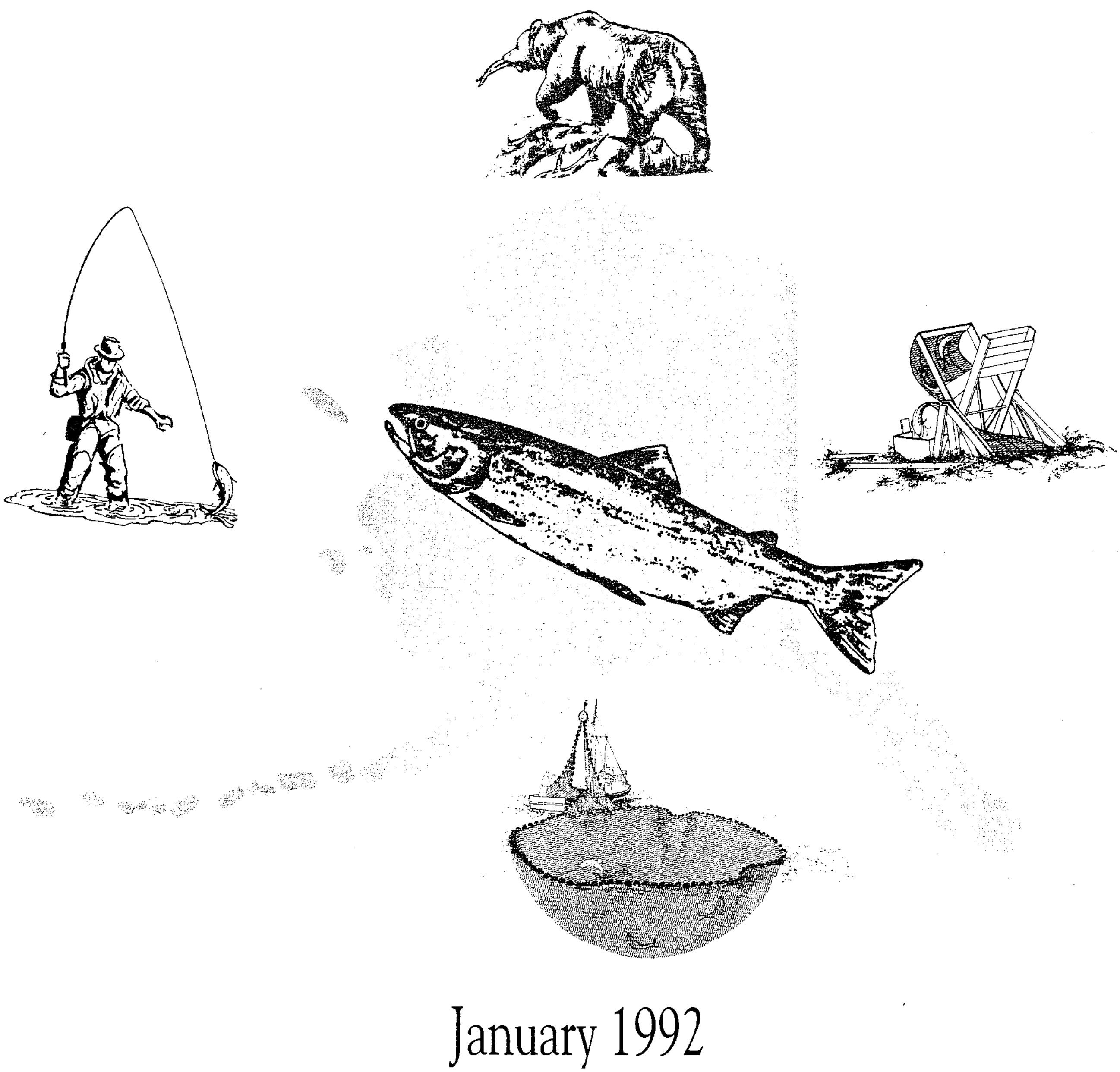
SONAR ENUMERATION OF FALL CHUM SALMON ON THE CHANDALAR RIVER, 1990

Alaska Fisheries Progress Report Number 92-1



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

Alaska Fisheries Progress Report

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ABSTRACT

From August 10 to September 27, 1990, two Bendix side-scanning sonar fish counters were used to enumerate fall chum salmon *Oncorhynchus keta* escapement into the Chandalar River, a tributary of the Yukon River. Sonar stations were set up across river from one another with the sonar beams aimed approximately perpendicular to the shoreline. A seasonal total of 78,631 chum salmon was counted, compared to 59,313 in 1986, 52,416 in 1987, 33,619 in 1988, and 69,161 in 1989. 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. The median passage date was September 10, 7 days later than in 1989. 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; females comprised 67% of the sample compared to 52% in 1989. Age 0.3 fish predominated in the 1990 sample (56%), as they have in three of the four previous years.

A helicopter survey of fall chum salmon spawning grounds was conducted on September 25, 1990, with an estimated count of 11,890 fish (10,736 live and 1,154 carcasses). The helicopter survey documented a much smaller proportion of the run (expansion factor of 6.17) than in 1989 (expansion factor of 2.70) under comparable survey conditions. 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 *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 of selected key index streams. These surveys are flown during peak spawning periods and estimate instantaneous escapement; not total escapement. From 1953 to 1959, the U.S. Fish and Wildlife Service (Service) conducted salmon escapement surveys on selected lower Yukon River tributaries (Barton 1984a). Since 1959, the Alaska Department of Fish and Game (Department) has had primary responsibility for collection of escapement data. In 1985, the Joint U.S./Canada Yukon River Technical Committee (JTC) identified the need for a side-scan sonar study to estimate the total escapement of fall chum salmon in the Chandalar River.

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

Two species of Pacific salmon migrate up the Chandalar River with chum salmon being the most abundant, followed by chinook salmon. The Yukon River is the only North American drainage having two 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), 33,619 in 1988 (Daum et al. 1991), and 69,161 in 1989 (Daum 1991). This progress report compares the 1990 Chandalar River sonar data with information from the 1986-1989 seasons. Genetic sampling has been completed and results will be presented in a future report by the Service's Alaska Fish and Wildlife Research Center.

STUDY AREA

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

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

MATERIALS AND METHODS

Fall chum salmon were counted with two 1981 Bendix side-scan sonar fish counters. Both counting systems were operational from August 10 through September 27, 1990. North and south bank transducers were deployed in the same locations used in the previous four 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 (30 m). Counting ranges on the north and south banks averaged 28.0 and 18.9 m, respectively (Figure 3). Each counting range was subdivided into 16 sectors.

The sonar counters were deployed and operated according to the guidelines described by Bendix Corporation (1981). Because of the relatively flat river bottom, the modular substrate normally used with this system was not deployed. Instead, the transducers were mounted on plastic frames and secured with sandbags at a depth of 0.6-1.5 m (design adapted from Barton 1986). Transducers were oriented perpendicular to shore and aiming was fine-tuned with three handwheels on the back of the transducer bracket. A wire fence weir (5 x 10 cm mesh) was installed 1 m downstream and extended 2 m beyond the transducer to keep salmon from passing 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 transducer was aimed low enough so that salmon 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 sectors of the counting range. When the container transected the sonar beam it registered as a valid count on the counter and simultaneously appeared as a sharp "spike" on the oscilloscope (Tektronix 323).

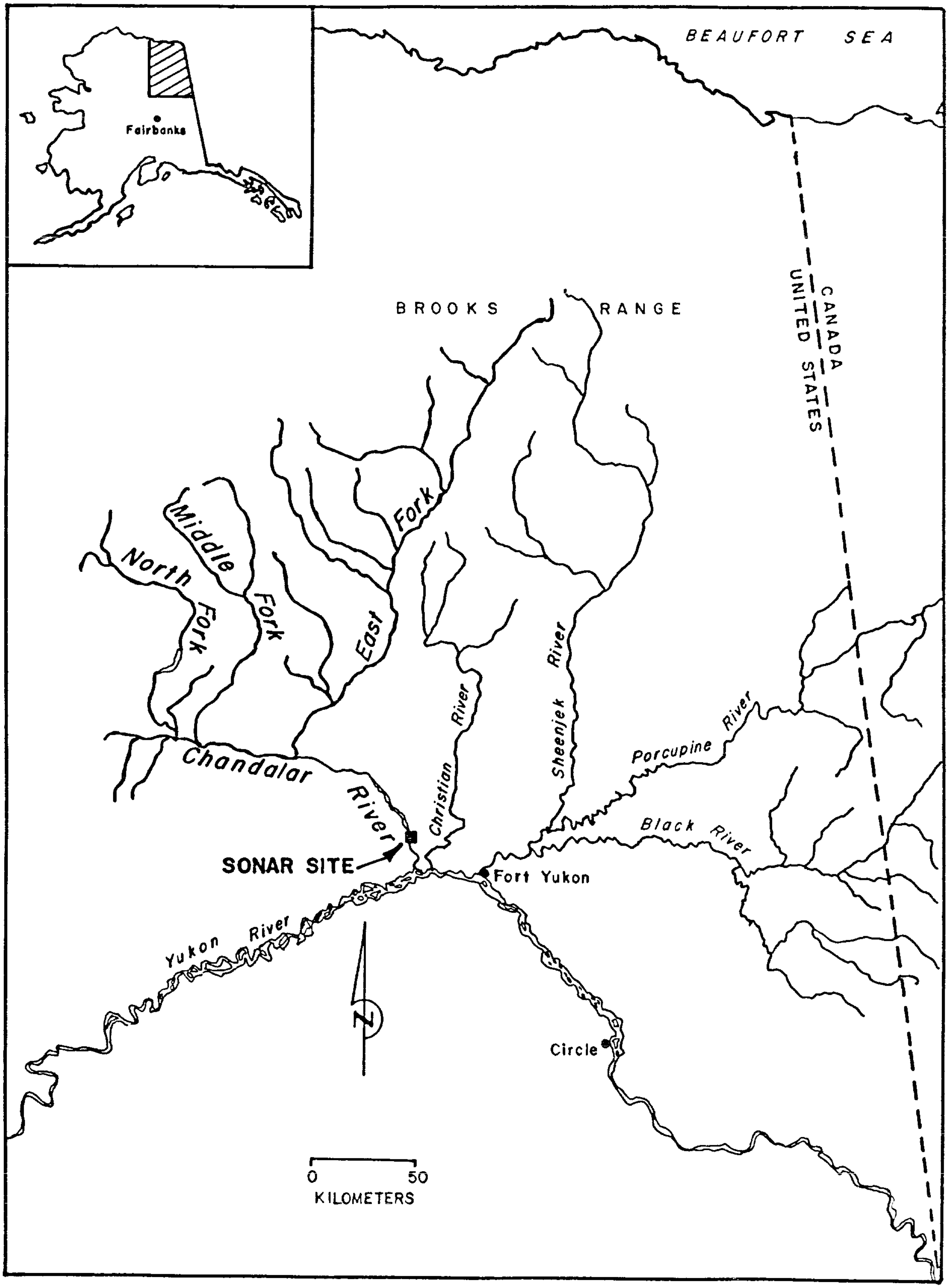

Figure 1. Major tributaries of the Yukon River near the U.S./Canada border.

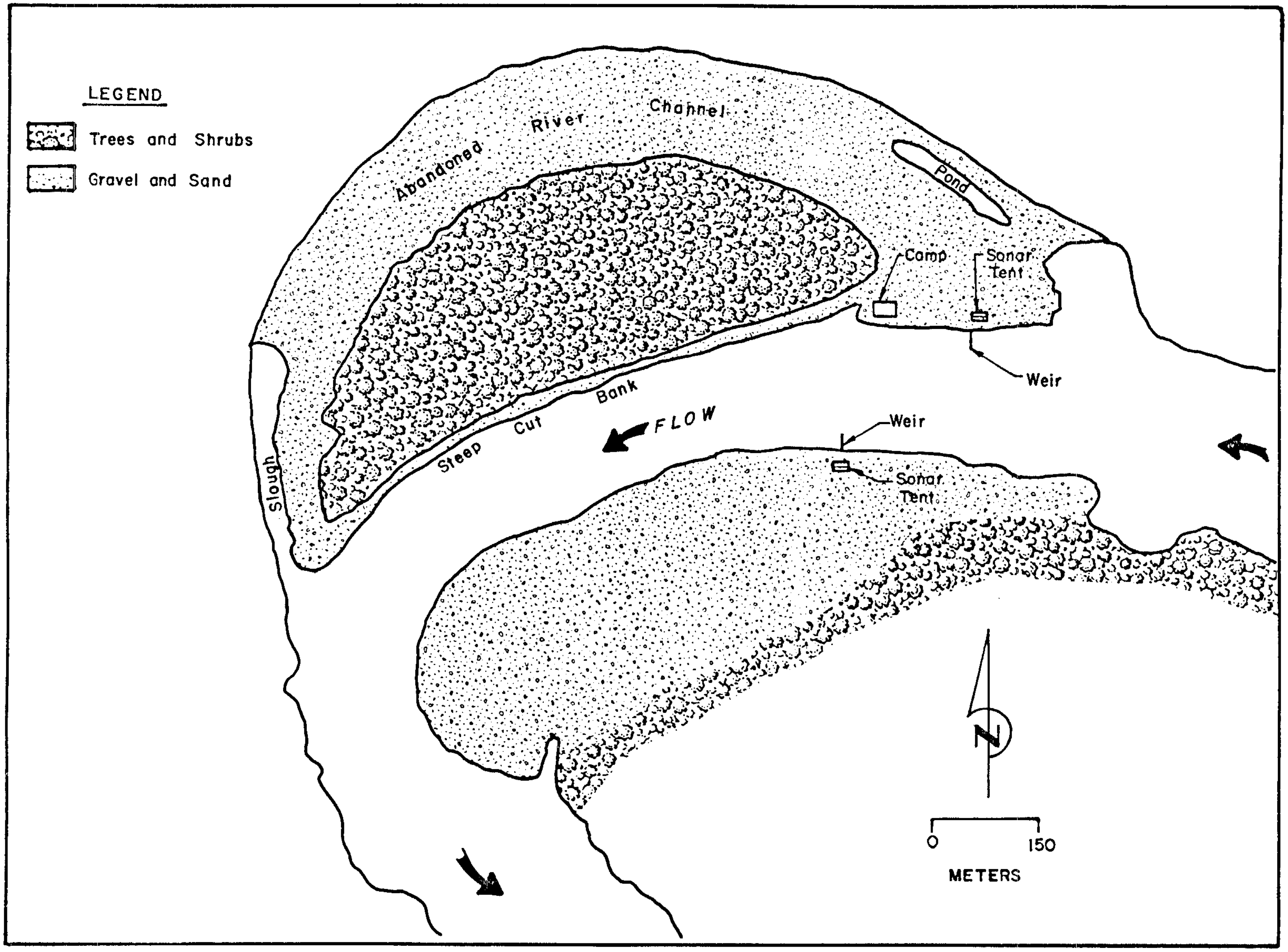

Figure 2. Site map of the Chandalar River sonar facilities.

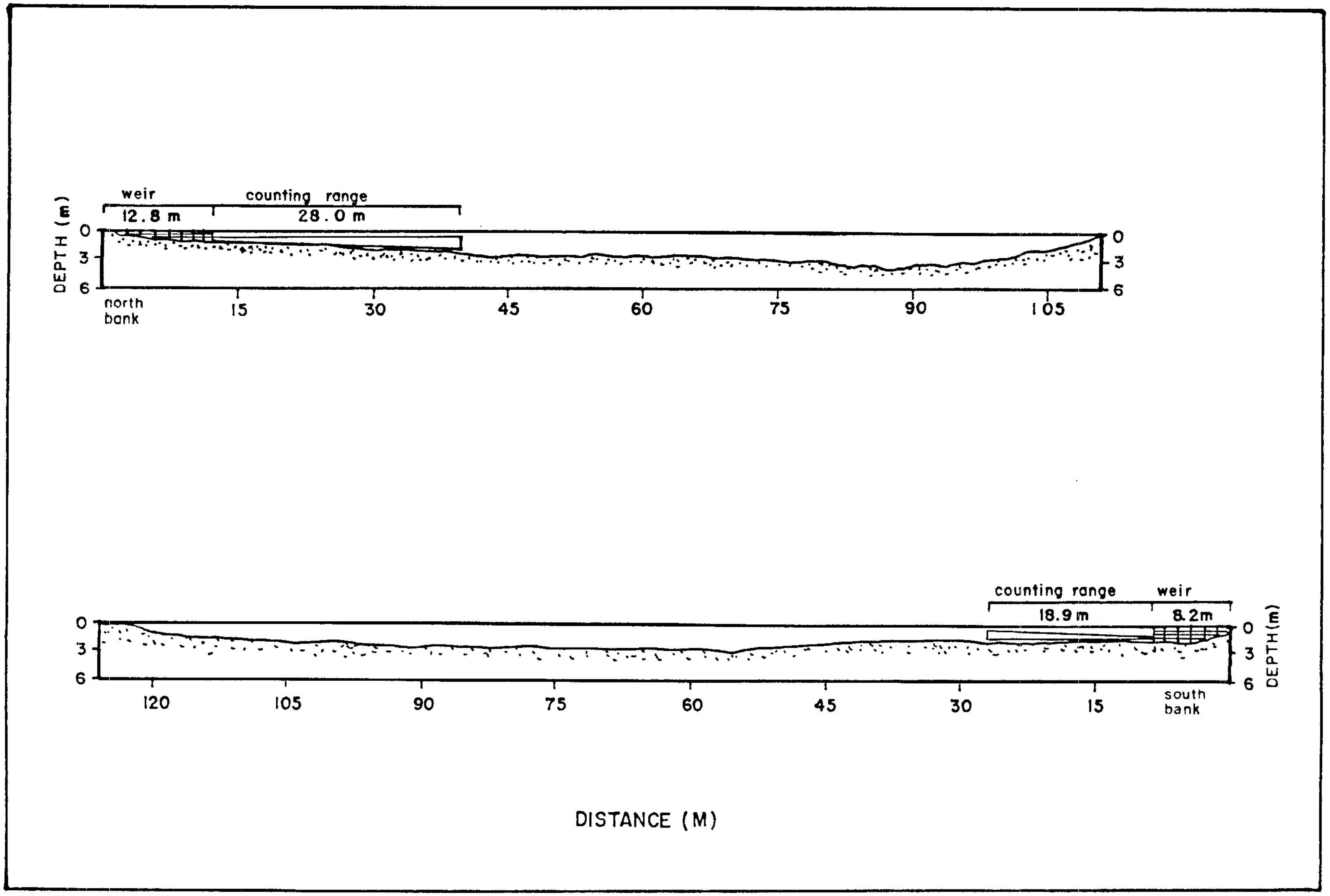

Figure 3. River channel profiles of the north and south bank sonar facilities. Weir lengths and counting ranges are approximations that change according to river discharge levels.

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 determine if the number of fish registered by the sonar counter equaled the number of fish passing through the sonar beam, comparisons were made between oscilloscope observations and counter output once every four hours for 30-minute "calibration" periods. When a fish passed through the beam, a returning echo was displayed on the oscilloscope and a corresponding count should have registered on the sonar counter. Adjustments to the fish velocity control (counter pulse rate) were made when the oscilloscope count exceeded 14 fish and the sonar count differed from the oscilloscope count by more than 15% during the 30-minute calibration. The new fish velocity control setting was calculated as follows:

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

Daily fish counts were adjusted using data from the six 30-minute calibration periods. 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.

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 reported data are 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, established in 1989, was used again in 1990 so water levels could be compared 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 with 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 25, 1990, sex and age composition data were collected from 154 chum salmon carcasses found on a spawning ground 8 km above Venetie Village. This was one of two spawning grounds sampled in 1989. Access to the sample site was by helicopter. Carcasses were collected at various depths (shoreline to 1.5 m deep) with a 2 m long spear. Chi-square analysis ($P = 0.05$) with the Yates correction for continuity (Zar 1984) was used to test for significant differences in sex ratios and age composition between the 1990 carcass sample and a 1990 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 sex ratios between the 1989 and 1990 Chandalar River carcass samples.

Vertebrae from the carcass collection (three per fish) were used for age determination. Vertebrae were cleaned, dried, and independently read twice by the author under direct light with a dissecting scope. Disagreements between readings were resolved with a third reading. Unreadable samples were discarded. Ages were reported by the European method (Foerster 1968) - number of freshwater annuli followed by number of saltwater annuli.

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 25, 1990 with a Hughes 500-D helicopter (90 m above ground level), from 10 km upstream of the sonar site to 21 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. 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 many braided parts of the river were surveyed, requiring repeated passes up and down river for coverage of all channels and sloughs. 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 salmon escapement count for the Chandalar River in 1990 was 78,631 fish, the highest estimate since the sonar operation started in 1986. The average yearly escapement prior to 1990 was 53,627 fish (SD = 15,005). 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.

Daily counts during 1990 were over 1,000 fish per day for 35 of the 49 counting days (Appendix 1). Operations terminated on September 27 with 954 fish counted. The highest daily count was 4,106 fish, recorded on September 15. Fifty percent of the estimated run (median passage) passed the site by September 10. The median passage date was 2-9 days later than in the four previous years.

The 1990 escapement curve showed a strong bimodal distribution, unlike escapement curves from previous years (Figure 4). The modes were August 23 and September 15, 23 days apart. The absence of a peak in early September contrasted with three of the four previous years, 1987-1989.

Peak run timing was similar between banks (Figure 5, Appendix 1), but the total count was not equally distributed between counting units. The south bank count was 24,635 or 31% of the total, compared to 35% in 1986, 69% in 1987, 61% in 1988, and 53% in 1989. 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 low relative to nearshore counts indicating that the majority of fish were detected (Figure 6). The first 11 of the 16 sectors accounted for 96% of the fish passing the south bank sonar and 95% of north bank fish. The majority of south bank fish were oriented close to shore with the highest frequency of occurrence in sector 3. North bank fish were concentrated in the middle of the counting range with the highest frequency in sector 9.

Water levels were relatively constant with gauge heights ranging from 1.4 to 2.0 m (Figure 7). Compared to 1989, water levels were less variable and river gauge readings averaged 0.2 m less. According to camp personnel, the 1987 and 1988 water levels were higher than 1989 (Daum 1991). Minimum and maximum water levels in 1990 differed by 0.6 m, compared to 0.9 m in 1986, 1.3 m in 1987, 2.3 m in 1988, and 1.3 m in 1989.

Daily water level (X) was positively correlated ($r = 0.56$; $P < 0.001$) with the percentage of fish using the south bank (Y). The regression equation was $Y = -44.8 + 46.0\ X$. As water level increases from 1.4 to 2.0 m, the predicted percentage of fish using the south bank increases from 20 to 47%, demonstrating a shift in bank preference as water level increases.

Adjustments to the counter's fish velocity control were needed for 26% of the calibration periods on the north bank and 6% on the south bank. The greater adjustment rate for the north bank sonar counter, also documented in 1987 (22% north, 9% south) and 1988 (21% north, 11% south), indicates greater variability in fish swimming speeds by that site. However, fish swimming speeds were not notably more variable at the north bank site in 1989 (21% north, 20% south).

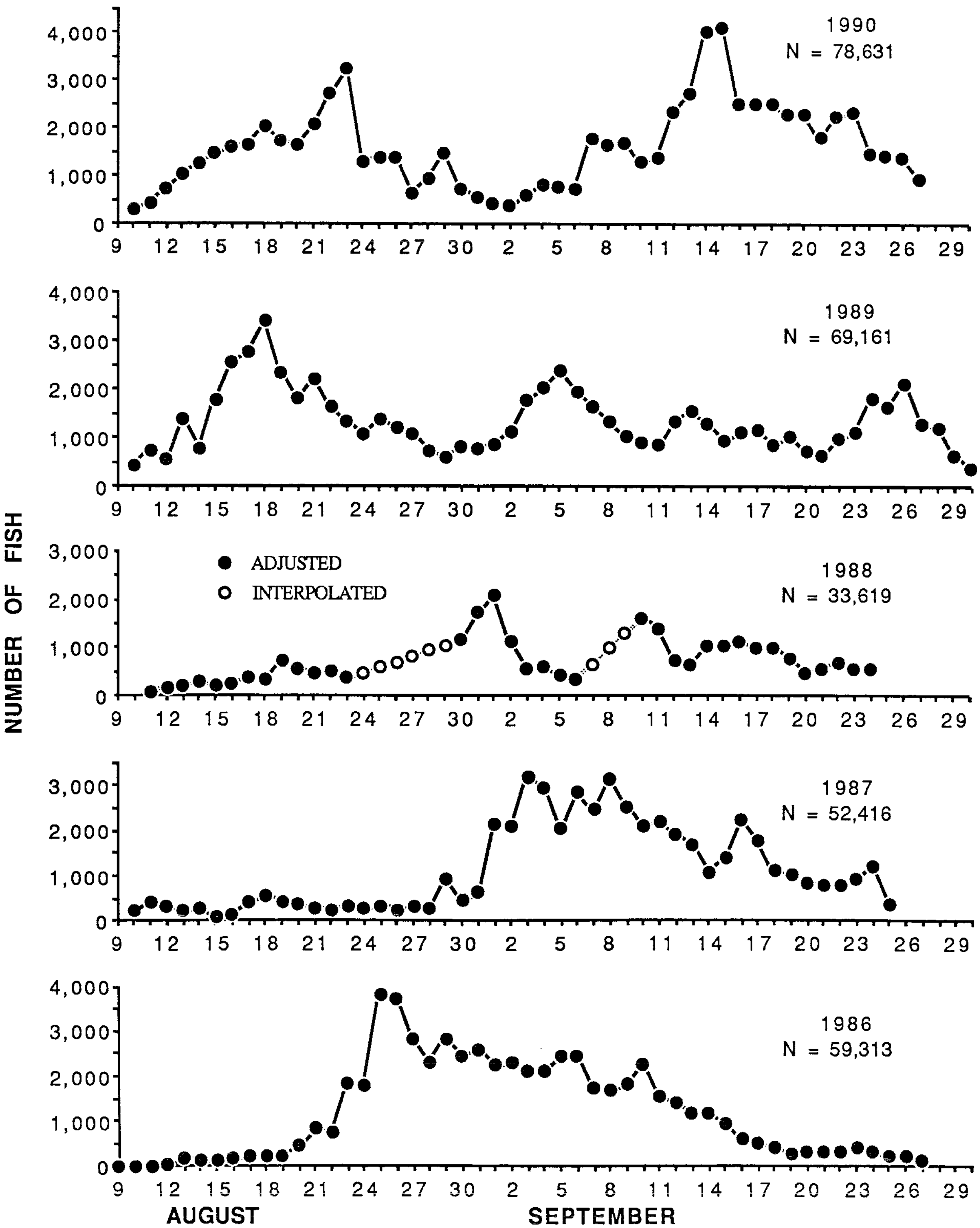

Figure 4. Chandalar River fall chum salmon run timing, based on daily sonar counts, 1986-1990.

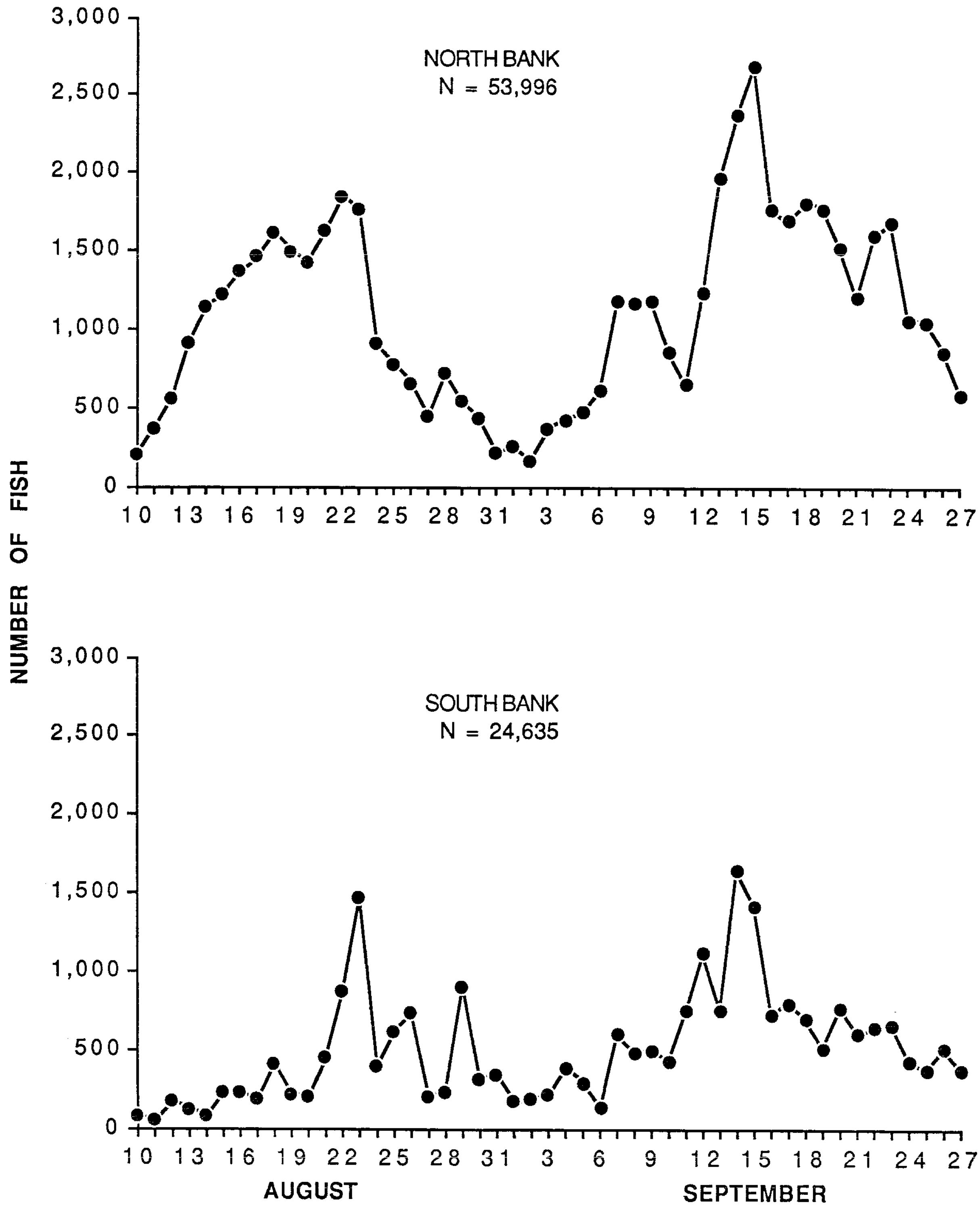

Figure 5. Distribution of Chandalar River fall chum salmon between the north and south banks, based on daily sonar counts, August 10-September 27, 1990.

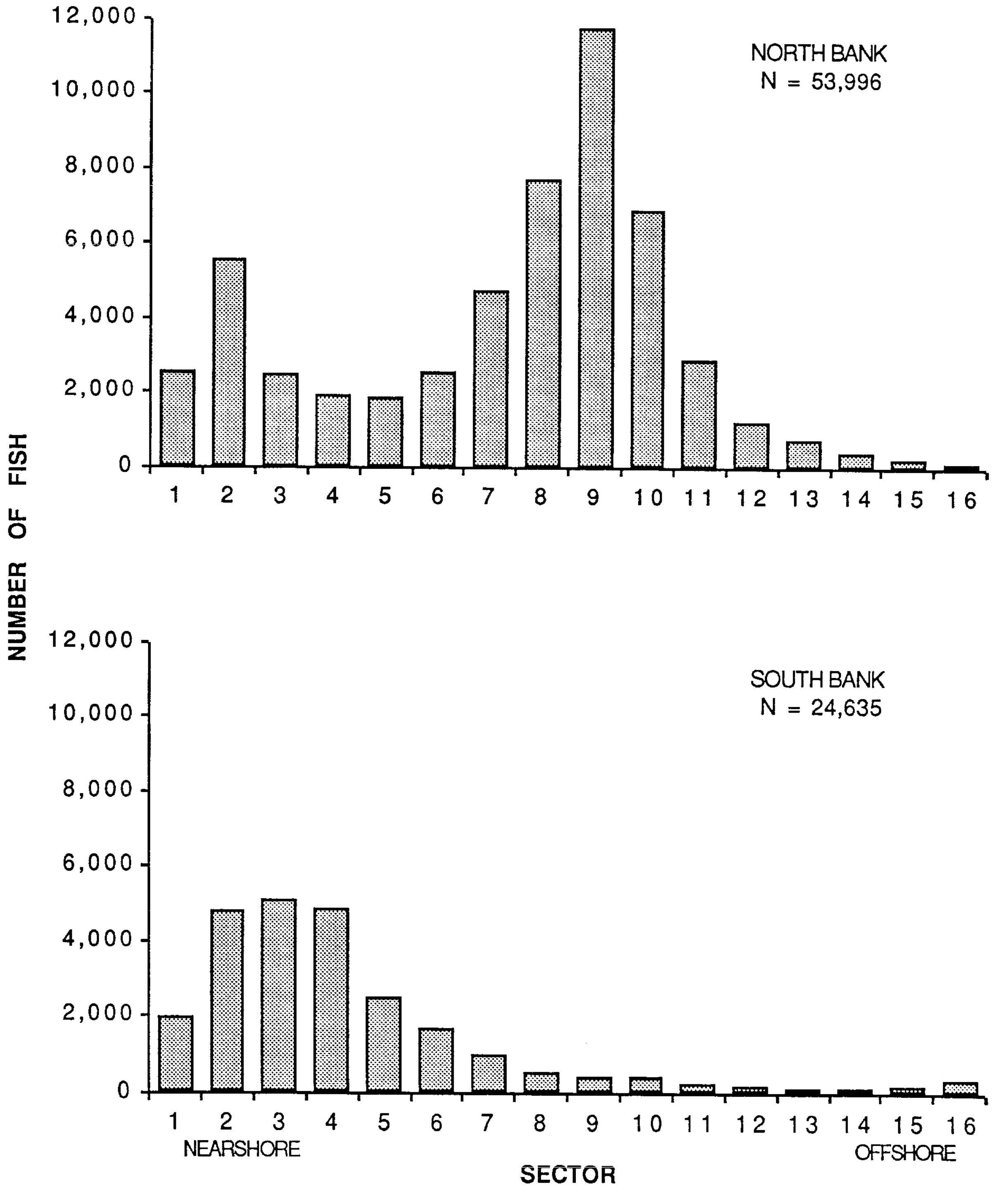

Figure 6. Total sector counts of Chandalar River fall chum salmon from the north and south bank sonar stations, August 10-September 27, 1990.

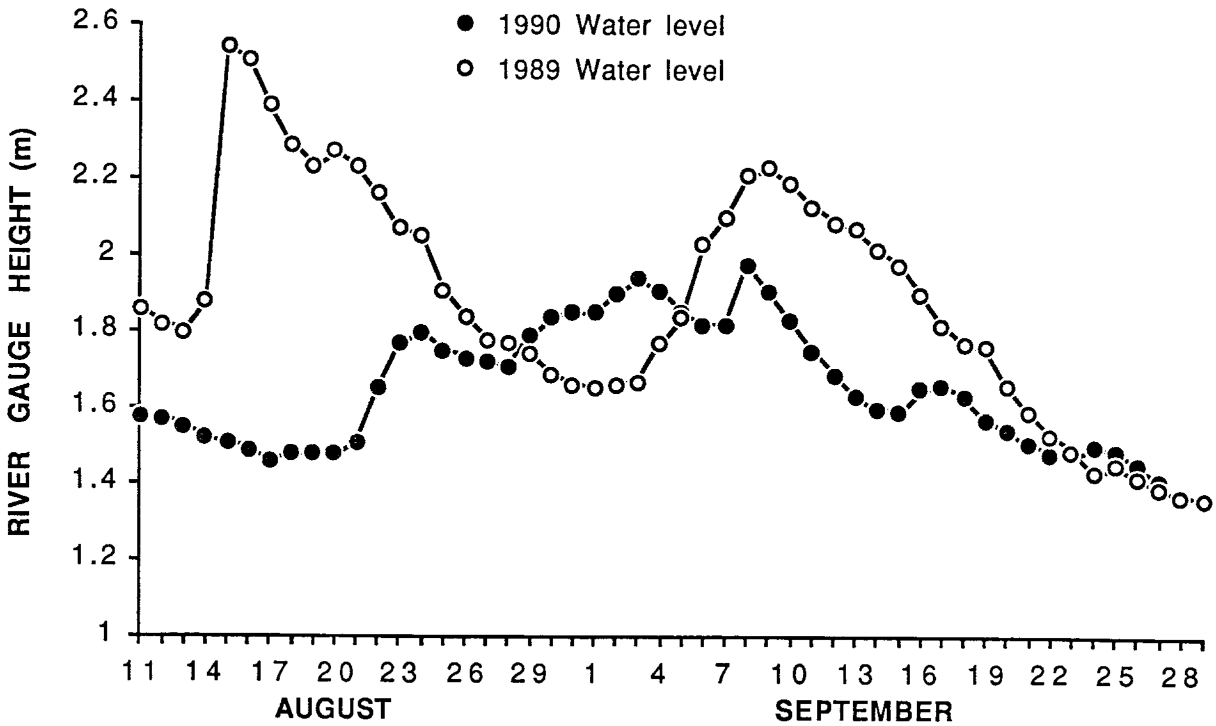

Figure 7. Daily water levels in the Chandalar River, August 11-September 29, 1989 and August 11-September 27, 1990.

Age 0.3 (56.2%) predominated the fall chum salmon carcass sample, followed by age 0.4 (39.2%), age 0.5 (3.9%), and age 0.2 (0.7%; Table 1). Vertebrae were unreadable for one fish from the original sample of 154. The sex composition of the 1990 carcass collection (66.9% females) was significantly different ($P < 0.01$) from the 1989 carcass sample (51.7% females, N = 149).

The sex ratio of mainstem Yukon River fall chum salmon at the Department's Ruby fish wheel project (51% females, N = 145) differed significantly from the Chandalar River 1990 carcass sample ($P < 0.01$; Table 2). Age 0.3 fish predominated in both samples, although the samples differed significantly in age composition ($P < 0.001$).

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 25, 1990, with an estimated count of 11,890 fish (10,736 live and 1,154 carcasses; Appendix 2). The survey was rated "good" overall, based on water visibility and lighting conditions. A large portion of the total count (43%) was found between 9 km above Venetie and the East Fork confluence.

The 1990 helicopter survey documented a much smaller proportion of the run than the 1989 survey. The 1989 aerial count of 20,232 fish was multiplied by an expansion factor of 2.70 to approximate the total sonar count of 54,665 two days prior to the survey[1] (Daum 1991). Even with similar survey conditions in 1990, only 11,890 of 73,416 fish (total passing the sonar site by September 23) were counted, for an expansion factor of 6.17. Both 1989 and 1990 surveys were timed about two weeks after median passage, but the proportion of carcasses was greater in 1990 (10%) than in 1989 (6%). In both years, more fish and a higher percentage of carcasses were found above Venetie than below Venetie. However, the disparity in expansion factors between years indicates that aerial surveys may not be reliable predictors of total escapement in the Chandalar River.

The difficulties in obtaining aerial counts which reliably estimate yearly fall chum salmon escapement on the Chandalar River include (1) the numerous sloughs and tributary streams and 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. Based on the 1989 helicopter survey, the Department identified several spawning areas which might provide consistent indices of total escapement. However, a markedly

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[1]Two days was considered a conservative estimate of time required for chum salmon to move from the sonar site 10 km upriver, where the aerial survey began.

Table 1. Age composition by sex of chum salmon in a carcass sample from the Chandalar River, 1990.

Sex	N	Age (% in parentheses)			
		0.2	0.3	0.4	0.5
Female	102[a]	0 (0)	60 (58.8)	37 (36.3)	5 (4.9)
Male	51	1 (2.0)	26 (51.0)	23 (45.0)	1 (2.0)
Both sexes	153	1 (0.7)	86 (56.2)	60 (39.2)	6 (3.9)

[a]Total sample was 103 females; vertebrae from one female were unreadable.

Table 2. Sex and age data collected from fall chum salmon samples in the Chandalar River and upper Yukon River test fishing project, 1990.

Location	Sex Composition (%)			Age Composition (%)				
	N	Male	Female	N	0.2	0.3	0.4	0.5
Chandalar River[a]	154	33.1	66.9	153	0.7	56.2	39.2	3.9
Upper Yukon River[b]	145	49.0	51.0	176	2.3	76.6	20.5	0.6

[a]Carcass collection at spawning grounds.
[b]Sample from fish wheels on north bank Yukon River; Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks, preliminary information.

smaller proportion of the run was counted in each of the potential index areas in 1990 (L. Barton, Alaska Department of Fish and Game, Fairbanks, personal communication).

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. Other ground survey methods (weirs, towers, boats, etc.), although less costly, would probably 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 five years of this operation.

The fall chum salmon escapement estimate of 78,631 was the highest count since the sonar operation started in 1986. Two years of helicopter survey data indicate that aerial counts, even under good survey conditions, may not be reliable indices of total escapement.

ACKNOWLEDGEMENTS

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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 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.

Bendix Corporation. 1981. Installation and operation manual, side-scan sonar counter. Electrodynamics Division, Division Report FISH-81-010, North Hollywood, California, prepared for the state of Alaska Department of Fish and Game, Anchorage, 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. 1991. Sonar enumeration of fall chum salmon on the Chandalar River, 1989. U.S. Fish and Wildlife Service, Fishery Assistance Office, Alaska Fisheries Progress Report, Fairbanks, Alaska.

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.

Daum, D.W., R.C. Simmons, and K.D. Troyer. 1991. Sonar enumeration of fall chum salmon in the Chandalar River, 1988. U.S. Fish and Wildlife Service, Fishery Assistance Office, Alaska Fisheries 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, Alaska Fisheries 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.

Zar, J.H. 1984. Biostatistical analysis, second edition. Prentice and Hall, Englewood Cliffs, N.J.

Appendix 1. Chandalar River daily adjusted chum salmon counts from north and south bank sonar stations, August 10-September 27, 1990.

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

Appendix 2. Helicopter aerial survey counts of Chandalar River fall chum salmon, September 25, 1990.

Survey area	Number of chum salmon observed	
	Live	Dead
10 km upstream of sonar camp to Venetie	3,245	33
Venetie to 8 km upstream	883	100
8 to 9 km above Venetie, including south channel outside floodplain	2,239	225
9 km above Venetie to East Fork confluence	4,339	795
East Fork confluence to 3 km up mainstem	30	1
East Fork confluence to 21 km up East Fork	0	0
Total	10,736	1,154

Note: Good water visibility and fair lighting conditions below Venetie. Good water visibility and good lighting conditions above Venetie.