AYK Region
Yukon Salmon Escapement
Report No. 29

Historic Data Expansion of Delta River Fall Chum Salmon Escapements and 1985 Population Estimates Based Upon Replicate Aerial and Ground Surveys

by

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December 1986

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ABSTRACT

Two methods were used to estimate total spawning escapements of Delta River fall chum salmon in 1975, 1976, 1977, and 1985. The two methods were based upon replicate point estimates (aerial and ground surveys) of escapement and average stream residence time data. A migratory time-density model was then developed for use in expanding peak point estimates of annual escapements in the historic data base to total abundance, thus allowing for more comparable results. It was determined that future point estimates should be made subsequent to November 1 and November 5, but prior to November 20, to maintain a tolerable error of not more than 15% with respective confidence levels of 90% and 95%.

INTRODUCTION

There has been an apparent decline in fall chum salmon escapements in recent years (since about 1980) to most known major spawning areas throughout the Yukon River drainage (ADF&G 1985, Buklis and Barton 1984, and Barton 1983). That this is true is most evident in decreased spawning escapements which have been primarily based upon low-level aerial survey estimates from small, single engine, fixed-wing aircraft. It is difficult at best, to quantify the exact decrease in escapements using aerial survey techniques due to the dependency of aerial surveys upon such factors as weather and water conditions, type of aircraft used, experience of pilot and observer, etc. However, Buklis and Barton (1984) estimated decreases in average escapements to approximate 42% and 58% in the Porcupine and Tanana river drainages, respectively, from the four-year period 1976-79 to the four-year period 1980-83. With exception of fall chum salmon spawning areas in the upper Tanana River in 1984 (including the Delta River), escapement estimates in 1982 and 1984 were the lowest ever recorded to major spawning areas throughout these two river drainages (Porcupine and Tanana). Average to above-average escapements were observed in 1985 to most areas.

Since aerial survey estimates can only be used to reflect trends in the relative abundance of spawners, due to underestimating total population of spawners (Cousens et al., 1982; Neilson and Geen 1981; Bevan 1961; Gangmark and Fulton 1952), a need has arisen to more precisely document fall chum salmon escapements to major spawning areas in the Yukon River drainage. Due to its accessibility and importance as a fall chum salmon spawning area, the Delta River was selected for studies in 1985. The primary objective was to estimate total spawning population based upon replicate foot surveys conducted throughout the duration of spawning and to develop a model for use in expanding point escapement estimates to total spawning escapement. Ancillary to this was to sample the 1985 fall chum salmon run for age, sex, and size composition.

DESCRIPTION OF STUDY AREA

The Delta River heads at Tangle Lakes near Paxon and flows north approximately 80 miles to the Tanana River at Big Delta (Figure 1). Only the upper 18 to 20 rivermiles are clear water. Downstream of the confluence of Eureka Creek, the Delta River takes the appearance of a typical glacial stream with turbid, silt-laden water and broad, braided channels. Its glacial nature is derived from numerous small tributary streams heading in the glacial ice fields of the Alaska Range.

A continuous alluvial apron exists in the Delta-Clearwater area by merging alluvial fans of the Delta and Gerstle rivers with those of small streams draining the north slope of the Alaska Range. The entire region is discontinuously underlain by permafrost, below which normally lies the water table of an extensive aquifer system.

Wilcox (1980) investigated and summarized the hydrology of the Delta-Clearwater region.

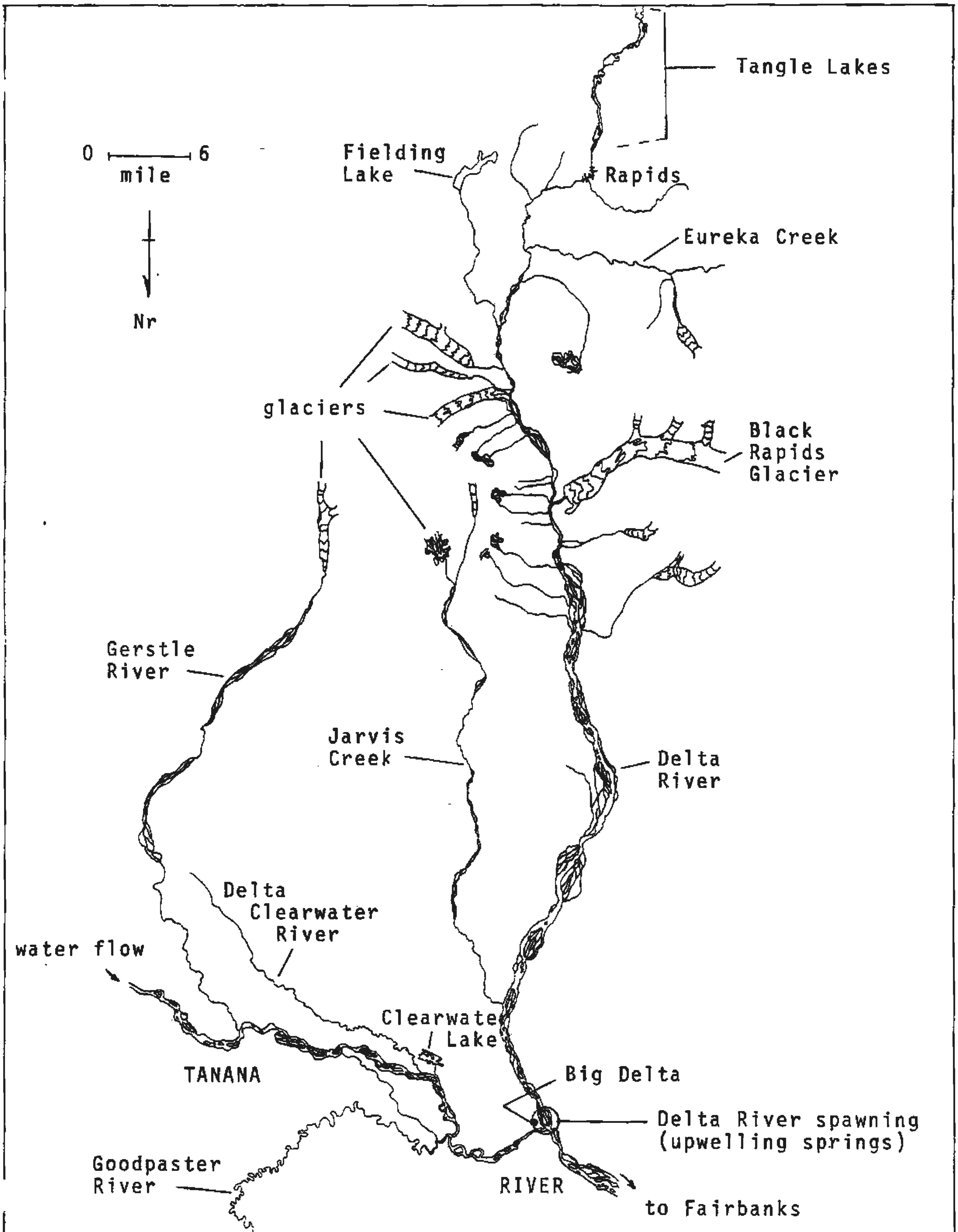


Figure 1. The Delta River drainage.

> "The alluvial aquifer system . . . is composed of thick sediments that overlie bedrock . . . . [It] is recharged by losing streams and by infiltration of precipitation . . . . Major discharge areas are along the Clearwater Creek [Delta Clearwater River] network, Clearwater Lake, and at springs near the mouth of the Delta River . . . . Aquifer discharge near Big Delta is recharged largely by seepage losses from the Delta River and Jarvis Creek . . . . Ground water levels fluctuate in response to seasonal recharge pulses to the aquifer from river and stream channel losses and from precipitation . . . . Water levels are lowest in late May or early June. River ice breaks up in April or May, and the recharge pulse begins; the ground-water level rises until it reaches a peak in October. At this time, the rivers freeze and recharge begins again. However, silt may clog the stream bed gravel and reduce permeability during much of the summer. Recharge may take place largely during periods of high flow when scouring and shifting of channels occur."

Andersen (1970) points out that glacial streams have a low variability in annual flow and thus large annual variations in ground water recharge are not likely to occur unless climate changes.

The Delta River flows high and turbid throughout the summer months with cold surface water runoff primarily from melting snow and ice. As freeze-up approaches, the flow of surface water gradually diminishes and eventually stops. Sub-permafrost springs which surface in channels of the lower river floodplain are the primary source of water flow between freeze-up and the following spring thaw. It is this concentrated area of upwelling spring water, in approximately the lower one mile of the river, which forms a unique fall chum salmon spawning area.

High-flow summer runoff carrying large amounts of sediments results in scouring and shifting of individual channels in the spawning area, and thus influence the amount of available spawning area from year to year. Although channel changes do occur, spawning in most years can be classified in three major areas: western channels which generally have the fewest number of spawners, mid or main river channels which generally have the greatest number of spawners, and eastern channels. The greatest degree of channel shifting from year to year occurs in the midriver and eastern channels. The eastern and western channel networks are not connected to the main river channel from approximately October through April, apart from the eastern channel network sharing a common mouth with the main river channel in some years. Most of the spring-fed areas remain relatively ice-free throughout the winter months.

Length of channels filled with spring water varies from a few to several hundred meters (m) while width may vary from less that 1 to 75 m. Maximum water depth ranges up to 1.2 m and surface water temperatures remain at 1° to 6°C throughout the winter (Francisco 1976). Skaugstad et al. (in print) found surface water temperatures in the Delta River ranging to a maximum of 5.8°C and intragravel water temperatures ranging from 0.5° to 6.6°C during winter investigations in 1981, 1983, and 1984. They reported that drops in water level in the spring-fed channels ranged between approximately 10 to 100 mm during the November to March period, with the exception of one year (winter 1983-84) in which water level in the main river channel rose

108 mm. This they attributed to a temporary warm spell which had no apparent effect on side channel water levels; side channel water levels fell 12 and 82 mm for the same period. On the average, water depth in early October declined approximately 100 cm in the main channel and 20-60 cm in the eastern and western channels.

Fall chum salmon begin to arrive in the Delta River in late September and spawning may continue well into December. In general, it can be stated that peak spawning in the Delta River occurs toward the end of October or in early November, although time of peak spawning may differ among channels. Coho salmon have been observed only in very low numbers (25-30) and mostly confined to the western channel network. Their arrival is generally later than that for chum salmon, occurring in late October, and several of these fish may actually spawn in areas farther up the Tanana River.

Fall chum salmon first enter the western channel, which is nearly always the first to become separated from the main river channel and clear from the influx of spring water. This normally begins in late September. Spawning usually occurs next in the eastern channels. The mid or main river channel is not utilized to a major extent until approximately mid-October when the river is nearly frozen to the bottom above the spawning area and most of the flow of cold silty surface water stops. The midriver channel usually accounts for the highest number of spawners annually. The entire flow to all channels during spawning, egg incubation, and fry development stages (late October through approximately April) is supplied by spring water. Wilcox (1980) states that total discharge of several perennial springs at the mouth of the Delta River was measured at about 30 ft^3/sec in March 1975, 1976, and 1977. Discharge estimates made at several locations in the main channel ranged from 0.2 to 5 ft^3/sec and 1.7 to 29.6 ft^3/sec in March 1982 and 1984, respectively (Skaugstad et al., in print).

Nature of the Delta River floodplain, spring-fed spawning habitat together with time of spawning make this region one of the most unique spawning areas in Interior Alaska. Although redds are abundant in most of the deeper glides between riffle zones or are constructed in deeper pools, many spawners deposit eggs in extremely shallow, quiet water zones or pools where water depth may be only sufficient enough to cover most of the salmon's head and ventral half of the body. Prior to reaching such areas, large numbers of salmon often overcrowd into pools immediately downstream of extremely shallow riffles which may extend to beyond 10 m in length. Many salmon successfully negotiate riffles where water depth may not exceed 3-5 cm. A few become entrapped or manage to end up stranded among the larger rocks and die unspawned. A few riffles are too shallow to allow any passage.

It is not uncommon for spawning to occur when air temperatures plunge well below 0°F in most years (-25° to -35°F). At such times, where spawning occurs in extremely shallow water, large ice formations often develop around the base of the dorsal fin and upper dorsal lobe of the caudal fin. Even some freezing of body tissue in the region around the dorsal fin has been observed.

Although precise studies on the wash-out rate of carcasses have not been conducted in the Delta River, it is believed that the shallow riffle zones together with other physical and hydrological characteristics of the spawning area tend to reduce dead or moribund salmon from drifting from the spawning grounds. This phenomenon is probably most applicable to those areas where spawning occurs well upstream. However, where spawning occurs in the lower 100 m or so of each channel the wash-out rate of salmon carcasses and moribund fish into the Tanana River may be much greater than suspected. Wash-out rate probably diminishes as the spawning period progresses, due to diminishing water levels and decreased velocity.

METHODS

Maps of the open water spawning channels were prepared for 1974 and 1975 from overhead aerial photographs taken by Trasky (1976) and Francisco (1977). Open water areas in 1977, 1984, and 1985 were prepared by drawing in the approximate location of channels, using the overhead aerial photographs taken by Trasky and Francisco as a base and photographs obtained from various land-based and aerial angles in 1977, 1984, and 1985 (Figures 2 through 4).

Foot surveys of the Delta River spawning area were made weekly beginning in late September and continuing through early December 1985. Both live and dead chum salmon were enumerated in each spawning channel, i.e., eastern, mid or main river, and western channels. Polaroid sunglasses were worn to reduce surface glare. A riverboat was used to gain access to western spawning channels as necessary when the main river channel was too high to allow crossing by foot.

An aerial survey of the Delta River spawning area was flown near peak spawning on October 26 for subsequent comparison with population estimates.

Two methods were employed to develop population estimates using the 1985 survey data. The first method involved plotting counts of live salmon by survey date and estimating the area under the curve (A) by the following equation:

$$A = \sum_{n=1}^{N-1} \left[\left(\frac{C_n + (C_n + 1)}{2} \right) \left(D_{n+1} - D_n \right) \right]$$

where: A = total number of salmon days
C_n = live salmon count on foot survey conducted on day n
D^n = date of survey
N = total number of surveys

The total number of salmon days (A) would give the number of live salmon in the Delta River if stream residence time was one day. Division by residence time yielded an estimate of total population. Residence time was based upon stream life data collected from the Delta River in 1973 and 1974 (Trasky 1974, 1976). Only foot survey observations were included in this analysis.

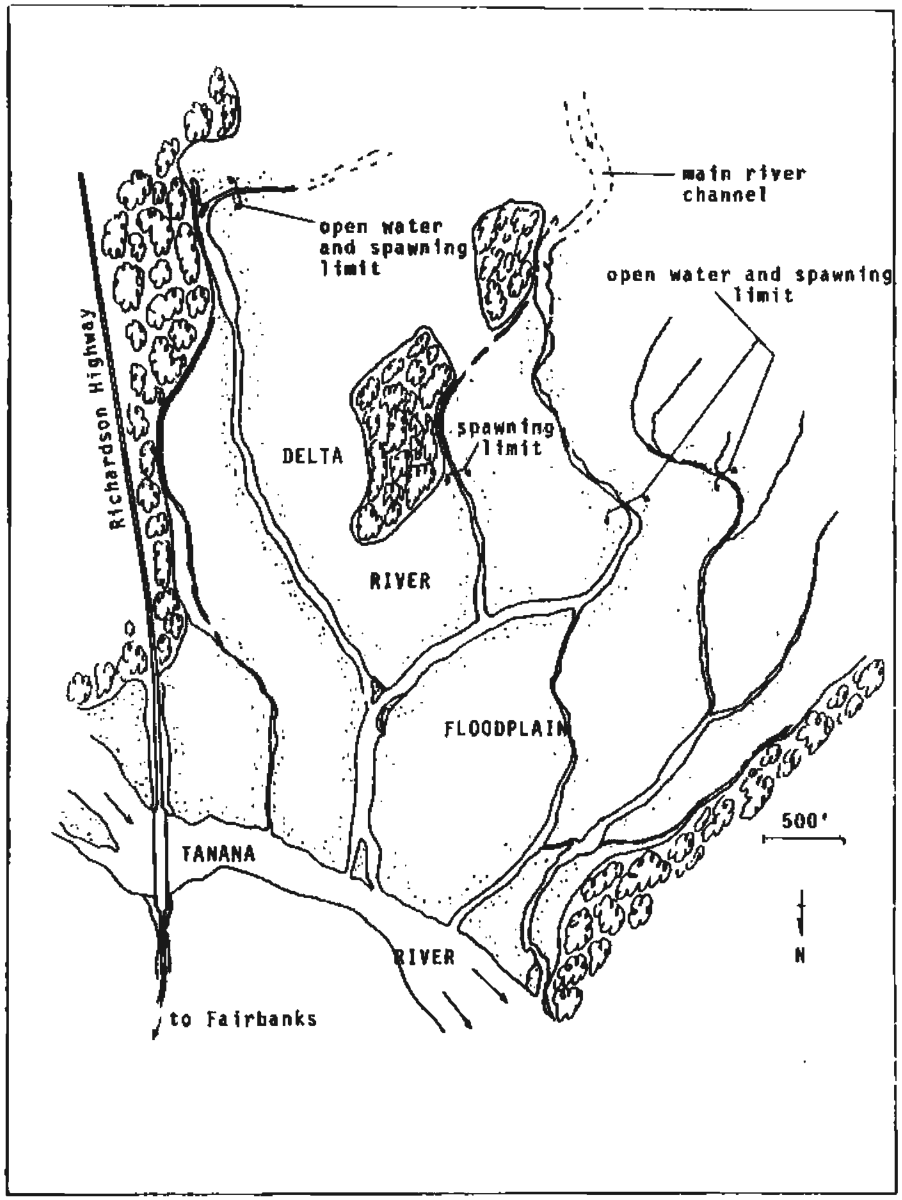
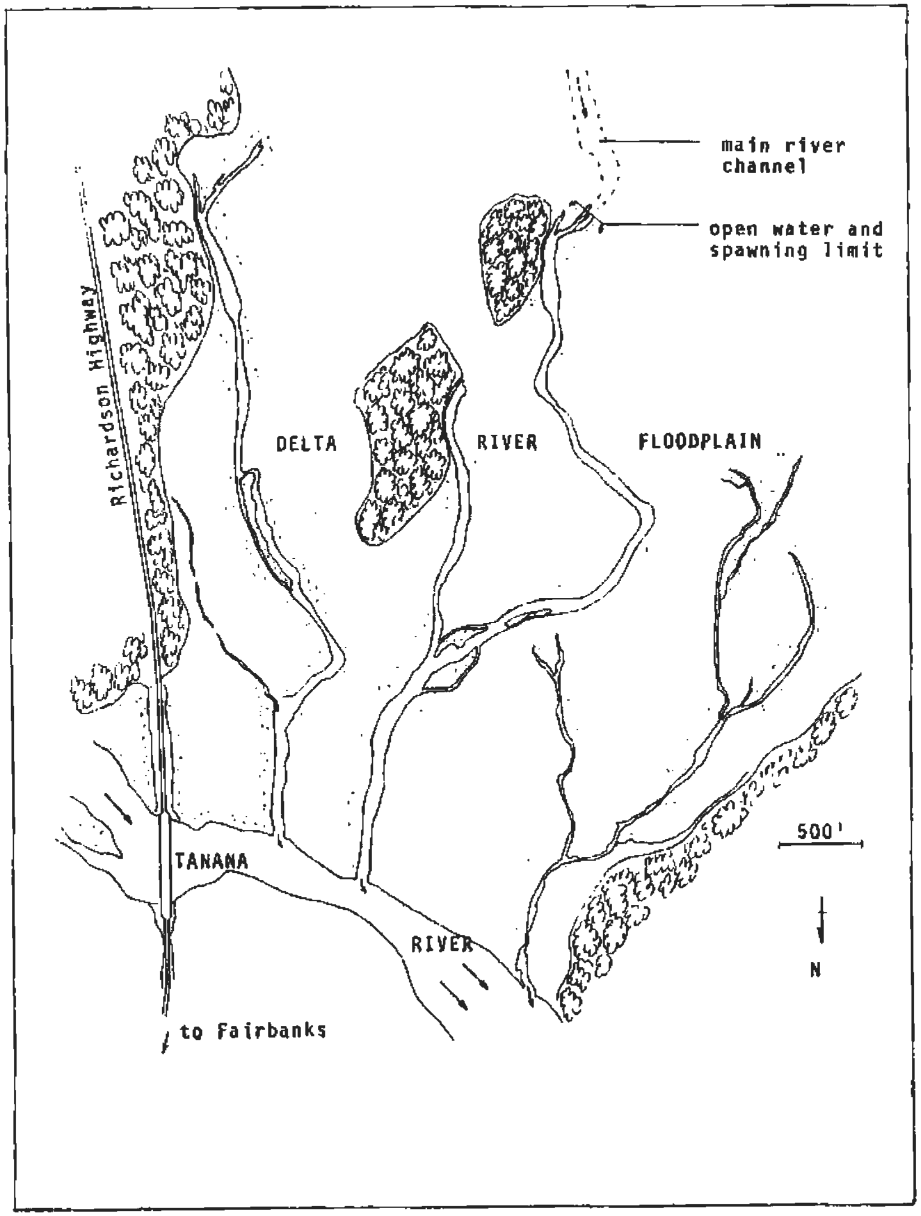


Figure 2. Delta River fall chum salmon spawning area October 1985.



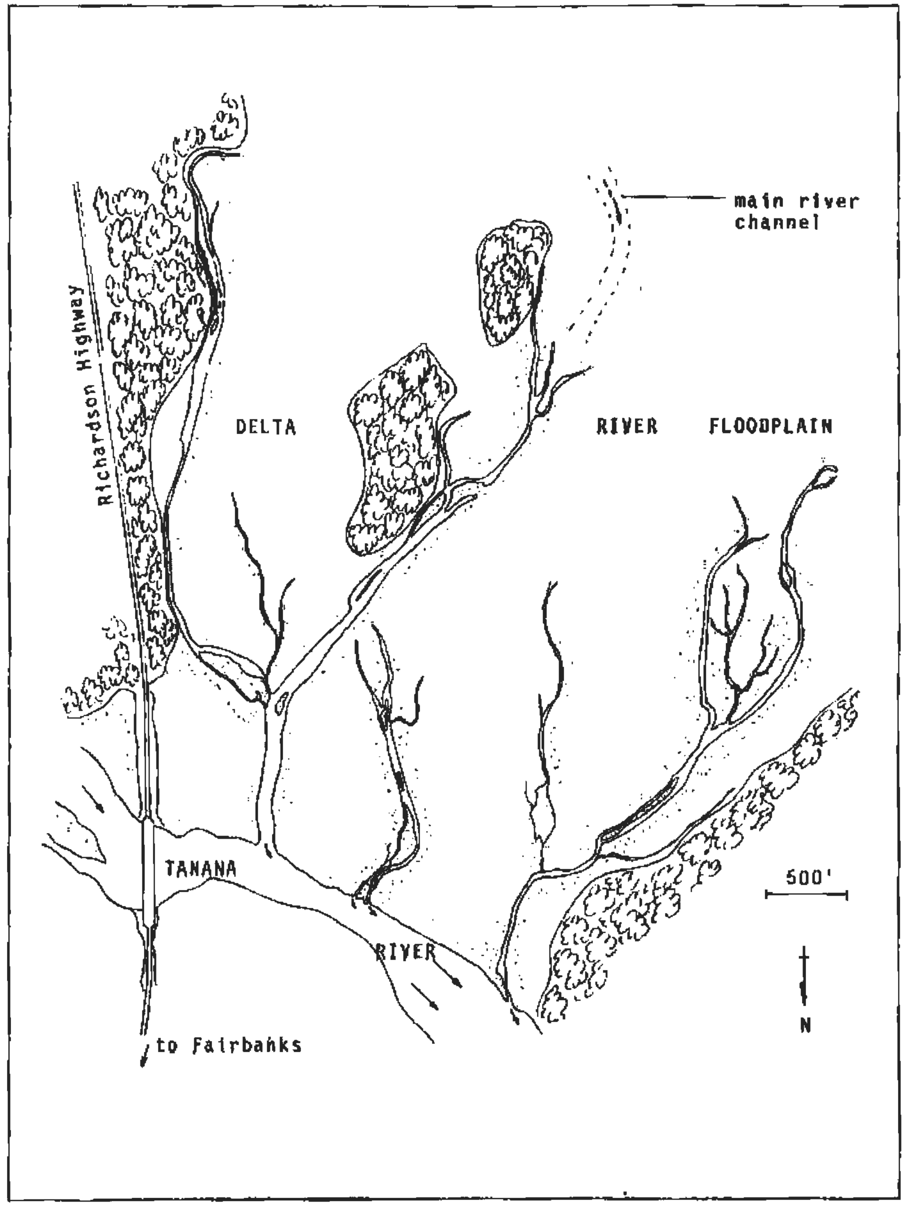


Figure 3. Delta River fall chum salmon spawning area October 30, 1984 (left) and November 1977 (right).

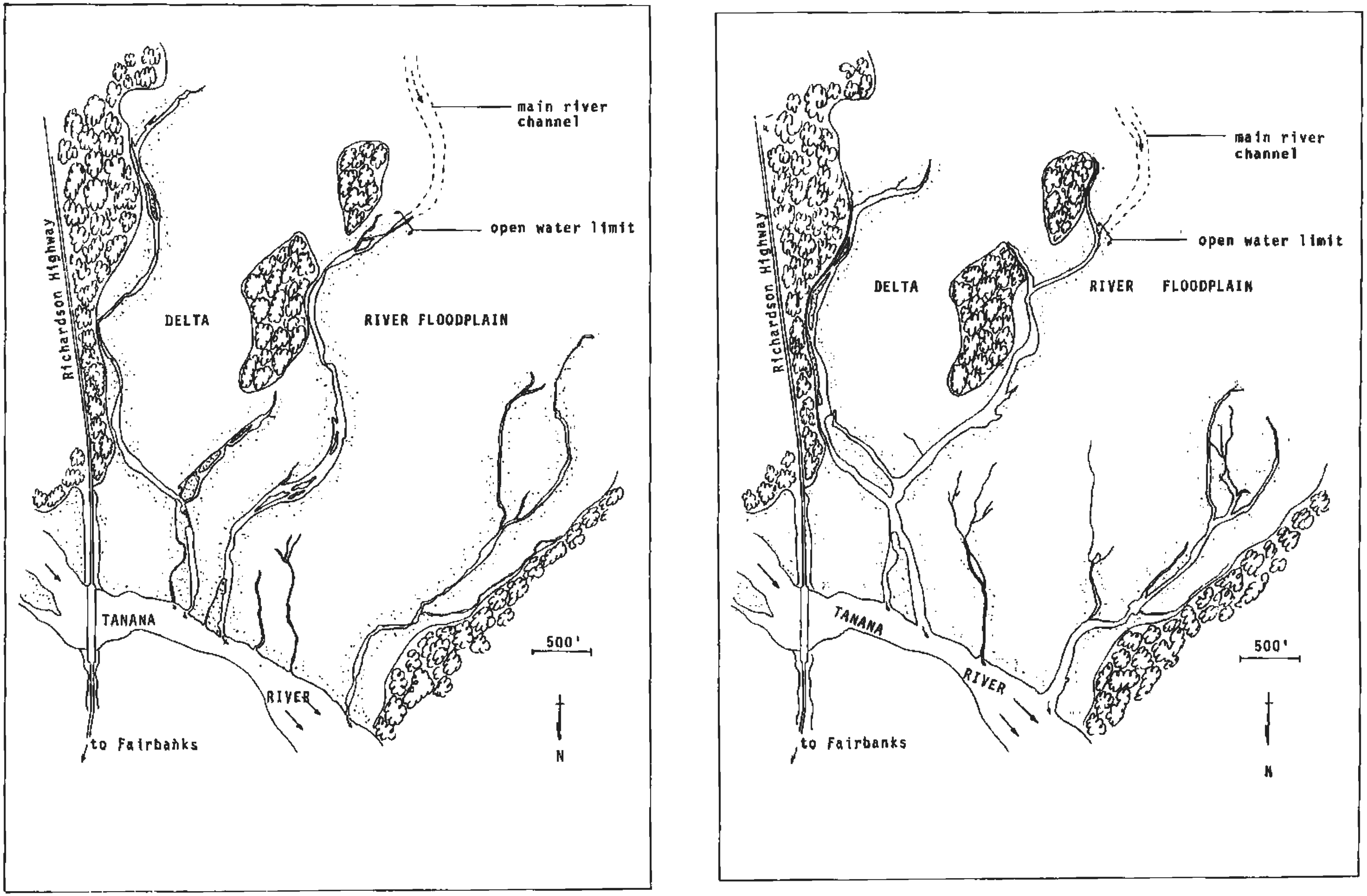


Figure 4. Delta River fall chum salmon spawning area November 7, 1975 (left) and November 1, 1974 (right).

The second method used to estimate total abundance in 1985 was as follows. The number of live salmon observed on a specified day was the sum of the number of live fish remaining from the previous survey(s) and the number of new fish entering the stream subsequent to the previous survey. The number of fish which had spawned and died between surveys was estimated from Trasky's studies on stream residence time (Appendix Table 1). Total run size was approximated by summing the numbers of new salmon estimated entering in each interval of time and adding this estimate to the number of carcasses counted on the last survey minus the estimated number of carcasses previously counted as live fish. Aerial observations on October 26 were included in this analysis. This second method of estimating total abundance is represented by the following equation:

$$\text{Total run size to date } D = \begin{bmatrix}\text{number of live fish}\\ \text{entering over each}\\ \text{time interval } i\end{bmatrix} + \begin{bmatrix}\text{number of carcasses}\\ \text{not previously}\\ \text{counted as live fish}\\ \text{(must be positive}\\ \text{or zero)}\end{bmatrix}$$

or:

$$D = \sum_{i=1}^{D} B_i + \left(E_D - \sum_{i=1}^{D-1} (1-P_{ij})B_i\right)$$

where: B_i = number of new fish entering the stream subsequent to the previous survey and is calculated as:

$$B_i = C_i - \sum_{j=1}^{i-1} B_j\, P_{ij} \qquad \text{note } B_1 = C_1$$

C_i = live salmon count on survey i

P_{ij} = proportion of the fish that entered on day j that are still alive on day i (from stream residence data in Appendix Table 1)

E_D = carcass count for survey on day D.

RESULTS AND DISCUSSION

Population Estimates

Trasky (1974, 1976) found average residence time of Delta River fall chum salmon to be 20.5 and 16.5 days in 1973 and 1974, respectively. In both years, average residence time was similar but slightly longer in the western channels as opposed to eastern channels, while being substantially shorter in the midriver channels. This he attributed to delayed spawning and later entry of chum salmon into the midriver channels. Pooling Trasky's data from each year's study results in the following average stream residence times (Appendix Table 1 and Figure 5).

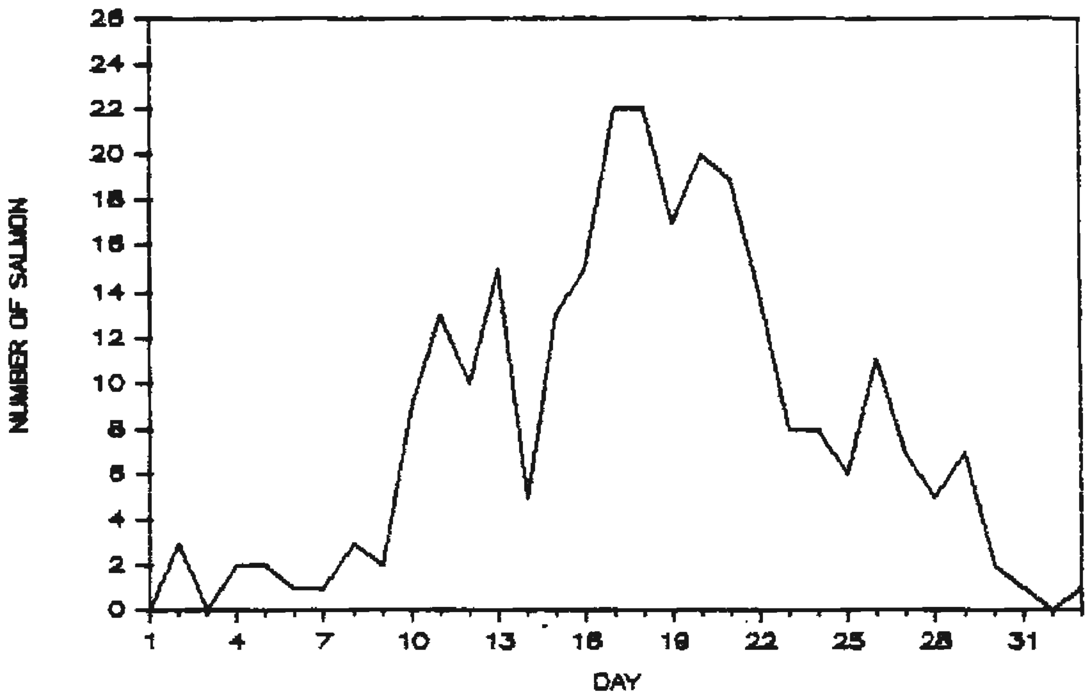


Figure 5. Average stream residence time for Delta River fall chum salmon based upon pooled data from 1973 and 1974. Data from Trasky (1974, 1976).

western channels 20.8 days
eastern channels 20.0 days
midriver channels 15.6 days
total all channels 18.2 days

Entry time and spawning in the various channels in 1985 were consistent with those identified in previous years; occurring first in the western channels, followed by the eastern and finally midriver channels (Figure 6 and Table 1). However, since channels are subject to annual change due to scouring from high flow spring and summer runoff, the overall average stream residence time from Trasky's pooled data (18.2 days) was used to estimate total population size in 1985. This further seems plausible since emigration among channels occurs. In both 1973 and 1974 Trasky found the western channels had the smallest available spawning area and greatest emigration, while the midriver channels possessed the greatest spawning area and least amount of emigration. Reasons for observed emigration were not clearly identified, but overcrowding was not considered to be the cause.

Total number of salmon days, i.e., area under the curve, was estimated to be 316,789 in 1985 using the first method to generate a total population estimate (Figure 7). Division by the mean residence time of 18.2 days yields a population estimate of 17,406 chum salmon. This estimate can be considered conservative as turbidity problems in portions of some channels early in the season and developing shore ice late in the season hindered live salmon counts.

Table 2 shows the estimated number of new salmon entering the Delta River in 1985 between subsequent surveys. Following the second method, summation of these estimates gives a total population of 17,147 chum salmon. Note that no new fish were observed entering the Delta River between November 1 and November 8. In fact, observations of live fish on November 8 were not of the magnitude to even compensate for those expected to still be alive from previous surveys based on resident time data. At least two possibilities could have occurred to explain this. First, the November 8 survey was made under poor survey conditions and a low estimate of live fish may have occurred, or secondly, inaccuracy associated with stream residence time may exist. November 8 survey results were omitted from this method of estimating total population.

It should also be pointed out that an accurate carcass count could not be made on the December 5 survey. First, many chum salmon carcasses had been removed subsequent to November 20 by subsistence-use permit holders and secondly, thin layers of surface ice in many spawning pools had accumulated, preventing accurate counts from being made. Consequently, the latter part of the equation associated with calculating a population estimate using method 2 was omitted, i.e., the number of carcasses counted on the last survey (December 2) minus the estimated number of carcasses previously counted as live fish.

The best estimate of total fall chum salmon escapement in the Delta River in 1985 is considered the midpoint between the two population estimates generated, or 17,276. The peak salmon count was made on the November 1 foot survey when 16,158 fish were enumerated (13,898 live; 2,260 dead).

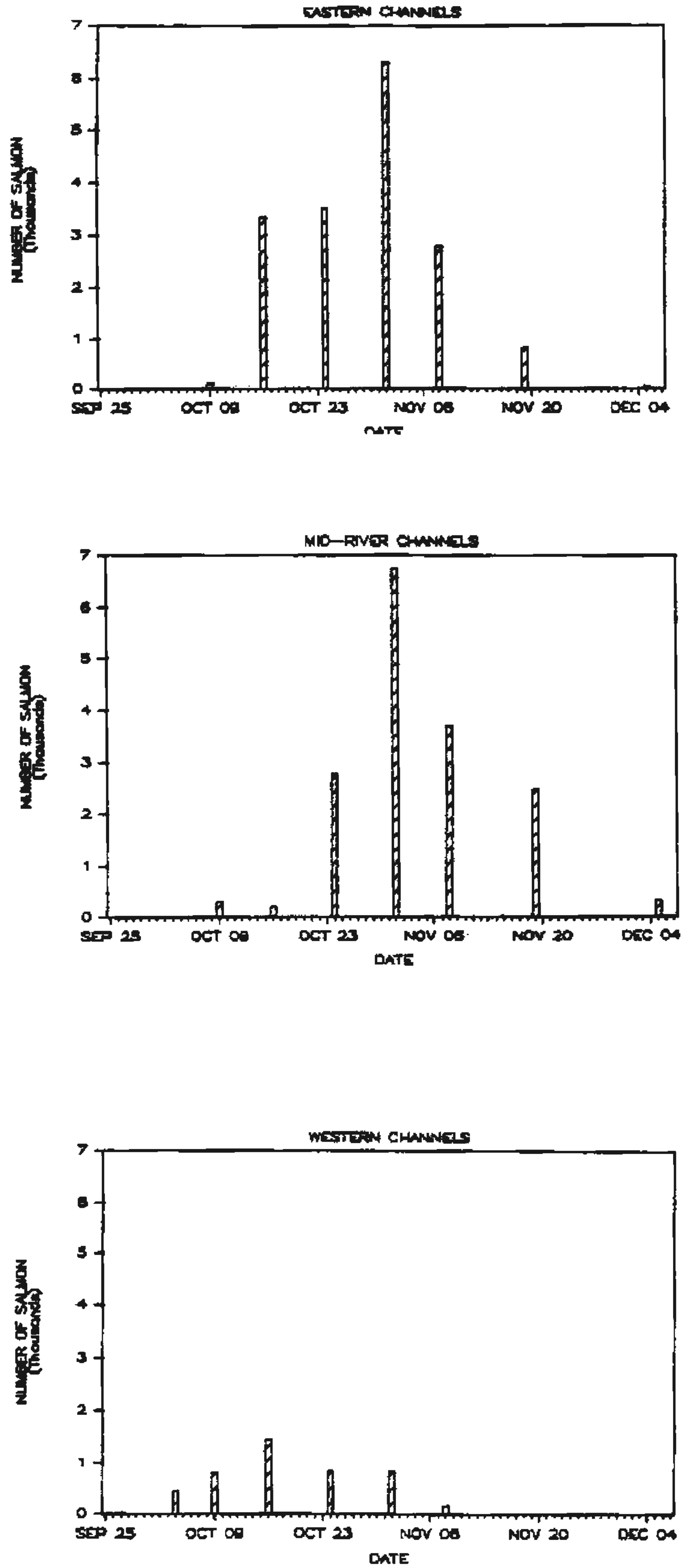


Figure 6. Counts of live fall chum salmon by spawning channel in the Delta River in 1985.

Table 1. Fall chum salmon escapement survey counts in the Delta River, 1985.

	TYPE	EASTERN CHANNELS a			MID OR MAIN RIVER CHANNELS b			WESTERN CHANNELS c			TOTAL DELTA RIVER AREA		
DATE	SURVEY	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL
SEP 27	FOOT			TURBID			TURBID	43	0	43	43	0	43
OCT 04	FOOT			TURBID	17	0	17	440	4	444	457	4	461
OCT 09	FOOT	98	0	98	296	1	297	797	26	823	1,191	27	1,218
OCT 16	FOOT	3,343	3	3,346	188	0	188	1,445	92	1,537	4,976	95	5,071
OCT 24	FOOT	3,545	153	3,698	2,782	60	2,842	826	73	899	7,153	286	7,439
NOV 01	FOOT	6,321	1,509	7,830	6,760	563	7,323	817	188	1,005	13,898	2,260	16,158
NOV 08	FOOT d	2,797	2,492	5,289	3,690	1,295	4,985	176	156	332	6,663	3,943	10,606
NOV 19	FOOT	808	6,120	6,928	2,463	5,894	8,357	29	519	548	3,300	12,533	15,833
DEC 05	FOOT	50	--	50	328	--	328	1	--	1	379	0	379
OCT 26	AERIAL										11,614	611	12,225

a Includes channel I.

b Includes channels II and II 1/2.

c Includes channel III.

d Poor survey

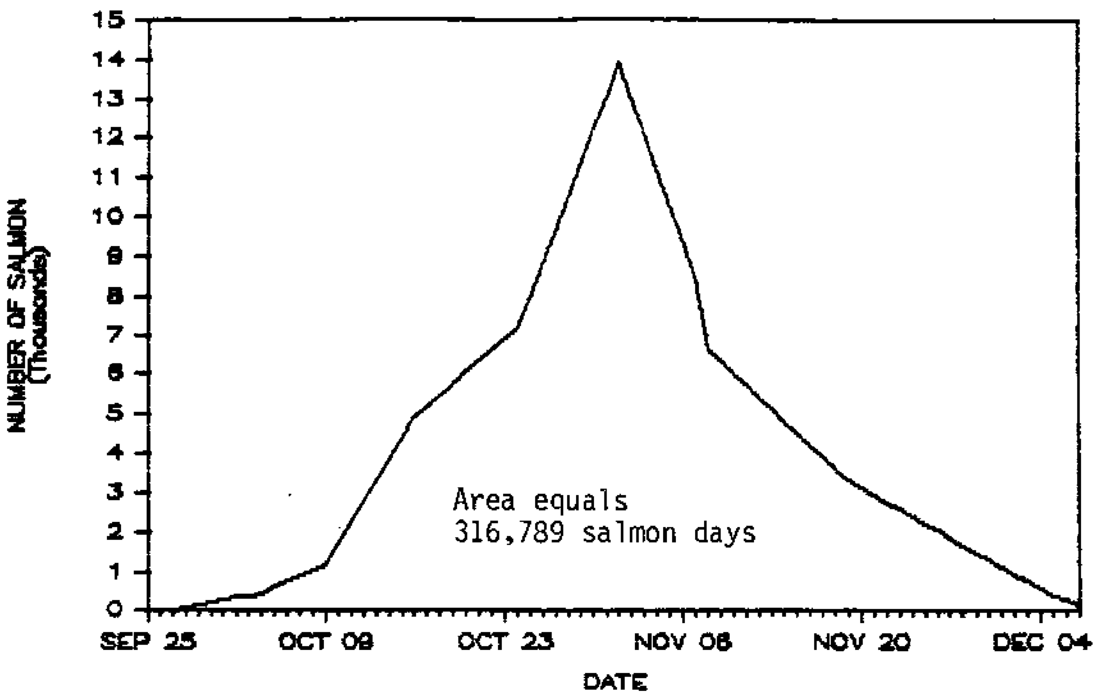


Figure 7. Spawner abundance curve for fall chum salmon in the Delta River in 1985 based upon live salmon counts by date.

Table 2. Estimated number of fall chum salmon entering the Delta River by survey date in 1985.[a]

DAY	DATE	INTER-VAL	SEP 27 DEAD	SEP 27 LIVE	OCT 4 DEAD	OCT 4 LIVE	OCT 9 DEAD	OCT 9 LIVE	OCT 16 DEAD	OCT 16 LIVE	OCT 24 DEAD	OCT 24 LIVE	OCT 26 d DEAD	OCT 26 d LIVE	NOV 1 DEAD	NOV 1 LIVE	NOV 8 e DEAD	NOV 8 e LIVE	NOV 19 DEAD	NOV 19 LIVE	DEC 5 DEAD	DEC 5 LIVE
1	9/25																					
		2																				
3	9/27		(0)b	43 c																		
		7	1																			
10	10/4			42	(4)	415 c																
		5	6		11																	
15	10/9			36		404	(27)	751 c														
		7	18		61		26															
22	10/16			18		343		726	(95)	3,889 c												
		8	15		203		199		175													
30	10/24			3		140		527		3,714	(286)	2,769 c										
		2	3		52		105		163		30											
32	10/26 d			0		88		421		3,551		2,739	(611)	4,815 c								
		6			71		285		1,046		94		144									
38	11/1					17		137		2,505		2,645		4,670	(2260)	3,924 c						
		7			17		131		1,797		703		968		133							
45	11/8 e					0		6		708		1,941		3,702		3,791	(3943)	(3,485)c				
		11					6		708		1,700		2,971		1,919							
56	11/19							0		0		241		732		1,872			(12533)	455 c		
		16									241		732		1,872				162			
72	12/5											0		0		0				293		86 c
		2																	76		1	
74	12/7																			217		85
			43		415		751		3,889		2,769		4,815		3,924		0		238		1	

a All observations based upon foot surveys unless otherwise noted. Live fish shown below new fish entering the stream are those remaining alive on subsequent surveys based upon stream residence time data from Trasky (1974, 1976). Dead fish shown below new fish entering the stream are number of salmon which died in that interval of time.

b The number in parentheses is actual number of carcasses observed.

c New fish entering the stream.

d Aerial survey.

e Survey results were not included in the analysis for this day - POOR SURVEY

This count was 93.5% of the final population estimate. By comparison, the October 26 aerial survey accounted for 12,225 salmon (11,614 live; 611 dead) and represented only 70.7% of the population estimate.

Age, Sex, and Size

A total of 357 fall chum salmon were sampled for age, sex, and size composition from October 21 to November 11, 1985. One hundred fifty of these fish were further sampled for subsequent protein electrophoretic analysis by the Canadian Department of Fisheries and Oceans. Only 256 (72%) of the scale samples were ageable. Age 4_1 fish predominated, representing 76% of the total sample, followed by age 3_1 fish (14%) and age 5_1 fish (9%). There was only one age 6_1 fish. The male-to-female ratio was 1.00:1.56, or 39% males and 61% females. Size-at-age data are shown in Appendix Table 2 for each sex.

HISTORIC DATA EXPANSION

The existing data base on fall chum salmon escapements to the Delta River was examined to determine whether data from other years could be used to generate population estimates by using one or both of the above techniques. Frequency and timing of surveys in only three years were sufficient to allow for population estimates: 1975, 1976, and 1977. Although replicate surveys were also made in 1984, timing of surveys was such that the entry pattern of fall chum salmon into the Delta River could not be precisely identified (Barton 1985, intra-Department memo). Thus, no population estimate could be generated for that year.

Individual survey results for 1975, 1976, and 1977 are given in Appendix Tables 3 through 5. Population estimates for each of these years, generated from plotting a spawner abundance curve, were based upon foot survey counts of live salmon only and an average stream residence time of 18.2 days. Population estimates were 3,895, 6,279, and 17,388 chum salmon for 1975, 1976, and 1977, respectively.

The estimates for 1975 and 1976 differ slightly from those calculated by Francisco (1976) and Francisco and Dinneford (1977), who used the same method, for two reasons. First, they included aerial survey counts of live salmon in plotting spawner abundance curves. Further, their estimates were in the form of a range for each year since they used the average residency time Trasky calculated in both 1973 and 1974, i.e., 20.5 and 16.5 days, respectively.

A second population estimate was generated for 1975, 1976, and 1977 following the second method, i.e., the summation of the estimated number of new salmon entering the Delta River between surveys based upon average stream residence data obtained by Trasky (Appendix Tables 6 through 8). Population estimates were 3,574, 6,346, and 16,365 chum salmon for 1975, 1976, and 1977, respectively. Only foot survey counts of live salmon were used to generate these estimates, with the exception of 1975 in which results of live salmon counts during one aerial survey were also included.

The four years in which population estimates were made by each method as well as the difference between each estimate are summarized below.

Year	Population estimate[a] method 1	Population estimate[a] method 2	Difference	Best estimate[b]
1975	3,895	3,574	321	3,734
1976	6,279	6,346	67	6,312
1977	17,388	16,365	1,023	16,876
1985	17,406	17,147	259	17,276

[a] Method 1 based upon estimated area under spawner abundance curve. Method 2 based upon summation of estimated new fish entering stream between surveys.

[b] The best estimate of chum salmon escapement in each of these four years was taken as the midpoint between the two estimates generated each year.

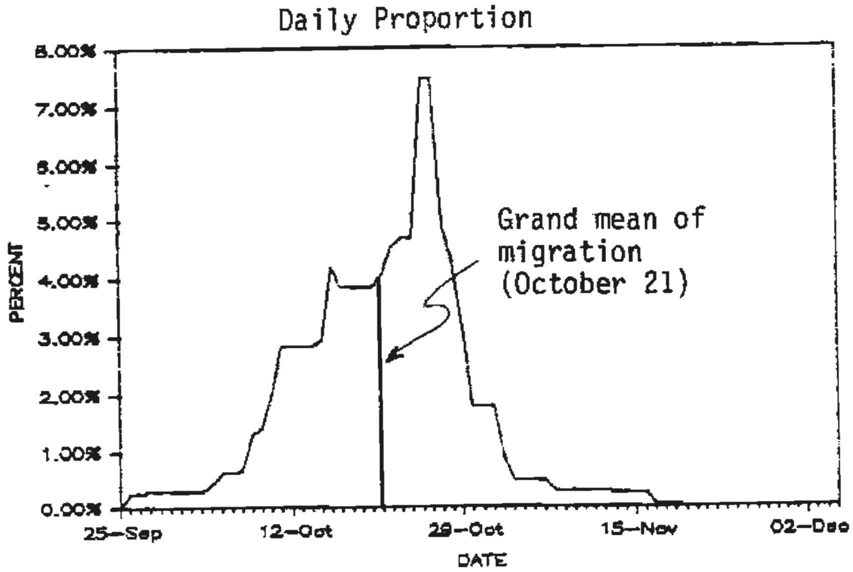
Average timing of fall chum salmon to the Delta River was examined by analyzing the estimated number of new salmon entering the river between subsequent aerial and ground surveys made each year in 1975, 1976, 1977, and 1985. The four-year average daily and cumulative proportions of new fish entering the Delta River by date are shown in Appendix Table 9 and Figure 8.

Mundy (1982, 1984) developed a time-density model to describe salmon run timing. The pattern of the migration is described by the mean date of passage (a measure of the central tendency) and the standard deviation (a measure of dispersion). The statistics are calculated from the proportion of the total escapement occurring each day.

Adult chum salmon entered the Delta River between September 25 and December 5 when examining the data from 1975-1977 and 1985. On the average, one-half of the run had entered by October 22 with less than 1% entering subsequent to November 14 (Appendix Table 9). The central half of the spawning population (25%-75%) entered the river over an average span of 11 days from October 16 to 26, while the bulk of the run (2.5% to 97.5%) entered over a much longer time period (an average of 37 days from October 4 to November 9).

The mean dates of run timing to the Delta River were October 18 in 1977; October 22 in 1975 and 1985; and October 23 in 1976. Median dates, the date on which 50% of the run was in the river, coincided with or closely followed mean dates. Median dates were October 19 in 1977; October 23 in 1975 and 1976; and October 25 in 1985.

The daily averages in cumulative proportion of the run entering the Delta River show a linear increase of approximately 3%-4% per day between October 11 and October 29. The variance associated with cumulative



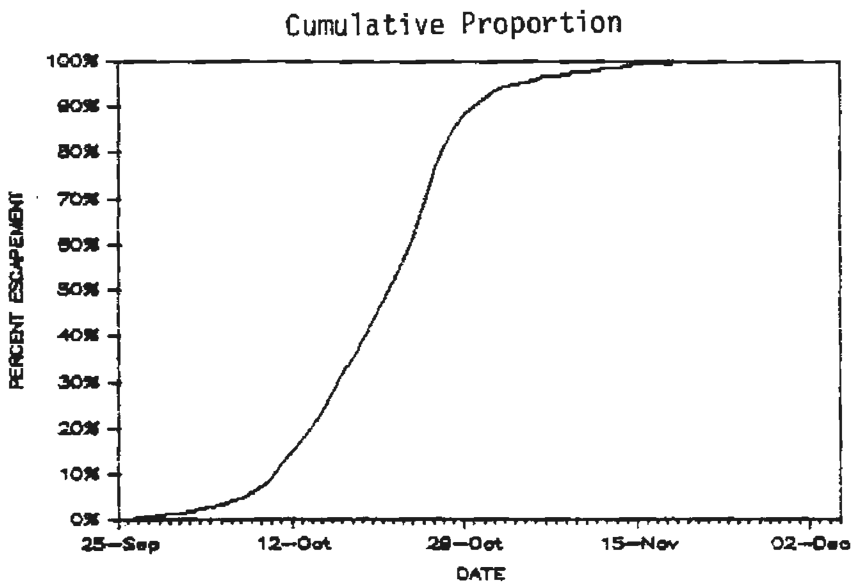


Figure 8. Fall chum salmon run timing based upon the 4-year average daily (top) and cumulative (bottom) percentages of new fish entering the Delta River in 1975, 1976, 1977, and 1985.

proportion estimates is greatest on October 24, peaking in the area of the grand mean of run timing (about October 21) (Figure 9). Since the migratory time-density curve is used to predict total run size from survey counts for a given year, the sample variance (s^2) was considered in constructing confidence intervals as opposed to the variance of the mean proportion (s^2/n) of that day. Thus, 95% confidence intervals were constructed as follows:

$$\bar{x}_i \pm t_{(0.025)} \sqrt{s^2_i}$$

where: $\bar{x}_i$ = mean of cumulative proportion of run on day i

$t_{(0.025)}$ = 3.182 (with 3 degrees of freedom)

s^2_i = sample variance for day i

The absolute error associated with a 95% confidence interval which occurs when predicting total run size from average cumulative proportions observed in the migratory time-density curve is shown in Figure 10. The straight line in Figure 10 portrays the tolerable percent error in a population estimate relative to any point in the run. It represents 15% error in the population estimate at the 90% and 95% confidence levels. Where the absolute error crosses and falls below the tolerable error line represents when acceptable population estimates can be made. For example, with a tolerable error of 15% and a confidence level of 95%, this point corresponds to November 6 on the migratory time-density curve. By that date, 96.62% of the run has entered the river, on the average. Any population estimates made subsequent to November 5 would result in an error of less than 15% at the 95% confidence level.

It should be noted that to maintain a 15% error limit in the estimate of run size, the confidence limits on the percentage of the run on a given date should be less than 1 - 1/1.15, or 13.04% of the estimated run proportion. For example, by November 6, 96.62% of the run is estimated to have entered the river with a 95% confidence level of ±12.62%. Note that 0.1262/0.9662=13.06%. Since the 95% confidence interval approximates the 13.04% criteria, the confidence limits around 96.62% of the run would be 96.62% ± (0.1306)(96.62%) or 84.00% of 109.24% of the run, respectively. The 109.24% is adjusted downward to 100% since the lower confidence limit can never fall below what was actually observed. Thus, if 5,000 fish were counted on November 6 in a given year, total run size would be estimated as 5,000/96.62% or 5,174 fish. The confidence limits would be 5,000/100% (5,000 fish) and 5,000/84.00% (5,952). Now, (5,952-5,174)/5,174 = 15% of the estimate of 5,174. Thus, the 15% relative error line in Figure 10 was plotted by multiplying the average daily cumulative proportions in the time-density curve by 13.04%. At a 90% confidence level the 13.04% criteria is met on November 2.

Eggers (1984, unpublished) showed that for situations of rapid salmon run entry and protracted dying (stream life) there was close agreement between peak abundance and cumulative escapement. Conversely, protracted entry and short stream life results in extreme divergence between peak abundance and cumulative escapement.

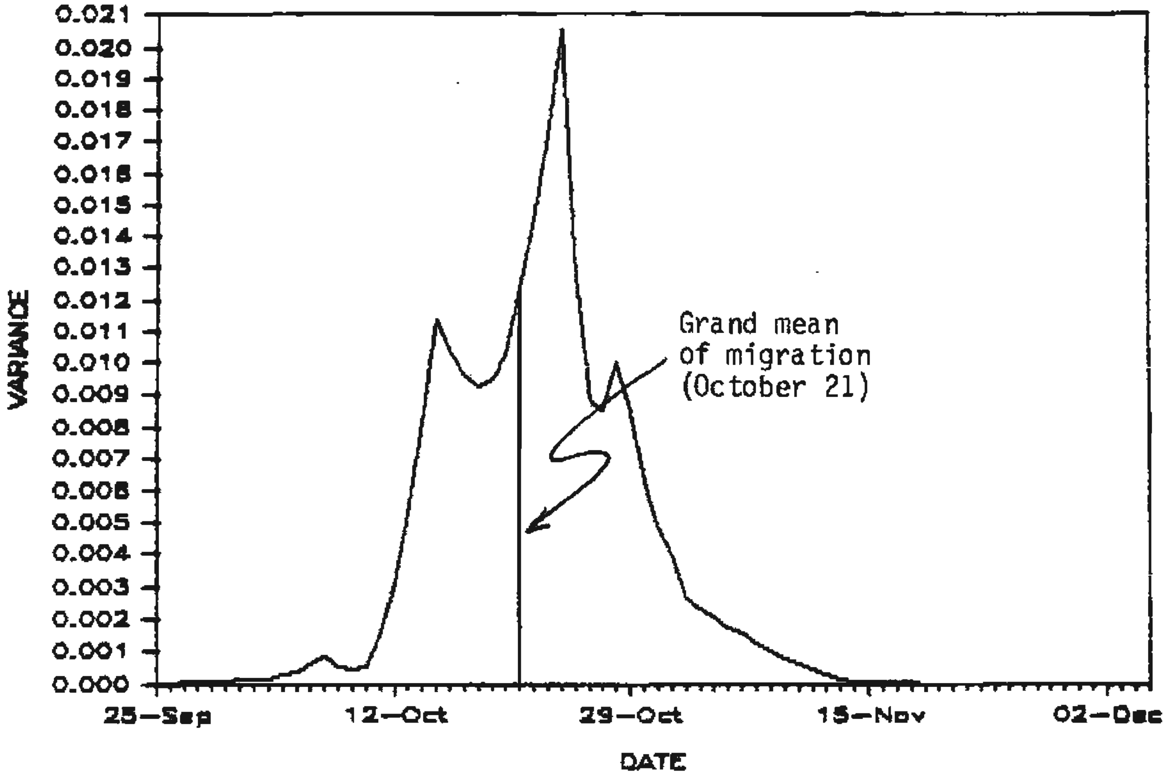
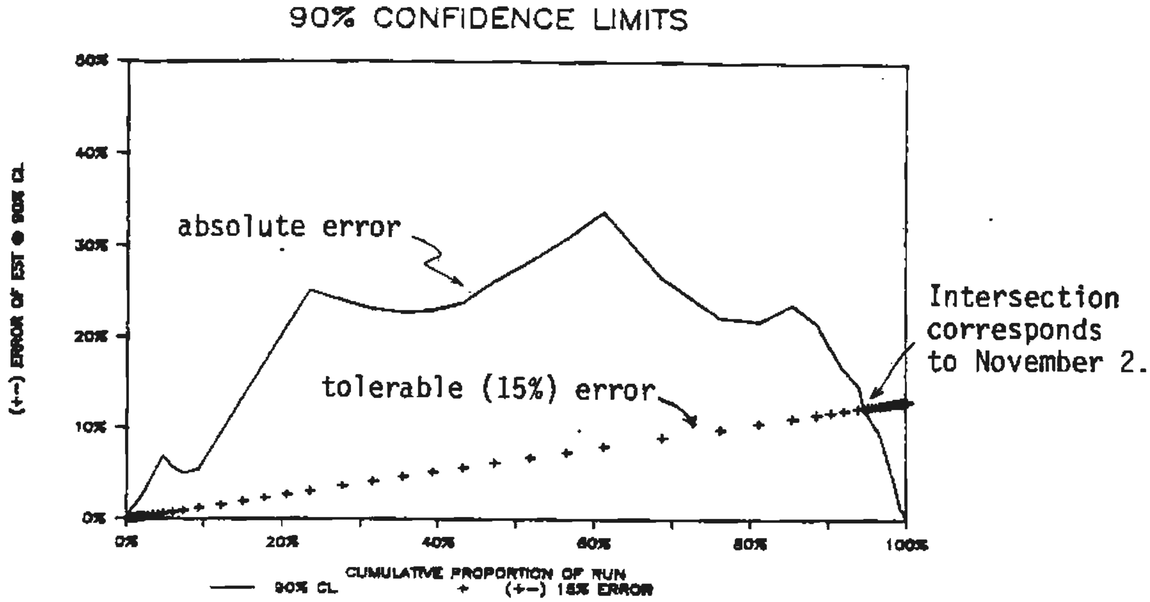


Figure 9. Variance of cumulative proportion of run size as a function of time for Delta River fall chum salmon, 1975, 1976, 1977, and 1985.



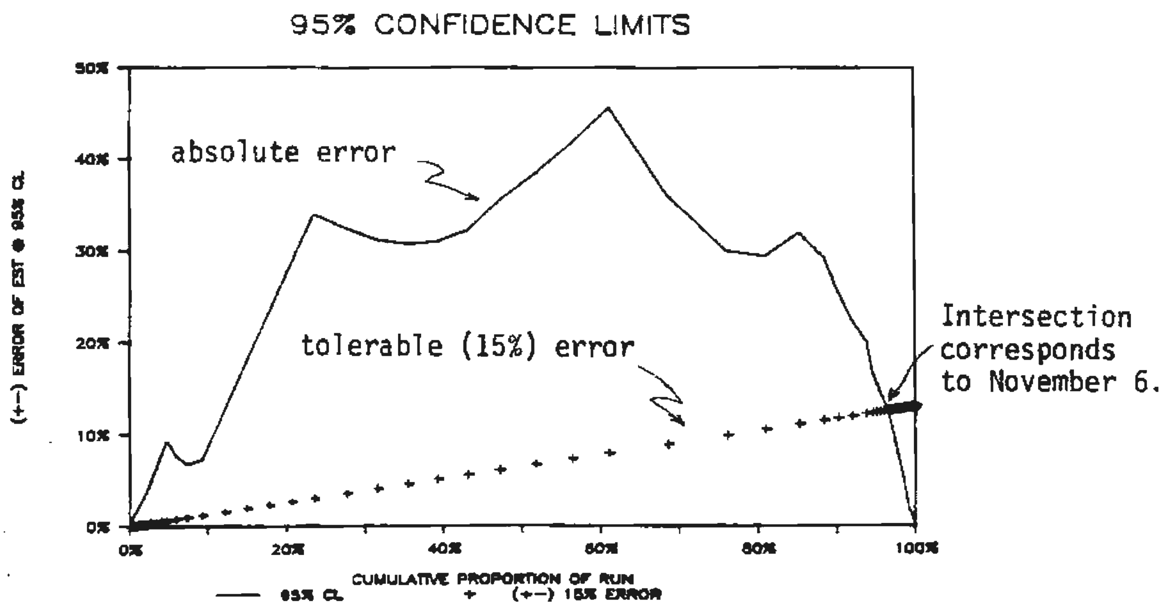


Figure 10. Absolute errors associated with a 90% (top) and 95% (bottom) confidence level based upon average cumulative proportion of run size, 1975, 1976, 1977, and 1985. Straight lines represent the tolerable (15%) error in an estimate relative to any point in the run.

Average run timing in the Delta River was compared to stream life observed in 1985. Stream life in this context was examined by plotting the daily percentage of live salmon which occurred in 1985 and thus, here differs from the concept of average stream residence time of individual fish. Results show stream life was protracted beyond the average run entry pattern in 1985 (Figure 11). Since 1985 data are only an estimate of stream life for a single year, the existing data base was examined to estimate average stream life. Limited observations from replicate ground and aerial surveys made in 1977, 1981, 1982, 1984, and 1985 were used (Appendix Table 10). A comparison of average entry (four years of data) versus average stream life (five years of data) for the Delta River is shown in Figures 12 and 13. Note that average stream life is only shown through November 20 in Figure 12 as very few estimates of the number of live salmon were made after that date in any of the 5 years examined. Nonetheless, on the average, rapid entry and protracted stream life of fall chum salmon occurs in the Delta River. For example, Figure 13 illustrates that by the time 99% of the run has entered the river 38% of the fish remain alive (see also Appendix Tables 9 and 10).

The average migratory time-density curve described for Delta River fall chum salmon using 1975, 1976, 1977, and 1985 data was used to expand peak survey counts made in 1973 and 1978-1984. Peak survey counts of live plus dead salmon on a given day was divided by the average cumulative proportion of the run estimated for that date from the migratory time-density curve. Survey counts made subsequent to the end of October but prior to November 20 were used when possible. Resulting population estimates for these years can be considered conservative since carcass washout rates are not taken into account. Estimates for 1972 and 1974 could not be made using the time-density curve as only live salmon were enumerated in those years on aerial surveys.

A second method was used to expand the 1972 and 1974 aerial survey counts. Expansion factors were obtained by using the limited data obtained in 1975, 1976, 1977, and 1985 in which aerial and ground counts made in those years were compared, when possible, to respective population estimates. Unfortunately, no carcass counts were obtained on any of the ground or aerial surveys made in 1975 or 1976, nor were carcasses enumerated on eight of nine foot surveys conducted in 1977 (Appendix Tables 3 through 5).

Four expansion factors are presented in Table 3 and summarized below:

Peak aerial counts (live fish only) expansion factor 1.475
Peak ground counts (live fish only) expansion factor 1.275
Peak aerial counts (live plus dead) expansion factor 1.241
Peak ground counts (live plus dead) expansion factor 1.069

Data are most complete for peak counts of live fish only for both aerial and ground counts. No doubt, excluding observer variability, differences in timing of surveys accounts for part of the difference in expansion factors shown in Table 3. Expansion factors for estimating total abundance from peak aerial counts of live fish were derived from surveys made October 19, October 26, November 4, and November 6. By comparison, expansion factors for peak ground counts of live fish were obtained from surveys conducted on October 28, October 29, November 1, and November 2; a much

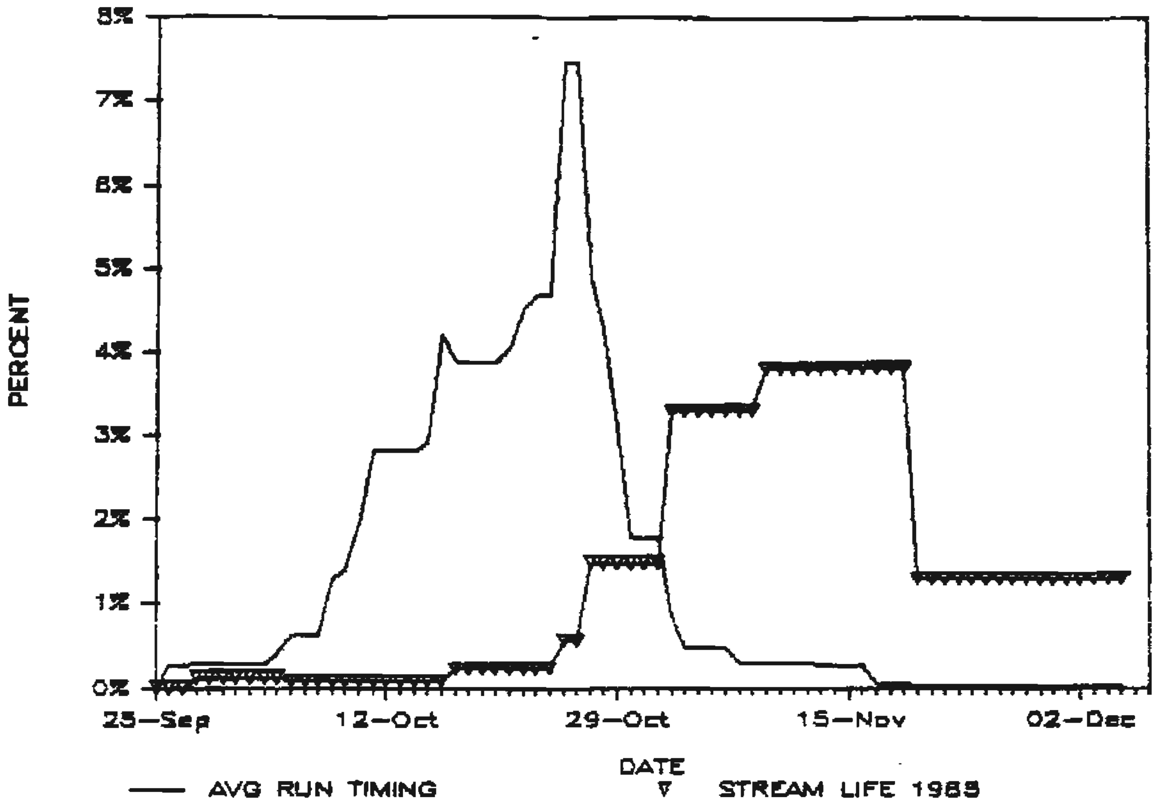


Figure 11. Delta River fall chum salmon stream life in 1985 compared to average run timing. Run timing based upon 1975, 1976, 1977, and 1985 data.

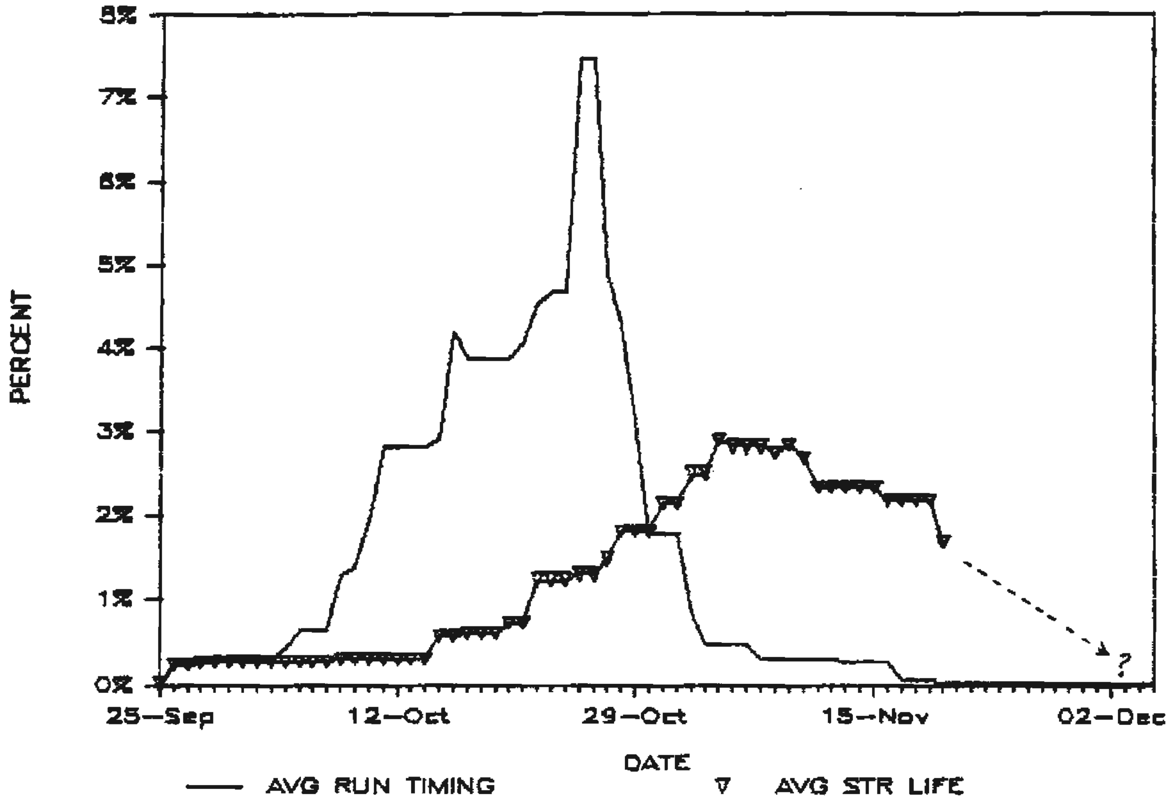


Figure 12. A comparison of average Delta River fall chum salmon stream life (1977, 81, 82, 84, 85) and run timing (1975, 76, 77, 85). Average stream life is only shown through 20 November as very few estimates of the percentage of live fish are available after that date.

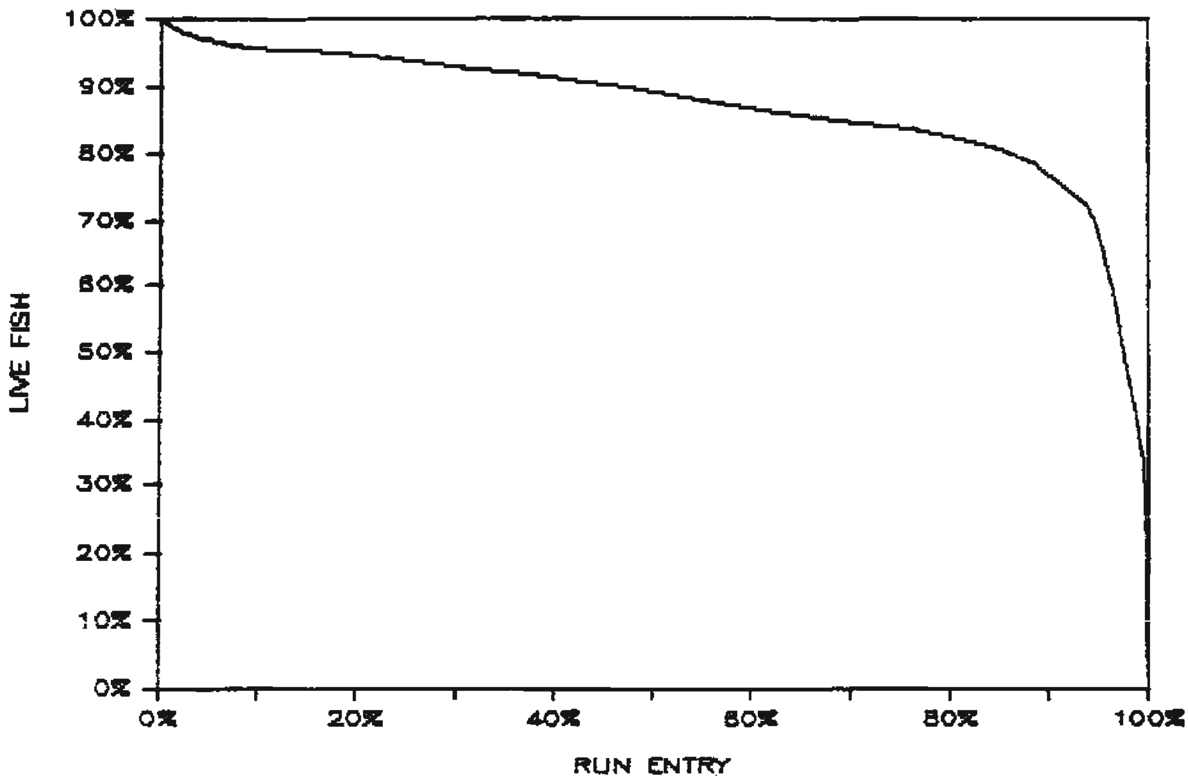


Figure 13. Average percentage of live chum salmon in the Delta River as a function of average run timing (i.e., entry pattern).

Table 3. Expansion factors for Delta River fall chum salmon escapements based upon the relationship of aerial and ground survey counts to population estimates made in 1975, 1976, 1977, and 1985.

YEAR	POPULATION ESTIMATE	PEAK AERIAL COUNT (LIVE FISH)	EXPANSION FACTOR	PEAK GROUND COUNT (LIVE FISH)	EXPANSION FACTOR	PEAK AERIAL COUNT (LIVE+DEAD)	EXPANSION FACTOR	PEAK GROUND COUNT (LIVE+DEAD)	EXPANSION FACTOR
1985	17,276	11,614	1.488	13,898	1.243	12,225	1.413	16,158	1.069
1977	16,876	9,471	1.782	14,495	1.164	15,785	1.069		
1976	6,312	4,779	1.321	4,253	1.484				
1975	3,734	2,850	1.310	3,089	1.209				
	AVERAGE		1.475		1.275		1.241		1.069

narrower time period. Nonetheless, the average expansion factors for peak live counts only (1.475 for peak aerial counts and 1.275 for peak ground counts) are considered fairly reliable.

The expansion factor of peak live and dead fish from aerial survey observations (1.241) is considered the least reliable of the four. Aerial estimates of carcasses on a given survey are likely always proportionally lower than the estimate of live fish because of the tendency of the aerial observer to concentrate more on making accurate live fish counts. Further, many carcasses in the Delta River are often obscured due to snow cover or frost built up on the carcasses during cold weather. Much more accurate counts of dead salmon can be made by ground surveys. It is likely this expansion factor is somewhat low.

Although the expansion factor obtained for live and dead fish from ground surveys (1.069) is based only on 1985 observations, it is considered most reliable. This is based upon the premise that carcass washout rate is relatively low in the Delta River. Although precise studies on carcass washout rates in the Delta River are lacking, results from 1985 surveys suggest washout rate to be low. For example, by the November 19 survey, there should have been 13,760 carcasses present (assuming no carcass washout rate and excluding predation) based upon Trasky's stream residence time data. These were fish which had previously been observed as live fish prior to that date. However, 12,533 carcasses were actually enumerated, a difference of only 1,227 fish. Carcass washout rates could not be examined subsequent to November 20 due to their removal by subsistence-use permit holders. Consequently, the expansion factor of 1.069 should not be applied to foot survey counts of live plus dead fish made subsequent to the opening date (November 20) for removal of carcasses for subsistence use.

Peak survey estimates were expanded for all years in the historic data base using these expansion factors to compare annual escapements in the Delta River (Table 4). In all but one instance (1983) estimates from the migratory time-density curve are lower than estimates made by using peak survey count expansion factors. This may likely be a function of carcass washout. Nonetheless, estimates made using the migratory time-density curve are considered the most reliable and are used when possible to expand the historic data base. Only in 1972 and 1974 were expansion factors from peak survey counts used.

Final "best estimates" of fall chum escapements to the Delta River are shown in Table 5 and Figure 14. Escapements have ranged from 3,734 (1975) to 23,508 (1981) during the past 14 years with an overall average of 9,890. With the exception of 1980 and 1982, two of the three lowest years on record, annual escapements during the past nine years have exceeded 7,700 fish, being greater than any year prior to 1977, except 1973. An apparent high abundance, four-year cycle is manifest for the years 1973, 1977, 1981, and 1985. It is of interest to point out that the 1973 and 1974 population estimates presented in this report (10,469 and 5,915, respectively) are very similar to the Peterson population estimates made in those years by Trasky (1974, 1976): 10,014 in 1973 and 5,718 in 1974.

Table 4. Expanded peak survey escapement estimates of fall chum salmon to total population estimates based upon the relationship of aerial and ground survey counts to population estimates made in 1975, 1976, 1977, and 1985.

YEAR	SURVEY DATE	SURVEY TYPE a	PEAK COUNT b	EXPANSION FACTOR c	SEASON ESTIMATE	REMARKS	FINAL EST EXP FACTORS
1972	31-Oct	A	3,650	1.475	5,384	NO CARCASS COUNT WAS MADE.	5,384
1973	26-Oct	A	7,821	1.475	11,536	TOTAL COUNT (LIVE AND DEAD) WAS 7,971 (x 1.241) = 9,892 POP EST.	11,536 h
1974	31-Oct	A	4,010	1.475	5,915	NO CRACASS COUNT WAS MADE.	5,915 i
1975		P	3,734	0	3,734		3,734
1976		P	6,312	0	6,312		6,312
1977		P	16,876	0	16,876		16,876
1978	30-Oct	A	9,549	1.475	14,085	TOTAL COUNT (LIVE AND DEAD) WAS 10,051 (x 1.241) = 12,473 POP EST.	14,085
1979	08-Nov	A	4,875	1.475	7,191	TOTAL COUNT (LIVE AND DEAD) WAS 8,125 (x 1.241) = 10,083 POP EST. d	10,083
1980	10-Nov	A	3,836	1.475	5,658	NO CARCASS COUNT WAS MADE. PEAK AERIAL CT ON 30-OCT (LIVE AND DEAD) WAS 4,637 (x 1.241) = 5,754 POP EST. e	5,754
1981	03-Nov	F	17,900	1.275	22,823	TOTAL COUNT (LIVE AND DEAD) WAS 22,375 (x 1.069) = 23,918. PEAK AERIAL CT ON 02-NOV (LIVE AND DEAD) WAS 10,664 (x 1.241) = 13,234 POP EST. f	23,918
1982	27-Oct	F	2,721	1.275	3,469	TOTAL COUNT (LIVE AND DEAD) WAS 3,433 (x 1.069) = 3,669 POP EST. f	3,669
1983	27-Oct	A	6,684	1.475	9,859	TOTAL COUNT (LIVE AND DEAD) WAS 7,007 (x 1.241) = 8,695 POP EST. PEAK AERIAL CT ON 01-NOV (LIVE AND DEAD) WAS 7,230 (x 1.241) = 8,972 POP EST.	9,859
1984	26-Oct	F	5,509	1.275	7,024	TOTAL COUNT (LIVE AND DEAD) WAS 7,196 (x 1.069) = 7,692 POP EST. PEAK GROUND CT ON 15-NOV (LIVE AND DEAD) WAS 12,327 (x 1.069) = 13,177 POP EST. g	13,177
1985	31-Oct	P	17,276	0	17,276		17,276

a Aerial index counts (A), foot index counts (F), population estimate (P).

b Live fish counts only.

c Expansion factors based upon comparison of peak aerial and foot counts of salmon versus population estimates made in 1975, 1976, 1977 and 1985:

Peak aerial counts (live fish only) expansion factor 1.475

Peak ground counts (live fish only) expansion factor 1.275

Peak aerial counts (live plus dead) expansion factor 1.241 (This is considered the least accurate conversion factor as carcass counts are probably low).

Peak ground counts (live plus dead) expansion factor 1.069 (This is considered the most accurate conversion factor prior to November 20).

d The expansion of live plus dead fish was used since the population estimate from expanding live fish counts only was less than the total number of fish actually observed (live plus dead).

e Results of the aerial survey on 30-Oct were used as opposed to the aerial survey counts on 10-Nov even though it was on this latter date the peak live count was observed. It was considered the 10-Nov survey was too late.

f Expansion of live PLUS dead ground counts was used as opposed to expansion of live ground counts only.

g Ground counts on 15-Nov were used for the population estimate because the population estimate made from ground counts on 31-Oct was less than the actual number of salmon observed on the 15-Nov survey.

h Peterson population estimate 10,014 (Trasky 1974).

i Peterson population estimate 5,718 (Trasky 1976).

Table 5. Population estimates of annual fall chum salmon escapements to the Delta River, 1972-85.

YEAR	SURVEY DATE	SURVEY TYPE a	SURVEY COUNT b	EXPANSION FACTOR	POPULATION ESTIMATE c	RANGE AT 95% CONFIDENCE LEVEL	RANGE AT 90% CONFIDENCE LEVEL
1972	31-Oct	A		1.475	5,384 d	--	--
1973	26-Oct	A	7,971	0.7614 e	10,469 f	7,971-17,242 (RELATIVE ERROR 64.6%)	7,971-14,752 (RELATIVE ERROR 40.9%)
1974	31-Oct	A		1.475	5,915 d,g	--	--
1975				0	3,734 h	3,574-3,895	3,574-3,895
1976				0	6,312 h	6,279-6,346	6,279-6,346
1977				0	16,876 h	16,365-17,388	16,365-17,388
1978	30-Oct	A	10,051	0.9026 e	11,136	10,051-15,496 (RELATIVE ERROR 39.1%)	10,051-14,061 (RELATIVE ERROR 26.2%)
1979	08-Nov	A	8,125	0.9725 e	8,355	8,125-9,328 (RELATIVE ERROR 11.6%)	8,125-9,053 (RELATIVE ERROR 8.3%)
1980	30-Oct	A	4,637	0.9026 e	5,137	4,637-7,149 (RELATIVE ERROR 39.1%)	4,637-6,487 (RELATIVE ERROR 26.2%)
1981	03-Nov	F	22,375	0.9518 e	23,508	22,375-28,052 (RELATIVE ERROR 19.3%)	22,375-26,706 (RELATIVE ERROR 13.6%)
1982	27-Oct	F	3,433	0.8106 e	4,235	3,433-6,640 (RELATIVE ERROR 56.7%)	3,433-5,784 (RELATIVE ERROR 36.5%)
1983	01-Nov	A	7,230	0.9383 e	7,705	7,230-9,791 (RELATIVE ERROR 27.0%)	7,230-9,146 (RELATIVE ERROR 18.7%)
1984	15-Nov	F	12,327	0.9932 e	12,411	12,327-12,630 (RELATIVE ERROR 1.76%)	12,327-12,572 (RELATIVE ERROR 1.2%)
1985				0	17,276 h	17,147-17,406	17,147-17,406

a Peak aerial index count (A), peak foot index count (F).
b Actual survey count of live and dead fish.
c Population estimate based on Delta River migratory time-density curve.
d Population estimate based on Delta River aerial and ground survey expansion factors.
e Cumulative proportion of escapement estimated on survey date from migratory time-density curve.
f Peterson population estimate 10,014 (Trasky 1974).
g Peterson population estimate 5,718 (Trasky 1976).
h Population estimate made from spawner abundance curve, numbers of new fish entering the stream, and stream residence time data.

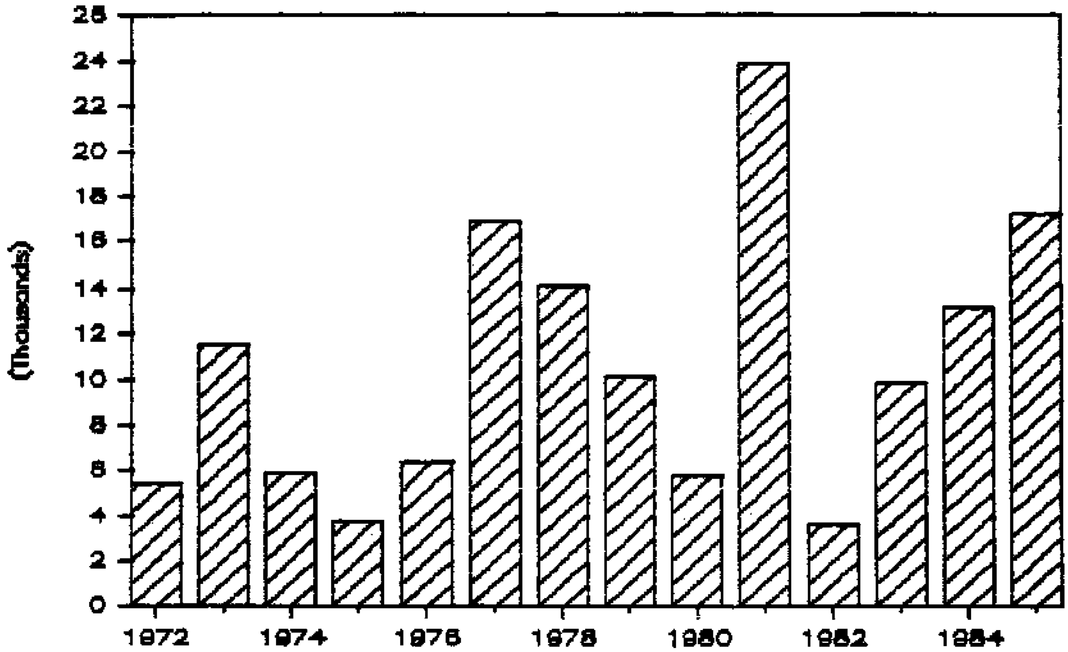


Figure 14. Comparative annual escapements of fall chum salmon in the Delta River 1972-85.

SUMMARY

1. Two methods were used to estimate total fall chum salmon spawning escapement to the Delta River in 1985. The first method involved plotting a spawner abundance curve and dividing the area under the curve by average stream residence time. The second method was a summation of estimated numbers of new fish entering the stream over time. Both methods were predicated upon replicate survey counts of live chum salmon made from late September through early December 1985 and average stream residence data collected in the Delta River in 1973 and 1974. The best estimate of total spawning escapement in 1985 was taken as the midpoint between the two population estimates, or 17,276 fall chum salmon.

2. Data in the historic data base on fall chum salmon escapements to the Delta River were sufficient to allow application of the methods used in 1985 to only three other years: 1975, 1976, and 1977. Resulting total escapement estimates in those years were 3,734, 6,312, and 16,876, respectively.

3. A migratory time-density curve was developed for Delta River fall chum salmon based upon the average daily cumulative proportions of run size using 1975, 1976, 1977, and 1985 data. The central half of the spawning population (25%-75%) entered the river over an average span of 11 days from October 16 to 26. The grand mean of run timing was October 21.

4. Results of the migratory time-density curve show that population estimates made from survey counts subsequent to November 1 and November 5 (but prior to November 20) result in absolute errors at the 90% and 95% confidence levels, respectively, which are less than a maximum tolerable error of 15%.

5. Delta River fall chum salmon exhibit a rapid run entry pattern and protracted stream life.

6. Expansion factors were derived using the limited data obtained in 1975, 1976, 1977, and 1985 in which peak aerial and ground survey counts made in those years were compared to respective population estimates. Expansion factors were used to estimate total spawning escapements in 1972 and 1974 only. Data in all other years, excluding 1975, 1976, 1977, and 1978, were expanded by using the migratory time-density curve.

7. Final estimates of annual fall chum salmon escapements to the Delta River show a range of 3,734 (1975) to 23,508 (1981) during the past 14 years with an overall average of 9,890. Escapements in 1980 and 1982 were two of the three lowest years on record.

8. The chum salmon sex ratio was 1.00:1.56 (39% males; 61% females) based upon carcass samples collected from October 21 to November 11, 1985. Age composition was 14% age 3_1, 76% age 4_1, 9% age 5_1, and less than 1% age 6_1 fish.

9. One hundred fifty chum salmon were sampled and forwarded to the Canadian Department of Fisheries and Oceans for subsequent electrophoretic analysis.

CONCLUSIONS

The migratory time-density curve developed for fall chum salmon spawners is a reasonable approach to estimating total escapements from point estimates (i.e., peak aerial or foot survey counts of live and dead salmon) in the historic data base as well as in the future. However, it should be applied to point estimates made subsequent to November 1 and November 5, but prior to November 20, to maintain a tolerable error of not more than 15% with respective confidence levels of 90% and 95%. Nonetheless, realizing a greater percent error may be acceptable for inseason management purposes, population estimates can be generated prior to November.

Population estimates generated from the migratory time-density model should be considered conservative as carcass washout rates, although believed to be relatively small, have not been accurately determined.

Population estimates generated from peak aerial or ground count expansion factors presented in this report are considered less reliable than using the migratory time-density model as they do not take into account timing of surveys with respect to peak spawning. Many peak counts may not necessarily have coincided with peak spawning in some years.

RECOMMENDATIONS

It is recommended that intensive replicate foot and aerial surveys be continued annually for at least one complete four-year cycle of Delta River fall chum salmon. Additional data will not only help define the variance associated with annual mean run timing, but will also allow for possible development of more than one time-density curve to address early, average, and late spawning runs. Studies should also be designed to determine average carcass washout rates for inclusion in the time-density model.

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pendix Table 1. Pooled fall chum salmon strea ɿidence time data for the Delta River, 1973 and 1974.[a,b]

STREAM RESIDENCE TIME (DAYS)	EASTERN CHANNELS		MID-RIVER CHANNELS b		WESTERN CHANNELS		ALL CHANNELS COMBINED				
	NUMBER SALMON	SALMON DAYS	NUMBER SALMON	SALMON DAYS	NUMBER SALMON	SALMON DAYS	TOTAL SALMON	SALMON DAYS	CUM	CUM % DEAD	CUM % LIVE
1	0	0	0	0	0	0	0	0	0	0.0%	100.0%
2	0	0	1	2	2	4	3	6	3	1.1%	98.9%
3	0	0	0	0	0	0	0	0	3	1.1%	98.9%
4	0	0	2	8	0	0	2	8	5	1.9%	98.1%
5	2	10	0	0	0	0	2	10	7	2.7%	97.3%
6	0	0	1	6	0	0	1	6	8	3.0%	97.0%
7	0	0	1	7	0	0	1	7	9	3.4%	96.6%
8	0	0	2	16	1	8	3	24	12	4.5%	95.5%
9	1	9	0	0	1	9	2	18	14	5.3%	94.7%
10	2	20	5	50	2	20	9	90	23	8.7%	91.3%
11	0	0	12	132	1	11	13	143	36	13.6%	86.4%
12	2	24	7	84	1	12	10	120	46	17.4%	82.6%
13	4	52	10	130	1	13	15	195	61	23.1%	76.9%
14	2	28	3	42	0	0	5	70	66	25.0%	75.0%
15	1	15	11	165	1	15	13	195	79	29.9%	70.1%
16	5	80	8	128	2	32	15	240	94	35.6%	64.4%
17	6	102	9	153	7	119	22	374	116	43.9%	56.1%
18	7	126	15	270	0	0	22	396	138	52.3%	47.7%
19	1	19	11	209	5	95	17	323	155	58.7%	41.3%
20	11	220	8	160	1	20	20	400	175	66.3%	33.7%
21	10	210	6	126	3	63	19	399	194	73.5%	26.5%
22	8	176	4	88	2	44	14	308	208	78.8%	21.2%
23	3	69	1	23	4	92	8	184	216	81.8%	18.2%
24	4	96	2	48	2	48	8	192	224	84.8%	15.2%
25	4	100	0	0	2	50	6	150	230	87.1%	12.9%
26	7	182	1	26	3	78	11	286	241	91.3%	8.7%
27	3	81	0	0	4	108	7	189	248	93.9%	6.1%
28	3	84	0	0	2	56	5	140	253	95.8%	4.2%
29	2	58	0	0	5	145	7	203	260	98.5%	1.5%
30	0	0	0	0	2	60	2	60	262	99.2%	0.8%
31	0	0	0	0	1	31	1	31	263	99.6%	0.4%
32	0	0	0	0	0	0	0	0	263	99.6%	0.4%
33	0	0	0	0	1	33	1	33	264	100.0%	0.0%
TOTAL	88		120		56		264		264		
AVERAGE	20.0		15.6		20.8		18.2				

a Data from Trasky 1974, 1976.

b Mid-river channels include channels II and II 1/2.

Appendix Table 2. Age, sex, and size composition of Delta River fall chum salmon, 1985.

	AGE 0.2				AGE 0.3				AGE 0.4				AGE 0.5			
	SAMPLE SIZE	PERCENT	MEAN LENGTH	STANDARD DEVIATION	SAMPLE SIZE	PERCENT	MEAN LENGTH	STANDARD DEVIATION	SAMPLE SIZE	PERCENT	MEAN LENGTH	STANDARD DEVIATION	SAMPLE SIZE	PERCENT	MEAN LENGTH	STANDARD DEVIATION
MALES	13	5.08%	610	29.2	75	29.30%	609	29.7	11	4.30%	634	18.9	1	0.39%	590	---
FEMALES	24	9.38%	566	35.4	120	46.88%	582	27.0	12	4.69%	587	30.1	0	0.00%	---	---
TOTAL	37	14.45%	583	38.5	195	76.17%	592	31.0	23	8.98%	610	35.4	1	0.39%	---	---

a Length measured mid-eye to fork-of-tail in millimeters. Ages expressed in European notation.

Appendix Table 3. Fall chum salmon escapement survey counts in the Delta River, 1977.

	TYPE	EASTERN CHANNELS a			MID OR MAIN RIVER CHANNELS b			WESTERN CHANNELS c			TOTAL DELTA RIVER AREA		
DATE	SURVEY	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL
OCT 04	FOOT			TURBID	400		400	345		345	745	0	745
OCT 10	FOOT			TURBID	699		699	1,184		1,184	1,883	0	1,883
OCT 20	FOOT	4,968		4,968	3,420		3,420	793		793	9,181	0	9,181
OCT 24	FOOT	7,224		7,224	4,201		4,201	794		794	12,219	0	12,219
OCT 28	FOOT	8,372		8,372	5,137		5,137	986		986	14,495	0	14,495
NOV 01	FOOT	5,644		5,644	4,894		4,894	870		870	11,408	0	11,408
NOV 07	FOOT	3,870	3,000	6,870	2,087	2,183	4,270	564	564	1,128	6,521	5,747	12,268
NOV 17	FOOT	763		763	966		966	143		143	1,872	0	1,872
NOV 25	FOOT	213		213	117		117	29		29	359	0	359
OCT 21	AERIAL	8,750	0	8,750	7,755	495	8,250	875	50	925	17,380	545	17,925
NOV 04	AERIAL										9,471	6,314	15,785

a Includes channel I.

b Includes channels II and II 1/2.

c Includes channel III.

DATA FROM DINNEFORD 1978, TABLE 11, P 28 AND BARTON 1984, TDR #121.

Appendix Table 4. Fall chum salmon escapement survey counts in the Delta River, 1976.

	TYPE	EASTERN CHANNELS a			MID OR MAIN RIVER CHANNELS b			WESTERN CHANNELS c			TOTAL DELTA RIVER AREA		
DATE	SURVEY	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL
OCT 07	FOOT	58		58	3		3	3		3	64	0	64
OCT 14	FOOT	599		599	667		667	10		10	1,276	0	1,276
OCT 21	FOOT	1,210		1,210	1,357		1,357	65		65	2,632	0	2,632
OCT 27	FOOT	1,968		1,968	2,219		2,219	47		47	4,234	0	4,234
NOV 02	FOOT	1,953		1,953	2,260		2,260	40		40	4,253	0	4,253
NOV 16	FOOT	611		611	764		764	35		35	1,410	0	1,410
NOV 24	FOOT	243		243	284		284	2		2	529	0	529
DEC 03	FOOT	3		3	2		2	2		2	7	0	7
OCT 19	AERIAL	2,751			2,028			0			4,779		4,779
OCT 28	AERIAL	2,969			1,428			91			4,488		4,488
NOV 04	AERIAL	1,748			1,895			69			3,712		3,712

a Includes channel I.

b Includes channels II and II 1/2.

c Includes channel III.

DATA FROM FRANCISCO AND DINNEFORD 1977, TABLE 2, P 11 AND BARTON 1984, TDR #121.

Appendix Table 5. Fall chum salmon escapement survey counts in the Delta River, 1975.

	TYPE	EASTERN CHANNELS a			MID OR MAIN RIVER CHANNELS b			WESTERN CHANNELS c			TOTAL DELTA RIVER AREA		
DATE	SURVEY	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL	LIVE	DEAD	TOTAL
OCT 08	FOOT	0	0	0	0	0	0	0	0	0	0	0	0
OCT 09	FOOT	200	0	200	0	0	0	0	0	0	200	0	200
OCT 15	FOOT										328		328
OCT 22	FOOT										1,686		1,686
OCT 29	FOOT										3,089		3,089
NOV 12	FOOT										1,949		1,949
NOV 19	FOOT										547		547
NOV 24	FOOT										22		22
NOV 06	AERIAL	475		475	2,050		2,050	325		325	2,850		2,850

a Includes channel I.

b Includes channels II and II 1/2.

c Includes channel III.

DATA FROM FRANCISCO 1976, P 32. FOOT COUNTS ESTIMATED FROM FIG 7. AERIAL CTS FROM BARTON 1984, TDR #121.

Appendix Table 6. Estimated number of fall chum salmon entering the Delta River by survey date in 1977.[a]

			OCT 4		OCT 10		OCT 20		OCT 24		OCT 28		NOV 1		NOV 7		NOV 17		NOV 25	
DAY	DATE	INTER-VAL	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE
1	10/2																			
		2																		
3	10/4			745 c																
		6	22																	
9	10/10			723		1,160 c														
		10	243		101															
19	10/20			480		1,059		7,642 c												
		1	62		57		84													
20	10/21 b			418		1,003		7,558												
		3	167		132		61													
23	10/24			251		870		7,497		3,601 c										
		4	138		317		199		68											
27	10/28			113		553		7,298		3,533		2,998 c								
		4	82		307		986		94		57									
31	11/1			31		246		6,312		3,439		2,941		(1,561)						
		3	28		96		955		328		45									
34	11/4 b			3		150		5,357		3,111		2,896								
		3	3		101		1,712		411		159									
37	11/7			0		49		3,645		2,701		2,737				(2,611)				
		10			49		3,324		2,153		1,727									
47	11/17					0		321		547		1,010						(7)		
		8					321		533		884									
55	11/25							0		14		126								219 c
		2							14		102								2	
57	11/27									0		24								216
			745		1,160		7,642		3,601		2,974		0		0		0		2	

a All observations based upon foot surveys unless otherwise noted.
b Aerial survey.
c New fish entering the stream.

Appendix Table 7. Estimated number of fall chum salmon entering the Delta River by survey date in 1976.[a]

			OCT 7		OCT 14		OCT 19 b		OCT 21		OCT 27		OCT 28 b		NOV 2		NOV 4 b		NOV 16		NOV 24	
DAY	DATE	INTER-VAL	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE
1	10/5																					
		2																				
3	10/7			64 c																		
		7	2																			
10	10/14			62		1,214 c																
		5	9		33																	
15	10/19 b			53		1,181																
		2	5		8																	
17	10/21			48		1,173				1,411 c												
		6	26		239				42													
23	10/27			22		934				1,369		1,910 c										
		1	5		23				80		21											
24	10/28 b			17		911				1,288		1,889										
		4	9		331				380		65											
28	11/2			8		579				909		1,824				933 c						
		2	4		170				652		485				32							
30	11/4 b			4		409				257		1,339				901						
		13	4		409				257		1,173				456							
43	11/16			0		0				0		166				445				799 c		
		8									166				445				284			
51	11/24											0				0				514		15 c
		9																	133		1	
60	12/3																			381		14
			64		1,214		0		1,411		1,910		0		933		0		418		1	

a All observations based upon foot surveys unless otherwise noted. Live fish shown below new fish entering the stream are those remaining alive on subsequent surveys based upon stream residence time data from Trasky (1974, 1976). Dead fish shown below new fish entering the stream are number of salmon which died in that interval of time.

b Aerial survey; these data were excluded.

c New fish entering the stream.

Appendix Table 8. Estimated number of fall chum salmon entering the Delta River by survey date in 1975.[a]

DAY	DATE	INTERVAL	OCT 8 DEAD	OCT 8 LIVE	OCT 9 DEAD	OCT 9 LIVE	OCT 15 DEAD	OCT 15 LIVE	OCT 22 DEAD	OCT 22 LIVE	OCT 29 DEAD	OCT 29 LIVE	NOV 6 b DEAD	NOV 6 b LIVE	NOV 12 DEAD	NOV 12 LIVE	NOV 19 DEAD	NOV 19 LIVE	NOV 24 DEAD	NOV 24 LIVE
1	10/6																			
		2																		
3	10/8			0 c																
		1																		
4	10/9					200 c														
		6			6															
6	10/15					194		134 c												
		7			40		5													
13	10/22					154		129		1,403 c										
		7			86		29		48											
20	10/29					67		101		1,355		1,566 c								
		7			55		65		303		53									
27	11/6 b					12		36		1,052		1,513		237 c						
		6			12		27		579		309		7							
33	11/12					0		8		473		1,204		230		34 c				
		7					8		387		677		48		1					
40	11/19							0		86		528		183		32		(281)c		
		5							80		326		69		5					
45	11/24									6		202		113		28				(327)c
		2							6		106		33		3					
47	11/26									0		96		80		25				
			0		200		134		1,403		1,471		157		8		0		0	

a All observations based upon foot surveys unless otherwise noted. Live fish shown below new fish entering the stream are those remaining alive on subsequent surveys based upon stream residence time data from Trasky (1974, 1976). Dead fish shown below new fish entering the stream are number of salmon which died in that interval of time.

b Aerial survey.

c New fish entering the stream.

Appendix Table 9. Fall chum salmon run timing based upon the 4-year average cumulative and daily percentages of new salmon entering the Delta River between subsequent surveys in 1975, 1976, 1977, and 1985.

DAY	DATE	1975 CUMS	1976 CUMS	1977 CUMS	1985 CUMS	4 YR AVE CUM	CUM MINIMUM	CUM MAXIMUM	CUM VARIANCE	1975 DAILY %	1976 DAILY %	1977 DAILY %	1985 DAILY %	4 YR AVE DAILY	VARIANCE DAILY
1	25-Sep	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.000000	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0
2	26-Sep	0.37%	0.08%	0.46%	0.13%	0.26%	0.08%	0.46%	0.000003	0.3731%	0.0776%	0.4552%	0.1254%	0.2578%	0.000003
3	27-Sep	0.75%	0.16%	0.91%	0.25%	0.52%	0.16%	0.91%	0.000014	0.3731%	0.0776%	0.4552%	0.1254%	0.2578%	0.000003
4	28-Sep	1.12%	0.23%	1.37%	0.60%	0.83%	0.23%	1.37%	0.000026	0.3731%	0.0776%	0.4552%	0.3457%	0.3129%	0.000002
5	29-Sep	1.49%	0.31%	1.82%	0.94%	1.14%	0.31%	1.82%	0.000044	0.3731%	0.0776%	0.4552%	0.3457%	0.3129%	0.000002
6	30-Sep	1.87%	0.39%	2.28%	1.29%	1.45%	0.39%	2.28%	0.000067	0.3731%	0.0776%	0.4552%	0.3457%	0.3129%	0.000002
7	01-Oct	2.24%	0.47%	2.73%	1.63%	1.77%	0.47%	2.73%	0.000095	0.3731%	0.0776%	0.4552%	0.3457%	0.3129%	0.000002
8	02-Oct	2.61%	0.54%	3.19%	1.98%	2.08%	0.54%	3.19%	0.000129	0.3731%	0.0776%	0.4552%	0.3457%	0.3129%	0.000002
9	03-Oct	2.98%	0.62%	3.64%	2.33%	2.39%	0.62%	3.64%	0.000169	0.3731%	0.0776%	0.4552%	0.3457%	0.3129%	0.000002
10	04-Oct	3.36%	0.70%	4.55%	2.67%	2.82%	0.70%	4.55%	0.000260	0.3731%	0.0776%	0.9105%	0.3457%	0.4267%	0.000012
11	05-Oct	3.73%	0.78%	5.73%	3.55%	3.45%	0.78%	5.73%	0.000415	0.3731%	0.0776%	1.1814%	0.8760%	0.6270%	0.000084
12	06-Oct	4.10%	0.85%	6.92%	4.42%	4.07%	0.85%	6.92%	0.000619	0.3731%	0.0776%	1.1814%	0.8760%	0.6270%	0.000084
13	07-Oct	4.48%	1.01%	8.10%	5.30%	4.72%	1.01%	8.10%	0.000852	0.3731%	0.1552%	1.1814%	0.8760%	0.6464%	0.000081
14	08-Oct	4.85%	3.74%	9.28%	6.17%	6.01%	3.74%	9.28%	0.000673	0.3731%	2.7329%	1.1814%	0.8760%	1.2908%	0.000103
15	09-Oct	5.60%	6.47%	10.46%	7.05%	7.40%	5.60%	10.46%	0.000453	0.7461%	2.7329%	1.1814%	0.8760%	1.3841%	0.000084
16	10-Oct	6.22%	9.21%	11.64%	10.29%	9.34%	6.22%	11.64%	0.000531	0.6249%	2.7329%	1.1814%	3.2401%	1.9448%	0.000154
17	11-Oct	6.85%	11.94%	16.31%	13.53%	12.16%	6.85%	16.31%	0.001580	0.6249%	2.7329%	4.6697%	3.2401%	2.8169%	0.000280
18	12-Oct	7.47%	14.67%	20.98%	16.77%	14.97%	7.47%	20.98%	0.003190	0.6249%	2.7329%	4.6697%	3.2401%	2.8169%	0.000280
19	13-Oct	8.10%	17.41%	25.65%	20.01%	17.79%	8.10%	25.65%	0.005361	0.6249%	2.7329%	4.6697%	3.2401%	2.8169%	0.000280
20	14-Oct	8.72%	20.14%	30.32%	23.25%	20.61%	8.72%	30.32%	0.008095	0.6249%	2.7329%	4.6697%	3.2401%	2.8169%	0.000280
21	15-Oct	9.35%	23.32%	34.99%	26.49%	23.54%	9.35%	34.99%	0.011378	0.6249%	3.1764%	4.6697%	3.2401%	2.9278%	0.000283
22	16-Oct	14.95%	26.49%	39.66%	29.73%	27.71%	14.95%	39.66%	0.010365	5.6080%	3.1764%	4.6697%	3.2401%	4.1735%	0.000130
23	17-Oct	20.56%	29.67%	44.33%	31.75%	31.58%	20.56%	44.33%	0.009598	5.6080%	3.1764%	4.6697%	2.0186%	3.8682%	0.000252
24	18-Oct	26.17%	32.84%	49.00%	33.77%	35.45%	26.17%	49.00%	0.009310	5.6080%	3.1764%	4.6697%	2.0186%	3.8682%	0.000252
25	19-Oct	31.78%	36.02%	53.67%	35.79%	39.31%	31.78%	53.67%	0.009530	5.6080%	3.1764%	4.6697%	2.0186%	3.8682%	0.000252
26	20-Oct	37.39%	39.20%	58.34%	37.81%	43.18%	37.39%	58.34%	0.010270	5.6080%	3.1764%	4.6697%	2.0186%	3.8682%	0.000252
27	21-Oct	42.99%	42.37%	63.84%	39.82%	47.26%	39.82%	63.84%	0.012408	5.6080%	3.1764%	5.5011%	2.0186%	4.0760%	0.000314
28	22-Oct	48.60%	47.39%	69.34%	41.84%	51.79%	41.84%	69.34%	0.014550	5.6080%	5.0163%	5.5011%	2.0186%	4.5360%	[illegible]
29	23-Oct	54.86%	52.41%	74.84%	43.86%	56.49%	43.86%	74.84%	0.017186	6.2595%	5.0163%	5.5011%	2.0186%	4.6989%	0.000348
30	24-Oct	61.12%	57.42%	80.34%	45.88%	61.19%	45.88%	80.34%	0.020514	6.2595%	5.0163%	5.5011%	2.0186%	4.6989%	0.000345
31	25-Oct	67.38%	62.44%	84.92%	59.92%	68.66%	59.92%	84.92%	0.012706	6.2595%	5.0163%	4.5799%	14.0404%	7.4740%	0.001966
32	26-Oct	73.64%	67.45%	89.50%	73.96%	76.14%	67.45%	89.50%	0.008833	6.2595%	5.0163%	4.5799%	14.0404%	7.4740%	0.001966
33	27-Oct	79.90%	72.47%	94.08%	77.77%	81.06%	72.47%	94.08%	0.008516	6.2595%	5.0163%	4.5799%	3.8141%	4.9174%	0.000104
34	28-Oct	86.16%	74.92%	98.66%	81.59%	85.33%	74.92%	98.66%	0.010025	6.2595%	2.4504%	4.5799%	3.8141%	4.2760%	0.000252
35	29-Oct	92.42%	77.37%	98.71%	85.40%	88.48%	77.37%	98.71%	0.008434	6.2595%	2.4504%	0.0478%	3.8141%	3.1429%	0.000674
36	30-Oct	93.25%	79.82%	98.76%	89.22%	90.26%	79.82%	98.76%	0.006372	0.8289%	2.4504%	0.0478%	3.8141%	1.7853%	0.000283
37	31-Oct	94.08%	82.27%	98.81%	93.03%	92.05%	82.27%	98.81%	0.004877	0.8289%	2.4504%	0.0478%	3.8141%	1.7853%	0.000283
38	01-Nov	94.90%	84.72%	98.85%	96.84%	93.83%	84.72%	98.85%	0.003547	0.8289%	2.4504%	0.0478%	3.8141%	1.7853%	0.000283
39	02-Nov	95.73%	87.17%	98.90%	96.99%	94.70%	87.17%	98.90%	0.002687	0.8289%	2.4504%	0.0478%	0.1474%	0.8686%	0.000122
40	03-Nov	96.56%	88.07%	98.95%	97.14%	95.18%	88.07%	98.95%	0.002349	0.8289%	0.8993%	0.0478%	0.1474%	0.4809%	0.000019
41	04-Nov	97.39%	88.97%	99.00%	97.29%	95.66%	88.97%	99.00%	0.002050	0.8289%	0.8993%	0.0478%	0.1474%	0.4809%	0.000019
42	05-Nov	98.22%	89.87%	99.04%	97.43%	96.14%	89.87%	99.04%	0.001791	0.8289%	0.8993%	0.0478%	0.1474%	0.4809%	0.000019
43	06-Nov	99.05%	90.77%	99.09%	97.58%	96.62%	90.77%	99.09%	0.001572	0.8289%	0.8993%	0.0478%	0.1474%	0.4809%	0.000019
44	07-Nov	99.21%	91.67%	99.14%	97.73%	96.94%	91.67%	99.21%	0.001279	0.1586%	0.8993%	0.0478%	0.1474%	0.3133%	0.000015
45	08-Nov	99.37%	92.57%	99.19%	97.88%	97.25%	92.57%	99.37%	0.001018	0.1586%	0.8993%	0.0478%	0.1474%	0.3133%	0.000015
46	09-Nov	99.52%	93.47%	99.24%	98.02%	97.56%	93.47%	99.52%	0.000787	0.1586%	0.8993%	0.0478%	0.1474%	0.3133%	0.000015
47	10-Nov	99.68%	94.37%	99.28%	98.17%	97.88%	94.37%	99.68%	0.000588	0.1586%	0.8993%	0.0478%	0.1474%	0.3133%	0.000015
48	11-Nov	99.84%	95.27%	99.33%	98.32%	98.19%	95.27%	99.84%	0.000420	0.1586%	0.8993%	0.0478%	0.1474%	0.3133%	0.000015
49	12-Nov	100.00%	96.17%	99.38%	98.47%	98.50%	96.17%	100.00%	0.000282	0.1586%	0.8993%	0.0478%	0.1474%	0.3133%	0.000015
50	13-Nov	100.00%	97.07%	99.43%	98.61%	98.78%	97.07%	100.00%	0.000162	0.0000%	0.8993%	0.0478%	0.1474%	0.2736%	0.000017
51	14-Nov	100.00%	97.96%	99.47%	98.76%	99.05%	97.96%	100.00%	0.000078	0.0000%	0.8993%	0.0478%	0.1474%	0.2736%	0.000017
52	15-Nov	100.00%	98.86%	99.52%	98.91%	99.32%	98.86%	100.00%	0.000029	0.0000%	0.8993%	0.0478%	0.1474%	0.2736%	0.000017
53	16-Nov	100.00%	99.76%	99.57%	99.06%	99.60%	99.06%	100.00%	0.000016	0.0000%	0.8993%	0.0478%	0.1474%	0.2736%	0.000017
54	17-Nov	100.00%	99.79%	99.62%	99.20%	99.65%	99.20%	100.00%	0.000011	0.0000%	0.0295%	0.0478%	0.1474%	0.0562%	0.000000
55	18-Nov	100.00%	99.82%	99.67%	99.35%	99.71%	99.35%	100.00%	0.000008	0.0000%	0.0295%	0.0478%	0.1474%	0.0562%	0.000000
56	19-Nov	100.00%	99.85%	99.71%	99.50%	99.77%	99.50%	100.00%	0.000005	0.0000%	0.0295%	0.0478%	0.1474%	0.0562%	0.000000
57	20-Nov	100.00%	99.88%	99.76%	99.53%	99.79%	99.53%	100.00%	0.000004	0.0000%	0.0295%	0.0478%	0.0313%	0.0272%	0.000000
58	21-Nov	100.00%	99.91%	99.81%	99.56%	99.82%	99.56%	100.00%	0.000004	0.0000%	0.0295%	0.0478%	0.0313%	0.0272%	0.000000
59	22-Nov	100.00%	99.94%	99.86%	99.59%	99.85%	99.59%	100.00%	0.000003	0.0000%	0.0295%	0.0478%	0.0313%	0.0272%	0.000000
60	23-Nov	100.00%	99.97%	99.90%	99.62%	99.87%	99.62%	100.00%	0.000003	0.0000%	0.0295%	0.0478%	0.0313%	0.0272%	0.000000
61	24-Nov	100.00%	100.00%	99.95%	99.66%	99.90%	99.66%	100.00%	0.000003	0.0000%	0.0295%	0.0478%	0.0313%	0.0272%	0.000000
62	25-Nov	100.00%	100.00%	100.00%	99.69%	99.92%	99.69%	100.00%	0.000002	0.0000%	0.0000%	0.0478%	0.0313%	0.0198%	0.000000
63	26-Nov	100.00%	100.00%	100.00%	99.72%	99.93%	99.72%	100.00%	0.000002	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
64	27-Nov	100.00%	100.00%	100.00%	99.75%	99.94%	99.75%	100.00%	0.000002	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
65	28-Nov	100.00%	100.00%	100.00%	99.78%	99.95%	99.78%	100.00%	0.000001	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
66	29-Nov	100.00%	100.00%	100.00%	99.81%	99.95%	99.81%	100.00%	0.000001	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
67	30-Nov	100.00%	100.00%	100.00%	99.84%	99.96%	99.84%	100.00%	0.000001	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
68	01-Dec	100.00%	100.00%	100.00%	99.87%	99.97%	99.87%	100.00%	.000000	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
69	02-Dec	100.00%	100.00%	100.00%	99.91%	99.98%	99.91%	100.00%	.000000	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
70	03-Dec	100.00%	100.00%	100.00%	99.94%	99.98%	99.94%	100.00%	.000000	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
71	04-Dec	100.00%	100.00%	100.00%	99.97%	99.99%	99.97%	100.00%	.000000	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000
72	05-Dec	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.000000	0.0000%	0.0000%	0.0000%	0.0313%	0.0078%	0.000000

	1975	1976	1977	1985
MEAN DAY	26	29	24	28
VARIANCE	51.1	92.1	56.3	77.5
STANDARD DEVIATION	7.15	9.6	7.5	8.8
MEDIAN DAY	29	29	25	31

Appendix Table 10. Average percent of live fall chum salmon in the Delta River by date based upon observations made in 1977, 1981, 1982, 1984, and 1985.

DAY	DATE	1977	1981	1982	1984	1985	AVERAGE	MINIMUM	MAXIMUM	VARIANCE
1	25-Sep	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.00000
2	26-Sep	99.88%	99.64%	99.92%	99.34%	100.00%	99.76%	99.34%	100.00%	0.00001
3	27-Sep	99.77%	99.28%	99.84%	98.68%	100.00%	99.51%	98.68%	100.00%	0.00003
4	28-Sep	99.65%	98.92%	99.75%	98.02%	99.88%	99.24%	98.02%	99.88%	0.00006
5	29-Sep	99.53%	98.55%	99.67%	97.36%	99.75%	98.97%	97.36%	99.75%	0.00010
6	30-Sep	99.42%	98.19%	99.59%	96.70%	99.63%	98.71%	96.70%	99.63%	0.00016
7	01-Oct	99.30%	97.83%	99.51%	96.05%	99.50%	98.44%	96.05%	99.51%	0.00023
8	02-Oct	99.18%	97.47%	99.43%	95.39%	99.38%	98.17%	95.39%	99.43%	0.00031
9	03-Oct	99.06%	97.11%	99.34%	94.73%	99.25%	97.90%	94.73%	99.34%	0.00040
10	04-Oct	98.95%	96.74%	99.26%	94.07%	99.13%	97.63%	94.07%	99.26%	0.00050
11	05-Oct	98.83%	96.38%	99.18%	93.41%	99.05%	97.37%	93.41%	99.18%	0.00062
12	06-Oct	98.71%	96.02%	99.10%	92.75%	98.96%	97.11%	92.75%	99.10%	0.00075
13	07-Oct	98.60%	95.66%	99.01%	92.09%	98.88%	96.85%	92.09%	99.01%	0.00090
14	08-Oct	98.48%	95.08%	98.93%	91.43%	98.80%	96.54%	91.43%	98.93%	0.00107
15	09-Oct	98.36%	94.50%	98.85%	90.77%	98.71%	96.24%	90.77%	98.85%	0.00126
16	10-Oct	98.25%	93.92%	98.77%	90.11%	98.63%	95.94%	90.11%	98.77%	0.00146
17	11-Oct	98.13%	93.34%	98.69%	89.45%	98.55%	95.63%	89.45%	98.69%	0.00169
18	12-Oct	98.01%	92.76%	98.60%	88.79%	98.46%	95.33%	88.79%	98.60%	0.00193
19	13-Oct	97.90%	92.18%	98.52%	88.14%	98.38%	95.02%	88.14%	98.52%	0.00218
20	14-Oct	97.78%	91.60%	98.44%	87.48%	98.30%	94.72%	87.48%	98.44%	0.00245
21	15-Oct	97.66%	91.02%	96.96%	86.82%	98.21%	94.14%	86.82%	98.21%	0.00251
22	16-Oct	97.54%	90.44%	95.49%	86.16%	98.13%	93.53%	86.16%	98.13%	0.00263
23	17-Oct	97.43%	89.86%	94.01%	85.50%	97.88%	92.94%	85.50%	97.88%	0.00276
24	18-Oct	97.31%	89.28%	92.54%	84.84%	97.64%	92.32%	84.84%	97.64%	0.00296
25	19-Oct	97.19%	88.70%	91.06%	84.18%	97.39%	91.71%	84.18%	97.39%	0.00321
26	20-Oct	97.08%	88.12%	89.59%	82.89%	97.14%	90.96%	82.89%	97.14%	0.00377
27	21-Oct	96.96%	87.54%	88.11%	81.60%	96.90%	90.22%	81.60%	96.96%	0.00440
28	22-Oct	94.32%	86.36%	86.64%	80.32%	96.65%	88.98%	80.32%	96.65%	0.00430
29	23-Oct	91.68%	86.38%	85.16%	79.03%	96.41%	87.73%	79.03%	96.41%	0.00438
30	24-Oct	89.04%	85.80%	83.69%	77.74%	96.16%	86.49%	77.74%	96.16%	0.00462
31	25-Oct	86.40%	85.22%	82.21%	76.45%	95.58%	85.17%	76.45%	95.58%	0.00487
32	26-Oct	83.76%	84.64%	80.74%	75.16%	95.00%	83.86%	75.16%	95.00%	0.00525
33	27-Oct	81.12%	84.06%	79.26%	73.87%	93.50%	82.36%	73.87%	93.50%	0.00525
34	28-Oct	78.48%	83.48%	76.17%	72.59%	92.00%	80.54%	72.59%	92.00%	0.00567
35	29-Oct	75.84%	82.90%	73.08%	71.30%	90.51%	78.72%	71.30%	90.51%	0.00629
36	30-Oct	73.20%	82.32%	69.99%	70.01%	89.01%	76.91%	69.99%	89.01%	0.00712
37	31-Oct	70.56%	81.74%	66.90%	67.02%	87.51%	74.74%	66.90%	87.51%	0.00877
38	01-Nov	67.92%	81.16%	63.81%	64.02%	86.01%	72.58%	63.81%	86.01%	0.01065
39	02-Nov	65.28%	80.58%	60.72%	61.03%	82.70%	70.06%	60.72%	82.70%	0.01155
40	03-Nov	62.64%	80.00%	57.63%	58.03%	79.38%	67.54%	57.63%	80.00%	0.01270
41	04-Nov	60.00%	77.50%	54.54%	55.04%	76.07%	64.63%	54.54%	77.50%	0.01279
42	05-Nov	57.72%	75.00%	51.45%	52.05%	72.76%	61.79%	51.45%	75.00%	0.01283
43	06-Nov	55.43%	72.50%	48.36%	49.05%	69.45%	58.96%	48.36%	72.50%	0.01291
44	07-Nov	53.15%	70.00%	45.27%	46.06%	66.13%	56.12%	45.27%	70.00%	0.01302
45	08-Nov	51.25%	67.50%	42.18%	43.06%	62.82%	53.36%	42.18%	67.50%	0.01312
46	09-Nov	49.35%	65.00%	39.09%	40.07%	59.00%	50.50%	39.09%	65.00%	0.01307
47	10-Nov	47.46%	62.50%	36.00%	37.94%	55.19%	47.82%	36.00%	62.50%	0.01268
48	11-Nov	45.56%	60.00%	34.56%	35.81%	51.37%	45.46%	34.56%	60.00%	0.01146
49	12-Nov	43.66%	57.50%	33.12%	33.69%	47.55%	43.10%	33.12%	57.50%	0.01038
50	13-Nov	41.76%	55.00%	31.68%	31.56%	43.74%	40.75%	31.56%	55.00%	0.00949
51	14-Nov	39.86%	52.50%	30.24%	29.43%	39.92%	38.39%	29.43%	52.50%	0.00876
52	15-Nov	37.96%	50.00%	28.80%	27.30%	36.11%	36.03%	27.30%	50.00%	0.00818
53	16-Nov	36.07%	47.50%	27.36%	25.94%	32.29%	33.83%	25.94%	47.50%	0.00746
54	17-Nov	34.17%	45.00%	25.92%	24.57%	28.47%	31.63%	24.57%	45.00%	0.00694
55	18-Nov	32.27%	42.50%	24.48%	23.21%	24.66%	29.42%	23.21%	42.50%	0.00662
56	19-Nov	30.37%	40.00%	23.04%	21.84%	20.84%	27.22%	20.84%	40.00%	0.00651
57	20-Nov	28.47%	37.50%	21.60%	20.48%	19.54%	25.52%	19.54%	37.50%	0.00572
58	21-Nov	26.58%	35.00%	20.16%	19.11%	18.24%	23.82%	18.24%	35.00%	0.00498
59	22-Nov	24.68%	32.50%	18.72%	17.75%	16.93%	22.11%	16.93%	32.50%	0.00430
60	23-Nov	22.78%	30.00%	17.28%	16.38%	15.63%	20.41%	15.63%	30.00%	0.00366
61	24-Nov	20.88%	27.50%	15.84%	15.02%	14.33%	18.71%	14.33%	27.50%	0.00308
62	25-Nov	18.98%	25.00%	14.40%	13.65%	13.02%	17.01%	13.02%	25.00%	0.00254
63	26-Nov	17.08%	22.50%	12.96%	12.29%	11.72%	15.31%	11.72%	22.50%	0.00206
64	27-Nov	15.19%	20.00%	11.52%	10.92%	10.42%	13.61%	10.42%	20.00%	0.00163
65	28-Nov	13.29%	17.50%	10.08%	9.56%	9.12%	11.91%	9.12%	17.50%	0.00125
66	29-Nov	11.39%	15.00%	8.64%	8.19%	7.81%	10.21%	7.81%	15.00%	0.00092
67	30-Nov	9.49%	12.50%	7.20%	6.83%	6.51%	8.51%	6.51%	12.50%	0.00064
68	01-Dec	7.59%	10.00%	5.76%	5.46%	5.21%	6.80%	5.21%	10.00%	0.00041
69	02-Dec	5.69%	7.50%	4.32%	4.10%	3.91%	5.10%	3.91%	7.50%	0.00023
70	03-Dec	3.80%	5.00%	2.88%	2.73%	2.60%	3.40%	2.60%	5.00%	0.00010
71	04-Dec	1.90%	2.50%	1.44%	1.37%	1.30%	1.70%	1.30%	2.50%	0.00003
72	05-Dec	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00000

MEMORANDUM

State of Alaska

TO: Distribution

DATE: March 18, 1987

FILE NO:

TELEPHONE NO: 456-4286

FROM: Louis H. Barton LHB
Upper Yukon Research Project Leader
Division of Commercial Fisheries
Department of Fish and Game
Fairbanks

SUBJECT: Delta River Fall Chum Salmon Surveys 1986

A total of one aerial and nine ground surveys was made of spawning fall chum salmon in the Delta River in 1986 (Table 1). Two methods were used to generate population estimates using the 1986 data as described in last year's Delta River report (AYK Yukon Salmon Escapement Report No. 29). The first method involved plotting counts of live salmon by survey date and estimating the area under the curve (i.e., number of salmon days). The result was 129,504 salmon days assuming the first fish entered subsequent to September 25 and that no fish remained alive subsequent to December 6. Division by residence time (18.2 days) yielded a population estimate of 7,116 fish. Only foot survey observations were included in this analysis since many carcass counts were included in the live salmon counts during the aerial survey.

The second method employed to estimate total abundance was as follows. The number of live salmon observed on a specified day was the sum of the number of live fish remaining from the previous survey(s) and the number of new fish entering the stream subsequent to the previous survey. The number of fish which had spawned and died between surveys was estimated from average stream residence time. Total run size was approximated by summing the numbers of new salmon estimated entering in each interval of time (Table 2). The population estimate was 6,290.

Both of the above population estimates can be considered conservative due to difficulty in obtaining precise salmon counts early in the season from turbidity problems and late in the season from the presence of ice in portions of the spawning area. Nonetheless, the best estimate of total fall chum salmon escapement in the Delta River in 1986 is considered the midpoint between the two estimates generated, or 6,703.

The salmon count (live plus dead) on each survey was employed in the Delta River time-density model to estimate, at the time of the survey, the total spawning population in 1986. Resulting population estimates are shown in Table 3 along with 95% and 90% confidence intervals (see also Figure 1).

Attachments

Distribution: Andersen
Arvey
Bergstrom
Brannian
Buklis
Cannon
Merritt
Randall
Whitmore
Wilcock

Table 1. Delta River fall chum salmon escapement surveys, 1986.

DATE	TYPE SURVEY	EASTERN CHANNELS a LIVE	DEAD	TOTAL	MID OR MAIN RIVER CHANNELS b LIVE	DEAD	TOTAL	WESTERN CHANNELS c LIVE	DEAD	TOTAL	TOTAL DELTA RIVER AREA LIVE	DEAD	TOTAL	
30-Sep	FOOT d			TURBID			TURBID	271	30	301	271	30	301	poor
06-Oct	FOOT d			TURBID	147	0	147	527	66	593	674	66	740	poor
14-Oct	FOOT d			TURBID	21	4	25	399	62	461	420	66	486	very poor - high turbid water
21-Oct	FOOT			TURBID	99	23	122	1,332	323	1,655	1,431	346	1,777	ch3 good
28-Oct	FOOT	215	7	222	2,454	126	2,580	1,348	283	1,631	4,017	416	4,433	
04-Nov	FOOT	392	60	452	2,635	364	2,999	1,172	627	1,799	4,199	1,051	5,250	
12-Nov	FOOT d	237	116	353	2,720	1,350	4,070	802	560	1,362	3,759	2,026	5,785	
19-Nov	FOOT d,e	105	84	189	1,679	757	2,436	284	226	510	2,068	1,067	3,135	ice and snow cover
26-Nov	FOOT f	32	—	32	740	—	740	100	—	100	872	—	—	
30-Oct	AERIAL	251	13	264	3,957	50	4,007	1,671	25	1,696	5,879	88	5,967	live ct includes some carcasses

a Includes channel I.

b Includes channels II and II 1/2.

c Includes channel III.

d Poor survey

e Carcass count is very low. Live count fair to poor due to ice cover.

f No carcass count was made.

FILE - NEWFSH86 17-Mar-87

Table 2. Delta River fall chum salmon population estimate based upon the summation of new salmon entering the river during each interval of time between surveys.

DAY	DATE	INTER-VAL	SEP 30 DEAD	SEP 30 LIVE	OCT 6 DEAD	OCT 6 LIVE	OCT 14 DEAD	OCT 14 LIVE	OCT 21 DEAD	OCT 21 LIVE	OCT 28 DEAD	OCT 28 LIVE	OCT 30 d,f DEAD	OCT 30 d,f LIVE	NOV 4 DEAD	NOV 4 LIVE	NOV 12 DEAD	NOV 12 LIVE	NOV 19 DEAD	NOV 19 LIVE	NOV 26 DEAD	NOV 26 LIVE
1	25-Sep																					
		5																				
6	30-Sep		(30)b	271 c																		
		6	8																			
12	06-Oct			263	(66)	411 c																
		8	60		19																	
20	14-Oct			203		393	(66)	(108)c,e														
		7	131		104																	
27	21-Oct			72		288			(346)	1,071 c												
		7	60		201				36													
34	28-Oct			11		87				1,035	(416)	2,884 c										
		2	9		25				20		32											
36	30-Oct d,e			2		62				1,014		2,852	(88) f	1,966 c,f								
		5	2		56				211		66											
41	04-Nov			0		6				803		2,786			(1051)	604 c						
		8			6				576		764				27							
49	12-Nov					0				227		2,022				577	(2026)	934 c				
		7							211		1,410				153		32					
56	19-Nov									16		611				423		902	(1067)	115 c		
		7							16		568				295		202		4			
63	26-Nov									0		43				128		700		111	(?)	(111)c,e
		11									43				128		580		56			
74	07-Dec											0				0		120		55		
			271		411		0		1,071		2,884				604		782		60			

Population estimate (i.e., summation on new fish entering stream) = 6,290

a All observations based upon foot surveys unless otherwise noted. Live fish shown below new fish entering the stream are those remaining alive on subsequent surveys based upon stream residence time data from Trasky (1974, 1976). Dead fish shown below new fish entering the stream are number of salmon which died in that interval of time.

b The number in parentheses is actual number of carcasses observed.

c New fish entering the stream.

d Aerial survey.

e Survey results were not included in the analysis for this day.

f Live counts include a large percentage of carcasses thus survey results were not included in analysis.

Table 3. Population estimates of fall chum salmon escapements to the Delta River in 1986 based upon observations of live and dead salmon by survey date and the Delta River time-density model.

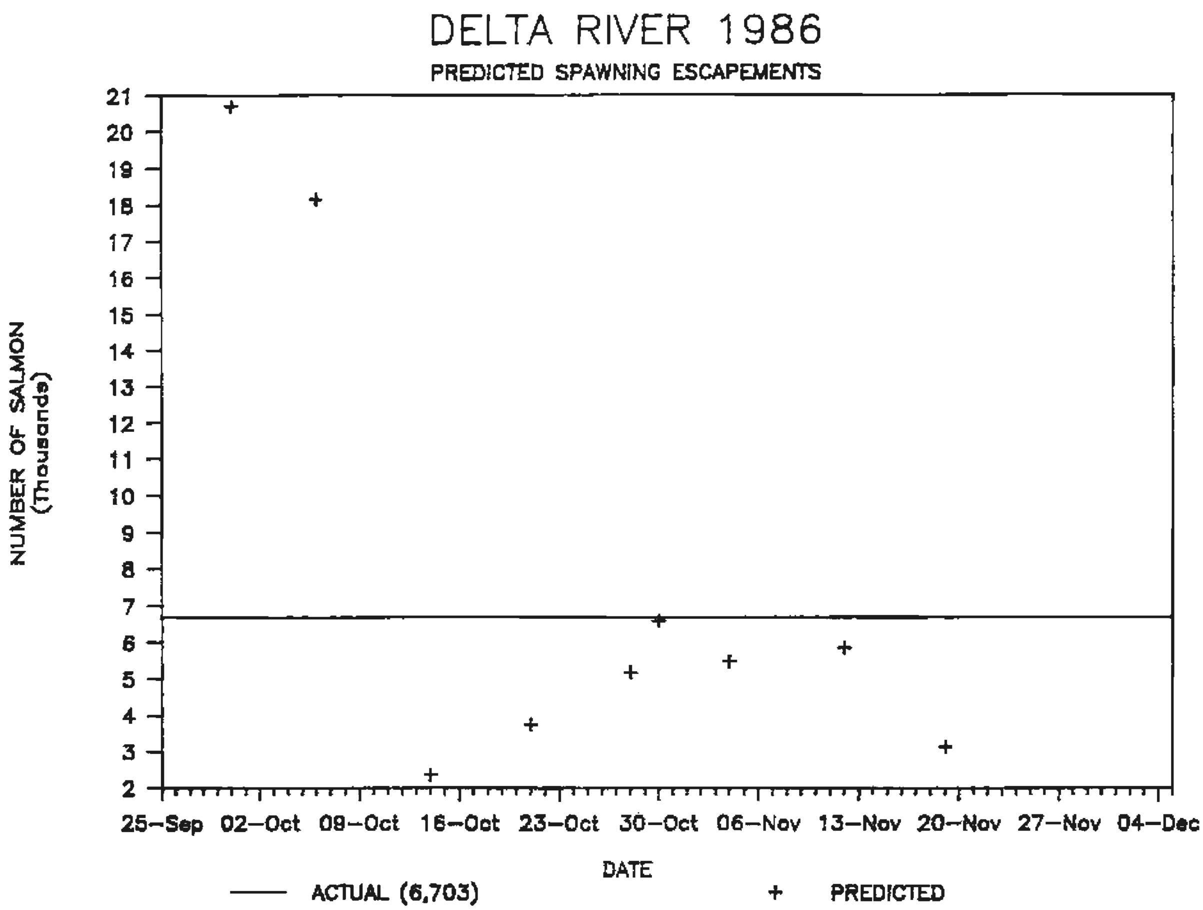
SURVEY DATE	SURVEY TYPE a	EXPANSION FACTOR b	SURVEY COUNT c	POPULATION ESTIMATE	RANGE AT 95% CONFIDENCE LEVEL	RANGE AT 90% CONFIDENCE LEVEL
30-Sep	F	0.0145	301 p	20,696	--	--
06-Oct	F	0.0407	740 p	18,165	--	--
14-Oct	F	0.2061	486 p	2,358	--	--
21-Oct	F	0.4726	1,777	3,760	2,149-15,044 (relative error 300.07%)	2,419-8,443 (relative error 124.53%)
28-Oct	F	0.8533	4,433	5,195	4,433-8,290 (relative error 59.58%)	4,433-7,176 (relative error 38.14%)
30-Oct	A	0.9026	5,967	6,611	5,967-9,200 (relative error 39.16%)	5,967-8,348 (relative error 26.28%)
04-Nov	F	0.9566	5,250	5,488	5,250-6,461 (relative error 17.73%)	5,250-6,176 (relative error 12.53%)
12-Nov	F	0.9850	5,785	5,873	5,785-6,210 (relative error 5.74%)	5,785-6,118 (relative error 4.18%)
19-Nov	F	0.9977	3,135 p	3,142	3,135-3,164 (relative error 0.69%)	3,135-3,158 (relative error 0.51%)
26-Nov	F	0.9993	872 p	--		--

a Foot (F), Aerial (A).

b Cumulative proportion of escapement estimated on survey date from migratory time-density model.

c Includes live and dead fish.

p Poor survey conditions.



DELTA RIVER 1986
PREDICTED SPAWNING ESCAPEMENTS
NUMBER OF SALMON
(Thousands)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
25-Sep
02-Oct
09-Oct
16-Oct
23-Oct
30-Oct
06-Nov
13-Nov
20-Nov
27-Nov
04-Dec
DATE
ACTUAL (6,703)
PREDICTED

Figure 1.