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SOCKEYE SALMON PROPAGATION IN BRITISH COLUMBIA

BY

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FOREWORD

This bulletin presents in concise form an account of an investigation of the relative efficiencies of the natural and artificial propagation of sockeye salmon at Cultus lake, British Columbia. The study was carried out under the auspices of the Biological Board of Canada, through its Pacific Biological Station, with Dr. R. E. Foerster, Chief Biologist of the staff, in charge of the investigation.

The original program was prepared by Dr. Foerster and myself, submitted to a special meeting of scientists and fishery administrative officers in Vancouver, unanimously endorsed by these persons and later carefully considered and adopted by the Biological Board.

As Director of the Pacific Biological Station, and as such responsible for all investigations carried out within its jurisdiction, I have followed the work closely, fully endorse the methods, the handling of the data and the conclusions, and recommend the publication of the present report.

W. A. CLEMENS

SOCKEYE SALMON PROPAGATION IN BRITISH COLUMBIA

By R. E. Foerster
Pacific Biological Station

Artificial propagation or hatchery production of sockeye salmon in British Columbia has long been one of the chief means by which the Dominion Department of Fisheries has endeavoured to maintain and, if possible, increase the supply of this species for an extremely valuable fishery. It was a natural development from the artificial methods of fish propagation, first originated in eastern Canada in 1856-57 by Richard Nettle and actively carried forward from 1865 by Samuel Wilmot, methods which were widely and enthusiastically acclaimed because they were reputed to provide the distinct advantages of (1) ensuring the fertilization of practically all eggs, whereas in Nature the wastage from non-fertilization was believed to be enormous, and (2) protecting the eggs and newly-hatched fry against spawning-bed marauders—predatory fishes, birds and mammals—which were accused of extensive destruction. The application of such promising practices to the valuable Pacific salmon seemed a wise and progressive action and commencing with a single unit at New Westminster in 1894, the construction and operation of hatcheries in British Columbia rapidly increased.

The advantages claimed for artificial propagation may have seemed to justify without question its general adoption. The efforts of fish culturists, spurred on by a popular enthusiasm for the rapid replenishment and increase of the Dominion's fisheries by reason of man's intervention and assistance, were indubitably sincere. For some species of fish the results may have more than met expectations. Yet for Pacific salmon the feeling has grown during recent years that, in spite of the increase in hatcheries and the output of eggs and fry, no beneficial results, to the extent implied and expected, have been reflected either in the annual catches or in the spawning escapements. This general attitude may be briefly summarized in the words of the British Columbia Fisheries Commission of 1922:

> "It was made quite evident to us that the old hatchery methods were of little commercial value. It was made equally plain that the retaining pond system which is still in the experimental stage and expensive by reason of the feeding of the fish, has, as yet, given no proof of its efficiency. . . . Consequently, we urge that before the service is extended, some definite experimental tests should be carried on for a series of years. We make the condition, however, that the operations be carried on and observations made directly under competent scientific supervision."

Fully acquainted with the conflicting opinions and finally realizing the need for a thorough investigation of the whole question, the Department of Fisheries, through its then Deputy Minister, requested the Biological Board to undertake a detailed study of fish cultural methods, particularly in relation to their improvement over natural propagation. Since, in British Columbia, the artificial propagation of sockeye salmon was being conducted on a very extensive scale, the fish cultural practices there were included. Fortunately a detailed program for an investigation of the natural and artificial propagation of sockeye salmon in British Columbia had already been drawn up in 1924 and this was now approved by the Biological Board as a part of its general research program. In the fall of 1925 the investigation commenced.

Cultus lake was selected as the site of the investigation because (1) it was accessible throughout the year, (2) it possessed a natural sockeye run, (3) a Dominion Government hatchery had been established there for a number of years, (4) the sockeye runs to Cultus were not too large to be readily handled

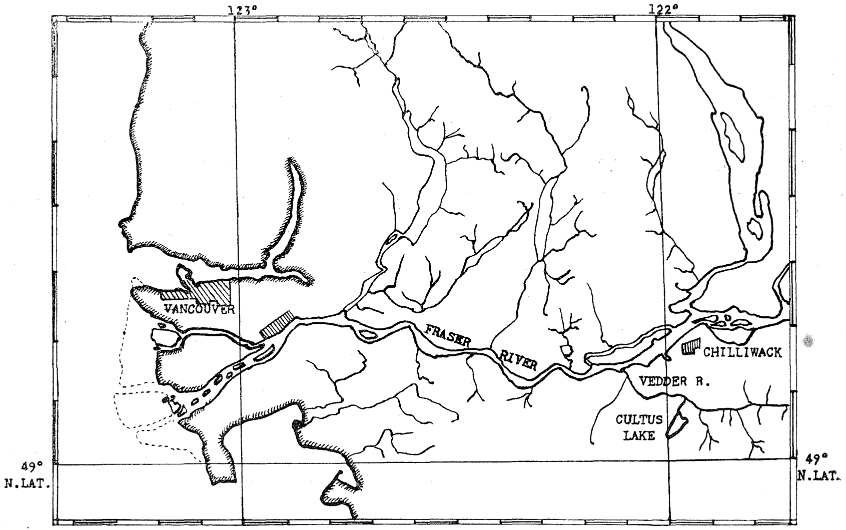

FIGURE 1. Sketch map (scale 25 miles to 1 inch) of south-western British Columbia showing the lower portion of the Fraser river and the relation to it of Cultus lake. The altitude of the lake is approximately 190 feet, its maximum depth approximately 137 feet (42 metres).

and (5) the size and character of the outlet stream (Sweltzer creek) permitted the erection and operation of a fine-meshed screen counting fence for the counting of young sockeye migrating from the lake to sea. All conditions appeared to be present, therefore, for testing under natural conditions the efficiencies not only of natural propagation but also of the two methods of artificial propagation, namely distribution of free-swimming fry and eyed egg planting.

BRIEF ACCOUNT OF THE LIFE-HISTORY OF SOCKEYE SALMON

Sockeye salmon upon their return from the sea normally migrate into those streams having lakes at their heads. After spending some time in the lakes and maturing, the adults seek out the tributary streams and spawn on the gravel beds. In some instances, such as at Cultus lake, they also spawn along the beaches where seepage apparently provides a suitable movement of water through the gravel. The following spring the fry emerge from the gravel and drop down to the lake, there to remain for one or more years. At Cultus lake, the great majority linger only one year and a relatively small but varying number remain two years before migrating seaward. In some seasons fry are found leaving the lake. In all probability these result from spawnings in the vicinity of the lake outlet and are following the natural tendency to drop downstream after hatching.

METHODS

In order to render all tests readily comparable the operations were systematized from the commencement as follows:

(1) All adult sockeye were retained below a counting weir (figures 2 and 3) constructed in Sweltzer creek approximately 250 yards below the outlet of Cultus lake. The weir consisted of a solid floor of planking, sealed at both up and downstream edges with sheet piling, and of two picket fences built thereon extending from bank to bank with cross-partitions forming a series of traps. V-shaped funnels in every alternate trap permitted entrance of the upstream migrating individuals while the traps not equipped with funnels were used, in stripping operations, for retention of nearly-ripe individuals. From the traps the fish were dipped out, examined for sex and counted. In years of natural spawning the fish were liberated above the weir to ascend to the spawning grounds in the lake. In years of artificial propagation they were retained below the weir until mature and then stripped.

(2) All calculations were based on the total number of eggs contained in all females counted at the weir or adjacent fences. To ascertain the average egg content per female each year, a sample of the females was taken and actual counts of contained eggs made. Because of the extended retention required, in years of artificial propagation, for females to mature, heavy mortality among females occurred. To allow for the loss so occasioned, a second series of calculations was drawn up based on the egg content of all females available for stripping. The two percentages obtained represent the limits for artificial propagation, the true value lying somewhere between them.

(3) In years of artificial propagation all hatchery records pertaining to (*a*) eggs collected, (*b*) losses in the hatchery, (*c*) number of eyed eggs planted or fry liberated, were kept in order that the percentage loss at each stage might be ascertained.

(4) The success of each method of propagation was indicated by the number of seaward migrants passing out of the lake. To obtain such data, a fine-meshed screen fence (figures 4, 5 and 6) was constructed in Sweltzer creek approximately 200 yards below the lake, whereby the migrants were directed into traps at the downstream end and counted (figures 7 and 8)). This is a feature which no

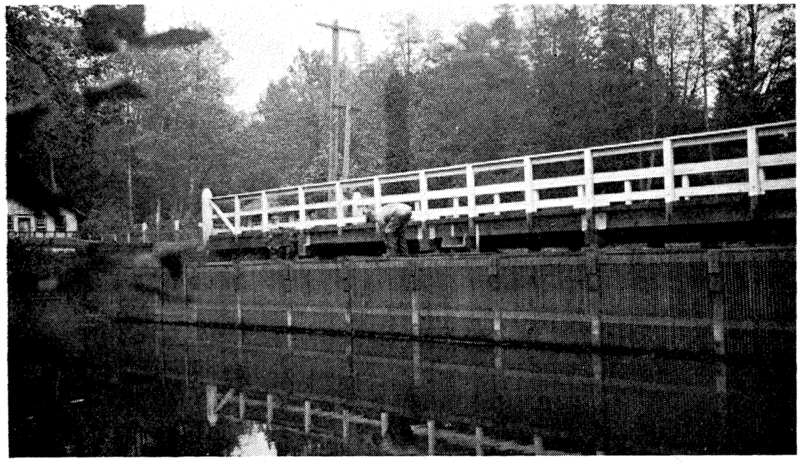

FIGURE 2. The adult salmon counting fence, viewed from the up-stream side, showing the arrangement of 1″×3″ pickets, regularly spaced by the insertion between them of small 1″×3″ blocks at top, centre and bottom. The picket sections are held together by long, iron rods at top, centre and bottom. The fence is perpendicular, not sloping, since the stream flow is not excessive. Immediately behind the fence is seen the highway traffic bridge and in the left background, the Cultus lake hatchery. Directly behind the operator on the fence is shown the mouth of a chute by means of which unripe salmon, dipped from the traps, are transferred back below a picket fence on the downstream side of the bridge.

FIGURE 3. An end view of the adult salmon counting fence from above, showing the series of traps from which the fish are dipped for counting or stripping. The down-stream walls of the traps are constructed of pickets similar to the up-stream face. The whole structure, approximately 5 ft. high, rests on a solid, plank platform.

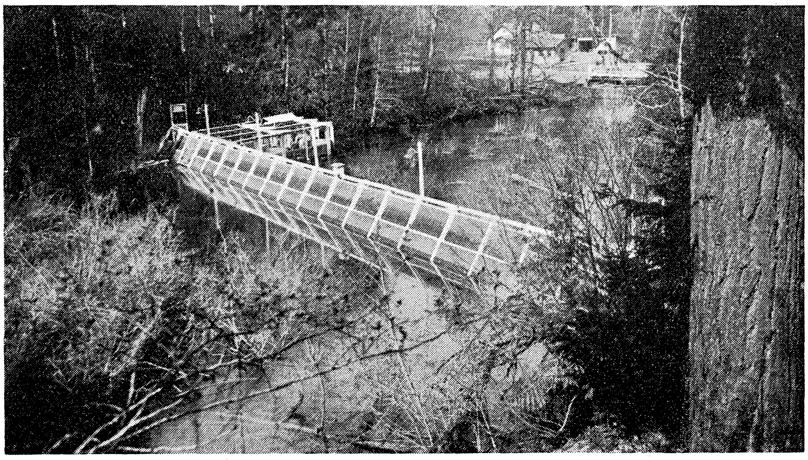

FIGURE 4. A bird's-eye view of the counting fence for seaward migrating salmon in Sweltzer creek. The fence is constructed at a slight angle to the stream flow and migrants are naturally guided into the retaining pens at the downstream end. The Cultus lake hatchery buildings and one end of the adult salmon counting fence are seen in the right background.

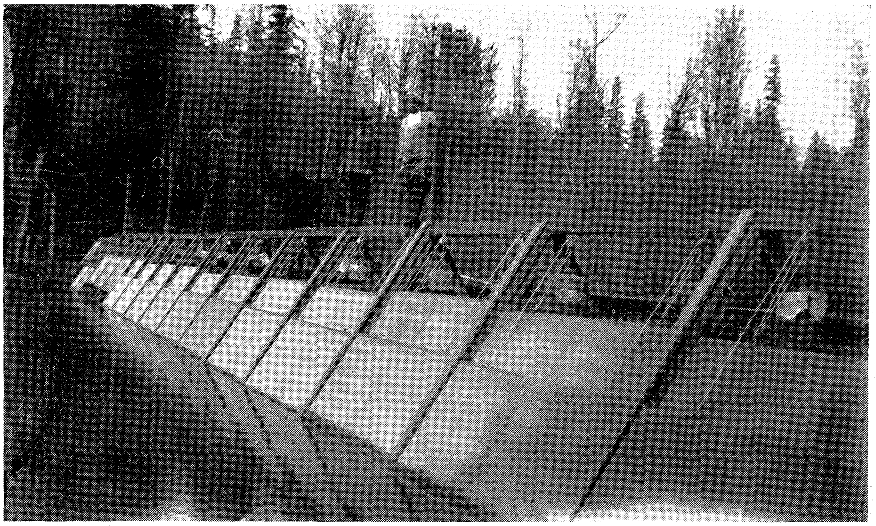

FIGURE 5. Seaward migrant counting fence showing position of double screens, counterweights for raising and lowering screens, and the open gates to retaining pens at the far end. The whole structure rests on a solid plank platform, sealed on both sides with sheet piling, and extending 2 ft. in front of and 6 ft. behind the fence. The fence is 186 ft. long and 9 ft. high.

other investigation has been able to embrace and through it the results have been much more quickly and accurately obtained. They represent the first occasion on which it has been possible to separate fresh-water losses from those covering the whole life-cycle of the fish. Most of the migrations occurred during the hours from dusk to dawn but, though electric light was provided for night counting, it was found more expedient to hold the nightly accumulations until the following day. As many as 350,000 migrants were safely so handled on one occasion.

(5) Each year's downstream migration consisted of three age groups, fry, yearling and two-year-olds, each resulting from a different spawning or "brood"

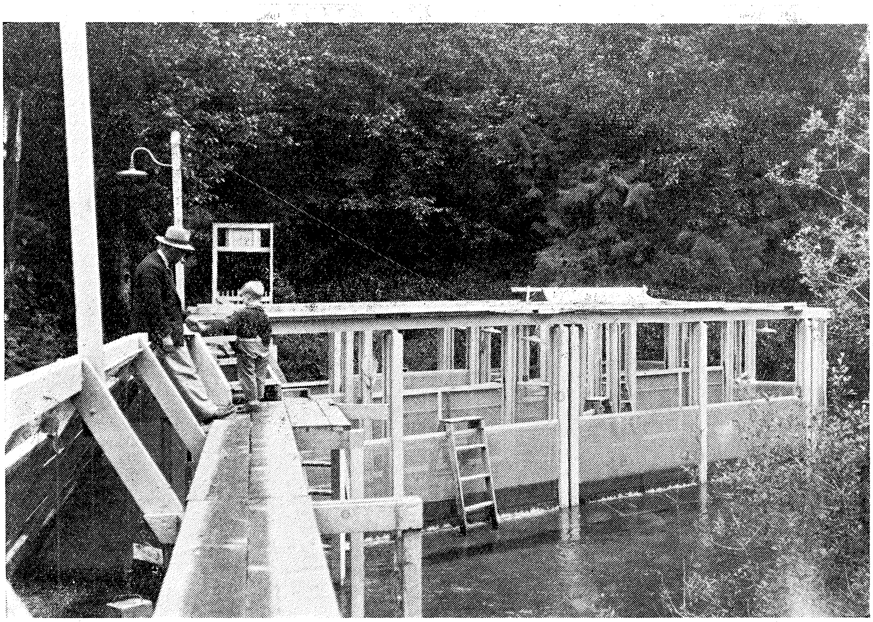

FIGURE 6. A close-up of the battery of six retaining pens in which migrants are counted. All screens are movable andare lifted out of the water when not in use. The pens also rest on a solid plank platform.

year. Counts of fry presented no difficulty, but the accurate separation, by size, of yearlings and two-year individuals in each migration, necessary in order to apportion the numbers of each to its proper brood year, was not practicable due to the overlapping of large one-year and small two-year-olds. The separation was therefore made by collecting and preserving samples (one for each 100 or 500 migrants counted, according to the size of the migration) each season, ascertaining the ages by means of scale-reading, and then dividing the total migration in the same proportion as the sample. In most years the proportion of two-year-olds was highest at the beginning of the migration and gradually dwindled as the season progressed. Therefore, in order to give due importance to this variation, the migration was divided into definite periods based upon the proportion of two-year-olds in the sample, and the numbers of each age group were thus ascertained for each period. The totals for the season were obtained by summing up the numbers of each age group in all periods.

In short, therefore, the efficiency of any method of propagation was deduced by determining the "in-go", *i.e.*, number of eggs contained in all females (*a*) arriving at the counting weir or (*b*) available for stripping, and the "out-go", *i.e.*, numbers of fry, yearling and two-year-old migrants leaving Cultus lake for the sea.

FIGURE 7. The apparatus used in counting seaward migrants. Placed right in the retaining pen it consists of a wooden trough, waist-high, with compartments at each end, covered by cloth screening, into which the fish are dipped, and a central portion built to hold a wire-screen hatchery basket into which the migrants are counted. The central basket is movable and when filled can be removed and emptied over the side of the pen, thus returning the fish to the creek to continue their seaward journey. The water can be drained off and replenished at any time. Four counters can work comfortably at such apparatus.

RESULTS

The data accumulated for each test of each of the three methods of propagation studied are assembled in brief form below. Only pertinent records are given and for consideration of details the reader should refer to the more complete reports in *Contributions to Canadian Biology and Fisheries, vol. 5, nos. 1-3, 1929* and *vol. 8, no. 27, 1934*, and the *Journal of the Biological Board of Canada, vol. 2, no. 3, 1936*. Further detailed reports in the series will be published as the data are worked up.

Natural Propagation

Year	1925	1927	1930
Number of males counted	1,540	26,049	4,853
Number of females counted	3,883	56,376	5,542
Average egg content per female	4,500	4,500	4,500
Females released to spawn	3,883	55,569	5,542
Eggs available for deposition	17,470,000	250,000,000	24,900,000
Total seaward migrants	197,563	2,637,573	788,637
Per cent of eggs available for deposition	1.13	1.05	3.16

FIGURE 8. Two counters engaged in counting at one of the cloth compartments. The fish, ranging in length from two to four inches, are picked up by hand, as many as four at a time, and speedily transferred to the holding basket at one side. When being counted in this way the fish can be closely examined for missing fins, parasites, separated into species, etc. Sampling to determine the age classes, length frequencies, etc., can be readily accomplished.

In the three tests of natural spawning, the *percentage efficiency is found to vary roughly from one to three per cent.* One popularly-termed "big" year, 1927, was included when the calculated egg deposition amounted to 250 million eggs.

It will be observed that in each of the three years the ratio of the sexes, males to females, varied and that in 1930, the year with the highest percentage efficiency, the sexes were more nearly equal. Whether the male and female sockeye in a spawning run definitely pair off and one male devotes himself only to one female, or whether a male may serve more than one female, has not been definitely determined, but there can be no doubt but that the ratio of sexes has a distinct bearing upon the extent of egg fertilization and hence upon the efficiency of natural spawning. If only that number of females equivalent to the number of males be considered in computing the efficiency of natural propagation, the percentages above would be increased to 2.86, 2.25 and 3.47 respectively. Since statistics of the commercial catches and reports from other sockeye areas in British Columbia indicate that the sexes are usually equal in number or the males slightly in excess over females, the situation presented by decidedly opposite proportions at Cultus lake produces a low percentage which should be considered a strictly minimum one.

Artificial Propagation with Liberation of Free-Swimming Fry

Year	1926	1929	1932
Number of males counted	3,122	1,645	741
Number of females counted	1,949	3,437	1,518
Average egg content per female	4,500	4,545	4,324
Total available eggs	8,770,000	15,620,000	6,564,000
Eggs available for stripping	7,596,000	13,476,000	4,640,000
Total fry for liberation	5,916,500	9,644,000	3,998,000
Total fry liberated	5,916,500	9,063,000*	3,998,000
Total seaward migrants	344,821	350,200	112,530
Per cent of total eggs	3.93	2.38	1.71
Per cent of eggs available for stripping	4.54	2.76	2.43
Per cent of fry liberated	5.83	3.86	2.81

*Approximately 500,000 fry were reserved for pond retention tests. Percentages have been computed to account for same.

It will be recalled that in order to make due allowance for the increased mortality caused by extra retention below the counting and stripping weir, two sets of percentages were computed, the first based on total available eggs, *i.e.*, eggs contained in all females counted, and the second on eggs available for stripping, *i.e.*, eggs contained in females stripped. The percentages which the total seaward migrants constitute of these two groups of eggs each year are given above and the true value lies somewhere between them. *The efficiency of artificial propagation where free-swimming fry are liberated varies*, therefore, *from 1.7 to 4.5 per cent.*

The actual stripping and hatchery operations differ notably in efficiency in the three years. Excluding the mortality in female sockeye during retention and stripping, the losses include eggs left in carcasses after stripping and eggs dying during incubation in the hatchery troughs. These amount for each of the three tests to 22.1, 28.5 and 13.8 per cent respectively. The actual losses in the hatchery amounted only to 7.5, 18.1 and 10.9 per cent respectively.

It is at once evident that the greatest mortality among young sockeye occurs after liberation. For each of the three years the numbers of fry which survived to migrant stage represented only 5.83, 3.86 and 2.81 per cent of the total fry liberation. The loss in the lake thus amounted to from 94 to 97 per cent of all fry liberated.

Artificial Propagation with Planting of "Eyed" Eggs

This method has come into practice of recent years not only as a means of accommodating in hatchery troughs a greater quantity of eggs than would be possible for fry production, but also as a method of cutting short the hatchery operation and returning the eggs to the natural environment at a much earlier stage. The eggs are retained in the hatchery only until the embryos show prominently the eye spots. By this time the embryos have reached a stage in which they will stand transfer and considerable handling. The eggs are removed from the hatchery troughs, placed in trays, stacked in boxes and transferred to the planting area. Arrived at the selected location where the stream bed possesses the proper type of gravel, water-flow, etc., the eggs are planted in lots of from 3,500 to 5,000 by the method initiated by Mr. C. W. Harrison, Supervisor of Hatcheries for British Columbia, and described in his paper "*Planting eyed salmon and trout eggs*" (*Trans. Amer. Fish. Soc., vol. 53, 1923, pp. 191-199*).

Year	1928	1933
Number of males	3,878	1,565
Number of females	11,461	1,906
Average egg content per female	4,511	3,800
Total available eggs	51,700,000	7,243,000
Eggs available for stripping	34,157,000	5,510,000
Eggs available for planting	2,649,800*	4,635,247
Total eggs planted	2,649,800	4,371,530†
Total seaward migrants	43,447	243,824
Per cent of total eggs	0.95	3.57
Per cent of eggs available for stripping	1.44	4.69
Per cent of eggs planted	1.64	5.58

*The planting areas being limited, most of the eggs collected were removed to other sockeye areas. The percentages tabulated are derived by calculating backward from eggs planted, making use of the percentage loss in each preceding stage (not shown in detail).

†Approximately 250,000 eggs were utilized in pond rearing tests. The percentages tabulated make due allowance for same.

Only two tests of egg planting were completed and the results show a decided variation, *the efficiencies ranging from approximately 1.0 per cent in 1928 to 4.7 per cent in 1933.* In the spring of 1929, the stream in which the majority of the eggs of the 1928 test were planted went dry for roughly 100 yards from the mouth, the water seeping through the gravel to the lake. The planting beds were not, however, affected, and subsequent spring rains, increasing the stream flow, provided a free passage for the emerging fry to the lake. A close inspection of the creek was made and no stranded fry were observed. It seems unlikely that the efficiency of 1928 was lowered unduly by the unusual stream conditions.

Aside from the readier transportability and somewhat lower production costs, which are not of particular significance in these computations of efficiency of propagation, the only advantage pertaining to eyed egg planting as compared with fry distribution lies in the avoidance of those losses occurring among fry at times of liberation. It is observed however, that the efficiencies of the two methods differ but slightly, each varying from approximately 1 to 4.5 per cent.

DISCUSSION

Comparison of Efficiencies of Methods Tested

In dealing with the relative merits of artificial propagation as compared with natural spawning it is necessary, as other workers, notably Dr. W. L. Calderwood, former Inspector of Salmon Fisheries for Scotland (*The artificial and the natural breeding of the salmon. Fish. Scot., Salmon Fish., 1924, no. 2, p. 20*), have pointed out, to emphasize that *the benefit of artificial propagation as compared with natural reproduction is measured not by the output of the hatchery nor by the fish so produced but rather by the* **difference** *between such production and that otherwise provided by nature.*

On such a basis, the Cultus lake returns, showing for natural propagation a product of from 1 to 3 per cent, and for artificial a survival of from 2 to 4.5 per cent, indicate that there is but little advantage provided by man's intervention. The latter would appear to produce an increased survival but when due weight is given to the variations existing between returns for each method of propagation, the differences between the methods themselves are not statistically significant. *It may be said, then, that artificial propagation has shown at Cultus lake no significant advantage over natural spawning.*

Applicability of Cultus lake results to other Areas

Considering, in consequence, the applicability of the Cultus lake results to the sockeye salmon situation generally in British Columbia the following may be said.

(1) For natural propagation Cultus lake would appear to present facilities less beneficial than most other natural spawning areas, chiefly by reason of the deficiency in numbers of male fish. The results obtained may therefore be considered decidedly minimum ones.

(2) For artificial propagation with liberation of free swimming fry, Cultus lake presents no observable differences from other areas and the data are deemed quite applicable.

(3) For "eyed" egg planting, however, it is possible that in some respects the planting beds may have been less suitable than in other areas, and the results may have been rendered lower than would be obtained generally elsewhere. To what extent such reservations should be applied it was impossible to ascertain, but it may be pointed out that, as far as these data are concerned, the only essential difference between egg planting and fry liberation concerns the possible difference between the natural hatch and migration down to the lake in the one case and the liberation of fry in the other. If in artificial propagation involving fry distribution the hatchery operations are efficient and the transfer of fry from the hatchery to the lake is conducted without undue losses, no other method could be expected to be more efficient up to this stage in the life history. In both practices, the amount of loss depends essentially upon the extent of depredation by predatory fishes, and whether the artificially liberated fry are more readily taken by predators than are fry emerging naturally from the planting areas is quite open to question. The results for artificial propagation involving planting of eyed eggs, therefore, may also be deemed applicable to other sockeye areas generally similar to Cultus lake.

Relation of Hatchery Egg Collections to Natural Egg Deposition

Since artificial propagation has been fostered as a distinct improvement over natural spawning and as producing greater numbers of fish, it may be justifiable to consider the relation of such operations generally to the runs to the main river systems of British Columbia. There are no complete data available concerning the extent of natural propagation of sockeye salmon in British Columbia, but from the information obtained coincidentally in the Cultus lake tests and elsewhere, computations of probable natural escapements and eggs deposited may be made from the annual commercial pack statistics. In the years 1932 and 1933 all sockeye migrants leaving Cultus lake were marked by the removal of both pelvic fins (1932) and the two pelvic fins and the adipose fin (1933). Extensive campaigns for recovery of returning sockeye bearing these marks were made throughout the fishing areas and at Cultus lake in the years 1934, 1935 and 1936, in order that the percentage return of adults from the sea might be determined. From the 1932 experiment a return of 3.7 per cent was obtained, of which approximately one-half was obtained from the fishing areas and one-half at Cultus lake. In 1933, the return was 3.5 per cent, but roughly 75 per cent were caught in the commercial fishery and but 25 per cent at Cultus. The spawning escapement was therefore one-half in 1932 and one-quarter in 1933. Assuming, therefore, for conservative allowance, that the latter proportion prevails and that the number of sockeye escaping to the spawning grounds constitutes one-quarter of the supply, *i.e.*, one-third of the commercial pack, that the fish average 12 to the case, that 50 per cent of the escapement is made up of females, and that the average female contains 4,000 eggs, the probable natural escapements in the fifteen years from 1918 to 1932 may be compared with the hatchery collections as in table I.

TABLE I.

Year	FRASER RIVER: Hatchery egg collection (millions)	FRASER RIVER: Commercial pack in cases	FRASER RIVER: Estimated natural egg deposition (millions)	FRASER RIVER: Eggs collected as per cent of natural deposition	RIVERS INLET: Hatchery egg collection (millions)	RIVERS INLET: Commercial pack in cases	RIVERS INLET: Estimated natural egg deposition (millions)	RIVERS INLET: Eggs collected as per cent of natural deposition	SKEENA RIVER: Hatchery egg collection (millions)	SKEENA RIVER: Commercial pack in cases	SKEENA RIVER: Estimated natural egg deposition (millions)	SKEENA RIVER: Eggs collected as per cent of natural deposition
1918	20.5	70,420	563	3.6	3.0	53,401	427	0.7	9.1	123,322	987	0.9
1919	52.6	103,200	826	6.4	11.5	56,258	450	2.5	17.1	184,945	1480	1.2
1920	36.5	111,053	888	4.1	12.1	121,254	968	1.2	17.1	90,889	727	2.3
1921	33.8	142,598	1141	3.0	18.4	46,300	370	5.0	15.9	41,018	328	4.9
1922	34.8	100,398	803	4.3	14.5	60,700	486	3.0	15.0	96,277	770	2.0
1923	54.5	79,057	632	8.6	15.4	107,174	857	1.8	18.7	131,731	1054	1.8
1924	48.5	109,112	873	5.5	16.0	94,891	759	2.1	17.1	144,747	1158	1.5
1925	45.8	147,408	1179	3.9	18.7	159,554	1276	1.5	18.5	81,146	649	2.8
1926	56.8	130,362	1043	5.4	19.8	65,581	525	3.8	23.5	82,360	659	3.6
1927	46.1	158,987	1272	3.6	20.6	64,461	517	4.0	16.3	83,996	672	2.4
1928	73.1	90,343	722	10.1	14.0	60,044	480	3.0	14.6	34,559	276	5.3
1929	34.6	173,467	1388	2.5	20.0	70,260	562	3.5	16.0	78,017	624	2.6
1930	44.9	455,886	3647	1.2	19.2	119,170	1353	1.4	17.1	132,372	1059	1.6
1931	62.5	128,158	1025	6.1	20.0	76,428	611	3.3	14.1	93,023	744	2.2
1932	32.1	146,957	1176	2.7	16.6	69,732	558	3.0	12.0	59,916	479	2.0
Average	45.1		1,145	4.7	16.0		680	2.7	16.1		778	2.5

It will be observed that the artificial propagation efforts involved but 4.7 per cent of all eggs in the estimated spawning escapement of the Fraser river system, 2.7 per cent for Rivers inlet and 2.5 per cent for the Skeena, proportions not expected to alter to any appreciable degree the extent of the fishery unless the benefits are particularly great, which they have been shown not to be.

NATURAL MORTALITY IN THE LAKE

It has been shown that after sockeye fry are liberated in Cultus lake, a mortality of from 94 to 97 per cent occurs. This, it may be presupposed, exists irrespective of whether the fry are reared naturally or in hatcheries and therefore presents perhaps the most urgent problem facing fish culturists. Can the mortality be reduced and at what cost? Observations at Cultus lake definitely point to predatory fishes—squawfish, char, trout, sculpins—as the agents chiefly responsible for this loss. Tests are now being conducted to determine the practicability of appreciably reducing the loss of sockeye by destroying predators and keeping their populations at a low level.

Retention of sockeye fry and fingerlings in ponds, thus removing them entirely from the danger of loss through depredations of predators, has been tested. Without going into detail it may be stated that such operations were found, under the best conditions, to be decidedly expensive. The ever-present danger of infection and disease involving the sudden loss of a large part, if not all, of the pond populations, renders pond retention still more questionable. In any event, the operations could never, without the outlay of very large sums of money, be enlarged sufficiently to handle any but a small fraction of the total natural seeding of any river system.

Artificial Propagation an Emergency Measure

It is possible that under certain circumstances, such as stocking new areas or rebuilding severely depleted runs in isolated streams, artificial propagation may be beneficial. These, however, are essentially unusual conditions requiring emergency treatment and it is largely as an emergency measure that the artificial propagation of sockeye salmon should be considered. Under such circumstances it may have a definite place and form a part of a broad program of fish culture.

Importance of Increased Natural Seeding

It is apparent that the success of the sockeye salmon fishery of British Columbia is largely dependent upon the volume and character of the natural spawning escapement. Possible benefit may be derived by reducing the lake-resident populations of predatory fishes, but attention should be devoted primarily to providing each year an adequate escapement. By limitations of the commercial pack, by prohibition of fishing at certain seasons and by a scientific survey of the spawning areas to ensure proper utilization of all available spawning grounds, the fishery may undoubtedly be effectively husbanded and efficiently "managed".

CONCLUSIONS

From the Cultus lake investigation of natural and artificial propagation data have been assembled, which show the following.

(1) For natural propagation the product, as represented by seaward migrants, constitutes from 1 to 3 per cent of the total eggs presumed to be deposited naturally. The rather unusual shortage of male sockeye may have resulted in a lowered return which under other circumstance may render natural propagation from 2 to 3.5 per cent efficient.

(2) The product of artificial propagation involving the liberation of free-

swimming fry ranges from 2 to 4.5 per cent of the total number of eggs available for stripping.

(3) From artificial propagation involving the planting of "eyed" eggs, from 1.5 to 4.7 per cent of the total eggs available for stripping are recovered as seaward migrants.

(4) During the year's residence in the lake from 94 to 97 per cent of the fry liberated therein perish. The loss has been attributed largely to predatory fishes—squawfish, char, trout and sculpins. Tests are now being undertaken to determine the benefits accruing from destruction of predators.

The above data may appear to show an appreciable benefit to be obtained from artificial propagation. On the contrary, however, due consideration of the ranges of variation in the percentages of efficiency for each of the three methods indicates that the differences which seem to exist between the methods are not significant. They do not portray any distinct advantage for any one of the three methods tested.

On the basis, therefore, of the above results, it may be concluded that in an area such as Cultus lake, where a natural run of sockeye occurs with a reasonable expectancy of successful spawning, artificial propagation for purposes of continuing the run to that area is unnecessary, and, if producing any additional results over natural spawning, these would not appear to be in any way commensurate with the cost.