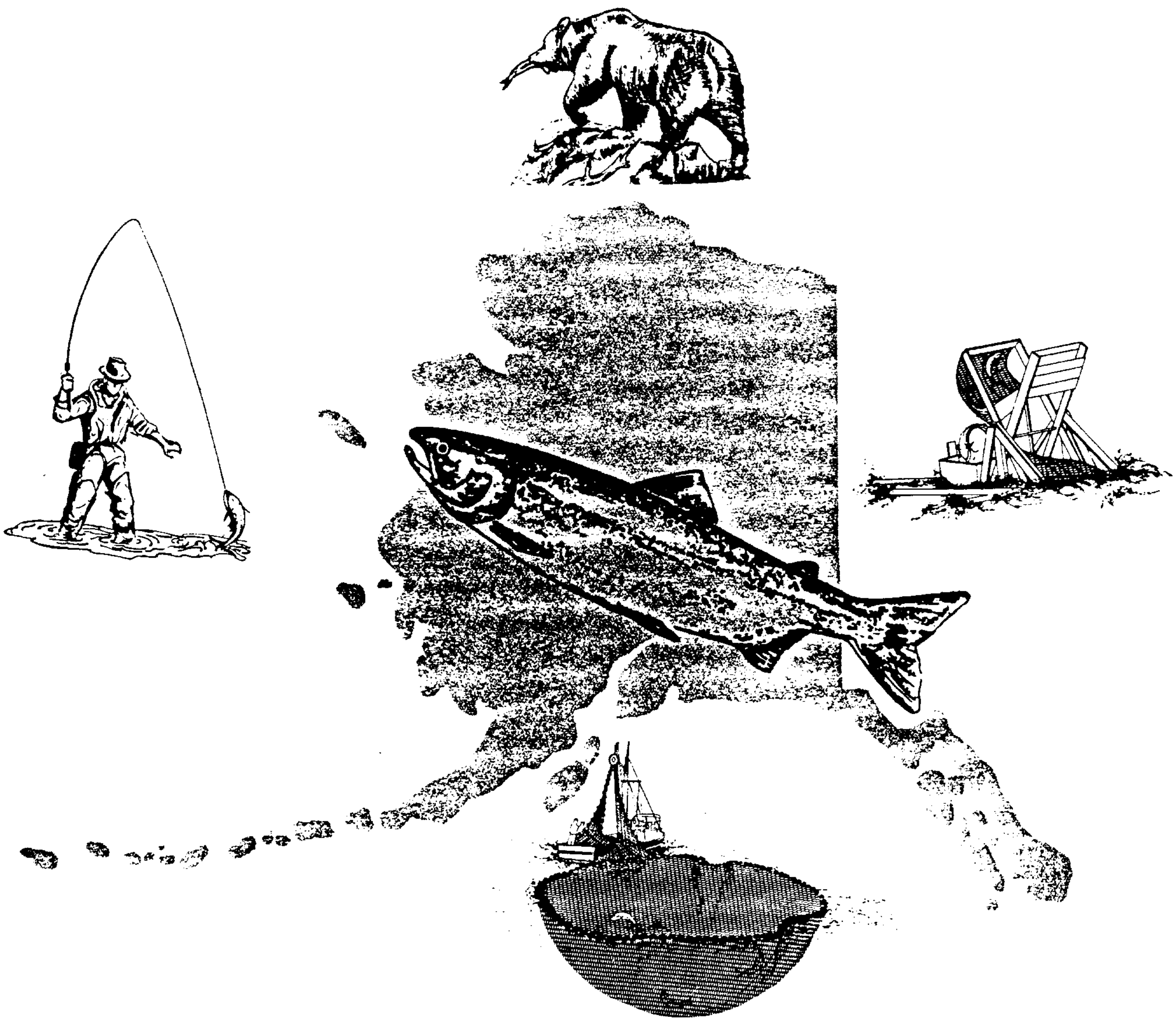
Alaska Fisheries Technical Report Number 16

SONAR ENUMERATION OF FALL CHUM SALMON ON THE CHANDALAR RIVER, 1986-1990



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Sonar Enumeration of Fall Chum Salmon on the Chandalar River, 1986-1990

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ABSTRACT

From 1986 through 1990, two Bendix side-scanning sonar fish counters were used to enumerate fall chum salmon *Oncorhynchus keta* escapement into the Chandalar River, a tributary of the Yukon River. Sonar stations were set up across river from one another with the sonar beams aimed approximately perpendicular to the shoreline. Seasonal totals ranged from 78,631 chum salmon in 1990 to 33,619 in 1988, averaging 58,628 annually. These are conservative estimates of annual escapement since counts do not include fish passing out of sonar range, fish present before the sonar equipment was in operation, and fish present after counting ceased. Sonar counting ranges were adequate for the detection of the majority of the run since most salmon were oriented nearshore.

Median passage dates ranged from September 1 (1986) to September 10 (1990). As water elevation increased, the percentage of fish using the south bank increased. Vertebrae were more reliable than otoliths or scales for aging Chandalar River fall chum salmon. Age 0.3 and 0.4 fish comprised between 92 and 100% of the annual sample. Age 0.3 fish predominated except in 1988 (age 0.4). Males (ages 0.3 and 0.4) were significantly greater in length than females of similar age. Gill net sampling selected for male chum salmon, whereas carcass collections were unbiased.

Three years of concurrent data from aerial surveys and sonar enumeration (1988-1990) indicate that aerial counts, even under good survey conditions, are not reliable indices of Chandalar River fall chum salmon total escapement. Aerial surveys substantially underestimated run size and were highly variable between years (expansion factors of 5.86 in 1988, 2.70 in 1989 and 6.17 in 1990).

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INTRODUCTION

Accurate salmon escapement counts on Yukon River tributaries are important for assessing annual harvest management guidelines, predicting run strength based on brood year returns, and influencing current U.S./Canada salmon treaty negotiations for allocating trans-boundary chinook *Oncorhynchus tshawytscha* and chum salmon *O. keta* stocks. Due to the size of the Yukon River drainage (854,700 km^2), estimating spawning escapement to all tributaries is not economically feasible. The primary method of survey is by aerial reconnaissance on selected key index streams. These surveys are flown during peak spawning periods and estimate instantaneous escapement; not total escapement. From 1953 to 1959, the U.S. Fish and Wildlife Service (Service) conducted salmon escapement surveys on selected lower Yukon River tributaries (Barton 1984a). Since 1959, the Alaska Department of Fish and Game (Department) has had primary responsibility for collection of escapement data. In 1985, the Joint U.S./Canada Yukon River Technical Committee (JTC) identified the need for a side-scan sonar study to enumerate the total escapement of fall chum salmon in the Chandalar River.

In limited use by the Department since 1960, side-scanning sonar equipment has recently undergone improvements which make it a far more accurate (although costly) method of estimating the number of migrating salmon in a river than aerial surveys. The Department has used this technique only when less expensive methods are not feasible, and only on major spawning streams. In 1990, hydroacoustic projects along the Yukon River included the Anvik River to enumerate summer chum salmon, the Sheenjek River to enumerate fall chum salmon, and the main channel of the Yukon River at Pilot Station to estimate total run sizes of chum, chinook, and coho salmon *O. kisutch*.

Two species of Pacific salmon migrate up the Chandalar River with chum salmon being the most abundant, followed by chinook salmon. The Yukon River is the only North American drainage having two runs of chum salmon (summer and fall). The majority of the fall run spawn in upper Yukon River tributaries including the Chandalar River. Spawning occurs from September through early November (Barton 1984b). A few summer chum salmon have been reported in the Chandalar River (Rost *in preparation*), but the majority spawn in lower Yukon River tributaries, including the Anvik, Koyukuk, and Tanana rivers (Barton 1984a). Summer chum salmon spawn from July to mid-August.

In 1986, a five-year study was initiated by the Service to (1) estimate total escapement of Chandalar River fall chum salmon with side-scanning sonar, (2) assess annual variability in run size and timing, (3) quantify age, sex, and size composition of the spawning population, (4) collect tissue samples for genetic stock identification (GSI), (5) test the accuracy of using aerial survey counts to estimate total escapement, and (6) provide the JTC with accurate escapement counts so conflicts over harvesting trans-boundary Yukon River salmon stocks can be resolved. This final report summarizes and discusses results presented in the five annual progress reports: 1986 (Simmons and Daum 1989); 1987 (Daum and Simmons 1991); 1988 (Daum et al. 1991); 1989 (Daum 1991); and 1990 (Daum and Troyer 1991).

STUDY AREA

The Chandalar River is a fifth order tributary of the Yukon River, drains from the southern slopes of the Brooks Range, and consists of three major branches: East, Middle, and North forks (Figure 1). Principal water sources include rainfall, snowmelt and, to a lesser extent, meltwater from small glaciers and perennial springs (Craig and Wells 1975). Summer water visibility in the lower river is typically less than 1.5 m. The region has a continental subarctic climate characterized by the most extreme temperatures in the state: -41.7 to 37.8°C (U.S. Department of the Interior 1964). Precipitation ranges from 15 to 33 cm annually with the majority falling between May and September. Breakup is typically in early June and freezeup in late September to early October.

The lower 19 km of the Chandalar River is influenced by a series of slough systems connected to the Yukon River. River banks are typically steep with overhanging vegetation and downed trees caused by active bank erosion. Gravel bars are absent in this area and the bottom substrate is composed primarily of sand and silt. Water velocities are generally less than 75 cm/s. Twenty-one to 22.5 km upstream from its confluence with the Yukon River, the Chandalar River is confined to a single channel with steep cut banks alternating with large gravel bars. The sonar facility was located in this section (Figure 2). Above this area, the river becomes braided with many islands and multiple channels.

MATERIALS AND METHODS

Fall chum salmon were counted with two 1981 Bendix side-scan sonar fish counters. Both counting systems were operational from the second week of August to the last week in September, 1986-1990. North and south bank transducers were deployed in the same locations each year and offset approximately 180 m from one another. Sonar equipment was needed on opposite river banks since river width (approximately 120 m) is greater than the maximum counting range (30 m). Counting ranges on the north and south banks averaged 28.0 and 18.9 m, respectively (Figure 3). Each counting range was subdivided into 16 sectors.

The sonar counters were deployed and operated according to the guidelines described by Bendix Corporation (1981). Because of the relatively flat river bottom, the modular substrate normally used with this system was not deployed. Instead, the transducers were mounted on plastic frames and secured in place with sandbags at a depth of 0.6-1.5 m (design adapted from Barton 1986). Transducers were oriented perpendicular to shore and aiming was fine-tuned with three hand wheels on the back of the transducer bracket. A wire fence weir (5 x 10 cm mesh) was installed 1 m downstream and extended 2 m beyond the transducer to keep salmon from passing upstream between the shoreline and the transducer. Fish moving close to shore would encounter the weir, be forced to move offshore, and then pass through the sonar beam.

To determine if the beam angles (2° and 4°) were aimed low enough so that salmon could not travel beneath the beam undetected, an artificial "fish" (1 L lead-weighted glass container attached to monofilament line) was suspended at various depths in each of the 16 sectors of the counting range. When the container passed the sonar beam it registered as a valid count on the counter and simultaneously appeared as a sharp "spike" on the oscilloscope (Tektronix 323). Adjustments revealed an almost clear oscilloscope picture when the beam was aimed

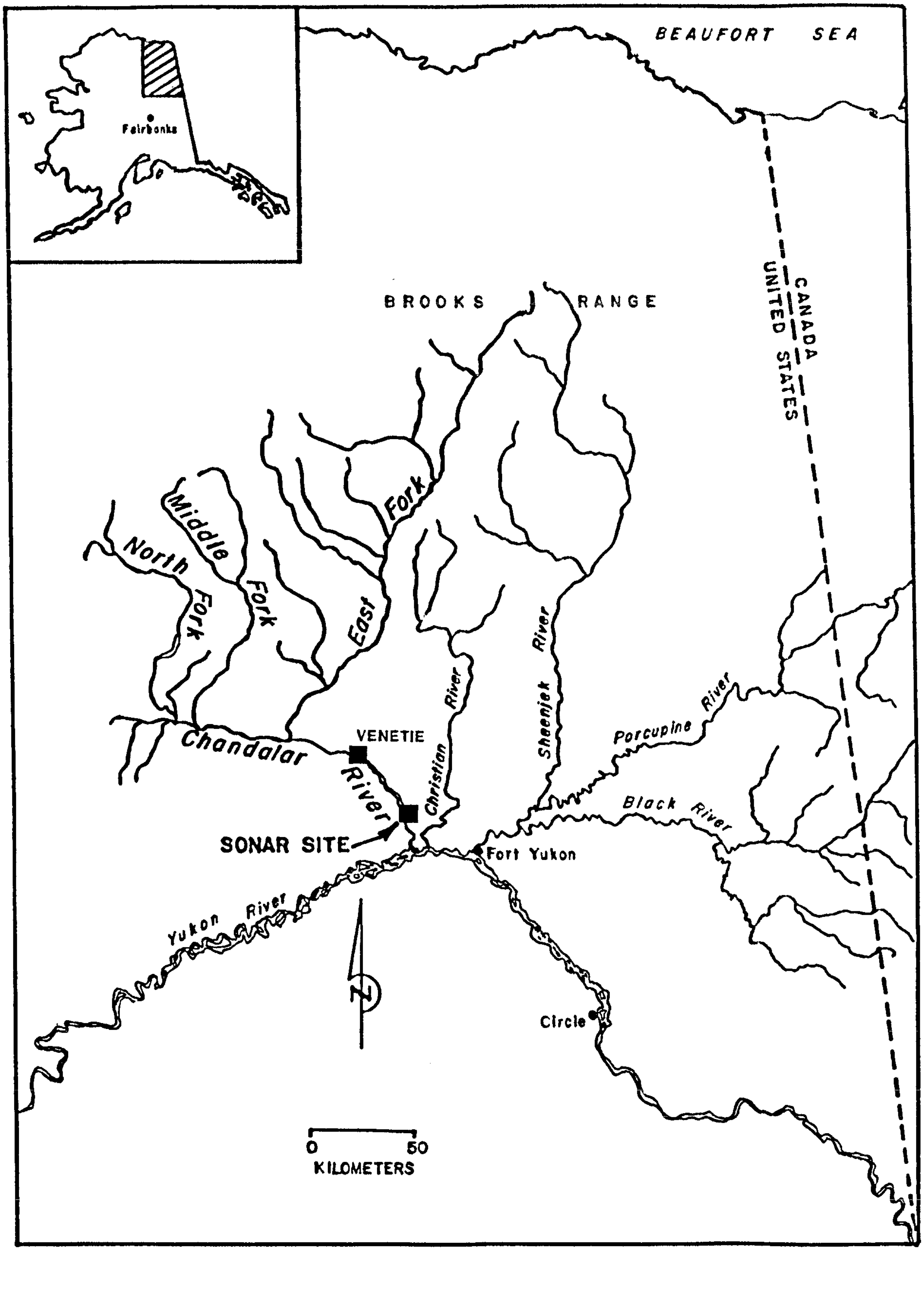

Figure 1. Major tributaries of the Yukon River near the U.S./Canada border.

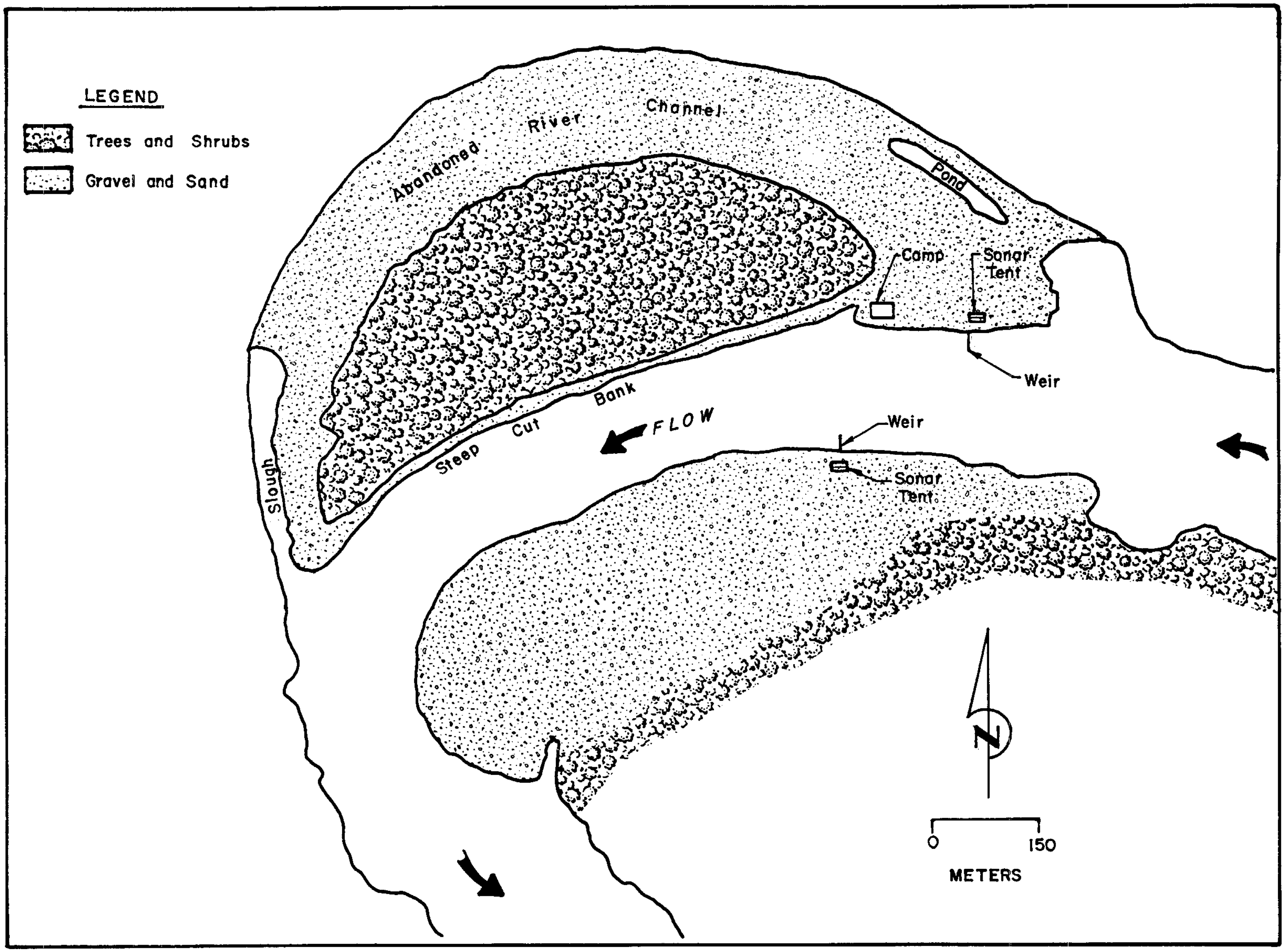

Figure 2. Site map of the Chandalar River sonar facilities.

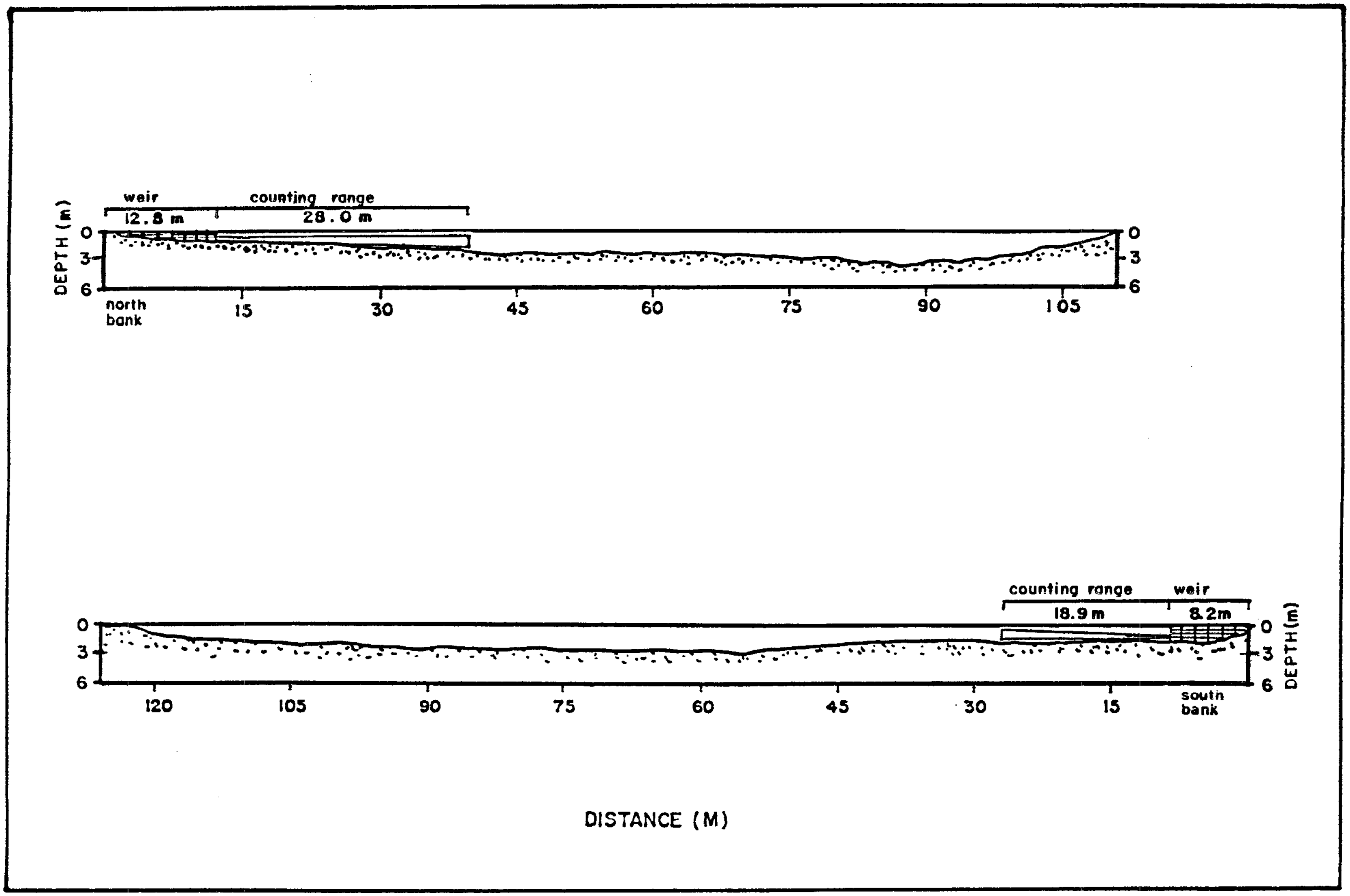

Figure 3. River channel profiles of the north and south bank sonar facilities (weir length and counting ranges are approximations that change according to river discharge levels).

between 5 and 10 cm off the bottom. Remaining "bottom spikes" were removed with a Bendix "rock inhibitor" electronic circuit component. This feature greatly improved the counting precision by eliminating bottom interference, allowing the beam to pass very close to the river bottom.

To verify that the number of fish registered by the sonar counter coincided with the number of fish passing through the sonar beam, comparisons were made between oscilloscope observations and counter output once every four hours for 30-minute calibration periods. When a fish passed through the beam, a returning echo was displayed on the oscilloscope and a corresponding count should register on the sonar counter. Adjustments to the fish velocity control (counter pulse rate) were made when the oscilloscope count exceeded 14 fish and the sonar count differed from the oscilloscope count by more than 15% during the 30-minute calibration period. Passage rates less than one fish every 2 min were assumed too low for adjustment determinations. If adjustments were made, the new fish velocity control setting was calculated as follows:

New fish velocity setting = (Sonar counts / Scope counts) x Fish velocity setting.

Daily fish counts were adjusted using data from the six 30-minute calibration periods. In 1986-1988, the formula for the daily adjusted count (D) was:

$$D = \Sigma T_a + \Sigma [(O_b / C_b) \times T_b];$$

T_a = Sonar count for 4-hour period when fish velocity control is not changed;
O_b = Oscilloscope count during calibration period when fish velocity control is changed;
C_b = Sonar count during calibration period when fish velocity control is changed;
T_b = Sonar count for corresponding 4-hour period when fish velocity control is changed.

In 1989 and 1990, the daily adjustment formula was slightly changed to include adjustments for periods when the counter's fish velocity setting was not changed. A more accurate estimate of actual run size should be calculated using this method. The improved formula for the daily adjusted count (D) was:

$$D = [(\Sigma O_a / \Sigma C_a) \times \Sigma T] + \Sigma [(O_b / C_b) \times T];$$

O_a = Oscilloscope count during calibration period when fish velocity control is not changed;
C_a = Sonar count during calibration period when fish velocity control is not changed;
O_b = Oscilloscope count during calibration period when fish velocity control is changed;
C_b = Sonar count during calibration period when fish velocity control is changed;
T = Total sonar count for corresponding 4-hour period.

The 1989 and 1990 seasonal totals of daily adjusted counts were compared using both methodologies. In 1988, counts were estimated for two periods of high water by linear interpolation between daily counts just before and after those periods. Registered "debris counts" were deleted. All data in this report appear in adjusted form.

In 1986, gill nets were used to verify fish species composition since the Bendix sonar unit could not differentiate between species. Two types of gill nets were used: variable mesh monofilament (36.6 and 12.2 m long by 2.4 m deep with equal panels of 1.3, 2.5, 3.8, and 5.0 cm bar mesh) and multifilament (18.3 m long by 3.0 m deep with 7.4 cm bar mesh). Nets were initially set from shore every 2 to 3 days and fished between 4 and 12 hours. To reduce mortalities, netting effort was decreased to approximately once per week when it became apparent that nearly all fish captured were chum salmon. By mid-September, instream leaf litter became so abundant that nets were no longer effective. Gill netting was abandoned after the 1986 season due to man-power constraints. A 6 m high counting tower was also deployed in 1986 to verify species composition. Due to poor viewing conditions, the tower was abandoned after the 1986 season.

A river elevation gauge was installed by the north bank sonar site and monitored throughout the season. Water elevation was recorded daily to the nearest 0.3 cm. A permanent gauging site was established in 1989 so comparisons in water levels could be made between years. It was hypothesized that increased flow causes an increase in the proportion of fish migrating up the south side of the river, i.e., a shift in bank preference. This hypothesis was tested using simple linear regression analysis (Zar 1984), comparing water elevation to the daily proportion of fish counted from the south bank in 1989 and 1990. Regression lines between years were tested for coincidence using a multiple regression model with dummy variables (Kleinbaum and Kupper 1978). Equality of sample variances between years was determined with Levene's test (Snedecor and Cochran 1980). If regression lines between years were coincident, data were pooled and a new regression equation was calculated.

Sex and age composition data were collected for each of the five years. Methodologies changed as it became apparent that specific collection methods and aging structures were biasing the results. From 1986-1988 samples were taken during peak passage at the sonar site with a multifilament gill net (18.3 m long by 3.0 m deep with 7.4 cm bar mesh). The prevalence of males in these three years of samples caused a reevaluation of sampling strategies. In 1989 and 1990, chum salmon carcasses were randomly selected from a major spawning ground located upstream of Venetie Village. Carcasses were collected at various depths (shoreline to 1.5 m deep) with a 2 m long spear. Sex composition data was also gathered from chum salmon caught by multifilament gill net throughout the 1989 season so a comparison could be made between collection methods. A chi-square test with Yates correction for continuity (Zar 1984) was used to compare sex composition between the two capture methods.

In 1986 and 1987, otolith and scale samples, respectively, were used to determine ages of Chandalar River fall chum salmon. From 1988-1990, a minimum of three vertebrae per fish were collected and used to determine age. Vertebrae were cleaned, dried, and independently read twice by the author under direct light with a dissecting scope. Disagreements between readings were resolved with a third reading. Unreadable samples were discarded. Salmon age is reported by the European method (Foerster 1968) - number of freshwater annuli followed by number of saltwater annuli.

Length data were collected from all age samples in 1987 and 1988. Salmon length was measured to the nearest centimeter from mid-eye to the fork in the caudal fin. Length data from 1987 and 1988 were compared by age class for each sex. Data were pooled if mean lengths and associated variances were not significantly different between years (Student's *t*-test and variance ratio test). Mean lengths of males and females by age were compared using Student's *t*-test.

From 1986-1989, tissue samples were collected for GSI. All fish were collected with a multifilament gill net, 30.5 m long by 3.0 m deep with 7.4 cm bar mesh. Heart, liver, retinal, and muscle tissues were taken from each fish, packed in dry ice, and transported to the Service's research lab in Anchorage for electrophoretic analysis. Results of the GSI analysis are reported in Wilmot et al. (1992).

Aerial surveys were conducted from 1988-1990 to determine the relationship between aerial and sonar counts and to develop an expansion factor. The expansion factor is the number by which an aerial count (which tends to underestimate the run) is multiplied to approximate the sonar count, the best estimate of total escapement. In 1988, the survey was flown with a Super-cub fixed-wing aircraft, and in 1989 and 1990 with a Hughes 500-D helicopter. The survey area was from 10 km upstream of the sonar site to the confluence of the East Fork. This survey area is consistent with past surveys and no major spawning areas had been identified above this point (Barton 1984b, Rost *in preparation*). In 1989 and 1990, the survey area was expanded above the East Fork confluence to insure that no major spawning areas were missed.

The aerial survey focused on maximizing visibility and coverage of the river, especially key spawning areas, and timing the survey as close as possible to peak spawning. The many braided parts of the river were surveyed, requiring repeated passes up and down river for coverage of all channels and sloughs. To determine peak spawning, three surveys were flown one week apart in 1988 during the latter part of the season. From the 1988 results, peak spawning was expected roughly 3 weeks after median fish passage at the sonar station. Surveys were flown 90 m above ground level during optimum lighting conditions (1130-1600 hours). Numbers of spawners, carcasses, and spawning areas were marked on U.S. Geological Survey topographic maps. Surveys were given a rating based on water clarity and light conditions.

RESULTS AND DISCUSSION

Adjusted fall chum salmon escapement counts ranged from 33,619 in 1988 to 78,631 in 1990 (Table 1; Appendices 1-5). The average annual count for the five-year period was 58,628 fish (SD = 17,143). These are conservative estimates of annual escapement since counts do not include fish passing out of sonar range, fish present before the sonar equipment was in operation, and fish present after counting ceased.

Table 1. Peak and median passage dates, and estimated escapement of fall chum salmon in the Chandalar River, 1986-1990.

Year	Passage date Peak	Passage date Median	Estimated escapement
1986	Aug 25	Sep 1	59,313
1987	Sep 3	Sep 8	52,416
1988	Sep 1	Sep 5	33,619
1989	Aug 18	Sep 3	69,161
1990	Sep 15	Sep 10	78,631

Run strength and timing were highly variable between years (Figure 4). Peak passage dates ranged from August 18 to September 15 (Table 1), a range of 29 d. However, median passage dates (date that 50% of the run had passed the sonar site) were less variable (10 d), ranging from September 1 to September 10.

Fish passage was not equally distributed between counting units. The south bank counts were 35% of the total in 1986, 69% in 1987, 61% in 1988, 53% in 1989, and 31% in 1990. Because of this annual variability, sonar counts from one bank could not be used to estimate total escapement.

Distribution of total counts by sector revealed that not all fish were within the range of sonar detection. However, outer sector counts were low relative to nearshore counts, indicating that the majority of fish were detected (Figure 5). The majority of south bank fish were oriented close to shore with the highest frequency of occurrence in Sector 2. North bank fish were concentrated in the middle of the counting range with the highest frequency in Sector 9. Annually, the first 11 of the 16 sectors accounted for between 89 and 99% of the fish passing the south bank sonar (mean = 93%, SD = 4) and between 83 and 98% of the north bank fish (mean = 93%, SD = 6).

The Chandalar River experienced large variations in water elevation, both during the season and between years (Figure 6). The minimum and maximum water elevations differed by 0.9 m in 1986, 1.3 m in 1987, 2.3 m in 1988, 1.3 m in 1989, and 0.6 m in 1990. In 1989 and 1990, water elevation (X) was positively correlated ($P < 0.001$) with the percentage of fish using the south bank (Y). Data from 1989 and 1990 were pooled since regression lines were coincident ($P > 0.05$) and variances equal ($P > 0.06$). The regression equation for the combined data was $Y = -60.77 + 57.55X$ ($r = 0.741$, $P < 0.001$). As water level increased from 1.4 to 2.5 m, the predicted percentage of fish using the south bank increased from 20 to 83%, demonstrating a shift in bank preference as water elevation increased.

Fish swimming speed was highly variable throughout the season as indicated by the number of adjustments made to the counter's fish velocity control. The average annual adjustment rate on the north bank was 22% (SD = 2.4) and the south bank was 11.5% (SD = 6.0).

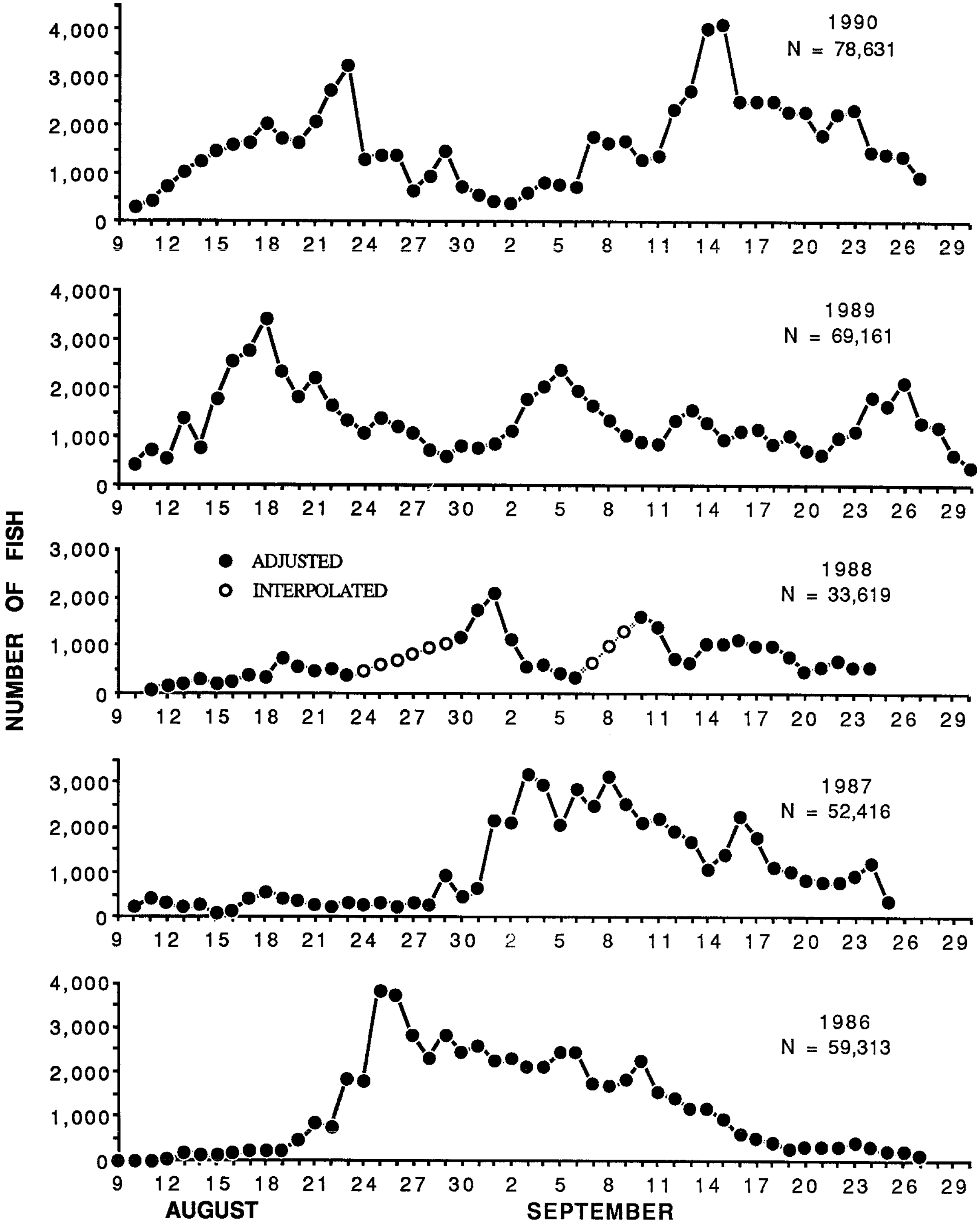

Figure 4. Chandalar River fall chum salmon run timing, based on daily sonar counts, 1986-1990.

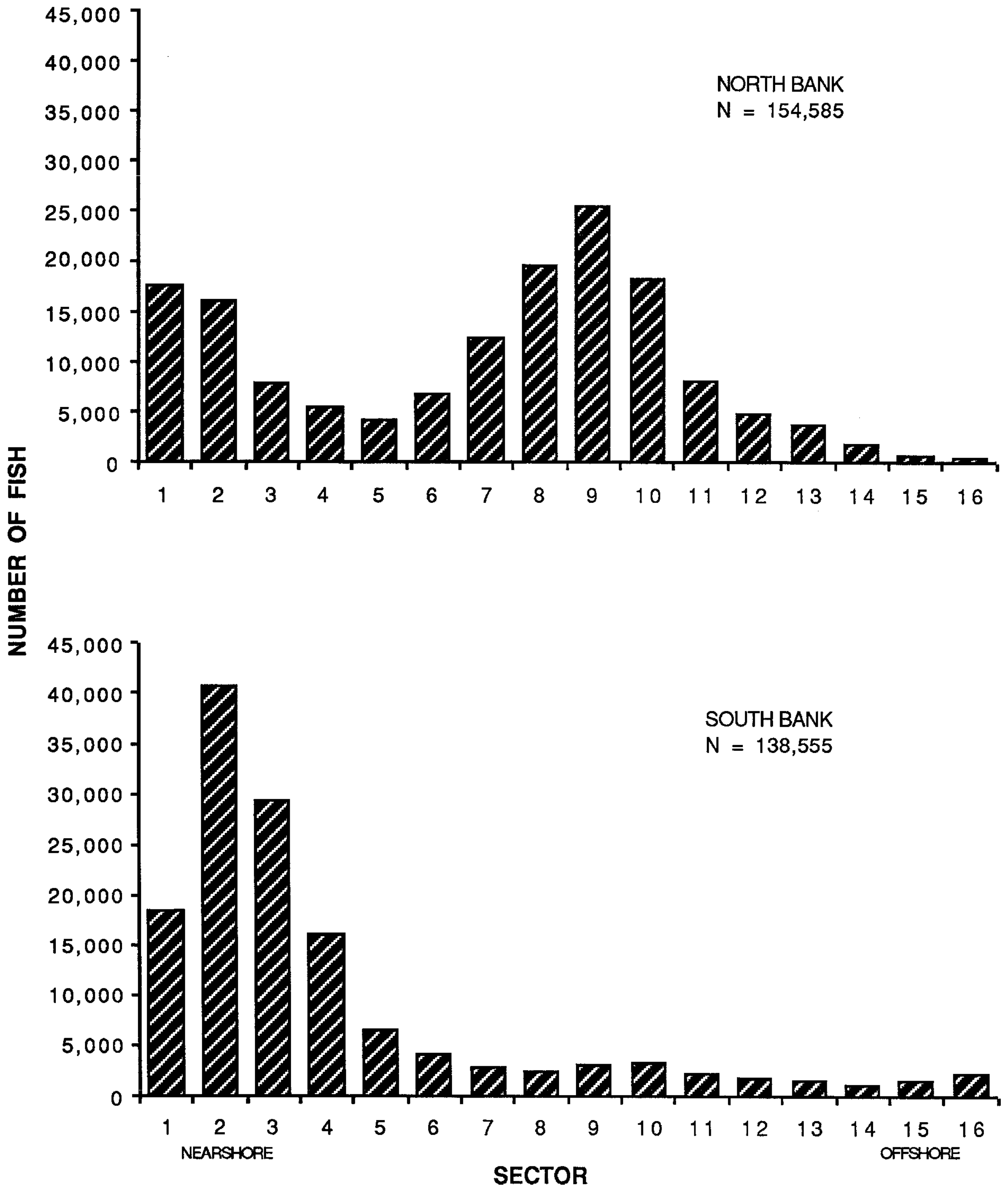

Figure 5. Total sector counts of Chandalar River fall chum salmon from the north and south bank sonar stations, 1986-1990.

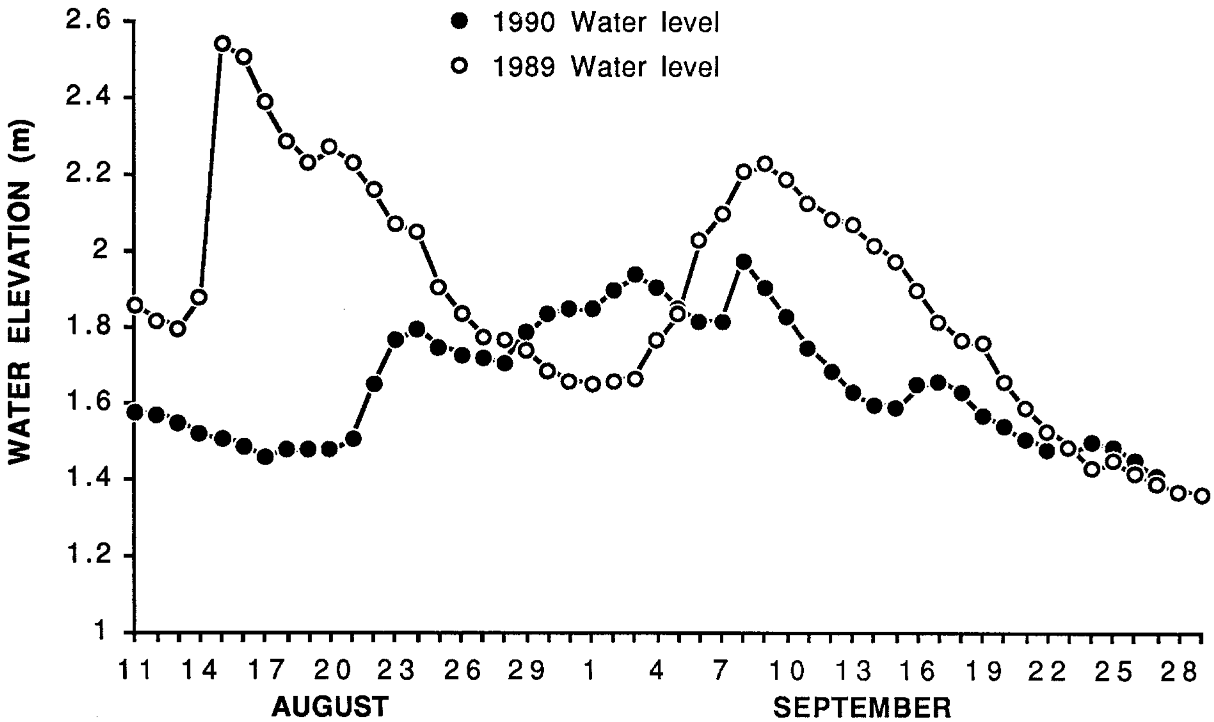

Figure 6. Daily water elevation in the Chandalar River, August 11-September 29, 1989 and August 11-September 27, 1990.

A comparison was made between the new and old equation used for adjusting daily counts so the differences due to the change in methodology could be quantified. The new method yielded a total escapement estimate 6.3% higher than the old technique in 1989 and 2.1% higher in 1990. The new method should produce a more accurate estimate of total escapement since it adjusts for all counting periods regardless of whether or not the fish velocity control setting was changed.

Additional sonar counts caused by fish species other than chum salmon were considered insignificant, since 99% of the multifilament gill net captures in 1986 were chum salmon. During 79 hours of effort, 186 chum salmon and 2 humpback whitefish *Coregonus pidschian* were captured. Variable mesh monofilament gill nets were abandoned due to poor gear efficiency caused by high water velocities. In order to accurately determine species composition on the Chandalar River, gear would need to be effective in capturing a wide variety of fish species, including chum salmon, Arctic grayling *Thymallus arcticus*, burbot *Lota lota*, longnose sucker *Catostomus catostomus*, northern pike *Esox lucius*, and whitefish species. Sampling should occur across the entire river using such techniques as drifting gill nets or seining, depending on water velocity, depth, bottom debris, and fish density. An extensive sampling effort for species composition was beyond the scope of this project.

Age 0.3 salmon predominated in all yearly samples except 1988 (Table 2). Ages 0.3 and 0.4 comprised between 92 and 100% of the annual sample. The prevalence of males in the 1986-1988 samples may be due, in part, to net selectivity for males, which have more kipe development than females. In 1989, the sex composition of the carcass collection (48% males, N=149) was significantly different ($P < 0.001$) than the gill net catch (67% males, N=170). Because gill nets are selective for spawning male chum salmon, carcass collection is the preferred method for obtaining unbiased samples.

Otolith and scale samples from the 1986 and 1987 seasons, respectively, indicated that these structures were unreliable indicators of age (50% of samples discarded in 1986 and 11% in 1987). Vertebrae appear to be the best structure for aging Chandalar River fall chum salmon. Only 1% of the vertebrae samples collected from 1988-1990 were unreadable (N=376).

Table 2. Sex and age data collected from fall chum salmon samples in the Chandalar River, 1986-1990.

	Sex composition (%)			Age composition (%)				
Year	N	Male	Female	N	0.2	0.3	0.4	0.5
1986[a]	150	68	32	75	0	65	35	0
1987[b]	150	76	24	134	0	55	42	3
1988[c]	73	74	26	73	3	42	54	1
1989[d]	149	48	52	146	4	71	21	5
1990[d]	154	33	66	153	1	56	39	4

[a] Otolith sample from gill net catch.
[b] Scale sample from gill net catch.
[c] Vertebrae sample from gill net catch.
[d] Vertebrae sample from carcass collection.

Lengths of Chandalar River fall chum salmon ranged from 51-70 cm. Data were pooled since no significant differences were detected between 1987 and 1988 mean lengths and associated variances (Table 3). Age 0.3 and 0.4 males were significantly larger than their female counterparts ($P < 0.05$ and $P < 0.005$, respectively).

The 1988-1990 aerial surveys were not reliable predictors of total escapement of fall chum salmon in the Chandalar River (Table 4). Expansion factors varied from 2.70 (1989) to 6.17 (1990), even though survey conditions were rated fair to good for all three years. The largest concentration of spawners was observed between 8 and 9 km upriver from Venetie Village. Shadows from heavy timber and turbidity caused by spawning fish adversely affected counting accuracy in this area. The total survey area appeared to cover the majority of the fall chum salmon spawning areas. No fish were observed up the East Fork in 1989 (6 km) or 1990 (21 km) and less than 0.3% of the total survey count was observed above the East Fork confluence. Unfortunately, only 3 km of the mainstem above the East Fork confluence was surveyed due to limited fuel and deteriorating light conditions.

The difficulties in obtaining aerial counts which reliably estimate yearly fall chum salmon escapement on the Chandalar River include (1) the numerous sloughs and tributary streams and the extensive braiding of large sections of river make full coverage impractical, (2) only rough estimates can be obtained for large concentrations of fish in areas of timber shading and turbidity, and (3) poor water visibility conditions caused by high water events are common. A limited coverage aerial survey may be adequate if focused on known spawning areas (index areas) where accurate counts can be obtained. However, surveying a few index areas intensively to obtain accurate counts runs the risk that those areas hold a limited number of fish, and do not accumulate spawners in proportion to total run size. Based on the 1989 helicopter survey, the Department identified several spawning areas which might provide consistent indices of total escapement. However, in 1990 fewer fish were counted in each of the potential index areas even though total escapement was higher (L. Barton, Department, Fairbanks, personal communication).

Past aerial surveys with fixed-wing aircraft have been conducted on this system since 1973 (except 1978-79) by the Department (Barton 1984b) and by the Service in 1985 (Rost *in preparation*). The highest reported count was 17,160 fish in 1974. The average annual count has been less than 5,000 fish, but survey conditions were usually rated as "poor". In contrast, the average annual sonar count from 1986-1990 was 58,628 fish. The Chandalar River is now recognized as a major producer of U.S. origin fall chum salmon (Bergstrom et al. 1991). Techniques other than aerial surveys may yield substantial increases in salmon escapement estimates for other difficult survey tributaries in the Yukon River system.

Table 3. Pooled length-at-age data collected from fall chum salmon in the Chandalar River, 1987-1988.

			Length (cm)		
Sex	Age	N	Mean	SE	Range
Males	0.2	2	53.0	2.00	51-55
	0.3	79	62.4	0.31	56-69
	0.4	71	64.7	0.32	55-69
	0.5	4	66.3	0.85	64-68
Females	0.3	26	61.1	0.52	57-68
	0.4	24	62.9	0.41	59-69
	0.5	1	70.0	- -	- -

Table 4. Aerial survey data, sonar count, and expansion factor for Chandalar River fall chum salmon, 1988-1990.

Aerial survey						
Survey date	Number of live fish	Number of carcasses	Total	Rating	Sonar count[a]	Expansion factor
09/28/88[b]	3,977	1,758	5,735	fair	33,619	5.86
09/19/89[c]	18,941	1,291	20,232	good	54,665	2.70
09/25/90[c]	10,736	1,154	11,890	good	73,416	6.17

[a] Sonar count two days prior to aerial survey, except in 1988 when final sonar count occurred on September 24 (4 days prior to survey).
[b] Survey using Super-cub fixed-wing aircraft.
[c] Survey using Hughes 500-D helicopter.

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Appendix 1. Chandalar River daily adjusted fall chum salmon counts from the north and south bank sonar stations, August 9 - September 27, 1986.

Date		South bank	North bank	Combined	Cumulative
Aug	9	5	4	9	9
	10	6	3	9	18
	11	-	-	- [a]	18
	12	-	35	35 [a]	53
	13	22	176	198	251
	14	14	120	134	385
	15	26	124	150	535
	16	40	124	164	699
	17	120	124	244	943
	18	121	121	242	1,185
	19	173	71	244	1,429
	20	212	238	450	1,879
	21	533	294	827	2,706
	22	262	510	772	3,478
	23	365	1,453	1,818	5,296
	24	789	1,021	1,810	7,106
	25	1,501	2,305	3,806	10,912
	26	1,956	1,784	3,740	14,652
	27	1,224	1,600	2,824	17,476
	28	890	1,427	2,317	19,793
	29	837	2,003	2,840	22,633
	30	706	1,761	2,467	25,100
	31	616	1,987	2,603	27,703
Sep	1	740	1,522	2,262	29,965
	2	670	1,638	2,308	32,273
	3	900	1,236	2,136	34,409
	4	587	1,531	2,118	36,527
	5	485	1,961	2,446	38,973
	6	737	1,728	2,465	41,438
	7	441	1,300	1,741	43,179
	8	701	986	1,687	44,866
	9	524	1,296	1,820	46,686
	10	570	1,694	2,264	48,950
	11	561	979	1,540	50,490
	12	659	764	1,423	51,913
	13	294	891	1,185	53,098
	14	361	805	1,166	54,264
	15	320	642	962	55,226
	16	296	304	600	55,826
	17	290	205	495	56,321
	18	205	222	427	56,748
	19	150	134	284	57,032
	20	159	143	302	57,334
	21	126	219	345	57,679
	22	115	228	343	58,022
	23	127	281	408	58,430
	24	154	167	321	58,751
	25	65	143	208	58,959
	26	79	134	213	59,172
	27	86	55	141 [b]	59,313
Total		20,820	38,493	59,313	

[a] System shut down for relocation.
[b] Represents 12 hour count.

Appendix 2. Chandalar River daily adjusted fall chum salmon counts from the north and south bank sonar stations, August 10 - September 25, 1987.

Date	South bank	North bank	Combined	Cumulative
Aug 10	207	- -	207	207
11	400	- -	400	607
12	306	- -	306	913
13	209	- -	209	1,122
14	263	- -	263	1,385
15	90	- -	90	1,475
16	138	- -	138	1,613
17	398	- -	398	2,011
18	561	- -	561	2,572
19	426	- -	426	2,998
20	366	- -	366	3,364
21	208	84	292	3,656
22	205	32	237	3,893
23	326	16	342	4,235
24	247	15	262	4,497
25	303	34	337	4,834
26	194	52	246	5,080
27	231	82	313	5,393
28	182	103	285	5,678
29	398	554	952	6,630
30	326	124	450	7,080
31	386	244	630	7,710
Sep 1	1,650	495	2,145	9,855
2	1,239	854	2,093	11,948
3	2,464	733	3,197	15,145
4	1,994	955	2,949	18,094
5	1,474	569	2,043	20,137
6	2,132	707	2,839	22,976
7	1,867	589	2,456	25,432
8	2,115	1,011	3,126	28,558
9	1,938	586	2,524	31,082
10	1,636	463	2,099	33,181
11	1,666	507	2,173	35,354
12	1,541	387	1,928	37,282
13	1,430	253	1,683	38,965
14	783	298	1,081	40,046
15	681	702	1,383	41,429
16	788	1,433	2,221	43,650
17	946	820	1,766	45,416
18	544	560	1,104	46,520
19	452	561	1,013	47,533
20	406	433	839	48,372
21	420	350	770	49,142
22	462	316	778	49,920
23	442	490	932	50,852
24	451	736	1,187	52,039
25	198	179	377	52,416
Total	36,089	16,327	52,416	

Appendix 3. Chandalar River daily adjusted fall chum salmon counts from the north and south bank sonar stations, August 11 - September 24, 1988.

Date	South bank	North bank	Combined	Cumulative
Aug 11	16	64	80	80
12	28	155	183	263
13	82	129	211	474
14	143	148	291	765
15	90	131	221	986
16	82	174	256	1,242
17	155	207	362	1,604
18	122	205	327	1,931
19	252	480	732	2,663
20	289	287	576	3,239
21	118	364	482	3,721
22	178	332	510	4,231
23	87	279	366	4,597
24 [a]	170	320	490	5,087
25 [a]	245	355	600	5,687
26 [a]	320	390	710	6,397
27 [a]	400	425	825	7,222
28 [a]	480	460	940	8,162
29 [a]	560	495	1,055	9,217
30	640	530	1,170	10,387
31	576	1,162	1,738	12,125
Sep 1	919	1,171	2,090	14,215
2	972	168	1,140	15,355
3	455	122	577	15,932
4	397	202	599	16,531
5	227	211	438	16,969
6	196	149	345	17,314
7 [a]	540	125	665	17,979
8 [a]	880	105	985	18,964
9 [a]	1,220	80	1,300	20,264
10	1,571	58	1,629	21,893
11	1,319	91	1,410	23,303
12	710	43	753	24,056
13	592	62	654	24,710
14	621	422	1,043	25,753
15	707	347	1,054	26,807
16	825	297	1,122	27,929
17	842	172	1,014	28,943
18	733	263	996	29,939
19	503	283	786	30,725
20	318	164	482	31,207
21	304	261	565	31,772
22	193	510	703	32,475
23	248	324	572	33,047
24	191	381	572	33,619
Total	20,516	13,103	33,619	

[a] Due to high water, escapement estimated by interpolation.

Appendix 4. Chandalar River daily adjusted fall chum salmon counts from the north and south bank sonar stations, August 10 - September 30, 1989.

Date		South bank	North bank	Combined	Cumulative
Aug	10	79	343	422	422
	11	258	480	738	1,160
	12	150	388	538	1,698
	13	491	894	1,385	3,083
	14	212	571	783	3,866
	15	1,219	568	1,787	5,653
	16	1,428	1,133	2,561	8,214
	17	2,149	617	2,766	10,980
	18	3,000	415	3,415	14,395
	19	1,827	519	2,346	16,741
	20	1,373	447	1,820	18,561
	21	1,429	790	2,219	20,780
	22	1,076	557	1,633	22,413
	23	635	713	1,348	23,761
	24	459	624	1,083	24,844
	25	570	820	1,390	26,234
	26	554	655	1,209	27,443
	27	513	570	1,083	28,526
	28	256	480	736	29,262
	29	240	355	595	29,857
	30	187	609	796	30,653
	31	207	567	774	31,427
Sep	1	336	538	874	32,301
	2	323	791	1,114	33,415
	3	987	764	1,751	35,166
	4	683	1,358	2,041	37,207
	5	1,208	1,179	2,387	39,594
	6	1,160	794	1,954	41,548
	7	1,378	246	1,624	43,172
	8	938	391	1,329	44,501
	9	701	340	1,041	45,542
	10	614	263	877	46,419
	11	563	273	836	47,255
	12	748	602	1,350	48,605
	13	971	570	1,541	50,146
	14	968	330	1,298	51,444
	15	613	310	923	52,367
	16	847	281	1,128	53,495
	17	942	228	1,170	54,665
	18	583	254	837	55,502
	19	900	148	1,048	56,550
	20	524	208	732	57,282
	21	352	276	628	57,910
	22	384	599	983	58,893
	23	264	871	1,135	60,028
	24	318	1,487	1,805	61,833
	25	189	1,461	1,650	63,483
	26	204	1,928	2,132	65,615
	27	187	1,100	1,287	66,902
	28	147	1,077	1,224	68,126
	29	151	498	649	68,775
	30	- -	386	386	69,161
Total		36,495	32,666	69,161	

Appendix 5. Chandalar River daily adjusted fall chum salmon counts from north and south bank sonar stations, August 10 - September 27, 1990.

Date	South bank	North bank	Combined	Cumulative
08-10	88	209	297	297
08-11	56	369	425	722
08-12	183	563	746	1,468
08-13	125	918	1,043	2,511
08-14	81	1,147	1,228	3,739
08-15	232	1,227	1,459	5,198
08-16	230	1,372	1,602	6,800
08-17	190	1,464	1,654	8,454
08-18	415	1,622	2,037	10,491
08-19	224	1,502	1,726	12,217
08-20	201	1,434	1,635	13,852
08-21	443	1,625	2,068	15,920
08-22	866	1,854	2,720	18,640
08-23	1,470	1,772	3,242	21,882
08-24	392	911	1,303	23,185
08-25	614	780	1,394	24,579
08-26	733	659	1,392	25,971
08-27	211	445	656	26,627
08-28	239	720	959	27,586
08-29	904	539	1,443	29,029
08-30	316	431	747	29,776
08-31	345	222	567	30,343
09-01	174	256	430	30,773
09-02	193	167	360	31,133
09-03	216	369	585	31,718
09-04	385	429	814	32,532
09-05	292	472	764	33,296
09-06	134	609	743	34,039
09-07	597	1,177	1,774	35,813
09-08	478	1,170	1,648	37,461
09-09	495	1,178	1,673	39,134
09-10	425	855	1,280	40,414
09-11	745	647	1,392	41,806
09-12	1,109	1,233	2,342	44,148
09-13	752	1,967	2,719	46,867
09-14	1,641	2,373	4,014	50,881
09-15	1,417	2,689	4,106	54,987
09-16	723	1,765	2,488	57,475
09-17	794	1,697	2,491	59,966
09-18	693	1,813	2,506	62,472
09-19	509	1,772	2,281	64,753
09-20	763	1,521	2,284	67,037
09-21	595	1,205	1,800	68,837
09-22	638	1,598	2,236	71,073
09-23	659	1,684	2,343	73,416
09-24	420	1,063	1,483	74,899
09-25	368	1,050	1,418	76,317
09-26	498	862	1,360	77,677
09-27	364	590	954	78,631
Total	24,635	53,996	78,631	