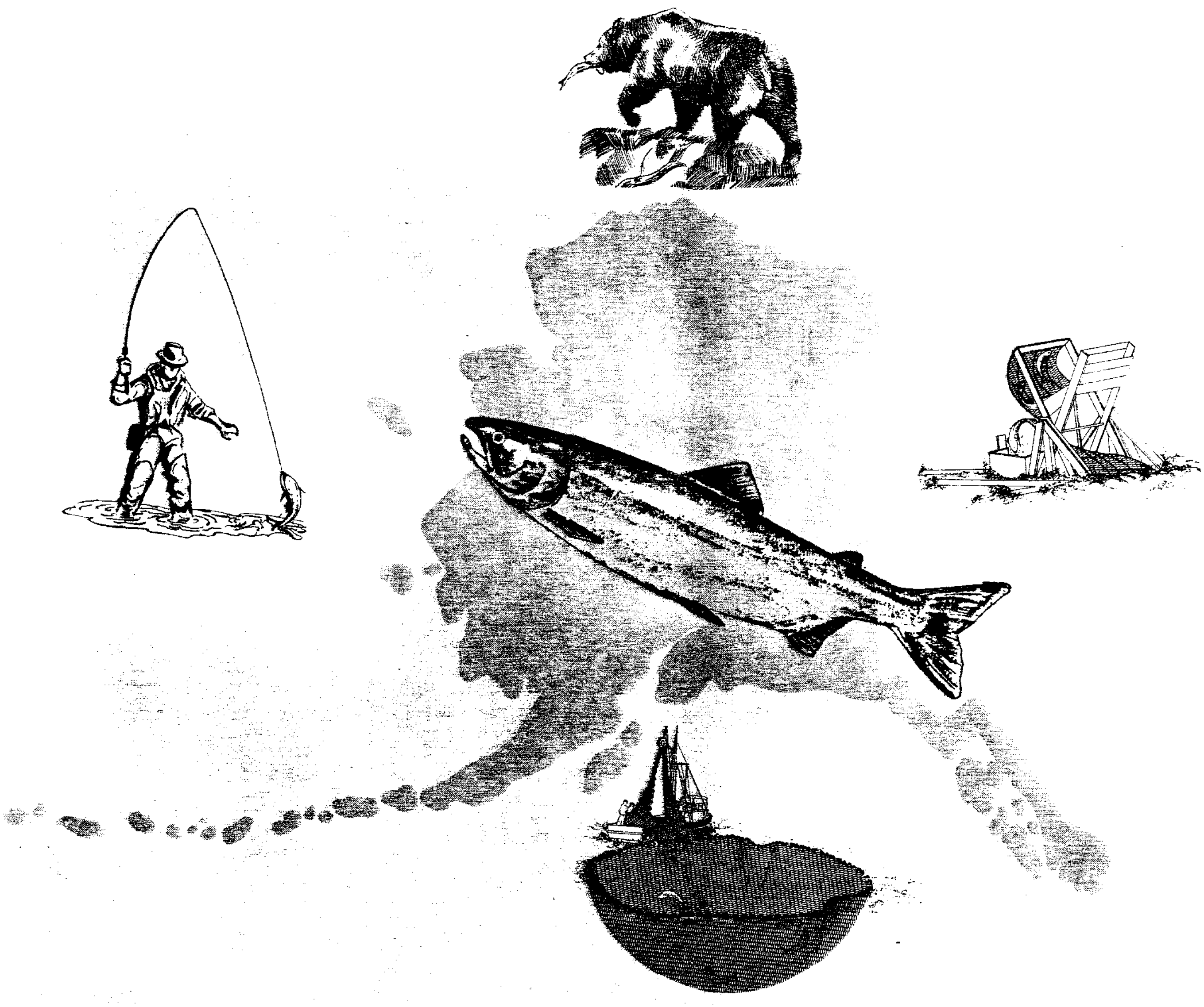
SONAR ENUMERATION OF FALL CHUM SALMON ON THE CHANDALAR RIVER, 1986

Progress Report



July 1989

Region 7
U.S. Fish and Wildlife Service
Department of the Interior

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

Progress Report

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ABSTRACT

From August 9 to September 27, 1986 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 59,313 chum salmon were counted; escapement peaked on August 25. This is a conservative estimate since some fish passed upstream either beyond the range of sonar detection or after the sonar equipment was removed. Counting ranges were adequate for the detection of the majority of the run since most salmon were oriented nearshore and close to the river bottom. Limited test netting suggested that fish species other than chum salmon did not exist in sufficient quantities to bias the sonar counts of the target species. Past aerial survey counts 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 forecasts based on brood year returns, and influencing current USA/Canada salmon treaty negotiations. 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, primary responsibility for collection of escapement data has been with the Alaska Department of Fish and Game (Department). 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 *Oncorhynchus keta* 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 1986, 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 strength.

Two species of Pacific salmon migrate up the Chandalar River with chum salmon being the most abundant, followed by chinook salmon *Oncorhynchus tshawytscha*. 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*) although 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) compare annual variability in run strength 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.

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.

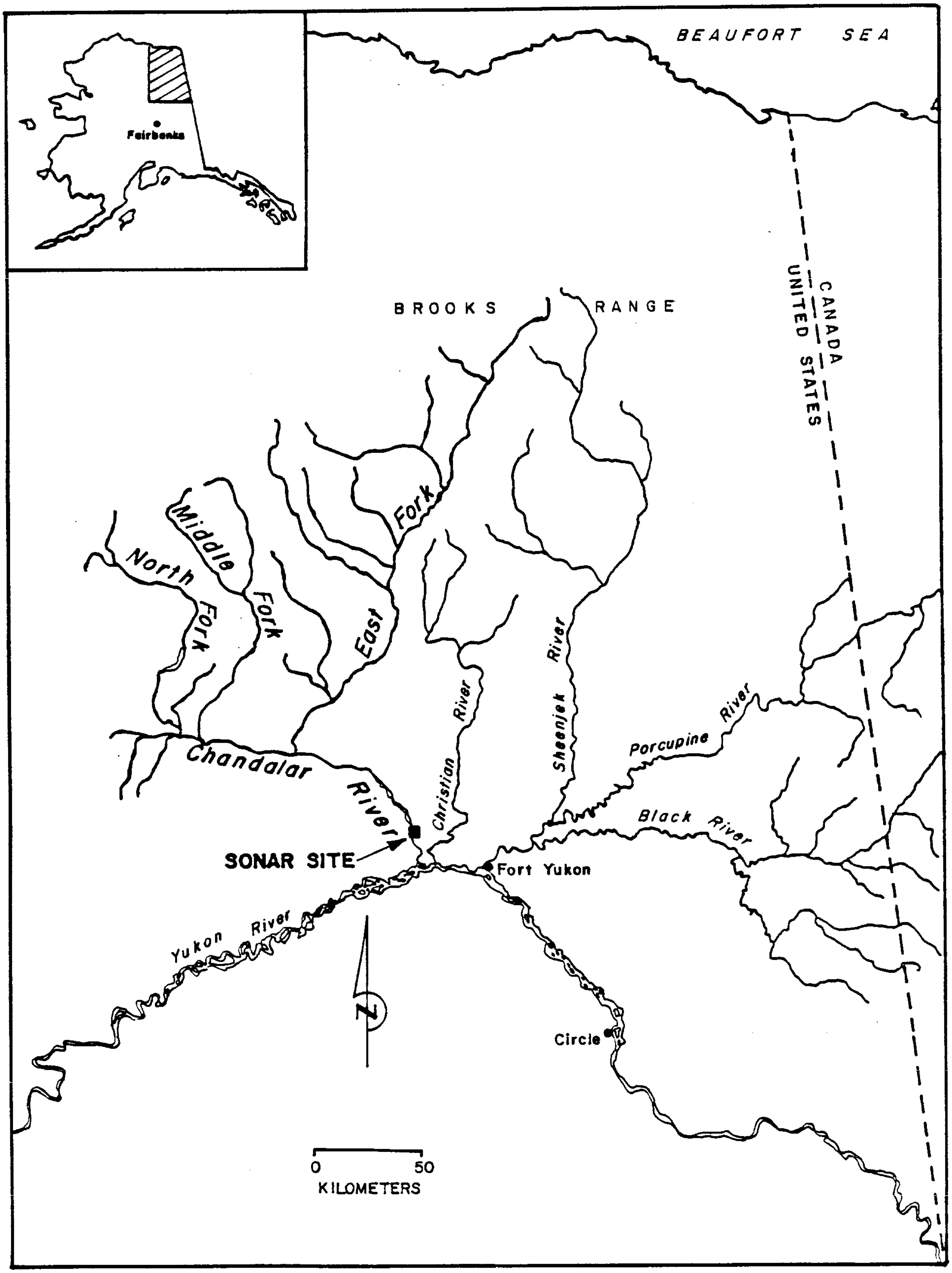

Figure 1. Major tributaries of the Yukon River near the USA/Canada border.

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 2.5 ft/s. Twenty-one to 22.5 km upstream from its confluence with the Yukon, 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

The criteria used for sonar site selection included: 1) a single-channel river site, 2) a uniform bottom contour with gradually sloping shorelines, 3) a uniform flow rate so that fish swimming speed was fairly constant, and 4) a location well below spawning areas to avoid milling fish and possible multiple counts of the same individual(s). A series of transects was run across the river with a Lowrance X-16 fathometer to locate areas with relatively smooth bottom contours. Depth transects were taken across the river channel, at 3 m intervals, with a telescoping surveyor's rod and recorded to the nearest 3.0 cm. Sonar equipment was needed on opposite river banks since river width was greater than the maximum counting range (30 m). After several days of trail and error, two sites 180 m apart were selected. These sites had the best bottom profiles within the selected reach and some potential cross-over by fish between the sites was accepted in order to ensure good bottom coverage by the sonar beam. 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.

Fall chum salmon were counted with two 1981 Bendix side-scan sonar fish counters. Both counting systems were operational from August 9 to September 27, 1986, except on August 11 and 12 when the systems were shut down for relocation. Because of the relatively flat sections of the river bottom, the modular substrates normally used with this system were 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 face. 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 a monofilament line, was dragged through each of the 16 sonar beam sectors that compose the total counting range. When the anchor transected the sonar beam it registered as a sharp "spike" or trace on the oscilloscope and simultaneously registered as a valid count on the 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 by retrofitting the counter with a "rock inhibitor" electronic circuit component that was built on-site by Bendix personnel. This feature greatly improved the counting precision by eliminating bottom interference, allowing the beam to pass very close to the river bottom.

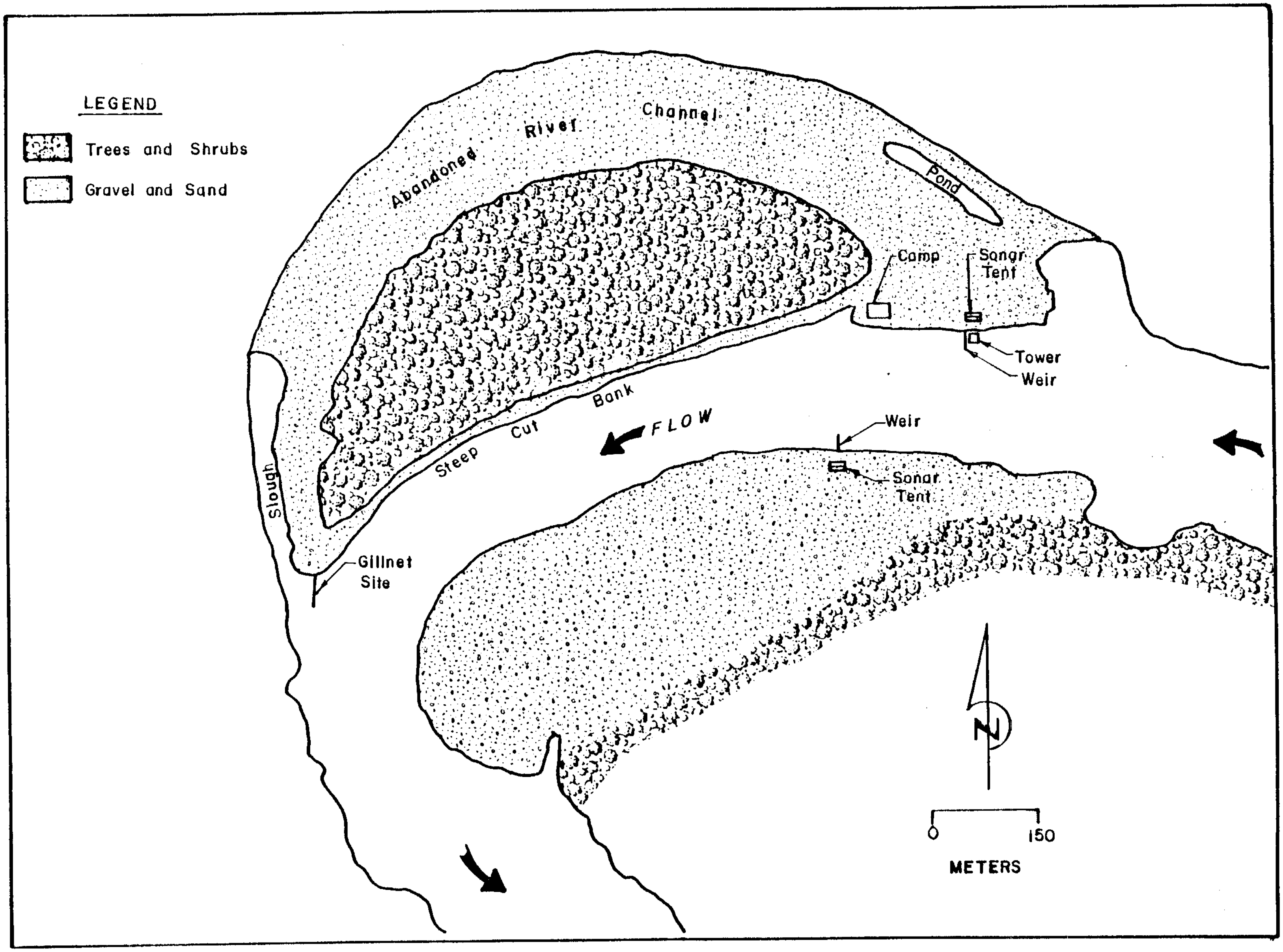

Figure 2. Site map of the Chandalar River sonar facilities.

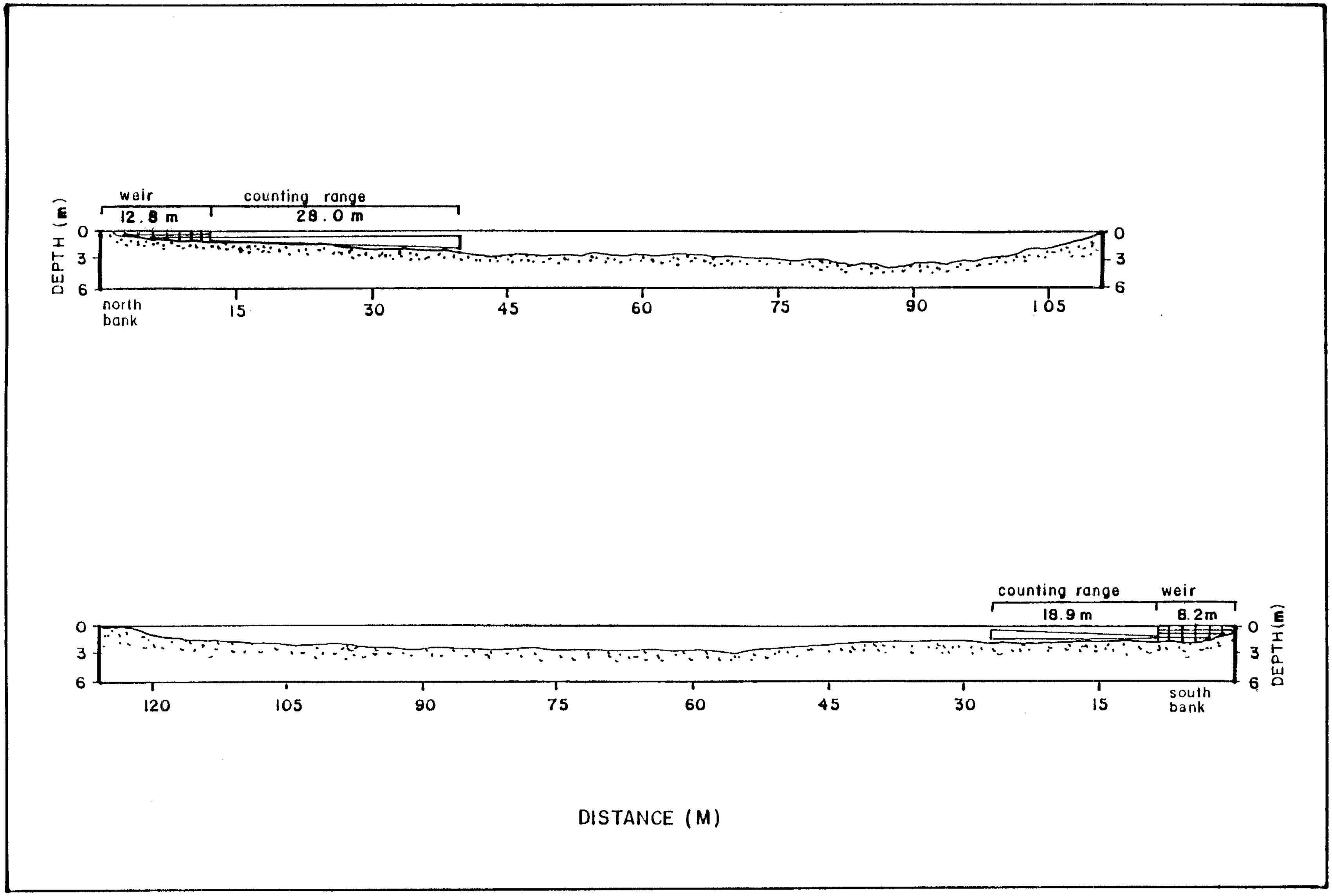

Figure 3. River channel profiles of the north and south bank sonar facilities. Weir length and counting ranges are approximations that change according to river discharge levels.

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 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. Adjustments to the fish velocity control (counter sensitivity) were made 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

Counter calibration was performed at least once every four hours until 30 fish were counted or 30 minutes had passed. To test the accuracy of the calibration method, periodic fish counts from a 6 m high counting tower, placed 10 m upstream from the north bank transducer, were compared to the north bank oscilloscope counts.

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 the calibration showed a 20% overcount at Hour 4, then overcounts of 5%, 10%, and 15% were assumed for Hour 1, 2, and 3 and the necessary count adjustments were made. Daily counts were adjusted based on sonar calibration results for the corresponding time period. Registered "debris counts" were deleted. All data in this report appears in its adjusted form.

Gill nets were the primary method used to verify fish species composition since the side-scan sonar model used could not differentiate between species. Gill netting was performed throughout most of the project's duration utilizing 36.6 and 12.2 m long by 2.4 m deep variable mesh monofilament nets with equal length panels of 1.3, 2.5, 3.8, and 5.0 cm bar mesh and 18.3 m long by 3.0 m deep multifilament nets with 7.4 cm bar mesh. Nets were set 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 in capturing fish and use of the counting tower became the only means to verify species composition.

During the period coinciding with peak counts, 150 chum salmon were collected for genetic stock identification. All fish were collected with multifilament gill nets, 18.3 m long by 3.0 m deep with 7.4 cm bar mesh, set perpendicular to the shore. A total of 50 fish were processed each day for three consecutive days. Heart, liver and muscle tissues were taken from each fish. Samples were cataloged, packed in ice, and flown the same day to Fairbanks, Alaska for freezing. Electrophoretic analysis was performed by Canada's Department of Fisheries and Oceans.

Length, weight, and age data were collected for all 150 sacrificed chum salmon. Salmon length was measured to the nearest millimeter from mid-eye to the fork in the caudal fin. Weights of fish were estimated to the nearest 0.1 kg with a 5.0 kg Pesola spring scale. A Student's two-tailed *t*-test was used to test for significant differences ($P<0.05$) between mean lengths and weights of females and males. Otoliths were collected for age determination since most individuals had nearly complete scale resorption. Otoliths were placed in a glycerine solution and read independently by two readers under reflected light with a dissecting scope. Samples that were unreadable or varied in age between readers were discarded. Salmon age was described using the Gilbert and Rich designation (Ambrose 1983) - number of winters from the time the parents spawned to time of capture followed by total winters spent in freshwater before seaward migration.

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 0.1 ft.

RESULTS AND DISCUSSION

The fall chum salmon escapement for the Chandalar River was 59,313 fish, based on adjusted counts between August 9 and September 27, 1986. This estimate is conservative since it does not include fish passing out of sonar range or fish present after the sonar facilities were removed.

Activation of the sonar systems was well timed for monitoring the majority of the fall migration. Only nine fish were counted on the first day of operation but the daily count quickly grew to nearly 200 fish four days later (Table 1). The number of fish increased dramatically on August 23 to 1,818 fish and peaked on August 25-26, with 7,546 fish counted in 48 hours (Figure 4). Fish were still being counted along both shores on September 27, when operations were terminated due to severe freezing conditions, with 141 fish counted by 1200 hours. Approximately 50% of the estimated total number of fish were counted by September 1.

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 distribution of fish relative to the shoreline was quite different between counting stations. Fish oriented along the south bank were closer to the shore with the highest frequency of occurrence in sector 2, about 10 m from shore with a mean depth of 1.4 m. Sector 1 counts were probably less than expected since the south side weir extended into that sector, reducing the available counting distance and area.

Fish traveling along the north bank were detected with the greatest frequency in sector 9, about 28 m from shore with a mean depth of 1.3 m. The location of the counting tower probably affected north bank fish distribution since fish were commonly observed moving away from shore as they approached the tower.

The total count was not equally distributed between the counting units. The north bank total was 38,493 fish or 65% of the total count. Counts from both banks tracked closely at the beginning of the run, but the south bank daily count dropped off more quickly after the run peaked on August 26 (Figure 6).

Diel fish distribution differed between the north and south sides of the river (Figure 7). Along the south shore there was a pronounced increase in the number of fish counted during the hours corresponding to low light conditions (2300-0700 hours). The north bank counts peaked three hours later and remained higher during daylight hours.

The counting tower was of limited use in calibrating the north bank counter and verifying species composition. Periodic rainstorms in the local foothills and mountain regions caused extreme water level fluctuations (Figure 8) and increased turbidity which made fish viewing difficult. The number of fish passing the sonar station was often difficult to estimate because of these conditions and/or tower avoidance. The tower will not be used in subsequent years of the four year study.

Table 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	% Cumulative
8-09	5	4	9	9	0.0
8-10	6	3	9	18	0.0
8-11	-	-	- [a]	18	0.0
8-12	-	35	35[a]	53	0.1
8-13	22	176	198	251	0.5
8-14	14	120	134	385	0.7
8-15	26	124	150	535	1.0
8-16	40	124	164	699	1.2
8-17	120	124	244	943	1.6
8-18	121	121	242	1,185	2.1
8-19	173	71	244	1,429	2.5
8-20	212	238	450	1,879	3.2
8-21	533	294	827	2,706	4.6
8-22	262	510	772	3,478	5.9
8-23	365	1,453	1,818	5,296	9.0
8-24	789	1,021	1,810	7,106	12.0
8-25	1,501	2,305	3,806	10,912	18.5
8-26	1,956	1,784	3,740	14,652	24.8
8-27	1,224	1,600	2,824	17,476	29.5
8-28	890	1,427	2,317	19,793	33.4
8-29	837	2,003	2,840	22,633	38.2
8-30	706	1,761	2,467	25,100	42.4
8-31	616	1,987	2,603	27,703	46.8
9-01	740	1,522	2,262	29,965	50.6
9-02	670	1,638	2,308	32,273	54.5
9-03	900	1,236	2,136	34,409	58.1
9-04	587	1,531	2,118	36,527	61.7
9-05	485	1,961	2,446	38,973	65.8
9-06	737	1,728	2,465	41,438	70.0
9-07	441	1,300	1,741	43,179	73.0
9-08	701	986	1,687	44,866	75.8
9-09	524	1,296	1,820	46,686	78.8
9-10	570	1,694	2,264	48,950	82.7
9-11	561	979	1,540	50,490	85.2
9-12	659	764	1,423	51,913	87.6
9-13	294	891	1,185	53,098	89.6
9-14	361	805	1,166	54,264	91.6
9-15	320	642	962	55,226	93.2
9-16	296	304	600	55,826	94.2
9-17	290	205	495	56,321	95.0
9-18	205	222	427	56,748	95.7
9-19	150	134	284	57,032	96.2
9-20	159	143	302	57,334	96.7
9-21	126	219	345	57,679	97.3
9-22	115	228	343	58,022	97.9
9-23	127	281	408	58,430	98.6
9-24	154	167	321	58,751	99.1
9-25	65	143	208	58,959	99.5
9-26	79	134	213	59,172	99.8
9-27	86	55	141[b]	59,313	100.0
Totals	20,820	38,493	59,313		

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

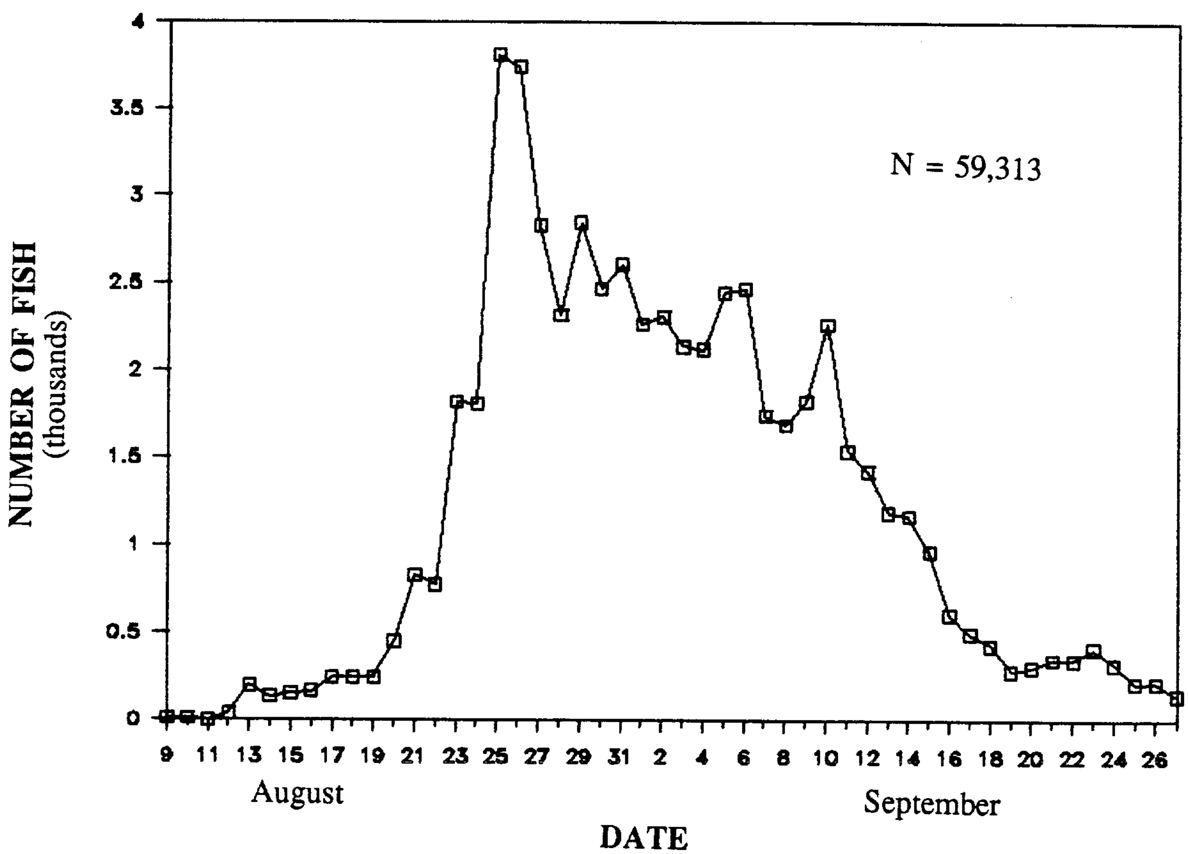

Figure 4. Chandalar River fall chum salmon run timing, based on daily sonar counts, 1986.

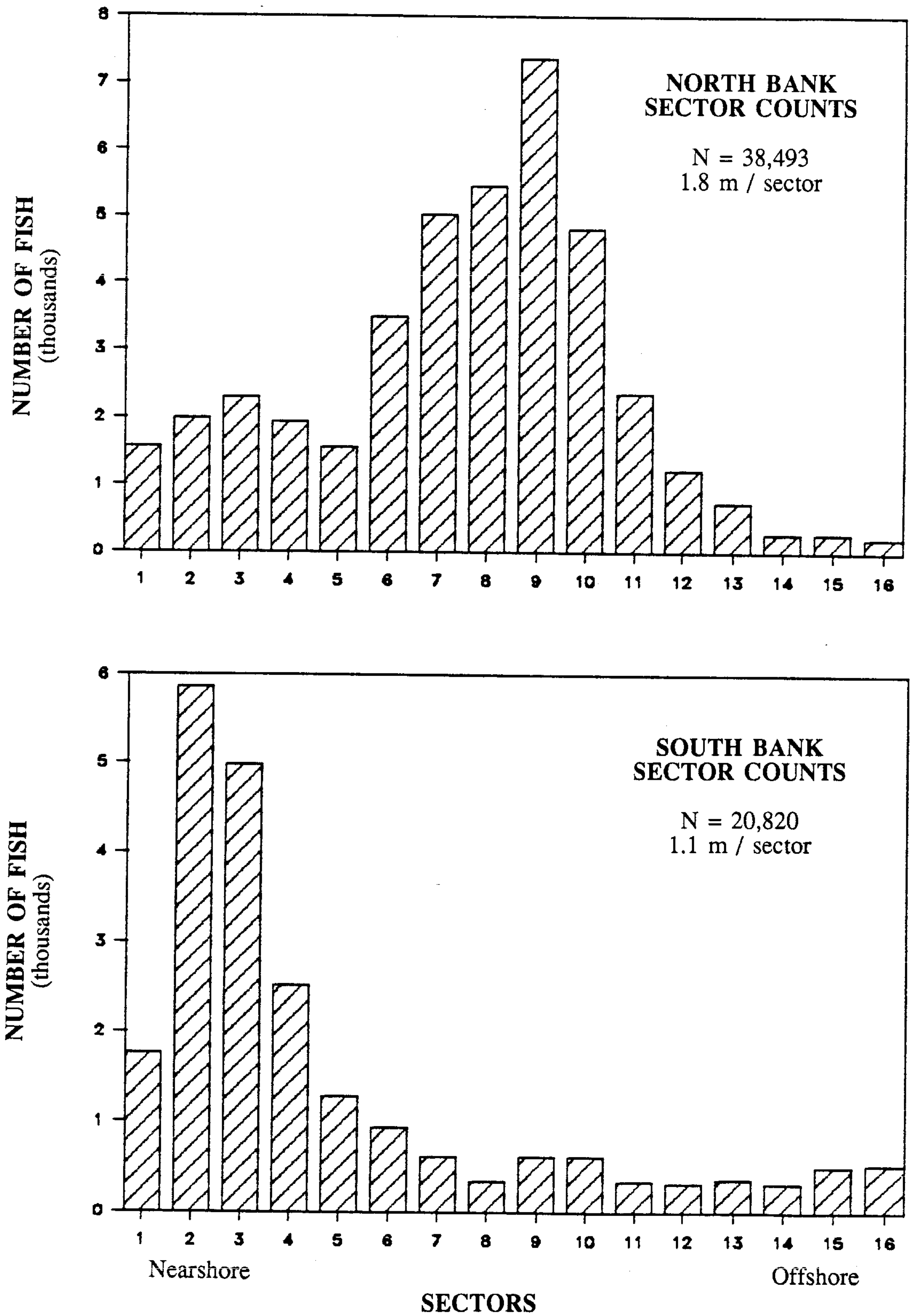

Figure 5. Total sector counts of Chandalar River fall chum salmon from the north and south bank sonar stations, August 9 - September 27, 1986.

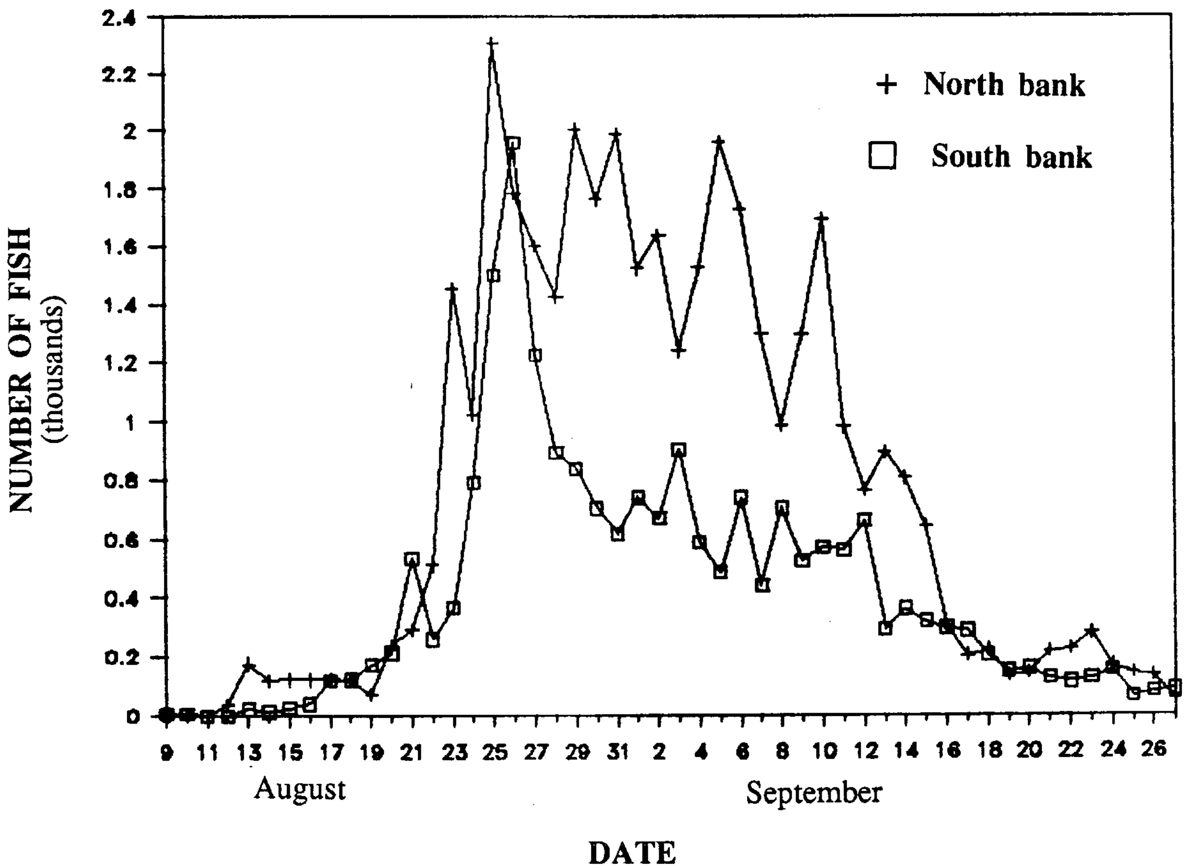

Figure 6. Distribution of Chandalar River fall chum salmon between the north and south banks, based on daily sonar counts, 1986.

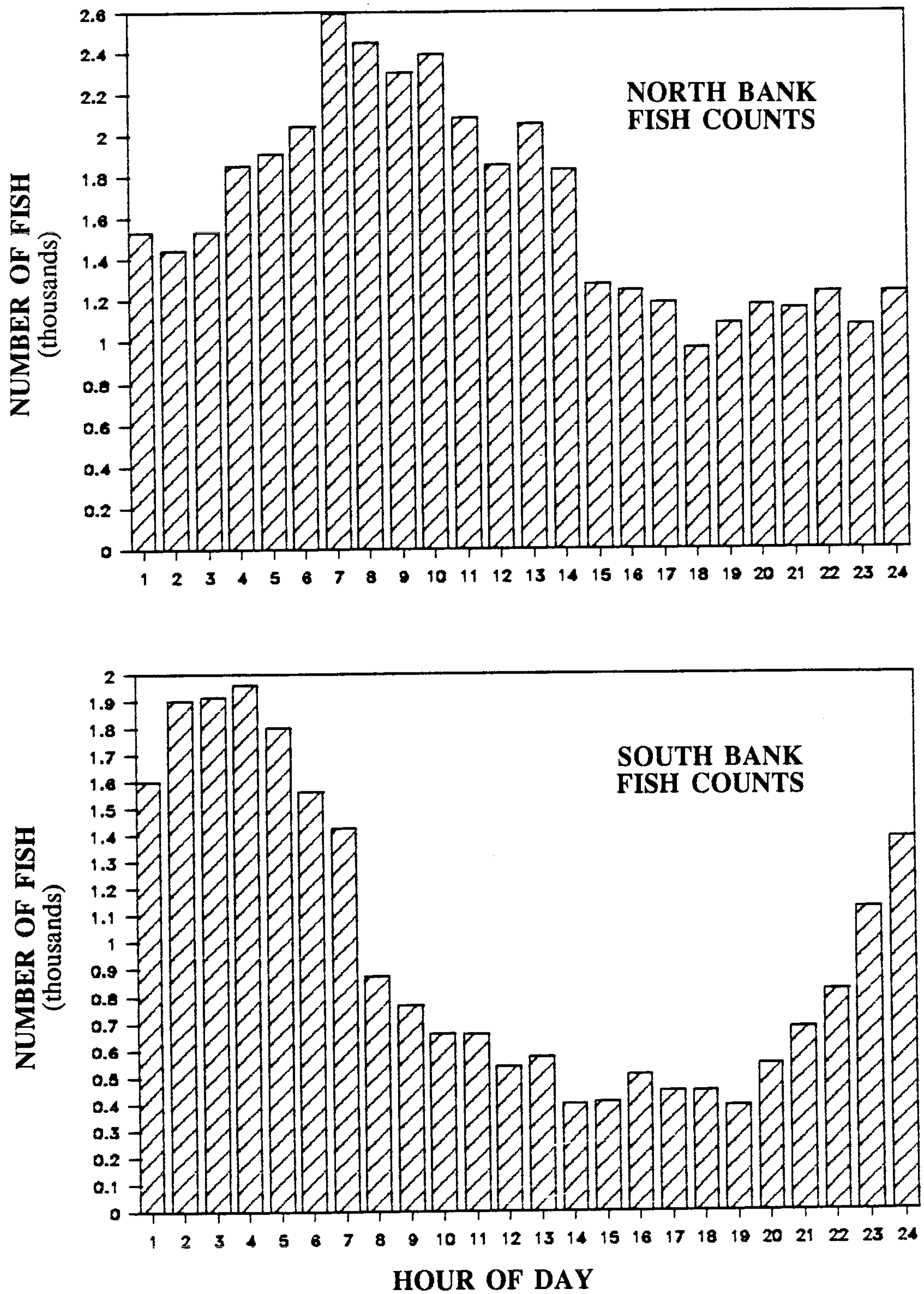

Figure 7. Distribution of total counts of Chandalar River fall chum salmon by time of day, August 9 - September 27, 1986.

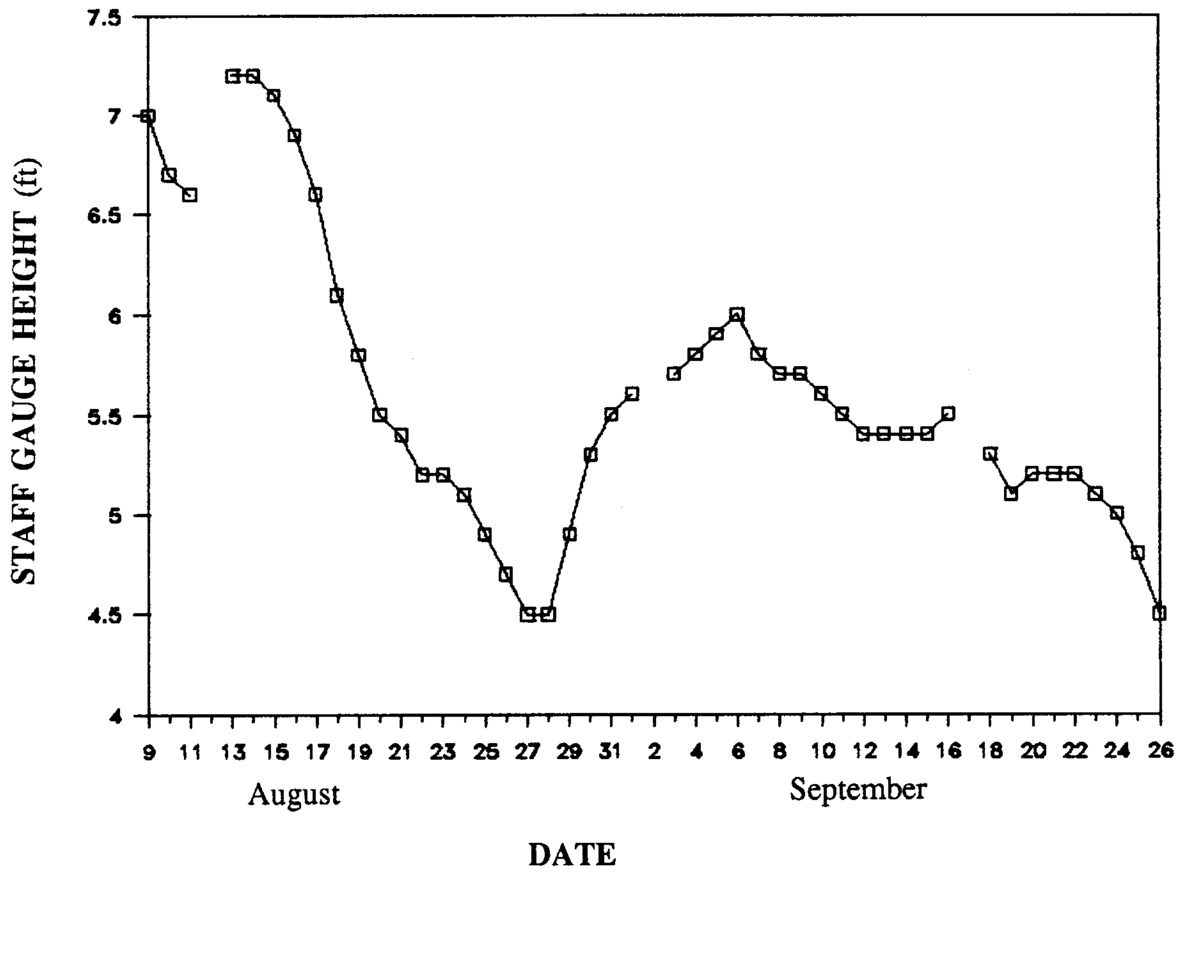

Figure 8. Daily water levels on the Chandalar River, August 9 - September 27, 1986.

During 55 hours of effort, gill nets set in the main channel of the river near the sonar stations caught 33 chum salmon (0.6 fish/hour) and 2 humpback whitefish *Coregonus pidschian*. High water velocity in the main channel caused the nets to angle downstream, reducing gear efficiency. Since 94% of the gill net captures were chum salmon, additional sonar counts caused by other fish species were considered insignificant.

Gill nets set in a slough and a deep channel eddy immediately downstream from the site (Figure 2) caught 151 chum salmon in 24 hours total effort (6.25 fish/hour). No other fish species were captured. The higher catch rates were probably due to increased gear efficiency and a higher density of fish in calmer water. None of the female chum salmon captured and sacrificed for genetic stock identification (48 fish) were in a ripened condition.

Male chum salmon had slightly higher mean length and weight than females (Table 2), but these differences were not significant ($P > 0.05$). Males made up 68% of the total sample.

Table 2. Length and weight data collected from 150 chum salmon in the Chandalar River, September 3-5, 1986.

		Length (mm)		Weight (kg)	
		Mean	SD	Mean	SD
Males	(N=102)	624.67	34.88	3.77	0.77
Females	(N=48)	614.77	23.74	3.25	0.48
Total	(N=150)	621.51	32.00	3.60	0.69

Of the 150 chum salmon otoliths collected, 75 (50%) were discarded because of unreadability or discrepancies between readings. Age 4_1 fish predominated (65%), followed by age 5_1 (35%). Barton (1986) found 37% of sampled scales unreadable from Sheenjek River fall chum salmon. In most years, age 4_1 fish typically dominate the age composition of Sheenjek River stocks. However, 1986 age composition consisted of 8% age 3_1, 41% age 4_1, 50% age 5_1, and less than 1% age 6_1 (L.H. Barton, Alaska Department of Fish and Game, Fairbanks, personal communication). Vertebrae will be collected for age determination in subsequent years of the study since otoliths are unreliable indicators of age in Chandalar river fall chum salmon.

Based on the fall chum salmon counts obtained from our 1986 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" each year the river has been surveyed.

CONCLUSIONS

Side-scanning sonar proved to be an effective method for enumerating fall chum salmon escapement in the Chandalar River. The site met all site selection criteria, counts of other fish species were minimal, water velocity and depth prevented fish milling behavior, and most fish passed within the sonar's counting range. 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.

The fall chum salmon escapement estimate of 59,313 was significantly higher than would have been predicted from previous aerial survey estimates. This escapement level likely represents an average return for this system, since escapement levels in the Sheenjek River, a nearby drainage, were considered average in 1986.

ACKNOWLEDGEMENTS

Special thanks are extended to the many people that participated in this project and who are largely responsible for its success: Suzanne Anderson, Ken Troyer, Derek Sundquist, Tony Booth, Barbara Hicks, Dean Cramer, and Dick Marshall for their help in establishing and running the station; Alan Menin for on-site sonar component modifications; Harvey Heffernan for creating the report's computer graphics; and the entire office staff for expediting supply orders and editing this report.

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