

FIGURE 7.—Dominant elements in the 1938 steelhead trout run, by weeks.

From table 22 and figure 7 it is apparent that the steelhead run extends broadly over the entire year, although the major part of the run comes during summer and early fall months—from the middle of June to about the first of October. This major portion shows 2 well marked modes, one at the week of July 9 and the other at the week of

August 20. These 2 modes are clearly indicated in each of the component elements into which it has been possible to divide the run as a whole—except possibly the catch above Bonneville Dam (fig. 7). The exact significance of these 2 modes is not apparent, but it is evidently a real phenomenon so far as the run of 1938 is concerned.

In addition to these 2 major modes there are at least 3 minor modes; one centering about the week of March 26, another about the week of May 7, and a third about the week of December 10. It is quite probable that each of these modes, both major and minor, represent races (stocks) or groups of races that dominate the run at those times. Only future observations will show how constant these modes are from year to year, and to which part of the Columbia Basin the fish go for spawning.

The run that centers about the week of March 26 evidently enters and passes through the lower river before the commercial fishing season opens. Up to the week ending April 16 the escapement of steelhead, as shown by the estimate of fish passing Bonneville, amounted to 13,934 fish, of which 724 were later counted over the dam at Rock Island—slightly over 5 percent. This part of the run is practically untouched by the commercial fishery. It should be kept in mind that, for this and the following period, the records of the number of fish of each species passing Bonneville is only an estimate based on "spot counts." It was not until May 7, 1938, that actual counting through gates placed in the fish ladders was begun.

For purposes of study we have separated the portion of the run from which the commercial catch is made into four parts—dividing them, first, at about the center of the period of scarcity that includes the latter half of May and the first half of June; secondly, between the 2 major modes, and finally separating the late fall run from the preceding portion that contained the second major mode. For the first period, April 17 to May 28, the total catch was 30,800 pounds, or 3,080 fish, on the basis of an average weight of 10 pounds. The estimated escapement past Zone 6 was 6,496, and the Rock Island count 660. The ratio of catch to escapement was only 0.48:1, and the percentage of the total run that may be referred to the upper Columbia races is 10.1. The estimated number of Rock Island fish in the total commercial catch is 311, with an aggregate weight of 3,110 pounds.

The second period extends from May 29 to July 30, roughly the months of June and July, and includes the first major mode. The total catch from the fish that entered the river at this time was nearly 750,000 pounds—some 72,500 fish. The estimated net escapement was less than 30,000 fish—the ratio of catch to escapement 2.57:1. Of this escapement only about 1 percent can be referred to the races breeding in the tributaries above Rock Island Dam. By inference only some 7,000 pounds of the total catch for the period can be considered as deriving from these races.

In the period from July 31 to September 24, the ratio of total catch to escapement was 2.16:1. This was not greatly different from that of the preceding period, but the catch was very differently distributed. Whereas, in the period from May 29 to July 30, only 4.5 percent of the total catch was made above Bonneville, in the next period, covering roughly the months of August and September, over 36 percent of the total catch came from the river above the dam. The estimated net escapement was over 37,000 fish. This was an increase of some 9,000 over that of June and July—a little over 30 percent.

It might have been expected that the closed season from August 25 to September 10 would have had a more favorable effect upon the escapement of those stocks of

fish that form the second of the two major peaks—roughly those that enter the river during the months of August and September. The count at the Bonneville Dam during these months was over twice that of the preceding 2 months, during which the first of the 2 major peaks appeared. A more complete examination of the data in table 22, however, shows that this improvement in the Bonneville count is by no means indicative of a corresponding improvement in the net escapement because the intensive fishery above Bonneville during September and October takes such a large number of steelheads that the actual escapement past the upper end of the fishing district is, relatively, not much greater than in the preceding period. The ratio of total catch to net escapement during June and July is 2.57:1, and during August and September is 2.16:1. (Both catch and escapement figures are, of course, estimates, and the periods of time are to be referred to the marginal dates of table 22.) It is to be noted that these ratios are considerably higher than 1.65:1, which was the figure given in the original report for the months of June, July, and August. The difference is obviously due to the fact that the data now available are much more complete, containing those for the last half of the main run as well as for the first half.

The steelhead run of the final period to be considered, from September 25 to the end of the year, is much less important than that of the two periods just considered and is characterized particularly by the relatively slight importance of the part of the run that passes Bonneville. The total count at Bonneville was only 1,552 steelhead trout, and the catch in the river below the dam was nearly 10 times as great. It is clearly indicated that the steelheads spawning in the tributaries below Bonneville form a much larger part of the late fall run than of those entering the river previous to September 25. Of the steelheads that do pass Bonneville, however, the data appear to show that a relatively large percentage spawn in the Columbia above Rock Island.

The last column of table 24 shows the percentages of Rock Island fish in the estimated escapement to the river above Celilo Falls for each of the selected periods. The percentage of Rock Island fish in the run up to April 16 was a little over 5; for the period ending May 28 was over 10 percent; for the period ending July 30 and including the first major mode, only 1 percent; for the period of the second major mode, ending September 24, 1.7 percent; but for the late fall period it was nearly 14 percent. Although the figures are not particularly reliable on account of the relatively few fish involved, it is interesting to note the indication of greater importance of the upper Columbia races in the late fall and winter runs and also in the early spring runs. These data at least indicate that a relatively large percentage of those steelheads that pass Bonneville during fall and winter spawn in the main Columbia River and its tributaries above Rock Island Dam, and that the Rock Island contingent in the main part of the steelhead run is, both absolutely and relatively, of much less importance than in fall and early spring months.

These data also provide some evidence that a larger proportion of late fall fish—entering the river after the first of October—spawn in tributaries below Bonneville. This is shown by the ratios of the catch below Bonneville to the Bonneville count for the different parts of the year (table 24). For the first part of the run to be affected by the commercial fishery, April 17 to May 28, this ratio was 0.291:1—only about one-fourth of the fish entering the river were taken below the dam. During the June and July run the ratio was 2.2:1. During the next 2 months, influenced by the closed period, it dropped to approximately 0.8:1. During the last 3 months of

the year, however, the ratio rose to nearly 10:1; i. e., about 10 fish were caught in the river below the dam for every 1 that reached the dam. Various explanations might be offered, but it seems most likely that, as suggested above, it is due to the fact that a large percentage of the fish entering the river during the late fall spawn in tributaries that enter the main river below the dam.

We have discussed the importance of the chinook catch above Bonneville during the first few weeks following the closed period, and the fact that the closed period has more effect in spreading the catch out over a longer fishing area than it has in the way of increasing the spawning escapement. Evidently the same effect is apparent in the case of the steelheads. This shift in the relative importance of the fisheries below and above Bonneville is shown somewhat more clearly by the percentages of

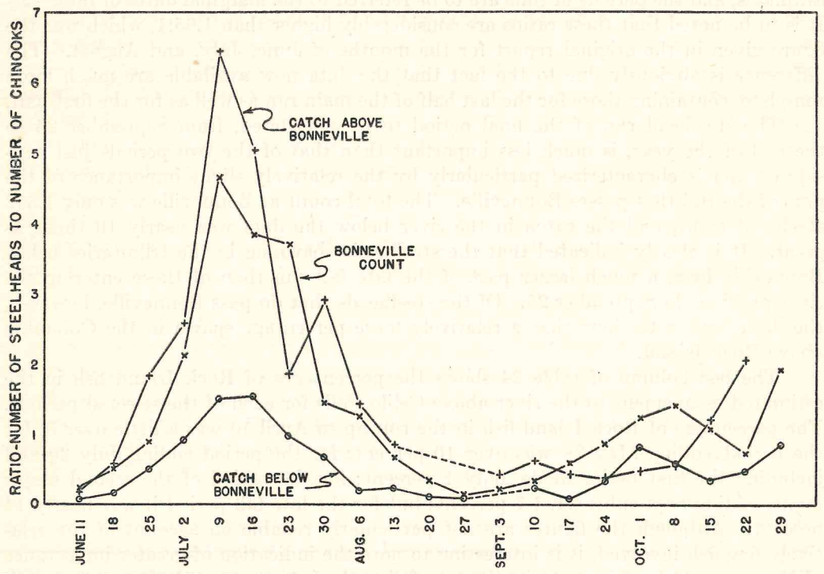

FIGURE 8.—Ratio of steelhead trout to chinook salmon in three important elements of the 1938 run, June 5–October 28, by weeks.

the total catch formed by the catches above Bonneville (table 24). For the months of June and July only 4.5 percent of the total catch was taken above Bonneville, but during August and September the percentage was 36.2. The relation of this to the net escapement also is shown by the percentages that the catch above Bonneville form of the Bonneville count. For the months of June and July only 10.3 percent of the fish counted past Bonneville were later captured in the fishery above the dam. During the months of August and September, however, 43.9 percent was taken.

As with the chinooks, the catch of steelheads above Bonneville during the first few weeks following the closed period of August 25 to September 10 exceeds the Bonneville count. This anomaly has been discussed and there seems to be no reason to doubt that the same factors were operating with the steelheads as with the chinooks. It has seemed possible in the case of the steelheads, however, that this phenomenon

might have been the result of misidentification of this species in the Bonneville count—steelheads being mistaken for the much more numerous chinooks. In order to test the possibility of such misidentification on a large scale in the Bonneville count, a study was made of the ratios of the number of steelheads to chinooks in (1) the catch below Bonneville, (2) the Bonneville count, and (3) the catch above Bonneville for each week over the period beginning June 5 and ending October 29. It is to be expected that such series of ratios would vary over the entire period with the relative numbers of fish of the 2 species, but the general trends of the ratios should be similar in the 3 localities in the absence of disturbing factors—such as misidentification in the Bonneville count. Figure 8 is a graph of these ratios wherein ordinary arithmetic coordinates are used, since the absolute values are the significant ones. It is apparent from this that the trends are very similar in the 3 localities; which is evidence that the identification at Bonneville was sufficiently accurate and probably was not responsible for the anomalous fact that more fish were recorded in the commercial catch above Bonneville than were counted over the dam.

The data thus graphed are interesting in themselves in addition to their bearing on this particular problem. It is quite obvious that, in numbers of fish, the steelheads approach the chinooks and, during the June–July period when chinooks are few, greatly exceed them. It is chiefly during the peak of the chinook run in August and September that the ratio is down to about 1:5 in the catch below Bonneville and the Bonneville count. The parallelism in the 3 trends up to about the middle of September is quite striking and is supporting evidence that, for this part of the run, the assumed rate of travel is satisfactory.

SILVER AND CHUM SALMON

As mentioned in the introduction, the purposes of the original report by Calkins, Durand, and Rich were such that consideration of the catches of silver and chum salmon was not important. In this revision, however, it is pertinent to include the data available on these 2 species, and to examine these for whatever light they may throw upon the characteristics of the runs. The general features of the runs of silvers and chums are so similar that it is convenient to treat them together.

The data for these species are given in modified form in tables 25 and 26. In converting poundage to numbers of fish an average weight of 10 pounds per fish has been used for both species. The same rate of migration up the river has been used as with the other species, although the rate of migration of both silvers and chums is more doubtful and of far less significance than in the case of the other species. There is, however, no good evidence that the rate of travel is any different in the case of these 2 species than in the others, although the obvious irregularities in the time at which the main portion of the catches is made in the different zones (tables 4 and 5) lead one to suspect that the rates of travel of these species may be somewhat different. This is a matter that should be investigated, but it is necessary for the present to assume the same rate of travel—which has been done in preparing the modified tables.

TABLE 25.—*Silver salmon run in the Columbia River, 1938*

[Catch in number of fish, assuming an average weight of 10 pounds. Data combined and arranged by corresponding weeks]

Week ending	Catch in Zones 1 and 2	Catch in Zones 3 to 5	Total catch	Bonneville count	Week ending	Catch in Zones 1 and 2	Catch in Zones 3 to 5	Total catch	Bonneville count
July 30	----------	1	1	----------	Oct. 29	20, 268	4, 128	24, 396	18
Aug. 6	1	2	3	----------	Nov. 5	23, 275	1, 979	25, 254	9
Aug. 13	54	13	67	115	Nov. 12	13, 346	1, 596	14, 942	4
Aug. 20	1, 454	238	1, 692	6, 964	Nov. 19	6. 209	831	7, 040	1
Aug. 27	2, 636	----------	2, 636	4, 766	Nov. 26	2, 275	864	3, 139	7
Sept. 3	----------	----------	----------	1, 933	Dec. 3	1, 592	547	2, 139	----------
Sept. 10	4	902	906	239	Dec. 10	5, 762	204	5, 966	----------
Sept. 17	4, 559	2, 470	7, 029	56	Dec. 17	1, 069	88	1, 157	----------
Sept. 24	23, 032	1, 166	24, 198	94	Dec. 24	186	49	235	----------
Oct. 1	14, 454	2, 838	17, 292	389	Dec. 31	154	----------	154	----------
Oct. 8	10, 578	5, 951	16, 529	240	Total	195, 232	34, 329	229, 561	15, 185
Oct. 15	32, 410	5, 346	37, 756	212					
Oct. 22	31, 914	5, 116	37, 030	138					

NOTE.—No catch was recorded for Zone 6.

TABLE 26.—*Chum salmon run in the Columbia River, 1938*

[Catch in number of fish, assuming an average weight of 10 pounds. Data combined and arranged by corresponding weeks]

Week ending	Catch in Zones 1 and 2	Catch in Zones 3 to 5	Total catch below Bonneville	Bonneville count	Catch in Zone 6	Week ending	Catch in Zones 1 and 2	Catch in Zones 3 to 5	Total catch below Bonneville	Bonneville count	Catch in Zone 6
Sept. 24	3	----------	3	2	----------	Nov. 26	6, 074	1, 210	7, 284	46	----------
Oct. 1	117	284	401	68	----------	Dec. 3	1, 083	440	1, 523	13	----------
Oct. 8	334	293	627	179	----------	Dec. 10	2, 286	57	2, 343	1	----------
Oct. 15	4, 839	1, 538	6, 377	945	7	Dec. 17	453	23	476	----------	----------
Oct. 22	15, 960	2, 931	18, 891	174	365	Dec. 24	44	8	52	----------	----------
Oct. 29	22, 370	5, 361	27, 731	236	28	Dec. 31	15	----------	15	----------	----------
Nov. 5	51, 458	7, 235	58, 693	225	195	Total	162, 694	27, 576	190, 270	2, 117	892
Nov. 12	41, 601	5, 084	46, 685	202	297						
Nov. 19	16, 057	3, 112	19, 169	26	----------						

For both silver and chum salmon it is quite apparent that such a small part of each run goes above Bonneville that the same sort of analysis that was made of the data for the other species would be meaningless for these. Obviously the chief spawning areas are in the tributaries that enter the main river below Bonneville—an inference that is in entire accord with the known facts of the distribution of these species. Not only in the Columbia River but generally throughout their entire range, both silver and chum salmon tend to spawn in the lower tributaries of the larger rivers or in the shorter coastal streams. The same is true of the pink salmon, which do not appear in the Columbia in commercial quantities. Under such circumstances it is not possible even to approximate the number of fish in the entire run because the sum of the fish taken below the dam and those counted past Bonneville do not form a sufficiently large percentage of the whole, and without at least approximate information as to the total number of fish in the run it is impossible to make the sort of analysis that has been done with the chinooks, bluebacks and steelheads.

The silver salmon first appeared in the river about the first of August, but the catch did not amount to much until after the closed period from August 25 to September 10. On the other hand, a very large part of the total count past Bonneville was made during the 2 or 3 weeks that were chiefly affected by the closed season. (In table 25, the weeks ending August 20, August 27, and September 3.) Several factors, alone or in combination, may account for these facts. First it appears that a much larger percentage of the earlier fish than of the later ones pass above the dam to spawn in the upper tributaries. Secondly, the intensity of fishing for this species

may be greater after the closed period than before. This may be due in part to a change in the gear used on the lower river after the height of the fall run of chinooks has passed. The silvers, being smaller fish, may be more readily caught with gill nets of smaller mesh than is most effective for the larger chinooks. However this may be, it seems reasonably certain that in 1938 there was a small but fairly well separated run of silver salmon that entered the river late in August.

The main part of the run of this species comes from about the middle of September to about the middle of November. There is some evidence of separate modes in the run during this time, but it is not conclusive or even very strongly marked. The height of the entire run in the lower river comes close to the middle of October.

Chum salmon do not begin to enter the river much before the first of October. From that date on the run gradually increases to a peak that comes about the first week in November. After this the run as gradually decreases to terminate late in December. There is no evidence of significant minor modes. As in the case of the silver salmon, comparatively few of these fish pass Bonneville Dam, although a small catch was recorded from Zone 6. It is clear that the majority of the fish of this species spawns in the tributaries below Bonneville Dam.

SUMMARY

1. Exceptional data are available for the study of the salmon runs of the Columbia River for 1938. For the first time the catch data for Oregon and Washington were given in similar form so that they could be combined. As a result, the daily catch in pounds of each species in each of 6 zones (corresponding to the parts of the river bounding the 6 contiguous counties of Washington) is available for study. Coincident with this the Bonneville Dam was closed and fish ladders were constructed, by means of which the fish surmounted the dam. On their way through the ladders the fish were conducted through narrow passages and over white surfaces, and the number of each species was recorded. There have also been available for study the counts of salmon passing through the fish ladders at the Rock Island Dam, on the upper Columbia River near Wenatchee, Wash.

2. By using appropriate conversion factors the catch in pounds has been converted into numbers of fish, so as to make these data directly comparable with the counts at Bonneville and Rock Island dams. Tables have been prepared in which are given (1) the weekly catch for each of 3 major areas representing natural groups of zones, (2) the total catch, (3) the Bonneville count, and (4) the Rock Island count. For each major area the data have been appropriately "lagged" so that, as nearly as possible, those for the same part of the run will lie on the same line as the table is read from left to right. This lag has assumed that fish entering the river and to be found in Zones 1 and 2 one week will be found in Zones 3, 4, and 5 the second week, at Bonneville and in Zone 6 the third week, and at Rock Island the fifth week. These modified tables form the basis for study and analysis.

3. The general course of the run of each species is shown so far as possible by the available data. The chinook salmon enter the river throughout most of the year, but two quite distinct peaks are shown: One near the end of April, the so-called "spring" run, and the other the latter half of August. There is a period of marked scarcity during June and July. The blueback run is of much shorter duration, the main portion lasting only 6 or 8 weeks and showing a marked peak toward the end of June. Steelhead trout enter the river throughout the year but the chief run is during the

months of June to September. There are 5 modes: minor ones about the end of March, the first of May, and the first of December, and major modes early in July and about the middle of August. The run of silver salmon extends from early in August to the end of the year, but centers rather broadly from the middle of September to the middle of October. The chum salmon run attains a well marked maximum about the first week in November, but extends from about the first of October to about the middle of December.

4. The main parts of the chinook, blueback, and steelhead runs spawn above Bonneville, but silvers and chums spawn chiefly in the tributaries below the dam.

5. There is some evidence of error in the identification of species in the Bonneville count.

6. The importance of the runs to the river above Rock Island (largely affected by the dam at Grand Coulee) is shown by the ratio of the Rock Island count to the estimated escapement. Some 4 percent of the very early chinooks passing Bonneville previous to the first of May appear later at Rock Island. Of the May run of this species, about 6 percent apparently went to this portion of the river. Of the June–July run, which is poor and apparently seriously depleted, some 15 percent is attributable to these races. During the remainder of the year only about 1 percent of the estimated escapement appeared here. Approximately 40 percent of the blueback run spawns above Rock Island. In the case of the steelheads, the early and late runs contain 10 percent or more of fish spawning above Rock Island; but during the main portion of the run, June through September, only about 1 percent of these fish go to this portion of the river.

7. The intensity of the fishery for chinooks, bluebacks, and steelheads is measured by the ratio of the commercial catch to the escapement, as calculated from the data given in the modified tables. For the May run of chinooks it is shown that only about 1 fish out of 7 escapes the commercial fishery and is available for the future maintenance of this run. During June and July, a period of great scarcity, only about 1 fish in 6 escapes, and during the remainder of the run, August through December, the escapement is considerably better but even at this time about twice as many fish are taken in the commercial fishery as remain to reproduce. These figures do not take into consideration the effect of the intensive oceanic fishery which would materially increase the catch–escapement ratio. In the case of the blueback salmon the ratio of catch to escapement is approximately 4:1, indicating that only about 1 fish out of 5 of this species escapes the fishery. The ratio for the steelheads varies with the season, but for the main part of the run, June to September, it is somewhat greater than 2:1; i. e., more than 2 out of 3 steelheads are taken in the fishery. Similar ratios for the silvers and chums cannot be determined because few fish of these species pass Bonneville; consequently no estimate of the net escapement can be made.

8. The weekly closed period, 6 p. m. Saturday to 6 p. m. Sunday, in force during the spring fishing season, May 1 to August 25, is almost entirely ineffective insofar as it may tend to increase the number of breeding fish on the spawning grounds. Its chief effect is to spread the fishing over a longer stretch of the river. This is the result of an intensive fishery conducted over a long area. The closed season from August 25 to September 10 is designed to protect the peak of the chinook run and a portion of the steelhead run, but it acts, in a larger way, much the same as does the weekly closed period in that it chiefly tends to extend the fishing areas. The effect of an increased escapement of fish through the fishing area below Bonneville is almost

entirely offset by the very intensive fall fishery that is concentrated in Zone 6, above Bonneville Dam.

9. The closed period of March and April protects from the commercial fishery the run of chinooks that enters the Willamette River during April and early May, but this run is subjected to an intensive sport fishery below the falls at Oregon City. Unfortunately there are no data on the sport catch or on the Willamette run as a whole. This closed period also protects a small run of chinooks to the main river, the principal portion of which passes through the commercial fishing area before the season opens on May 1.

10. The main runs of all species of salmon to the Columbia River are practically unprotected from exploitation. If all existing restrictions were removed, it is doubtful whether the catch would be materially increased, or, conversely, that the remaining brood stock would be materially decreased. The only present aids to the conservation of these runs are apparently those afforded by artificial propagation, stream improvement, and, possibly, the restrictions that apply to the use of traps and wheels.

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