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SOCKEYE SALMON - R.E. Foerster

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The fishing industry of British Columbia is well-equipped with men, gear and skills, and it depends in the main on a highly intensive fishery for relatively few species, among which the salmons are by far the most important. Its future depends on the maintenance of these stocks and on the discovery of others which can be exploited profitably. It follows that the Pacific Biological Station, in order to provide the knowledge on which the best development of the industry can be based, must devote a great deal of its efforts to solving the problems of maintaining the important salmon stocks both by regulating the fishery for them and by preserving or improving the conditions for their reproduction in fresh water. Attention must also be given to the problems of regulating intensive fisheries for other species including herring, crab, and some groundfish. A small but increasing effort is spent on exploration for unused stocks. As a background for all these projects it is necessary to improve our knowledge of physical and biological conditions in the sea and in fresh water, and of the factors controlling the numbers and activities of the many species with which we are concerned.

Regulation of fishing. The preponderant importance of salmon to the British Columbia fisheries, and their great vulnerability as they approach and enter rivers to spawn, give the regulation of the salmon fishery a special importance. If entirely unrestricted it could catch almost all the salmon and reduce the stocks to a very low level. The Department of Fisheries, with the support of the industry, has regulated it with commendable success and it has survived more than a half-century of intensive fishing, with yields somewhat reduced but still substantial. There is, however, need for more precise knowledge. The purpose of the regulations is to permit enough salmon to pass through the fishery to the spawning grounds and it is important to know just how many must be allowed to spawn in order to keep the catch at a maximum. The numbers of young salmon produced by known numbers of spawners have been and are being studied in several streams and lakes with varying conditions, emphasis being placed on sockeye salmon, with pink and chum salmon next. It is necessary to learn the effects of changing natural conditions on the production of young salmons and on the size of the salmon stocks and to distinguish these effects from those of the fishery.

Good equipment and organization make possible very intensive fishing of the herring stocks when they concentrate in inshore waters before spawning. There is danger of over-fishing and the fishing is under regulation. The effects of the fishery on the herring stocks is being studied to improve the basis for regulation to keep the yield at a maximum. Other intensive fisheries include those for crab and certain species of groundfish and these, too, are being studied from this point of view.

The whale fishery, being under international regulation, is a special case. In accordance with the policies and program of the International Whaling Commission, the general biology of whales in British Columbian waters and the relation of these stocks to those of other areas are being studied.

Prediction of changes in the abundance of fish stocks is important both to profitable fishing and to effective regulation. The same studies improve the basis for both regulation and for prediction. In some cases, especially that of the herring fishery, predictions have become accurate enough to be useful.

Softening the impact of industrial development. The increasing use of fresh water for power, irrigation, and other industrial and domestic purposes is a serious threat to salmon production both by diverting water to other uses and by installing dams which obstruct both the upstream movements of spawning adults and the return of the young to the sea. These problems are not yet as acute in British Columbia as in some other areas but they are becoming more so. The Station is cooperating with other agencies in developing means of guiding salmon past obstructions.

The extent of various types of industrial pollution is under observation and their effects on valuable species are being studied in the laboratory and in the field. In the case of pulp mill pollution especially, it has been possible to advise the administration and the industry how to avoid damage to fisheries.

Improvement of conditions for salmon reproduction. The growing demand for salmon and the growing effects of industrial development on natural production combine to make it important to examine ways of increasing production artificially. "Fish culture", in the broadest sense, may eventually become essential if stocks are to be maintained at a high level. Some present work has potential value for such a development and more may be needed in the near future. In 1954 an experimental planting of pink salmon eyed eggs was made in an artificial spawning bed. Progress was made in a study of the conitions necessary in the gravel for the survival and development of salmon eggs and fry. Other phases are also under study.

Exploration for fisheries development. The fishing industry in British Columbia has depended in the main on species caught readily in large quantities in inshore waters. The halibut fishery, which is the responsibility of the International Pacific Halibut Commission rather than of this Station, is an exception in that vessels travel considerable distances to the fishing grounds, and there has been a tendency for fishing operators generally to become more mobile and extend farther seaward. It is nevertheless true that the potentialities of more distant fisheries, especially for tuna, are virtually unknown. Exploratory fishing, and even reconnaissance, are very expensive in offshore waters, thus limiting the activity of the industry and making government participation essential. The possible importance of offshore fishing to the long-term future of the industry and the greater knowledge of offshore distribution of salmons needed by the International North Pacific Fisheries Commission are turning attention seaward. In the meantime, explorations have been limited to less ambitious operations to discover unused stocks of inshore species, such as shrimp.

Background for fisheries research and development. All of the research and development projects ~~maintained~~ MENTIONED above and, indeed, the recognition of ~~preserving~~ PROMISING new lines of endeavour depend on a broad knowledge of oceanographic conditions and of the biology of species which do or can contribute to the fisheries. It is necessary to know the conditions in the sea which determine the distribution, movements and numbers of the fish and shellfish on which our fisheries depend. This knowledge, which is essential both to the most efficient fishery and to the most effective regulations alike, has been developed energetically in inshore waters; attention now and in the future must be directed more and more seaward. It is necessary also to learn the manner in which the conditions affect the behaviour and the numbers of the important species. This is being attempted both by experimentation in the laboratory and by observation in the field--the former to reveal the action of individual factors and the latter to discover their actual effect in the complex conditions which prevail in nature. These oceanographic and biological studies, which are so essential to progress in fisheries research and development, must keep pace with more direct studies of the problems of the fishery if the latter are to be solved effectively.

SOCKEYE SALMON

During 1954 progress was made in the research program designed to provide information on (a) the relation of numbers of adult spawning sockeye (the escapement) to the numbers and size of seaward-migrating young produced, (b) the factors affecting and limiting natural production of young sockeye, and (c) the annual variations in age, size and sex composition of the sockeye in the commercial catches of four of the major sockeye-producing areas of the Canadian Pacific coast. Investigations were carried on at Babine Lake which accommodates more than half the spawning escapement of the Skeena River system; at Lakelse Lake, where the effort is directed primarily towards fundamental studies of their life history in fresh water; at Port John, where incidental observations on sockeye in a small, coastal-lake area are made in conjunction with a pink and chum salmon program; and at coastal canneries where the catches of the Rivers Inlet, Smith Inlet, Skeena River and Nass River fisheries are sampled. An important feature of having observations and data from several sockeye areas, which differ in size, geographical position and climate is that a greater range of natural conditions is involved, and hence correlations between production and pertinent limiting factors, such as climate and lake conditions, can be more clearly evaluated.

Smolt production from natural spawning at varying adult population densities. While the studies at all three field stations, Babine, Lakelse, and Port John, are providing information, the data from Babine are of particular significance since they have to do with the major sockeye-producing area of the Skeena River system. Here the program centres around the Babine River adult-counting weir and the installations which have been developed to estimate the size of the annual smolt run from the lake.

(a) Babine Lake spawning runs and seedings. The adult salmon spawning escapement to Babine Lake area each year has been enumerated since 1946, as shown in the following table:

Year	Sockeye	Percentage "jack" sockeye	Spring	Pink	Coho	Chum
1946	475,705	12.2	10,528	28,161	12,489	18
1947	522,561	50.0	15,614	55,421	10,252	7
1948	560,000[X]					
1949	509,132	9.4	7,433	13,663	11,938	5
1950	543,658	33.0	6,838	38,728	11,654	7
1951[XX]	152,457	7.2	2,778	50	2,122	0
1952[XX]	376,947	7.4	5,915	2,706	10,554	1
1953	714,614	3.9	8,353	1,018	7,648	17
1954	503,422	1.9	5,925	4,604	3,094	66

X Estimated from comparison with stream survey counts and fence counts of previous years.

XX The runs of 1951 and 1952 were blocked by the Babine River rock slide. The effective spawning in 1952 was less than the number of adults indicates, many fish being damaged or delayed so as to prevent spawning.

The sockeye salmon are of particular interest and, since 1951, the runs have shown considerable variation in magnitude and composition as a result of the rock slide in the Babine River early in 1951. This variation in spawning density has made it possible to obtain pertinent information on the percentage production of young sockeye. This will be of value in assessing the adult spawning escapement required in an area such as Babine for the optimum production of young.

Of course, numbers of fish do not give the full picture of the egg deposition potential of a run. The proportion of females, the size of fish, and their physical condition are important factors. All of these are studied each season. Female fish in the 1954 sockeye run represented about 60% of the total, normal males around 38%, while the "jacks" (males maturing in their third year) contributed less than 2%. The high proportion of females, combined with their larger-than-average size produced the second largest potential egg deposition so far recorded for Babine Lake, viz., slightly over one billion eggs. Only the 1953 run of 714,614 sockeye brought more eggs into the area since the investigation commenced in 1946.

A record peak count of 38,755 sockeye on September 1 probably resulted from the special weekly closures (July 31 to August 2 and August 6 to 8) and a week's suspended fishing (August 9 to 14) during a tendermen's strike. A record low number of injured sockeye in the 1954 run gave further evidence of the effectiveness of the removal in early 1953 of the 1951 rock slide. Twenty-four-hour operation of the counting weir during three periods of the season's run indicated that few sockeye moved upstream at night, and that around 90% of the daily run occurred between 7 A.M. and 7 P.M., the usual hours of weir operation.

(b) Babine Lake smolt production. The smolt runs each spring indicate the extent or percentage of production from the egg deposition two years earlier, e.g., the smolts of 1954 resulted mainly from the egg deposition of 1952, since most of the smolts spend one year only in the lake. Smolt estimations commenced only in 1951 and the records of production for the four years are as follows:

Eggs deposited in	1949	1950	1951	1952
Potential deposition	869×10^6	583×10^6	198×10^6	$^{x}411 \times 10^6$
Smolts resulting	4.2×10^6	4.5×10^6	3.1×10^6	2.8×10^6
Percentage survival	0.48	0.77	1.57	0.68

x Probably two-thirds of these were not actually available (See text). Calculated on presumed actual egg deposition, the percentage survival becomes approximately 2%.

The smolt run of 1954 (brood year 1952) gave the lowest recorded percentage since estimations were begun, if based on the total eggs contained in all females passing the counting weir. However, that part of the 1952 run which passed the rock slide had been seriously delayed, and its up-river ascent severely handicapped. Observations on the spawning grounds indicated that about two-thirds of the females had died unspawned. This appreciably reduced the actual egg deposition and if the smolt production be based on actual egg deposition the rate of survival becomes approximately 2%. Thus, as shown by the 1953 smolt count, there is a tendency for smaller egg depositions to have a greater percentage smolt production, though the actual numbers of smolts migrating are lower than for large egg depositions. The extent of smolt production from the two heavy egg depositions of 1953 and 1954 - to be obtained in 1955 and 1956 - will be of special interest in indicating where the optimum level of sockeye production for the Babine Lake area may lie.

(c) Lakelse Lake smolt production. Only one smolt production determination has been possible since the counting weir for adults and smolts was installed in 1952. From 12,000 adults counted into the lake in 1952, a smolt migration of 379,000 in 1954 indicated a production of 1.8%. For years prior to 1952 (1944, 1945, 1946, 1950, 1951) counts or estimates of the numbers of sockeye on the spawning beds are available, as well as the numbers of smolts produced. These data are being examined critically and the smolt production percentages obtained for the varying spawning population densities which occurred.

Consideration of the smolt counts already available (6 years) indicates that the size of the smolt run from Lakelse Lake has varied within rather narrow limits (mean = 460,000; range = 373,000 to 596,000). Whether or not this lack of wide variability is due to a relative constancy of the spawning escapement awaits examination of data for the 1944-51 spawning runs and presumed egg depositions. Unlike the smolts from other areas, no clear-cut inverse relationship has been found between the mean size of smolts and the magnitude of the migrations.

(d) Port John smolt production. Five years' data are available on smolt production from known egg depositions. Since the smolts emigrating from Port John Lake have been found to be chiefly two-year-old fish, i.e., had spent two years in the lake, consideration must be given to the numbers of one- and two-year smolts in each season's migration. Smolt enumerations have varied from approximately 11,000 to 19,500, with egg depositions ranging from approximately 300,000 to 2,000,000. Tentative calculations suggest a smolt production in the Port John area of from around 0.5% to 1% from calculated egg depositions but precise determinations await completion of full analysis of all the pertinent data.

Factors affecting and limiting natural production of young sockeye. An understanding of the factors that influence, either favourably or adversely, the production of young sockeye to the seaward-migrating smolt stage (1) makes possible a clearer appreciation of the variations in adult sockeye production from year to year, (2) will be of value in predicting the return of adults from known seedings, and (3) provides the information necessary for increasing or rehabilitating stocks in low-producing areas, or for maintaining production in areas where industrial expansion may tend to make conditions less suitable.

Lakelse Lake was selected in 1949 as the site for such study. Techniques have been established for enumerating the sockeye runs each year at various stages of their freshwater life-history, such as egg deposition, fry hatch and smolt migration. Methods describing the physical and organic environment of the sockeye during their freshwater residence, such as, year-round meteorological observations, stream and lake levels and temperatures have been developed. Assessments of the distribution and abundance of food crops (plankton, etc.) are made, as well as annual determinations of the abundance, composition and diet of competitor and predator populations of fish in the lake.

(a) Survival from spawning to emergence of fry. Scully Creek, a small sockeye-producing tributary of Lakelse Lake, has been used for five years as an indicator of fry production from a known number of eggs available. Under varying climatic and adult spawning densities an average fry production of 11.8% (range 9.3% to 13.7%) was obtained. In 1954 a production of 10.1% occurred from an egg deposition of 958,000. In 1953-54 a method of estimating fry production in the main spawning stream of the Lakelse area, Williams Creek, was devised; a production of approximately 7.5% from an estimated 17,750,000 egg deposition was obtained. These fry production records can be compared with the similar data obtained at a test stream, Six Mile Creek, Babine Lake (19% in 1954, 12% in 1951), and at Port John (13.4% in 1954; a mean of 9.5% for earlier years, with range from approximately 1.7% to 25.5%). Stream water flow conditions and abundance and activity of predator fish are found to be important factors affecting survival of eggs, alevins and fry.

(b) Survival during lake residence. During the one-year residence in the lake, heavy losses occur. Records of all factors having an important bearing on survival are being obtained, as stated above. While data on the production of smolts from calculated egg depositions are being obtained from Babine and are available for Lakelse for earlier years, the 1955 smolt counts will give the first determination for Lakelse of smolt survival from estimated fry produced. This and subsequent findings will be comparable with those obtained at Port John, a much smaller area with quite different conditions prevailing.

Since previous studies (at Cultus Lake) have indicated a heavy loss of lake-resident sockeye to predator fish in the lake, whose numbers may be reduced and controlled, special attention is being given to the abundance of predator species in Lakelse Lake, their diets and activities, with a view to subsequent experiments in reduction in their numbers and the effect on sockeye survival. At the same time populations of other lake fish which may compete with sockeye for food are under examination; their reduction and control may also be advantageous. These studies involve extensive creel census work, capture of lake fish by traps and gill nets for

population estimation, food, rate of growth, age composition analyses, etc. Several years' records have been obtained and are being analysed.

Studies conducted by Dr. W.E. Johnson, working under a post-doctoral fellowship from the National Science Foundation of the United States but with some facilities and field assistance from the Fisheries Research Board, are aimed at relating the distribution, growth and survival of lacustrine sockeye with seasonal and annual changes in the density and distribution of zooplankton. In 1954 workable methods were developed for measuring plankton density and distribution and for capturing young sockeye in Lakelse Lake. It is planned to extend observations to a number of lakes with varied conditions.

Studies of the sockeye salmon fishery. Each season for the past 30 years the catches of the Rivers Inlet, Smith Inlet, Skeena River, and Nass River gill-net fisheries, have been sampled to determine the age, sex, and size compositions. The age data indicate the brood years from which the sockeye in the catches originated. For the 1953 and 1954 catches the percentages of the major age-groups in the samples were:

Area	Age-group	1953	1954	40-year average*
Rivers Inlet	4_2	73	60	49
	5_2	26	39	50
Smith Inlet	4_2	89	61	27
	5_2	10	38	72
Skeena River	4_2	48	48	45
	5_2	43	43	43
Nass River	4_2	23	35	18
	5_2	22	20	11
	5_3	46	40	63

* Except for Smith Inlet, which is based on only a 7-year average.

Were it practicable to obtain each season a reasonably approximate estimate of the numbers of sockeye escaping to the spawning grounds and the age composition of the spawners, the numbers of sockeye returning each year from the ocean could be related to the brood-year spawning population and the overall rate of production computed. This has not heretofore been possible. A study was conducted this season, however, to ascertain how the spawning escapement for the Skeena River might be adequately assessed and the pertinent age and sex data collected. It seems that it can best be done immediately above the fishing limits by graduated-mesh gill-net gear or by traps.

For the Skeena River system, past catch sample data have been analyzed to throw light on trends in the sockeye production. The findings suggest that a gradual decline in the catches in the early period of the fishery (1911-33) was associated with decreasing catches of 5-year-old fish rather than 4-year-old fish and that the more recent gradual in the annual commercial catch has been associated with a reversal of this trend. There was also indication that large sockeye catches have contained more 5-year-old than 4-year-old individuals. Examination of past tagging data indicated that the gill-net fishery took more larger than smaller fish, relatively more 5-year-old than 4-year-old individuals, and more males than females.

Review of data for the Rivers Inlet area indicates that the sockeye runs are often dominated by one age-class in both catch and escapement.

particularly when very large runs occur. These runs tend to perpetuate themselves, those dominated by 4-year fish returning in four years and those dominated by 5's returning in five years. Whether age at maturity may have a genetic basis is being examined.

The occurrence of more than one age-group in the sockeye runs complicates greatly the assessment of production from brood years. It makes difficult an analysis of trends and of annual variations. Prediction of returns from known smolt migrations, such as Babine and Lakelse, becomes less definite. Observations now being made will throw further light on the problem which is of importance both to Industry and to the management agency, the Department of Fisheries.

PINK AND CHUM SALMON

Pink and chum salmon, which constitute about 60% by weight of the total salmon landings of British Columbia, have a much wider distribution than sockeye in the smaller streams of the province. This fact, together with the absence of a lake-dwelling phase during the life history, has dictated a somewhat different investigational program.

Since 1947, detailed information on the freshwater conditions which affect abundance has been sought at two field stations -- Nile Creek, on Vancouver Island, and Port John, near Ocean Falls. At the former, certain methods for improving the survival of the eggs and young fish have also been tested. At the same time, efforts have been made to keep in touch with conditions and problems in other areas and other types of stream by surveys and short-term observations. During 1954 the Nile Creek station has been closed since it was felt that it had substantially fulfilled its original objectives and that the freeing of personnel and funds would permit the investigators to apply more widely the information now available and to attack effectively certain problems of current or continuing importance.

Other work on pink and chum salmon has included the tagging of adults in the sea for the purpose of tracing the routes and destinations of the migrating fish and estimating the intensity of the fishery to which various stocks are exposed.

At the present time emphasis is being laid on problems which can be expressed in the questions--What kinds of gravel and what sort of stream flow are required to promote effective reproduction, whether from natural spawning or by artificial planting of eggs? How many spawning fish should be allowed or encouraged to occupy a given area of stream bottom in order to produce the best result for the fishery. The first problem entails laboratory experiments on the porosity of gravel and the oxygen requirements of developing eggs, as well as field observations. The second problem demands field data on the reproductive efficiency of spawning populations of varying density.

Nile Creek. The final operations at this field station included counts and observations on the adult runs of 1953 and on the downstream migration of young fish in 1954.

The adult escapement of both pinks and chums showed a very low survival during the ocean phase (estimated at 0.23% and 0.13% respectively). The former species, however, approximately maintained the numbers present in the parent year, namely, a little over a hundred fish. This stock is of particular interest since it was established two generations previously by introduction of eggs in 1949. The chum run was insignificant (44 fish). The coho run (524 fish) was the second largest recorded.

The percentage output of fry from the small seedings provided by these 1953 pinks and chums was the highest recorded for natural, unprotected spawnings in this stream, representing respectively 23.6% and 13.6% of the available eggs.

General findings from the Nile Creek program include the following:

(1) The output of fry is determined to a large extent by the survival of the eggs during the early stages of development, that is, before the "eyed" stage is reached.

(2) Survival is greater in gravel that is protected from fluctuations in water flow.

(3) Survival of fry during the short downstream migration to the sea has varied from 35% to 62%.

(4) Freshwater survival in Nile Creek has improved during the last few years but the escapements have not increased because of a very low rate of return from the sea. This suggests that the fishing intensity is heavy in relation to the productivity of this stream.

Port John. An important part of the work of this field station has been to follow the annual changes in the numbers of spawning fish and to record the natural conditions associated with varying reproductive efficiency.

The adult pink salmon escapement of 1953 (1,599 fish) represented an abnormally low return from the sea of the fry migrants reaching the ocean in the spring of 1952 (0.67%, as compared with over 3% for all previous returns). Heavy fishing of the Hooknose Creek run may have contributed largely to this result. The chum salmon run of 4,355 fish was the second largest recorded in the seven years during which the station has been operated.

Both species achieved a relatively high output of fry in the spring of 1954, pink salmon showing an efficiency of 13.9%, chums 16.4%. The previously reported tendencies for the two species to show similar survival rates in a given year and to produce better results when the autumn stream flow is low, were maintained.

Estimation of fry by sampling with fyke-nets. In continuation of previous work a series of experiments was performed at Port John to test the efficiency with which fry runs can be estimated by sampling with a standardized type of fyke-net. Nets with an opening 1 ft. x 2 ft. were set in various positions and the catches were compared with the total numbers of fish recorded at the counting weir. A single net was sufficient to reveal the direction of nightly fluctuations in the abundance of migrants but the proportion of the run captured by a net varied according to its position. Five nets spaced across the stream and presenting a total width of one-third of the latter caught approximately one-third of the migrating fish. Eighty-five percent of the fry migrated in the top 6 inches of the water. In the nightly migration, pink salmon fry preceded chums by about half an hour.

Tagging in Johnstone Strait. An intensive salmon fishery is prosecuted in and near Johnstone Strait, which forms a natural funnel for fish migrating to many areas in southern British Columbia. Effective management requires knowledge of the destinations of the fish that are being exploited, the timing of the passage of the various stocks through the Strait, and the extent to which these stocks are fished at other points along their migration routes.

Extensive tagging of pinks and chums was conducted in the latter part of 1953 in the western approaches of Johnstone Strait (Area 12) and also at the eastern end of the channel (Area 13).

Recoveries of pink salmon tagged in Areas 12 and 13 amounted to 45% and 33% respectively. In comparison with results obtained in 1945, the fishing rate in Area 12 was found to have changed little, while in Area 13 the rate showed an increase from 26% to 33%. Distribution of recoveries showed that from late July to early September fish migrating to all the main areas east and south of Johnstone Strait were present in the latter. After early September the Johnstone Strait population consisted entirely of fish bound for the Fraser River. Fraser River fish accounted for about 50% of all tags recovered.

Recoveries of chum salmon tagged in Areas 12 and 13 amounted to 47% and 36% respectively, both these figures representing substantial increases over the findings of 1945, when the corresponding percentages were 34% and 22%. Fish migrating through Johnstone Strait in the early part of the season were moving mainly towards Bute Inlet, Toba Inlet, Puget Sound and the Fraser River. In mid-September these runs were augmented by fish travelling to the east coast of Vancouver Island and, still later, by runs to Burrard and Jervis Inlets. Fraser River fish showed throughout the season and provided 44% of all recoveries.

Experimental planting of pink salmon eggs. Small-scale attempts to establish new runs of pink salmon have met with little success, but the absence of runs in alternate years in some highly productive areas, and in all years in others which appear suitable, suggests that development of successful techniques for this purpose might be very valuable. As an experiment along these lines over 2,500,000 eggs collected in September and October, 1954, at Lakelse River were planted in Jones Creek, a small tributary of the lower Fraser River which has substantial natural spawning of pink salmon in the "odd" years (e.g. 1951, 1953) but hardly any in the "even" years (1952, 1954). The transfer was made when the eggs were in the "eyed" stage of development, and they were planted in an artificial gravel bed with partially controlled water flow. Survival of the eggs and conditions in the gravel are being followed and the production of fry and return of adults will be observed.

SPRING AND COHO SALMON

The troll fisheries catch spring and coho salmon almost exclusively. Recent tagging and marking experiments show that considerable intermixing of stocks exists in the ocean. Because of the need for international co-operation in the conservation of these two valuable species, a close liaison has been maintained with the Pacific Marine Fisheries Commission. For the past few years, the trollers have been concerned over the condition of the stocks of both species and particularly over the catching of many small fish in certain areas. To protect these small fish, certain regulations of minimum sizes and closed seasons have been proposed. In order to evaluate the probable usefulness of such measures information has been obtained on ocean migrations, growth, food, and maturity of spring and coho salmon. In 1954 a study was initiated to assess the tagging and releasing mortalities of troll-caught fish.

Fishery in 1954. The commercial troll catch is usually about two-thirds of the total catch of spring and coho salmon. The sport catch, chiefly in Georgia Strait, is about 3% as large as the commercial catch. In 1954, the catches of both species were poor. This is particularly disappointing in the case of the coho salmon, because the catch in the brood year of 1951 was probably the highest on record. Following a good spawning, the dry summer of 1952 apparently affected the survival of young salmon in the streams severely. Poor ocean-feeding conditions were reported in 1953. The result has been a low adult return.

Sampling of commercial catches. In order to obtain returns from the large marking program conducted in United States streams, approximately 75,000 fish of both spring and coho salmon were scrutinized for missing fins. Over 200 marked fish were found, mostly from catches made off the west coast of Vancouver Island. The findings confirm earlier results that relatively few coho and spring salmon marked in United States get as far as northern Hecate Strait.

The sampling for age and size shows that a large part of the troll fish in both species are caught in their third year. Both older and younger spring salmon are taken by the commercial fisheries and younger coho salmon are often caught by the sportsmen. Most of the small spring salmon are caught off the west coast of Vancouver Island. Early this season the coho salmon were smaller in size than in the previous two years.

Food and maturity. Herring was the dominant food in the stomachs collected, in July 1953, from both spring and coho salmon off the southwest coast of Vancouver Island. The large spring salmon were caught more readily on large lures and contained more herring in their stomachs than small fish. The herring consumed were smaller than most of the fish caught by the nearby summer herring fishery. It appears that the heavy winter fishery of large herring in this region does not directly affect the spring salmon food supply.

Female spring salmon, from the above feeding area, were separated (by the size of the eggs and gonads) into maturing and immature fish at a fork length of 75 centimeters. Both stages were found in male fish up to 85 centimeters. It is estimated that two-thirds of the spring salmon caught in this region were immature. Thus immature spring salmon cannot be clearly separated by size and a minimum size designed to protect immatures would result in the release of many fish.

Mortality when cuaght and released. By trolling for small spring and coho salmon and then releasing the live fish into a pound, the initial mortality caused by catching and releasing (without tagging) was estimated at 30% to 50% and the final mortality at 50% to 75%. When small salmon are released, during a closed season or below a minimum size, the mortality involved, together with the natural ocean mortality, is probably higher than the gain in weight of the survivors. In tagging experiments, when only fish in good condition are used, the releasing mortality is probably about one-third.

EXPERIMENTAL STUDIES ON FISH BEHAVIOUR AND SURVIVAL

The major reason for commencing experimental research on the behaviour and survival of fish has been the inability of biologists, engineers, or anyone else, to meet the mounting toll which the creation of high dams is having on salmon, particularly the young salmon. Although it is generally conceded that the problem of passing adult salmon over dams (up to 100 feet) is being about half met, that for the young fish going over spillways or

through turbines has hardly been touched. Although the condition is not yet so acute in British Columbia, its future importance is indicated by what is happening on the lower Columbia River. Of 120 large dams planned, 61 have been built. One of the latest, McNary Dam, has cost over $20,000,000 in fishways for adults migrating upstream. Little or no expenditure has gone into safeguarding the young downstream migrants.

One reason why this problem has not been solved is the lack of knowledge of the behaviour, capabilities and responses of the fish; in addition to the complexity of the problem has not been commonly recognized. The aim is to safeguard millions of young fish daily, during peak runs, efficiently and effectively. Not only must this be achieved, but also the problems arising from pollution, silting, impounded waters and changed river flows must be met.

Objectives of present research are twofold. The immediate approach is concerned with determining methods of directing salmon during their downstream or upstream migration. It is during these critical periods that measures to get them past obstructions are needed. The second approach is of a more long-term nature. Laboratory experiments are in progress designed to establish the limits of tolerance, the preferred levels, and the general capabilities of the fish to meet the physical and chemical aspects of their environment - temperature, salinity, oxygen content, and foreign chemicals.

Guiding sockeye smolts. From the study of guiding young salmon, conducted in a large experimental trough, there has emerged a possible system of directing sockeye smolts by the use of a curtain of hanging chain. Efforts have been concentrated on defining the most effective conditions of operation both by testing within the trough and through the construction of a prototype chain deflector in the Lakelse River.

Somewhat conflicting results between the trough and river experments have resulted. These appear to be mostly attributable to the relative direction and rate of flow in the river. Present findings indicate: (1) Unvibrated, illuminated chain placed directly in the path of migrants has nothing but momentary influence on their continued progress downstream. (2) Good deflection can be achieved with sockeye if the chain is vibrated (4-inch interval between stands, 144 r.p.m., 4-inch amplitude) and if the flow does not exceed 0.5 ft. per sec. (3) Much of the initial deflection can be lost if attractive, alternative downstream paths are not presented to the fish. Repeated experiences along the deflector result in breakdown of close schooling and penetration through the curtain of chain.

The results show promise. Research on attractive by-pass openings is planned.

Adult salmon repellent. Work on the isolation of this repellent, present in the skin of some mammals, has moved one step nearer completion. A primary identification of the general nature of the material was achieved last year. Recently, more sensitive techniques of extraction, concentration, and separation have been introduced. The threshold dilution just producing an alarm reaction now appears to be approximately 1 part in 80,000,000,000. Field testing has been conducted by the Pacific Biological Station, chemical extraction by the Pacific Fisheries Experimental Station.

The study has done much to set the pattern of research required for investigation of olfactory perception. If it is possible to obtain some odour concentrate attractive to salmon, the combined use should prove of considerable value in directing the adults.

Toxicity of pollutants. Proposed increases in the production of pulp and paper have made it necessary to examine the potential toxic effects of sulphate effluent from pulp mills on young salmon. The influence of varying temperatures, salinities, oxygen concentrations, time of exposure and developmental stage of the fish precludes any simple treatment. A start has been made by using the oceanographic conditions at the head of Alberni Inlet as a typical pattern for temperature, salinity, and mixing. Maximum safe exposure times for sockeye under-yearlings were determined for a number of concentrations. In the presence of adequate oxygen, four weeks' exposure to a concentration of 3.3% sulphate effluent was considered safe. Oxygen requirements of the fish increase with increasing concentration of effluent. It is concluded that the maintenance of an adequate oxygen level is the most serious problem arising from the presence of kraft mill effluent.

Similar type experiments to determine safe concentrations of sodium arsenite have been performed on young chum salmon. For an exposure of 12 hours a dilution of 12.2 parts per million is required. This chemical has been proposed for use in the treatment of rafts to protect them against teredo infection in saltwater.

CONDITIONS FOR SURVIVAL AND DEVELOPMENT OF SALMON EGGS

Field observations have shown that the survival of salmon eggs to hatching and emergence of fry varies greatly and that changes in abundance of salmon stocks may often be caused in large part by changes in conditions in the gravel of spawning beds. Knowledge of what these conditions are, how they vary and how they affect survival, is important to an understanding of the natural fluctuations of salmon stocks; it is also important if we are to improve these conditions and so increase salmon production. The uses of water for other purposes is already encroaching on salmon spawning grounds and artificial gravel beds are already being tried in a few instances.

Equipment that successfully measures the rate of flow of water past salmon eggs in various kinds of gravel has been developed. Velocities of more than 4 inches per hour are needed for water moderately saturated with oxygen. Laboratory equipment has been developed and installed to measure survival in various combinations of age, temperature, water flow, carbon dioxide and oxygen. The first results show that at a temperature of 41°F. and a flow of about 30 feet per hour, an oxygen content of two parts per million is too low for chum salmon eggs to survive to hatching.

This experimental work is still in progress. Information is also being gathered on the natural survival of eggs in gravel with various conditions of flow and oxygen content so that the laboratory results can be used to explain survivals or mortalities in nature. It is hoped that eventually measures may be taken to assure satisfactory conditions and artificially increase production of young salmon.

HERRING

When they concentrate in inshore areas during the autumn and winter (before spawning in March), herring are fished intensively by a well-equipped and well-organized fleet of purse seiners; there is also some fishing at other times and with other methods. To avoid danger of leaving too few spawners to maintain the catch, herring fishing is under regulation which restricts fishing seasons, gear, and the total quantities which may be caught in a number of defined areas. The purpose of the Station's

SOCKEYE SALMON - R.E. Foerster

S O C K E Y E S A L M O N - R.E. Foerster

The principle governing much of the research conducted by the Sockeye Salmon Investigation is that the return of adults to the commercial fishery and the spawning grounds is largely dependent on the output of seaward-migrating young (smolts) from the nursery areas. The aim of the various research projects is to determine the factors controlling the production of smolts resulting from known depositions of eggs and to relate the output of smolts to the return of adult fish.

To achieve this aim, studies are being conducted on the freshwater production of sockeye in three areas--at Babine and Lakelse Lakes in the Skeena River drainage and at Port John in the central coast region. In addition to these projects, annual examinations of the sockeye catches are carried out on the Skeena River and Nass River, and at Rivers Inlet and Smith Inlet fishing areas.

At Babine Lake, the principal sockeye-producing area of the Skeena River, annual assessments are made of adult runs and the resultant smolt seaward migrations. The program is providing critical information on the influence of different-sized egg depositions on the production of smolts. Due to serious reductions in the escapements of 1951 and 1952, resulting from the Babine rock slide, and to an unusually heavy escapement in 1953, a wide range of potential depositions has been observed. These data, extended by subsequent observations, will provide information in three ways. Firstly, they will indicate whether or not production of smolts in Babine is being limited by the freshwater environment and, if so, will provide a basis for establishing the maximum deposition required for the optimum smolt output. Secondly, the premise that the magnitude and composition of adult runs is determined by the abundance, size and age of smolts can be appraised. These studies may provide procedures for predicting the total adult returns from known spawnings. Thirdly, the present annual assessments provide the regulatory branch of the Department of Fisheries with information on the condition of the important Babine runs and their relative reproductive success. This service was invaluable in the study of the effects of the Babine rock slide.

Studies on the survival of fry at Six Mile Creek were terminated this year. The extreme climatic difficulties involved in gaining reliable information made continued operation unprofitable. However, the information collected in the past will be useful for comparison with data on fry production in other areas. The facilities of the Six Mile camp are being maintained for possible experimental studies in the future.

At Lakelse Lake data similar to those collected at Babine on population changes are being interpreted in terms of the physical and organic environment. The objective of the Lakelse researches are to determine and measure the factors which control and limit production of the sockeye, from egg to smolt. Their usefulness will be in development of procedures for augmenting or rehabilitating natural stocks, and maintaining stocks in environments that have been altered through industrial expansion. To this end, counting fences and reliable estimating techniques have been developed to enumerate and sample the adult run to the lake, the adults reaching the spawning streams, the resultant fry, and the smolts leaving the lake. Concurrent with enumeration, continuous records of the changing environment are made. In the last two years the program has involved the development

and assessment of standard techniques. Using the routine program as a basis, three types of research projects have been initiated. Firstly, using information from the routine program, correlations are being sought between the reproductive success of the sockeye in different years and various environmental factors. Secondly, short-term fundamental studies are being conducted on some phases of the life-history of the sockeye. For example, studies of the effects of plankton distribution and density on the growth and abundance of lacustrine sockeye are under way. Thirdly, projects involving manipulation of environmental conditions followed by assessment of the results of the change on the sockeye are planned. An important study of this kind will be a fish removal program, for which the collection of one more year's control data must be obtained.

At Port John, a small watershed in the central coastal region, sockeye enumerations similar to those described for Lakelse Lake are being carried out. The total numbers of sockeye produced in the area are small, but the average rate of survival (from egg to smolt) is higher than that observed in other areas. Comparisons of sockeye-producing capacity and general ecology in different areas will provide some significant correlations between environment and sockeye production. Such comparative studies are long-term; syntheses of data from a wide range of salmon-producing lakes in North America will be necessary.

For many years, the sockeye catches of the central and northern regions--Nass River, Skeena River, Rivers Inlet, Smith Inlet--have been sampled to determine the average size of fish and the age composition of the runs. These data are essential for characterising that segment of the adult salmon population taken by the fisheries and relating production to appropriate brood years, since there are two or more age-groups prominently involved.

The need for providing a closer link between freshwater studies and information derived from the fishery has been recognized. This year critical studies of the Skeena sampling program were undertaken, and past Skeena catch and escapement data were examined to determine trends in the catch and some of the changes which the fishery makes on the composition of the runs returning from the sea.

As a special project, members of the staff have participated in the preparation of the second report on the effects of the rock slide on the adult run to Babine Lake.

THE SKEENA FISHERY

H. Godfrey

During the past summer a large volume of data relating to Skeena sockeye catches and escapements was analysed for the purpose of obtaining useful information on the Skeena sockeye fishery and its relationship to the production of Skeena sockeye salmon. This was combined with a personal familiarization with the fishery and the lower part of the river system.

Much of the results, however informative, is not suitable for presentation here, but the topics that are discussed are considered more complete than others, or at least as complete as the available data and form of analysis will allow.

A. Comparison of catch and escapement.

A gill-net fishery not only removes individuals from the runs of returning adults, but it also changes the size, sex, and age-class composition of the runs. This is because the nets are selective for sizes,

and because there are significant differences between the sizes of fish of different sex and of different age.

Because of changes in the size of the fish as they migrate up the rivers after having passed through the fishery, it is usually impossible to compare directly the kinds of fish taken by the fishery and the kinds of fish in the escapement. Such comparisons can be made, however, using fish tagged before they enter the fishery, if their lengths are recorded when they are tagged.

In 1947 and 1948 a large number of sockeye salmon were captured by seine off the mouth of the Skeena River, and were measured and tagged. Recoveries were made from the catch and from the escapement, for which comparisons are shown in Figure 1. In both years the sizes of fish tagged were very similar to the sizes among the combined recoveries (catch and escapement). It can be said, therefore, that the recoveries were sufficiently representative of the tagged population. There were important differences between the size distributions of recaptures in the escapement, and the recaptures in the commercial catch. In both years recoveries in the commercial catch contained relatively more larger fish, and fewer smaller fish. Since the bi-modality of the curves beyond 17 inches (maximum length of "jacks" or 3-year males) indicates the two major age-classes (4- and 5-year-old fish), it is also evident that more 4-year-old fish escaped than 5-year-old fish. Since, also, males were larger than females (within each age-class), then relatively more females must have escaped than males. This last is an interesting conclusion, since both in the commercial catches and in the escapements (at least the large Babine escapement) there were relatively more females than males among 4- and 5-year-old fish, so that the runs that returned from the sea must have had considerably higher proportions of females than of males. The production of the male "jack" salmon is undoubtedly related to this phenomenon.

B. The trend of the Skeena catch.

Changes in the production of Skeena sockeye could be understood better if it were possible to estimate the numbers of adults of different ages in the escapements as well as in the catch. However, escapements have not been so described, so that only the catches (which were sampled for age determinations) can be used to obtain some approximate indications of trends or changes. The catches of 4- and 5-year-old Skeena sockeye from the same brood stock, in the years 1910 to 1952, are shown in Figure 2, with accompanying regression lines. In the period 1911 to 1933 the catch of the combined 4's (year n) and 5's (year n + 1) declined ($b = -1.63$); during the subsequent period (1933-52) they gradually increased ($b = +1.22$). The decline in the earlier period is associated with a decrease in the average catch of 5-year-old fish ($b = -1.75$), rather than of 4-year-old fish ($b = -0.178$). The average gain in the later period is associated with an increase in the average catch of 5's ($b = +1.16$), rather than of 4's ($b = -0.008$).

An interesting feature of this analysis occurs in the tendency during the early period (1910-25) for a 5-year cycle in the combined catch of 4- and 5-year-old fish from the same brood stock, which was related to an apparent 5-year cycle among the 5-year-old fish. Because of the varying production of 4- and 5-year-old fish in the Skeena, it could not be expected that either 4- or 5-year cycles would persist for long; nor did they do so, at least on the basis of the catch data. The apparent 4-year cycle in the combined catch in the later period (during which time, as already noted, the average catch of 4's remained relatively constant) should not persist if, as stated above, the average catch of 5-year-old fish is increasing. An

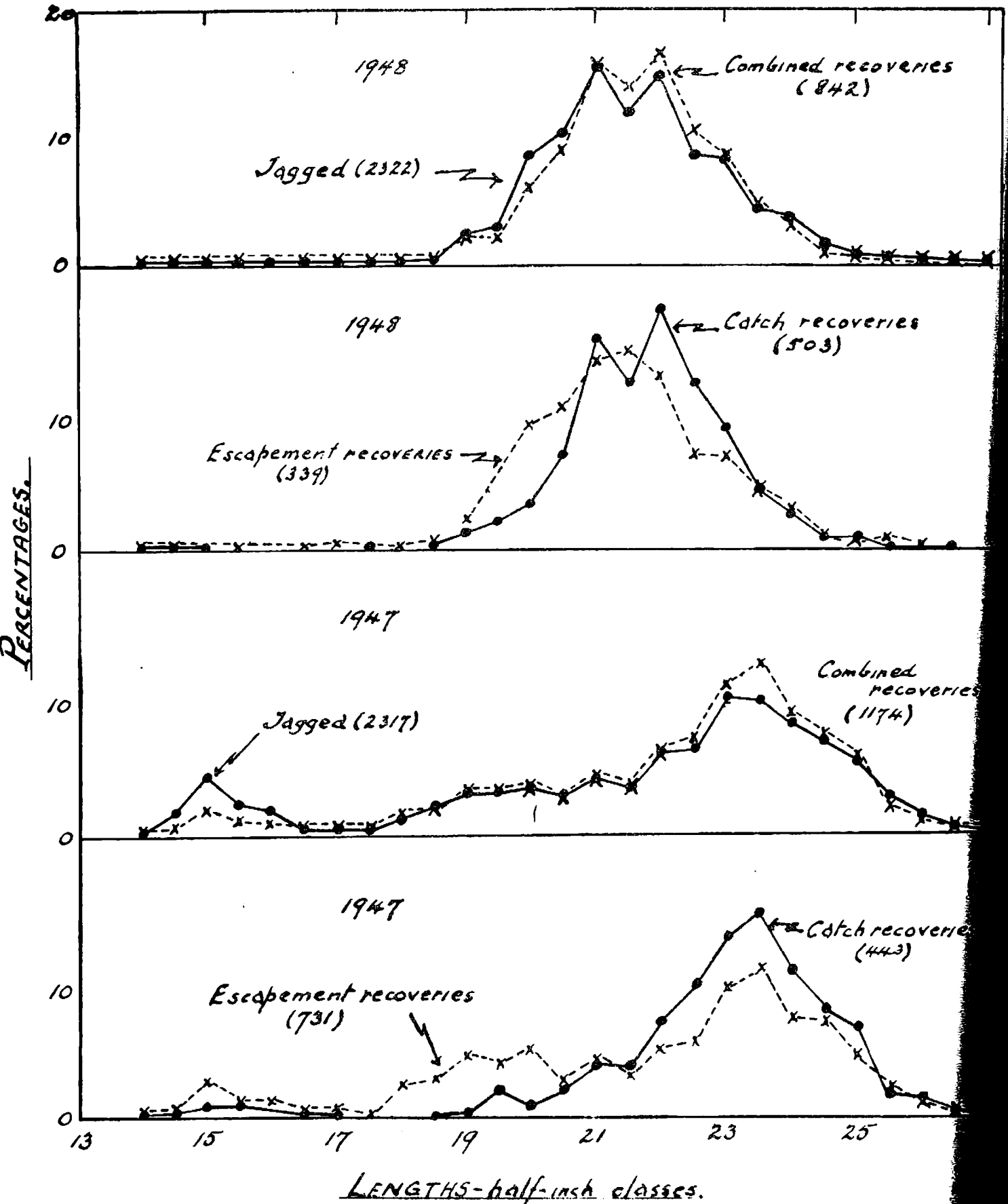


Fig. 1. Comparisons of the percentages of tagged sockeye belonging to different inch length classes among the tagged samples, the commercial catch reco samples, and the escapement samples, 1947 and 1948.

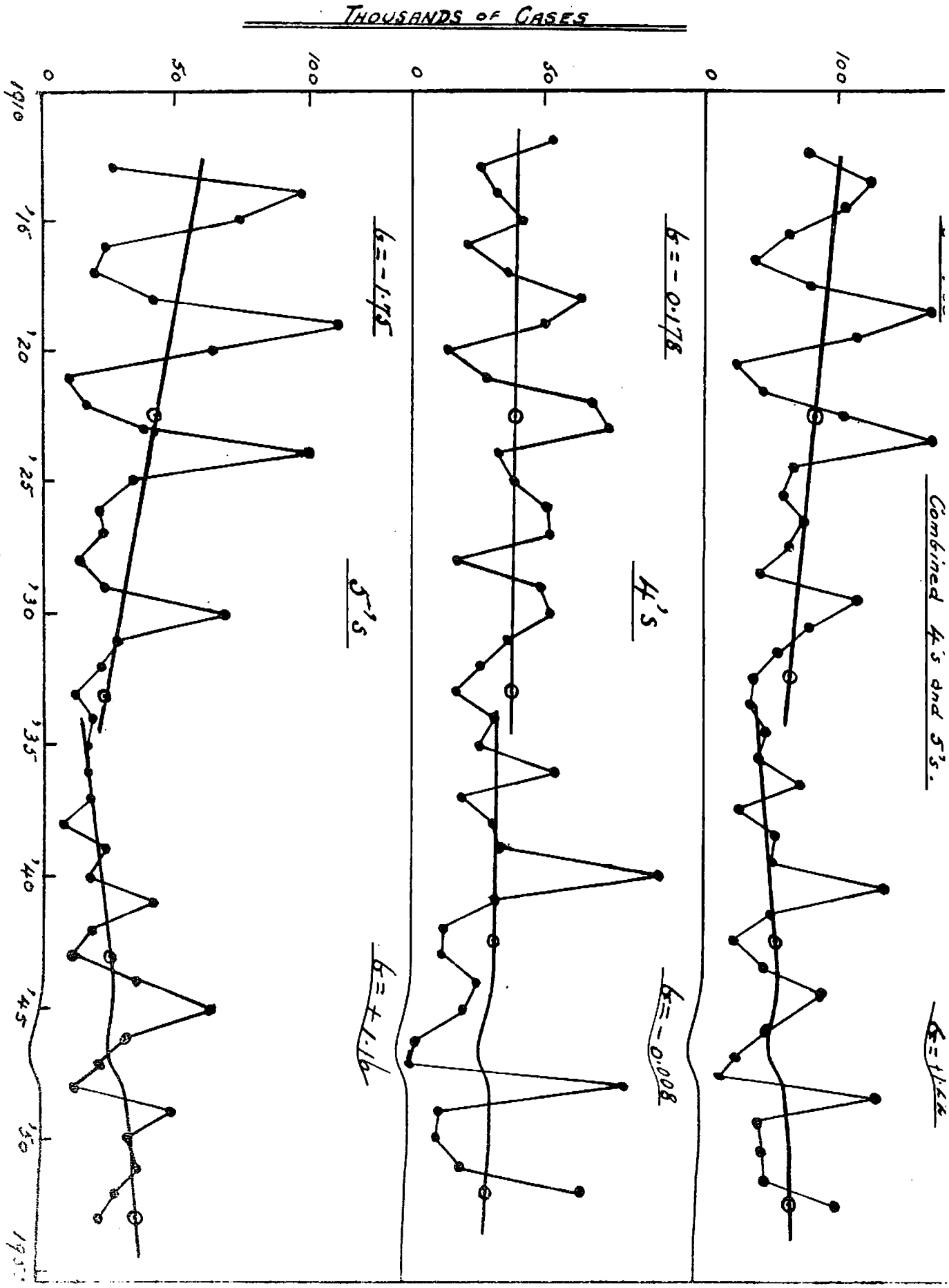


Fig. 2. Trends in the catch of Skeena River sockeye of two age-classes of the same brood stock, 1912-1953.

indication of a relationship between 4- and 5-year-old fish is discussed in the following section.

C. Size of catch and age composition.

One of the more perplexing problems of Skeena sockeye population is that of their age-class composition, and the relationship between age and survival to adult return. Skeena sockeye runs have at least four age-groups, but the two that make up 90% of the runs are the 4_2 and 5_2 fish. Because information is not available on the age composition of the escapement, it is difficult, and perhaps impossible, to demonstrate the true relationship between the production of 4-year-old fish and production of 5-year-old fish. Nevertheless, the attempt has been made, through examining the catch statistics, to determine whether there is a relationship between the magnitude of the catch and the proportions of the two age-classes. The catch will, of course, be that of the same brood stock.

The relationship between the catch of 5's and the catch of 4's plus 5's is highly significant ($r = +0.85 \pm 0.04$). This, of course, is expected, since the combined catch included large numbers of the other variate (5's). The interesting point is that the fitted linear regression line ($b = +1.304$) indicates that as the combined catch increases, the proportions of 5's increase; in other words, that larger catches are usually associated with more 5's than 4's (and small catches with more 4's than 5's). However, when the percentages of 5's are plotted against the combined catch of the common brood stock, the linear relationship is seen to be less valid: the points are scattered, although, still, with the largest catches, there are more 5's than 4's. Now the average catch of 4's (1908-52) was 36.1 (thousands of cases), with a standard deviation of 21.7 ± 3.4; and that of 5's, 34.4, and 25.6 ± 4.0. The similarity of the means results from the fact that most catches were medium-sized, when the proportions of 5's and 4's were fairly similar. It is therefore suggested that the situation in respect to the catches of 4's and 5's of common brood stock is probably as follows: (1) that with most catches the proportions of 4's and 5's fluctuate about a common mean - that is, that with an average catch they tend to be fairly equal; (2) the occasional large catches have a greater proportion of 5's than of 4's. This situation could reflect the phenomena of cyclic trends among the two age-classes. In a preceding section it was said that the decline in the earlier period of the Skeena catches was associated with a decline in the average catch of 5's rather than of 4's; and that the increase in the average catch during the latter period was associated with an increase in the average catch of 5's and not of 4's.

The catches of Rivers Inlet sockeye have also been examined to compare their variability with that of the Skeena catches. Here the picture is a little more definite (perhaps reflecting the greater homogeneity of that population, since it involves only one major spawning area as compared with several in the Skeena system). There seems to be a definite increase in the percentage of 5's as the combined catches of 4's and 5's increased. Furthermore, the catch of 5's showed much greater variability than that of 4's, having a mean and standard deviation of 43.6 and 34.8 ± 5.5, respectively, as compared with 4's, 36.5, and 18.7 ± 3.0. This again resulted from the fact that the less frequent, very large catches consisted mostly of 5-year-old fish.

The analysis must remain incomplete until it is possible to include the age composition of the escapement with that of the catch. If that can be done, and the relationship between the two age-classes determined, the factors affecting adult return will be better understood.

D. Seasonal trends in sex ratios.

The sex ratios of the Skeena sockeye catch for the past 30 years (as determined by sampling) have been analysed to obtain a better understanding of the characteristics of the Skeena runs. There have been occasions when it has been considered that the preponderance of certain sexes or sizes early in the season might be indicative of the kind of run that would follow. The catch consists mostly (about 90%) of the 4_2 and 5_2 age-classes, and the proportions of these two groups have varied greatly from year to year. The seasonal changes in sex ratios have been determined for each of the two age-classes separately; and only the recent years, 1940 to 1953, will be referred to at this time.

Among the 5_2 fish the final proportion of females has always been greater than that of males, roughly 65:35%, on the average. Early in the run the proportion of females has usually been a little greater than, or at least equal to, the proportion of males; after that the proportions of females have increased fairly steadily throughout the season.

In the case of the 4_2 fish the situation is more varied. In the total catches females have usually exceeded males, but less so than among the 5's. In a few instances males have either slightly exceeded, or have been equal to, females. In most years the runs have started off with an excess of males, and as they have progressed the proportions of females have increased. In a few cases there was no definite trend, but merely variation during the season.

E. Comparative sampling of sockeye catch.

In past years the Skeena sockeye catch has been sampled at one cannery. To determine whether this was sufficient to provide a representative sample of the whole Skeena catch it would be necessary to make comparisons with other canneries. This would be particularly necessary, if, as does happen in the Skeena fishery, the effort of different companies is concentrated in different parts of the fishing area. Skeena River, Area 4, is separated by imaginary lines from Area 3 (Nass River) and Area 5 (Banks Island). Some companies expend most of their fishing effort in the outer waters of the area (where intermingling of Skeena fish with other populations is known to occur), while other keep there fleets closer to the river mouth boundary.

To obtain an idea of the effort needed, and of the kind of information that could be gained by comparative sampling, sampling was carried out simultaneously (early in the season) at three canneries.

The analysis has not been completed, but a preliminary examination shows that although there were differences between the samples, they were not very great, and cannot be taken as definitely indicative of different populations having been fished. This does not mean that the same population was being fished. Frequently different salmon populations, or geographic races, show only insignificant size differences; and, furthermore, it could happen that the returning adults were similar in their sex ratios and age-class composition. Indirect evidence, such as the distribution of the Skeena fleet, and observed differences in the quality and the flesh colour of the fish caught, does suggest that if any proposed program calls for a thorough sampling of the Skeena catch, comparative sampling at the several canneries will be necessary to determine the best procedure.

A summary of the comparative data is presented: (all figures are percentages)

	Sex Ratios		
	M	F	Total sample-numbers
North Pacific	46.4	53.6	537
Oceanside	46.5	53.5	348
Sunnyside	46.0	54.0	346

	Age-classes			
	4_2	5_2	5_3	6_3
North Pacific	39.7	43.2	13.0	4.1
Oceanside	37.9	43.7	15.2	3.2
Sunnyside	34.1	50.6	10.7	4.6

	Ratio of 4_2:5_2	
	4_2	5_2
North Pacific	47.9	52.1
Oceanside	46.5	53.5
Sunnyside	40.3	59.7

	Mean lengths and weights of 4_2's					
	North Pacific		Oceanside		Sunnyside	
	M	F	M	F	M	F
Length - inches	22.4	22.5	23.0	22.8	23.3	22.9
Weight - pounds	5.0	4.9	5.5	5.3	5.4	5.2

	Mean lengths and weights of 5_2's					
	North Pacific		Oceanside		Sunnyside	
	M	F	M	F	M	F
Length - inches	26.4	25.0	26.4	25.1	26.4	24.8
Weight - pounds	8.4	7.0	8.3	7.1	8.0	6.5

BABINE LAKE

F. C. Withler

Babine Lake investigations are concerned largely with gross assessment of the sockeye population of the watershed. The lake's large size and numerous spawning areas preclude intensive study of all its spawning areas with the result that most effort is directed toward evaluating the relationship between the size and composition of the runs of adult sockeye to the lake and the resultant smolt outputs.

From 1946 to 1948 the Babine counting fence demonstrated the magnitude of the Babine run as part of the program to evaluate the relative sizes of spawning stocks of the Skeena watershed. Since then the operation has been maintained to provide the background necessary to study the relation of stock to smolt output. In 1951 and 1952 the fence data supplied valuable information on the effects of the Babine River slide and provided a gauge of success of corrective measures instituted by the Department of Fisheries. Other salmon species passing the fence are enumerated and all information on the size of escapements are made available to the Department.

The attempt to estimate the size of the Babine smolt run in 1951 without constructing a standard counting weir proved sufficiently successful to employ the method for obtaining annual estimates of smolt output. The disastrous effects of the Babine River rock slide on the spawning runs of 1951 and 1952 provided otherwise unobtainably small potential egg depositions to illustrate the stock-to-output relationship over a wide range of stock intensity. Smolt production figures for 1953 and 1954 have illustrated the effect of the slide on smolt production. Extensive examinations of smolts taken during the runs demonstrate the effect on smolt size, as well as smolt numbers, of various stock intensities.

Fry survival studies at Six Mile Creek were suspended in the summer of 1954 in the face of difficult operation and a disproportionate drain of effort by the physical conditions attending travel and operation. The estimate of the fry run for 1954 provides a second survival figure for the stream. Studies of predation on fry, the loss between egg and fry, the behaviour of the spawning run and the physical conditions attending the adults and young in the stream were carried out in conjunction with the main objective of providing survival figures.

Where possible, in conjunction with the main work of population assessment, special studies of conditions which are unique to the Babine Lake population or to the watershed are undertaken. Hence considerable effort has been expended to follow up the consequences of the Babine River rock slide; waterfowl predation on young salmon in the strategic Fort Babine area has been examined; and the behaviour of salmon at the counting fence has been investigated. Wherever possible, local studies on spawning behaviour and conditions in the area are pursued in close cooperation with Department of Fisheries personnel.

A. Adult studies.

F. C. Withler and K. V. Aro

Following the construction of the Babine River adult counting fence in 1946 the runs of sockeye salmon to the Babine Lake watershed have been enumerated annually, except in 1948 when floods damaged the structure. The size of the 1948 run was estimated by observations on the spawning grounds. Since the initial discovery that the runs to the Babine watershed constitute about 70% of the Skeena escapement the fence count has been accepted as the best single measure of the sockeye escapement to the Skeena River. The data

from the weir have taken on further importance since 1951 when the blockage on the Babine River occurred.

The 1954 adult count, herein reported, is important not only because the run was the second to pass the site of the former blockage but also because the run was the first to return which contained issue of the sockeye which surmounted the slide. These returning sockeye which are a part of the 1951 brood left the lake as yearlings in the spring of 1953 and returned in 1954 as "jacks" or 3-year-olds after spending one year in the sea.

Extensive sampling is carried out on sockeye passing the fence because mere enumeration of the run may give a false picture of the runs' spawning potential. It is possible now to estimate within very narrow limits the number of sockeye eggs potentially available for deposition in the Babine area. These spawning potentials have been shown to vary more widely than the size of annual runs.

Although spring, pink, coho, and chum salmon do not spawn exclusively above the fence, these species are counted each year to provide indices of the sizes of those runs to the river. Many fish of these species were also the progency of fish in runs which had been affected by the Babine slide.

1. Salmon enumeration at the Babine fence in 1954.

The Babine fence was operated from the time the panels were installed on July 22 until they were removed on October 4. Installation of the panels was delayed beyond the usual time because of the possible detrimental effect of the high water conditions on some of the underwater portions of the fence. The counts of the five species of salmon which passed through the weir during the period of operation in 1954 are compared in the following table with counts obtained in other years.

Year	Sockeye	Percentage "jack" sockeye	Spring	Pink	Coho	Chum
6	475,705	12.2	10,528	28,161	12,489	18
7	522,561	50.0	15,614	55,421	10,252	7
8	560,000[A]					
	509,132	9.4	7,433	13,663	11,938	5
	543,658	33.0	6,838	38,728	11,654	7
	152,457	7.2	2,778	50	2,122	0
	376,947	7.4	5,915	2,706	10,554	1
	714,614	3.9	8,353	1,018	7,648	17
	503,422	1.9	5,925	4,604	3,094	66

[A] Estimated from comparison with stream survey counts and fence counts of previous years.

The 1954 counts are of interest in that many of the salmon were the progeny fish which were affected by the Babine River rock slide in 1951 and 1952.

The count of sockeye salmon in 1954 was comparable to those in non-slide years. The count of 144 sockeye on July 23, the first day of operation, and the fact that a few sockeye had been caught a few days earlier in the Indian fishery above the fence indicate that a number of sockeye had passed before the panels were installed. However, these numbers were so small as to be of no

significance. After July 23 the run increased to form a characteristic early peak of 15,119 sockeye on July 29, declined to a low of 1,455 sockeye on August 10, and rose again, first slowly and then very rapidly, to form the main peak of 38,755 sockeye on September 1. This peak occurred later than in any other non-slide year with the exception of 1949 when it occurred on September 2. The count on the peak day was 6,000 in excess of the count on the largest peak in previous years. The lateness and large size of the peak suggest that these fish passed through the estuary of the Skeena River during the week-ends when special closures were in effect (July 31 to August 2 and August 6 to August 8) and/or during the week (August 9 to August 14) when the fishery was closed owing to a tendermen's strike. Following the peak the run fell rapidly until October 3 when only 14 sockeye passed the fence.

Spring salmon passed the fence in slightly lesser numbers than in other non-slide years. The lower numbers of springs may be due in part to low returns of 2- and 3-year-old fish which were the progeny of the runs affected by the Babine slide in 1951 and 1952. Since spring salmon spawn below as well as above the fence the count is only an index of the run to the Babine River.

The run of pink salmon was higher than in the cycle year 1952, when the pink run was reduced to a low level by the slide, but was much lower than in the earlier cycle years. As with springs, some pinks spawn below the fence.

Coho salmon appeared in lower numbers than in other non-slide years but somewhat in excess of the number in the slide-affected cycle year 1951.

The chum salmon run was many times greater than that of any previous year but was still too low to be of any significance.

2. Sockeye sampling at the Babine fence. K.V. Aro

To obtain details on the size and sex ratio of Babine sockeye, samples amounting to 1% of the previous half day's count were measured and sexed throughout the period of the run. In addition a "jack count" was made for an hour daily, in which the numbers of jacks (3-year males) and larger sockeye were noted. The proportion of normal, injured, and net-marked individuals among the large sockeye were also recorded.

The jack count, which represented 16.8% of the total sockeye count, showed that 1.9% of the run were jacks. These jacks are the first of the progeny of those fish which spawned in the slide year of 1951 to return from the sea. The percentage and the calculated number of jacks is the lowest which has been recorded since Babine fence operations began. The jack count also showed that among the larger sockeye 8.2% had net marks, 2.5% were injured, and 89.3% were normal. The percentage of injured fish was lower than in any previous year whilst that of fish with net marks was slightly less than average.

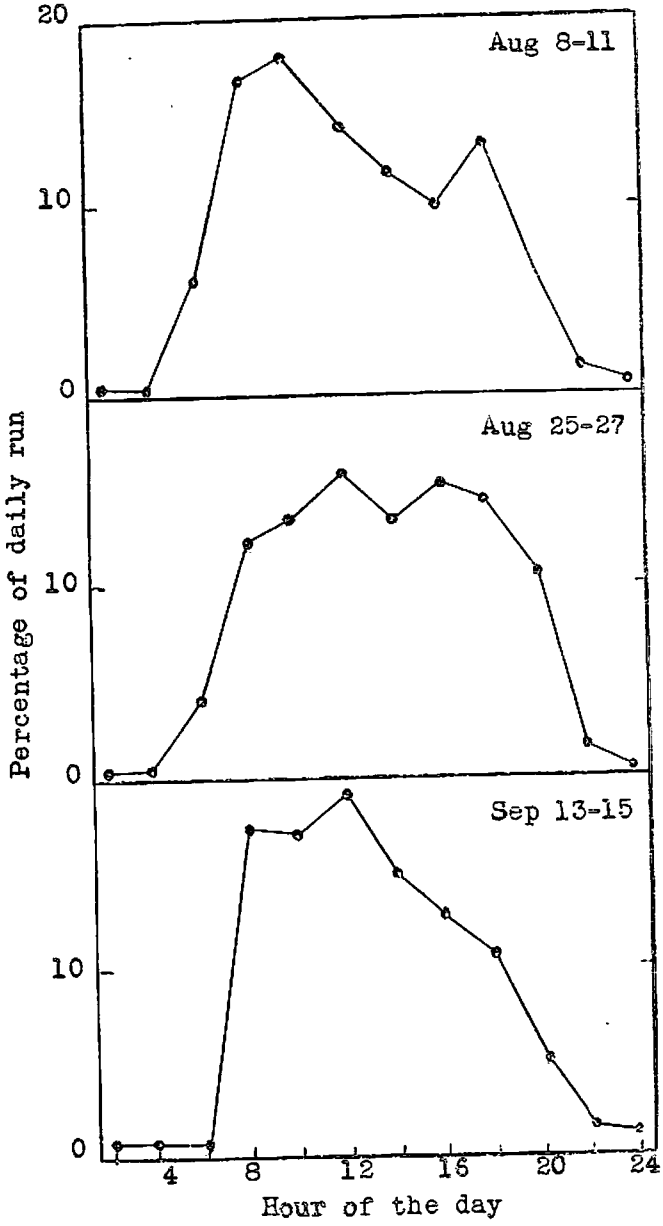
The 1% proportionate sample showed that 39.7% of the large sockeye were males and 60.3% were females. The average sizes of the jacks, larger males, and females were 38.3, 66.6, and 63.0 centimetres respectively. Both the larger males and the females were several centimetres larger than usual.

No egg samples were taken in 1954. Instead a probable egg content of 3,555 was calculated from the regression formula of the number of eggs on length calculated from egg samples of other years. The potential egg deposition is, then, the product of the probable egg content and the calculated number of females (297,574) or about 1,058,000,000. This seeding has only been exceeded by that of 1953 and is due to the large number of females and

to the larger number of eggs which they contained.

Dead spawners drifting against the Babine fence were examined to determine the success of sockeye spawning in the Lower Babine River. On October 3 over 90% of the female and almost 100% of the male dead showed signs of having spawned successfully.

3. Hourly fluctuations in the daily movement of sockeye through the Babine fence. F.C. Withler and K.V. Aro



Twenty-four hour movement of sockeye at the Babine fence.

To determine the preferred hours of ascent through the counting fence sockeye were counted twenty-four hours daily for several consecutive days at three different times in the season. Counts were recorded every two hours on the odd hour (Daylight time) for these periods. The percentages of the daily runs which passed in the two hours straddling the even hour are shown on the accompanying graph. Almost the entire daily run passed the fence in daylight hours between dawn and dusk. The daily peak occurred before or at noon, sometimes with a secondary peak in the afternoon. The study also showed that about 90% of the daily run passed the fence in the usual hours (7:00 A.M. to 7:00 P.M.) of fence operations.

4. Reports on the Babine River rock slide. H. Godfrey

A report on the effects of the rock slide in the Babine River on the salmon runs of 1951 and 1952 has been published as Bulletin No. 101, of the Fisheries Research Board of Canada. The Slide was removed during the winter of 1952-53. Subsequent to its removal investigations were conducted during 1953 to make certain that the cleared channel no longer obstructed migrating fish, and also to compare the spawning of an unblocked run with affected runs of 1951 and 1952. The results of these researches have been described in a second report, which has also been submitted for publication in the Bulletin series.

The effects of the Slide, and the situation since its removal may be summarized briefly:

Sockeye salmon. An estimated two-thirds of the 1951 run, amounting to about 300,000 fish, was lost at the Slide. There were further losses in fish that died unspawned on the spawning grounds. These were not estimated, but were less severe than in the following year.

In 1952, again about two-thirds of the large run perished at the Slide--an estimated 700,000 fish. Because of extremely adverse water conditions, there was almost complete blockage of the early part of the run. Efforts to maintain marginal escape channels were successful in aiding the escape of a large number of fish that otherwise would have perished. Losses in unspawned fish in the Babine streams were serious. It was estimated that only 30-42% of the females that reached Babine Lake spawned successfully; and that these amounted to only 7-10% of the Babine females that had escaped the fishery. In comparison with former years, the spawning of 1952 was only 22-31% of "normal".

In 1953, approximately 90% of fish tagged below the former point of obstruction reached the Babine fence without delay. The large run at the fence was in excellent condition, in respect to both injuries and sexual maturity. An estimated 95% of the females spawned successfully and there were no indications of any abnormal losses in unspawned fish.

Resiliency of reduced spawning stocks has been demonstrated. The survival to smolts from the potential number of eggs available has been 0.48%, 0.77%, 1.52% and 0.68%, for the seedings of 1949 to 1952, respectively. The production rate for 1952, based upon the probable number of eggs deposited (which allowed for the loss in unspawned females), was 1.48-2.07%.

The actual (estimated) numbers of smolts produced in 1953 and 1954 from the two slide years were 3.0 and 2.8 millions, as compared with 4.2 and 4.5 millions in 1951 and 1952. The adult returns of Babine sockeye will therefore probably be lower than average. There may be some compensation in better survival due to larger smolts produced in 1953 and 1954; the magnitude of the total Skeena return will also depend upon the success of spawning in the Slide years in the rest of the Skeena system.

Pink salmon. Pink salmon also suffered very heavy losses at the Slide, but numerical estimates could not be made. Rehabilitation of Babine pink runs is expected to come early from spawning that normally occurs below the Slide, and also from survivors of the block that may have spawned successfully above and below it.

Based upon the results of the 1953 tagging, it was estimated that roughly a third of the total Skeena escapement of pinks was affected by the Slide.

Coho salmon. In 1952, coho salmon experienced relatively fewer losses at the Slide because they arrived there later after conditions had

improved. Cohos also spawn in the main river and tributaries, so that some survivors that did not reach the fence may nevertheless have spawned successfully.

Using results of the 1953 tagging, it was estimated that about a sixth of the total Skeena coho escapements were affected by the Slide.

Spring and chum salmon. The run of springs at the fence in 1952 was about one-half of the average of pre-slide years. Since spring salmon also spawn in the Babine River and its tributaries, survivors of the block may also have done so successfully.

The chum run at the fence has always been small, averaging 8 fish for 1946 to 1953. The run of 1954, of 66 fish, has been the largest of the years the fence has operated.

General. With all species, female salmon suffered heavier losses due to the blockage than males, injured more than uninjured, and mature fish more than fresher fish. Delay at the Slide resulted in fish maturing in the river before they reached the spawning grounds, and this is believed to have contributed greatly to the losses in fish that died in streams without having spawned.

The authors of Bulletin No. 101 were H. Godfrey, W.R. Hourston, J.W. Stokes, and F.C. Withler; those of the second report were H. Godfrey, W.R. Hourston and F.C. Withler.

F.C. Withler

B. Smolt studies.

To circumvent the time- and effort-consuming task of constructing a smolt counting fence in the Babine River, an attempt was made in 1951 to estimate the size of the sockeye smolt emigration from the Babine watershed by marking and recovery technique employing structures available at that time, i.e., the old Fort Babine marking trap and the Babine fence. The measure of success achieved encouraged development of more efficient trapping devices and their operation each year since. Using estimates from Babine fence data of potential egg depositions in the Babine watershed from 1949 to 1952, it has been possible to calculate survival to smolt stage from eggs carried into the system each year. These survivals have ranged from 0.48% to 1.57% - low when compared to egg-to-smolt survival figures for other areas. The Babine River rock slide of 1951-52 reduced escapements to far below normal, providing smaller egg depositions than could otherwise be achieved. Conversely, the estimates of smolts resulting from the blocked runs were valuable in assessing the final effects of the slide on the population. For instance, the smolt run for 1954, reported herein, was the product of the spawners of 1952 which were severely damaged and delayed as well as reduced in number. The 1955 run will result from a deposition of 1.3 billion eggs, the largest recorded since fence operation.

To complement the information on numbers in each run, samples of smolts are taken to give the relationship between size of run and size of smolt. To date, the relationship at Babine appears to be inverse. Supplementary information on sex ratio and parasitism has been obtained.

All Babine sockeye smolts pass through a short river into Nilkitkwa Lake, thence into the Lower Babine River. The possibility of exceptional bird predation on fry and smolts in this region has been investigated by the collection and examination of waterfowl in 1953 and 1954.

1. Estimation of size of runs from 1951 to 1954. F.C. Withler and K.V. Aro

Employing the technique used from 1951 to 1953 to obtain an estimate of the size of the Babine smolt run, the 1954 smolt run was estimated to be 2.8 million, the lowest recorded in four years of operation. The technique involves the capture and marking of portions of the sockeye smolt run as it passes the outlet of Babine Lake, and subsequent examination of large samples of the run at the outlet of Nilkitkwa Lake, some eight miles downstream from the Fort Babine trapping device. Ratios of marked to unmarked smolts in the samples are used to estimate the size of the run which passed the upstream trapping structure.

Total numbers of smolts marked and released annually, the total samples recovered, and total marked fish found therein are given in the following table. Final estimates of the run for each year have been adjusted to conform with known changes in the mark/catch ratio at Fort Babine and to allow for a late installation of trapping structures in 1951, when a portion of the run had passed before trapping began.

Year	No. of smolts marked	No. of marked smolts recovered	Size of sample examined	Estimated size of run	95% limits
1951	34,689	200	21,855	4.2×10^6	3.7 to 4.8×10^6
1952	33,880	646	86,391	4.5×10^6	4.2 to 4.9×10^6
1953	61,950	2,498	124,396	3.1×10^6	3.0 to 3.2×10^6
1954	42,631	1,156	81,082	2.8×10^6	2.7 to 3.0×10^6

Certain errors associated with the possibility of increased mortality due to marking by fin-clipping, and with the likelihood of disproportionate intensities of marking with relation to the run passing Fort Babine each day cannot be assessed and have been treated as constant each year. The annual estimates, therefore, should be proportionate to one another despite discrepancies between actual and estimated numbers each year.

Assuming that all smolts are 1-year-olds (see "Age, sex, growth, and parasite studies of sockeye smolts", below) survival from eggs potentially available in the spawning run to resulting smolts may be calculted from Babine fence data. The figures applying to the brood runs from 1949 to 1952 appear below.

	1949	1950	1951	1952
Eggs potentially available	869×10^6	583×10^6	198×10^6	411×10^6
Year smolts appear	1951	1952	1953	1954
Estimated no. of smolts	4.2×10^6	4.5×10^6	3.1×10^6	2.8×10^6
Survival from egg to smolt	0.48%	0.77%	1.5%	0.68%

A tendency for greater numbers of smolts to result from increased egg depositions probably obtains at Babine; an increase in the survival to smolts from smaller egg depositions is, however, also indicated. The 1952 spawning run was seriously affected by the Babine River rock slide of 1951-52, and estimates made on the spawning grounds in 1952 indicated that only about one-third of the females spawned successfully in that year. Assuming this to be the case, and that only about one-third of the eggs potentially available were

actually available, the percentage survival from that year would be approximately 2%, a higher survival than any so far observed at Babine Lake. (However, there was also an undetermined loss in unspawned females in 1951 which would raise the 1.57% shown in the above table.)

The smolt runs of 1953 and 1954 which resulted from the slide-blocked broods of 1951 and 1952 were lower than the 1951 and 1952 smolt runs, but higher than would be expected in view of the low numbers of the 1951 brood and the damaged and delayed character of the 1952 brood, if a directly proportionate relationship between brood and subsequent smolt production were assumed.

The 1955 smolt run will be the product of the 1953 brood, unaffected by the slide, which also produced the largest potential egg deposition recorded since Babine fence counts began.

2. Time and speed of migration. F.C. Withler

Late ice break-up on Babine Lake delayed installation of smolt estimation apparatus for the 1954 smolt run. The first day of trapping at Fort Babine was delayed one week beyond the latest previous date which occurred in 1952. The catches suggest that the smolt run was correspondingly delayed and most of the run was subjected to marking and recovery. The following table compares the timing of the 1954 run with past years.

Year	Trapping started	Trapping ended	Peak catch
1951	May 23	July 1	June 1 and 6
1952	May 27	July 3	June 5
1953	May 21	June 30	June 8
1954	June 3	July 2	June 9

In conjunction with the run estimation procedure, 3,685 smolts were marked at Fort Babine by passing distinctively coloured threads through the backs before release; subsequently 179 of these were recovered at the Nilkitkwa Lake trap. The length of time required for these fish to travel the eight-mile distance is given below with similar data for other years.

Year	No. of thread marks recovered	Range of time out	Average time out
1951	11	2-6 days	3.4 days
1952	100	1-11 days	3.4 days
1953	62	1-8 days	2.9 days
1954	179	1-9 days	2.4 days

The general high water condition of the Babine Rivers might account for the relatively rapid travel of smolts through Nilkitkwa Lake in 1954; however, higher water levels obtained during the smolt run of 1952.

Throughout the smolt run records of water level, water temperature and weather conditions are kept in addition to the daily readings maintained at the Babine fence throughout the field season.

3. Age, sex, growth, and parasite studies of sockeye smolts. F.C. Withler and E. Dombroski

Daily samples of sockeye smolts have been taken either for special study or in conjunction with the smolt run estimation project from 1950 to 1954. Examination of all samples taken up to and including the spring of 1953 has been completed by Mr. Dombroski.

Examination of scales has shown that the smolts leaving Babine Lake are predominately 1-year-olds. The table following gives the proportions found annually in the samples from 1950 to 1953. Also given are the sex ratios in each age-group, which do not depart significantly from a 50:50 assumption.

Year	1-year-olds		2-year-olds	
	Males	Females	Males	Females
1950	1,296	1,320	9	5
1951	1,428	1,367	6	4
1952	826	828	6	5
1953	629	605	8	14

Lengths and weights of all smolts also have been recorded. That considerable differences exist between average sizes in different years is shown in the table below.

Year	Number in sample	Fork length (mm.) Range	Fork length (mm.) Average	Weight (grams) Range	Weight (grams) Average
1-year fish					
1950	2,616	54-104	83.0 ± 6.3	1.3-10.6	5.5 ± 1.3
1951	2,795	58-111	82.4 ± 6.9	1.6-12.8	5.6 ± 1.5
1952	1,654	55-109	80.4 ± 6.5	1.3-12.7	4.9 ± 1.3
1953	1,234	70-111	86.0 ± 6.5	2.4-13.5	6.2 ± 1.5
2-year fish					
1950	14	104-122	110.4 ± 5.1	7.7-15.8	11.9 ± 2.2
1951	10	91-117	100.7 ± 7.7	6.6-15.4	9.4 ± 2.7
1952	11	96-114	104.4 ± 4.9	8.8-12.1	10.1 ± 1.5
1953	22	90-151	114.7 ± 17.2	7.0-35.1	14.8 ± 7.0

When the average size of smolts for each year is compared with the estimated size of the run in that year (see "Estimation of size of runs from 1951 to 1954" above), for the three years recorded, an inverse relationship between size of run and size of smolt exists.

Included in the examination of smolt samples of 1952 and 1953 was a notation regarding the presence or absence of infection by cestodes or nematodes. In both years about 35% of the smolts were infected with the cestode Eubothrium salvelini (Schrank, 1790) and 20% by the nematode Philonema oncorhynchi Kuitunen-Ekbaum, 1933. Six to 7% of the smolts harboured both parasites. Fish infected by cestodes only, or by cestodes and nematodes both, were significantly smaller than uninfected fish or those with nematodes only. Nematode infected smolts were significantly larger than uninfected individuals in 1952 but not so in 1953.

4. Wildfowl food studies in the Fort Babine area. F.C. Withler and I.V.F. Allen

During the springs and summers of 1953 and 1954 Mr. Allen collected 55 waterfowl in the Fort Babine area to determine the possibility of, and grossly, the extent of, predation upon young salmon, particularly sockeye. The Upper and Lower Babine Rivers provide extensive spawning grounds for sockeye, and all sockeye smolts emigrating seaward must pass through the area.

Eleven species were collected in the two years. The number of specimens of each species and an indication of whether or not salmon remains were found in the digestive tracts are given in the following table.

Species	Common name	No. examined	Young salmon remains
Gavia immer (Brünnich)	Common loon	1	+ smolts
Colymbus grisegena Boddaert	Red-necked grebe	7	
Glaucionetta islandica (Gmelin)	Barrow's goldeneye	4	
Mergus merganser Linnaeus	American merganser	8	+ fry
Larus argentatus Pontoppidan	Herring gull	5	
Larus delawarensis Ord	Ring-billed gull	2	+ fry
Larus canus Linnaeus	Short-billed gull	7	+ fry
Larus philadelphia (Ord)	Bonaparte gull	10	+ fry
Chlidonias nigra (Linnaeus)	Black tern	6	+ fry
Megaceryle alcyon (Linnaeus)	Belted kingfisher	3	
Histrionicus histrionicus (Linnaeus)	Harlequin duck	2	+ fry

Two other waterfowl species were observed in the area - the Spotted sandpiper (Actitis macularia (Linnaeus)) and the American bittern (Botaurus lentiginosus (Montagu)). Neither was collected.

The following table shows the numbers of young salmon found in digestive tracts of birds collected in 1953 and 1954 and the number of specimens of all species which contained them.

	1953	1954	Total
Young salmon taken	64	240	304
Number of specimens containing young salmon	9	7	16

A report of the study is being prepared by Mr. Allen.

C. Fry production studies at Six Mile Creek. K.V. Aro

An adult-fry fence was constructed at Babine Lake in 1950 to illustrate the degree of spawning success of sockeye and to describe the factors limiting the survival from egg to fry. Six Mile Creek was chosen as the site because it was of moderate size, it possessed a moderate-sized run, and it was the most suitable stream on the lake for fencing. Access would be difficult but not impossible.

During the summer and fall of 1951 and 1953 adult sockeye were counted and sampled to determine the potential egg deposition. The effect of stream conditions and the gross behaviour of the spawning run was

assessed by numerous stream surveys and by tagging. Progressive losses during development to fry emergence were followed by examination of the eggs in the redds; and the final survival from egg to fry was determined in the spring from the fry fence counts.

Six Mile, like all smaller streams in the area, is subject to excessively high water levels during the spring run-off and to low water levels during the remainder of the year. High water levels and tremendous amounts of organic debris which are brought down by the water have hampered fry fence operations to the point where counts have had to be suspended for periods during the peak of the run. The numbers of fry therefore, have had to be estimated. During summers of low precipitation water levels have become reduced to the extent where it has been impossible for adult sockeye to enter the stream. In order to have the fry fence operational by the time of the peak of the fry run it is necessary to move personnel and equipment to Six Mile about a month earlier while the ice is still relatively safe for travel. Even at the best of times this is a difficult and hazardous undertaking. This is followed by a period of complete isolation of up to six weeks until the lake becomes navigable. Although these difficulties are not insuperable, the cost in time and effort is prohibitive in view of the limited number of experienced personnel available. Hence following the cessation of the 1954 fry count the investigation was discontinued. Installations and equipment were dismantled and stored for use in any future projects undertaken at Six Mile.

Reports summarizing the work at Six Mile will be prepared.

1. Egg survival in 1953 and 1954.

In the summer and fall of 1953 a total escapement of 1,273 female sockeye spawners carried an estimated 4,344,500 eggs into Six Mile Creek.

During stream surveys carried out throughout the run, 1,193 dead females were examined for eggs retained. From this sample it was found that 3.6% of the eggs carried into the stream had not been deposited but were retained in the bodies of the fish.

Further examinations of egg survival were made on November 6, 1953, and on April 6 and 7, 1954 when five and four redds, respectively, were dug. The materials obtained from these redds will be examined later to determine survival to various stages up to fry emergence.

Adult sockeye were allowed to spawn in the fall of 1953 in two spawning pens which had been sunk into the gravel bottom of the stream. The contents of the two pens were dug up and examined on April 12 to 14, 1954. A pen in which one female and 2 male sockeye had spawned produced 2,016 live alevins, which represents a survival of about 60%. A survival of 16%, representing 931 live alevins, occurred in the other pen in which two pairs of sockeye spawned. Some badly decomposed egg material was found in both pens.

Conditions affecting natural propagation in 1954 up to the time of emergence seemed favourable. Light snowfall during the winter permitted deep frost penetration but good water flows which covered most of the stream bottom kept the developing eggs moist.

2. The sockeye fry run in 1954.

The fry fence at Six Mile Creek was made ready for operation in mid-April 1954. However, because of the abnormally cold spring and the subsequent late run-off, the water flow was insufficient to operate the fence

until May 5 when the first fry appeared. In the period which followed difficulty was experienced at first because low temperatures caused the fence to freeze and later because high water levels and tremendous amounts of debris exceeded the fence's capacity. The fence was operated part of each night until May 10 and from May 22 to 25. Fence operations were totally suspended from May 11 to 21, and on May 26 and 27. From May 28 until June 14, when the count was discontinued, the fence was operated without undue difficulty.

A method of estimating the number of fry migrants by means of sampling nets was used to determine the size of the run during periods when the fence was not in operation. This involved fishing in the stream with sampling nets for certain periods throughout the day both when the fence was operational and non-operational. A significant positive correlation was found to exist between concurrent fence counts and net catches. Using this relationship the number of fry was calculated from net catches during periods when fence counts were suspended.

The estimated number of fry was 819,000, a survival of approximately 19% of the eggs carried into the stream in 1953. Taking into account the inaccuracies introduced by freezing and high-water difficulties, the limits of error of this figure are probably from 15% to 22%. The 1954 survival figure exceeds the 12% figure estimated in 1951.

The 1954 fry run began on May 5 and rose very rapidly to an estimated peak of 98,000 fry on May 13. The intensity of migration appeared to be related to water flow in the stream. After May 13 the run declined slowly with two lesser peaks of 68,000 fry on May 17 and of 26,000 fry on May 26, until only 296 fry were counted on June 14. The sampling net catches indicated that migration took place during twilight and darknwss though some fry were caught in daylight during periods of high water level when scouring probably occurred. During the first half of the run the migration reached a peak between 9:00 and 10:00 P.M. Standard time. However, as the season progressed the nightly peak shifted to between 10:00 and 11:00 P.M.

From observations made at Six Mile since 1951 it is thought that the run-off conditions experienced in the spring of 1951 and 1954 are normal.

LAKELSE LAKE

M.P. Shepard

In 1949, Lakelse Lake was established as a research areas, wherein studies aimed at establishing the principles governing the freshwater production of sockeye salmon could be carried out. The mechanical basis for these studies, namely a series of counting fences, was assembled during the years 1949 to 1952. From 1952 to the present the work has been directed toward the establishment of techniques for enumerating sockeye runs at various stages of their freshwater life-history and toward the development of a standard system for describing the physical and organic environment of the sockeye during their freshwater residence. Considerable effort has been spent on gaining a clear-cut understanding of the effects of enumeration techniques on the sockeye populations. Such studies are necessary to differentiate between natural and artificial effects.

The development phase is, with certain exceptions, at an end. Enumerations are now made of the adult run entering the Lakelse drainage, of the adults reaching the spawning grounds, of the fry resulting from the seeding of these adults, and of the smolts leaving the lake a year or two later. Routine description of the environment includes: year-round observations on meteorology, lake temperatures and levels, and annual assessments

of the abundance, composition and diet of predator and forage species.

Techniques for the routine description of plankton crops, nutrient chemical concentrations and competitor fish populations are still in the process of development and should be on a standard basis by the spring of 1955.

This extensive program of ecological description provides an exceptional basis for the conduct of specific, short-term research programs. While the accumulation of many years' data will provide valuable correlations between sockeye production and environmental factors, intensive and limited research on specific problems is needed to provide fundamental information in a short time. This year several research projects of this nature were undertaken. In August, Dr. W.E. Johnson, recently of the University of Wisconsin, began an intensive study of the relation of sockeye production to plankton distribution and density. As an initial step, Dr. Johnson has developed a workable method for the capture of lacustrine sockeye. Members of the Station staff are conducting studies on the effects of sex ratio on the spawning of adult sockeye, and on the effect of gravel size on the incubation of sockeye eggs. Background information for the planning of a fish control program is being gathered. Certain manipulative studies, including the alteration of the sex ratio of fish entering Scully Creek, were postponed because the small adult run to the lake this year would have prevented the use of past data as a control for this year's experiments.

An important part of the work, not fully covered here, is the tabulation and analysis of data collected at Lakelse from 1944 to 1952. The intensive field program of the last two years has prevented an active attack on this information. Many useful data, especially those concerning the salmon runs, are being examined and assessed in terms of the present program.

A. Sockeye fry studies — J.G. McDonald

The 1954 program was a continuation and expansion of that of past years. Effort was directed mainly toward assessing and comparing the production of sockeye fry from Scully and Williams creeks, the two main spawning areas of the Lakelse watershed.

These two tributaries are utilized by over 90% of the effective escapement to the lake. On the basis of their fry production the fry output of the total spawning area may be estimated. An enumeration of the survivors in 1955 (as seaward migrants) will provide information sufficient to assess the mortality occurring during the period of lake residence.

1. Scully Creek fry production — J.G. McDonald and O.K.L. Fingerhut

a) The escapement and potential egg deposition. A total number of 627 sockeye were passed upstream in a period beginning August 5 and ending September 6. The numbers of each sex, the potential egg deposition and other pertinent data are given in the following table in comparison with similar data from past years:

Year	Escapement Males	Escapement Females	Jack Males	Sex ratio* Male:Female	Potential deposition	No. of fry migrants	Percent production
1949-50	565	485	28	1:0.86	1,766,370	242,346	13.7
1950-51	195	121	146	1:0.62	377,775	35,129	9.3
1951-52	809	384	21	1:0.48	1,221,696	165,782	13.6
1952-53	556	507	40	1:0.91	2,053,350	249,882	12.2
1953-54	370	251	6	1:0.67	958,067	97,134	10.1

* jacks excluded

An estimated 100 individuals did not pass through the weir but were observed spawning below. Therefore, the total escapement to the creek was approximately 727 sockeye.

b) The fry migrants. Weir operation began March 22 and continued until May 9 when a break-through from a nearby drainage system rendered the weir inoperative for a period of seven days. Remedial measures were carried out and weir operation was resumed on May 17.

The number of migrants during the period of abnormally high water levels was estimated by the operation of a fry trap (described in last year's report). The operation of the trap concurrent with weir operation before and after the high water period permitted an assessment of the reliability of the estimate. In 22 tests an average of 11.3% of the daily migrants was captured. This ratio was quite constant from day to day (standard deviation = 1.66%). The total number of fry migrating from May 9 to May 16 is therefore estimated to be $\frac{100}{11.3}$ x 2,091 (number captured in trap) = 18,504. The number of fry counted and estimated throughout the migratory period is given below:

Period	Number counted	Number estimated
Mar 22-May 9	40,489	
May 10-May 16	-	18,504
May 17-Jun 6	37,141	
Jun 6	-	1,000
Total		97,134

c) Percent production of fry. A total of 97,134 fry was estimated to have survived from the potential deposition of 958,067 eggs. The production of fry is therefore 10.1%. The fry production occurring at Scully Creek from 1949 to 1954 is summarized in a previous table.

2. Williams Creek fry production. J.G. McDonald and J.A. Paul

a) The escapement and potential deposition. Pertinent data for 1953 were given in last year's Annual Report. The total number of sockeye spawning in Williams Creek was 8,508. A male to female ratio of 1:0.990 and an average egg content per female of 4,183 resulted in an estimated potential deposition of 17,765,201 eggs.

b) The fry migrants. The construction and operation of a fry weir was not considered feasible in this creek. A method of estimating the mi-

grant population was initiated, based on the premise that if a certain proportion of the discharge was strained for fry then a similar proportion of fry would be captured. In order to avoid error due to a non-random distribution of migrants a "string" of nine traps (trap design described in last year's Annual Report) was placed across the three outlet channels. Each trap strained a section of water extending from the surface to the bottom.

The traps were operated continuously. The fry were removed and counted each hour during the period of migration.

The efficiency of the trap was tested by:

(1) measuring, daily, the percentage of discharge strained;

(2) releasing fry upstream from the traps and calculating the percentage recaptured;

(3) operating a trap at Scully Creek, concurrent with weir enumeration.

These tests demonstrated the following:

(1) Straining efficiency was optimum. The measured discharge strained equalled the calculated discharge strained.

(2) The percentage of fry calculated to have been recovered after release upstream was in close agreement, in two tests, to the percentage of discharge strained. In a third test the calculated percent recovery was high.

(3) In twenty-two tests at Scully Creek an average of 11.3% $\pm$ 1.66 of the migrants were captured daily in the trap straining 11.0% of the flow upstream of the weir.

Trap operation began April 1 and terminated June 8. The weekly number of fry captured is given below:

Week ending	Number of fry captured
Apr 11	677
18	2,922
25	10,387
May 2	12,692
9	27,135
16	26,133
23	29,287
30	18,242
Jun 6	6,137
13	1,074+
Total	136,000

The total number of migrants was estimated on the basis that the percentage captured in each channel was equal to the percentage of discharge in the channels strained by the traps. Main, East and West channels strained 10.8, 8.8 and 6.9% respectively.

The number of migrants carried by each channel and the estimated total run are given below:

	Total Captured	Estimated % migrants captured	Total migrants estimated
Main channel	115,000	10.8	1,064,000
East channel	16,000	8.8	182,000
West channel	5,000	6.9	72,000
Estimated total			1,318,000

Trap operation terminated June 8 when 385 fry were captured. The number migrating after this date is estimated to have been 20,000. This estimate is based on the numbers migrating up to a date at the beginning of the run when a similar number was captured. The total migrant population is therefore estimated to be 1,318,000 + 20,000 = 1,338,000 fry. This number represents the survivors from a deposition of 17,765,201 eggs, giving a survival from egg to fry of 7.5%.

3. Lakelse Lake fry output 1953-54. J.G. McDonald

The total fry output has been estimated on the basis of the success of production reported for Williams and Scully creeks and the total spawning escapement to Lakelse Lake in 1953. As minor spawning streams are more typical of the conditions existing at Scully Creek, a production percentage of 10.1% has been applied to them.

Lakelse escapement - 1953		Sex ratio	Egg deposition	Percent production	Fry output
Williams	8,508	1:0.99	17,765,000	7.5	1,338,000
Scully	627	1:0.67	958,000	10.1	97,134
Others	160	1:1	305,400	10.1	30,845
Totals	9,295		19,028,400	7.7	1,551,934

4. The history of artificially fertilized sockeye eggs placed in artificial redds. J.G. McDonald and O.K.L. Fingerhut

A preliminary experiment was conducted to suggest answers to the following questions:

a. What size of gravel is conducive to optimum egg development and survival?

b. Does a loss of eggs occur? (i.e., do dead or unfertilized eggs disintegrate, thus introducing error into the present methods of redd sampling?)

c. What is the influence on survival of insect and other forms present in the gravel?

A measured amount (by volume) of fertilized eggs was placed in gravel contained in plywood and screen boxes. Three sizes of gravel were used (small, medium and large) which ranged from less than 1/4 inch diameter to 2 inches diameter. Nine boxes of each gravel size were used, each

containing roughly one cubic foot of gravel. The boxes were then placed in the stream bed where there was sufficient depth of water to guard against dessication and freezing.

A sample of eggs in each gravel type was examined in October 1953, six weeks after fertilization and all boxes were throughly examined in March of this year. The following is a general summary of the findings:

(1) Almost all eggs had died by the time the early eyed stage was reached. This was believed due to heavy silting of the gravel resulting from the position of the boxes in respect to water current.

(2) The medium- and large-sized gravel was more conducive to egg development and survival than the small gravel.

(3) A large number of eggs placed in the boxes could not be accounted for.

(4) Fungus was much more prevalent in eggs in the larger gravel types.

(5) At an initial stage of "fungusing", the eggs, upon cursory examination, may be erroneoulsy identified as in the early eyed stage.

(6) The larval forms of insects were found in the boxes and in the egg layer. Chironomid larvae ("blood worms") were extremely abundant. In some instances these larvae were found inside the dead eggs.

The large mortality of the eggs at an early stage greatly reduced the value of this experiment. A repetition with further control is required to evaluate more fully the influence of the various factors discussed above.

B. Smolt studies. M.P. Shepard

The relation between the number of eggs deposited and the number and weight of the resultant smolts provides an index of sockeye production at Lakelse Lake. Since 1952, annual counts and measurements have been made at the Lakelse River fence to provide the key data on sockeye yield.

1. The smolt run of 1954. M.P. Shepard and R.M. Humphreys

The annual count of sockeye smolts at the Lakelse River fence began on April 15, and continued until mid-August. During this period, a total of 375,000 sockeye smolts passed through the weir. The peak of the run occurred on May 27, while 90% of the run was enumerated between May 15 and June 5. For six days near the end of the run, high water permitted only a partial count to be made. During this period it is estimated that about 4,400 sockeye passed through the fence undetected. Thus, the total run was approximately 379,400.

Concurrent with the enumeration of the sockeye smolts, 91,000 coho smolts were passed through the fence. In addition to these fish, it was estimated that about 8,400 smolts passed downstream, undetected during the period in June when the fence was not in operation. Thus the total coho run was approximately 99,400.

As a result of studies on the effects of fence operations on the condition of young sockeye conducted in 1953 (see MS. Rep. Fisheries Research Board of Canada No. 559, 1954), changes in fence design were made to

increase the efficiency of the operation and to ease the passage of fish through the fence. The chief changes were the provision of larger traps and the institution of a visual counting system, wherein fish were enumerated without handling or removal from the water. Using a glass-bottomed viewer, fish were counted as they passed through an underwater shute. It was impossible to differentiate between sockeye and coho smolts passing through the viewer and therefore, daily samples, comprising approximately 25% of the run, were examined to determine the proportional representation of sockeye and coho. Improvement in fence design over the past two years was reflected by a lowering number of smolts killed by the fence operation. In 1952, it was estimated that up to 5% of the run suffered mortality. In 1953 this percentage dropped to 1.61% and in 1954, mortality was cut to less than half of that (0.74%).

In 1953, a marking experiment was carried out on Scully Creek fry to provide information on the age of the smolts emigrating from the lake. By examining samples of smolts at the Lakelse River counting weir for the presence or absence of marks, the tentative conclusion, derived from scale studies, that the majority of the Lakelse smolts are yearlings can be tested. A total of 11,253 fry were marked by excision of the left pelvic fin. At the Lakelse River weir, in the spring of 1954, 54,312 smolts were carefully examined. Of these 12 had deformed fins; 6 of these were probably genuine marks; the others were labelled as possible marks. In 1952 a similar experiment was carried out wherin fry were marked by removal of both pelvic fins. In 1953, 2 smolts out of a sample of 110,500 bore "genuine" marks, while 5 others bore possible evidence of excision.

One of the "possible" marks from the 1954 examination resembled a 1952 mark. Examination of samples of fish in the 1955 run are necessary before any final conclusions are drawn. The evident and extensive differential mortality suffered by marked fish makes quantitative assessment of the results difficult. Tentatively, however, the results of the 1952-54 experiments suggest that the majority of the Lakelse smolts spend only one year in the lake.

2. Size, age and sex composition of Lakelse smolts. M.P. Shepard

Since 1952 annual assessments of the composition of the Lakelse smolt run have been made. In the following table the results of preliminary analyses of the data are summarized. Two sets of observations made in 1946 and 1948 are included.

Year	Sample size	Numbers of fish				Av. length of 1's (cm.)	Av. weight of 1's (gm.)
		Male[1x]	Female	Male[2x]	Female		
1946	210		209		1	7.61	4.57
1948	44		43		1	7.63	-
1952	1661	866	778	12	5	8.18	5.60
1953	1377	740	621	5	11	8.52	5.79
1954[xx]	1582	855	719	2	6	8.13	5.55

[x] 1 = yearling fish; 2 = 2-year-old fish

[xx] Figures for 1954 are tentative pending thorough analysis.

Although the early information is scanty, the data suggest that smolts examined from 1952 to 1954 were distinctly larger than those taken

during 1946 and 1948. There is no distinct relation between smolt size and the numbers of smolts emigrating from the lake (see part IV of the Lakelse reports). It is of interest to note that in the last 3 years males have consistently outnumbered females; the average male:female ratio is 1.15:1. This difference is statistically significant.

The proportion of 2-year-old fish in the samples is low, averaging 0.9% for the five years of observations.

C. Adult studies. D. MacKinnon

The chief activity of the adult sockeye program at Lakelse Lake is the annual enumeration of the size and composition of the run. This is accomplished chiefly by counting, sampling, tagging and observing the fish at two critical points in their freshwater history. One of these ponts is at the Lakelse River fence as they enter the lake and the other is at the Williams and Scully creek fences as they enter the major spawning streams. This information is taken to provide a base line for the many problems and potential problems concerning the role of the adult in a sockeye production unit. The chief problem is of a general nature and can be stated as: "What role does the amount of seeding play in the production of sockeye smolts?". The approach to this is to relate the variation in numbers, composition and environment of the runs to variation in numbers of progeny. Until more is known about this and other potential limiting factors (any one of which may decide the carrying capacity of the lake) it is only safe to assume that seeding is a factor limiting production. With this in mind, studies are being carried out to determine what factors limit the deposition of eggs. In this respect the mortality of adults in fresh water prior to spawning has become an important problem. Causal analysis of this mortality has resulted in an intensive study of the effect of the river fence on the condition of the fish. This study has been projected to the mouth of the Lakelse River this year in an attempt to determine whether injuries and subsequent mortality are artificial and caused by the fence or whether they are normal and can be expected to occur in other systems.

Estimation of the size of spawning populations by stream surveys is receiving considerable attention. Originally designed to provide a method of visual estimation they have also served the useful purpose of providing information for the evaluation of past data from stream surveys made before adequate fences were built.

Observation of spawning behaviour and preliminary sex ratio experiments were commenced to determine the minimum proportion of males necessary to fertilize effectively the eggs of the females present.

1. River mouth observations. D. MacKinnon

The high incidence of injury and subsequent mortality of adult sockeye prompted an investigation of the fish before they arrived at the river fence at the entrance to the lake. It was hoped that some clues to the injury problem would result from tagging and observing samples of the run at the mouth of the Lakelse River. As was anticipated, much time was lost in evolving a capturing technique and finding an observation place.

It was found that gill netting in the relatively quiet water at the mouth of the river was the only practical method of capturing fish. It was, of course, necessary to patrol the net and remove fish as soon as they were caught. Observation for incidence of injury as the run passed

through was practised at only one place. This was in a small clearing in a large log jam.

Forty-five fish were captured, tagged, examined for injuries and released. Twenty-four of these fish were captured in the first two days and the remaining 21 during the following two weeks. A striking difference in the success of recapture at the river fence indicated that the first group of fish (83% recovery) were the last of the main body of the Lakelse run, while the last group of fish (33% recovery) were "stragglers" of the Lakelse run and "wanderers" from other Skeena River runs. This is pointed out by the fact that two of the latest fish to be tagged were recaptured in the Skeena River. One went 80 miles downstream and was taken in the commercial fishery while the other went 80 miles upstream and was captured in the Indian fishery. All other recaptures were made at Lakelse Lake.

Of the 21 tagged fish captured at the entrance to the lake, 10 showed no change in condition while the other 11 showed added injuries (average of 2 injuries per fish).

Of the 94 fish observed at the log jam, only 10% bore injuries. This is in contrast to the 33% injury ratio observed at the river fence.

The number of fish tagged and observed is too small to provide any conclusions. However, it is indicated that many of the injuries occur in the Lakelse River.

The average time taken to travel the 12 miles of the Lakelse River was 6 days. Much of this time was probably delay as a result of handling during tagging.

A survey of injury and delay factors in the river shows that predation may cause a small part of the injury. As many as 20 seals were seen in the lower three miles of the Lakelse River. A few signs of bear but no direct evidence of eagle predation were seen. Log jams abound in the river. One of these covers nearly a half-mile of stream bed. In many places the submerged branches provide a reticulum that could easily be a serious cause of injuries.

2. Adult escapement to Lakelse Lake, 1954. M.P. Shepard and R. Tkachuk

A total of 7,671 adult sockeye was counted through the Lakelse River fence between June 17 and August 31. Since then a small late run of sockeye has occurred, but data on this are not yet available. The peak of the run occurred on June 26 when 830 fish were counted. In general the run was somewhat later than in 1952 and 1953, the other years of operation of the Lakelse River fence.

The results of the fence operation are marred by the fact that a gap under the floor of the fence was discovered late in the run. It became evident that an appreciable number of fish escaped through this hole. However, data gathered from tagging studies gives a reasonable estimate of this undetected loss. Three sources of information were used to gain this estimate:

(a) River fence tagging. A total of 357 tags was applied to fish at the river fence. Only 222 of these tags were accounted for on the spawning grounds, indicating a loss of 135 tags. Prior to the spawning run, 6 river tags had been recovered on dead fish in the lake. The proportion of tags in the sample of dead fish found in the lake was 6 times greater than the proportion of tags in the spawning population, indicating that a marked differential tagging mortality had occurred. These data permitted a computation of the lake loss, and when added to the spawning ground count gives an

estimate of the total run to the Lake (see table below).

(b) Lakelse River-mouth tags. Forty-five tags were applied to sockeye at the mouth of the Lakelse River (see Report No.1 of this section). Of these, 21 were trapped at the Lakelse River fence. Records were made of tag numbers. Upstream from the fence (among dead fish washed down on the river fence, among dead floating in the lake, and among fish examined on the spawning grounds), some of these tags were recovered a second time. Other tags could not be traced to the river fence and presumably passed through the gap in the fence. On the basis of these data, an estimate of the total run to the river was made (see table below).

(c) In 1952 and 1953, it was estimated that for each dead fish observed floating in Lakelse Lake, respective totals of 31 and 32 fish had died and were not recovered. In 1954, 33 dead fish were recovered. Assuming that the ratio of dead found: total dead was about the same as in past years, a second and independent estimate of the loss in the lake was obtained. The results of this estimate were added to the spawning ground count to provide a third estimate of the total run (see table below).

Data source	Total river run	95% Fiducial* limits
(a) River fence tagging	8,368	7,967 - 9,104
(b) Lakelse River mouth tagging	8,483	8,295 - 9,505
(c) Dead on lake surveys	8,569	-
Average	8,473	

* Fiducial limits = total number of fish actually counted through the fence or on the spawning grounds + fiducial limits of estimated loss through the fence or estimated loss in lake.

Thus there is a close agreement between the three estimates. It is felt, therefore, that the average estimate of 8,473 is a close appromimation of the true run to the Lakelse River fence.

A sample of the run was tagged. The length, sex, condition of the fish and a scale sample were taken. The results of the tagging experiment and of the injury descriptions are included in Report No. 4 of this section. The provision of more pens this year increased the precision of the sampling.

Analysis of the length, age and sex data has not yet been made. Tabulations of last year's results are included in the next report.

3. Age, size and sex composition of the 1953 adult run. M.P. Shepard and D.R. Foskett

In 1952 and 1953, samples of the adult run to Lakelse Lake were taken for determination of length, age and sex. In the following table the 1952 and 1953 data are summarized. As outlined in last year's report, the determination of sex of the river fish is not completely accurate. Data from tagging experiments wherein sexing of fish tagged at the river fence is carried out on the spawning grounds, is required before further breakdown of the data is possible.

Age class	Per cent composition 1952	1953
3_2	0.4	0.0
4_2	11.5	28.1
5_2	82.1	60.5
5_3	0.0	9.7
$5_2 + 5_3$	82.1	70.2
6_2	0.2	0.3
6_3	5.7	1.0
$6_2 + 6_3$	5.9	1.3
Total number in sample	927	288

Although the proportions of the various age classes have varied somewhat, 5_2 fish formed the dominant group in both years. The appearance of 5_3 fish in the 1953 run contrasts with the complete lack of this group in 1952.

4. Distribution, survival and injuries of adult sockeye. M.P. Shepard, D. MacKinnon, and R.M. Humphreys.

As outlined in the preceding reports, the run of adult sockeye at Lakelse was examined at three locations: at the mouth of the Lakelse River, at the Lakelse River fence (located near the outlet of Lakelse Lake into the river), and on the spawning grounds. Comparisons of counts, estimates and data on the composition of the run at the different localities give information on the extent of mortality occurring after the adults have begun their migration into the Lakelse drainage and on their distribution on the spawning grounds.

a) Distribution and survival. As outlined in Report No. 2 of this section, it was estimated that 8,473 adult sockeye entered Lakelse Lake prior to July 31. Fence counts on the two main spawning streams of the lake (Williams and Scully) and estimates on the other streams indicate that no more than 7,698 sockeye reached the spawning grounds. The others, (775) were presumed to have died in the lake. Calculations based on tag recoveries (see Report No. 2) support this figure. Thus, it is estimated that a 9% mortality occurred. As shown in the following table, this figure is less than in 1952 and 1953 when losses of 32.1% and 21.4% were estimated by the same method.

	1952		1953		1954	
	Number	Percent	Number	Percent	Number	Percent
Lakelse River	17,726	100	11,815	100	8,473	100
Williams Cr.	9,932	56.0	8,508	71.9	6,789	80.1
Scully Cr.	1,103	6.2	627	5.3	714	8.4
Others	1,000	5.6	160	1.4	195	2.3
Total spawning	12,035	67.8	9,295	78.6	7,698	90.8
Presumed dead	5,691	32.1	2,520	21.4	775	9.2

The distribution of spawners in the lake is also summarized in the table. It will be noted that the ratio of Scully to Williams spawning fish has remained about the same over the three-year period. The 1954 run is probably the second lowest since the Lakelse field station began operation in 1944. Although reliable data are lacking for several years, the 1950 run is believed to have been lower than 7,000. The production of fry next spring and smolts in 1956 will be watched with interest.

5. The Williams Creek spawning run. D. MacKinnon and H.D. MacIntosh

This year's run to Williams Creek was slightly later than in previous years. The run began August 8 and rapidly built up to a peak on August 12. By August 17, 90% of the fish were through the fence. The remaining 10% moved through the fence in small groups. By September 1, the run was virtually completed. The count through the fence was 3,213 males and 3,576 females giving a maximum deposition of 14,661,600 eggs. The average length of females was 61.1 and of males 67.1 cm. Analysis of tag returns, sex product retention, and length frequency of the fish found dead on the fence is not yet completed.

The distribution of these fish on the spawning ground was followed by a series of stream surveys. The stream was divided into four sections this year. Sections 1, 2 and 3 compare with the downstream area reported in the 1952 and 1953 Annual Reports while Section 4 is the upstream area. The table below shows the relative distribution of adults on the spawning grounds.

	Total No. observed	Section 1	Section 2	Section 3	Section 4
Aug 9	75	24.0	64.0	12.0	0
16	2,332	9.3	39.2	29.5	22.0
24	4,026	13.9	39.7	30.4	15.7
Sep 3	1,010	20.0	55.8	9.8	14.4

Roughly 20% of the run spawned in Section 4. This is in striking contrast to the distribution in the previous two years when 67% and 57% of the fish sapwned in this area. One of the main reasons for this difference is that, in the upper reaches of the creek, less spawning ground was available this year. The stream divided above this area and the new branch cut through a heavily wooded area with few stretches of gravel. Another possible

reason is that a marked improvement occurred in the stream bed immediately downstream from this area. Winter freshets apparently cleared debris and created new spawning stretches. A third possible reason is that the run was 20% smaller than that of 1953 and 40% smaller than that of 1952. It may be that reduced population pressure in the lower stretches obviated the full utilization of upstream area.

6. Observations on spawning activity. D. MacKinnon

The dynamics of a section of Williams Creek spawning ground was followed daily from the time the first fish arrived (August 8) until the last fish died and drifted away (September 11). The main object of this study was to determine the role of the male in an integrated group of spawners.

A section of spawning ground measuring 100 feet by 40 feet was divided into 10 equal 20-foot by 20-foot squares by means of a string stretched between stakes above the surface of the water. The daily number of fish of each sex in each square were recorded along with qualitative observations on behaviour. These observations were made from a 16-foot tower. Attempts were made to recognize and follow individual fish by distinctive marks, scars or tags. It was important to know whether the males would attend more than one female and whether the females would dig more than one redd.

The spawning sections filled with fish in a fairly predictable manner. The downstream sections characterized by shallow (15 to 20 inches) fast-moving water were chosen first while the upstream section characterized by deeper (20 to 40 inches) slow-moving water was chosen only after the lower sections were fully utilized. The fish also moved to the periphery where the water in some cases was shallow enough (under 12 inches) to expose their dorsal fins; many of these peripheral redds were left high and dry by receding water.

Immediately prior to the peak of spawning activity (August 16), a freshet washed out the grid. High murky water suspended observation for eight days. The grid was reconstructed and observations resumed on August 24. It was interesting to note that the fish that could be identified were still in the same position.

The chief damage by the freshet was that much of the opportunity to identify particular fish was lost. Despite this loss, enough observations were taken to point out that the females stayed on their own redds throughout the whole spawning period. The few exceptions were those that were spawning at the periphery of the group. Receding water in these cases caused the fish to leave partially developed redds. The males did not leave their females during the complete course of spawning activity. Late in the spawning period, however, the males left their females to guard the nests and gathered in groups of from 2 to 10 fish. The few fresh females and the occasional partially spawned female on the grounds were attended by these "roaming" groups of males.

The sex ratio changed from predominately male early in the run to exactly equal at the peak of the run, then to a slight excess of females for two days after the peak and finally back to a male predominance for the balance of active spawning. The last few fish on the grounds were females holding over their nest in the last stages of life. Many of the excess males in the later stages probably came from the periphery which was outside the grid and not quantitatively followed.

At the peak of spawning, 70 pairs occupied the 444-square-yard grid. This allowed approximately 6.3 square yards per redd. In the most concentrated sections there were approximately 4 square yards per pair. Last year's data for roughly the same area showed approximately 3.5 square yards for each redd.

The behaviour pattern was essentially the same as that reported in the Annual Report for 1953. The only obvious exception was that there was much less substitute male activity this year. A typical spawning unit this year was one male to one female during the major spawning period and generally four or five partially spent males to each female during the later stages of the spawning period. At no time this year or last year was actual deposition witnessed.

7. Sex ratio experiments. D. MacKinnon

Three pens, each measuring 10 feet by 6 feet with four-foot picket-type walls, heavy screen bottoms and removable screen tops were constructed to confine spawning sockeye. These pens were set in the water near the mouth of the west channel of Williams Creek at a point where a 10-inch layer of gravel on the bottom of the pen provided a water depth of 18 inches. Ripe sockeye taken from the Williams Creek fence were tagged distinctively and put in the pens in such a way that one pen had a surplus of males (6 males to 2 females), another had a surplus of females (6 females to 2 females) and a third had an even sex ratio (4 males to 4 females). Observations were recorded at least once a day until all fish were dead. Samples of the eggs in the gravel of each pen were taken at the end of the experiment.

The salient observations were:

(a) Fish paired and spawned in all three boxes

(b) The pens were large enough to support a maximum of 3 redds.

(c) The 3 surplus females (without room for redds) were vigorously attacked by the 3 territory-defending females and died unspawned within 3 days of confinement. The 2 males and the remaining 3 females spawned completely.

(d) The 4 surplus males (without mates) also died within a week. However, 3 of them died spawned out while the fourth died 2/3 spawned. The interesting feature is that at no time during observations were these surplus males seen to enter into the spawning act. They gathered at the downstream wall of the pen as did the surplus females mentioned above. This suggests that deposition of fertilized eggs takes place at night.

(e) In the control pen one fish of each sex died within a few days of being introduced into the pens. Again the female died unspawned while the male had spent 2/3 of its milt.

(f) The redds in both the control pen and in the pen with surplus females were in identical positions. One redd was slightly upstream from centre and the others were at the extreme left and right sides of the downstream end. Presumably water flowing through the upstream redd would miss the two downstream redds.

(g) Approximately 3,000 eggs were recovered from the gravel of each pen by redd sampling. During sampling, it was noted that the eggs were in concentrated groups at the very bottom of the gravel. It was surprising to find in each pen the main source of eggs was the extreme right and left sides about 3 feet above the downstream end. Observations consistently showed the chosen position of the dominant female to be slightly upstream from centre. A comparison of the efficiency of fertilization will result from the analysis of the egg samples.

D. Sockeye production at Lakelse Lake, 1944-54. M.P. Shepard

With the completion of the 1954 sockeye smolt enumeration, 6 years' data relating depositions of eggs with resultant smolt outputs have been obtained. From 1944 to 1952, the estimation of annual egg depositions involved spawning ground surveys in conjunction with tagging programs. The results derived in this period are therefore approximations, subject to considerable error. In the past three years, the establishment of sound enumeration techniques, including fences, has permitted detailed studies on estimation methods. The application of the new knowledge to the assessment of old data will bring about extensive revisions in the estimates of spawning escapements made in the past. The reassessment work is in the preliminary stage and cannot be reported on at this time. Dependable information on the magnitude of 5 smolt runs is available. The estimates of adult runs from 1952 to 1954 are also considered to be accurate. In addition to these measures, the first estimation of the total fry output into Lakelse Lake was made this year (see section A of the Lakelse report). In the following table the known production figures are summarized:

Brood year	Adult run	Potential deposition	Fry	Smolts	Av. weight of smolts (grams)	Percent survival from egg to smolt
1944	*	*	-	557,000	4.57	*
1945	*	*	-	373,000	-	*
1946	*	*	-	*	*	*
1950	*	*	-	596,000	5.60	*
1951	*	*	-	394,000	5.75	*
1952	12,000	21.6×10^6	-	379,000	5.55	1.8
1953	9,300	19.9×10^6	1.5×10^6	-	-	-
1954	7,700	17.5×10^6	-	-	-	-

* Estimates are being re-examined and corrected; revised data are not yet available.

- No data taken, or data not yet available.

Two general conclusions may be drawn from the data:

(a) The size of the smolt run at Lakelse has varied within rather narrow limits (mean = 460,000, range 373,000 to 596,000). It is not believed that the estimate of the 1948 smolt run (1946 brood-year) will deviate seriously from this general order. Whether or not this lack of extreme variability is due to a relative constancy of the spawning escapement cannot be determined until amended estimates of the adult runs of 1944 to 1951 are made.

(b) Unlike the smolts of certain other areas (e.g., Babine and Cultus Lakes, B.C.), there is no clear-cut relationship between the size of individual smolts and the magnitude of runs. At Babine and Cultus, an inverse relationship existed between smolt size and the number of emigrants.

E. Limnology of Lakelse Lake. R.J. LeBrasseur

The emphasis of the 1954 limnological program has been on the assessment of past plankton sampling methods and the characterization of water circulation in the lake. These studies are directed towards the development of a routine description of the environment of the young sockeye during their year-long stay in the lake.

Efforts are being made to summarize past data on plankton abundance, water temperatures and meteorology.

1. Plankton.

As in the past, the plankton program was aimed at assessing the size of the entomostracan crop. This year critical studies on plankton sampling methods were carried out as well as routine samplings of the crop. Bi-weekly sampling was undertaken throughout as much of the year as possible to give a picture of the relative magnitude of the crop and of seasonal variations in the crop size.

Sampling methods. In last year's Annual Report, it was suggested that B.C.-Wisconsin-type plankton nets were inadequate for quantitative sampling of plankton populations. To test the efficiency of the nets, a pump was used to sample plankton concurrently with standard net sampling.

The disadvantages of quantitative sampling with the net which are obviated by the pump are:

(1) clogging of the meshes and the resultant back flow;
(2) the volume of water is not accurately known;
(3) the initial disturbance of the water column caused by the lowering of the net;
(4) the presence of the tow rope which could disturb the plankton;
(5) the difficulty of obtaining samples from a given level.

To compare the sampling efficiences of the net and pump, twelve series of duplicate samples were taken. The calculations of the density of the most predominant entomostracan, Cyclops sp., based on the net samples were 23% lower than similar computations from the pump samples.

To test the reliability of one sample, taken either by net or pump, replicate hauls were made at one station. The variations between the replicate hauls with either equipment in the same area and at the same time were nearly equal (standard deviation = approximately 10% of the mean for large counts). The observed variations were greater than if the discrepancies had been due solely to sampling error; the plankton counts do not conform to the theoretical distribution. However, the observed variations are not excessive, and it is likely that gross changes in the seasonal or annual density of plankton can be detected by the present methods.

It has been suggested that sampling at the deepest station would give an adequate representation of the plankton in the lake as a whole. To test this, comparisons of the average concentration of plankton for a number

of stations with the concentration for the deep-hole station were made. Examination of past and present data (1949-54) shows that the ratio between the deep-hole station density estimates and those for the lake as a whole varied between 0.13 and 2.27. The mean was 1.11 and the standard error was 0.105.

These studies, and further analyses yet to be carried out, will permit a critical analysis of ten years of plankton collections at Lakelse. The prime purpose will be to establish whether or not annual variations have occurred in the abundance of Lakelse plankton and if so, whether or not these changes in density are associated with variations in the output of sockeye smolts from the lake.

The design of an effective routine sampling program awaits completion of the analyses. At the time of writing, extensive sampling is being undertaken on the fall populations of plankton at Lakelse, using a Clarke-Bumpus sampler, and dry-weight analyses of the samples are being carried out as opposed to the present net sampling and counting methods.

Distribution studies. Partial analysis of the sampling data (involving 80 samples taken at night at 5 to 11 stations) indicates that the distribution of plankton in the lake was similar to that noted in previous years (see V.H. McMahon, J. Fish. Res. Bd. Can. 11:1954); the concentration of plankton increased from the south to the north end of the lake. As in other years, the spring concentrations of the dominant species (Cyclops sp., Epischura spp.) were higher than during the summer.

Examination of the influent streams for plankton showed that only Clearwater Creek, which drains two lakes, had plankton. Plankton samples taken in the Clearwater lakes showed that the plankton was very sparse, only Cyclops, Cladocera and insect larvae being found. Samples were also taken at the Lakelse River fence. Qualitative analyses of these samples indicate that a considerable volume of plankton is lost to the river. Further analyses of the present data supplemented by another summer's sampling should provide an accurate picture of this loss and yield very valuable information on the distribution of plankton in the lake. Comparison of plankton distribution and currents will be made when counts of the late summer plankton samples have been completed.

Acknowledgement is made of the very valuable assistance given by Mr. V.H. McMahon. He was responsible for nearly all the identifications and counts made of the entomostracan plankton during the summer as well as helping in other ways.

2. Physical-chemical environment.

(a) Meteorology. Meteorological data from 1944 to the present are being abstracted. They include observations of air temperature, surface water temperature, wind force and direction, precipitation, cloud cover, barometric pressures and ice cover and lake levels. Data have also been obtained from the Department of Transport to supplement the Lake observations.

The winter conditions of 1953-54 were quite similar to the long-term average. The exceptional feature was a freshet in the first week of February when a sudden rise in temperature was accompanied by heavy rains. During a 4-day period the lake rose 24 inches. One of the possible results of the freshet was the movement of trout and char into the Lakelse River much earlier than usual, and before the River fence could safely be put into

operation. The summer was cooler (by 2-4°F.) than the long-term average and the prevailing winds were more persistent than usual. The colder conditions were accompanied by a general lateness in biological events (e.g., smolt run).

(b) Chemistry. The lake chemistry program was essentially the same as that for 1953. Data from 1949 to the present have been summarized. The year 1954 shows an increase in nutrients (phosphates and nitrates) over 1953 and 1952. The relatively complete plankton enumerations and consistent collection of chemical data in 1954 will show whether the variations in plankton concentration are associated with variations in nutrients. These determinations await the completion of the plankton counts now in progress.

(c) Temperature. Lake temperatures are taken bi-weekly at the deepest station. A summary of the observations at this Station since 1944 has been prepared. The results are expressed in terms of the mean water temperature of the 80-foot column of water. The data cover a relatively long period but they are incomplete, particularly for the winter and early spring months. In 1954 the bi-weekly mean temperature varied between 1° and 2° F. below the long-term average.

In a series of replicate plankton samples the variability of the counts was found to exceed that attributable to the sampling techniques. The question then arose as to whether this variation could be caused by water movements. To describe the circulation of water in the lake, 14 bathythermograph stations were selected and observations were made throughout the summer. Three series of observations were taken when the prevailing wind force was greater than one (Beaufort Scale). Two were taken when the wind was absent or less than one. By following the distribution of the isotherms, the water movements could be determined.

The distribution of the surface isotherms for the steady state, a prevailing southerly wind, shows a piling up of warm water along the east shore and towards the north end of the lake. Immediately below the warm water is an isothermal gradient rising from the north end to the south end. Below this region the isotherms run parallel to the lake surface.

On the basis of these observations a very general description of the currents in Lakelse Lake can be postulated. A surface current flows northward in the direction of the wind. Along the northeast shore vertical mixing between the warm surface and the colder profundal zone occurs. The mixed water moves southward along the lake, rising from a depth of 40 to 60 feet at the north end to the surface at the south end. The water of the profundal zone shows no horizontal movement and only slight vertical mixing.

During the period of calm the isotherms all run nearly parallel to the surface and the once cold areas of the shallow south and west shores now have the warmest water. This is probably a result of more efficient heating in the shallow areas than in the deeper zones. The only evidence of horizontal flow is in the region of the outlet of the lake. The river discharge, as in the former case, is made up largely of the very warm water found along the southwest shore. Only one observation of cold water moving down the river has been made. In this instance the movement of water was from a region of upwelling off the southeast shore, at a time of south winds with a Beaufort force greater than three.

Attempts are being made to relate the distribution of the plankton to the known circulation patterns. The completion of late season plankton counts are required before further analyses can be made.

F. Fishes of Lakelse Lake. T.H. Bilton and M.P. Shepard

Studies of the fishes have centered on the description of the life histories of the piscivorous species present in the lake. The emphasis of the 1954 program has been on increasing the prescision of estimates of the adult cut-throat and squawfish populations of the lake. As field work is continuing at the time of writing, opportunity for analysis of this year's results has been restricted. Utilizing knowledge gained from the routine program, plans are being laid to conduct a final intensive study of the lake fish (including juvenile fishes) preparatory to the conduct of a fish removal program. In view of the low seeding at Lakelse this year, tentative plans for a squawfish removal program in 1955 have been postponed until 1956.

1. Gill-netting experiments. T.H. Bilton and M.P. Shepard

A standard gill-netting program, aimed at establishing the relative densities and compositions of lake fish populations was initiated in the fall of 1952. All parts of the lake are sampled with approximately the same intensity three times a year; in the spring, in the fall and in the winter. The catches of major species per net-night are compared in the table below.

Species	Spring		Fall		Winter	
	1953	1954	1952	1953	1952-53[x]	1953-54
Peamouth	3.70	3.72	4.98	1.77	-	.01
Cut-throat	1.39	0.82	1.67	1.69	-	.50
Squawfish	0.65	0.69	1.48	0.65	-	.20
Dolly varden	0.10	0.18	1.51	0.33	-	.15
Average water temperature	10.0	9.7	12.0	9.7	-	1.0

[x] Lack of solid ice during the winter of 1953 prevented netting.

Before interpretations on the relative abundance of the various species can be drawn from catch data, the sources of variability associated with gill-net sampling must be clearly understood. Some of the factors affecting the catch/net-night for any series of sets are outlined below:

(a) Sampling error. In the Annual Report of 1952 data on the variability of individual sets and of netting series involving up to 36 sets was presented. The 95% confidence limits on the mean catch of such series were approximately $\bar{x} \pm .25\bar{x}$.

(b) Distribution. The catches will reflect the presence or absence of fish at the sampling stations. For example in the table above, the low catches of dolly varden observed in the spring are probably due to the emigration of these fish from the lake.

(c) Activity. The number of fish caught in gill-nets is undoubtedly affected by the behaviour of the various species at the time of netting. Wide-ranging and rapidly-swimming fish will tend to be caught more often than fish whose movements are localized and not rapid. In this respect, lake temperature and the stage of maturity of the fish will affect the catches. In the table above, it will be noted that the fall catches of peamouth, squawfish and dolly

varden were much higher in 1952 than in 1953. The chief difference in the environment in these two years was in water temperature. It is postulated that the higher catches of these three species in 1952 were due primarily to the stimulating effect of higher temperatures. Plots of catches per net-night against water temperature suggest that peamouth and squawfish are most affected by temperature.

It will be noted that the catches of cut-throat were almost equal in the fall of both years. Study of gill-net and trap-net data show that, with the exception of the early spring spawning period, cut-throat maintain a similar, dispersed distribution throughout the year. Evidence from experimental sets also indicate that cut-throat are wide-ranging. Repeated sets at a single position tend to deplete local populations of peamouth and squawfish, whereas continual recruitment of cut-throat into a local area prevents depletion of this species. It will also be noted that seasonal variation in cut-throat catches is less than variations in the catches of other species, suggesting that the effect of temperature on the activity of cut-throat is less than that on the other species involved. These data suggest that the habits and activity of the cut-throat are less affected by seasonal environmental changes than those of the other species and that as a result, catches of cut-throat are less subject to variability than those of the more sensitive fish.

The relatively low catches of all species in the winter months probably reflect the restrictive effects of cold temperatures on their movements.

As yet there is no clear-cut reason for the discrepancy between the peamouth catches of the fall of 1953 and the spring of 1954.

(d) Abundance. From the foregoing descriptions of some of the sources of variability in gill-net sampling, it is apparent that a very thorough knowledge of the factors affecting "catchability" is needed before quantitative assessment of relative abundance is possible. In conjunction with marking programs, and limnological investigations, it is felt that within two years sufficient standard set series will have been made to permit fairly precise annual estimations, based solely on gill-net results.

While the data collected in the past two years are scarcely sufficient to draw conclusions on population changes during that period, certain suggestions can be made. Limnological conditions during the netting carried out during the springs of 1953 and 1954 were quite similar; the catches of all species, excepting the cut-throat of 1954, were quite close in magnitude, suggesting that these populations had not changed in size in the past year. The 1954 cut-throat catch was only 60% of that of 1953. Although analyses of marking data for 1954 are not yet complete, there are preliminary indications that a decline in cut-throat abundance did occur.

2. Marking experiments. T.H. Bilton and M.P. Shepard

In last year's report, tentative estimates of the size of certain predator and forage fish populations were presented. In the fall of 1953 and the spring of 1954 further marking experiments were conducted to increase the precision of these estimates. Information on the recovery of marked fish and the computation of population sizes awaits the completion of this year's field program (in late November).

Marking of dolly varden and cut-throat trout was conducted at the Lakelse River fence in October of 1953. Marking and tagging of dolly varden, cut-throat and squawfish taken from trap nets in the various influent streams

and along the shoreline of the lake was carried out from April to July of 1954. In all 2,866 predator fishes were marked or tagged. To date, 217 recoveries have been made and subsequent samplings should add to this number by approximately 50%. Thus about 10% of the fish marked during the 1953-54 season will probably be recaptured by the end of November. The results of these experiments combined with data on the continuing returns from the 1952 marking experiments should increase the precision of the population estimates greatly.

Cursory examination of the marking and tagging data reveals the following information:

(a) Cut-throat trout marked in Lakelse Lake have been recaptured at the Lakelse River fence. To date only two such recaptures have been made. No fish marked at the river fence, either in 1952 or 1954, have been recovered in the lake. These data suggest that while there is some mixing of lake and river populations, the interchange is not great.

(b) Dolly varden marked at the river fence in the fall were recaptured in the lake during the same fall and again at the river fence the following spring, indicating an annual migration of some of the fish to and from Lakelse Lake. In the fall of 1952, there were two unconfirmed reports of marked fish being taken in the Copper River (approximately 12 miles from the mouth of the Lakelse River). Further evidence of the mixing of Lakelse dolly varden stocks with other groups of fish in the Skeena River was obtained this year. A tagged dolly varden released downstream from the Lakelse River fence was recaptured at Telegraph Point near Prince Rupert, approximately 80 miles from the point of tagging.

(c) Squawfish and peamouth marked in 1952 again tended to return to localized areas (e.g., Mailbox Point, Hotsprings Creek) to spawn. The implications of this finding in the design of a fish removal program are evident.

3. Creel census, 1954. T.H. Bilton

The creel census began its fifth year on May 5. As in past years as many fishermen as possible were contacted. From each, the following information was collected; the number of hours fished, the numbers of each species of fish caught, time of catch, type of bait or lure used, area in which fish were caught, the weather and number of marked or tagged fish recaptured. When time permitted, all the fish in each angler's catch were sampled for length, sex, state of sexual maturity and scales.

(a) The catch.

Cut-throat. Following a general trend over the five-year period of the creel census, the catch per hour of cut-throat taken in the lake rose above that of past years and the catch per hour on the Lakelse River (draining the lake) dropped to a new low. In the table below, the catch figures for the past five years are summarized. The drop in the river catch is no doubt a true reflection of the abundance of the trout at the time of angling; the count of cut-throat at the Lakelse River weir has dropped for the last two years. As mentioned in last year's report, the great majority of the angling is restricted to the area of the river upstream from the weir. As in 1953,

it is felt that the low return to fishermen angling above the weir was due to a shift in the concentration of fish from above to below. The increase in the catch per hour on the lake cannot be assessed until marking and tagging data are analysed. Preliminary evidence from the population estimate program suggests that the increased catch in 1954 was due more to a change in availability of the fish than to a change in abundance.

It was estimated that approximately 40% of the anglers fishing at the lake were contacted. Thus, assuming that those contacted were representative of all fishermen, the total number of fish examined would approximate 40% of the total removal of cut-throat. On this basis it is estimated that, in 1954, anglers took about 1,650 cut-throat from the lake.

Dolly varden. Capture of dolly varden was restricted to the river. The catch per hour was the second highest observed in the 5 years of the creel census. The recorded catches are not true measures of the number of dollies caught; in years when cut-throat catches are good, anglers tend to return dollies to the water, while in years when cut-throat catches are low (e.g., 1954) anglers retain the dollies rather than return home with few or no fish.

Location	Year	Hours fished	Cut-throat		Dolly varden	
			Observed catch	Catch per hour	Observed catch	Catch per hour
River	1950	409.5	574	1.40	20	.048
	1951	382.0	418	1.08	88	.230
	1952	821.5	912	1.11	397	.899
	1953	883	625	0.71	242	.274
	1954	482.5	306	0.64	158	.328
Lake	1950	647	668	1.03	13	.020
	1951	442.5	383	0.82	8	.018
	1952	620	669	1.08	0	0
	1953	415	534	1.29	0	0
	1954	185.5	355	1.93	0	0

(b) Catch figures and population abundance.

Whether or not catch per effort accurately reflects the abundance of fish in the lake depends, in part, on the extent to which factors other than abundance influence catch. Analyses of data on cut-throat catches from 1950 to 1953 were carried out to determine to what extent various factors such as meteorology, gear and skill effect the catch figures. The following conclusions were drawn:

(1) The success of angling was not clearly related to weather, time of day or gear.

(2) The catch per hour of individual fishermen varied greatly. By classifying anglers according to their fishing experience and local knowledge into "good, medium and poor" groupings, it was found that the catches of the "good" anglers were the least variable. From these studies it is felt that the catches of the experienced residents, fishing the lake in a similar manner each year are more likely to reflect changes in abundance than the combined catches of all types of anglers. The average catch of these "good" anglers has remained relatively constant over the period 1950-1952 (average catches per hour: 2.29 in 1950, 2.05 in 1951 and 2.26 in 1952,

no breakdown available for 1953), suggesting that there was no radical change in the cut-throat population during these years.

(c) Rates of exploitation

It was estimated (see Annual Report, 1953) that the catchable cut-throat population of Lakelse during 1952 and 1953 was approximately 20,000 (approximate limits 14,000 to 34,000). In these years the annual removal of trout by anglers averaged 2,100 fish, suggesting a rate of exploitation of about 10.5% (approximate limits 6.2 to 15.0).

PORT JOHN

J.G. Hunter

At Port John, in the central coast area, the operation of a system of counting fences presents an unusually complete picture of the losses occurring at various stages of the freshwater life-history of the sockeye salmon population. Enumerations are made of the number of adults entering fresh water from the sea, the number of adults reaching the spawning grounds, the number of fry moving into the nursery lake and the number of smolts moving to sea two years later. The data, gathered in the past 5 years, have indicated that the rate of production of smolts is, in some years, higher than in any other area previously studied. The biological implications of this finding have yet to be assessed in detail and must await the gathering of comparable material from other areas (e.g., Lakelse Lake, B.C., Bare Lake, Alaska).

A. Adult sockeye salmon escapement, Port John, 1953

Adult sockeye at Port John began their upstream movement in Hooknose Creek on June 18. Hooknose Creek is 1.5 miles long so that the fish need spend very little time in the stream before passing into the lake. The first sockeye entered the main spawning stream, Tally Creek (tributary to the lake), on August 30. Therefore, the maximum time spent in the lake before spawning must have been at least 73 days. Data in the following table suggest that considerable numbers of salmon are lost through natural mortality during this extended pre-spawning period.

	Jacks	Males	Total Males	Females	Total
Hooknose weir count	559				1,279
Computed Hooknose composition	559	256	815	464	1,279
Accounted for above Hooknose weir:					
Through Tally Creek weir	405	163	568	295	863
Estimated spawned below Tally Creek weir	5	15	20	13	33
Estimated spawned in other streams	19	14	33	13	46
Dead at Hooknose weir	2	2	4	2	6
Number accounted for	431	194	625	323	948
Number unaccounted for	128	62	190	141	331
Percent loss	24.66	24.22	23.31	30.39	25.89

It is not possible to determine at the Hooknose Creek weir the sex of those sockeye which enter early in the season; counts at the Hooknose weir distinguish only "jack" salmon from the remainder. The numbers of males, apart from "jacks", and females entering through Hooknose weir are calculated from the ratio of males and females found in Tally Creek at spawning time.

Egg deposition. Eight females were examined for egg content and 108 were examined for egg retention. Thirteen entered Tally Creek but failed to spawn. Deposition and egg loss are shown in the following tabulation:

	Number of females spawned	Average egg content	Potential deposition	Percent egg loss by retention
Tally Creek	274	2,809	769,666	0.73
Remainder of lake	33	2,809	92,697	0.73
Total	307	2,809	862,363	0.73

The total run of sockeye salmon into Port John this fall was about average when compared to runs of previous years. The same percent of the total Port John run entered Tally Creek as in the year previous and the percentage loss of sockeye in the lake is the same as in the previous year.

B. Production of sockeye salmon fry at Port John in 1954

Sockeye fry began their downstream movement from Tally Creek into Port John Lake on April 12 and 95% of the migration was completed by June 10. The time required for egress was a full month longer than in the preceding year. From a potential deposition of 769,666 eggs in Tally Creek in 1953, 103,040 sockeye fry emerged to pass downstream. This production from Tally Creek constituted a 13.4% survival which, though not the greatest survival recorded, is considered high.

The total production of fry for the whole lake area, based upon this percentage survival, was 115,450 fry. Mortality from fence operations removed 489 of these fish, leaving an estimated total of 114,961 sockeye fry in Port John Lake.

This number of fry is the largest yet recorded entering the lake.

Stream temperature and water-level readings are available for the period of fry migration.

C. Sockeye smolt production at Port John in 1954

Sockeye smolts commenced their downstream movement through Hooknose fence on April 12, reached a peak near May 10 and completed their egress by June 10. A count of 19,483 smolts was recorded. Before assigning the smolts to the appropriate brood-year egg deposition and fry release, the ages must be determined. This is now underway.

Of the total smolts, 31 were killed by fence operations, and 101 marked fish and 189 smolts for age analysis were removed from the run. A total of 19,162 smolts was released to sea.

In the spring of 1952, 5,075 sockeye fry were marked by the removal of the two pelvic fins to confirm the reading of 1- and 2-year scales. The returns of marked fish from this release are as follows:

Year	Age	Number of marks recovered	Percent of all returns
1953	1	21	4.03
1954	2	500	95.97

These 521 mark recoveries constitute a 10.3% survival from the 5,075 marked fry. It has been shown from both scale reading and length frequency distribution that the greatest part of the Port John smolt run is made up of 2-year-old smolts. Survival of unmarked fry to age II smolts varies from approximately 30 to 60%. This suggests an additional mortality has been incurred by marking the fry.

SOCKEYE SALMON SAMPLING

D.R. Foskett

This study continues the analysis of samples taken each year from the Nass River, Skeena River, Rivers Inlet and Smith Inlet sockeye salmon catches which was begun by the Provincial Fisheries Department in 1912. The age and size composition are determined each season, and also the sex ratios, to build up a very useful series of data on the changes in the composition of the catch from year to year. For the Rivers Inlet area a special study is being made of the composition of the spawning escapement to determine in what respects the gill-net fishery may be selective and influence the perpetuation of the populations. A survey has also been made, for the last few years, of the size of the escapement and its distribution to the many spawning areas in and tributary to Owikeno Lake. The Rivers Inlet area represents a sockeye-producing region as yet little affected by logging, etc., and in that respect represents an opportunity to follow the effect on salmon streams and on salmon production of removal of the forest cover, whenever that commences.

A. Sockeye salmon catch sampling

The analysis of the 1953 catch samples has been completed and paper No. 39 in the series "Contributions to the Life History of the Sockeye Salmon" has been prepared and submitted to the British Columbia Department of Fisheries for inclusion in their Annual Report for 1953. An outline of the information given in this paper is presented below. The 1954 samples have not yet been completely analysed. Data on the percentage of the various ages in the samples, however, are included for comparison.

1. Nass River sockeye

A total of 1,694 sockeye was sampled from the 1953 Nass River sockeye catch of 18,162½ cases. Of these 45.7% were in the 5_3 age-group, 22.8% in the 4_2 age-group, and 21.5% in the 5_2 age-group. These figures agree fairly well with those of 1952 when the respective percentages were 46, 28, and 19 and are not too far from the averages for the previous 10 years which were 52%, 22% and 13% respectively for the 5_3, 4_2 and 5_2 age-groups.

The 1953 sockeye were relatively large, the 5_3 fish coming very close to the largest recorded since 1941 in both length and weight in both sexes. The 4_2 male fish equalled the length records and exceeded the weight records of the previous 12 years while the female fish of the same group, though slightly under the previous length records, exceeded the average weight records for the same period.

The sex ratio was fairly normal, the percentage of males being 46, 50, and 44 in the 5_3, 4_2 and 5_2 age-groups respectively.

The 1954 sockeye samples in the Nass River area consisted of the same three main age-classes in the same order of relative abundance. They varied only slightly in the percentage of abundance, the percentages being 40.1, 35.0, and 20.1, respectively, for the 5_3, 4_2 and 5_2 age-groups.

2. Skeena River sockeye

The 1953 Skeena River sockeye sample consisted of 2,121 fish from a catch yielding 65,003 cases. This catch was approximately 5,000 cases below the average for recent cycles. Two age-groups, 4_2 and 5_2, formed 90% of the catch sample, the former being 48.0% and the latter 42.8% of the total. These percentages show a variation from the average situation, the percentages for the previous 10 years averaging 34% 4_2 fish and 62% 5_2 fish. In length the fish compared very favourably with those of previous years, exceeding length records of the past 12 years except for the 4_2 males, which were exceeded only by 0.1 inch by the 1952 sample. In average weight the fish in these two age-classes exceeded the samples of the past dozen years.

The 1954 Skeena River sockeye sample was very similar to that of 1953, the two dominant age-groups again being the 4_2 and 5_2 groups and the percentages being the same as in 1953, namely, 48 and 43 respectively.

3. Rivers Inlet sockeye

The Rivers Inlet sockeye catch in 1953 was mainly the return of the 1949 spawning, 73% of the sample being 4_2 age-group fish and 26% being 5_2 age-group. The catch of 132,925 cases, the fifth largest for the area, was the result of a very heavy spawning since the poor catch of 39,495 cases in the cycle year, 1949, was a reflection of poor weather conditions affecting the fishery rather than of a poor run. The 4_2 fish were fairly large though less than the averages of the same group in 1951 and 1952. However, the 5_2 sockeye in the sample exceeded the records of the past 12 years in both length and weight. Sex ratios again showed the prevalent trend of this and the Smith Inlet area in that males were in excess in the 4_2 age-group and females in the 5_2 age-group. Though it does not show up in the commercial catch records, spawning-ground surveys reveal that in some years at least, large numbers of males mature at 3 years of age.

The 1954 catch sample was composed of 59.8% 4_2 fish and 38.8% 5_2 fish, indicating that the main return was from the 1950 spawning and the bulk of the remainder came from the 1949 spawning. The 1950 spawning was largely 5-year-old fish whose progeny may be expected to return chiefly as 5-year fish in 1955. The 1949 spawning was predominantly 4-year fish whose progeny, returning in 1953, were chiefly responsible for the large pack in that year. Thus, with no large segment of either population due to return in 1954, the result was the small run experienced this year.

4. Smith Inlet sockeye

The 1953 Smith Inlet sockeye sample was comprised of 89% 4_2 age-group fish and 10% 5_2 age-group fish. As in the Rivers Inlet area, the 4_2 fish were fairly large but did not make any records while the 5_2 age-group either equalled or exceeded the length and weight records of recent years for both sexes. This would suggest that oceanic conditions are similar in the feeding areas of both these large central area runs.

The 1954 Smith Inlet sockeye sample was also dominated by 4_2 age-group fish but the percentage of 60.7 was considerably lower than that of the 1953 sample. The 5_2 group was represented by 37.9%.

B. Rivers Inlet area - special studies

Scouring conditions due to heavy rains and consequent flash floods in the Rivers Inlet area during the spawning survey trip in 1953, though not severe enough to affect the redds, did reduce the number of spawned-out fish available for sampling on certain streams and thus satisfactory comparisons of catch and escapement could not be made. Plankton samples were obtained, however, for study of lake productivity, and for comparison with other sockeye nursery areas.

Sockeye runs in the Rivers Inlet area are often dominated by one age-class in both the catch and escapement, this situation being particularly noticeable in the very large runs which have resulted in catches of over 100,000 cases. These runs tend to perpetuate themselves, those dominated by 4-year-old fish returning in 4 years and those dominated by 5-year-old fish returning in 5 years. This seems to indicate that the age of maturity of these sockeye has a genetical basis. In addition, the fact that the majority of large runs in the Rivers Inlet area are predominantly of one age-class would suggest that perhaps there is a greater percentage survival of eggs when both parents are of the same age than when they are of different ages. A small experiment was initiated in the Rivers Inlet area this fall to test this hypothesis; it could not be carried out in duplicate, however, as originally planned. Spawnings of each age-group were made, together with reciprocal crosses. The eggs were placed in baskets and buried in the gravel of one of the streams. Results will be determined by the percentage of eggs hatched.

P I N K A N D C H U M S A L M O N - F. Neave

PINK AND CHUM SALMON - F. Neave

As was stated in last year's report, the work of this investigation is mainly directed to establishing facts, principles and prodecures which can be used (a) in diagnosing the biological condition of a fishery; (b) in determining the effectiveness and feasibility of remedial or improvement measures; and (c) in prediction of abundance from year to year or over longer periods.

In recent years these studies have been mainly carried out at field stations located at Nile Creek on Vancouver Island, and at Port John near Ocean Falls. During 1954 the Nile Creek field station was closed since it was felt that it had substantially fulfilled its original objectives and that the freeing of personnel and funds would permit a broader attack on problems which are regarded as particularly important.

One such problem is represented by the recurrent question: What constitutes an optimum, or at least a desirable escapement of salmon? It is felt at the present time that information in this field can be accumulated more rapidly by comparative data from streams with different densities of spawning populations than by an intensive study of a single locality. Another long-standing problem is the non-occurrence of pink salmon in alternate years in certain important fishing areas and the lack of clear understanding as to the cause of this absence and the possibility or otherwise of remedying the situation.

A contribution to the former problem can be expected from the appearance at Port John in 1954 of an escapement permitting examination of much higher densities of spawning fish than have hitherto been under observation at this station. An experimental introduction of a missing cycle of pink salmon is being made in a tributary of the Fraser River. Neither of these projects is reported elsewhere in the present account, since the initial field work is only now in progress.

In the present report, the year's activities have been grouped into four categories, the two field stations being separated from studies which are not or are only in part carried out at these places. The categories are artificial, since major contributions to "Spawning Ground Studies" have been made at Nile Creek and Port John and "Applied Studies" also make use of information derived from these sources. Individual investigators have spent varying periods at the field stations and elsewhere, their work being distributed as seemed in best accordance with the general objectives outlined in the first paragraph above.

An extension of the pink and chum salmon investigation to include a limited programme of "Ocean Studies" was proposed for 1954-55. This was to have included observations on the distribution and growth of young salmon after reaching the sea and on the selective effects of the fishery on the maturing fish. Limitations of funds and personnel prevented adoption of this project.

NILE CREEK — W. P. Wickett

This field station on the southeast coast of Vancouver Island was operated from September 1945 to July 1954. Data on the freshwater survival of chum and pink salmon have been recorded for the natural populations and

for eggs in an area protected from water fluctuations. Large changes in water flow can take place because of the nature of the watershed. The lower two-thirds of the Nile Creek watershed was logged from 1932 to 1938 by the large, clear-cut method. In 1938 a severe fire destroyed old vegetation on the logging area. The area is now fully reforested with trees 6 to 8 feet high from 1941 and 1945 seedlings.

The program of assessment of natural survival acts as a control for studies on incubation improvement. A change from the previous years was made in 1953. Adult salmon were carried in fry cans from the weir to the controlled-water section so that the eggs could be planted by the fish. The experiment was not carried out as planned because the supply of fish was very small and bears removed completely both live and dead fish. However, useful information on survival at a low spawning intensity and on spawning behaviour was obtained.

A. Adult studies, 1953

Both pink and chum runs showed very small ocean survival. The pink run replaced itself but the chum run was only 44 fish. The coho run of 524 fish was the second largest to date.

The female pink salmon were very small and some escaped through the pickets of the trap. Counts of live and dead fish indicate that an estimate of 48 females would be the maximum.

Data on 1953 survival in the sea and egg deposition are as follows:

	Brood year migrants	Adult return			Ocean survival %	Egg count per female	Egg deposition	
		Male	Female	Total			Natural	Protected
Pink	51,038	58	48*	106*	0.23	1800*	48,600	37,800
Chum	32,747	30	14	44	0.13	2500*	22,500	5,000
Coho	5,950	284	240	524	8.8	2900	702,000	-

* Estimated

B. Fry studies, 1954

For the third consecutive year winter conditions were favourable with no extremes of temperature or discharge. The combination of favourable conditions and lack of competitors for spawning sites explains the high survivals recorded.

The protected pink salmon eggs (i.e., from fish spawning in the controlled-water section) were deposited in very unfavourable, dirty and compacted gravel. The corresponding chum eggs were deposited in loose relatively clean gravel. The salmon were removed by bears after most of them had spawned, so that the interference was not too great. Three of the pink salmon died unspawned and this loss is accepted in the production percentage though not in the emergence percentage.

The coho fry counts have little meaning since there is no complete migration through the weir at this stage, but the yearling migrants count is again apparently related to rainfall.

Data on 1953-54 freshwater survival are as follows:

	Eggs available in 1953	Percent emergence	Migrants: Live	Migrants: Dead	Migrants: Total	Percent survival during migration	Percent output
Pink							
Natural	48,600	38.4	14,422	1,322	15,744	61.1	32.5
Protected	37,800	14.5	3,933	16	3,949	84	10.5
Chum							
Natural	22,500	29.3	3,048	12	3,060	46.2	13.6
Protected	5,000	49.2	2,013	7	2,020	82	40.4
Coho			Yearlings				
Natural	702,000		6,994	-	6,994		0.75

C. Preliminary findings from Nile Creek chum salmon studies, 1945-53

A study of Departmental reports and an examination of meterological records indicated floods in brood years could be the cause of large reductions in subsequent populations. Therefore, two methods of protecting eggs during the time of maximum floods were devised. In the first procedure, eggs were eyed in "drip-incubators" and then planted in the main stream above a counting weir. In the second, "green" eggs were planted in a controlled-water-flow section of gravel. Natural reproduction above a counting weir at the head of tidal influence served as a control as well as giving information on the level of freshwater survival in this stream.

Preliminary findings are:

1. The movement of chum salmon into the stream is influenced by strong onshore southeast winds and by rise of water, though the reaction to rise of water is not so marked as that of the coho salmon.

The percentage of chum reaching the second fence is related to the mean gauge height during the migration (October-November).

2. From natural spawnings, 1945-52, the percentage production (or survival from deposition to migration) has been 0.08-7.0%. It varied with the percentage survivals during the pre-eyed stage, for the four years that data are available.

	Percent survivals	
	To eyeing	To migration
1949	0.69	0.08
1947	2.2	0.38
1946	8.2	0.40
1948	87.0	6.03

The survival to the eyed stage has been calculated, knowing the survival of planted eyed eggs and the survival of naturally-spawned eggs for the full period. The survival for the later stage of both sets of eggs is assumed to be similar. The planting of eyed eggs was discontinued after 1949.

The importance of survival to the eyed stage in determining the subsequent output of fry has led to a study of the oxygen supply to eggs during their early development. The main demand of the pre-eyed egg on its environment is an adequate supply of oxygen. A report now in press on this phase shows that inadequate oxygen supplies can exist in the gravel.

3. The survivals from the eyed stage to emergence from the gravel have been 18% to 31%.

4. The survival of the fry from predators during downstream migration has varied from 35% to 62%.

5. Survival in the sea has varied from 0.40% to 1.8%.

6. Survival to emergence is greater in gravel that is protected from fluctuating water discharge, as shown below:

	Percent emergence
Natural	0.21-18.0
Pre-eyed stage in hatchery; remainder in natural stream	2.1 -17.4
Full period in controlled section	5.1 -25.7

7. Freshwater survivals were very low but have improved. Survival in the sea has been too low to compensate for the low freshwater survival. This might suggest that reduced fishing effort is required.

D. Observations on pink salmon behaviour

1. Spawning

The actual spawning of Pacific salmon has seldom been observed and conflicting views have been expressed regarding the behaviour of the fish at this time. At Nile Creek the deposition of eggs and milt was clearly observed from a distance of 6 feet. In the controlled-water section a

partially blind female was paired with a mate also partially blinded by fungus. Because deposition has not been seen in daylight to the writer's knowledge, it is assumed that reduced light is normally required for the act.

No eggs or milt were observed in over an hour's close observation while standing in the stream (1,500-1,600 hours). The male would attack a stable-broom when it was moved within 3 feet of the female. The female carried out digging around the periphery and in the centre of the redd, frequently passing under the male after digging. A few eggs were dropped incidentally during digging. A large male with normal vision became the dominant male with increasing familiarity with observer and broom. The latter was made to simulate the actions of a dominant male. The sighted male was driven off easily but a quite violent blow was required to drive off the partially-blinded male. The dominant male was inclined to hold over the redd regardless of the wanderings of the female. After about an hour and a quarter, the female made a few slow upstream passes through the centre of the redd. Suddenly the female and 6 males (including the partially-blinded one) sank into the deepest part of the redd and a dense cloud of milt was ejected by the males. Eggs were briefly roiled up in it. After a brief milling, the procedure was repeated. The pattern of generalized digging by the female, and fighting amongst the males was then resumed.

2. Fry migration

At night, migrants were observed and timed swimming downstream in the surface film of that portion of the stream illuminated upstream from the fence. They followed the path of the fastest moving water, water speed 0.5 ft./sec. Fry speed observed was 2.0 ft./sec. or 1.5 ft./sec. in excess of current. In addition, marked fry released 400 yards upstream at 2,200 hours were dipped out of the water as they approached the fence 10 to 20 minutes later.

In daylight, between 0625 and 0715 P.D.T., a school of 11 pink fry that had been prevented from entering the migrant trap was observed to swim upstream into the fastest part of the current, where the velocity was 0.5 ft./sec.

The cruising speed at a temperature of 6-7° C. was calculated as follows:

Distance fry moved upstream over the bottom	= 170 ft.
Time taken 0625-0715 P.D.T.	= 3,000 sec.
Water speed = 0.5 ft./sec.	= 1,500 ft./3,000 sec.
Cruising speed of fry = 1,670 ft./3,000 sec.	= 0.56 ft./sec.

PORT JOHN — J.G. Hunter

The Port John field station is continuing to provide increasingly useful data on the relation between salmon abundance and freshwater conditions. The advantage which it holds over the Nile Creek station (except in relation to the effects of extreme water levels which the latter was set up to examine) is due to the larger size of the salmon runs and the greater variety of species. In addition to providing a quantitative record of changes in the local salmon populations, Hooknose Creek is being used as a testing ground for widely applicable methods of sampling and estimating populations of adult and juvenile salmon.

It should be pointed out that work of the Port John personnel, directed by Mr. J.G. Hunter, is not confined to pink and chum salmon and that certain aspects are reported under "Sockeye Salmon" and "Experimental Biology".

A. Adult studies

Adult pink and chum salmon migration at Port John, 1953

The pink and chum salmon run occurred in Hooknose Creek at the same time as it has in previous years, creek water levels controlling the upstream movement to a large extent. A summary of the statistics gathered during the course of the migration is shown in the following table:

Species	Number of adults	Percent female	Average egg content	Potential deposition	Percent loss of eggs by retention
Pinks	1,599	55.60	1,672	1,464,672	0.12
Chums	4,355	51.21	2,741	6,016,495	0.66

Average egg content and retention for pink salmon was based on 11 and 43 samples respectively, and for chum salmon 35 and 37 samples respectively.

Meteorological, stream discharge and water temperature readings were made twice daily.

The numbers of pink salmon returning in 1953 were far below the number expected. The 1,599 pink salmon constitute an ocean survival of 0.67% from fry escapements while all returns from previous fry releases gave ocean survivals over 3.0%. Commercial fishery statistics suggest increased fishing intensity could have been responsible for this low ocean survival.

Chum salmon entering in 1954 constitute the second largest run recorded in the creek. The escapement is considered to be good and is the result of many 3-year-old fish returning from the large fry escapement in the spring of 1951.

B. Fry and smolt studies

1. Output of pink and chum fry from Hooknose Creek, 1954

The downstream weir on Hooknose Creek was installed March 24, which is about the same time as in previous years. The pink and chum fry were just beginning their seaward migration. The peak of their migrations occurred at the end of April for pink salmon and the first week in May for chum salmon. The output of fry in relation to the egg deposition is shown in the following tabulation:

Species	Average egg content	Potential deposition	Number of fry	Percent survival
Pinks	1,672	1,464,672	204,250	13.9
Chums	2,741	6,016,495	984,504	16.4

A good correlation exists between percent survival of pink and chum fry and October water discharge. The continued operation of Port John is building up a body of statistics permitting comparison and correlation of different survival values and the factors controlling these values. Data in the following two tables permit comparison between results of the different years of operation of the Port John field station.

Pink salmon - Hooknose Creek

Year of spawning	Spawning stock	Fry produced	Percentage survival Freshwater	Ocean
1947	5,576	33,349	0.9	5.2
1949	1,173	54,061	6.4	3.2
1951	1,670	242,993	16.4	0.7
1953	1,599	204,250	13.9	-
1948	1,160	64,312	8.2	3.1
1950	1,857	234,396	15.1	3.7
1952	8,685	1,227,025	14.4	-

Chum salmon - Hooknose Creek

Year of spawning	Spawning stock	Fry produced	Percentage fresh-water survival
1947	10,191	108,746	1.0
1948	1,022	77,539	7.4
1949	718	44,463	6.2
1950	2,382	431,399	15.1
1951	1,329	269,701	16.9
1952	871	182,200	19.4
1953	4,355	984,504	16.4

Since chum salmon spawn at different ages, ocean survival cannot be readily ascertained from a known fry release. A marking experiment on chum salmon of the 1947 year-class showed an ocean survival value of 2.6%. An average ocean survival for chum salmon can also be shown by the sum of the adult returns in the years 1951, 1952, and 1953 based upon the sum of the fry escapements of 1947, 1948, and 1949 year-classes. This calculation suggests an average ocean survival of 2.8%. This survival may be considered as higher than actually occurred since the 3-year-old returns from the low and partially marked fry escapements of 1948 have not

been included while the three-year-old returns from the large fry escapement of 1950 are included.

Pink salmon ocean survival is slightly more than chum survival when returns from the 1951 year-class are not considered. Evidence suggests that heavy fishing may have markedly affected the normal return of this year.

2. Sampling for pink and chum salmon fry, Port John, 1954

An effort to evaluate the efficiency of small nets in capturing a sample of the migrating pink and chum fry was made at Port John this spring.

A series of five nets (fyke type) with openings 1 ft. x 2 ft. were placed at intervals across the stream. These nets covered one-third of the stream width to a depth of one foot. Calculated on the basis of water volume these nets covered 36% of the stream.

Correlation of net catches and fence count gave highly significant results for single net catches of both pink and chum fry.

The different nets did not capture fry in the same ratio as volume of water passed by each net. Nets near mid stream caught more fry. The relative catches of different nets, although showing a variance, tended to maintain the same distribution throughout the migration.

Pink and chum fry both showed the same behaviour in relation to depth in their downstream movement. The top 3 inches of water carried 65% of the fry, the top 6 inches 85% while the top 9 inches carried 95% of the migrating fry.

A slight time difference between pink and chum fry was noted in their daily downstream movements. Neither species began their egress until dark and then the pink fry preceded the chum fry by about one-half hour.

The nets covered a total of one-third the stream width, suggesting a factor of 3.00 for ascertaining total fry run from the net catches. The results actually obtained gave a factor of 3.15.

3. Coho studies, Port John, 1954

The small run of coho salmon that enters Hooknose Creek cannot readily be dealt with in a manner comparable to the studies of pink and chum salmon. Coho salmon fry continue to pass downstream after the fry collecting weirs have been removed and replaced by the adult fence used for trapping the mature pink, chum and sockeye salmon. Although it is not possible to measure the survival from egg to fry nor from fry to smolt stage in the coho, some measure of egg to smolt and smolt to adult is possible. In the spring of 1954, 5,987 smolts were counted out of Hooknose weir from a calculated potential deposition of 573,648 eggs. This constitutes a survival from eggs to smolts of 0.958%. Survivals from 1949 to 1954 range from 0.645% to 2.152%.

From a release of 3,620 smolts in 1952, 106 jack coho returned the same fall and 189 mature three-year-old fish in the fall of 1953. This made a total return of 295 adults or an ocean survival of 8.14%. Ocean survival of smolts from 1946 to 1952 has ranged from 19.09% to 3.79%.

SPAWNING GROUND STUDIES

W. P. Wickett

As pointed out in the Nile Creek studies, pre-eyed losses seem to determine the population size of chum salmon. The oxygen supply has been shown to be inadequate in certain portions of the gravel where pre-eyed eggs have died. Data have been gathered on two phases of the problem, (a) lethal concentration of O_2 for hatching chum eggs, and (b) development of a satisfactory model of standpipe for sampling the gravel water for oxygen concentration and determining the hydraulic head and permeability in the gravel at the depths that eggs are deposited.

The results referred to above are reported in the sections under "Experimental Biology" and "Oceanography" as the major portion of the work was carried out by these groups.

APPLIED STUDIES

In 1953 two projects were undertaken by the investigation in response to wishes of the Industry and the Department of Fisheries.

The results of these undertakings became known in 1954 and in the case of one of them represented the main work of an investigator during the latter year.

A. The 1952-54 pink salmon cycle in the Queen Charlotte Islands

F. Neave

In the spring of 1953 an attempt was made to evaluate the fry-migrant production resulting from the heavy escapement of pink salmon which occurred in the Queen Charlotte Islands in 1952 (see Annual Report, 1953). Fry runs were sampled during the period of downstream migration in a number of streams in the Masset Inlet and Skidegate Channel areas. The opinion was expressed that the fry output was sufficient to produce another large run of adults in 1954 unless marine conditions proved to be unusually unfavourable.

On the basis of the catches made during August and September, 1954, it appears that the anticipated large run failed in part to materialize. In the west central area of the Islands catches were greater than those of the parent year. In other areas they were much lower.

The total magnitude of the 1954 run will not be known until the size of the spawning escapements to the various streams has been reported. If the escapements confirm the pattern shown by the catches the marked difference in survival between closely adjacent areas will merit further study. It is recognized that ocean conditions subsequent to the seaward migration of young fish can be responsible for discrepancies. It is also possible that some or all of the Queen Charlotte Island stocks of fish normally require a higher percentage output of fry to maintain their numbers than do the fish of the areas from which ideas of reproductive sufficiency have been largely derived.

That there is considerable validity in the principle of forecasting adult runs from fry output was shown again at Port John this year, where the advent of a record run of mature fish was accurately anticipated from the numbers of fry observed in 1953. It is felt that further study can rather rapidly improve the usefulness of this prediction technique.

B. Pink and chum salmon tagging experiments in Johnstone Strait and Discovery Passage, 1953

J. I. Manzer

At the request of the Department of Fisheries, pink and chum salmon were tagged in 1953 in Johnstone Strait and Discovery Passage to determine (1) the destination and migration period of the different stocks migrating through these waters, (2) the intensity of fishing to which each was subjected, as compared with earlier years, (3) the catch in Johnstone Strait and Discovery Passage of fish migrating to various fishery administrative areas, and (4) speed and pattern of migration. In Area 12 (Upper Johnstone Strait) tagging of both species was carried out mainly near Alert Bay; in Area 13, in Discovery Passage. Since tagging in each area occurred during the period when 99% of the total seasonal catch was made, it is unlikely that any major runs were omitted from the tagging. The method of conducting the experiments was outlined in this Station's 1953 Annual Report (page 63). Locations or areas referred to in this report are shown in the accompanying figure.

Pink salmon. A total of 3,448 pink salmon were tagged: 1,663 in Area 12 and 1,775 in Area 13. Recoveries made outside the tagging areas indicate that migration was mainly to the east and southeast. All major mainland inlets and sounds from Loughborough Inlet to Puget Sound yielded tags, with the Fraser River producing the greatest number. Limited migration occurred to the east coast of Vancouver Island.

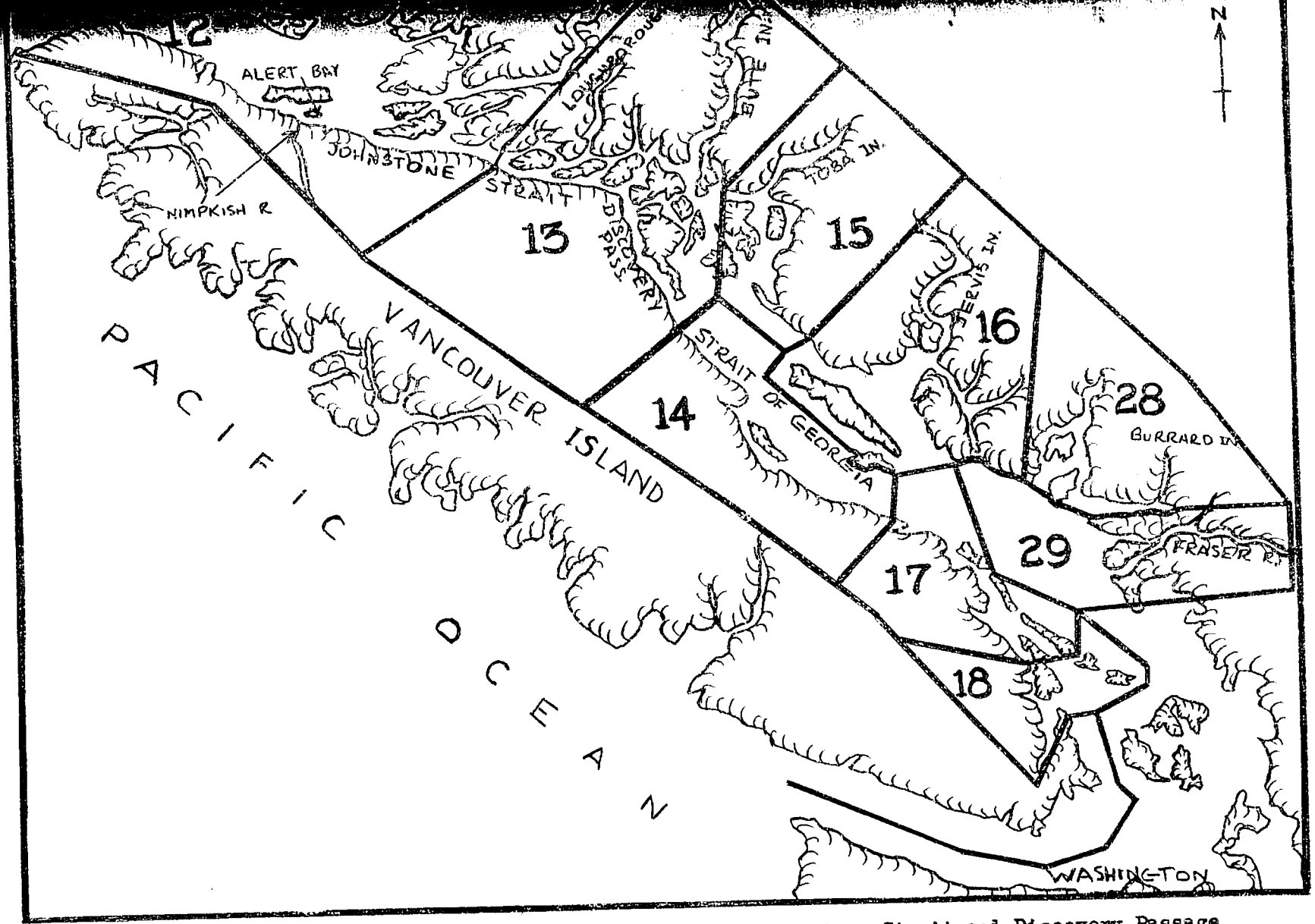
The migration period of the different stocks through Johnstone Strait and Discovery Passage overlapped to a considerable extent. From late July until early September all stocks were present, the important ones being those to Area 28, Area 16, Washington and the Fraser River. After early September and until early October only Fraser River fish were found.

Recoveries of fish tagged in Areas 12 and 13 amounted to 45% and 33% respectively. A comparison of these rates with those for 1945 indicates that the fishing rate for Area 12 fish has not changed appreciably, while that for Area 13 fish has increased from 26% to 33%.

During the main pink salmon season, fish migrating at the beginning and end of the season were exploited less heavily than those migrating during mid-season.

The catch of pink salmon in Johnstone Strait and Discovery Passage during tagging amounted to 4,858,000 fish. On the basis of tag recoveries the division of this catch according to the presumed destination of the fish was estimated to be:

Stock	No. of fish	Percent
Area 13 Inlets	383,000	7.9
Area 14	39,000	0.8
Area 15	55,000	1.1
Area 16	866,000	17.8
Area 18	37,000	0.8
Area 28	408,000	8.4
Area 29	2,381,000	49.0
Washington	689,000	14.2
Total	4,858,000	100.0



Tagging and recovery areas of pink and chum salmon in Johnstone Strait and Discovery Passage

Since these estimates cannot be corrected for the catch of fish migrating to streams in Area 12 and Area 13, nor for fish recovered in an area while migrating southward, they are too high for northern stocks and too low for southern ones. However, they indicate the predominance of the Fraser River fish in the Johnstone Strait and Discovery Passage catch.

A study of the rate of travel indicates that, in general, the average time between tagging and recovery increased with the distance between the two points. It was again found that Fraser River recoveries were made later than those in adjacent areas immediately to the north and south, supporting the belief that fish to that area remain off the mouth of the river before resuming migration.

Chum salmon. A total of 2,604 chum salmon were tagged: 894 in Area 12 and 1,710 in Area 13. Tags recovered outside the tagging areas indicate that migration was to the east and southeast, with 81% of the recoveries being returned from the mainland coast and 19% from the east coast of Vancouver Island. Along the mainland, all fishery administrative areas yielded tags, but Area 29 produced the greatest number. Area 16 yielded the second highest. Along the east coast of Vancouver Island recoveries were mainly obtained from Area 14 and Area 17, with the latter producing the greatest number. Of the 9 tags taken to the west of the tagging locations, 2 were recovered from the Nimpkish River area.

Several stocks of chum salmon migrated through Johnstone Strait and Discovery Passage at the same time. Bute Inlet, Toba Inlet, Washington, and Fraser River fish appeared first during the latter part of August. During mid-September these runs were augmented by runs to the east coast of Vancouver Island. Towards the end of September and early October runs to Burrard Inlet and Jervis Inlet appeared. With the exception of the Burrard Inlet run, all runs were present on the tagging grounds when fishing terminated on November 3rd.

Since 1945 the total rate of exploitation of fish tagged in Area 12 has increased from 34% to 47%, and for Area 13 fish from 22% to 36%. The increase in the rates for each area amounts to 38% and 64%, respectively. The increase in exploitation of Area 12 fish was mainly due to the heavier fishing in Area 13 and in the Strait of Georgia. In the Strait of Georgia the greatest increase occurred in Area 16, while the rate in Area 29 remained relatively constant. The increased rate in 1953 for Area 13 fish was due to the increase in fishing throughout the Strait of Georgia generally, but especially in Area 16 and Area 29.

Chum salmon migrating during the early and late parts of the season were not exploited as heavily as those during mid-season.

The catch of chum salmon in Johnstone Strait and Discovery Passage totalled 1,513,000 fish. The division of this catch according to various stocks was estimated to be:

Stock	No. of Fish	Percent
Area 13 Inlets	26,000	1.7
Area 14	130,000	8.6
Area 15	35,000	2.3
Area 16	313,000	20.7
Area 17	140,000	9.3
Area 18	32,000	2.1
Area 28	143,000	9.4
Area 29	667,000	44.1
Washington	27,000	1.8
Total	1,513,000	100.0

Predominance of the Fraser River fish is again indicated.

The pattern of migration for chum salmon was found to be similar to that for pink salmon.

A summary of the results of the experiments which were thought to be of administrative significance was prepared and forwarded to Fisheries Department personnel whose districts are particularly involved. The experiments will be reported on fully in the Board's Bulletin series.

EXPERIMENTAL BIOLOGY - J.R. Brett

E X P E R I M E N T A L B I O L O G Y J.R. Brett

The main theme of research in Experimental Biology involves contributing to a solution for safeguarding the passage of migrating salmon around obstructions, particularly those created by the use of water for power. Examination of the problem indicated that a fruitful path of investigation lay in determining how salmon could be effectively directed in their freshwater migrations, such that their safe passage could be ensured. Basic information of this nature is scant.

Investigations on young salmon have been conducted in a large experimental trough in which a variety of guiding techniques could be readily tested. From this study has emerged a possible system of directing sockeye migrants by the use of a curtain of hanging chain. Efforts have been concentrated on defining the most effective conditions of operation by further testing within the trough, and a major effort has been made to translate the trough findings to actual field conditions. This latter has been attempted by the construction of a prototype chain deflector in the Lakelse River. Work on the adult migration has involved investigating the effect of odours on the upstream movement of coho and chinook salmon. The discovery that some odour emanating from the skin of mammals had a repellent effect, even at extreme dilutions, was of considerable significance. The possible use of a concentrated repellent to disperse salmon away from potentially dangerous areas is evident. In conjunction with the Fisheries Experimental Station at Vancouver, attempts to isolate the active ingredient and to test it for sustained activity have currently been undertaken. This olfactory response has pointed up the need for more generalized studies on sensory perception in salmon. It is most desirable to obtain information on attractive odours.

The second theme of research is concerned with defining the significance of the physical and chemical elements of the environment to survival and distribution of fish. Laboratory experiments on the minimum oxygen requirements of chum salmon eggs, on the salinity tolerance of young sockeye, and on the toxicity of various pollutants have been undertaken.

EXPERIMENTS ON GUIDING DOWNSTREAM MIGRATING SOCKEYE YEARLINGS - J.R. Brett and D.F. Alderdice

The investigation of how to guide young sockeye during their downstream migration was commenced at Lakelse Lake in 1953. By the use of a large experimental trough and by testing a variety of potential deflectors, it was discovered that chain hung vertically in the form of a "curtain" was an effective deflector when the interval between strands of chain did not exceed 4 inches. These tests were conducted at an angle of 45° to the flow.

An expanded program of investigating this means of guiding young sockeye was conducted during the 1954 sockeye migration. Questions concerning the type of chain, the angle of deflection, the cause of deflection, possible benefits resulting from vibrating the chain, and the effect of rate of flow, needed to be investigated. Most important of all was the question of whether the method would work under actual field conditions with normal-run migrants, unhandled and unconfined within a trough. To test this latter relation a hanging chain deflector, 56 feet long, was built at a 45° angle to the upstream face of the Lakelse River counting weir. A hand-driven vibrator was designed and coupled to the aluminum tubing which carried the suspended chain. This deflector was located in such a manner as to influence the fish which would normally move into Pen I of the weir and guide them into Pen II.

A. Results of the trough experiments.

(1) Complete confirmation of the 1953 trough results was obtained. Experimentally, a schooling species of young salmon (e.g., sockeye) can be guided by a row of hanging chain. A non-schooling species (e.g., coho) does not respond in the same manner.

(2) The angle of deflection was found to be very important. The maximum angle which still results in high deflection (for flows of 0.5 ft. per sec. and less) appears to be about 57° to the direction of flow. Beyond this angle, effectiveness is progressively reduced for unvibrated chain.

(3) The type of chain is not important.

(4) The response is dependent mainly upon vision. Light sufficient for vision appears to be possible for these fish at very low levels of intensity (considerably below an incident intensity of 0.001 foot candles).

(5) The effectiveness of a given interval of chain is increased when vibrated (144 r.p.m., 3-4 inch stroke). The sight of a moving object is apparently a greater stimulus in causing deflection.

B. Results of the river deflector experiments.

The results from these experiments were quite clear in some instances and conflicting in others. The possibility of such confliction became apparent before any experiments were conducted. Despite the fact that the deflector was built at a 45° angle to the face of the weir, the presence of a new abutment built in the river bank to carry the vibrator, and a natural upstream constriction in the river flow, resulted in a current flow almost at right angles to the line of deflection. This placed the new deflector in the position of a face-on block, not, as intended, as a guiding influence, causing the fish to angle off downstream in a manner comparable with the 1953 trough experiments. Trough tests conducted immediately placed us in the uneviable position of correctly predicting that such a combination would not work. This rather surprising angle of flow had its more fortunate aspects. If it were possible under these adverse conditions to achieve a measure of deflection, and to relate this to the trough experiments, clarity of the field problem would result.

Limited consideration of the data collected supports these conclusions:

(1) Unvibrated, illuminated chain placed directly in the path of migrants has nothing but momentary influence on their continued progress downstream.

(2) Good deflection can be achieved with sockeye if the chain is vibrated (4-inch interval between strands, 4-inch stroke, 144 r.p.m.) and the flow does not exceed 0.5 feet per second.

(3) Much of the initial deflection can be lost if attractive, alternative downstream paths are not presented to the fish. Repeated experiences along the deflector resulted in the breakdown of clost schooling and penetration through the curtain of chain.

(4) As flow increases above 0.5 feet per second the effectiveness of such a block is reduced. The constant "pressure" of the current results in the fish moving into direct contact with the chain and, despite being actually struck by the moving links, they pass through the interval between strands.

The results of these direct field tests have been most beneficial in providing experience in the real problem - directing natural-run migrants, free from the relative simplicities and oddities presented in an experimental trough. The latter provides the ideas and possible techniques, but not the answers. It is now apparent that deflection in the trough is readily achieved because the alternative path, away from chain and into the other half of the trough, is both attractive and within the visual range of the fish. No such relation exists where 56 feet of hanging chain is faced. and that much less if it were 560 feet.

In the field the presence of many other fish, steelhead, dolly varden and suckers, sometimes sent the young salmon darting in all directions, oblivious of any deflector.

It is only possible to speculate on the success of a similar type deflector operating under the specified conditions now set forth, namely, illuminated, vibrated, not more than an angle of 57° to flow when that does not exceed 0.5 feet per second, and coupled with an attractive alternative route. It is our opinion that these conditions are not particularly difficult to meet. Research on attractive openings must be commenced.

ISOLATION OF THE REPELLENT FACTOR IN MAMMALIAN SKINS DETERRENT TO ADULT SALMON

D.F. Alderdice and J.R. Brett

In the course of investigation sensory perception in salmon it has been established that salmon exhibit an olfactory sensitivity to a substance produced by the skin of certain mammals. When introduced into the water, the repellent substance causes an interruption in the upstream migration of coho and spring salmon. The response to the repellent has recently been confirmed for sockeye and chum salmon.

In 1953 a knowledge of many of the physical properties of the repellent was developed with a view toward isolation of the active material and identification of its structure. It is considered that such a substance may find an application in the manipulation of salmon runs, particularly with reference to the increasing utilization of water resources by industry.

Gross separation techniques are now known. The second stage of isolation now in progress requires the use of more sensitive techniques which will differentiate between substances whose physical and chemical properties are too similar to allow successful separation by gross procedures. Continuous electrophoretic techniques have allowed collection of the active principle separated both from materials carrying strongly negative and from others with strongly positive charges. Since the active principle carries a small charge, adjustments are now being made to expand the neutral range to effect separation of the repellent from other molecules occurring within this range.

It is considered that the knowledge of physical properties of the repellent already gained and the employment of sensitive isolation procedures currently being tested will allow extraction, isolation and concentration of the repellent substance.

Further information may be obtained from the Annual Report of the Pacific Fisheries Experimental Station where these extraction procedures are being carried out. Field testing of the extractions has been the continued responsibility of the Pacific Biological Station.

POLLUTION STUDIES - D.F. Alderdice and J.R. Brett

A. Toxicity of kraft mill effluent.

Kraft mills discharge large volumes of effluent into waters inhabited at various times of the year by migratory stages of salmon. Recent indications of increases in the production of pulp and paper have made it necessary to examine what levels of effluent concentration are tolerable to young Pacific salmon. No information on the effect of the particular combination of present-day sulphate effluents discharged into saltwater estuaries inhabited by young salmon was previously available. If the downstream migrant may be assumed to be the more vulnerable stage in the cycle, the conclusions from this stage of development may then set the level of effluent concentration tolerable to Pacific salmon.

The problem is quite complex. The influence of varying temperatures, salinities, oxygen concentrations, time of exposure and developmental stage of the fish precludes any simple treatment.

As a representative study, the relations recorded at the head of Alberni Inlet were taken as likely type conditions. Sockeye salmon underyearlings averaging 5.04 cm. fork length and cultured at 18°C. were exposed to various concentrations of kraft effluent at 18°C. and a salinity of 20 o/oo. Solutions were made up from 24-hour composite samples of kraft effluent usually from 24 to 36 hours old. Tests were conducted in static volumes of these solutions and changed every 12 hours. Some trouble was experienced with low oxygen conditions at the end of several 12-hour periods but, in general, these tended to point up an increased oxygen requirement for fish held in the higher concentrations. Toxicity of the several concentrations of effluent tested are listed in the following table.

Test solution per-cent effluent	Median effective dose in minutes	"Safe exposure" in minutes*
18	1,190	---
10	1,300	300
8.5	2,550	450
7	2,700	1,000
6	5,400	1,550
5	11,000	3,400

* Semi-graphic estimation, pending analysis

If it may be assumed that migrants remain in the estuary of a river for a period of between 1 to 4 weeks, effluent concentrations in that region should allow safe exposure for an appropriate time period. Estimated safe exposure concentrations of kraft effluent* for sockeye underyearlings exposed for periods of 1 to 4 weeks at 18°C., salinity 20 o/oo, are as follows:

Exposure, weeks	Concentration, % effluent
1	4.0
2	3.6
3	3.5
4	3.3

* Semi-graphic estimation, pending analysis

Observations of hypoxial behaviour and the oxygen levels at which they occurred in the test solutions suggested that critical oxygen requirements rise from a minimum level of about 2 p.p.m. in the lowest effluent concentrations to about 5.4 p.p.m. in the 18% effluent test solution. In view of these results, it may be ventured that in situations where oxygen depletion of a water mass by the oxygen demand of the effluent is insufficiently counterbalanced by dilution and exchange, the synergistic action of toxicity and low oxygen conditions may lower the minimum acceptable dilution of effluent or, conversely, raise the minimum acceptable concnetration of oxygen required for safe exposure.

B. Toxicity of sodium arsenite.

Methods of treating flat rafts and Davis rafts against teredo infection while in salt water are being investigated in British Columbia. Sodium arsenite solutions have been demonstrated as effective agents for teredo control. In line with this developmental work the Department of Fisheries asked the Fisheries Research Board for information on the toxicity of sodium arsenite to fish.

Of the two types of raft which are treated, it would appear that the greater potential danger to marine organisms would occur in the locations for treatment of Davis rafts. Consequently, a species of economic importance which may be expected to frequent such treatment sites was selected as the test animal. Young chum salmon averaging 4.71 cm. fork length were cultured at 14 to 15°C. and tested at three concentrations of sodium arsenite at a mean temperature of 14.6°C. and a salinity of 18.1 o/oo. These concentrations were selected to cover a range in which it is considered exposure under field conditions would occur. The sodium aresenite vehicle used in the tests was "Penite 6X", a commercial preparation used in some of the raft treatment studies. Test solutions used in the bioassays were analysed by the B.C. Research Council for sodium aresnite content.

Results of the toxicity tests are given in the following tabulation.

Sodium arsenite as p.p.m. As_2O_3	Median lethal exposure, in minutes	"Safe exposure", in hours
410	88	1
85	398	3
12.2	2,600	11.6

The median lethal exposure at the three concentrations tested are hyperbolic functions of sodium arsenite concentration. Safe exposure at each concentration represents the extension of the provisional probit curve to zero mortality. Safe exposure limits (shown in the previous table) therefore, may be estimated from a double log plot of safe exposure time against concentration, within the concentration limits indicated.

Under field conditions, high concentrations probably would be applied to rafts to ensure complete teredo kill before dilution by seawater rendered the diminishing concentration of sodium arsenite ineffective. Since the effects of exposure are probably additive in a series of concentrations diminishing with time, total sublethal experience would depend on the rate of diminution in toxicity of the area in which treatment occurs. Dilution may be expected to be rapid. Under conditions approaching the characteristics of this series of tests, the safe exposure times listed may be regarded as a good approximation of the limits of sublethal experience.

ENVIRONMENTAL FACTORS

A. Minimum oxygen requirements for chum salmon eggs.

D.F. Alderdice, J.R. Brett and W.P. Wickett

To determine the minimum suitable conditions for successful development of salmon eggs, or the cause of death when mortality has occurred, experiments on oxygen requirements have commenced (see Pink and Chum Salmon Report, page 50).

The oxygen uptake of incubating salmon eggs is dependent on three main environmental variables. Temperature of the water medium influences the rate of uptake, while oxygen content and the velocity of the water perfusing the egg mass determine the availability of oxygen for respiration.

Chum salmon eggs collected at the Nile Creek field station were transported to the laboratory and cultured at 5°C. prior to experimentation. Oxygen requirements for eggs in the first series completed were determined at 5°C. at a developmental stage just prior to and during hatching.

Respiratory requirements were evaluated in a series of solutions varying in degree of oxygen saturation. Continuous flows of water at selected levels of oxygen saturation were introduced into the egg chambers by adjustment of the rates of flow to each chamber of saturated and desaturated water supplies. Desaturated water was produced by equilibrating water in a stripping column to an atmosphere of nitrogen.

The first series of tests was carried out at maximum flow rates to each chamber so that oxygen availability would be dependent only on the level of oxygen in the perfusing media. Mortality in the samples was followed for one week. The eggs were transferred to normal oxygen conditions in order to follow any post-experimental mortality until hatching was completed.

Results are illustrated in the following table:

	Mean oxygen concentration, p.p.m.					
	0.255	0.292	1.41	1.97	4.20	12.47
Survival in test period (%)	0	10	90	100	100	100
Survival in total hatch (%)	0	10	70	100	100	100
Hatch in test period (%)	30*	20*	70	60	30	20

*Including alevins which hatched and subsequently died.

The results suggest that at 5°C. chum salmon eggs at the developmental stage considered are tolerant of low oxygen concentrations to a minimum between 1.41 to 1.97 p.p.m. when velocity of the perfusing system does not limit oxygen availability. The level of oxygen concentration at which 50% of a sample would survive in a period of one week is about 0.65 p.p.m.

The data suggest a dependence of hatching rate on the level of oxygen concentration of the perfusing medium. Rate of hatching in the experimental period is minimal in the sample near saturation. Increases in the hatching rate progress to a maximum in the region of transition from tolerance to resistance against low oxygen. Further decreases in oxygen

level below the zone of resistance produce a stress on the organism inhibiting further development. It would appear that the increased rate of hatching provides a compensatory mechanism which allows eggs more quickly to become independent of the limiting effects on respiration imposed by the egg capsule.

B. Salinity tolerance in young sockeye — J.G. Hunter

Experiments to determine the tolerance of young sockeye salmon to sea water have been made. Analysis of this work is not yet complete but facts point to a total survival in sea water of concentrations up to approximately 20 $^{o}/_{oo}$. Repetition of this work on sockeye of increasing sizes shows tolerance to increased salinities, suggesting tolerance is related to the volume/oral surface area ratio.

It was not possible to show acclimation to sea water by prolonged immersion in sub-lethal concentrations of sea water.

CRUISING SPEEDS OF YOUNG SALMON

J.R. Brett and Mary Lennox

Cruising speeds of fish were measured by determining the maximum sustained steady-rate of swimming maintained for at least one hour. They constitute a measure of two fundamental aspects of fish performance: (1) the actual physical ability to swim, and (2) the capacity of the animal to do sustained work, i.e., metabolic performance (which may or may not be directed into the act of swimming).

These measurements are of value in determining what rate of flow of water does not exceed the capacity of a fish to stem the flow. In cases where water is screened for irrigation or for turbine use, or any other use which is potentially destructive to fish, that rate of intake must not exceed the cruising speed of the fish. Information of this nature is almost entirely lacking.

Present experiments demonstrate that for salmon underyearlings the rates are less than 1 foot per second (0.68 m.p.h.) in almost all instances. At temperatures of 5° C. and less, the cruising speeds average about 0.5 feet per second. Systematic cataloguing of the cruising speeds of all underyearlings and yearlings of Pacific salmon at temperatures ranging from 1° C. to the upper lethal levels of 24-25° C. is in progress. Work on coho and sockeye is reaching completion.

As a measure of metabolic performance, the highest cruising speeds have provided an index of the temperatures at which the fish are most likely to succeed, and consequently the temperatures at which they are most likely to be found. This has been borne out by the studies on coho and sockeye. Coho show an optimum performance in the vicinity of 20° C. and maintain a high level of performance even approaching the lethal level. They are found in streams and inshore shallows of lakes in mid-summer. Their activity is greatly reduced by low temperatures.

In contrast, young sockeye display their optimum at about 15° to 16° C., and have a greater ability to perform at low temperatures than do the coho. The fact that sockeye tend to be offshore in deeper waters of the lake and only move into the streams during the early spring supports the proposition that the swimming speeds are a profitable laboratory measure of ecological temperature relations. Measurement of lethal temperatures and preferred temperatures have not distinguished so clearly the fundamental differences between these species.