Sonar Enumeration of Fall Chum Salmon in the Chandalar River, 1987

Alaska Fisheries Progress Report

David W. Daum
Rodney C. Simmons

U.S. Fish and Wildlife Service
Fishery Assistance Office
101 12th Avenue, Box 17
Fairbanks, Alaska 99701

March 1991

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The correct citation for this report is:

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

ABSTRACT

From August 10 to September 25, 1987, 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 52,416 chum salmon was counted, compared to 59,313 in 1986; escapement peaked on September 3, nine days later than 1986. This is a conservative estimate of annual escapement since counts do not include fish passing out of sonar range, fish present before 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. 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 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 Yukon River Joint 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 1987, 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 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, and (5) provide the Yukon River Joint Technical Committee with accurate escapement counts so conflicts over harvesting transboundary Yukon River salmon stocks can be resolved. In 1986, the sonar escapement estimate for Chandalar River fall chum salmon was 59,313 (Simmons and Daum 1989). This progress report compares the 1987 Chandalar River sonar data with information from the 1986 season.

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

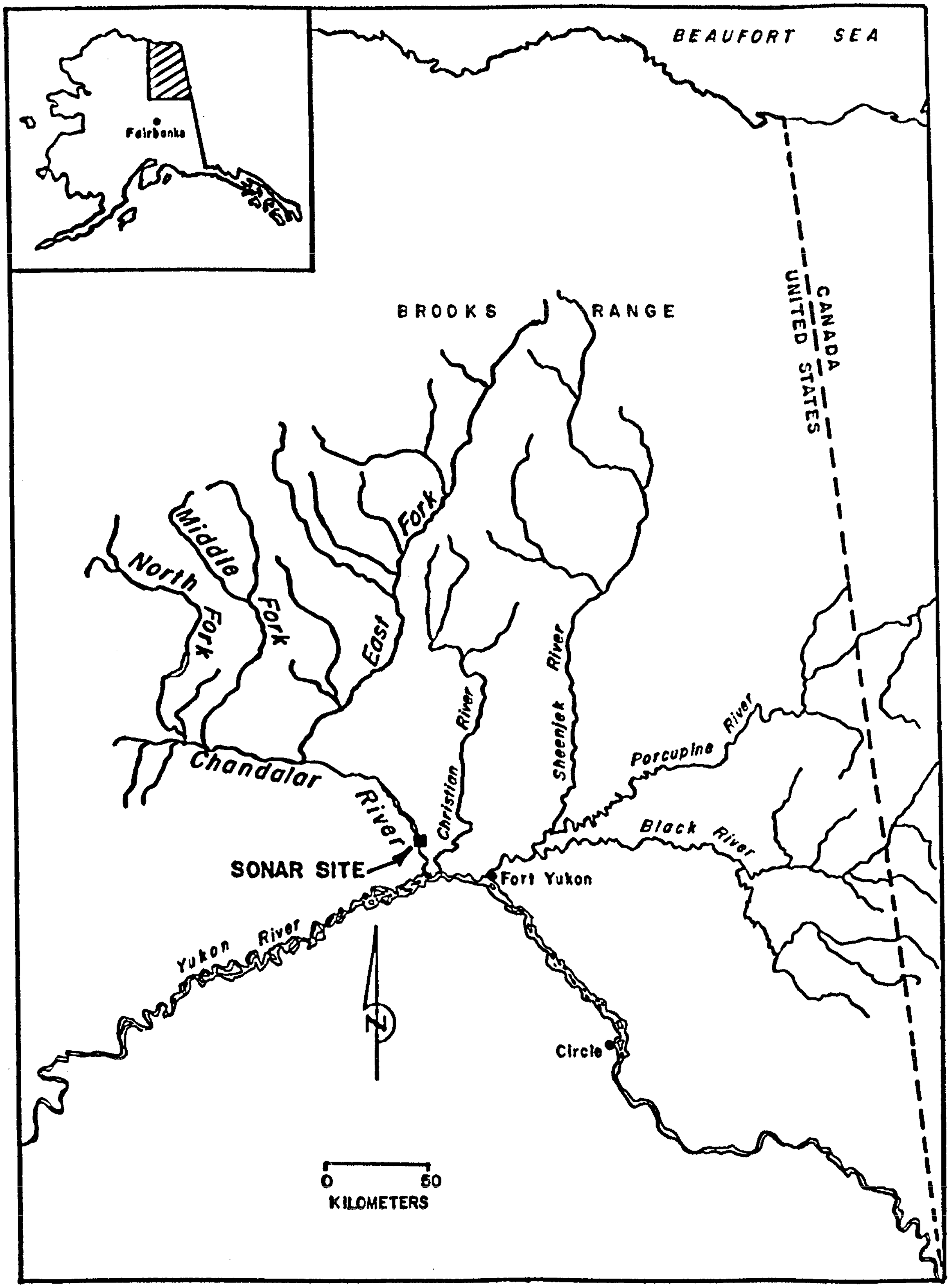

Figure 1. Major tributaries of the Yukon River near the U.S./Canada border.

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. The systems were operational from August 10 to September 25, 1987, although north bank counts were not included from August 10 to August 20 due to unreliable readings caused by bottom interference. North and south bank transducers were deployed in the same locations used in the previous year 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 4 kg collapsible anchor attached to monofilament line, was pulled through each of the 16 sonar beam sectors that compose the total counting range. When the anchor 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 after each

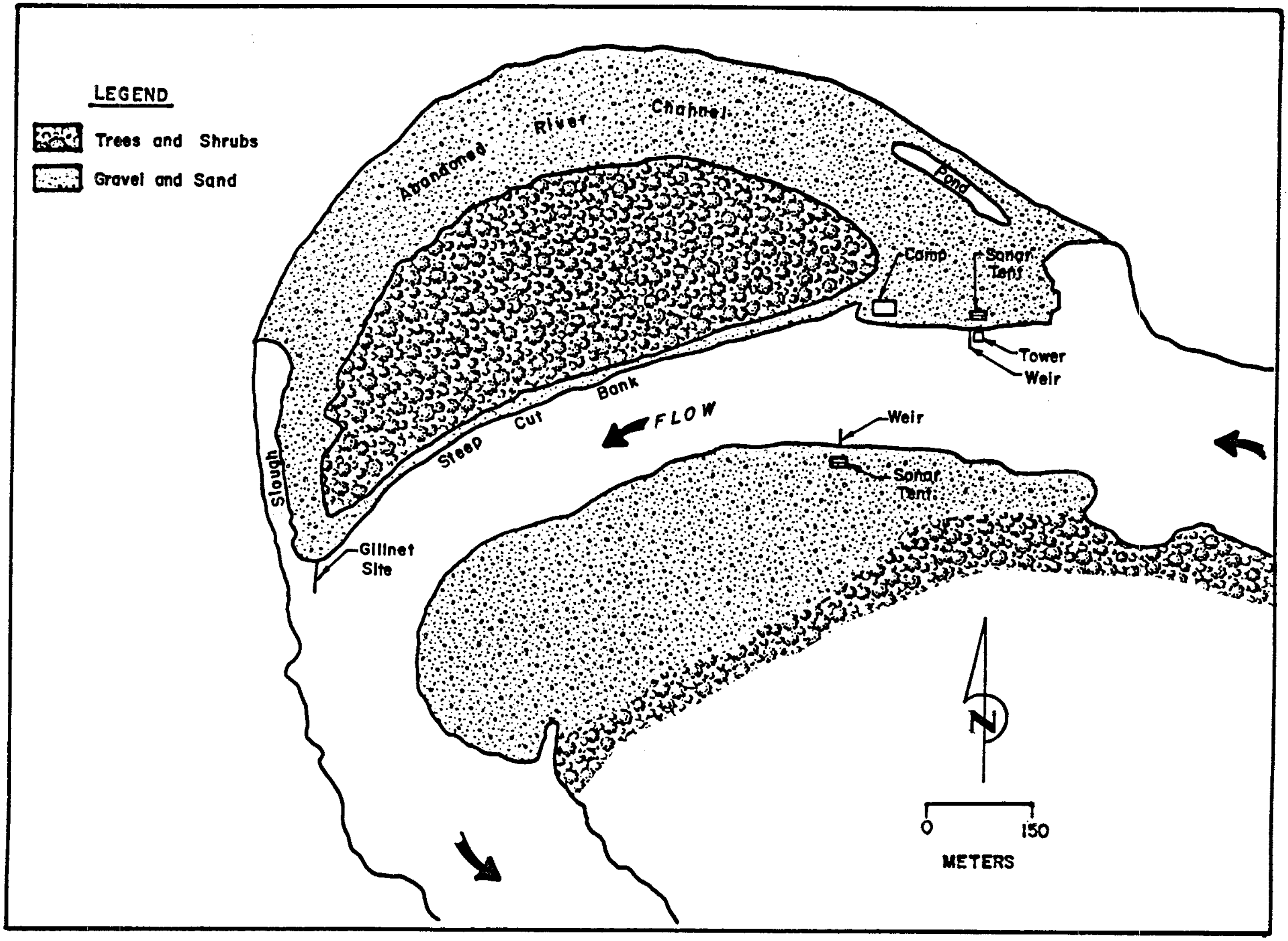

Figure 2. Site map of the Chandalar River sonar facilities.

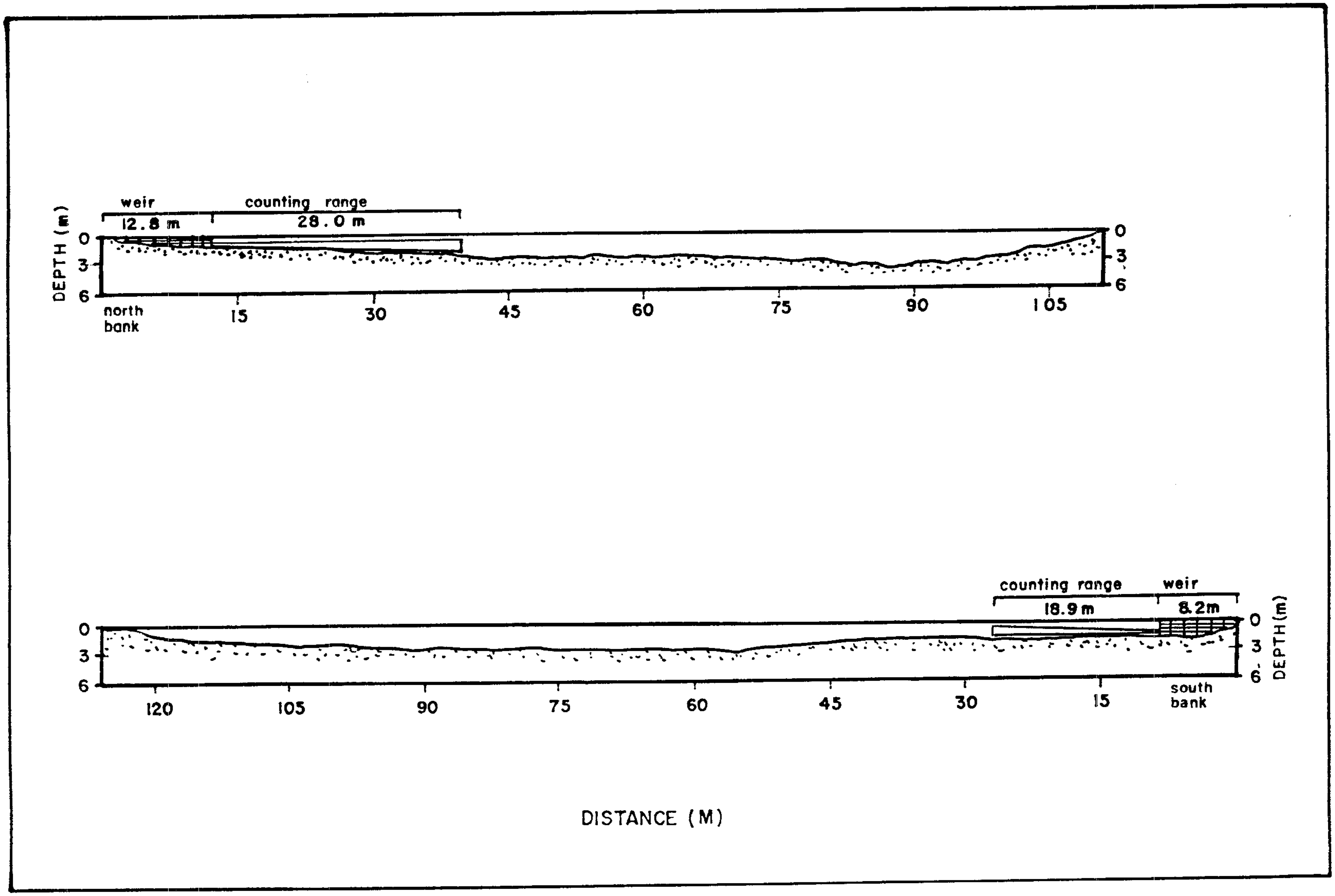

Figure 3. River channel profiles of the north and south bank sonar facilities. Weir length and counting ranges are approximations that change according to river discharge levels.

calibration period for discrepancies 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 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). 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 150 chum salmon was collected on September 3-5 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 ice, and transported to the Service's Alaska Fish and Wildlife Research Center in Anchorage for electrophoretic analysis.

Length and age data were collected from all 150 chum salmon. 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 and males. Scales and vertebrae were collected for age determination since 50% of the otoliths collected in 1986 (Simmons and Daum 1989) were unreadable. The "preferred scale" from all 150 fish and a subsample of 50 vertebrae were collected. The preferred scale is on the left side of the fish, located where the second row of scales above the lateral line intersects the diagonal row of scales running from the posterior insertion of the dorsal fin to the lateral line. Scales and vertebrae were sent to the Department's Commercial Fish Division, Anchorage for age analysis. Salmon age was described using 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 1200 hours to the nearest 0.3 cm.

RESULTS AND DISCUSSION

The adjusted fall chum salmon escapement count for the Chandalar River in 1987 was 52,416 fish (Table 1), compared to 59,313 in 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 had 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 and 140,086 in 1987 (Barton 1987, 1988).

Daily counts during 1987 were over 1,000 fish per day for 20 of the 47 counting days. When operations were terminated on September 25 due to freezing conditions, 377 fish were counted. The escapement count peaked on September 3, nine days later than 1986. Fifty percent of the estimated run passed the site by September 8, compared to a median passage date of September 1 in 1986. Median passage dates on the Sheenjek River were August 31 in 1986 and September 10 in 1987 (Barton 1987, 1988). This year's escapement curve was similar to the 1986 graph (Figure 4).

Table 1. 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	

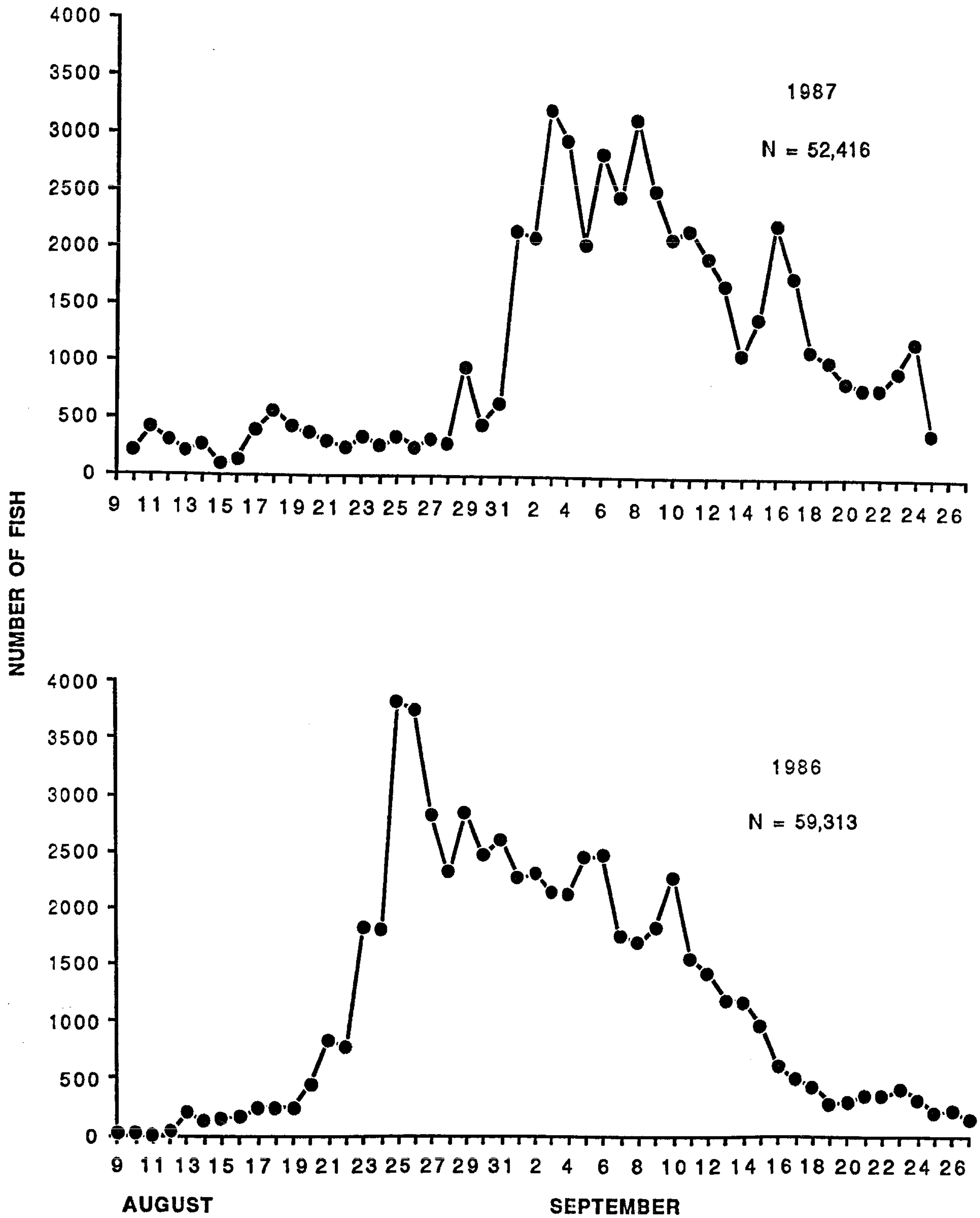

Figure 4. Chandalar River fall chum salmon run timing, based on daily sonar counts from 1986 and 1987.

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 nearshore counts indicating that the majority of fish were detected (Figure 5). The first 11 of the 16 sectors accounted for 99% of the fish passing the south bank sonar and 98% of north bank fish. The majority of fish were oriented close to shore with the highest frequency of occurrence in Sector 2 for both banks.

The total count was not equally distributed between counting units. The south bank count was 36,089 fish or 69% of the total (Table 1; Figure 6), compared to 35% in 1986. Higher water levels in 1987 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.

Fish counts increased during the hours corresponding to low light conditions (2100-0800 hours; Figure 7). The 1987 diel distribution was similar to the 1986 season (Simmons and Daum 1989).

The Chandalar River experienced large variations in water level over the season (Figure 8). Although 1987 water levels cannot be compared directly to 1986 levels, personnel at the camp indicated that the river level was much higher for most of the 1987 season.

Adjustments to the counter's fish velocity control were needed for 22% of the calibration periods on the north bank and 9% on the south bank. The greater variability in fish swimming speed on the north bank site is probably due to physical differences in bottom contour and channel configuration which cause a broader range of water velocities.

Of the 150 chum salmon scales collected, 16 (11%) were unreadable, while none of the 50 fish vertebrae examined were rejected. Based on scale readings, age 0.3 fish predominated (55%), followed by age 0.4 (42%), and age 0.5 (3%; Table 2). In 1986, the predominate age-class was age 0.3 (65% of the sample). Vertebrae will be collected for age determination in subsequent years of the study since otoliths (Simmons and Daum 1989) and scales are unreliable indicators of age in Chandalar River chum salmon.

Table 2. Length-at-age data collected from 134 chum salmon in the Chandalar River, September 3-6, 1987.

Sex	Age	N	Percent	Length (cm) Mean	SE	Range
Males	0.3	58	57	62.7	0.36	56-69
	0.4	41	40	65.1	0.44	58-69
	0.5	3	3	66.0	1.15	64-68
Females	0.3	16	50	60.8	0.55	57-65
	0.4	15	47	63.5	0.54	61-69
	0.5	1	3	70.0	--	--
Total	0.3	74	55	62.3	0.32	56-69
	0.4	56	42	64.7	0.37	58-69
	0.5	4	3	67.0	1.29	64-70

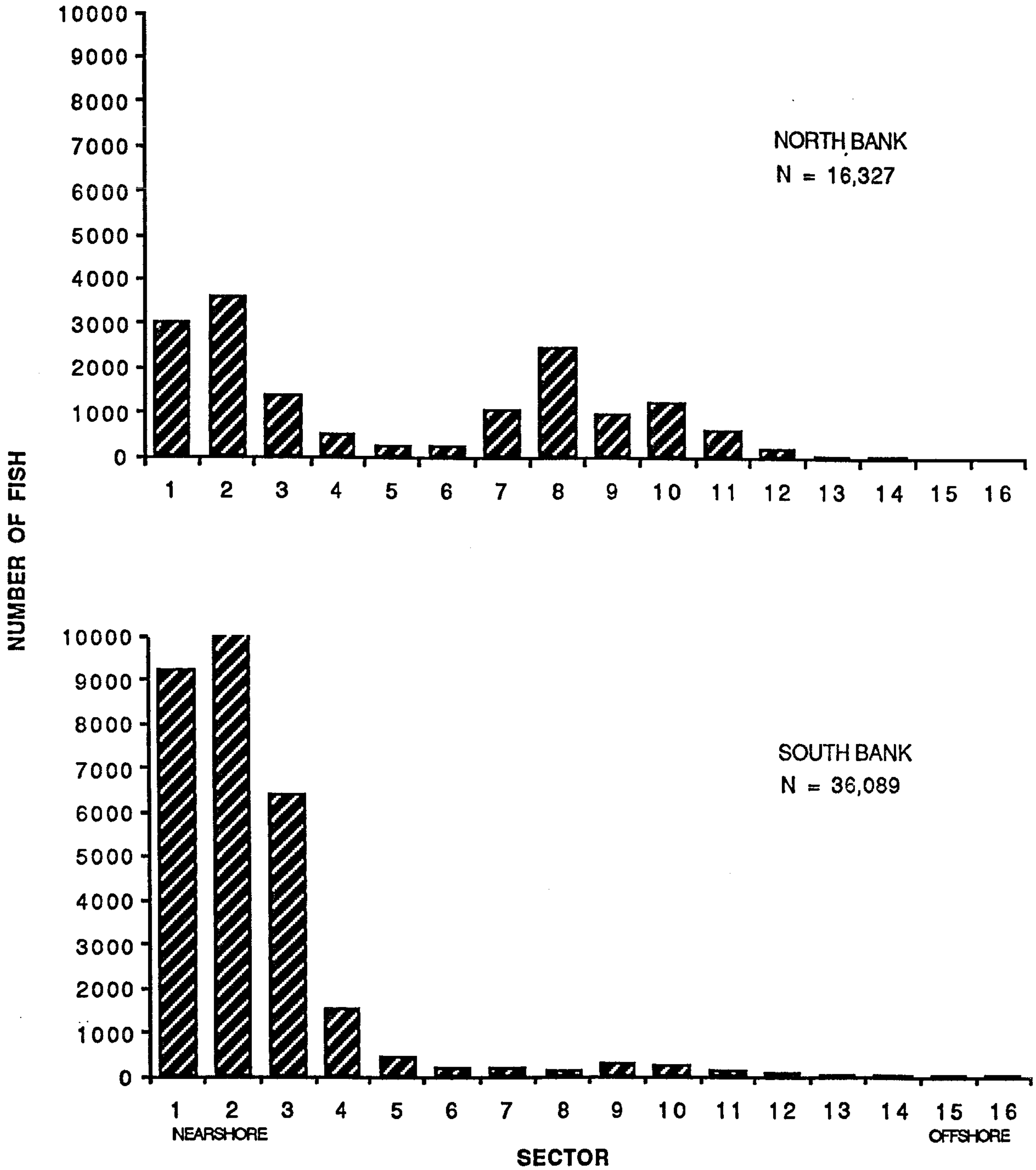

Figure 5. Total sector counts of Chandalar River fall chum salmon from the north and south bank sonar stations, August 10 - September 25, 1987.

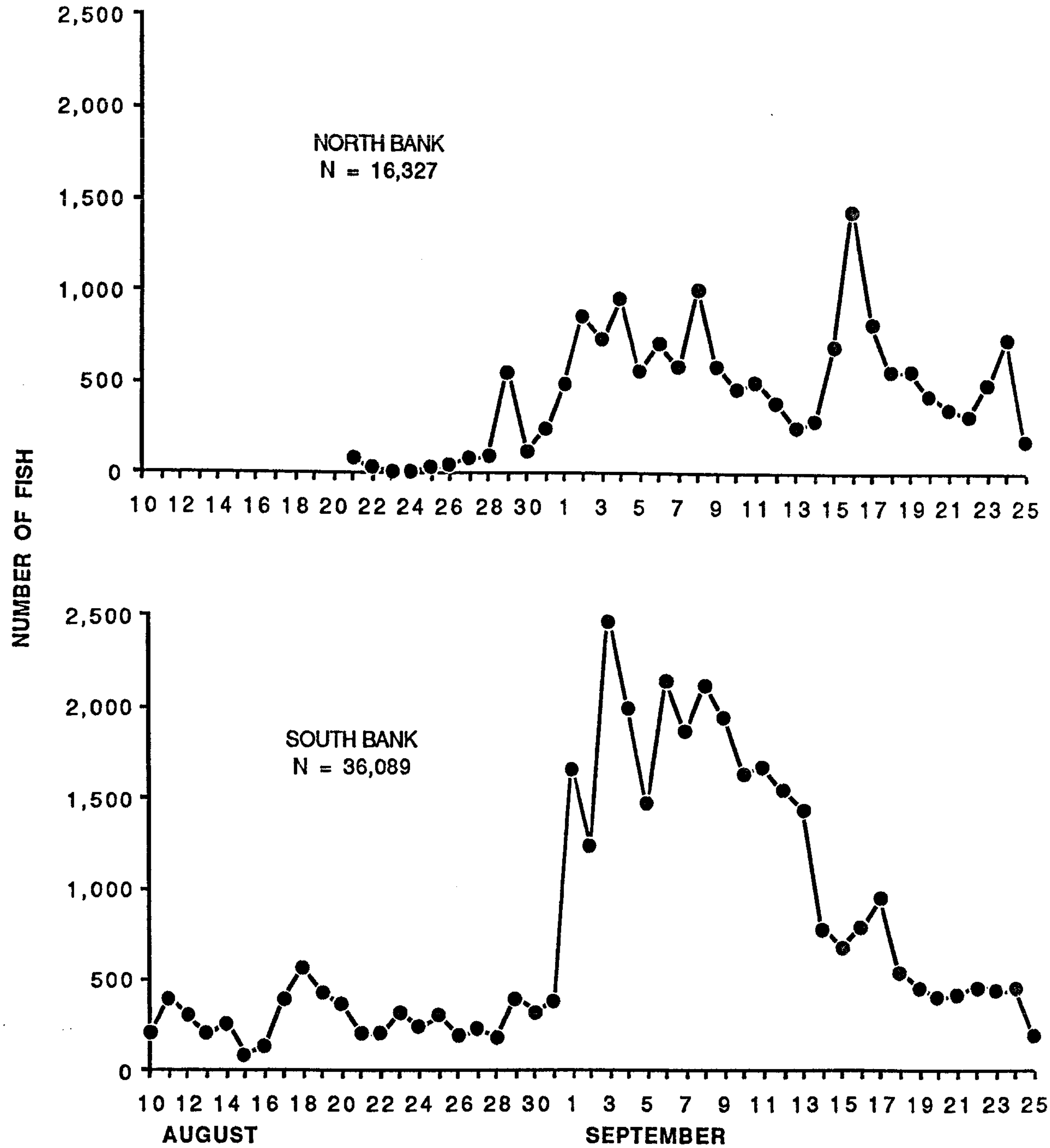

Figure 6. Daily distribution of Chandalar River fall chum salmon between the north and south banks, August 10 - September 25, 1987.

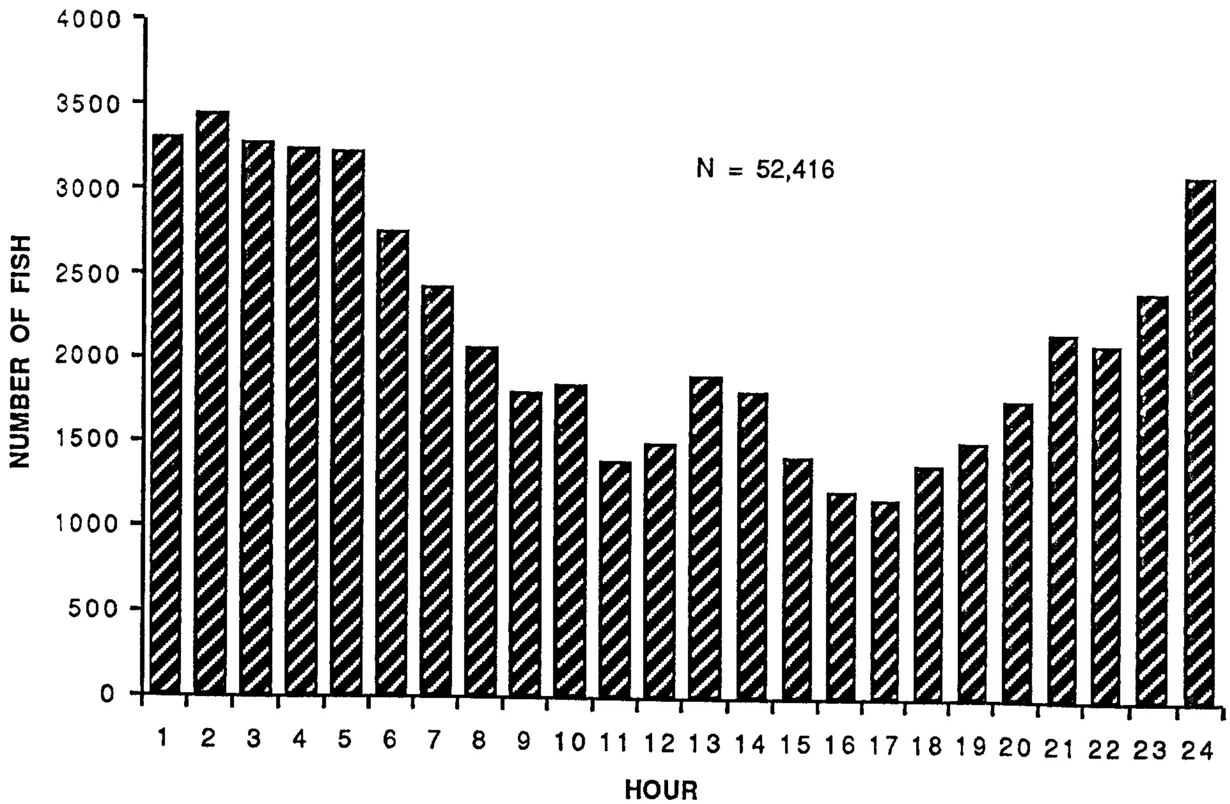

Figure 7. Hourly distribution of Chandalar River fall chum salmon, August 10 - September 25, 1987.

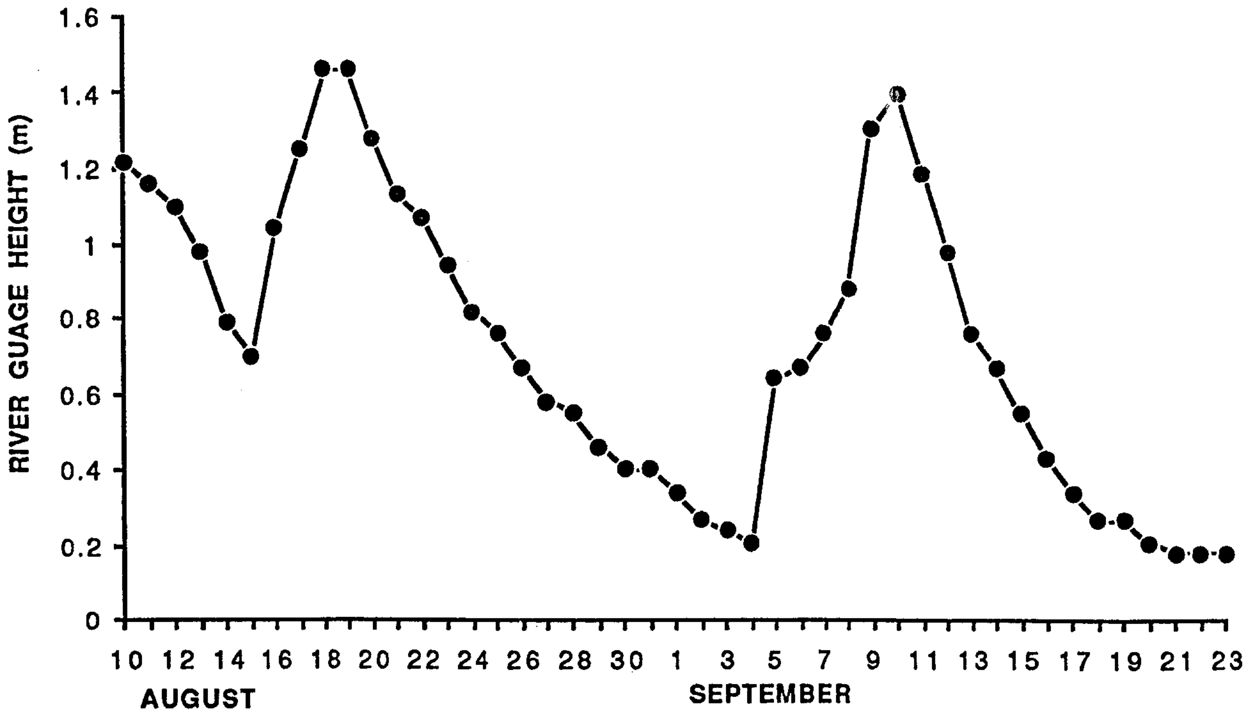

Figure 8. Daily water levels on the Chandalar River, August 10 - September 25, 1987.

Males comprised 76% of the total sample in 1987, compared to 68% in 1986. The prevalence of males in both sample years may be due, in part, to net selectivity for males, which have more kipe development than females. Males were significantly larger than females at ages 0.3 and 0.4 ($P<0.05$).

Based on fall chum salmon counts obtained from 1986 and 1987 Chandalar River sonar operations, prior aerial survey estimates of escapement have substantially underestimated the size of this run. 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".

In summary, side-scanning sonar proved to be an effective method for enumerating fall chum salmon escapement in the Chandalar River. The fall chum salmon escapement estimate of 52,416 was similar to the 1986 estimate. This escapement level likely represents an average return for this system. 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.

ACKNOWLEDGEMENTS

Special thanks are extended to the people that participated in this project and who are largely responsible for its success: S. Anderson, R. Price, D. Sundquist, and K. Wedemeyer for their help in establishing and running the station; John Wilcock, Alaska Department of Fish and Game, Commercial Fish Division, for ageing chum salmon scales and vertebrae; A. Menin for his technical assistance in "tuning" our sonar counters; and the entire office staff for expediting supply orders and editing this report.

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