INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION

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

ANNUAL REPORT

1944

COMMISSIONERS

EDWARD W. ALLEN
FRED J. FOSTER
A. L. HAGER
CHARLES E. JACKSON
TOM REID
A. J. WHITMORE

NEW WESTMINSTER, B. C.
CANADA
1945

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DISTRIBUTION OF SOCKEYE SALMON SPAWNING GROUNDS IN THE FRASER RIVER WATERSHED

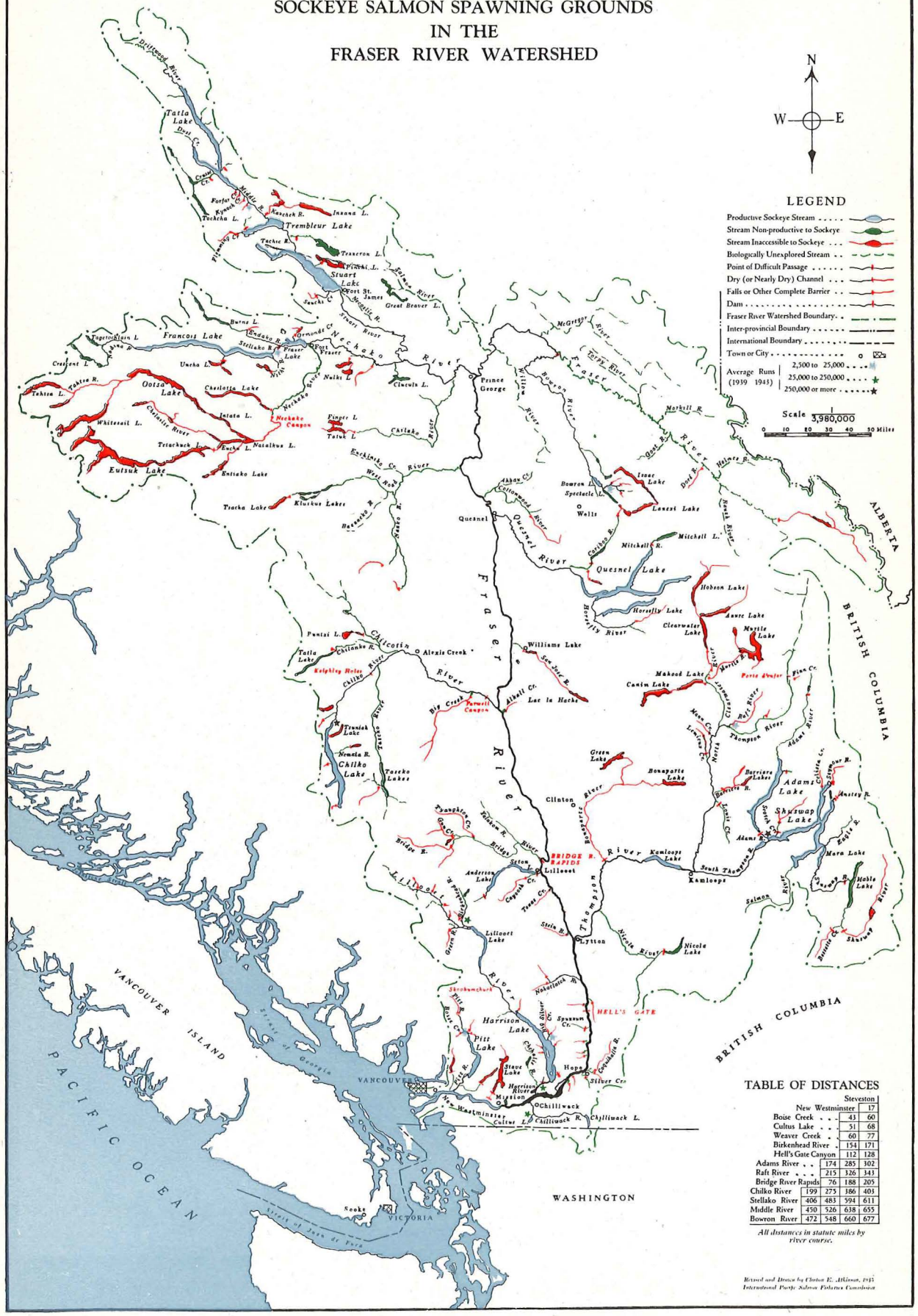


TABLE OF DISTANCES

	New Westminster	Steveston
Boise Creek	43	60
Cultus Lake	51	68
Weaver Creek	60	77
Birkenhead River	154	171
Hell's Gate Canyon	112	128
Adams River	174	285 302
Raft River	215	326 343
Bridge River Rapids	76	188 205
Chilko River	199	275 186 401
Stellako River	406	483 594 611
Middle River	450	526 638 655
Bowron River	472	548 660 677

All distances in statute miles by river course.

Revised and Drawn by Clinton E. Atkinson, 1945
International Pacific Salmon Fisheries Commission

REPORT OF THE
INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION
FOR THE YEAR 1944

Sockeye salmon, spawned in the Fraser River watershed for many years, formed the basis for the most prosperous fishery of the Puget Sound - Gulf of Georgia region. Due to various causes, this dwindled to about one-tenth of its former magnitude. Because many of these salmon, when they return to spawn in British Columbia, first pass through the State of Washington waters, an international problem was presented.

Five treaties were negotiated aiming at the rehabilitation of this fishery. Four failed of ratification but the fifth, as to which ratifications were exchanged between the United States and Canada on July 28, 1937, provided for the appointment of the International Pacific Salmon Fisheries Commission and prescribed its powers and duties.

The Commission has authority to investigate and control the fishery of the territorial waters and high seas adjacent to British Columba and the State of Washington between the 48th and 49th parallels, the Strait of Juan de Fuca, and the Strait of Georgia as far north as Lasqueti Island, and the Fraser River as far as Mission. The Commission is composed of three men from each country and its expenditures are borne equally by the two governments.

The treaty provides for a thorough investigation of the natural history of the sockeye salmon and the Commission is given the power to improve streams, establish and maintain hatcheries, recommend the removal of obstructions to salmon migration, and to use any other measures that may be required for the restoration of depleted runs of sockeye salmon. It has the authority, after eight years of preliminary study, to regulate the taking of salmon by prescription of gear or limitation of licenses, season, or area so that the catch may be divided between the two countries as equally as may be practicable. Any action must be approved by at least two of the Commissioners from each country. The governments will be responsible for the enforcement of regulations prescribed by the Commission.

The convention was ratified, subject to the understanding that no type of gear would be authorized by the Commission for use in waters where such gear is contrary to the laws of the State of Washington or the Dominion of Canada. It was further provided that fishery regulations would not be enforced prior to the completion of scientific investigations covering two complete cycles or eight years and that an Advisory Committee would be appointed consisting of five men from each country — each representative from a stated branch of the industry.

Shortly after the convention was ratified, a Director of Investigations was appointed and scientific research on the natural history of the sockeye salmon, as required by the treaty, was begun.

In order to control the fishery properly it is essential that adequate and reliable statistics be available. Accordingly a program was formulated that would provide for the collection and analysis of information from the commercial fishery, the Indian fishery, and the spawning escapement. Results from these three phases of the fishery will be of the greatest importance for regulation of the Fraser River sockeye salmon fishery.

Before regulation can be attempted, and while the various statistics are being studied, other phases of the life history of the sockeye salmon must be examined. A review of past historical accounts has revealed a number of interesting features that have contributed to the depletion of the fishery. Biological investigations have shown the seriousness of the mortality that has resulted from conditions in the Hell's Gate Canyon which is located on the Fraser River 130 miles from salt water. Other problems having to do with the rehabilitation of the Fraser River fishery are being approached in such a way as to provide for the maximum annual production of sockeye salmon.

Removal of a number of obstructions to the normal migration and dispersion of sockeye salmon to their spawning areas has already begun. The sum of two million dollars, made available by Canada and the United States, will be utilized within the next five years for the removal of obstructions to migration. When it has become certain that no unnecessary loss from obstructions will occur to that portion which escapes the commercial and Indian fisheries, methods for rebuilding the remnants of the once abundant up-river runs will be undertaken.

The Commission held the first of its three 1944 meetings at the offices of United States Fish and Wildlife Service in the Merchandise Mart in Chicago. At this meeting, held on June 10 and 11, the plans, schedules and specifications for the proposed Hell's Gate Fishways were studied in detail and matters of liability and responsibility were discussed. Requests for tenders on the approved contract were given out on July 5 to contractors in Canada and the United States. All tenders submitted were opened at the offices of the Commission in New Westminster at 10.00 A.M. on August 2 with the Commissioners and many prospective bidders present.

On August 3, 4, 5, and 6 a further meeting of the Commission was held in Vancouver, B. C., for the purpose of considering the tenders submitted for the Hell's Gate project and to investigate the ability of each bidder to fulfill the terms of the contract. The lowest bid was accepted and the contract was awarded to the Coast Construction Company Limited of Vancouver, B. C.

On December 3 the Hell's Gate project was inspected by the Commissioners in order to examine the progress made in the first few months of construction. At a third meeting, held at the Hotel Vancouver on December 4 and 5, the Commission discussed the Hell's Gate project with representatives of the

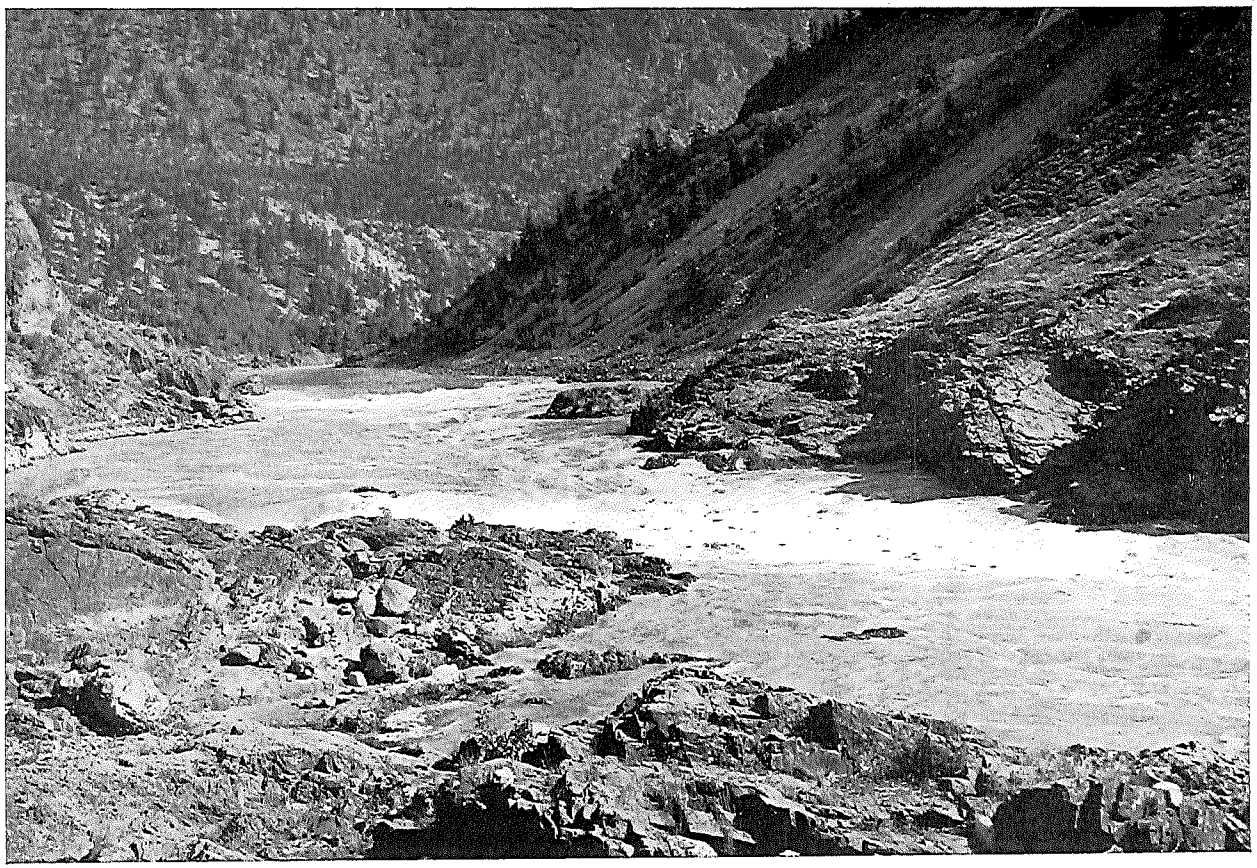
contractor. Members of the scientific staff of the Commission reviewed the activities of the past field season. On December 5 the Advisory Committee met with the Commission to hear reports on the various projects under investigation. The present members of this Committee are as follows:

Organization Represented	Canada	United States
Packers	Richard Nelson	C. J. Collins
Gill Net Fishermen	Homer Stevens	Chester Karlson
Troll Fishermen	A. E. Carr	Sevrin Leite
Purse Seine Fishermen		Lee Makovich
Sport Fishermen	M. W. Black	Ken McLeod

During the year the Commission lost the services of Messrs. J. E. Mason and L. E. Whitesel to the armed forces, and of D. R. Foskett to the Fisheries Research Board of Canada.

INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION,

EDWARD W. ALLEN, *Chairman*
FRED J. FOSTER
A. L. HAGER
CHARLES E. JACKSON
TOM REID, M.P.
A. J. WHITMORE, *Secretary.*



General view of Bridge River Rapids.

REPORT ON THE INVESTIGATIONS OF THE INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION ON THE FRASER RIVER SOCKEYE FOR THE YEAR 1944

by

B. M. BRENNAN

At the November, 1943, meeting of the Commission the Director was authorized to prepare requests to the governments of Canada and the United States for appropriations to be used in remedying thirty-seven obstructions or points of difficult passage affecting the spawning migration of sockeye salmon in the Fraser River system. These projects range in importance from the major undertaking at Hell's Gate to removal of such minor obstructions as log jams. The sum of one million dollars was requested from each of the two governments and these funds were made available to the Commission on April 1, 1944.

For the Hell's Gate project the engineering division prepared plans and specifications which were reviewed by the Commisson at the June 10 meeting. Fortunately much of the pertinent hydraulic information for use in correcting the difficult stretch of water at Hell's Gate canyon was already available from studies made possible by the several previous emergency appropriations.

The tenders, accompanied by copies of the contract and specifications, beginning on July 5, were sent to prospective bidders in the United States and Canada. They were opened and analyzed on August 2 at the offices of the Commission in New Westminster. The successful bidder, Coast Construction Company Limited of Vancouver, began work during the latter part of August. Because of unpredictable fluctuations in the water level of the Fraser River the contractor is required to complete his part of the project at Hell's Gate before spring freshets of 1945 interfere with the operations.

Blockade conditions at Bridge River Rapids will be the next project for correction by the Commission. Biological information has been collected at Bridge River Rapids during the past several seasons. The engineering surveys and studies initiated this year will be combined with the biological studies in order to determine the best remedial measures that may be used in connection with this blockade. Similar biological and engineering studies have been undertaken at Farwell Canyon, a point of difficult passage for salmon migrating up the Chilcotin River to the Chilko spawning grounds and at Skookumchuck Rapids, an area of turbulent and difficult water for sockeye on the Lower Lillooet River.

Only slight mortality to the valuable Chilko run of sockeye was apparent at Hell's Gate this season. Although there was a block of 15 days during the first part of the run, a sudden rise in water level of more than 14 feet in 48 hours made it possible for the bulk of the run to ascend. There are indications that the temporary salvage measures in operation during the two previous seasons assisted a significant number of salmon over this point during the blockade levels of August 20 to September 13. The brail alone assisted approximately 12,460 salmon. It is hoped that the sockeye salmon migrating during 1944 will be the last to be affected by the serious conditions arising from this block which has caused severe mortality to the valuable runs once frequenting the spawning areas above Hell's Gate Canyon.

This year a trial measure of escapement has been formulated which takes into consideration comparable population counts from 27 major spawning streams. From field observations made since 1938, this comparison includes all of the streams that furnish significant numbers of sockeye to the total escapement. The data already available from 1940 and subsequent years are sufficient to allow for comparisons with this and future years. The total estimated spawning escapement to the key streams in 1944 was 421,858 as contrasted with the 762,886 sockeye enumerated in 1940. Thus for 1944, the spawning escapement was only 51.4% as great as for the brood year (1940).

A comparison of the portions found in the six most important areas is given in the following table:

Stream	Per Cent. of Total 1940	1944
Chilko River and Lake	71.4	71.1
Harrison River Rapids	5.7	(0.02)
Cultus Lake	9.7	3.4
Birkenhead River	3.6	13.7
Weaver Creek	2.2	3.9
Big Silver Creek	1.3	1.2
Other Streams	6.1	6.7

The significant shifts in the distribution consisted of a decrease in the percentage of the spawning population entering Cultus Lake and Harrison River Rapids and an increase in the proportion returning to Birkenhead River.

The frontispiece of this report is a four color map showing the distribution of the sockeye salmon spawning areas, the major obstructions, and other features dealt with in our investigations. This map is based upon information given in the folded map included in the Annual Report for 1943, but has been further revised. Because of the great reduction in size, this map only gives 190 names as compared with 387 on the original map. It is anticipated that the new map will provide the reader with a ready reference for the various locations discussed both in this and in forthcoming reports.

In addition to the review of the Commission's activities for 1944, there are several special reports which deal with commercial fishery statistics, Indian fishery statistics, salmon tagging in salt water, an engineering report on the Hell's Gate project, and an index of the success of spawning. A summary of the spawning ground escapement, which has been assembled from the observers' reports by Mr. C. E. Atkinson, follows.

SUMMARY OF THE ESCAPEMENT TO THE VARIOUS SPAWNING AREAS, 1944

District and Stream	Dates of Run		Estimated No. Sockeye Present			Sex Ratio (%)			
						Males		Females	
	Arrival	End	Minimum	Maximum	Probable	3 Yr.	4 and 5 Yr.	3 Yr.	4 and 5 Yr.
Lower Fraser									
Upper Pitt River	Sept.				Present				
Widgeon Slough †	Oct.	Dec. 7	977	1,123	1,050	2.8	49.6		47.6
Cultus Lake *	Aug. 30	Jan. 6			14,200	1.2	33.1	0.2	65.5
Harrison									
Big Silver Creek	Sept. 1	Oct. 7	1,298		5,192		60.5		39.5
Douglas Creek	Sept. 5	Oct. 7	36	100					
East Creek	Oct.	Nov. 2	62		65				
Harrison River	Nov. 15	Dec. 7	46	100					
Hatchery Creek	Oct. 11	Nov. 7	63		63				
Weaver Creek †‡	Oct. 3	Nov. 7	13,417	19,465	16,441	0.2	30.9		68.9
Lillooet									
Birkenhead River †	Sept. 2	Oct. 31	52,313	63,101	57,707	40.2	27.0		32.8
Upper Lillooet Streams †	Sept.	Oct.	9,887	12,921	11,404	40.2	27.0		32.8
South Thompson									
Adams River	Sept. 30	Nov. 14	1,154		1,367	1.2	25.3		73.5
Little River					200				
Seymour River					200				
North Thompson									
Raft River	Aug. 2	Sept. 15	921	1,200	1,082		41.3		58.7
Seton-Anderson									
Seton Creek	Oct.		100		Blocked fish				
Gates Creek	Sept. 5	Oct. 20			400				

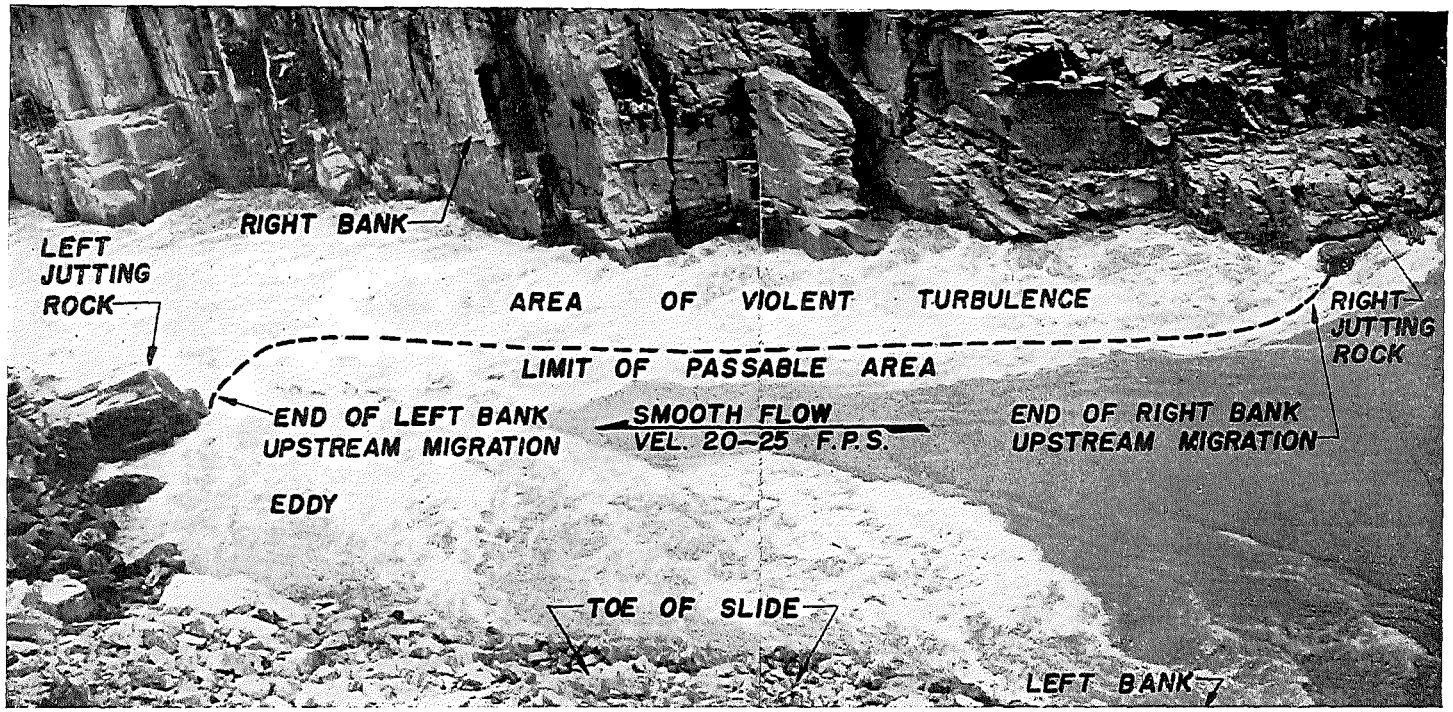
SUMMARY OF THE ESCAPEMENT TO THE VARIOUS SPAWNING AREAS, 1944 — (Continued)

District and Stream	Dates of Run		Estimated No. Sockeye Present			Sex Ratio (%)			
						Males		Females	
	Arrival	End	Minimum	Maximum	Probable	3 Yr.	4 and 5 Yr.	3 Yr.	4 and 5 Yr.
Chilcotin									
Chilko River and Lake †	Aug. 21	Nov. 1	284,919	372,391	328,655	0.1	50.9		49.0
Quesnel									
Horsefly River	Sept.		3						
Little Horsefly River	Oct.		2						
Nechako									
Endako River		Sept.	1						
Ormonde Creek	Aug.	Sept. 22	15						
Stellako River †	Sept. 7	Nov. 10	2,497	4,316	3,294		45.7		54.3
Stuart									
Forfar Creek	Aug.		46						
Hoy Creek	Sept.		3						
Kynoch Creek	Aug.		350						
Middle River	Sept.		22						
Rossette Creek	Aug.		2						
Northeast									
Upper Bowron River * (including Moose Creek)	July 26	Sept. 15			1,700		57.9		42.1

* All fish counted through weir.

† Population estimated by tagging program.

‡ Population determined by indices.


RIGHT BANK
LEFT JUTTING ROCK
AREA OF VIOLENT TURBULENCE
RIGHT JUTTING ROCK
LIMIT OF PASSABLE AREA
END OF LEFT BANK UPSTREAM MIGRATION
SMOOTH FLOW VEL. 20–25 F.P.S.
END OF RIGHT BANK UPSTREAM MIGRATION
EDDY
TOE OF SLIDE
LEFT BANK

Hell's Gate.

REPORT ON THE ENGINEERING INVESTIGATION OF HELL'S GATE, FRASER RIVER

by

MILO C. BELL

Action for the remedying of the Hell's Gate block is under way. During the latter part of August the contractor began the work on his plant to start the construction of two fishways in the Hell's Gate Reach. Five years of Biological and three years of Engineering examination at the Hell's Gate Reach have been terminated and the actual construction of the fish passes begun.

The Engineering investigation started in a minor way in 1941. The Commission, having no special appropriation for Engineering, assigned two men to make marginal readings, to record the surge, the drop, and velocities at Hell's Gate. In 1942 the Commission obtained from the two Governments an appropriation of $45,000 to be used primarily for Engineering work. This made possible a complete survey of the Hell's Gate Reach and an analysis of all the data on hand. Some extremely interesting facts became evident in regard to the conditions at the Gate. The hydraulic control shifted at various river levels. The extent of this shifting ranged from the Gate upstream to the point where the slide material had entered the river, a distance of 300 feet. The reasons for the possible passage of fish at certain water levels became evident. In studying the river, it was found that, on the left bank looking downstream at approximately elevation 25 feet and lower, the central flow which moved at high velocity and impinged on the "left jutting rock" in the Gate, shifted out and upstream thus removing the surface drop of 6 feet at this point. The total drop in the Reach is about eight or nine feet, depending on the river stage. Below 25 feet this total drop distributes itself along the broken shoreline which is a sloping bank composed of large detached rock. However, from elevation 25 feet up, the major part of this drop, poured around or over the "left jutting rock," and it was this immediate drop, velocity, and turbulence through which the fish were unable to ascend at stages above 25 feet.

On the right bank it was found that the point of block occurred upstream approximately 240 feet from the Gate. This point of block which has been called the "right jutting rock" lies immediately below the area in the river where the slide material entered the stream in 1914. It was found that from approximately river elevation 40 feet and down, six to eight feet of drop occurred at the "right jutting rock," the drop, velocity, and turbulence preventing the passage of fish. Above elevation 40 the upwelling effect so distributes the drop along the right bank that the fish could pass at certain water levels.

From the Biological examination made by the Commission's Staff, certain basic facts were determined and presented as evidence requiring the removal of this block. These were: since the dumping of the rock into the river in 1913 in Hell's Gate and the slide of 1914 which fell directly into the Reach from the rocky bluff some 400 feet above the river bed, there have been periods of delay each year in the salmon runs passing through Hell's Gate. The Dominion Fisheries Department removed the major portion of the slide material in 1914 and 1915. After this removal there remained from six to eight feet of drop through the Hell's Gate Reach. Lacking evidence to the contrary, it was believed that this action alleviated the block. The extensive investigations by the Commission indicate, however, that critical conditions exist between river stages 26 and 40 and perhaps at other river stages above elevation 40. With this new evidence available, Engineering studies were initiated to recommend a solution.

To present the problem a brief description of Hell's Gate follows: Hell's Gate lies approximately 130 miles inland from the mouth of the river. The river at this point is in a deep trench between mountain ranges, the Gate itself being only 120 feet wide at low water stage, with the walls of the Canyon rising approximately 90 feet vertically from the river surface and then sloping up steeply to the crests of the mountain ranges. Through this gap flows the water from the drainage basin of some 80,000 square miles. Those unfamiliar with measurements in terms of square miles might compare this area with the State of Washington which has only some 67,000 square miles within its borders. The rise and fall of the Fraser River at this point has, three times during the 34 years of record, measured 90 feet between the low flow stage and the high flood stage, with an average annual variation of some 60 feet. The flow information is recorded by means of a gauge painted on the vertical face of rock in the large pool immediately below Hell's Gate.

The flow data at Hell's Gate have been correlated with the measurement and discharge of the Fraser River near Hope, B. C. The Dominion Water and Power Bureau has, since 1912, recorded the flow of the Fraser River at that point. C. E. Webb of that Bureau also participated in the investigation of the Hell's Gate Reach made in 1926-28 by a Board of Engineers. From his work and by additional correlations made during the Commission's investigations, a complete picture of the block stages and their duration since 1915 has been assembled. Such hydrographic data have been invaluable in this problem for, without information on discharge, the duration of the blocks, and the periods when they occur, the scope and time elements of the problem could not have been ascertained without a detailed investigation by the Commission which would have extended over a period of years.

Between 1926 and 1928 the "Inquiry into the Fraser River Conditions" made by the Board of Engineers appointed by the Dominion Government included soundings and contours in the Hell's Gate Reach. The underwater contours have been used by the Commission in its investigations. All of the above information referred to has been gladly furnished by the Dominion Department of Fisheries, and other information at hand has been furnished by

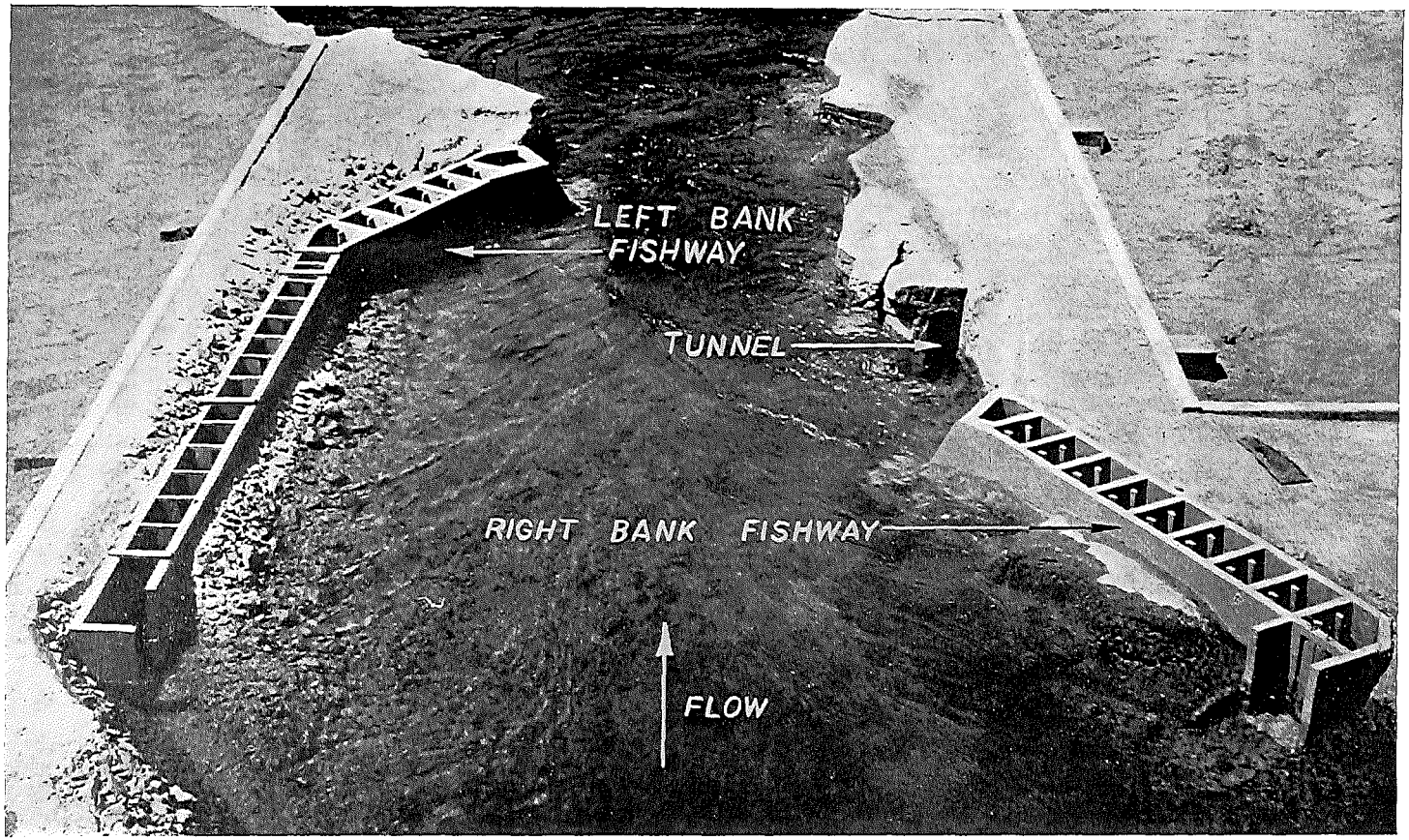
J. McHugh, Engineer (retired) for that department. The Commission has continued to receive the cooperation of Mr. Webb and his Department, both in connection with old records and the furnishing of day by day records, which have been necessary to carry on our investigations.

In summing up the situation from the preliminary investigation, it was evident why little, if any, passage is possible on the left bank above 25 feet and on the right bank below 40 feet. The control of the river is variable in a 300 foot distance. The velocity in the center of the river is more than 20 feet per second, which is excessive for passage of salmon. A drop from eight to nine feet had to be overcome to pass the fish runs successfully.

It was possible, of course, to remove by excavation on either bank or remove subaqueously sufficient material in the bed of the river so as to widen or deepen the river at this point and remove the drop. The results of such removal introduced some serious unknowns, as, by not having soundings of the river upstream from the Hell's Gate Reach, it could not be predetermined as to what marginal condition would occur in the reaches above if the drop were removed at Hell's Gate. For instance, if the present drop is natural and occurred before the slide of 1914, the channel upstream would have adjusted itself to that condition, and new and critical conditions could easily have been created by the lessening of the river's depths some 9 feet. A reduction in river depths would increase velocities and create a new pattern of flow in the reaches above the Gate. If, however, this drop had been created by the slide in 1914, a theoretical rearrangement of the drop at the Gate might not have created any serious situation upstream except that during the construction of the railroads large quantities of excavated rock were deposited into the reaches above the Gate. This dumping has completely altered the original bank conditions and the cross sections of the natural river channel. Therefore, even had it been known that there had been no drop through Hell's Gate prior to 1914, the present drop could not be safely altered without a complete investigation of the river channel above. It was also not known as to how much material would have to be removed to reduce the drop without an extensive investigation as to the controls of this section of the river.

The next line of attack was to create marginal paths which would not interfere in any way with the river but would permit the ascent of salmon. The magnitude of the velocity, the upwelling and turbulence through the Hell's Gate Reach, the changing point of control, and the fact that prohibitive swimming velocity existed but a few feet out from the shore quickly determined that minor marginal corrections would be impracticable. It became more and more evident that the river margins should not be altered in any way unless it could be proved beforehand that such corrections would not introduce new blocks and would improve the Reach for the passage of fish.

To predetermine the effect of any changes to the present river conditions required the construction of a hydraulic model of the Hell's Gate Reach. Such a model was constructed at the University of Washington in the Hydraulics Laboratory Testing Basin, on a scale of one foot in the model equalling 50 feet

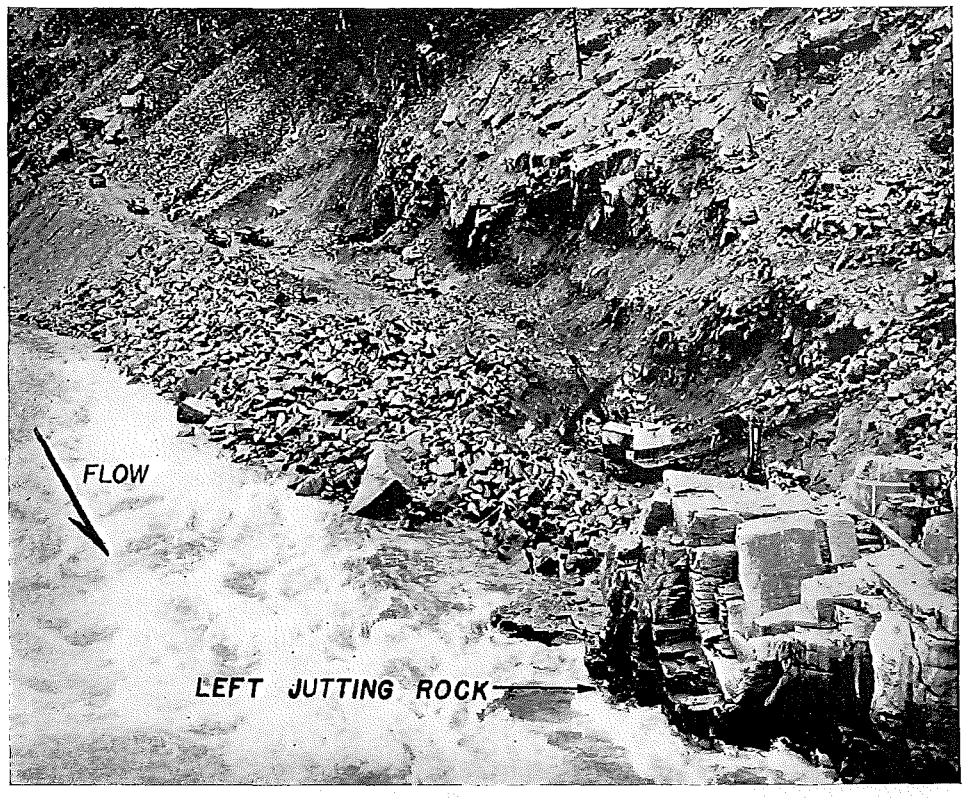


Hell's Gate Model Fishways in operation.

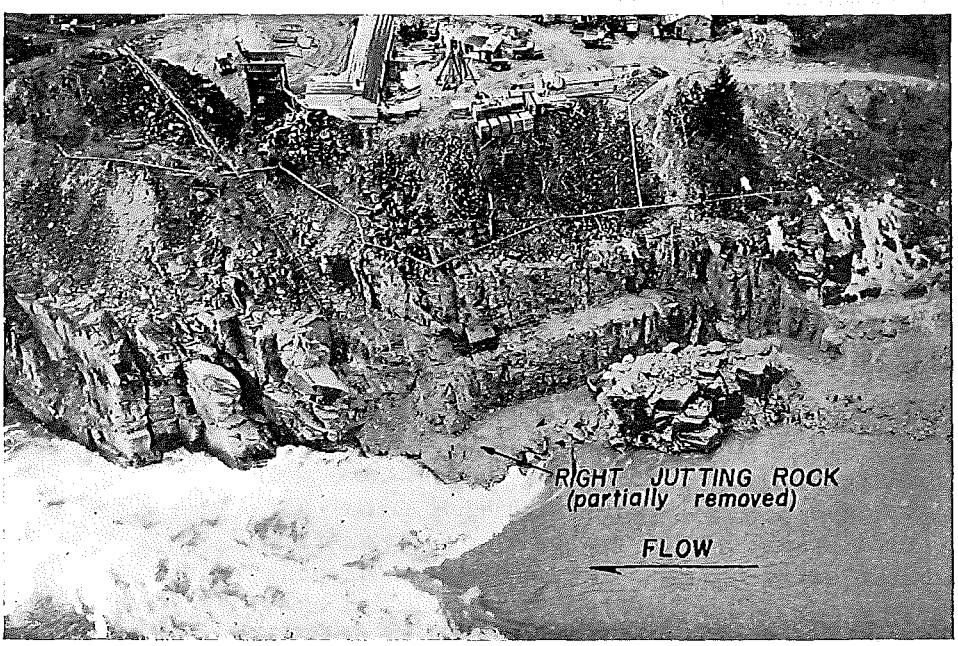
in the river. C. W. Harris, Professor of Civil Engineering, University of Washington, was retained as the Hydraulics Consultant, and E. S. Pretious, Assistant Professor of Civil Engineering, University of British Columbia, was retained as a Hydraulic Engineer to construct and operate the model. The model has become a most valuable tool. The available discharge records, the surveys of the marginal drops, the studies of the velocity paths with the known differences in elevation made possible the accurate calibration of this model.

It was decided to try various schemes in the model for possible remedial action, the first step being the removal of certain sections of the bank. The model was cast of concrete in a manner that would permit adjustment to the banks. The "right jutting rock" and bank area were removed with interesting results in that the pool above dropped some two feet at gauge 25, but at gauge 50 this drop was only one-half foot. The "left jutting rock" and bank area were removed with equally interesting results. At gauge 25 the pool dropped only a few inches but at 50 some two feet of drop in pool level above the Gate was recorded. A combination of the removal of both left and right jutting rocks and bank areas gave, from gauge 25 to gauge 50, a drop in pool level of only 2½ to 3 feet. These excavations introduced high velocities along the bank, and completely altered the pattern of flow, the upwelling, and the possible paths of travel for the fish through the Reach. Obviously only the removal of the banks adjacent to the right and left jutting rocks was not the solution.

During the time that the model was being constructed and calibrated, two temporary remedial measures for assisting the fish runs of 1942 were being undertaken at the "left jutting rock" at Hell's Gate. One measure consisted of a brailing device with a flume which deposited the fish some 500 feet upstream from the Gate. The other was a temporary fish pass, blasted through the "left jutting rock," which had a dual purpose in that it made possible the study of the activities of the fish as well as acting as a temporary fish pass. This temporary pass being only six feet in width, however, limited the quantity of water for attraction. It was necessary to place the pass in such a position in the rock that the entrance was not favourably located in the eddy below the "left jutting rock" for attracting fish into the pass. The upper working limit before the pass drowned out was elevation 36. Sufficient numbers of fish passed through, however, to give a preview of the effects of the surge in the river, the use of slotted openings in the baffles, and indicated that any fishway would have to be carefully placed if used as a solution. It was further demonstrated, when considering marginal paths, that such paths would be more or less self-regulating. The temporary fishway embraced the use of conventional stop-logs to create the pools which again showed the limitations of this type of gravity fishway when flooded out both by surges and the rapidly changing river level. The river level change has amounted to more than 4 feet in a day at various times. It was also noted again that when changes were being made in the number of stop-logs for regulation of flow, fish refuse to pass through the fishways at that time. Again it was shown that there must not be changes in the pattern of flow if passes or fishways are to function at all times.



Hell's Gate, left bank, at close of 1944.



Hell's Gate, right bank, at close of 1944.

The special funds were exhausted before any plans were completed in detail. At the Commission's request to press to completion the final solution based upon the findings made both in the field and from the model, a skeleton staff carried on, awaiting an additional appropriation for the Engineering work.

A special appropriation was made in 1943 which made it possible to complete the model studies carried on during the interim and to add to the staff the necessary structural designers to go forward with the detailing of structures.

The basis of the model studies was that no alteration was to be made in the drop through the Gate and that no alteration was to be made in the flow pattern of the river by the remedial measures to be proposed. Two fishways were built into the model, the one on the right bank being 20 feet wide and 220 feet long, the one on the left bank being 20 feet wide for the first 160 feet and 12 feet wide for the remaining 300 feet. The left bank structure was designed to reduce the turbulence and surge at the "left jutting rock," or the place of entrance into this fishway. This change will permit fish to rest directly opposite the entrance to the fishway. Reduction in turbulence prevents the sharp changes of river level in the eddy, thus increasing the attraction to the fishway, as sudden changes have the bad effect of immediately increasing or arresting the attraction or entrance velocities. The exit end of this fishway was extended above the Gate into quiet water or a natural eddy at this point, and so tailored into the bank that no drop would be created by the water entering the exit channel and then flowing down over the bank. Were this exit placed parallel with rapidly flowing water, a drop would occur at the downstream edge of the exit channel which would adversely affect the path of those fish passing along this bank below elevation 25. The Left Bank fishway functioned from elevation 23 to elevation 55, or a range of 32 feet. On the right bank the fishway structure began at the point where the fish are now blocked at the "right jutting rock" and conducts the fish upstream to a small back eddy. This fishway will operate from elevation 20 to elevation 55, or a range of 35 feet. In order to assist the fish to the fishway entrance through the turbulent water below the right bank entrance, an auxiliary path in the form of a tunnel, 134 feet long, 12 feet wide and 42 feet high, was created. This path is auxiliary to the one the fish now use to arrive at the same point and no alteration has been made in the natural path, the actual tunnel to be driven in the solid rock wall starting at the Gate and continuing to the eddy which exists below the entrance to the right bank fishway.

A major problem involved was the creation of a suitable internal path in the fishway structures in order to pass the fish without injury or delay. The velocity through these structures, without using baffles, would approximate the same velocity now found in the central part of the river which would be prohibitive for passing fish. Pools had to be created by the use of baffles. It was known, and further proved by the operation of the temporary fishway, that such pools should not require adjustment during the time of passage of the fish. The baffles would have to create uniform conditions insofar as velocity and turbulence were concerned at all operating levels. Conventional horizontal baffles did not meet these conditions. Experiments went forward on the use

of openings in the baffles which would meet the requirements of self-regulation. The final solution was arrived at by the use of two vertical slots, 24 inches in width in each baffle to the full height of the structure. By directing the flow of water through these slots into the central portion of the next downstream baffle a pleasing pattern in each pool was created. These slots were adopted for all of the 20 foot wide sections. The designs permit one foot of difference in elevation between the pool levels in the 20 foot wide sections. With this design the pool velocity and head differences between pools remain constant at all operating levels, the only variable being the quantity of water flowing through the fishway. It was also found that it is possible to pass more water through these fishways than through a conventional type of fishway as the full depth of the pool can be used. This feature proves to be highly advantageous as it increases the attraction flow from the entrance. In order to provide for additional flexibility in these structures four adjustable features are included in the design. Entrance gates will be installed making it possible to vary the discharge velocity from the entrance opening. Wooden nose strips will be provided at all of the slotted openings, which, if removed, will materially increase the flow through the fishway. Gates, 13 feet in height from the floor and 3 feet in width, will be provided in each baffle which can be used to assist in clearing out any deposited sand or gravel and will, when open, increase the flow through the fishway by 50 per cent. Two Butterfly gates will be installed at the exit end of each fishway which will make possible the closing of the fishways for removal of any debris which might find its way through the protective gratings. The structures will be submerged at times as much as 30 feet and will be protected against damage by the use of trash racks at the entrance and deck grills over the full length of the fishway.

A major consideration in the investigations at Hell's Gate has been the need of developing a plan which required a minimum of time for study and design to eliminate further costly losses of fish life there. Annual loss to the sockeye fishery has exceeded, and can again exceed many times the cost of correcting the block. The fishways, as described, will more nearly meet the many requirements for a solution to eliminate the Hell's Gate Block than would any any other scheme studied.

SCIENTIFIC MANAGEMENT OF THE FRASER RIVER SOCKEYE

by

W. F. THOMPSON

Everyone wants a large run of salmon every year in the Fraser River, but from the technical viewpoint the road to that is through much work and a deep understanding of the needs of the sockeye.

The sockeye salmon treaty was adopted to perpetuate and increase the catch of sockeye. The knowledge of how to do this must be obtained and this knowledge must apply to the catch in a direct and definite way. It is only what has happened in the past that will show what present needs are. There are other facts required, of course. To make regulation efficient and practical, information as to the industry and the fishing fleet may be needed, but is secondary to the understanding of what is to be remedied by this regulation. To divide the catch, so that political and economic difficulties in the functioning of the treaty may be avoided, is necessary but is not the purpose of the treaty. Either of these two, the details of regulation or the arrangements to share the catch, is administrative in nature and can be assisted by technical knowledge if necessary. But to the difficult task of understanding the needs of the fishery, all the skill and patience of purposeful scientific research should be brought.

For guidance in such a program of research, for a means of analysis of what has happened, and as an aid to future management, an index to the good and bad fortunes of the runs is needed. It must measure the success of each year's run, past and future, in reproducing itself by a return of its offspring from the sea. This is as basic to the work of the treaty as account books are to a business.

A scientific report has been prepared, dealing with the effect of the obstruction at Hell's Gate upon the catch of sockeye salmon. Not the least interesting and significant part of this report is the orderly treatment of existing statistics of the fishery, to form the index, showing the causes of depletion and tracing the year by year effect of obstructions upon the productivity of the river. Because it is the first intensive study of the Fraser River sockeye runs by such means, it brings many things to light.

To do this graphs of the index values have been made showing how successful each annual run has been in reproducing itself four years later. Such graphs cover many years, and are made effective by the care used to express the condition of the fishery in a uniform fashion for each year. The method developed is usable, not only for study of the obstruction, but for any other condition which affects the catch. For that reason it is of general interest.

The obstruction at Hell's Gate has been typical of the problems which the Commission will encounter in preserving and increasing the run of sockeye. Its effect shows clearly in the index, and from this effect it has been possible to find the cause. It has been the reason for a high death rate in certain races that were already under a strain from the commercial fishery. It is this death rate, natural or man-produced, which the sockeye salmon treaty was designed to control. The effects of the obstruction were comparable to, and in some ways the same as, those of overfishing, because they both contributed to the death rate. If overfishing is ultimately found to occur, it may possibly appear first in the weakest parts of the species such as those races which endure unfavorable conditions. There are undoubtedly many such conditions other than the Hell's Gate water levels.

It is known that species can withstand heavy mortalities at one stage of life because under natural conditions they can compensate for them by a higher survival rate at other stages. Otherwise the sockeye and other salmon would have long ago vanished under even a moderate fishery. But the question will always be as to when and in what part of the species the natural plus the man-made death rate will prove to be too much for this resilience. It can only be answered when the effect appears in the run, consequently in the catch taken from it, and when this effect is traced to its cause, if necessary by study of each race on its spawning grounds. So the basic method of research upon the effect of obstructions and of fishing is the same, **to devise such means as will show whether and when and how the mortality exceeds the power of the species to compensate,** thus causing the run to decline.

This means that the run must be compared from year to year, with accuracy sufficient to measure the success it has in reproducing itself. To do this there is needed some form of historical treatment based on a standardized record of catches.

In fisheries which depend on species such as the halibut, living a long period of years during which the individuals are subject to capture, the success of reproduction in any one year is distributed over many years of catch. The resultant stock is a mixture of the fish produced over a long period. It is possible in such a fishery to use the **catch per unit of gear** as a measure of this combined abundance. However, it does not indicate the success or failure of any one year's spawning without a complicated and difficult age analysis to segregate the yield from that of other years. This catch per unit of gear, as used in the halibut fishery, is an index, but it is not one that can be used in the salmon except as will appear below.

In the sockeye salmon each generation is spawned by parents which die at once. The new generation returns, usually as four-year-olds, to become a parent run in its turn. It is then possible to follow a run from generation to generation, the catch from each generation being distinct in high degree. It is not a mixture of survivors from many spawnings as is true of species other than salmon. The successive generations of the same group of races and of the same year of the

cycle can be compared to give year by year index values to the success of the return of the individual runs.

This method has been used in a rough and ready fashion by the salmon fishermen and canners from the beginning of the salmon industry, just as the catch per unit of gear has been by halibut fishermen, who show in their logs the records of changing success in making a catch from their favorite grounds. It was many years before this common-sense index was built into a continuous, well authenticated record of what had happened to the halibut fishery. And this is what is planned for the salmon, to be done in a systematic way by building a method of keeping statistics.

An index using the catch alone is easily calculated in the same manner that the industry has compared the catch in any year with what was expected from the catch of the parent year. The run of 1900 produced a return of 50 per cent, when the catch in 1904 fell to a half that of the parent year, and this percentage can be said to indicate the success of the parent run of 1900 in reproducing itself through all the vicissitudes of fresh and salt water life. This can be done to obtain the values for all the successive years of the record. But it takes no account of the size of the escapement to the spawning grounds, the variable proportion which the catch forms of the total, and the distribution of the return over more than one year because not all sockeye are four years old on return from the sea.

To make such an index acceptable and usable, either the limits within which the index values will vary must be given, or the escapement must be determined with precision. Even at present the latter is an almost impossible task in the Fraser River, because its cost would be prohibitive, and it certainly cannot be done for the years that are past. It remains to define the limits which make this seemingly simple index usable by the Commission staff in a practical form. To do so requires a somewhat mathematical approach. This is explained in full in the report and is given in a shortened form here.

The limits of the index as they are affected by the escapement can be readily set by assuming conditions that are frankly just beyond what is probable. This can be done by assuming that the escapement is practically non-existent at one extreme, and by assuming that it is so large as to make the catch inconsiderable in comparison at the opposite extreme. The two will include all the possible variations.

If there is no escapement, then the catches include the whole of the runs. The ratio of the catches, and hence of the runs as a whole, can be stated by using the letter C with a subscript, thus: C_o or C_4, to identify whether it belongs to the parent year or the year of return. The ratio is $\frac{C_4}{C_o}$ if the return is to be in terms of a fraction of the parent run, which can be readily given as a percentage if desired.

If, on the contrary, the escapement is very large, so that the catch is by comparison very small, then the take of each piece of gear will not be sensibly

diminished by the catches previously made by other gear; and in consequence each individual catch will reflect the size of the whole run, not of a fragment left by other gear. Then the total catch of each year will vary as the amount of gear used. It follows that the runs in two years can be compared by using the average catch of a unit of gear. For convenience, the letter f can be used to indicate the amount of fishing in terms of what may be called average units of gear, again with a subscript to identify the year, thus: f_o and f_4. Then the average catches of a unit are $\frac{C_4}{f_4}$ and $\frac{C_o}{f_o}$. Because they vary as do the total runs of the two years, the ratio of the return run to that of the parent year will be $\frac{C_4}{f_4}$ divided by $\frac{C_o}{f_o}$ and when this is done it can be stated as $\frac{C_4}{C_o} \cdot \frac{f_o}{f_4}$.

These limits, $\frac{C_4}{C_o}$ and $\frac{C_4}{C_o} \cdot \frac{f_o}{f_4}$, arrived at by considering the escapement, also include the extremes as far as gear competition is concerned. When there is no escapement the chances of the last gear to take fish have been reduced to the minimum possible by maximum competition. They could be no smaller had the amount of gear been infinite. Then the first limit applies. But when escapement is very large so the catch is inconsiderable by comparison, the chances of any piece of gear are not noticeably reduced and there is no gear competition. Then the second limit holds.

To secure the most probable value between these limits there is a mathematical way of expressing the actual competition of gear. Instead of the actual number of units of gear, a figure is used reflecting the reduction which competition makes in their efficiency. Without explaining the mathematics, the ratio of the total runs to give the desired percentage becomes $\frac{C_4}{C_o} \cdot \frac{1 - e^{-f_o r}}{1 - e^{-f_4 r}}$ In this the letter r stands for the theoretical fishing capacity of the average unit of gear.

The average unit of gear, f, is arrived at by finding the relative catching power of such gear as traps, purse-seines, and gill-nets from their records over a series of years, and by stating them all in terms of one of the types, preferably gill-nets as the smallest unit.

By mathematics, it is then possible to show that the last ratio given, the most complicated one, becomes equal to one or the other of the first two limits when the escapement reaches its extremes. But this cannot be discussed here.

The value of the index is dependent upon the accuracy with which the amount of fishing can be determined. We may be frankly skeptical as to this in the past records of the fishery. But from what we have, it is possible to calculate the limits as far as we can know them, and see whether they affect any conclusions that may have been drawn. If the limits do not affect these conclusions then the size of the escapement and the degree of competition in the gear is immaterial. This makes the index a very usable and convenient one. In practice, the limits are not far apart, and coincide when fishing becomes equal from year to year.

As a matter of fact, if the amount of fishing is not known for the whole fishery, the index can be calculated from whatever part is adequately known, and doubt as to the total amount of gear fished can thus be avoided. The effect of the age of the fish at return must also be considered. This, too, can be incorporated in the index by reasonably simple means. The necessity and the method of doing these two things are described in the scientific report upon which this summary is based.

The advantages of such an index are many. It should tend to concentrate the attention of research men upon those problems which actually affect the catch. It provides a channel of attack upon these practical problems, and should help to avoid random life history research upon the salmon. It gives meaning and direction to a research program.

In a river such as the Fraser, there is no way of precisely determining the escapement, hence the degree to which the index can be used without knowledge of the escapement makes it a most valuable asset. Moreover, there is a decided advantage in direct comparison of the parent and return runs, such as it provides. It is apparent that the size of the escapement in successive years is not likely to be a good criterion of the success of reproduction. Not only is the species capable of compensating itself to some degree, perhaps very considerably, for a reduction in the number of spawners, but it is fair to assume that the number of these required by different races in different years must vary widely just as environments differ. After all, there can be no means of judging how many there should be except by the ultimate return of the offspring required to maintain the yield. If that is true, it should be logical to proceed directly to a measurement of the end result of any particular degree of restriction or of any alteration in conditions, rather than to depend entirely on a difficult intermediate step such as a count of the escapement which must vary with conditions as yet unknown.

By the very nature of the index it furnishes values which are independent, one year from the other. The success of return is determined for each year separately. The clear-cut contrast between adjacent years can then be compared with the year by year variations in any factor which may be under investigation and not solely with averages or trends. The way in which variations will occur, by chance or by virtue of the peculiar circumstances governing them, should make possible more ready identification of their causes. In the report on the obstruction, the effect of the delay below it can thus be traced by corresponding fluctuations in the catch as shown in the index. The value of this in the comparison between fishing and the catch can be readily understood when it is seen that the amount of fishing in adjacent years varies widely, and the pattern of this variation should be reflected by the index. If fishing is too great a considerable year by year range in its amount is presented for study of its effects upon the catch. It is in the extreme manifestations of any factor that its effect can best be detected, and overfishing should show first in the years when fishing is heaviest.

There are many problems before such an index is fully usable, and these problems form a program of investigation for statisticians and biologists. The statisticians must determine the catch and the amount of fishing more accurately, and from these determine the values of the index. The biologists must obtain adequate samples of the runs, show what the age composition is, and study the fortunes of the several races. The stream observers must determine the escapement as closely as possible in each spawning stream because each race contributes to the index values. And in the end the index values must be analyzed to find out why and where they vary, whether it is because of what has happened in the gravel, in the lake, or in the sea, because of obstructions to migration, or because of the fishery. There should be definite changes upon which research can be focused. Whenever any scientist can secure any data as to what is happening in the environment of the sockeye salmon or in the fishery, the staff of the Commission should have available a means of determining whether the supply of sockeye is actually affected.

It is fortunate that the utility of the index could be tested in studying the effect of the obstruction at Hell's Gate. It has yielded a history of the Fraser River runs which explains acceptably what has happened to the catch in two great periods of depletion. It has shown the continuing effects of the obstruction at Hell's Gate.

The dangerous water levels there end sometimes early and sometimes late during the months of September and October. Their effect increases as they extend into new parts of the season, or diminishes when they are confined to July and August. The varying duration of the resultant periods of delay in passage has been expressed as another index for comparison with the index of success of return of the runs.

It was hardly to be expected that the degree of correlation between these two would be very close when all the sources of error in calculating the indices are considered. But at the time this is written the correlation has been found to be high, and significant even by rigorous scientific tests. For further information on this, reference must be made to the report upon which this explanation is based. It seems to the writer that the successful application of an index in this study at Hell's Gate proves that it can be used.

Its use has been productive even when it was based on the somewhat crude statistics available for past years. What will the more accurate records and broader biological knowledge of the future show?

SOCKEYE SALMON TAGGING AT THE SALMON BANKS, ICEBERG POINT, LUMMI ISLAND, AND THE SAND HEADS

by

DONALD C. G. MacKAY, GERALD V. HOWARD,
and STANLEY R. KILLICK

INTRODUCTION

This is the second in a series of preliminary reports dealing with the tagging of sockeye salmon by the International Pacific Salmon Fisheries Commission. The results obtained from tagging at Sooke and Johnstone Strait have been reported previously (MacKay, Howard, and Killick, 1944) and it now seems desirable to present a corresponding report on the results of tagging at Salmon Banks in the San Juan Islands, Iceberg Point, Lummi Island, and the Sand Heads. For the remaining tagging locations (West Beach, Point Roberts, and Rosario Strait) the number of tags placed was too small to warrant analysis at this time.

Tagging was carried out in the areas herein considered, as follows: Salmon Banks 1939-1941, Iceberg Point 1939-1941 (but with very small numbers in 1940 and 1941), Lummi Island 1939-1941, and Sand Heads 1938-1941.

The chief aims of the present analysis were to ascertain the times taken in migration, to learn something of the migrating behavior, to determine whether the "races" of migrating salmon segregate en route, and to discover the destinations of migrating salmon.

METHODS

The method used in tagging at the Salmon Banks, Iceberg Point, Lummi Island (except in 1941), and at the Sand Heads of the Fraser River was essentially the same as that employed in Johnstone Strait. This method has been described previously (1944) by the present authors. The salmon were obtained directly from the purse seiners. At the Sand Heads in 1941 the Commission used a chartered seine boat and did their own fishing.

The tagging at Lummi Island in 1941 was carried out by a different method. The tagging crew was stationed at Legoe Bay, and sockeye for tagging were purchased from reef-netters working in the bay. The actual tagging was carried out from a rowboat.

Posters were widely distributed offering a reward for tags returned with the following information: (1) date of capture, (2) place of capture, (3) kind of gear used, and (4) vessel making catch.

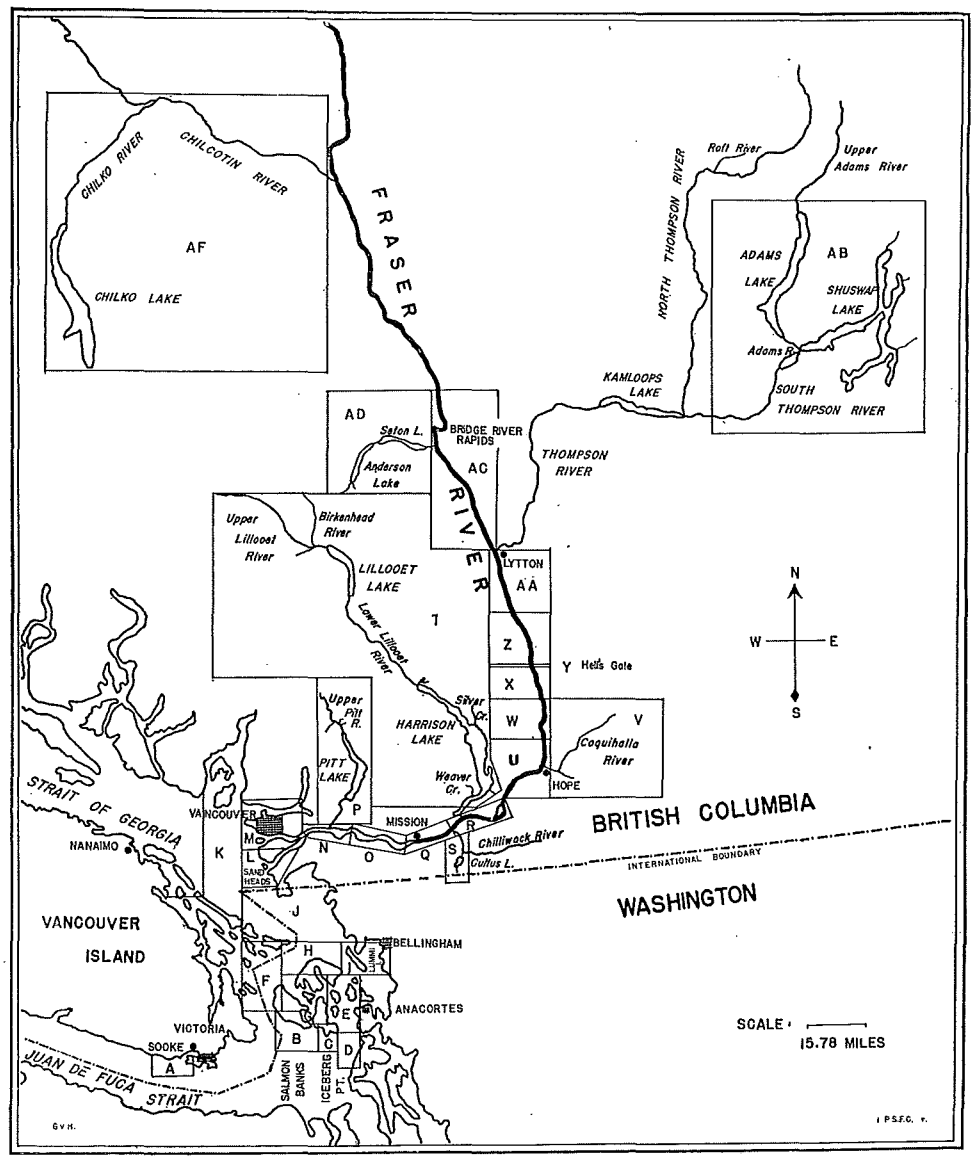


Fig. 1

Map showing recovery areas for tagged sockeye salmon.

For purposes of analysis and presentation, the tag recoveries have been grouped into large areas (see Figure 1) in the same manner as was done in the first report. While these areas are to a large degree arbitrary, they do conform as nearly as possible to established fishing areas and spawning areas.

RESULTS

Recoveries

1. Salmon Banks

Sockeye salmon tagging was carried out at the Salmon Banks during the seasons of 1939-1941 inclusive. Thirteen hundred and thirty-seven tags were put on in 1939, 869 in 1940, and 376 in 1941, or a total of 2,582 tags for all three years. The recoveries from this experiment totalled 1,635 or 63.3% of the total number tagged (see Table I).

The majority of tags were recovered from the Canadian commercial fishery (886 or 54.2% of the total recovered). The United States commercial fishery yielded 563 or 34.4% and the Fraser River watershed 115 or 7.0%.

In tagging experiments some tags are nearly always returned with information that is obviously incomplete or inaccurate. Such tags are referred to as "questionable" in the present paper and 71 or 4.4% of the Salmon Banks returns have been so classified.

During all three years only 57 tags were returned from the major spawning grounds (see Table II). These 57 tags were distributed as follows: 17 from the South Thompson, 15 from the Harrison-Birkenhead district, 11 from the Chilcotin, 9 from Cultus Lake, and 5 from the Pitt River.

During the same period the principal Indian fishing stations returned 54 Salmon Banks tags of which most (41) were recovered in the Fraser River Canyon between Hope and Lytton (see Table III). Nine were recovered from below Hope and 4 from between Lytton and Bridge River Rapids.

Each year a few tagged salmon were recovered at Hell's Gate, minor spawning grounds, and small Indian fishing stations. However, since the number is small they have not been tabulated separately; they are included under the heading of Fraser River watershed in Tables I, IV, V, and VI.

For a discussion of the time between tagging and recovery, retrograde migration, and of a possible delay off the mouth of the river, see later sections of this report.

2. Iceberg Point

Tagging at Iceberg Point, approximately 4 miles southeast from the Salmon Banks (see Figure 1), was carried out during the seasons of 1939-1941 inclusive. However, since only 58 sockeye were tagged in 1940 and only 70 in 1941 the returns for these two years are not included in the present preliminary analysis.

Table I

SALMON BANKS TAGGING SUMMARY 1939 - 1941

	1939			1940			1941			All Years		
	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged
Total Tags Placed	1,337			869			376			2,582		
Recoveries												
(a) U. S. Commercial Fishery	331	35.4	24.8	163	34.0	18.8	69	31.4	18.4	563	34.4	21.8
(b) Canadian Commercial Fishery*	496	53.0	37.1	254	53.0	29.2	136	61.8	36.2	886	54.2	34.3
(c) Fraser River Watershed	70	7.4	5.2	34	7.1	3.9	11	5.0	2.9	115	7.0	4.5
(d) Questionable Recoveries	39	4.2	2.9	28	5.9	3.2	4	1.8	1.1	71	4.4	2.7
Total Recovered	936	100.0	70.0	479	100.0	55.1	220	100.0	58.5	1,635	100.0	63.3

* Treaty waters only.

Table II

TAGGING RECOVERIES FROM THE MAJOR SPAWNING GROUNDS

TAGGING LOCATION		1938	1939				1940			1941			1939 - 1941			Per 1000 fish Tagged 1939-1941		
		Sand Heads	Iceberg Point	Salmon Banks	Lummi Island	Sand Heads	Salmon Banks	Lummi Island	Sand Heads	Salmon Banks	Lummi Island	Sand Heads	Salmon Banks	Lummi Island	Sand Heads	Salmon Banks	Lummi Island	Sand Heads
MAP AREA		L	C	B	I	L	B	I	L	B	I	L	B	I	L	B	I	L
NUMBER TAGGED		2585	974	1337	1144	2352	869	724	82	376	690	1743	2582	2558	4177			
RECOVERIES Location	Map Area																	
South Thompson*	AB	362	6	16	10	80	1	2	1	0	0	0	17	12	81	6.6	4.7	19.4
Chilcotin	AF	0	0	0	0	0	11	2	0	0	0	3	11	2	3	4.3	0.8	0.7
Harrison-Birkenhead	T	38	4	6	6	27	7	7	1	2	1	33	15	14	61	5.8	5.5	14.6
Cultus Lake	S	0	4	5	0	20	4	0	2	0	0	1	9	0	23	3.5	0.0	5.5
Pitt River	P	0	4	5	3	0	0	0	0	0	0	0	5	3	0	2.0	1.2	0.0
Totals		400	18	32	19	127	23	11	4	2	1	37	57	31	168	22.0	12.1	40.2

* There were very small runs to Adams River in 1940 and 1941 and there was a long blockade at Hell's Gate in 1941.

Table III

TAGGING RECOVERIES FROM THE PRINCIPAL INDIAN FISHING LOCATIONS

TAGGING LOCATION		1938	1939				1940			1941			1939 - 1941			Per 1,000 fish tagged 1939 - 1941		
		Sand Heads	Iceberg Point	Salmon Banks	Lummi Island	Sand Heads	Salmon Banks	Lummi Island	Sand Heads	Sand Heads	Lummi Island	Sand Heads	Salmon Banks	Lummi Island	Sand Heads	Salmon Banks	Lummi Island	Sand Heads
MAP AREA		L	C	B	I	L	B	I	L	B	I	L	B	I	L	B	I	L
NUMBER TAGGED		2,585	974	1,337	1,144	2,352	869	724	82	376	690	1,743	2,582	2,558	4,177			
RECOVERIES Location	Map Area																	
Below Hope	Q R U	16	14	3	8	27	1	5	1	5	4	36	9	17	64	3.5	6.6	15.3
Hope to Lytton	W, X Z AA	164	23	30	42	258	7	6	2	4	1	64	41	49	324	15.9	19.2	77.6
Lytton to Bridge River Rapids	AC	3	2	3	0	18	1	6	0	0	0	0	4	6	18	1.6	2.4	4.3
Totals		183	39	36	50	303	9	17	3	9	5	100	54	72	406	21.0	28.2	97.2

In 1939, 974 tags were placed at Iceberg Point of which 605, or 62.1%, were recovered (see Table IV). The majority of the redeemed tags were obtained from the Canadian commercial fishery (336, or 55.5%). The United States commercial fishery provided 190, or 31.4%, and the Fraser River watershed 59, or 9.8%. "Questionable" recoveries constituted only 20 or 3.3% of the total returns.

Table IV

ICEBERG POINT TAGGING SUMMARY 1939

	No. of Tags	% of Total Recoveries	% of Total Tagged
Total Tags Placed	974		
Recoveries			
(a) U. S. Commercial Fishery	190	31.4	19.5
(b) Canadian Commercial Fishery*	336	55.5	34.4
(c) Fraser River Watershed	59	9.8	6.1
(d) Questionable Recoveries	20	3.3	2.1
Total Recovered	605	100.0	62.1

* Treaty waters only.

3. Lummi Island

The tagging program at Lummi Island was conducted during the seasons of 1939-1941 inclusive. The number of salmon tagged totalled 2,558 of which 1,337 or 52.3% were recovered (see Table V). As with tagging at the Salmon Banks the majority of recoveries were obtained from the Canadian commercial fishery (872 or 65.2% of the number recovered) with the United States commercial fishery second (323 or 24.2%). Recoveries from the Fraser River watershed numbered 110 or 8.2% and the "questionable" recoveries were only 32 or 2.4%.

The percentage of recoveries from the Canadian commercial fishery was higher (see Table V) in the odd years (1939 and 1941) than in the even year (1940). This is in agreement with the observations of the present authors in their previous paper with respect to the Sooke and Johnstone Strait tagging experiments. In the odd years the intensive fishing for pink salmon, which involves similar gear, increases the fishing effort.

Recoveries from the major spawning grounds for all three years totalled only 31 of which 14 were from the Harrison-Birkenhead district, 12 from the

Fig. 2
Tagging at the mouth of the Fraser River, September, 1938.

Table V

LUMMI ISLAND TAGGING SUMMARY 1939 - 1941

	1939			1940			1941			All Years		
	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged
Total Tags Placed	1,144			724			690			2,558		
Recoveries												
(a) U. S. Commercial Fishery	132	21.9	11.5	92	27.5	12.7	99	24.8	14.3	323	24.2	12.6
(b) Canadian Commercial Fishery*	390	64.7	34.1	198	59.3	27.3	284	71.0	41.2	872	65.2	34.1
(c) Fraser River Watershed	72	11.9	6.3	31	9.3	4.3	7	1.7	1.0	110	8.2	4.3
(d) Questionable Recoveries	9	1.5	0.8	13	3.9	1.8	10	2.5	1.5	32	2.4	1.3
Total Recovered	603	100.0	52.7	334	100.0	46.1	400	100.0	58.0	1,337	100.0	52.3

* Treaty waters only.

South Thompson region, 3 from the Pitt River, and 2 from the Chilcotin River system (see Table II).

From the principal Indian fishing locations 72 Lummi Island tags were redeemed of which 49 were from the Hope to Lytton section of the river, 17 from below Hope, and 6 from Lytton to Bridge River Rapids (see Table III).

4. Sand Heads

The tagging experiment at the Sand Heads was conducted during the four years 1938-1941 inclusive. Six thousand seven hundred and sixty-two salmon were tagged of which 4,039 or 59.7% were recovered (see Table VI). The percentage of returns was highest in 1939 when it reached 75.3 (1,770 returns from 2,352 tagged sockeye). The majority of the recoveries came from the Canadian commercial fishery (2,697 or 66.8%) with the Fraser River watershed next (1,169 or 28.9%) and the United States commercial fishery third (103 or 2.6%). "Questionable" recoveries numbered 70, or 1.7% of the total number recovered.

Analysis of the results demonstrates that there is relatively little migration in a direction away from the Fraser River (see section on retrograde migration). The relatively small number (103) of tagged sockeye caught in the United States commercial fishery is therefore not surprising. The fish were tagged just off the mouth of the river and did not have to run the full gauntlet of the commercial fishery. For the distribution of returns from the spawning grounds see Table II.

In 1938 and 1939 the majority of the spawning ground recoveries were from the South Thompson district. In these years 90.5% and 63% of the total recoveries of 400 and 127 respectively were from this area. In 1941 the majority of tags (33 out of 37) were recovered from the Harrison-Birkenhead district. For the three years 1939-1941 inclusive (see Table II) there were 168 returns from the spawning grounds which were distributed as follows: South Thompson 81, Harrison-Birkenhead 61, Cultus Lake 23, and Chilcotin 3. When the returns for 1938 are included, the total recovered during all four years is found to be 568 and the totals for the various districts become 443, 99, 23, and 3 respectively.

Recoveries from the principal Indian fishing locations (see Table III) for the three years 1939-1941 inclusive totalled 406 of which 324 were taken in the Hope to Lytton section of the river, 64 in the section below Hope, and 18 between Lytton and Bridge River Rapids. If the returns for 1938 are taken into consideration also, the totals become 589, 488, 80, and 21 respectively.

With the exception of 1940, when only 82 sockeye were tagged in the Sand Heads area, a higher percentage of returns was obtained from the Canadian commercial fishery in the odd years than in the even year 1938 — a conclusion that is in agreement with that for the Sooke and Johnstone Strait fisheries reported in the earlier paper.

Time Between Tagging and Recovery; Evidence of Delay En Route

Table VII shows the median number of days elapsing between the times of tagging and recovery for each of the major areas of recapture. The reasons

Table VI

SAND HEADS TAGGING SUMMARY 1938 - 1941

	1938			1939			1940			1941			All Years		
	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged	No. of Tags	% of Total Recoveries	% of Total Tagged
Total Tags Placed	2,585			2,352			82			1,743			6,762		
Recoveries															
(a) U. S. Commercial Fishery	66	5.5	2.5	36	2.0	1.5	0	0.0	0.0	1	0.1	0.1	103	2.6	1.5
(b) Canadian Commercial Fishery*	550	45.1	21.3	1,266	71.6	53.8	36	83.7	43.9	845	83.8	48.4	2,697	66.8	39.9
(c) Fraser River Watershed	585	48.0	22.6	436	24.6	18.6	7	16.3	8.5	141	14.0	8.1	1,169	28.9	17.3
(d) Questionable Recoveries	17	1.4	0.7	32	1.8	1.4	0	0.0	0.0	21	2.1	1.2	70	1.7	1.0
Total Recovered	1,218	100.0	47.1	1,770	100.0	75.3	43	100.0	52.4	1,008	100.0	57.8	4,039	100.0	59.7

* Treaty waters only.

for using the median rather than some other measure of central tendency were given in the first report and will not be repeated here. It should be stated that during the interval between tagging and recapture the fish do not necessarily move continuously or consistently toward the river mouth. However, as is shown elsewhere in this paper, movement away from the river appears to be of minor importance. Delay off the mouth of the river is known to occur, especially in certain years, and will inevitably add to the time required to reach the up-river areas.

In experiments of this kind some salmon are usually recovered within a few days in the area in which they were tagged. The number of such cases and the interval between tagging and recovery may be found in Table VII in the present instance. For example, it will be seen that 87 salmon tagged at Salmon Banks were recovered in that area (Area B on map) after a median interval of 2 days.

With a few exceptions, the time in days required to reach a given destination increases directly with the distance from the point of liberation (see Table VII). The table shows that the median time from Salmon Banks to the mouth of the Fraser River varied between 9 and 29 days in different years, that from Lummi Island it was 7 to 18.5 days, and from Iceberg Point 28.5 days. Where it is possible to compare the returns for 1939 and 1940 it is seen that the number of days is shorter for 1940 in almost every instance. The time taken to reach Adams River in the South Thompson (Area AB on map) was 68 days from Salmon Banks in 1939, 56 days from Lummi Island in the same year, and 49 and 39 days from the Sand Heads in 1938 and 1939 respectively.

A comparison of the median migration times with those previously obtained for Sooke and Johnstone Strait would be of interest. However, because of the large number of items it would be impracticable to mention more than a few. It was shown, for example, that the time required for migration from Sooke to Point Roberts was 6 to 7 days. In Table VII it is shown that the time to Point Roberts was 4 to 6 days from Salmon Banks, 3 to 7 days from Lummi Island, and 6 days from Iceberg Point. Comparable conclusions cannot be given for the Sand Heads data because of the location of this tagging area (see Figure 1).

For Sooke and Johnstone Strait it was found that, in a majority of the areas of recapture, fish tagged in 1941 were recaptured in the shortest median times. A similar conclusion is justified in the present instance from the results presented in Table VII; the chief exceptions are to be found among fish tagged at the Sand Heads.

The results of the investigation indicate that a definite delay occurs at all points of tagging (see Tables VIII and IX and Figure 3). Whether this is a result of tagging or whether it is a natural phenomenon is not known at the present time. This delay is quite pronounced at the Salmon Banks and at the mouth of the Fraser River; it is less evident at Lummi Island. The large number of recoveries at the Sand Heads results from the large commercial fishery in that vicinity in addition to the fact that the salmon delay off the mouth of the river for varying lengths of time before migrating up-river.

Table VII

Median number of days between times of tagging and recovery for areas shown on map. Minimum size of sample = 10 returns. Numbers in parentheses represent sample sizes.

Place of Recovery	Map Area	TAGGING STATIONS										
		Salmon Banks			Lummi Island			Sand Heads				Iceberg Point
		1939	1940	1941	1939	1940	1941	1938	1939	1940	1941	1939
Salmon Banks	B	2 (87)	2.5(32)	1 (21)	4 (15)							4 (35)
Iceberg Point	C	4 (13)	2 (14)									1.5(14)
West Beach	D	3 (30)			4 (11)							3 (17)
Rosario Strait	E		3 (10)									
Haro Strait - Stuart Island	F	2 (36)										
Lummi Island	I	4 (32)	4 (18)		3 (14)	2 (15)						6 (17)
Point Roberts	J	6 (87)	4 (62)	4 (19)	7 (72)	4 (54)	3 (72)	7 (60)	6.5(26)			6 (82)
Gulf of Georgia	K	28 (20)			35 (10)			7 (47)				30 (13)
Mouth of Fraser	L*	29 (279)	16 (135)	9 (78)	18.5(250)	8 (122)	7 (197)	10 (343)	16 (806)	11 (24)	14 (497)	28.5 184)
N. Arm of Fraser	M	20 (107)	9 (47)	9 (23)	14 (75)	8 (39)	7 (49)	8.5(52)	13 (130)		12 (91)	14.5(74)
N. Westminster - Haney	N	45 (48)	18 (39)	17.5(20)	23 (36)	14 (27)	15 (27)	29 (57)	17 (237)	21.5(10)	13 (154)	44 (38)
Haney - Mission	O	51 (26)	16 (21)	14 (11)	34 (13)			28 (17)	17.5(58)		13.5(60)	40.5(18)
Cultus Lake	S								60 (20)			
Harrison River System	T							37 (38)	27.5(26)		42 (32)	
Laidlaw to Emory Creek	U								25.5(20)		59 (31)	
Emory Creek to Spuzzum	W										49 (37)	
Spuzzum to Hell's Gate	X								49 (13)			
Hell's Gate to Keefers	Z	56 (25)			48.5(30)			28 (80)	31.5(198)		43 (21)	55 (19)
Keefers to Lytton	AA								19 (31)			
Adams R. & S. Thompson	AB	68 (14)			56 (10)			49 (354)	39 (77)			
Lytton to Lillooet	AC								9 (14)			
Chilko River	AF		29 (11)									

* This area includes Sand Heads.

Table VIII

Comparison of days out before recapture of fish tagged during periods of August 10 - August 23, August 24 - September 6, September 7 - September 20 and September 21 - 29 (each date inclusive) for sockeye salmon tagged at the Sand Heads during the years 1938, 1939, and 1941. The number of days out is the median. Sample size (10+) is in parenthesis.

		SAND HEADS TAGGING			
		Days Out		Days Out	
Area	Year	Aug. 10—Aug. 23	Aug. 24—Sept. 6	Sept. 7—Sept. 20	Sept. 21—Sept. 29
L	1938		7 (231)	27 (112)	
	1939		11 (78)	24 (266)	13 (462)
	1941	5.5(142)	15 (37)	14 (251)	
N & O	1938		31 (33)	25 (41)	
	1939		26 (23)	24 (123)	11 (149)
	1941	9.5(26)	16 (12)	14 (140)	
T	1938		41 (26)	32 (12)	
	1939		33 (10)	24 (15)	
	1941			45.5(22)	
Z	1938		32 (40)	23.5(40)	
	1939		41.5(16)	29 (89)	33 (93)
	1941			35.5(16)	
AB	1938		52 (160)	45 (194)	
	1939		45.5(10)	38 (52)	32 (15)
	1941				

From the Salmon Banks and Lummi Island to Point Roberts no prolonged delay is indicated; however, a distinct delay is evident off the mouth of the Fraser River (see Table IX). This delay becomes longer as the season progresses — until at least September 10. The delay appears to have been least in 1941 when the salmon passed through the commercial fishery quite rapidly. This confirms a similar finding based upon the tagging at Sooke.

From the Sand Heads the delay off the mouth of the Fraser becomes longer as the season progresses up to the period of September 7 - September 20; after this date the delay decreases. This finding is made possible by the fact that tagging was carried out in this locality until a later date than in any other tagging location used by the Commission. The delay at the Sand Heads after September 7 - September 20 was shorter in 1941 than in the other years.

The results further indicate that sockeye salmon migrating from Salmon Banks and Lummi Island to the mouths of the Fraser River did so in a shorter time during the early half of the tagging season (July 13 - August 9) than during the later half (August 10 - September 6) of the season. This finding is also in agreement with the results obtained from the tagging at Sooke. It should be pointed out, however, that this observation applies only to migrations in salt water and in the lower parts of the Fraser River.

Table IX

Comparison of days out before recapture of fish tagged during periods July 13 to August 9 inclusive, and August 10 to September 6 inclusive, for sockeye salmon tagged at Salmon Banks and Lummi Island during the years of 1939 - 1941. The number of days out is the median. Blanks occur where sample size was smaller than 10. Sample size is in parenthesis.

		SALMON BANKS TAGGING		LUMMI ISLAND TAGGING	
		Days Out		Days Out	
Area	Year	July 13—Aug. 9	Aug. 10—Sept. 10	July 13—Aug. 9	Aug. 10—Sept. 10
I	1939	4 (15)	4 (17)		
	1940	4 (14)	———		
	1941	———	———		
J	1939	5 (21)	6.5(66)	6 (27)	8 (45)
	1940	4 (51)	4 (11)	4 (51)	———
	1941	4 (11)	———	3 (62)	———
L	1939	29 (103)	32 (176)	7 (91)	27 (159)
	1940	9 (45)	25.5(90)	7 (89)	13 (33)
	1941	6 (19)	11 (59)	7 (140)	7 (40)
N & O	1939	50.5(32)	46 (42)	16.5(22)	37 (27)
	1940	8 (31)	48 (29)	14 (23)	10.5(10)
	1941	12.5(14)	23 (17)	11 (15)	25 (11)

A comparison of the "days out" from the date of tagging to the date of recovery is found in Tables VIII and IX. These tables show the changes in the migration rate at different periods of the season to five major recovery areas including the point of tagging. In Table VIII, Area L (the Sand Heads) represents the point of tagging and it should be noted that in two years out of three the delay evidenced off the main channel of the Fraser mouth reaches its peak between September 7 and September 20. Thereafter the rate of migration appears to be accelerated.

Although Hell's Gate is approximately half way between the tagging areas and the Adams River, the sockeye took a longer time to traverse the distance to Hell's Gate than to cover the remaining distance to Adams River (see Table VII). The delay in the commercial fishing areas was primarily responsible for this characteristic migration but varying water levels at Hell's Gate and other factors may have been responsible also.

The data are limited but there is a definite indication that the Chilko River run arrives at the spawning grounds from the various tagging areas in a shorter time than does the Adams River run. It should be noted that these two spawning areas are about equi-distant from the tagging locations. Because the Chilko area supports an early run and the South Thompson supports a late run, this evidence is an indication that the earlier runs may migrate faster than the later runs.

Distribution of Fresh Water Recoveries

Relatively few (819) tags[1] have been recovered from the major Fraser River spawning grounds as a result of salt water tagging experiments in which more than 22,000 sockeye were tagged and more than 12,000 recovered. Reasons for the small return (approximately 3.5% of the recoveries) from the spawning grounds are several and include the following: (1) intensity of the commercial fishery, (2) obstructions in the river, (3) intensity of the Indian fishery, (4) impossibility of examining all the fish on the spawning grounds, (5) natural mortality, and (6) loss of tags from the fish. It is expected that the fishways now being constructed at Hell's Gate will permit a greater percentage of fish to reach the spawning grounds. The resultant increase in tag recoveries will extend our present knowledge of the migrations of sockeye salmon.

Recoveries from Localities not on the Route to the Fraser River

Only 10 of the 12,876 sockeye salmon tagged at Salmon Banks, Iceberg Point, and Lummi Island were recovered from localities that are clearly not on the route to the Fraser River. The data may be summarized as follows:

Tagged at Iceberg Point, 1939, 1 recovered in Lower Johnstone Strait.
Tagged at Salmon Banks, 1939, 2 recovered near Cape Flattery and 1 in Juan de Fuca Strait.
Tagged at Salmon Banks, 1940, 1 recovered at Swiftsure.
Tagged at Salmon Banks, 1941, 1 recovered in Lower Johnstone Strait and 1 in the Baker River, Washington.
Tagged at the Sand Heads, 1938, 1 recovered in Upper Johnstone Strait and 1 in Lower Johnstone Strait.
Tagged at Lummi Island, 1940, 1 recovered near Cape Flattery.

Retrograde Migration

The tagging data have been analyzed from the standpoint of determining whether or not the tagged salmon move only in the direction of the Fraser River. It was thought possible that at times there might be a definite retrograde migration or, in other words, a temporary migration away from the direction of the river. A consideration of each of the three major tagging areas from this point of view follows:

Little evidence of retrograde migration has been found for the salmon tagged at the Salmon Banks during the seasons of 1939, 1940, and 1941 (see Figure 3). Only two such tags were recovered from the Sooke traps. However, since Sooke is the only moderately large fishery within a reasonable distance back from the Salmon Banks, conclusive evidence with respect to this fishery is lacking.

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[1] Including only the experiments here reported (see Table II) and those for Sooke and Johnstone Strait reported previously (1944).

Lummi Island would appear to be an excellent tagging point for determining the direction of migration. For this area the evidence (see Figure 3) indicates that few tagged sockeye were recovered to the southwest (see Figure 1), as far as Sooke. Only 35 in 1939, 13 in 1940, and 12 in 1941 were recovered from areas in a direction (in relation to the point of tagging) away from the Fraser River.

In addition to the tags recovered at Sooke (retrograde migration) the following tags should be noted: Cape Flattery 3, Juan De Fuca 1, Swiftsure 1. These tags had been put on at the Salmon Banks and Lummi Island from 1939 to 1941. The recoveries were so few in number for any one year that they have not been considered in Figure 3.

Tagging at the Sand Heads indicates no retrograde migration beyond Point Roberts with the exception of two tags recovered at Lummi Island in 1939. It is interesting in this connection to report that in 1941 only one tag was returned from Point Roberts. This fact supports a previous observation that in 1941 sockeye salmon tagged at Sooke passed rapidly through the commercial fishing areas.

In general, the migration from the Salmon Banks to the Fraser River appears to be a forward movement with but very few sockeye moving in an opposite direction (i. e. away from the river).

Analysis of the tag recoveries has shown that on the days of tagging when some sockeye moved in a retrograde manner, other sockeye were being recovered in the direction of the Fraser. Thus the population present on these days was comprised of sockeye moving in both forward and backward directions. The retrograde salmon did not appear in separate groups at distinct periods of the season. Their scattered and singular appearance removes the possibility that these fish might represent separate races bound for spawning grounds other than in the Fraser River system (e.g. in the State of Washington).

Figure 3 shows the varying recovery percentages for tags put on at the three stations under consideration. It is readily seen that only a very small percentage of the sockeye move in a direction other than toward the Fraser River. The bulk of the recaptures occur en route to the Fraser River and in the river itself. Retrograde migration does occur but its small magnitude renders it unimportant as far as the fishery is concerned.

Segregation of Races in the Commercial Fishery

An important objective in connection with the tagging experiments was the determination of the times when the various races of sockeye passed through the commercial fishery. An analysis from this standpoint is difficult because relatively few of the tags were returned from the spawning grounds. Some data are available for the runs to the following areas: Harrison, South Thompson, and Chilko (see Figure 1). Table X shows the periods when tagging was carried out at the Salmon Banks, Lummi Island, and Sand Heads.

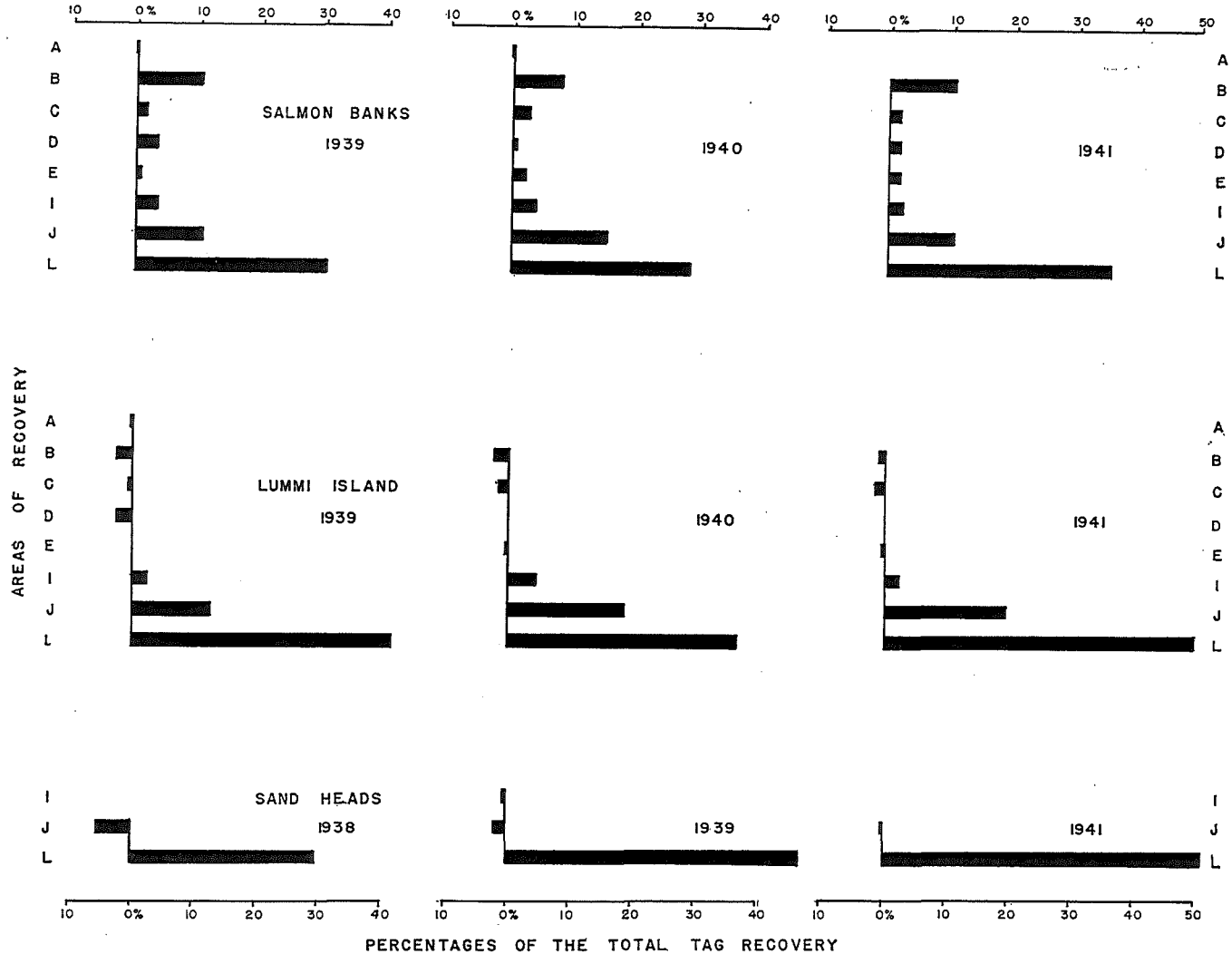

Fig. 3

CHART TO SHOW DEGREE OF RETROGRADE MIGRATION

The percentages of the total tags recovered are plotted from the location of tagging (0%), *i.e.* Salmon Banks, Lummi Island, and the Sand Heads. Each percentage to the left of the 0% vertical line represents a retrograde movement of the sockeye in relation to the Fraser River. Each percentage to the right of the 0% vertical line represents either a recovery at the tagging location or a forward movement towards the Fraser River.

Table X

DURATION OF TAGGING BY LOCALITIES AND YEARS

Salmon Banks					
1939	July	28	— September	4
1940	July	29	— August	18
1941	July	16	— August	27
Lummi Island					
1939	July	24	— August	23
1940	July	29	— August	16
1941	July	8	— August	23
Sand Heads					
1938	August	27	— September	15
1939	August	13	— September	29
1940	August	20	— September	13*
1941	July	24	— September	20
Iceberg Point					
1939	July	20	— September	5
1940	August	15	— August	16
1941	August	3	— August	12

* Also on July 27, 1940.

The spawning ground recoveries show that the Harrison races passed through the Sand Heads fishery between August 30 and September 8 in 1938, between August 29 and September 22 in 1939, and between August 11 and September 17 in 1941. The Harrison area is characterized by two main runs, one to the Birkenhead River and one to Weaver Creek and Harrison River Rapids. Unpublished data show that the earlier Birkenhead River run had passed the Sand Heads by the end of August 1941, and that the later runs to Weaver Creek and Harrison River Rapids then began to appear. The tagging at the Sand Heads did not commence early enough in either 1938 or 1939 to obtain recoveries from the Birkenhead River. Those tagged fish recovered in the Harrison district in these two years were found for the most part in the late runs. Thus, it appears that the early Birkenhead River run passes the Sand Heads fishery during the month of August and that the late Weaver Creek and Harrison River Rapids runs pass through this same area during the month of September and possibly later. Tagging did not continue long enough here to determine the duration of these late runs.

In 1938 the South Thompson races passed Sooke[2] between July 23 and September 3 and the Sand Heads between August 29 and September 30. In 1939 they passed Salmon Banks, Lummi Island, and the Sand Heads between August

[2] Unpublished data.

3 and September 1, July 28 and August 23, and September 1 and September 25, respectively. Sockeye of these races were in the Sand Heads area between July 30 and September 8 in 1942.

In 1940 the Chilko fish were passing through Johnstone Strait[3] between July 20 and August 8 and the Salmon Banks between July 29 and July 31. For reasons given below it is probable that tagging at the Sand Heads began too late in each season to include the early Chilko run of sockeye.

From these data it is evident that the Chilko sockeye pass through the commercial fishery prior to the South Thompson and Harrison races (with the possible exception of the Birkenhead River run). Knowing the approximate migration rates from Salmon Banks (16 days)[4] and Johnstone Strait (20 days) to the uppermost commercial fishery area (Haney to Mission), it may be assumed that most of the Chilko sockeye have left the commercial fishery before the end of August. In the years for which data are available it is noted that the Harrison and South Thompson races are just entering the Sand Heads area at this time. This does not apply to the one Harrison run to the Birkenhead River. So far, it appears that the late Harrison and South Thompson runs pass through the commercial fishery during the same period. This analysis is of a preliminary nature but a partial segregation is apparent.

SUMMARY AND CONCLUSIONS

The results of tagging sockeye at the Salmon Banks, Iceberg Point, Lummi Island, and the Sand Heads have been summarized in the foregoing pages; a more complete report is proposed for a later date. Data relative to the distribution of returns, migration times, retrograde migration, delay en route, etc., have been presented for each of the areas considered. It has been shown, for example, that the time in days required to reach a given destination increases directly with the distance from the point of liberation. For a majority of the areas of recapture, fish tagged in 1941 were recaptured in the shortest median times. This and many of the other conclusions agree with those obtained from tagging at Sooke and Johnstone Strait and presented in the earlier report. Delay in migration off the mouth of the river and at each tagging location is indicated. Salmon tagged at Salmon Banks and Lummi Island apparently migrated more rapidly toward the river during the first half of each season than they did later in the same seasons. Very few tags were recovered on the spawning grounds; reasons contributing to this result are advanced. The evidence indicates that an overwhelming majority of the sockeye salmon tagged in the localities considered were bound for the Fraser River. It further appears that very few tagged sockeye moved any considerable distance in a direction away from the Fraser River. At least a partial segregation of races in the commercial fishery is indicated.

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[3] Unpublished data.

[4] Based on recoveries for 1940 (See Table VII) since there were very few fish in 1939 and cycle years.

ACKNOWLEDGMENTS

The tagging experiments outlined herein were carried out under the directorship of Dr. W. F. Thompson and under the immediate supervision of of Dr. J. L. Kask. The writers wish to express their indebtedness to the canners and other members of the fishing industry, to cooperating biologists of the Fisheries Research Board of Canada, to the Dominion Department of Fisheries, and to the members of the staff of the International Pacific Salmon Fisheries Commission.

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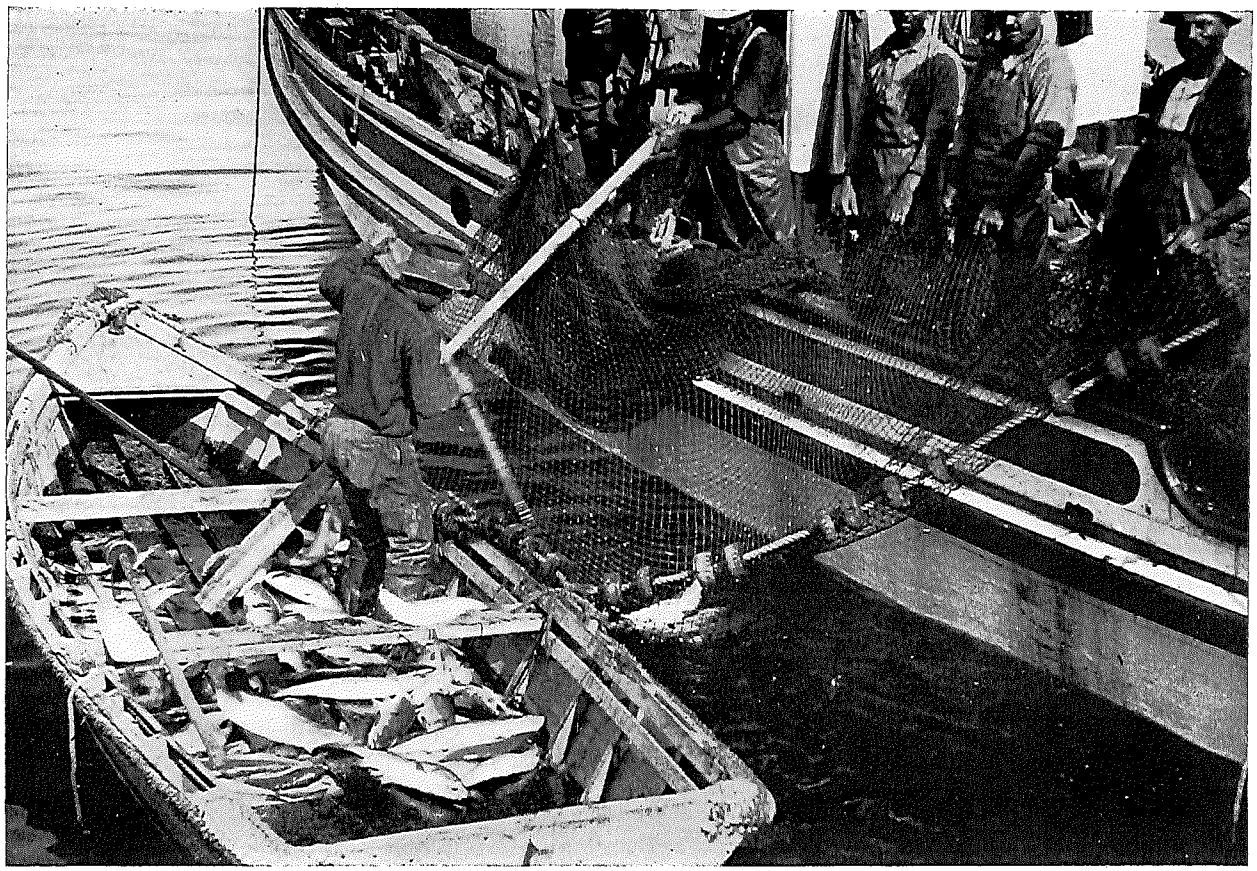


Brailing the last few fish from a purse seine in Puget Sound.

YIELD STATISTICS OF THE SOCKEYE SALMON FISHERY OF THE FRASER RIVER

by

WM. TOMKINSON and C. P. IDYLL

INTRODUCTION

The International Pacific Salmon Fisheries Commission is charged with the responsibility of managing the Fraser River sockeye salmon fishery, beginning in 1946. Since the management of a natural resource requires an accurate accounting of the yield of that resource, one of the Commission's major projects is the development of an efficient system of collecting all data pertaining to the yield of this fishery. These data include the fundamental information as to total landings and total pack as well as other information the application of which is not so immediately apparent. Among these latter data are facts pertaining to the fishing boats — their individual catches, areas of fishing and the effort expended. The age and racial composition as well as other biological information regarding the run must be obtained from sampling the commercial catch.

THE PROBLEM

The statistics relating to the yield of this fishery supply material for the solution of three major aspects of the Commission's work. The first of these is the calculation of an index of success of spawning to show variations in yield.[1] The calculation of the index depends upon the collection and refinement of catch and fishing intensity statistics. Determination of fishing intensity requires knowledge of the types of gear used, any changes therein and measures of their relative efficiency.

The second aspect of the Commission's work to be dealt with on the basis of landing statistics is the formulation of regulations designed to assist in the protection and rehabilitation of the sockeye salmon runs to the Fraser River. The basis of such regulations must be the record of the condition of the run. Changes in this condition will be reflected in part by the returns to the industry, and accurate accounting of such returns must be made to guide the course of regulation in succeeding years.

The third problem to be solved by statistics is the division of the catch between the United States and Canada. Article VII of the Sockeye Treaty states: "Inasmuch as the purpose of this Convention is to establish for the High Contracting Parties, by their joint effort and expense, a fishery that is now largely nonexistent, it is agreed by the High Contracting Parties that they should

[1] W. F. Thompson, "Scientific Mangement of the Fraser River Sockeye." Int. Pac. Sal. Fish. Comm., Ann. Rep., 1944. pp. 23-28.

share equally in the fishery. The Commission shall, consequently, regulate the fishery with a view to allowing, as nearly as may be practicable, an equal portion of the fish that may be caught each year to be taken by the fishermen of each High Contracting Party."

It is characteristic of the Fraser River sockeye salmon to appear suddenly on the fishing grounds, to be relatively very abundant for a short period and then to proceed quickly beyond the reach of the commercial fleets of either one or of both countries. This is shown by the seasonal occurence curves (see Figures 1-5). Furthermore the size of any year's run is extremely difficult to predict before the season begins, with sufficient accuracy to permit an equal division of the catch to be determined in this manner. Thus the division must be effected by some method which will be based on the size of the catch by each country as revealed by the daily landings. This method must be flexible and adapted to quick change, and obviously depends on the ability of the Commission to obtain accurate and prompt reports of the total landings in both Canada and the United States. The development of a system to obtain such reports has been an important concern of the Commission during the past several seasons.

PERSONNEL AND ORGANIZATION

The Commission has been actively engaged in the collection of statistics relative to the commercial fishery since 1938. In the first year the work was of an exploratory nature and most of the landing data were obtained at the close of the season. In 1939 some landing data were obtained during the season, and the groundwork for the present methods was laid. The general procedure which has been followed in succeeding seasons was developed by Mr. F. Heward Bell who was in active charge from 1939 to 1941 inclusive. Since this time the program for the Canadian fishery has been under the supervision of Mr. Wm. Tomkinson and that for the United States fishery under Mr. C. P. Idyll. In each season these men have been provided with temporary student assistants.

THE YIELD STATISTICS

The available yield statistics of the sockeye fishery include the number of cases packed, the number of fish landed daily and the distribution of the catches by date, area of origin, and type of gear used. Biological information is also obtained from samples of the daily catches.

SOURCES OF STATISTICAL DATA

Pack and landing figures have been obtained from the canneries and the major buying firms since 1938 (see Tables I and II). In 1938 the information was solicited by mail and statements of the number of cases packed and the number of sockeye landed were prepared by the canneries. Since these data are not complete they have been omitted from the tables. In 1939 some data were collected by mail and others by employees of the Commission. In 1940 and all successive years the data have been collected personally during the season by members of the Commission staff.

Periodic visits are made to all canneries operating, and a record is made of the daily landings of each boat. These landings are secured from the fish tickets, which are copies of the fishermen's receipts for fish delivered, or from cannery summary sheets, or from the cannery ledgers. If the original copying is done from fish tickets it is checked against the company ledger, or a recapitulation sheet; if the original copying is done from the ledger, a check is made from the tickets. Every effort is made to reduce errors due to faulty transcription or duplication of entry. All statistical information pertaining to individual canneries or fishermen is kept confidential.

The need for immediate determination of the daily total landing in numbers of sockeye has been pointed out above in reference to the project of dividing the catch. Various methods were instituted in the season of 1944 to implement this rapid compilation of the daily landing totals. Since the operations of the canning industry in the two countries are somewhat different the collection of the statistics varies also. In Washington, Anacortes is the major center of canning operations. There are also plants in several other towns. A Commission representative, stationed at Anacortes, secures daily reports from the Washington canneries by telephone, from which is prepared an estimate of the total U. S. daily landing. This is reported to the New Westminster office by telephone. In Canada a Commission employee determines the total daily landing at Steveston and reports this to New Westminster. From New Westminster all other buyers in the district are contacted and the total daily landing for Canada is thus obtained. Preliminary landing figures from the two countries are thereby available in New Westminster very soon after the fish have been landed, and the calculations necessary for the division of the catch can be made.

To reduce error in the final determination of the total daily landing, reference is made to the fish tickets or buyer tallies and wharf tallies at each cannery or buyer from whom the preliminary reports were previously obtained. Arrangements have been made for the Commission to obtain carbon copies of the original fish tickets in Washington State. Carbon copies of buyers' tally sheets in Canada were obtained by the Commission in 1944 and this procedure will be continued.

The system of using fish tally sheets is not yet universal with the Canadian buyers. The Commission is attempting to secure the cooperation of all buyers to make this a general practice for the development of a uniform system.

As a check on the final determination of the daily landing total, periodic tests are made. In these tests the average number of fish per 48 lb. case is calculated. Any great deviation of this value from the average for the whole season is taken to indicate some error, which is then traced.

Existing governmental agencies which collect fishery statistics are also a source of information. The files and reports of the Washington State Department of Fisheries and the Dominion Department of Fisheries are used frequently to check landing and pack figures. These organizations supply historical data as well as those for current years.

For the seasons during which the Commission has been collecting statistics, the number of sockeye landed has been recorded and totalled according to Table I. In this table are included all sockeye known to have been caught in waters defined by the Convention. They show the portions of each annual catch taken in the waters of each separate country, regardless of where the fish were canned. In 1940 there were a large number of sockeye caught in Canadian waters which were packed in Washington State. In 1942 surplus fish from Steveston were shipped to many canneries distributed in other parts of British Columbia. As far as possible these shipments have been accounted for and included in the proper position in Tables I and II. All parts of Table I are the result of investigation and tabulation by the staff of the Commission.

Table I

NUMBER OF SOCKEYE CAUGHT IN TREATY WATERS

Year	In Canadian Waters	In American Waters	Total
1944	1,003,829	436,182	1,440,011
1943	349,011	242,822	591,833
1942	5,047,599	2,921,805	7,969,404
1941	2,116,723	1,560,482	3,677,205
1940	937,042	709,661	1,646,703
1939	568,943	552,179	1,121,122

The total number of cases of sockeye packed from these waters has also been determined. These figures are presentd in Table II. Canadian data are from the Dominion Department of Fisheries. Washington State data are from the Washington State Department of Fisheries. In each case these figures are supplemented by information gathered by the Commission staff.

Table II

NUMBER OF CASES OF SOCKEYE PACKED FROM TREATY WATERS

Year	Canadian Pack	American Pack	Total Pack
1944	88,150½	37,379	125,529
1943	30,277	19,057	49,334
1942	426,979	263,458	690,437
1941	159,279	110,605	269,883
1940	93,361*	59,354	152,715
1939	47,539	43,511	91,050

* Includes fish packed in Washington but caught in British Columbia.

Figures 1 to 5 are presented to illustrate the seasonal occurence of the Fraser River sockeye runs. The points in the charts represent the number of sockeye *landed* each day. Further investigation will be required before the charts can be corrected to show the total number of sockeye actually *caught* each day. Detailed analysis of the information given by these figures will be made in a later paper.

Statistics of the fishing operations are gathered directly from the fleets. A program providing log books or fishing record books to the fishermen was initiated in 1940. The work of that year was purely experimental and was started too late in the season to produce substantial results. In succeeding years, results have been encouraging. In the 1943 and 1944 seasons the log books provided by the Comission were issued to all the purse seine vessels operating in Puget Sound during the sockeye season. Fishing record books were issued to a large number of all the gill net fishermen in the Fraser River area in these later years with constantly increasing cooperation by the fishermen in the matter of keeping the record. Reef net fishermen and gillnetters in the Puget Sound area are being successfully incorporated into the system (see Table III).

Where possible, these log books are copied once a week during the fishing season. Very encouraging cooperation has been maintained by the fishermen in this project, and extremely useful data gathered. Some data not otherwise available have resulted from the log books. Among these are accurate designation of place of fishing, intensity of fishing expressed in the number of hauls or drifts, and indication of the date when the fish were caught as opposed to the date of delivery of the fish. Information concerning the boat and the gear used each season is also gathered, to determine relative fishing efficiencies. All this information on fishing intensity, location of fishing, gear used, and catch is recorded on 8″ x 11″ boat cards, from which analysis can be made.

Samples of the commercial catch are taken at the canneries several times a week. Each sockeye is measured, weighed and sexed, and a scale sample taken. Information concerning age, condition and races is obtainable from these data.

To gain a more precise knowledge of the fishery, members of the Commission staff frequently accompany the fleets. At such times, observations are made of the actual fishing methods, counts are made of the individual hauls and biological data are gathered from samples of the fish. Again the cooperation of the fishermen and cannery tendermen has been gratifying.

Much of the pack and landing data in the Commission's files consist of hand-copied records from fish tickets, company ledgers, etc. In addition, a great deal of current and historical material has been copied by microfilm photography. By this latter method voluminous records can be copied accurately in a short time and stored in a small space.

Historical statistics are also being collected. Landing and pack statistics are gathered for as many previous seasons as possible. Much of this material comes from the ledgers of companies which operated in earlier days of the industry. The Commission staff is endeavouring to copy these books on

Table III

SUMMARY OF FISHING RECORD BOOKS

Year	PUGET SOUND										FRASER RIVER		
	PURSE SEINE				GILL NETS			REEF NETS			GILL NETS		
	No. of Boats Fishing*	No. of Log Books	No. of Records Copied	% of Records Copied	No. of Books Issued	No. of Records Returned	% Return	No. of Books Issued	No. of Books Returned	% Return	No. of Books Issued	No. of Records Returned	% Return
1940	140	75	25	33.3							154	70	45.4
1941	158	118	106	90	15	5	33.3				294	115	39.1
1942	137	132	123	92.4							406	117	28.8
1943	150	150	130	86.6	13	5	38.5	35	9	25.6	481	131	27.2
1944	60	60	57	95	36	26	72.2	22	6	27.7	550	320	58.2

*In the case of the other types of gear the actual number of boats fishing has not yet been determined.

microfilm for permanent record before they are destroyed. Already many companies have discarded the books containing valuable information on the size and characteristics of the former runs. A continued effort will be made to get the material still extant.

ACKNOWLEDGMENTS

In an investigation of this type the successful collection of information depends on the good-will of the people engaged in the industry. The Commission has been particularly fortunate in having excellent cooperation from the fishermen and those in the canning industry. Thanks are due to many hundreds of fishermen who have kept log books, and supplied verbal information concerning their fishing activities. Similarly, cannery officials and office staffs have in all cases freely supplied the Commission with data desired concerning landing and pack. Government officials in both countries have provided data as mentioned above.

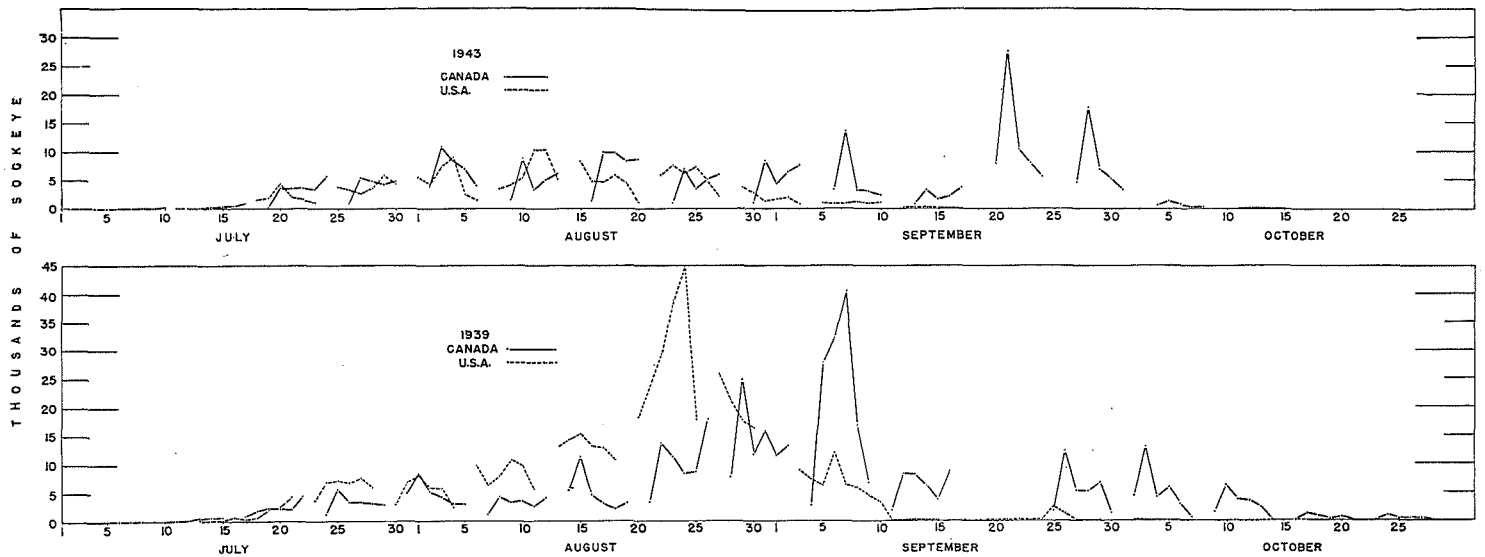


Fig. 1

Seasonal occurrence of sockeye, showing the daily landings of sockeye in treaty waters in the years 1939 and 1943.

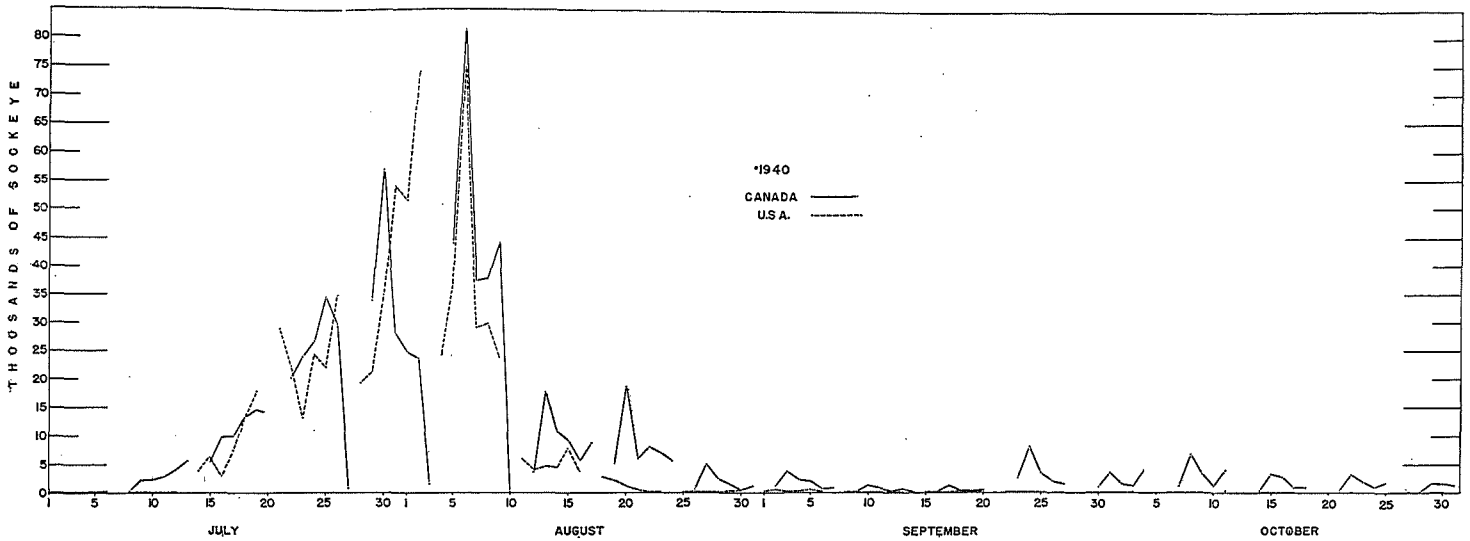


Fig. 2

Seasonal occurrence of sockeye, showing the daily landings of sockeye in treaty waters in the year 1940.

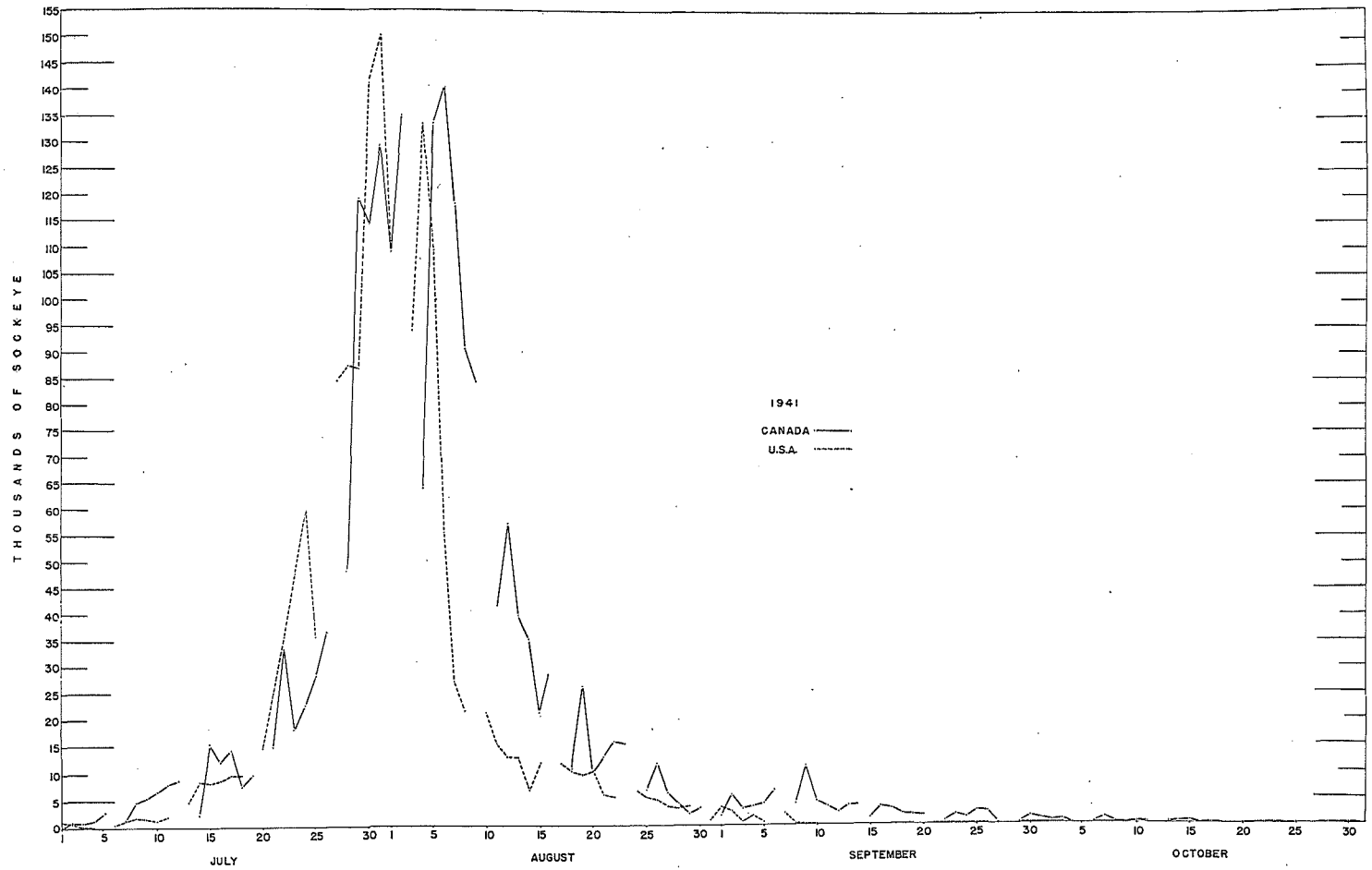


Fig. 3

Seasonal occurrence of sockeye, showing the daily landings of sockeye in treaty waters in the year 1941.

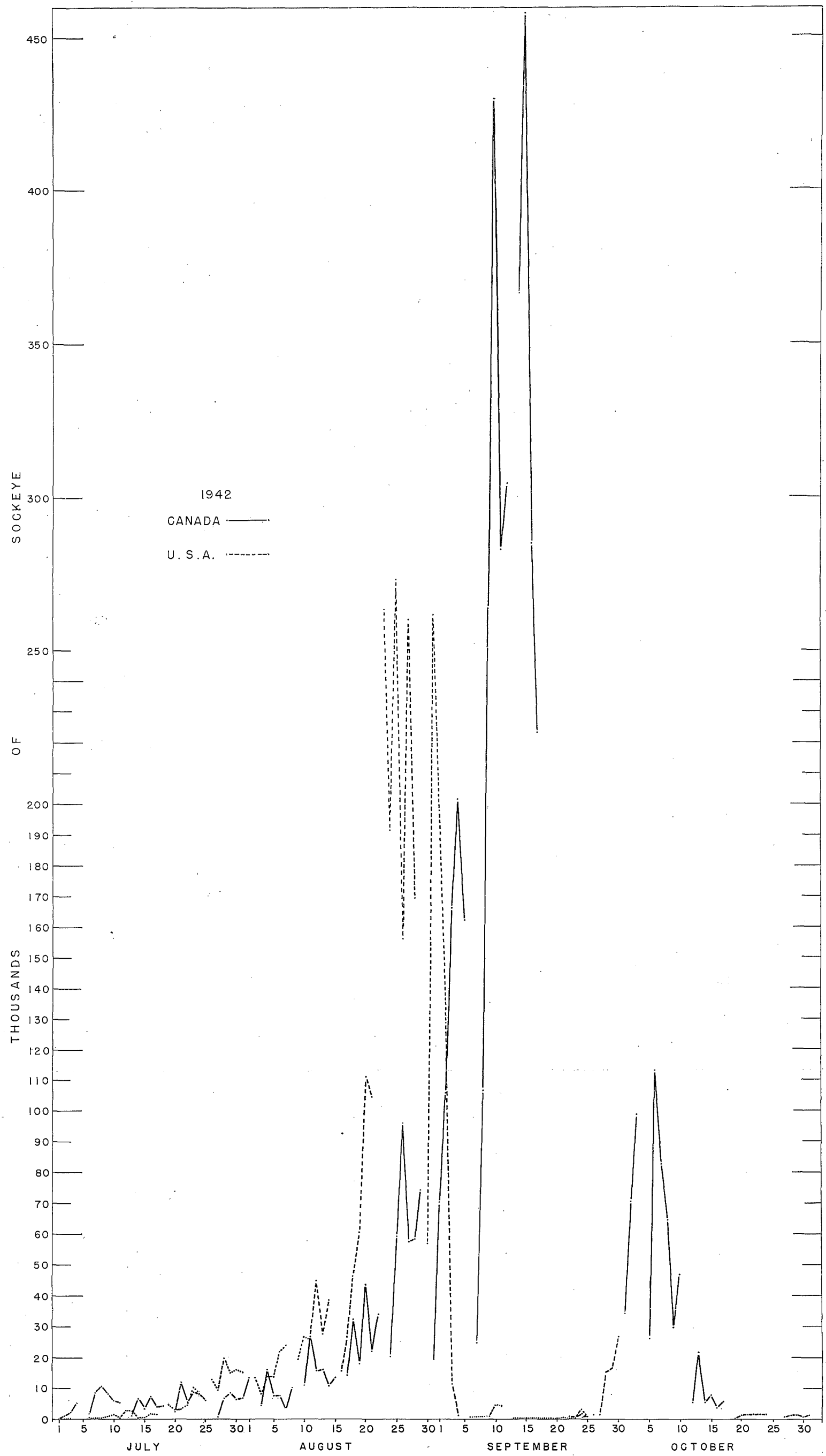


Fig. 4

Seasonal occurrence of sockeye, showing the daily landings of sockeye in treaty waters in the year 1942.

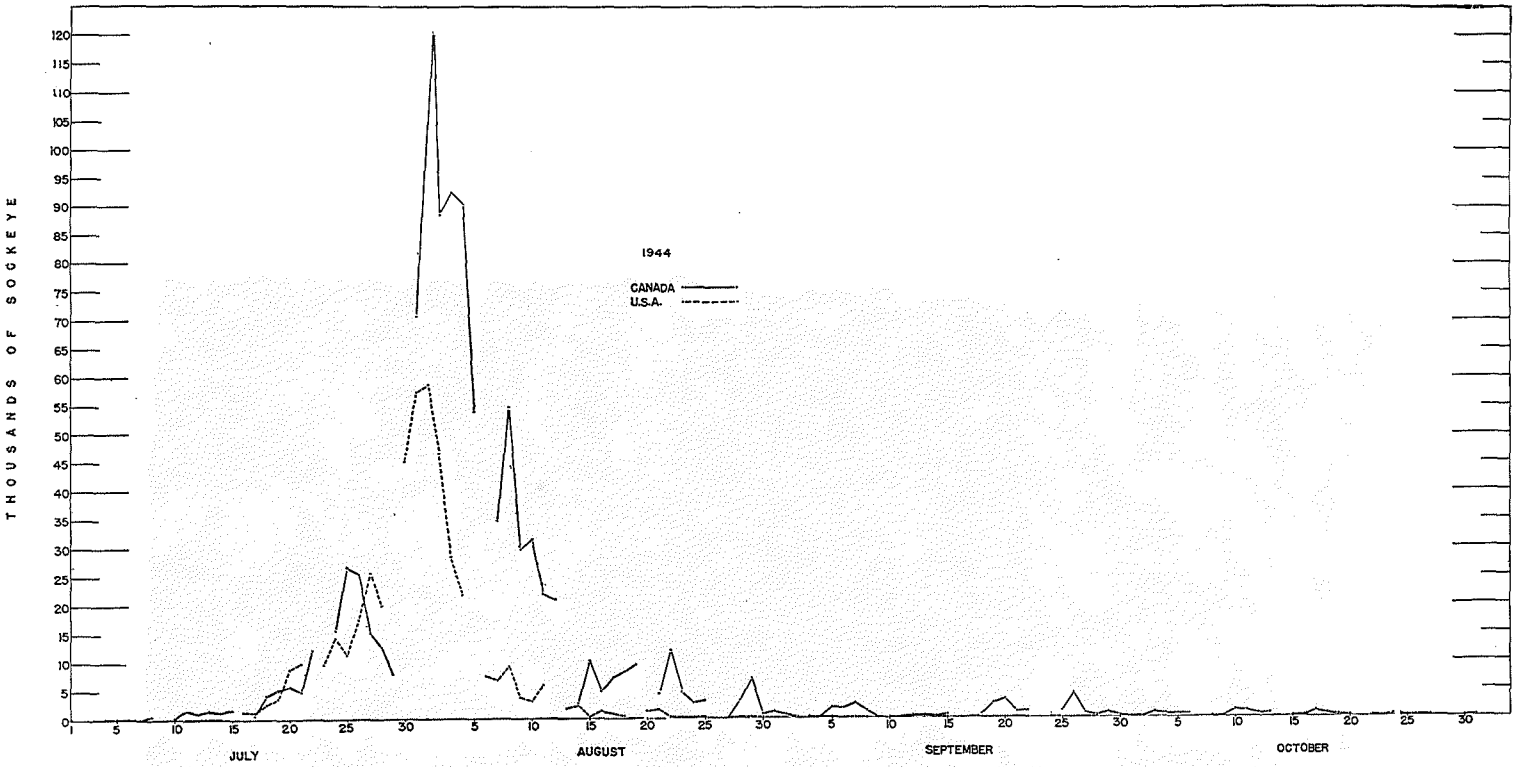
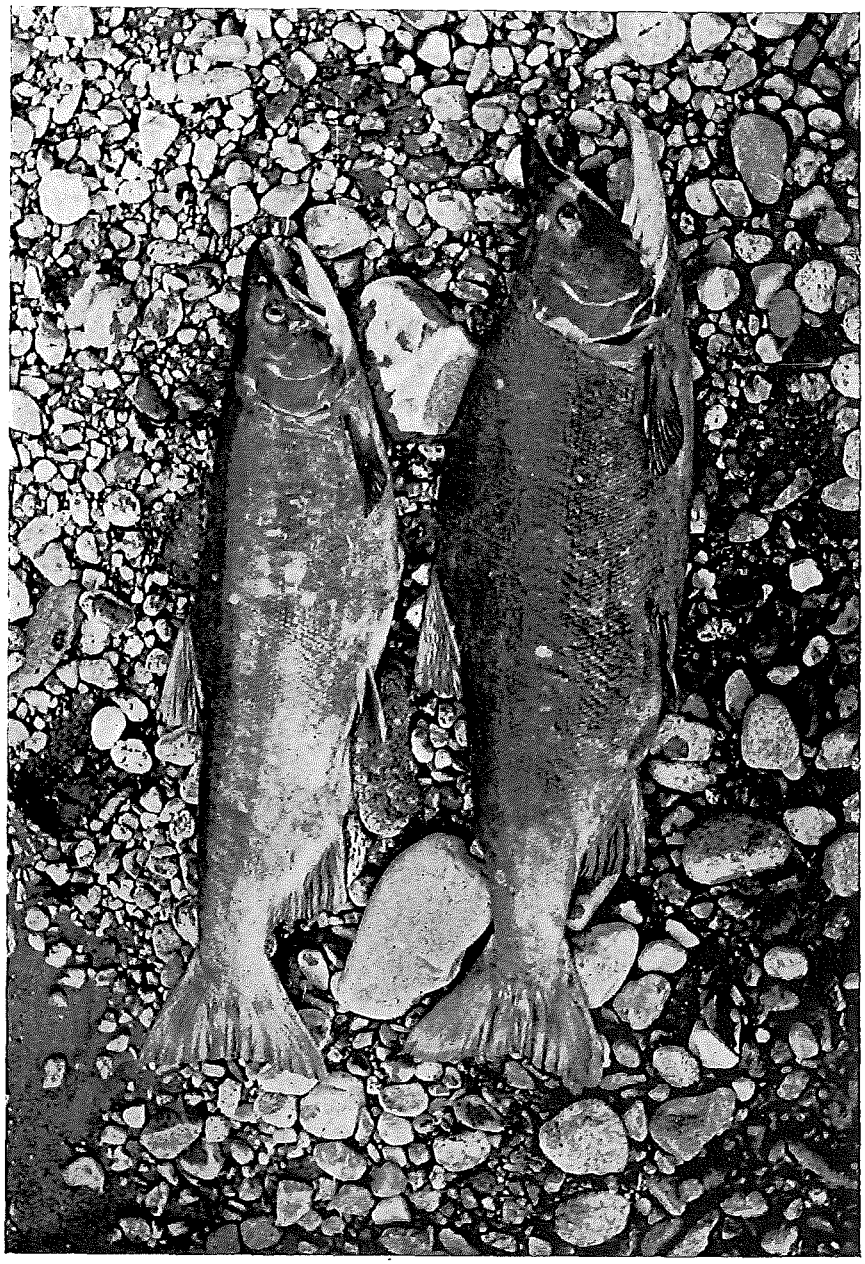


Fig. 5

Seasonal occurrence of sockeye, showing the daily landings of sockeye in treaty waters in the year 1944.



Partially spawned male (below) and female (above) sockeye salmon. Pitt River, 1940.

SOCKEYE SALMON CATCH STATISTICS FOR THE INDIAN FISHERY OF THE FRASER RIVER WATERSHED 1941 - 1944

by

GERALD V. HOWARD

INTRODUCTION

The total number of salmon returning to a river system as adults in any one year consists of two portions, a mortality group (either the result of fishing or natural causes) and an escapement group which reaches the spawning streams. Since the evaluation of a total run is a fundamental requirement for the control of the sockeye salmon fishery of the Fraser River, methods for measuring the individual components must be devised. One portion of the total run consists of the valuable commercial fishery and also the relatively less important Indian fishery. In each year the number of fish taken by the Indians is actually much smaller than either the number caught by the commercial fishery or the number escaping to the spawning grounds (see Table I). However, as it becomes necessary to give the small and nearly extinct races the protection required for their rehabilitation, representative statistics for the Indian fishery must be available if regulation of the commercial fishery is to be carried out intelligently.

The Indian fishery on the Fraser River is controlled by the Dominion Department of Fisheries. This department has the power to specify the locations for fishing, the gear to be used, the number of fish to be taken, and the time during which the fishery may be pursued. The Indians are permitted to take the salmon only for their own consumption; they are not allowed to sell them. Hence, this is not a commercial fishery.

The three main types of gear used by the Indians for taking salmon are the dip net, the set net, and the gaff hook. The preference for any type of gear is largely dependent upon the prevailing conditions in each fishing locality.

A large portion of the salmon catch is preserved by the Indians for winter use and the remainder is eaten fresh. The methods for preservation include drying, salting, smoking, and canning and are dependent upon the locality and the weather conditions.

As the International Pacific Salmon Fisheries Commission is concerned specifically with the sockeye salmon, this paper deals solely wth catch statistics relative to this species. The report covers the years 1941 to 1944 inclusive, the only years for which adequate statistics are available. During the period 1938-1940, only limited and preliminary observations were made on the Indian fishery and these observations were made only in certain districts. As a result the

Table I

DISTRIBUTION OF THE TOTAL FRASER RIVER SOCKEYE SALMON RUNS *
1941 - 1944

	1941		1942		1943		1944	
	No. of Sockeye	% of Total	No. of Sockeye	% of Total	No. of Sockeye	% of Total	No. of Sockeye	% of Total
Indian Fishery	52,920	1.2	46,708	0.4	27,042	3.5	42,820	2.3
Commercial Fishery	3,677,205	84.2	7,969,404	64.0	591,833	77.4	1,440,011	76.8
Spawning Grounds‡	637,768	14.6	4,439,912	35.6	145,847	19.1	392,420	20.9
Totals	4,367,893	100.0	12,456,024	100.0	764,722	100.0	1,875,251	100.0

* From the records of the International Pacific Salmon Fisheries Commission.

‡ Best estimates.

statistics are not complete for these earlier years. Since that time, the collection of these data has become an important part of the Commission's program and it is anticipated that the statistics will become more accurate and complete as each additional year's information is obtained.

METHODS

Division of the Watershed into Districts

Indians fish for salmon in various localities along the banks of the Fraser River and its tributaries. For purposes of collecting statistics and in order to conform with the spawning ground investigations, the watershed has been divided into ten main districts with their respective sub-divisions, which are listed in Table II. In these districts the field observers have collected the Indian fishery statistics in conjunction with the performance of their other duties, except in the following four districts where the numbers of Indians fishing and the quantities of fish taken warranted two special observers: Lower Fraser, Canyon, Bridge River Rapids, and Lytton to Lillooet.

Collection of the Statistics

The methods utilized to obtain the catch statistics require frequent visits to all the Indian fishermen and the accuracy of these statistics varies directly with the frequency of the visits. No one of the three methods devised has been found to be entirely satisfactory for the entire watershed; therefore, one of the three methods has been used in obtaining the total estimated catch in each area. The method used in each instance has been selected with a view to obtaining as accurate an estimate of the catch as possible. The three procedures may be outlined briefly as follows:

1. The first method for estimating the catches is based upon both "actual" and "verbal" counts. The **actual** counts were made by counting the fish on the drying racks and the **verbal** counts were obtained by asking the fishermen how many salmon they had caught. In cases where the fish had been removed from the racks before they had been counted by the observer, it was sometimes possible to ascertain the catch by counting the fish tails or heads on the ground near the racks. The numbers of sockeye caught as reported by the Indians were usually considered to be much smaller than the true figures; the counts obtained verbally represent minimum values. The success of the procedure as a whole was greatest when visits were made to each Indian every one or two days. The method proved to be fairly satisfactory at Bridge River Rapids where a special observer has been stationed each season since 1941. Here it has been possible to visit the Indians in the locality each day because all the fishing stations are confined to a small area.

2. The second method is based upon tag[1] ratios. In certain areas of the Canyon district the observer obtained accurate counts of the numbers of sockeye

[1] An extensive sockeye tagging program was conducted concurrently at Hell's Gate.

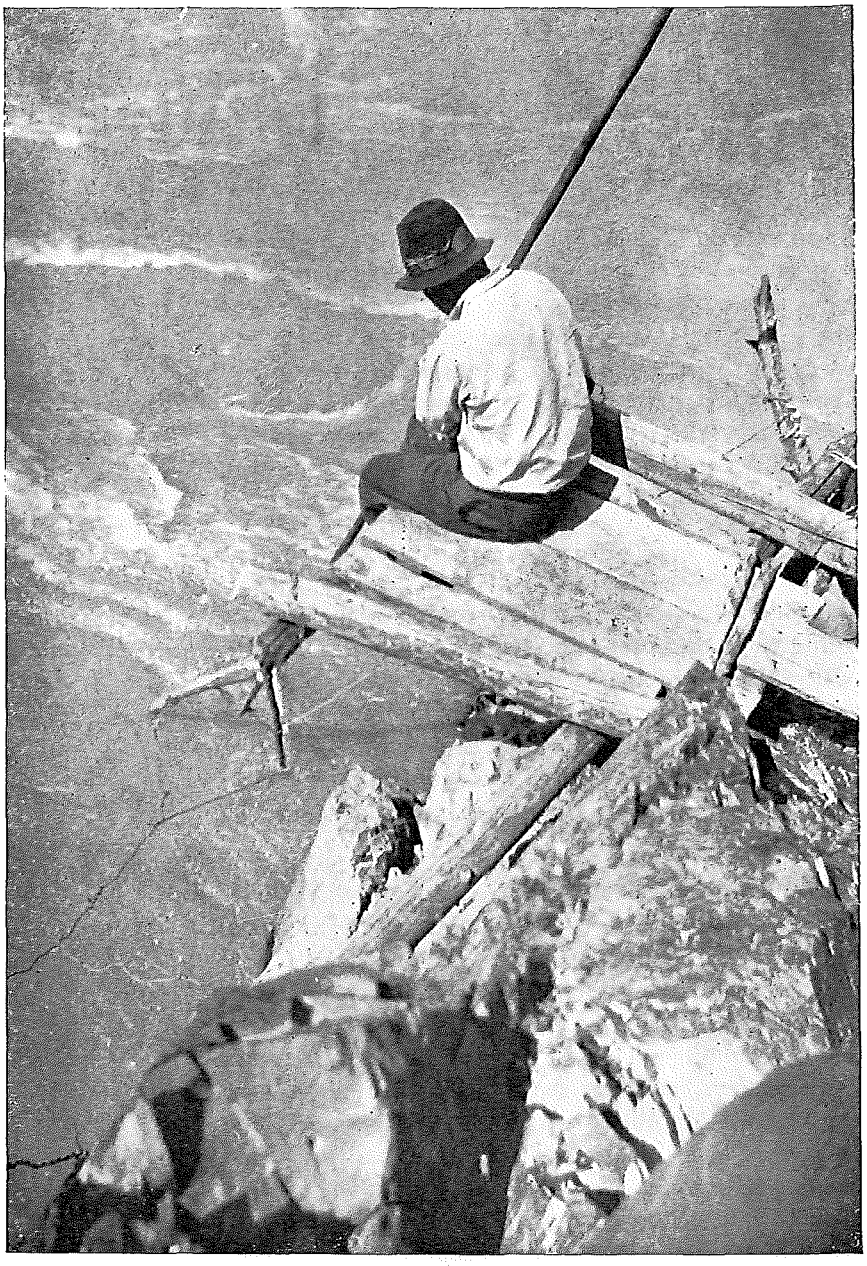


Fig. 1

Indian fisherman with dip net fishing for sockeye salmon at Bridge River Rapids, 1943.

caught by one or two Indian fishermen. These counts included the numbers of tagged as well as untagged sockeye taken. The ratio between tagged and untagged sockeye was then calculated and upon computation of this ratio the estimated catches of the other Indians within these areas were determined from their tag recoveries. It should be pointed out that the Commission paid rewards to the Indians for the return of the Hell's Gate tags and so most of the tags recovered by the Indians were returned.

3. A third method of determining the catches was devised during the 1944 season. This method, which was used during the past season, is also based upon the use of tag ratios. Using the data from the tagging program at Hell's Gate the density of tagged to untagged fish in the migrating population was determined weekly. From these data the Indians' catches above Hell's Gate were estimated each week from the number of tags they turned in to the Commission. This method was also applied where similar tagging programs were carried out at Bridge River Rapids on the Fraser River and at Skookumchuck Rapids on the Lillooet River.

In most cases an estimate by only one of these methods was available and the resulting estimates are presented in Table II. In those districts where it was found possible to use more than one method the one that appeared to be the most reliable was used. The extent to which each of the three methods was used may be determined from Table II. Tag ratios were never used to determine the catches in any areas where the Indians were able to fish selectively for tagged sockeye. The fishermen are unable to fish with any degree of selectivity in localities where the water is turbid.

There are many factors which affect the accuracy of the estimated catches obtained by any one of the three methods outlined. Certain errors are recognized and it may be possible to make adjustments for apparent deficiencies when sufficient data have been accumulated. In order to get the true value of the Indian catch it would be necessary for the observer to count each individual sockeye caught by each fisherman. The **actual** and **verbal** counts are dependent upon counting all the fish at the racks and the accuracy of the information obtained from the fishermen. The estimates ascertained from tag ratios include certain possible errors of a mathematical nature which are essentially a problem in sampling.

RESULTS

Table II lists the ten districts and their respective sub-divisions or areas. It shows for each the estimated sockeye catches, the number of Indian fishermen responsible for these catches, and the average number of sockeye for each fisherman. In some instances the table is not complete.

The Catches

Table II shows that the Indians caught the following estimated numbers of sockeye: 52,920 in 1941, 46,708 in 1942, 27,042 in 1943 and 42,820 in 1944. The three districts contributing the greatest numbers of sockeye in these four years were: Canyon, Bridge River Rapids, and Chilcotin.

Table II

SOCKEYE SALMON CATCHES BY DISTRICTS AND THE AREAS WITHIN THESE DISTRICTS
1941 - 1944

DISTRICT AND AREAS	1941				1942				1943				1944			
	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman
Harrison-Birkenhead																
Skookumchuck	225†		4	56	—		—	—	—		—	—	295§		4	74
Lillooet Lake	408†		—	—	275†		2	138	—		—	—	1,796§		8	225
Birkenhead River	3,313†		—	—	3,253†		16	203	3,113†		15	208	2,761§		52	53
Total	3,946	7.5	—	—	3,528*	7.6	18*	196	3,113*	11.5	15*	208	4,852	11.3	64	76
Lower Fraser																
Seabird Island	440‡		5	88	200‡		5	40	35‡		1	35	794†		11	72
Katz and Ruby Creek	1,826†		16	114	360‡		4	90	720‡		5	144	115‡		1	115
Total	2,266	4.3	21	108	560	0.1	9	62	755	2.8	6	126	909	2.1	12	76
Canyon																
Union and American Bar	2,761‡		14	197	2,587‡		13	199	1,170‡		12	98	773‡		4	193
Yale	3,398‡		23	148	2,426‡		20	121	2,238‡		14	160	2,555‡		12	213
Spuzzum	356‡		4	89	867‡		9	96	788‡		8	99	284‡		3	95
Lower Gorge	126‡		3	42	281‡		5	56	144‡		4	38	483‡		2	241
Upper Gorge	765‡		10	77	1,764‡		9	196	209‡		4	52	1,610§		3	537
Boston Bar	125‡		5	25	355‡		5	71	442‡		3	147	22§		1	22
Boothroyd	879‡		14	63	2,278‡		11	207	1,332‡		8	167	1,986§		13	153
Cisco	1,280‡		14	91	1,445‡		12	120	1,037‡		13	80	4,165§		24	174
Total	9,690	18.3	87	111	12,003	25.7	84	143	7,360	27.2	66	112	11,878	27.7	62	192
Lytton to Lillooet	2,940‡	5.5	32	92	5,215‡	11.2	31	168	4,224‡	15.6	49	86	3,506§	8.2	18	194
Bridge River Rapids																
Lillooet	3,500†		20	175	2,391†		17	141	1,507†		15	100	746†		11	68
Rapids	10,000†		35	286	6,776†		45	151	4,046†		42	96	6,082†		60	101
Pavilion	400†		6	67	561†		7	80	746†		9	83	749†		23	32
Total	13,900	26.2	61	228	9,728	20.8	69	141	6,299	23.3	66	95	7,577	17.7	94	81

Table II (Continued)

SOCKEYE SALMON CATCHES BY DISTRICTS AND THE AREAS WITHIN THESE DISTRICTS
1941 - 1944

DISTRICT AND AREAS	1941				1942				1943				1944			
	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman	Catch	% of Total Catch	No. of Fishermen	Average No. per Fisherman
Chilcotin																
Farwell Canyon	2,971†		18	165									2,851†		14	204
Hance's Canyon	1,029†		12	86									310†		3	103
Martins	599†		3	200									1,513†		6	252
Anahim	600†		6	100									264†		3	88
Alexis Creek	2,745†		20	137	No Fishing				No Fishing				2,078†		15	139
Bull Canyon	1,226†		6	204									—		—	—
Siwash Bridge	4,532†		20	227									3,187†		24	133
Keighley Holes	2,445†		8	306									2,411†		9	268
Henry's Crossing	—		—	—									615†		4	154
Total	16,547	31 3	93	180									13,229	30.9	78	170
Upper Fraser																
Alkali Creek to Shelley	1,699†	3.2	63	27	2,597†	5.6	—	—	1,562†	5.8	102	15	185†	0.4	—	—
Nechako																
Nautley Reserve	528†		8	66	1,196†		8	149	528†		—	—	272†		7	39
Stella Reserve	679†		9	75	836†		7	119	1,132†		—	—	345†		7	49
Total	1,207	2.3	17	71	2,032	4.4	15	135	1,660	6.2	—	—	617	1.5	14	43
Stuart Lake	725†	1.4	42	17	1,035†	2.2	—	—	194†	0.7	—	—	32†	0.1	—	—
Thompson																
North Thompson River		No Fishing			5†		—	—	125†		4	31	10†		1	10
South Thompson River					10,005†		—	—	1,750†		12	146	25†		1	25
Total					10,010	21.4	—	—	1,875	6.9	16	117	35	0.1	2	18
Grand Total	52,920				46,708				27,042				42,820			

* Incomplete. † Method 1. ‡ Method 2. § Method 3.

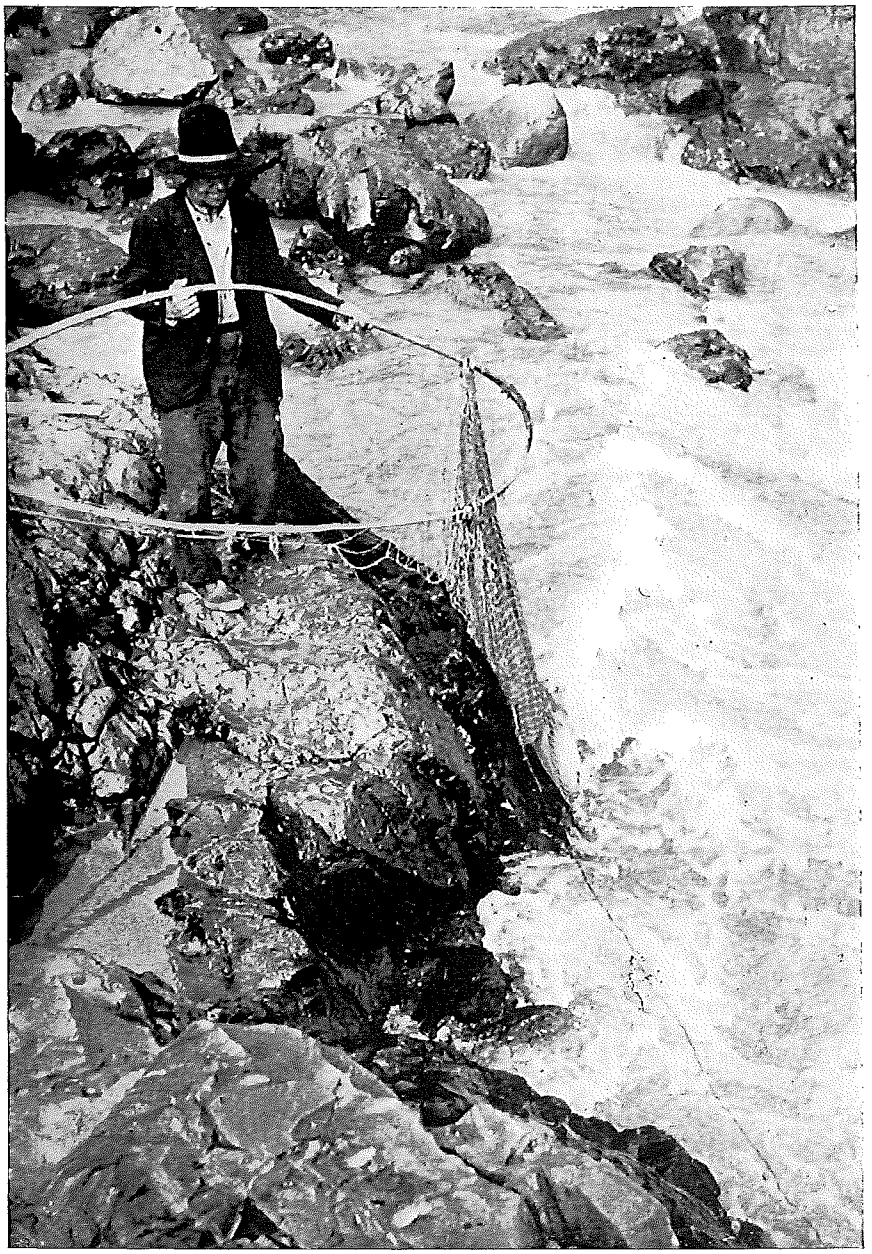


Fig. 2

Indian fisherman taking in his dip net at Bridge River Rapids, 1943. A sockeye salmon may be seen in the bottom of the net.

The Indians were not permitted to fish in the Chilcotin district in either 1942 or 1943. This regulation was enforced as a conservation measure because the sockeye runs to this district were small in these two years. However, in the remaining two years of the cycle, 1941 and 1944, the Chilcotin district had large runs and these Indians accounted for 31.3% and 30.9% (see Table II) respectively of the total Indian catch of the Fraser River watershed. This situation explains to a large extent why the total 1943 catch is much smaller than those of the other three years. The 1942 catch would have been affected in the same direction if it had not been for the large Adams River run in 1942 when the South Thompson Indians caught an estimated 10,005 sockeye or 21.4% of the total Indian catch. This district affects the total catch in a manner that appears to overshadow the fact that there was no fishing in the Chilcotin in 1942.

There was relatively little fishing for sockeye in the Thompson district except in the year 1942. There is only one year (1938, 1942, etc.) in the cycle when there is a large sockeye run to this area.

The other two important fishing districts, Canyon and Bridge River Rapids, have consistently large catches in all four years. This is because these districts are situated in a locality through which the majority of the Fraser River races must pass on their way to their spawning grounds. This is particularly true for the Canyon district which includes that part of the Fraser River between Hope and Lytton. All the main runs pass through this section of the river where they are subjected to an intense Indian fishery. Except for those fish destined to spawn in the Thompson River system, the sockeye also pass through the Bridge River Rapids district. There they are again subjected to another intense fishery by the Indians. The same situation holds for the Lower Fraser and Lytton to Lillooet districts where there are fewer Indians fishing and the catches are correspondingly smaller.

The remaining four districts, Harrison-Birkenhead, Upper Fraser, Nechako, and Stuart Lake, do not show large catches when they are examined individually but they all contribute to the total catch.

The Numbers of Fishermen

Table II shows the number of fishermen in each district and its component areas insofar as this information is available. The number of fishermen was not comparable from year to year. No reason for the fluctuations is apparent. The effort remained reasonably consistent within each district during each of the four years. That is, if the number of Indians increased or decreased, the effort of each varied in an inverse manner. It appeared that each tribe required a consistent number of sockeye for its needs and that this factor controlled the fishing effort rather than the number of Indians fishing. The evidence for this statement is not conclusive but the tendency is apparent.

The Average Catches

Table II shows the average catch of the fishermen of the different districts and their sub-divisions. These catches fluctuate and are not comparable from

year to year. This phenomenon is the result of the changing numbers of fishermen in each district and of the varying numbers of fish present from year to year.

SUMMARY

The Fraser River watershed (1941 to 1944) has been divided into ten districts for the purpose of collecting statistics on the sockeye salmon fishery of Indians within these districts.

The Internationl Pacific Salmon Fisheries Commission, in close cooperation with the Dominion Department of Fisheries, has estimated the numbers of sockeye taken by the numerous Indian fishermen within these districts and areas. The three methods which were used to calculate these estimated catches are: **verbal** and **actual** counts and two different applications of tag ratios.

This study has revealed that the Indians caught the following numbers of sockeye salmon: 52,920 in 1941, 46,708 in 1942, 27,042 in 1943 and 42,820 in 1944. These are estimates based upon the best available information.

The problem of determining the numbers of sockeye caught by the Indians each year is a difficult one. However, the estimates will approach the true values more closely as the present methods are expanded and become more refined.

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