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SKEENA SALMON INVESTIGATIONS

F.C. Withler

The purpose of the Skeena salmon investigation is to provide the biological background necessary for management of Skeena salmon stocks. Attention is focussed on sockeye and pinks, which form the bulk of the commercial catch in the Skeena Gill-net Area.

While it is true that variations in both the freshwater and marine environment exert important effects on survival, there is an increasing body of evidence indicating that the abundance of the Skeena stocks is largely dependent on the size and distribution of the spawning escapements. In general, for Skeena sockeye and pinks, small escapements have tended to provide small returns and large escapements to provide larger returns. It is recognized that the freshwater environment must eventually limit production when the capacity of either the spawning or the nursery areas is approached. Indeed, in certain parts of the Skeena system, there are indications that spawning populations have approached this limiting level in recent years. But it is the general case that present Skeena spawning stocks are below the size necessary to tax the capacity of the freshwater environment, and hence it is probable that substantial increases in the long-term yield can be achieved by providing larger escapements.

Much of the work of the Skeena salmon investigation is directed toward determining the likely size of escapements to each of the major production areas which will provide the greatest sustainable yield to fishing. This work involves enumeration of spawners using each of these areas and the estimation of the numbers of progeny resulting from these spawnings, both as young fish going to sea and as returning adults.

<u>For sockeye salmon</u>, the Babine-Nilkitkwa watershed is the major producing area of the Skeena system, accommodating over 75% of the annual spawning escapement. This area is essentially divided into two parts. One part, the area adjacent to the outlet, is characterized by having a large run of late-running fish with a relatively restricted lake nursery area (about 10% of the total lake surface area); the other part, the area remote from the outlet, has earlier runs of fish of about the same magnitude but with a relatively vast lake nursery area (about 90% of the lake surface). Studies of the growth and distribution of young sockeye during their year of lake residence and estimations of the number of seaward-migrating smolts indicate that in recent years neither the spawning grounds nor the nursery area of the main lake basin has been fully used. On the other hand, as indicated by depressed growth in some years, sufficient fry have been produced from spawnings in the outlet area to tax the capacity of the small nursery area there. For the past two years, regulations of the fishery therefore have been directed toward increasing the escapements to the main basin area. As a consequence of the increased spawnings provided by these regulations, the production of young fish in the main basin has been raised markedly, without any evidence of depressed growth. Whether or not this encouraging increase in production of young fish will result in a corresponding increase in adult production must await the return of these fish 2 to 4 hears hence.

<u>For pink salmon</u>, spawning is concentrated mainly in three large tributaries of the Skeena---the Kispiox, accommodating an early run; the Lakelse, a late run; and the Kitwanga, an intermediate run.

Since intensive study of the pink salmon stocks began only in 1956 (sockeye studies began in 1944), less is known concerning the capacities of Skeena pink spawning systems than of the major sockeye areas. However, analysis of past catch statistics suggests that, as with sockeye, spawnings in years of abundance more often resulted in large returns than did spawnings in years of scarcity. It was encouraging to note that the 1957 pink run, which provided the greatest catch since 1930, was produced by one of the largest pink spawning escapements of recent years. Even this large catch, however, was much less than those which were sustained over more than a decade prior to 1931 and at a time when both the demand for pink salmon and the ability of the fleet to capture them were much less than now. This evidence, added to the fact that recent spawning densities have in general not appeared excessive, indicates that the only hope for restoring the catches to their former high levels rests on the provision of substantially greater escapements. This is especially true of the Kispiox River whose runs appear to be more depressed than those of the other two. With this background, regulations for the past three years have been directed toward allowing more spawners to escape the fishery.

The information required for management of the Skeena sockeye and pink fisheries involves intensive study of the stocks from the time the adults first enter the fishery until the progeny of the survivors return to the sea. The projects involved in this program include:

(1) Tagging of the adult fish as they approach and pass through the fishing area. Recoveries of tags in the fishery and on the spawning grounds provide information on the timing of runs to the various spawning areas. These data are necessary to permit proper harvesting of individual runs.

(2) Analysis of the commercial catch records. The Department of Fisheries collects records of the daily landings of salmon in the Skeena and also from adjacent fishing areas through which Skeena salmon pass. The records are used in conjunction with escapement statistics to estimate the contribution of the various runs to the fishery.

(3) Sampling of the commercial catch. Samples are obtained to determine the age, size and sex composition of the commercial catch so that the contributions to the catch by each brood year will be known for sockeye (these results are reported elsewhere in these reports).

(4) Test fishing above the commercial fishing boundary. The catches of standardized fishing operations are used to estimate the numbers of fish escaping the fishery. Such estimates provide measures of the effectiveness of different regulations in controlling the exploitation of the stocks by the fishing fleet, and, hence during the season, permit adjustment of the regulations to offset unexpected fluctuations in abundance of fish or fishing efficiency.

(5) Estimation of Indian food catches. Department of Fisheries officers collect statistics on the numbers of salmon taken by natives in the area between the commercial fishing boundary and the spawning grounds.

(6) Estimation of spawning escapements. These critical data are obtained by foot and aircraft surveys by Department officers and Board personnel

and, for the important Babine sockeye stocks, by an actual count through a weir. Considerable work is currently devoted to developing more accurate, yet economical, methods of assessing spawning runs. Attempts are made to determine the age composition of the sockeye escapement (through length-frequency analyses) so that, in conjunction with comparable data from the commercial catches, the total return from a given year's spawning may be estimated.

(7) Estimates of pink fry production. On the three major pink rivers, small trap-nets are operated each spring to provide indices of fry output from observed spawnings. Such observations of production over a series of years in which different-sized spawnings occur will demonstrate the size of spawning which is likely to provide the greatest return to fishing.

(8) Observations of growth and distribution of young sockeye in lakes. Sampling young sockeye in the Babine-Nilkitkwa nursery areas has provided information about the consequences of varying the size of spawning escapements to the different parts of the watershed. These studies are providing estimates of the capacity of the nursery areas to support young sockeye, and permit estimation of the size and distribution of spawning stocks required for most effective use of these rearing areas. Important fundamental studies on the relationship between the growth and distribution of young sockeye and their plankton food and other factors are also being conducted.

(9) Estimation of sockeye smolt runs. Estimates of the total sockeye smolt run from the Babine-Nilkitkwa area each spring, by mark and recapture techniques, provide measures of the freshwater production resulting from different-sized spawnings. These estimates provide preliminary indications of the return of adults from Babine spawnings, and in so doing aid in interpreting fluctuations in abundance brought about by environmental factors both in fresh water and in the sea.

The 1957 Skeena salmon catch and escapement

The estimated total stock of Skeena sockeye in 1957 was 765,000, not including "jacks" (precocious males). Of this total, the Skeena gill-net fishery removed 279,000, leaving an escapement past the upriver commercial fishing boundary of some 485,000. Of this total escapement, 433,000 entered the Babine Lake watershed, where another 20,000 were caught in the Indian food fishery. Of the remaining 50,000+ sockeye entering other watersheds, probably 10,000 more were caught by Indians, leaving a total spawning escapement of 455,000.

The low 1957 sockeye catch was brought about in two ways. First, sockeye fishing began after a good portion of the run had passed, because the opening date had been delayed until July 7 by regulation, and further delayed in practice by a fishing tie-up pending fish price negotiations. Second, the sockeye run itself was low, being the result of a moderate-sized return of 4-year-olds coupled with a poor return of 5-year-olds.

The escapement, on the other hand, was about average as compared to those prior to the Babine River slide. In proposing the 1957 Skeena regulations to permit the desired sockeye escapement, the Skeena Salmon Management Committee had been guided by two important considerations, viz., that the anticipated total run would be moderate in number, and that the early sockeye runs to Babine Lake were depressed. The late opening of fishing permitted the early Babine sockeye to escape. This early escapement offset the reduction in total escapement which would have resulted had the smaller-than-expected run been fished heavily throughout the season. As a result, about 63% of the total run escaped the fishery and, as in 1956, a higher than usual proportion of the spawners entering Babine Lake spawned in early-run streams adjacent to the main basin.

In sharp contrast to the sockeye run, the 1957 Skeena pink run exceeded expectations. The 1955 pink escapement had been slightly over 1 million after a catch of about 2 million. The best expectation of return in 1957 was that the run would be as large as in the parent year, 1955. In fact, the total run was approximately 3.7 million, of which 2.8 million or 75% were caught (2.3 million in the Skeena Gill-net Area, 0.5 million in the outside Nass sub-Areas). Thus, in spite of shortened weekly fishing times as compared to 1955, the catch was much larger, and the escapement was reduced slightly from just over 1 million in 1955 to just over 900,000 in 1957. Since the ratio of return to escapement for the 1955 brood appears to have been higher than for most years in the past, the large 1957 return can be attributed to an exceptionally high survival of young from a better-than-average escapement.

The 1957 Skeena gill-net catch of spring salmon was 13,420, which is below average for the period since 1950. Although the total run was small (since the escapement was also only moderate), the lowered catch was largely due to the delayed opening of salmon fishing to July 13, brought about by the fishing tie-up mentioned above.

The 1957 gill-net catch of coho salmon in the Skeena Area was 51,659, which is below the average for the years since 1950. The escapement was judged by Department of Fisheries officers to have been moderate. Some extra protection for the coho run, which is most abundant in the Skeena fishing area during August, was provided by the 4-day weekly close periods from August 11 to September 1, which were proposed primarily to provide an adequate pink escapement.

The 1957 Skeena chum catch was 34,959, which is well below average. The escapement was also poor.

Salmon tagging in and around the Skeena Gill-net Area in 1957.

K.V. Aro

Following the success of the preliminary tagging carried out in 1956 in the waters adjacent to the Skeena Gill-net Area, a more extensive tagging program was embarked upon in 1957. The purposes of this tagging were to determine the times, speeds, and routes of migration of the various species of Skeena salmon and also to determine whether significant numbers of Skeena-bound salmon are present at any time during the fishing season in the adjacent Nass and Ogden Channel fishing areas.

The tagging, in which conventional Peterson-type disc tags fastened with nickel pins, were used was carried out from the chartered drum-seiner Cape Blanco during the period from June 5 to August 22. Tagging was carried out in the following seven general areas:

(1) in Ogden Channel, Beaver Pass, and at the northern end of Principe Channel;

(2) near Grace Island at the northern tip of Porcher Island, and around Stephens Island;

(3) near Kinahan Island;

(4) near Green Island, Bristol Rock, and in Hudson Bay Passage;

(5) around Arniston and Whitly Points, Holliday Island, and the Gnarled Islands, all at the northern end of Dundas Island, and in Caamaño Passage;

(6) in the southwestern half of Portland Inlet;

(7) around Birnie and Finlayson Islands.

The numbers of salmon of the different species tagged in each of these seven areas are listed in the following table:

Species	Ogden Channel	Grace Island	Kinahan Island	Green Island	Arniston Point	Portland Inlet	Birnie-Finlayson	Total
Sockeye	36	17	...	36	926	392	127	1,534
Spring	1	...	...	3	36	85	5	130
Pink	1,398	482	380	32	3,076	916	630	6,914
Coho	25	4	1	5	222	34	15	306
Chum	164	8	...	5	127	835	5	1,144
Steelhead	2	...	...	1	19	...	1	23
Total	1,626	511	381	82	4,406	2,262	783	10,051

Tags were recovered later from the commercial, Indian, and sports fisheries, from fish-wheels and fish-weirs operated by the Department of Fisheries and by the Fisheries Research Board, and from spawning streams by Departmental and Board personnel. A total of 3,822 tags were recovered from the commercial fishery and 543 tags from freshwater areas. This return, which is slightly in excess of 43%, is the highest recovery from any tagging carried out in the vicinity of the Skeena River. The distribution of the tag returns by statistical area is indicated in the accompanying table.

The tagging data indicates that in 1957 most of the Skeena salmon entered the Skeena Gill-net Area from the north around the tip of Dundas Island. The remainder of the salmon entered the area through the passages to the west and from the south through Ogden Channel. Skeena fish were present in varying amounts throughout the season in these adjacent areas.

		Sockeye	Spring	Pink	Coho	Chum	Steelhead	Total
Alaska	Marine	10	1	105	3	77	1	197
	Stream	..	..	2	1	..	..	3
Area 3	Marine	131	18	494	30	166	..	839
	Stream	52	2	1	..	1	..	56
Area 4	Marine	276	8	1,935	41	51	4	2,315
	Stream	286	5	153	17	5	4	470
Area 5	Marine	20	..	283	6	6	..	315
	Stream	4	..	9	..	1	..	14
Area 6	Marine	2	..	23	2	2	..	29
7	"	2	..	19	3	..	..	24
8	"	..	..	9	1	..	..	10
9	"	..	..	4	1	..	..	5
10	"	..	..	2	..	..	..	2
11	"	4	..	11	..	..	..	15
13	"	..	..	2	..	..	..	2
20-27	"	1	..	1	..	..	..	2
29	"	1	..	2	1	..	..	4
Unknown	"	7	..	44	..	12	..	63
Total		796	34	3,099	106	321	9	4,365

Test fishing and tagging in the Skeena estuary — K.V. Aro

Two chartered gill-net boats were employed again in 1957 to carry out test fishing immediately above the Skeena River fishing boundary in order to obtain information concerning the size and composition of the daily escapement of salmon. Information concerning the time of passage of sockeye and pink runs to different spawning areas was obtained by tagging those fish which were in suitable condition.

Fishing was carried out for one-hour periods over the slack tides with a 200-fathom net composed of 10 panels of different-sized web, from 3 1/2" to 8" stretched measure in 1/2" intervals. A total of 270 sets were made from June 3 to September 8.

The number of salmon caught, the number tagged, and the number of tags recovered in 1957 are shown in the following table with the comparable figures for 1955 and 1956:

Species	Year	Number caught	Number tagged	Tags recovered from fishery	Tags recovered from upriver
Sockeye	1955	1,173	822	113	69
	1956	2,344	1,386	39	203
	1957	2,351	1,234	150	197
Spring	1955	782	376	48	22
	1956	696	439	26	28
	1957	924	514	77	42
Pink	1955	3,590	1,488	28	34
	1956	1,408	974	24	8
	1957	5,734	3,321	215	102
Coho	1955	483	233	27	2
	1956	422	265	17	1
	1957	315	158	39	3
Chum	1955	124	45	1	0
	1956	151	79	12	1
	1957	283	89	8	0
Steelhead	1955	inadequate record			
	1956	310	199	10	5
	1957	137	54	8	2
Total	1955	6,152	2,964	217	127
	1956	5,231	3,342	128	246
	1957	9,744	5,370	497	346

Seasonal variations in exploitation of the 1957 Skeena sockeye and pink runs

M.P. Shepard

Catches of salmon made by the test-fishing boats are studied to provide information on the variation in escapement from the commercial fishery. These estimates of escapement in conjunction with catch statistics permit determination of the seasonal changes in rate of exploitation.

Test-fishing catches as indices of escapement. As outlined in these reports for 1956-57, comparisons of the seasonal patterns of test-fishing catches with those of the escapements reaching the spawning grounds suggested that the test-fishing catches were, within each season, proportional to the daily escapements.

To investigate the sources of error inherent in deriving escapement estimates from test-fishing catches, a factorial analysis was made of the effects of changes in fishermen, nets, boats, cloud cover, wind force and direction, rainfall, time of day, tides and presence of debris and of seals, on test catches of sockeye. To avoid the masking effects of the fishery on the size of test catches, these analyses were restricted to those of the period June 8 to July 31, 1956, when there was a complete closure of the Skeena fishery. The analyses showed that only two factors exerted demonstrable effects on the magnitude of the test-fishing catches: one fisherman caught consistently more fish than did the other, and catches made at very low tides tended to be proportionately higher. In the following analyses involving the test-fishing catches, the data have been adjusted to compensate for differences in efficiency of the fishermen. No correction was made for tidal effects because it is impossible to determine whether the observed differences were caused by changes in catchability, or real changes in the abundance of fish passing the test-fishing site. Comparable analyses of pink salmon catch data fail to demonstrate any effects of the factors studied.

Assuming that the test-fishing catch/hour is roughly proportional to the number of fish migrating upstream, an index converting catch/hour to number of adult migrants can be computed for each year. Estimates of the tot annual spawning escapement of both pinks and sockeye are provided through stream surveys and fence counts. By summing the daily catch/hour figures and dividing this number into the total estimated escapement to areas upstream fr the test-fishing site, the estimated daily escapement indicated by a catch of one fish/hour is obtained. The data are summarized in the table below:

Year	Sum daily catch/hour		Total escapement** (1,000's fish)		Escapement per daily catch of 1 fish/hour	
	Sockeye	Pink	Sockeye	Pink	Sockeye	Pink
1955	377	1,672	125	1,058	333	630
1956	834*	522	441	260	530	498
1957	769*	1,929	485	910	632	472

*Adjusted to correct for differences in efficiency of boat skippers.
**Upstream from test-fishing site.

As noted in last year's reports, there was a relatively large difference bet the escapement indices derived from the 1955 and 1956 data. At that time th discrepancy was largely attributed to differences in the nets used in the tw years. The fishing procedure in 1956 and 1957 was essentially identical, a as a consequence the indices are much more similar. The pink indices in the latter two years differ by only 5%; the sockeye indices by 16%.

<u>Seasonal changes in exploitation in 1957</u>. Using the escapement indices described above to estimate the weekly escapement from the fishery, the weekly catch figures provided by the Department of Fisheries, the weekly rates of exploitation in the Skeena Area were derived. These figures are su marized in the table below:

Week ending	Sockeye			Pink			Days fishing	Delive
	Comm. catch	Estim. escap.	Rate of expl.	Comm. catch	Estim. escap.	Rate of expl.		
	1,000's fish		%	1,000's fish		%		
July 21	41.7	64.6	39.2	29.0	51.2	36.2	3	1,0
28	49.4	67.9	42.0	182.6	126.1	59.1	3	1,4
Aug. 4	75.3	35.4	68.0	738.9	139.3	84.1	4	3,1
11	60.8	41.5	59.4	777.7	206.5	79.0	4	2,8
18	35.6	24.4	59.2	501.9	286.2	63.7	3	2,1
25	7.8	10.7	42.1	74.5	81.1	47.8	3	1,0
Sept. 1	1.2	1.0	54.5	12.0	13.4	47.2	4	5

In 1957 the weekly rate of exploitation for sockeye varied between 39 and 68%, and for pinks between 36 and 84%. The data indicate in two ways that the percentage removal is closely related to the amount of effort expended in catching the fish. On the average a substantially greater proportion of the stock escaped during 3-day fishing weeks than in 4-day weeks (an average of 46% of the sockeye and 51% of the pinks were caught during 3-day weeks, whereas 58% of the sockeye and 70% of the pinks were removed during 4-day weeks). Also, for weeks in which fishing time was comparable, there tended to be a higher rate of exploitation when the greatest number of boats (as reflected by the number of deliveries) was fishing. For example, the greatest rate of exploitation for both sockeye and pinks was achieved in the 4-day week ending August 4, in which there was the greatest number of deliveries.

A point of special interest in these data is the extremely high rate of exploitation of the 1957 pink run. At the time of the run, the test-fishing catches indicated that the escapement past the fishing boundary was no better than in 1955. Had it not been for this evidence, the remarkable effectiveness of the fishing fleet would not have been known, with the result that serious reduction of the spawning run would have been caused by extension of fishing time.

Salmon enumeration in 1957 at the Babine fence

K.V. Aro

In 1957, as in all years since 1946 (except in 1948 when floods damaged the weir), the salmon runs to the Babine Lake watershed were counted at the Babine River weir. Since the sockeye escapement to Babine Lake usually constitutes about 70% of the total escapement to the Skeena River, the weir count provides the best index of the Skeena sockeye escapement. The counts have been particularly valuable since 1951 in determining the effect of the partial block of the Babine River to salmon by the rock slide.

The counts of the five species of salmon which passed the counting fence in 1957 are compared in the following table with the counts obtained in other years:

Year	Sockeye		Spring	Pink	Coho	Chum
	Large	Jack				
1946	417,841	57,864	10,528	28,161	12,489	18
1947	261,460	261,101	15,614	55,421	10,252	7
1948*	650,000					
1949	461,139	47,993	7,433	13,663	11,938	5
1950	364,356	179,302	6,838	38,728	11,654	7
1951	141,415	11,042	2,778	50	2,122	0
1952	349,011	27,936	5,915	2,706	10,554	1
1953	686,586	28,028	8,353	1,108	7,648	17
1954	493,677	9,745	5,925	4,604	3,094	66
1955	71,352	30,624	3,528	2,151	8,947	3
1956	355,345	18,164	4,345	2,691	9,250	3
1957	433,149	50,162	7,509	25,865	4,421	15

*Total sockeye estimated from comparison with stream surveys and fence counts of other years.

The run of sockeye salmon in 1957 was close to the pre-slide average. It began with a single fish on July 6, followed the usual pattern attaining an early peak of 15,486 fish on July 27 and a main peak of 18,058 sockeye on August 31. Counting was discontinued on October 29, on which day only 4 sockeye passed the fence.

In 1957, as in 1956, a proportionately greater number of sockeye spawned in the streams tributary to the southern and central portions of the lake than in most recent years. Most of the larger streams in these areas had larger spawning populations than in the past eleven years.

The spring salmon run in 1957 was average in number. However, a larger proportion of the fish were jacks. The count of spring salmon provides only an index of the run since springs spawn below the fence as well as above it.

The pink salmon run was the third cycle following 1951, the year when the run of pink salmon through the Babine fence was reduced to 50 fish by the rock slide. The 1957 run was of comparable size to some of the pre-slide runs. As with springs, some pinks spawn below the fence.

The run of coho salmon in 1957 was the second cycle to the 1951 run which also was reduced in size by the rock slide. The 1954 and 1957 runs of coho have indicated a gradual recovery so that the 1957 run was twice that of 1951.

A few chum salmon again reached the Babine fence.

Sockeye sampling at the Babine fence

K.V. Aro

In order to describe the composition of the 1957 run, 1% of the previous half-day's run was sampled twice daily for length and sex, and a "jack count" was carried out for an hour daily.

In 1957 jack and large sockeye were counted separately in the daily counts rather than together, giving a total count of 433,149 large and 50,162 jack sockeye. The jack count, which covered 11% of the run, indicated that the sockeye run was composed of 431,485 large and 51,826 jack. The reasonably good agreement between the two sets of figures, particularly with a smaller proportion sampled than usual, suggests that jack counts of previous years are reasonably accurate. The percentage and number of jacks in the sockeye run was greater in 1957 than in most years. The jack count showed also that 8.8% of the large sockeye had net marks, 1.6% had other injuries, and 89.6% had no injuries. The percentages of fish with net marks was higher and with other injuries lower than in most other years.

As in all other years except in the two slide-affected years, the female sockeye in 1957 outnumbered the large male sockeye. The 1% sample indicated that 49% of the large sockeye were males and 51% females. The 1% sample also indicated that the jacks, large males, and females were smaller than average. Length-frequency plots suggest that the age composition of the large sockeye was some 80% 4-year-olds and 20% 5-year-olds.

The average egg content in 1957 was calculated to be 3,063 eggs per female. Since the number of female sockeye estimated to have survived the Indian fishery was 212,804, the potential egg deposition would be in the vicinity of 652 million. This is close to the average of pre-slide years.

The 1957 Skeena pink salmon escapement

J.G. McDonald

The table below shows the estimated escapement to the Skeena and its major tributaries in 1955 and 1957. The estimates are based on inspections of the streams by Fishery Officers. Since 1955 their observations have been supplemented by those made by Research Board personnel.

Some of the figures given in last year's report have been revised in the light of more recent information.

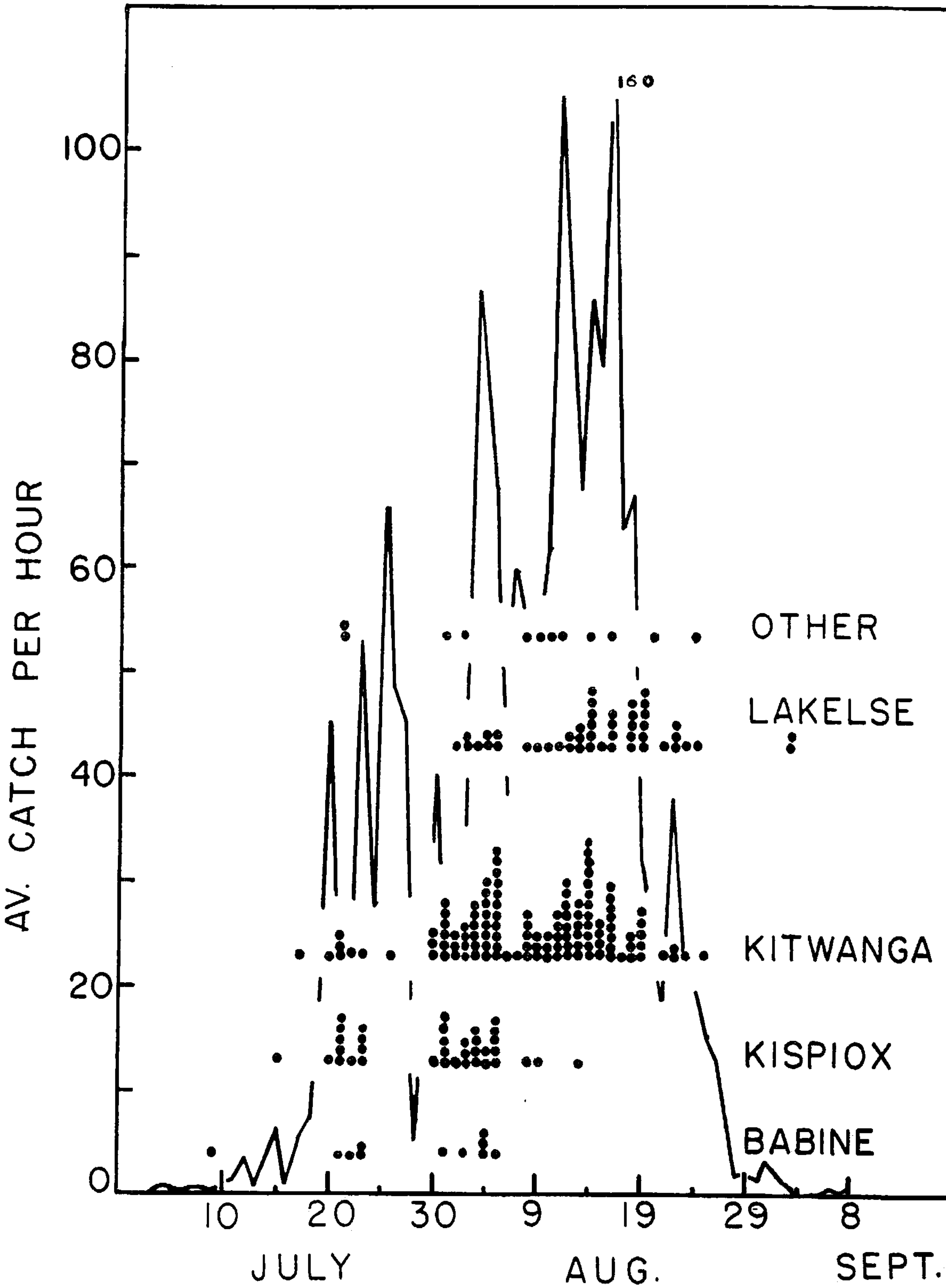
Place	1955	1957
Kispiox River	540,000	360,000
Kitwanga River	125,000	160,000
Lakelse River	175,000	140,000
Babine River	5,000	27,500
Bear River	6,000	15,000
Coastal Streams	78,000	45,000
Others	129,000	163,000
Total	1,058,000	910,000

The escapement in 1957 was slightly less than that in the parent year. There occurred decreases in the runs to the Lakelse and Kispiox Rivers. This was partly compensated for by an increased number of spawners to some of the other grounds. Both the Bear and Babine River runs, although still very small, showed a substantial increase over 1955. The number of spawners passed through the Babine fence in 1957 was over five times the number in the parent year. This shows good progress in the recovery of the odd-year cycle following the devistating effect on that cycle by the Babine River slide of 1951.

The 1957 escapement followed much the same pattern of distribution as was recorded in past years. The bulk of the spawning occurred in the Lakelse, Kispiox and Kitwanga Rivers. Of considerable interest and promise was the greater incidence of pink spawning in the Skeena River itself. Very light and scattered spawning has been noted here in the past. Observations by ground and air this year showed pinks had spawned on numerous bars and in side channels from Terrace downstream to the tidal zone. The surveys did not indicate that this spawning was intensive in relation to that which occurred elsewhere, but it could be considerably greater than that noted in the Skeena in past years.

Considerable effort is being put toward improving methods of estimating the sizes of spawning runs. Aerial photography has been used to locate and enumerate both spawners and spawning redds. This technique is

THE TIMING OF THE 1957 PINK RUNS FROM TAG RECOVERIES



the migration and spawning times of the various pink runs which is apparently related to the distance of the spawning ground from salt water. The runs proceeding furthest upstream (the Babine and Kispiox weirs) are followed by that to the Kitwanga River which is about central in the system. The last major run to ascend to the spawning grounds is that to the Lakelse River which is relatively near to the sea.

Pink fry output from major Skeena spawning areas, 1957 J.G. McDonald

Standard trap-netting at the mouths of major pink-producing tributaries was carried out in the springs of 1956 and 1957. The method involved fishing a small-meshed trap-net at frequent intervals during the time that fry migrate from the spawning grounds to the sea. The total catch of fry per unit effort provides a relative index of the fry output from these tributaries each year.

Trap-netting was carried out on the Lakelse, Kispiox and Kalum Rivers in 1956. This year the work was repeated on the Lakelse and Kispiox Rivers but the Kalum, found to be a relatively small pink producer, was dropped in favor of the more productive Kitwanga River.

Indices of the total fry output have been calculated on the basis of the average catch per hour adjusted by the relative efficiency of the trap. The latter was determined by the proportion of the stream width covered by the trap at each tributary.

The indices are given below with the estimated number of spawners which produced each fry run.

Area	Parent year	Escapement	Index of total fry output
Lakelse	1955	175,000	3.2
	1956	55,000	1.9
Kispiox	1955	540,000	10.6
	1956	75,000	1.4
Kitwanga	1955	125,000	..
	1956	35,000	3.7

Catches of pink fry were considerably lower in 1957 than in 1956. The 1957 fry output from the Lakelse River was approximately 60% of that in 1956. The 1957 index for the Kispiox was only 13% of that of 1956.

The relatively large escapement to the Kispiox River in 1955 and the small escapement the year following produced proportionately as many fry. In other words, percentage survivals from the larger and smaller seedings were about the same: the 1956 seeding was approximately 1/7 that of the previous year and produced about 1/7 as many fry.

The situation on the Lakelse River varied to some extent. The spawner-to-fry survival was higher in 1956-57 than in 1955-56. The 1956 escapement, which was less than 1/3 that of 1955, produced a fry output about 3/5 as large.

Since the escapements to the Lakelse and Kispiox Rivers in the past two years have comprised at least 1/2 of the total for the Skeena, their combined fry output may provide a general indication of that for the whole watershed. The total escapement in 1955 was estimated to be four times that of 1956. The data obtained from the fry trapping indicates that fry survival did not change to any considerable extent in the two years and that fry output has been roughly proportional to escapement size.

Ecology of young sockeye salmon during their lake life

W.E. Johnson

This study is concentrated in the Babine-Nilkitkwa Lakes nursery area (see map) where intensive work began in 1956. Preliminary surveys of this area in the late summer and fall of 1955 indicated a total population of 50 to 60 million age-0 sockeye salmon, at least 67% of which were concentrated in the 11% of the total lake area which lies north of Halifax Narrows (that is, in Nilkitkwa Lake and the North Arm of Babine Lake). Mean size of young sockeye in these regions of great concentration was much smaller than in the sparsely populated remainder of Babine Lake. It was concluded that the slow growth in areas of dense population was a result of crowding, and that the unequal distribution was a result of the unequal distribution of the spawning parent population and a limited dispersal of young from their points of lake entrance as fry---such limited dispersal being a result of the multibasin nature of this lake system.

These initial findings and conclusions were supported by the 1956 smolt estimate and the 1956 lake studies.

The seaward migration of age-I sockeye smolts in 1956 was estimated as 20 million (plus an unknown number, not likely exceeding 5 to 10 million, which migrated before the mark and recapture estimate went into operation). This would be of the general order of numbers one would expect from a lake population of 50 to 60 million the previous fall. Also, of the 20 million smolts estimated, roughly 1/2 (the earliest migrating) were very small in size (mean weight about 2 grams) as compared to the others (mean weight about 5 grams). The small smolts were believed to originate from lake regions north of Halifax Narrows and, because they were the earliest migrating, probably constituted considerably more than 50% of the run.

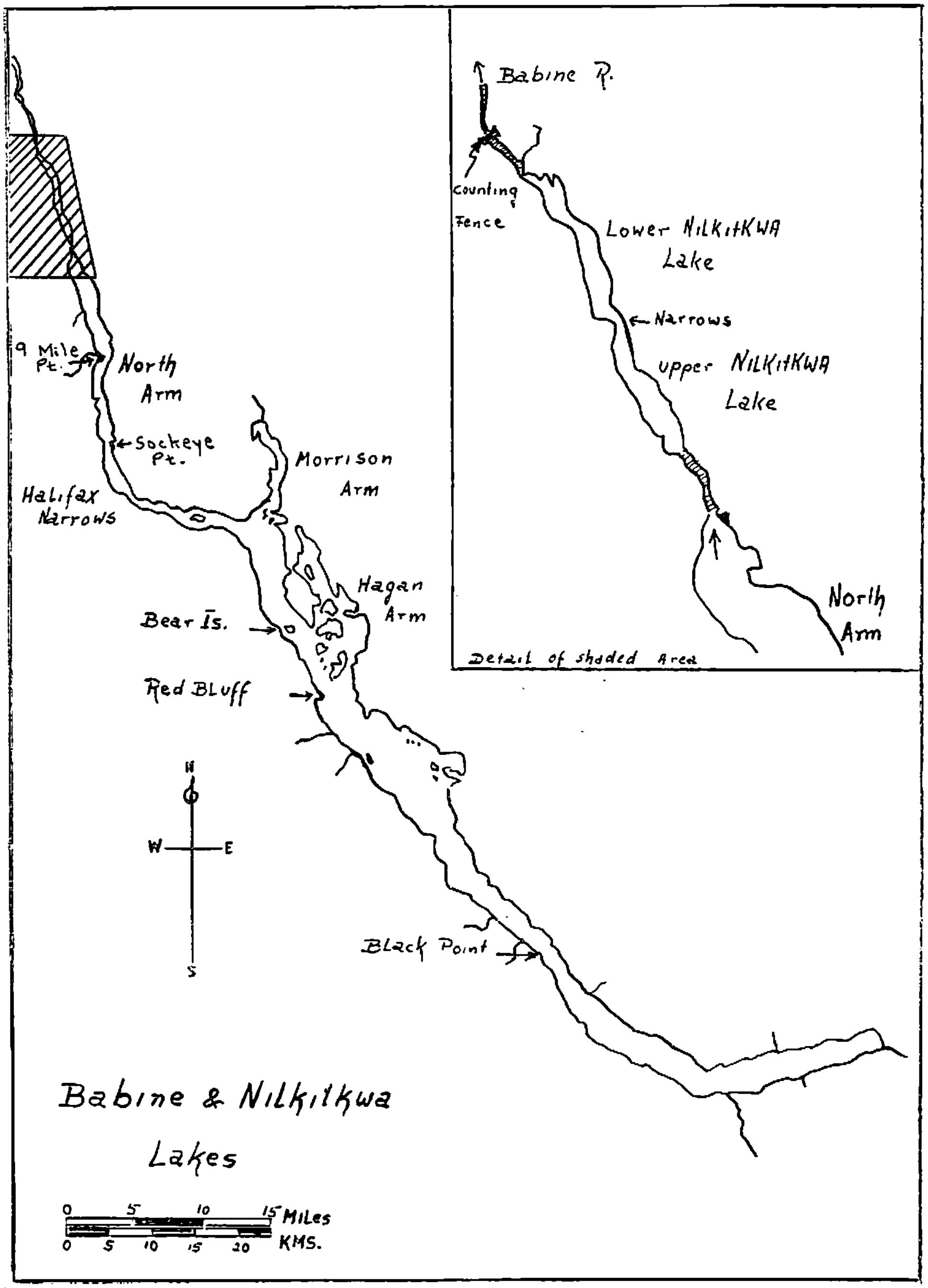
In 1956 the age-0 sockeye populations in Nilkitkwa Lake and the North Arm were sparse as compared to 1955 and growth was good, supporting the view that slow growth in 1955 was a result of crowding. In 1956 not one age-0 sockeye was taken in the entire lake region from 9-Mile Creek in the North Arm south to Bear Island. This lake region has only one tributary spawning ground, the Morrison River, and it had only 1,800 spawners in 1955. This result strongly supports the theory of limited distribution of young sockeye in this system from their points of entrance as fry.

A general summary of 1955 and 1956 age-0 sockeye abundance and distribution is given in the accompanying table along with the 1957 data.

1957 Results: Babine-Nilkitkwa Lakes

The 1957 studies were far more intensive than any earlier. The results are now in preparation for publication and only a brief summary is given here.

Density and distribution of age-0 sockeye. In 1957, intensive sampling of young sockeye was carried on in five lake regions north of Halifax Narrows which are more or less discrete basins: the two halves of Nilkitkwa



Outline map of Babine and Nilkitkwa Lakes.

Summary of 1955-57 estimated lake populations and estimates of related spawning and smolt populations.

	Number of adult sockeye spawning (thousands)	Number of age-0 sockeye in lake (millions)	Number of age-I smolts (millions)
	1954	1955	1956
North of Halifax Narrows	261	35 to 45	10+
South of Halifax Narrows	189	10 to 20	10
Total	450	45 to 60	20+
	1955	1956	1957
North of Halifax Narrows	30	2 to 3	
South of Halifax Narrows	31	3 to 5 (+ 6 to 9)*	
Total	61	5 to 8 (+ 6 to 9)*	6 to 7
	1956	1957	1958
North of Halifax Narrows	125	26	
South of Halifax Narrows	163	31 (+ 26)*	
Total	288	58 (+ 26)*	

*The figures in parenthesis are the additional millions estimated which were believed progeny of kokanee and residual types.

Lake, upper and lower (separated by a distinct narrows); and the three more or less distinct basins of the North Arm: north, central and southern. Limitation of available effort permitted only occasional sampling in regions south of Halifax Narrows. The following tabulation lists the estimated population densities and total populations of the different areas in late August, based on catch per unit of standard effort with tow-net gear:

Lake region	Fish per acre	Total population (millions)
North of Halifax Narrows:		
Lower Nilkitkwa	4,860	2.9
Upper Nilkitkwa	5,750	3.5
North Arm: north basin	2,720	13.6
" " : central basin	2,050	5.7
" " : south basin	260	0.8
Total		26.5
South of Halifax Narrows:		
Halifax Narrows to Bear Is.	50	0.6
Morrison Arm	90	0.4
Hagan Arm	not sampled	..
Red Bluff to Black Pt.	680	31.3
Black Pt. to south end	890	24.9
Total		57.2* (31.5)
Grand Total		83.7* (58.0)

*Based on plots on normal curve probability paper, the samples from regions south of Halifax Narrows appear to be composed of 2 widely overlapping size groups; the smaller, contributing an average of roughly 45% of the total, are believed to be the progeny of kokanee and/or residuals which spawned in great numbers in 1956. Thus the total estimates of sea-type progeny would be as shown in parentheses.

Growth rates of age-0 sockeye. Sampling in the five regions north of Halifax Narrows was sufficient to follow growth rates in detail. Distinctly different growth curves were shown by the fish in each of these five regions, substantiating the view that each region did have its own more or less discrete population. Expressed as the mean weight attained by mid-October, the following comparison of growth rates is presented:

Lake region	Mean weight in grams
Lower Nilkitkwa	2.2
Upper Nilkitkwa	1.8
North Arm: north basin	3.5
" " : central basin	3.7
" " : south basin	5.+

Regarding growth rates south of Halifax Narrows: if the hypothesis that the populations there are composed of 2 groups holds true, fish of the larger group (progeny of sea-run sockeye) appear to have shown a growth rate most comparable to those in the south basin of the North Arm. That is, a mean weight of about 5 grams by mid-October.

Factors determining growth rate of age-0 sockeye. Most of the age-0 sockeye in all regions of this nursery area appear to have entered the lake and taken up a pelagic, zooplankton-feeding existence by late June of both years thus far studied. Barring genetic differences, it is felt that their rate of growth is largely determined by three factors: (1) temperature, (2) food abundance, and (3) competition (population density). Regarding temperature: during the period from late June to October in both of the years (1956, 1957) and in all the various lake regions under consideration there have been only minor differences in the relatively near-surface waters inhabited by these fish. It is believed that differences in growth have been a result of differences in the other two factors, i.e., zooplankton abundance and intraspecific competition (no significant amount of interspecific competition is indicated in this nursery area). The accompanying tabulation presents information on growth and these two factors.

As can be readily seen, there is no simple relationship between growth and either of the two factors individually. Also, the two factors are not independent of each other---extreme high density of the fish population contributes to lower food abundance through cropping. However, certain conclusions seem justifiable. For Nilkitkwa Lake and the north and central basins of the North Arm it appears that growth is rather constant up to population densities somewhere beyond approximately 3,000 fish per acre above which there is an inverse relationship with density. At all the lower population densities the age-0 sockeye seem to attain a weight of roughly 3.5 grams by mid-October when the mean dry weight of zooplankton (0-10 m.) is in the range of 14 to 38 mg./cu.m. The higher growth (5.+ grams by mid-October) shown by the fish in the south region of the North Arm and, apparently, in all regions south of Halifax Narrows, seems clearly related to the much higher levels of zooplankton abundance in these areas.

Zooplankton studies. Sampling of zooplankton was carried out at 45 stations in Babine and 6 in Nilkitkwa Lake. Limitations of available effort restricted most frequent and thorough sampling to regions north of Halifax Narrows. As in 1956, zooplankton abundance in all regions increased greatly from time of ice breakup in mid-May to late June. Highest levels were attained in regions south of Halifax Narrows and in the south portion of the North Arm, and these high levels were maintained throughout the summer and fall period of observation. In the other regions zooplankton decreased considerably through July to lower levels which persisted throughout the period of observation. In these regions it was interesting to note a sharper decrease to lower levels in 1957 than did occur in 1956; this probably was a reflection of the much greater density of young sockeye in 1957 than in 1956.

The much higher abundance of zooplankton in the main body of Babine Lake and the adjacent region of the North Arm than in the remainder of the North Arm and Nilkitkwa Lake might be explained in large part by the following theoretical consideration: Regions south of Halifax Narrows are of much greater mean depth and have epilimnia of greater depth with respect to depth to which photosynthesis can be carried on (euphotic or trophogenic zone) than regions

Lake region and year	Mean weight of age-0 sockeye in mid-October (in grams)	August Population density age-0 sockeye per acre	July-October Mean dry weight of zooplankton in surface 10 meters (mg./cu.m.)
Lower Nilkitkwa 1957	2.2	4,860	9
Upper Nilkitkwa 1957	1.8	5,750	7
North Arm: north basin 1957	3.5	2,720	22
" " central basin 1957	3.7	2,050	38
Nilkitkwa 1956	3.7	1,420	14
North Arm: north basin 1956	3.6	50	34
" " south basin 1957	5.+	26	60
Babine: Black Pt. to south end 1957	5.+	890	65*

*All other regions south of Halifax Narrows show comparably high plankton abundance.

north of Halifax Narrows. Such conditions would allow for a quicker depletion of nutrients in regions north of Halifax Narrows, except for the immediate southern area receiving continual outflow from the main lake. In addition, nutrient depletion in Nilkitkwa Lake is probably accelerated by the extensive development of higher aquatic plants there. All this consideration of course assumes a dependence of zooplankton abundance on phytoplankton abundance. It is hoped that this study may be expanded at some future date to explore such relations in the total productive process.

Preliminary findings with sea-scanar echo-sounding gear. Preliminary observations with a sea-scanar were made at Babine Lake in 1957. This instrument was installed in a river-type boat, the unsuitability of which restricted observation largely to the more protected waters north of Halifax Narrows. The high sensitivity of this instrument proved sufficient for detection of age-0 sockeye. The most important findings concerned vertical and horizontal distribution.

(a) Vertical distribution. Observations to date indicate a daylight distribution of young sockeye throughout the surface 6 meters, with greatest concentration at about 3 meters depth. In the evening twilight there is a mass movement towards the surface with a maximum near-surface concentration occurring with the early moments of darkness. After dark there appears to occur a slow settling to greater depths which proceeds until the first moments of daylight. Then a few fish start appearing near the surface and soon after they have all taken up their typical daytime distribution in the surface 6 meters.

(b) Horizontal distribution. Observations to date indicate that young sockeye (and other pelagic fish) in any one basin frequently show an extremely non-uniform distribution. Horizontal concentration appears to be related to lake circulation. Observations suggest a mechanism (previously observed and described for zooplankton) of horizontal transport and concentration of the fish which might be of universal application to motile pelagic organisms which have definite depth preferences.

Further observations will be necessary to evaluate the usefulness of scanar records in estimating numbers of young fish.

Observations at other lakes

Brief visits were made to Bear, Sustut, Motase, Alastair and Lakelse Lakes in the Skeena system and to Long Lake---the nursery lake at Smith Inlet. One week was spent at Owikeno Lake---the nursery lake at Rivers Inlet.

Bear Lake. Two short visits to Bear Lake were made---June 7-8 and August 25-26. Relatively high temperatures and very abundant zooplankton at the time of both visits indicate the high potential of this lake as a nursery area for sockeye. Only very small catches of young sockeye were made---13 in June and 5 in August. Enroute from Bear Lake in August, brief stops were made at Sustut and Motase Lakes where temperature observations and plankton collections were made and water samples taken.

Lakelse Lake. Two days, September 13-14, were spent at Lakelse Lake enroute from the Rivers Inlet area. A plankton-temperature survey was carried out and tow-net collections of sockeye made on both nights. Zooplankton abundance was moderately low and comparable to the same season in 1955. Catches of age-0 sockeye per unit effort (5 and 8) indicated a sparse population, as is usual for Lakelse Lake. The mean weight of 3 grams depicts a rate of growth comparable to that of age-0 sockeye there in 1955.

Alastair Lake. This lake was visited in conjunction with a spawning ground survey from Lakelse Lake on September 15-16. Water temperatures were somewhat lower than at Lakelse Lake and zooplankton of comparable abundance to Lakelse Lake. An overnight gill-net catch of 32 young sockeye suggested a sizable population. Of the 32, 11 were age-0 with a mean weight of 2.4 grams and 21 were age-I with a mean weight of 4.6 grams.

Long Lake. A brief visit was made to this lake September 4-6, 1957, enroute to Owikeno Lake. Observation was hampered by torrential rains which raised the lake level approximately 5 feet from September 5 to 6. Long Lake is the nursery area for the sizable Smith Inlet stock of sockeye. It lies in an extremely steep-sided valley of the coast range and has a length of about 16 miles. The width varies from 1/2 to 1 mile with two narrows which more or less divide the lake into 3 basins. Depth is probably considerable; two soundings of more than 300 feet were made. Temperatures of the surface water (0-5 m.) were in the range 14° to 16° C. and were comparable to those at Babine in early September. Zooplankton was quite sparse and most comparable in quantity to Nilkitkwa Lake at the same season of the year.

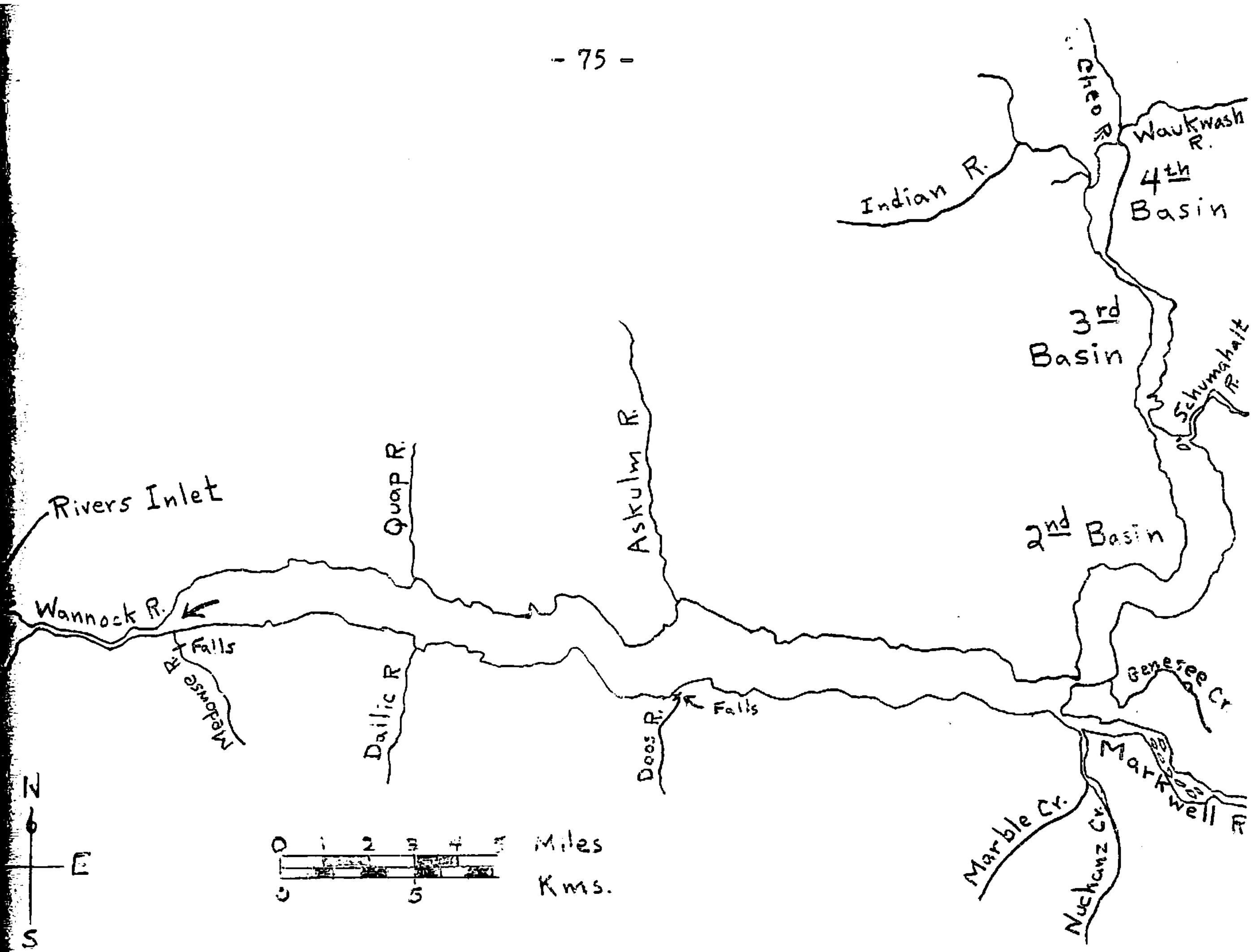
Young sockeye (all of age-0) were taken with gill nets, by tow-netting from aircraft, and from trout stomachs. Catches, though not with standard gear, would appear to indicate only a moderate population. Mean size of the age-0 sockeye taken by the various means was 2.1 grams. Very large catches of three-spined stickleback made in the pelagic region of this lake indicate a very large population of this potentially competitive species.

On leaving Long Lake, a landing was made on Wyclees Lagoon, into which Long Lake drains, and a temperature series and a plankton collection were made. This lagoon (area about 10 square miles) receives water from Smith Inlet only at the highest tides and its surface waters, at least, are essentially fresh. The temperature of its surface waters appeared comparable to Long Lake and (except for a few marine forms) its zooplankton appeared comparable to that of Long Lake. This lagoon would appear to be a suitable nursery area.

Owikeno Lake. The period September 6 to 12, 1957, was spent at Owikeno Lake, the sockeye nursery area at the head of Rivers Inlet. This lake, with a total area of about 34 square miles, is composed of 4 distinct basins (see map). It lies in a valley system of the coast range whose steep-sided walls rise abruptly from the lake shores (altitude less than 50 feet) to altitudes up to 8,000 feet. Although no hydrographic survey of the lake has been carried out, a limited number of soundings made some years ago by D.R. Foskett indicate relatively great depths throughout, especially in the main basin (1,200 and 1,000 feet recorded).

Extensive temperature observations and plankton collections were carried out and tow-net collections of young sockeye were made in each of the 3 small basins and in the two halves of the largest basin.

Near-surface (0-10 m.) water temperatures in the main basin averaged about 13°C. as compared to 10° to 11°C. in the three smaller basins. Zooplankton



Outline map of Owikeno Lake and tributary spawning grounds.

was considerably more abundant in the large main basin than in the others, but its quantity was generally low throughout (roughly in the range 2 to 15 mg./cu.m. dry weight for the surface 20 meters).

The following samples of young sockeye (all age-0) were taken by tow-netting:

Region	Number	Mean weight in grams	95% confidence limits
Main basin: west half	404	0.65	0.63 - 0.67
Main basin: east half	699	0.88	0.86 - 0.90
Second basin	482	0.94	0.92 - 0.96
" "	16	0.90	0.76 - 1.04
" "	30	1.06	0.91 - 1.21
Third "	19	0.59	0.44 - 0.74
Fourth "	51	0.69	0.55 - 0.83

(Three-spined sticklebacks were taken in all samples, but in far greater numbers in the three smaller basins.)

Regarding the size of the catches: owing to various difficulties, especially the unsuitability of boats used for towing, only the first three catches tabulated can be regarded as roughly the result of a standard unit of effort each. These catches indicate a density of roughly 5,000 age-0 sockeye per acre in the two largest basins or a total population of roughly 100 million.

Regarding the size of the age-0 sockeye: First, the mean size in all regions of this lake is very small (whenever the smolts migrating from Owikeno Lake have been sampled they have been very small---a mean size of about 2 grams). Thus slow growth appears characteristic of young sockeye of this lake. As to the probable causes of slow growth, available evidence offers little explanation. Temperatures appear lower than average for sockeye lakes studied so far, and the character of the water, as well as what samples have been taken, indicate a scarcity of zooplankton food. In addition, it may be that populations have been of sufficient density to depress growth rates in most or all previous years. With respect to this latter point, collections planned for 1958 should prove interesting for all indications point to the 1957 spawning escapement as the smallest on record and to the probability of a much smaller than average lake population in 1958.

Regarding the differences in size from one lake region to another, little can be said from the evidence at hand. One of the differences, however, invites conjecture---the significant difference in size of young sockeye from the two halves of the main basin. The temperature and plankton survey of this main basin, although indicating comparable levels of these two factors throughout, suggest that the two halves of this basin have water masses which are at least partially independent. Therefore, it is possible that the differences in growth shown, if real, are a result of a higher density of the age-0 sockeye population in the west half of this basin. Although little is known about the total spawning escapement and its distribution to the various spawning grounds for any one year, the Wannock, Quap and Dallic Rivers (all tributary to this west half of the main basin) are conceded to be among the most important.

Density may be the cause of slow growth in the third and fourth basins. These small basins receive fry from three major spawning areas---the Indian, Cheo and Waukwash Rivers.

Regarding areas where growth was highest: the second basin has only one major tributary spawning ground---the Shumahalt River; and the east half of the main basin has two tributary spawning grounds of moderately major importance---the Markwell and Askulm Rivers.

More precise observations, over longer periods, would be necessary to reveal satisfactorily the causes of differences in growth among the young sockeye.

Size of Babine sockeye smolt runs, 1951-1957

K.V. Aro

Since 1951 the size of sockeye smolt runs out of the Babine watershed has been estimated by means of a marking and recovery technique using smolt traps at the outlets of Babine and Nilkitkwa Lakes. From the estimates so obtained and from estimates of potential egg depositions in the spawning years it has been possible to calculate the survival from egg to smolt.

The 1957 smolt run, using the technique used since 1951, was estimated to be 6.4 million. The method employed involves the capture and marking of portions of the run as it passes the outlet of Babine Lake, and the subsequent recovery of some of the marked fish in catches eight miles downstream at the outlet of Nilkitkwa Lake. Ratios of marked to unmarked smolts in the samples are used to estimate the size of the run.

The total numbers of smolts marked and released, the total numbers of marked fish recovered, and the total samples examined each year 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 late installation of trapping structures in years when portions of the run had passed before trapping began.

Year	Number of smolts marked	Number 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
1955	113,931	1,287	270,546	30.9×10^6	28.6 to 32.6×10^6
1956	72,707	1,802	649,588	21.1×10^6	18.5 to 22.9×10^6
1957	68,666	1,496	170,772	6.4×10^6	6.0 to 6.8×10^6

Certain errors associated with the possibility of increased mortality due to marking by fin-clipping and the likelihood of disproportionate intensities of marking with relation to the run passing Fort Babine each day cannot be assessed and have been assumed to be constant each year.

Assuming that all smolts are 1-year-olds, survivals from eggs potentially available (in spawners) to emigrating smolts are shown in the table below for the brood years from 1949 to 1954.

Brood year	Eggs potentially available	Year smolts appear	Estimated number of smolts	Survival egg to smolt
1949	853×10^6	1951	4.2×10^6	0.49%
1950	591×10^6	1952	4.5×10^6	0.76%
1951	194×10^6	1953	3.1×10^6	1.60%
1952*	409×10^6	1954	2.8×10^6	0.68%
1953	$1,241 \times 10^6$	1955	30.9×10^6	2.49%
1954	$1,020 \times 10^6$	1956	21.1×10^6	2.07%
1955	105×10^6	1957	6.4×10^6	6.10%

*Only about one-third of this run spawned successfully, thereby reducing the potential egg deposition and raising the estimate of smolt survival to about [illegible]%.

Sampling of Babine sockeye smolts K.V. Ar

Since 1950, samples of sockeye smolts have been collected at the outlets of Babine and Nilkitkwa Lakes. Examination of the smolts from 1950 to 195 indicated that the sex ratio, though indicating slight variation from year to year, did not depart significantly from a 50:50 assumption. Scale examination has shown, as indicated in the following table, that the smolts are predominantly 1-year-old fish.

Year	1-year-old	2-year-old
1950	2,616	14
1951	2,795	10
1952	1,654	11
1953	1,234	22
1954	972	0
1955	1,944	2
1956	2,208	7
1957	1,657	53

Comparison of the average lengths and weights of 1-year-old smolts in the table below indicates differences in the average size from year to year.

Year	No. in sample	Fork length (mm.)		Weight (gm.)	
		Range	Average	Range	Average
1950	2,616	54-104	83.0	1.3-10.6	5.5
1951	2,795	58-111	82.4	1.6-12.8	5.6
1952	1,654	55-109	80.4	1.3-12.7	4.9
1953	1,234	70-111	86.0	2.4-13.5	6.2
1954	972	62-110	86.4	2.8-12.6	6.3
1955	1,944	56-105	81.4	1.6-11.0	5.4
1956	2,208	50- 99	77.8	1.1-10.1	4.7
1957	1,657	67-102	84.2	2.8-11.1	5.9

Johnson has demonstrated that sockeye smolts can vary considerably in size from one nursery area to another within Babine Lake and from Nilkitkwa Lake. The 1957 smolts were fairly uniform in size and on the average were larger than in most years.

Examination of smolts from 1950 to 1956 indicated that a large proportion of smolts were infected by cestodes and/or nematodes.

Sockeye smolt samples from the Kitwanga, Kispiox, and Bulkley Rivers

K.V. Ar

During the spring of 1957, 50 sockeye smolts were captured from the Kitwanga River, 2 from the Kispiox River, and 6 from the Bulkley River. Examination of the scales showed that all the smolts were 1-year-old fish with the exception of one individual from the Bulkley River which had spent two years in the lake before migrating. The sex ratio of the Kitwanga smolts was 26 males to 24 females. The lengths and weights of the Kitwanga smolts are shown in the following table:

Fork length (mm.)		Weight (gm.)	
Range	Average	Range	Average
79-101	89.3	4.6-9.8	7.2

Comparison of the Kitwanga smolts with those from Babine Lake indicates that those from Kitwanga Lake are larger. The 2 smolts captured in the Kispiox River were equal in size to the Kitwanga smolts while those captured in the Bulkley River were smaller.

Examination of the smolts showed an absence of the cestodes and nematodes which are common among Babine Lake smolts.

S T R E A M   S A L M O N   I N V E S T I G A T I O N S

W.P. Wickett

Productivity. A major "break-through" in our understanding of stream productivity occurred this year. The average fry production of pink and chum streams that have been studied by the Board was noted to differ in different parts of the coast. Using the Mark VI standpipe water meter, average permeabilities of Nile, Hooknose, and McClinton Creeks have been found. Average fry production is known in each for six or more years. Permeabilities and fry production rise together. Permeability and density of spawners per square yard that gives the largest fry output also rise together. Densities can be calculated using the area of the stream given by length times bank-to-bank width or the actual area used by the fish. Either calculation indicates that average densities in the past few years are much less than will give the maximum fry output in the above streams. Such other streams as have been studied are also underseeded. Most useful information for management can be found using the instrument in a relatively short time.

Quality standards for gravel water. A velocity of 50 cm. per hour and an oxygen content of 8 mg. per hour are suggested as criteria of suitability for salmon production for stream gravels under study re pollution or other problems.

Freshwater factors and salmon production. In addition to the effects of permeability of gravel and numbers of spawners, water levels are found to affect survival in three major ways: low water at migration stresses the adults sometimes to the point of death before spawning, low water during early incubation lowers survival of eggs due to oxygen lack, floods destroy large numbers of eggs and alevins when the floods are of great magnitude. These factors are associated with major reductions of the fisheries in the past.

Proposed program for assisting natural populations. A program is suggested in which the above knowledge will be applied to learn how to modify the natural environment so as to increase future salmon production.

Quality standards for subsurface water of spawning streams

A low oxygen supply has been suggested by the author as the cause of the low rate of survival of salmon eggs up to the fry stage as found in British Columbia.

The least survival of chum and coho eggs, placed in standpipes set in various parts of the stream bottom of Nile Creek, was found where there was the least oxygen and velocity in the sub-surface water. Development was delayed where there was low oxygen although the temperature tended to be warmer.

Surveys of Vancouver Island streams during the years 1954-56 with the 1949 equipment did not give accurate values of velocity, but a minimum value of about 10 cm./hr. for apparent velocity through the gravel seemed to be needed for survival of eggs to the eyed stage. At least 5 mg./l. of oxygen seemed to be required.

Alderdice, Wickett and Brett (1958) found the later stages of chum salmon eggs under stress at over 7 p.p.m. oxygen, although in the absence of other stresses, such as waste products, 2 p.p.m. oxygen is the lower lethal limit.

Wickett (these reports, 1955) found that a velocity of 1,000 cm./hr. through a column of chum eggs would keep 50 layers developing normally. A velocity of 8 cm./hr. allowed the equivalent of 2 layers (240 eggs) to develop normally to the strongly eyed stage.

The formula, developed by the author, that relates uptake of oxygen by layers of salmon eggs and supply of oxygen by moving water, gives a calculated value of 2.4 layers of eggs for the above example. This is reasonable agreement. The rest of the eggs in the low velocity column were in progressively retarded and moribund condition. They resembled samples of eggs from natural redds with low survival.

A velocity of 8 cm./hr. allowed 2 layers of eggs to develop naturally. Individual pockets of eggs in nature may have more layers than this. An arbitrary standard of 50 cm./hr. is suggested. This would be sufficient for 10 layers of eggs.

Where standards of quality for sub-surface water must be set for pollution control, it is recommended that the values 8 p.p.m. oxygen and 50 cm./hr. velocity be used. The results of this work are being applied to monitor the effects of logging on salmon streams in Alaska and the western United States.

Permeability of spawning gravel and salmon production

The Mark VI Standpipe Water Meter allows accurate surveys for permeability, velocity of water and oxygen content of water of the gravel. It makes possible surveys of spawning grounds to study the survival of individual salmon redds. In the course of earlier surveys it became apparent that low survival was most likely to be found in those parts of any stream where the permeability was low. Streams vary in discharge and this was shown by the author to affect the average velocity at a series of points in a gravel stretch at Nile Creek.

The average velocity of water in the gravel of a stream might be a guide to conditions for survival if only recorded once in a season. However, it might well be that streams would vary in their average permeabilities and therefore vary in the range of velocities that are possible in the gravel surrounding the incubating eggs.

The above relation follows from Darcy's Law which was found to apply to spawning gravels by Pollard during his work on the development of the standpipe water meter:

$$\text{i.e., } V = KS$$

where V = velocity
K = permeability
S = hydraulic gradient.

If the hydraulic gradient can vary with various water stages, then the permeability coefficient is the best index of the average velocity to be expected. The oxygen supply to the eggs and therefore the average survival of eggs can be expected to be influenced.

Neave has shown that the total fry output is related to the density of spawners in Hooknose Creek at Port John. Fry output rises as the density increases to 0.6 fish per square yard and falls thereafter with higher densities. Pritchard found that the highest spawning density produced the most fry at McClinton Creek. Taking his figures for bank-to-bank measurement this gives 1.4 fish/sq. yd. Nile Creek produced the most fry in 1945 from the section of the stream that had a density of 0.24 fish/sq. yd.

Average permeabilities for the above streams have been found in the last year to be 4,100 cm./hr., 9,600 cm./hr. and 1,900 cm./hr. respectively. Density at the maximum output of fry plotted against average permeability gives a straight line passing through the origin.

The application of this information could be very useful. It appears that the optimum number of spawners for a stream can be estimated if the area and permeability of the gravel are known. Surveys of streams to date indicate that many more spawning pink and chum salmon are needed. This confirms observations made on spawning grounds when pink salmon were more numerous in both catch and escapement.

In this connection Pritchard's unpublished reports on the pink run to McClinton Creek in 1928 are of interest. Where the fish were actually spawning, he noted that there were only about 4 fish/sq. yd. rather than higher numbers per square yard he had found in other streams of the Queen Charlotte Islands. McClinton Creek is between 50 and 100 feet wide bank to bank, but the average width of the water surface during most of the year is no more than 30 feet. Two independent estimates of water-covered spawning area are of the order of 10,000 square yards. In the six years of Pritchard's study, then, 155,000 spawners at an average density of 4 fish/sq. yd. gave the greatest fry output.

Similarly, Hooknose Creek gave its largest output at about 1.2 fish/sq. yd. if we use Hunter's estimate of the area actually used by the fish.

Which of the two types of area estimates should be used will depend on further experience. Bank-to-bank measurements are much easier to make. From

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STUDIES ON SALMON PRODUCTION AT PORT JOHN

F. Neave and R.C. Wilson

Sockeye

Adult sockeye salmon escapement, Port John, 1957. The number of adult sockeyes entering Hooknose Creek in 1957 was 1,353, divided as follows: females, 321; large males, 247; jacks, 785. Although the total numerical strength of the run can be regarded as moderate, the number of females was not large. Furthermore, only 50% of the latter reached the spawning grounds in the tributaries of the lake. Egg deposition was therefore much below average. The proportion of females which failed to reach the lake tributaries has been as high as 30% in some previous years. In 1957 the situation was apparently aggravated by the extremely low water levels that prevailed throughout much of the spawning season. Some of the fish which did not reach Tally Creek (the main spawning stream) attempted to spawn in Hooknose Creek.

Of the returning jacks, 759 (96.7%) were found to be marked by removal of the adipose and right ventral fins---the result of the marking of the outgoing smolts in the spring of 1956. Of the large fish, 492 (86.6%) had been marked by removal of the adipose and left ventral fins. To these can be added 151 marked jacks which returned in 1956, giving a return to date of 643 marked fish from 13,779 smolts which reached the sea in 1955. This represents a survival, after marking, of 4.7%.

Figures pertaining to the 1957 spawning of sockeye in Tally Creek were:

Females reaching weir	Average egg content	Females released above weir	Potential deposition
158	2,901	148	429,348

The number of fish spawning below the Tally Creek weir and in other streams was of very small significance in 1957, the estimated additional number of eggs deposited in these places being only 8,700.

Production and disposal of sockeye fry in 1957. The estimated potential deposition of sockeye eggs above the Tally Creek weir in 1956 was 1,316,127. The downstream migration of fry took place between April 23 and June 11, 1957, and produced a count of 75,189 at the weir. The survival at this point was 5.71---somewhat lower than the arithmetic mean of 7.7 obtained for the previous seven years. The findings over this period suggest that the greatest fry production can be expected from a potential deposition of 700,000 to 900,000 eggs.

The above-mentioned sockeye fry (minus 300 which died in the trap) were transported from Tally Creek to the mouth of Hooknose Creek. At the latter place they were released in batches of 20,000 to 30,000 within the limits of tidal influence. This was done in continuation of experiments to test the possible survival advantage of early entrance into the sea.

While no sockeye fry from above the Tally Creek weir were permitted to enter the lake, it is considered that the latter body of water may have received approximately 17,000 fry hatched below the Tally Creek weir or in other tributaries of the lake.

Sockeye smolt production. The run of seaward-migrating smolts trapped at the weir on Hooknose Creek in 1957 was relatively small (11,808). This was inevitable, since the lake population from which it originated had been drastically reduced by the transplantation of fry to salt water. The percentage survival, however, was extremely high. The 1957 smolt run, as determined by D.W. Jenkinson from a one-percent sample of the migrants, consisted entirely of fish which had remained 2 years in the lake and thus were survivors of the fry entering the lake in the spring of 1955. These were estimated to number 15,414. To the 11,808 smolts counted in 1957 may be added an estimated 475 one-year-old smolts which went to sea in 1956, giving a total survival from fry to migrating smolt of 79.7%. This figure provides further evidence of the relatively small importance of predation in this lake---at least when sockeye densities are low.

All outgoing sockeye smolts released from the Hooknose Creek weir in 1957 were marked by removal of both ventral fins. This was done in order to assist in the segregation (in returning adults) of lake-reared fish from fish which were transported to tidal water as fry.

Pink and chum

Adult pink and chum migration in 1957. Although the 2,333 pink salmon which entered Hooknose Creek in 1957 constituted the largest odd-year escapement in 10 years, they were still far less numerous than the even-year fish of 1952, 1954 and 1956.

The chum salmon escapement (3,698) was the third largest recorded in the 10-year history of the Port John field station.

Statistics relating to the spawning of the two species in 1957 are as follows:

Species	Number of adults	Percent females	Average egg content	Potential deposition	Percent loss of eggs by retention
Pink	2,333	53.7	1,825	2,142,550	1.60
Chum	3,698	53.6	2,489	4,838,616	0.84

The average egg content and the loss due to retention were based on 23 and 12[illegible] samples respectively for pink salmon, and 33 and 198 for chums.

Ocean survival. The pink salmon escapement is presumed to represent the survivors from a total of 85,256 fry which were counted as they went to sea in the spring of 1956. The percentage survival of 2.71 is very close to the 9-year average.

The ocean survival of chum salmon cannot be estimated so closely, since the survivors do not all come back in the same year. The majority of the 1957 escapement, however, should have come from the fry migrants of 1954, whi[illegible] amounted to 984,500. The ocean mortality of this species (whether due to fishing or other cause) must therefore be presumed to have been much greater than that of the pinks returning in the same year.

Output of pink and chum salmon fry in 1957. The mid-point of the down-stream migration of pink salmon fry resulting from the spawnings of 1956 was reached on April 29 and that of chum salmon fry on May 3. These are close to the average dates for the preceding 9 years. The output of fry in relation to the egg deposition was as follows:

Species	Potential deposition	Number of fry	Percent survival
Pink	15,811,800	454,148	2.87
Chum	4,074,477	69,830	1.71

The very low percent survival for both species confirmed previous evidence that the spawning populations were too dense to produce a good fry output. Judging from the findings made thus far at Hooknose Creek, the most favourable size of spawning population is 10,000 to 12,000 fish. The population in 1956 was about 25,000 fish.

Coho

Coho smolts migrating to sea in the spring of 1957 numbered 6,704. They were the survivors from an estimated deposition of 645,696 eggs in the Hooknose Creek watershed in 1955. The survival was therefore 1.04% to this stage. The previously established range is from 0.6% to 4.0%.

The ocean survival of cohoes from the brood year of 1954 is represented by the jacks which returned in 1956, plus the large males and females in 1957. These were: jacks, 225; large males, 152; females, 151; a total of 528. This is a return of 11.7% from the 4,513 smolts which left the stream in 1956. The return from the 1955 smolts was 11.9%, while the ocean survival recorded from previous years has varied from about 4% to 20%.

In addition to the large males and females reported above, the 1957 coho escapement included 417 jacks.

The estimated potential deposition in 1957 was 391,200 eggs.

BEHAVIOUR OF MIGRATING JUVENILE SALMON

W.S. Hoar

The first objective of investigations at Port John in 1957 was to examine critically the earlier descriptions of the migrating juveniles and to compare these descriptions with the activities seen in areas which are now considered more natural than those used at the outset of the work.

During the course of this re-examination of the basic behaviour patterns of the young salmon, the following additional points have been demonstrated:

(1) Coho salmon fry will school as actively as pink, chum and sockeye under certain conditions. This schooling behaviour could be "released" in three different ways---all involving a displacement of fish from territories.

(2) When the four species of fry were exposed in the same way to predation by crows, none of the coho or sockeye were captured, few of the chums were taken but most of the pinks disappeared. The findings substantiate earlier comparisons based on the nature of the hiding reactions of the species. Pinks delayed in rivers must be extremely vulnerable to predators.

(3) An adequate demonstration can be made, in a 360-cm. trough, of schooling migrants <u>swimming with a current</u> at low light intensity.

(4) When the responses of the four species of salmon fry to current are measured under strictly comparable conditions, the reaction of the pink and coho fry is much less vigorous than that of the other two species. In this as in several other respects the pink reacts differently from the other two strongly schooling species. This is discussed in connection with its migratory behaviour.

The second objective was to study again the tendencies of the schooling migrant fry to swim steadily forward in continuous channels and to learn constant directions.

A series of experiments with a winding maze showed that the fish could not learn such a pattern. The experiments suggested, however, a line of investigation which may prove fruitful. There was some evidence that the tendency of the schools to swim steadily forward dropped off sharply after the middle of May and it is thought that this may reflect a decline in what the behaviour student refer to as "internal motivation". It may be possible to measure changes in the motivation of migration with such an apparatus. The presence or absence of such motivation may become a critical point for consideration when waterways are altered for man's various purposes.

In another series of tests, schools of chum fry were conditioned for 2 hours to swim to and fro in a straight channel and then transferred to a right-angled channel in which they could swim to and fro along the same compass direction or one opposite to it or along the full length of the two arms before completely turning (180°). The experiment was designed to test for a "compass orientation" or a celestial navigation. When trained to travel back and forth along one compass direction the fish showed no tendency to select this direction if given a choice of this or the direction at right angles to it. In contrast to the controls, however, they did show a tendency to turn at the junction of the two arms of the right-angled trough rather than continuing for its full course. This is interpreted as a conditioning to act after travelling a definite distance or a definite time---some type of learning process.

The following two manuscripts were prepared and have now been accepted for publication in the Journal of the Fisheries Research Board of Canada.

"Rapid learning of a constant course by travelling schools of juvenile Pacific salmon".

"The evolution of migratory behaviour among juvenile salmon of the genus <u>Oncorhynchus</u>".