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A REVIEW OF
THE BABINE LAKE DEVELOPMENT PROJECT
1961 - 1977

By

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ABSTRACT

In 1962, the Babine Lake Development Project was initiated to provide additional sockeye fry, in order to fully utilize the rearing capacity of the Babine main lake basin. Two spawning channels were constructed at Fulton River and one at Pinkut Creek, with partial river-flow control facilities at each location. Production expectations of Fulton Channel No. 1 have been exceeded. The major producer of sockeye fry is Fulton Channel No. 2. Low egg-to-fry survivals have been experienced in the original Pinkut Creek spawning channel, due to technical difficulties. This channel has recently been rebuilt on improved specifications. Density-dependent factors have prevented increased fry production in Fulton River and in Pinkut Creek. Benefits of partial flow control are derived from the insurance of maintained spawning and incubation flows and tempered spring freshets. The viability of spawning channel fry is comparable to that of natural fry, and increased fry outputs are followed by increased numbers of smolts.

When large numbers of fry are produced, however, the smolt output has been found to be less than anticipated. Reasons for this loss are discussed.

Key words: Babine Lake,, sockeye, spawning channels, Fulton River, Pinkut Creek, flow-control, fry production, egg-to-fry survival, density-dependent factors, spawning, incubation, freshets, viability, smolts.

RESUME

En 1962, on a entrepris le programme d'exploitation de lac Babine pour augmenter le nombre d'alevins de Saumon rouge afin d'utiliser pleinement la capacité d'élevage du bassin principal du lac. On a construit deux frayères dans la rivière Fulton et une dans le ruisseau Pinkut, avec des installations de réglage partiel du débit aux deux endroits. La production de la frayère Fulton n° 1 a dépassé les attentes mais la frayère n° 2 est plus féconde en alevins de Saumon rouge. Dans la frayère du ruisseau Pinkut, le taux de survie d'oeufs à alevins a été faible à cause de difficultés techniques. Cette frayère a été reconstruite dernièrement d'après des spécifications améliorées. Les facteurs liés à la densité ont empêché une augmentation de la production d'alevins dans la rivière Fulton et le ruisseau Pinkut. Le réglage partiel de l'écoulement est avantageux parce qu'il assure le maintien des débits propices à la ponte et à l'incubation et modère les crues printanières. L'alevin des frayères a une viabilité comparable à celle de l'alevin naturel et l'augmentation d'alevins est suivie d'une hausse de saumoneaux de descente.

Cependant, lorsqu'un grand nombre d'alevins est produit, le nombre de saumoneaux de descente est inférieur à ce qui avait été prévu. Les raisons de cette perte sont étudiées.

Mots clefs: lac Babine, Saumon rouge, frayères, rivière Fulton, ruisseau Pinkut, réglage du débit, production d'alevins, survie d'oeuf à alevin, facteurs liés à la densité, ponte, incubation, crues, viabilité, saumoneaux de descente.

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INTRODUCTION

Babine Lake (Fig. 1), the largest lake of the Skeena River drainage, is the major contributor of sockeye salmon on the Skeena River system which, as a whole, ranks as second or third in British Columbia as a producer of sockeye salmon. The importance of the Babine escapement was recognized early, and in the fall of 1945, an enumeration fence was constructed on the Lower Babine River. In 1951, the Babine slide severely reduced the escapement of that year and the next. This resulted in the formation of the Skeena River Management Committee in 1954, whose objectives were: to investigate the condition of Skeena River stocks; to improve management of the runs; and to increase the yield, if possible. Studies by Johnson (1956; 1958; MS, 1961) suggested that the rearing capacity of the main lake basin was being underutilized because of the limited spawning area available in tributary streams for the production of fry. This led to the Babine Lake Development project which was based on three premises: (1) the main basin of Babine Lake was being underutilized by the sockeye fry; (2) additional fry could be produced by the development of spawning channels and regulation of stream flows; and (3) fry produced in spawning channels are of comparable quality to naturally-produced fry, and are equally viable to the adult stage. Fulton River was selected as the first development site because it was the largest producer of sockeye salmon to the main lake. The Fulton River Project was to consist of partial flow control facilities on the Fulton River, completed in 1968, and two artificial spawning channels, completed in 1965 and 1971. As the second largest producer, Pinkut Creek was an additional development site and included partial flow control facilities, completed in 1966, and one spawning channel, completed in 1968. The three channels together were expected to provide additional spawning grounds for about 200,000 adult sockeye, and to produce 100 million fry. A fourth channel on Morrison Arm was considered, but has not yet been built. Studies were conducted by McDonald for three brood years of Fulton River fry and two brood years of Channel No. 1 fry, beginning with the 1965 brood year. The purpose of

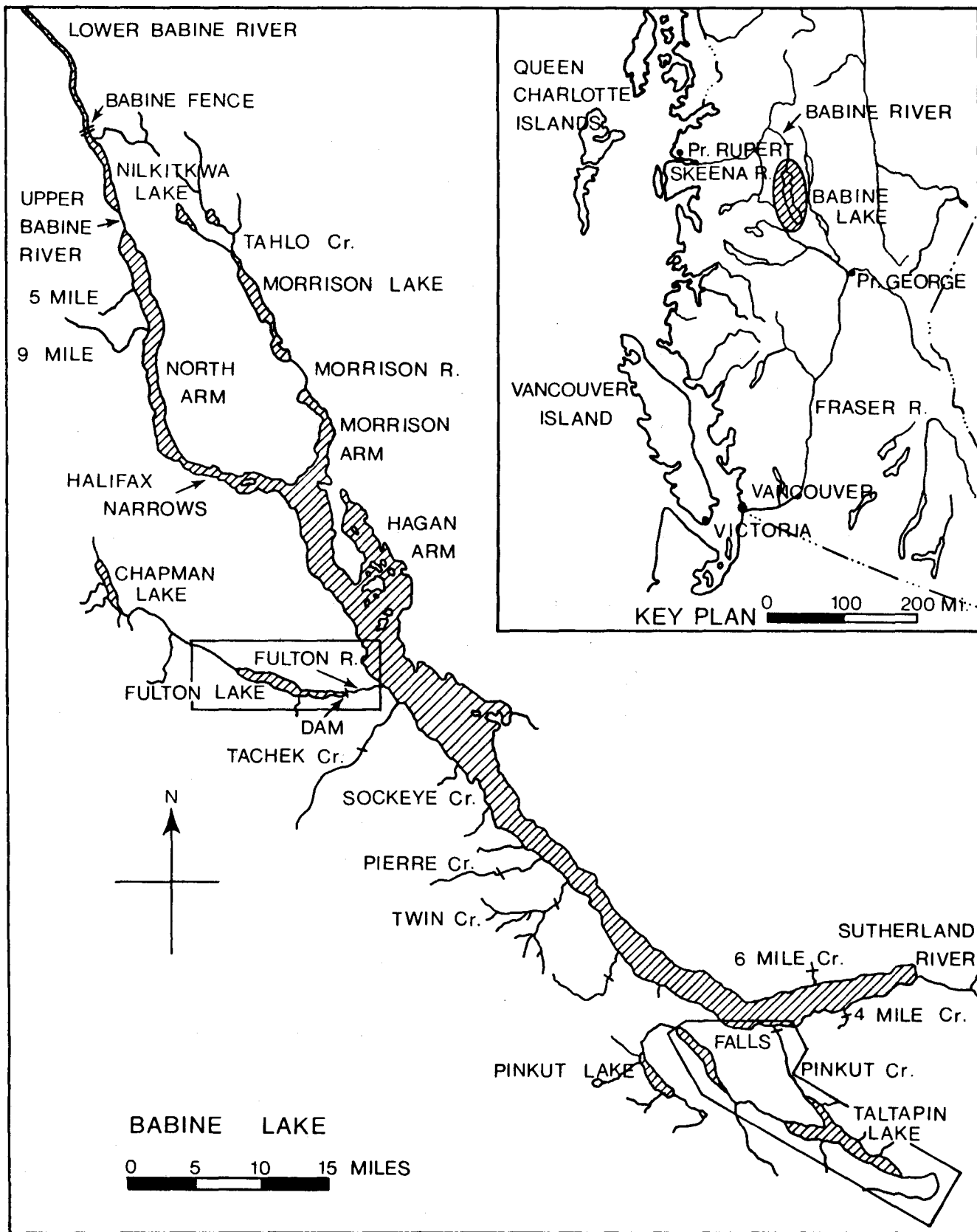


Figure 1: Geographic location of the Fulton River and Pinkut Creek enhancement projects on Babine Lake, B.C.

these studies was to: (1) compare the viability of fry produced by artificial spawning channels against the viability of naturally-produced fry; and (2) to determine the parts of the lake used as a nursery area by Fulton River fry. McDonald (1969) found no significant difference in fry-to-smolt survival between Fulton River fry and Channel No. 1 fry. Dispersal of both groups was rapid and, initially, into the southward part of the main lake basin. Their distribution was not uniform, and the fry were found to be concentrated in various parts of the main lake basin at different times. Fry from the Fulton River system were also found to be extensively mixed with fry from the other main lake tributaries.

To evaluate the success of the Babine Development Project at increasing the production of fry over that of natural streams, a biological assessment has been carried out since before development. The objectives of the assessment program have been to measure the production and quality of fry produced by the development projects, the number of smolts emigrating from Babine Lake and the number of returning adults. This report describes individual components of the development project, including their operation, their production of fry and the return of adults, and an evaluation of the Babine Development Project as a whole.

PHYSICAL DESCRIPTION OF FULTON RIVER AND PINKUT CREEK DEVELOPMENT PROJECTS

FULTON RIVER DEVELOPMENT PROJECT

This section provides a brief physical description of the Babine Development component projects. A detailed description of each project is given by Ginetz (1977).

The Fulton River Project consists of partial flow control facilities, two artificial spawning channels and enumeration facilities (Fig. 2).

The partial flow control facilities (Fig. 3) consist of: (1) a vertical gate shaft with a concrete-lined tunnel, which provides water to a valvehouse for regulation of flow into the river; and (2) a 40-foot-high dam, creating a 76,000 acre-feet reservoir in Fulton Lake and allows a maximum regulation of 4,200 cfs into the river. Normal flows in Fulton River are 150 cfs during spawning, 200 cfs during incubation and up to 3,500 cfs during the spring runoff. In years of high runoff, the dam may be overtopped, resulting in uncontrolled flows, normally in June or July.

Because of the recreation and conservational importance of Fulton Lake, approximately 1,800 acres of lakeshore were cleared before the flooding. The program involved Federal liaison with British Columbia government agencies--Forest Services, Parks Branch, Fish and Wildlife Branch and Water Resources (Heskin, 1967).

Channel No. 1 was completed in 1965, and was the first artificial spawning channel of the Fulton River Development Project (Fig. 4). Composite timber and concrete divider walls were used, in addition to rip-rap-sided berms to maximize use of the available area while allowing suitable access to all legs of the channel. The channel is 4,900 feet long, 30 feet wide at the gravel surface, and has a gradient of .0009. Water is supplied from an adjacent river pool by a submerged pipeline, and provides an operational discharge of 75 cfs. Water velocity in Channel No. 1 is 1.8 feet per second, and the depth is 1.3 feet. Gravel composition ranges

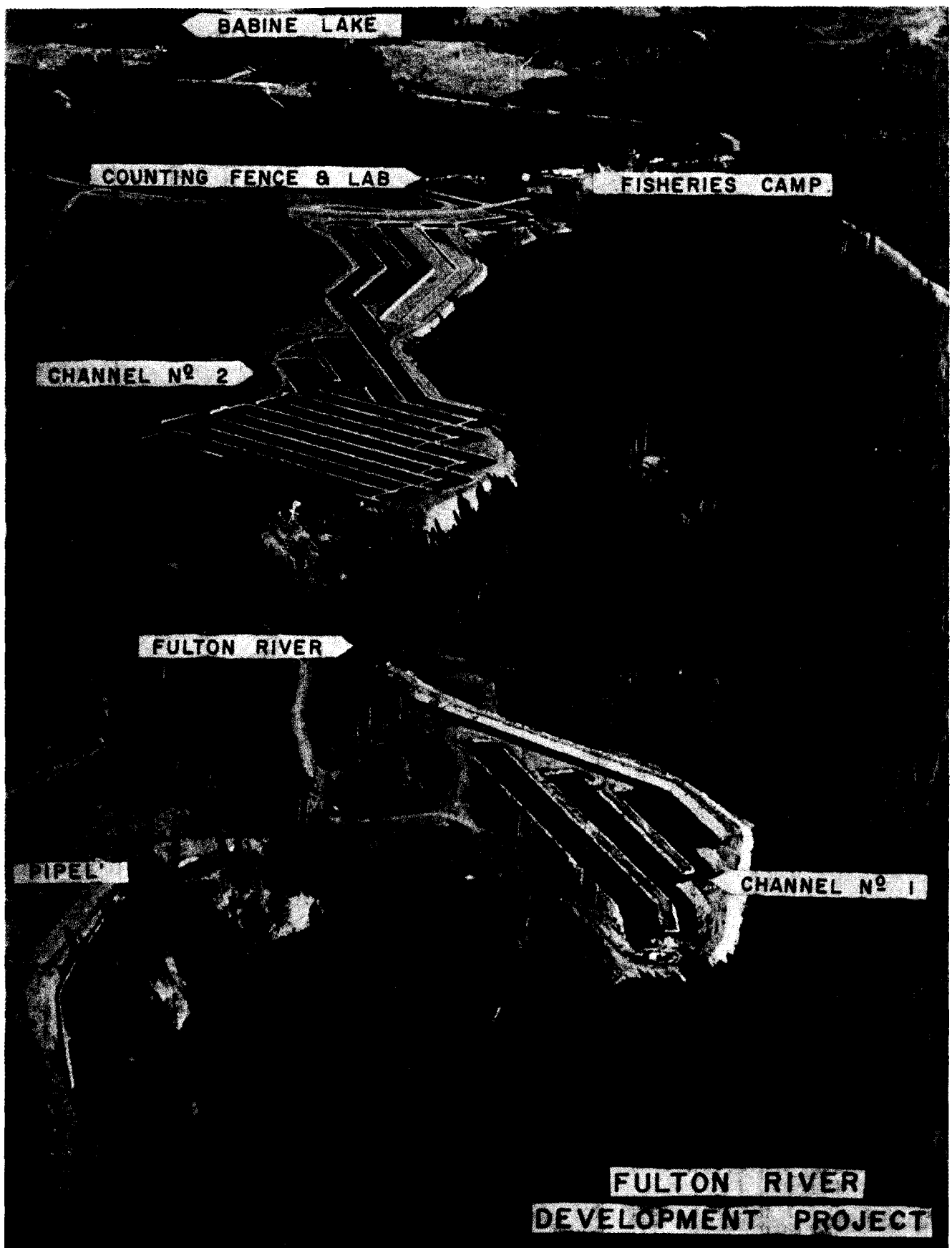


Figure 2: Aerial view of the Fulton River enhancement project.

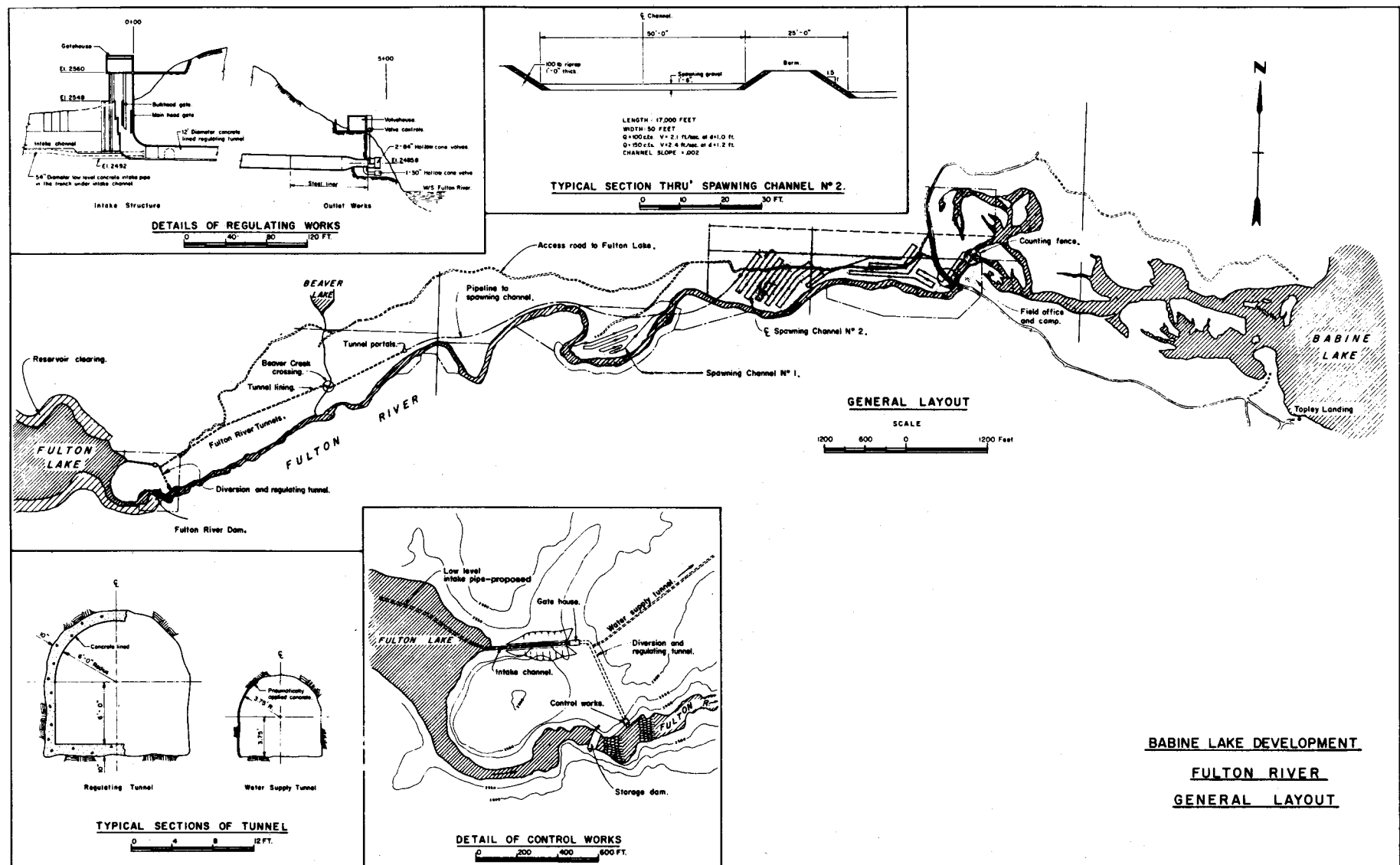


Figure 3: Schematic layout of the Fulton River enhancement project, including a profile of the water regulatory works.



Figure 4: Fulton River Spawning Channel No. 1, shortly after completion in 1966.

from 3/4-inch to 4-inch, with a large portion in the 3/4-inch to 2-inch size range. Gravel depth is 18 inches. The design capacity of the channel was estimated to be 22,000 adult sockeye on the 12,887 square yards of spawning gravel.

Channel No. 2 was completed in 1971, and is located approximately 1-1/2 miles downstream from Channel No. 1. Channel No. 2 was built on an "impervious" clay fill and has concrete-lined berms and concrete divider walls. It is 16,700 feet long, 50 feet wide at the gravel surface and has a gradient of .002. Water is supplied from a pipeline connected to the main regulating works at Fulton Lake. The maximum discharge is 150 cfs, but the normal operational level is 100 cfs. A small amount of leakage to the river is known to occur in certain locations, but it is of no consequence. Water velocity is 2.0 feet per second, and the depth is 1.0 feet. Gravel composition is similar to that of Channel No. 1, and gravel depth is likewise 18 inches. The design capacity was estimated at 135,000 adult sockeye on 87,420 square yards of spawning gravel.

PINKUT CREEK DEVELOPMENT PROJECT

The Pinkut Creek project consists of a spawning channel (Fig. 5) and partial flow control facilities.

The flow control facilities, constructed in 1966, consist of two six-foot-high weirs at the outlet of Taltapin Lake (Fig. 6) and a concrete, 54-inch diameter pipeline capable of discharging about 200 cfs. As with the Fulton River project, Provincial agencies were involved in the planning to insure that recreation and conservation potential were maintained at Taltapin lake. Reservoir clearing, however, was not required. The operating range is about 70 cfs, but in May and June, the weir is normally overtopped by the spring flows, which peak at about 2,000 cfs. The optimum spawning capacity was estimated to be 15,000 adult sockeye on the 12,000 square yards of spawning gravel.

The Pinkut Creek Spawning Channel, completed in 1968, was located on a marshy area beside the mouth of Pinkut Creek. Channel berms

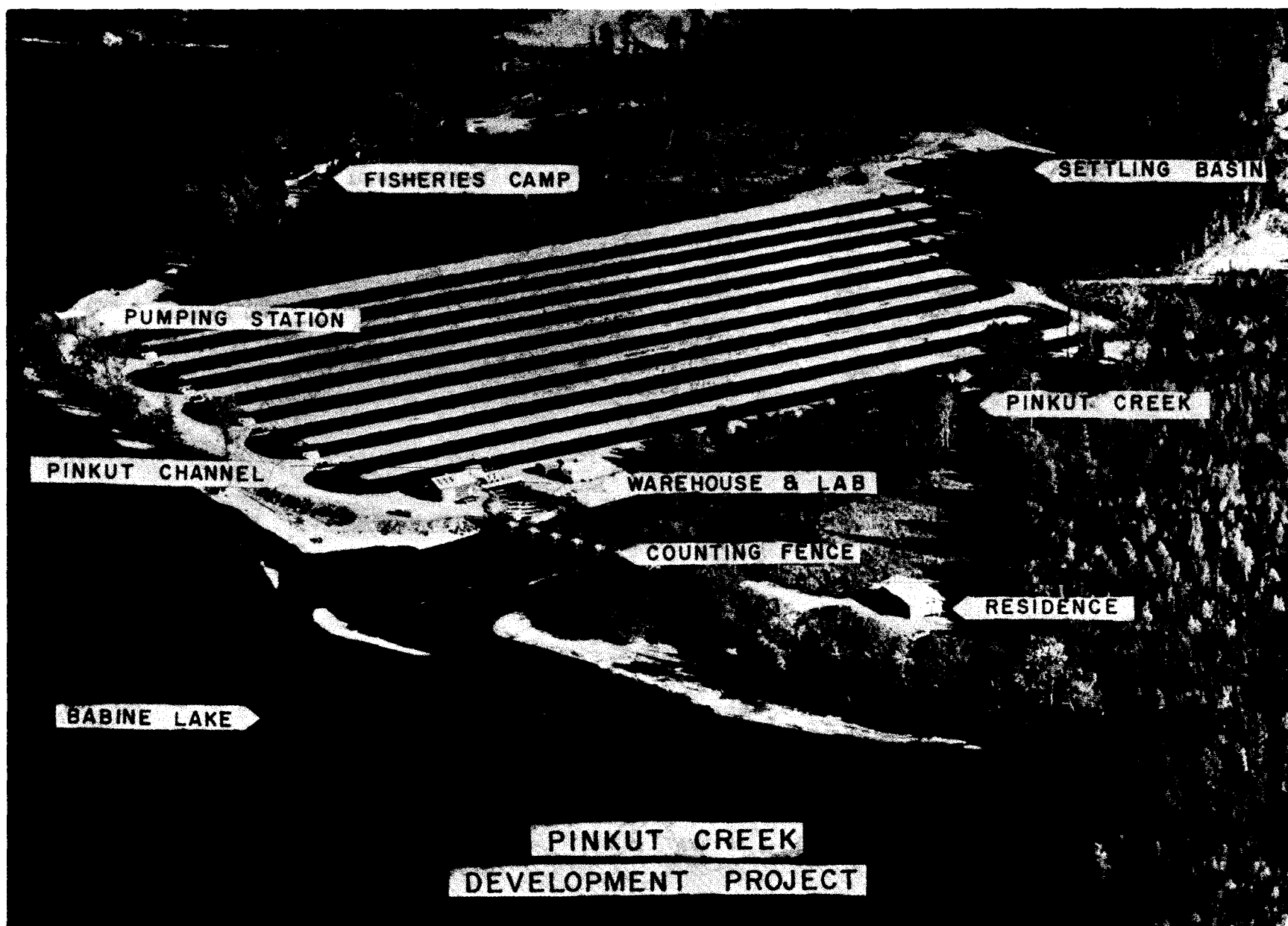


Figure 5: Aerial view of the Pinkut Creek enhancement project, excluding the Taltapin Lake regulating works.

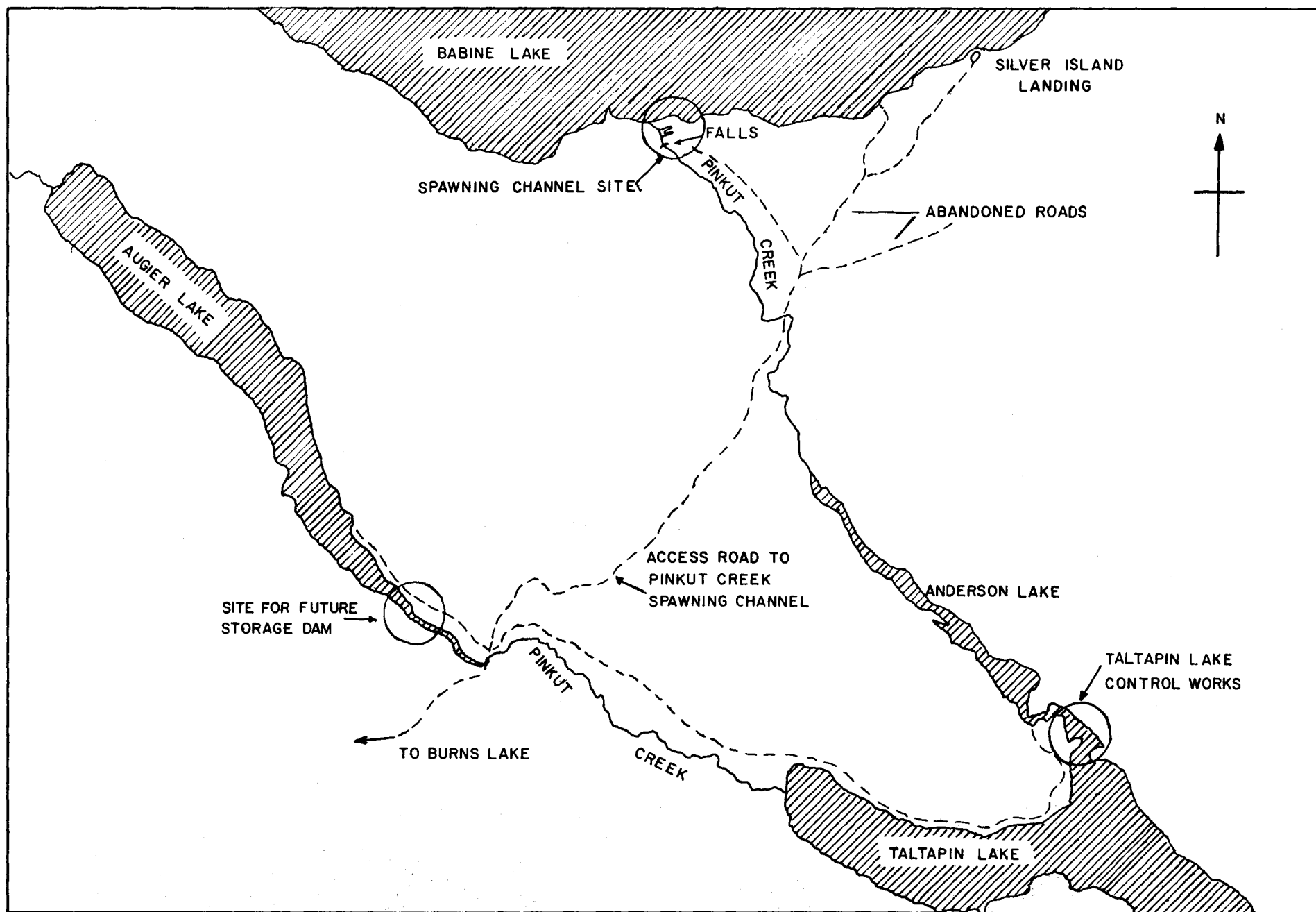


Figure 6: Location map of the Pinkut Creek enhancement project in relation to the Pinkut Creek watershed.

consisted of clay cores covered with gravel (3/4-inch to 4-inch diameter), built on an "impervious" clay fill. The channel is 9,200 feet long, 40 feet wide at the gravel surface, and has a gradient of .0009. Water is provided by a partial diversion weir on Pinkut Creek, with a concrete supply tunnel leading to a desilting basin at the head of the channel. Maximum discharge is 75 cfs, however, normal operational flows are between 45 and 55 cfs. During cold winter periods, the channel flow may be supplemented with warm water pumped from Babine Lake by a system which was installed in 1970. Water velocity is 1.8 feet per second, and the average depth is 1.25 feet. Gravel depth and composition are similar to those described for the Fulton River channels. The design capacity was estimated at 63,000 adult sockeye on the 39,500 square yards of spawning gravel. In 1976-1977, the channel was rebuilt, the major changes being the addition of two desilting basins and concrete lining of the berms.

A combined adult and fry enumeration fence was constructed in 1968 across the outlets of the river and spawning channel. Converging throat traps similar to those on the Fulton River enumeration fence were installed on both Pinkut Creek and the Pinkut Spawning Channel.

In 1968 and 1969, due to extreme weather conditions, scouring from anchor ice formation caused large egg and alevin mortalities. In 1970, this situation was improved by the construction of an auxilliary system to supply warm lake water to various locations along the channel.

EVALUATION OF FULTON RIVER FLOW CONTROL

INTRODUCTION

Studies of the Fulton River sockeye population began in 1961, because of a proposed hydro-electric development by the British Columbia Hydro and Power Authority which was later cancelled. These studies were continued because of the proposed fisheries development.

The Fulton River drains 532 square miles of the northern side of the Babine mountain range, and flows easterly through Chapman Lake (2.7 square miles), and Fulton Lake (3.5 square miles), emptying into Babine Lake. At the outlet of Fulton Lake, separated from Babine lake by one mile of rock canyon and three miles of valley, is a 40-foot-high waterfall. To provide flow control, a dam, having a spillway crest 25 feet above the low-water level of Fulton Lake, was constructed at the falls.

Fulton River is the spawning stream for the largest stock of sockeye in the main Babine Lake basin. Spawning occurs throughout the lower part of the stream, except for about 100 feet at the falls. Excluding jacks, spawning populations have ranged from 15.2 thousand to 170.1 thousand, averaging 80.5 in the predevelopment period from 1949 to 1966 (Table 1). The optimum spawning density for the 75,000 square yard spawning area was estimated to be 1.25 square yards/female. This represents a spawning population of 60,000 females or 120,000 adult sockeye at a 50:50 sex ratio. This density was used as a design criteria for the development of future sockeye spawning channels on the Babine system.

An early run exists, entering the river in early August and spawning prior to the main run. Historically, this run consisted of less than 1,000 fish, but it has increased, and, in some recent years, has exceeded 40,000 adults. The main run enters the river between August 20 and September 25, peaking in the first week of September. The sockeye hold in pools for up to three weeks before the peak spawning occurs in late September and early October.

TABLE 1: BABINE SOCKEYE ESCAPEMENTS IN THOUSANDS OF FISH DURING THE PERIOD 1949-1977

(INCLUDING JACKS)

	<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1954</u>	<u>1955</u>	<u>1956</u>	<u>1957</u>	<u>1958</u>	<u>1959</u>	<u>1960</u>	<u>1961</u>	<u>1962</u>	<u>1963</u>
Potential Stock ¹	509.0	543.0	152.0	377.0	715.0	504.0	102.0	373.0	483.0	843.0	815.0	312.0	970.0	594.0	761.0
<u>North Arm</u>															
<u>Niikitkwa Region</u>															
Upper Babine River	240.0	130.0	20.0	85.0	150.0	140.0	15.5	70.0	130.0	160.0	165.0	41.0	200.0	210.0	141.5
Lower Babine River	150.0	145.0	12.0	75.0	130.0	100.0	15.0	55.0	70.0	110.0	130.0	60.0	175.0	75.0	55.4
9-Mile Creek	0.1	1.0	0.4	0.1	2.5	1.0	0.1	0	4.0	0	2.4	2.0	4.0	0.5	1.2
5-Mile Creek	0	0.1	0.1	0	0.3	0.3	0.1	0	0.2	0	0.6	0	0.5	0.1	0
Total Spawners	390.1	276.1	32.5	160.1	282.8	241.3	30.7	125.0	204.2	270.0	298.0	103.0	379.5	285.6	198.1
<u>Main Lake Region</u>															
Morrison System	1.6	0	3.2	0.8	26.0	24.0	1.8	29.0	29.0	19.0	147.0	11.0	25.0	13.5	57.1
Fulton River	35.0	60.0	35.0	35.0	140.0	110.0	17.0	90.0	120.0	90.0	120.0	40.0	175.0	86.0	91.8
Pinkut Creek	11.0	14.7	5.8	7.5	24.0	25.0	4.0	24.0	30.0	45.0	80.0	30.0	47.0	21.4	65.0
Pierre Creek	4.4	17.9	12.5	3.5	20.0	17.0	4.0	20.0	23.0	80.0	34.0	11.0	55.0	4.5	36.9
Grizzly Creek	1.5	3.0	2.3	3.5	6.0	3.1	0.5	5.0	7.0	30.0	14.0	12.0	30.0	5.0	14.8
Twin Creek	2.3	8.1	5.0	0.4	10.0	14.0	2.5	5.0	6.0	20.0	9.0	6.0	15.0	1.4	14.8
4-Mile Creek	1.7	4.7	0.9	0.2	2.0	2.2	0.4	0.4	2.5	7.0	5.4	2.0	2.0	3.0	3.7
Tacheek Creek	2.6	0	2.6	0	2.5	1.9	0.3	0	6.8	3.0	6.0	2.0	0	0.6	3.7
Sockeye Creek	0.2	0.9	0.8	0	0.6	0.9	0.5	0	2.5	2.0	4.0	2.0	0	1.1	3.1
6-Mile Creek	0	1.2	0	0	2.7	1.8	0.1	0.1	0.6	2.5	3.5	1.0	0	1.0	1.8
Pendleton Creek	1.1	1.3	0	0	1.5	1.1	0	0	0.3	0	2.5	0	0	0.2	0
Others ³	0.4	1.2	0	0	6.8	2.5	0.1	0.1	0.8	2.5	7.4	1.0	0.2	1.0	2.2
TOTAL SPAWNERS	61.8	113.0	68.1	50.9	242.1	203.5	31.2	173.6	228.5	301.0	432.8	118.0	349.2	138.7	294.9
TOTAL % OF JACKS	9.4	33.0	7.2	7.4	3.9	2.0	30.4	4.8	10.4	3.7	3.9	15.7	2.9	7.7	22.7

¹Babine fence count, less Indian food catch and commercial harvest (when applicable).²Estimate derived from stream counts, tag and recovery, average "not accounted for" 1949-1963.³Intermittent counts in small marginal streams.

TABLE 1 (cont'd.)

BABINE SOCKEYE ESCAPEMENTS IN THOUSANDS OF FISH DURING THE PERIOD 1949-1977

	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1949-1977 Means</u>
Potential Stock	888.0 ²	644.0	571.0	632.3	605.4	814.0	828.0	370.6	938.8	985.8	953.9	921.7	711.6	961.4	668.3
<u>North Arm Nlkitkwa Region</u>															
Upper Babine River	250.0	120.4	70.0	135.0	185.0	303.0	234.0	321.0	189.0	153.0	203.5	92.0	127.2	121.2	151.8
Lower Babine River	48.0	122.0	114.0	55.0	37.0	60.0	84.0	96.0	70.0	40.0	35.0	3.0	3.0	40.4	74.6
9-Mile Creek	1.5	0.5	1.0	1.0	0.6	1.0	1.2	1.2	0.8	1.1	1.0	0.1	0.9	0.9	1.1
5-Mile Creek	0.1	0.2	0.2	0.1	0.1	0.4	0.3	0.2	0.1	0.1	0.5	0.3	0.1	0	0.2
Total Spawners	299.6	243.1	185.2	191.1	222.7	364.4	319.5	418.4	259.9	194.2	240.0	95.4	131.2	162.5	227.8
<u>Main Lake Region</u>															
Morrison System	26.0	8.5	11.5	15.5	46.0	22.4	7.2	8.0	8.6	26.3	31.3	23.0	6.4	12.6	22.1
Fulton River	116.7	123.3	59.2	140.5	128.8	149.0	252.1	299.1	345.4	318.6	273.5	444.1	363.4	514.3	164.8
Pinkut Creek	144.5	23.8	21.5	33.4	24.7	43.5	35.2	40.9	94.4	132.3	133.4	114.8	50.2	89.3	48.9
Pierre Creek	22.0	10.0	11.0	40.0	25.0	25.0	44.0	14.2	25.1	60.9	42.9	20.1	2.4	10.0	24.0
Grizzley Creek	8.0	5.0	6.0	3.0	7.5	9.0	5.4	2.4	0.8	13.9	12.0	4.5	1.4	6.0	7.7
Twin Creek	9.0	3.0	2.5	10.0	12.0	16.7	18.0	7.0	6.8	21.0	18.5	17.0	1.8	9.0	9.4
4-Mile Creek	2.1	1.4	1.5	4.0	4.0	4.5	2.5	6.0	7.4	11.0	7.3	1.7	0.8	8.8	3.5
Tachek Creek	3.0	0.7	0.3	1.0	0.5	2.3	2.4	0.5	1.2	0.9	2.9	1.1	0.5	3.5	1.8
Sockeye Creek	1.5	0.1	1.4	0.7	1.2	2.1	4.8	0.7	0.7	0.6	3.5	2.6	1.3	1.7	1.4
6-Mile Creek	1.5	0.1	0.3	1.2	1.0	0.3	0.6	0.4	1.4	4.8	0.9	0.1	0.5	1.5	1.1
Pendleton Creek	1.4	0	0	0	0	0	0	0	0	0	0.1	0	1.0	0.6	0.4
Others	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0
TOTAL SPAWNERS	338.5	175.9	115.2	248.6	250.7	274.8	372.2	379.2	491.8	590.3	531.3	629.0	429.7	657.8	285.9
TOTAL % OF JACKS	6.8	9.9	31.9	4.6	8.8	18.9	20.0	6.3	27.6	19.1	23.8	11.0	18.4	2.4	12.9

Significant fry migration usually begins in late April, and is complete by the third week of June. The peak, occurring between late May and early June, depends on river discharge, particularly in years when the dam is overtopped by Fulton Lake.

Spawner distribution in the river is uneven, and depends on gradient and streambed composition. Spawner densities are highest in areas of low gradient where gravel composition is one-inch to two-inches in diameter. Lowest density spawning occurs in areas of higher gradient, where the streambed consists of boulders and outcrops of bedrock. It has been estimated that 55 percent of all spawners utilize heavy-density areas, while only 10 percent use the light-density areas.

SPAWNING AND INCUBATION WATER FLOWS

Prior to completion of the Fulton River dam in August, 1968, water flows are known to have varied considerably. Spawning flows ranged from 25 cfs to approximately 1800 cfs (September, 1966). These varying conditions, combined with the effects of extremely low incubation flows (25 cfs - April, 1962), contributed to a large variation in egg-to-fry survivals (11.0 - 31.0%).

Since the fall of 1968, spawning flows have been regulated between 100 and 165 cfs. When spawning is over, the river is flushed at about 1500 cfs, usually once, to remove carcasses. Incubation flows are then maintained at approximately 250 cfs.

The Fulton Lake reservoir provides a maximum storage of 40,000 cfs - days. Care is taken in the fall to store enough water to provide for winter flows to the river and spawning channels. Rule curves are established and followed closely, with the level of Fulton Lake being checked at least once a week. Snow courses are taken at the beginning of March, April and May, and reservoir levels are reduced if a heavy spring runoff is expected.

ADULT SOCKEYE PROGRAM

Sampling Technique

Prior to installation of the permanent enumeration fence in 1966, adults were enumerated by tag and recovery programs, and tower counts approximately 700 feet upriver from the present fence site. Samples are now taken at the fence and along the banks for testing of sex, age composition, length and egg retention. Samples are also taken over the range of lengths for fecundity counts.

Since 1966, upstream migrants have been counted at the main fence. The Channel No. 2 fence, continuous with the river fence, is operated so as to divert the peak of the run into the channel. Remaining adults are allowed through the river fence, a portion from the main migration being directed into Channel No. 1 further upriver. In 1977, as in recent years with an excess of Channel No. 2 fish, channel water is diverted into the river in order to attract channel fish through the river fence. Depending on the number of spawners and the rate of upstream migration, fish may be counted into the river and Channel No. 2 simultaneously. Estimates of spawners below the enumeration fence are estimated from shore and/or with the aid of aircraft.

Population Characteristics

Spawning populations to the Fulton system have ranged from 59.2 thousand (1966) to 502.0 thousand (1977) in the past 12 years (Table 2). Babine Lake sockeye escapements have been purposefully increased during this period to allow adequate spawners for the new channels. In 1971 and 1975 to 1977, escapements to Fulton River have been above the design loading of 120,000 adults. Over-escapement of Fulton stock through the commercial fishery has been the cause of overloading the river in the past three years. During the record escapement of 1977, the spawning densities of the two channels were maintained within normal limits. 318,000 adult spawners were directed into the river, which resulted in a loading density of 0.37 sq. yds. per female.

TABLE 2: Adult sockeye escapement in thousands to the Pinkut Creek and Fulton River systems from 1965 to 1977.

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1965-1977 Average	1949-1966 Average
Fulton River	123.3	40.4	114.2	99.2	60.6	111.3	142.6	81.4	100.0	64.3	274.4	140.6	355.4	131.4	
Channel No. 1		18.8	21.8	26.0	21.0	25.5	24.7	21.6	25.3	12.5	14.9	16.8	19.1	20.7	
Channel No. 2					23.7	58.8	115.5	106.5	112.1	62.4	108.2	110.7	127.6	91.7	
Fulton System	123.3	59.2	136.0	125.2	105.3	195.6	282.8	209.5	237.4	139.2	397.2	268.1	502.0	213.9	80.5
Pinkut Creek	23.8	21.5	31.7	8.8	8.3	9.2	8.8	16.8	36.9	44.5	57.1	21.2	20.2	23.8	
Pinkut Channel				13.5	28.8	19.8	21.7	57.1	63.3	51.7	48.1	-	64.6		
Pinkut System	23.8	21.5	31.7	22.3	37.1	29.0	30.5	79.9	100.2	96.2	105.2	21.2	84.8	52.6	31.8
Development Total (Pinkut & Fulton)	147.1	80.7	167.7	147.5	142.4	224.6	313.3	283.4	337.6	235.4	502.7	289.3	586.8	266.0	
Development Percent (Pinkut & Fulton)	25.4	20.7	27.8	26.8	21.6	33.9	38.4	41.7	42.3	32.4	61.2	49.8	62.6	39.3	
Babine System	580.0	389.0	603.0	552.0	660.0	662.0	816.0	680.1	797.5	727.0	820.8	580.6	938.0	677.4	504.9

Age Composition

The majority of spawners in the Fulton system are 4_2 and 5_2 fish. The $4_2/5_2$ ratio has varied from 40/60 in 1968 to 94/6 in 1975 (Fig. 7). The Fulton River has been similar in age composition to the total system, except in 1973, when there was a 45/55 ratio in the river and a 56/44 ratio in the total system. Since 1964, a cyclical trend of 5_2 fish being dominant every four years has occurred; however, there is no similar pattern of age composition in the Pinkut Creek system. Godfrey (1958) and Larkin and McDonald (1968) have studied age at maturity of sockeye salmon and could find no genetic or environmental factors of significance in the Skeena system, though early environmental conditions may be important. The $4_2/5_2$ age patterns have also been investigated with respect to: selection and overexploitation by the commercial fishery; differential yield between the basically $4_2/5_2$ Babine stocks and the non-Babine stocks of the Skeena who are the main contributors of 6-year-old's and the sub-3 age groups; and, "dominance" effects of spawning populations on populations of other years through such factors as genetics, competition, disease or conditioning.

The proportion of jacks in the Fulton River system has increased in "post-development" years (Table 3). Since 1969, the first return of jacks from the natural spawning in Channel No. 1, jacks have comprised an average of 22.9 percent of the total escapement. In the "pre-development" years from 1960 to 1967, jacks had comprised an average of only 14.2 percent. This increasing proportion of jacks is expected in a sockeye population in which all age classes are enhanced and are subject to the effects of a gillnet fishery which selectively does not harvest jacks. The effect is seen in the jack returns to both the Fulton River and Pinkut Creek systems (Table 4).

The 1977 return of jacks to the Fulton system was unusually low, amounting to only 16,947 or 3.3 percent of the Fulton stock. This was the second smallest numerical return of jacks in post-development years and, due to the large, overall return, was the lowest percentage of jacks. Since 1973, jacks have been removed at the Babine counting fence both commercially and in the special native food fishery.

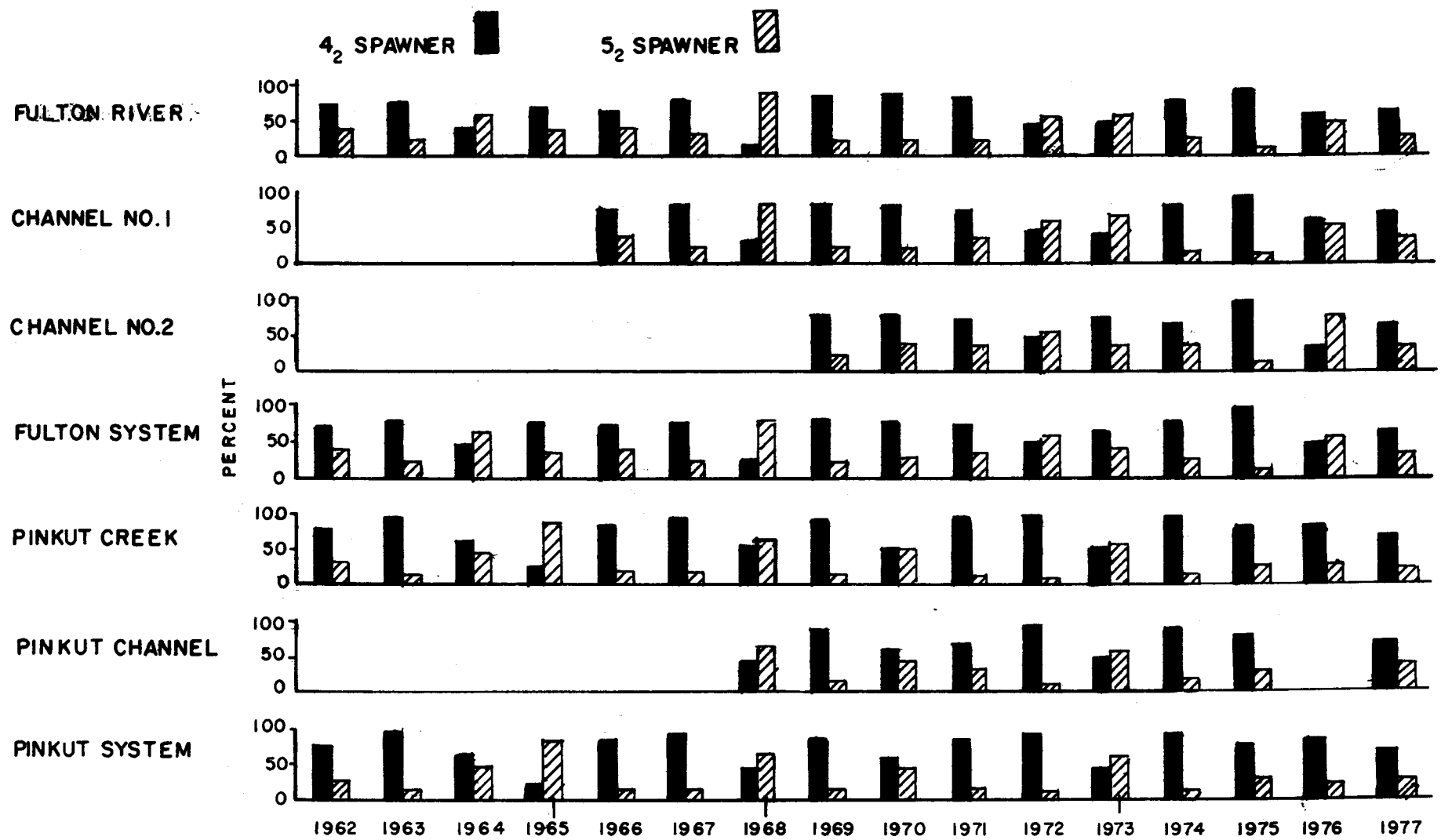


Figure 7: Annual age class of spawners in the Fulton River and Pinkut Creek systems.

TABLE 3: Escapement of adult and jack sockeye to the Fulton River system, from 1961 to 1977.

Phase	Return Year	Jacks	Adults	% Jacks
Pre-Development Returns	1961	19,278	170,100	10.2
	1962	-*	86,400	-
	1963	54,824	98,600	35.7
	1964	3,240	116,760	2.7
	1965	15,707	123,293	11.3
	1966	30,478	59,522	33.9
	1967	4,495	135,976	3.2
	1968	2,754	99,244	2.7
	Average	(18,682)	(111,236)	(14.2)
	1969	43,715	105,260	29.3
Post-Development Returns	1970	56,527	195,532	22.4
	1971	16,339	282,801	5.5
	1972	135,901	209,478	39.3
	1973+	81,250	237,309	25.5
	1974+	139,265	139,211	50.0
	1975+	46,604	399,153	10.5
	1976+	45,371	288,071	20.7
	1977+	16,947	502,030	3.3
	Average	(67,990)	(262,094)	(22.9)

*No available estimate.

+Years of jack harvest at the Babine Fence.

TABLE 4: Percentage of total Babine Lake jack sockeye escapement to the Fulton River and Pinkut Creek systems.

Phase	Year	Babine Total	Fulton %	Pinkut %	Percent of Total
Pre-Development Returns	1960	49,000	-	-	
	1961	28,000	68.9	-	
	1962	46,000	-	-	
	1963	173,000	31.7	-	
	1964	60,000	5.4	2.4	7.8
	1965	64,000	24.5	15.9	40.5
	1966	182,000	16.7	3.8	20.6
	1967	29,300	15.3	5.7	21.0
	1968*	53,400	5.2	4.5	9.6
1960 - 1968 Average		76,100	24.0	6.5	19.9
Post-Development Returns	1969 ⁺	154,000	28.4	4.2	32.6
	1970	166,000	34.1	3.7	37.8
	1971	54,600	29.9	19.2	49.2
	1972	258,582	52.5	7.9	60.4
	1973	208,352			
	++	188,336	43.1	17.1	60.2
	1974	256,772			
	++	226,923	61.4	16.4	77.8
	1975	137,396			
	++	100,942	46.2	9.5	55.7
	1976	255,458			
	++	130,970	57.6	9.8	67.4
1969 - 1977 Average	1977	45,383			
	++	23,397	72.4	4.9	77.3
		144,861	47.3	10.3	54.6

*Beginning of Fulton River flow control.

⁺First return of naturally-produced Channel No. 1 jacks.

⁺⁺Jack escapement after native food fishery and commercial harvest of jacks at the Babine Fence.

Egg Depositions and Retentions

Potential egg deposition in the Fulton River amounted to 604.7 million, or 8,063 eggs per square yard in 1977. Potential egg deposition has been as low as 985 eggs per square yard (1966), but normally ranges between 2,000 and 3,000.

Retention is observed to increase above 3 percent when potential egg deposition is greater than approximately 2,500 eggs per square yard (Fig. 8). The circled years are from the pre-flow control period, and, in some years, may not be representative of spawning success under present conditions. In 1977, the egg retention in Fulton River was greater than any previously recorded retention, due to the large number of spawners. The average egg retention might have been higher, but the total run entered the spawning grounds in three main waves.

SOCKEYE FRY PROGRAM

Enumeration Techniques

Sockeye fry enumeration on the Fulton River began in 1962, using mark and recovery techniques. A travelling vertical sampler was used from 1963 to 1966, and migration estimates were calculated using actual catches and river discharge with the formula:

$$N = \frac{Q_s S}{\sum QN}$$

N = nightly migration
Qs = river discharge
S = total fry catch
 $\sum QN$ = sum of discharge through nets at each station.

This was unreliable during periods of flooding or when the nets became filled with debris. Fry estimates from 1962 to 1965 are therefore of limited accuracy. Flooding and debris in 1966 prevented any downstream estimate, and the migration was interpolated from the previous five years' data.

In 1967, the permanent fry and adult counting fence was constructed 5,000 feet above the river mouth on the lower-most spawning riffle. Permanent fry traps, similar to those described by Tait and Kirkwood (1962),

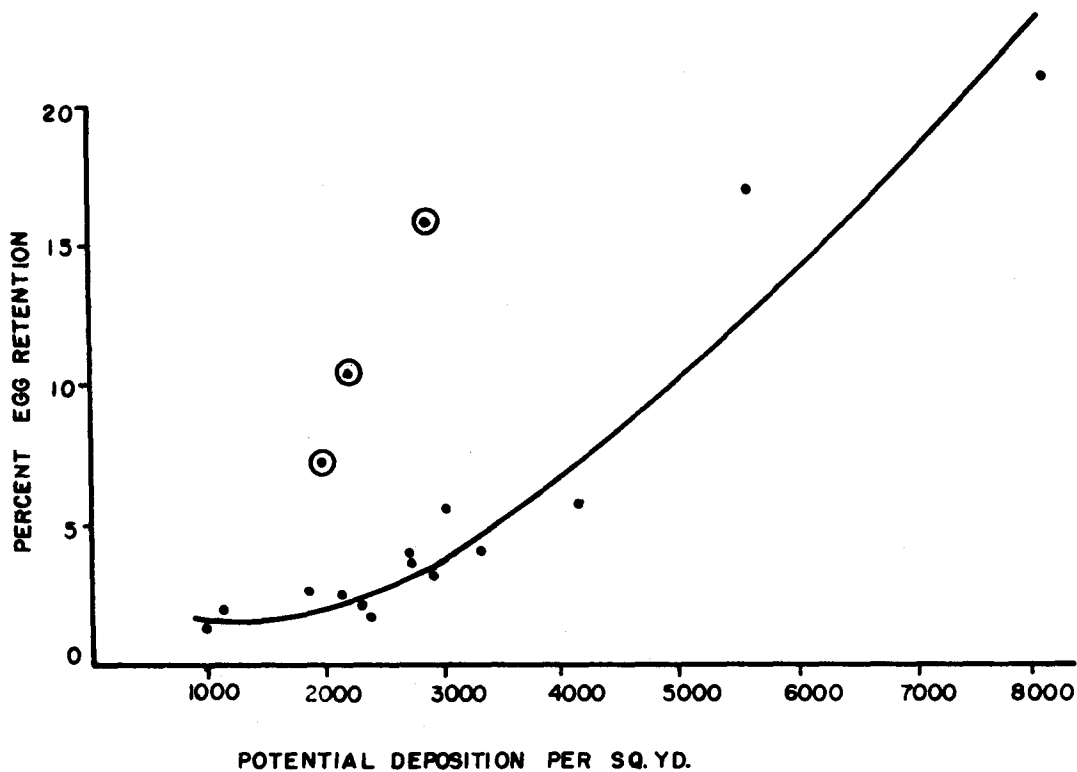


Figure 8: Relationship between potential egg deposition and percent egg retention in Fulton River.

were set along the fence to fish one foot in twenty across the width of the river. The traps are such that the entire water column is fished, regardless of the water depth. Time check and area check factors are applied to the nightly catches to extrapolate the total nightly fry migration. A detailed description of sampling calculations is given in the 1961-76 report by Ginetz (1976).

Hydraulic sampling, based on studies by McNeil (1964), has been developed since 1963 as an alternate means to assess egg-to-fry survival (Table 5).

Fry Production and Egg-to-Fry Survival

Flow control began on the Fulton River in 1968 (Table 6). By improving the flow conditions of potentially bad years, the average egg-to-fry survival was expected to increase from 20 to 30 percent. Expectations

of increased survival were based on the assumption that flow control would stabilize spawning flows and prevent egg deposition in fringe areas, reduce the shifting of gravel during spawning and incubation periods, and prevent premature fry migrations. Immature fry emerging voluntarily or otherwise would not be swept by high river discharges into Babine Lake at times of low food availability. Flow control did not, however, reduce the number of predators, and may have increased their numbers by improving their habitat.

Analysis of the Fulton River flow control project does not include the 1969 brood year, because of heavy silting caused by two mud slides, approximately 100 yards upriver from Channel No. 1.

In years of controlled flow conditions, egg-to-fry survival has been closely correlated ($.05 > p > .01$) to egg depositions per square yard (Fig. 9). Egg-to-fry survival in pre-flow control years indicated a greater variability over a small range of egg depositions, and survivals of 30 percent or more resulted from depositions below 2,000 eggs per square yard. The egg-to-fry survival since 1968 may be due to over-estimates of production in the early years. The vertical sampler and mark-recovery methods used prior to 1966, were less accurate than converging throat traps used since 1967, and the 1966 estimate was only an interpolation based on previous years' data.

Maximum egg-to-fry survivals since flow control have not been as high as was expected. Survivals of about 20 percent have been attained at depositions up to 2,500 eggs per square yard.

Average fry production has increased from 384 fry per square yard (28.8 million fry) in pre-flow control years, to 668 fry per square yard (50.1 million fry), due to increased egg-to-fry survival at higher egg depositions and to the larger average deposition in the flow control period (Fig. 10).

High spawner density and wave spawning are limiting factors of production in Fulton River. This is supported by studies by Ginetz (1972),

TABLE 5: Comparison between annual egg to fry survival rates derived from the hydraulic sampling and enumeration fence techniques at Pinkut Creek and Fulton River.

BROOD YEAR	PINKUT				FULTON					
	RIVER		CHANNEL		RIVER		CHAN. #1		CHAN. #2	
	Hyd. Samp.	Down Stream	Hyd. Samp.	Down Stream	Hyd. Samp.	Down Stream	Hyd. Samp.	Down Strdam	Hyd. Samp.	Down Stream
1963	19.1					31.4				
1964	2.0					12.5				
1965	13.5					12.5				
1966	16.9	13.8				31.0		69.1		
1967	9.9	6.6				16.7		48.9		
1968	16.4	10.0	23.4	33.8		17.6		42.7		
1969	-	19.8	59.9	40.5		12.6		21.3		67.3
1970	18.5	19.9	-	58.0		20.5		31.0		31.5
1971	20.7	-	62.6	54.2	17.0	14.8	38.6	50.7	32.9	41.7
1972	16.8	-	-	30.0	16.5	19.9	43.0	52.1	52.4	26.5
1973	12.1	10.1	16.3	24.8	14.4	18.3	42.2	43.7	42.6	45.1
1974	15.0	9.3	-	8.9	25.1	21.0	47.2	63.5	30.2	36.7
1975	12.6	-	17.0	33.1	-	12.9	55.4	54.0	36.2	40.0
1976	20.7	22.5	-	-	18.9	17.3	23.1	58.9	24.1	61.5

TABLE 6: Sockeye fry production at Fulton River.

(spawning area = 75,000 sq. yds.)

Brood Year	Total Spawning (adults)	Female Spawning	Egg Deposition (millions)	Fry Production (millions)	Egg-to-Fry Survival (%)	Area/Female (sq. yds.)
1961	170,100	85,050	237.7	26.5	11.0	0.88
1962	86,426	44,936	136.5	41.7	30.5	1.67
1963	98,560	53,900	148.0	46.5	31.4	1.39
1964	116,500	62,500	187.0	24.5	12.5	1.20
1965	123,100	72,600	189.0	23.6	12.5	1.03
1966	59,216	34,648	77.5	24.0	31.0	2.16
1967	114,224	56,050	171.6	28.8	16.7	1.34
Natural flow average						
7 years	109,732	58,526	163.9	30.8	20.8	1.38
1968	99,244	64,565	213.6	38.7	17.6	1.16
1969*	60,555	28,350	81.7	11.2	12.6	2.65
1970	111,289	66,360	189.9	38.9	20.5	1.13
1971	142,574	71,589	209.3	31.0	14.8	1.05
1972	81,387	50,867	167.4	33.4	19.9	1.47
1973	99,975	47,868	150.0	27.5	18.3	1.57
1974	64,284	43,516	131.5	27.7	21.0	1.72
1975	274,426	146,857	352.9	45.5	12.9	0.51
1976	160,561	95,875	289.3	50.1	17.3	0.78
Flow control average						
9 years	121,588	68,427	198.4	33.8	17.2	1.34

*Heavy silting.

Figure 9: Regression of sockeye egg-to-fry survival on actual egg deposition per square yard in Fulton River.

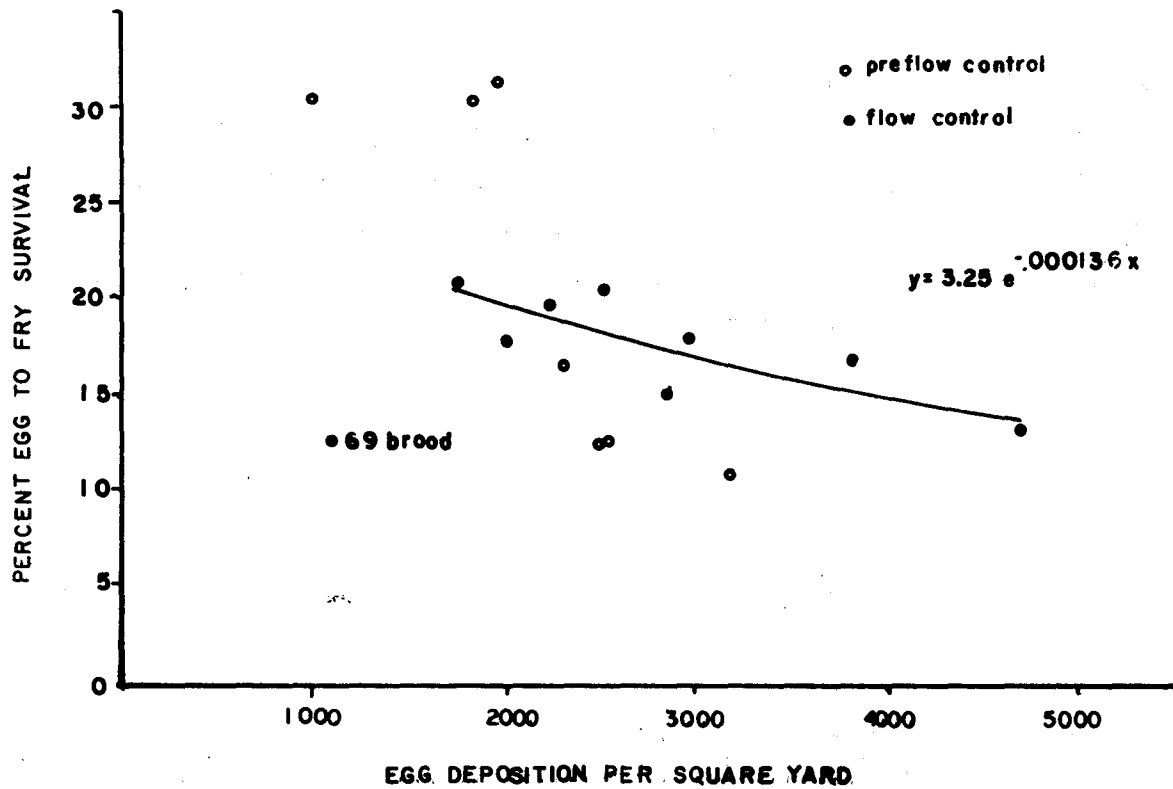
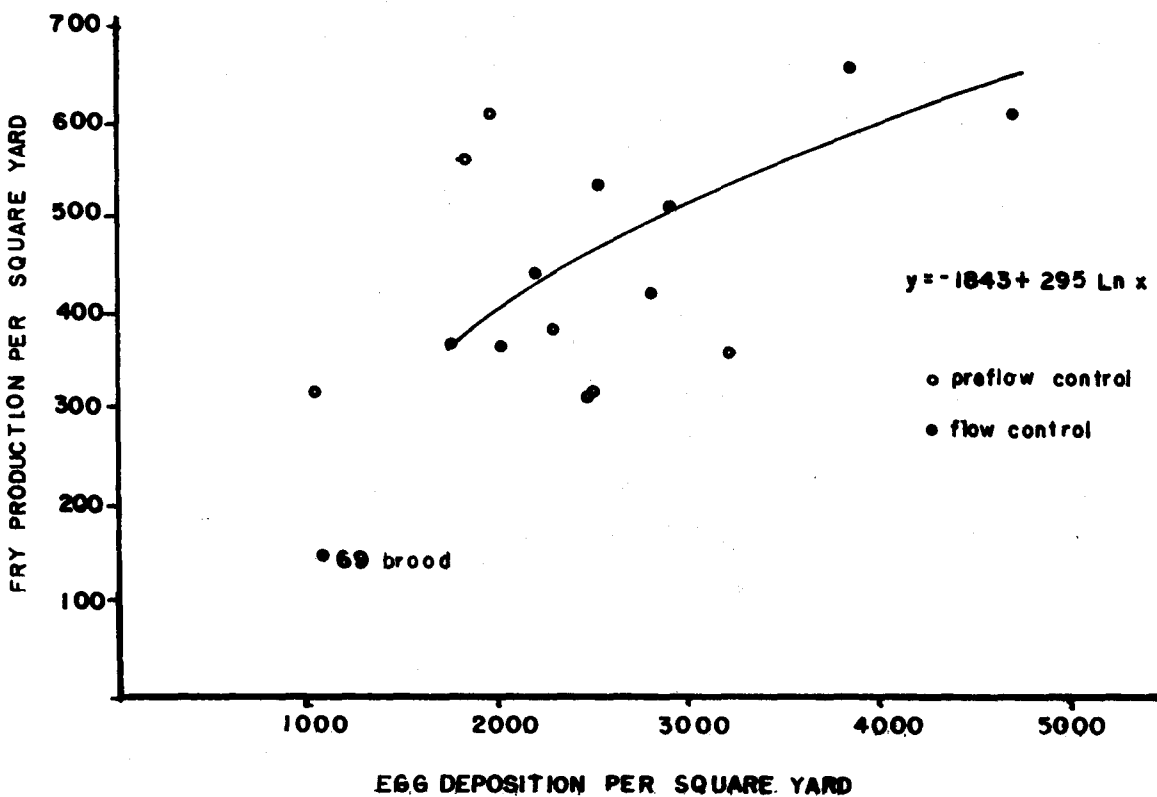


Figure 10: Regression of sockeye fry production per square yard on actual egg deposition per square yard in Fulton River.



who found that high egg mortality occurred early in the incubation period, and that much of it was due to the superimposition of redds. The relation of adult density and egg-to-fry survival is shown in Figure 11. An optimum spawning density is not clearly defined, but survival begins to decrease more rapidly when the average spawning area is less than approximately 1.25 square yards per female.

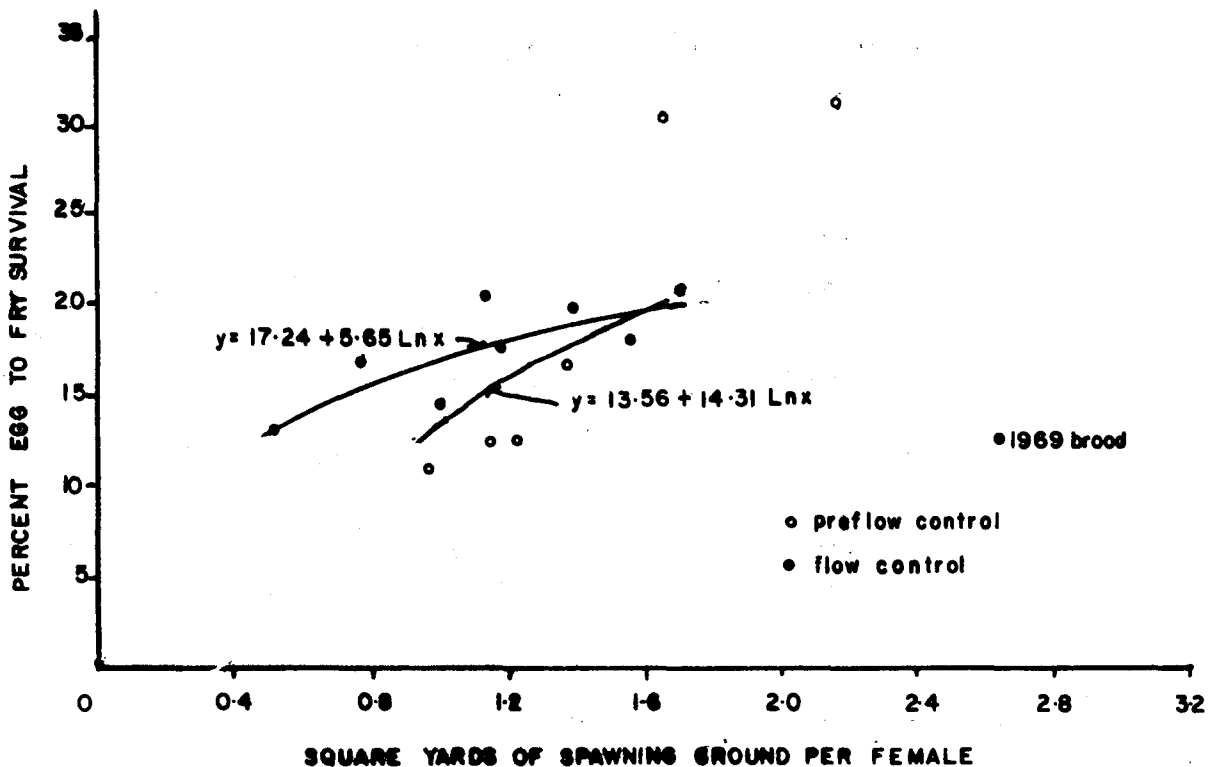


Figure 11: Regressions of sockeye egg-to-fry survival on square yards of spawning area per female in Fulton River.

Flow control on the Fulton River has succeeded by increasing egg-to-fry survival at higher spawning densities. Low survivals, around 12 percent, occur less frequently, and can be attributed to unusual conditions such as heavy silting or high adult spawning densities. Larger egg depositions and increased egg-to-fry survival at greater egg depositions have resulted in an increased average fry production.

Average egg-to-fry survival has not increased since flow control because the average spawning density has been increased to a range where survival is limited by density-dependent factors. The data suggests that at depositions above 2,500 eggs per square yard, equivalent to average spawning areas of less than approximately 1.25 square yards per female, production becomes less efficient. Egg retention is known to increase when potential deposition becomes greater than approximately 2,500 eggs per square yard, which suggests spawner interaction at higher densities may be related to egg-to-fry survival.

Fry Migration Timing

Fry migration from the Fulton River normally occurs over a period from early April to mid-June (Fig. 12). Since flow control began, there has been a gradual shift of the peak migration date from late May or early June to the third week of May (Table 7). This may be the result of early discharges from the reservoir intended to prevent uncontrolled flows later in the spring. A second possible explanation is the appearance of a larger, early production because of the increased size of the early Fulton River run. The dependence of fry migration on river discharge and temperature are shown in Figure 13. The 1977 migration peaked on the night of May 9, the earliest date since 1961, coinciding with a peak in river discharge while water temperatures were rising and above 4°C. The migration then slowed as discharge dropped, and by 70 percent of the migration, the timing was consistent with the previous ten-year average. Flow control may affect fry survival by causing fry to migrate earlier in the spring when there might be less food available in Babine Lake.

Fry Quality

Fry lengths of the pre-development years ranged from 28.2 mm (1965) to 30.3 mm (1964), averaging 29.5 mm (Table 8). Since 1968, fry lengths have been similar, averaging 29.6 mm, but with less variation from year-to-year. Mean 1977 fry length was 29.2 mm, slightly below the 1964-77 average.

Figure 12: Mean weekly number of Fulton fry migrating to Babine Lake in relation to average weekly water temperature and discharge from 1967 to 1977.

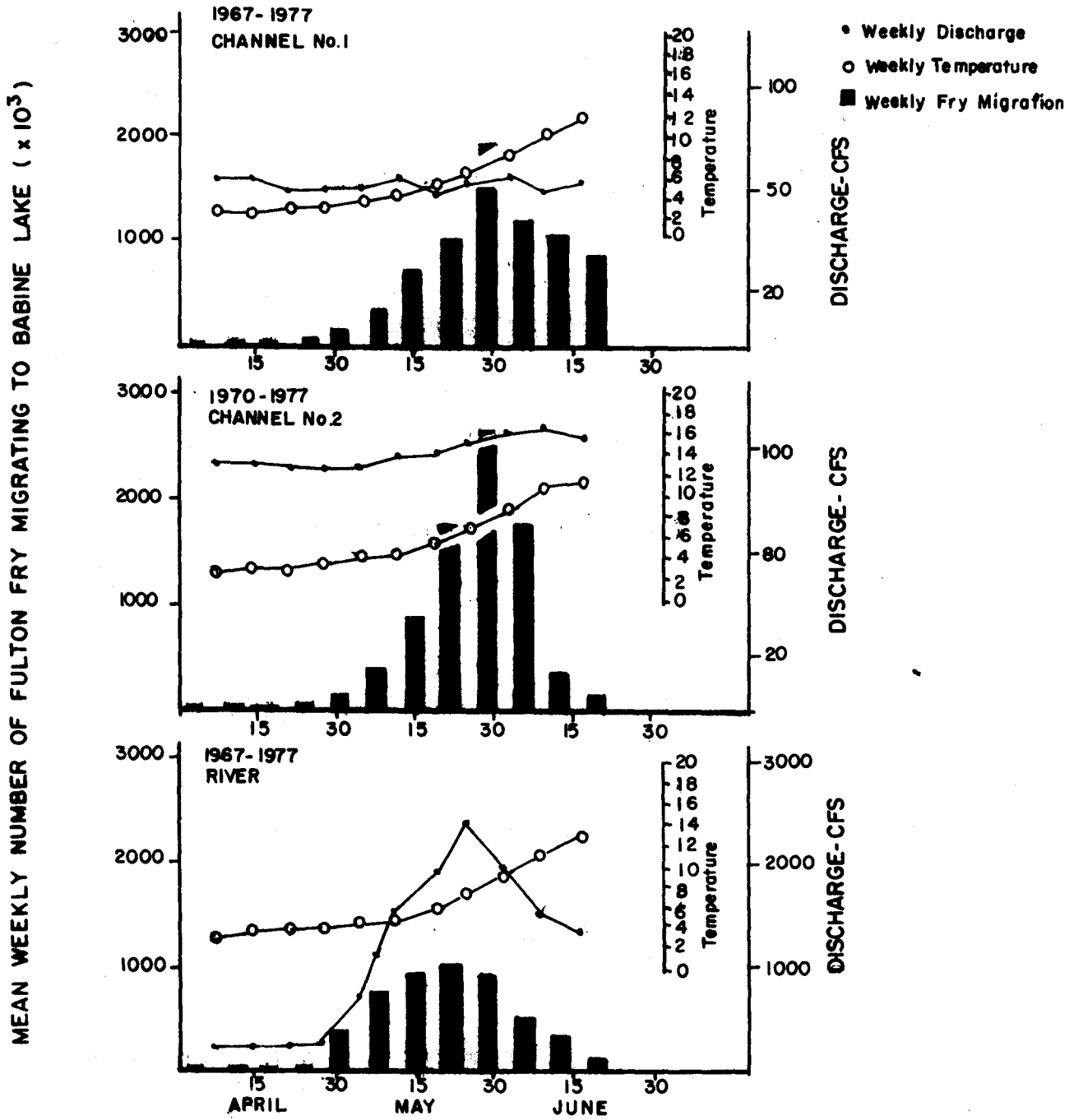


TABLE 7: Peak timing of sockeye fry migrating from the Fulton River system to Babine Lake.

Fry Year	Location		
	Fulton River	Channel No. 1	Channel No. 2
1962	May 28		
1963	May 23		
1964	June 4		
1965	-		
1966	June 6		
1967	June 2	June 9	
1968*	May 21	June 3	
1969	May 25	June 1	
1970	May 17	May 27	May 18
1971	May 15	May 21	May 21
1972	May 19	May 24	May 30
1973	May 20	May 26	May 31
1974	May 19	May 29	June 1
1975	May 13	May 16	May 27
1976	May 10	May 17	May 26
1977	May 9	May 30	May 30

*Beginning of flow control.

TABLE 8: Weighted mean length in mm of sockeye fry migrating from the Fulton River system to Babine Lake.

Fry Year	Mean Length (mm)		
	Fulton River	Channel No. 1	Channel No. 2
1964*	30.3		
1965*	28.2		
1966*	29.3	29.1	
1967	29.4	29.0	
1968*+	29.3	29.8	
1969*	29.8	30.2	
1970	29.9	29.0	30.5
1971	30.0	29.2	30.3
1972	29.6	29.6	30.0
1973	29.2	29.8	29.9
1974	29.8	29.6	30.4
1975	29.8	29.2	30.2
1976	29.3	28.8	29.7
1977	29.2	29.4	29.5
Average	29.5	29.4	30.1
1970-77 Average	29.6	29.3	30.1

*Annual means not weighted for number of fry.

+ Beginning of flow control.

Pre- and post-development-period fry weights are very similar, averaging 153.9 mg and 152.8 mg, respectively, and 153.1 mg combined (Table 9). The mean weight of river fry in 1977 was 148.0 mg.

The mean developmental index ($K_D = \frac{10\sqrt[3]{\text{mg}}}{\text{mm}}$) has varied considerably in both the pre- and post-development periods, ranging from 1.74 in 1970 to 1.88 in 1965 (Table 10). The development index is used as a measure of yolk absorption, and is not a condition or performance factor (Bams, 1970). For sockeye fry at Fulton River, K_D values above 1.80 are associated with early migrations caused by floods or spring freshets washing immature fry from the gravel. Given adequate yolk reserve, fry from Fulton River may survive without significant mortalities for approximately two weeks (Paine, 1970; Bilton and Robbins, 1973). Fry which undergo up to four weeks of starvation however, sustain high mortalities even after food became available. The first half of the 1977 migration occurred approximately five days earlier than normal because of high discharge, but a premature migration is not supported by the K_D value. The developmental index of fry sampled the night prior to the peak, however, was 1.90, signifying an initial migration of immature fry, after which the migration slowed, and remaining fry migrated at a normal stage of development (Fig. 14). Fulton River fry length and weight in 1977 was smaller than usual, but the average developmental index was normal.

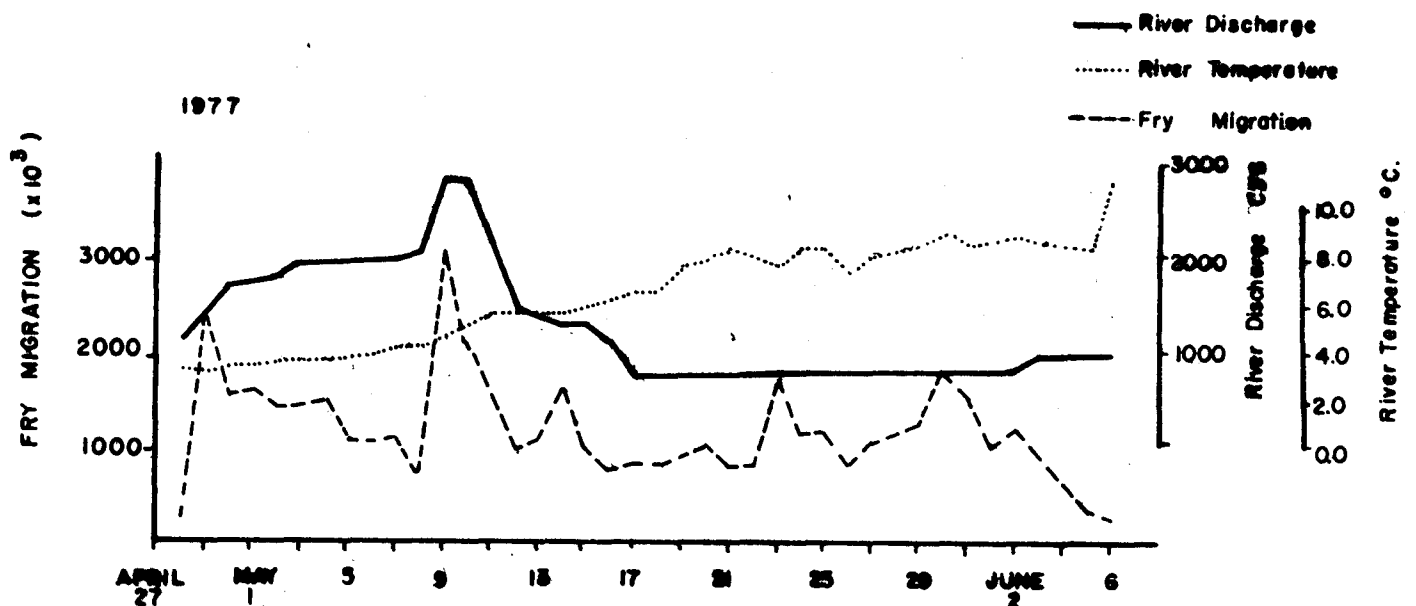


Figure 13: Daily number of Fulton River fry migrating to Babine Lake in relation to average weekly water temperature and discharge for 1977.

TABLE 9: Mean weight in mg of sockeye fry migrating from the Fulton River system to Babine Lake.

Fry Year	Mean Weight (mg)		
	Fulton River	Channel No. 1	Channel No. 2
1964*	160.0		
1965*	150.0		
1966*	148.2	147.2	
1967	157.6	138.5	
1968*+	146.9	140.1	
1969*	172.2	176.7	
1970	145.0	126.5	149.1
1971	152.4	138.3	149.3
1972	152.0	149.7	146.6
1973	154.5	155.0	153.6
1974	151.6	156.7	150.1
1975	145.4	144.2	153.8
1976	159.4	138.3	143.2
1977	148.0	142.5	141.7
Average	153.0	146.1	148.4
1970-77 Average	151.0	143.9	148.4

*Annual means not weighted for number of fry.

+ Beginning of flow control.

TABLE 10: Mean developmental indices of sockeye fry migrating from the Fulton River system to Babine Lake.

Fry Year	Mean Developmental Index (K_d)		
	Fulton River	Channel No. 1	Channel No. 2
1964*	1.79		
1965*	1.88		
1966*	1.80	1.81	
1967	1.82	1.78	
1968*+	1.80	1.74	
1969*	1.87	1.86	
1970	1.74	1.73	1.74
1971	1.78	1.77	1.75
1972	1.80	1.79	1.75
1973	1.84	1.80	1.79
1974	1.79	1.82	1.75
1975	1.76	1.79	1.77
1976	1.85	1.80	1.76
1977	1.81	1.76	1.76
Average	1.81	1.79	1.76
1970-77 Average	1.80	1.78	1.76

*Annual means not weighted for number of fry.

+ Beginning of flow control.

1977

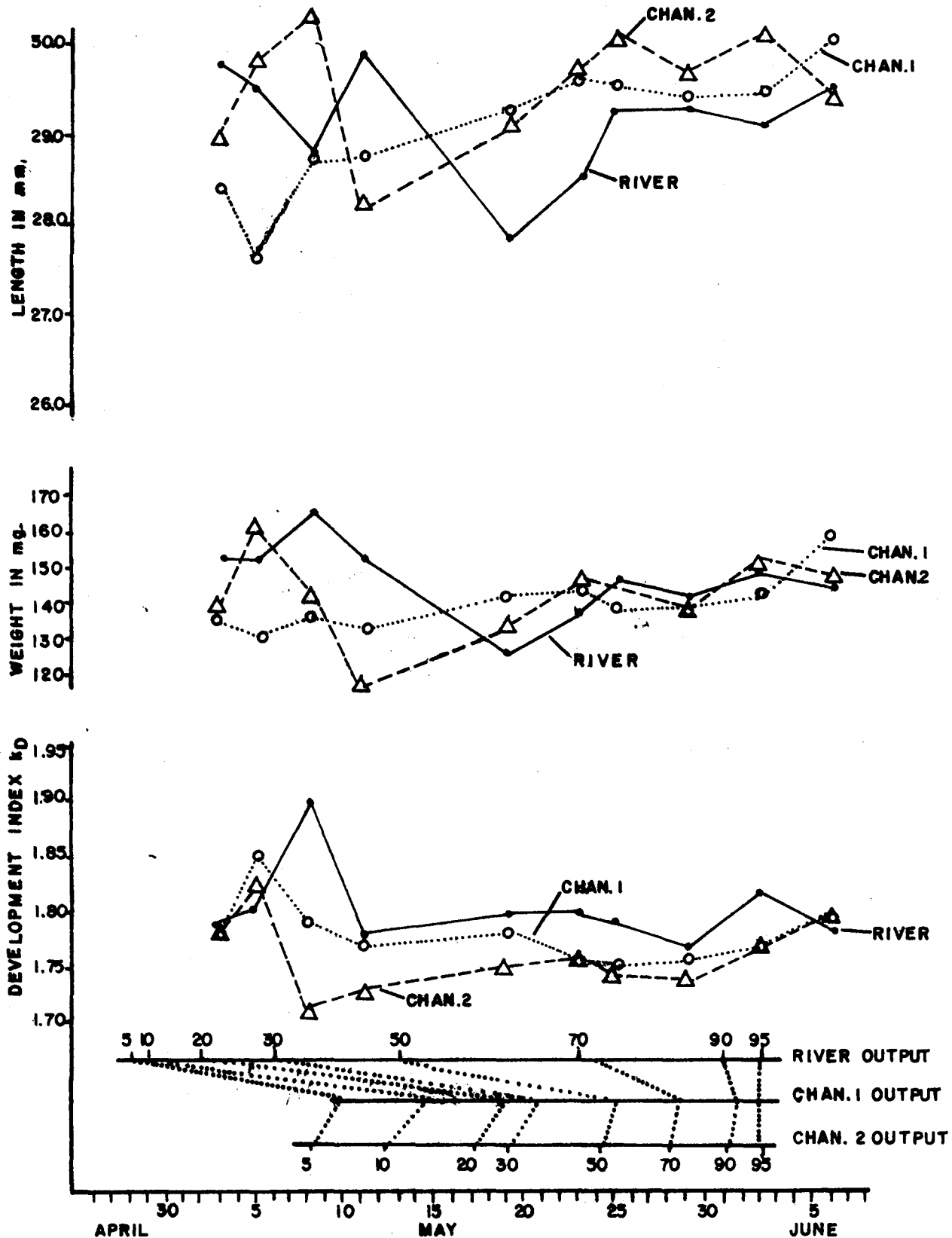


Figure 14: Average lengths in mm, average weights in mg, and average developmental indices of Fulton River, Channel No. 1 and Channel No. 2 fry at intervals during the 1977 spring migration. Also shown is the progress of the runs in time.

EVALUATION OF SPAWNING CHANNEL NO. 1

INTRODUCTION

Fulton Channel No. 1, with 12,887 square yards of spawning area, was completed in October, 1965, too late to allow natural spawning of sock-eye. To stock the channel, 1.2 million eggs taken from Fulton River spawners were incubated to the eyed stage and planted at the end of November. An 82 percent survival was obtained from this egg plant. Since then, the channel has been stocked naturally. Egg-to-fry survival was originally expected to be 40 percent, but survivals in all but two years have exceeded expectations.

This section of the report deals with years of natural operation of the channel. Production, survival and quality of the fry produced are analyzed with respect to associated physical and biological factors relating to the channel.

OPERATIONAL HISTORY OF CHANNEL NO. 1

Loading time in 1966, the first year of natural adult spawning, was lengthy due to the high river flows being more attractive to the adult sockeye, making diversions into the channel difficult. The loading time for Channel No. 1 was prolonged in 1969 also, due to problems with the loading of Channel No. 2. The majority of spawners were being held below the main fence, and only small numbers were available for loading into Channel No. 1. This problem occurred in 1970 and 1971 as well, but since then, with reduced river flows and more rapid movement of spawners through the main fence, the loading time for Channel No. 1 has been reduced (Table 11)..

In 1967, intermediate fences were installed in the channel to separate individual legs when it was realized that spawners were congregating in the top end (Fig. 15). An estimated 48 percent of the 26,300 adults were crowded into the top 22 percent of the channel, and it was not known how evenly distributed they would become when spawning commenced.

Ten thousand adults were released into the river through the channel intake, and the channel was reloaded at the bottom end. The intermediate fences were used to maintain spawner distribution until 1973, when studies indicated that less interference with spawners and reduced loading times could compensate for removal of the fences.

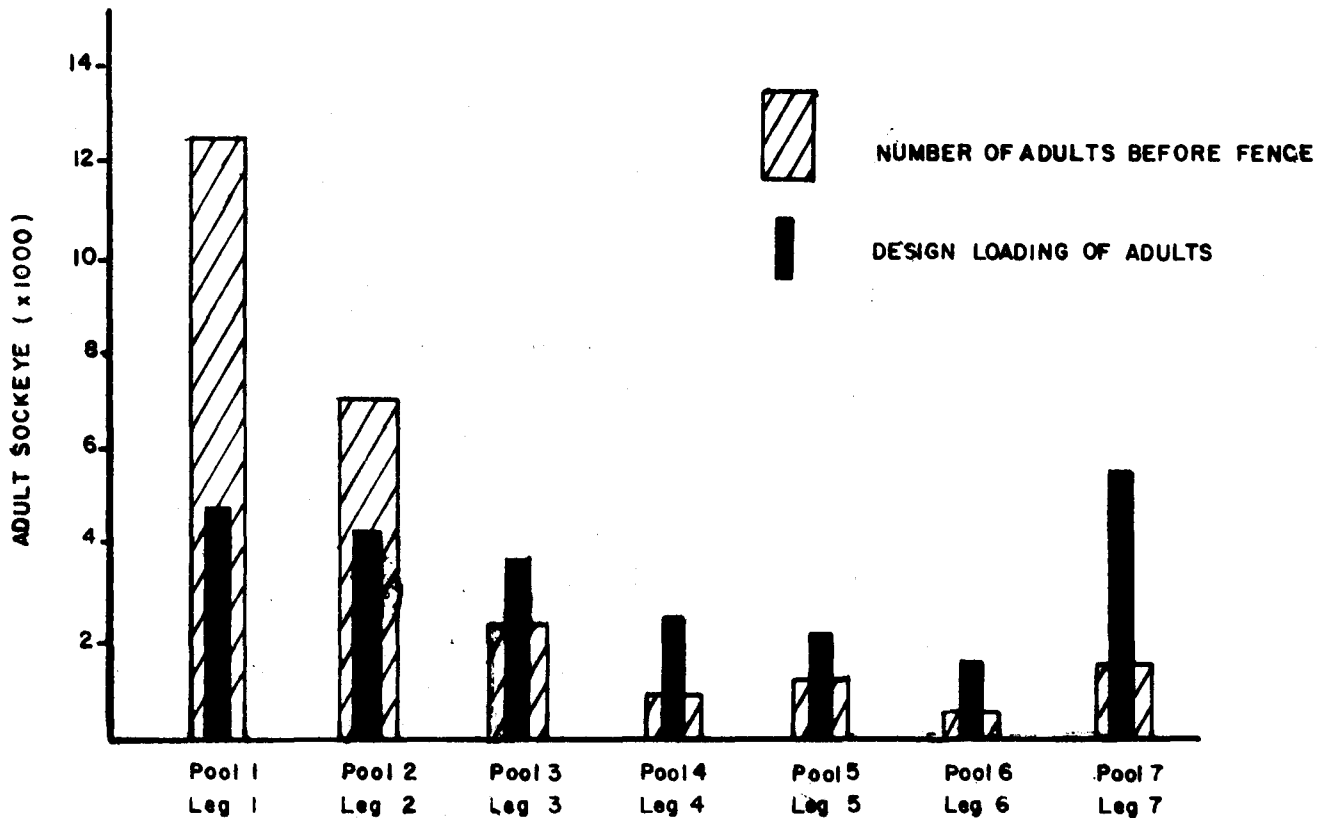


Figure 15: Adult sockeye distribution in Channel No. 1 before installation of intermediate fences and reloading of the channel in 1967.

From 1966 to 1971, spawners were loaded into the channel over the entire migration, a duration of more than 90 days. Studies by Ginetz (1971) found that redd superimposition was causing a large egg mortality. To reduce the loading time, adults have since been selected from the peak of the run. The fish then tend to spawn at one time, spreading themselves more evenly, due to interactions with other fish, thus practically eliminating wave spawning.

Egg-to-fry survival rates declined from 1965 to 1970 as the result of silt accumulating in the gravel. This bed-load increased considerably in 1969, when a slide occurred upriver from the channel intake. In 1970, the gravel was removed for cleaning and replacement, after which intensive gravel scarification has been carried out annually.

TABLE 11: Adult loading time (in days) for the Fulton River and Pinkut Creek spawning channels.

Year	Channel No. 1	Channel No. 2	Pinkut Channel
1966	51	-	-
1967	24	-	-
1968	32	-	32
1969	49	30	63
1970	37	30	19
1971	36	38	53
1972	10	41	41
1973	4	36	18
1974	20	24	35
1975	3	20	12
1976	6	23	-
1977	5	15	16

ADULT SOCKEYE PROGRAM

Sampling Technique

Adult sockeye were originally counted into the channel with the aid of a floating window over a flashboard at a straight, wire-mesh fence. Enumeration problems arose when downstream movement occurred past the raised panels. Since 1968, use of a "V" shaped broomstick fence began in order to prevent downstream movement. Samples of the population are tested for sex, age, post-orbital hypural length, fecundity and degree of spawning success (egg retention). The intermediate fences served a secondary

purpose as collection sites for carcass samples. Since then, samples have been taken from along the banks at temporary collection fences and from the broomstick fence. In 1977, the samples were taken from the broomstick fence.

Population Characteristics

From 1966 to 1977, spawning populations have ranged from 12.5 thousand in 1974, to 25.5 thousand in 1970. The design spawning density of Channel No. 1 was 1.25 square yards per female, or 20,620 adults at a 50:50 sex ratio. This was used as the target loading density until 1973. It was then decided that egg-to-fry survival was density-dependent, so 1.50 square yards per female became the target in 1974 and 1975. Due to large escapements in 1976 and 1977, spawning densities were increased to an average of 1.28 and 1.15 square yards per female, respectively. The adult loading in 1977 totalled 19,079. Channel No. 1 is loaded from the peak of the river migration; therefore, length, age, sex and fecundity of the river and Channel No. 1 are similar.

Jack populations have ranged from 9,814 (35 percent) to 719 (3.2 percent). As in the case of river stock, jack populations have increased over the years. The 1977 jack return, however, was the second lowest in the operational history of Channel No. 1, with only 727 jacks (3.7 percent).

Egg Retention and Deposition

Potential deposition has ranged as high as 60.8 million (4,718 eggs per square yard) and resulted in a retention (not including unspawned) of 5.1 percent. Retention data of individual legs in 1968, 1969 and 1971, years during which intermediate fences were used to maintain spawner distribution, exhibit a curvilinear relationship (Fig. 16, corr. = 8,868). Channel averages from 1967 to 1974 fit the curve well (Fig. 17, corr. = 9,154). Reduced loading times may have compensated for the absence of fences in 1973 and 1974, but retention since 1975 has been unexpectedly high (Table 12).

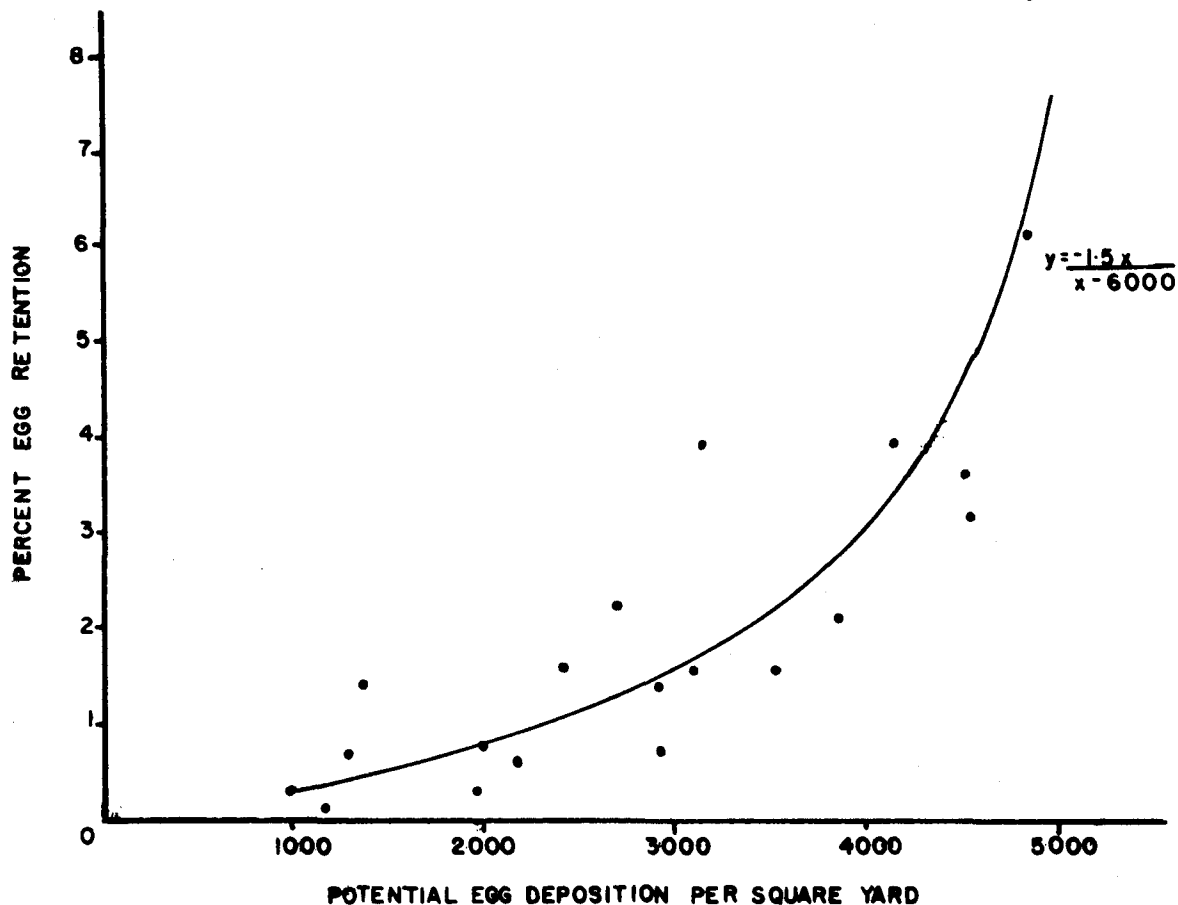


Figure 16: Relationship between potential egg depositions and percent egg retention in individual legs at Channel No. 1 at Fulton River in 1968, 1969

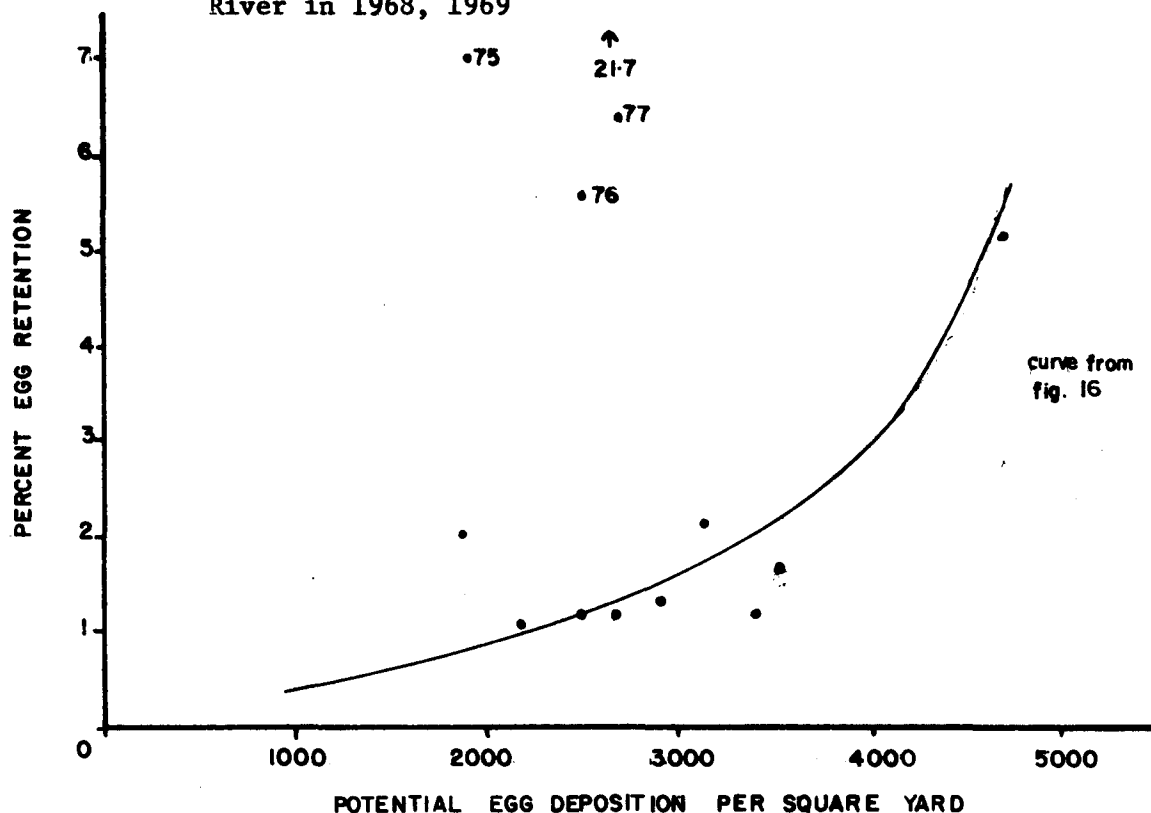


Figure 17: Relationship between potential egg deposition and percent egg retention in Channel No. 1 at Fulton River from 1967 to 1977.

TABLE 12: Average egg retention and spawning area per female in Fulton River, Channel No. 1 and Channel No. 2, from 1961 to 1977.

Year	Fulton River		Channel No. 1		Channel No. 2	
	Retention (%)	yds ² Female	Retention (%)	yds ² Female	Retention (%)	yds ² Female
1961	5.0	0.88				
1962	6.7	1.05				
1963	9.4	0.76				
1964	3.3	0.64				
1965	14.1	0.61				
1966	1.2	1.27	1.3	1.11		
1967	-	-	1.2	0.83		
1968	5.0	1.16	5.1	0.76		
1969	1.7	2.65	1.1	1.36	0.4	4.14
1970	3.4	1.13	1.3	0.89	1.4	1.36
1971	2.9	1.05	2.1	1.01	0.7	1.51
1972	2.0	1.47	1.7	0.96	1.4	0.76
1973	2.3	1.57	1.2	1.18	0.5	1.60
1974	2.4	1.72	2.0	1.65	0.6	2.04
1975	15.2	0.51	7.0	1.55	1.8	1.52
1976	5.8	0.78	5.6	1.28	1.0	1.33
1977	23.2	0.37	21.7	1.15	7.1	1.26

Prior to 1975, retention had not been greater than 2.0 percent, except in two years. The potential deposition in 1977 was only 2,716 eggs per square yard, yet retention amounted to an unprecedented 27.4 percent. This may have been the result of over-spawning in the top end of the channel due to the absence of fences and, additionally, the sampling technique is questionable. All of the carcasses sampled for retention in 1977 were taken from the broomstick fence, and it is not known how representative the samples are of the over-spawned upper end or of the under-spawned lower end.

SOCKEYE FRY PROGRAM

Enumeration Technique

Two sets of fan traps are used at Channel No. 1. The first set is located at the head of the channel to remove river fry, thereby allowing the second set at the channel exit to accurately assess Channel No. 1 production. The traps are of a folding, tapered design with perforated bottoms and sides, except in the runners along the bottoms of the folds. The water remaining in the runners carries the fry into 6-inch diameter pipes connected to live boxes, with a minimum of fry handling. The entire fry run can be trapped and volume counted, or a subsampling technique is used in which three-foot-long marquisette socks are inserted into the outlet of each trap during standard index periods. A detailed description of trapping procedures and fan traps is given by Ginetz (1977). In 1977, the total run was caught and volume counted to obtain an accurate estimate from Channel No. 1, and transported to a release point below the main fence where they would not interfere with the nightly river estimate.

Production and Egg-to-Fry Survival

Production and egg-to-fry survival has ranged from 458 fry per square yard (5.9 million) at 21.3 percent survival in 1970, to 1,979 fry per square yard (25.5 million) at 69.9 percent survival in 1967, the first production of Channel No. 1 (Table 13). In the first year of channel

TABLE 13: Sockeye fry production at Fulton Channel No. 1

(spawning area = 12,887 sq. yds.)

Brood Year	Total Spawning (Adults)	Female Spawning	Egg Deposition (millions)	Fry Production (millions)	Egg-to-Fry Survival (%)	Area/Female (sq. yds.)
1966	18,186	11,648	36.9	25.5	69.1	1.11
1967	21,752	10,695	32.8	16.0	48.9	1.20
1968	26,043	16,944	57.7	24.7	42.7	.76
1969	21,034	9,472	27.8	5.9	21.3	1.36
1970	25,483	14,535	43.3	13.4	31.0	.89
1971	24,746	12,716	39.4	20.0	50.7	1.01
1972	21,600	13,493	44.6	23.2	52.1	.96
1973	25,272	10,963	34.3	15.0	43.7	1.18
1974	12,530	7,805	23.6	15.0	63.5	1.65
1975	14,874	8,304	23.6	12.7	54.0	1.55
1976	16,834	10,052	30.3	17.8	58.8	1.28
Av. 1966-76	20,759	11,511	35.8	17.2	48.7	1.18

operation, however, there was little or no silt, more spawning area because of less sluffing-in of the ripp-rapp sides of the channel, and, generally, conditions which may not have been similar in following years. The highest survival in Channel No. 2 also occurred in the first year of operation (Table 14). Because of pristine conditions, the first year should perhaps not be regarded when assessing a channel.

The low production in 1970 was believed to be the result of accumulating silt, particularly in 1969, when a slide upriver from the channel intake deposited large amounts of silt in the river, some of which was deposited in the channel. In the summer of 1970, the gravel was therefore removed and cleaned. Production increased, but the design expectations were not exceeded until 1972. Gravel scarification is now carried out annually, and spawning densities have been reduced to maintain higher survivals.

Excepting the years 1966 and 1969, egg-to-fry survival in Channel No. 1 increases in the lower range of egg depositions (Fig. 18) and at reduced spawning densities (Fig. 19). Because survival in the channel is twice that of the river at similar loading densities, it may be that the improved incubation environment has removed a large portion of the dependency of egg-to-fry survival on egg density. Survival in the channel may be related to a greater degree to the density and interaction of spawning adults.

Fry production would be expected to increase less at higher egg depositions as indicated by the negative slope of percent egg-to-fry survival against egg deposition, but the available data does not clearly show this. Figure 20 indicates that the data is described by a linear relation which is constrained to pass through the origin because of the definition of such a relationship.

An optimum loading of Channel No. 1 is not readily discernable from the linear relations shown, but fitted curves do not greatly improve the description of the data. A high egg-to-fry survival rate of 55 percent

should result from a loading density of 1.40 square yards per female, corresponding to an egg deposition of 27.8 million eggs (2,160 eggs per square yard).

This loading density efficiently utilizes spawners which have not been exploited in the commercial and Indian food fisheries. Because production and survival are related to density-dependent factors, an increased loading density would reduce the efficiency of Channel No. 1, and the use of spawners, which have always been high, relative to Channel No. 2 and to Fulton River in particular.

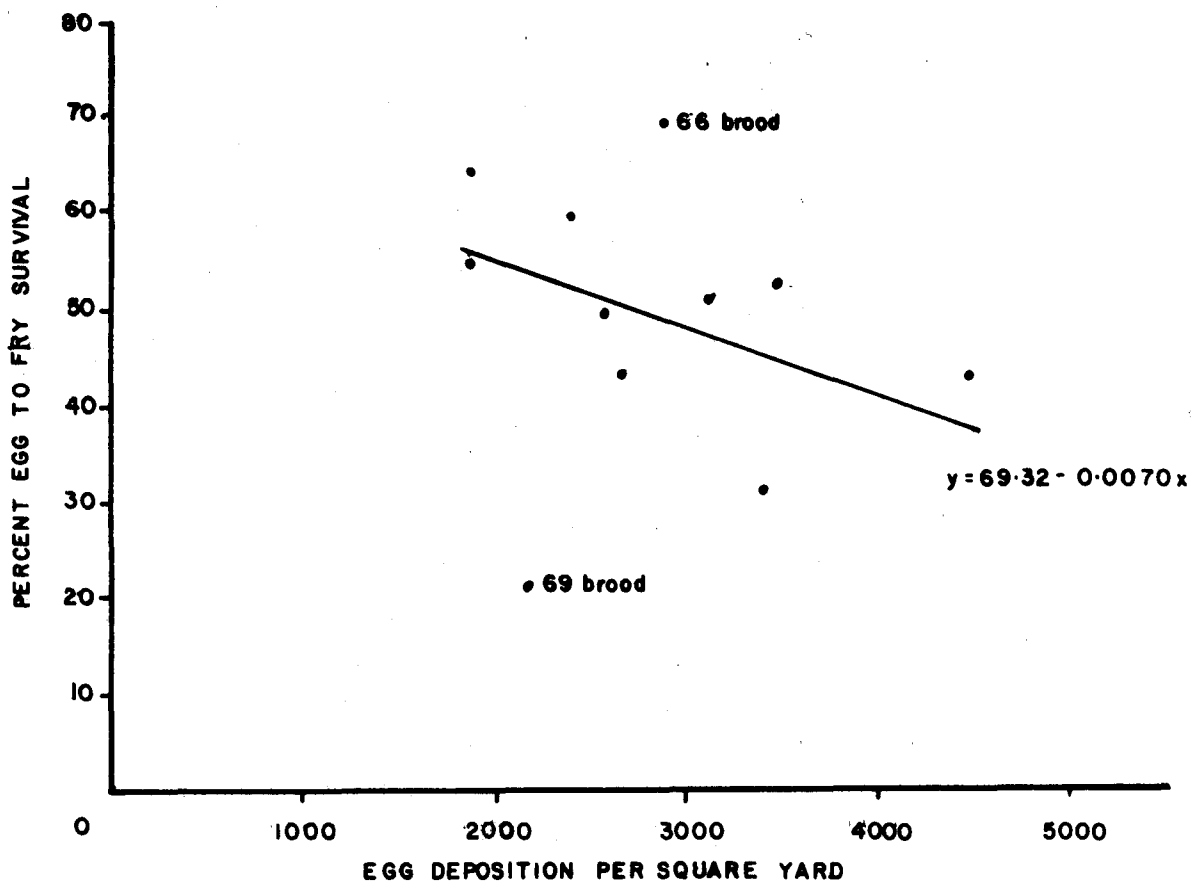


Figure 18: Regression of sockeye egg-to-fry survival on actual egg depositions per square yard in Channel No. 1 at Fulton River.

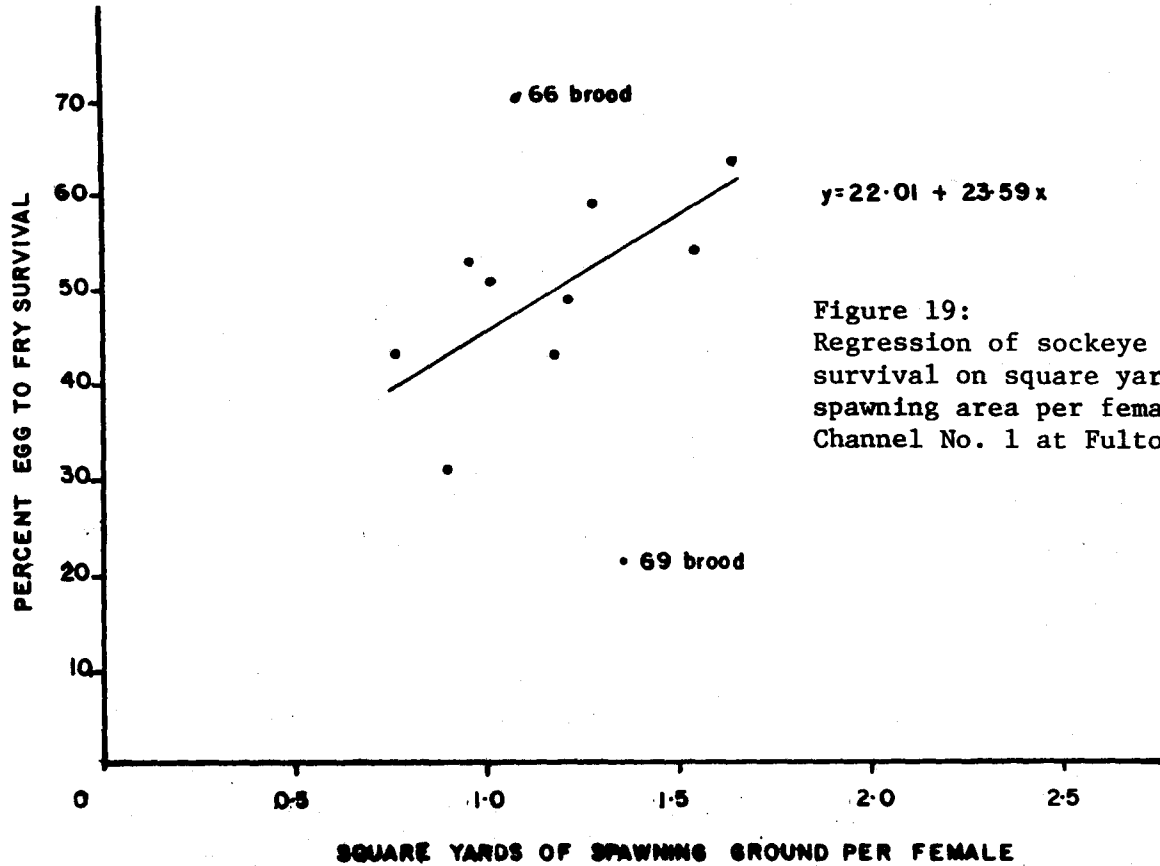


Figure 19:
Regression of sockeye egg-to-fry survival on square yards of spawning area per female in Channel No. 1 at Fulton River.

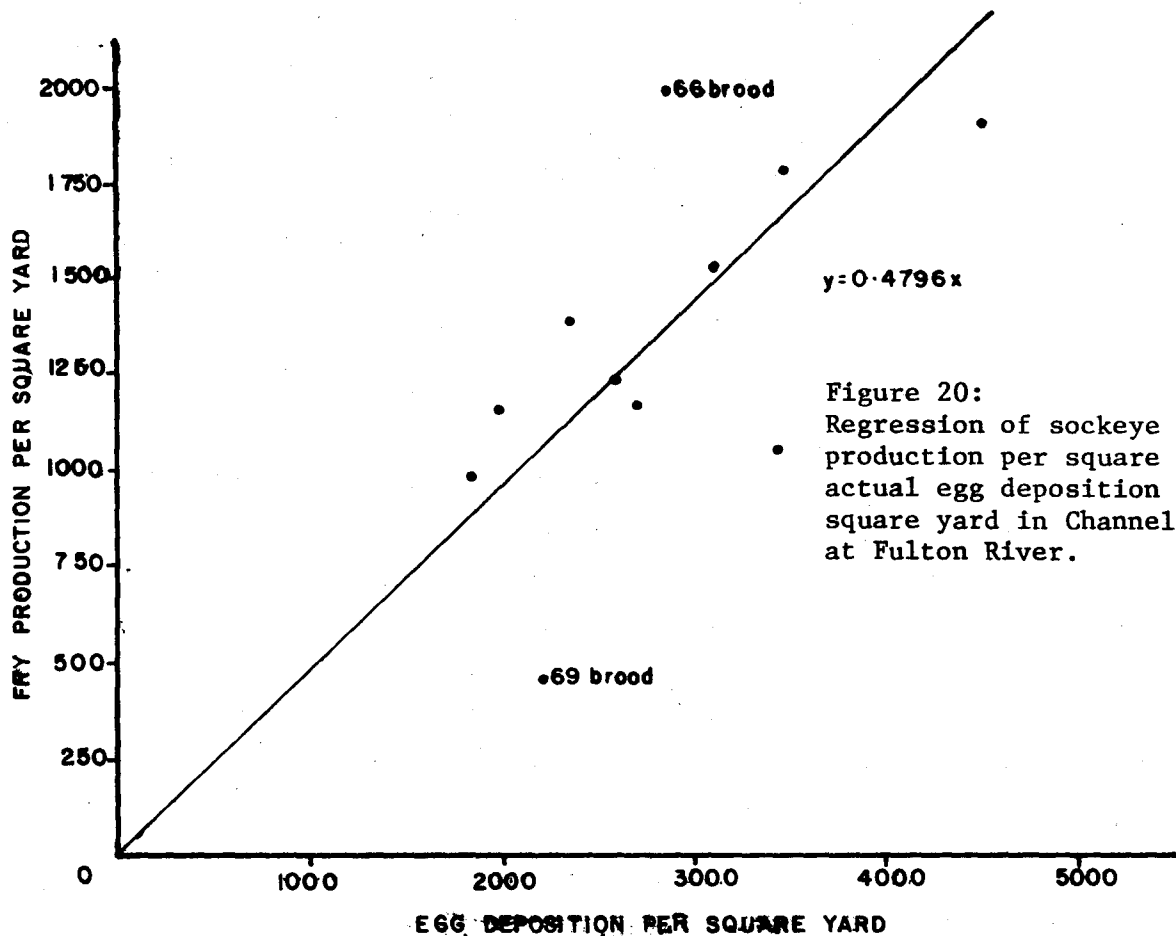


Figure 20:
Regression of sockeye fry production per square yard on actual egg deposition per square yard in Channel No. 1 at Fulton River.

Migration Timing

Similar to the Fulton River, there had been a steady trend from 1967 to 1976 for the peak of the Channel No. 1 fry migration to occur at successively earlier dates (Table 7). Due to the nature of the water supply to Channel No. 1, the river discharge, which is a determining factor of migration in the river, has only a slight influence on channel flows. In most years, the determining factor of fry migration from Channel No. 1 is water temperature. Due to the length and shallow depth of the channel, the mean water temperature on a warm day will rise a few degrees centigrade above that of the river.

The relative timing of the peak migration from Channel No. 1 is normally one week later than in the river, but the 1977 peak channel migration occurred on the night of May 30, three weeks after the river peak. The timing of egg depositions in Channel No. 1 and in the river were comparable in 1976, and the pattern of water temperatures within the channel was normal. The large separation of migration peaks was most likely due to high river discharges in early May, causing an early peak in the river migration, followed by a reduction in river discharge. Low river levels then made it difficult to divert water into the channel. The resultant low flows most likely delayed the channel migration, even though the mean water temperature had increased sufficiently above 4°C to trigger migration (Fig. 21).

Fry Quality

Channel No. 1 fry lengths have ranged from 28.8 mm in 1976, to 30.2 mm in 1969, but are usually in the 29 mm range, averaging 29.4 mm (Table 8). Their mean length increases throughout the migration (Fig. 22). Generally, Channel No. 1 fry are slightly shorter than the river fry, but in 1977, this relative situation was reversed in the second half of the migration, due to the river fry being shorter than usual (Fig. 14).

Channel No. 1 fry normally weigh less than fry from the rest of the Fulton River system, averaging 143.9 mg (Table 9) since 1970. However,

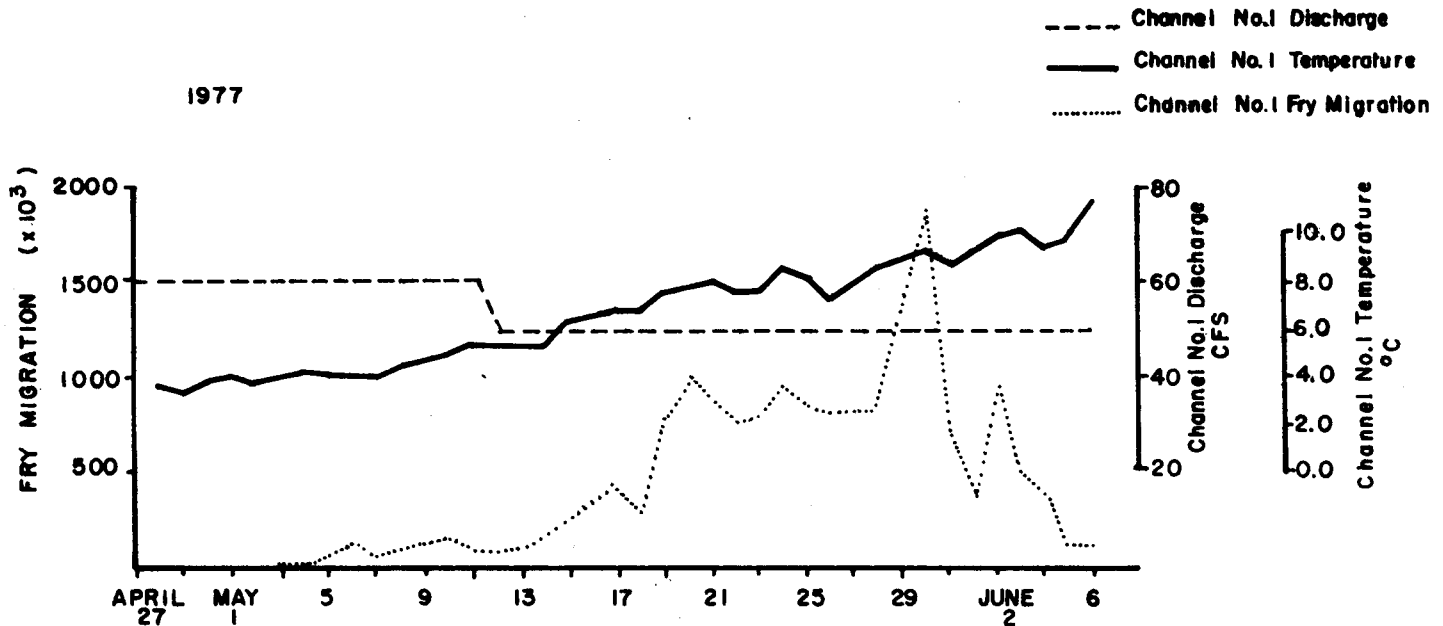


Figure 21: Daily number of Fulton Channel No. 1 fry migrating to Babine Lake in relation to average weekly water temperature and discharge for 1977.

fry from the latter part of the lakeward migration are typically heavier and, at that time, are often the heaviest fry from the Fulton River system.

The mean developmental index ($K_D = \frac{10 \sqrt[3]{mg}}{mm}$) of channel No. 1 fry is 1.79 (Table 10), and the index also is known to change over the period of migration. The earliest Channel No. 1 fry migrate at a developmental index of 1.82. A K_D value greater than 1.80 normally indicates a prematurely migrating sockeye fry. Due to the increase in the average length of migrating Channel No. 1 fry, the developmental index drops to about 1.77, and the majority of the fry migrate at a more advanced development stage in the second half of May and the early part of June. Paired comparisons of fry quality (Appendix Table I) show that differences between Channel No. 1 and Fulton River fry are usually not significant. The smaller size of the Channel No. 1 fry in 1970 and 1971 may be the result of poor gravel quality in those years.

McDonald found that the time of lake entry significantly affected the size of river and channel fry rearing in Babine Lake and the resulting

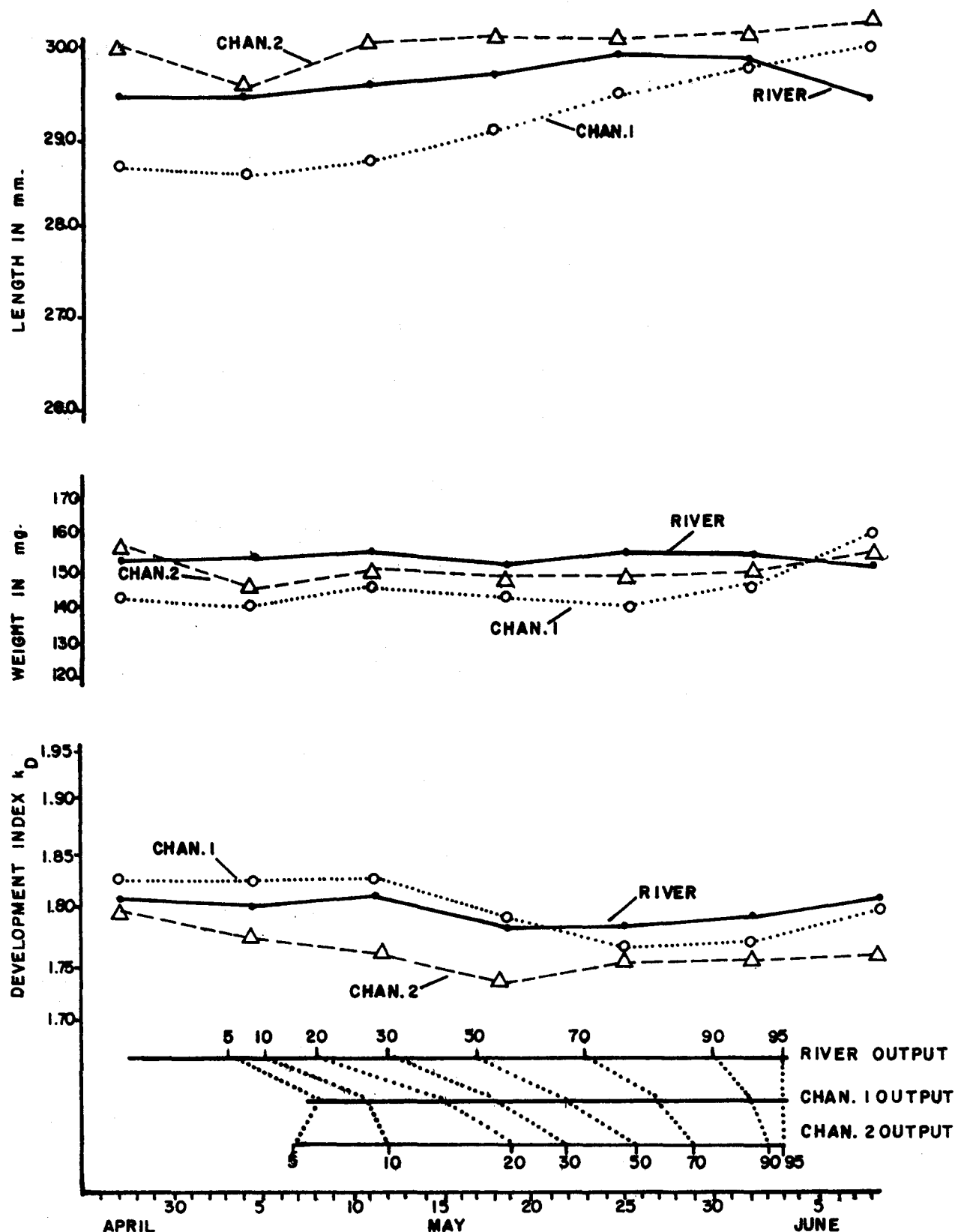


Figure 22: Average lengths in mm, average weights in mg, and average developmental indices of Fulton River, Channel No. 1 and Channel No. 2 fry at intervals through the mean spring migration from 1967 to 1976. Also shown is the average progress of the runs in time.

size of seaward migrants. Later entry into Babine Lake and the lag in dispersal of Channel No. 1 fry was responsible for the shorter length of channel fry at the beginning of their lake residence. This size difference persisted up to the seaward migrant stage, but no significant difference between the survival of river and channel fry was evident. An historic comparison of river and Channel No. 1 fry is provided in Table 14. The significance of the timing of lake entry and of fry quality with respect to the final adult return is not yet clear, but these may become more important considerations in the future operation of spawning channels.

EVALUATION OF SPAWNING CHANNEL NO. 2

INTRODUCTION

Channel No. 2 was completed in 1971, with a design loading of 70,000 females on 87,420 square yards of spawning gravel. At 2,500 eggs deposited per female, it was expected to produce 70 million fry at 40 percent egg-to-fry survival, but fry production has been below expectations. Poor efficiency was believed to have been due to high loading densities and declining gravel quality. Problems with maintaining adult densities within sections of the channel and the cost of cleaning the spawning beds annually have arisen because of the immense size of Channel No. 2. New gravel cleaning equipment has been designed, and the fry enumeration technique is being investigated. As techniques for gravel cleaning, adult loading and fry enumeration are developed, production and survival rates should rise to design expectations, and the accuracy of production estimates should improve.

OPERATIONAL HISTORY OF CHANNEL NO. 2

The first stage of Channel No. 2 (47,681 square yards) was completed in the fall of 1969, in time for adult entry. Unfortunately, some differences, undetectable to water quality analysis, exist between channel and river water, which caused adults to become reluctant about entering the channel. To attract adults into the channel, river water was introduced in early years by small (1 cfs) gas-driven pumps, and later by large (8 cfs) submersible electric pump. Because of the reluctance of the adults to remain in channel water, spawning distribution was uneven, and large sections of the channel were under-spawned or over-spawned.

In 1972, returning jacks from the 1969 brood year showed no hesitation upon entering the channel, and returning 4₂ adults in 1973 likewise entered the channel readily. Since that year, the loading of the channel has not required an introduction of river water. 1977 was the first return of second generation of 4₂ spawners. Their channel origin was evident by their attraction to channel water and the record rate at which the channel was loaded (Table 12).

Anchor ice formation during particularly cold periods in the winter of 1970-71 caused high alevin mortalities. Because of the length of Channel No. 2, heat loss throughout the three miles of channel lowered the water temperature from $+2.0^{\circ}\text{C}$ to 0.0°C at the downstream end. The icing problem was overcome by increasing the flow from 100 cfs to 140 cfs. The rate of temperature decrease along the channel was reduced, and water exited at $+0.25^{\circ}\text{C}$. This procedure is now used to prevent anchor ice formation whenever air temperatures approach -20°C .

Algae blooms in the top one-third of the channel have presented problems from the beginning of production. Occurring in May and June, thick mats of Ulothrix sp. appear in the channel. In some years, algae has formed a solid layer covering the gravel beds. Gravel scarification is carried out in the summer, which consists of drying the spawning beds and algae, then overturning the gravel and flushing out the channel. Along with accumulated silt, most of the algae is removed, but new growths in the spring still present a problem for migrating fry. The algae is probably nutrient-limited, occurring at the top end where it also receives direct sunlight, and the temperature increases. Trees have been planted along the berms for their shade but, as yet, are too small to serve this purpose.

ADULT SOCKEYE PROGRAM

Sampling Technique

In the first year of operation, all adults were held below the river fence for diversion into Channel No. 2. As the loading of the channel has become easier with the increased return of channel-origin stock, spawners have been taken from the peak of the run. Fish entering the channel are counted over flashboards as adults or jacks. As they enter the channel loops, they are counted a second time as male or female adults and jacks, with the aid of counting windows and flashboards. Accuracy of this visual sex identification technique is checked by means of a dead pitch in the top loop. This is the first part of the channel to be loaded

and the most difficult, because the fish are the least sexually developed. In 1977, the estimated sex ratio was within 2 percent of results from the dead pitch.

One thousand adult samples are taken for age and length composition, unspawned and the degree of spawning success (retention). Samples are taken at the eight diffusers behind channel loops and from the main fence for a thorough sample distribution of the channel population. Equal sized samples were taken on four separate occasions, timed to correspond to the die-off. Fecundity, age and length samples are taken at the beginning of the migration from various locations for general application to the Fulton system.

Population Characteristics

Channel No. 2 spawning populations have ranged from 23,700 adults in 1969, to 127,600 adults in 1977 (Table 2). The small number of spawners in 1969 was due to difficulties in attracting fish into the channel and to the fact that construction of the lower loops was not complete. In 1977, the spawning density of the lower half of the channel was slightly increased because of the large escapement of 502,300 adults to the Fulton system.

Age composition of Channel No. 2 adults reflect that of the Fulton system as a whole in having a majority of 5₂ spawners every fourth year, the last 5₂ dominant year being 1976. Differences in age composition between Channel No. 2 and the river are small, and may be due to sampling errors. The pattern of sex ratios is similar to that of the river. Generally, a ratio of approximately 50:50 occurs in odd years, while the percentage of females is higher in even years. In 1977, the percentage of females in Channel No. 2 was initially 47.3 percent, but increased over the run to a total composition of 58.7 percent. This increase in female composition during the run is normal; however, this was the largest variation yet from the pattern of odd-year sex ratios.

Jack populations in Channel No. 2 have varied considerably, but tend to be large in years of low adult male returns. In 1974, the jack population (82,326) outnumbered the adult population (62,397). The Channel No. 2 jack population in 1977 amounted to only 4,666 (3.5 percent), the smallest return in channel operation. When jack returns are larger than usual, there is a tendency for the 42:52 ratio of the males from the same brood to be greater than average, although the correlation is not significant.

Egg Deposition and Retention

Channel No. 2 egg deposition in 1977 was 207.2 million or 2,370 eggs per square yard greater than in any previous year except 1972. Large depositions were allowed in the lower half of the channel because of the over-escapement to the Fulton system, but the top half was not increased because of suspected poorer survivals in that area. In the past, depositions have ranged from 734 eggs per square yard in 1969, to 2,521 in 1972, and average 1,904 eggs per square yard.

Adult densities are controlled within the channel loops to reduce the problem of over-spawning in large areas. In 1971, and 1975 to 1977, years in which data is specifically recorded by loop, the degree of spawning success has not correlated significantly with potential egg deposition per square yard. The data does, however, loosely agree with the lower portion of the retention curve of Channel No. 1 (Fig. 23). Over the range of spawning densities commonly used in Channel No. 2, retention has not been an important factor. Until 1977, total retention, including unspawned, had not exceeded 2 percent. The high retention in 1977, which amounted to 7.1 percent including unspawned, was partly due to the slightly increased spawning densities in the lower half of the channel.

SOCKEYE FRY PROGRAM

Enumeration Technique

Converging throat traps have been used to assess fry production since the spring of 1970. Six traps, three placed across each of the two

bays, are located at the channel exit. The traps with 9-inch mouths extending the entire depth of the water column sample are one-seventh of the width of each bay. The middle trap of each bay serves as an index trap, and one to three times a week, time and area checks are carried out. The trapping procedure is similar to that used in the river. Fry are counted at the same facilities, and on nights of large migration, volumetric counts are made. The enumeration technique allows fish handling to be reduced to less than one percent. A detailed description of the migration calculations is given by Ginetz (1977).

Standard migration calculations are based on the assumption that fry migrate with an even, lateral distribution through the channel exit. With all traps fishing, 13.37 percent of the fry are assumed to be sampled. In 1975, horizontal and vertical ladder sampling was carried out to check on the accuracy of the fry trapping. It was found that the lateral distribution of fry was skewed towards one side of the exit, and standard calculations were underestimating fry production by at least six percent. All previous production estimates were then adjusted accordingly.

Dyed fry release and recovery tests were also carried out in 1975, but were inconclusive because of the small numbers of fry used, so in 1977, the tests were repeated on a larger scale. These tests indicated that the degree to which the migration was skewed and the resulting trapping efficiency was dependent on river discharge and level beside the channel exit. A regression of total trapping efficiency versus river level was applied to the nightly 1977 calculations which increased the migration estimate by 14.8 percent. The effects of river discharge on the efficiency of the Channel No. 2 enumeration are still being investigated. Until the past enumeration data can be adjusted accordingly, the 1977 migration estimate will be raised by six percent to make it comparable to past records.

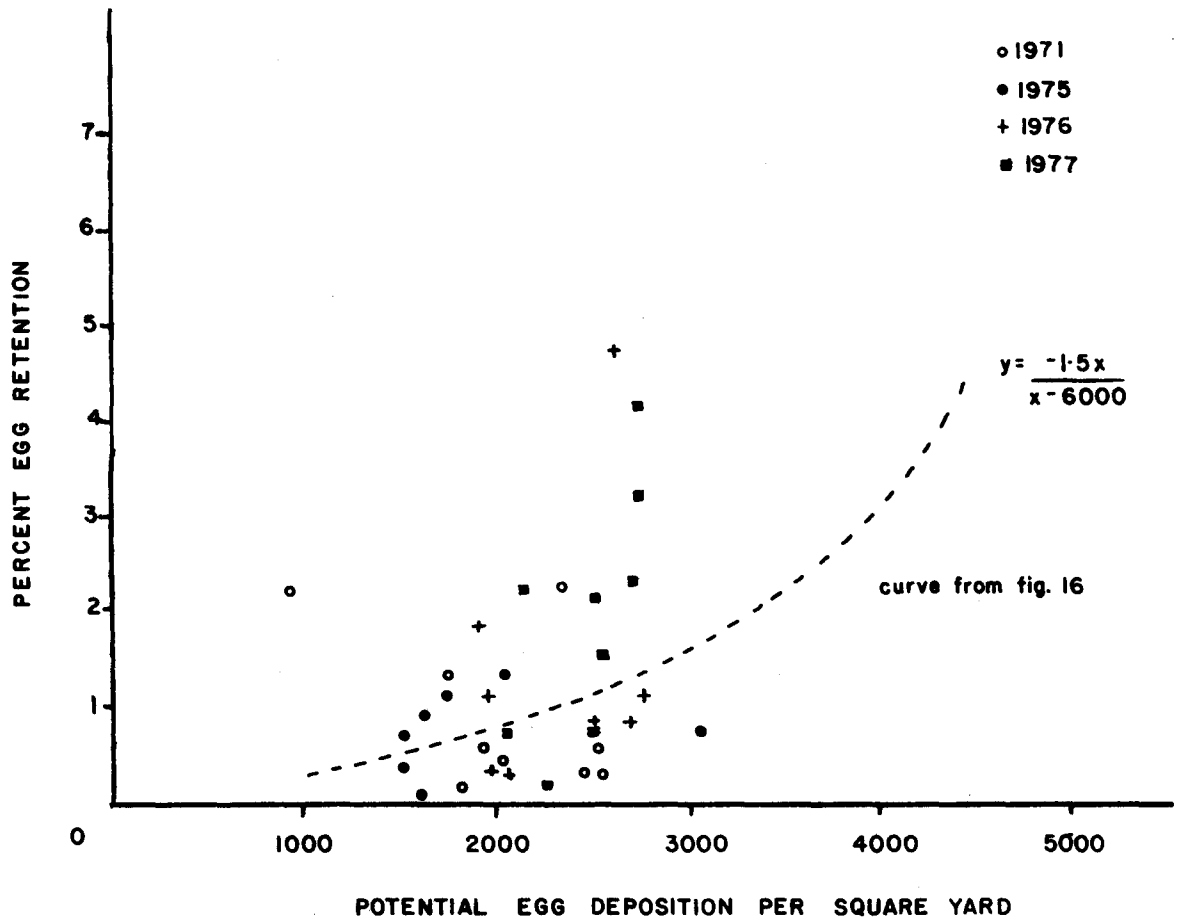


Figure 23: Relationship between potential egg deposition per square yard and percent egg retention in individual legs of Spawning Channel No. 2 at Fulton River.

Fry Production and Egg-to-Fry Survival

The second and final phase of construction on Channel No. 2 was not completed until the summer of 1970. Previously, Channel No. 2 had respectively produced 291 and 428 fry per square yard (25.4 and 37.4 million) from the 1969 and 1970 brood years (Table 14). Survival of the 1969 brood, the first operational year, was 72.5 percent and has been the highest survival in Channel No. 2. The first year of operation enjoyed the pristine conditions of a new channel; therefore, further analysis of production and survival does not include data from the 1969 brood.

TABLE 14: Sockeye fry production at Fulton Channel No. 2.

(spawning area = 87,420 sq. yds.)

Brood Year	Total Spawning (Adults)	Female Spawning	Egg Deposition (millions)	Fry Production (millions)	Egg-to-Fry Survival (%)	Area/Female (sq. yds.)
1969*	23,770	11,516	35.0	25.4	72.5	4.14
1970*	58,786	35,035	101.7	37.3	36.7	1.36
1971	115,481	57,957	175.2	82.2	46.9	1.51
1972	106,491	66,557	220.4	69.9	31.7	1.29
1973	112,062	54,798	168.7	75.0	45.1	1.62
1974	62,397	42,925	132.0	48.5	36.7	1.36
1975	108,199	57,453	171.6	68.6	40.0	1.49
1976	110,676	65,515	212.8	141.8	66.6	1.41
Average 1970-76	96,299	54,320	168.9	74.8	43.4	1.25

*Spawning area = 47,700 sq. yds.

The operational techniques of Channel No. 2 have been improved over the years to increase the egg-to-fry survival. Low survivals in 1972 led to studies by Ginetz (1972) who found that large egg mortalities were occurring at a critical, early development stage. This was the result of mechanical disturbances by successive waves of spawners. To reduce this mortality, attempts are now made to reduce the loading time of each loop, in order to place spawners on the grounds in one wave. Spawning then takes place over a shortened period, and the presence of the respective adults at the redd sites reduces the degree of redd superimposition.

A particular mortality problem in Channel No. 2 has been caused by spring growths of algae in the top legs. Algae of the Ulothrix sp. traps fry attempting to migrate downstream, and by its decomposition, creates a high biological oxygen demand, leading to suffocation of the fry. Gravel scarification to remove most of the algae, along with accumulated silt, is carried out annually, but cost has been a restrictive factor preventing more thorough cleaning. New gravel cleaning equipment has been designed which will hopefully be more efficient at no greater cost, and lead to increased survival.

Insufficient gravel in the 1.0 to 2.5-inch size range was available at the time the top end of the channel was built. It is believed that the larger-than-desired gravel could also be contributing to low egg-to-fry survival in the top legs by vibration of the eggs due to turbulence in the large interstices. cursory gravel analysis in the summer of 1977 failed to show a difference in gravel composition throughout the channel, so more extensive gravel sampling may be carried out in the future.

Hydraulic sampling, which has been carried out in Channel No. 2 since 1971, has indicated lower survivals in the top legs. In February of 1977, Wolfe traps were installed at the bottom of the second leg to assess production and survival from the top two legs. Egg-to-fry survival was estimated to be less than 10 percent, agreeing with previous hydraulic sampling results. In addition, small numbers of immature fry were found to be migrating from the top two legs as early as late February,

one and one-half months before the regular fry enumeration program began. It is not known if fry from the top end migrate from the channel early in the spring before enumeration begins, or if they move only to a point along the channel where the warmer water from Fulton Lake has cooled sufficiently to suppress migration.

Survival of the 1976 brood is confusing, with respect to previous years, due to an unexpectedly high survival. Explanation of this exceptional year could be that a more thorough scarification was carried out in the summer of 1976, but this may not totally account for an increase in survival. A significant correlation ($.05 > p > .01$) exists between percent egg-to-fry survival and square yards per female spawner when the 1976 brood is not included (Fig. 24).

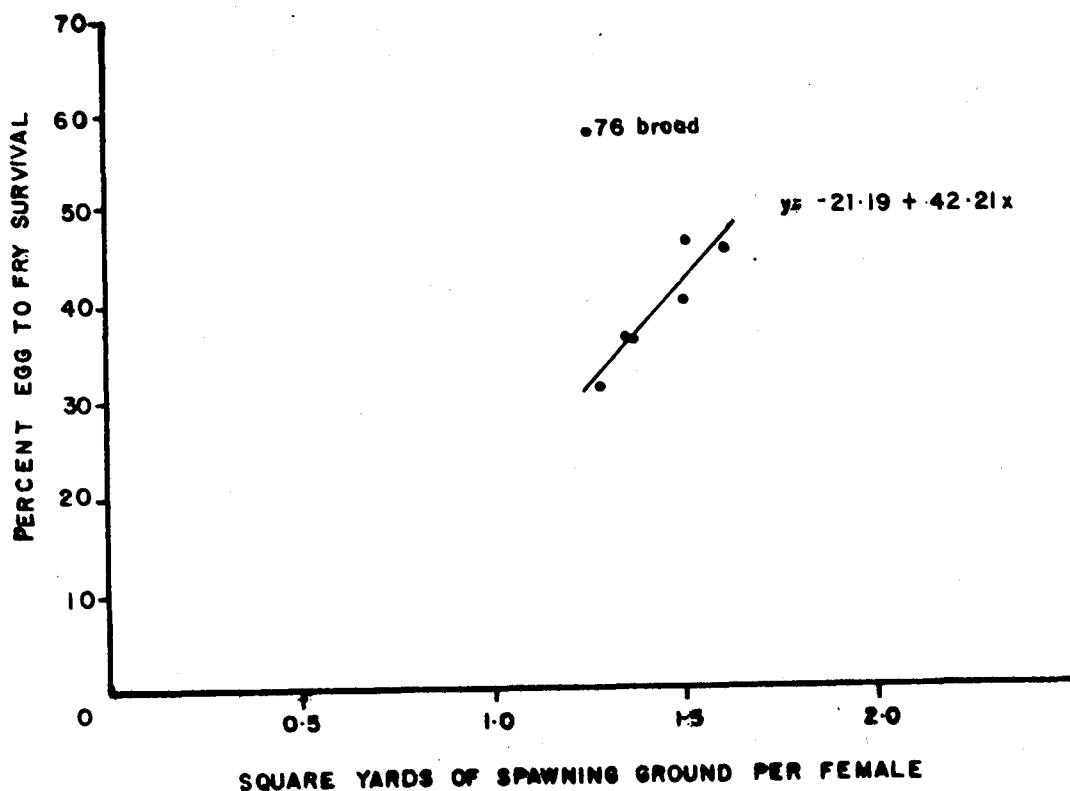


Figure 24: Regression of sockeye egg-to-fry survival on square yards of spawning area per female in Channel No. 2 at Fulton River.

An egg-to-fry survival of 45 percent is accordingly obtainable at spawning densities of 1.57 square yards per female, equivalent to a female spawning population of 55,680. At the 1970 to 1975 average deposition of 3,087 eggs per female, this corresponds to a deposition of 1,966 eggs per square yard. Although correlations are not significant with the limited data available, depositions similar to that above, excepting the 1976 brood, have appeared to be an optimum for Channel No. 2. The 1971 deposition of 2,004 eggs per square yard resulted in the production of 940 fry per square yard (Fig. 25) at an egg-to-fry survival of 46.9 percent (Fig. 26). It should be noted that egg retention at this spawning density is less than one percent, thus there is no indication of undue spawner interaction.

A difference in efficiency exists between the two Fulton channels. Excluding the 1966 and 1969 brood years, Channel No. 1 has produced an average of 1,361 fry per square yard, averaging 49.5 percent egg-to-fry survival from an average loading of 2,837 eggs per square yard. Excluding the first year of operation, Channel No. 2 has produced an average of 876 fry per square yard at 43.4 percent egg-to-fry survival from an average loading of 2,071 eggs per square yard. As indicated by the slopes of the relations in Figures 19 and 24, survival in Channel No. 1 is not as density-related as in Channel No. 2. Channel No. 1 is also more efficient, as indicated by the greater value of the intercept. Explanations for the discrepancy between the two channels and for the efficiency of Channel No. 2 being below its design expectations are probably related to their differing physical characteristics.

Channel No. 2 is more exposed without the shading effects of surrounding hills and forest enjoyed by Channel No. 1, and its operational flows are shallower and swifter, resulting from a steeper gradient. Channel No. 2 also contains a greater number of spawners, in some loops as many as the total population of Channel No. 1, which may increase the amount of adult interaction and reduce the individual spawning efficiencies. To maximize production, spawning densities are reduced in the top legs where survival is lower, and loading is completed in the shortest possible period to minimize the deleterious effects of wave spawning. It

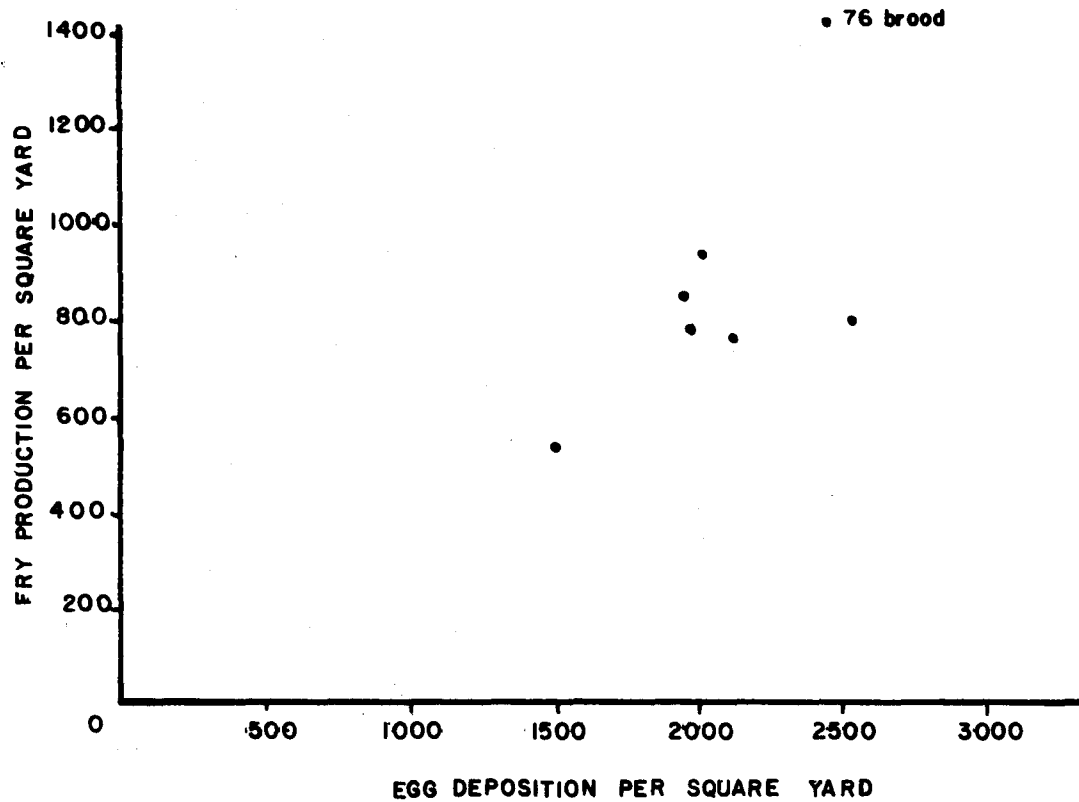


Figure 25: Fry production per square yard versus egg deposition per square yard.

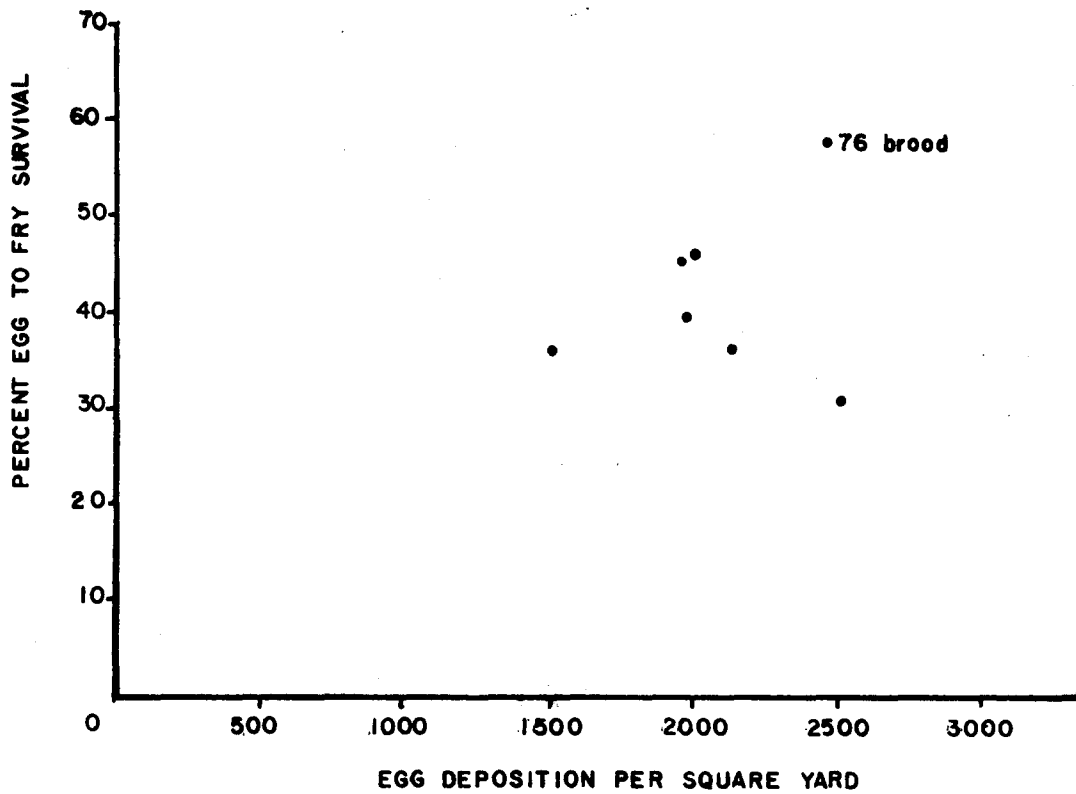


Figure 26: Percent sockeye egg-to-fry survival versus egg deposition per square yard.

also appears that the standard fry enumeration technique of Channel No. 2 may be underestimating production, and the production efficiency of the two channels may be more similar than it now appears. This question is being extensively investigated, and should be resolved in the near future.

Fry Migration Timing

The water supply to Channel No. 2, drawn directly from Fulton Lake, is now held constant at 100 cfs continuously throughout the fry migration. Discharge then has no variable effect on the pattern of migration, which begins in earnest when the mean weekly water temperature exceeds 4.0°C (Fig. 12). The peak usually occurs at the end of May and, except for the first two years of production, has ranged from May 26 to June 1 (Table 7). Loading time and peak spawning are important factors in the peak migration date. Active spawning begins in the top legs, five days to one week earlier than in the lower legs. It can be seen that in 1969 and 1970, when only the top half of the channel was operational, the fry migrations took place earlier than in later years.

The peak migration from Channel No. 2 in some years occurs up to 11 days after Channel No. 1. Loading time is a factor in the difference between peak migration dates. The loading of Channel No. 2 is usually completed in three weeks, while Channel No. 1 now requires less than one week. In 1976, Channel No. 1 was loaded before the lower half of Channel No. 2, which holds the bulk of spawners. The migration from Channel No. 1 was delayed by lowered flows in 1977, resulting in a peak migration date similar to that of Channel No. 2.

Fry Quality

Fry from Channel No. 2 have consistently been longer than fry from Channel No. 1 or the Fulton River, averaging 30.1 mm since 1970 (Table 8). The mean weight of Channel No. 2 fry, however, is very similar to fry from the other two sources, and varies with the others from year to year (Table 9). They average 148.4 gms, which is less than the average weight of river fry, and heavier than that of Channel No. 1 fry.

In all but three years, fry from Channel No. 2 have migrated as the most developmentally advanced of the Fulton fry, as indicated in Table 10, by their lower developmental indices ($K_D = \frac{10\sqrt[3]{\text{mg}}}{\text{mm}}$). The mean pattern of fry quality over the duration of migration is shown in Figure 21. Except for a slight increase in the weight of Channel No. 1 fry and a decrease of length and weight of river fry in the latter part of April and early June, the relations stated above remain very constant throughout the migration. Paired comparisons of fry quality in Appendix Table II and Appendix Table III show that the differences between Channel No. 2 fry and the other Fulton River system stocks are significant.

The annual means of fry quality in Tables 8, 9 and 10 have been adjusted for relative abundances of fry at the time of each quality sampling. Differences in quality between fry from the Fulton River and from the two channels depend on the extent of development. This is affected by the timing of egg deposition, incubation temperatures and the time of migration, which is dependent on such factors as water temperature and discharge.

The effects of fry quality and migration timing on fry-to-smolt survival, however, may be too complex to allow a simple timing adjustment of fry quality to be meaningful. For example, the earlier migration of Channel No. 1 fry in Babine Lake may compensate, to some degree, for their smaller size and less advanced development compared to Channel No. 2 fry. Even with the differences in fry quality and migration timing, fry marking experiments have not shown any significant differences in fry-to-smolt survival among Fulton River, Channel No. 1 and Channel No. 2.

EVALUATION OF PINKUT CREEK FLOW CONTROL

INTRODUCTION

Studies began at Pinkut Creek in 1963 as part of the same Babine Lake evaluation study which included the Fulton system. Five years of predevelopment production data are available for comparison with the later flow control years.

Pinkut Creek flows into the western side of Babine Lake, 11 miles from the southern end (Fig. 1). The Pinkut Creek drainage area (Fig. 6) is approximately 720 square miles, and includes three lakes--Taltapin Lake (8.6 square miles), Augier Lake (3.7 square miles) and Pinkut Lake (2.1 square miles). Although Pinkut Creek is 50 miles south of the Fulton River, runoff characteristics of the two systems are similar. Low flows in the winter are followed by floods caused by snow-melt, usually peaking in June. The autumn floods observed at Fulton are not as prominent at Pinkut.

Pinkut Creek is the second most productive salmon stream tributary to the Babine Lake basin, even though, due to a set of impassable falls, spawning is restricted to the lower 12,000 yards of stream. Sockeye escapements to the stream ranged from 3.2 thousand to 146 thousand between 1949 and 1966, averaging close to 33 thousand annually (Table 1). The optimum spawning population for the 12,000 square yards of spawning area is estimated to be 15,000 sockeye. Due to declining production of the first Pinkut spawning channel and because of its closure in 1976-1977 for reconstruction, adults had been airlifted over the falls to the upper Pinkut Creek area from 1973 to 1976. An additional four miles of spawning stream are available in the upper creek. With the aid of aerial and map surveys, this extra spawning area has been estimated to be sufficient for 40,000 adults. The airlift was not required in 1977 because of the completion of the new Pinkut spawning channel in time for the returning adults.

In the lower Pinkut Creek, where gravel composition is more or less constant and gradients are not high, spawner distribution is uniform. In the upper Pinkut Creek, spawning is dependent on the nature of the stream. High gradients with large boulders are totally avoided by the spawners.

Adults arrive at Pinkut Creek earlier in the fall than at Fulton River. A small early run enters in the first week of August, and the main run does not peak until at least the third week of August. The peak of spawning occurs approximately two weeks earlier than at Fulton.

The fry migration is also slightly ahead of Fulton River, beginning in Late April, peaking in the second week of May, and is usually complete in the first week of June.

SPAWNING AND INCUBATION WATER FLOWS

Before construction of the flow control works at the outlet of Taltapin Lake, spawning and incubation flows had been recorded as low as seven cfs. Minimum flows in Pinkut Creek are now 100 cfs upstream of the channel intake. The channel is constructed so as to draw 50 cfs from the river and return it above the main river spawning area. Rule curves established from stream metering data are used to provide a minimum flow of 100 cfs during spawning and incubation.

Due to an extreme climate, serious icing problems occur on Pinkut Creek. Scouring of the bottom by ice causes large alevin mortalities almost every winter. Fry migrations are additionally influenced by spring freshets. Discharges above 300 cfs are known to cause early emergence, resulting in fry being swept prematurely into Babine Lake.

ADULT SOCKEYE PROGRAM

Sampling Technique

A continuous fence spans both the river mouth and the channel entrance. Adults may be loaded into the river and channel alternatively or simultaneously in the same manner as at Fulton. The original policy was to load the lower river first and utilize the remaining stock to load

the channel. When the airlift began in 1973, the lower channel was used as a collection site for stock to be airlifted to the upper river. Following completion of the airlift, the lower river and channel would then be loaded simultaneously. With completion of the new channel in 1977, there was no requirement for an airlift, and the river was loaded simultaneously with the channel.

Fish are counted over flashboards as adults or jacks at the river fence. An adult sex ratio is later obtained by means of a dead pitch during the die-off. Samples are taken to obtain information on fecundity, age and length composition, the degree of spawning success (retention) and the percentage of unspawned. Sampling is normally carried out throughout the migration, spawning and die-off period, with 1,000 samples taken overall.

In years during which the airlift was carried out, only retention data would be taken from samples in the upper river. Because the populations of the upper and lower river and of the channel are considered homogenous, sampling data obtained at the river fence is applied to all other areas.

Population Characteristics

In the pre-flow control years from 1961 to 1967, spawning populations in Pinkut Creek ranged from a low of 21,400 adults in 1963, to a high of 144,540 in 1964, and averaged 50,289. In the flow control period, populations have averaged 23,240 (Table 2) which is considered near optimal for Pinkut Creek. This decrease in the number of spawners does not represent a real decline of stock because the extra fish are directed to the channel, whereas in the past, they have contributed to overspawning in the creek and lowering of the egg-to-fry survival. In years of the airlift operation, 16,000 adults were transferred to the upper river in 1973, 24,000 in 1974, 40,100 in 1975, and 28,965 in 1976. The number of jacks transported averaged about 100 per year.

Because of selective controls on commercial fishing, the average percentage return of Pinkut fish in the Babine system escapement has been

increased from 6.8 in pre-channel years to 12.4 percent. The increased stock was necessary to fully utilize the additional area of the spawning channel.

Age composition does not follow the same pattern of 5₂ dominant fish every four years as occurs at Fulton. The run consists mainly of 4₂ fish, with 5₂ fish having been dominant in 1963, 1968, 1973 and 1976 (Fig. 7).

The sex ratio has a reversal every year, with the female majority in even years, along with a larger percentage of jack sockeye. In odd years, adult males are dominant, but to a lesser degree than are the females in even years. Jacks are also less abundant in odd years.

The percentage of jacks has increased as it has at Fulton, from 5.7 percent of the Pinkut jack escapement (1964 to 1970) to 12.1 percent since 1971, the first return of jacks from a flow control brood year (Table 4). This is probably due to the effects of a selective commercial fishery. The number of jacks has been reduced since 1973 by the jack fishery at the Babine Fence.

Egg Deposition and Retention

Egg depositions in Pinkut Creek have ranged from 833 to 21,667 eggs per square yard, but are normally between 1,500 and 3,000. Figure 27 shows that retention is normally below 2 percent, until potential egg deposition becomes greater than approximately 2,200 eggs per square yard, or a corresponding spawning density of 1.4 square yards per female. In 1964, the potential deposition averaged 21,667 eggs per square yard. The reported retention for that year of less than 2 percent is very likely inaccurate, and was not considered in this analysis.

SOCKEYE FRY PROGRAM

Enumeration Techniques

Production estimates from Pinkut Creek began in 1973, these being derived from hydraulic sampling procedures similar to those

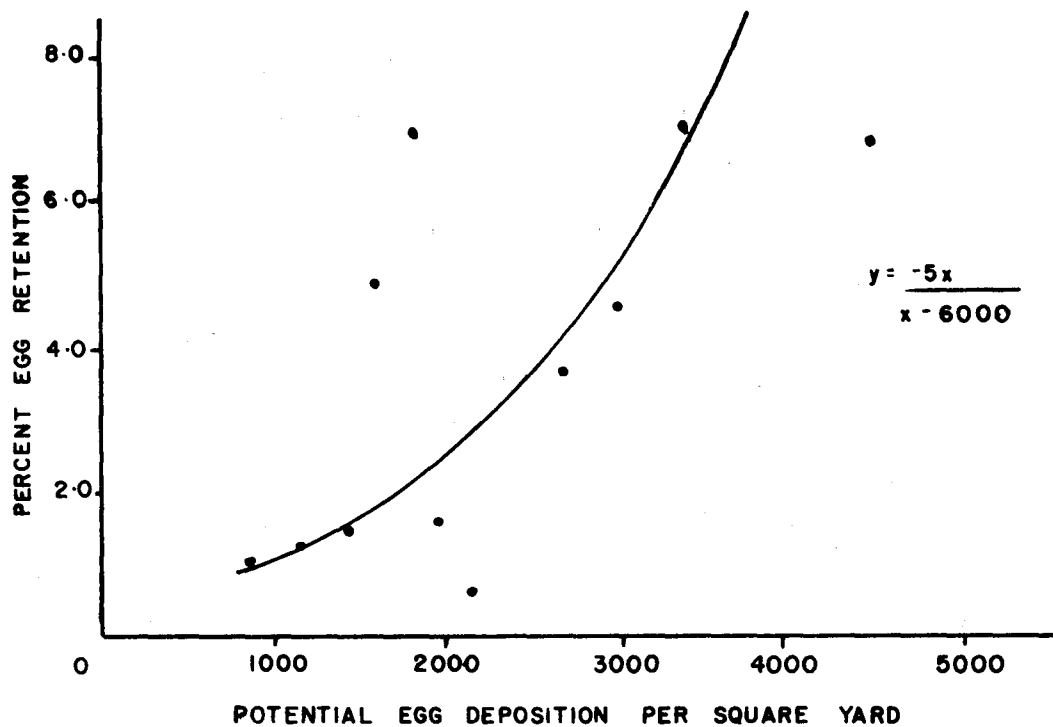


Figure 27: Relationship between percent egg retention and potential egg deposition per square yard in Pinkut Creek.

described by McNeil (1964). An estimate of the total fry output is calculated from the number of live eggs and alevins obtained from hydraulic sampling, and the ratio of the spawning area of the river to the sampling area. Unfortunately, information on spawning and deposition were not accurate prior to 1966; therefore, any discussions dealing with deposition and survival are based on data collected since then, when estimates of spawning and deposition have been more accurate.

Travelling vertical samplers were used in 1966 and 1967, but their effectiveness was limited by debris and high flows. In 1968, converging throat traps similar to those at Fulton were installed to increase the accuracy of migration estimates. Hydraulic sampling has been conducted annually to provide a number of years of comparable data, and serves as a backup in years when flood conditions and debris limit the use of convergent throat traps, as was the case in 1977, when trapping could be carried out only intermittently. Survival estimates from trapping and from

hydraulic sampling were within 2 percent of one another. Improvement of hydraulic sampling technique, including randomized sites to reduce sampling effort, have resulted in reliable survival and production estimates (Table 5).

Fry Production and Egg-to-Fry Survival

Between 1963 and 1967, production in Pinkut Creek averaged 480 fry per square yard (5.8 million), and survival averaged 11.1 percent (Table 15). Since flow control began, production has declined to an average of 268 fry per square yard (3.2 million) because of reduced depositions resulting from splitting the Pinkut spawners between the creek and channel. Survival has increased to 14.9 percent as a result of lower depositions and controlled spawning and incubation flows.

The 1976 brood is not included in further analysis of Pinkut Creek because of its large, unexplained deviation from previous years, and because egg-to-fry survival of the 1976 brood has been observed to be very unusual in the Fulton River system as well. This unexplained increase may be associated with general climatic conditions capable of affecting both systems.

There were a number of years during flow control in which a large segment of the spawning population were directed into the channel, causing reduced spawning densities in Pinkut Creek. By visual analysis of Figure 28, there appears to be a levelling-off of egg-to-fry survival rates at approximately 20 percent when the effects of spawner density are reduced. Within the normal range of spawning densities, between one and two square yards per female, egg-to-fry survival is dependent on the average spawning area per female. The relation between survival and spawning area in Pinkut Creek is significant ($.05 > p > .01$). An egg-to-fry survival of 14 percent should be obtainable from a spawning density of 1.64 square yards per female, or a spawning population of about 14,600 adults at a 50:50 sex ratio. At the mean 1968 to 1975 apparent deposition per female in Pinkut Creek (2,967 eggs per square yard), the corresponding egg density is 1,809 eggs per square yard. Figure 29 indicates ($.05 > p > .01$) that such a

TABLE 15: Sockeye fry production at Pinkut Creek.

(spawning area = 12,000 sq. yds.)

Brood Year	Total Spawning (Adults)	Female Spawning	Egg Deposition (millions)	Fry Production (millions)	Egg-to-fry Survival (%)	Area/Female (sq. yds.)
1963			57.6	11.0	19.1	0.59
1964	144,540	81,760	255.7	4.5	1.8	0.15
1965	23,780	18,000	53.2	6.9	13.0	0.67
1966	21,463	8,528	24.8	3.7	14.9	1.41
1967	31,742	14,033	40.9	2.7	6.6	0.86
Natural Flow Average			86.4	5.8	11.1	0.74
1968	8,805	5,806	19.0	1.9	10.0	2.06
1969	8,294	3,472	10.0	1.8	18.0	3.46
1970	9,214	5,268	16.5	3.3	20.0	2.28
1971	8,778	4,213	13.1	2.2	16.8	2.85
1972	16,828	8,380	21.5	3.0	14.0	1.43
1973	36,923	17,912	30.6	3.1	10.1	1.21
1974	44,542	28,142	30.7	3.0	9.8	1.00
1975	57,107	25,798	20.6	2.6	12.6	1.55
1976	50,192	29,422	35.7	8.1	22.7	0.96
Flow Control Average	26,743	14,268	16.5	3.2	14.9	1.87

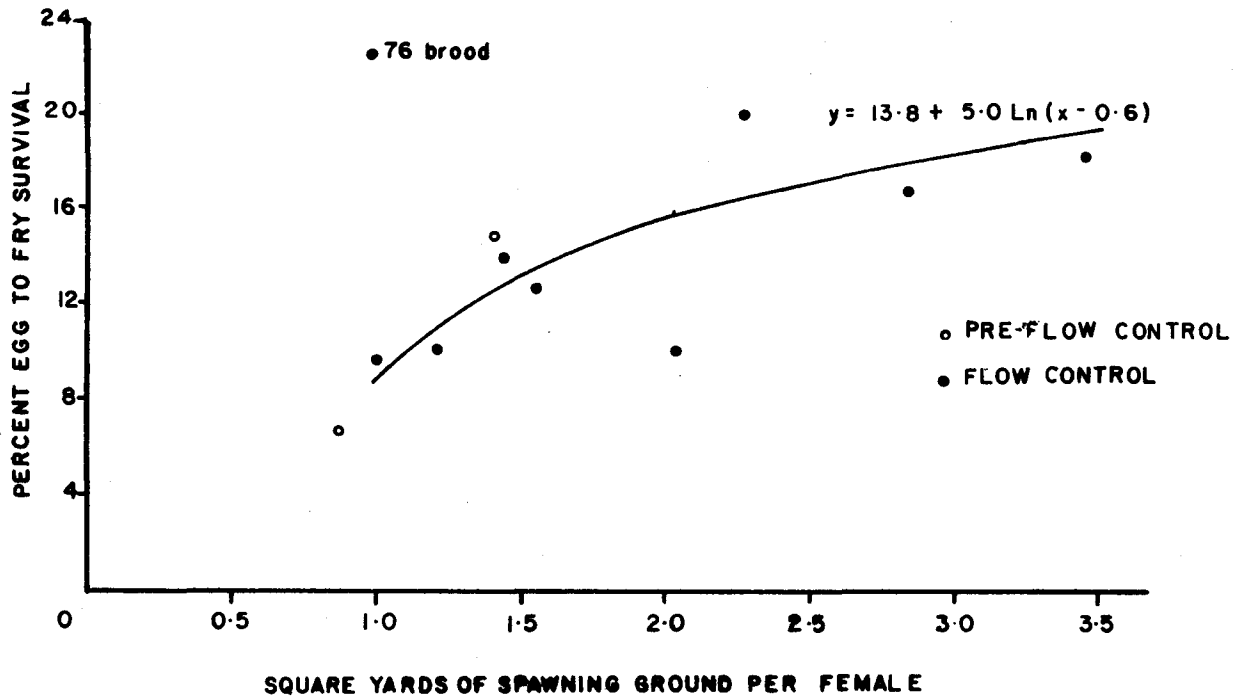
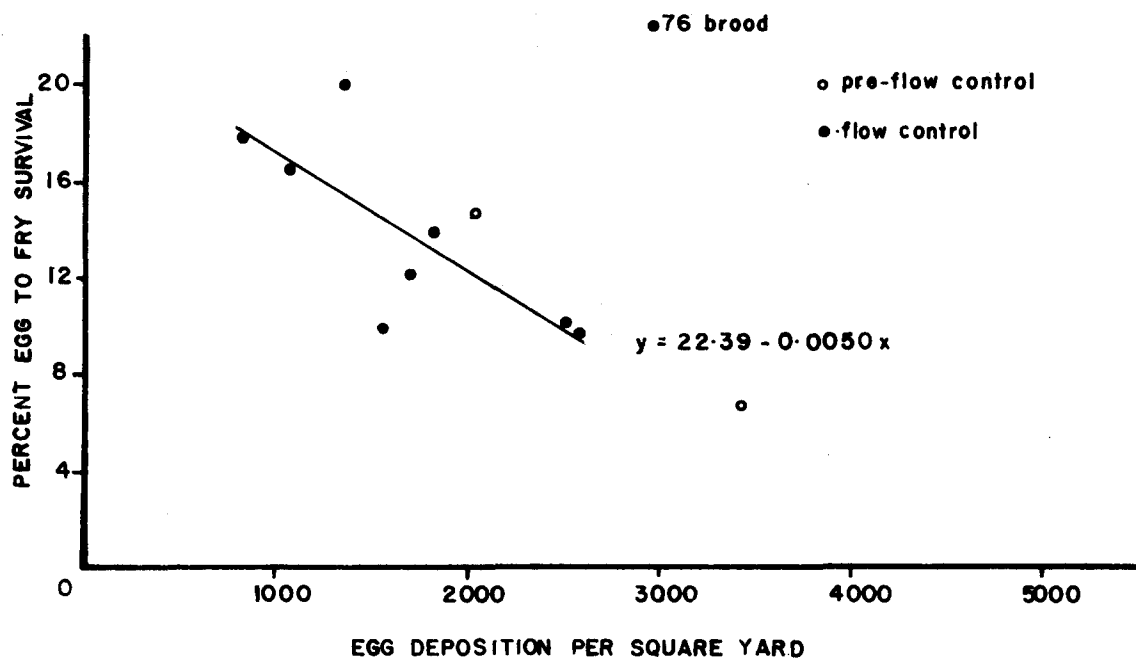


Figure 28: Regression of sockeye egg-to-fry survival on square yards of spawning area per female in Pinkut Creek.

Figure 29: Regression of sockeye egg-to-fry survival on actual egg depositions per square yard in Pinkut Creek.



deposition will result in an egg-to-fry survival of 13.3 percent, a similar survival to that obtained from Figure 27 at that female density. For the data in Figure 29, a linear regression provides a better correlation to the data than several curves that were tried. The correlation of fry production per square yard and egg deposition per square yard is not significant (Fig. 30), but suggests that optimum deposition in Pinkut Creek will produce 228 fry per square yard, or a total of 2.7 million fry. With respect to the previous two analyses of Pinkut Creek, this estimate is conservative and should be nearer to 250 fry per square yard (3.0 million). No data has been omitted because of adverse conditions such as severe icing, but the 1976 brood was not included because of its extremely high survival. When such anomalies as this occur, production and survival estimates may be occasionally surpassed, though the maximum egg-to-fry survival in Pinkut Creek has not proven to be greater than 22.7 percent under the present conditions of flow control.

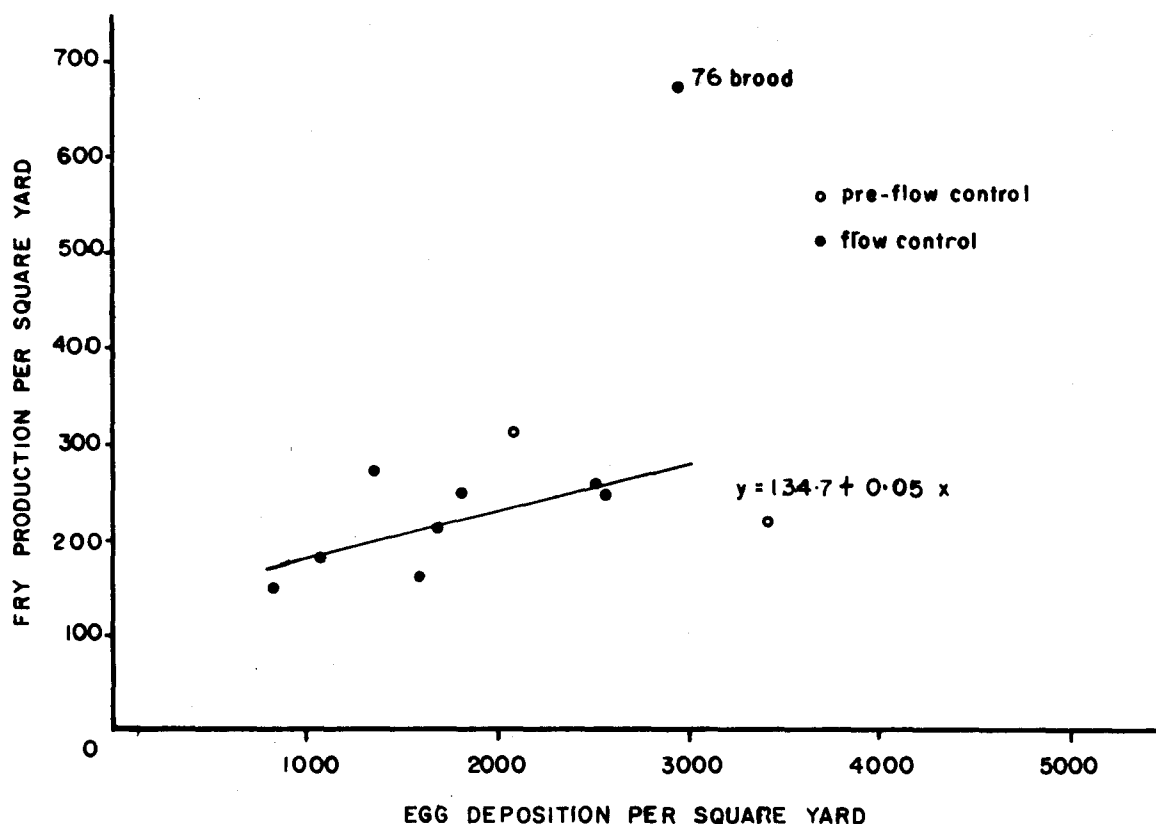


Figure 30: Regressions of sockeye fry production per square yard on actual egg depositions per square yard in Pinkut Creek.

Unfortunately, only two years of accurate data are available from the pre-flow control period, but they do not differ significantly from later data. If the two sets of data are combined, the significance of the relations between egg-to-fry survival and square yard per female, and between egg-to-fry survival and egg deposition per square yard are both increased to $p < .01$. It therefore cannot be shown that flow control has improved the spawning and incubation conditions of Pinkut Creek. Egg-to-fry survival has not changed its dependence on density-related factors. What is not measured in this report, however, is the protection which flow control provides against low winter flow conditions that would result in decreased egg-to-fry survival, and against early and completely uncontrolled spring freshets which would prematurely displace alevins into Babine Lake.

Fry Migration Timing

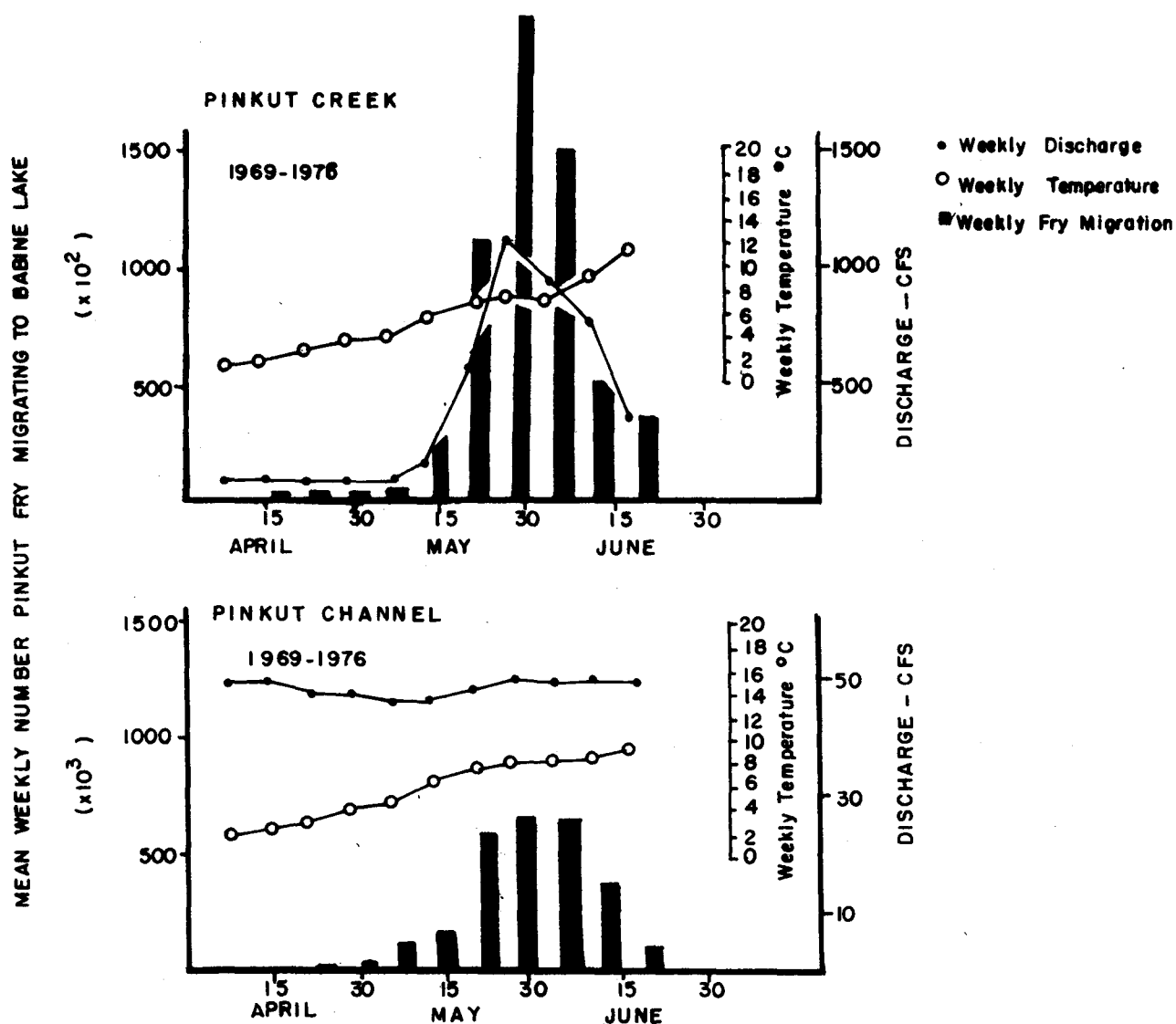
No information on the timing of fry migrations in pre-flow control years is available for comparison with fry migrations since 1968. The peak migration from Pinkut Creek has usually occurred in the fourth week of May (Table 16). The pattern of migration is closely related to increases in river discharge above the incubation flows of 100 cfs

TABLE 16: Peak timing of sockeye fry migrating from the Pinkut Creek System to Babine Lake

Year	Location	
	Pinkut Channel	Pinkut Creek
1969	May 20	May 21
1970	May 20	May 19
1971	May 28	May 27
1972	May 31	May 30
1973	May 29	May 28
1974	May 25	May 26
1975	May 20	May 27
1976	June 2	May 25
1977	-	May 5

(Fig. 31). Water temperatures above 4°C are also required for a migration to begin in earnest. The 1977 fry migration peaked on May 5, unprecedently early, and was caused by warming water temperatures, followed closely by a rising river discharge (Fig. 32). The 1975 migration also began and peaked when early water temperatures rose before the seasonal increase in river discharge. Fry migration from Pinkut Creek to Babine Lake is dependent,

Figure 31: Mean weekly number of sockeye fry migrating in Pinkut Creek and Pinkut spawning channel in relation to average weekly water temperature and discharge from 1969 to 1976.



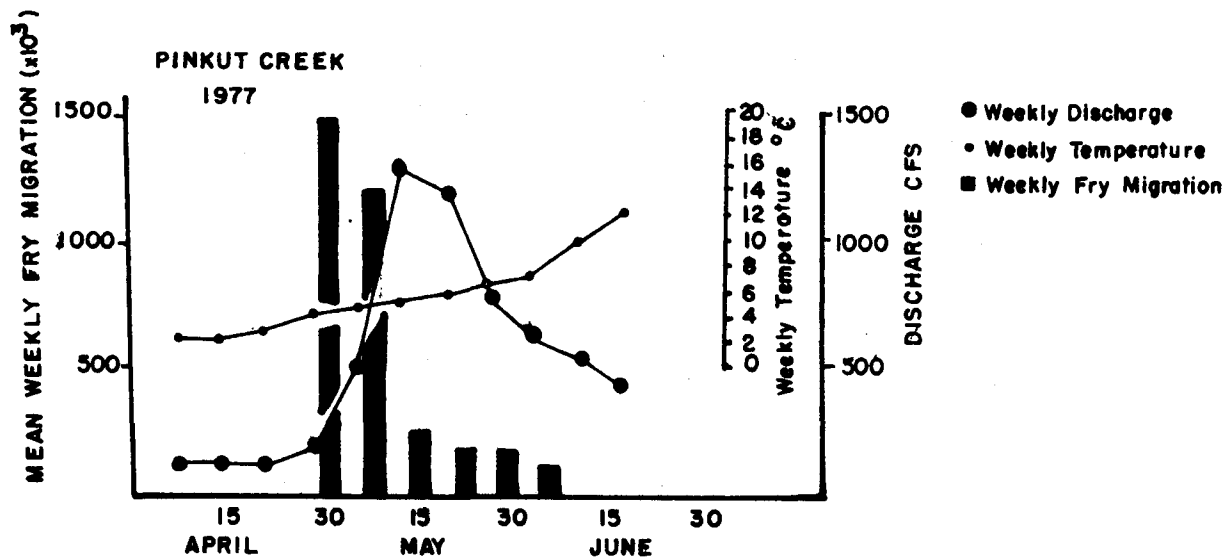


Figure 32: Mean weekly number of sockeye fry migrating in Pinkut Creek in relation to average weekly water temperature and discharge for 1977.

therefore, on increases in river discharge and temperature, accelerating the most when the effects of both factors are combined. In most years, the migration is influenced to the greatest extent by river discharge.

Fry Quality

Mean fry length has ranged from 28.5 mm in 1977, to 29.6 mm in 1976, averaging 29.0 mm since 1969 (Table 17). Annual variation in length of Pinkut Creek Fry has been less than that for channel fry, and have averaged approximately 0.5 mm shorter. Mean weight of river fry has ranged from 124.5 to 159.5 gm, averaging 145.4 gm, and is very similar to that of channel fry (Table 18). River fry are normally similar to channel fry in weight, but shorter because of their less advanced development at the time of migration. This is supported by the average developmental index ($K_D = \frac{10\sqrt[3]{wt}}{mg}$) of Pinkut Creek fry being 1.80, compared to 1.77 in the channel (Table 19). Because of their larger yolk reserves, the river fry, which migrate at the same time as channel fry, are believed to be more capable of survival should they enter the lake at a time of low food abundance. Relative differences in length, weight and development index are constant throughout the migration (Fig. 33).

TABLE 17: Weighted mean length in mm of sockeye fry migrating from the Pinkut Creek system to Babine Lake.

Fry Year	Mean Length (mm)	
	Pinkut Creek	Pinkut Channel
1969	29.1	30.6
1970	28.9	28.2
1971	29.5	30.2
1972	28.8	29.6
1973	28.6	29.0
1974	29.1	29.8
1975	29.2	29.5
1976	29.6	29.4
1977	28.5	-
Average	29.0	29.5

TABLE 18: Weighted mean weight in mg of sockeye fry migrating from the Pinkut Creek system to Babine Lake.

Fry Year	Mean Weight (mg)	
	Pinkut Creek	Pinkut Channel
1969	141.4	147.4
1970	124.5	113.7
1971	144.8	140.2
1972	144.4	137.3
1973	151.6	152.2
1974	153.1	159.1
1975	153.3	151.5
1976	159.5	157.0
1977	135.7	-
Average	145.4	144.8

TABLE 19: Weighted mean development indices of sockeye fry migrating from the Pinkut Creek system to Babine Lake.

Fry Year	Mean Development Index (K_D)	
	Pinkut Creek	Pinkut Channel
1969	1.79	1.73
1970	1.72	1.71
1971	1.78	1.72
1972	1.82	1.74
1973	1.87	1.84
1974	1.84	1.81
1975	1.76	1.79
1976	1.83	1.83
1977	1.81	-
Average	1.80	1.77

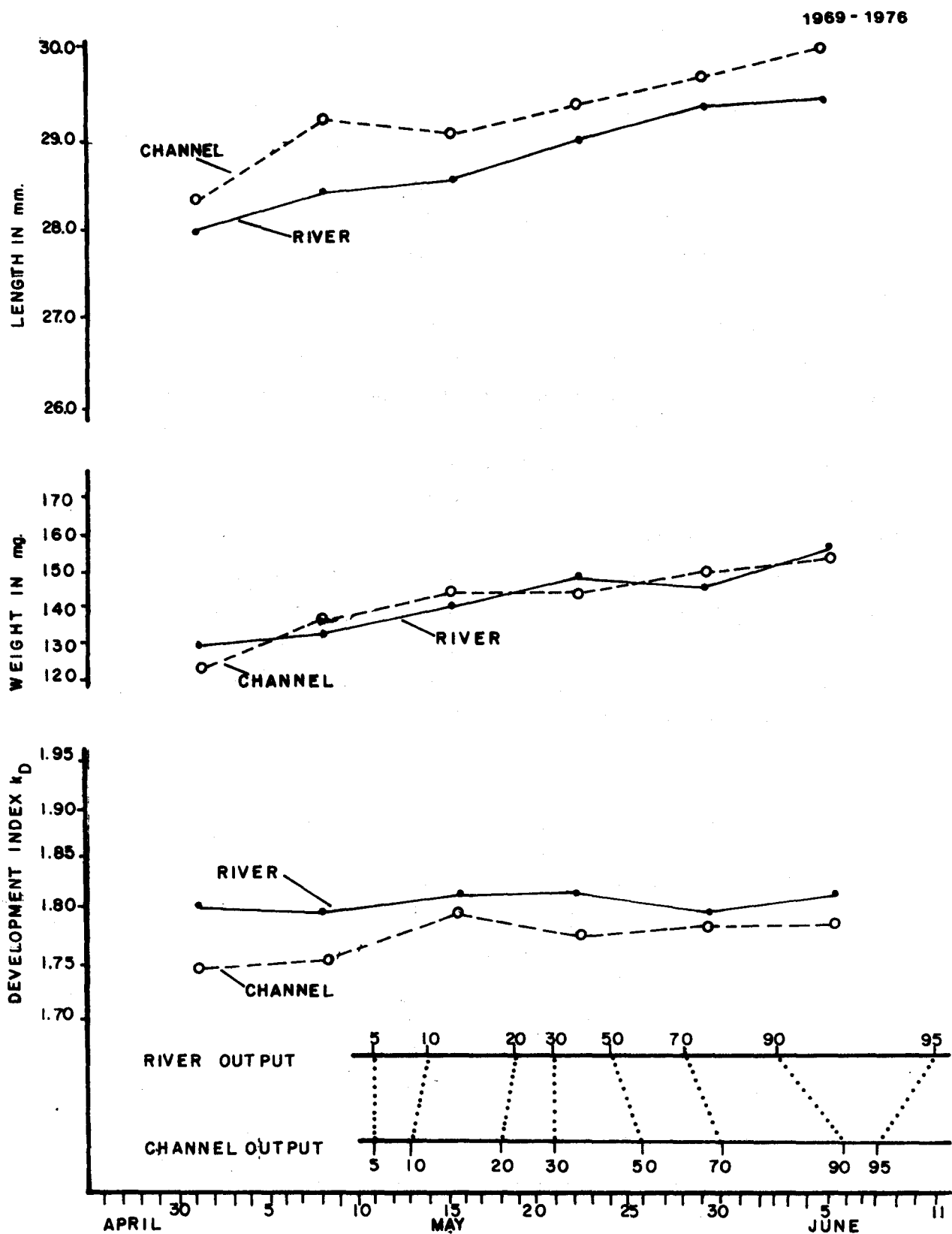


Figure 33: Average lengths in mm, average weights in mg, and average developmental indices of Pinkut Creek and Pinkut channel fry at intervals through the mean spring migration from 1969 to 1976. Also shown is the average progress of the runs in time.

EVALUATION OF THE PINKUT CREEK SOCKEYE AIRLIFT

As described in the preceding section, the Pinkut Creek airlift was carried out from 1973 to 1976. Because adults were taken from the lower section of Pinkut Creek, and because the resultant fry from the airlifted brood are enumerated at the lower river fence, the upper and lower river populations are considered to be identical. The only sampling carried out in the upper river is confined to examination of carcasses to determine the degree of spawning success, and hydraulic sampling to determine egg-to-fry survival in relation to survival in the lower river. Survival in the upper and lower river has been very similar except in 1973, the first operational year of the airlift (Table 22). The airlift is considered to be economically feasible because of the number of fry produced and because of the otherwise excess number of spawners in those years. The airlift has now been discontinued due to completion of the new Pinkut spawning channel. Construction of a fishway and removal of the falls have been investigated as long-term alternates to the airlift program, but due to the height and nature of the falls, these plans do not appear to be feasible. The new channel, plus the lower river, however, will provide adequate spawning area for the Pinkut Creek sockeye population.

TABLE 20: Pinkut Creek airlift sockeye fry production from 1973 to 1976.

Brood Year	Deposition (millions)	Production (millions)	Survival (%)	Fry Year
1973	25.2	6.0	23.8	1974
1974	49.5	4.6	9.3	1975
1975	52.1	6.6	12.6	1976
1976	48.4	10.9	22.5	1977
Average	43.8	7.0	17.0	

EVALUATION OF THE PINKUT CREEK CHANNEL

INTRODUCTION

In order to provide additional spawning area for the production of sockeye fry to more fully utilize the estimated rearing potential of the main lake basin of Babine Lake, a 39,475 square yard spawning channel, with a capacity of 63,000 adults, was constructed on a low-lying area of muskeg adjacent to the main spawning grounds at the mouth of Pinkut Creek.

Survival in the first years of operation was very low due to unforeseen icing problems along the length of the channel. Extensive silting and difficulties in controlling adult densities in each of the legs have also presented problems to efficient operation. A rehabilitation program was carried out in 1976-1977 to alleviate some of these problems, so better results should be obtained in the future.

Due to reconstruction, the channel was not operational in the 1976 brood year. This section of the report deals with the past operation and results of the original channel.

OPERATIONAL HISTORY OF THE PINKUT CREEK SPAWNING CHANNEL

Unforeseen icing problems began in the first year of operation. Water entering the channel at 32.0°F was forming anchor ice and causing high alevin mortalities by scouring of the bottom. Additionally, ice dams rerouted water between channel legs, sometimes leaving large sections completely devoid of any water flow. To alleviate this problem, a secondary system was then designed to pump warmer water from 200 feet below the surface of Babine Lake and distribute it throughout all portions of the channel. The lake water, approximately 37.5°F, warmed the channel water from 32.0°F to 32.5°F, and reduced the formation of frazzle ice.

Silting was another serious problem of the old Pinkut channel. The settling basin was incapable of removing particles of less than .5 microns in diameter. Clay sediment from the impervious fill berms was also being introduced from breakdown of the gravel sides by spawning

activity and anchor ice formation. Ice dams, which caused water to flow across the legs, also led to erosion of the berms. Annual scarification of the spawning gravel was not sufficient because of the large amount of organic and inorganic material entering the channel in one operational year. Silt deposition would be observed as the result of spawning, though the gravel had been scarified shortly beforehand.

Adult control structures were inadequate to prevent the movement of adults between the legs, leading to extensive superimposition of redds in some areas and underspawning in others. In later years, the spawning densities were reduced to prevent loading problems, but any beneficial effects were masked by the deteriorating channel conditions.

The channel has now been rebuilt so as to correct these operational problems (Fig. 34). A new complex of three center-inflow peripheral outflow settling basins has been designed to remove more of the finer sediment from the incoming river water, and the berms have been lined with shotcrete to prevent erosion. The gravel has been removed, cleaned and replaced, and there are more outlets for the warm lake water system. The adult control structures have also been rebuilt on a design similar to the proven structures of Fulton Channel No. 2. The new channel is expected to produce in excess of 40 million fry.

ADULT SOCKEYE PROGRAM

Population Characteristics

The Pinkut channel was originally designed to hold 63,000 adults. This loading was only approached in 1972 and 1973, after which the spawning density was reduced because of poor channel conditions (Table 2).

Age and sex compositions are identical to the river. Age 4₂ stock has dominated the run in all years except in 1973, and females predominate in even years, with a lesser degree of dominance by males in odd years.

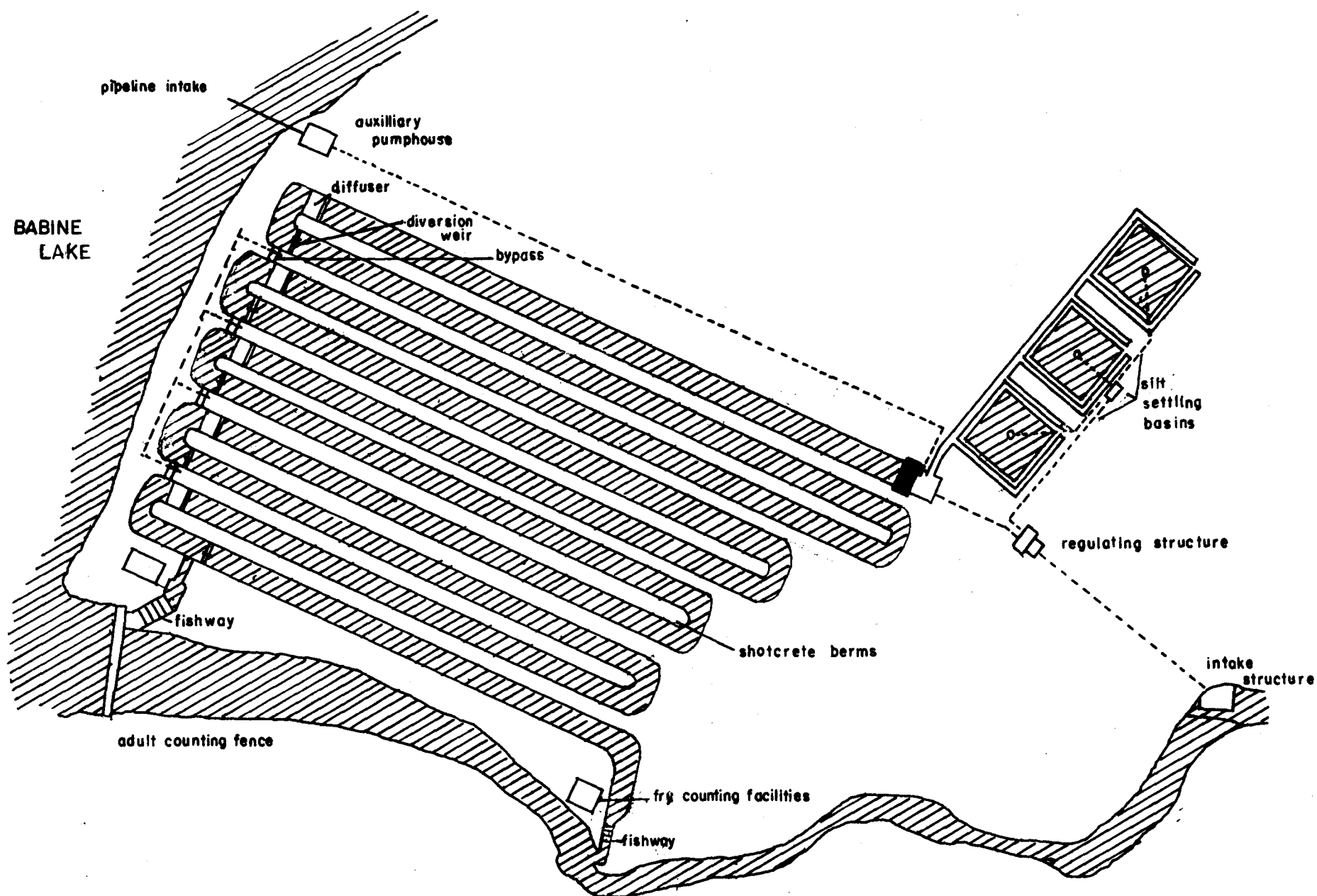


Figure 34: Schematic layout of the Pinkut Creek spawning channel and regulating works after reconstruction.

The 3₂ male population has ranged from 1,062 in 1968, the first year of operation, to 18,916 in 1973. There was a general increase of 0.45 percent per year in composition, averaging 16.6 percent from 1968 to 1975, but the percentage of jacks has never been as large as at Fulton. Since 1973, part of the jack population has been removed by a special fishery at the Babine River fence.

Egg Deposition and Retention

Potential egg deposition has ranged from 785 to 2,513 eggs per square yard (31.0 to 99.2 million eggs). Retention has not been high in most years and was always less than 3 percent (Fig. 35). A definite dependence of retention on potential egg deposition appears to exist. Retentions of less than 1 percent occur at potential depositions below 1,700 eggs per square yard, while retentions average 2.4 percent at depositions of approximately 2,500 eggs per square yard. These higher depositions may not be sufficient to critically affect survival in the gravel. Increased retentions at 2,500 eggs per square yard are consistent with data from Pinkut Creek, indicating the beginning of crowded spawning conditions and increased spawner interaction.

SOCKEYE FRY PROGRAM

Enumeration Technique

Fry enumeration has been carried out since 1969, using two converging throat traps similar to those at Fulton. As shown in Figure 12, the traps are located at an exit behind Leg 9. The main part of the channel flow is directed through this outlet at night by the placement of stop-logs below Leg 10. In most years, Leg 10 was never utilized because of the unavailability of sufficient spawners, but in years of use, an estimate of production was obtained from hydraulic sampling data and added to the trapping results to give a total channel production estimate.

Each of the two traps fishes a one-foot-wide section of a 5-foot-wide rectangular-shaped culvert; therefore, a correction factor of five was initially applied to standard trapping calculations. Sample nightly calculations are described by Ginetz (1977).

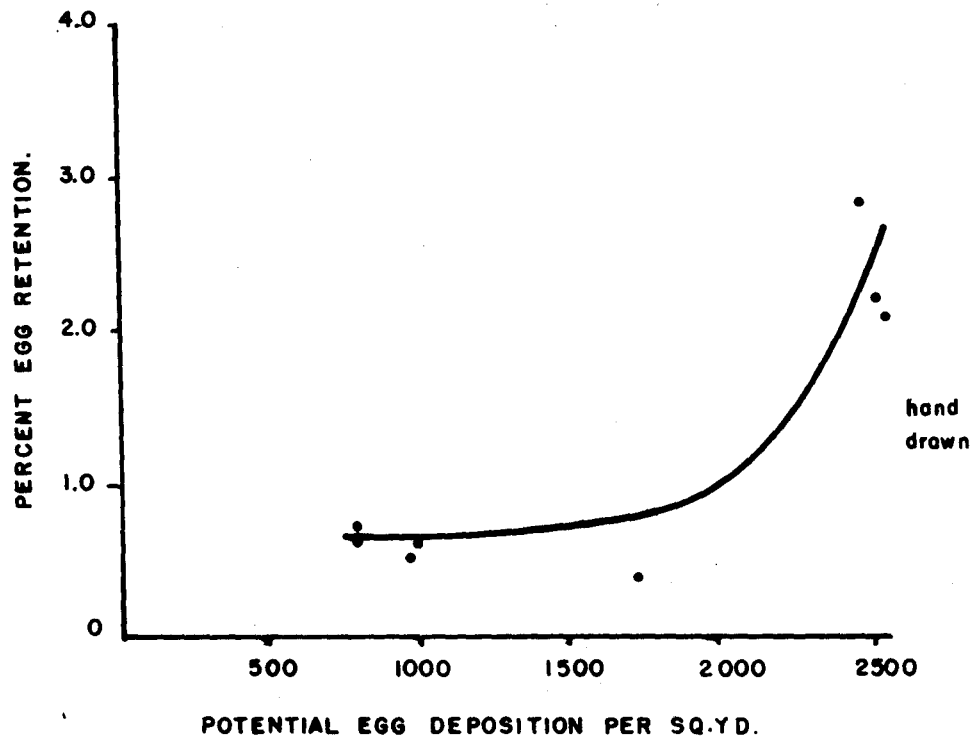


Figure 35: Relationship between percent egg retention and potential egg depositions per square yard in the Pinkut Creek spawning channel.

As in the case of Fulton Channel No. 2, standard calculations assumed fry migrate in an even, lateral distribution. Dye tests and horizontal ladder trapping were carried out to check the accuracy of this assumption.

The horizontal ladder consisted of five marquisette bags 6 inches in height and 12.0 inches wide, arranged to fish the five-foot cross-section of each culvert. Trapping was carried out at 6-inch intervals from the surface to the bottom (three feet) at a distance of approximately six feet downstream from the mouth of the converging throat traps. A four-year average indicated that standard calculations overestimated production by approximately 10 percent (Table 21). Production estimates have been adjusted accordingly.

TABLE 21: Annual average catches by percent of the horizontal ladder trap used to assess catchability of the Pinkut Channel converging throat traps. Trap No. 3 in each bay represents position of each converging throat trap.

	Percent of Total Catch Per Trap										Trap No. 1 Error		x Error of No. 1 Traps
	Bay 1 Traps					Bay 2 Traps							
Year	1	2	3	4	5	1	2	3	4	5	1	2	
1971	15.7	24.6	23.3	22.0	14.4	17.3	25.2	21.7	22.0	13.8	+16.5	+ 8.7	+12.60
1972	16.1	27.8	23.3	21.5	11.3	17.2	26.9	20.0	23.2	12.7	+16.5	0.0	+ 8.25
1973	17.8	27.3	21.6	20.9	12.4	17.7	25.6	21.1	21.1	14.5	+ 8.0	+ 5.5	+ 8.75
1974	18.1	28.9	22.6	20.6	9.8	14.7	30.1	22.4	20.5	12.3	+13.0	+12.0	+12.50
Average	16.9	27.2	22.7	21.2	11.9	16.7	26.9	21.3	21.7	13.3	+13.5	+ 6.5	+10.03*

*Correction factor applied to annual channel production estimates.

Fry dyed with Bismark Brown or Neutral Red were released at the top end of each culvert, about six yards upstream from the mouth of each converging trap in which the fry were recovered. Results supported those obtained from the horizontal ladder tests.

Fry Production and Egg-to-Fry Survival

Fry production has ranged from 210 to 735 fry per square yard (8.3 million to 29.0 million), averaging 469 fry per square yard (18.5 million). In the first four years, the channel was loaded to only one-third capacity and, in spite of winter icing problems, poor gravel quality and difficulties in preventing the movement of spawners between the channel loops, egg-to-fry survival averaged 46.6 percent (Table 22). A principal limiting factor of total production in the first four years of operation was the lack of spawners. Also, survival would probably have been higher had the adults been distributed more evenly throughout the channel. From observations and studies by Ginetz (1972), it was concluded that gravel quality had declined to a sub-optimum level.

Analysis of fry survival and production in the Pinkut Creek spawning channel is confounded by past difficulties and operation changes associated with this channel. In the first year of operation, formation of ice dams and anchor ice within the channel legs caused a partial breakdown of the clay-filled berms, resulting in extensive siltation. The introduction of warmer water from Babine Lake to reduce the formation of anchor ice and reduce egg and alevin mortalities began in 1970, and the number of female spawners has ranged as low as 40 percent of the design population.

The relation between egg-to-fry survival and square yards per female (Fig. 36) is highly significant (.005 p). It should be noted, egg-to-fry survival is closely related to the density of females at low and at high spawning densities. This suggests that survival in the old Pinkut channel was very dependent on the density of spawners. However, at a spawning density of 1.5 square yards per female, similar to the optimum densities of the Fulton River channels, the expected egg-to-fry survival

TABLE 22: Sockeye fry production at Pinkut Creek spawning channel

(spawning area = 39,475 sq. yds.)

Brood Year	Total Spawning (Adults)	Female Spawning	Egg Deposition (millions)	Fry Production (millions)	Egg-to-Fry Survival (%)	Area/Female (sq. yds.)
1968	13,479	9,045	30.8	10.4	33.8	4.36
1969	28,784	12,654	37.5	15.2	40.5	3.12
1970	19,762	11,848	37.9	22.0	58.0	3.33
1971	21,665	9,666	30.8	16.7	54.2	4.09
1972	57,083	35,791	96.6	29.0	30.0	1.10
1973	63,260	30,688	97.1	24.1	24.8	1.29
1974	51,655	32,951	93.4	8.3	8.9	1.20
1975	48,083	22,939	67.3	22.3	33.1	1.72
Av. 1968-1975	37,971	20,698	61.4	18.5	30.1	2.53

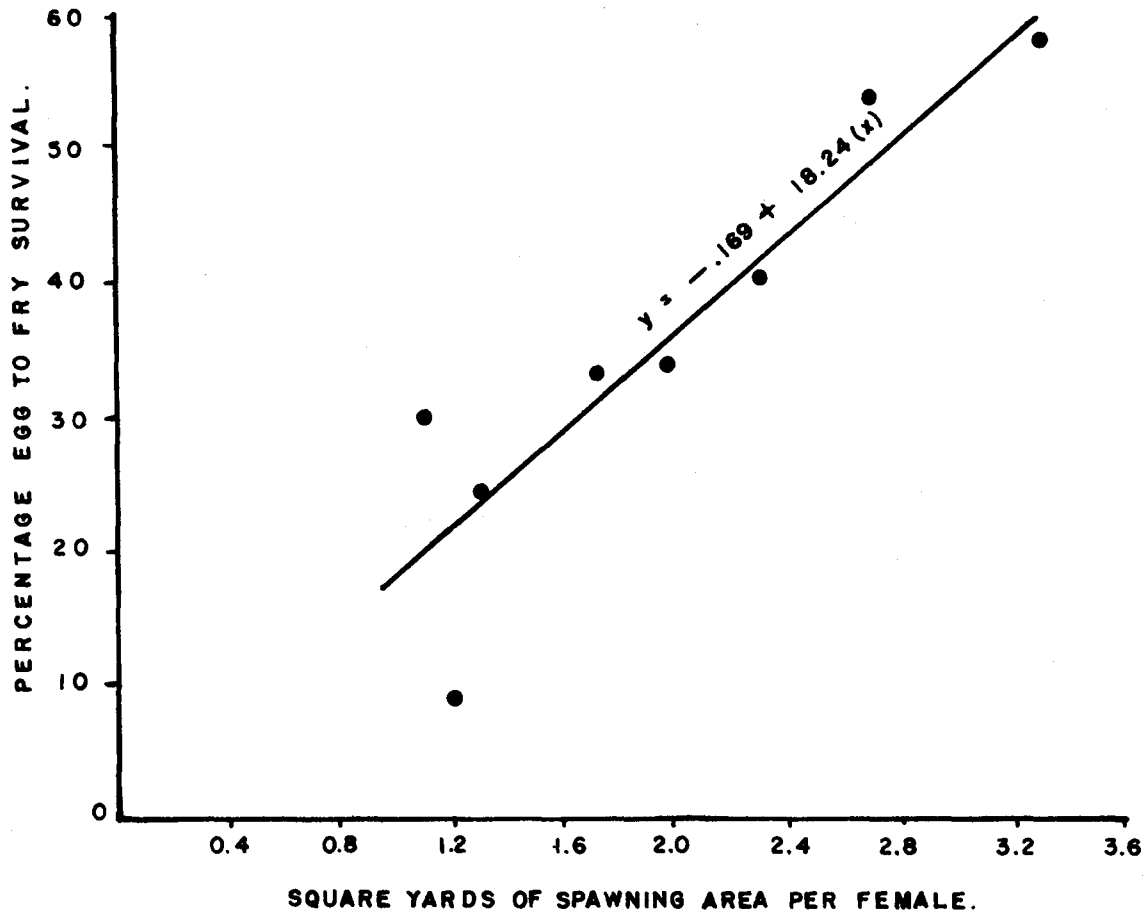


Figure 36: Regression of sockeye egg-to-fry survival in square yards of spawning area per female in the Pinkut Creek spawning channel.

would be only 27 percent. To obtain an egg-to-fry survival rate of 45 percent, the old Pinkut channel could only be loaded to a density of 2.48 square yards per female, or a spawning population of 16,000 females. The density dependence of egg-to-fry survival is also described significantly (.025 p) by its relation to egg deposition per square yard (Fig. 37). By the slope of the relationship, which is greater than that of the similar analysis in Pinkut Creek, egg-to-fry survival was more density-dependent in the spawning channel than in the creek. However, by comparison of the intercepts, the old spawning channel was more efficient than Pinkut Creek. Fry production per square yard and egg deposition per square yard are compared in Figure 38. The relationship is not significant, and fry production increases less efficiently as egg depositions increase. Figure 38 includes

a fitted curve which, because of the definition of this relationship, passes near the origin, but does not rise above the line of slope equal to 1.

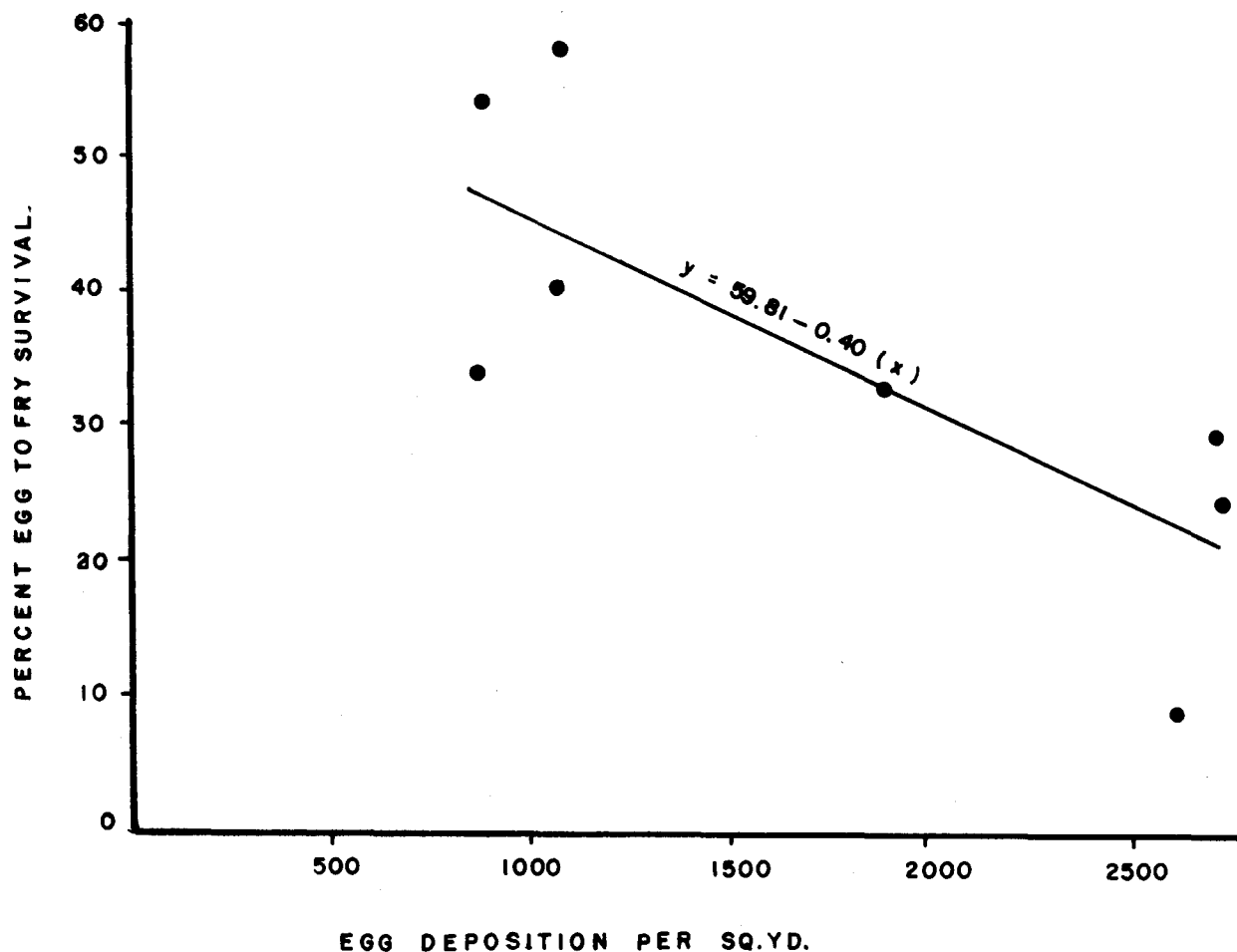


Figure 37: Regression of sockeye egg-to-fry survival on actual egg depositions per square yard in the Pinkut Creek spawning channel.

Fry Migration Timing

The fry migration from the Pinkut channel has peaked between May 20 to June 2, varying around May 25 (Table 16). Since discharge in the channel remains constant throughout the migration period, water temperature increasing to above 4°C is the usual key factor triggering migration. The influence of water temperature is shown in Figure 30. The channel fry migration coincides with that of Pinkut Creek very closely, and between 1969 and 1974, peaked within one day of each other. The

similarity in peak migration dates is due to the effects of increased discharges in Pinkut Creek being matched by the effects of increased channel water temperatures, which occur at similar dates.

Fry Quality

The mean length of sockeye fry from the Pinkut channel decreased from 30.5 mm in 1969 to 28.2 mm in 1970, after which fry length remained in the 29 mm range, averaging 29.5 mm since 1969 (Table 16). Mean weight also decreased from 147.4 gm in 1969 to 113.7 gm in 1970 (Table 17). In the remaining years, mean weight was often greater than in 1969, ranging from 137.2 mg to 157.0 mg.

A decrease in mean length and weight also occurred among river fry from 1969 to 1970, but the relative decreases were greater in the channel. Gravel conditions are offered as an explanation for the poor fry quality. It is known that a poor incubation environment during development of both egg and alevin stages causes increased activity of the respiratory system. More yolk is utilized for maintenance and less for growth, resulting in a smaller fry.

The mean developmental index ($K_D = \frac{10\sqrt[3]{wt}}{L}$) of channel fry has averaged 1.77 in the eight-year period from 1969 to 1976 (Table 18). Pinkut channel fry are almost consistently more developed than Pinkut Creek fry, due to their greater length and maturity. These differences are often significant, as shown in Appendix Table IV. Until 1972, the channel was loaded later than Pinkut Creek, which may have delayed the mean deposition date of the channel. Higher incubation temperature in the channel is the most likely cause of the advanced development.

In most years, channel fry have averaged longer than river fry (Table 17). This relationship is very constant throughout the migration period (Figure 33). Mean weight between the two groups has been similar both annually and throughout the migration period. No consistent relationship between the weights of the two groups is obvious. Channel fry have always been the more-developed throughout the migration, even though the peak migration times coincide.

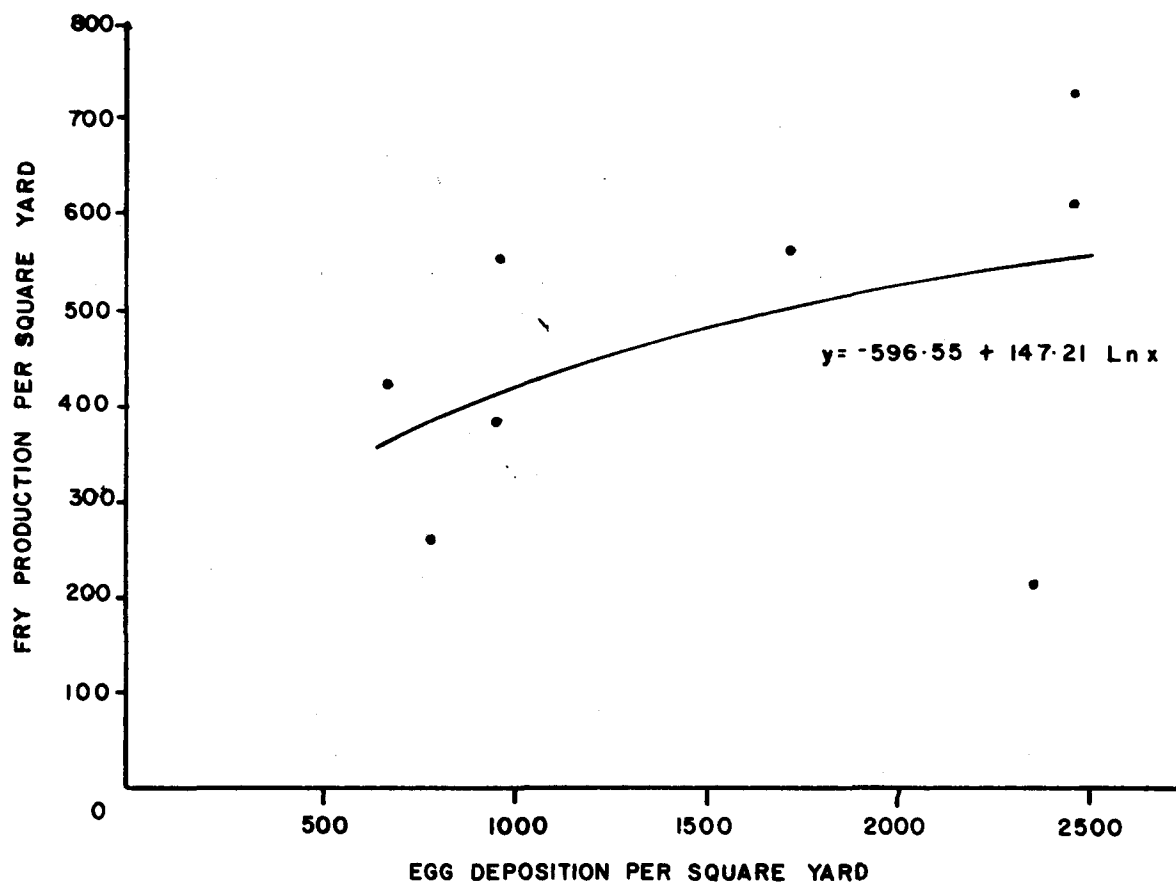


Figure 38: Regression of sockeye fry production per square yard on actual egg deposition per square yard in the Pinkut Creek spawning channel.

GENERAL DISCUSSION

Egg-to-fry survival in the Fulton River is dependent on density-related factors such as egg deposition and spawning area per female. Flow control has increased egg-to-fry survival at higher spawning densities, as shown in Figure 23. Benefit is also derived from the stabilization of flow which reduces the probability of extreme conditions decimating the run by destruction of incubating eggs and alevins, and by displacement of fry prematurely from the gravel.

Changes in the quality of river fry are annual, but insignificant. High river flows sometimes remove fry from the river prior to normal migration, which would be brought about by increases in water temperature. These fry appear to have, however, adequate yolk reserves to maintain them until food becomes sufficiently abundant in Babine Lake.

Channel No. 1 has surpassed expectations, producing an average of about 17 million fry. With controlled water flow and desirable gravel-bed conditions, survival is density-dependent on egg deposition and spawning area per female. Channel No. 1 is also the most efficient producer of the Fulton River system.

The peak fry migration date occurs more regularly in Channel No. 1 than in the river. This is due to the fact that water flow is held constant within the channel, and the onset of fry migration is stimulated largely by increases in water temperature. The peak migration from the channel occurs approximately one week later than in the river. Channel fry are normally shorter and lighter than river fry at the same date of migration. When differences in migration timing are adjusted, the fry are more similar, but the difference in quality is still real. The majority of channel fry are more advanced and migrate later than river fry.

Channel No. 2 is the major producer of fry, averaging 82 million fry annually since full production began. Survival is dependent on egg density and spawning area per female, but gravel composition, growth of

algae in the upper legs and maintenance difficulties due to the immense size of the channel have been suggested as reasons for the difference in survival between the two Fulton channels. Results of 1977 indicate that Channel No. 2 is capable of producing at levels far beyond those of the past; however, it is not known at this date what caused this increase in survival or whether the increase is long-term.

Migration from Channel No. 2 takes place approximately one week later than from Channel No. 1, and two weeks later than from Fulton River. As in the case of Channel No. 1, migration is dependent on increased water temperature. Because of the extended incubation period, virtually all fry from Channel No. 2 are fully developed at the time of migration. Channel No. 2 fry are longer than river or Channel No. 1 fry. Mean weight is similar to that of the other stocks, slightly less than river fry, and more than Channel No. 1 fry. They are the most developed fry from the Fulton system at the time of migration.

Migration from Channel No. 2 is dependent on increasing water temperature, and because of the extended incubation period, virtually all fry from Channel No. 2 are fully developed at the time of migration.

In summary, of the Fulton River system, Channel No. 2 is the largest fry producer, followed by the Fulton River and then by Channel No. 1. Channel No. 1, however, is the most efficient producer of the two channels. Channel No. 2 fry are the longest and the most advanced (the lowest K_D value) from the Fulton system. The river fry are longer than the Channel No. 1 fry, but there is no consistent relation between the developmental indices of these two groups. Fulton River fry are usually the heaviest fry from this system, but there is no constant relation between weight of fry from the two channels. The peak date of fry migration normally occurs first in the river, followed by Channel No. 1, and then by Channel No. 2.

Fry production from Pinkut Creek has been reduced since development because of smaller spawning populations in the river. Survival is closely related to the spawning area per female, and has increased slightly.

The implementation of flow control on Pinkut Creek cannot be shown to have changed the dependence of egg-to-fry survival on density-related factors such as egg deposition or the average spawning area per female. The timing of the peak migration, as in the case of Fulton River, is dependent on both discharge and water temperature. Peak migration is normally the result of increased discharge, but in years of initially low discharge the onset of migration has been brought about by increasing water temperature. Fry quality has not changed with the implementation of flow control, and fry maturity is dependent on the timing of migration.

Pinkut Creek channel production has been low, averaging 18.5 million fry, because of initial under-utilization, winter icing problems, declining gravel quality and possibly high egg densities resulting from inadequate adult control structures, but is still a larger producer than Pinkut Creek. In most years, survival has been severely limited by channel conditions. These are generally poor enough to cause survival to be limited by egg depositions and spawning area allotments per female which are low, relative to other channels. Survival, however, was higher than in Pinkut Creek. A major reconstruction designed to eliminate past problems has been completed and is expected to result in survivals of greater than 40 percent.

The timing of the fry migration from the Pinkut channel is dependent on increases in water temperature. Peak migration is normally similar to that of the river, except during years in which river migration was brought about by an early spring increase in discharge. In such years, the channel migration would peak when brought about by rising temperature at a more usual date.

Channel fry are more developed than river fry at the time of migration. This is due to additional heat units received during incubation from warm lake water pumped into the channel during periods of extreme cold. In the event of a delayed plankton bloom, channel fry may be at a disadvantage compared to Pinkut Creek fry which migrate with greater reserves of yolk. This disadvantage is hopefully compensated for by a more rapid dispersal of the channel fry because of their advanced development.

Before completion of the enhancement project construction, concern was voiced over the viability of fry to the adult stage of channel-produced fry as compared with river fry. Fin clipping studies by McDonald (1971) have found no evidence that either type of fry is inferior to the other up to the smolt stage. Further evidence such as the specific return of Channel No. 2 origin adults, preferring that water when previous generations avoided it, shows that stocks returning to the Skeena system have a high composition of channel-origin fish. This is to be expected, assuming equal survival of channel and river-origin fry, because of the large number of fry produced in channels. It can be concluded that channel-produced fry are equal to fry produced in a river.

An analysis of the quality of fry produced by the enhancement project can be inferred by comparing fry production against smolt output (Fig. 39). Over the period of 1963 to 1976, the combined output of Fulton and Pinkut varies significantly with the corresponding smolt output ($\alpha < .01$). Increasing fry outputs resulted in greater numbers of smolts leaving the main lake basin up to and including 1973. Smolt production then declined in the next two years even though fry output increased. Any combination of several reasons may explain the unexpectedly low smolt output after larger numbers of fry were produced. An increased predator population as the result of increased availability of food may now be taking a larger number of sockeye fry. Another reason may be a critically low plankton abundance brought about as the result of over-cropping by juvenile sockeye or by reduced primary production because of a change in the lake's chemistry. The effects of decomposition of the adult return on fertilization of the lake have been discussed by Stockner and Shortreed (1975). It has been indicated that some changes have occurred in the diversity of plankton in recent years (Rankin, 1976, pers. comm.). Mortality in the lake has also been proposed as a result of increased parasitic infection of juvenile sockeye. Fry production has remained high, and smolt output has shown an increase from the drop in 1975. This leads to the speculation that either the carrying capacity of Babine Lake has been reached, or that smolt density-regulating mechanisms such as those suggested above are operating within the lake.

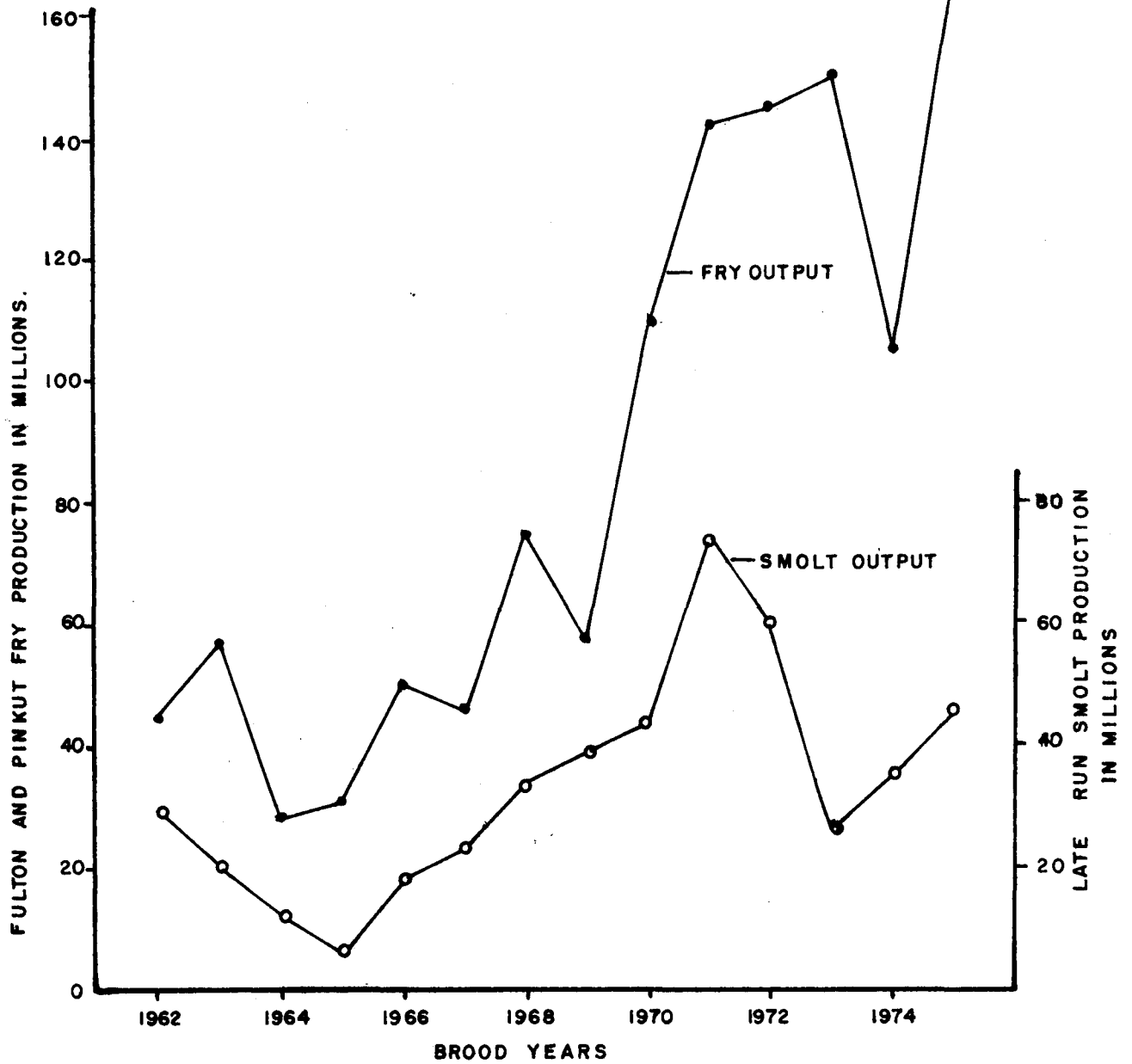


Figure 39: Fry production from the Fulton River and Pinkut Creek systems in relation to the late run Babine Lake smolt production from the 1962 to 1974 brood years.

It must be kept in mind that the success at which an enhancement facility operates will depend on characteristics unique to each facility and to each stock of fish being enhanced. Coastal fish arriving at their spawning grounds may be fully mature, spawn within three weeks and die. Fish destined for inland streams may arrive over a six to eight-week period at varying degrees of maturity such as happens at Babine. This situation inevitably leads to wave spawning, and a measure of success at which the facilities operate is the extent to which wave spawning can be controlled within the channels. With proper operational and maintenance procedures, the loading densities in use at Babine result in survivals between 40 and 50 percent and sometimes higher.

Spawning channels in use on the Fraser River system enjoy higher survivals, but they do so at the expense of reduced loading densities. For example, in most years, Weaver Creek has been loaded at a density of approximately 2.0 square yards per female or greater (Cooper, 1977). The resulting survivals were above 80 percent, and in 1974, when the area allotment amounted to 1.3 square yards per female, the egg-to-fry survival was 61.5 percent, which supports the view that egg-to-fry survival in spawning channels is dependent on adult loading densities. Weaver Creek has the additional advantage of being near the coast so that adults arrive and spawn in under three weeks, reducing the effects of wave spawning on survival and production.

With further studies and future years of data, the Babine enhancement program will be fully evaluated in terms of the initial premises on which the project was approved. Spawning channels appear to be an effective means of enhancing a sockeye population, but the full effects of such a project on the ecology of Babine Lake and the interactions with other stocks are not yet fully understood. It must be remembered that projects of such a scale can significantly alter the system(s) in which they interact. Accordingly, due care must be taken when dealing with and planning any such projects in the future. In this respect, the history of the Babine development project, and studies of the lake system and sockeye stocks should serve as a reference for enhancement projects of the future.

ACKNOWLEDGEMENTS

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APPENDIX TABLE 1: Summary of annual mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from Fulton River and Channel No. 1.

Sample Location	Date	N	Mean Length (mm)	S ²	Δl (mm)	U	Z	P	Mean Weight (mg)	S ²	Δl (mg)	U	Z	P	Index (K _D)	S ²	Δl (K _D)	U	Z	P
River	1966	651	29.33	2.97	.28	81 ^b		.05	148.17	395.42	.93	84 ^b		>.05	1.80	.008	-.01	81.5 ^b		>.05
Chan.1		702	29.05	4.04					147.24	799.61					1.81	.008				
				1.36 ^c				<.01		2.02 ^c				<.01		1.00 ^c				>.01
River	1967	1890	29.40	1.53	.43	454.0 ^b	-2.784	.0020	154.75	500.79	16.28	228.0 ^b	-5.132	0	1.82	.005	.04	255.5 ^b	-4.846	0
Chan.1		1890	28.97	2.07					138.47	599.73					1.78	.004				
				1.35 ^c				<.01		1.20 ^c				<.01		1.25 ^c				<.01
River	1970	1449	29.89	1.50	.95	32 ^b	-6.042	0	142.67	455.85	14.78	24 ^b	-6.166	0	1.74	.002	0	301 ^b	-1.858	.0316
Chan.1		1450	28.94	1.89					127.89	413.74					1.74	.005				
				1.26 ^c				<.01		1.10 ^c				<.01		2.50 ^c				<.01
River	1971	950	29.84	1.43	.57	74 ^b		<.001	150.45	383.66	10.66	41 ^b		<.001	1.78	.005	.01	165.5 ^b		>.05
Chan.1		950	29.27	1.65					139.79	453.16					1.77	.005				
				1.15 ^c				<.01		1.18 ^c				<.01		1.00 ^c				>.01
River	1972	800	29.42	1.69	.12	119 ^b		>.05	149.76	329.35	1.00	125.5 ^b		>.05	1.80	.004	-.01	124 ^b		>.05
Chan.1		800	29.30	2.01					148.76	465.26					1.81	.005				
				1.19 ^c				<.01		1.41 ^c				<.01		1.25 ^c				<.01
River	1973	797	29.11	2.24	-.18	116 ^b		>.05	154.24	385.02	-.80	126 ^b		>.05	1.84	.006	.01	112.5 ^b		>.05
Chan.1		800	29.29	1.69					155.04	545.00					1.83	.006				
				1.33 ^c				<.01		1.42 ^c				<.01		1.00 ^c				>.01
River	1974	400	29.83	2.54	.38	25 ^b		>.05	153.02	559.98	-3.14	17 ^b		>.05	1.79	.008	-.04	17.5 ^b		>.05
Chan.1		550	29.45	2.05					156.16	419.17					1.83	.006				
				1.24 ^c				<.01		1.34 ^c				<.01		1.33 ^c				<.01
River	1975	448	29.99	1.98	.81	5.0 ^b		<.001	148.55	482.98	.55	30.0 ^b		>.05	1.76	.005	-.05	27.5 ^b		>.05
Chan.1		500	29.18	2.72					147.97	778.92					1.81	.008				
				1.37 ^c				<.01		1.61 ^c				<.01		1.60 ^c				<.01
River	1976	500	29.27	2.38	.39	20 ^b		.117	154.93	399.32	4.42	4 ^b		.001	1.83	.007	-.03	17 ^b		.065
Chan.1		494	28.88	1.97					139.11	360.54					1.79	.006				
				1.21 ^c				<.01		1.11 ^c				<.01		1.17 ^c				<.01
River	1977	500	29.82	1.28	1.42	473 ^d	-5.414	>.05	152.63	314.15	18.53	546.5 ^d	-4.751	>.05	1.79	.002	-.01	1099 ^d	-0.878	>.05
		436	28.40	1.63					134.10	385.04					1.80	.002				
				1.27 ^c				<.01		1.22 ^c				<.01		1.00 ^c				<.01

River, river samples; Chan.1, spawning channel no. 1 samples; N, number of fry in sample; S², variance of the mean; Δl, difference between means of parameter (R-1); U,Z,P, statistics of the Mann-Whitney test.

^b Test on sample means, n₁ = n₂ = 8.

^c Test on homogeneity of variances.

^d n₁ = n₂ = 11

APPENDIX TABLE II: Summary of annual mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry, in paired samples from Fulton River and Spawning Channel No. 2.

Sample	Date	N	Mean Length (mm)	S ²	Δl (mm)	U	Z	P	Mean Weight (mg)	S ²	Δl (mg)	U	Z	P	Index (K _D)	S ²	Δl (K _D)	U	Z	P
River	1970	1449	29.89	1.50	-.56	104 ^a	-4.922	0	142.67	455.85	-6.78	135 ^a	-4.440	0	1.74	.002	0	3.84 ^a	-5.68	.2850
Chan.2		1450	30.45	7.07					149.45	437.22					1.74	.004				
				4.71 ^c				<.01		1.04 ^c				<.01		2.00 ^c				<.01
River	1971	950	29.84	1.43	-.31	115.5 ^b		>.01	150.45	383.66	.17	166 ^b		>.01	1.78	.005	.02	121 ^b		>.01
Chan.2		950	30.15	1.45				>.01	150.28	442.91				<.01	1.76	.004				<.01
				1.01 ^c				>.01		1.15 ^c				<.01		1.25 ^c				<.01
River	1972	800	29.42	1.69	-.52	38 ^d		<.001	149.76	329.35	3.06	89.5 ^d		>.05	1.80	.004	.04	15.5 ^d		<.001
Chan.2		800	29.94	1.68				>.01	146.69	375.09				<.01	1.76	.002				<.01
				1.01 ^c				>.01		1.14 ^c				<.01		2.00 ^c				<.01
River	1973	797	29.11	2.24	-.25	83 ^d		.05	154.24	385.02	6.01	63.5 ^d		.001<p<.01	1.84	.006	.04	31		<.001
Chan.2		792	29.36	2.23				>.01	148.23	361.55				<.01	1.80	.008				<.01
				1.00 ^c				>.01		1.06 ^c				<.01		1.33 ^c				<.01
River	1974	400	29.83	2.54	-.45	13.5 ^f		.01<p<.05	153.02	559.98	5.93	8.0 ^f		.001<p<.01	1.79	.008	.05	5.0 ^f		.001
Chan.2		550	30.28	1.68				<.01	147.09	411.85				<.01	1.74	.004				<.01
				1.51 ^c				<.01		1.36 ^c				<.01		2.00 ^c				<.01
River	1975	448	29.99	1.98	-.06	39.0 ^g		>.05	148.55	482.98	-4.85	40.0 ^g		>.05	1.76	.005	-.01	36.5 ^g		>.05
Chan.2		500	30.05	1.88				<.01	153.40	575.52				<.01	1.78	.005				<.01
				1.05 ^c				<.01		1.19 ^c				<.01		1.00 ^c				<.01
River	1976	397	29.27	2.38	-.42	9.5 ^f		.0085	154.93	399.32	11.39	7.0 ^f		.0030	1.83	.007	.07	4 ^f		.0010
Chan.2		500	29.69	1.54				<.01	143.53	261.69				<.01	1.76	.004				<.01
				1.55 ^c				<.01		1.53 ^c				<.01		1.75 ^c				<.01
River	1977	475	29.82	1.28	0.84	788 ^e	-3.157	>.05	152.63	314.15	13.49	769 ^e	-3.189	>.05	1.78	.002	.01	112.1 ^e	-.724	>.05
Chan.2		486	28.98	1.82				<.01	139.14	459.77				<.01	1.78	.004				<.01
				1.42 ^c				<.01		1.46 ^c				<.01		2.00 ^c				<.01

River, river samples; Chan.2, Spawning Channel No. 2 samples; N, number of fry in samples; S², variance of the mean; Δl, difference between the means of parameter (River-Chan.2); U,Z,P, statistics of the Mann-Whitney test.

^a n₁ = n₂ = 29

^b n₁ = n₂ = 19

^d n₁ = n₂ = 16

^e n₁ = n₂ = 11

^f n₁ = n₂ = 8

^g n₁ = n₂ = 9

^c Test on homogeneity of variances.

APPENDIX TABLE III: Summary of annual mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from Fulton Spawning Channels No. 1 and No. 2.

Sample Date	N	Mean Length (mm)	S ²	Δi (mm)	U	Z	P	Mean Weight (mg)	S ²	Δi (mg)	U	Z	P	Index (K _D)	S ²	Δi (K _D)	U	Z	P
Chan.1 1970	1450	28.94	1.89	-1.51	3 ^b	-6.493	0	127.89	413.74	-21.56	2 ^b	-6.509	0	1.74	.005	0	304.5 ^b	-1.804	.0356
Chan.2	1450	30.45	7.07					149.45	437.22					1.74	.004				
			3.74 ^c				<.01		1.06 ^c				<.01		1.25 ^c				<.01
Chan.1 1971	950	29.27	1.65	-.22	37 ^b		<.001	139.79	453.16	-10.48	45 ^b		<.001	1.77	.005	.01	137 ^b		>.05
Chan.2	950	30.15	1.45					150.28	442.91					1.76	.004				
			1.14 ^c				<.01		1.02 ^c				<.01		1.25 ^c				<.01
Chan.1 1972	800	29.30	2.01	-.64	51 ^b		<.001	148.76	465.26	2.06	96.5 ^b		>.05	1.81	.005	.05	25.5 ^b		<.001
Chan.2	800	29.94	1.68					146.69	375.09					1.76	.002				
			1.20 ^c				>.01		1.24 ^c				<.01		2.50 ^c				<.01
Chan.1 1973	800	29.29	1.69	-.07	99.5 ^b		>.01	155.04	545.00	6.81	59 ^b		<.01	1.83	.006	.03	65.5 ^b		.001<p<.01
Chan.2	792	29.36	2.23					148.23	361.55					1.80	.008				
			1.32 ^c				<.01		1.51 ^c				<.01		1.33 ^c				<.01
Chan.1 1974	550	29.45	2.05	-.33	18 ^b		.001<p<.01	156.16	419.17	9.07	14 ^b		<.001	1.83	.006	.09	0		0
Chan.2	550	30.28	1.68					147.09	411.25					1.74	.004				
			1.22 ^c				<.01		1.02 ^c				<.01		1.50 ^c				<.01
Chan.1 1975	500	29.18	2.72	-.87	17.0 ^b		.025	147.97	778.92	-5.43	32 ^b		>.05	1.81	.008	.03	39.5 ^b		>.05
Chan.2	500	30.05	1.88					154.30	575.52					1.78	.005				
			1.45 ^c				<.01		1.35 ^c				<.01		1.60 ^c				<.01
Chan.1 1976	494	28.88	1.97	-.32	15.5 ^b		.001<p<.01	139.11	360.54	-4.42	27 ^b		>.05	1.79	.006	.03	29 ^b		>.05
Chan.2	500	29.67	1.54					143.53	261.69					1.76	.004				
			1.28 ^c				<.01		1.38 ^c				<.01		1.50 ^c				<.01
Chan.1 1977	500	28.40	1.68	-.58	957 ^d	-2.082	>.05	134.10	385.04	-5.04	1078 ^d	-1.183	>.05	1.80	.002	.01	1030 ^d	-1.514	>.05
Chan.2	486	28.98	1.82					139.14	459.77					1.78	.004				
			1.12 ^c				<.01		1.19 ^c				<.01		2.00 ^c				<.01

Chan.1, spawning channel no. 1 samples; Chan.2, spawning channel no. 2 samples; N, number of fry in sample; S², variance of the mean; Δi, difference between means of parameter (Chan.1-Chan.2); U,Z,P, statistics of the Mann-Whitney test.

^b n₁ = n₂ = 10

^d n₁ = n₂ = 11

^cTest on homogeneity of variances.

APPENDIX TABLE IV: Summary of annual mean lengths, weights and developmental indices, their difference and statistical significance, in paired samples from Pinkut Creek and the Pinkut Spawning Channel.

Sample Date	N	Mean Length (mm)	S ²	Δl (mm)	U	Z	P	Mean Weight (mg)	S ²	Δl (mg)	U	Z	P	Index (K _D)	S ²	Δl (K _D)	U	Z	P
River	1969	548	29.00	1.87	-1.47	0	<.001	142.43	269.29	-5.75	22 ^b		.001<p<.01	1.80	.005	.07	6.5 ^b		<.001
Chan.		550	30.47	1.25				148.18	444.43					1.73	.003				
				1.45 ^c			<.01		1.65 ^c				<.01		1.67 ^c				<.01
River	1970	1434	28.87	2.22	.65	211 ^b	.0006	124.70	390.07	11.67	120 ^b	-4.673	0	1.73	.005	.02	268.5 ^b	-2.364	.0090
Chan.		1450	28.22	2.00				113.03	364.39					1.71	.005				
				1.11 ^c			<.01		1.07 ^c				<.01		1.00 ^c				>.01
River	1971	900	29.29	2.22	-.61	109.0 ^b	.05	144.20	330.57	5.55	68.0 ^b		<.001 ^b	1.79	.006	.06	31.5 ^b		<.001
Chan.		900	29.90	1.87				138.65	344.19					1.73	.004				
				1.19 ^c			<.01		1.04 ^c				<.01		1.50 ^c				<.01
River	1972	200	28.70	1.81	-.94	0 ^b	.014	139.93	296.56	4.67	3 ^b		.100	1.81	.006	.08	.5 ^b		.022
Chan.		200	29.64	1.96				135.26	362.33					1.73	.005				
				1.08 ^c			>.01		1.22 ^c				>.01		1.20 ^c				>.01
River	1973	760	28.59	3.11	-.72	96.5 ^b	.01<p<.025	151.61	401.87	-1.42	150.0 ^b		>.05	1.87	.010	.05	93.0 ^b		.01<p<.025
Chan.		900	29.31	1.85				153.03	380.78					1.82	.004				
				1.68 ^c			<.01		1.07 ^c				<.01		2.50 ^c				<.01
River	1974	493	29.12	2.26	-.72	22.5 ^b	.01<p<.025	152.85	434.67	-6.45	27 ^b		.05	1.83	.006	.02	30.5 ^b		>.05
Chan.		500	29.83	1.74				159.30	453.55					1.81	.006				
				1.30 ^c			<.01		1.04 ^c				>.01		1.00 ^c				>.01
River	1975	1000	29.18	2.77	-.14	41.5 ^b	>.05	150.54 ^d	386.65	-2.49	4500 ^d	-1.221	.1110	1.79 ^d	.004	.03	3321.5 ^d	-4.102	0
Chan.		1000	29.32	1.84				153.03	1476.10					1.76	.002				
				1.51 ^c			<.01		3.82 ^c				<.01		2.00 ^c				<.01

River, river samples; Chan., channel samples; N, number of fry in sample; S², variance of the mean; Δl, difference between means of parameter (R-CH); U,Z,P, statistics of the Mann-Whitney test.

^b n₁ = n₂ = 10

^d n₁ = n₂ = 100

^cTest on homogeneity of variances.