ANNUAL

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The study of 4- and 5-year-olds provides only a limited picture of the distribution of chums on the high seas. Especially late in the season, immature 3-year-old and younger fish form large proportions of research vessel catches. Extension of the present study to include examination of these younger fish is necessary to provide a balanced description of the distribution of stocks originating from the two continents. In addition, chum scales collected since 1957 should be examined and the results compared with those derived from the 1956 and 1957 data.

B. Skeena Salmon Investigation

J. McDonald and F.C. Withler

Since the formation of the Skeena Salmon Management Committee in 1954, this Station has been responsible for providing the biological information required for management of the Skeena salmon stocks. This has necessitated a close examination, and the further development, of the biological principles and tools for management. The resulting information, while applied directly to the management of Skeena stocks by the Committee, may be applied more generally.

The present objective of salmon management is to provide the largest possible sustained yield. This requires fullest possible use, by the salmon, of their freshwater and marine environments. Pacific salmon reproduce in fresh water and grow mainly in the sea. Although annual variation in ocean conditions has important effects on growth and survival, it is generally conceded that the freshwater environment, and particularly the amount and quality of the spawning and rearing area available, finally limits production. Sound regulation of the salmon fishery must therefore provide the escapement which will best utilize the freshwater environment and result in the largest return.

The Skeena salmon investigations have therefore been chiefly concerned with determination of the escapement size required to produce the greatest yield to the fishery, and how to regulate fishing to provide this escapement.

(1) Determination of optimum escapements

Sockeye. Babine sockeye compose over 80% of the total Skeena run. Management of Skeena sockeye is therefore, for the most part, management of the Babine stock. In realizing its objective of providing optimum spawning escapements, the Committee was immediately faced with the problem of greatly reduced returns from the slide-affected Babine sockeye escapements of 1951 and 1952. Stringent fishing restrictions were necessary in the years of 1955, 1956 and 1957 to restore these runs to at least their former level.

At the same time, studies showed that the major part of Babine Lake was not being fully utilized by young sockeye. Because the young fish did not disperse far from the streams of their origin, better utilization depended upon re-distribution of adult escapements. Young sockeye were more dense and smaller in the northern lake basins adjacent to the large outlet spawning grounds than were sockeye in the southern lake basins which compose 90% of the total lake area. In most years the escapement to the grounds adjacent to the northern basins was sufficient to provide enough young to make best use of this limited nursery area. The amount of available spawning area adjacent to the large southern basins would finally limit use of the great potential of this part of the lake as a rearing area, but observation showed that escapements in this area were even less than those needed to fully use the streams.

Past tagging of sockeye in the fishing area and subsequent recovery of tags on the spawning grounds had shown that sockeye, proceeding to streams tributary to the southern lake basins, passed through the fishing area during the early and middle portions of the sockeye fishing season. Therefore it was possible, by appropriate regulation, to adjust the distribution of the Babine escapement and thus better use the spawning and nursery areas. Since 1956 early sockeye fishing has been restricted. As a result the proportion of the total Babine escapement (and resultant young sockeye) using the main lake area has been increased.

Since 1955, the Babine sockeye escapement has been restored to about its pre-slide level, and in 1958 and 1959 the escapements approached the apparent optimum required for best use of the spawning and nursery areas. The effect of the near optimum escapements in 1958 and 1959, together with better distribution of spawners and their young, has resulted in a gratifying increase in the numbers and size of young fish produced. (See next section - "Lake Sockeye Studies").

<u>Pinks</u>. Intensive study of Skeena pink stocks began in 1956. Prior to this time, little was known of the escapements to the major spawning grounds or the timing of individual runs through the fishery. Extensive taggings and surveys have since provided a working knowledge of these runs for management purposes.

Analysis of past catch statistics revealed that spawnings in years of abundance more often resulted in large returns than did spawnings in years of scarcity. It was also evident that the existing stock level was far below that which produced the large catches prior to 1931.

Observations in major producing streams support this conclusion. Since studies began in 1956, fry output has been roughly proportional to the abundance of parent escapements, suggesting that recent escapements have been well below the capacity of the spawning grounds to produce young pinks.

(2) <u>Regulation of the fishery</u>

Tentative regulations designed to provide desired escapements are established half a year in advance of the main fishing season. To establish such regulations it is necessary to know the times that different runs pass through the fishery, the likely abundance of the returning runs, and the effectiveness of the probable fishing fleet in exploiting them. During the fishing season, the regulations can be changed to adjust for deviations of existing conditions from those that were expected.

The greatest problem in establishing regulations in advance of the season is predicting the likely abundance of the runs. At present the best advance indication of the abundance of the returning runs is the abundance of young fish which went to sea. Recent studies have shown, however, that survival in the sea may vary greatly from year to year and, in the case of sockeye, that the age of return may also vary. These fluctuations make precise prediction difficult. To improve prediction, factors associated with these variations are being investigated. These studies show that for sockeye, marine survival and age of return are related to growth both in fresh water and in the sea. Thus, knowledge of the size of young sockeye going to sea, and that of "jacks" which return a year or two in advance of the main body of the run, will assist in prediction of the total return. With information on the abundance of the run, data on the times of passage of runs through the fishery (from past tagging experiments) and on the efficiency of the fishery (from study of catch and escapement statistics) are then used to establish tentative regulations to provide the desired division between catch and escapement.

During the season, detailed comparisons of catch figures with immediate estimates of escapement (derived from test fishing above the fishery), permit assessment of the effectiveness of regulations. Adjustments can then be made as the abundance of the run or the effectiveness of the fishery demands.

1. The 1960 Skeena salmon catch and escapement

J. McDonald and K.V. Aro

The escapements of sockeye and pink salmon needed to return these stocks to their former relatively high level, and ultimately to provide the greatest possible sustained return to the fishery, can only be provided by close regulation of the fishery. To regulate for the escapement needs of each species and of each major stock comprising the total run of each species is complicated by a considerable degree of intermixing within the fishing area and by the ability of the fleet to catch a large proportion of the fish present in the area in a very short time. A record of the catch and escapement to major spawning and nursery areas provides a means of assessing the effect of the regulations on the stocks.

The Skeena Salmon Management Committee, when recommending the 1960 regulations for sockeye and pinks, considered the following:

(a) The need to increase the sockeye escapement to the under-used spawning streams tributary to the large nursery area of the southern portion of Babine Lake was still evident. Sockeye which spawn in these streams pass through the fishing areas from mid-June to mid-July.

(b) The total Skeena sockeye run, which would be composed of 4-year-olds from the 1956 spawning and 5-year-olds from the 1955 spawning, was expected to be small. The 1955 spawning was the poorest on record for the Skeena and was expected to provide a total return of less than 200,000 5-year-olds. The 1956 spawning was moderate in number and, in the Babine watershed, well distributed over the spawning grounds. It was expected that approximately 500,000 or slightly more sockeye would return from this run as 4-year-olds in 1960. These expectations indicated that, even if the 1960 sockeye were not fished, the numbers returning would be adequate only for a good escapement.

(c) The 1960 Skeena pink run, which was returning from the moderate seeding and resultant fry production of the 1958 run was expected to number about 2,000,000.

(d) The fishing industry had faced in the past few years and would face again in 1960 hardships imposed by small sockeye runs brought about by the Babine River rock-slide. Various representatives of the industry had pointed out that very poor prospects were in sight for the 1960 British Columbia salmon runs generally and had expressed concern that severe regulation of the 1960 Skeena salmon runs would work undue hardship on the industry.

Bearing the above considerations in mind the committee recommended the following regulations for the 1960 Skeena salmon fishery:

(a) That fishing for sockeye commence on July 10, by which time some early-run sockeye would have passed the fishing area.

(b) That for the 3 weeks from July 10 to July 31, 2 1/2 days per week fishing be permitted to harvest the middle season sockeye.

(c) That from July 31 to August 28, 3 days per week fishing be permitted to harvest the expected moderate run of pinks. It was borne in mind that heavy fishing to harvest early-run pinks might jeopardize the late-season sockeye escapement which would be passing during the last week of July and the first week of August.

As fishing progressed, it became apparent that the sockeye run was even smaller than expected, and was especially small in the early portion of the season. Figure 15 shows, for the Skeena Gill-net Area, the numbers of days fishing recommended by the Committee prior to the season, the actual number of days fishing allowed each week, the weekly number of gill-net boat deliveries, and the estimated weekly total abundance of sockeye and pinks (catch plus escapement estimates derived from test fishing above the upriver commercial fishing boundary). The diagram illustrates that the escapement of sockeye was small prior to the commencement of sockeye fishing on July 10. During the last three weeks of July and the first week of August the run remained small, and about 45% of the sockeye entering the Skeena Gill-net Area were caught. During the second and third weeks of August when fishing was reduced to 2 days per week about 20% of the small numbers of sockeye present were caught. The total catch of sockeye in the Skeena Gill-net Area amounted to 186,000 pieces.

The escapement was also small, amounting to about 320,000. Of these, 263,000 entered the Babine-Nilkitkwa watershed. This was one of the smallest escapements to Babine since counts began in 1946. The spawners were well distributed over the Babine spawning grounds, with slightly over half entering streams tributary to the under-used southern basins. Water conditions appeared favourable for spawning. Escapements to other Skeena sockeye spawning areas were lower than average.

The 1960 Skeena pink run was one of the poorest on record. The total run, slightly in excess of 500,000, was not even as great as the parent escapement. The return of pinks was also poor in most other areas of British Columbia and southeastern Alaska, strongly suggesting that the young from the 1958 spawning encountered extremely unfavourable ocean conditions for growth and survival. Figure 15 illustrates the weekly abundance of pinks in the Skeena Gill-net Area and the division of the stock by week into catch and escapement upriver. It became apparent by the end of the first week of August that the pink run would be very small. Consequently, additional 24-hour closed periods

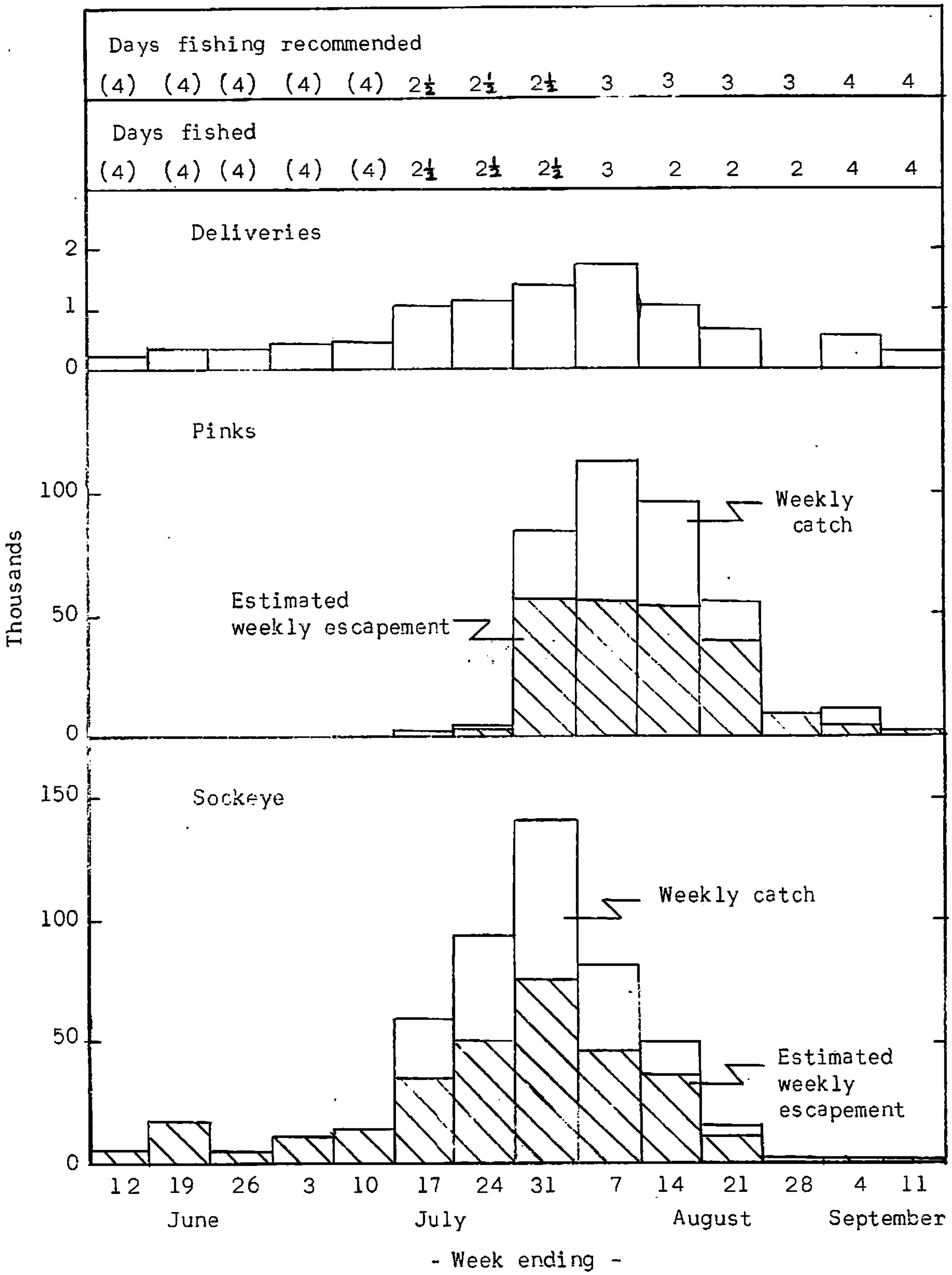


Fig. 15. Catch, escapement (based on test-fishing catches), and fishing effort (boat deliveries by week), Skeena sockeye and pinks, 1960. Days fishing in brackets refer to days when spring salmon nets only were permitted.

were recommended by the Committee during the second and third weeks of August in order to provide additional spawners. A complete closure was recommended for the same purpose during the week ending August 28. The total catch of pinks in the Skeena Gill-net Area was 170,000. An additional 100,000 Skeena-bound pinks probably were taken in Ogden Channel.

The total escapement was 273,000, one of the lowest recorded on the Skeena River. Some 215,000 spawned in tributaries of the Skeena River or in the river itself, while 58,000 spawned in coastal streams adjacent to the Skeena Gill-net Area. The effect of the fishery on the early part of the pink run was reflected in the small escapements to the Kispiox and Kitwanga Rivers. The closures later in August permitted a somewhat larger (111,000) escapement to the Lakelse River.

The 1960 Skeena gill-net catch of spring salmon was about 19,000, which is below average for the period since 1950. The escapement to the Bulkley, Morice, Kispiox, Lower Babine, and Khyex Rivers were reported by Department officers to be light, and to the Kitsumgalum and Bear Rivers to be average. The runs to the Ecstall River and Johnson Creek were reported to have been better than in the cycle years.

The 1960 gill-net catch of coho salmon in the Skeena area was approximately 36,000, which is slightly over half the 1950-58 average. The escapements to the Bulkley, Bear, Kitsumgalum and Kitwanga Rivers and to the streams tributary to the Skeena estuary were reported to be light and to the Morice, Babine, and Lakelse Rivers of medium intensity.

The 1960 Skeena gill-net catch of chums was about 21,000 pieces, which is less than half of the 1950-59 average. The escapements to the streams in the Skeena-Lakelse area and to the streams tributary to the Skeena estuary were reported to be light.

2. <u>Escapement indices from test fishing</u>

K.V. Aro and S. Tanaka

Estimates of the escapement of sockeye and pink salmon throughout each season since 1955 have been obtained from the catches of these species in standard gill-net drifts above the upriver commercial fishing boundary. These estimates, together with catch statistics, permit an assessment of seasonal and annual changes in the rate of removal by the fishery.

The seasonal patterns of test-fishing catches have been compared with those of the escapements to the spawning grounds. The comparison has shown that throughout each season the test-fishing catches were generally proportional to the escapement. An index of the escapement as indicated by test fishing catches has been derived for each season by summing the average daily test-fishing catch per hour and dividing this sum into the total escapement to areas upriver from the test-fishing site. The indices for the years 1955 to 1959 are shown in Table XII.

Table XII. Test-fishing indices and escapement abundance for Skeena pinks and sockeye, 1955 to 1960.

Year	Sum daily catch/hr* Sockeye	Pink	(1,000's fish) Total escapement Sockeye	Pink	Escapement per daily catch of 1 fish/day Sockeye	Pink
1955	377	1,672	125	987	333	584
1956	834	522	441	202	530	387
1957	769	1,929	485	868	632	451
1958	1,203	1,149	884	556	735	484
1959	1,111	1,909	854	1,383	769	724
1960	407	195	313	215	770	1,104

*Adjusted to correct for differences in efficiency of boat skippers.

There has been considerable variation in the indices for sockeye and pink escapements during the six years of test fishing. Sources of variation include:

(a) Differences in efficiency of nets. During the early part of the 1955 season, a standard commercial sockeye net was used instead of the special graded mesh nets used later in the season and in subsequent years. The commercial net, having considerably more surface of a mesh size suitable for catching sockeye than the experimental net was much more efficient at catching sockeye. For this reason, the test-fishing index for sockeye in 1955 was much lower than in subsequent years. Comparisons of the areas of the two nets composed of sockeye catching mesh indicate that the commercial net would be expected to catch about twice as many fish as the experimental net. Correcting for this difference for 1955 sockeye, the "escapement per daily catch of 1 fish/day" index in Table XII should be corrected to 510, much closer to values for the other 5 years.

(b) Differences in efficiency of skippers. As outlined in previous reports, it has been found that since 1956, there has been a consistent difference in catching efficiency between the two skippers averaging about 30%. This difference has been accounted for in preparation of Table XII.

(c) Effects of environmental factors. The effects of a number of environmental factors including time of day, wind velocity and direction, cloud cover, tide level, amount of debris in the river, number of seals in vicinity of net on test-fishing catches were examined. It was found that none exerted consistent effects except the stage of the tide. Test-fishing sets are made only on slack tides. When tide levels were very low (below about 5 feet), it was found that test-fishing catches increased markedly. This suggests that at very low tides, when much of the Skeena River at the test-fishing site dries up, the fish are concentrated more in the deep channel where test fishing is conducted.

(d) Effects of net saturation. The data in Table XII suggest that the indices are higher in years when escapements were large than when they were small (excepting data for 1960). This in turn suggests the possibility that the catching efficiency of the nets may decrease as they become increasingly filled with fish. To correct for the effects of such net saturation, a number of theoretical conditions were considered and tested by application to the actual test-fishing catch data. The situation that seemed to apply best to the test-fishing data was based on the assumption that each fish caught in the net frightens away a set proportion of those subsequently reaching the net. The following equation represents the relationship between catch and the relative abundance of fish under these circumstances:

$$qN = \frac{e^{ac} - 1}{at}$$

Where q = efficiency of empty net

N = number of fish reaching the net

a = proportion of fish reaching net repelled by a catch of one fish in the net

c = catch of fish in net

t = time

Application of this formula to test-fishing catch data throughout each season provided weekly escapement indices that paralleled the changing abundance of escapements revealed by later spawning ground counts closer than did indices derived from uncorrected data.

Even with such sources of variation, test fishing has provided a reasonably reliable index of the abundance of the escapement. In Figure 16, escapement indices derived from test fishing, corrected for the various effects noted above, are compared with estimates of escapements observed on the upriver spawning grounds. The test-fishing indices vary closely in proportion to the actual escapements. From the graphs it can be seen that deviations from expected abundances of escapements are about as great at low levels of abundance as at high, indicating that the percentage error in the test-fishing indices likely is greater when the run is small.

3. <u>Babine fence counts in 1960</u> F. P. Jordan

Babine Lake is the largest producer of sockeye in the Skeena system. The escapement to Babine in past years has constituted over 80% of the total escapement to the Skeena. Operation of a counting fence on the Babine River has provided an accurate record each year since 1946 (except in 1948 when the fence was inoperative) of the abundance, timing and of the length, sex and age composition of the run. Counts have also been made of all other species of salmon and steelhead trout ascending past the fence. These data have been of particular importance since 1951 in assessing the effects of the partial block to migration by the Babine River rock-slide and the success of measures taken

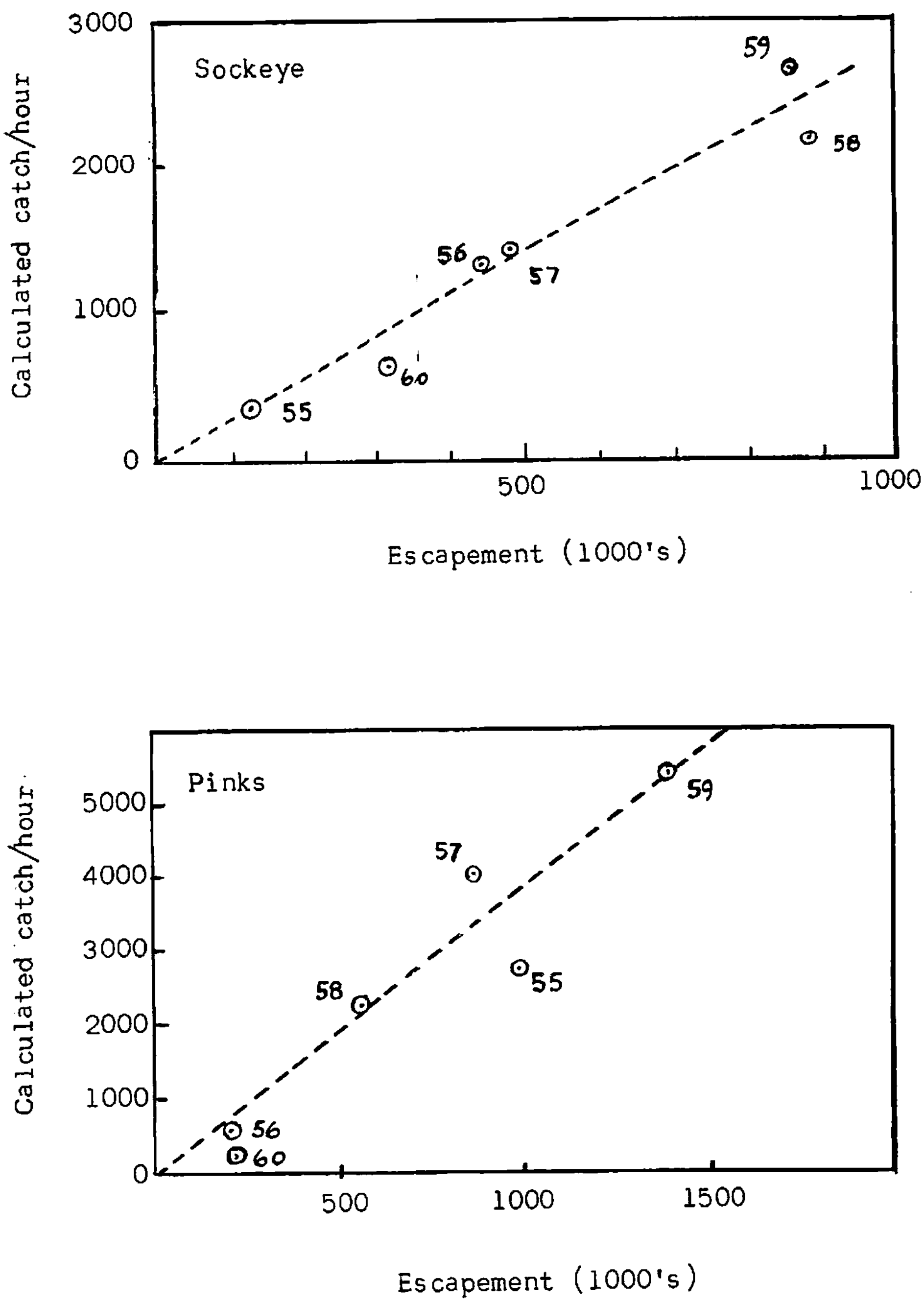


Fig. 16. Comparison of test-fishing escapement indices with escapement estimates based on spawning ground counts and estimates for 1955 to 1960.

by the Skeena Salmon Management Committee toward rehabilitation of the slide-affected stocks.

The numbers of the five species of Pacific salmon which were counted in 1960 are compared in Table XIII with counts made in the other years of operation:

Table XIII. Counts of salmon passing the Babine fence.

Year	Sockeye Large	Sockeye Jack	Spring	Pink	Coho	Chum
1946	444,551	31,154	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
1958	812,043	30,769	8,274	6,600	7,606	8
1959	782,868	31,920	9,597	56,766	10,947	20
1960	262,719	49,396	2,855	4,876	6,794	6

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

The run in 1960 of 262,719 "large" sockeye was smaller than average. The count began on July 12. The daily count rose to a peak of 18,130 large sockeye on August 7. The early peak is characteristic of most years and consists of early-running fish to the smaller streams at the south end of the lake. Following the peak, the run declined and rose again to a second peak of 10,211 large sockeye on August 27. This portion of the run is mainly composed of fish which spawn in the Upper and Lower Babine and Fulton Rivers. Following the second peak on August 27, the run declined until only 118 large sockeye were counted on September 28. Fence operations were then discontinued. The run of spring salmon was less than average. During the early part of the season the run consisted mainly of "jacks", while later, the run was predominantly composed of large fish. Since spring salmon spawn below as well as above the fence, the count represents only a portion of the total Babine River run. The pink salmon run was about average for even-year cycles following the rock-slide. As is the case for springs, some pinks spawn below the fence. The coho run was a return in a cycle year of the 1951 slide-affected run. The runs in this cycle have shown a steady improvement from the count of 2,122 in 1951. A few chum salmon again reached the Babine fence.

To examine the composition of the 1960 Babine sockeye run, 1% of the previous half-day's fence count was sampled twice daily for length and sex. In addition, sampling was carried out to determine the proportion of the large fish which were "normal", net-marked, or injured.

Females in the 1960 sockeye run outnumbered the large male sockeye as in all other years with the exception of the slide years 1951 and 1952. The 1% sample indicated that 55.7% were females and 44.3% were males. As shown in Table XIV, these figures are about average for the 1946 to 1960 period.

Table XIV. Percentages of male and female sockeye passing the Babine fence.

Year	% male sockeye	% female sockeye
1946	43.52	56.48
1947	45.56	54.44
1948	--	--
1949	40.99	59.01
1950	43.74	56.26
1951	51.88	48.12
1952	58.90	41.10
1953	44.15	55.85
1954	39.72	60.28
1955	47.16	52.84
1956	48.62	51.38
1957	49.00	51.00
1958	39.38	60.62
1959	39.56	60.44
1960	44.30	55.70

Sampling to determine the condition of large sockeye showed that 9.9% had net marks, 5.1% had other injuries and 85% had no injuries or net marks. These figures were similar to those obtained in past years, with the exception of 1951 and 1952 when many slide-damaged fish were observed. A comparison with sampling in previous years of fence operation is shown in Table XV.

Table XV. Condition of sockeye passing the Babine fence.

Year	Normal	Net-marked	Injured
1946	--	--	--
1947	84.5	11.35	4.2
1948	--	--	--
1949	86.9	6.22	6.8
1950	84.2	12.34	3.5
1951	51.6	18.33	31.1
1952	69.2	1.00	29.9
1953	93.0	4.27	2.7
1954	89.3	8.26	2.5
1955	87.2	6.12	6.7
1956	94.2	4.27	1.5
1957	90.2	8.26	1.5
1958	83.5	13.91	2.6
1959	91.5	4.17	4.3
1960	85.0	9.88	5.1

"Jack" sockeye, as well as the large male and female sockeye, were smaller than average in 1960. In Table XVI, their average size in 1960 is compared to that observed in previous years.

Table XVI. Average length, in centimetres, of sockeye in the proportionate samples.

Year	Large males	Jacks	Females
1949	61.5	37.4	59.9
1950	57.7	38.3	57.1
1951	60.1	38.9	58.4
1952	58.9	38.3	57.7
1953	62.4	38.6	60.3
1954	66.6	38.3	63.0
1955	55.7	38.2	57.9
1956	58.1	36.0	57.1
1957	57.6	37.8	57.0
1958	61.6	38.5	59.4
1959	62.3	37.4	60.4
1960	55.6	36.5	55.2

The average egg content in 1960 was calculated to be 2,915 eggs per female. Based on the number of females estimated to have survived the Indian fishery above the fence (138,391), the potential egg deposition at Babine was approximately 403 millions.

J. McDonald

4. Babine Lake sockeye smolt output

Knowledge of the number, size, and age composition of smolts emigrating each year from Babine Lake provides a measure of the production from parent escapements of known size and distribution. The abundance of smolts may also provide advance indications of the number which will be available to the fishery, two or three years later.

Estimates of the smolt output have been made annually since 1951 through a marking and recovery program. Smolts were marked and released near the lake outlet. The abundance of the smolt run was estimated from the proportion of marked fish among those captured further along the migration route.

Observations since 1958 have shown that significant numbers of smolts leave the lake at about the time of ice-breakup and before the usual mark and recovery program had begun. The small size of these "early" smolts, together with results from tagging, suggests that they were mainly from the adjacent Nilkitkwa-North Arm nursery area. The main body of smolts which followed were larger in size, and came mainly from the more distant main lake basins. This recent information suggests that the estimates of the smolt output in years prior to 1958 included only the population emigrating from the main lake basins rather than from the Babine Lake system as a whole. The data for the earlier years are being re-examined and attempts will be made to revise the estimates for the years prior to 1958.

In 1958 and 1959 estimates of the number of "early" smolts were based on net catches and school counts, whereas the main runs of smolts were estimated by use of the conventional mark and recovery method. Extension of the mark and recovery program in 1960 permitted, for the first time, an estimate of the total smolt migration in this way.

From May 3 to June 26, 1960, 71,305 smolts were tagged and released. Of the 655,381 smolts examined three miles downstream from the tagging site, 987 were tagged, giving a tagged to untagged ratio of 1:664 and a seasonal recovery of 1.38% of the tagged fish. When adjustments were made to account for a calculated tagging mortality, the estimated smolt output was 45 million. The "early" run was in the order of 15 million and the "late" run in the order of 30 million.

The estimated smolt output and the survival from egg to smolt for the brood years 1956 to 1958 are shown in Table XVII.

Table XVII. Potential sockeye egg deposition, estimated number of smolts and survival from egg to smolt, Babine Lake.

Brood year	Potential egg deposition (millions)	Year smolts migrated	Estimated number smolts (millions)	Survival egg to smolt (percent)
1956	523	1958	22	4.2
1957	653	1959	39	5.9
1958	1,543	1960	45	2.9

The smolt output from the 1958 brood stock was the largest yet estimated from the Babine system. Although the output was large, the data indicate that the survival from egg to smolt was lower than that resulting from the spawnings of 1956 and 1957.

5. Growth and age of return in Skeena sockeye

H.T. Bilton and
J. McDonald

Skeena sockeye mature mainly as 4- and 5-year-olds. The proportion of the stock maturing as either 4's or 5's varies greatly from brood year to brood year, creating a major problem in attempts to forecast the likely abundance of the run in any one year. Work on other species suggests that in some cases age of maturity may be associated with the rate of growth. To investigate this possibility for Skeena sockeye, recent data on age of maturity, size and growth rates as deduced from scale measurements have been examined. Although these studies are in a preliminary stage, two promising leads have appeared.

(a) Size of "jack" sockeye and age of return. Although most Skeena sockeye mature as 4- and 5-year-olds, some also mature as 3-year-olds or "jacks". The latter, which are almost exclusively male fish, are too small to be taken to any extent in the Skeena fishery. Since 1946, annual counts and length measurements have been made of jack sockeye entering the Babine Lake system (the main Skeena sockeye producing area). The average size of jacks has varied from year to year from as low as 36.0 cm to as high as 40.6 cm. In Figure 17, the proportions of returning runs that came back as 4-year-olds and 5-year-olds are compared with the average size of jacks for brood years since 1943. The results indicate that for a given brood year, when jacks were small, the proportion of the stock returning as 4-year-olds tended to be small, whereas when jacks were large, the stock tended to return predominantly as 4-year-olds. Statistically, the correlation coefficient for this relationship (+0.72) is highly significant. Thus it would appear that when growth is relatively good early in the sockeye's life, the fish tend to return to spawn at an earlier age than when growth is slow. This relationship offers a means of predicting, a year in advance, the likely proportions of the run that will subsequently return as 4's and 5's. Thus, from knowledge of the average size of jacks appearing in 1960, it should be possible to determine whether the progeny of the 1957 brood will return mainly as 4-year-olds in 1961 or as 5-year-olds in 1962. Data for future years will permit further assessment of the reliability of this relationship.

(b) Growth in fresh water and the age of return. The foregoing section suggests that growth rates early in the life history of the sockeye may have important effects on the ultimate age of maturity of the fish. To examine whether or not the growth rate during the year spent in fresh water affected the subsequent age of maturity, scales of young sockeye smolts emigrating from Babine Lake and of adults returning two to three years later to the commercial fishery were examined.

Among smolts emigrating from Babine Lake, there was a very strong relationship between the size of the fish and the number of rings or circuli on their scales. As an example of this, Figure 18 shows the relationship between circulus counts and body length for smolts leaving Babine Lake in 1956. On the scales of returning adults it is possible to recognize the part of the scale laid down in fresh water and thus to count the number of fresh-water circuli and to

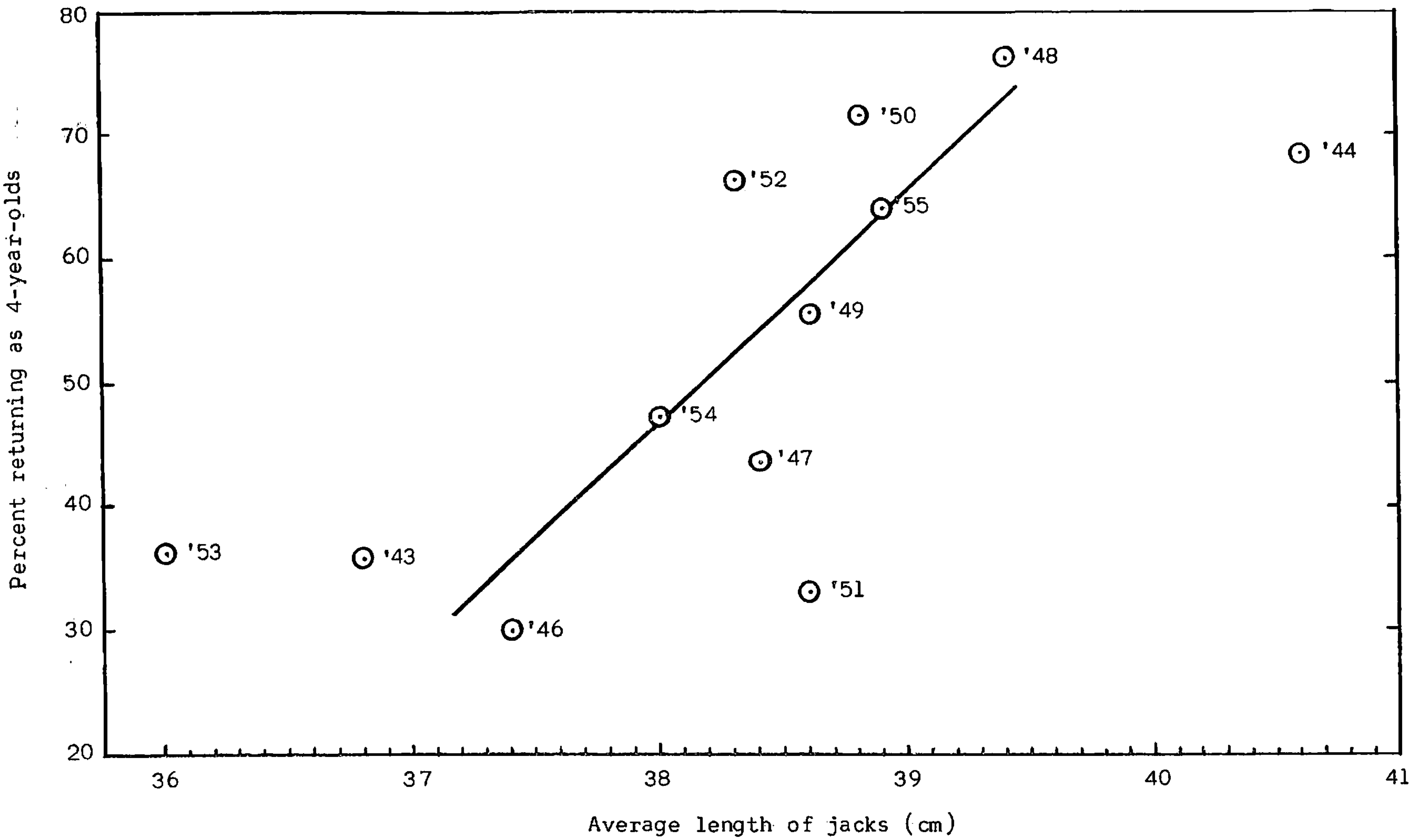


Fig. 17. Relation between age of return and size of jacks for the brood years 1943 to 1955 in Skeena sockeye.

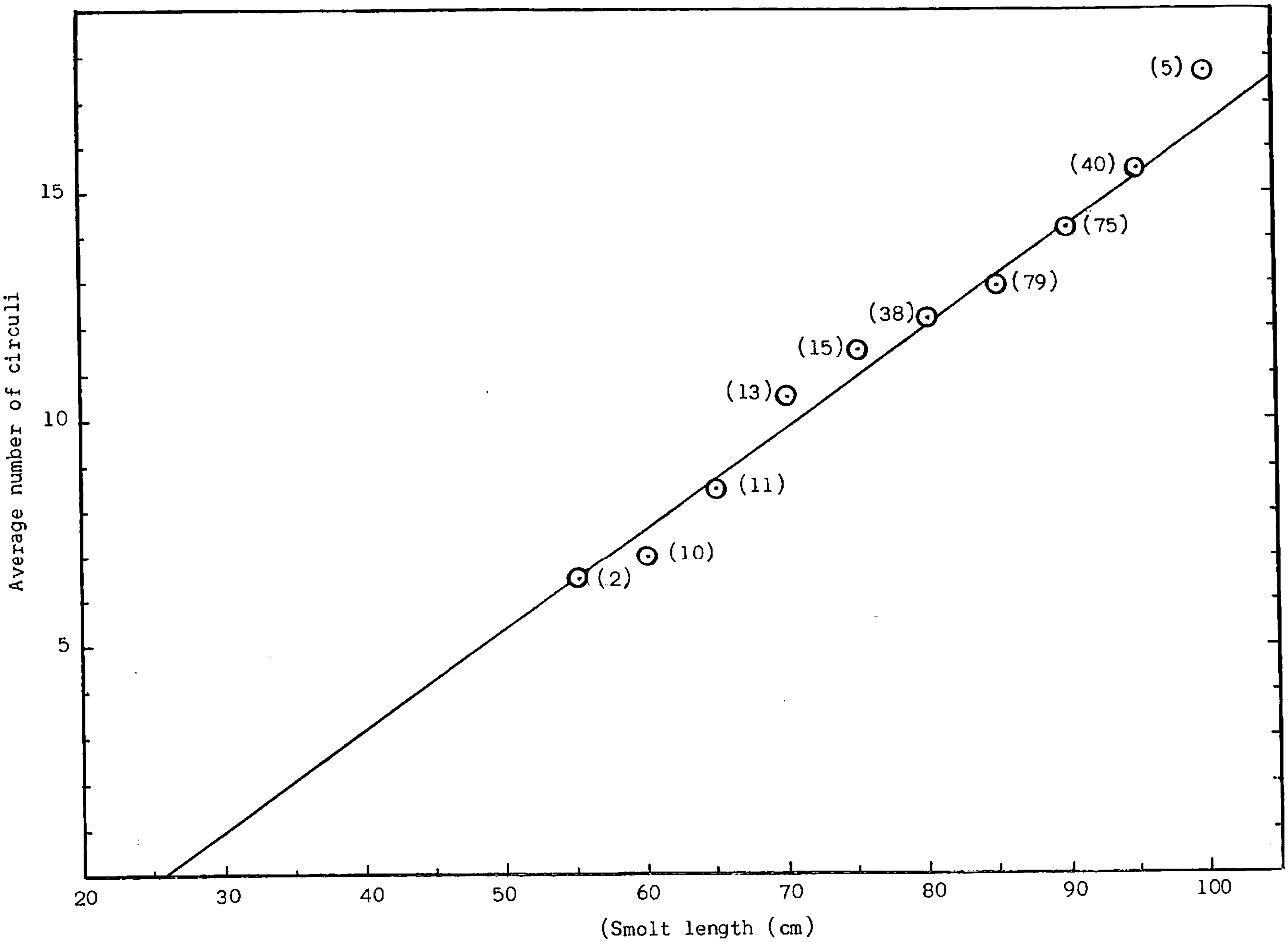


Fig. 18. Relationship between circulus count and body length for smolts emigrating from Babine Lake in 1956. (Figures in brackets indicate number of specimens used to compute values for each point.)

determine the approximate size of the fish as it left fresh water two to three years before. Examination of scales of 4-year-old and 5-year-old fish originating in the brood years from 1952 to 1955 shows that, in most years, 4-year-olds exhibited much higher circulus counts than did 5-year-olds (see Fig. 19). This in turn suggests that in any given year, the small smolts tended to mature at an older age than did the large ones. For the last brood year studied (1955), however, the difference in circulus counts was very small, suggesting that in this case factors other than freshwater growth were exerting important effects on the age of maturity.

These studies are continuing and will be extended to examine the relative importance of growth in fresh water and in the sea in determining the age at which Skeena sockeye mature and return to spawn.

6. The 1960 Skeena pink salmon escapement

J. McDonald

Officers of the Department of Fisheries carry out annual surveys of Skeena spawning areas to estimate escapement size. In recent years, where more detailed information is required for management, these surveys have been supplemented by ground and air surveys, tagging and recovery procedures, and fence counts by Fisheries Research Board personnel. For the most part, this additional work has been confined to the relatively large spawning areas and escapements. These produce the major portion of the Skeena pink salmon and it is in these areas where accurate estimates of the number of spawners are the most difficult to obtain.

In 1960 the escapement to the Kispiox River was estimated by a tagging and recovery program. Fences were operated on the Lakelse, Kitwanga, and Babine Rivers. The escapements to other areas were estimated by the Department of Fisheries stream surveys. The estimated total escapement in 1960 and in other recent years is given in Table XVIII.

Table XVIII. Estimated escapement of Skeena pink salmon, 1955 to 1960.

Place	1955	1956	1957	1958	1959	1960
Kispiox River	540,000	75,000	360,000	66,000	650,000	45,000
Kitwanga River	125,000	35,000	160,000	158,000	250,000	27,000
Lakelse River	175,000	75,000	140,000	262,000	185,000	122,000
Babine River	5,000	3,000	27,000	10,000	77,000	7,000
Bear River	6,000	Nil	15,000	Nil	20,000	Nil
Skeena River	10,000	5,000	50,000	50,000	150,000	10,000
Others	119,000	10,000	113,000	10,000	54,000	5,000
Coastal Rivers	78,000	75,000	105,000	116,000	95,000	45,000
Total	1,058,000	278,000	970,000	672,000	1,478,000	261,000
Total upstream of test-fishing site	987,000	202,000	868,000	558,000	1,383,000	215,000

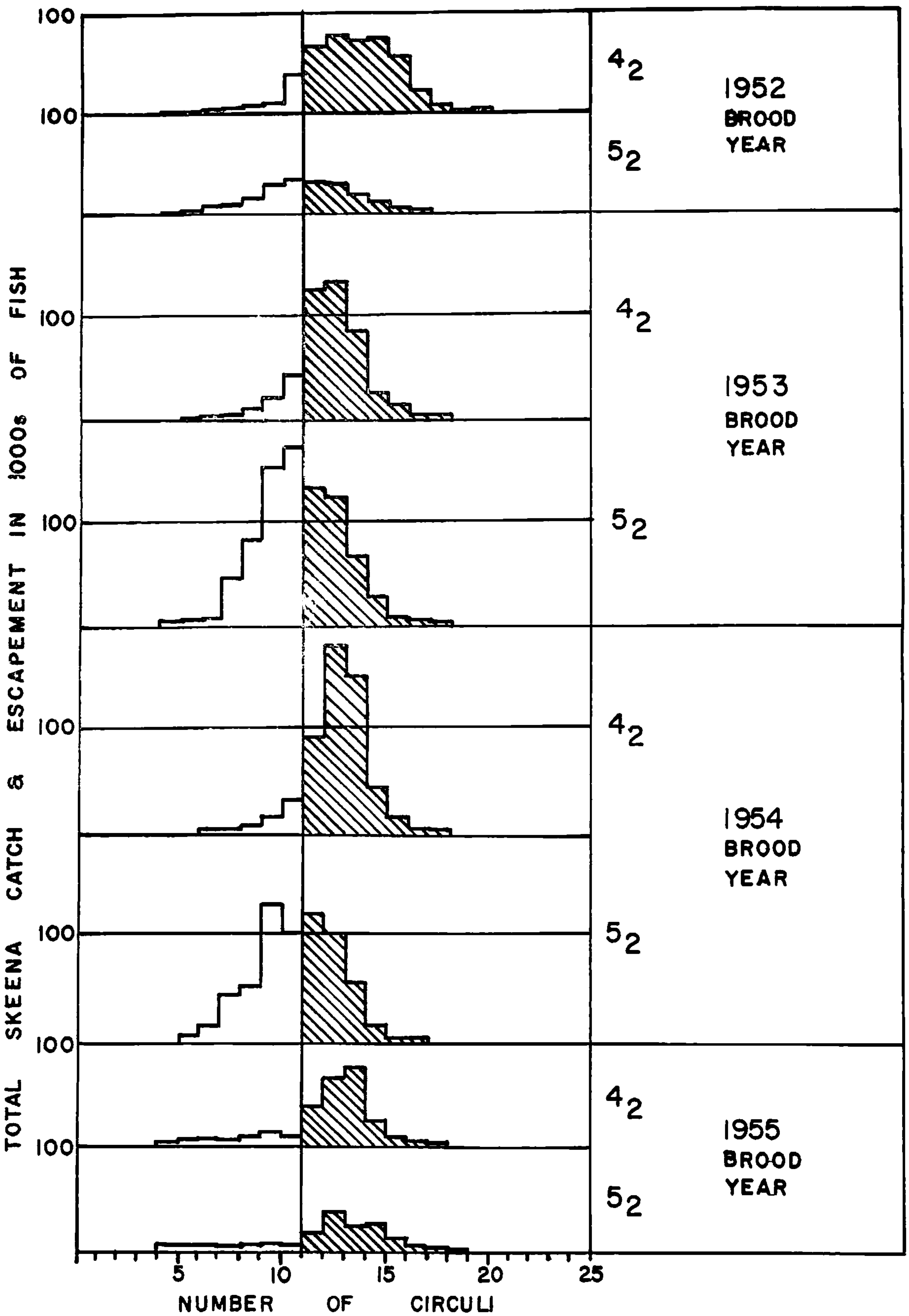


Fig. 19. Freshwater circulus counts for 4_2 and 5_2 sockeye collected from the Skeena River catch and escapement for the years 1956 to 1960.

The 1960 escapement was about 2/5 of that in the parent year and was comparable in size to the escapement in the cycle year of 1956. The escapements in 1956 and in 1960 were probably as small as any which have occurred since the beginning of the fishery. In 1960, the greatest decrease from the brood year occurred on the Lakelse and Kitwanga Rivers and on the main stem of the Skeena River, although in the latter instance estimates of the numbers of spawners are less firm. The escapements to the Kispiox and Babine Rivers were about 3/4 of those in the 1958 brood year.

7. Freshwater survival from the 1959 pink salmon escapement J. McDonald

Estimates of the number of spawners and the abundance of resulting seaward migrating fry have been obtained from several large spawning areas tributary to the Skeena River each year since 1956. These data provide information on survival in fresh water (egg to fry) and, together with information on the catch, indicate survival in the sea (seaward migrant to returning adult). The purpose of this work is to determine the escapement size required to produce the greatest yield to the fishery, and secondly, to develop means of predicting the likely number of adults returning from escapements and fry outputs of known abundance.

Method of estimating fry output. A standard method of trap-netting for pink fry was developed in 1956 and used from 1956 to 1959 on the Lakelse, Kitwanga, and Kispiox Rivers. Nets with openings 2 ft. wide and 1 ft. deep were operated at the surface of the rivers. Nets were fished at a number of stations across each river at frequent intervals during the period of fry migration. The average number of pink fry captured per hour during each period of operation was used to calculate indices of the annual fry output from each river.

Experimental trap-netting carried out in 1958 and 1959 indicated that the vertical distribution of the migrants at the trapping sites varied from river to river depending upon the depth of water. This work also showed that the vertical distribution may change diurnally and therefore daytime catches were not directly comparable to night-time catches. This new information clearly showed that fry catches in the standard net would only provide a very gross indication of changes in fry abundance and that the indices obtained from one river were not comparable to those obtained on another.

Because of these shortcomings, the method was revised in 1960 to account for changes in the vertical distribution of the migrants and to provide an estimate of the fry output from each river in absolute terms. A vertical column of nets, each with an opening 6" x 12", was used. This net column was capable of capturing fry from top to bottom in each river. These traps were fished at various stations across each river throughout the fry migration. The total number of fry migrants was calculated from the average catch per hour and the proportion of the cross sectional area of the river 'covered' by the nets.

Egg to fry survival, 1959-1960. Data on the estimated number of parents, egg deposition, fry output, and survival from egg to fry are given in Table XIX.

Table XIX. The estimated number of parents, egg deposition, fry output and survival from egg to fry, 1959-1960.

River	Estimated number parents	Estimated egg deposition	Estimated fry output	Survival egg to fry
		(millions)		(percent)
Lakelse	185,000	167	30	18
Kispiox	650,000	585	132	23
Kitwanga	250,000	225	34	15

Comparative data of the survival from other escapements and spawning grounds of this size are not available. However, the survivals observed on the Skeena tributaries are high compared to averages recorded over a number of years at Port John, B. C., and McClinton Creek, B. C. They are comparable to the survival observed in "good" years at the other two locations.

In 1959, the total pink salmon escapement to the Lakelse, Kitwanga, and Kispiox Rivers was over one million or about 2/3 of the total escapement to the Skeena system, including coastal streams within the Skeena Gill-net Area. Conditions for survival in the 3 rivers examined were probably better than those on most other streams as the discharge of the Lakelse, Kispiox, and Kitwanga Rivers is stabilized to a considerable extent by their relatively large drainage systems and lakes near their headwaters. The probable survival from egg to fry from other areas must therefore be considered below that recorded on the rivers examined. If it is assumed that the survival in the other stream was about 2/3 that recorded on the three major spawning areas, then the total fry output from the Skeena in 1960 would be in the order of 265 million.

C. Lake Sockeye Studies

W. E. Johnson

1. Young sockeye in Babine Lake

Distribution and abundance throughout the lake system. Because of rather limited dispersion from their natal streams, the distribution of young sockeye throughout the complex Babine lake nursery area (Fig. 20) is largely governed by the distribution of the parent spawners to the various tributary spawning grounds. In this respect, the Babine system can be divided into two general regions: (1) the areas north of Halifax Narrows (Nilkitkwa Lake and the North Arm of Babine) which serve the young produced by the late-running fish which spawn on the outlet Babine River grounds, and (2) the lake areas south of Halifax Narrows which accommodate the young from earlier-running fish which spawn on the grounds tributary to these areas. In the first region there is a small lake area (10% of the total) with a large amount of spawning ground; that is, the size of the nursery area is the factor limiting further sockeye production. In the second region, the opposite situation prevails - there is an extremely large lake nursery area with tributary spawning grounds of limited capacity.

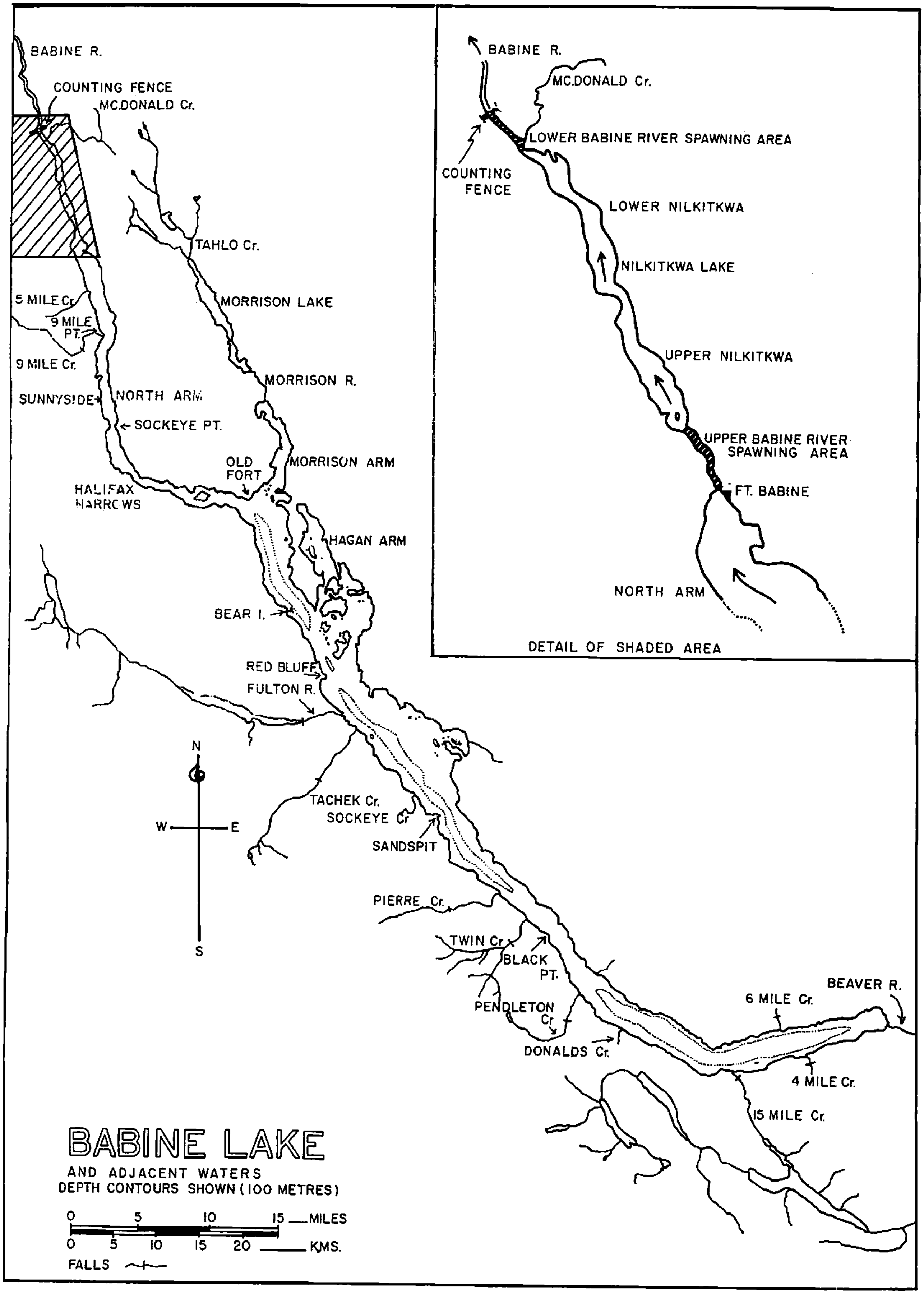

BABINE R.
COUNTING FENCE
MC.DONALD Cr.
TAHLO Cr.
MORRISON LAKE
5 MILE Cr.
9 MILE PT.
9 MILE Cr.
MORRISON R.
SUNNYSIDE
NORTH ARM
SOCKEYE PT.
OLD FORT
MORRISON ARM
HALIFAX NARROWS
HAGAN ARM
BEAR I.
RED BLUFF
FULTON R.
N
W
E
S
TACHEK Cr.
SOCKEYE Cr.
SANDSPIT
PIERRE Cr.
TWIN Cr.
BLACK PT.
PENDLETON Cr.
DONALDS Cr.
6 MILE Cr.
BEAVER R.
4 MILE Cr.
15 MILE Cr.
BABINE LAKE
AND ADJACENT WATERS
DEPTH CONTOURS SHOWN (100 METRES)
0 5 10 15 MILES
0 5 10 15 20 KMS.
FALLS
BABINE R.
MC.DONALD Cr.
LOWER BABINE RIVER SPAWNING AREA
COUNTING FENCE
LOWER NILKITKWA
NILKITKWA LAKE
UPPER NILKITKWA
UPPER BABINE RIVER SPAWNING AREA
FT. BABINE
NORTH ARM
DETAIL OF SHADED AREA

Fig. 20

Prior to 1955, in all the years for which we have escapement records, more than half (and up to 86%) of the Babine sockeye were later-running fish which spawned on the outlet spawning grounds. As a result, the majority of young sockeye produced in those years utilized the limited lake nursery areas north of Halifax Narrows, and the resulting smolts produced in many of these years must have been quite small in size. Since 1956, regulation has served to achieve a better distribution of spawners by protecting the earlier-running fish which spawn south of Halifax Narrows. As shown in Table XX, this policy has achieved a better distribution of young sockeye. With this change towards greater numbers of young south of Halifax Narrows, their mean growth rate has been increased and smolts of greater mean size are being produced. As past studies of sockeye have indicated that large smolts enjoy a better rate of ocean survival than do small smolts, it is expected that the greater number of large smolts produced at Babine will result in a higher overall rate of sockeye production.

In 1960, the estimated total number of young sockeye in the lake system (progeny of the 1959 spawning) was comparable to that of 1959 (progeny of 1958 spawners). Also, the mean size of fish north of Halifax Narrows was slightly larger in 1960 than in 1959. This indicates that the smolt output in 1961 will be comparable to the record smolt run of 1960 and that the smolts will be of slightly greater mean size. If this proves true, then there will be no evidence of any adverse effect of the large 1959 lake population on the second successive large lake population of 1960.

Growth rate of young sockeye salmon. During their one year of lake residence in the Babine system young sockeye attain most growth in the first few months, that is, during the period of summer thermal stratification. For example, fish weighing 0.2 grams when entering the lake as fry in mid-June attain 4.5 grams by mid-October, but weigh only about 5.5 grams when emigrating from the lake as smolts the following spring. Observations of the growth rate of under-yearling sockeye, their abundance, and the abundance of their zooplankton food in the various lake basins of this system in the years 1956 to 1959 provide a basis for comparing mid-June to mid-October growth rates under a wide range of conditions. Near-surface water temperatures for this period have been roughly comparable throughout, and there are no known genetic differences involved; thus, growth rate is believed to have been largely determined by intraspecific competition and food abundance. The results strongly support this belief.

Using logarithmic scales throughout, Figure 21 presents graphically the relationship of growth rate to food abundance and intraspecific competition. Figure 21a implies a general direct relationship between growth rate and zooplankton abundance over the range shown, Figure 21b shows the growth rate is increasingly depressed by intraspecific competition after population densities exceed approximately 7,000 fish per hectare (3,000 per acre).

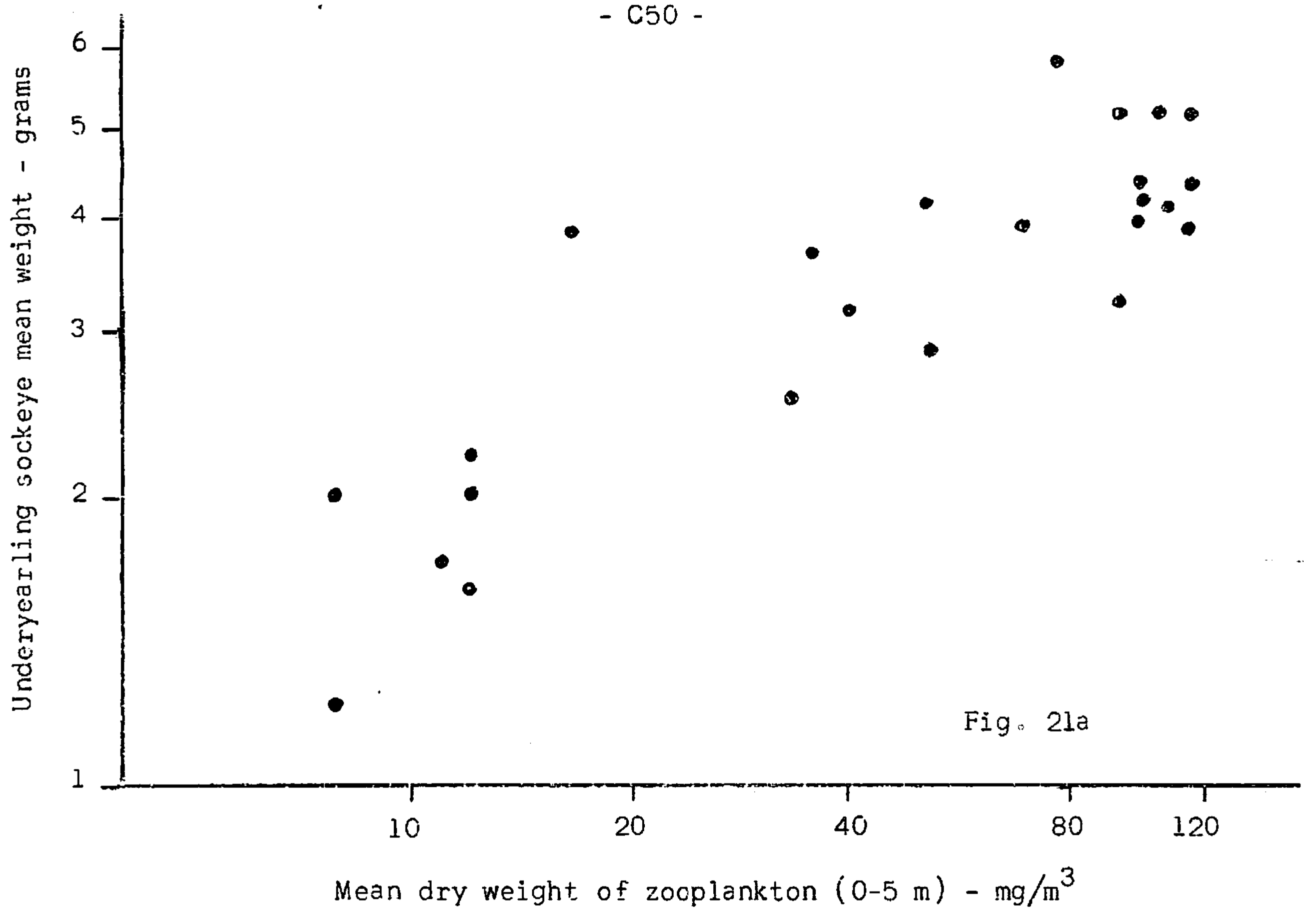
At a glance it appears that there is a simple explanation of the relationship between growth rate, competition and food abundance, i.e. that with an increasing number of young sockeye present an increasing reduction of the food supply is brought about resulting in an increasing reduction of the growth rate. Although cropping of the zooplankton by large populations of young sockeye is obvious in much of these data, critical examination (beyond the scope of this brief report) does not verify such a simple explanation of growth-competition-food relations based on food abundance alone. Detailed examination suggests there is an effect of competition on growth rate which is expressed independently

Table XX. Distribution and size of young sockeye in the Babine Lake system

Lake Region	Number of adult sockeye spawning excluding "jacks" (thousands)	Estimated number of age-0 sockeye in late August (millions)	Approximate mean weight of age-0 sockeye in mid-Oct. (grams)
	1954	1955[b]	
North of Halifax Narrows	256.3	38.2 to 52.9	1.5
South of Halifax Narrows	185.6	7.1 to 19.3	4.0+
Total	441.9	45.3 to 72.2	
	1955	1956	
North of Halifax Narrows	19.2	2.0	3.8
South of Halifax Narrows	27.8	3.1 + (7.4)[a]	4.0+
Total	47.0	5.1 + (7.4)[a]	
	1956	1957	
North of Halifax Narrows	119.5	26.5	3.3
South of Halifax Narrows	148.9	34.8 + (22.3)[a]	4.0+
Total	268.4	61.3 + (22.3)[a]	
	1957	1958	
North of Halifax Narrows	188.2	45.0	2.4
South of Halifax Narrows	202.8	46.5 + (20.0)[a]	4.0+
Total	391.0	91.5 + (20.0)[a]	
	1958	1959	
North of Halifax Narrows	270.0+	66.0	2.7
South of Halifax Narrows	290.0+	85.1 + (20.0)[a]	4.0+
Total	560.0+	151.1 + (20.0)[a]	
	1959	1960	
North of Halifax Narrows	290.0+	62.0	3.0
South of Halifax Narrows	300.0+	86.0 + (20.0)[a]	4.0+
Total	590.0+	148.0 + (20.0)[a]	

[a] Additional millions of age-0 sockeye believed progeny of "kokanee".

[b] 1955 data from very limited sampling, so estimates only roughly approximate - probably much too low.



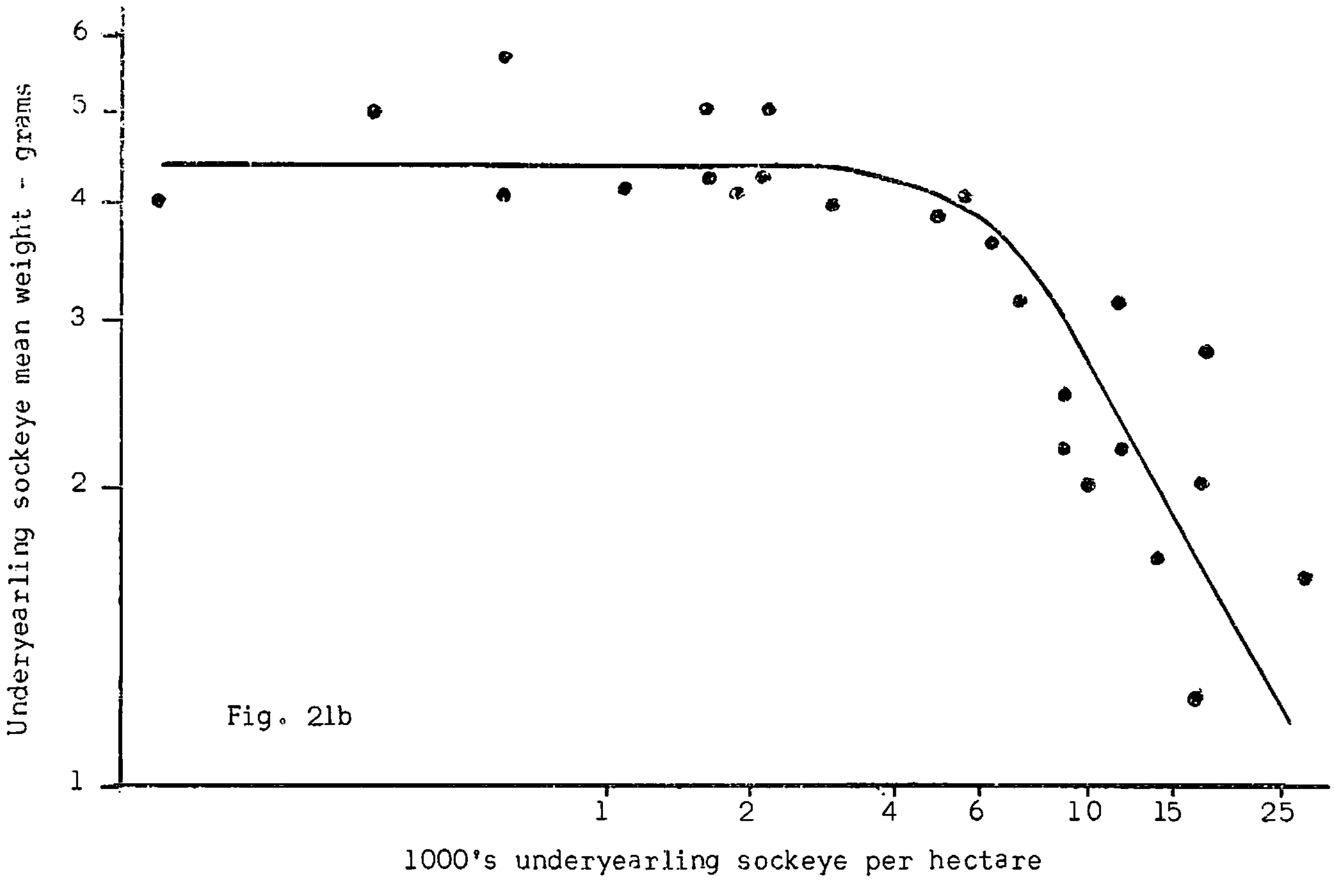


Fig. 21. Density and size of young sockeye in the Babine Lake system.

of absolute food abundance. In spite of the complexities of the mechanisms involved, the rather well-defined relation between growth rate and population density as shown by the solid line in Figure 21b can serve to evaluate the potentials of this lake nursery area.

Capacity of the Babine system as a sockeye producer. The curve in Figure 21b demonstrates the growth rate of young sockeye which may be expected at various levels of population density. In an earlier study at Cultus Lake, Foerster has shown that there is a direct relationship between smolt size and subsequent survival rate to maturity. Evidence that this relationship might hold generally is available from recent research on sockeye in Alaska. Combining the curve of Figure 21b and Foerster's relationship between smolt size and survival rate, Figure 22 describes the relationship between lake population density per unit area and the likely numbers of returning adults per unit area. No units are given for the likely number of returning adults as we cannot reasonably apply the same survival rates found by Foerster for Cultus Lake sockeye. However, for consideration of this general relationship we need only assume that there is a direct relation between smolt size and survival.

The relationship shown by Figure 22 follows the law of diminishing returns. With the progressive addition of more units of production (young sockeye) there is an increase in total production (returning adults) up to a point where the addition of further units of production results in a decrease in total production. The critical point (where production is at a maximum) corresponds to a late-August lake population of approximately 10,000 young sockeye per hectare (4,050 per acre). At this population density young sockeye would attain a size of about 2.5 grams by mid-October and emigrate as smolts of about 3 grams mean weight. For such optimum or maximum production, then, the Babine Lake system would require an evenly distributed late-August young sockeye population of 4,050 per acre or a total of the order of 500,000,000 - which would give a smolt output of roughly 200,000,000.

This estimation of the maximum potential is based only on the potential of the lake nursery area for rearing of smolts. In the Babine system there are insufficient spawning grounds to produce naturally the numbers of fry required, and achievement of such a maximum production would of course require large-scale fish culture techniques as yet unproven.

In considering the practicable potential of this sockeye-producing area, we must again make the broad separation into those regions located north and south of Halifax Narrows.

The region north of Halifax Narrows is characterized by having large-capacity spawning grounds (the Babine River above and below Nilkitkwa Lake) in relation to the lake nursery area available. With this situation the ultimate potential of the lake area can be realized and the problem becomes one of providing an escapement of the proper size to these outlet spawning grounds. Escapements of the order of 250,000 to 300,000, as provided in 1958 and 1959, appear to be of the proper magnitude.

The region south of Halifax Narrows is characterized by the opposite situation. An extremely large lake nursery area is available in proportion to the capacity of the tributary spawning grounds. The problem of attaining the highest natural production of sockeye from this region is then one of providing escapements which will make fullest possible use of the available spawning

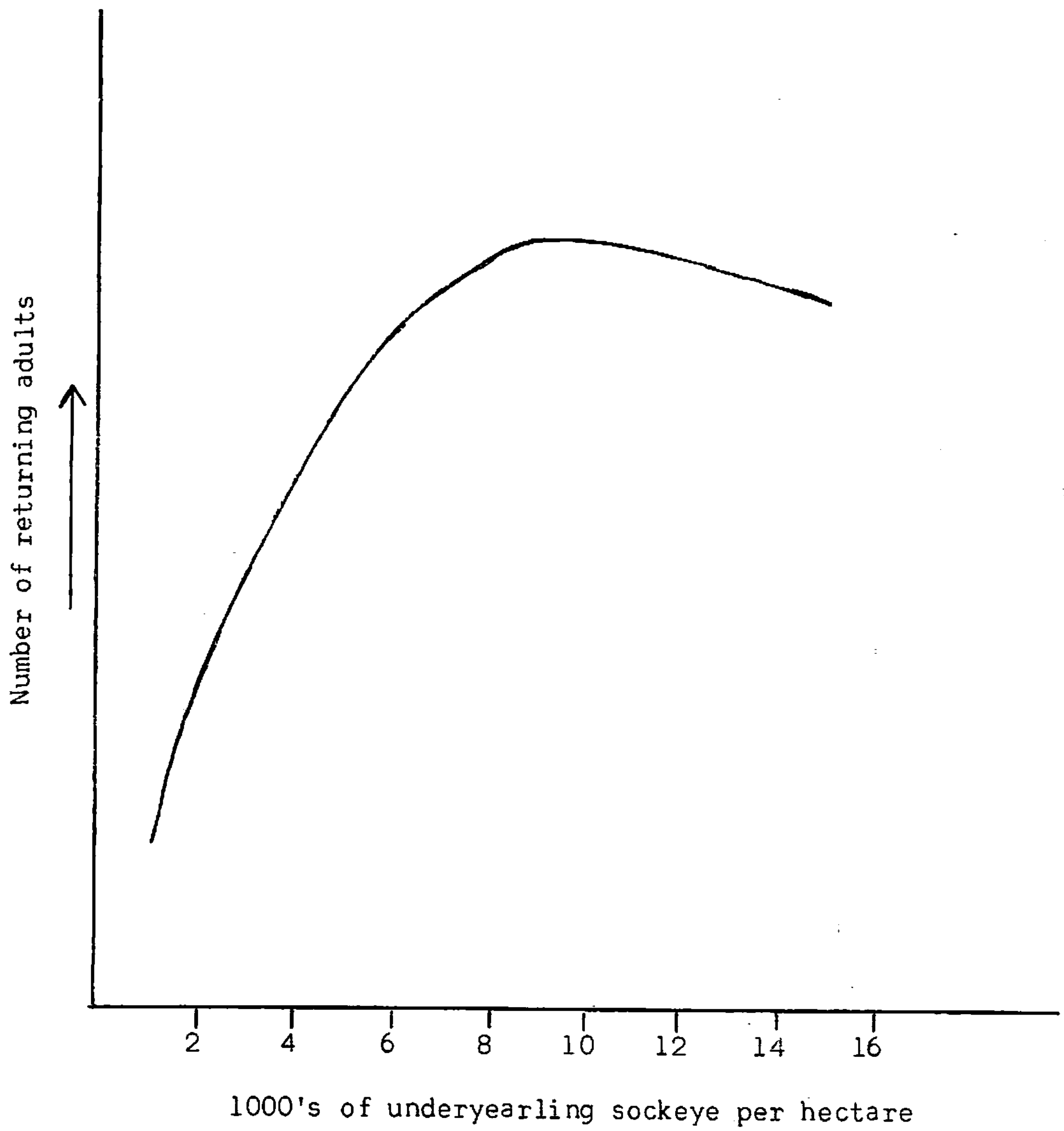


Fig. 22. Density of young sockeye and probable numbers of returning adults per unit area.

grounds. Such has been the aim of recent regulations and the large escapements of 1958 and 1959 have approximated this ideal.

2. Depth distribution of sockeye and other lake fishes

An attempt to study the vertical distribution and diurnal vertical migrations of fish in Babine Lake was made during the 1960 season using special monofilament gill-nets. It was hoped that these nets would fish efficiently during daylight hours as well as at night and thus serve as a means of better interpretation of echo-sounding records. Unfortunately, this did not prove to be the case in the rather clear waters of Babine Lake: catches were very small, especially during daylight hours, and of course there is the chronic enigma of how to interpret negative results, prevalent in any passive fishing method such as gill-netting. Also, there were problems involved in the handling of large, deep gill-nets by hand from small boats, especially in sets at great depths and in cases where nets were tended frequently during a 24-hour period. Nevertheless, these gill-net catches, together with results of gill-net fishing carried on in the previous two years, do seem to indicate some probable features of fish distribution and diurnal movement vertically in the light of what is seen with echo-sounding gear.

The following applies to the period of summer thermal stratification of the lake:

Sockeye fingerlings. Sea-scanar studies have shown that during daylight hours, sockeye fingerlings appear to be distributed throughout the 0-20 foot depth range but with greatest concentration centering about a depth of about 10 feet. In the evening twilight there is a mass movement toward the surface with a maximum near-surface concentration occurring in the early moments of darkness. After dark a dispersion over a greater depth range occurs - possibly a slow settling proceeds through the night. Soon after dawn the typical daylight distribution is again assumed. The smallest meshed gill-nets were received too late in the season to permit a full testing. However, the few sets made in late October did not contradict the findings; fingerlings were taken only at night and nearly all at depths less than 25 feet.

Kokanee (of age group II and older) were taken readily in all parts of the Babine system in offshore, near surface sets. Daytime catches were mainly in the depth range 0-30 feet, with highest catches in the 10-15 foot interval. Night catches were spread over a greater depth range (0-60 feet) but highest catches were very near surface (0-10 feet). This suggests the probability of a vertical distribution and diurnal vertical migration pattern similar to that of the closely related sockeye fingerlings.

Rainbow trout rarely have been caught at depths greater than 30 feet. Most were taken in the 0-15 foot interval. This is true for both day and night catches.

Lake trout (char) have been taken at various depths down to 170 feet. Daytime catches have all been from depths greater than 50 feet. Overnight sets have taken considerable numbers at shallower depths, especially in the range 10-50 feet.

Ling were taken primarily at depths greater than 70 feet and as deep as 180 feet. Only 3 specimens were taken in shallower sets (in the 50-70 foot range).

Whitefish. The few taken in daylight sets were from the 50-100 foot depth range. Those taken in overnight sets were nearly all in the 0-50 foot range.

Peamouth and squawfish were taken only in overnight sets and nearly always at depths less than 30 feet. These two species were taken most commonly in the shallower regions of the lake system (Nilkitkwa Lake, North Arm, Morrison Arm and Hagan Arm) and only rarely in offshore sets in the main basins of Babine. Largest catches were associated with areas of shallow mean depth or with inshore areas.

3. Serum proteins of kokanee and anadromous sockeye

Mr. Ian Carlson, graduate student at the University of British Columbia, has carried out a program of study of the blood serum proteins of Babine sockeye and kokanee using electrophoretic techniques. He has evaluated the specificity of protein constituents of the blood of both anadromous sockeye from various Babine spawning grounds and kokanee from various spawning grounds and various parts of the lake. Results are now in preparation for presentation.

4. Surveys of two potential sockeye producing areas

In earlier geological times some of British Columbia's major sockeye producing lakes (notably Owikeno and Long Lakes in the Rivers and Smith Inlets areas) were inlets of the sea. This fact suggests that sockeye producing lakes might be produced artificially by damming of inlets. One question that this possibility raises is whether or not suitable conditions for rearing sockeye could be provided in a reservoir consisting of a layer of fresh water overlying one of sea water.

Sakinaw Lake. In its recent history Sakinaw Lake has had intrusions of salt water at higher tides. Such intrusions are believed to have been infrequent in recent years - more information of the exact history is being sought.

A visit was made to Sakinaw Lake on April 29, 1960. Temperatures and water samples for salinity determination were taken at a central station at various depth intervals down to the maximum depth possible with the gear used. The depth to bottom at this station is unknown. Table XXI lists the resulting data.

The data are sufficient to show that this lake is one in which a surface freshwater layer overlies a deep reservoir of stagnant salt water. The uniform low salinity and the temperature structure to a depth of approximately 80 feet could be typical for a wholly freshwater lake in this region. The increase in temperature and salinity below this depth shows the presence of an underlying reservoir of salt water heavily laden with hydrogen sulfide and devoid of oxygen.