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1994 YUKON RIVER BORDER SONAR PROGRESS REPORT

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ABSTRACT

Side-looking scientific fisheries split beam hydroacoustic equipment was deployed in the Yukon River near Eagle, Alaska from 1 September through 22 September 1994 to collect target strength and three-axis position data on standard calibration spheres and on migrating chum salmon. *In situ* target strength estimates of standard targets were larger than predicted theoretical values. Uncertainty in up/down phase angle determination was greater than documented for right/left phase angle determination in standard target data.

Key Words: chum salmon, split beam, fisheries hydroacoustics, Yukon River

INTRODUCTION

The Yukon River flows 3,700 km (2,300 mi.) from its headwaters in Canada's Yukon Territory to Norton Sound on the Bering Sea Coast of Alaska. Chinook salmon (*Oncorhynchus tshawytscha*) and chum salmon (*O. keta*) travel through various fisheries as they migrate up the Yukon River toward their spawning grounds, some of which are in Canada. Alaskan fisheries are managed by the Alaska Department of Fish and Game (ADF&G) while Canadian fisheries are managed by the Canada Department of Fisheries (CDFO). Fisheries managers in Alaska and Canada have long been interested in the number of salmon that cross the border, and past research activities to evaluate border passage have been based on relative fishwheel capture rates, tag/recovery data, and aerial surveys of spawning streams. However, because of the variability inherent to these assessment techniques, the U.S./Canada Yukon River Joint Technical Committee (JTC) has identified the need for more accurate, timely data on the number of salmon passing the U.S./Canada border.

In response to the need for more accurate abundance estimates, the JTC appointed a Sonar Planning Subcommittee (SPS) to develop a plan for investigating the feasibility of using sonar to estimate the number of Yukon River salmon entering Canada. The SPS was comprised of representatives from ADF&G, U.S. Fish and Wildlife Service (USFWS) and CDFO. In 1991, SPS members agreed to a four year project plan and USFWS staff attended a formal week-long hydroacoustic workshop. Split-beam hydroacoustic equipment was purchased, potential sonar sites were surveyed, and the land status of the potential sites was determined. In 1992 and 1993, split-beam sonar equipment was successfully deployed, calibration data were acquired, and baseline data were collected on free-swimming fish for two weeks each during the chinook and chum salmon migrations in July and September, respectively, for use in evaluating the performance of the sonar hardware and software (Huttunen and Skvorc, 1996). In addition, gillnet samples of migrating and resident fish were collected in the vicinity of the sonar project location. Project operations in 1994 were limited to three weeks in September. Split beam sonar equipment was deployed only on the right bank to test the feasibility of ensonifying the complex right bank river bottom, collect acoustic data on calibration spheres and free swimming fish, and to perform beam mapping experiments. No test fishing was conducted in 1994.

This report summarizes the results achieved during the 1994 field season. Fourth year (third field season) objectives specified in the 1994 Yukon River Border Sonar Project Operational Plan were:

1) Collect acoustic data on fish abundance on the right bank at the existing sonar site 24 hours per day during the fall chum salmon migration, from approximately 26 August through 23 September.
2) Archive all raw data following established data management protocol.
3) Optimize sonar beam coverage of the right bank at the existing site given a two-transducer deployment.
4) Conduct in situ split-beam sonar calibrations following procedures established in 1992 and 1993.
5) Identify fish species present in the study area during periods of specific interest (determined

inseason).

6) Acquire additional acoustic and non-acoustic data to describe the spatial distribution of fish present during the period of sonar operations.
7) Acquire additional acoustic target strength and non-acoustic fish length data for developing acoustically-based procedures to estimate the size class distribution of fish present in the study area.
8) Measure detected noise levels on both banks in order to determine the minimum detectable target strength possible while maintaining a minimum 10 dB signal to noise ratio (SNR).

METHODS

Site Description

The Yukon River at the U.S./Canada border is characterized by a single channel with islands and stable banks (Figure 1). The existing site, located 2 km downstream from Eagle, Alaska at river km 1,952 (river mile 1213) was chosen because of the single, narrow channel, proximity to the border at river km 1,970 (river mile 1,224), and nearly linear bottom slope outward some distance from both banks (Figure 2). Numerous transects were conducted in the immediate vicinity of the sonar site using a Lowrance model X-16[1] portable depth sounder to determine the exact location to deploy the right bank near shore and offshore sonar equipment. The river at the sonar site varies from 275 m to 305 m in width and from 10 m to 15 m in maximum depth depending on the time of year and water level. The left bank bottom is mainly large cobble; it begins at the base of a cliff and slopes steeply to the thalweg at about 65 m. The right bank is sandy with sporadic rocky outcrops. The bottom shape on the right bank is complex with a gradually-inclined shelf, a steeply-sloped shelf-break, and a bottom that slopes gradually to the thalweg at roughly 240 m (Figure 2).

Upon arrival in 1994 it was necessary to construct a new right bank sonar tent at the location used the previous three field seasons. Construction was completed in two days using the existing platform and precut materials.

Climatological and Hydrological Data Acquisition

Water level was recorded daily on the right bank at the site using a staff gauge to register daily river levels. Ambient air temperature was measured once per day using a min/max Fahrenheit thermometer, while water temperature was sampled once per day using a standard Celsius scaled thermometer.

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[1] Use of a company's name does not constitute product endorsement by ADF&G.

Water velocity measurements were taken every 3 to 5 days over the near shore and offshore transducers by timing a floating (2"x4"x4") wooden block over a known distance.

As a means to verify the accuracy of our transects and produce a scaled bottom profile, measurements of depth at range were made using a Lowrance X-16 fathometer and a 180 m ("Optimeter" brand) optical range finder. Measurements were taken at 5-10 m increments, from right bank to mid river and left bank to mid river.

Sonar Data Acquisition

Split-beam sonar equipment deployed on the right bank consisted of Hydroacoustic Technology Inc. (HTI) model 240 Digital Echo Sounder (DES) to send and receive electronic signals, an HTI model 340 Digital Echo Processor (DEP) with an internal HTI model 404 Digital Chart Recorder Interface (CRI) with four gray scale capability connected to a Panasonic model KXP-1624 dot-matrix printer, and a Tektronix model 410A digital storage oscilloscope (DSO). Digitized raw echoes were recorded on a Panasonic model SV-3700 digital audio tape (DAT) recorder for archival and postseason analysis. International Transducer Corporation (ITC) elliptical split-beam transducers with nominal beam dimensions of 2.5°x10°, 4.0°x10.0°, and 6.0°x10.0° were used to transmit and receive sound pulses. Transducers were mounted on aluminum tripods placed 4m and 42m offshore, and remotely-aimed with a Remote Ocean Systems (ROS) model PT-25 dual-axis pan and tilt rotator and ROS model PTC-1 pan and tilt control unit with real-time angular relative position feedback accurate to 0.3°. Sonar systems and support equipment were powered by a single Honda EM3500 gasoline generator.

Sound pulses were generated by the transceiver at a frequency of 200 kHz and pulse width of 0.4 ms. Effective listening range varied from 40 m to 50 m. Returning echoes were filtered for correct frequency (within plus or minus 2.5 kHz), half-amplitude pulse width (within plus or minus 0.05 ms), minimum peak amplitude threshold voltage equivalent to -45 decibels (dB), and range. They were then routed through the CRI in the DEP to the printer. Chart recording thresholds were adjusted as conditions and aim warranted, although we normally tried to keep chart recording thresholds 3 dB lower than DEP acquisition thresholds. Echogram chart recordings were collected whenever electronic data were being collected.

The DES and DEP were user-configured in software. The DES was configured for transmit power, pulse duration, trigger source, data routing, frequency bandwidth, receiver gain, pulse repetition frequency (PRF), calibration pulse spacing, time-varied gain (TVG), effective range, attenuation coefficient, receiver channel selection criteria, and internal/external calibration operation. The DEP allowed user-controlled filtering of returning echoes for pulse width, start and end processing range, range-dependent minimum peak voltage thresholds, maximum allowable angle off-axis in the horizontal and vertical planes, and maximum composite angle off-axis in dB. Tracking parameters which were user-configured in the DEP included the minimum number of pings required to constitute a fish, the maximum consecutive number of pings allowed to drop out within a single tracked fish, the maximum allowable rate of change in range (expressed in m/s), and the maximum and minimum allowable tracked fish velocities (m/s). Echogram (chart recording) parameters, also user-controlled in DES software, included resolution (dots per inch), paper speed (pings per inch), echogram measurement units, sound velocity, paper width, printing area and offsets, print direction, sync reference, start and end processing ranges, range marks, echogram mode, minimum voltage threshold, and annotation.

Information from all processed signals were automatically written to three separate ASCII files at specified time intervals; a file with a *.raw* extension containing information from all echoes which met filtering criteria, a file with an *.ech* extension containing information from each echo aggregated into groups likely to have come from a single tracked fish, and a file with an *.fsh* extension containing one line of summary information from each tracked fish. File nomenclature was controlled in proprietary software, and consisted of the bank (R), Julian date, and the hour and minute that the file was opened. For example, R2600815 would be the name of a file from the right bank opened on Julian date 260 (17 September 1994) for a sampling interval that began at 0815 hours.

Whenever possible, the sonar equipment ran continuously 24 h per day, seven days per week, except for periods of up to five hours per day for conducting system calibration and related research, and half-hour periods around 0600 hours and 2100 hours. During those times, the generator was refueled and maintained. The equipment was monitored continuously from 0600 hours through 2200 hours daily, and typically operated unmonitored during the remainder of the day.

Data Management and Processing

Since this was the first application of this version of modified split-beam software to sample free swimming fish in the Yukon River, it was necessary to once again verify the system's ability to detect and track fish. Inseason analysis was limited to visually scanning the echograms for fish traces in real time. Detection's were tallied by 10 m range interval and recorded onto hard copy forms.

Each morning, the previous day's electronic data were downloaded from the DEP hard drive and all chart recordings, tally sheets, and electronic data were transported to the office in Eagle. There, all data were catalogued, and hand tally data were entered onto standard electronic spreadsheet format. Computer-generated electronic (ASCII) data were also transferred to electronic spreadsheet format, and scanned to verify that equipment settings were proper and that the electronic data were not obviously corrupted. This process also generated backup copies of the raw data, which were archived into industry standard archival (.ZIP) format for long term storage. Chart recordings were annotated for date, time, and bank, and catalogued for storage.

Subsequent data processing involved reprocessing select high quality DAT's using broader user-specified beam angles to test for otherwise acceptable echoes which were excluded because of uncertainty in phase. To accomplish this, allowable beam angles were relaxed to the limits of the linear portion of the electrical angle to mechanical angle stiffness plots provided by the manufacturer. Beam angles were relaxed from 4.5°x10.8°, 7.3°x11.1°, and 2.7°x9.5° to 9.0°x24.0°, 15.0°x24.0° and 5.0°x18.0°, respectively. The same sonar equipment used to collect the original data was used during DAT reprocessing. In addition, all acquisition parameters other than effective beam angle remained unchanged during reprocessing. Electronic files for both the original and reprocessed data were reduced to include only echoes certain to have come from upstream fish, based on first-X and last-X positions. This was accomplished by locating tracked fish from electronic (*.ech*) data files on simultaneously collected echograms based on range, residence time in the beam, change in range, and proximity to nearby targets. All assemblages of valid echoes not likely to have originated from fish (bottom traces, for example) were deleted from the data files. In addition, echoes from a single fish which was electronically tracked as two or more fish were manually combined in the data files. Acoustic data from fish that were tracked in both processing runs were compared ping by ping.

Sonar Beam Pattern Geometry

We calculated maximum potential beam dimensions based on river bottom profiles from depth soundings at the site. The greatest possible beam dimension in the vertical plane was calculated as:

$$\theta = 2 \cdot \arctan\left(\frac{d}{2r}\right) \tag{1}$$

where: θ = angular beamwidth
d = depth
r = range

We chose elliptical beam transducers whose narrow axis most completely filled the water column, while maintaining a minimum acceptable 10 dB signal to noise ratio from the suite of transducers manufactured for this project. The transducers were positioned in the river as nearly perpendicular to the current as possible. The wide axis of the beams were oriented close to a horizontal position and near the bottom of the river in order to maximize target residence time in the beam.

In Situ Calibration

We suspended standard spherical targets of known acoustic size at many positions in the beam regularly throughout the period of data collection to verify the system's ability to detect target position and estimate acoustic size. All standard target data were collected with the beam roughly centered vertically in the water column to obtain the greatest SNR, and acquisition thresholds were reduced to the lowest values possible. Targets were suspended in an equatorial net bag, from either a fixed pole or a frame, at known distance beneath the water surface on a strand of 12# test monofilament line. The frame was constructed of 3.81 cm. diameter steel tubing and consisted of two vertical poles 4 m apart, welded to a 1 m x 4 m rectangular base, open in the front. The targets we suspended in the beam were 38.1 mm stainless steel spheres.

Initially, we placed the target in the center of the frame and measured the peak echo voltage of each target as close to the maximum response axis (MRA) as possible. We determined initial target position on the MRA by aiming the beam until the paired up-down and right-left phase angles were aligned on a DSO. The targets were then moved known distances off the MRA vertically and horizontally while leaving the beam position unchanged. At each position the target was ensonified for approximately 3-4 minutes (900-1200 pings) and all acoustic data were written to electronic file and stored in DAT format. Using calibration data and user input filtering parameters in the signal processing software, the DEP calculated target strength and three axis position estimates in real time. Finally, we compared the DEP-generated position and target strength values to the measured position. Theoretical target strength values were calculated following Urick (1983) as:

$$TS = 10 \log\left(\frac{\sigma}{4\Pi}\right) \qquad \textbf{(2)}$$

where: TS = target strength in dB
σ = backscattering cross-section in m^2

In Situ Background Noise Levels

Background noise corrupts both phase and amplitude information. Therefore we have specified a minimum 10 db SNR in order to minimize the bias of *in situ* estimates of target strength. Peak detected background noise levels were measured at various ranges directly on a DSO numerous times during the course of acoustic *in situ* system calibration.

RESULTS

Sonar Site Location

Based on bottom profiles obtained in 1994, the nearshore transducer was placed in nearly the same position as during the 1993 project operations, while the offshore transducer was deployed at the 40 m shelf break. The right bank was characterized by a linear bottom to a shelf break at about 40 m (Figure 2). Outward from the inflection, the right bank bottom was slightly convex toward the thalweg. The right bank substrate composition was primarily silt and gravel nearshore, changing to gravel and small boulders moving towards the thalweg. No unexpected difficulties were encountered while deploying either the nearshore or offshore transducers, although a substantial anchoring system consisting of two 9 kg anchors was required to secure the offshore tripod. Immediately after aiming, we were able to detect bottom and fish echoes from both transducers.

Climatological and Hydrological Data

River level and water temperature at the sonar site dropped throughout project operation, dropping a total of 0.5 m (1.5 ft) and 7.5° C (Table 1). Changing water level forced us to move the nearshore transducer occasionally during the field season. Water velocity readings were taken four separate times over each transducer, with velocities remaining constant over the nearshore and offshore transducers at 0.3 m/s and 1.3 m/s.

Figure 3 is a plot of depth at range measurements collected in 1994. The similarity between the depth at range plot and a normal transect bottom profile (Figure 2) at the sonar site is striking.

Sonar Data Acquisition

In all, 313.7 h of simultaneous echogram and electronic split-beam acoustic data were collected during sonar operations in 1994 (Table 2). Of that, 172.2 h were collected from the nearshore transducer and 141.5 h were collected from the offshore transducer. Additionally, 15 h of standard target work and 22 h of DAT data were recorded. Table 3 shows daily echogram tallies expanded for time not sampled on both the nearshore and offshore transducer.

Data Management and Processing

Using widened beam dimensions, we reprocessed 14 hours of DAT data from three different beam angle transducers. From this data set, 82 upstream targets were tracked using the original half-power phase-determined effective beam angle. Reprocessing with widened allowable phase-determined beam angles added an additional 80 successfully tracked upstream fish. This represented an increase of 96% over the originally tracked data. The number of tracked upstream fish in both the reprocessed and the original data are shown by beam angle in Figure 4. Figure 5 shows the number of originally-tracked and reprocessed upstream fish on seven different days. On all occasions, we found that loosening beam angle constraints without changing threshold consistently resulted in a greater number of upstream tracked fish, with daily increases ranging from 24% to 78%. In addition, using all fish tracked in either processing run, the average number of echoes comprising an originally tracked fish was 8.3 while an average 9.4 echoes comprised reprocessed fish. For fish which were originally tracked, those tracked using widened beam angles contained an average 1.4 additional echoes within, and 2.7 additional echoes outside the spatial boundaries of the originally tracked fish (Table 4).

Beam Fitting

At project onset the river was approximately 300 m wide. A 4.2 m deep shelf break was detected 40 m from the right bank, and the 9.2 m deep thalweg was located 240 m from the right bank (Figure 3). Based on depth at range measurements the nearshore and offshore bottom slopes were 5.2° and 1.0°. To optimize river coverage and retain at least 10 dB SNR's at these bottom slopes, we deployed nominal 6.0°x10.0° and 2.5°x10.0° (effective 7.2°x10.8° and 2.7°x9.5°) elliptical beam angle transducers in the nearshore at separate times. The offshore area was ensonified with a nominal 4.0°x10.0° (effective 4.6°x10.8°) elliptical beam angle transducer for the project duration.

In Situ Calibration

Cursory analysis of standard target data on a frame from 11 September 1994 showed that of 14 positions in the beam sampled, the rate of echo detection varied between 58% and 90% (Table 5). We found no obvious relationship between SNR and percent detection or between mean Beam Pattern Factor (BPF) and gross percent detection (Figure 6). The variability between target position in the beam and corresponding DEP-calculated target position is shown in Figure 7. Overall, we noted far less variability in the phase-determined horizontal (x-axis) position (Figure 8), than in vertical (y-axis) position (Figure 9). A complete analysis of the standard target data acquired on 11 September, including identification and description of sources of uncertainty in phase-determined target location will be detailed in a subsequent report.

In Situ Background Noise Levels

Typical peak background noise levels varied from -57 dB (50 mV) to -51 dB (100 mV) on the right bank during *in situ* calibration activities on 11 September 1994. Signal to noise ratios at the 14 sampled positions ranged from 8 dB to 15 dB.

DISCUSSION

We gained further experience in the capabilities and use of an upgraded version of the 200 kHz split beam sonar system during the 1994 field season. This knowledge will enhance our capacity to evaluate the feasibility of using this particular equipment to assess the number of salmon migrating up the Yukon River past the sonar site near Eagle, Alaska. However, our progress toward accomplishing that task was hindered in a variety of ways as we encountered difficulties with various elements of sonar data acquisition and processing.

Split-beam technology is not new (Carlson and Jackson 1980) but as far as we know, the previous two field season deployments near Eagle, Alaska in 1992 and 1993 were the first attempts to examine the ability of scientific split-beam hydroacoustic equipment to assess migratory fish abundance in a river (Huttunen and Skvorc, 1996). Riverine split-beam deployment was particularly innovative because of horizontal transducer orientation and resulting high noise levels reflected from river surface and bottom boundaries. We have noted an undetermined degree of uncertainty in phase-determined target position information, which in turn limits the system's ability to accurately calculate target strength. It also limits the ability of the system to accurately track targets as they move through the beam and therefore determine direction of travel. Further, it remains our position that current version target tracking software will require further refinement before it can be considered fully capable of automatically tracking individual fish through the beam.

This was the third field season of a feasibility project designed to evaluate whether or not it is feasible to assess the number of chinook and chum salmon migrating past the border into Canada on the Yukon River using split-beam sonar equipment. Delays in systematic data acquisition were initially realized as hardware and software deficiencies were again encountered. Data acquisition was inhibited due to a malfunctioning DEP. This prevented us from simultaneously collecting 24 hour data from both the nearshore and offshore transducers. This problem was overcome by using the multiplexing (MUX) function on the DES and sampling each transducer for 30 min. of each hour. Although this option allowed for data acquisition from both transducers, it effectively reduced the total amount of data collected by half. In addition we experienced an initial delay in operation due to an updated version of the DEP acquisition software not being forwarded with the sounding equipment. The malfunctioning DEP was repaired during the field season by the manufacturer but not in time for full season utilization. The manufacturer also provided the latest version processing software inseason.

Acoustic data analysis was further hindered by processing software which was limited in its ability to annotate charts, and which occasionally malfunctioned. The version of processing software used during 1994 was not able to annotate charts for both time and range simultaneously, which inhibited our abilities to identify electronically tracked targets on chart recordings, a limitation carried forward from the 1993 field season. This problem was overcome on site by taking the signal for the chart recorder directly from the DES which could provide time annotation while the DEP provided range intervals. This is not an acceptable method for chart annotation, however, since the DES cannot multiplex between transducers when configured in this fashion. Therefore, a technician must manually return chart recording control to the DEP prior to the established multiplexing time if the system is to switch active transducers. In addition, processing software periodically acquired large numbers of echoes for no apparent reason. This resulted in the DEP tracking large numbers of erroneous targets. This malfunction caused the DEP to overload and shut down on several occasions. When this malfunction occurred during unmonitored periods of operation, large time blocks of data were lost.

A further limitation to successful acoustic data acquisition and analysis on this project during its initial field season in 1992 was caused by a system design characteristic which increased the probability of ambiguous system operation. The DES and DEP were both user controlled in software. However, each piece of hardware was independently controlled by a separate set of manually entered control parameter values. Because many tracking and filtering decisions are based in part on DES acquisition settings, any discrepancy between manually entered DES and DEP settings can result in ambiguous data. The problem was ameliorated in 1993 by a software modification that wrote all DEP settings as header information to all automatically created data files. This enhancement made it possible for an operator to subsequently review acquisition and processing parameter values for discrepancies. We remain convinced, however, that in order for the sonar system to be considered fully operational, a software or hardware modification must be developed to allow either the DEP or the DES to interrogate the other component for all input settings required by controlling and processing software.

In spite of these hardware and software limitations the system was able to calculate the target strength and three axis position of a fixed calibration sphere and free swimming fish in real time in 1994. We found that for a 38.1 mm stainless steel standard target the probability of detection varied from 58 to 90 percent, even though target signal was substantially greater than acquisition threshold, and the SNR was greater than 10 dB for all but one position sampled. Target strength estimates for the standard target measured at various positions in the beam ranged from -35 dB to -39 dB, all of which were larger than the theoretically expected target strength of -42 dB (Foote, 1982; Foote and MacLennan, 1984). Phase-calculated target position estimates in the horizontal axis were very close to measured values. However, vertical position estimates were found to be more variable. Since noise perturbs both phase and amplitude information, collection of the data was done at close proximity to the transducer (but beyond the nearfield zone) and at midwater to permit the greatest SNR possible. The inability of the processor to accurately fix vertical position, with high SNR's, could in turn lead to exclusion of additional echoes in lower SNR conditions (i.e. normal data acquisition). The possibility of echoes excluded due to uncertainty in position led us to examine echo detections in free-swimming fish. To do this we reprocessed DAT data using widened beam parameters while retaining all other original data acquisition and processing parameters. This allowed echoes previously excluded due to uncertainty in position into the revised data set. When comparing original data to reprocessed results, we found that we tracked almost twice as many upstream targets using less constraining beam angles. An echo by echo comparison reveled that in reprocessed fish, echoes were added between and beyond those of the originally tracked fish. We expected to acquire additional echoes on either end of an originally tracked fish due to the increased effective beam width. Additional echoes detected within the original narrow beam width constraints during reprocessing strongly suggests some unknown degree of uncertainty in phase-determined target position. Therefore, it will be necessary to quantify the uncertainty in phase-determined position information before confidently using direction of travel for fisheries management purposes.

One of the uncertainties remaining involves the relationship between target strength and mean length of migrating salmon at the sonar site. Due to disastrously low returns of chum salmon to the Yukon River in 1993, the weak return anticipated in 1994, and management actions taken inseason based on down river assessment, no test fishing was done at the Yukon River border sonar site in 1994. It was also impossible to document the spatial distribution of migrating fish, since the mid-section of the river was neither acoustically nor physically sampled. Questions regarding the spatial distribution of chinook and chum salmon at the Yukon River border sonar site will have to be addressed before a sampling design to estimate total abundance can be successfully implemented.

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Table 1. Hydrological and climatological data collected at the Yukon River border sonar site near Eagle, Alaska, 30 August through 21 September 1994.

Date	Water velocity (m/s) at range(m)		Water Temp. (C)	Depth Guage	Ambient Air Temp. (F) Min/Max
	nearshore	offshore			
08/30	0.3 @ 2 m	1.3 @ 45 m	14.0		34/62
08/31					36/64
09/01					29/64
09/02			13.0		30/67
09/03					30/60
09/04	0.3 @ 2 m	1.3 @ 20 m			36/62
09/05			12.0	63.5	38/48
09/06				57.0	24/52
09/07				54.5	24/60
09/08	0.3 @ 2 m	1.3 @ 40 m	12.5	49.5	36/49
09/09			10.5	44.5	19/50
09/10			10.5	40.5	37/48
09/11				34.0	32/41
09/12			9.0	30.5	26/42
09/13			8.0	28.5	28/53
09/14	0.3 @ 2 m	1.3 @ 40 m	8.0	26.5	36/44
09/15			9.0	25.5	36/49
09/16			9.0	25.5	36/60
09/17			9.0	24.5	26/54
09/18				23.5	33/38
09/19			9.0	22.0	25/57
09/20			7.0	21.5	25/42
09/21			6.5	19.0	

Table 2. Summary of split beam sonar data collected at the Yukon River border sonar site near Eagle, Alaska, from 1 September through 21 September 1994.

	Right Bank nearshore		Right Bank offshore		
Total Date	Time (h)	Range (m)	Time (h)	Range (m)	Hours
9/01	4.4	45	0		4.4
9/02	16.3	45	1.0	45	17.3
9/03	14.0	45	2.1	45	16.1
9/04	9.1	40	9.1	40	18.2
9/05	8.6	45	7.8	45	16.4
9/06	6.9	45	6.8	45	13.7
9/07	9.2	45	10.2	45	19.4
9/08	7.6	45	7.5	45	15.1
9/09	7.7	45	7.9	45	15.6
9/10	9.5	45	9.3	45	18.8
9/11	9.6	45	9.3	45	18.9
9/12	11.8	45	11.5	45	23.3
9/13	8.0	45	8.2	45	16.2
9/14	5.4	45	5.3	45	10.7
9/15	4.3	50	4.5	45	8.8
9/16	9.3	50	10.0	50	19.3
9/17	7.6	50	8.0	50	15.6
9/18	5.5	41	5.6	45	11.1
9/19	6.4	50	6.4	50	12.8
9/20	7.5	50	7.5	50	15.0
9/21	3.5	50	3.5	50	7.0
Total	172.2		141.5		313.7

Table 3. Expanded sonar tallies of free-swimming fish at the Yukon River border sonar site near Eagle, Alaska, by day for 1 September through 21 1994.[1]

Date	Nearshore	Offshore	Total
9/01	1,249	0	1,249
9/02	1,048	360	1,408
9/03	1,325	216	1,541
9/04	1,209	393	1,602
9/05	1,447	509	1,956
9/06	2,499	514	3,013
9/07	1,838	419	2,257
9/08	2,037	366	2,403
9/09	2,203	527	2,730
9/10	2,017	630	2,647
9/11	1,601	669	2,270
9/12	1,864	297	2,161
9/13	1,415	278	1,693
9/14	1,184	178	1,362
9/15	1,475	458	1,933
9/16	1,638	477	2,115
9/17	1,113	315	1,428
9/18	1,059	326	1,385
9/19	1,505	374	1,879
9/20	1,545	390	1,935
9/21	1,109	532	1,641
Total	32,380	8,228	40,608

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[1] Counts are expanded for time not sampled on each transducer but not for unensonified area.

Table 4. Summary of detected upstream fish at the Yukon River border sonar site near Eagle, Alaska using half-power (narrow) and relaxed (wide) beam angle constraints on three transducers by day, 1994. (1)

Transducer S/N 006

	Number of Fish Tracked		Average Number of Pings Detected per tracked Fish		Average Number of Pings Excluded from Original Tracked Fish:	
Date	9.0x24.0 Wide	4.5x10.8 Narrow	9.0x24.0 Wide	4.5x10.8 Narrow	4.5x10.8 Within Narrow	4.5x10.8 Beyond Narrow
09/06	2	2	15	8	1	6
09/07	2	2	14.5	10	0	4.5
09/09	28	16	12.3	8.3	1.4	6
09/13	1	0	17	0	0	0
09/19	3	1	7	8	1	2
09/20	1	0	7	0	0	0
09/21	4	1	5.8	6	0	1
Summary	41	22	11.5	8.3	1.2	5.5

Transducer S/N 009

Date	15.0x24.0 Wide	7.3x11.1 Narrow	15.0x24.0 Wide	7.3x11.1 Narrow	7.3x11.1 Within Narrow	7.3x11.1 Beyond Narrow
09/06	30	5	6.4	6.6	1.6	1
09/07	19	8	7.4	5.6	1.5	2.4
09/09	9	6	11	11.7	1.3	0.7
09/13	24	14	12.1	10.9	2.4	2.6
Summary	82	32	8.8	9.3	1.9	2

Transducer S/N 005

Date	5.0x18.0 Wide	2.7x9.5 Narrow	5.0x18.0 Wide	2.7x9.5 Narrow	2.7x9.5 Within Narrow	2.7x9.5 Beyond Narrow
09/19	6	4	13	13.3	1	2
09/20	16	13	7.2	6.6	0.2	0.3
09/21	18	11	7.9	5.7	1.7	2
Summary	40	28	8.4	7.2	0.9	1.2

Pooled data						
Summary	163	82	9.4	8.3	1.4	2.7

(1) Widened beam angle constraints were established using the full linear range of the appropriate electrical angle to mechanical angle stiffness plots provided by the equipment manufacturer.

Table 5. Summary of in situ target strength and position estimates from a 38.1mm stainless steel target suspended in a stationary frame measured with split-beam hydroacoustic equipment at the Yukon River border sonar site near Eagle, Alaska, 11 September 1994.

Measured Position of Target (m)[1]		Number of Pings Transmitted	Number of Echoes Received	Percent of Pings Detected	Mean Voltage Returned (mV)	Mean X Position (m)	Mean Y Position (m)	Mean Beam Pattern Factor (dB)	Beam Pattern Standard Deviation	Mean Target Strength (dB)	Target Strength Standard Deviation
left\right	up\down										
0.30	0.15	1055	869	82	277	0.31	0.12	-5.35	1.08	-36.70	1.78
0.00	0.15	953	650	68	364	0.03	0.07	-1.22	0.78	-39.16	1.04
-0.15	0.15	995	899	90	337	-0.20	0.00	-1.87	0.33	-38.57	0.53
-0.30	0.15	1257	1050	84	259	-0.32	0.09	-5.00	0.89	-37.70	0.85
0.30	0.00	942	800	85	281	0.31	0.01	-4.12	0.64	-37.94	0.93
0.15	0.00	925	790	85	358	0.16	0.04	-2.33	1.36	-37.64	1.49
0.00	0.00	1160	1026	88	412	-0.01	0.01	-0.15	0.17	-39.14	0.61
-0.15	0.00	1081	922	85	443	-0.20	-0.09	-2.51	0.70	-35.50	0.77
-0.30	0.00	1421	1027	72	292	-0.34	-0.11	-6.06	1.32	-35.60	1.12
0.30	-0.15	941	754	80	296	0.28	-0.19	-6.55	1.26	-35.02	1.20
0.15	-0.15	964	707	73	378	0.13	-0.19	-3.93	1.30	-35.51	1.52
0.00	-0.15	1118	945	85	436	0.00	-0.17	-2.66	1.33	-35.55	1.59
-0.15	-0.15	1292	812	63	338	-0.19	-0.19	-4.81	1.40	-35.59	1.63
-0.30	-0.15	1420	823	58	198	-0.32	-0.01	-1.87	1.08	-40.40	1.07

[1] Measured target position is positive (+) when the target was moved up or right of the maximum response axis (MRA) and negitive (-) when moved down or left of the MRA as viewed from the rear of the transducer.

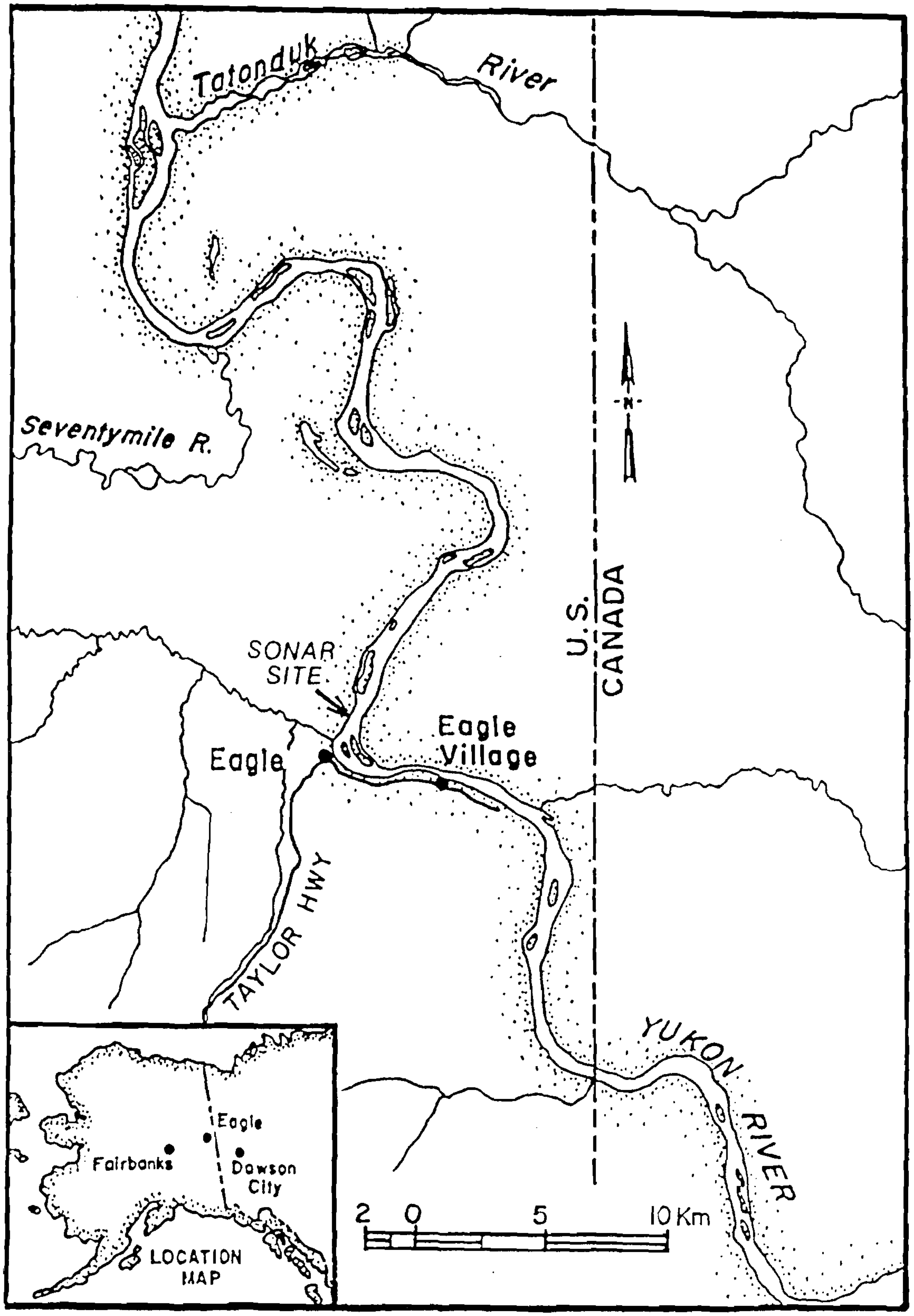

Figure 1. Location of Eagle, Alaska hydroacoustic sample site on the Yukon River (US Fish and Wildlife Service and Alaska Dept. of Fish and Game, 1992).

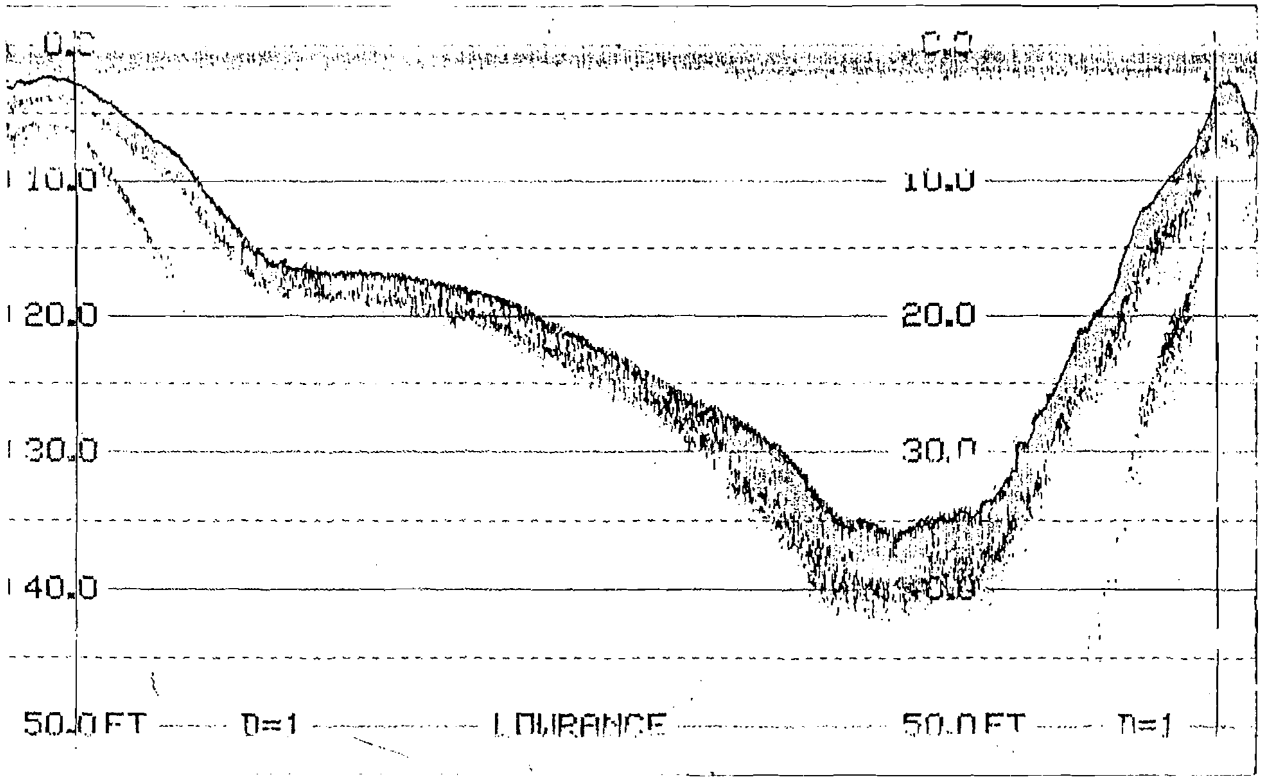

Figure 2. Reverse image bottom profile collected using down looking sonar (Lowrance X-16) at the Yukon River border sonar site near Eagle, Alaska on 26 August 1994.

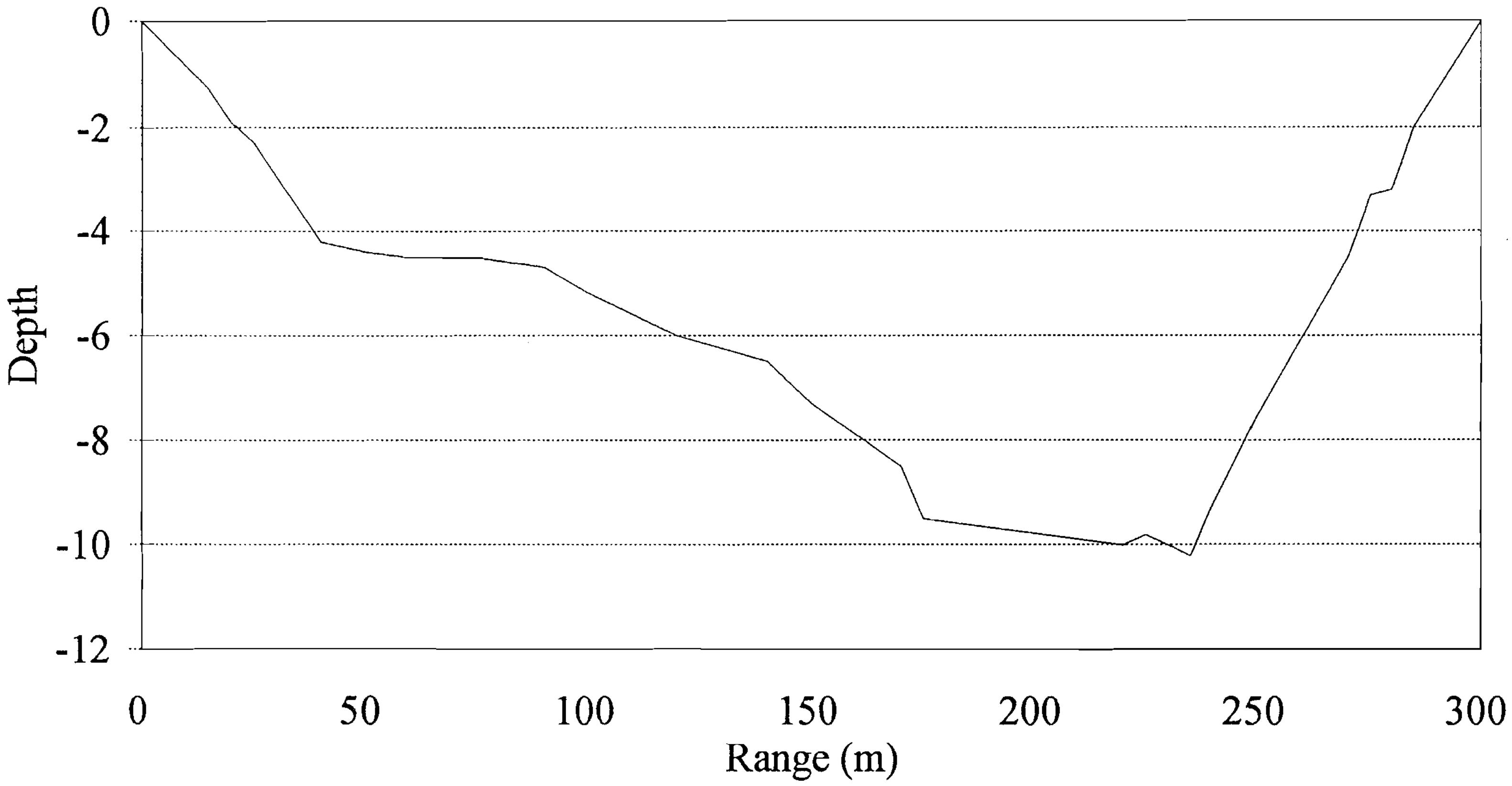

Figure 3. Bottom profile calculated from depth at range data collected at the Yukon River border sonar site near Eagle, Alaska on 12 September 1994. Range is described from the right bank.

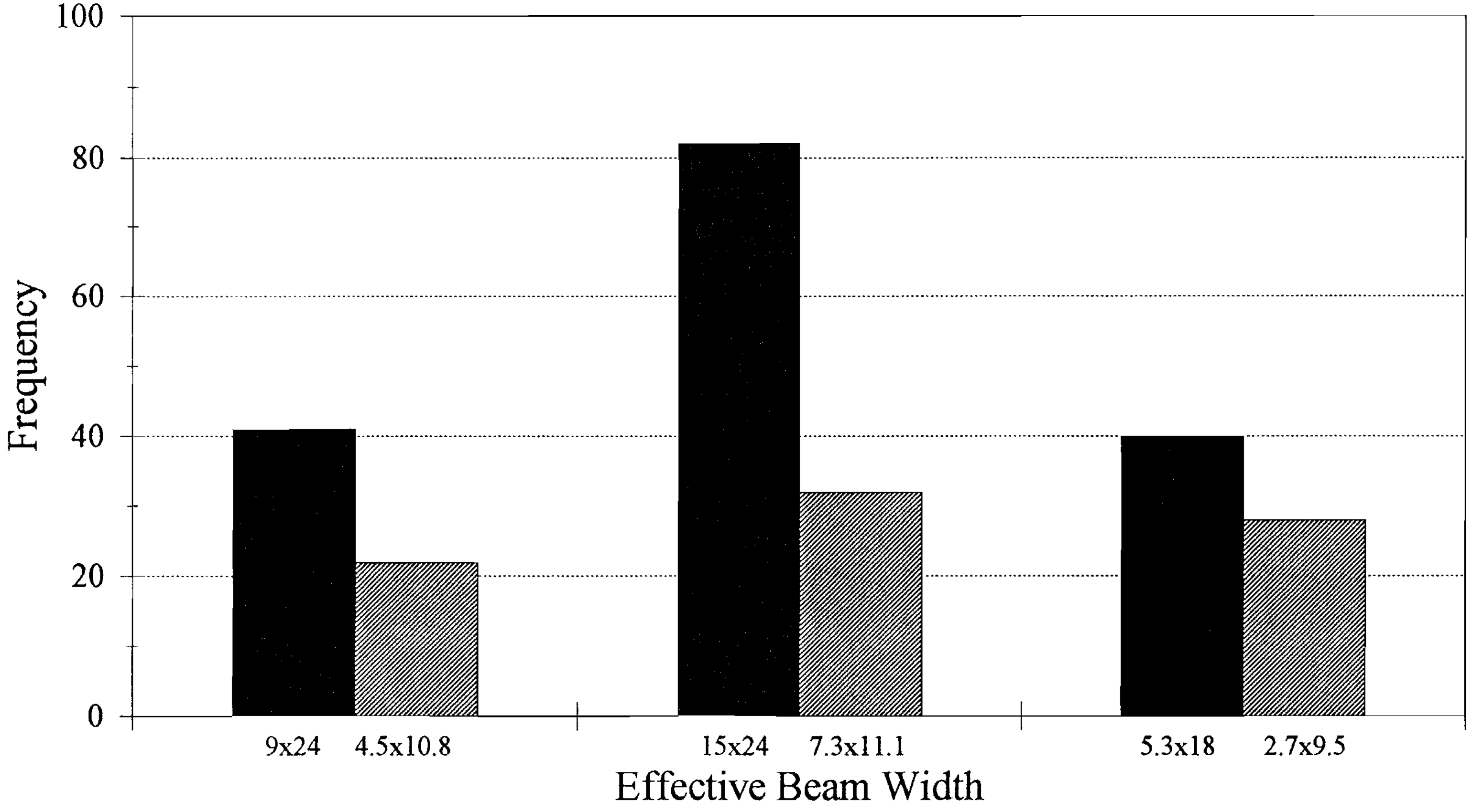

Figure 4. Number of upstream fish detected at widened effective beam angles (solid bars) and half-power effective beam angles (striped bars) on the right bank at the Yukon River border sonar site near Eagle, Alaska using 200kHz split beam sonar equipment and 4.5 x 10.8, 7.3 x 11.1, and a 2.7 x 9.5 degree transducer on 6, 7, 9, 13, and 19-21 September 1994.

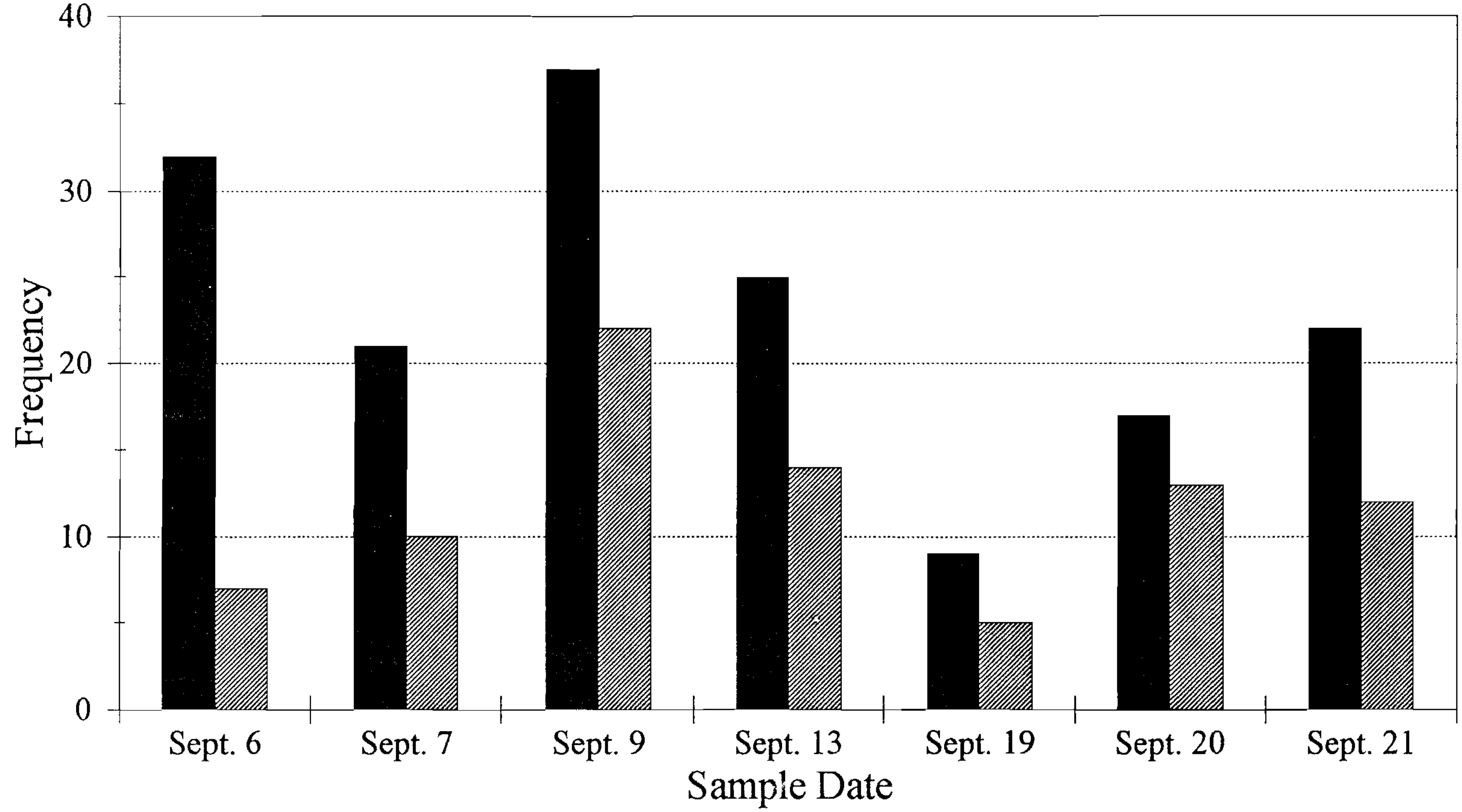

Figure 5 Total number of upstream fish detected at widened effective beam angles (solid bars) and half-power effective beam angles (striped bars) on the right bank at the Yukon River border sonar using 200kHz split beam sonar equipment by date, 1994.

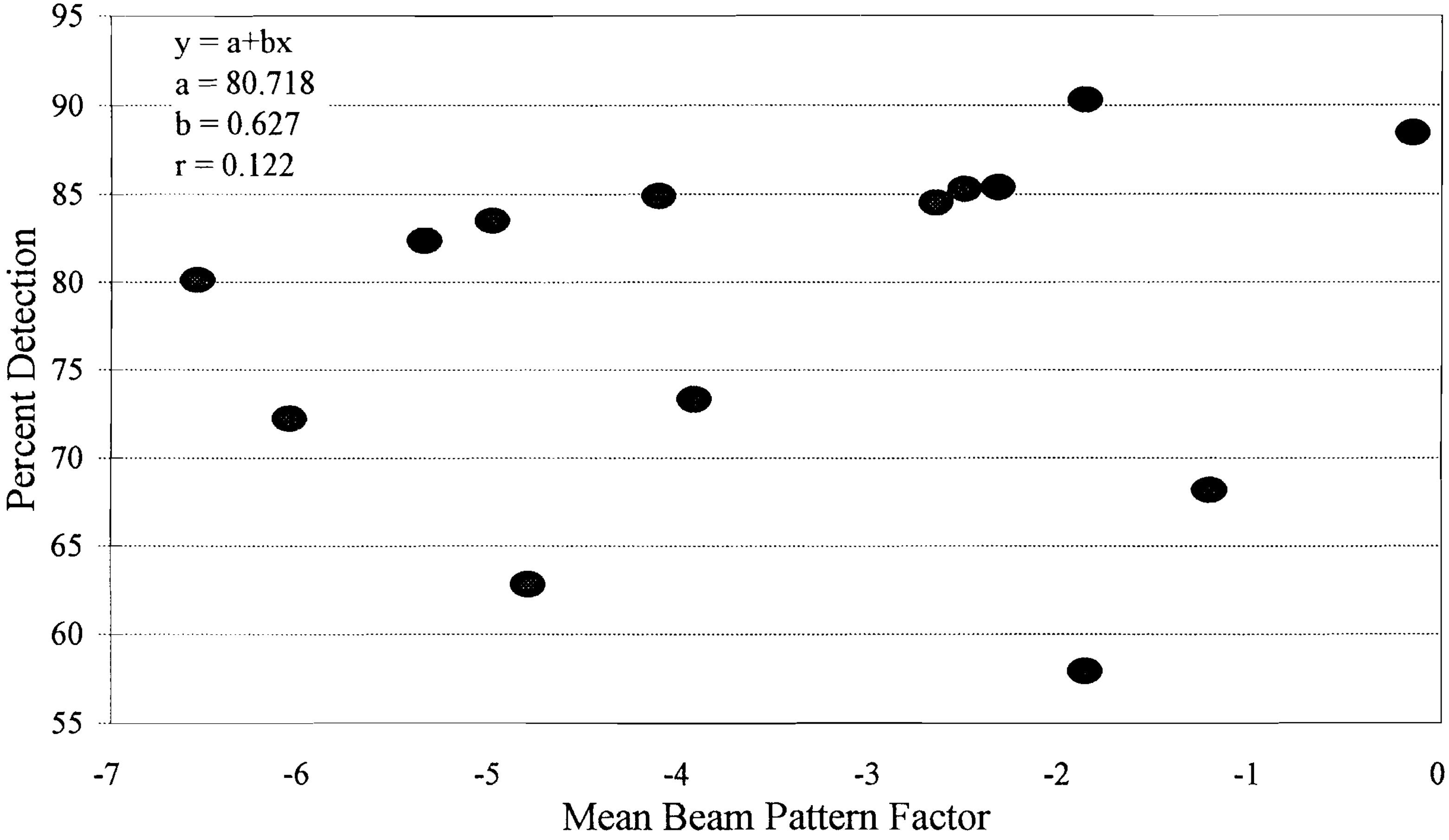

Figure 6. Comparison of mean beam pattern factor with percent detection for a 38.1 mm stainless steel standard target ensonified at various positions in the beam using 200kHz split-beam sonar equipment on 11 September 1994 at the Yukon River border sonar site near Eagle, Alaska.

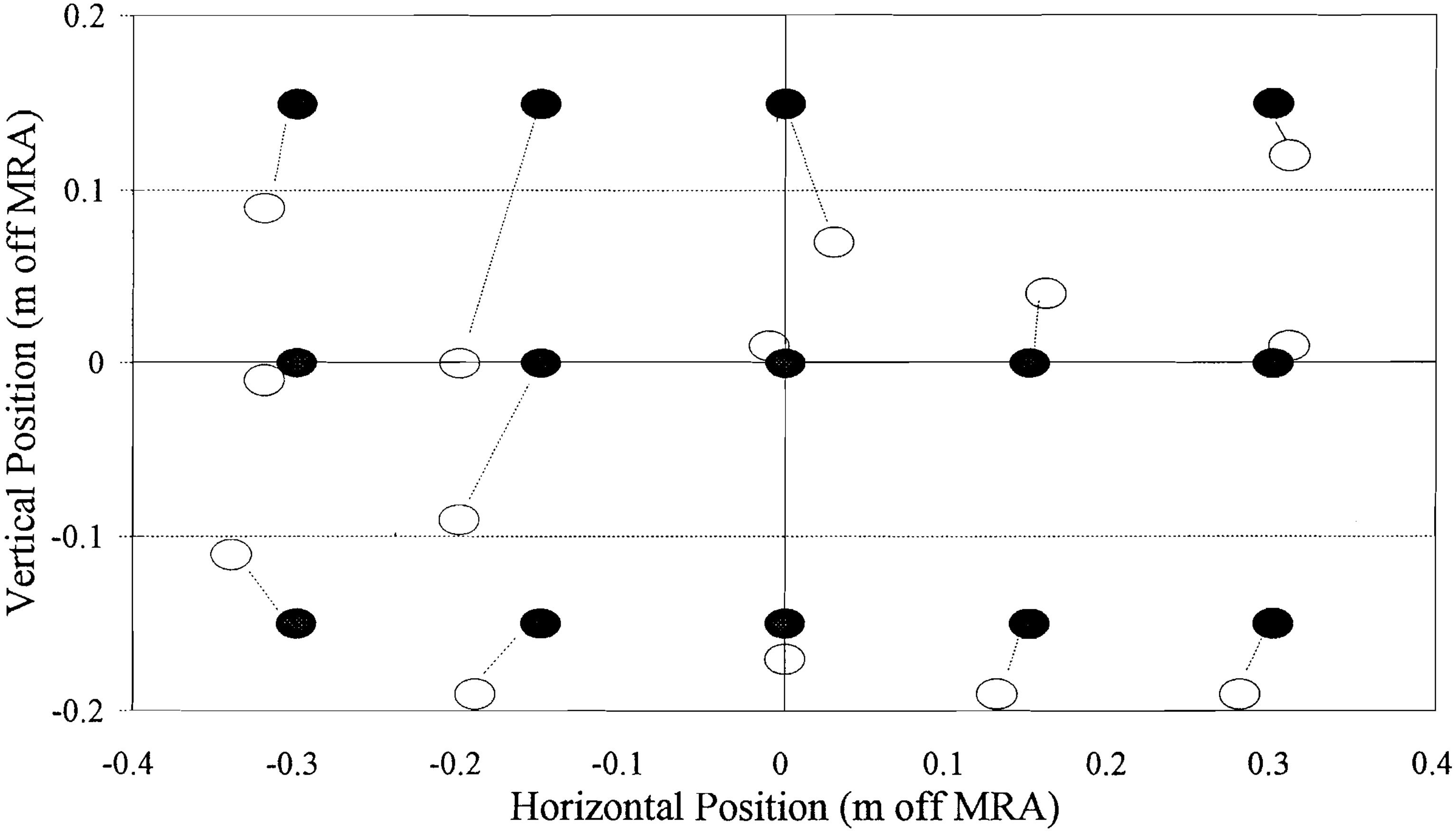

Figure 7. Measured position of a 38.1 mm stainless steel standard target (solid dot), and the processors's calculated position for the same target (open dot) for standard target data collected at the Yukon River border sonar site near Eagle, Alaska using a CDFO frame on 11 September 1994.

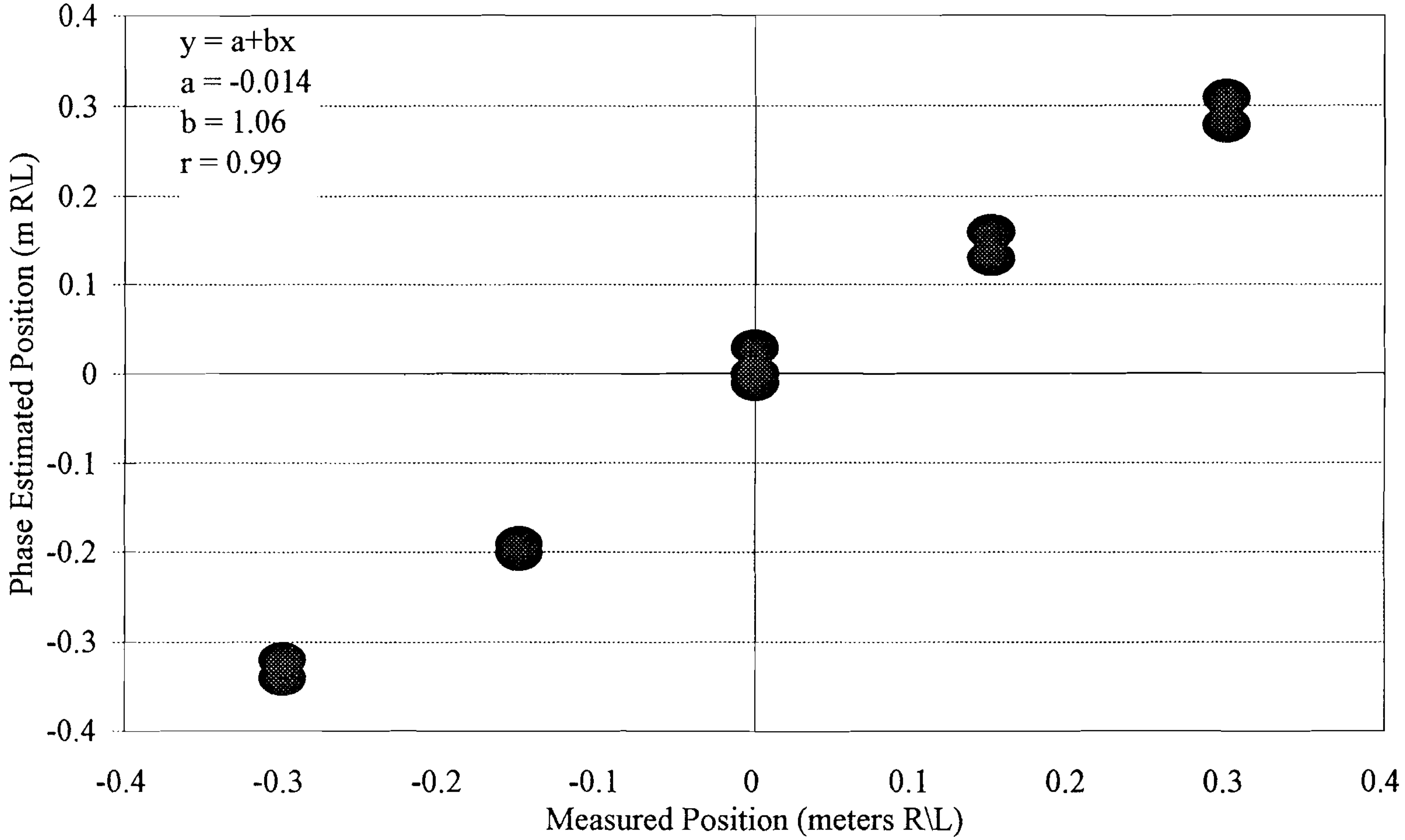

Figure 8. Comparison of phase estimated horizontal position with known measured horizontal position of a 38.1 mm stainless steel standard target ensonified using 200kHz split-beam sonar equipment at the Yukon River border sonar site near Eagle, Alaska on 11 September 1994.

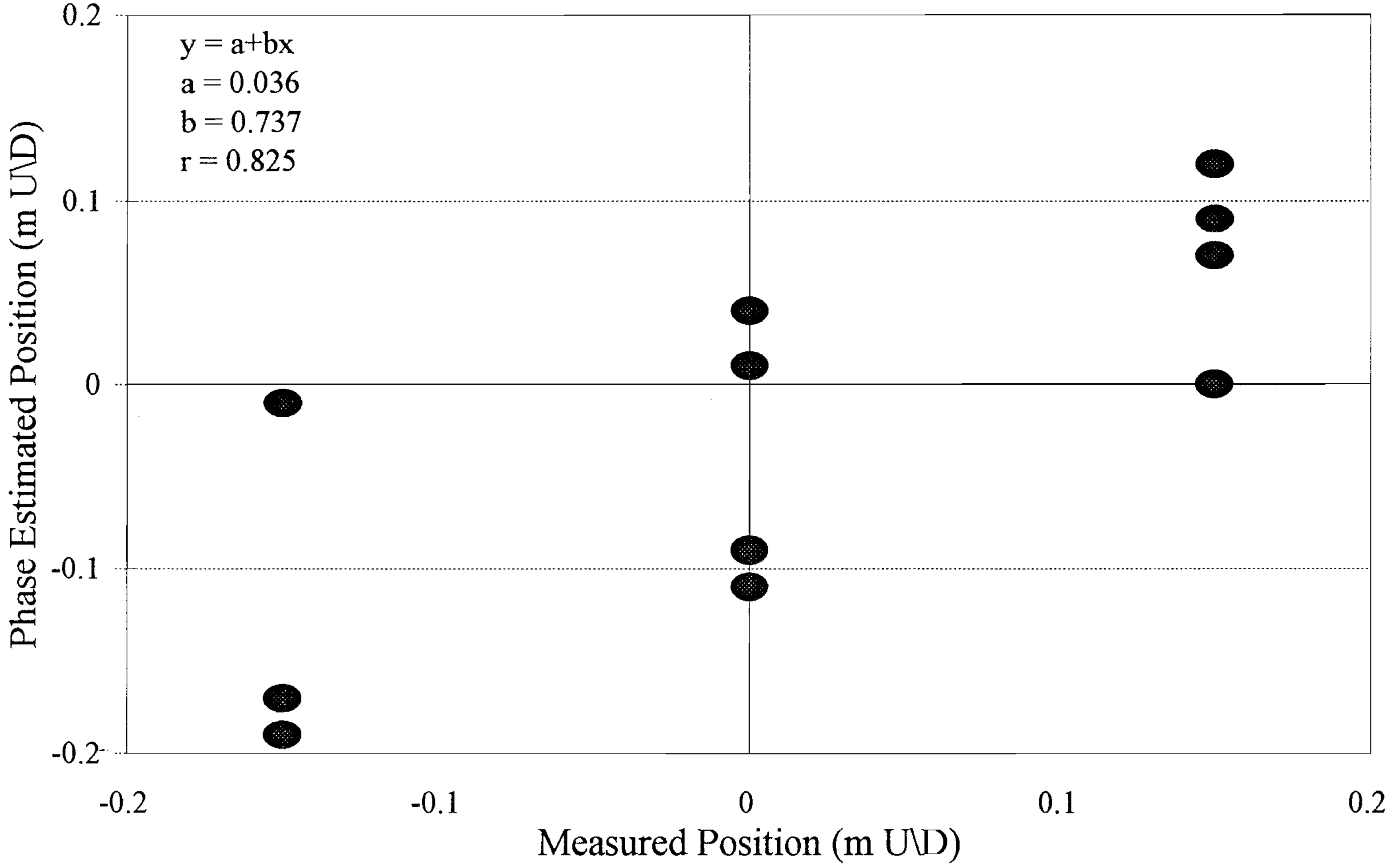

Figure 9. Comparison of phase estimated vertical position with known measured vertical position of a 38.1 mm stainless steel standard target ensonified using 200kHz split-beam sonar equipment at the Yukon River border sonar site near Eagle, Alaska on 11 September 1994.