Sonar Enumeration of Fall Chum Salmon on the Chandalar River, 1989

Alaska Fisheries Progress Report

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ABSTRACT

From August 10 to September 29, 1989, 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. A seasonal total of 69,161 chum salmon was counted, compared to 59,313 in 1986, 52,416 in 1987, and 33,619 in 1988. 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. Escapement peaked on August 18, 14 days earlier than 1988. Counting ranges were adequate for the detection of the majority of the run since most salmon were oriented nearshore. As water level increased, the percentage of fish using the south bank increased. Carcasses collected from spawning grounds were used for sex and age composition data; males comprised 48% of the sample and age 0.3 fish predominated (71%). Gill net sampling of mature chum salmon significantly selected for male fish.

A helicopter survey of fall chum salmon spawning grounds was conducted on September 19, 1989, with an estimated count of 20,232 fish (18,941 live and 1,291 carcasses). The helicopter survey was a more accurate estimator of escapement (expansion factor of 2.70), compared to the 1988 fixed-wing survey (expansion factor of 5.86). Aerial survey counts from previous years have substantially underestimated the size of this stock, apparently due to the vastness of the river, poor water visibility, and fluctuating water levels.

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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 transboundary chinook *Oncorhynchus tshawytscha* and chum salmon *Oncorhynchus keta*. 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) selected the Chandalar River for a side-scan sonar study to estimate the total escapement of fall chum salmon in this 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 1989, 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 salmon run size.

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 unique in having two distinct runs of chum salmon (summer and fall). The majority of the fall run spawn in upper Yukon River tributaries including the Chandalar River. 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).

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 sex and age composition of the spawning population, (4) collect tissue samples for genetic stock identification, (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 transboundary Yukon River salmon stocks can be resolved. Previous sonar escapement estimates for Chandalar River fall chum salmon were 59,313 in 1986 (Simmons and Daum 1989), 52,416 in 1987 (Daum and Simmons 1991), and 33,619 in 1988 (Daum et al. 1991). This progress report compares the 1989 Chandalar River sonar data with information from the 1986-1988 seasons.

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

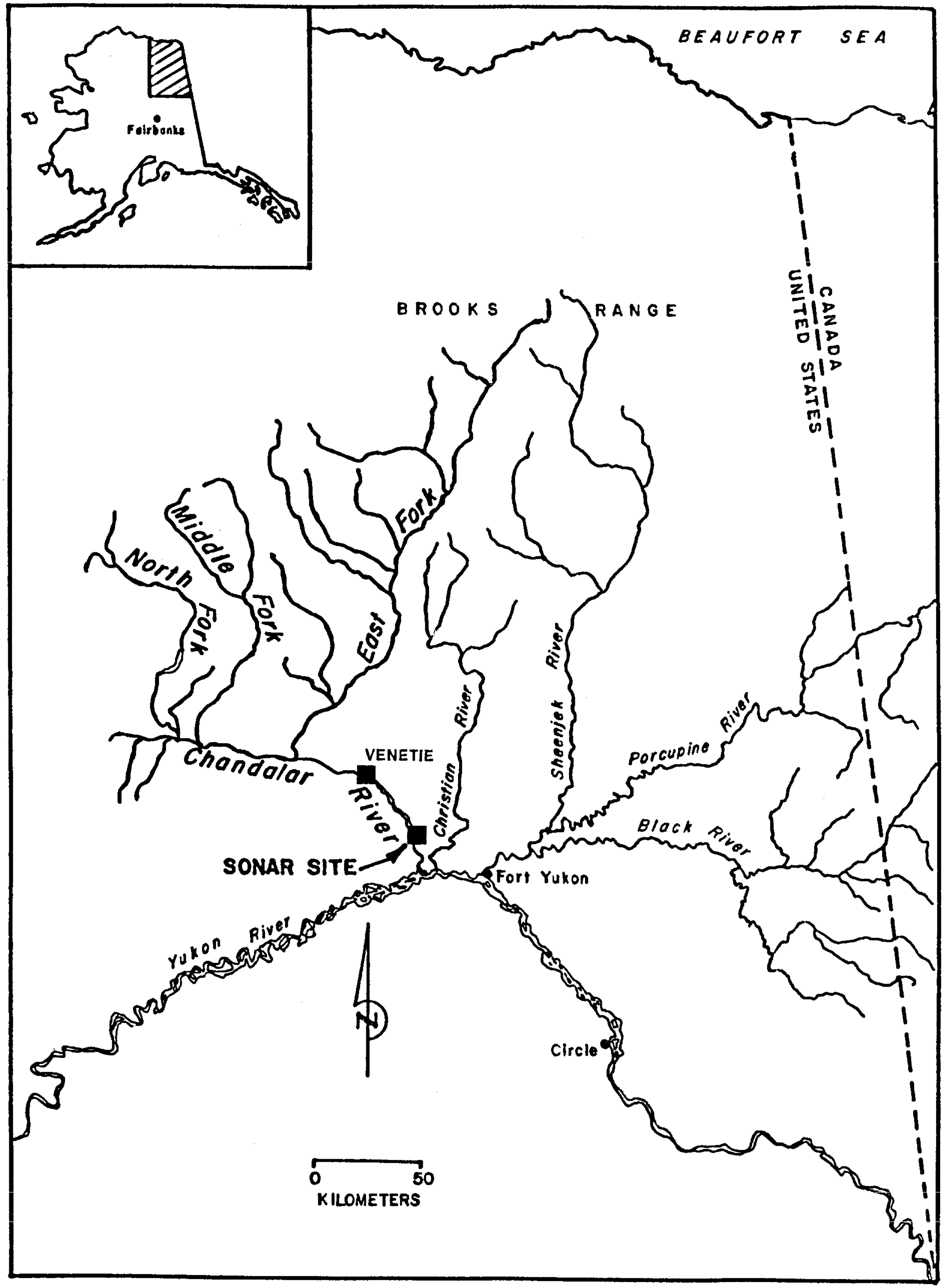

Figure 1. Major tributaries of the Yukon River near the U.S./Canada border.

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 August 10 to September 29, 1989, with the north bank counter running through September 30. North and south bank transducers were deployed in the same locations used in the previous three years and offset 180 m from one another. Sonar equipment was needed on opposite river banks since the river width is greater than the maximum counting range (30m). 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 with sandbags at a depth of 0.6-1.5 m (design adapted from Barton 1986). Transducers were aimed perpendicular to shore and fine adjusting with three hand wheels on the back of the transducer bracket. This mounting system proved to be more portable and faster to move than the previous method of using metal sleeved brackets attached to metal posts (Simmons and Daum 1989). 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 fish could not travel beneath the beam undetected, an artificial "fish," a 1 L lead-weighted glass container attached to monofilament line, was suspended at various depths in each of the 16 sonar beam sectors that compose the total counting range. When the container passed the sonar beam it registered as a sharp "spike" or trace on the oscilloscope and simultaneously registered as a valid count on the sonar counter. Adjustments revealed an almost clear oscilloscope picture when the beam was aimed 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.

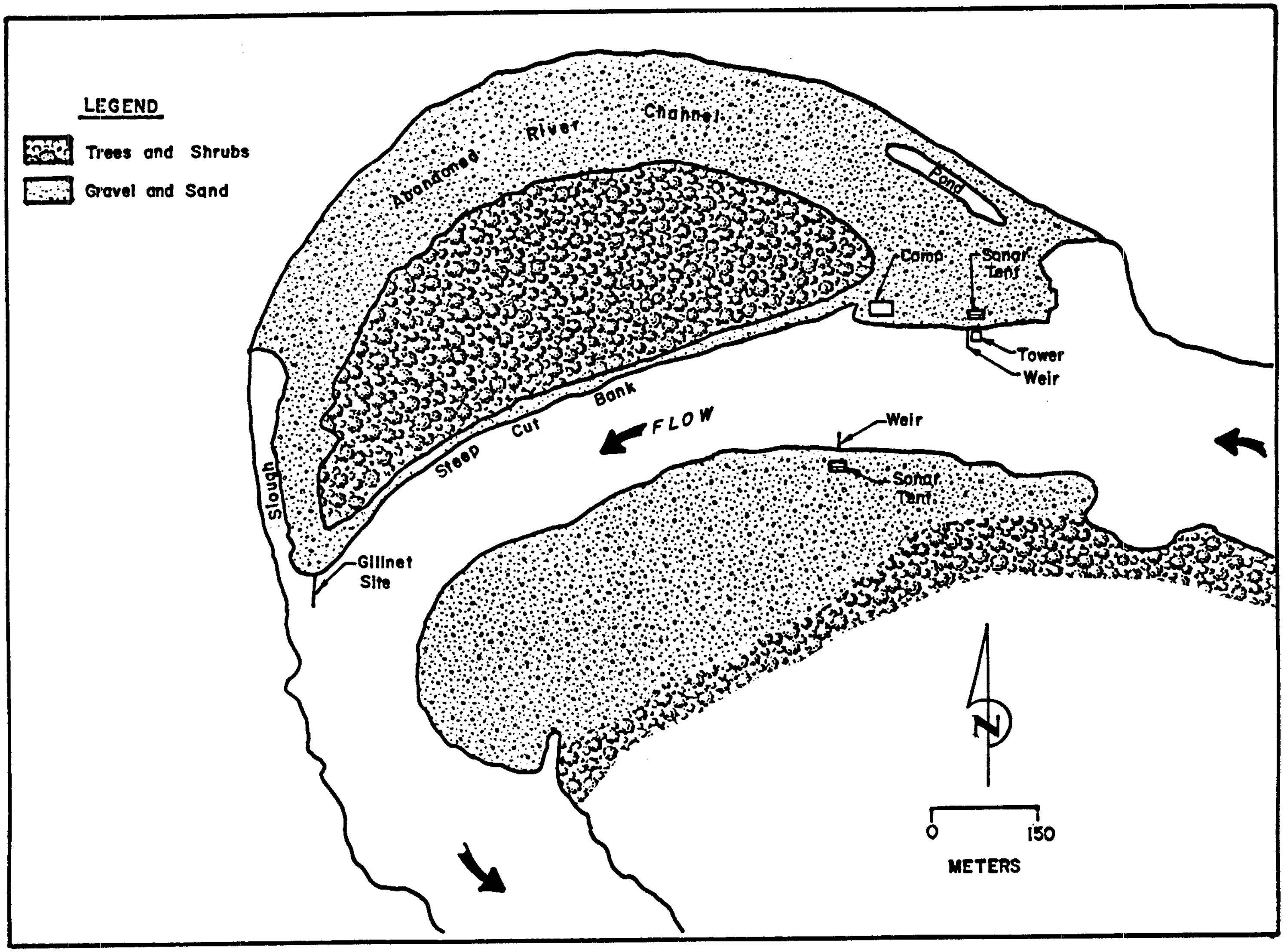

Figure 2. Site map of the Chandalar River sonar facilities.

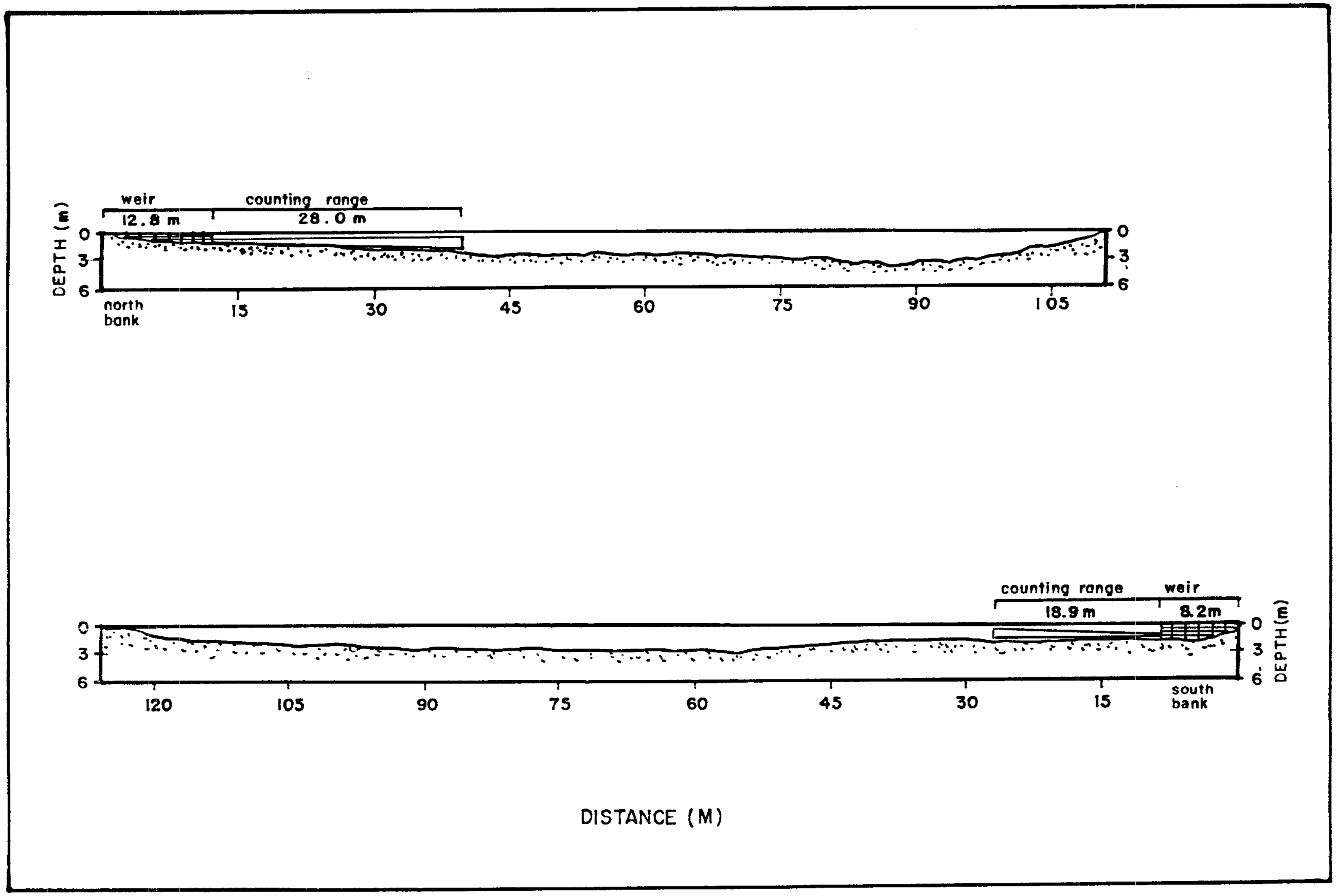

Figure 3. River channel profiles of the north and south bank sonar facilities. Weir length and counting ranges are approximations that change according to river discharge levels.

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 periods. When a fish passes through the beam, a returning echo is displayed on the oscilloscope and a corresponding count should register on the sonar counter. Adjustments to the fish velocity control (counter ping rate) were made for discrepancies of more than 15% between the oscilloscope and counter readings when more than 14 fish were recorded by the oscilloscope in the 30-minute calibration period. The new fish velocity control setting was calculated as follows:

(Sonar counts / Scope counts) x Fish velocity setting.

Fish counts were adjusted daily using data from the six 30-minute calibration periods. The 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.

Since this year's formula also included adjustments for periods when the counter's fish velocity setting was not changed, a more accurate estimate of actual run size should be calculated. The differences in total adjusted count using both methodologies were compared.

Additional sonar counts caused by fish other than chum salmon were assumed insignificant, since 94% of main channel experimental gill net captures in 1986 were chum salmon (Simmons and Daum 1989). Registered "debris counts" were deleted. All data in this report appears in adjusted form.

A river water-level gauge was installed by the north bank sonar site and monitored throughout the season. Water level was recorded daily at 1700 hours to the nearest 0.3 cm. A permanent gauging site was established 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 ($P = 0.05$; Zar 1984), comparing daily water level to the daily proportion of fish counted from the south bank.

On September 19, 1989, sex and age composition data were collected from 149 chum salmon carcasses found on two spawning grounds (8 and 9 km above Venetie Village). Access to sample sites was by helicopter. 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 (30.5 m long by 3.0 m deep with 7.4 cm bar mesh) throughout the 1989 season. Chi-square analysis ($P = 0.05$) with the Yates correction for continuity (Zar 1984) was used to test the hypothesis that sex ratios were 1:1 for the carcass sample, gill net samples (1986-1989), and a 1989 sample of mainstem Yukon River fall chum salmon (from the Department's fish wheel project near Ruby, Alaska, 611 km downriver from the Chandalar River). Chi-square analysis was also used to test for differences in the 1989 age composition between the Chandalar River carcass sample and mainstem Yukon River fish wheel sample.

Vertebrae from the carcass collection (three per fish) were used for age determination. Otolith and scale samples from the 1986 and 1987 seasons indicated that these structures were unreliable indicators of age in Chandalar River fall chum salmon (Simmons and Daum 1989; Daum and Simmons 1991). Vertebrae were cleaned, dried, and independently read twice by the author under direct light with a dissecting scope. A third reading was made of the samples in which ages disagreed and a final age was assigned based on majority agreement. Samples that were unreadable were discarded. Salmon age was described by the European method (Foerster 1968) - number of freshwater annuli followed by number of saltwater annuli.

A sample of 75 chum salmon was collected on September 27-28 from the sonar site for genetic stock identification. 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 Alaska Fish and Wildlife Research Center in Anchorage for electrophoretic analysis.

One aerial survey was conducted to determine the relationship between aerial and sonar counts and to develop a reliable 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, a more accurate estimate of total escapement. The survey was flown on September 19, 1989 with a Hughes 500-D helicopter (90 m above ground level), from 10 km upstream of the sonar site to 5 km up the East Fork.

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. Based on previous aerial survey results, peak spawning was expected roughly 3 weeks after median fish passage at the sonar station (Daum et al. 1991). The survey was made during optimum lighting conditions (1130-1600 hours). Numbers of spawners, carcasses, and spawning grounds were marked on 1:250,000 scale U.S. Geological Survey topographic maps. The survey was given a rating based on water clarity and light conditions.

RESULTS AND DISCUSSION

The adjusted fall chum escapement count for the Chandalar River in 1989 was 69,161 fish, the highest estimate since the sonar operation started in 1986. The adjusted count is a conservative estimate of annual escapement because counts do not include fish passing out of sonar range, fish present before the sonar facilities were in operation, and fish present after counting ceased. Past sonar escapement counts ranged from 33,619 fish in 1988 to 59,313 fish in 1986.

Daily counts during 1989 were over 1,000 fish per day for 34 of the 52 counting days (Appendix 1). Operations terminated on September 30 with 386 fish counted. Fifty percent of the estimated run (median passage) passed the site by September 3. Past median passage dates ranged from September 1 in 1986 to September 8 in 1987.

The 1989 escapement curve showed a strong tri-modal distribution, unlike previous years (Figure 4). The early peak was driven by south bank fish counts while the late peak was caused by high north bank counts.

The total count was not equally distributed between counting units. The south bank count was 36,495 or 53% of the total (Figure 5, Appendix 1), compared to 35% in 1986, 69% in 1987, and 61% in 1988. Because of this annual variability, sonar counts from one bank would not be suitable 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 small relative to nearshore counts indicating that the majority of fish were detected (Figure 6). The first 11 of the 16 sectors accounted for 91% of the fish passing the south bank sonar and 83% of north bank fish. The majority of fish were oriented close to shore with the highest frequency of occurrence in Sector 1 for the north bank and Sector 2 for the south bank.

The Chandalar River experienced large variations in water level over the season (Figure 7). Although 1989 water levels cannot be compared directly to previous annual levels, personnel at the camp indicated that the river level was lower than the 1987 and 1988 seasons. Daily water level (X) was positively correlated ($r = 0.72$; $P < 0.001$) with the percentage of fish using the south bank (Y). The regression equation was $Y = -49.7 + 16.2 X$. As water level increased from 1.4 to 2.5 m, the percentage of fish using the south bank increased from 23 to 68%, demonstrating a shift in bank preference as water level increased.

Adjustments to the counter's fish velocity control were needed for 21% of the calibration periods on the north bank and 20% on the south bank. The frequency of north bank adjustments were similar to previous seasons, but south bank adjustments occurred twice as often. The greater variability in fish swimming speed on the north bank site, found in previous years, was not apparent in 1989.

A comparison was made between the new and old equations used for adjusting daily counts so that the error due to the change in methodology could be quantified. The new method yielded a total escapement estimate 6.3% higher than the old technique. 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.

Age 0.3 (70.5%) predominated the fall chum salmon carcass samples (N = 149), followed by age 0.4 (20.5%), age 0.5 (4.8%), and age 0.2 (4.1%); 3 vertebrae samples (2.0%) were unreadable. From the carcass collection of 149 chum salmon, the number of males (48.3%) did not differ significantly from the number of females ($P = 0.75$; Table 1). However, the gill net samples from 1986-1989 were between 67-76% male and these samples all differed significantly from a 1:1 sex ratio ($P < 0.001$). Carcass collections appear to be a more unbiased method than gill netting for estimating the sex and age composition of spawning fall chum salmon populations. The prevalence of males in previous years may be due, in part, to net selectivity for males, which have more kipe development than females.

Similar to the Chandalar River carcass sample, mainstem Yukon River fall chum salmon at the Ruby fish wheel did not differ significantly from a 1:1 sex ratio ($P = 0.72$; Table 2). Age 0.3 fish predominated in both samples (71 and 85%), although age composition was significantly different ($P < 0.001$) between sites.

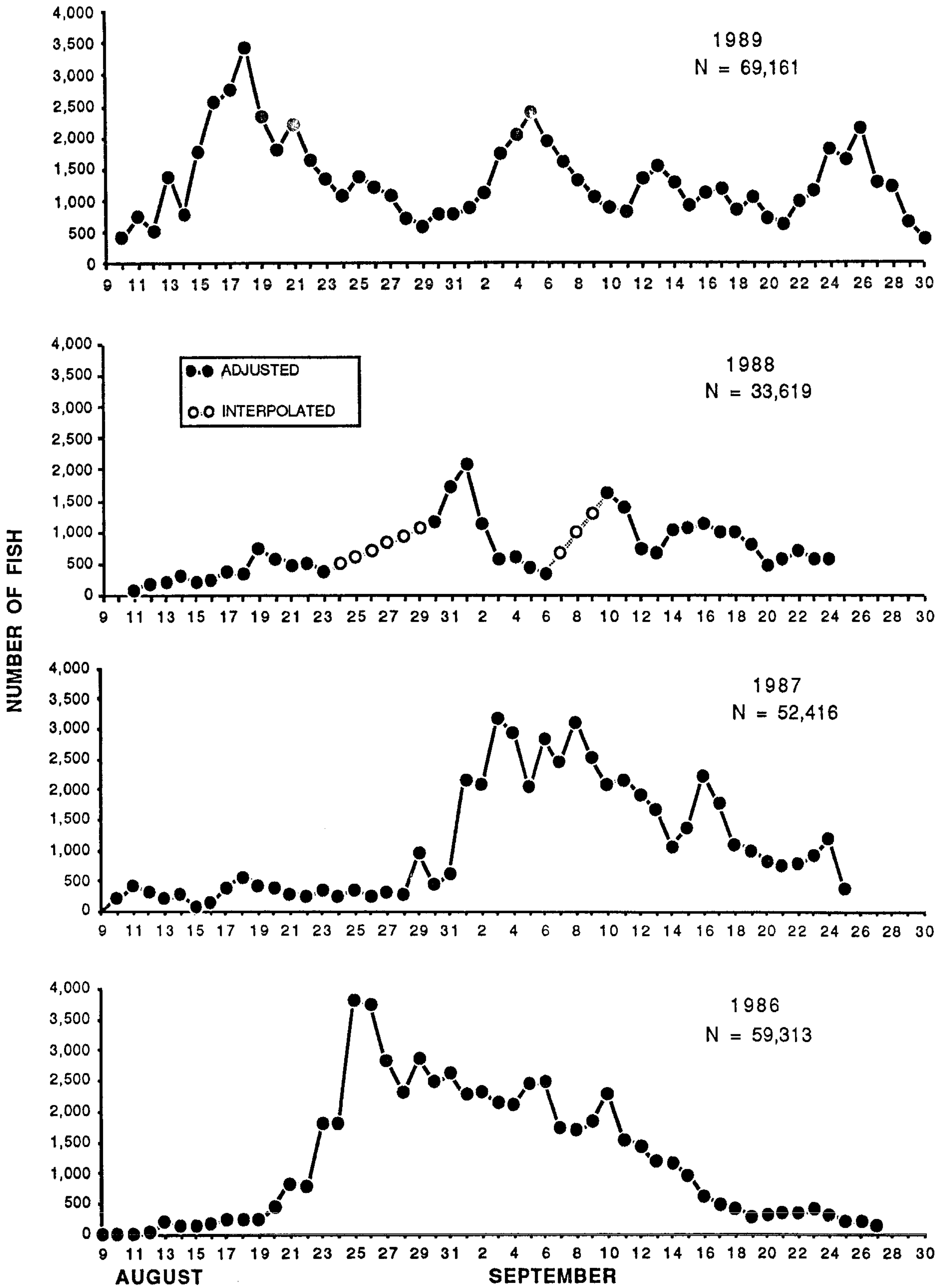

Figure 4. Chandalar River fall chum salmon run timing, based on daily sonar counts; 1986-1989.

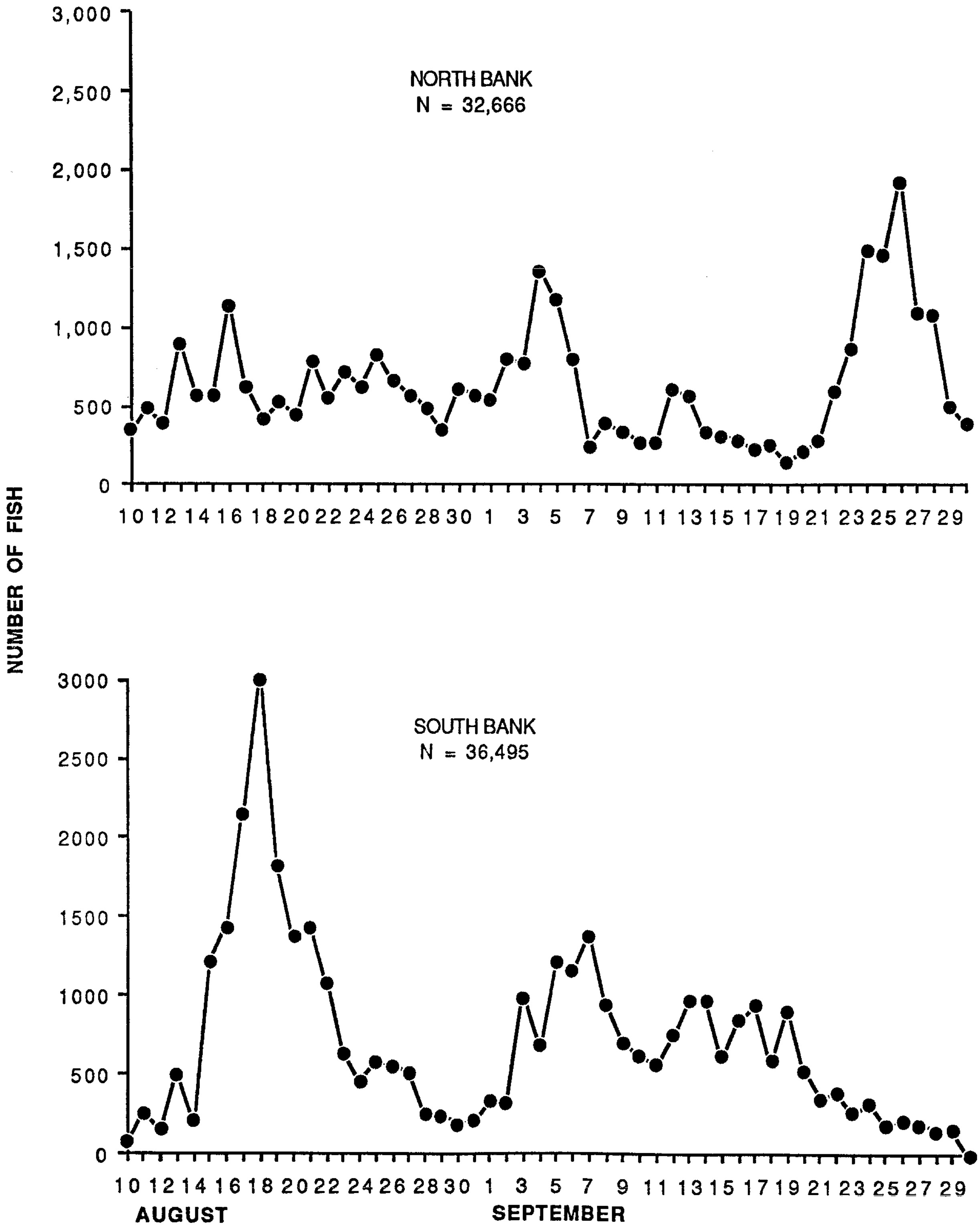

Figure 5. Distribution of Chandalar River fall chum salmon between the north and south banks, based on daily sonar counts, August 10-September 30, 1989.

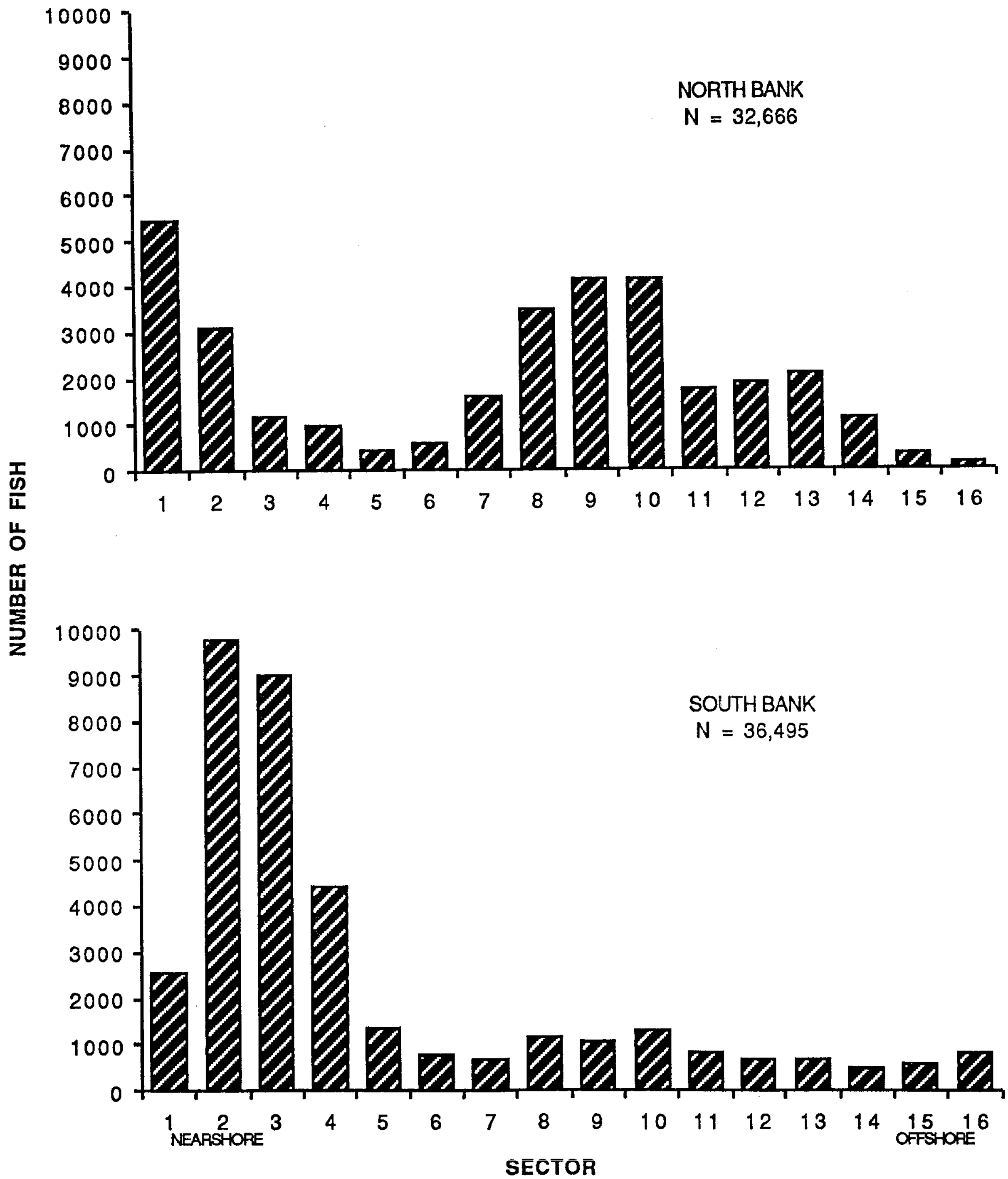

Figure 6. Total sector counts of Chandalar River fall chum salmon from the north and south bank sonar stations, August 10-September 30, 1989.

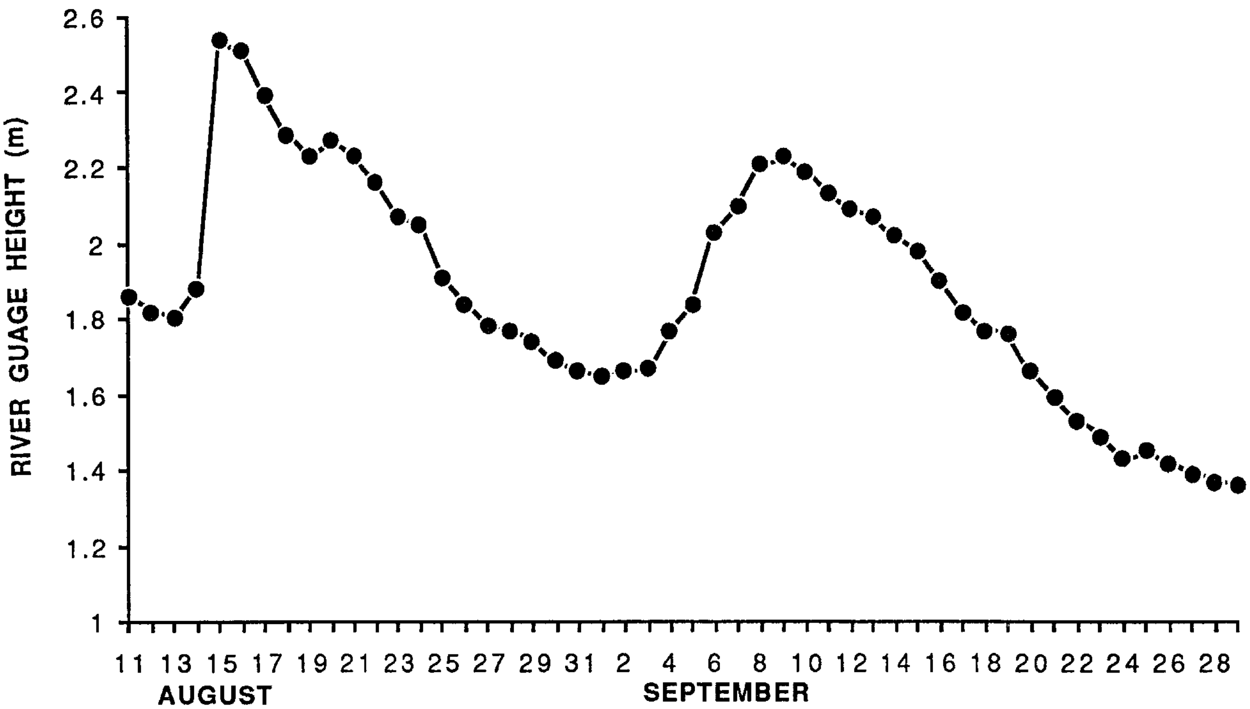

Figure 7. Daily water levels in the Chandalar River, August 11-September 29, 1989.

Table 1. Sex composition and chi-square statistics for fall chum salmon in the Chandalar River, 1986-1989.

Year	N	Males(%)	Chi-square	*P*
1986[a]	150	68	18.727	< 0.001
1987[a]	150	76	39.527	< 0.001
1988[a]	73	74	15.836	< 0.001
1989[a]	170	67	19.112	< 0.001
1989[b]	149	48	0.107	0.75

[a]gill netting at sonar camp during peak fish passage.
[b]carcass collection at spawning grounds.

Table 2. Sex and age data collected from fall chum salmon samples in the Chandalar River and upper Yukon test fishing project, 1989.

				Age(%)			
Location	N	Males(%)	Females(%)	0.2	0.3	0.4	0.5
Chandalar River[a]	149	48.3	51.7	4.1	70.5	20.5	4.8
Upper Yukon River[b]	1,015	49.4	50.6	1.3	85.0	13.6	0.2

[a]carcass collection at spawning grounds.
[b]fish wheel on north bank Yukon River; J. Wilcock, Alaska Department of Fish and Game, Anchorage, personal communication.

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*) and 1988 (Daum et al. 1991). The highest reported count from previous surveys was 17,160 fish in 1974. The average annual count has been less than 5,000 fish, but survey conditions are usually rated as "poor".

A helicopter survey of fall chum salmon spawning grounds was conducted on September 19, 1989, with an estimated count of 20,232 fish (18,941 live and 1,291 carcasses; Appendix 2). The survey had a "good" overall rating, based on water visibility and lighting conditions. A large portion of the total count (33%) was found in two large concentrations, 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 aerial count of 20,232 fish, multiplied by an expansion factor of 2.70, approximates the total sonar count of 54,665 on September 17. The 1989 helicopter survey was more accurate at predicting total escapement when compared to the 1988 survey using a Super-cub fixed-wing aircraft (expansion factor 5.86). In 1990, a helicopter survey is scheduled during peak spawning so that the precision of the helicopter expansion factor can be estimated.

The difficulties anticipated in establishing aerial counts as reliable estimators of 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. The use of index areas to estimate total escapement of fall chum salmon in the Chandalar River will be investigated by the Department's Commercial Fish Division.

In summary, side-scanning sonar proved to be an effective method for enumerating fall chum salmon escapement in the Chandalar River. Most fish passed within the sonar's counting range and counts of other fish species were assumed minimal. Other ground survey methods (weirs, towers, boats, etc.), although less costly, would not be adequate for monitoring escapement in this system because of it's large size, poor water visibility, and fluctuating water levels. Using counts from one bank to estimate total escapement is not possible due to the annual variability in fish distribution between banks found during the four years of this operation.

The fall chum salmon escapement estimate of 69,161 was the highest count since sonar operation started in 1986. Further study is needed to assess the accuracy of using total or index area aerial counts to estimate total escapement.

ACKNOWLEDGEMENTS

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Appendix 1. 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 2. Helicopter aerial survey counts of Chandalar River fall chum salmon, September 19, 1989.

Survey area	Number of chum salmon observed Live	Dead
10 km upstream of sonar camp to Venetie	3,914	5
Venetie to 8 km upstream	569	0
8 to 9 km above Venetie	6,592	70
9 km stream to East Fork confluence	7,831	1,203
East Fork confluence to 3 km up mainstem	35	13
East Fork confluence to 6 km up East Fork	0	0
Total	18,941	1,291

Note: Good water visibility and good lighting conditions.