# 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

# 1943

COMMISSIONERS

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


NEW WESTMINSTER, B. C.
CANADA
1944

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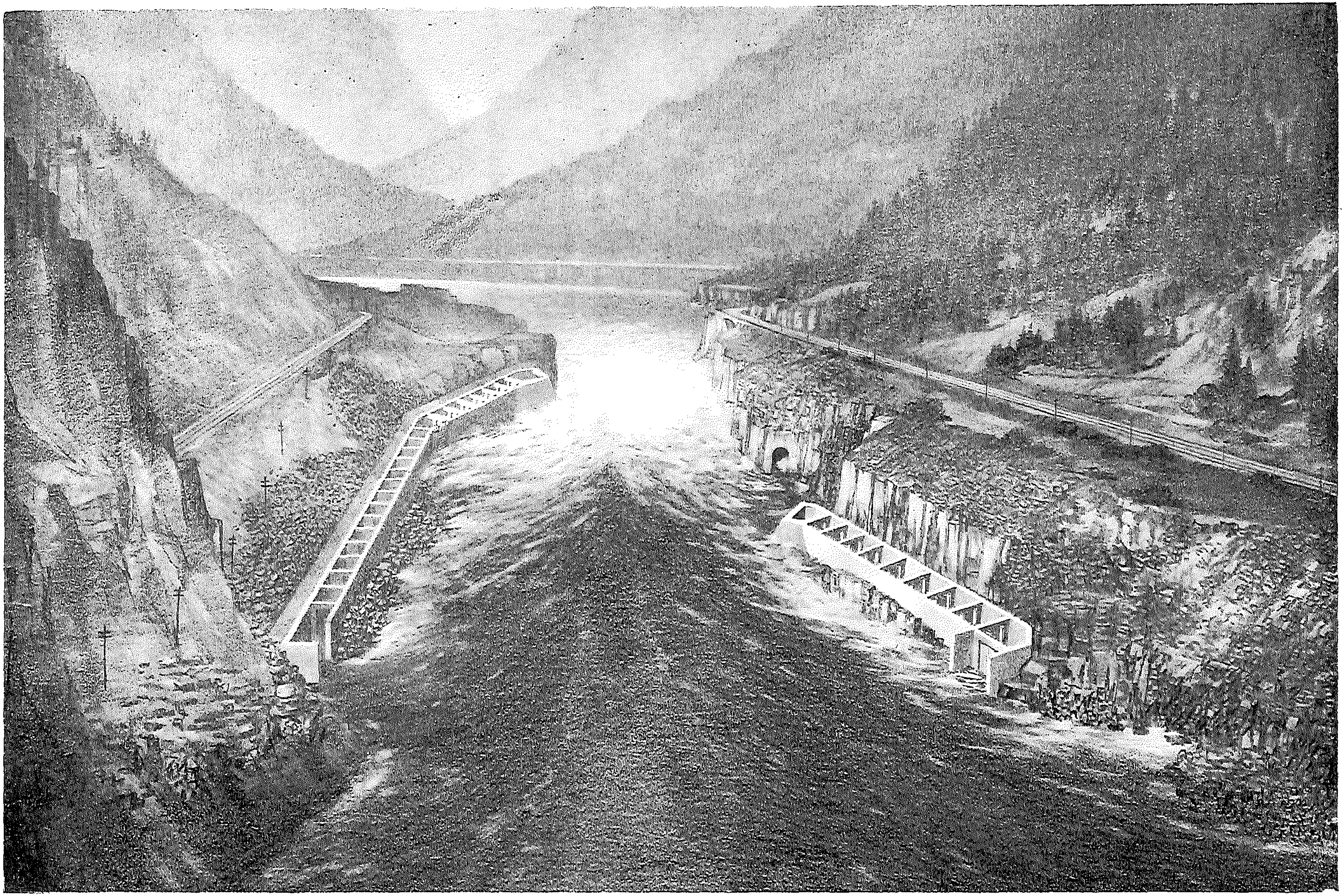


Proposed fishways for Hell's Gate Canyon, Fraser River.

# REPORT OF THE INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION FOR THE YEAR 1943

Results of the Commission's scientific investigation have proved that blockades to salmon migration constitute one of the major reasons for the depletion of the Fraser River sockeye salmon fishery. During 1943 plans for a permanent solution at Hell's Gate, the most serious obstruction, were formulated. Removal of such blocks to migration is a prerequisite to further rehabilitation measures. Every year of delay before restoration of the salmon runs means a loss of a much desired food supply.

The Commission was established by treaty between the governments of the United States and Canada in order to restore the Fraser River sockeye salmon fishery to its former size which, at present prices, would have an annual value of more than $35,000,000 in good years. In order to accomplish this program of rehabilitation, the Commission has authority to conduct fish-cultural operations, to improve the natural spawning grounds, and to develop and use whatever methods may be necessary to increase the stock. Its broad powers include the study of obstructions to the migration of sockeye salmon and the making of recommendations to the respective governments for the removal of such blockades as may be found to cause damage to the fishery. The treaty also provides that the Commission shall have power to regulate the commercial fishery; this includes the power to prescribe the gear mesh which may be used and to limit or prohibit the taking of sockeye salmon within the treaty waters. By arrangement between the two countries, however, actual regulation will be deferred until scientific investigations for a period of two cycles of salmon runs (eight years) have been conducted.

At the first Commission meeting of the year, held at New Westminster, B. C., on April 26th, the program of scientific investigations for the season was presented by the Director. The need for a special appropriation to prepare the final plans for the Hell's Gate Fishways was outlined, and plans to request $10,000 from each country were approved. The Advisory Board met with the Commission on April 28th when the results of the investigations and plans for the future studies were reviewed.

On November 24th the Commission met at Vancouver. The scientific and engineering studies of the Hell's Gate obstruction were discussed in detail. Progress on the extensive studies of the Hell's Gate model reproduced at the University of Washington on a scale of one to fifty feet was reported by Professor C. W. Harris, engineering consultant; a permanent solution for remedying blockade conditions at Hell's Gate was outlined. As a result of investigations at Hell's Gate and Bridge River Rapids as well as preliminary observations at minor obstructions in the Fraser River watershed, it was decided to recommend to the two governments the immediate removal of certain known obstructions to salmon migration. On November 26th, the Advisory Board met with the Commission and, upon being informed of the plans for overcoming the obstructions, enthusiastically endorsed the proposal.

At this meeting Mr. Tom Reid, M.P., retired as Chairman and Mr. Edward W. Allen as Secretary. Mr. Allen was elected Chairman and Mr. A. J. Whitmore, Secretary.

The program adopted for 1943 was a continuation of the one formulated in 1938. A most urgent part of the year's work has been that of completing the biological investigation of the obstruction at Hell's Gate. However, the other important phases of the research program have not been neglected. The salt water tagging at Sooke was conducted in a manner similar to that of previous years. The collecting of commercial fishery statistics, so vital to regulation, was continued as was data on the escapement of sockeye to the spawning areas.

The emergency fish ladder that had been constructed in the fall of 1942 was carefully observed. The success of the fishway during the earlier stages of the blockade is not known since it was entirely submerged during high water and much debris had collected. However, from August 26th until September 13th, 6,447 sockeye and 2,228 salmon of other species were counted as they passed through the ladder.

The fishing gear and flume, which had been used during the previous year, were reconstructed for use in case of a serious blockade. Between July 25th and September 15th, 1,097 sockeye were transported above the block by this means. The installation and repair of these salvage appliances were sponsored by the industry under a fund contributed by the canning companies of British Columbia and the Puget Sound district of Washington.

In order to be relieved of administrative detail so he could devote his maximum effort to the pursuit of fisheries research, Dr. W. F. Thompson resigned as Director but was retained as Scientific Consultant. Mr. B. M. Brennan, former Director of the State of Washington Department of Fisheries and a member of the Commission, resigned as Commissioner and was appointed by the Commission to the position of Director. Mr. Fred J. Foster, Director of Fisheries for the State of Washington, was appointed by the President of the United States to replace Mr. Brennan as a Commission member. Dr. Donald C. G. MacKay, University of Connecticut professor, succeeded Dr. J. L. Kask as Assistant Director. Two staff members were called into the armed forces during the year: A. E. Peterson, now with the U. S. Navy, and R. W. Simmons, with the U. S. Army.

The report of the Director, which follows, gives in more detail an account of the season's activities. In addition, there are contributions by members of the staff and the consultant in which the Hell's Gate investigations, salt water tagging, and the methods for enumerating spawning salmon are discussed.

INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION,

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

Sockeye salmon jumping, Raft River, August, 1940.

# REPORT ON THE INVESTIGATIONS OF THE INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION ON THE FRASER RIVER SOCKEYE FOR THE YEAR 1943

by

B. M. BRENNAN, *Director*

The season of 1943 contributed valuable information to the study of the Hell's Gate blockade problem. The Commission has long realized that the menace of Hell's Gate and its early solution would influence all decisions with respect to a rehabilitation program above the obstruction. To recommend expenditures above Hell's Gate that would be nullified by a block stage in the river at the Canyon would be both impractical and unsound. The Commission has therefore pursued with diligence the investigation to procure the necessary factual biological evidence and engineering data to justify an expenditure sufficient to provide a permanent solution.

Although the 1943 run of sockeye was the poorest in history, sufficient fish were tagged below Hell's Gate to obtain enough additional information to bring this phase of the investigations to a conclusion. The temporary measures employed by the Commission to expedite the passage of salmon through Hell's Gate this season consisted of a passageway cut through the solid rock of the left bank, referred to in the 1942 report, which passed some 9,000 fish by actual count. A positive count could not be made due to the turbulence and opacity of the water in the fish pass and because the cut was entirely submerged during the early part of the season; no evidence could be obtained as to what occurred at that time. The brail equipment installed to assist the 1942 run and also described in the 1942 report was discontinued when it was observed that the disturbance created by dipping the net in the water distracted the fish to such an extent that they ceased to proceed through the fish pass. The assistance thus rendered the upstream migrants paid dividends on the spawning grounds. Injuries were lessened, fish arrived earlier and in better condition, and in spite of the small run a fifty per cent increase in escapement over the brood year was observed on all spawning areas with the exception of Adams River. As the bulk of this run passed through the Gate after the block lifted, the obstruction could not be credited with this decline.

With funds provided by special appropriation the engineering staff have been directing their efforts towards the permanent solution of the Hell's Gate obstruction. A model of the river reach at Hell's Gate, located on the grounds of the Hydraulic Laboratory of the University of Washington in Seattle, has been most helpful in determining basic information applicable to the final plan.

Progress made in the engineering field, strengthened by the biological justification, now gives the Commission sufficient data to request of the two Governments the funds necessary for undertaking the construction of the permanent remedial measures.

During 1943 the sockeye salmon spawning grounds were carefully patrolled as in previous years. Data on the distribution of the escapement portion of the stock were obtained and are given on pages 12 and 13 of this report. Because of less serious water levels at Hell's Gate as well as the temporary measures employed for salvage of sockeye runs, the returns to the upper spawning areas were exceptionally favorable. Some regions such as Chilko showed an increase over that for 1939 of more than 600%. However, the total escapement appears to be somewhat less than for the cycle year. This is largely the result of a near failure of the Cultus Lake run which totalled more than 73,000 sockeye in 1939 and only 11,875 in 1943.

The distribution of the escapement as obtained from the table may be given as follows:

| | |
|---|---|
| Birkenhead River | 46.3 % |
| Chilko River | 12.0 % |
| Cultus Lake | 10.2 % |
| Stellako River | 8.3 % |
| Adams-Little Rivers | 8.1 % |
| Other streams | 15.1 % |

These data include only that part of the escapement that can be successfully enumerated and it should be remembered that there are still a number of streams for which salmon populations can not be accurately determined. A consideration of the problems associated with the enumeration of spawning populations of sockeye salmon is presented in a separate article in this report. It is anticipated that in the not too distant future, the errors of escapement enumeration may be further reduced.

Special reports dealing with Hell's Gate, Spawning Ground Enumeration, and Salt Water Tagging have been included in this report. There is also a summary of the escapement to the various spawning areas during the year 1943 which has been prepared by Mr. C. E. Atkinson from reports submitted by members of the field staff. A special feature of this report is the spawning ground map (enclosed in pocket in back cover) and explanatory notes concerning same to be found at the end of this report.

Unspawned female sockeye, Scotch Creek.

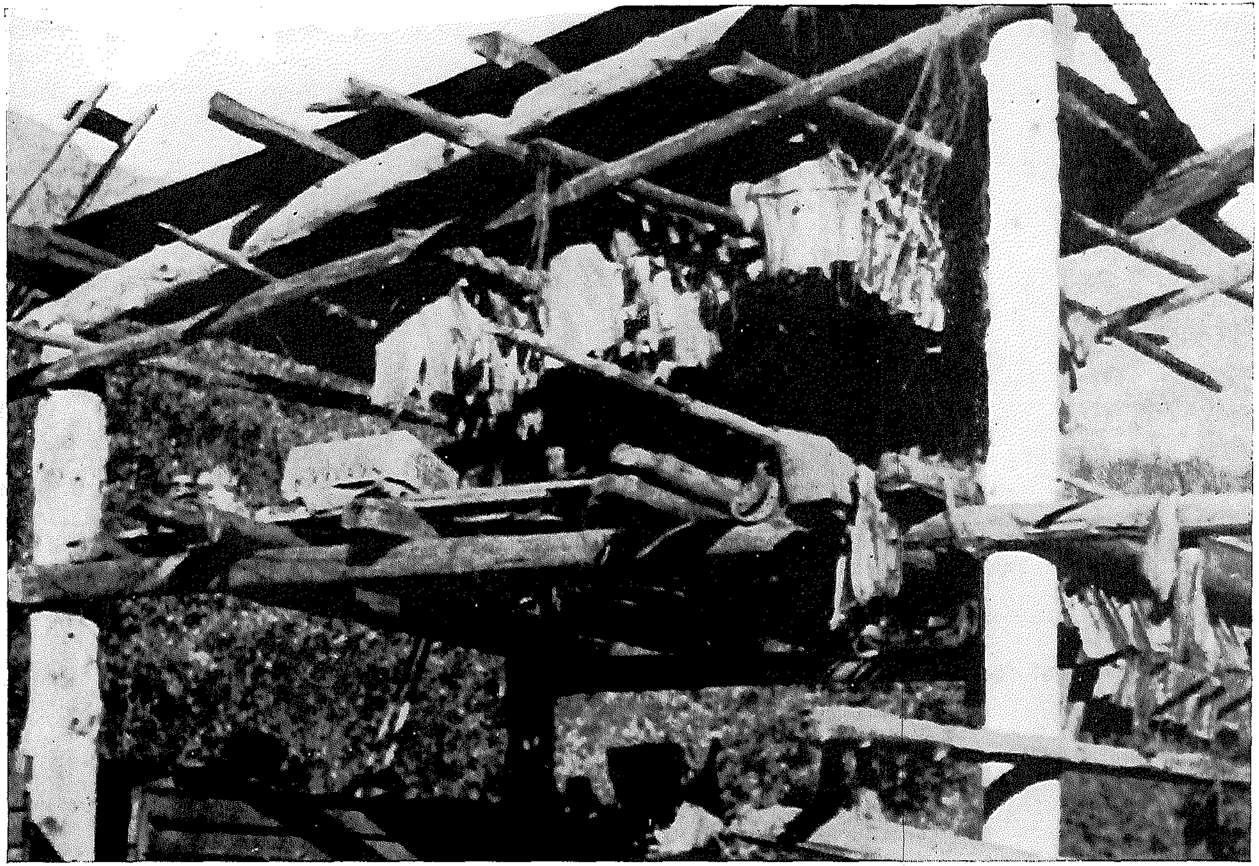
## SUMMARY OF THE ESCAPEMENT TO THE VARIOUS SPAWNING AREAS, 1943

| 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** | | | | | | | | | |
| Boise Creek (2) | Sept. 1 | Oct. 3 | 2,903 | 8,903 | 5,520 | | 51.3 | | 48.7 |
| Four Mile Creek | Sept. 2 | Oct. 14 | 165 | | Present | | 68.6 | | 31.4 |
| Seven Mile Creek (2) | Sept. 10 | | 70 | 2,333 | 420 | | 21.4 | | 78.6 |
| Upper Pitt River | | | 3,000 | | Present | | 40.2 | | 59.8 |
| Widgeon Slough | Oct. 20 | Nov. 23 | 205 | | 293 | | 43.6 | | 56.4 |
| Cultus Lake (1) | Aug. 25 | Jan. 4 | | | 11,875 | 0.4 | 32.7 | 1.2 | 65.7 |
| **Harrison** | | | | | | | | | |
| Big Silver Creek | | Oct. 16 | 3 | | Present | | | | |
| Douglas Creek | Sept. | | | | Present | | | | |
| East Creek | Oct. 26 | Nov. 17 | 9 | | 9 | | | | |
| Harrison River | Nov. 10 | Nov. 30 | 1,114 | | Present | | 5.2 | | 94.8 |
| Harrison Lake | Oct. | | 28 | | Present | | | | |
| Hatchery Creek | Oct. 14 | Nov. 14 | 63 | | 77 | | 8.6 | | 91.4 |
| Weaver Cr. (3) | Oct. 15 | Nov. 20 | 2,210 | 3,906 | 3,128 | 0.4 | 16.1 | | 83.5 |
| **Lillooet** | | | | | | | | | |
| Birkenhead River (3) | Sept. 3 | Oct. 31 | 39,969 | 61,367 | 50,668 | 3.4 | 35.7 | | 60.9 |
| Upper Lillooet Streams | | | | | Present | | | | |
| **South Thompson** | | | | | | | | | |
| Adams River | Sept. 28 | Nov. 19 | 7,790 | | 10,000 | | 34.1 | | 65.9 |
| Little River | Sept. 28 | Nov. 15 | 1,519 | | Present | | 34.5 | | 65.5 |
| Seymour River | Aug. 20 | Sept. 20 | 200 | | Present | | | | |

## SUMMARY OF THE ESCAPEMENT TO THE VARIOUS SPAWNING AREAS, 1943 — (Continued)

| District and Stream | Dates of Run Arrival | Dates of Run End | Estimated No. Sockeye Present Minimum | Estimated No. Sockeye Present Maximum | Estimated No. Sockeye Present Probable | Sex Ratio (%) Males 3 Yr. | Sex Ratio (%) Males 4 and 5 Yr. | Sex Ratio (%) Females 3 Yr. | Sex Ratio (%) Females 4 and 5 Yr. |
|---|---|---|---|---|---|---|---|---|---|
| **North Thompson** | | | | | | | | | |
| Raft River | Aug. 15 | Sept. 30 | 3,430 | | 4,000 | | 49.3 | | 50.7 |
| **Seton-Anderson** | | | | | | | | | |
| Seton Creek | Aug. 23 | Oct. 7 | 54 | | Probably result of Blockades | | | | |
| **Chilcotin** | | | | | | | | | |
| Chilko River (3) | Aug. 21 | Oct. 24 | 8,343 | 19,937 | 13,546 | 7.0 | 33.3 | | 59.7 |
| **Nechako** | | | | | | | | | |
| Endako River | Aug. 19 | | | | 46 | | | | |
| Stellako River (2) | Sept. 7 | Nov. 12 | 7,962 | 10,589 | 9,142 | | 33.6 | | 66.4 |
| **Stuart** | | | | | | | | | |
| Forfar Creek | Aug. 1 | | 350 | 450 | 400 | | | | |
| Hoy Creek | | | 2 | | 2 | | | | |
| Kynoch Creek (3) | Aug. 1 | | 2,100 | 2,200 | 2,150 | | 43.6 | | 56.4 |
| Narrows Creek | | | 5 | | 5 | | | | |
| Rossette Creek | Aug. 1 | | 400 | 500 | 450 | | | | |
| **Northeast** | | | | | | | | | |
| Lower Bowron River | Aug. 26 | Sept. 23 | 68 | | 145 | | | | |
| Upper Bowron River (1) (including Moose Creek) | Aug. 4 | Sept. 23 | | | 6,215 | | 39.3 | | 60.7 |

(1) All fish counted through weir.
(2) Population estimated by tagging program.
(3) Population determined on indices.



Drying rack for salmon as used by the Indians for their food supply in the Birkenhead District.

# THE OBSTRUCTION AT HELL'S GATE IN THE CANYON OF THE FRASER RIVER

by

W. F. THOMPSON

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The International Pacific Salmon Fisheries Commission submitted in January, 1944, a report to the governments of the United States and Canada on the obstruction to the migration of sockeye salmon in the canyon of the Fraser River. This was in support of a recommendation for the removal of the difficulty by the construction of fishways.

The report has a wide scope. It presents proof of the existence of the obstruction and of the damage it has done. It contains much else of great interest. It explains the changes shown by the catch statistics, bears on the subject of overfishing, modifies conclusions as to times and rates of migration up the river, and contributes to such fundamental subjects as the racial composition of the sockeye run. Its publication necessitates the use of data collected over a period of five years. Because this will take some time, the following brief review of the conclusions as they pertain to the obstruction is presented, although it cannot include all the conclusions reached or present the supporting data.

The report describes tagging experiments carried on at Hell's Gate, a turbulent narrows in the Fraser River, about 130 miles from its mouth, in the canyon by which it passes from the interior plateau through the coastal ranges. These experiments were part of a more general program to ascertain the movements and mortalities of the returning adults. The objective was to determine the principal causes of depletion, whether in the activities of the fishermen or in physical factors. It will be found to have necessitated research upon many phases of the life of the sockeye and of its fishery.

It has usually been assumed that the Fraser River sockeye fishery owes its decline to a major disaster in 1913, since in that year the big run of a four-year cycle occurred for the last time. The catch of that year was far in excess of those of three other years of the cycle, so far that it approximated three times their sum. But it met obstructions in the Fraser Canyon caused by railroad construction and the return in 1917 was reduced by over 70 per cent. The loss, cumulative over the years since, has been tremendous. Had the "big" year recurred in each four-year cycle as expected, the seven resultant seasons in the thirty years since 1913 should have seen packed over 15 million cases more than they did.

But the report shows that depletion occurred in two main periods, from 1899 to 1903, and from 1910 or 1911 to and after 1917. Not only the "big" year, but the three "off" years of each cycle were involved. When these are taken into account, the possible loss since the first years of depletion reaches an astounding total, at present prices equal to about one and one-quarter billions of dollars.

Analysis of records of direct observation, of hatchery takes of eggs, and other information throws much light on what happened. The depletion which became evident between 1899 and 1903 was associated with a dam at the outlet of Quesnel Lake. This dam is gone and was not responsible for the second, and more important period of depletion, after 1910. This depletion took place in those spawning grounds **above** Hell's Gate canyon, not in those **below**. It affected in the main, the earlier runs of each season, and those spawning later have come to provide the greater part of the sockeye catch. The depletion has been over a series of years in each period, not in one. Occasional recovery and relapse have been erratic, suggesting a variable cause of mortality. Certain formerly very productive areas such as Quesnel are nearly entirely barren, others have stocks which are sometimes increased, sometimes reduced. The existing records, from which these facts were drawn, indicate a cause of depletion in the canyon still existent, and variable and seasonal in its effect.

The records therefore do not indicate overfishing as the primary cause. Overfishing would presumably tend to affect all races equally. But the great catches may have left the runs in poorer condition to withstand a heavy mortality. Periods of intense fishing during years of heavy yield preceded those of lessened catch and decreased fishing. The resultant correlation between fishing and depletion is suggestive of cause and effect. But we do not yet know which was cause and which effect. The relationship of overfishing to the present condition of the Fraser River is a study in itself, treated but incidentally in the present report.

The history of the obstructions in the canyon is reviewed. The catch records indicate that they must have occurred over a period of years, from 1910 on, but the spectacular failure of the escapement of 1913 to pass the canyon has received almost all the blame for depletion, mainly because of the magnitude of the run affected. It is certain that runs of the three remaining years of the cycle were depleted too, and there may have been additional factors in operation.

In 1913, however, the effect of rock dumped into the Fraser at several places which were difficult of passage by salmon under even ordinary conditions attracted attention. Rock was blasted away to provide passage for the fish along the river margins. A heavy slide in 1914 directly at Hell's Gate was removed in large part during that and the following year. Finally the canyon was stated to be as passable for sockeye as it ever had been.

Close examination of the records since 1913 shows, however, that recurrent difficulties have been experienced ever since. It was not necessarily apparent that they were of a character to prevent ultimate passage, which observers claimed always occurred. In themselves they did not warrant expensive remedial action. Only rarely were dead fish actually seen below Hell's Gate, and this in itself was good reason to doubt their presence.

Even had dead fish been found in some numbers, it would not necessarily have caused depletion of the runs any more than the fisherman's catch would. Biologists know a species is capable of compensating itself for a considerable mortality in excess of that which is average, and some occasional deaths in the canyon would not mean disaster under ordinary circumstances. They might, indeed, occur normally if there were no obstructions whatever. They might occur only in exceptional years, and very rarely. The crucial problem was, therefore, to determine whether the difficulties actually led to mortality of a serious degree, with sufficient frequency to merit attention.

Observation of the obstruction in 1941 came at an opportune time to supply some necessary facts in regard to this. Great masses of fish accumulated below Hell's Gate for a distance of six or seven miles. They ultimately disappeared, but in the meantime sufficient had been learned of the story to show that mortality could occur and yet not be obvious to the observer. Without this knowledge, the results of the tagging could not have been interpreted nor could the long continued failure to detect the damage be understood.

It appeared that fish delayed below the obstruction proceeded to pass through the physiological changes which normally occur during their usual migration. When they first appeared, they fought the currents vigorously, filling the surfaces of the rapidly moving eddies. At the stage when they should have reached the headwaters, vigorous movement dwindled, and the now highly colored fish fell back into the quieter reaches and lesser eddies. They then began to appear on the river riffles and to pass in and out of creeks where they could find conditions most nearly approximating those of their spawning beds. Finally, when in their home streams they should have settled to the bottom gravel and begun to spawn, the delayed migrants sank deeper in the Fraser water. But the river was densely clouded with glacial silt, and the fish disappeared from view. They could be seen only as they happened to enter and leave the clear-water creeks and small rivers during their restless and abortive search. Of course their numbers in the main river could not be ascertained, but at least some of them could be found, just by feeling for them with a gaff hook. As they weakened with time, the strong currents brought some few of them to the surface momentarily as they were carried downstream. And as they died they sank into deeper holes, rarely drifting upon the banks where they could be seen. But such observations were not proof that any great proportion failed to pass. They showed how death could occur and not be seen. No one could prove that more than a few thousand fish died, certainly not a million. And 1941 was a most exceptional year as far as water levels were concerned.

To determine this mortality, to see how often it occurred, and to show whether it could be heavy enough to damage one part of the run and not the other, one of the most extensive salmon tagging experiments ever undertaken was completed between 1938 and 1942. Some 34,124 sockeye salmon were tagged at or near Hell's Gate of which 10,663 were recovered — about 31 per cent. While this was not as high as the percentage of salt water tags returned, it was extraordinary for returns within the river. The tagging and recovery of these fish has been a very great task.

The first results showed that the various races passed Hell's Gate at different times. In general those passing farthest up-stream were earliest. The exact times of their normal passage were, of course, obscured by the delay below Hell's Gate.

The tags also proved that the periods of delay at Hell's Gate were associated with certain levels of water within the possible range of ninety or more feet. Delay was shown by the progressive accumulation of tagged fish below the obstructed points on each side of the river. Release from the block allowed these accumulated tags to pass up-river en masse.

From tags recaptured by our own operatives below Hell's Gate it was shown that the accumulation took place at levels above 45 feet, and at those between 27 and 40 feet. The tags were recovered from the delayed migrants in progressively greater numbers as the period of their delay lengthened and reference in each case to the date of tagging showed that the accumulation had taken place over the whole period that water levels created difficult conditions for passage.

When the water fell below 27 feet, the accumulated fish, and the tags with them, were released and passed up-stream. When sampled en route by recoveries at such places as Bridge River, they showed the same composition as to dates of tagging that was evident just before release through the obstruction. On arrival on the spawning grounds, as at the Stellako in 1942, this was still true. Although a more or less equal number had been tagged daily, it was apparent that the percentage of these numbers which finally passed up-stream was progressively less, the longer the delay. Whereas between 40 and 50 per cent of recently tagged fish passed, but 5 per cent of those tagged 30 days earlier did so. This meant that the fish failed in proportion to the delay. Had the runs reaching the obstruction been in equal abundance during all parts of the period of delay, instead of greater toward the end, the loss would have approximated 50 per cent in such a year as 1940, when the water was between 27 and 40 feet inclusive, for a period of over 40 days. Occurring in proportion to the delays, the mortalities were annual, not exceptional.

The missing fish were accounted for down-stream. In each creek, the population of tagged fish was renewed nearly daily as sockeye passed in and out and the tags removed by our observers were quickly replaced by new. While it was not possible to recover the same high percentage as from those above, the recoveries in the creeks and on the riffles in the river were greatest in those fish which had been subjected to greater delay. This was the opposite of that found true of recoveries up-stream, thus showing where the missing fish had gone. This indicated, we believe, a real loss to the species because reproduction was far from perfect in the substitute environment. While spawning occurred to some extent, examination of eggs laid in the creek gravels below Hell's Gate showed that few had survived and that their numbers were very small in proportion to the fish which must have been present. Because no lakes are accessible to these fish, it is very doubtful whether even a small number of the resultant young survived. At all events, no consistent runs return to these creeks four years later even after many fish have been known to take refuge in them. Hence, for the purposes of the report, the sockeye delayed below Hell's Gate until too late for them to continue, are called mortalities.

The effect of this mortality on the catch four years later cannot be understood without realizing the logical consequences of the existence of races, each bound for its own section of the river. The run of sockeye salmon through the canyon consists of a number of such races, some of which attempt to pass when the obstruction is at its worst, while others arrive too late to be affected by it. The race using Quesnel Lake is an example of the former, that using the lower Adams River, of the latter. These races then must probably experience the entire range of possible mortalities, from nearly all to none.

The various races are in fact in widely different stages of depletion. Those presenting themselves during the usual season of difficult water levels are now very few in number of individuals. They are rarely in sufficient number to make much of a showing in the eddies below Hell's Gate however numerous they may once have been. The numbers tagged give no measure of their abundance, because an effort was made to tag an equal number daily. A mortality of 50 per cent among the tagged fish would therefore represent in ordinary years but a relatively small number of actual deaths, a fact which helps to explain why the effect of the delays has not been readily visible below Hell's Gate. But the mortality must be considered in the light of the numbers which should be passing, not those now remaining. The remnants of races affected are undoubtedly extremely valuable, and what has happened to them is of the utmost significance as indicating the cause of their depletion, of the condition of the Fraser River sockeye run, and the prospects for the future.

The races escaping the difficulty in the canyon might well be in such abundance as to overpopulate, or tend to overpopulate their spawning grounds, if we can judge from experience with other species of fish. If so, they would attain a certain level of abundance, around which they would vary more or less widely as other factors would affect them. But in contrast, those races at a low level of abundance would underpopulate their grounds, and would be expected to have as a result the most favorable spawning and living conditions. They should reproduce at a high rate. These latter borderline races, strongly affected by the obstruction at Hell's Gate, may hence possibly respond quickly and positively to any chance increase in the numbers allowed to reach the spawning grounds. If so, some trace of this response should be present in the commercial catch, when conditions vary to allow it.

The obstruction at Hell's Gate is above a water level of 26 feet. This level is reached usually by falling water shortly before or after September 1st. The greatest variability in the duration of the difficult water levels is thus usually found after September 1st, in fact, in the two months of September and October. Races passing during the period of difficult conditions are now less important to the catch because they become bare remnants of survivors. Fish passing later, during September and October may include portions of such races as those using the Chilko and Stellako Rivers, and these are still in such abundance as to affect appreciably the catch of sockeye when conditions favor them. It is in these races, on the very border between depletion and abundance, that the natural safeguards against extinction would be most effective, and in which increases in the numbers passing Hell's Gate would be most productive of return.

Because of these considerations, variation in the commercial catch was compared with variation in the number of days the obstruction was present in the months of September and October. The commercial catch would be expected to show the effects four years later, according to whether the return run was greater or lesser than the parent run. Since the catch is the best existent measure of the run, the return catch was expressed as a percentage of the parent catch and this was compared with the percentage of days in September and October during which the river was not passable.

The comparison showed a high degree of correlation between the duration of difficult water levels at Hell's Gate and the catch four years later. This completed the chain of proof.

The removal of the obstruction was therefore recommended.

The significance of the findings in regard to the races of sockeye on the Fraser River must not be overlooked. They are plainly in various stages of depletion, some of them being mere remnants. But the resilience of these injured races under the present fishery and regulation is very apparent. In this lies hope for the future of the Fraser River sockeye.

These races could have been injured in the way they have been only if they possess a high degree of individuality. Each of them must have been fitted by its characteristic timing of migration, as well as by many other of its habits and structures, to its particular combination of fresh and salt water environments. How many characters are thus peculiar to such a race is, of course, as yet unknown. But surely we know enough of this individualism to realize that each race is adapted in a complex way to its way and place of life, and that it is not likely that any other race can replace it efficiently. These races must be valued accordingly.

It is possible that many of these races still exist within the Fraser watershed. If they are released from excessive mortalities they may be expected to show a high degree of recuperative power, each multiplying at a rate which will make it once again valuable to the catch. The purity of their strains must be safeguarded against mixture with transplanted races, or against crossing of adjacent strains during artificial propagation, until the removal of the obstruction allows this development of whatever values they may have as breeding stock. These still existent colonies may determine the future yield of the Fraser River sockeye.

# SOCKEYE SALMON TAGGING AT SOOKE AND JOHNSTONE STRAIT

by

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

## INTRODUCTION

Sockeye salmon have been tagged by the International Pacific Salmon Fisheries Commission at Sooke (see map) each year since 1938 and at Johnstone Strait (northwest of the Strait of Georgia) during the seasons of 1940 and 1941. They have also been tagged at the Sandheads (1938, 1939, 1940 and 1941), at Lummi Island (1939, 1940 and 1941), and at the San Juan Islands (1939, 1940 and 1941). The results of tagging in all of these locations are being studied at the present time and will be presented upon completion. It is proposed to present here a summary report on the results of certain aspects of the Sooke and Johnstone Strait tagging.

The chief aims of the investigation were to trace the routes of migration, to ascertain times taken, and to determine the mortality and fishing intensities. The solution to each of these problems would constitute a step toward our greater understanding of the life history and behavior of this valuable fish and would contribute to the knowledge necessary for an equal division of the catch between Canada and the United States — a duty with which the Commission is charged.

## METHOD OF TAGGING

Since the Sooke fishery consists solely of traps, the sockeye for tagging could be secured only on days when the traps were being lifted. They were taken from the spiller of the trap and put into live-boxes. These live-boxes were constructed of a rectangular pipe frame (6′x4′x3′) tightly covered with a strong mesh netting. When filled, the live-boxes were towed some distance from the traps so that when released the tagged fish would not be recaptured immediately.

The method of tagging was as follows: A tagging box was used to hold the fish while they were being tagged. The tagging equipment consisted of a pair of long-nosed pliers and a quantity of 3″ nickel pins and celluloid tags. Three men usually comprised the crew; namely, one man to dip out the fish, another to hold the fish, and a third man, in charge of the crew, to insert the tag. The salmon was dipped from the live-box and placed in the tagging box. The nickel pin plus a blank tag was inserted through the body just below the centre of the dorsal fin. A numbered tag carrying the Commission's address and the amount of the reward was then put on the protruding free end of the pin which was then cut to the proper length and twisted so that the tag was held secure and flush against the fish. As soon as the tag had been put in place, the fish was measured and a scale sample taken posterior to the dorsal fin and above the lateral line. Scars and abnormalities were noted and the tagged fish released. The entire procedure of tagging was done with the greatest possible speed and the fish were seldom out of the water more than 35 to 40 seconds.

The tagging procedure at Johnstone Strait was identical with that at Sooke; however, the means of securing the salmon was different. In Johnstone Strait the tagging boat contacted the seiners as they were completing their hauls. The sockeye for tagging were dipped from the pursed net before it was finally lifted by the fishermen. Purchase slips for the fish were made out at the current price and given to the captain of the boat. Tagging commenced as soon as the sockeye had been secured. Upon completion of the tagging another seine boat was approached and more sockeye were purchased. This method of securing fish was dependent upon the cooperation of the fishermen and it has proved to be particularly satisfactory in the Johnstone Strait fishery.

It should be emphasized that the recoveries reported represent the minimum numbers recovered. Some tags are inevitably lost before they can be turned in to the Commission, others are occasionally kept as souvenirs by the finders, still others are not collected because of the impossibility of examining every fish on the spawning grounds. However, the returns from these experiments have been satisfactorily large, the investigation having been carried out on an extensive scale. In every experiment of this type, some tags are returned with incomplete or obviously inaccurate information. Such tags have been referred to as "questionable" in Tables VII and VIII.

For purposes of analysis and presentation, the returns have been grouped into large areas (see map). While these areas are to a large degree arbitrary yet they do conform as nearly as possible to established fishing areas and to those areas used in the log books supplied to sockeye fishermen by the Commission.

## RESULTS

During the six years of tagging at Sooke 6,654 sockeye salmon have been tagged, of which 3,234 or 48.6% have been recovered. The areas in which most recoveries were made are shown in Table VII which presents the results for each year of the experiment.

During the two years, 1940 and 1941, 2,715 salmon were tagged in Johnstone Strait and of this number 1,524 or 56.1% were recovered (see Table VIII).

It will be noted that for both Sooke and Johnstone Strait the percentage of recoveries from the commercial fishery as a whole is usually higher for the odd years, viz. 1939, 1941 and 1943. These are the years in which pink salmon fishing, which involves similar gear, is commercially important. The increased

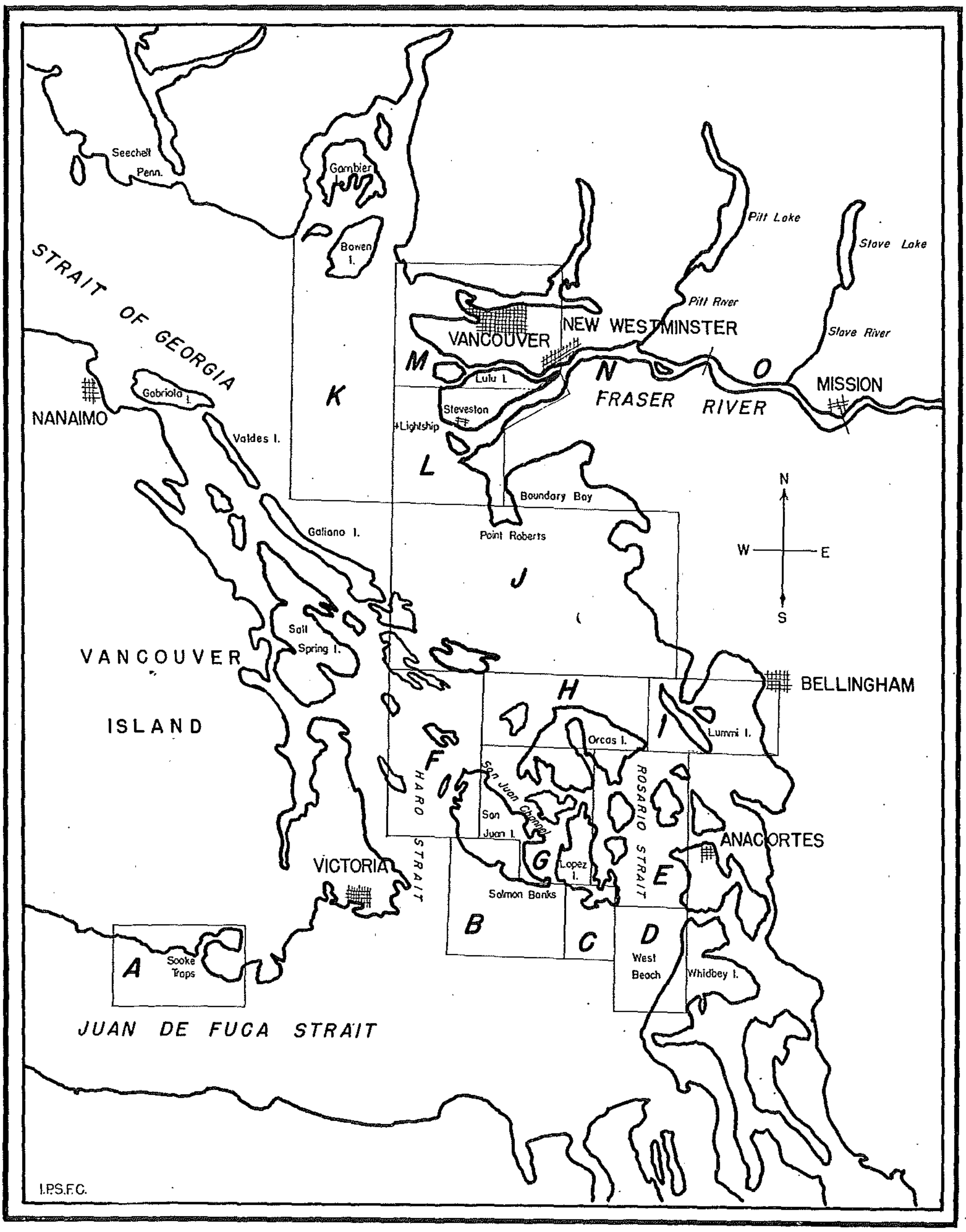


*Fig. I*

Map showing principal recovery areas for salmon tagged at Sooke and Johnstone Strait.

recovery of tagged sockeye probably results from the increased fishing effort in these years.

**Time Between Tagging and Recovery**

The number of days between the times of tagging and recovery includes both time taken for travel and time spent in delay. Moreover, travel may not always be in the direction of the river and different individuals may differ markedly in their migrating behavior. Since the arithmetic average is apt to be influenced by a few individuals that take an unusually long time to reach their destination, it was thought best to use the median, or central value, as a measure of time. Either measure would give the same order of events, the median giving a slightly smaller, and probably more characteristic, value.

From Sooke and Johnstone Strait the median numbers of days to various areas have been calculated and are presented in Table IX. For example, the number of days elapsing between tagging at Sooke and arrival at Point Roberts is shown to be between 6 and 7 days in different years, at the mouth of the Fraser 9 and 15 days, at Adams River 57 and 67.5 days, etc.

In a majority of the areas of recapture, fish tagged in 1941 were recaptured in the shortest median times (See Table IX). The reality of this observation must be tested by further analysis. If tagging in cyclic returns of this run should confirm this observation, it would indicate a racial difference that would be fundamental to regulation.

Fish tagged at Sooke and at Johnstone Strait during a given period arrive in the Canadian commercial fishing areas at the mouth of the Fraser River after approximately the same number of days. This is of interest especially since the distance traversed is very much greater in the case of the Johnstone Strait fish.

As high as 9.6% of the fish tagged at Sooke have been recovered from areas not on the route to the Fraser River. Tags later recovered from these areas were placed at Sooke mainly prior to the first week in July. At this time fish, which later migrate to these areas, intermingle at Sooke. The distribution of these returns is indicated in Table I. Conclusions of this type can hardly be drawn for fish tagged in Johnstone Strait since the rivers in this area are insufficiently patrolled to afford comparable data.

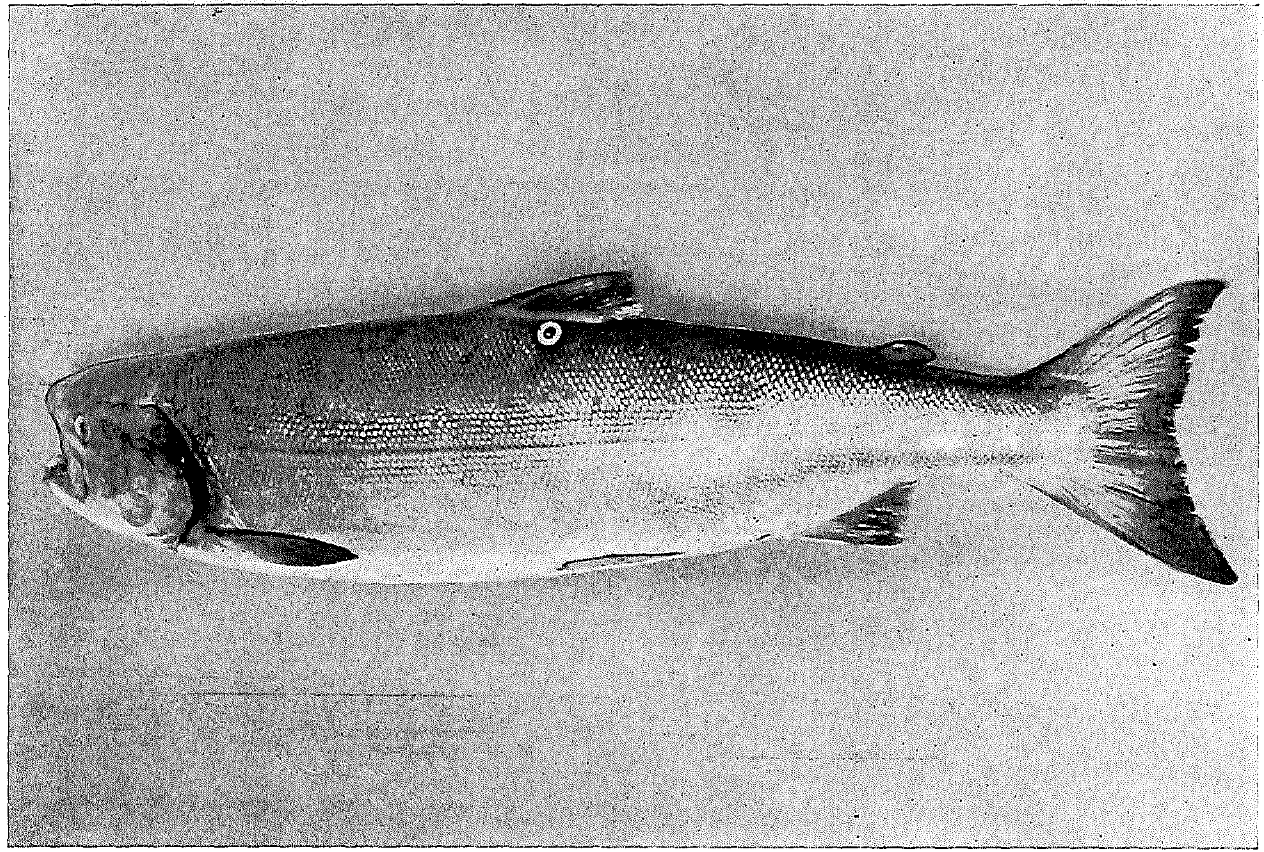

*Fig. II*

Illustration of a tagged sockeye salmon.

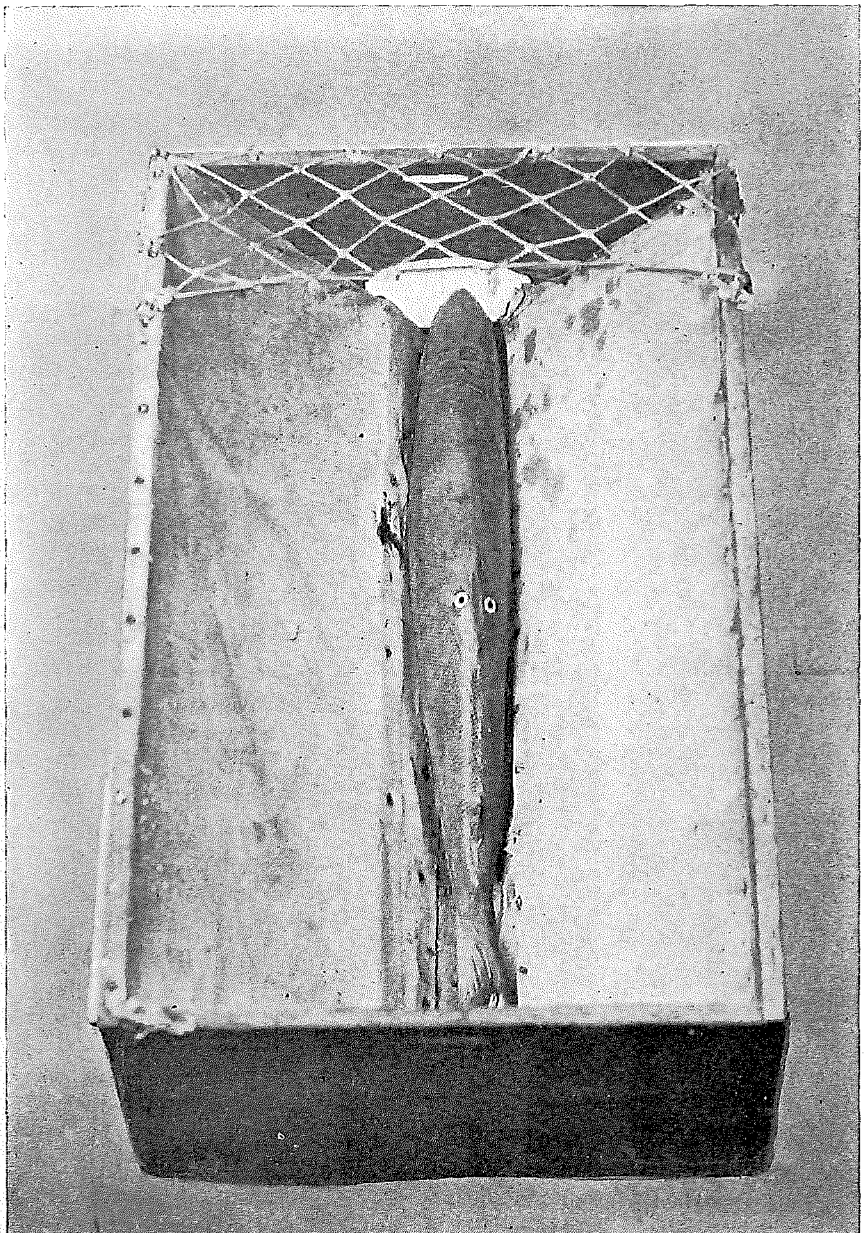

*Fig. III*

Sockeye salmon in tagging box.

## TABLE I

Localities other than those on the direct route to the Fraser River in which two or more sockeye tagged at Sooke have been recovered in any one year. The data are presented by years for the period 1938-43 inclusive.

| Recovery Location | YEAR | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 | Total |
| Skagit Bay and River | | 6 | 17 | 15 | 1 | 2 | 41 |
| Issaquah Creek | | | 16 | | | | 16 |
| Baker River | | 5 | 10 | 18 | | 6 | 39 |
| Swinomish Creek | | | 4 | | | | 4 |
| Quinault River | | | 2 | 1 | | | 3 |
| Stilaguamish River | | 2 | | | | | 2 |
| Hobarton River | | 2 | | | | | 2 |
| Nitinat | 13 | 42 | 6 | 8 | 1 | | 70 |
| Barkley Sound | 13 | 6 | 4 | 1 | | | 24 |
| Alberni Canal | 9 | 3 | | | | | 12 |
| Upper Johnstone Strait | 2 | 1 | 3 | 1 | 2 | | 9 |
| Lower Johnstone Strait | 2 | 2 | 17 | 1 | 1 | 1 | 24 |
| Total | 39 | 69 | 79 | 45 | 5 | 9 | 246 |
| % of Total Tagged | 4.0 | 6.6 | 8.5 | 5.3 | 0.3 | 0.8 | 4.0 |
| Commencement of Tagging | June 11 | May 25 | June 13 | June 12 | July 2 | July 8 | |

When the tagging season is considered as consisting of two periods, an earlier one ending August 9th, and a later one beginning on August 10th, the present indications are that the rate of migration of fish tagged at Sooke is more rapid in the earlier half of the season (See Table VI). The migration rate thereafter gradually decreases as the season progresses; for Johnstone Strait no such change is apparent.

The results for all years except 1941 indicate a distinct delay off the mouth of the Fraser River on the part of all fish tagged at Sooke; fish tagged in Johnstone Strait show this delay less clearly.

### Routes to the Fraser River

Evidence from tagging indicates that Johnstone Strait fish pass directly into the Gulf of Georgia. Sooke fish, on the other hand, pass through one of two main channels (viz. via Rosario Strait to Point Roberts or via Haro Straits to Point Roberts) or possibly a third (viz. via San Juan Channel to Point Roberts) en route to the Gulf of Georgia. The returns show that the Johnstone Strait and Sooke runs join in the Gulf of Georgia. The Sooke fish do not enter into the Johnstone Strait fishery nor do the Johnstone Strait fish enter into the fishery south of Point Roberts except to a very small extent.

After leaving the Strait of Georgia it is necessary for the fish to choose one of the entrances to the Fraser River. The southern entrance (area L on map) is much the largest and is characterized by the greatest volume of water and the most fishing. The great majority of tags recovered near the entrance to the river were recovered there. In one year (1938) as high as 5% of the tagged fish recovered were from the North Arm (Area M). However, no biological significance should be attached to this fact in the absence of further evidence.

**Distribution of Fresh Water Recoveries.**

From Tables VII and VIII it is apparent that the percentage returns from up-river areas are relatively high for the even years and low for the odd years; they vary in a manner complementary to those from salt water. This is shown by the following tables (Tables II and III) in which the actual numbers of returns from up-stream are presented together with the number of returns per thousand fish tagged.

**Table II**

**UP-RIVER RETURNS FROM SOOKE TAGGING**

| Year | Tagged | Total Up-stream Returns | Returns per 1000 Fish Tagged |
|---|---|---|---|
| 1938 | 980 | 59 | 60 |
| 1939 | 1,042 | 44 | 42 |
| 1940 | 930 | 26 | 28 |
| 1941 | 849 | 8 | 9 |
| 1942 | 1,800 | 97 | 54 |
| 1943 | 1,053 | 32 | 30 |
| Total for even years | | | 142 |
| Total for odd years | | | 81 |

**Table III**

**UP-RIVER RETURNS FROM JOHNSTONE STRAIT TAGGING**

| Year | Total Tagged | Total Up-stream Returns | Returns per 1000 Fish Tagged |
|---|---|---|---|
| 1940 | 1,555 | 61 | 39 |
| 1941 | 1,160 | 20 | 17 |

Attention is called to the fact that returns from salt water are exceptionally high in the odd years of the purse seine fishery on the United States side of the border (See Tables VII and VIII). This results from the fact that in those years the United States fleet is large and the season is long. Whatever additional circumstances contribute to this result can be brought to light only through further analysis.

Tag recoveries from the major spawning grounds for all years are shown in Table IV.

Table IV

**TAGGING RECOVERIES FROM THE MAJOR SPAWNING GROUNDS**

| Location | Tagged at Sooke | | | Tagged at Johnstone Strait | |
|---|---|---|---|---|---|
| | 1938-43 | 1940-41 | Per 1000 Fish Tagged 1940-41 | 1940-41 | Per 1000 Fish Tagged 1940-41 |
| Number Tagged | 6,654 | 1,779 | | 2,715 | |
| **Recoveries** | | | | | |
| South Thompson* | 101 | 1 | 0.6 | 2 | 0.7 |
| Chilcotin | 2 | 2 | 1.1 | 16 | 5.9 |
| Harrison-Birkenhead | 13 | 7 | 3.9 | 3 | 1.1 |
| Cultus Lake | 4 | 2 | 1.1 | 1 | 0.4 |
| Pitt River | 3 | 2 | 1.1 | 0 | 0.0 |

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

The Commission's observers recaptured 19 Sooke tags and 3 Johnstone Strait tags at Hell's Gate. Most of the remaining tags that were returned were recovered by the Indians at their various fishing stations along the banks of the Fraser River and its tributaries. The most notable of these locations with the numbers of tagged fish recovered in each are shown in Table V.

Table V

**TAGGING RECOVERIES FROM THE PRINCIPAL INDIAN FISHING LOCATIONS**

| Location | Tagged at Sooke | | | Tagged at Johnstone Strait | |
|---|---|---|---|---|---|
| | 1938-43 | 1940-41 | Per 1000 Fish Tagged 1940-41 | 1940-41 | Per 1000 Fish Tagged 1940-41 |
| Number Tagged | 6,654 | 1,779 | | 2,715 | |
| **Recoveries** | | | | | |
| Below Hope | 19 | 4 | 2.2 | 10 | 3.7 |
| Hope to Lytton | 95 | 11 | 6.2 | 23 | 8.5 |
| Lytton to Bridge River Rapids | 9 | 2 | 1.1 | 9 | 3.3 |

## SUMMARY AND CONCLUSIONS

Sockeye salmon have been tagged by the Commission at Sooke during six seasons (1938-43 inclusive) and in Johnstone Strait during 1940 and 1941 as well as in other localities to be reported upon at a later date. Tags placed at Sooke varied in yearly number between 849 (1941) and 1800 (1942) and for all six years numbered 6,654 of which 3,234 or 48.6% were recovered. In the Johnstone

Strait experiment 2,715 tags (1,555 in 1940 and 1,160 in 1941) were used of which 1,524 or 56.1% were recovered.

From these extensive data certain preliminary conclusions have been drawn such as the time taken between tagging and recovery in a given area. Salmon tagged early in the season at Sooke include a considerable proportion destined for spawning grounds on the west coast of Vancouver Island and in the State of Washington; the later runs (July 1 and later) consist mainly of Fraser River fish.

The percentage of returns from the commercial fishery as a whole is usually higher in the odd years, the years in which the pink salmon fishery is important commercially. The returns from up-river areas, on the other hand, vary in a complementary manner and are highest in the even years. The period between tagging and recovery was shortest for the fish tagged in 1941. Preliminary results indicate that fish tagged at Sooke during the first half of the season migrate more rapidly than do those tagged later in the season. A distinct delay off the mouth of the Fraser River is indicated for fish tagged at Sooke in all years except 1941. Relatively few tags were recovered from up river areas.

## ACKNOWLEDGMENTS

The writers wish to thank all the scientists, purse seine fishermen, canners, and other members of the fishing industry whose efforts have made the present study possible. In particular they wish to express their thanks to Drs. W. F. Thompson and J. L. Kask, Mr. H. Goodrich and the staff of the Sooke Harbour Fishing and Packing Company, and Messrs. M. B. Schaefer, J. A. R. Hamilton, E. D. Knight, F. C. Withler, Wm. Tomkinson, C. P. Idyll, P. A. Olson, A. E. Peterson and O. J. Heggem.

## Table VI

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 Sooke during the years 1938-43. The number of days out is the median.

| Area | Year | Number Recovered | Days Out July 13—August 9 | Number Recovered | Days Out August 10—Sept. 6 |
|---|---|---|---|---|---|
| Areas B, C, D, and E | 1938 | 18 | 5.5 | 22 | 7.0 |
| | 1939 | 27 | 4.0 | 24 | 7.0 |
| | 1940 | 28 | 5.0 | 2 | 18.0 |
| | 1941 | 45 | 5.0 | 16 | 4.0 |
| | 1942 | 40 | 4.0 | 36 | 4.0 |
| | 1943 | 43 | 3.0 | 59 | 5.0 |
| Area J | 1938 | 10 | 9.5 | 34 | 7.0 |
| | 1939 | 19 | 5.0 | 31 | 8.0 |
| | 1940 | 21 | 6.0 | 11 | 12.0 |
| | 1941 | 42 | 6.0 | 21 | 6.0 |
| | 1942 | 37 | 8.0 | 38 | 6.5 |
| | 1943 | 16 | 6.0 | 37 | 8.0 |
| Area L | 1938 | 51 | 12.0 | 61 | 25.0 |
| | 1939 | 84 | 7.0 | 61 | 29.0 |
| | 1940 | 70 | 12.0 | 71 | 49.0 |
| | 1941 | 82 | 9.0 | 61 | 10.0 |
| | 1942 | 72 | 10.5 | 87 | 30.0 |
| | 1943 | 88 | 10.5 | 48 | 22.0 |
| Areas N and O | 1938 | 11 | 18.0 | 10 | 39.0 |
| | 1939 | 13 | 10.0 | 7 | 47.0 |
| | 1940 | 15 | 16.0 | 17 | 41.0 |
| | 1941 | 12 | 12.0 | 12 | 12.5 |
| | 1942 | 26 | 9.5 | 24 | 34.5 |
| | 1943 | 22 | 17.0 | 25 | 26.0 |

Table VII

SOOKE TAGGING SUMMARY

1938 to 1943

| | 1938 | | | 1939 | | | 1940 | | | 1941 | | | 1942 | | | 1943 | | | 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 | No. of Tags | % of Total Recoveries | % of Total Tagged | No. of Tags | % of Total Recoveries | % of Total Tagged |
| ........ | 980 | | | 1042 | | | 930 | | | 849 | | | 1800 | | | 1053 | | | 6654 | | |
| ........ | 98 | 22.3 | 10.0 | 168 | 30.1 | 16.1 | 85 | 19.3 | 9.1 | 176 | 35.0 | 20.7 | 205 | 25.8 | 11.4 | 198 | 39.4 | 18.8 | 930 | 28.8 | 14.0 |
| ercial * ...... | 223 | 50.8 | 22.8 | 237 | 42.5 | 22.7 | 233 | 53.1 | 25.1 | 238 | 47.3 | 28.0 | 427 | 53.9 | 23.7 | 243 | 48.4 | 23.1 | 1601 | 49.5 | 24.0 |
| ies .. | 59 | 13.4 | 6.0 | 44 | 7.9 | 4.2 | 26 | 5.9 | 2.8 | 8 | 1.6 | 0.9 | 97 | 12.2 | 5.4 | 32 | 6.4 | 3.0 | 266 | 8.2 | 4.0 |
| all ........ | 49 | 11.2 | 5.0 | 96 | 17.2 | 9.2 | 89 | 20.3 | 9.6 | 72 | 14.3 | 8.5 | 21 | 2.7 | 1.2 | 26 | 5.2 | 2.5 | 353 | 10.9 | 5.3 |
| ........ | 10 | 2.3 | 1.0 | 13 | 2.3 | 1.3 | 6 | 1.4 | 0.6 | 9 | 1.8 | 1.1 | 43 | 5.4 | 2.4 | 3 | 0.6 | 0.3 | 84 | 2.6 | 1.3 |
| ........ | 439 | 100.0 | 44.8 | 558 | 100.0 | 53.5 | 439 | 100.0 | 47.2 | 503 | 100.0 | 59.2 | 793 | 100.0 | 44.1 | 502 | 100.0 | 47.7 | 3234 | 100.0 | 48.6 |

aters Only.

Table VIII

## JOHNSTONE STRAIT TAGGING SUMMARY

1940 — 1941

| | 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 |
| Total Tags Placed | 1555 | | | 1160 | | | 2715 | | |
| **Recoveries** | | | | | | | | | |
| (a) U. S. Commercial Fishery Recoveries | 5 | 0.7 | 0.3 | 6 | 0.8 | 0.5 | 11 | 0.7 | 0.4 |
| (b) Canadian Commercial Fishery (Johnstone Strait) Recoveries | 258 | 34.8 | 16.6 | 257 | 32.8 | 22.2 | 515 | 33.8 | 19.0 |
| (c) Canadian Commercial Fishery Recoveries* | 403 | 54.4 | 25.9 | 456 | 58.2 | 39.3 | 859 | 56.4 | 31.6 |
| (d) Fraser River Watershed Recoveries | 61 | 8.2 | 3.9 | 20 | 2.6 | 1.7 | 81 | 5.3 | 3.0 |
| (e) Questionable Recoveries | 14 | 1.9 | 0.9 | 44 | 5.6 | 3.8 | 58 | 3.8 | 2.1 |
| Total Recovered | 741 | 100.0 | 47.6 | 783 | 100.0 | 67.5 | 1524 | 100.0 | 56.1 |

* Treaty Waters Only.

### Table IX

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: SOOKE 1938 | SOOKE 1939 | SOOKE 1940 | SOOKE 1941 | SOOKE 1942 | SOOKE 1943 | JOHNSTONE STRAIT 1940 | JOHNSTONE STRAIT 1941 |
|---|---|---|---|---|---|---|---|---|---|
| Sooke | A | | 5.0 ( 14) | | 5.0 ( 19) | 8.0 ( 12) | | | |
| Salmon Banks | B | 6.0 ( 33) | 5.0 ( 36) | 4.0 ( 15) | 5.0 ( 35) | 4.0 ( 31) | 4.0 ( 43) | | |
| Iceberg Point | C | | | 6.5 ( 10) | 5.0 ( 15) | | | | |
| West Beach | D | | 5.0 ( 14) | | 5.0 ( 10) | | 4.0 ( 50) | | |
| Rosario Strait | E | | | | 4.0 ) 11) | 4.0 ( 33) | | | |
| Lummi Island | I | | 5.0 ( 23) | 11.5 ( 10) | 6.0 ( 15) | 5.5 ( 18) | 4.5 ( 24) | | |
| Point Roberts | J | 7.0 ( 45) | 6.0 ( 70) | 7.0 ( 35) | 6.0 ( 73) | 7.0 ( 93) | 7.0 ( 53) | | |
| Gulf of Georgia | K | 15.0 ( 23) | 23.5 ( 10) | | | 16.0 ( 53) | | | 11.0 ( 12) |
| Mouth of Fraser | L | 14.0 (118) | 11.0 (152) | 15.0 (162) | 9.0 (162) | 14.5 (228) | 13.5 (150) | 13.0 (202) | 12.0 (208) |
| N. Arm of Fraser | M | 19.0 ( 53) | 12.0 ( 47) | 14.0 ( 27) | 12.0 ( 36) | 24.0 ( 57) | 14.5 ( 26) | 13.0 (135) | 12.0 (156) |
| N. Westminster — Haney | N | 33.0 ( 14) | 11.0 ( 14) | 26.0 ( 19) | 12.0 ( 21) | 14.0 ( 54) | 14.0 ( 36) | 19.0 ( 33) | 14.0 ( 49) |
| Haney — Mission | O | | | 16.0 ( 17) | 12.0 ( 10) | 12.0 ( 22) | 29.0 ( 19) | 20.0 ( 11) | 14.0 ( 14) |
| Hell's Gate | Y | | 32.0 ( 10) | | | | | | |
| Boston Bar Area | Z | | 51.5 ( 16) | | | | | 57.0 ( 14) | |
| Adams R. & S. Thompson | AB | 67.5 ( 34) | | | | 57.0 ( 63) | | | |
| Chilko River | AF | | | | | | | 40.0 ( 15) | |
| Plumper Is. — Robson's Bight | AM | | | | | | | 3.5 ( 82) | 3.0 (112) |
| Adams R., Johnstone St. | AN | | | | | | | 5.0 ( 54) | 3.0 ( 55) |
| Hardwick Is. — Rock Bay | AO | | | | | | | 7.0 ( 61) | 5.5 ( 24) |
| Rock Bay — Discovery Passage | AP | | | | | | | 7.0 ( 44) | 6.0 ( 43) |

# THE PROBLEM OF ENUMERATING SPAWNING POPULATIONS OF SOCKEYE SALMON

by

C. E. ATKINSON

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In order to control a commercial fishery intelligently it is helpful to know the magnitude of that portion of the annual adult migration which reaches the spawning grounds, since its maintenance and increase are the objects of regulation and of the removal of obstructions. A record of this is also as yet the only readily available basis for estimating the returns four years later. However, to count the number of fish in even a small area presents such obvious difficulties that it seems equivalent to guessing the number of beans in a large jar. Biologists have conceived various methods of making a fish census and although the results may not give the exact number present, the probable minimum and maximum population limits can be evaluated by the application of suitable statistical methods.

The enumeration of breeding salmon is fortunately less complex than is a census of the populations of fish usually dealt with. The return of salmon to the stream in which they were hatched segregates the various components or races of the escapement into fractions more measurable than the whole. Observation and study are simplified by the confinement of the spawning grounds to localized areas. The breeding stock is composed of three-, four-, five-, and six-year-old salmon, with the majority returning in their fourth year. All Pacific salmon die after spawning, affording an opportunity to obtain more adequate samples of the breeding population after death than before.

A better guide for the prediction of the return four years hence would be a census of the immature stock of salmon, because it would eliminate the unpredictable variations due to earlier mortality. But the enumeration of the adults on the spawning grounds will continue to be our only basis for forecast until a satisfactoy technique has been found to count this juvenile population in all the races which contribute to the catch.

Even were the young counted, it would still be true that the return is composed of catch plus escapement, and both must be known to correlate with the count of young when such is made.

The purpose of this report is to review the elements composing a population of spawning salmon and to consider the various expedients based on them which will facilitate their enumeration. It is not intended to touch here upon the mathematics of the estimates, but rather upon the circumstances under which these are applicable and upon the types of indices which may be worthy of trial. In the Annual Reports of this Commission for the years 1941 to 1943, escapement tables have been given and since many of the figures are very rough approximations, it is hoped that this discussion of the problems involved may assist those interested in interpreting or evaluating the results.

## THE SALMON POPULATION

A salmon population is considered to be the total number of fish present in a defined spawning area at or during a specified time, while the term "total run" specifically applies to the total number of fish that may have been present in a spawning area during the entire breeding season. There are three categories of fish: those yet to arrive, those still alive, and those dead. The problem of enumeration deals with each of these and seeks to establish the relationship between each and the ultimate total run. To illustrate the inter-relationships a hypothetical population has been set up in Table I and plotted in Figure I.

Three general methods for measuring the magnitude of a salmon run can be used: (1) The total run may be individually counted through an opening in a fence or weir. (2) The total number of salmon may be estimated by determining the ratio established by marking a known number in the run, or by counting a sample which has a known ratio to the total. (3) A comparison of the magnitude of the runs from year to year may be based on counts which can be assumed to be a constant but actually an unknown proportion of the whole. Thus certain observations made at regular intervals throughout the season, such as the number of salmon passing a certain point within a known unit of time, may be used in a comparative way.

Although the theory of each of these methods is valid, the possible mortality of the adults between the place where counts or other observations are made and the spawning grounds can introduce a considerable error in the measurements. Such deaths have been especially prominent as a result of the serious blockades at Hell's Gate. Many of the fish are so exhausted from the delay that upon release they are too weak to reach the spawning grounds and they die en route. If such deaths occur above the place where observations are made, the population computed will be above the true value. The mortality cannot well be estimated, but this source of error can be lessened by determining the population just below the area of spawning.

The simplest and most accurate method for obtaining a count of a salmon run free from statistical variation is by the use of a weir. Most of the spawning, however, occurs in the larger rivers where installation of a weir would be very expensive. Even in the smaller streams this procedure is not entirely satisfactory since often a few of the fish have failed to pass through the structure. Inasmuch as only an insignificant part of the run is adversely affected, a weir is still found to be the most practical method for use in the small streams.

In the tagging method a number of salmon are captured below the spawning area, tagged or marked, and released. Later the spawned out fish are

## TABLE I

## A HYPOTHETICAL SALMON POPULATION GIVING THE DAILY NUMBERS OF ENTERING SALMON, LIVE SALMON PRESENT AND DEAD SALMON

| Day | Number of Salmon | | | | |
|---|---|---|---|---|---|
| | Entering | Cum. Total | Present Alive | Dead | Cum. Total |
| 1 | 1 | 1 | 1 | | |
| 2 | 5 | 6 | 6 | | |
| 3 | 4 | 10 | 10 | | |
| 4 | 3 | 13 | 13 | | |
| 5 | 4 | 17 | 17 | | |
| 6 | 8 | 25 | 25 | | |
| 7 | 10 | 35 | 35 | | |
| 8 | 11 | 46 | 45 | 1 | 1 |
| 9 | 13 | 59 | 58 | | 1 |
| 10 | 12 | 71 | 69 | 1 | 2 |
| 11 | 7 | 78 | 76 | | 2 |
| 12 | 6 | 84 | 82 | | 2 |
| 13 | 5 | 89 | 85 | 2 | 4 |
| 14 | 4 | 93 | 89 | | 4 |
| 15 | 3 | 96 | 91 | 1 | 5 |
| 16 | | 96 | 89 | 2 | 7 |
| 17 | | 96 | 88 | 1 | 8 |
| 18 | 2 | 98 | 87 | 3 | 11 |
| 19 | 1 | 99 | 82 | 6 | 17 |
| 20 | 1 | 100 | 76 | 7 | 24 |
| 21 | | | 67 | 9 | 33 |
| 22 | | | 55 | 12 | 45 |
| 23 | | | 40 | 15 | 60 |
| 24 | | | 26 | 14 | 74 |
| 25 | | | 17 | 9 | 83 |
| 26 | | | 12 | 5 | 88 |
| 27 | | | 10 | 2 | 90 |
| 28 | | | 6 | 4 | 94 |
| 29 | | | 3 | 3 | 97 |
| 30 | | | 1 | 2 | 99 |
| 31 | | | 0 | 1 | 100 |

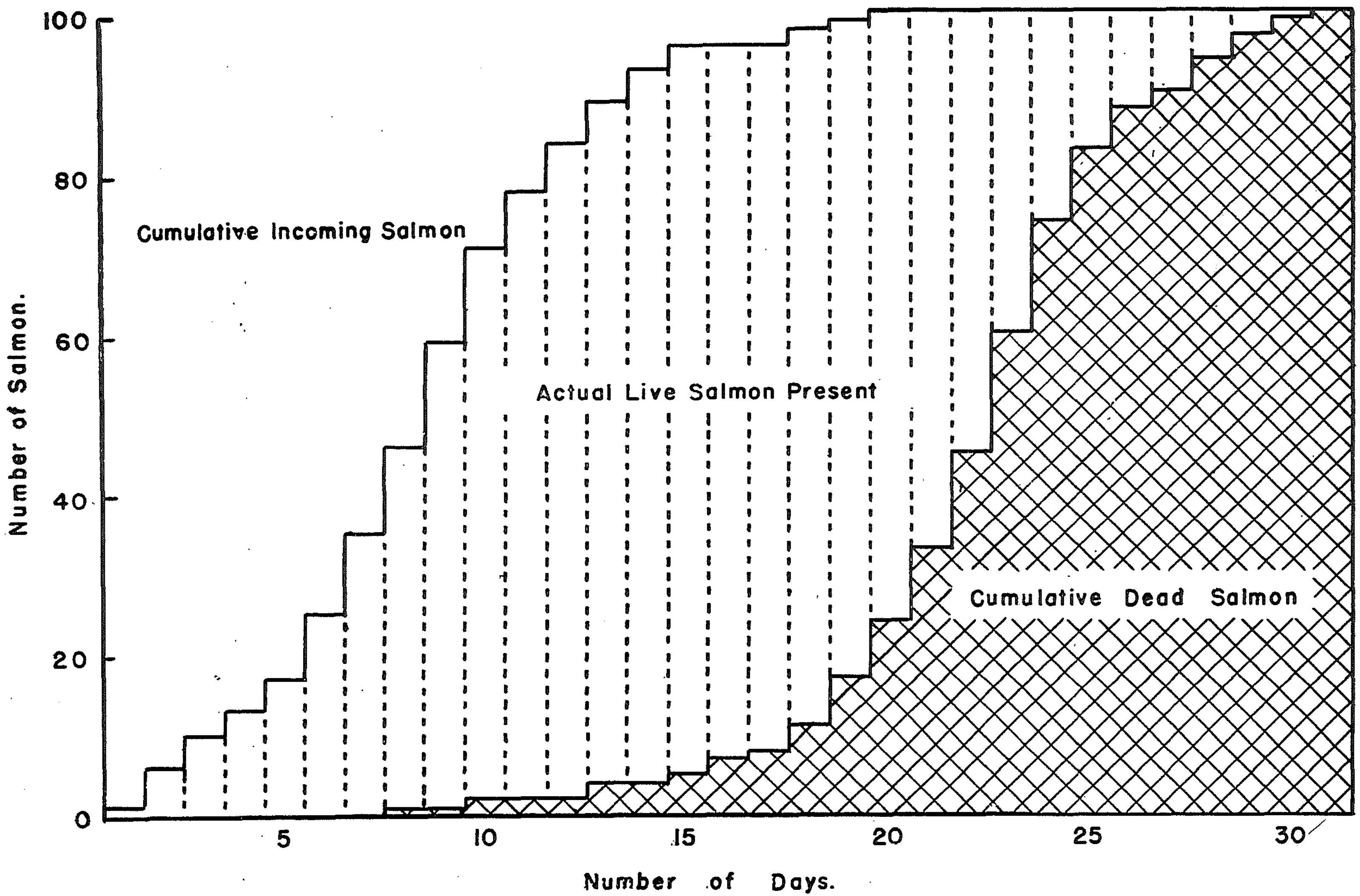


*Fig. I*

A Graphical Representation of the Hypothetical Sockeye Population Given in Table I.

recovered dead and from the proportion of tagged to untagged among them, the total population can be approximated by the following equation:

$$N = n \cdot \frac{T}{t}$$

where

$N$ = Total population,
$n$ = Total dead examined,
$T$ = Total fish originally tagged,
$t$ = Total tags recovered from the dead examined.

In order to obtain a satisfactory estimate of the population, either the tagged samples must represent all parts of the run or the samples of dead must represent all parts. To decrease error in the results both are made as true as possible. Then by suitable statistical analysis an estimate of the true population can be made.

Other indices are available if counts can be obtained in a consistent manner throughout the season and if these can be assumed to reflect the magnitude of the run. The results do not necessarily give the total population as in the tagging method, but only a relative figure for comparison with other years. Although much less versatile in application than figures for the total population, the information may be just as useful for regulation, for example, an index number of 5.4 compared with 2.5 may serve as well as absolute numbers of 6,936 against 3,207. This method is the only practical way of measuring certain other populations of fish and the results have been very useful.

Two such indices which measure the incoming salmon should be studied. The first is the Indian catch per unit of effort, which may produce data comparable from year to year. However, the fishing station must not be located near an obstruction where fish may accumulate because of difficulty in passing. Fishing should be pursued at all water levels and throughout the entire salmon run. Each stand at the station must be equally efficient in taking salmon, and the catch must not be limited by the ability to handle it. Two such locations may exist in the Chilcotin River, one at Siwash Bridge and another at Alexis Creek, and there may be similar fishing stations in other salmon streams. The validity of indices based upon such a catch must be proved.

The second is an index based upon a visual count of the number of fish passing a certain point. This is uncertain because it is not possible to define rigidly the area of water observed, to see the fish clearly, or to count them in any number.

In the case of both these indices variations in water level affect the dimensions of the area chosen for observation and may even alter the current and shift the course of migration. Further study of the effect of the time of day, weather or other factors must be made before the efficiency of either can be thoroughly understood.

It should be stressed again that the successful use of any index depends upon the adequacy of the sample observed, a careful test of the index, and the consistent use of the results from year to year.

*Fig. II*

Dead sockeye salmon in Shuswap Lake, mouth of the Adams River, November, 1938.

For Pacific salmon a total run may be determined by use of the recoveries of dead since the total dead will equal the total population. The procedure tested is to mark off an area on the stream and, preferably each day, recover in a consistent and uniform manner all dead that have accumulated within reach along the shore. If the area is a constant part of the whole spawning ground, and its dead a fair sample bearing a fixed relation to all dead, the counts thus obtained should vary as do the totals of all dead. If so, the results can be used either as an index of the comparative magnitude of the run or, if the ratio of the dead thus examined to the total dead is known and constant, the counts can be used to determine the actual total number present.

There are certain aspects of the distribution of the dead salmon that deserve attention. Observations have shown that, probably because of the sexual modification of the body proportions, the male salmon when dead tend to accumulate in the upper portion of the stream. In order to avoid error from the disproportionate sex ratio, the numbers of males and females examined must be kept separate and their populations calculated independently, using different multiples.

Another source of possible error is found in those carcasses that have accumulated in the deep holes where recovery is impossible. After a week or more, some of these fish will float to the surface and collect along the shore and thus increase the number of dead in the sample. By using the so-called "fresh dead" (or fish that have been dead for less than approximately three days), this error may be lessened. Daily recovery of fresh dead will minimize the effect of fluctuations in water level on the results. Any variation can be attributed to a radical change either in the length of shore line of the sampling area, or in the velocity of the river current. The method assumes that the number drifting into the area and drifting out have a constant relationship from year to year.

Since the occurrence of natural variables (i. e. water levels, temperatures, weather conditions, etc.) are functions of chance, then the results from a series of observations will give the average population under average conditions and the probable limits can be established by statistical methods.

The counts of live fish in a spawning area produce data for an enumeration of the population which are more difficult to interpret. The actual number of live fish present at any time is dependent upon the incoming group and upon the rate of mortality as shown in Figure 1. The longer the lives of the salmon on the spawning grounds or the shorter the period of entrance, the nearer the maximum live count will approach that of the total run because fewer will have died before the last arrival.

Several methods will be considered in spite of possible inherent errors. From observations at Cultus Lake, Birkenhead River, Chilko River, Kynoch Creek, and other streams, there has been found a surprising agreement in the dates of arrival of the spawners, the numbers of incoming fish, and the subsequent rates of mortality. Only minor variations occur from year to year.

Accordingly the maximum or other live counts may be used for comparison. This has been done on the Birkenhead River where the maximum live counts have been used to estimate the total population.

Another method is based upon the distribution of live fish on the spawning areas. For several years the distribution of the adults on the spawning areas has been found to be correlated with the actual live counts. It is possible that a rough approximation of the total can be made by observing the areas that are populated. This procedure should be especially valuable to an untrained observer since no actual counts need be made.

Under certain circumstances the total run in an area may be determined by combining for any day the actual live fish present, the total number of salmon arriving afterwards, and the proportion of the total already dead. This relation may be expressed by the following formula:

$$N = L + \frac{M}{D} N + R$$

where

$N$ = Total population,
$L$ = Live count at a specified time,
$M$ = Cumulative mortality at that time from the area sampled,
$D$ = Total dead for entire season from area sampled,
$R$ = Replacement by subsequent arrivals.

Then for the 23rd in Table I

$$N = 40 + 0.60N + 0.$$
$$N = 100.$$

The proportion, $\frac{M}{D}$, can be calculated even though a limited area is used but only if the sample of dead from such an area can be assumed to vary with the total. It cannot be calculated until the end of the season unless some estimate of $D$, the total for the area for the entire season, can be obtained from the results of past experience for the date and area in question. Because it is usually difficult to obtain the number, $R$, of salmon still to arrive, the best results are obtained after all fish have reached the spawning ground, when $R$ = O. The counts of live fish must be assumed correct.

## SUMMARY

The problem of enumeration of spawning sockeye salmon is much less complex than that of measuring the usual fishery stock. The total run of spawning salmon may be divided into the three components: (1) fish still to come, (2) live fish present, and (3) dead fish. The best measurement of a total run of salmon is based upon either the counts of incoming fish or the total dead. The live counts, on the other hand, are dependent upon the lengths of time between arrival and death. A brief discussion of several methods for the enumeration of spawning salmon has been given and the inherent sources of error in each have been pointed out.

# NOTES CONCERNING A MAP TO SHOW THE DISTRIBUTION OF SOCKEYE SALMON SPAWNING GROUNDS IN THE FRASER RIVER SYSTEM

by

C. E. ATKINSON and DONALD C. G. MacKAY

The spawning grounds of the sockeye salmon are distributed widely throughout the 90,000 square miles of the Fraser River watershed. Many of these areas are little known and it has been felt for some time that information pertaining to these regions should be made more readily available. The difficulty of locating places mentioned in the Commission's investigations has been brought to our attention repeatedly by persons unfamiliar with the geography of the area. For these reasons and in order to render more meaningful the reports of the Commission, a map has been prepared to present the various features of the Fraser River system that are intimately associated with the study of the sockeye salmon.

## ACKNOWLEDGMENTS

The project was begun in 1940 under the direction of Dr. W. F. Thompson. Each of the Commission's spawning ground observers contributed as many data as possible and Major J. A. Motherwell, Mr. R. W. McLeod, and other officers of the Dominion Department of Fisheries were consulted for additional information. A search of the available reports, literature, and correspondence completed the basic research and the first map was drafted in 1940 by Messrs. R. I. Jackson and H. S. Tremper. It was immediately apparent that much of the information was incomplete and publication was consequently postponed. Subsequently additional information was gathered and, during the winter of 1943-44, Mr. D. R. Foskett incorporated all the known facts into a detailed map of the watershed. The map used as a basis for the work was the Wall Map of British Columbia, No. IA, published in four parts by the British Columbia Department of Lands in 1933. The final map was prepared for lithographing by Mr. L. M. Clement, cartographer.

A map is only as accurate as the specific data utilized. In this case the basic biological information is the outcome of extensive exploratory work by the staff of the Commission and by the officers of the Dominion Department of Fisheries. Especial acknowledgment should be made of the services of Messrs. W. J. Barker, W. P. Forsythe, D. Lockwood, F. J. Winlow, W. M. Ferrier, T. G. Harvey and J. E. Kew of the Dominion Department of Fisheries, and of Drs. W. F. Thompson and J. L. Kask and Messrs. G. V. Howard, S. R. Killick, A. E. Peterson, M. B. Schaefer, G. B. Talbot, H. S. Tremper, D. R. Foskett,

R. I. Jackson, D. R. Johnson, J. E. Mason, A. H. Seymour and L. E. Whitesel of the International Pacific Salmon Fisheries Commission.

## THE MAP

The lithographed map (contained in a pocket in the back cover of this report) is 31x38 inches in size and contains 387 place names. Prominently shown in colors on this map are:

1. Productive sockeye streams (shown in black with lakes in blue).
2. Non-productive sockeye streams (shown in green with lakes in green).
3. Inaccessible streams (shown in red with lakes in red).
4. Biologically unexplored streams (shown by broken green lines).
5. Points of difficult passage (indicated by single red line across streams).
6. Inaccessible falls or rapids* (indicated by double red lines across streams).
7. Dams (indicated by a special symbol in red).
8. Streams in which the average 1939-42 sockeye salmon run was 250,000 or more (shown by large solid black stars).
9. Streams in which the average 1939-42 Sockeye salmon run was 25,000 to 250,000 (shown by small solid black stars).
10. Streams in which the average 1939-42 sockeye salmon run was 2,500 to 25,000 (shown by large open stars).
11. Boundaries of the Fraser River watershed (shown by heavy broken green lines).
12. Interprovincial boundary (shown by broken black line and black dots).
13. International boundary (shown by broken black line with two dots intervening between each two lines).

It should be noted that the blue color used to represent the salt-water has been extended up the river for a considerable distance. This has been done to indicate the commercial fishing area on the Fraser River which terminates at the Mission Bridge.

When the first data were being accumulated the intention was to include the locations of the Indian fishing stations with appropriate symbols to designate the type of gear used. This could have been carried out fairly successfully for the scattered locations in the Upper Fraser; however, in the Lower Fraser (throughout the Canyon) and in the vicinity of Lillooet where the fishing stations include nearly every jutting rock along the river it was found impossible to include this information.

The data presented in the map have been summarized in Table I. In this table a stream that is productive, either in whole or in part, is checked in the column headed "productive sockeye streams." Likewise, if part of the same

* This includes a few other types of complete blockades such as dry channels, beaver dams, etc.

stream is non-productive, it is checked under that heading; if any part of the same stream should be known to be inaccessible or biologically unexplored, it is checked for these points also.

Many rivers and streams are known by several names. Where this is the case, the Geographical Gazetteer of British Columbia (1930) has been taken as the final authority. Not nearly all of the small tributaries of the Fraser River have been included on the map and not all of those shown have their names printed on the map. This was done purposely since it was desired to emphasize the important sockeye streams and at the same time to eliminate most of the small unimportant tributaries which would cover much of the map and make it difficult to use. Only the rivers of the Fraser watershed are shown; places that are important to the Commission's investigations have been emphasized. Detailed maps of the various spawning grounds are in preparation. Table I lists only those streams the names of which appear on the map even though points of difficult passage or other features may be indicated on unnamed streams. The map illustrates those lakes and streams now frequented regularly by the sockeye salmon, whether during spawning, fresh water growth, or migration. Even small tributaries if they are important spawning areas are shown. In contrast, only the major details of non-productive streams are shown and even less detail is given for the biologically unexplored areas. Highways, railways and other lines of communication are not included. Only those towns often used as headquarters for the field work are shown.

## THE SPAWNING GROUNDS

All the known spawning streams are indicated on the map and all except the smallest tributaries have been named. With this information, the localities mentioned in the Annual Reports of the Commission (1937-1943) and in the escapement tables contained in certain of these reports (1941-1943) may be more easily interpreted. As a further aid to the evaluation of the various spawning runs the important areas have been divided into three groups on the basis of the average magnitude of the runs for the four year period 1939-1942. These are as follows:

| | | |
|---|---|---|
| Group 1. | Large solid star, average 250,000 or more | Adams and Little Rivers<br>Chilko River |
| Group 2. | Small solid star, average 25,000 to 250,000 | Cultus Lake<br>Birkenhead River<br>Harrison River Rapids and Weaver Creek |
| Group 3. | Small hollow star, average 2,500 to 25,000 | Pitt River (Upper)<br>Stellako River<br>Bowron River (Upper)<br>Middle River, Kynoch and Forfar Creeks<br>Raft River |

Catching sockeye for tagging, Adams River, 1938.

By this means the average importance of the present runs may be evaluated readily.

After an examination of the map, the very small area devoted to the production of the Fraser River sockeye fishery will be apparent. Sockeye spawning areas are located in only a few tributaries of each major drainage system. The necessity for the fingerlings to spend at least one year in a fresh-water lake is, perhaps, the fundamental limiting factor of the productive areas.

## NON-PRODUCTIVE SOCKEYE STREAMS

Our interpretation of a non-productive area should be clarified. All of the streams indicated by the solid green line have been visited by observers. In the exploratory examination of such areas, the data collected include careful inquiries of the local ranchers, trappers, and Indians for any past or present evidence of a sockeye salmon run. When a number of queries all indicate the absence of sockeye, the data are considered to be correct and the stream is classified as non-productive. In this category are included those streams occasionally frequented by sockeye weakened by adverse conditions encountered during migration. In many of these cases a stream or lake may appear extremely impressive in character but may lack gravel suitable for spawning. The exact qualities that constitute a satisfactory spawning ground for sockeye salmon remain a biological problem.

## INACCESSIBLE STREAMS

Perhaps the easiest data to obtain are those defining the barren, obstructed areas as represented in red. Generally, this type of information has required only a visit to the site of the obstruction and, if found to be unquestionably a total block to further migration of salmon, the headwaters have been considered to be barren. In only a few instances has a question arisen as to the completeness of the block in which case an examination similar to that for non-productive streams has been undertaken. Preliminary biological surveys of a few of the barren areas have been made with a view to the possibility of eventually overcoming the blocks and opening up vast new spawning areas, thus increasing the yield of the Fraser River. The most impressive such area is that above the Nechako Canyon.

## UNEXPLORED STREAMS

There still are, within the 90,000 square miles in the Fraser River watershed, a number of major streams that are biologically unexplored. These streams are located in remote and primitive areas, examination of which would present difficulties equivalent to those of an exploratory expedition. Each year additional data are collected regarding these streams. In general, there have been no indications that these regions support any important sockeye runs — probably none at all.

## OBSTRUCTIONS

Three types of obstructions are designated: dams, total barriers, and areas of difficult passage. No segregation has been made to indicate by symbol the presence or absence of a fishway but from the character of the watershed above the obstruction this information can be deduced. Represented by double lines are usually impassable falls or rapids; included are a few other barriers that without doubt completely obstruct salmon migration. By "points of difficult passage" is meant those places in which sockeye are only able to proceed up stream with difficulty.

## ERRATA

In the process of publishing the Sockeye Salmon Spawning Grounds Map certain minor errors and omissions have occurred inevitably. Those that are apparent at the present time are listed below.

| Stream | River System | Remarks |
|---|---|---|
| Widgeon Slough | Pitt River (Lower) | Widgeon Slough, with an annual run of less than 1,000 sockeye, was omitted. |
| Mystery Creek and Twenty Mile Creek | Harrison River | These creeks were omitted; occasionally a few sockeye enter them to spawn. |
| Owl Creek | Harrison River | Owl Creek, between the dam and the Birkenhead River, (a productive portion of the stream), has been omitted. |
| Pemberton Creek | Harrison River | Pemberton Creek is a tributary of Green River rather than of the Lillooet River as shown. |
| Shuswap River (Lower) | South Thompson River | A portion of the Shuswap River (between the lake and the rapids) has been omitted. |
| Anstey River | South Thompson River | Anstey River enters Shuswap Lake without passing through Hunakwa Lake. |
| Raft River | North Thompson River | The distance between the mouth of the river and the falls is about 5 miles. |
| Kazchek Creek | Stuart River | A few sockeye (and many kokanee) enter the lower part of the creek to spawn. |
| Narrows Creek | Stuart River | The bar on Narrows Creek should be red — not black. |
| Middle River | Stuart River | The source of the Middle River is just below the mouth of Gluskie Creek. |
| Driftwood River | Stuart River | An unexplored portion of the Driftwood River has been omitted. |
| Bowron River (Upper) | Bowron River | The Upper Bowron River flows directly into Bowron Lake with Spectacle Lake as a tributary. |

## REFERENCES

Geographical Gazetteer of British Columbia, Victoria, B. C., 1930. Pp. xx + 291.

Wall Map of British Columbia, British Columbia Department of Lands, Map No. IA. in four parts, Victoria, B. C., 1933.

## TABLE I

## SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pitt River** | | | | | | | | | | |
| Alouette River | | x | x | | | x | x | | | |
| Pitt River, Upper | x | | x | | | x | | | | } |
| Four Mile Creek | x | | x | | | x | | | | } x |
| Corbold Creek | x | | x | | | x | | | | } |
| Boise Creek | x | | x | | | x | | | | } |
| Blue Creek | | | | x | | | | | | |
| **Harrison River** | | | | | | | | | | |
| Chehalis River | | | | x | | | | | | |
| Harrison River | x | | | | | | | | } x | |
| Weaver Creek | x | | | | x | | | | } | |
| Hatchery Creek* | x | | x | | | | x | | | |
| Cogburn Creek | x | | x | | | x | | | | |
| Big Silver Creek | x | | x | | | x | | | | x |
| Douglas Creek | x | | x | | | x | | | | |
| Lillooet River, Lower | | | | | x | | | | | |
| Sloquet Creek | | | | x | | | | | | |
| Lillooet River, Upper | x | | | x | | | | | | |
| Birkenhead River | x | x | | | x | | | | x | |
| Green River | x | | x | | | x | | | | |
| Pemberton Creek | x | | x | | | x | | | | |
| Owl Creek | x | | x | | | | x | | | |

* Name not on map.

TABLE I—(Continued)

## SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Harrison River**—(Continued) | | | | | | | | | | |
| Miller Creek | x | | | x | | | | | | |
| Ryan Creek | x | | | x | | | | | | |
| McKenzie Creek | x | | x | | | x | | | | |
| Railway Creek | x | | x | | | x | | | | |
| North Creek | x | | x | | | x | | | | |
| **Thompson River** | | | | | | | | | | |
| Nicola River | | x | | | | | x | | | |
| Coldwater River | | x | | | | | | | | |
| Bonaparte River | | x | x | | | | x | | | |
| **North Thompson River** | | | | | | | | | | |
| Louis Creek | | x | x | | | | x | | | |
| Barriere River | | x | | | | | x | | | |
| Lemieux Creek | | x | x | | | | x | | | |
| Mann Creek | | x | x | | | x | | | | |
| Clearwater River | | x | x | | x | x | | | | |
| Murtle River | | x | x | | | x | | | | |
| Raft River | x | | x | | | x | | | | x |
| Mad River | | x | x | | | x | | | | |
| Finn Creek | | x | x | | | x | | | | |
| North Thompson River, Upper | | x | | x | x | | | | | |
| Blue River | | x | | x | | | | | | |

TABLE I—(Continued)

SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **South Thompson River** | | | | | | | | | | |
| South Thompson River | x | | | | | | | | | |
| Adams River, Lower | x | | | | | | x | x | | |
| Adams River, Upper | x | | | | x | | | | | |
| Momich River | x | x | | x | x | | | | | |
| Scotch Creek | x | | x | | x | x | | | | |
| Seymour River | x | | x | | | x | | | | |
| Anstey River | x | | x | | | x | | | | |
| Eagle River | x | x | | | | | | | | |
| Shuswap River | | x | x | | x | | x | | | |
| Bessette Creek | | x | x | | | | x | | | |
| Salmon River | | x | | | | | | | | |
| **Chilcotin River** | | | | | | | | | | |
| Chilcotin River, Lower | | | | | x | | | | | |
| Big Creek | | x | x | | | x | | | | |
| Chilcotin River, Upper | | x | | x | | | | | | |
| Chilanko River | | x | | | x | | | | | |
| Chilko River | x | | | | x | | | x | | |
| Lingfield Creek | | x | | | x | | | | | |
| Nemaia River | | x | x | | | x | | | | |
| Gold Creek | | x | x | | | x | | | | |
| Taseko River | | x | | | | | | | | |
| Tchaikazan River | | x | x | | | x | | | | |
| Lord River | | | | x | | | | | | |

TABLE I—(Continued)

**SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND**

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Quesnel River** | | | | | | | | | | |
| Quesnel River | | | | | x | | | | | |
| Cariboo (Swamp) River | | x | x | | x | x | | | | |
| Horsefly River | x | | x | | | x | | | | |
| McKinley Creek | | x | | x | x | | | | | |
| Mitchell River | x | x | | | x | | | | | |
| **West Road River** | | | | | | | | | | |
| West Road River, Lower | | x | | | | | | | | |
| Euchiniko Creek | | | | x | | | | | | |
| Nazko River | | x | x | | | x | | | | |
| Clisbaco River | | x | x | | | x | | | | |
| West Road River, Upper | | x | x | x | | x | | | | |
| Baezaeko River | | | | x | | | | | | |
| **Nechako River** | | | | | | | | | | |
| Chilako River | | x | x | | | x | | | | |
| Dahl Creek | | x | | x | | | | | | |
| Bednesti Creek | | x | | x | | | | | | |
| Sinkut River | | x | x | | | x | | | | |
| Ormonde Creek | x | | x | | | x | | | | |
| Endako River | x | x | | | | | | | | |
| Shovel Creek | x | | x | | | x | | | | |
| Stellako River | x | | | | x | | | | | x |

## TABLE I—(Continued)
## SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Nechako River**—(Continued) | | | | | | | | | | |
| Nithi River | x | | | | | x | | | | |
| Nadina River | x | x | | | | | | | | |
| Nechako River, Upper | | x | x | | | x | | | | |
| Cheslatta River | | x | x | | | x | | | | |
| Ootsa River | | | x | | x | | | | | |
| Tahtsa River | | | x | | | | | | | |
| Whitesail River | | | x | | | | | | | |
| Entiako River | | | x | | | | | | | |
| Chelaslie River | | | x | | x | | | | | |
| **Stuart River** | | | | | | | | | | |
| Necoslie River | | | | x | | | x | | | |
| Sauchi Creek | x | | x | | | | | | | |
| Cunningham Creek | | x | | | | | | | | |
| Tachie River | x | | | | | | | | | |
| Kuzkwa River | | x | | | x | | | | | |
| Felix Creek | x | | | x | x | | | | | |
| Fleming Creek | x | | x | | | x | | | | |
| Inzana Creek | | | x | | | | | | | |
| Middle River | x | | | | | | | | | } |
| Kynoch Creek | x | | x | | | x | | | | } x |
| Forfar Creek | x | | x | | | x | | | | } |
| Rossette Creek | x | | x | | | x | | | | |

## TABLE I—(Continued)

## SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stuart River**—(Continued) | | | | | | | | | | |
| Gluskie Creek | x | | x | | | x | | | | |
| Cruise Creek | | | | x | x | | | | | |
| Dust Creek | x | | | x | | | | | | |
| Narrows Creek | x | | | x | x | | | | | |
| Ankwil Creek | x | | | x | | | | | | |
| Driftwood River | x | | | x | | | | | | |
| Kotsine Creek | | | | x | | | | | | |
| **Bowron River** | | | | | | | | | | |
| Bowron River, Lower | | | | | x | | | | | |
| Indian Point, Creek | | | | x | | | | | | |
| Bowron River, Upper | x | | | x | | | | | | |
| Pomeroy Creek | x | | x | | | x | | | | |
| Huckey Creek | x | | x | | | x | | | | |
| Sus Creek | x | | x | | | x | | | | |
| **Other Tributaries of the Fraser River Below Lillooet** | | | | | | | | | | |
| Coquitlam River | | x | x | | | | x | | | |
| Stave River | | x | x | | | | x | | | |
| Chilliwack River | x | | | x | | | | | | |
| Cultus Lake | x | | | | | | | | x | |
| Wahleach Creek | | x | x | | | x | | | | |

## TABLE I—(Continued)
## SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Other Tributaries of the Fraser River Below Lillooet**—(Continued) | | | | | | | | | | |
| Hunter Creek | | x | x | | | x | | | | |
| Silver Creek | | x | | | x | | | | | |
| Coquihalla River | | x | x | | | x | | | | |
| Nicolum River | | x | x | | | x | | | | |
| Choate Creek | | x | x | | | x | | | | |
| Emory Creek | | x | x | | | x | | | | |
| Yale Creek | | x | x | | | x | | | | |
| Spuzzum Creek | | x | | | x | | | | | |
| Scuzzy River | | x | x | | | x | | | | |
| Anderson River | | x | x | | | x | | | | |
| Nahatlatch River | x | | x | | x | x | | | | |
| Bear Creek | x | | x | | | x | | | | |
| Stein River | | x | x | | | x | | | | |
| Texas Creek | | x | x | | | x | | | | |
| Seton Creek | x | | | | | | x | | | |
| Cayoosh Creek | | x | x | | | x | | | | |
| Portage Creek | x | | | | | | | | | |
| Gates Creek | x | | | | x | | | | | |
| **Above Lillooet** | | | | | | | | | | |
| Bridge River | | x | x | | | x | | | | |
| Yalakom River | | x | | x | | | | | | |

TABLE I—(Continued)

**SUMMARY OF FACTS SHOWN ON FRASER RIVER SOCKEYE SPAWNING GROUND**

| Rivers by Systems | Productive Sockeye Streams | Non-Productive Sockeye Streams | Inaccessible Streams | Unexplored Streams | Points of Difficult Passage | Inaccessible Falls or Rapids | Dams | Average Run (1939-1942) 250,000 or More | Average Run (1939-1942) 25,000 to 250,000 | Average Run (1939-1942) 2,500 to 25,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Above Lillooet**—(Continued) | | | | | | | | | | |
| Tyaughton Creek | | x | x | | | x | | | | |
| Gun Creek | | x | x | | | x | | | | |
| San José River | | x | x | | | x | | | | |
| Cottonwood River | | x | x | | x | x | | | | |
| Ahbau Creek | | | | x | | | | | | |
| Lightning Creek | | x | | | | | | | | |
| Salmon River | | | | x | | | | | | |
| Willow River | | | | x | | | | | | |
| McGregor River | | | | x | | x | | | | |
| Torpy River | | | | x | | | | | | |
| Morkill River | | | | x | | | | | | |
| Goat River | | | | x | | | | | | |
| McKale River | | | | x | | | | | | |
| Dore River | | | | x | | | | | | |
| Holmes River | | | | x | | | | | | |
| Raush River | | | | x | | | | | | |
| McLennan River | | | | x | | | | | | |
| Fraser River, Upper | | | x | | | x | | | | |