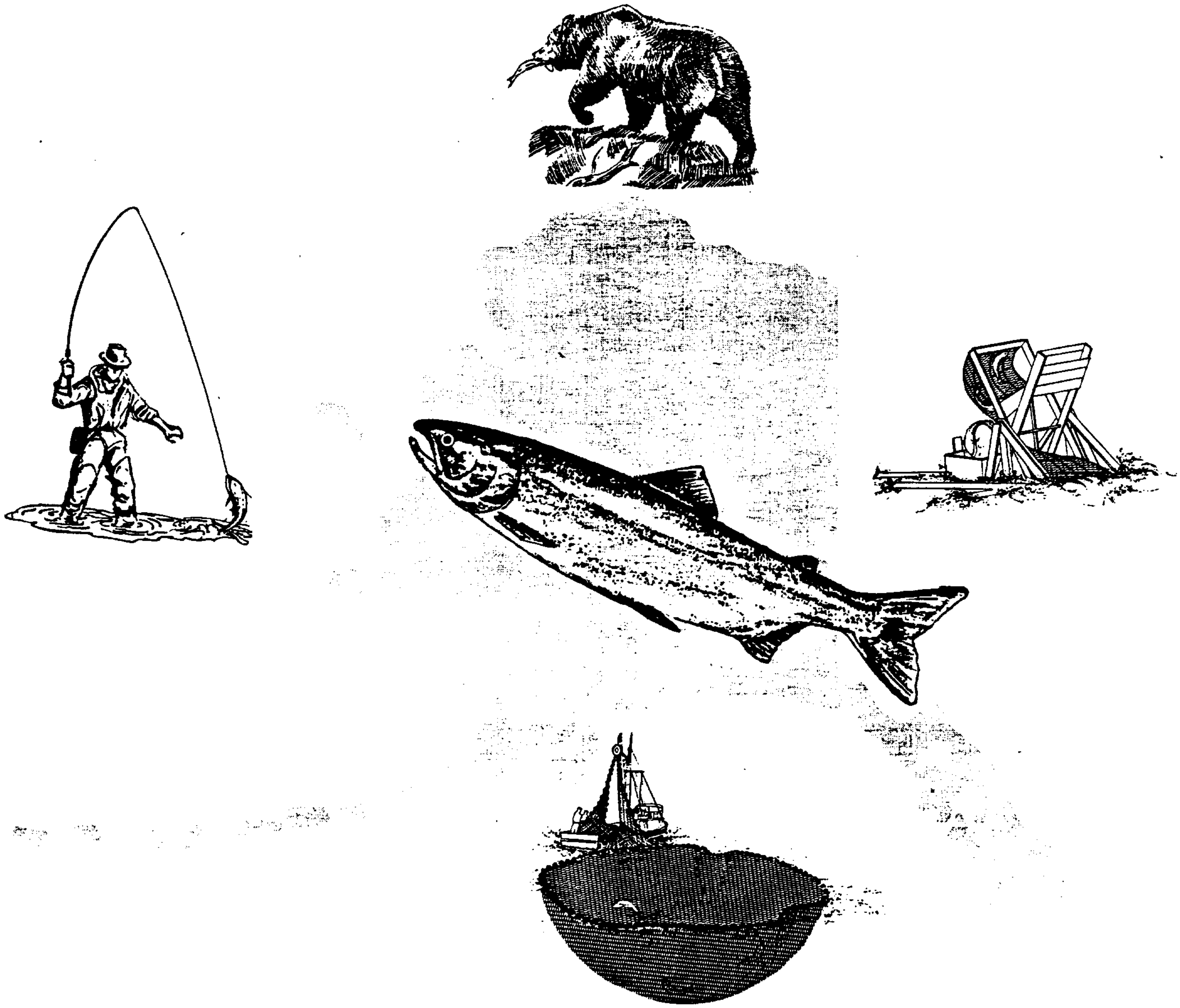
SONAR ENUMERATION OF FALL CHUM SALMON IN THE CHANDALAR RIVER, 1988

Alaska Fisheries Progress Report



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U.S. Fish and Wildlife Service
Department of the Interior

Sonar Enumeration of Fall Chum Salmon on the Chandalar River, 1988

Alaska Fisheries Progress Report

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ABSTRACT

From August 11 to September 24, 1988, 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 33,619 chum salmon was counted compared to 59,313 in 1986 and 52,416 in 1987; escapement peaked on September 1, seven days later than 1986 and two days earlier than 1987. This is a conservative estimate of total 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. Counting ranges were adequate for the detection of the majority of the run since most salmon were oriented nearshore. Three aerial surveys of fall chum salmon spawning grounds were conducted in September, 1988. The highest count was 5,735 fish (3,977 live and 1,758 carcasses) on September 28. Aerial survey counts substantially underestimate 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 Canada/United States salmon treaty negotiations for allocating transboundary chinook *Oncorhynchus tshawytscha* and chum salmon *O. 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 Canada/United States Yukon River Technical Committee selected the Chandalar River for a side-scan sonar study to enumerate 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 and other methods. The Department has used this technique only when less expensive methods are not feasible, and only on major spawning streams. In 1988, 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 Koyukuk and Tanana rivers (Barton 1984a).

In 1986, a four 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 and size 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 Yukon River Joint Technical Committee 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) and 52,416 in 1987 (Daum and Simmons 1991). This progress report compares the 1988 Chandalar River sonar data with information from the 1986 and 1987 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 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

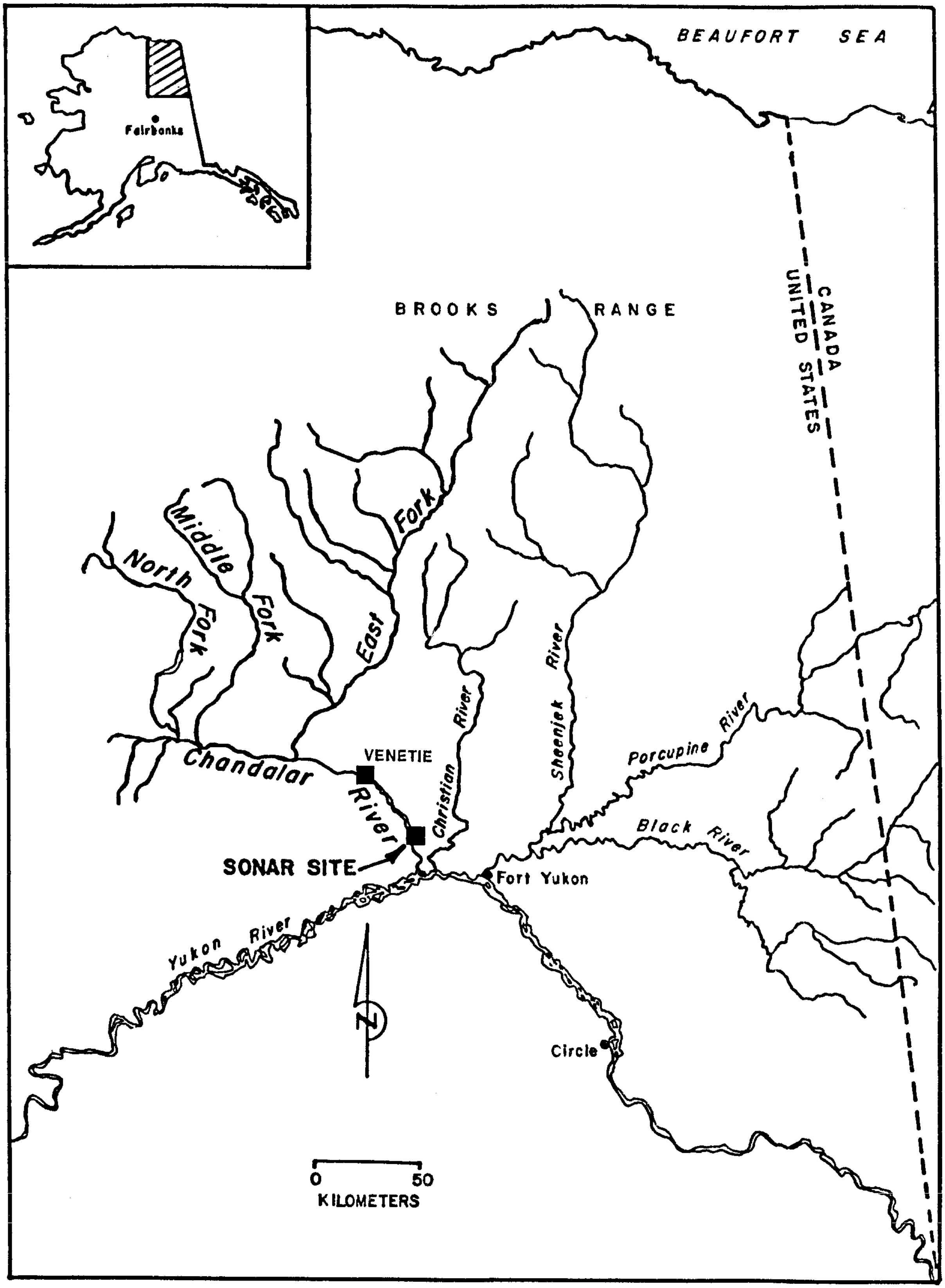

Figure 1. Major tributaries of the Yukon River near the U.S./Canada border.

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 11 to September 24, 1988, except for two periods of extremely high water: August 24-29 and September 7-9. North and south bank transducers were deployed in the same locations used in the previous two 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). The 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.

Because of the relatively flat river bottom, the modular substrate normally used with this system was not deployed. Instead, the transducers were aimed perpendicular to shore at a depth of 0.6-1.5 m by mounting them on metal sleeved brackets attached to metal posts driven into the stream bottom. The transducers were aimed by adjusting three hand wheels on each 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. Any 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 liter glass container attached to a monofilament line, was suspended at various depths in each of the 16 sonar beam sectors that compose the total counting range. When the glass 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.

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 the counter's output. When a fish passed through the beam, a returning echo was displayed on the oscilloscope and a corresponding count should have been registered by the sonar counter. Counter calibration was performed at least once every four hours until 30 fish were counted or 30 minutes had passed. Adjustments to the fish velocity control (counter sensitivity) were made for discrepancies

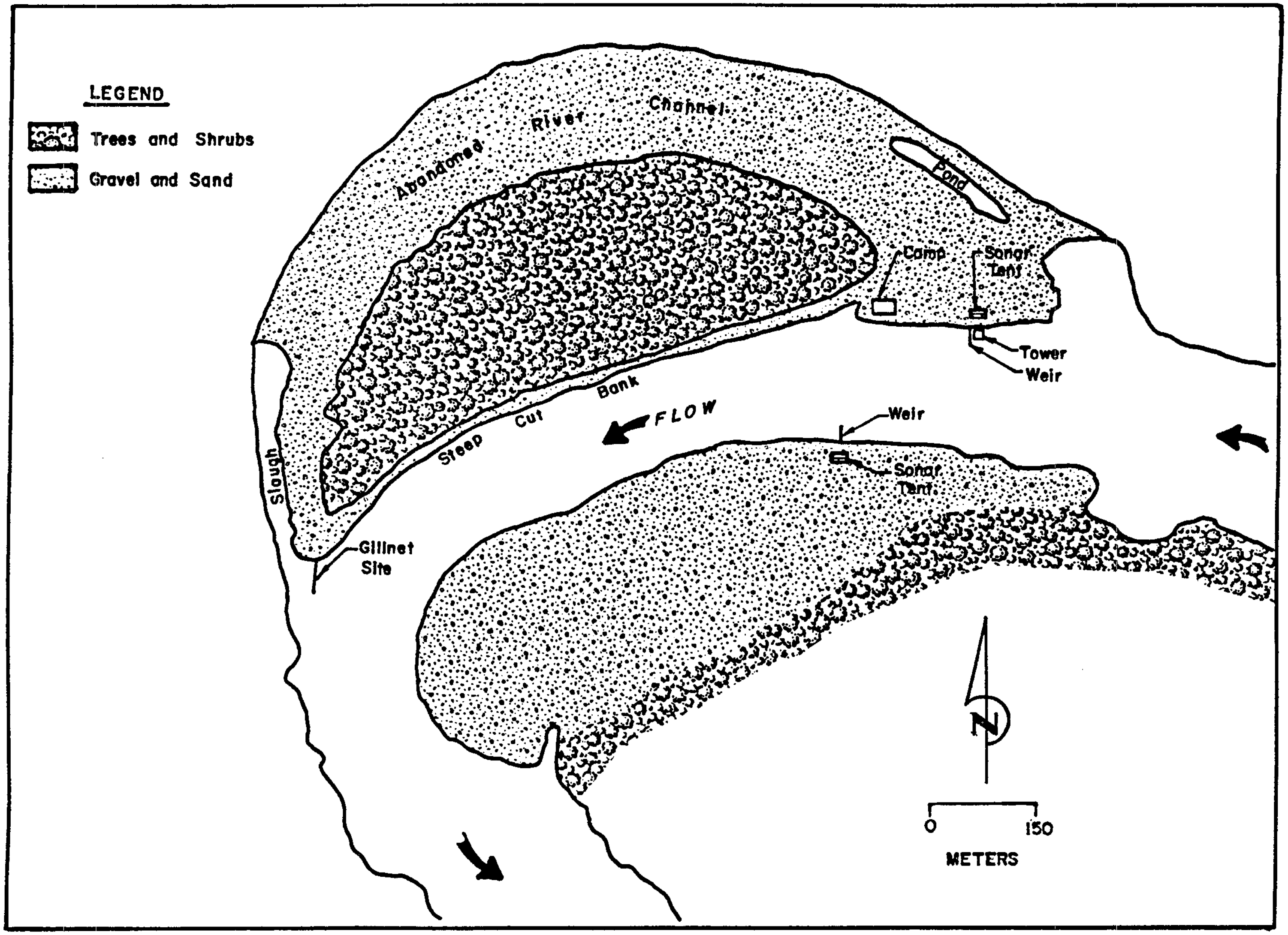

Figure 2. Site map of the Chandalar River sonar facilities.

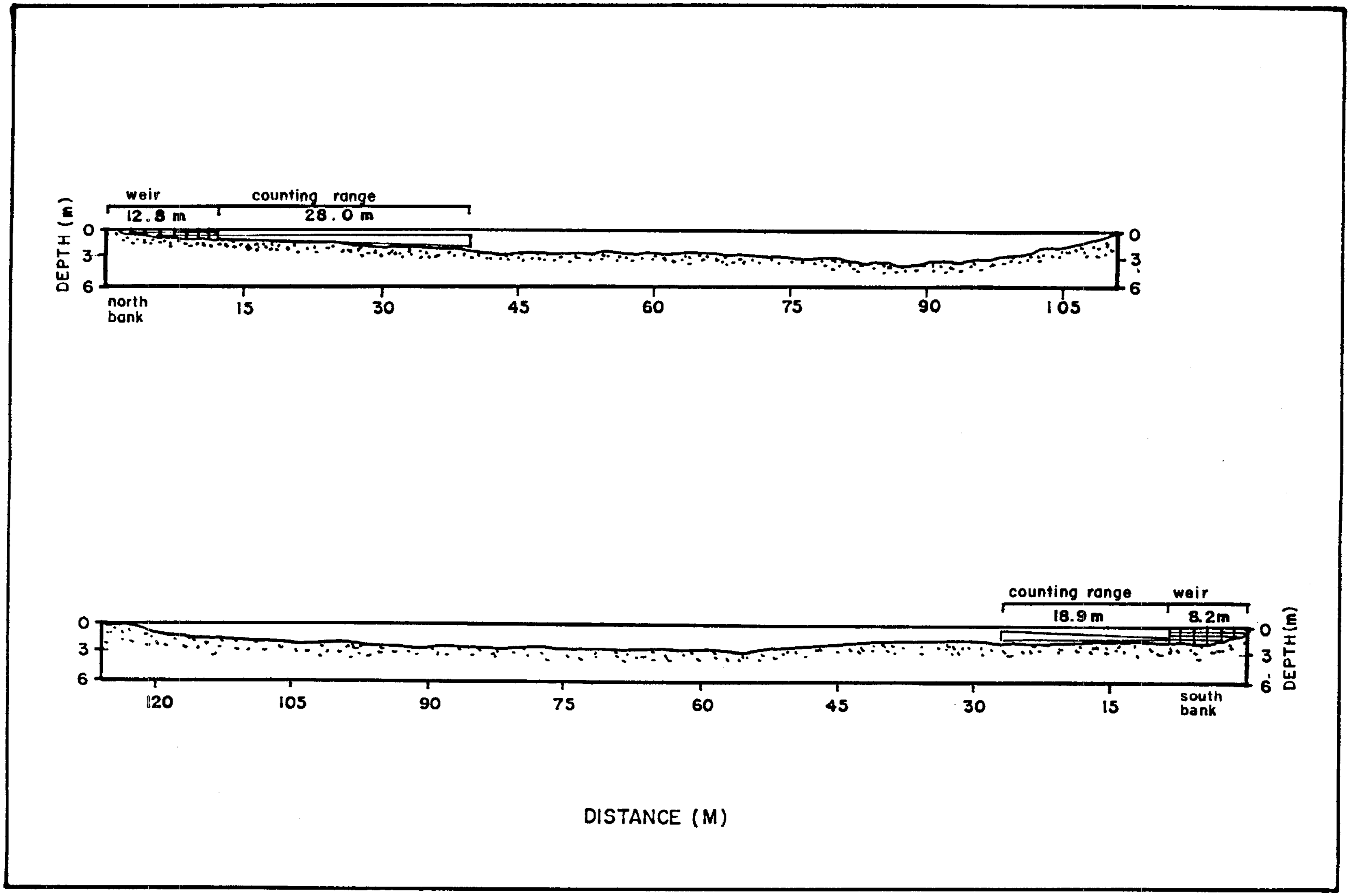

Figure 3. River channel profiles of the north and south bank sonar facilities. Weir length and counting ranges are approximations that change according to river discharge levels.

of more than 15% between the oscilloscope and counter readings. The new fish velocity control setting was calculated as follows:

(Sonar Counts / Scope Counts) x Fish Velocity Setting

Daily counts were adjusted based on sonar calibration results for the corresponding time period. Fish counts were adjusted when a 15% difference existed between the oscilloscope and counter readings. The rate of overcounting or undercounting was assumed to increase uniformly over the four hour period (e.g., if calibration showed a 20% overcount at hour 4, then overcounts of 5%, 10%, and 15% were assumed for hours 1, 2, and 3). Counts were estimated for the two periods of high water by linear interpolation between daily counts just before and after those periods. Registered "debris counts" were deleted. 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). All data in this report appears in adjusted form.

A sample of 73 chum salmon was collected on September 4-6 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, flash frozen, and transported in liquid nitrogen to the Service's Alaska Fish and Wildlife Research Center in Anchorage for electrophoretic analysis.

Length and age data were collected for all 73 chum salmon sacrificed. Salmon length was measured to the nearest centimeter from mid-eye to the fork in the caudal fin. A Student's two-tailed *t*-test was used to test for significant differences ($P<0.05$) between mean lengths of females, males, and age classes. A minimum of three vertebrae per fish were collected for age determination. Vertebrae were cleaned, dried, and read under reflected light with a dissecting scope. Salmon age was described by the European method (Foerster 1968) - number of freshwater annuli followed by number of saltwater annuli.

A river water-level gauge was installed by the north bank sonar site and monitored throughout the season. Water level was recorded daily at 0900 hours to the nearest 0.3 cm.

Aerial surveys were conducted to determine the relation of aerial to 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. In this first year of gathering both sonar and aerial data it was necessary to establish a standard aerial survey method. The method focused on maximizing visibility and coverage of the river, especially key spawning areas, and timing the survey as close as possible to peak spawning. Peak spawning was expected roughly 2-3 weeks after peak fish passage at the sonar station (L.H. Barton, Alaska Department of Fish and Game, Fairbanks, personal communication).

Surveys were flown at 100 km/h (91 m above ground level) with a Super-cub fixed-wing aircraft on September 14, 20 and 28, bracketing peak spawning. The surveys began 10 km upriver from the sonar camp (12 km below the farthest downriver spawners observed) to the confluence of the East Fork and the main river. The many braided parts of the river were flown in 3 to 4 km sections requiring repeated passes up and down river for coverage of all channels and sloughs. At least one recount was made of all concentrations exceeding 200 fish. Numbers of spawners, carcasses, and spawning grounds were marked on 1:63,360 scale U.S. Geological Survey topographic maps. Each survey was given a rating based on overall visibility, water clarity, and light conditions.

RESULTS AND DISCUSSION

The adjusted fall chum escapement count for the Chandalar River in 1988 was 33,619 fish (Table 1), compared to 59,313 in 1986 and 52,416 in 1987. Low numbers were expected throughout the Yukon River drainage since four year-old fish (age 0.3), an important spawning cohort, were produced from one of the poorest escapements on record (Barton 1986). The adjusted count is a conservative estimate of total 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. On the Sheenjek River, 116 km upstream from the Chandalar River (Figure 1), sonar escapement estimates for fall chum salmon were 83,197 in 1986, 140,086 in 1987, and 41,073 in 1988 (Barton 1987, 1988; Barton, Alaska Department of Fish and Game, Fairbanks, personal communication).

Daily counts during 1988 were over 1,000 fish per day for 12 of the 45 counting days. When operations were terminated on September 24 due to severe freezing conditions, 572 fish were counted. The escapement count peaked on September 1, seven days later than 1986 and two days earlier than 1987. Fifty percent of the estimated run had passed the site by September 5; compared to median passage dates of September 1 in 1986 and September 8 in 1987. Median passage dates on the Sheenjek River were August 31 in 1986, September 10 in 1987, and September 6 in 1988 (Barton 1987, 1988; Barton, Alaska Department of Fish and Game, Fairbanks, personal communication).

This year's escapement curve was unlike the 1986 and 1987 graphs (Figure 4). The rapid increase in daily counts followed by a relatively slow decline observed in the previous two years was not apparent in 1988. The high water events in 1988 may have caused an irregular escapement curve, though it is not clear if high water actually slowed fish passage or the run was simply underestimated during these periods.

Distribution of total counts by sector revealed that not all of the fish were within the range of sonar detection. However, outer sector counts were small relative to the nearshore counts indicating that the majority of fish were detected (Figure 5). The first 11 of the 16 sectors accounted for 89% of the fish passing the south bank sonar and 96% 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 total count was not equally distributed between the counting units. The south bank count was 20,516 fish or 61% of the total (Table 1; Figure 6), compared to 35% in 1986 and 69% in 1987. Higher water levels in 1987 and 1988 may have caused some fish to switch from the north to south bank. Because of this annual variability, sonar counts from one bank may not be suitable to estimate total escapement.

The Chandalar River experienced large variations in water level over the season (Figure 7). Although 1988 water levels cannot be compared directly to previous annual levels, personnel at the camp indicated that the river level was much higher for most of the 1988 season.

Adjustments to the counter's fish velocity control were needed for 21% of the calibration periods on the north bank and 11% on the south bank. These were similar to results for the 1987 season (22% north, 9% south). The greater variability in fish swimming speed on the north bank site is probably due to physical differences in bottom contour and channel configuration and a wider range of water velocities.

Table 1. Chandalar River daily adjusted fall chum salmon counts from the north and south bank sonar stations, August 11 - September 24, 1988. Asterisks represent sonar "down days" due to high water.

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	170	320	490	5,087
* 25	245	355	600	5,687
* 26	320	390	710	6,397
* 27	400	425	825	7,222
* 28	480	460	940	8,162
* 29	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	540	125	665	17,979
* 8	880	105	985	18,964
* 9	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	

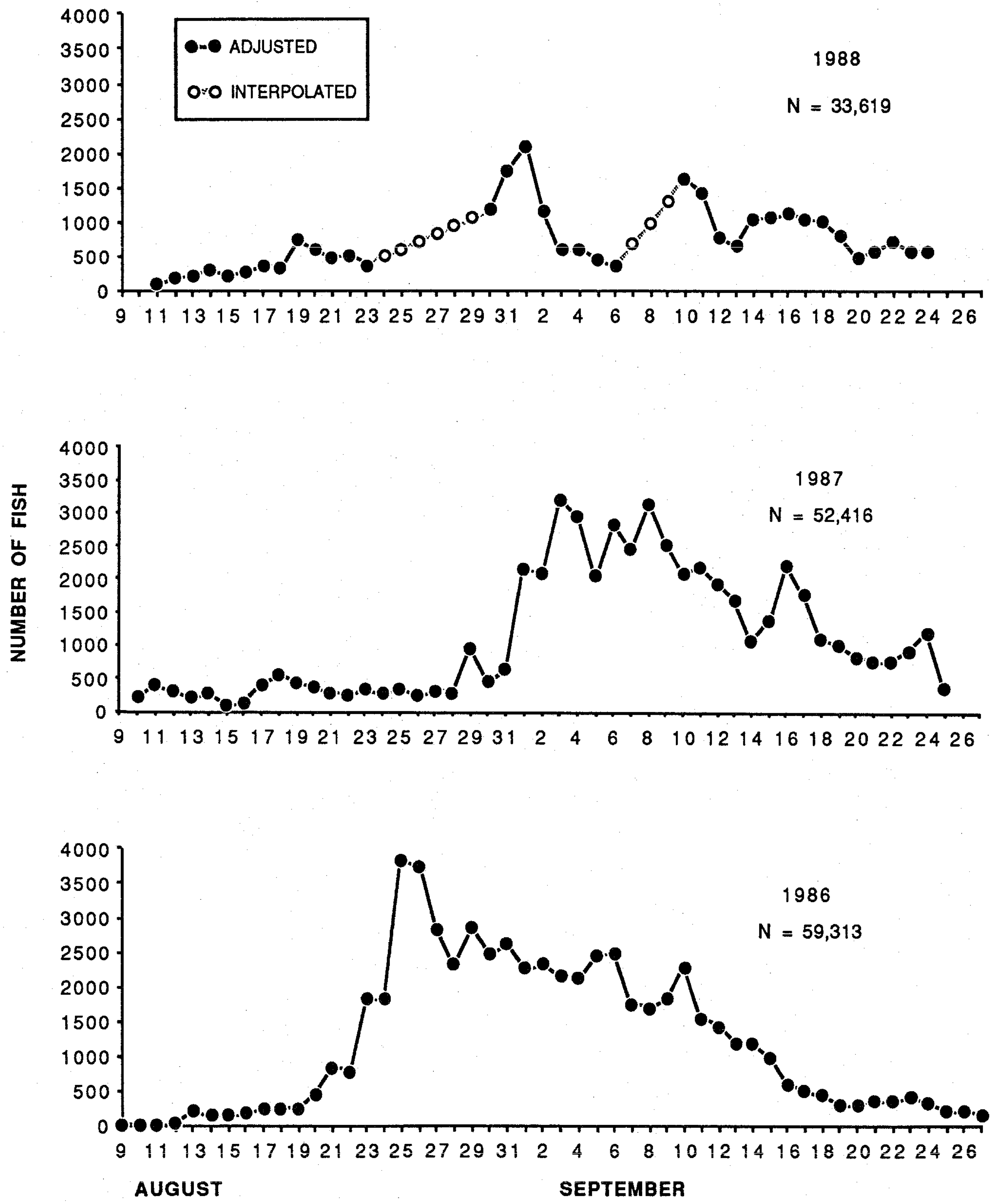

Figure 4. Chandalar River fall chum salmon run timing, based on daily sonar counts, 1986-1988.

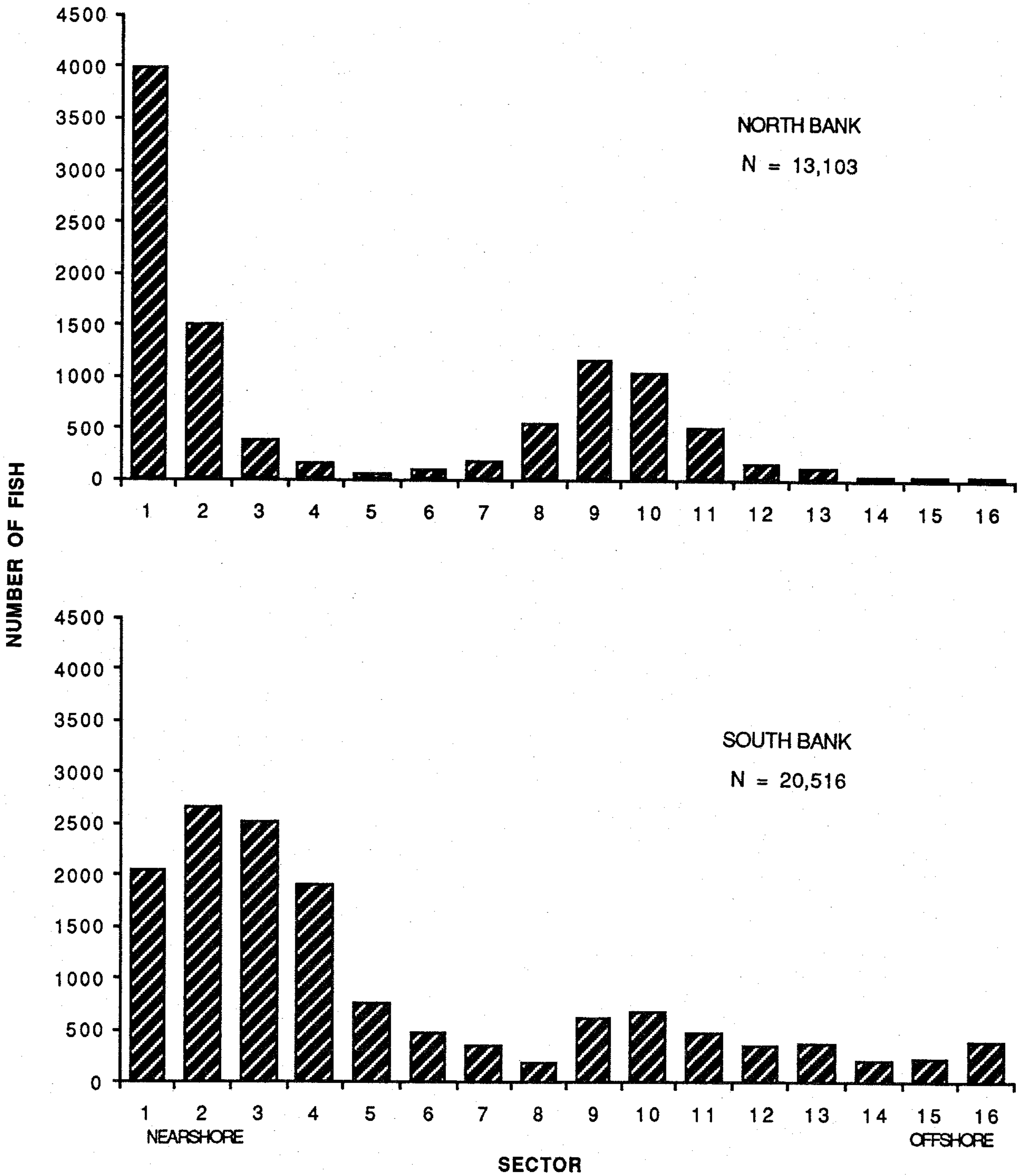

Figure 5. Total sector counts of Chandalar River fall chum salmon from the north and south bank sonar stations, August 11 - September 24, 1988.

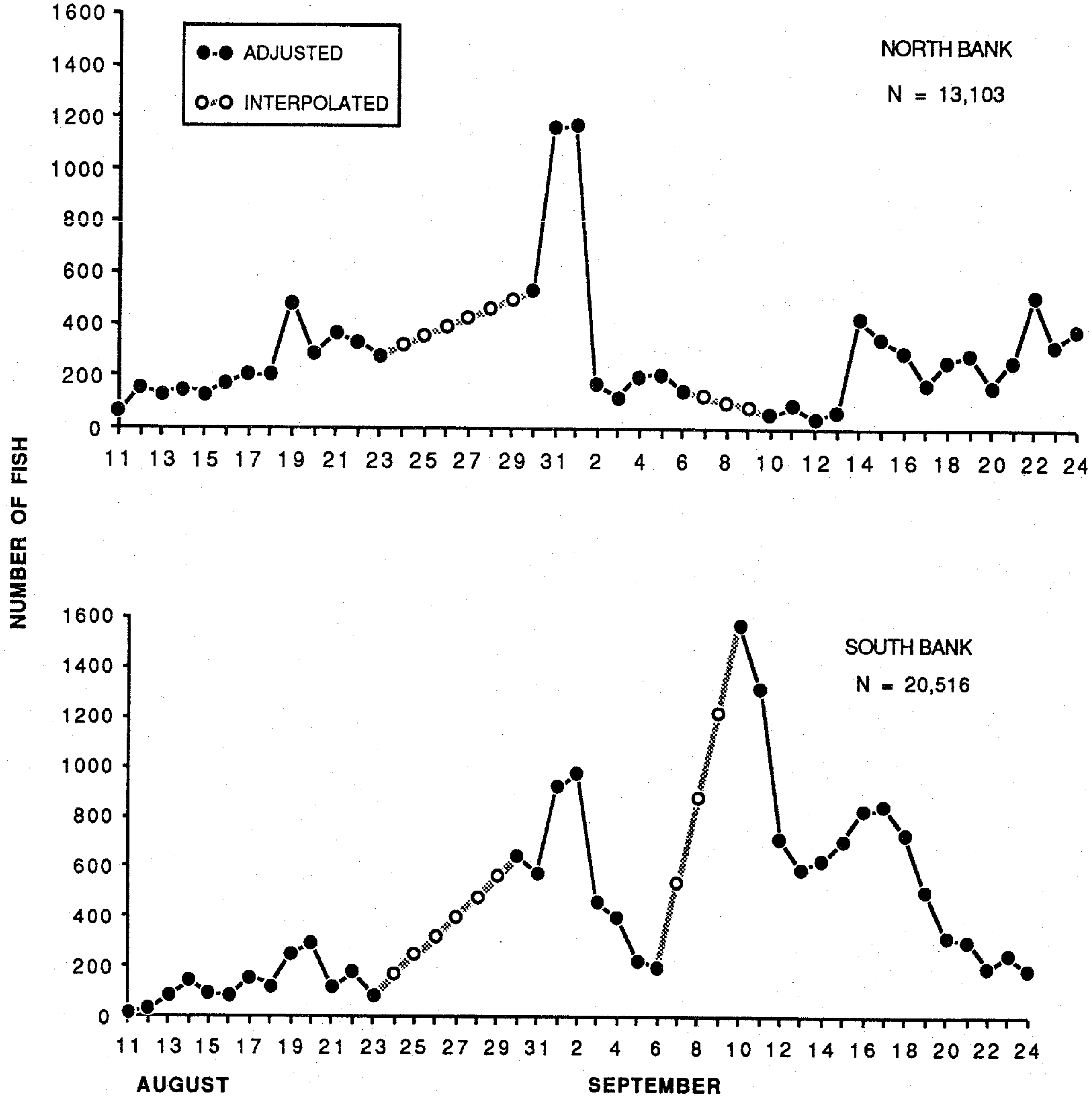

Figure 6. Distribution of Chandalar River fall chum salmon between the north and south banks, based on daily sonar counts, August 11 - September 24, 1988.

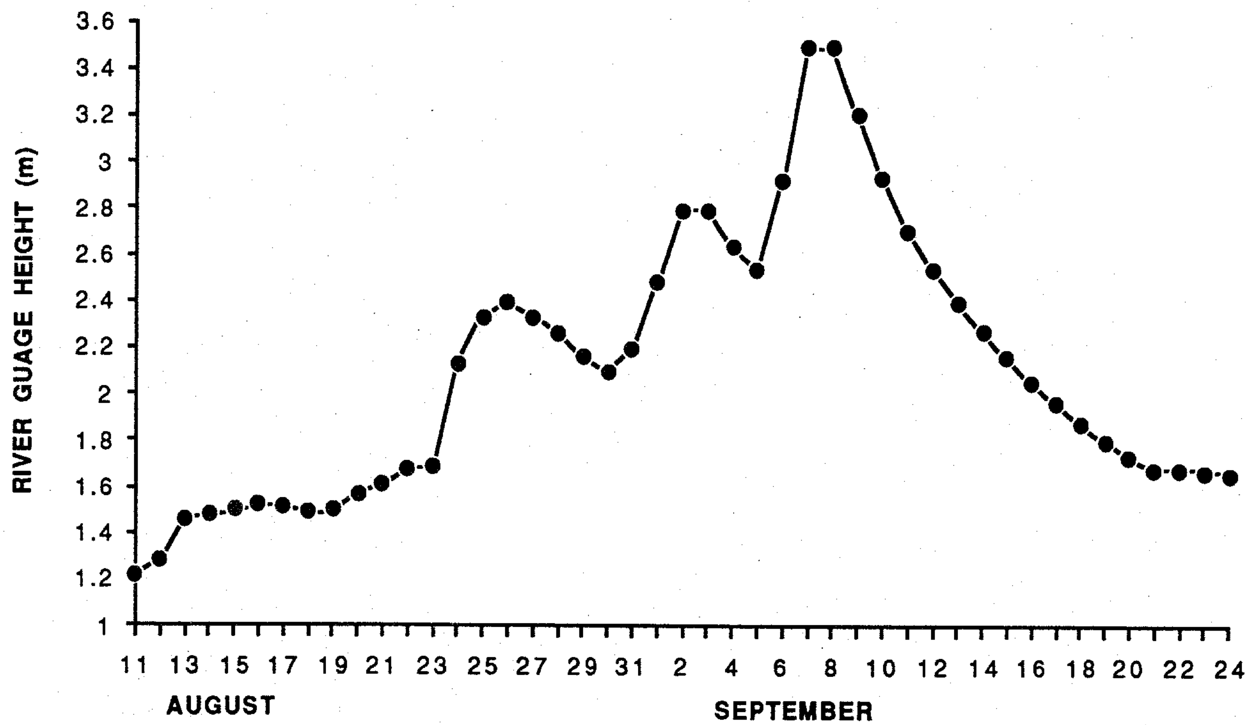

Figure 7. Daily water levels on the Chandalar River, August 11 - September 24, 1988.

Of the 73 fish collected for ageing and genetic analysis (Table 2), age 0.4 predominated (54%), followed by age 0.3 (44%), age 0.2 (1%), age 0.5 (1%). In 1986 and 1987, the predominate age-class in the fish sampled was age 0.3. Males comprised 74% of the total sample in 1988. The prevalence of males in all three years may be due in part to net selectivity for males, which have more kipe development than females. Carcasses will be randomly sampled at spawning ground locations in 1989 which should eliminate the bias associated with gill netting. Age 0.3 fish were not significantly different in length than age 0.4 (P=0.40). Males and females were not significantly different in length at age 0.3 (P=0.54), but males were larger at age 0.4 (P=0.02).

Aerial counts of Chandalar River fall chum salmon were 918, 4,107 and 5,735 on September 14, 20, and 28, respectively. Peak spawning apparently occurred during September 20-28, based on the accumulation of carcasses (Table 3). The first survey was flown under poor water visibility conditions; the second and third surveys had fair water visibility conditions. In the two later surveys, most of the fish were found in a single spawning channel, below a stream entering the Chandalar River from the south, 8 km upriver from Venetie. The highest aerial count, 5,735 total chums on September 28, is multiplied by an expansion factor of 5.86 to approximate the total sonar count of 33,619.

Aerial surveys 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 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" each year the river has been surveyed.

Two difficulties are anticipated in establishing aerial counts as a reliable estimator of yearly fall chum salmon escapement on the Chandalar River. First, the numerous sloughs and tributary streams and the extensive braiding of large sections of river make full coverage impractical. Second, over 50% of the fish observed were concentrated in a shaded narrow channel with undercut banks and could only be roughly estimated. A limited coverage aerial survey may be adequate if it is focused on known spawning areas (index areas) and accurate counts can be obtained. Aerial photography may be used as a counting aid in index areas of high fish density where only certain sections of the channel are visible. 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.

In 1989, a helicopter survey is scheduled to be flown during peak spawning. This method may give a more accurate count of spawning and dead chum salmon, especially in areas of high density. Correction factors will be compared between the 1989 and 1990 season using total counts and selected index area counts.

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; water velocity and depth at the sonar site prevented fish milling behavior; and counts of other fish species were 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 three years of this operation.

Table 2. Length-at-age data collected from 73 chum salmon in the Chandalar River, September 4-6, 1988.

Sex	Age	N	Percent	Length (cm)		
				Mean	SE	Range
Males	0.2	1	2	55.0	--	--
	0.3	22	41	60.5	0.97	48-66
	0.4	30	55	64.1	0.46	55-69
	0.5	1	2	67.0	--	--
Females	0.3	10	53	61.5	1.05	58-68
	0.4	9	47	61.9	0.64	59-66
Total	0.2	1	1	55.0	--	--
	0.3	32	44	60.8	0.74	48-68
	0.4	39	54	63.6	0.41	55-69
	0.5	1	1	67.0	--	--

Table 3. Aerial survey counts of Chandalar River fall chum salmon, September 14, 20, and 28, 1988.

Date	Survey location	Number of live fish	Number of carcasses	Total
Sep 14	Below Venetie	600	0	600
	Above Venetie	317	1	318
	Total survey	917	1	918
Sep 20	Below Venetie	622	20	642
	Above Venetie	3,010	455	3,465
	Total survey	3,632	475	4,107
Sep 28	Below Venetie	1,051	86	1,137
	Above Venetie	2,926	1,672	4,598
	Total survey	3,977	1,758	5,735

The fall chum salmon escapement estimate of 33,619 was much lower than the 1986 and 1987 estimates. This escapement level likely represents a low return for this system; escapement levels in the Sheenjek River, a nearby drainage, were also considered low in 1988 (Joint Canada/United States Yukon River Technical Committee, Yukon River technical report, March 6-8, 1990, Whitehorse, Yukon Territory, Canada, unpublished data).

Further study is needed to assess the accuracy of using aerial counts to estimate total escapement.

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REFERENCES

Barton, L.H. 1984a. Distribution and abundance of chinook and chum salmon escapements in the Yukon River drainage, Alaska. Pages 9-10 *in* L.S. Buklis, editor. Proceedings of the first Yukon River fisheries interagency meeting. Alaska Department of Fish and Game, Anchorage, Alaska.

Barton, L.H. 1984b. A catalog of Yukon River salmon spawning escapement surveys. Alaska Department of Fish and Game, Technical Data Report Number 121, Juneau, Alaska.

Barton, L.H. 1986. Enumeration of fall chum salmon by side-scanning sonar in the Sheenjek River in 1985. Alaska Department of Fish and Game, Yukon Salmon Escapement Report 28, Fairbanks, Alaska.

Barton, L.H. 1987. Sheenjek River salmon escapement enumeration, 1986. Alaska Department of Fish and Game, Yukon Salmon Escapement Report 33, Fairbanks, Alaska.

Barton, L.H. 1988. Sheenjek River salmon escapement enumeration in 1987. Alaska Department of Fish and Game, Regional Information Report 3F88-15, Fairbanks, Alaska.

Craig, P.C., and J. Wells. 1975. Fisheries investigations in the Chandalar River region, northeast Alaska. Canadian Arctic Gas Study Ltd. Biological Report Series 33:1-105. Calgary, Alberta.

Daum, D.W., and R.C. Simmons. 1991. Sonar enumeration of fall chum salmon on the Chandalar River, 1987. U.S. Fish and Wildlife Service, Fishery Assistance Office, Progress Report, Fairbanks, Alaska.

Foerster, R.E. 1968. The sockeye salmon, *Oncorhynchus nerka.* Fisheries Research Board of Canada, Bulletin 162, Ottawa, Canada.

Rost, P.J. *In preparation.* Aerial surveys for summer and fall salmon in the upper Yukon River drainage, 1985. U.S. Fish and Wildlife Service, Fishery Assistance Office, Progress Report, Fairbanks, Alaska.

Simmons, R.C., and D.W. Daum. 1989. Sonar enumeration of fall chum salmon on the Chandalar River, 1986. U.S. Fish and Wildlife Service, Fishery Assistance Office, Progress Report, Fairbanks, Alaska.

U.S. Department of the Interior. 1964. A report on fish and wildlife resources affected by the Rampart dam and reservoir project, Yukon River, Alaska. U.S. Fish and Wildlife Service, Juneau, Alaska.