AYK Region
Yukon Salmon Escapement
Report No. 36

SONAR FEASIBILITY STUDIES
IN THE LOWER KUSKOKWIM AND YUKON RIVERS,
1980 - 1983

by

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DEPARTMENT OF FISH AND GAME

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

Page

Page

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

Enumeration of adult salmon escapement in the main channels of the Kuskokwim and Yukon rivers has been complicated by silty water that precludes visual counting. Sonar feasibility studies were conducted in the lower reaches of these river systems. A single-hit unit, which provided numerical counts on a paper tape, was used in the Kuskokwim River in 1980 and 1981; results of this phase of the study were inconclusive. The single-hit unit was used in conjunction with a multiple hit unit on the south bank of the Yukon river near Pilot Station in 1982. The multiple-hit unit provided directional orientation of targets on an echogram. In this phase of the study, the single-hit system was found to generate counts from motor boats, rain, waves, ambient river noise and debris when deployed in an area, shown by echograms of the multiple-hit system to contain few fish targets. Only the multiple-hit unit was used in 1983; it was used again in the Yukon River, near Pilot Station, on the north bank.

Although the channel width of the Yukon river in the study area was 670 meters, the majority of salmon swam within 100 meters from either shore. Salmon were distributed throughout the water column. Diel distribution of hourly counts illustrated no definite pattern. Coefficient of variation analysis indicated that sampling periods should be approximately 20 minutes per region near-shore and off-shore; near-surface and near-bottom. Arrival time analysis indicated that the spatial distribution of adult salmon was of a contagious type. Target strengths were determined by an indirect method (Ehrenberg et al. 1981) using 2°, 6°, and 10° transducers; they were,

respectively -28.2, -22.1 and -18.4 decibels (dB). Swimming speeds of adult salmon were determined by change-in-range targets according to their off-axis orientation relative to transducer aiming angles. Swim speeds ranged from 0.036 to 2.204 m/s, with a grand mean of 0.601 m/s. The estimated adult salmon passage along the north bank for 22 days, between 21 June and 15 July, was 184,000 fish.

INTRODUCTION

Salmon fisheries management in the two largest western Alaska rivers, the Yukon and Kuskokwim (Figure 1) has been complicated by factors that prevent accurate determination of stock strength and migratory timing. Predominant among these factors include the extensive river mouth deltas with multiple river channels, and silty water that precludes visual enumeration of migrating salmon. The most intensive commercial salmon harvest occurs in the lower 100 miles of the main channels of these rivers. Escapement information cannot be obtained until some stocks reach relatively clear water spawning tributaries, often hundreds of miles upstream from harvest locations in the lower reaches of the main river. In-season abundance assessment presently relies upon comparative commercial fishery statistics and gill net test fishing conducted by Alaska Department of Fish and Game (ADF&G) personnel. These indirect assessments are difficult to interpret, thus forcing management of these stocks to be on the conservative side; but even present management strategies may be too liberal. The need for accurate and timely data for salmon management resulted in a search for reliable and direct abundance indicators.

Escapement estimates for a number of Alaska rivers have been derived from the quantitative use of riverine Sonar (Menin and Paulus, 1975). Sonar was, therefore, identified as a possible method for salmon enumeration in the Kuskokwim and Yukon rivers. In 1978 and 1979, respectively, two sonar systems were developed that were subsequently tested during this feasibility study.

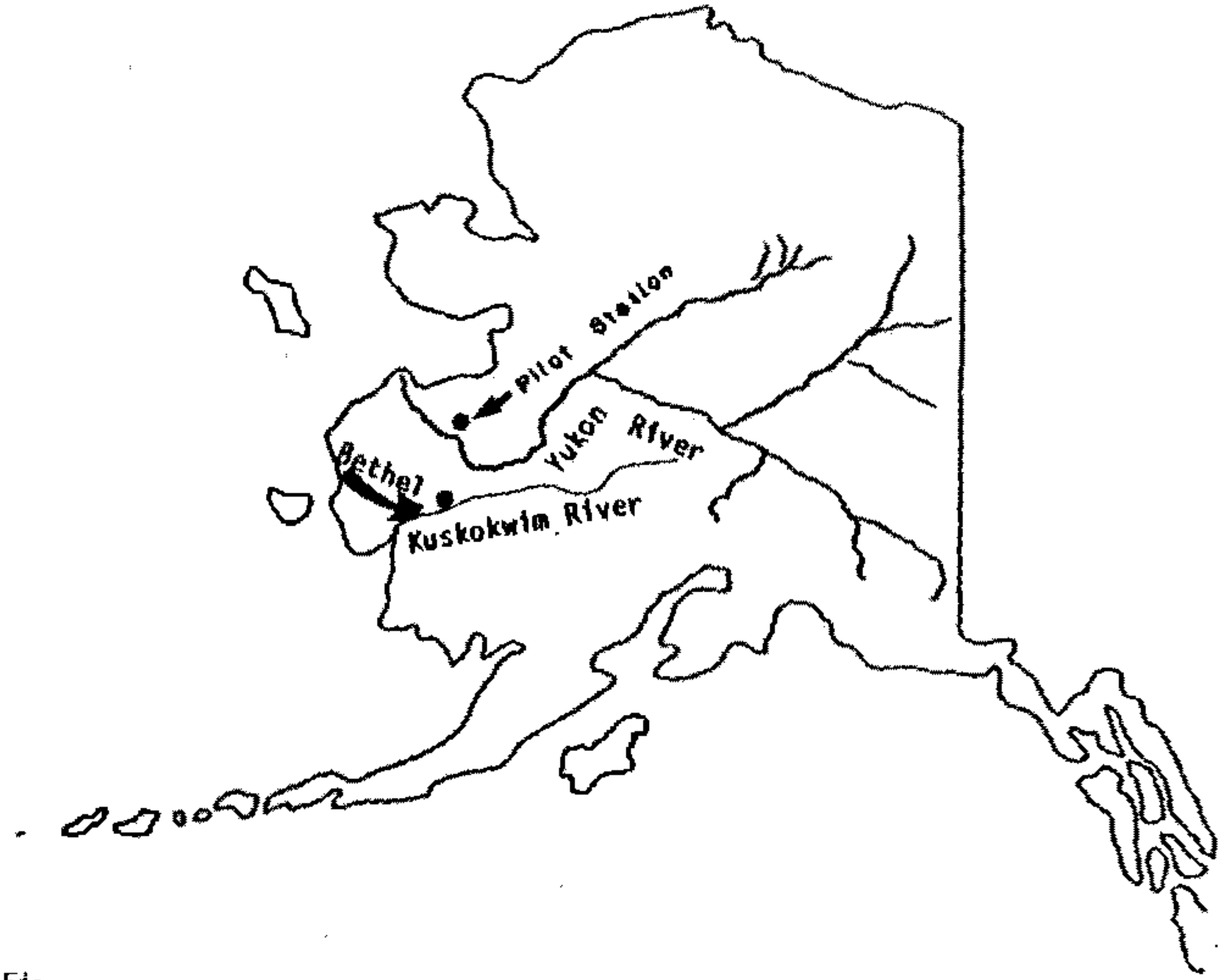

Figure 1. Location of main river sonar locations; Bethel, 1980 and 1981; and Pilot Station, 1982 and 1983.

The Bendix Corporation[1/] under contract to the Alaska Department of Fish and Game, developed a sonar unit in 1979 specifically designed to count adult salmon. The unit was termed "Acoustic Fan Scan Salmon Counter". Its operating characteristics are detailed in Appendix A.

A general purpose sonar system was developed by BioSonics, Inc.[2/] in 1978. The operating characteristics of this system are detailed in Appendix B.

The general purpose system differs from the fan scan unit in that transducers can be aimed at oblique angles to the river flow, providing change-in-range information on targets. A second difference is that processed signals of the change-in-range system can be recorded on a chart recorder whereas the shore based counter of the fan scan unit prints numerical counts. One of the major advantages of the change-in-range technique is that while enumerating fish, the system displays upstream swimming fish, boat noise, river noise and downstream moving targets as individually unique trace-types on echograms.

This report summarizes the evaluation of the fan scan unit within the introductory section. The major purpose of the report is to present results

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2/ Biosonics, Inc.
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of hydroacoustic research in the Yukon River in 1983 with the change-in-range sonar technique.

STUDY SITES AND FISHERY DESCRIPTION

Kuskokwim River:

The study site on the Kuskokwim River was 134 km (83 mi) upstream from the mouth, or 8 km (5 mi) upstream from Bethel (Figure 2). The overall wetted width (during high tide) of the river channel at this location was 675 m (2,215 ft.). A large sand bar interrupted this distance and extended nearly to the opposite shore. The resultant navigable width of the "U" - shaped channel was 230 m (755 ft.); maximum depth was 17 m (56 ft.). This site was used in 1980 and 1981

Fish Resources:

All five species of Pacific salmon are indigenous to the Kuskokwim River drainage: chinook (*Oncorhynchus tshawytscha*); sockeye (*O. nerka*), coho (*O. kisutch*), pink (*O. gorbuscha*) and chum salmon (*O. keta*). These are the species of primary commercial significance. Principal large non-salmon species found in the lower reaches of the main channel include several species of whitefish and cisco (Coregonus sp.), and occasional sheefish (*Stenodus leucichthys*.

Commercial Fishery:

The greatest amount of fishing effort and the largest commercial salmon catches occur from the mouth of the Kuskokwim River to 108 km) 174 miles upstream- which defines the boundaries of the District 1 fishery. Set and

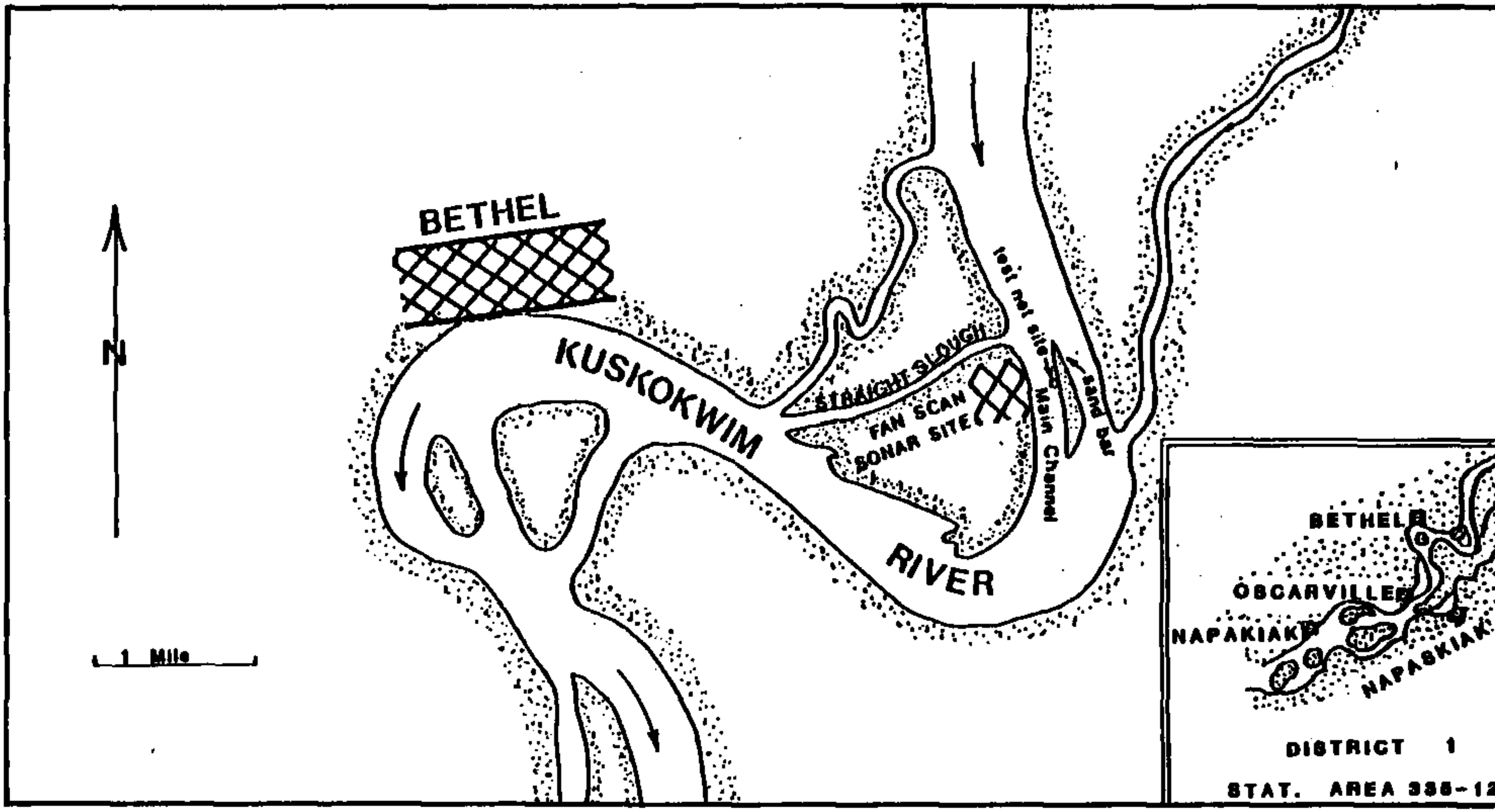

Figure 2. Location of the main river sonar site near Bethel, lower Kuskokwim River, 1980 and 1981.

drift gill nets are the legal types of commercial gear operated in the Kuskokwim River. Gill nets cannot exceed 50 fathoms in length. Nets are fished from open skiffs averaging 7 m (23 ft) in length.

Yukon River:

The study site on the Yukon River was 198 km (123 mi) upstream from the mouth, near Pilot Station (Figure 3). It is the narrowest reach of the main channel of the Lower Yukon River with stable banks. The profile of the channel is "/" - shaped and is not interrupted by islands. The site is within the zone of major commercial fisheries.

Most of the hydroacoustic interrogations done in 1982 were from the south bank, where the channel width was 580 m (1903 ft). The major emphasis during the 1983 season was conducted slightly upstream from the 1982 site, on the north bank. The channel width at this location was 670 meters (2198 ft).

Fish Resources:

All five species of Pacific Salmon are indigenous to the Yukon River drainage with chum salmon being the most abundant. It is estimated that chinook, coho, pink, and sockeye salmon follow in order of abundance. Principal large non-salmon species found in the lower reaches of the main channel include sheefish and whitefish.

Commercial Fishery:

Over 1931 km (1200 mi) of the Yukon River is open to commercial salmon fishing. Set and drift gill nets are legal types of gear in the lower river (from the mouth to 492 km (306 mi upstream); fishwheels are legal gear in the

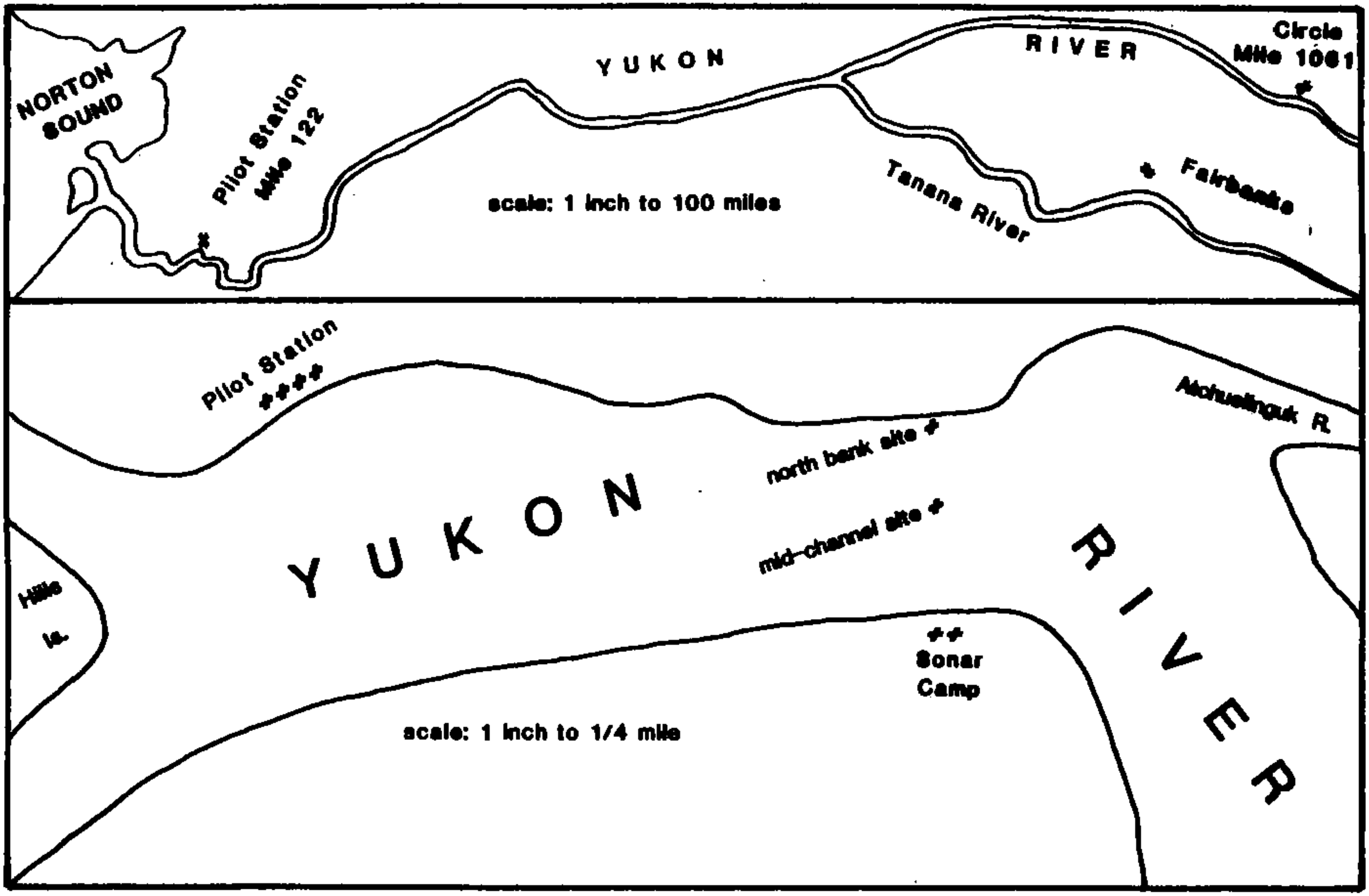

Figure 3. Location of the main river sonar camps and study sites near Pilot Station, lower Yukon River, June and July, 1982 and 1983.

upper river. Most fishermen operate small outboard powered skiffs, 5 to 6 m (16-20 ft) in length. Approximately 75 percent of the salmon are caught from the mouth of the Yukon River to 262 km (163 mi) upstream.

EQUIPMENT

Fan Scan Unit:

Transducers of the Fan Scan system were designed to operate on the river bottom and at a depth of at least 8 m. Each of the two transducers, spaced 15 m apart, scanned upwards in a fan-shaped pattern by sequentially transmitting 100 microsecond bursts of 300 KHz ultrasound from 32 individual ceramic elements for each of the 64 acoustic signals. The criterion to count as a fish was soley to exceed a predetermined voltage threshold. Numerical counts were printed out on a thermal paper tape from the shore-based echo processor.

Change-In-Range Unit:

The hydroacoustic data acquisition system consisted of a 420 KHz transceiver, a voltage thresholder, a chart recorder, one each 2°, 6°, and 10° transducer, a dual-axis rotator for transducer aiming and an oscilloscope for monitoring the system. The transceiver was a BioSonics model 101. It was selected because of its flexibility and long range capability. The high frequency (420 kHz) was chosen in order to keep the cost and size of transducers at a minimum (for a given transducer size, cost and size decrease with an increase in frequency). The high frequency also increases the target strength and allows the use of short pulse durations. Both of these features are desirable in riverine enumeration.

The chart recorder was the data collector. This was appropriate since fish were distributed such that they could be individually resolved. The chart recorder used was an EPC model 3200S.[3/] It was chosen because of its flexibility, and large paper size (19.2 inches (48.8 cm) wide) relative to other chart recorders. A threshold was placed before the chart recorder to allow only fish with a certain target strength to be displayed. This helped to achieve maximum clarity of the display.

Calibration data is presented in Appendix C. Table C-1 and figures C-1 and C-2. A wiring diagram is shown in Appendix Figure C-3. A schematic of the change-in-range unit is shown in Figure 4.

Background Of Fan Scan Studies:

Hydroacoustic assessment of adult salmon runs in the main channel of the Kuskokwim River was conducted with the Fan Scan unit in 1980 and 1981. Major problems encountered with the Fan Scan System in the Kuskokwim River are listed below.

1. Transducer cables were frequently caught on bottom debris. Stresses used to free the cables resulted in breakage or internal damage

2. The heavy silt load of the river made it necessary to retrieve and redeploy the transducer pods every 3 or 4 days to prevent burial of the

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[3/] EPC Labs, Inc.
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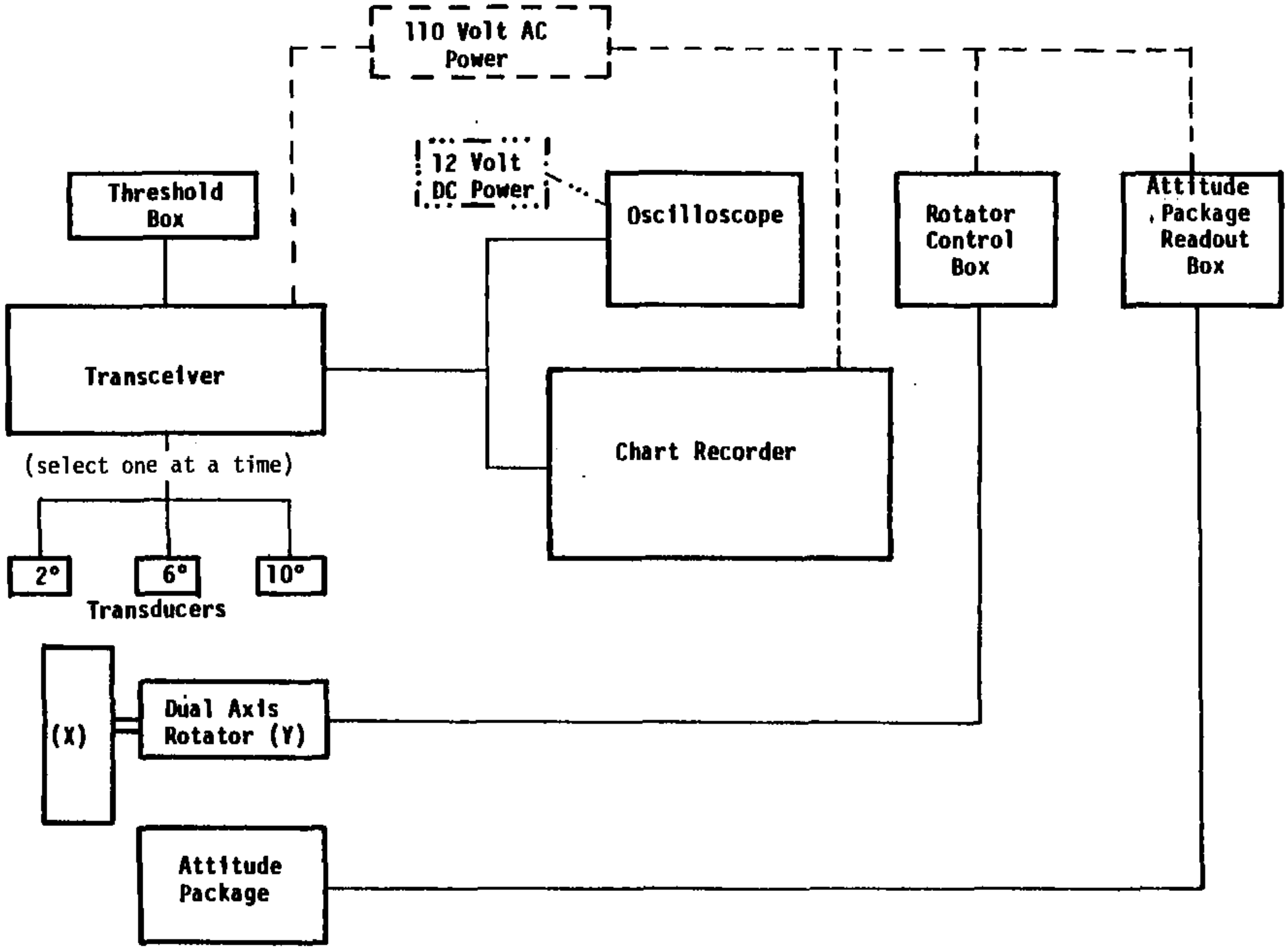


Figure 4. Multiple-hit sonar system block diagram showing the interrelationship of components and power supplies.

pods. When a pod did become buried, it was a very labor-intensive and time-consuming chore to free it.

3. A 1-2 m range in tidal fluctuation seemed to have had an adverse effect on the counting system. The question of whether higher counts observed during the low and lower high tide hours were due to actual increases in the numbers of salmon swimming upstream, or to increased drift carried by swifter currents was not fully answered during the initial two years of field study.

4. Malfunctions occurred when air bubbles became entrapped in the transducers and when there were breaks in the electrical cables.

5. The unit accumulated many counts as a result of boat engine noise, debris in the water column, wave action and rain. There was no way, after the fact, to determine which were caused by fish versus other factors.

6. Censoring the print-out counts (i e. subtracting suspect counts resulting from debris, engine noise, etc.) was a subjective procedure largely based on the intuitive judgement of the observer. Different observers censoring the same sets of data may or may not have used the same set of value judgements to accept or reject questionable counts.

Comparison Of Fan Scan And Change-In-Range Units:

Hydroacoustic feasibility studies were conducted in the lower Yukon River near Pilot Station (Figure 3) in 1982. A change-in-range (general purpose) system and the Fan Scan were used. The general purpose system consisted of an echo sounder-receiver, transducers, a dual axis rotator, and a Ross chart recorder.

The river was approximately 580 m wide at the counting location. There was no tidal effect, but there was a very strong eddy caused by high discharge. The intensity of the eddying currents varied considerably within any hour.

Only one transducer of the Fan Scan System was deployed because of concern that a near-shore unit would interfere with commercial drift nets. The transducer was deployed in 9 m of water, 126 m from shore. Maximum intensity of the eddy was in this zone.

The general purpose transducer was secured to the rotator. Transducer and rotator assembly were mounted on a tri-leg base and deployed in 2 m of water, 23 m from shore. It scanned sideways through the water column and was angled approximately 45 degrees downstream to detect directional movement (i.e. change-in-range) from target traces on the echogram

Counts displayed by the Fan Scan were associated with the intensity of the eddying currents; the greater the intensity the higher the counts and vice versa.

Echograms of the other system displayed the river noise and directional targets as uniquely different components of the processed signals. Echograms also showed that very few fish traces (upstream oriented) were in sampled sectors of the water column beyond 80 meters from shore. Therefore, it was concluded that most of the Fan Scan counts were a result of river noise.

Background Of 1982-1983 Change-In-Range Studies:

Most of the data collected in 1982 was from the south bank of the Yukon River. Information concerning the horizontal and diel distribution of adult salmon was obtained. The majority of counts were within 95 meters from shore. Hydroacoustic scanning of the water column from mid-channel revealed few fish targets, (i.e. one fish per four hours). No consistent trend in diel distribution was observed.

The general purpose sonar system was tested again in 1983 from the north bank of the Yukon River (Figure 3). A total of 33 days was spent in operation at this site (13 June to 15 July).

Objectives Of The 1983 Study:

The objectives were to determine the spatial and temporal distribution of adult salmon as well as the following key components: target strengths; swim speeds; arrival time (time between successive arrivals of fish entering the acoustic beam); and coefficients of variation of counts through time. All of these factors were needed to establish an enumeration program for the Yukon River.

METHODS AND PROCEDURES

River Profile:

Prior to the deployment of transducers into the water in 1982 and 1983, transects were run to determine the bottom profile at the site. A high degree of accuracy was needed, thus a method using a sextant and fathometer was devised (after Leveen 1979) to obtain the offshore distance for each depth reading. The method is detailed in Appendix D. Surface water current velocities were taken along the transects with a digital flow meter. Near-bottom river current velocities were estimated from a vertical-velocity curve (U.S.G.S. 1982). The 95% depth (distance below water surface in percentage of total depth) was chosen, because it left a lower velocity stratum of water beneath it that allowed for fish passage.

Deployment Procedures:

After the bottom profile was made, a site was selected at which to deploy the transducer pod. A wooden frame (Figure 5) was built for deployment and retrieval of the pod (Figure 6). The frame was secured within a 6.4 m(21 ft) skiff. A tag-line attached to the transducer pod was used to raise and lower it by passing the line through two snatch blocks. Power was supplied by a hydraulic gurdy mounted near the bow of the skiff.

The two rear legs of the transducer pod were hinged and had spring-loaded self-locking mechanisms. Depending upon which side of the skiff deployment was made, the inboard rear leg was folded up to avoid contact with the skiff and minimize the distance that the pod was slung from the skiff.

An underwater release hook was used to lower the pod to the bottom and release it. The tagline was buoyed to prevent entanglement with the transducer and rotator. A heavy nylon line was tied to the upstream oriented leg of the pod and ran to shore where it was secured to a tree.

The three legs of the pod rested on the bottom. Transducers were mounted on

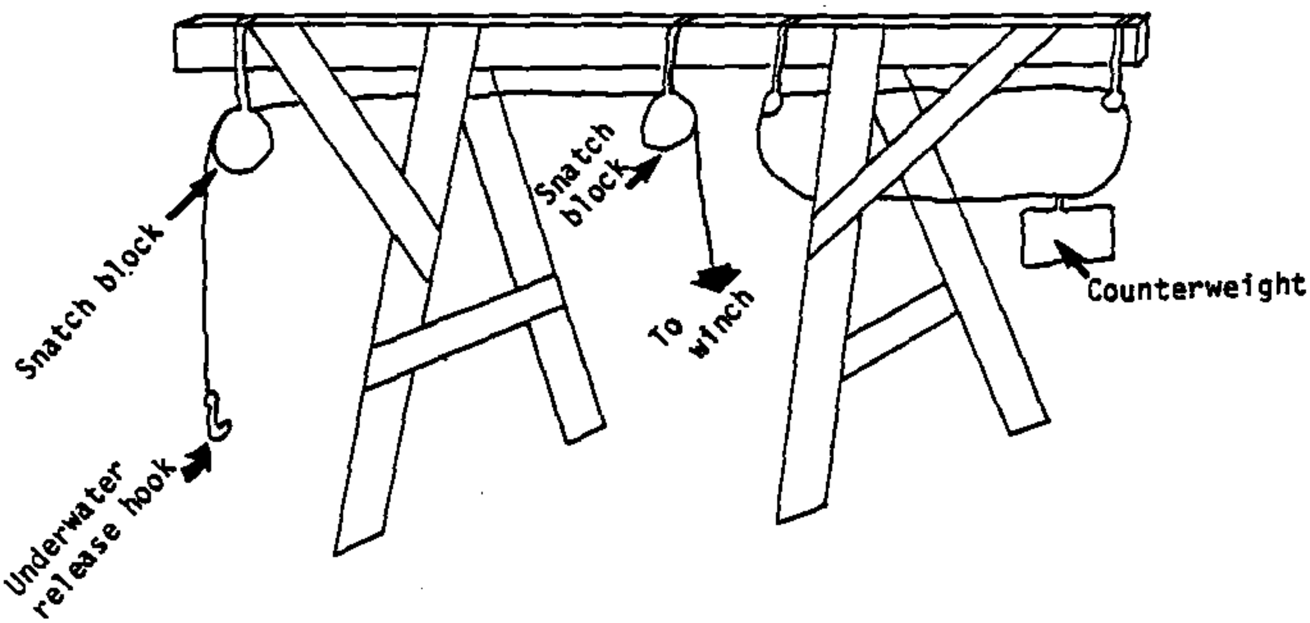


Figure 5. Illustration of the boat crane used to deploy and retrieve the transducer pod assembly.

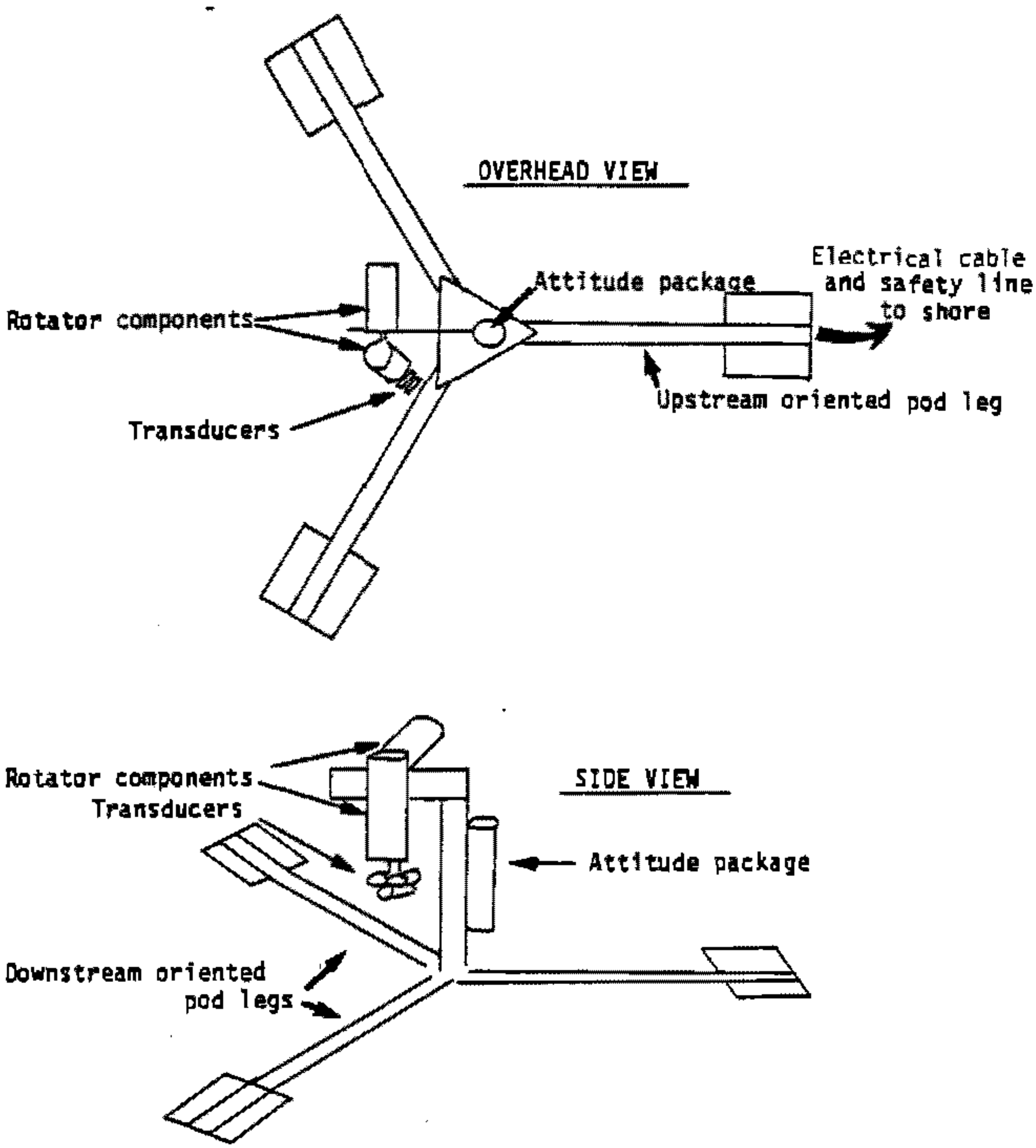


Figure 6. Illustration of the sonar pod. The three legs lay flat upon the bottom.

the rotator so that they were scanning sideways. The transducers were rotated on the horizontal axis to face about 45° downstream. This was done to achieve the change-in-range effect.

Change-In-Range:

Sonar beams were fitted into the vertical dimension of the water column and objects surpassing a threshold voltage were recorded as traces on the chart recorder echogram. These acoustic signals scanned the near shore and off shore regions. The signals differed in (area coverage) size according to the beam width of the transducer used. Profiles of the river made previous to transducer deployment allowed careful positioning of the acoustic beams. Conceptual diagrams of beam fitting are presented in figures 7 and 8.

By aiming the main axis of the transducer downriver, fish moving upstream were displayed as long to short traces on the echogram (Figure 9). That is to say, they entered the sonar beam at a certain distance from the transducer and exited the beam at a distance that was closer to the transducer. Conversely, objects moving downstream through the acoustic screen were displayed as short to long traces (Figure 10).

Environmental Observations:

Daily environmental observations were recorded. These included air and water temperature, wind direction and velocity, wave height, total observed sky cover, precipitation, surface water velocity, as well as water level data. The format is shown in Appendix E.

River Height:

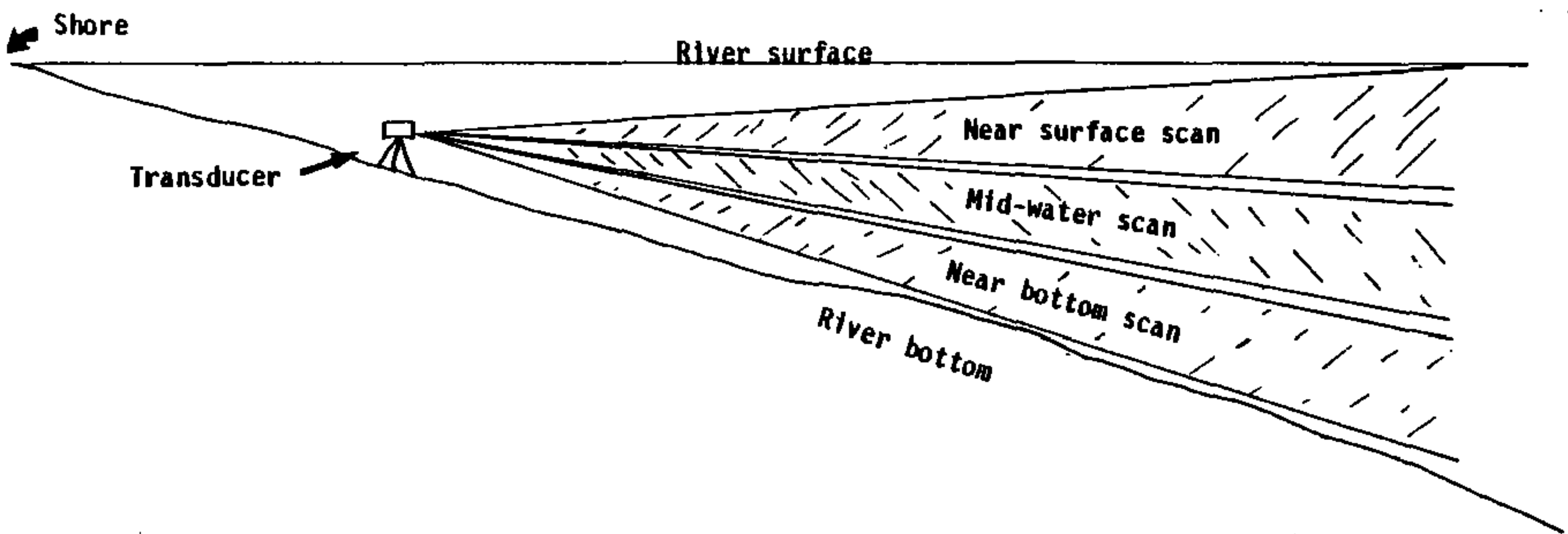


Figure 7. Rotation of the 2° transducer for determining the vertical distribution of salmon. North bank, lower Yukon River, near Pilot Station, 1983.

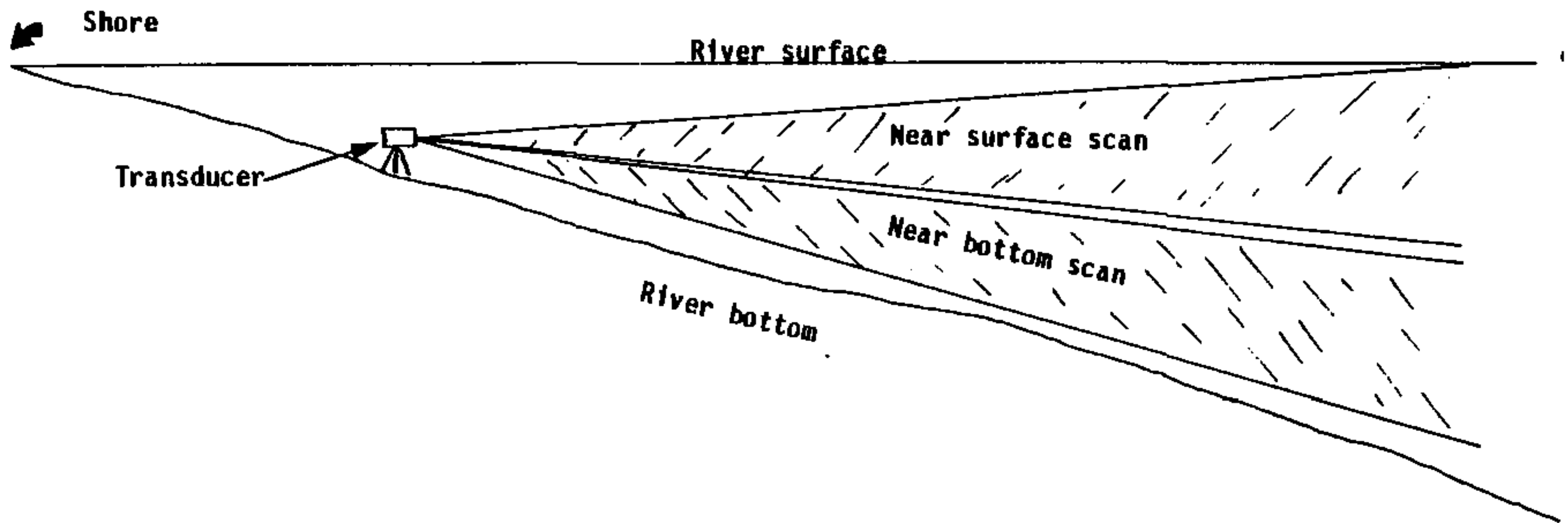


Figure 8. Rotation of the 6° transducer for determining the vertical distribution of salmon. North bank, lower Yukon River, near Pilot Station, 1983.

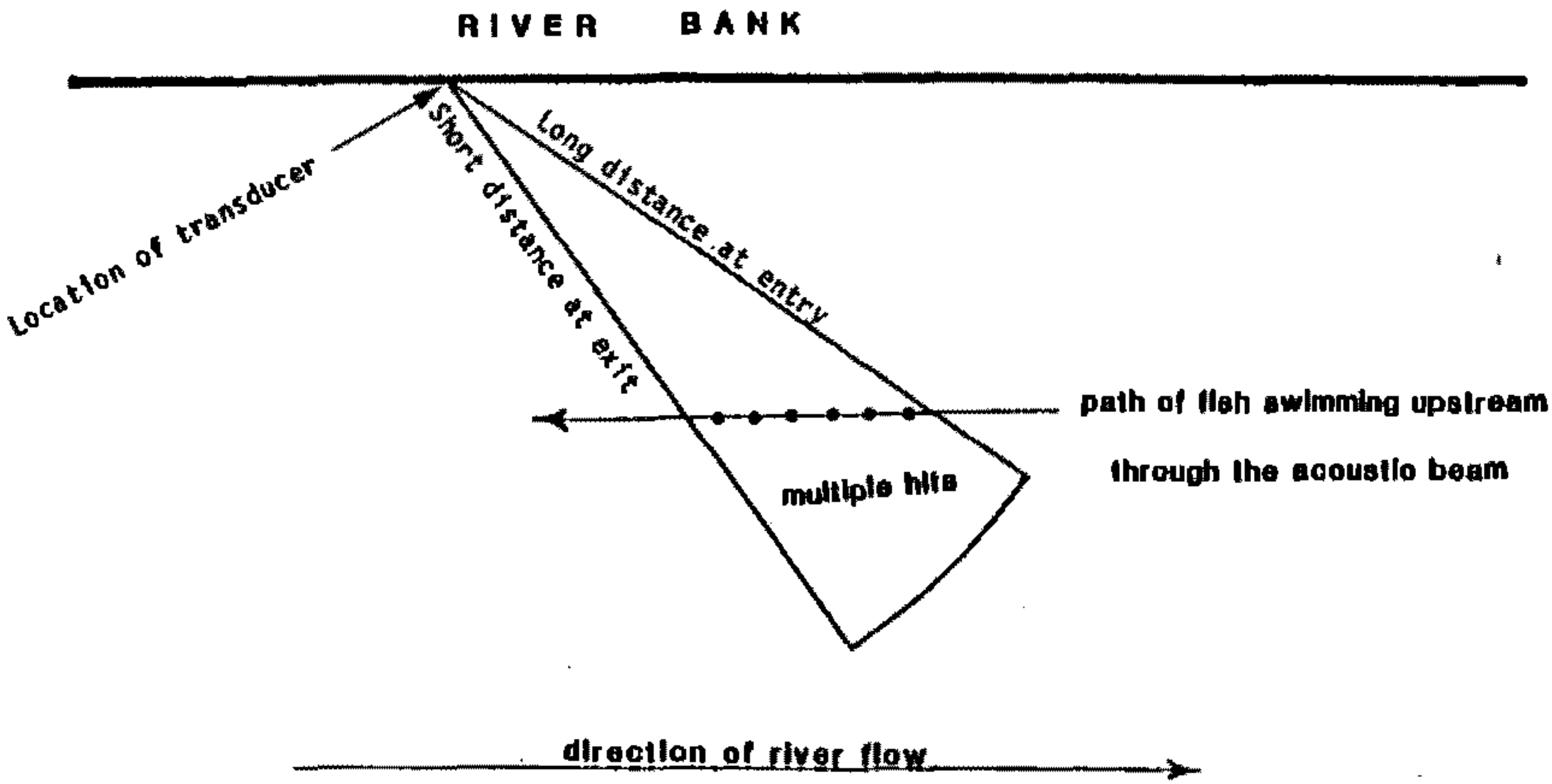
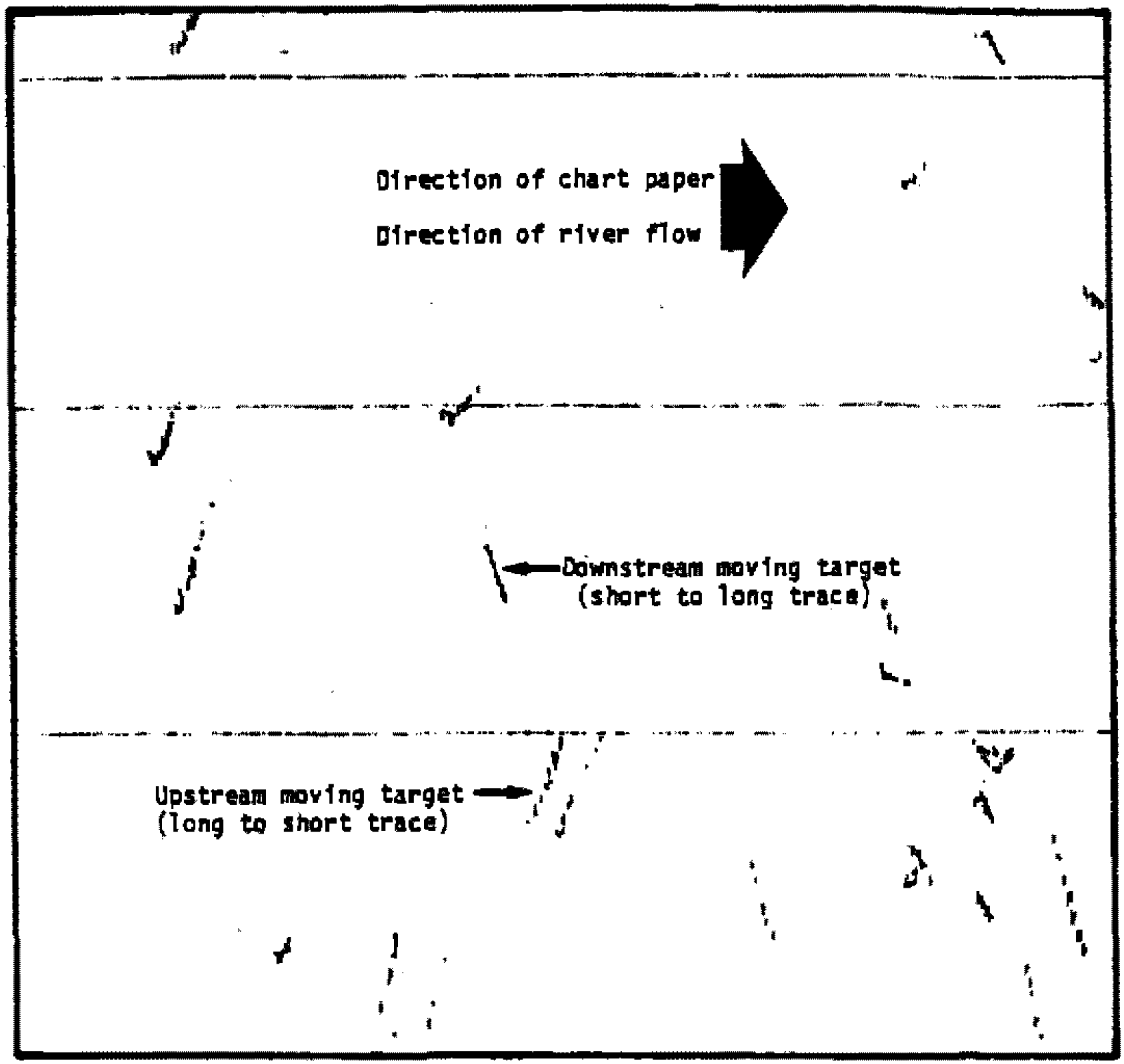


Figure 9. Illustration of a fish swimming upstream through the acoustic beam. It is being hit a multiple of times by the acoustic signal. The fish enters the long axis of the beam and exits through the short axis, leaving a "long-to-short" directional trace on the echogram. (After Acker and Hendershot, 1979).



Location of transducer

Figure 10. Echogram showing upstream (long-to-short) and downstream (short-to-long) moving targets.

A daily record was kept of the water level of the river. A stake was set at the shoreline on the first day at the campsite. Nylon twine was tied tightly around the stake. Distance from the twine marker to the water level served as the zero or starting level. Successive measurements were added to or subtracted from this distance. A hand level was used to determine changes in water level over horizontal distances from the original stake and marker.

<u>Data Acquisition</u>:

Data collection began on 21 June and continued through 15 July. except for 3 days due to equipment failures. The sampling interval was one hour; that is, the time duration from the start of one set of sampling periods to the start of another set. Each sampling period was 15 minutes long and was unique in the region that was insonified and/or the transducer used. As many as three periods per hour (sampling interval) were sampled.

System status information that was recorded on the chart paper at the beginning of each sampling period is presented below.

Date
Location
Operator
Time of day: from to
Chart recorder channel
Chart recorder paper speed
Transducer
Rotator aiming angle: X = Y =
Sounder: Transmit power (dB)
Receiver gain (dB)
Pulse width (ms)
Band width (kH3
Blanking distance (m)
Range setting (m)
Separation (m)
Threshold: (Volts)

The remaining time after sampling was used to log data and perform maintenance.

Sampling periods (15minute blocks of time) were selected throughout the study for detailed analysis of horizontal, vertical, and hourly distribution, time between successive arrivals, the optimum duration of the sample period, and fish swimming speed. Data collected from echograms for these periods included the following:

1. Distance offshore at which the fish entered the beam.

2. Distance offshore at which the fish exited the beam.

3. Angle of the trace that the fish left on the paper relative to the zero line.

When the above-listed information was matched with chart size, chart speed, and range displayed, the total time that the fish was in the beam was also calculated. With this information, the time between the entrance of each fish into the beam was calculated.

All reported distances offshore were perpendicular to the shoreline. They were corrected from slant range by the formula:

$$D_{ji} = \left(\frac{d_{ji}}{487.5}\right)\left(T_i\right)\left(750\right)\left(\cos\left(\Phi + (0.5)\ \alpha\right)\right)$$

where corrected: D_{ij} = Offshore distance (in meters) for the j th fish in the ith period.

d_{ij} = The distance in mm from the zero line on the chart recorder to the first mark left by the fish.

T_i = Chart recorder time base in seconds during period i.

Φ = The angle (degrees) at which the transducer was aimed upstream or downstream relative to a line drawn perpendicular to the shoreline.

α = Beamwidth used (degrees)

487.5 = Chart recorder paper width (mm).

750 = round trip velocity of sound in m/sec.

Horizontal Distribution:

Corrected offshore distances (D_{ij}) were grouped into 5 meter strata. The number of detections were normalized to compensate for the effect of beam spreading; that is, the area of the acoustic beam increases with distance. Areas included in each 5 m interval were calculated by the formula:

****

$$A_n = \left[(.5\, r^2 n) \frac{\alpha \pi}{180} \right] - \left[(.5 r^2\, n\text{-}1) \frac{\alpha \pi}{180} \right]$$

where:

A_n = Area (m^2) within sector n.

r_n = Distance in meters from the transducer to the outer edge of sector n.

α = beam width in degrees.

Normalizing constants for each sector were then found by:

$$C_n = \frac{A_1}{A_n} \qquad 10$$

where:

C_n = Normalizing constant for sector n.

A_1 = Area in m^2 for sector 1

A_n = Area in m^2 for sector n

Norma..izing constants are presented in Appendix F, tables F-1 and F-2.

Vertical Distribution:

Vertical distribution of upstream migrants was examined. Data were collected during sampling periods when bottom, middle, and surface regions (strata) were interrogated consecutively over a series of sampling intervals. The number of upstream migrants in each statum was averaged over the number of periods sampled.

That is:

$$N_{ij} = \frac{C_{ij}}{P_{ij}}$$

where: N_{ij} = Average number of upstream migrants detected in stratum i during interval j.

C_{ij} = Number of upstream migrants in stratum i during interval j.

P_{ij} = Number of periods sampled in stratum i during interval j.

Diel Distribution:

The time of day of upstream fish movement was examined to determine whether there was a consistent daily pattern of fish migratory behavior. Hourly counts were normalized by making the highest hourly count of each day equal to 1.0 and then calculating normalized counts as:

$$N_{ij} = \frac{C_{ij}}{H_j}$$

where: N_{ij} = Normalized count of upstream migrants in period i on day j.
C_{ij} = Count of upstream migrants in period i on day j.
H_j = Highest count on day j.

The normalized data were then plotted by hour of day as a scattergram.

Sampling Time Analysis:

The objective was to determine the minimum length of time in minutes of the basic sampling unit. This unit is the amount of time spent using a single transducer to cover a single specific stratum.

Echogram data were analyzed by using the coefficient of variation (C.V.).

This statistic is used to express the standard deviation as fraction of the mean, measuring relative as opposed to absolute variability. It is defined C.V. = 100 $s/_x$, where:

s = the standard deviation

$\bar{X}$ = the mean.

The standard error of the coefficient is defined as:

$$S.E._{C.V.} = \frac{C.V.}{\sqrt{2n}} \sqrt{1 + 2 \left(\frac{C.V.}{100}^{2} \right)}$$

Sampled time blocks on echograms were divided into 3-minute periods for interrogations conducted with the 2° and the 6° transducers. The 2° transducer interrogated three strata of the water column: near-surface, mid-water, and near-bottom, while the 6° transducer scanned only the mid-water stratum.

Upstream oriented targets were enumerated for each 3 minute period. Eighty 3-minute periods were sampled with the 2° transducer, covering 7 hours during 2 and 3 July 1983. Seventy-nine 3 minute periods, were sampled with the 6° transducer, for a total of 9 hours on 25 June and 10 hours during 2 and 3 July.

Coefficients of variation were determined for 3 to 30 minute time blocks in 3 minute steps. That is, 3 minute periods were combined to form 6 minute periods, again to form 9 minute periods, etc.

<u>Arrival Time Analysis</u>:

The objective was to classify the spacing of fish as random, regular, or contagious, by measuring the time between successive arrivals of upstream migrants from echogram traces. The chart speed of the recorder was known, so the distance between targets was converted to time in seconds.

Arrival time density was classified as low, medium , and high. Each arrival time density distribution was compared with a Poisson distribution and subjected to a Chi-square goodness-of-fit test for agreement.

The purpose of fitting a Poisson distribution to numbers of rare events in nature is to test whether the events occur independently with respect to each other (Sokal and Rohlf 1969). Agreement with a Poisson distribution is the accepted test for randomness (Elliott 1971). Although no tests can prove randomness, agreement with a Poisson distribution means that the hypothesis of randomness is not disproved (Elliot op. cit.).

How a population is dispersed spatially and temporally determines the relationships between the variance (02) and the arithmetic mean (u) as indicated below (Elliot op. cit):

(1) Random distrtibution: variance is equal to the mean,

(2) Regular distribution: variance is less than the mean,

(3) Contagious distribution: variance is greater than the mean.

<u>Transducer Aiming:</u>

Target strength and swim speed analysis were dependent upon the downstream angle of the acoustic axis of the sonar beam. Angular positions were determined by placing the transducer pod on the beach and orienting it in the planned deployment attitude. The transducers were aimed straight across the river (perpendicular to the shoreline) and angular coordinates were read from the dual-axis rotator control box, which provided a reference for all other aiming positions.

<u>Target Strength</u>:

Target strength is a measure of the amount of energy reflected relative to the amount of energy incident on the target. Formal definition is covered in Burczynski (1979). The target strength of an individual fish at a given frequency is a function of the fish's position in the beam and the angle at which the fish presents itself referenced to the acoustic axis (center of the beam). Target strength is an important parameter for consideration during any hydroacoustic study since the mean target strength will aid in the selection of an efficient threshold to allow the clearest chart presentation and estimation of the effective transducer beam angle.

The procedure used was the indirect technique for estimation of the mean acoustic back scattering cross section (Ehrenberg, et al. 1981). The procedure needs only to have peak echo voltages from each fish during the sampling period, and system calibration information. Peak echo voltages were read off of an oscilloscope screen by technicians at various periods throughout the season and tabulated into distributions (Appendix Tables G-1 to G-4). The peak of the distribution is then chosen as a minimum acceptable voltage (E_{min}) and all subsequent voltages (E_j) are divided by this (Ej/Emin 1). The peak of the distribution is chosen as E_{min} so as to eliminate bias by recording only those signals greater than the background noise (Wiemer and Ehrenberg, 1975). The statistic E^2 is then calculated as follows:

$$\tilde{\hat{E}} = \frac{1}{N} \sum_{j=1}^{N} (E_j/E_{min})^2, \text{ where } E_j/E_{min} \geq 1$$

Using curves provided in Ehrenberg, et al., the corresponding value of A is found, where A is the amplitude of the scattering cross-section. Finally, the mean target strength is found by:

$$\overline{TS} = 10 \log \frac{A^2 E^2_{min}}{C^2}$$

Where C is a constant determined during system calibration. That is, C = SL + G x + P + G - 40 log R

where: SL = Source Level
Gx = Through system gain
P = Transmit power setting
G = Receiver gain setting
R = Range (m) setting during calibration

Target strengths were calculated for four different periods Appendix H. Maximum target strength occurs when the side aspect of the fish is perpendicular to the acoustic axis; this is the normal reference point. Therefore, the initial target strength estimates had to be corrected for the mean fish approach angle to the acoustic axis during sampling periods in order to estimate fish swimming speed. The mean off-axis angle, for each period, is listed in Appendix Table H-1.

Dahl (1982) measured and plotted smoothed mean target strength as a function of off-axis angle for a number of insonifications of one each 40 cm, 52 cm, and 61 cm salmonids. We used one of these plots in which the drop in dB from the maximum fish target strength was displayed at 10 degree intervals. The data, derived from Dahl, are presented in Appendix Figure H-1. A linear regression of these data, in the form:

$Y = a + bX$

where: Y = drop in dB from maximum target strength
a = intercept
b = slope
X = angle (degrees) from perpendicular to side aspect provided a correction factor for the approach angle.

The regression equation is:

$$Y = -0.10788 - 0.24034X$$

$$R^2 = 0.944$$

This equation serves as a means of estimating the corrected off-axis angle of fish swimming upstream through the acoustic screen.

Swimming Speeds:

Fish swimming speed was used to evaluate the size of the beam, the pulse repetition rate and chart speed needed to best identify fish. Swim speed can also be used to estimate residence time for total abundance estimation (Clark and Clark 1983).

For example, if the average swim speeds for chinook and chum salmon, respectively, are known for the lower reaches of the Yukon River (i.e. in commercial fisheries management districts Y-1, Y-2, and Y-3), then the elapsed time that a pulse of one, the other or both species will remain in the respective districts can be estimated. This information, coupled with abundance estimates expanded through time, and estimates of commercial and subsistence harvest, may provide instantaneous rates of fishing mortality and escapements partitioned by fishing district.

Representative periods were selected over a number of days. Fish speeds were calculated for 21, 23, 25, 27 June and 2 and 3 July 1983. The procedure for determining swim speed is presented in Appendix I. A computer program, written in BASIC, for calculating fish swimming speeds is presented in Appendix J. This program uses the methods and procedures outlined in Appendix I.

Abundance Estimates:

A 15 minute period each hour (occasionally one period every other hour) was used to estimate rate of fish passage. Counts were expanded to give a mean count per hour, and these in turn were expanded to give 24 hour counts.

A power curve of the form Y=axb was fitted to horizontal distribution data from 22 June and 2 July for strata 2 to 6 (i.e. 5 to 29.9 m). Curve values were converted to cumulative proportion by 5 meter intervals as measured from the transducer (Table 1). This provided an empirical model for use in expanding counts.

Areas of acoustic beams were determined within sampled zones by the formula:

****

$$A = (.5r^2) \frac{\alpha\pi}{180}$$

where: r = Distance in meters from the transducer.
= Beam width in degrees.

Areas of the sampled zones were determined from river profile data, which were reduced to standard geometric components. Areas of the components were summed for sampled zones.

Table 1. Proportion of targets counted by range in 5 meter intervals from the transducer to 59.9 meters straight-range distance toward mid-channel. 1

	Range From Tansducer toward Mid-Channel									
	0-4.99	5-9.99	15.19.99	20-24.99	25-29.99	30-34.99	40-44.99	45-49.99	50-54.99	55.59.99
Proportion	.85436	.08095	.01315	.00767	.00499	.00349	.00196	.00154	.00125	.00102
Cumulative	.85436	.93531	.96237	.97552	.98319	.98818	.99166	.99773	.99898	1.00000

1/ Data source: 6^{o} transducer; horizontal distribution; 6/22/83 at chart recorder second/sweep = 1/4; and 7/2/83 at chart recorder second/sweep = 1/

2/ Power curve: $Y = a x^{b}$ where
Y = estimated proportion by stratum
a = 6380.99432, regression coefficient
x = stratum mid-point
b = 2.14502, regression coefficient
$R^2 = 0.975$

3/ Tranducer deployed 24 m from north bank shore at a depth of 2.5 m.

Both upstream moving targets and downstream moving targets were detected within the insonified zone. Verification of dual directional movement of salmon was provided with a set gill net. The procedure that we followed was to subtract downstream moving targets from upstream moving targets for each sampling period.

Daily abundance estimates were determined by the following formulas:

$$\hat{T} = \frac{(S/B)\ E}{\Sigma p}$$

where: $\hat{T}$ = Estimated number of fish per 24 hours.
S = Total area sampled (m^2).
B = Area of acoustic beam (m^2).
$E = 24\ (\hat{X}_k)$, the unweighted count expanded for 24 hours.

$$\bar{X}_k = \frac{\sum_{j=1}^{N} X_j}{N}(4)$$

, the estimated mean number of counts per 15 minutes expanded to 1 hour.

Σp = cumulative proportion weighting factor obtained from Table 1.

RESULTS AND DISCUSSION

River Profile:

Data from a 40° slant range transect (i.e. looking 40° downstream from perpendicular to the direction of river flow) were used to determine areas of insonified zones. Slant range distances along this transect were converted to straight off-shore distances. The resultant profile of this transect is depicted in Figure 11.

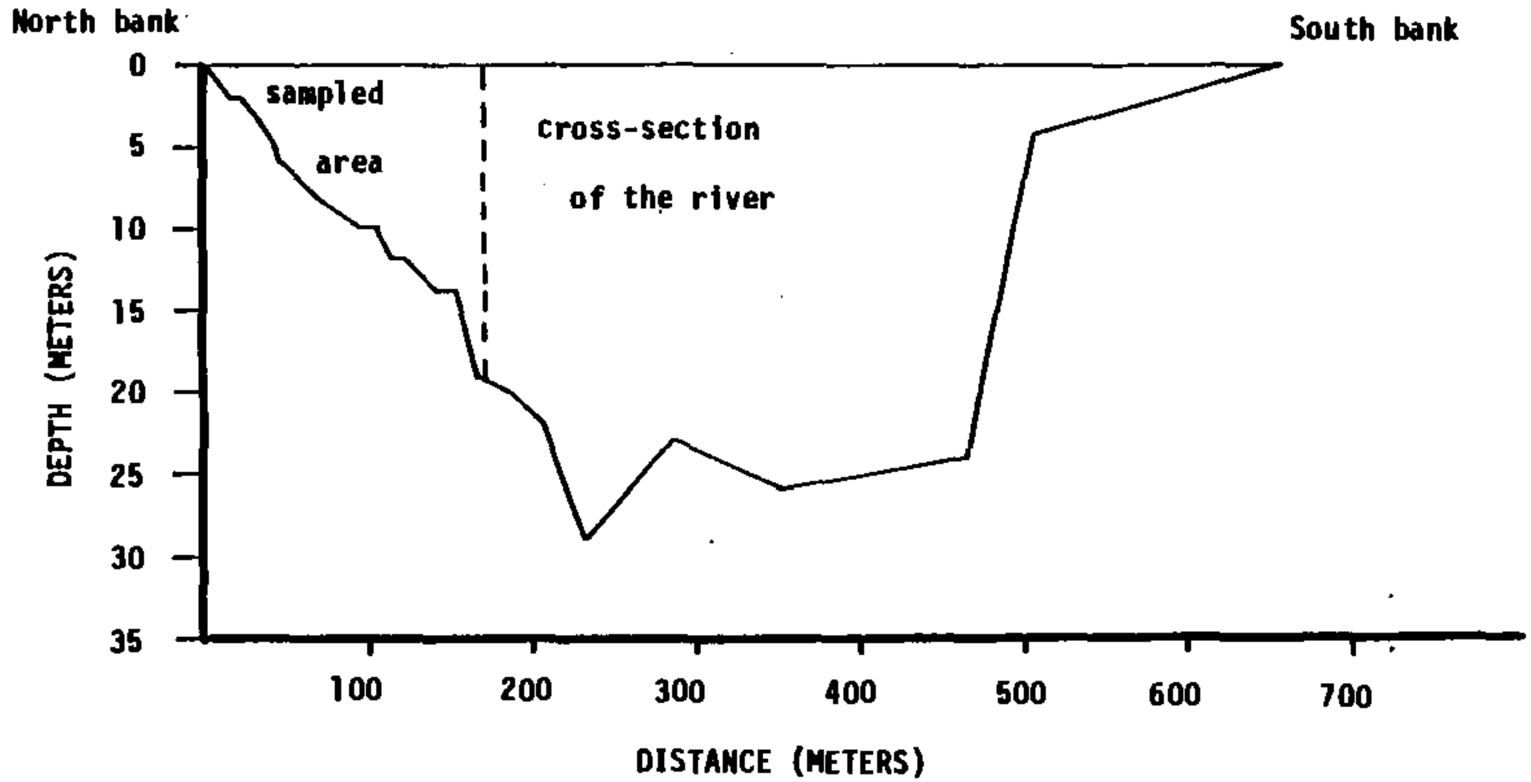


Figure 11. Straight range profile of the Yukon River, near Pilot Station, converted from a 40° slant range transect based from the north bank sonar site. July 1983.

The maximum distance from the transducer that was sampled was 250 meters (820 feet) slant range or 150 m (492 ft) straight range distance. The transducers were deployed 24 m from shore, so the maximum straight-offshore distance sampled was 174 m (571 ft).

River Height and Surface Velocities:

The water level of the Yukon River fluctuated to a large extent from late May to mid-July 1983. The record of water levels is presented in Figure 12. Surface velocities are listed in Table 2.

The water level dropped 46 cm (18 in) from 30 May to 6 June, then it rose 119 cm (47 in), reaching a peak on 17 June. Water levels declined thereafter by 163 cm (64 in), reaching a low on 2 July. The water level rose and fell within a 9 cm (3.5 in) range from 2 to 15 July. The sonar pod was not deployed from the south bank in 1983, because of a building sand bar and fluctuating water level.

Surface water velocity apparently affected the frequency of occurrence of salmon counts in near-shore versus off-shore zones. This subject will be discussed further in the following section.

Horizontal Distribution:

The maximum straight offshore distance that an upstream moving target was detected, was 84 m (or 60 m from the transducer, which was located 24 m from

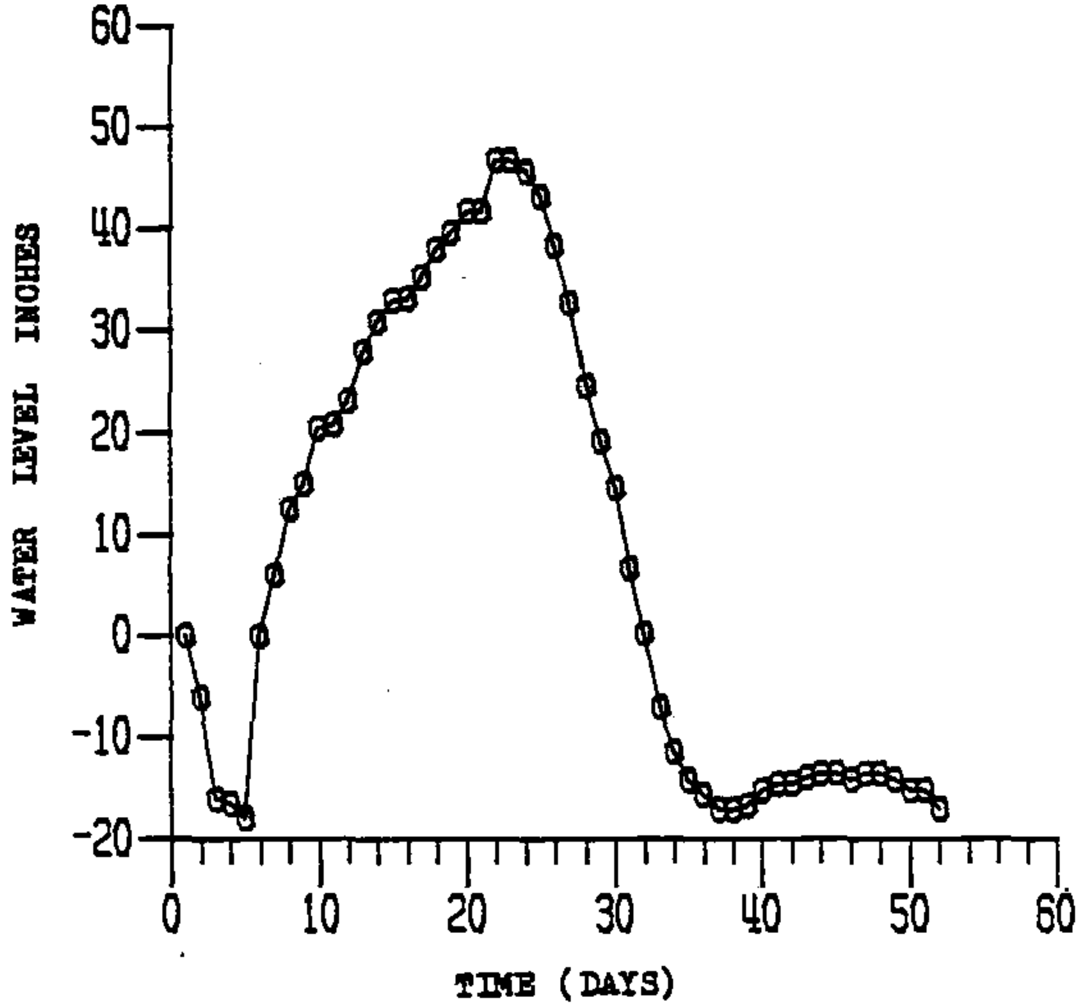


Figure 12. Measured fluctuation of the water level; lower Yukon River, near Pilot Station from 30 May to 16 July 1983.

Table 2. Depth, distance, and surface water velocities collected along a 40° transect, looking downstream from the north bank sonar site, lower Yukon River, near Pilot Station. Slant range was converted to straight-offshore range (i.e. perpendicular to the shoreline). The transect was run from 30 June to 1 July 1983. Earlier surface velocity measurements were collected on 18 June 1983 as noted.

	Station	Depth m.	Straight range m.	$\bar{X}$ water vel. cm/sec	Std. dev. water vel.
South bank	1	0.00	655	------	------
	2	4.27	506	53.67	5.[illegible]
	3	23.77	462	119.00	11.[illegible]7
	4	26.21	351	145.33	11.7[illegible]
	5	23.47	260	134.00	7.[illegible]
	6	26.65	233	166.33	15.[illegible]
	7	21.95	206	133.33	11.[illegible]
	8	19.51	185	149.33	.[illegible]
	9	16.59	167	142.33	[illegible].02
	10	14.33	152	155.00	[illegible].17
	11	13.72	141	143.67	[illegible].04
	12	13.11	131	143.33	10.12
	13	11.89	123	------	------
	14	11.58	115	130.67	5.06
	15	10.36	103	126.00	4.39 *
	16	9.75	96	131.33 *	11.7[illegible] *
	17	8.23	66	115.00 *	15.[illegible] *
	18	5.79	45	63.33 *	21.[illegible] *
	19	5.18	43	------ *	------ *
	20	4.88	40	------ *	------ *
	21	4.27	37	------ *	------ *
	22	3.66	34	------ *	------ *
	23	3.05	30	------ **	------ **
	24	2.13	24	------ **	------ **
	25	1.83	18	------ **	------ **
	26	1.52	15	------ **	------ **
	27	1.22	12	------ **	------ **
	28	0.61	6	------ **	------ **
	29	0.30	3	------ **	------ **
North bank	30	0.00	0	------	------

* Surface water velocity in this region on 6/18/83 were 155.00 ± 15.76 cm/sec

** Surface water velocity in this region on 6/18/83 were 50.40 ± 11.[illegible] insonified zones. Slant range distances along this transect were converted to straight off-shore distances. The resultant profile of this transect is depicted in Figure 11.

The maximum distance from the transducer that was sampled was 250 meters (820 feet) slant range or 150 m (492 ft) straight range distance. The transducers were deployed 24 m from shore. so the maximum straight-offshore distance sampled was 174 m (571 ft).

River Height and Surface Velocities:

The water level of the Yukon River fluctuated to a large extent from late May to mid-July 1983. The record of water levels is presented in Figure 12. Surface velocities are listed in Table 2.

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Surface water velocity apparently affected the frequency of occurrence of salmon counts in near-shore versus off-shore zones. This subject will be discussed further in the following section.

Horizontal Distribution:

The maximum straight offshore distance that an upstream moving target was detected, was 84 m (or 60 m from the transducer. which was located 24 m from shore). Results obtained in 1982 from the south bank of the river, where indicated that virtually all fish targets were detected within 93 m from shore.

The maximum straight-offshore distance that a non-directional target was detected in 1983 was 113 m. The maximum straight range distance from the transducer that was sampled, was 150 m, given a 53° downstream aiming angle. This corresponds to a slant range distance of 250 m (note that the maximum range of the BioSonics Model 101 transceiver was factory set at 250 m).

The distinction between "straight-offshore distance" and "straight range distance from the transducer" is a matter of how far the transducer is from shore. For example, a transducer is deployed 10 m offshore and aimed 30° downstream. A target is seen at 50m along this aiming angle; this is the slant range distance. The cosine of aiming angle multiplied by 50 m equals the straight range distance, 43 m, from the transducer. The transducer is 10 m from shore, so the target's straight offshore distance is 53 m.

The frequency of fish occurrence was higher near the transducer (near shore) and decreased with distance offshore. Surface current water velocity increased with distance from shore. Horizontal distribution data collected with the 2 degree and the 6 degree transducers at various ranges through time are presented in Figures 13 to 18.

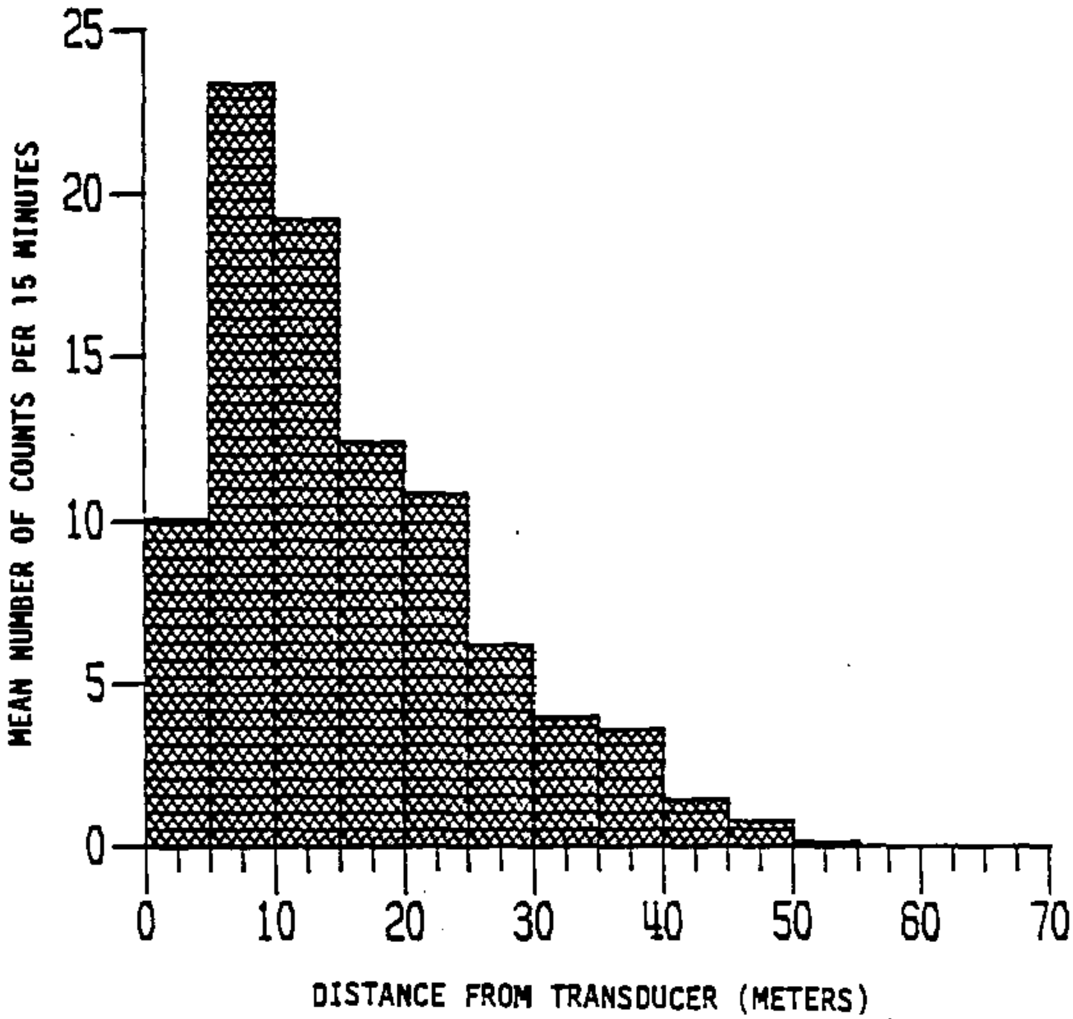

Figure 13. Horizontal distribution of adult salmon observed from the north bank sonar site. Normalized mean values of the frequency of occurrence by stratum. Sample size = five 15-minute periods from 0600 to 1030, 22 June 1983. Collected with a 6 degree transducer at 1/4 second/sweep of the EPC chart recorder (pulse repetition rate = 4); sampled range = 138 m. Mid-water scan. Lower Yukon River, near Pilot Station.

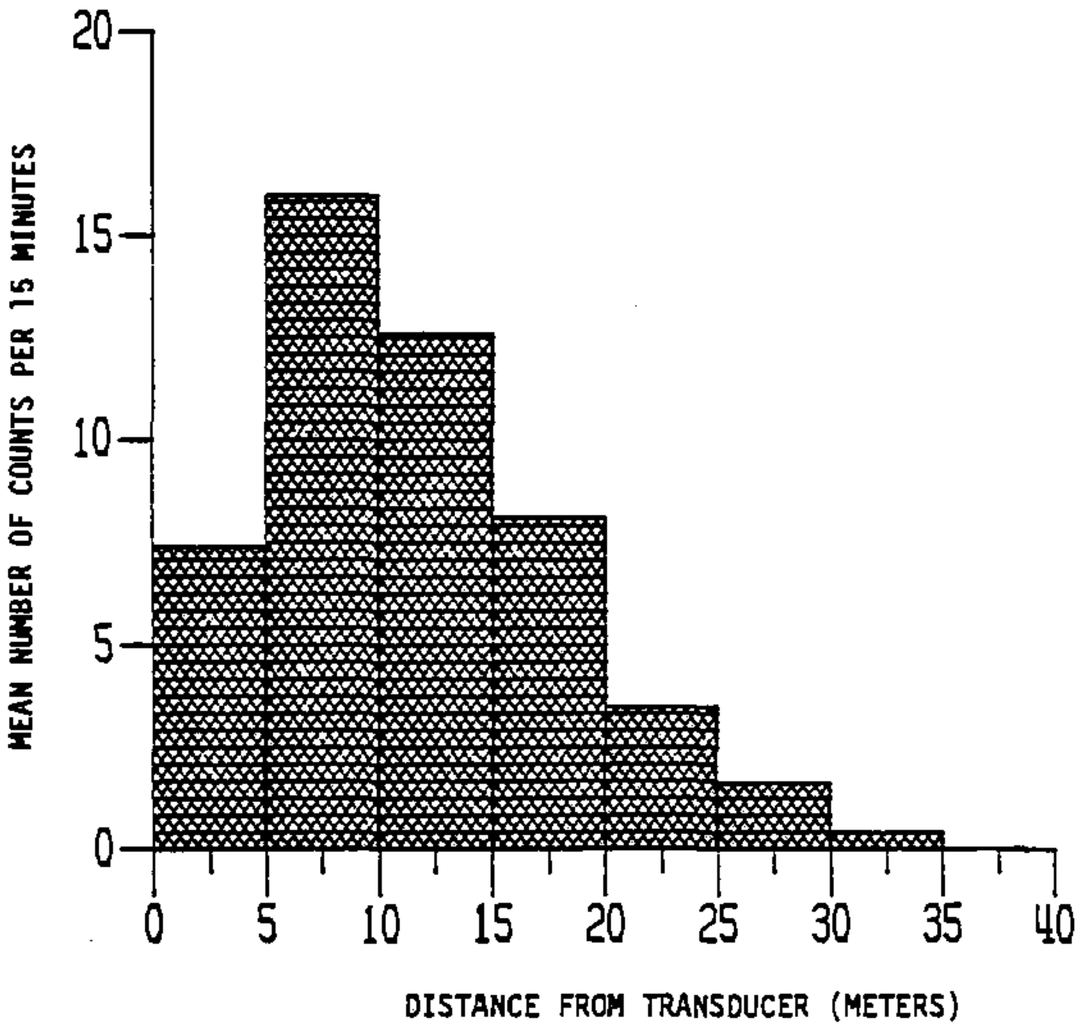

Figure 14. Horizontal distribution of adult salmon observed from the north bank sonar site. Normalized mean values of the frequency of occurrence by stratum. Sample size = nineteen 15-minute periods from 0015 to 2230, 26 June 1983. Collected with a 6 degree transducer at 1/16 second/sweep of the EPC chart recorder (pulse repetition rate = 8/second); sampled range = 35 m. Mid-water scan. Lower Yukon River, near Pilot Station.

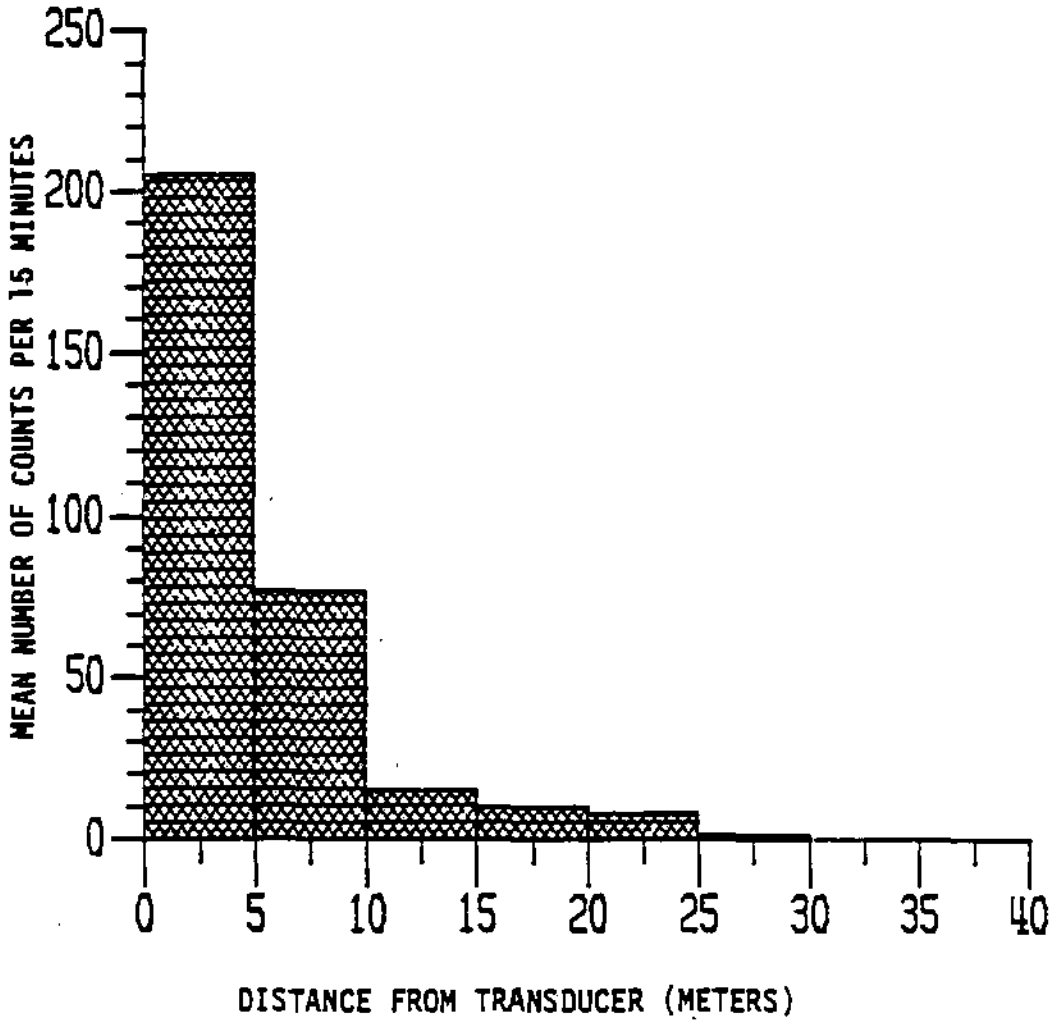

Figure 15. Horizontal distribution of adult salmon observed from the north bank sonar site. Normalized mean values of the frequency of occurrence by stratum. Sample size = two 15-minute periods from 1730 to 1945, 2 July 1983. Collected with a 2 degree transducer at 1/16 second/sweep of the EPC chart recorder (pulse repetition rate = 8/second); sampled range = 27 m. Near-bottom scan. Lower Yukon River, near Pilot Station.

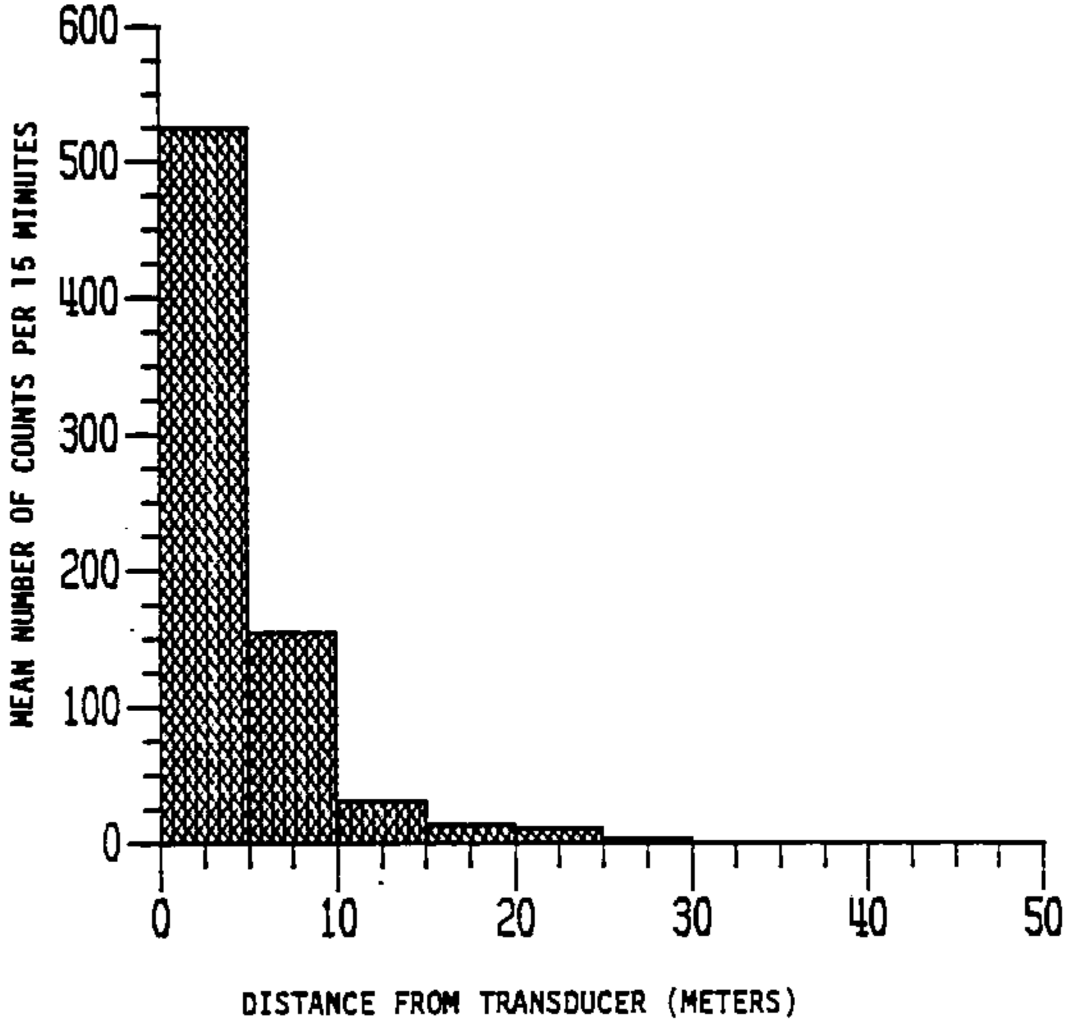

Figure 16. Horizontal distribution of adult salmon observed from the north bank sonar site. Normalized mean values of the frequency of occurrence by stratum. Sample size = four 15-minute periods from 1415 to 2030, 2 July 1983. Collected with a 6 degree transducer at 1/16 second/sweep of the EPC chart recorder (pulse repetition rate = 8/second); sampled range = 27 m. Mid-water to near-bottom scan. Lower Yukon River, near Pilot Station.

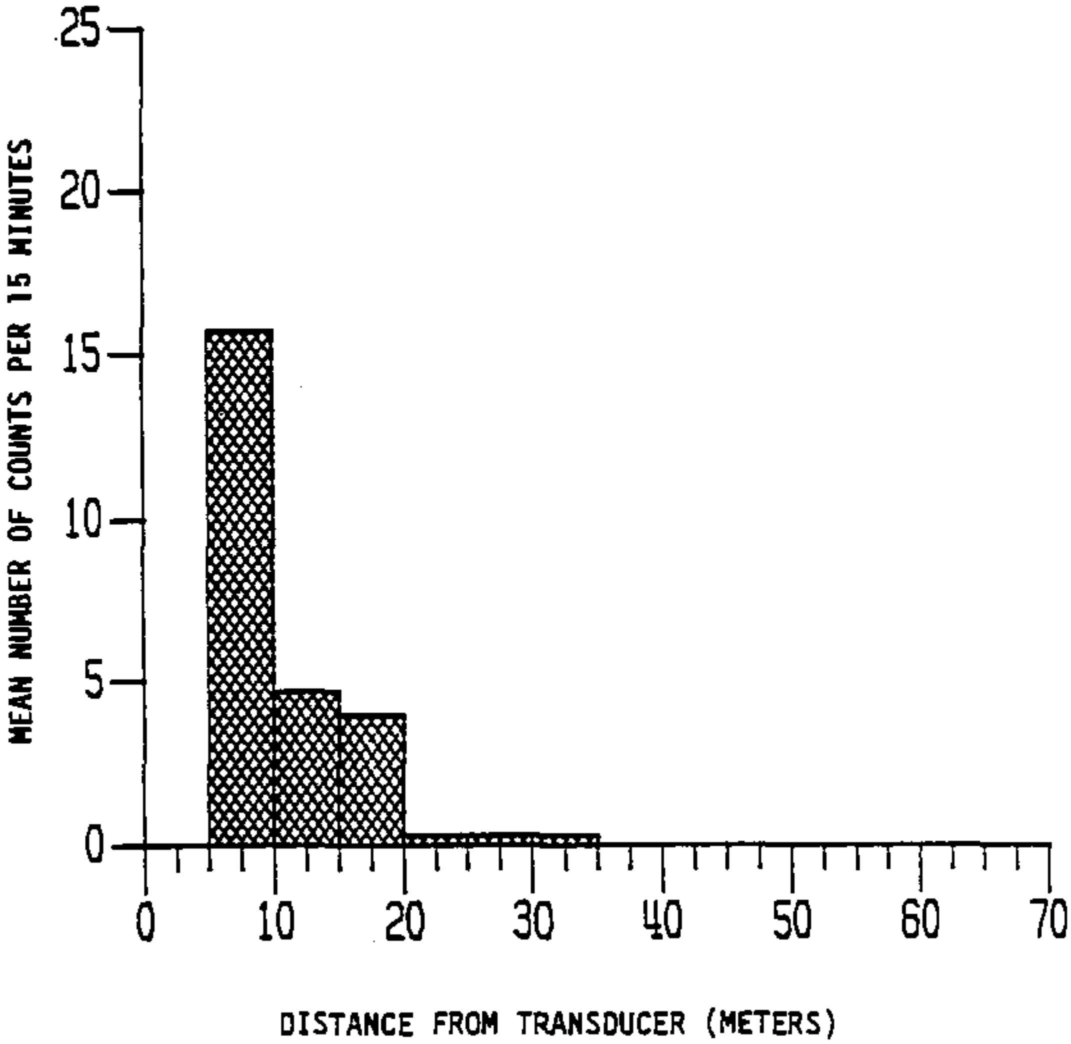

Figure 17. Horizontal distribution of adult salmon observed from the north bank sonar site. Normalized mean values of the frequency of occurrence by stratum. Sample size = three 15-minute periods from 1645 to 2100, 2 July 1983. Collected with a 2 degree transducer at 1/2 second/sweep of the EPC chart recorder (pulse repetition rate = 2/second); sampled range = 150 meters. Mid-water scan. Lower Yukon River, near Pilot Station.

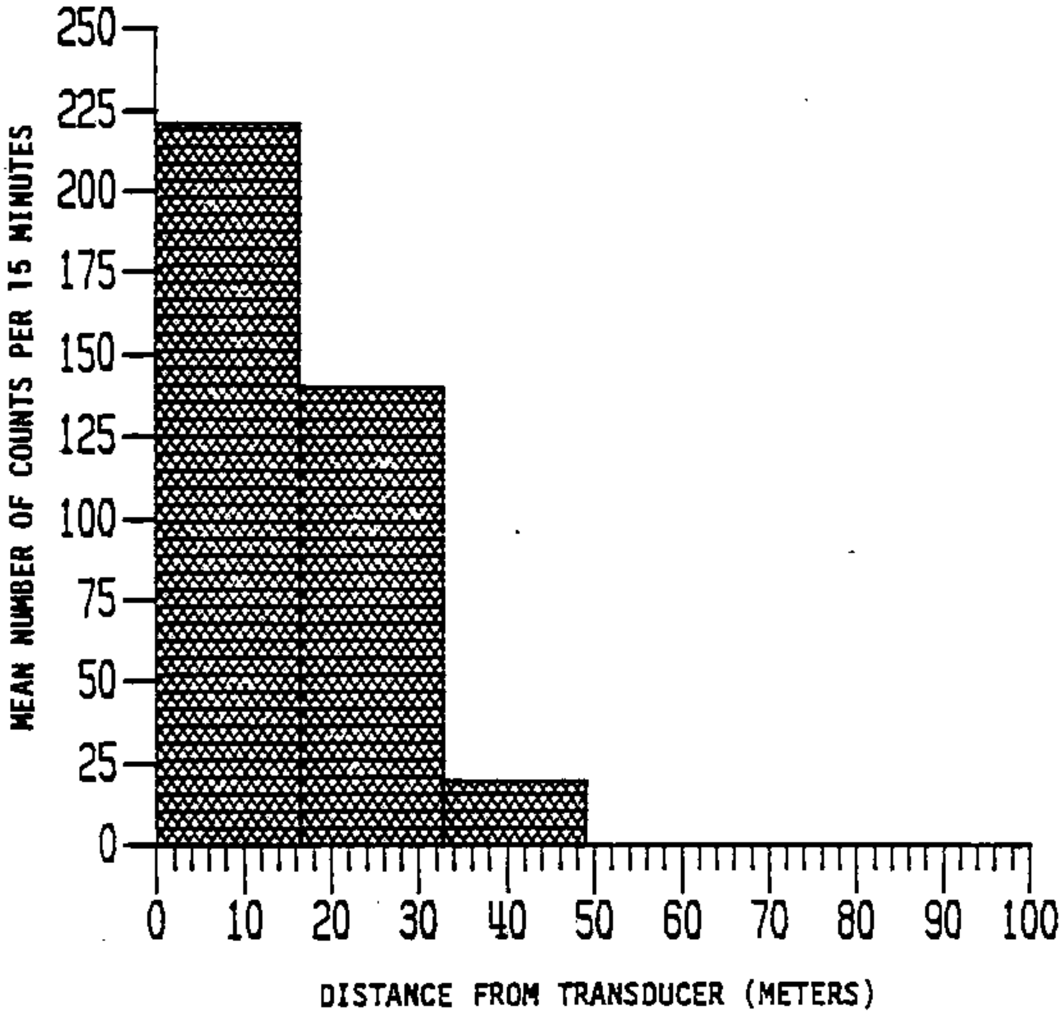

Figure 18. Horizontal distribution of adult salmon observed from the north bank sonar site. Normalized mean values of the frequency of occurrence by stratum. Sample size = twelve 15-minute periods from 2200, 11 July to 2200, 13 July 1983. Collected with a 6 degree transducer. Oscilloscope counts (upstream moving targets only). Sampled range = 99 m. Trigger interval from 0.1 to 0.2 second. Mid-water scan. Lower Yukon River, near Pilot Station.

Low fish target frequency in the 0-5 meter range depicted in Figures 13 and 17 can be are attributed to the nondetection, because of the lower pulse repetition rate required to sample greater ranges. The ping rate for frequencies depicted in Figure 13 was 4 per second while that for Figure 17 was 2 per second. Because the beam area is small near the transducer, fish targets have less time in the beam

On the other hand, the low number of counts observed in the 0-5 meter range, depicted in Figure 14 (26 June 1983), appears to reflect the actual fish density near shore. This is considered a low density rate of fish passage.

Data collected with a 2° and a 6° transducer through alternating time blocks on 2 July 1983. are presented in figures 15 and 16. respectively. Aiming angles and sampling ranges were the same for both sets of interrogation. Distributions illustrated are considered high density rates of fish passage. Oscilloscope counts presented in Figure 18 were also considered a high density rate of fish passage.

An interpretation of data presented in figures 14, 15, 16, and 18 is that during periods of low density fish passage, fish cluster less within the relatively narrow zone (20-25m) of low velocity current, than during periods of medium and high density passage. The mean and standard deviation of surface current velocity over the transducer on 6/18/83 was 50.4 ± 12.1 cm/sec (1.65 ± 0.40 fps). On the same date, current velocities ranged from 135 cm/sec (4.43 fps) to 180 cm/sec (5.91 fps) at 25 to 50 meters toward mid-channel, respectively, from the transducer.

The data indicate that fish target density decreases and surface water velocity increases as a function of distance from nearshore to offshore. This relationship is shown in Figure 19. The critical surface water velocity, above which upstream moving targets were not observed, appears to be approximately 132 cm/s (4.33 fps).

However, the respective 95% depth river current velocity, given this "critical" surface velocity (132 cm/s), is estimated at 69.5 cm/s (2.28 fps). The 95% depth velocity for the observed surface velocity of 180 cm /s is estimated at 94.7 cm/s (3.11 fps). These estimated near-bottom velocities are well within tolerance limits of adult salmon (chinook, coho and sockeye) cruising speeds (Bell 1973). While Bell (op. cit.) does not include chum salmon in his figure of relative swimming speeds, we have captured chums along with chinook and/or coho in swift currents of the Lower Yukon River study area.

The definition of "cruising speed," provided by Bell (op. cit.) is "one that can be maintained for long periods of time (hours)," i.e. migration. Other classifications of swimming speeds described by Bell (op. cit.) are, "sustained speed," which is "one that can be maintained for minutes," i.e. passing through difficult areas; and "darting speed," "a single effort, not sustainable," i.e. swimming from rock to rock.

Therefore, the inference is that salmon could be further offshore, close to the bottom and undetected. This is possible, because the transducers are mounted on a frame and scan sideways through the water column, from near-surface to near-bottom. The acoustic beam is conical, so when it is

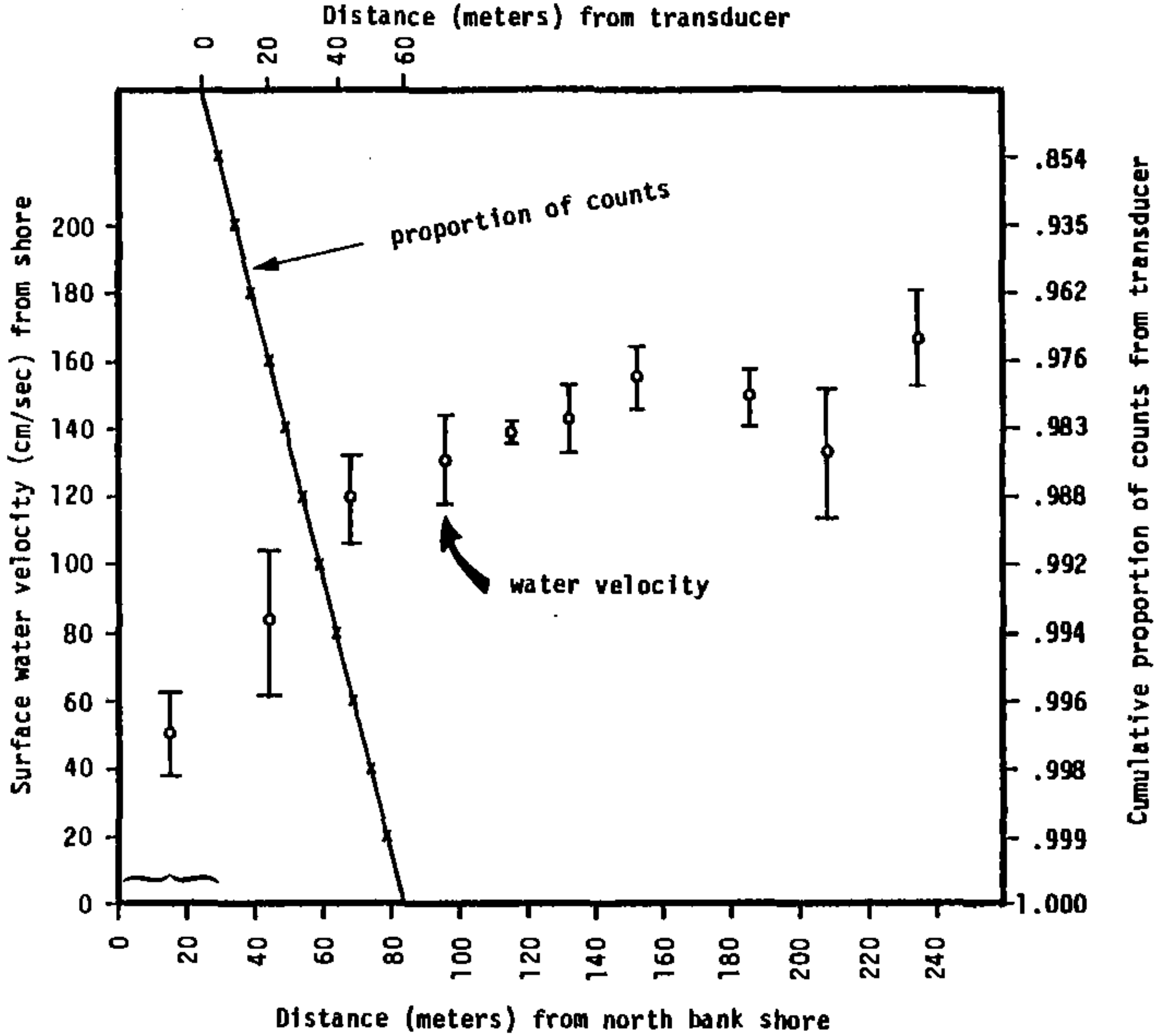

Figure 19. Relationship between the cumulative proportion of salmon counts from the transducer toward mid-channel, and surface water velocities (mean ± 1 std. dev.) from the north bank shore toward mid-channel. June and July 1983. Lower Yukon River near Pilot Station.

aimed toward the bottom the widest part of the beam will hit the substrate first regardless of the range. Scanning closely along a rocky bottom results in an echogram covered with "noise" marks from the resultant multi-pathed echoes, which may, in fact, also include partially concealed fish traces.

The acoustic beam cannot follow bottom contours, so fish that may be swimming between outcroppings at different ranges from the transducer, may or may not be recorded on echograms depending upon size of fish, body surface area of fish exposed to the acoustic beam, water depth, and size of the outcroppings.

Results of this phase of the study will help to determine optimal stratification of sampling effort. They also indicate that new methodologies are needed to sample closely along river bottoms, where contours permit, to account for salmon in this difficult-to-sample-zone.

Vertical Distribution:

Numerical dominance of fish between near-surface and near bottom strata was variable and switched back and forth through time. This variability is graphically illustrated in figures 20 - 22. No consistent trend in vertical distribution was demonstrated by the data.

One surface and one bottom stratum were sampled each hour over a period of hours or days. Data from this sampling schedule, the first sample (e.g. near-surface) followed by the second (near-bottom) etc., were tested for autocorrelation. Scattergrams of "nearest neighbor" plots are presented in figures 23 and 24. Resulting low coefficients of correlation indicate that

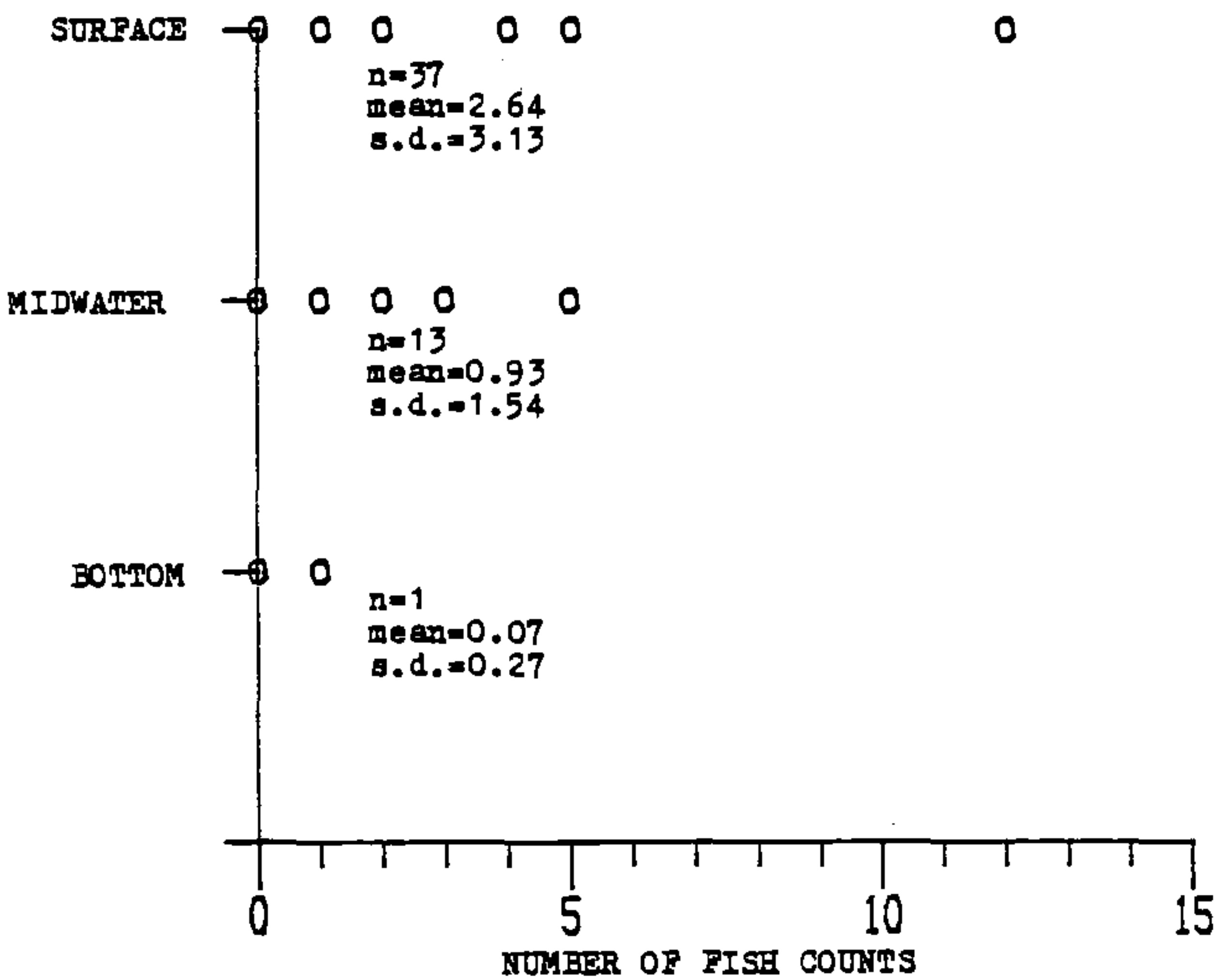

Figure 20. Vertical distribution of adult salmon observed during fourteen 15 minute periods from 2000, 26 June to 2400, 27 June 1983. Collected with a 2 degree transducer at 1/4 second/sweep. North bank site. Lower Yukon River, near Pilot Station.

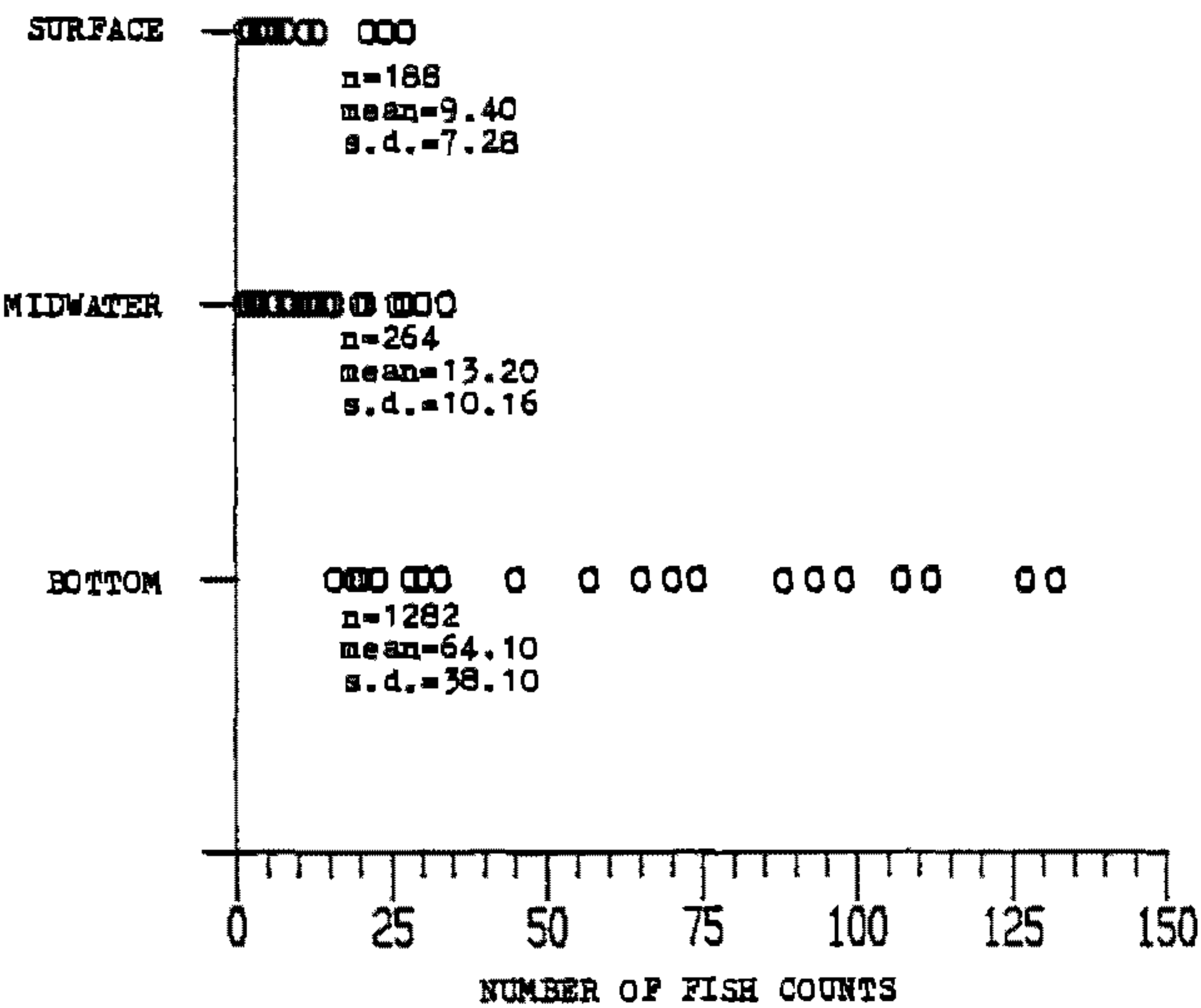

Figure 21. Vertical distribution of adult salmon observed during twenty 15 minute periods from 1700, 1 July to 1000, 3 July 1983. Collected with a 2 degree transducer at 1/16 second per sweep. North bank site. Lower Yukon River, near Pilot Station.

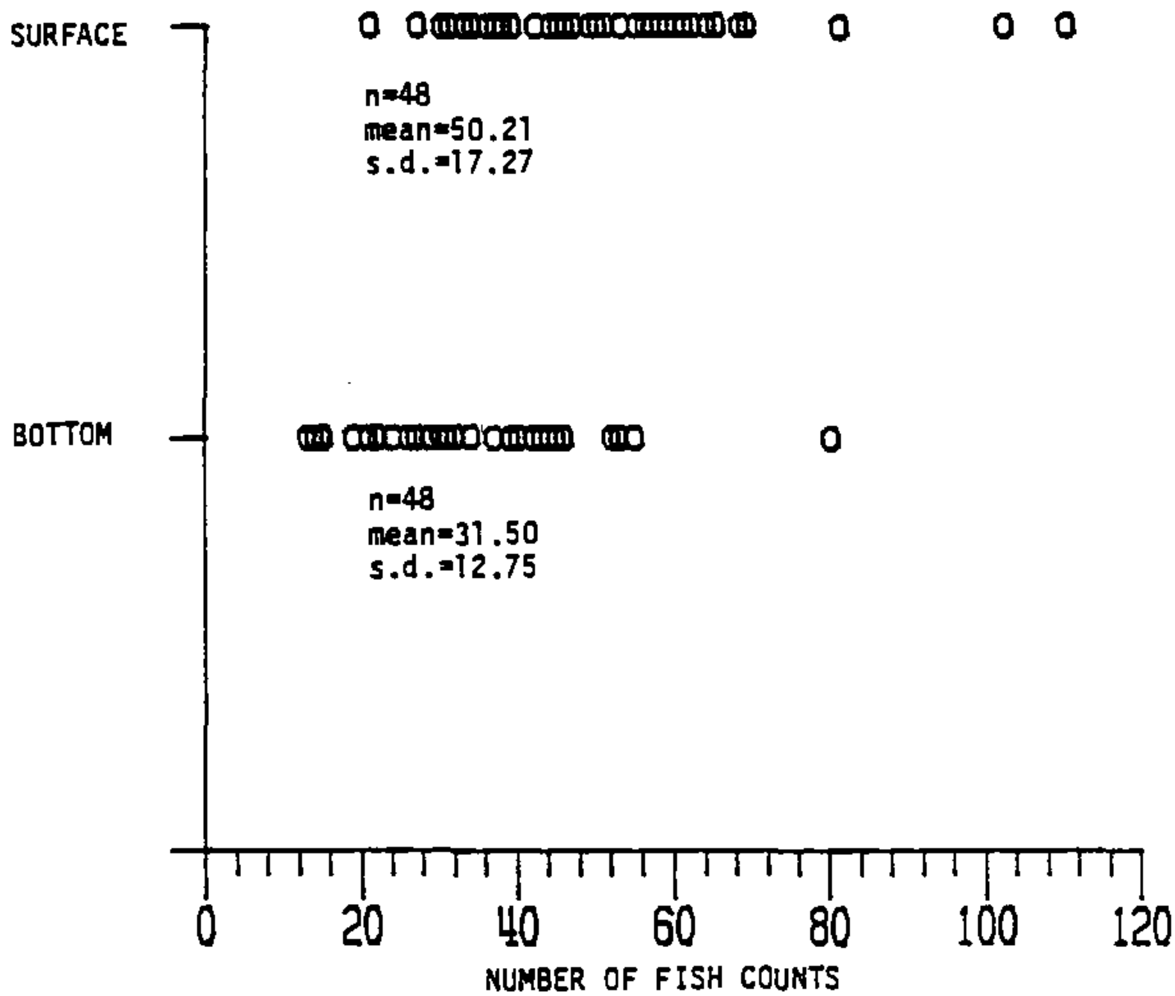

Figure 22. Vertical distribution of adult salmon observed during 96 15-minute periods from 0000, 14 July to 2400, 15 July 1983. Collected with a 6 degree transducer. Range was 55 meters. Oscilloscope scan. North bank site. Lower Yukon River, near Pilot Station.

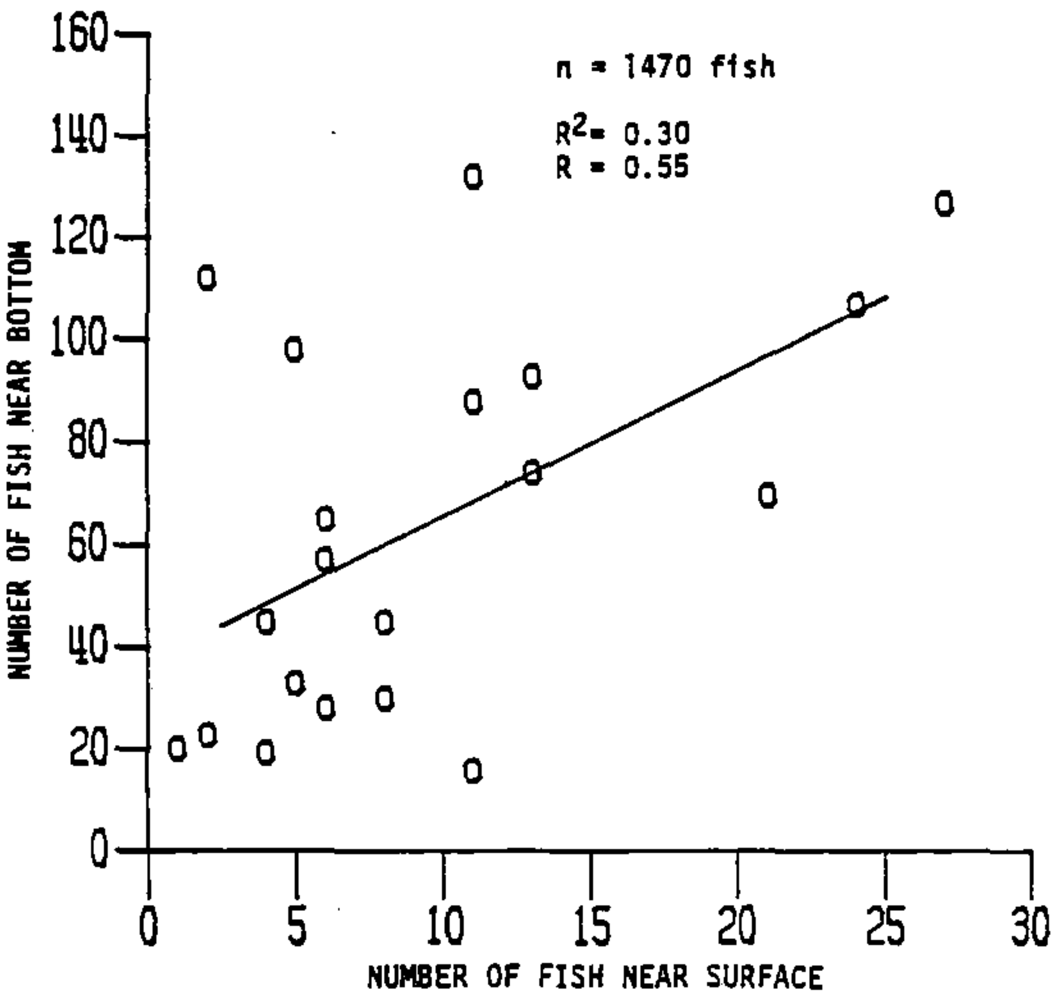

Figure 23. Relationship between "nearest neighbor" counts of adult salmon in the lower Yukon River (i.e. the first 15 minute surface count followed by the first 15 minute bottom count, etc.). Collected with a 2 degree transducer. Range 27 meters (straight). Date: 2 and 3 July 1983, near Pilot Station.

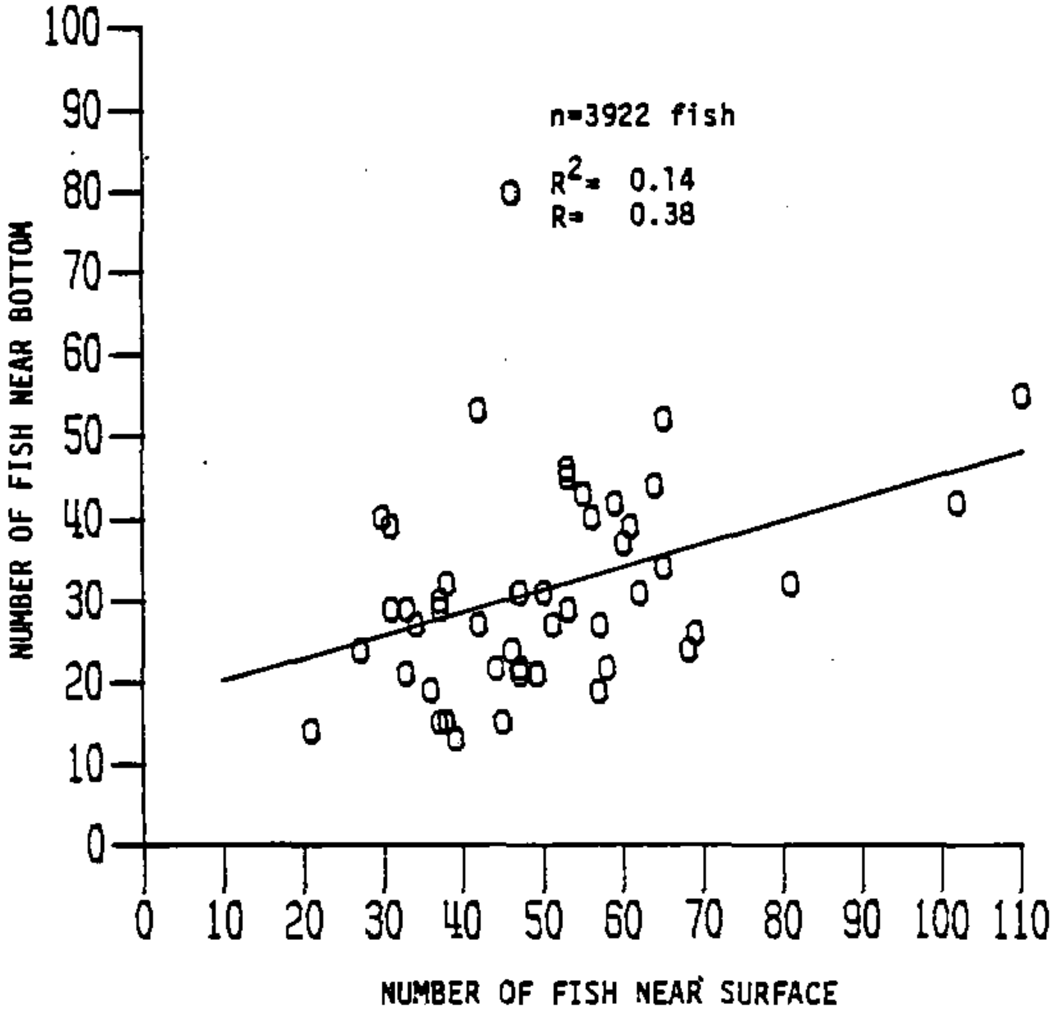

Figure 24. Relationship between "nearest neighbor" counts of salmon in the lower Yukon River (i.e. first 15 minute surface count followed by the first 15 minute bottom count, etc.). Collected with a 6 degree transducer. Range 58 meters(straight). Date: 14 & 15 July 1983. Near Pilot Station.

one cannot predict abundance distribution throughout the water column from sampling a single stratum. It is not known whether variability in numerical dominance is a random behavioral component or is patterned by species and stock mixtures and/or current velocity influences.

Diel Distribution:

Data collected over a 13 day period indicate no consistent trend in daily passage (Figure 25). This is consistent with results obtained at the south bank of the river in 1982 The lack of a diel pattern means that sampling effort must be spread uniformly through each 24 hour period.

Sampling Time Analysis:

A total of 79. 3-minute echogram time blocks were examined from data collected with the 6° transducer. The region of interrogation was midwater to near bottom. A total of 1621 fish were detected during the sampling period. The coefficient of variation (C.V.) decreases slowly over pooled time periods with a minor plateau at 15 minutes, but begins to rise again at 24 minutes. The plateau at 15 minutes may be an artifact of the 15 minute sampling periods that were used for data collection. The standard errors of C.V. were large for all periods and had considerable overlap with each other (Figure 26, Appendix Table K-1).

Analysis of data for the 2° beam represented interrogations of the near-surface, midwater, and near-bottom regions. A total of 30, 3-minute samples were examined for the near-surface region, in which 57 fish were

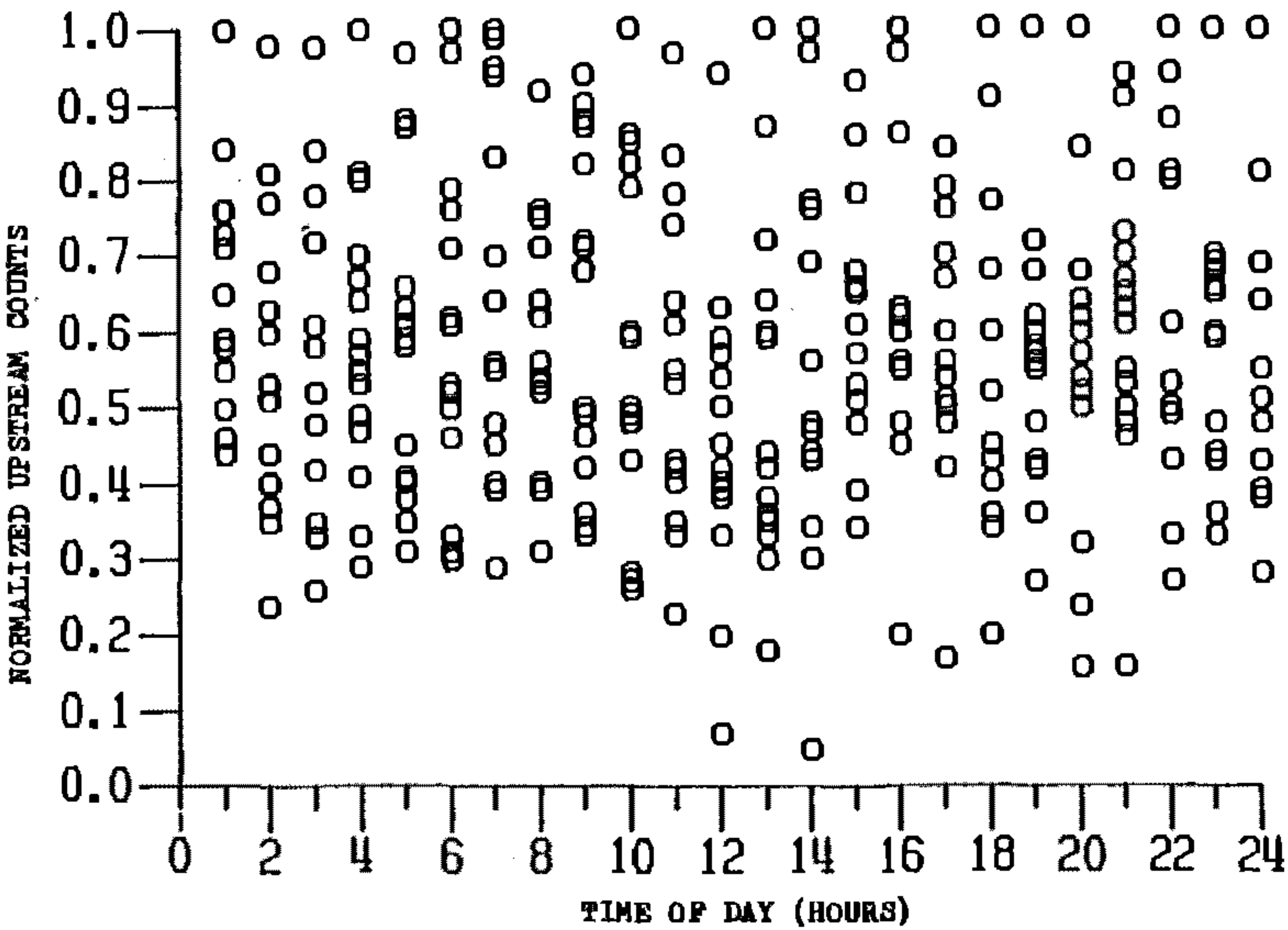

Figure 25. Distribution of salmon counts by time of day (0000-2400). Collected 24 and 25 June, and 5 to 15 July 1983. North bank sonar site. Lower Yukon River, near Pilot Station.

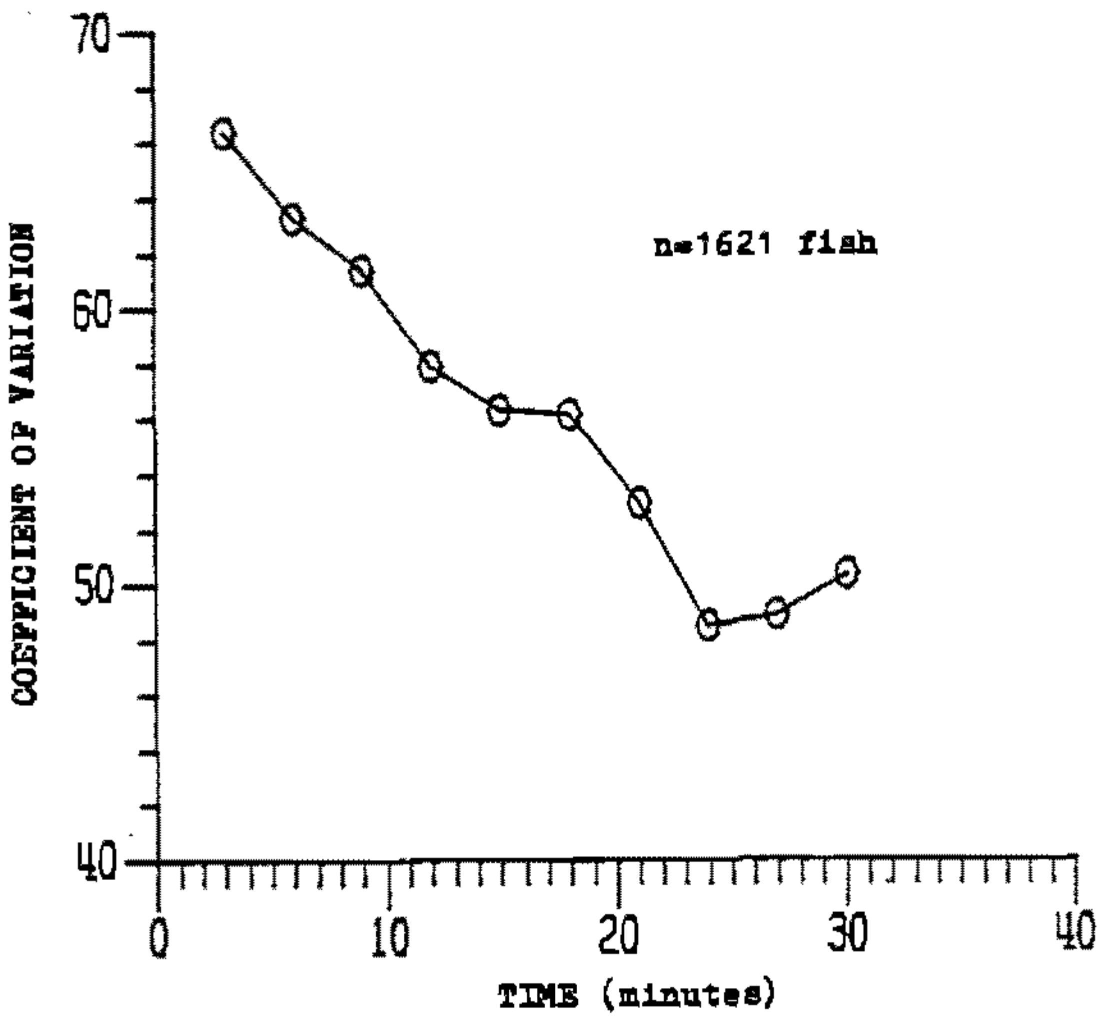

Figure 26. Coefficients of variation for numbers of fish counted by successive 3-minute time blocks. Collected with a 6 degree transducer scanning the mid- to lower regions of the water column from 0315, 25 June to 0230, 3 July 1983. Lower Yukon River, near Pilot Station.

detected. The C.V. reaches an initial low point at 12 minutes and subsequent lower values at 21 and 27 minutes, respectively (Figure 27). The standard errors of C.V. are uniformly small relative to the large range in values of the C.V.'s (Appendix Table J-2).

A total of 25, 3-minute samples from the 2° scan of the midwater region include 78 fish detected. The lowest point is located at 18 minutes (Figure 28). The standard errors of CV are of moderate size initially and become progressively larger. The range of the C.V.'s is smaller than that observed for the near-surface region (Appendix Table K-3).

The 2° scan of the near bottom region was comprised of 25, 3-minute samples in which 339 fish were detected. The lowest point is at 24 minutes (Figure 29). The C.V.'s for this region had the narrowest range of values in comparison to the midwater and near-surface regions. However. the standard errors of C.V., though comparable to those of the near-surface in absolute terms, were very large in relative terms (Appendix Table K-4), indicating much overlap and little distinction among pooled time-groups.

All data for the 2° beam from near-surface, midwater. and near-bottom were pooled and a new set of C.V.'s was produced. The values of these C.V.'s were high and had a narrow range. The lowest point was at 21 minutes (Figure 30). The standard errors had a broad range and were high (Appendix Table K-5).

These results imply that the optimum sampling time is between 18 and 27 minutes, with a mean and standard deviation of 22 $\pm$ 3.5 minutes. The lowest point on the C.V. distributions indicates that if more time is spent in a

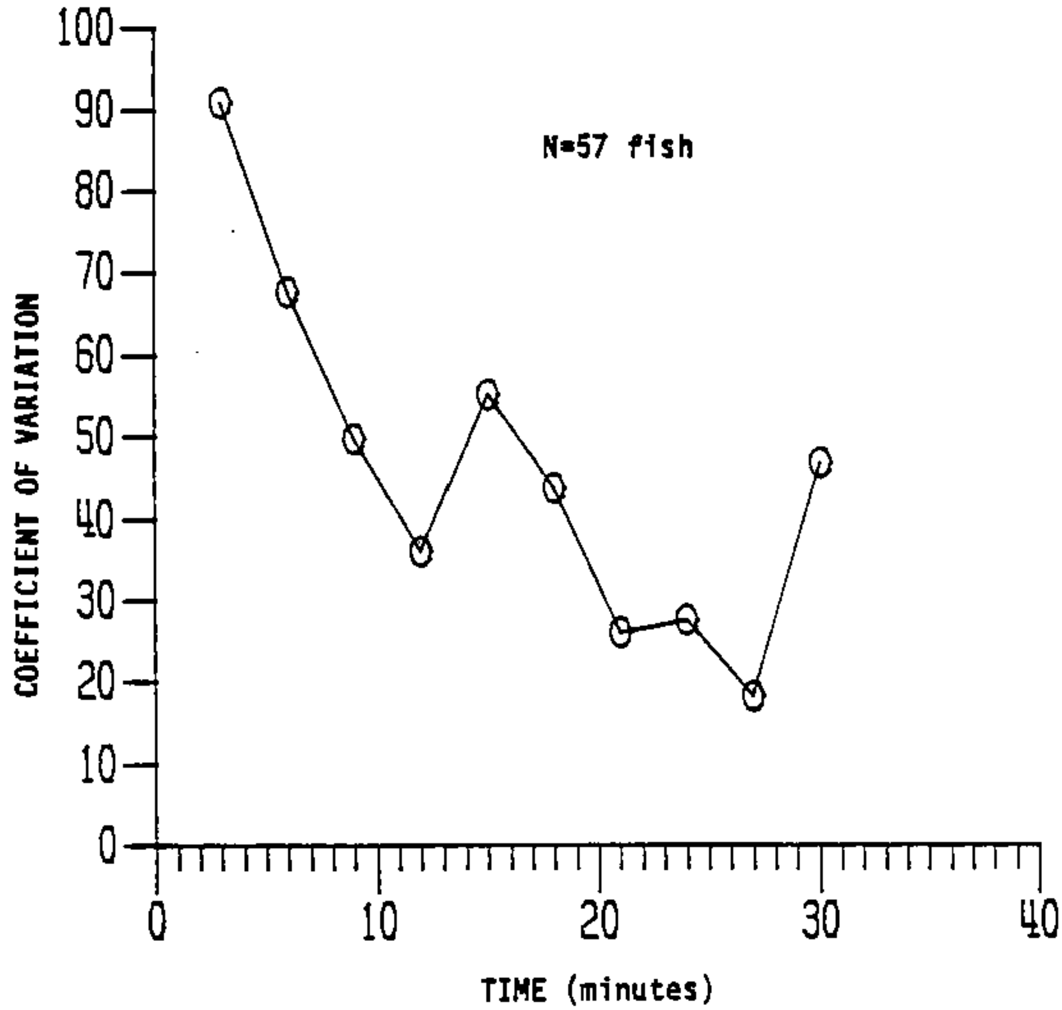

Figure 27 Coefficients of variation by successive 3-minute time blocks. Near-surface scan. Collected with a 2 degree transducer from 1500, 2 July to 0315, 3 July 1983. Lower Yukon River, near Pilot Station.

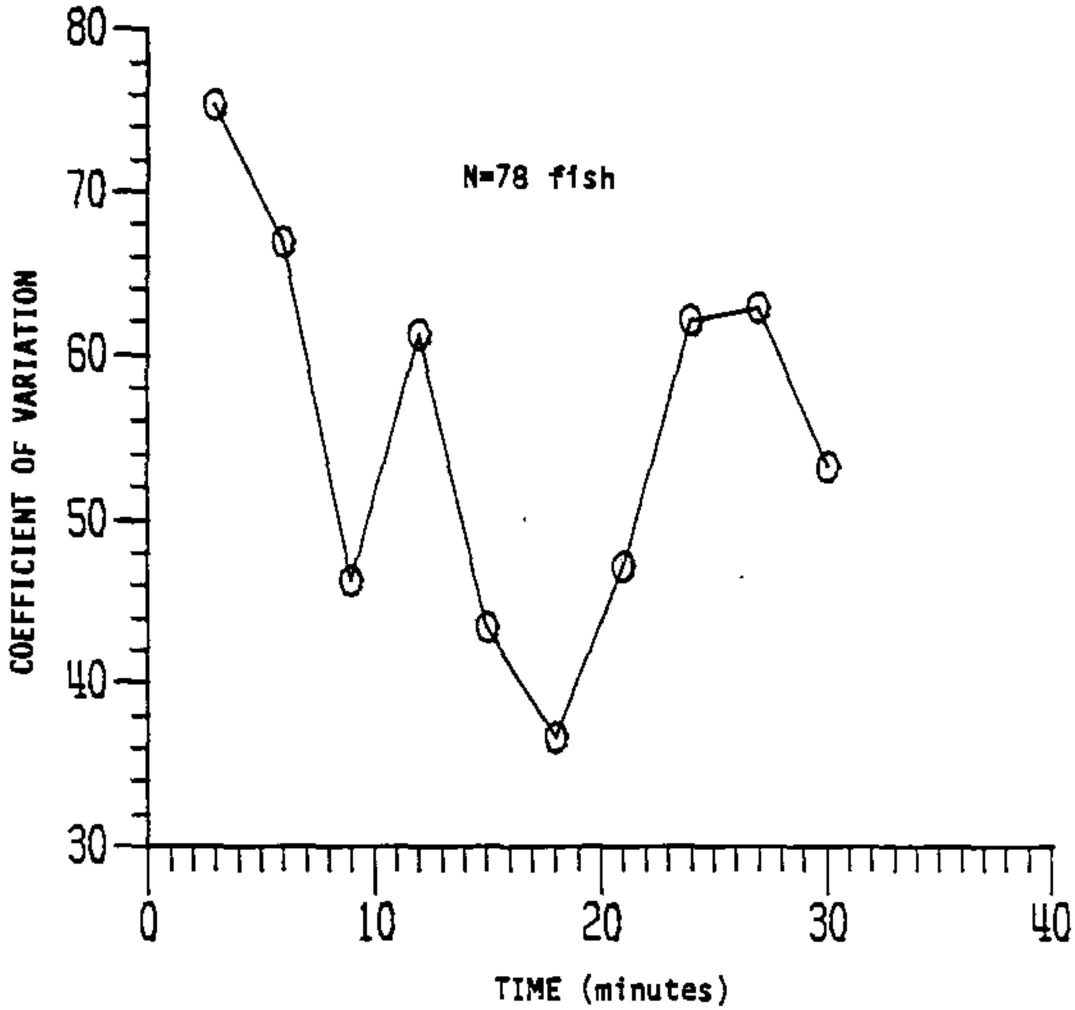

Figure 28. Coefficients of variation by successive 3-minute time blocks. Mid-water scan. Collected with a 2 degree transducer from 1515, 2 July to 0130, 3 July 1983. Lower Yukon River, near Pilot Station.

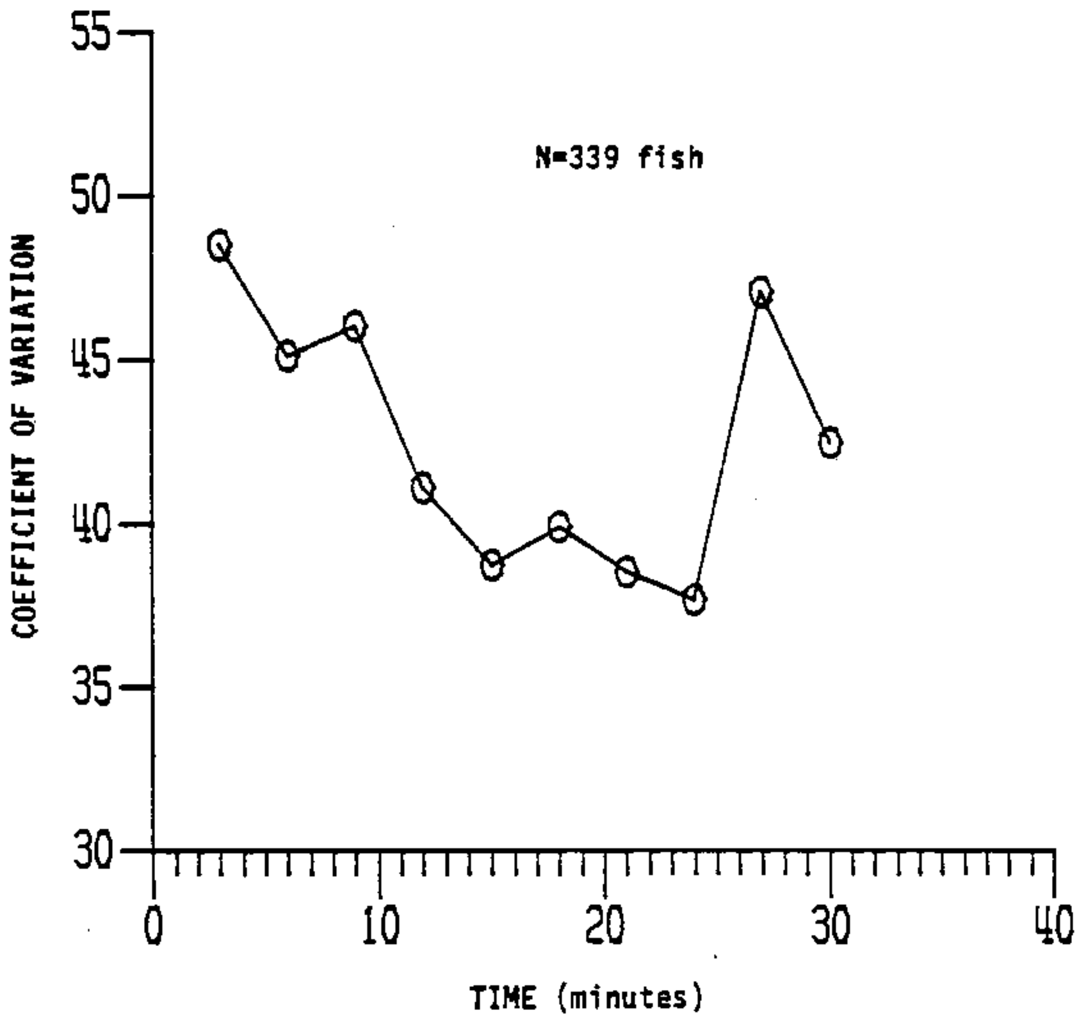

Figure 29. Coefficients of variation for numbers of fish counted by successive 3-minute time blocks. Near-bottom scan. Collected with a 2 degree transducer from 1530 2 July to 0145 3 July 1983. Lower Yukon River, near Pilot Station.

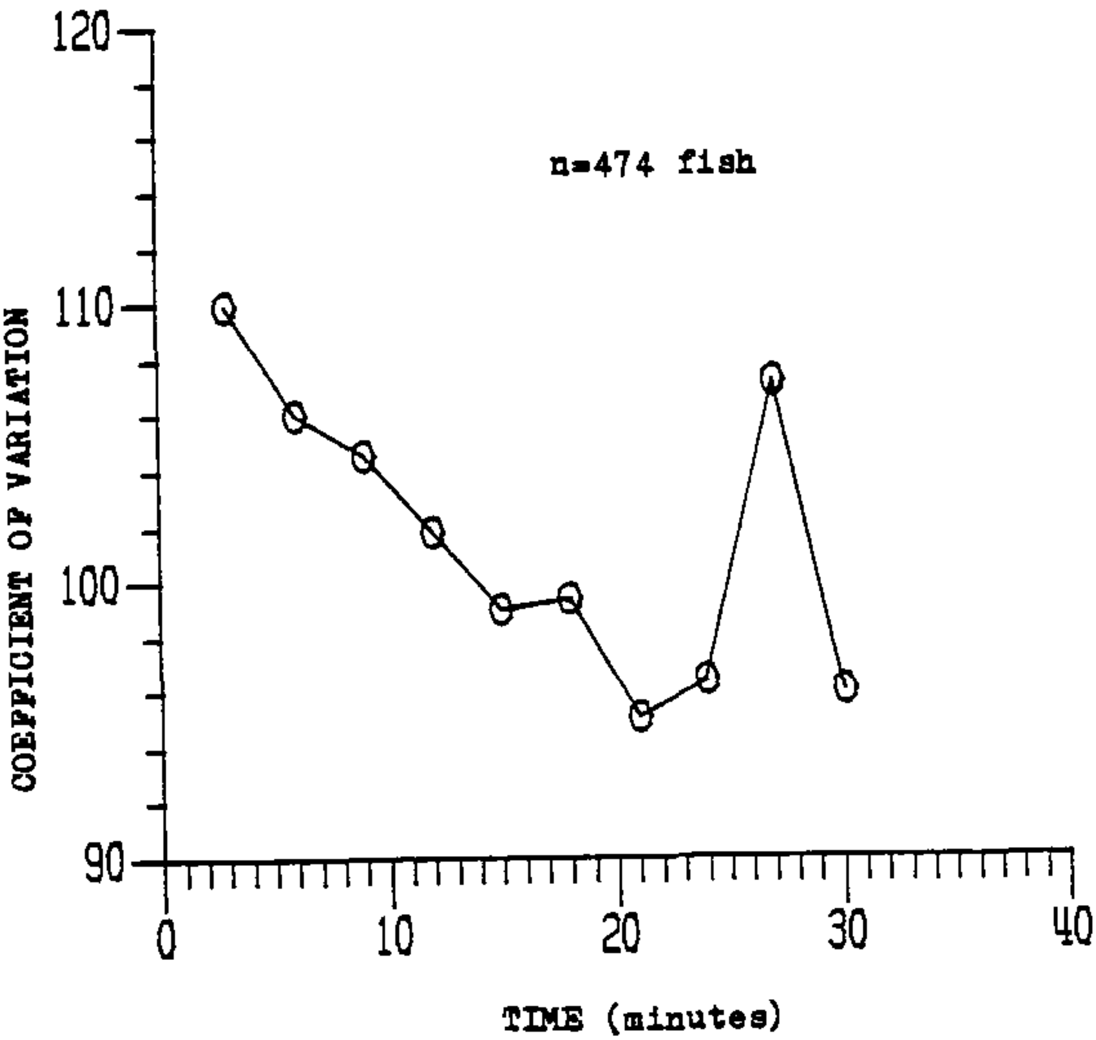

Figure 30. Coefficients of variation for numbers of fish counted by successive 3-minute time blocks. Near-bottom, midwater, and near-surface regions of the water column pooled. Collected with a 2 degree transducer from 1500, 2 July to 0315, 3 July 1983. Lower Yukon River, near Pilot Station.

particular sampling region, additional information will not be gained and the variance will not decrease. The appropriate allocation of total time between sampling regions is not indicated in the analysis.

Arrival Time Analysis:

Results of the Chi-square distribution were significantly different from the Poisson distribution (Table 3). The following relationships were determined for the mean and variance of the classified density distributions:

1. Low density - mean = 53.53 seconds
   variance = 5875.42

2. Medium density - mean = 20.35 seconds
   variance = 697.44

3. High density - mean = 7.68 seconds
   variance = 86.28

In accordance with definitions given by Elliott (op. cit.), distributions of passing fish were considered a contagious type. The time between successive arrivals ranged from 0 (simultaneously) to 571 seconds. The mean number of seconds between successive arrivals for low, medium, and high density fish passage was 53.5, 20.4, and 7.7 seconds respectively (Figures 31 to 33). These densities reflect an index of fish passage rate per 15 minutes. The approximate rates are 17, 44, and 117 fish per 15 minutes, respectively.

Table 3. Chi-square goodness of fit test for arrival time distributions. Data collected from the north bank, lower Yukon River, near Pilot Station, June and July 1983. Time group refers to fish whose time intervals (in seconds) between sucessive arrivals at the acoustic beam correspond to the observed number of fish per group. The Poisson distribution corresponds to the expected frequencies.

Low Density

Time Group (seconds)	Observed	Expected (Poisson)
0 - 20	60	3.99
21 - 25	5	20.67
26 - 30	9	42.83
31 - 35	2	39.13
36 - 40	7	17.57
41 - 570	46	4.82

Chi-square = 1218.72 > X^2 99.5; 5 d.f. = 16.75

Medium Density

Time Groups (seconds)	Observed	Expected (Poisson)
0 - 10	56	10.44
11 - 15	14	48.50
16 - 20	14	46.20
21 - 180	35	13.86

Chi-square = 278.13 > X^2 99.5; 3 d.f. = 12.84

High Density

Time Group (seconds)	Observed	Expected (Poisson)
0 - 5	61	57.47
6 - 10	26	52.27
11 - 55	26	3.25

Chi-square = 172.40 > X^2 99.5; 2 d.f. = 10.60

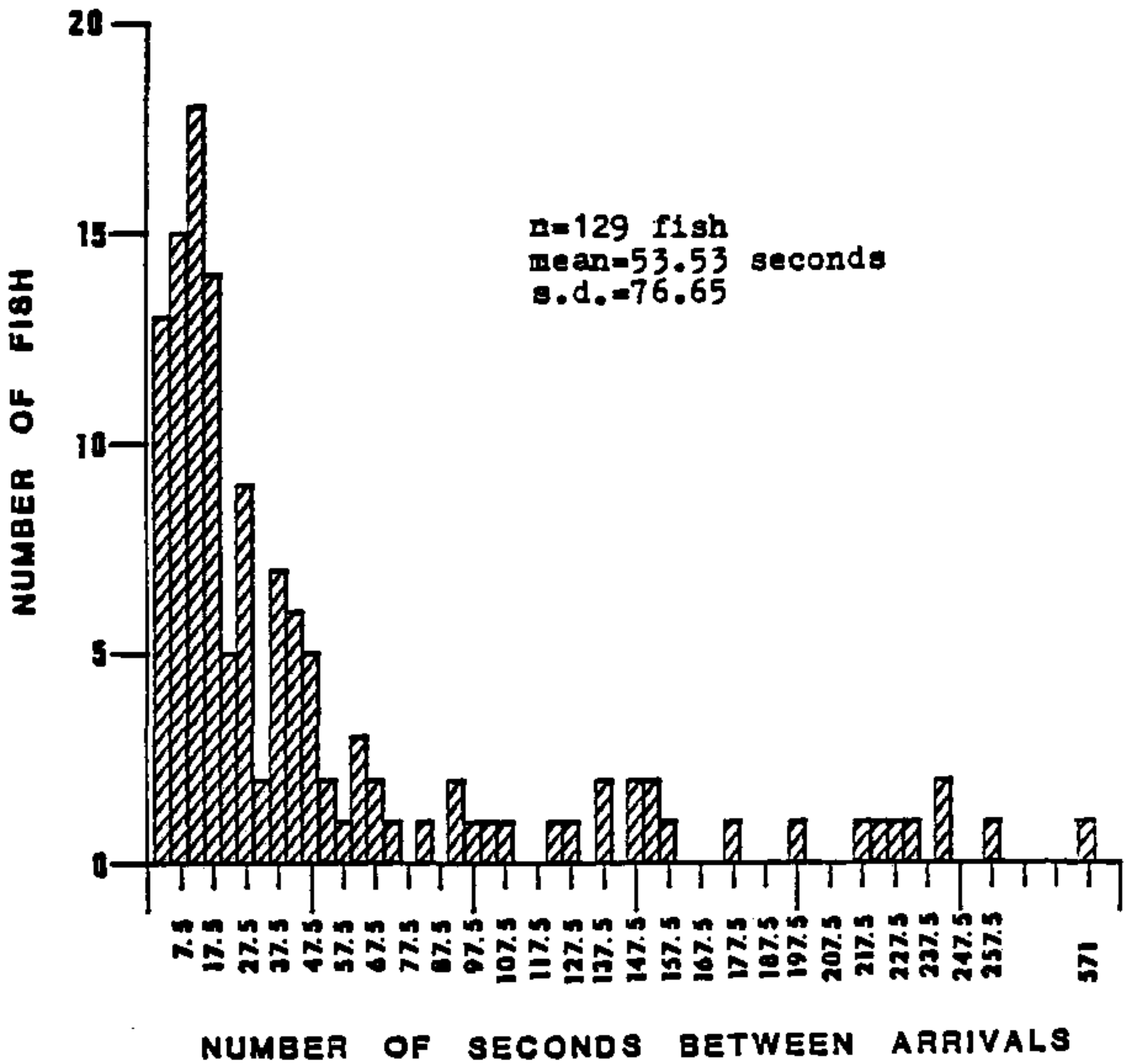

Figure 31. Time between successive arrivals of fish. Low density. Used a 2 degree transducer; 0715-1945, 2 July 1983. Lower Yukon River, near Pilot Station.

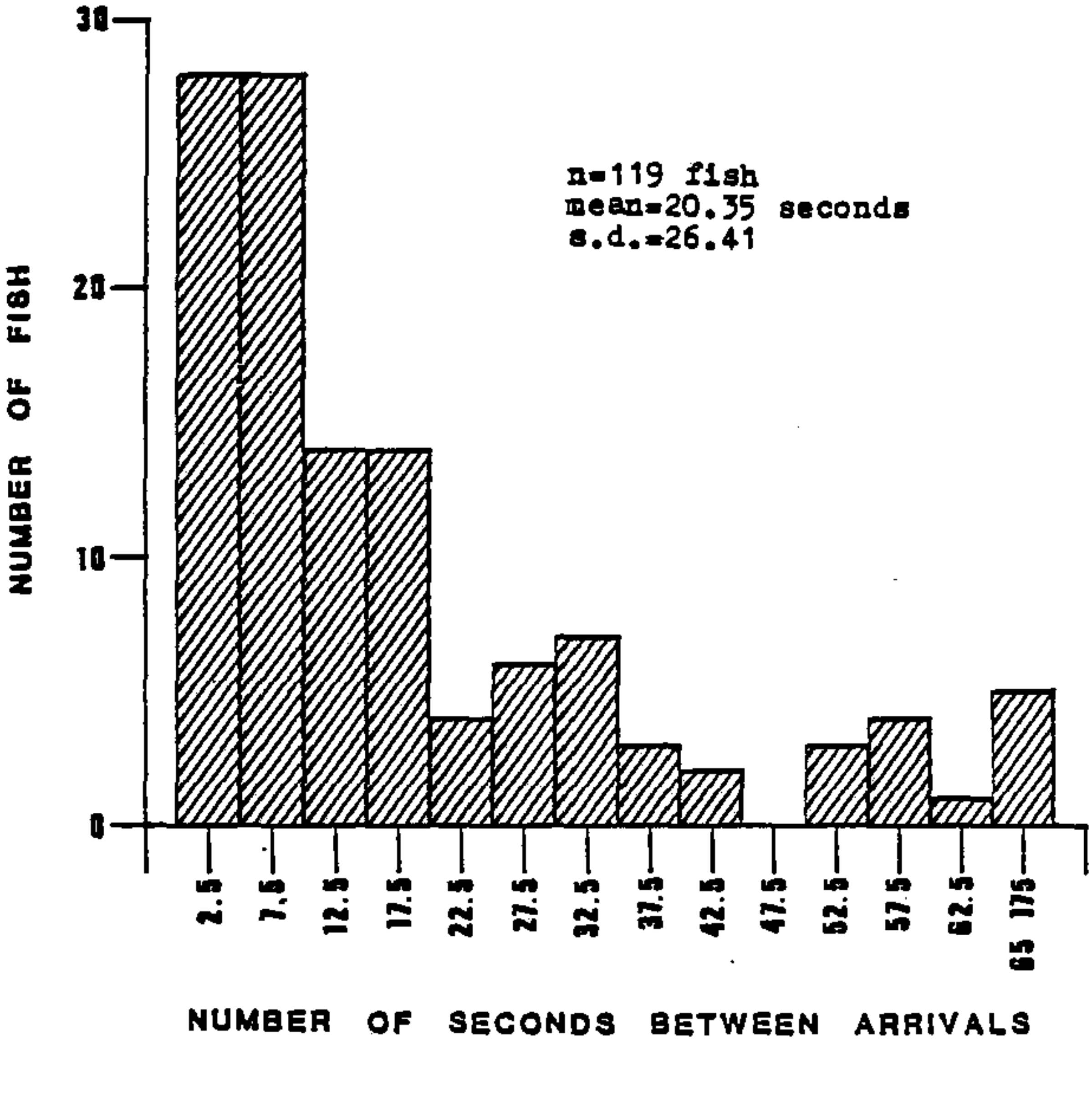

Figure 32. Time between successive arrivals of fish. Medium density. Used 6 and 10 degree transducers; 0815-1215; 2 July 1983. Lower Yukon River, near Pilot Station.

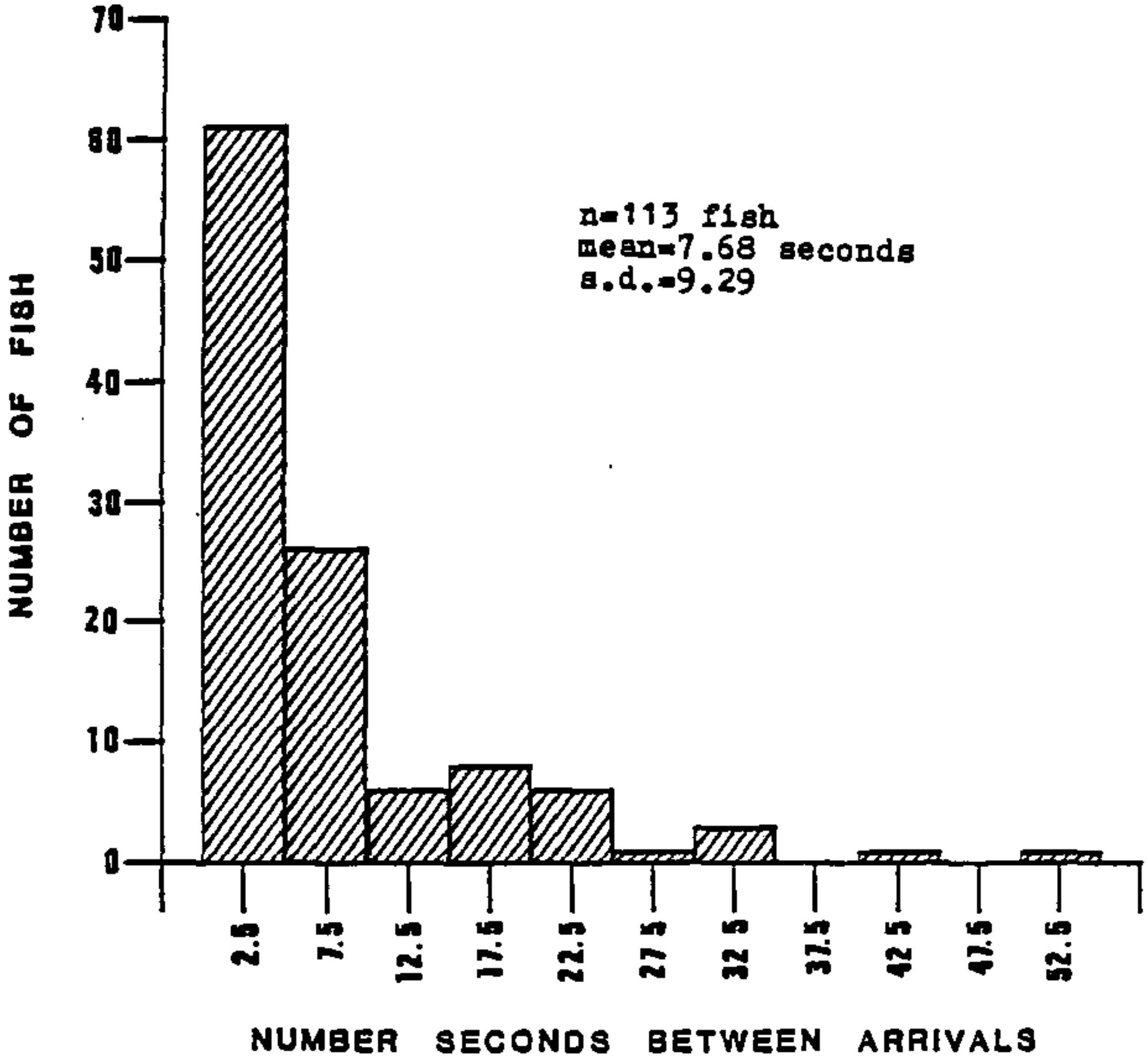

Figure 33. Time between successive arrivals of fish. High density. Used a 2 degree transducer; 1100-1115, 2 July 1983. Lower Yukon River, near Pilot Station.

Target Strength:

Target strength was calculated during four different periods from 23 June to 28 June 1983, using 3 different transducers (2°, 6° and 10°). A total of 956 oscilloscope observations of targets were made (Appendix Tables G 1 to G 4).

First, the target strength was calculated using the technique outlined in Ehrenberg et al. (op. cit.) and then corrected using the off-axis formula obtained from Dahl (op. cit.) (Appendix Figure H 1). The corrected target strengths (Table 4) ranged from -15.7 dB (n= 58) while using a 10° transducer, to -23.6 dB (n=208) while using a 2° transducer. The 6° transducer (the transducer most commonly used) provided a target strength of -23.0 dB (n=485). This measured target strength, and the overall mean target strength of -21.94 dB compare favorably with the -24 dB measured of Dahl (op. cit.) obtained during laboratory measurements of a 61 cm salmonid. The extremes at -15.7 dB and -23.6 dB are probably due to small sample sizes and, in the case of the 2° beam. technical difficulties in reading the peak echo voltage in such a short period of time that it was displayed on the oscilloscope.

Swimming Speed:

Estimated swimming speeds of salmon ranged from 0.036 meter per second (0.118 feet per second) to 2.204 m/s (7.231 ft/s). Swim speed estimates by sampling date are presented in Table 5. The grand mean and standard deviation of all pooled samples are .601 ± 0.334 m/s (1.972 ± 1.096 ft/s), respectively. This overall average translates to 2.2 km/hr (1.3 mi/h) or 51.9 km 1 day (32.3 mi/day).

Table 4. Calculated and corrected target strength measurements of salmon collected during 4 periods in the Lower Yukon River, 1983.

Date	Transducer	Calculated Target Strength (dB)	Aiming Angle (degrees)	Absolute Angular Off-Axis Correction (dB)	Corrected Target Strength dB	N
23 June (Daytime)	6	-34.1	45.7	11.09	-23.0	485
23 June, 2100 to 25 June, 1640	10	-30.6	45.7	11.09	-19.5	205
24 June (Daytime)	10	-26.8	45.7	11.09	-15.7	58
28 June 0130-1530	2	-35.9	50.8	12.32	-23.6	208

Table 5. Estimated swimming speeds of salmon (m/s) in the Lower Yukon River, near Pilot Station, 1983.

Notation: n = sample size, number of upstream moving targets measured from echograms.

$\bar{x}$ = arithmetic mean swimming speed

s = standard deviation of the mean

Date	Tranducer used	Statistics
6/21/83	6°	n = 50 $\bar{x}$ = 0.6750 s = 0.3701
6/23/83	10°	n = 50 $\bar{x}$ = 0.7690 s = 0.3257
6/25/83	6°	n = 51 $\bar{x}$ = 0.6317 s = 0.3409
6/27/83	10°(n=7); 6°(n=43)	n = 50 $\bar{x}$ = 0.6220 s = 0.3247
7/2/83	6°	n = 49 x = 0.4743 s = 0.2971
7/3/84	6°	n = 50 x = 0.4294 s = 0.3416

Because of the Yukon River's fluctuating water level (Figure 20), we wanted to know if there is a relationship between river height and swim speed (Figure 34), the inference being the higher the river stage,[4/] the faster the current velocity. In the study section of the river described in this report, stage of current flow is directly related to current velocity (U.S.G.S. pers. comm. 1984).

Swim speed frequency distributions were testd for symmetry (Snedecor 1950); they were not normally distributed (Snedecor op. cit.). So river height and mean swim speed were ranked (Snedecor and Cochran 1980) as shown in Table 6, and a Spearman's rank correlation coefficient (Gibbons 1971) was computed. The test statistic, Z = 1.98 was significant at the 5% level of probability, but not at the 1% level.

The test results imply. even with this small sample, that salmon swimming speed may be directly related to river height and the respective river current velocities through which they are swimming. The actual sub-surface current velocities in the vertical water column through which the sampled fish swam is not known. As mentioned earlier. surface current velocity transects were run on 18 June and from 30 June to 1 July 1983. So any extrapolation of these data to sub-surface currents for dates listed in Table 2 would be tenuous.

Daily Estimates:

4/ River stage is the height of the water surface above or below an established datum plane (U.S.G.S. 1982).

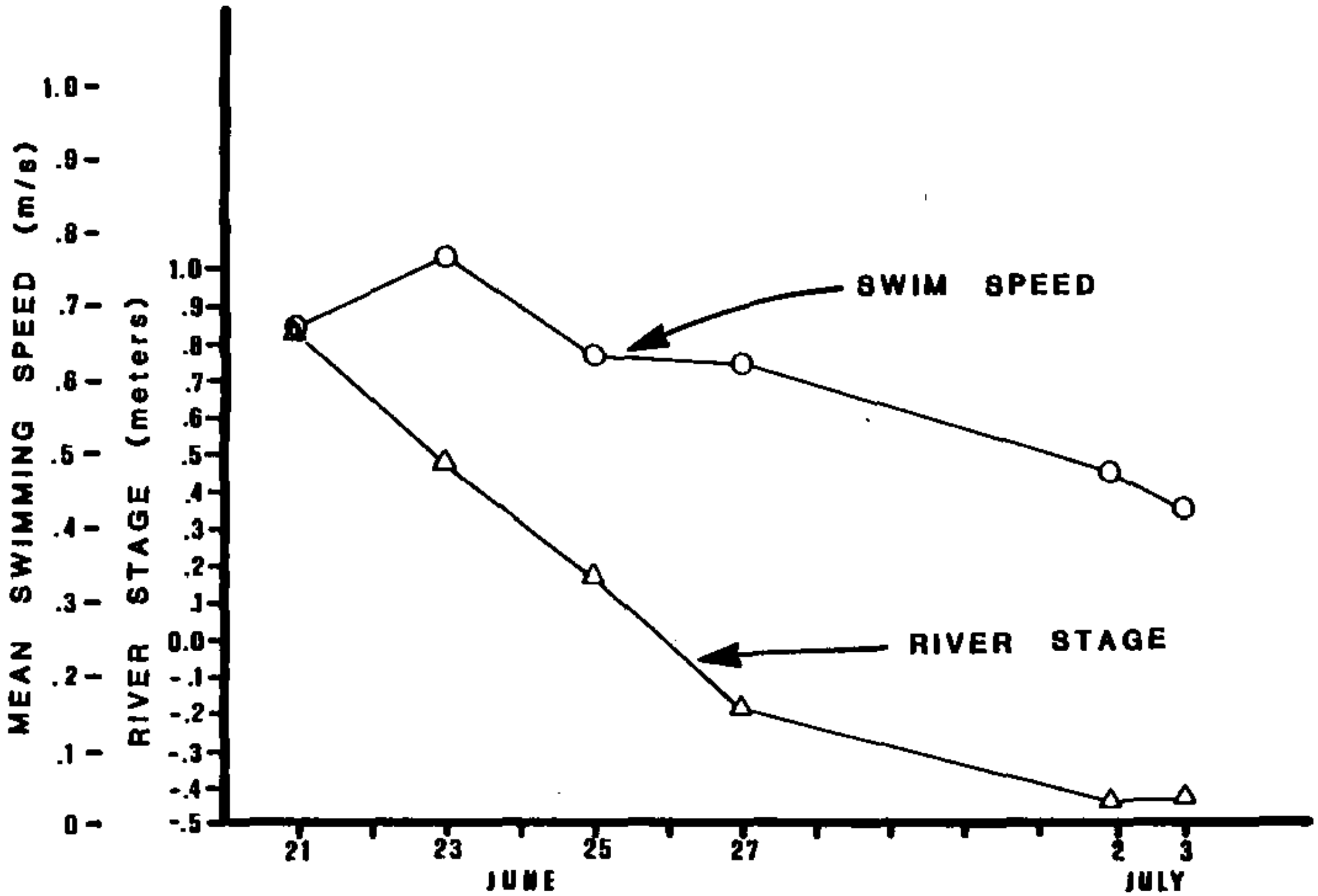

Figure 34. The observed relationship between river stage and mean swimming speed of adult salmon (moving upstream) in the lower Yukon River, near Pilot Station. June 21 to July 3, 1983.

Table 6. The relationship between mean swimming speed of salmon and stage 1/ of the lower Yukon River, near Pilot Station, 1983; and their relative ranks for Spearman's rank correlation coefficient (r_s).

Date	Swim Speed (meters/sec)	Rank	River Stage (meters)	Rank
6/21/83	0.6750	5	0.8287	6
6/23/83	0.7690	6	0.4858	5
6/25/83	0.6317	4	0.1683	4
6/27/83	0.6220	3	-0.1810	3
7/2/83	0.4743	2	-0.4350	1
7/3/83	0.4294	1	-0.4223	2

$r_s = 0.886$

A test for the null hypothesis, swim speed and river stage are independent is made using:

$$Z = r_s \sqrt{n-1}$$

$$Z = 1.981 > \alpha .05 = 1.96$$

1/ River stage is the height of the water surface above or below an established datum plane.

Estimates of daily and cumulative fish passage are shown in Figure 35. Days for which no data were collected were left blank; no interpolation was done. The negative count observed on 1 July was the net value after subtracting downstream moving targets from upstream moving targets.

Daily estimates of fish passage ranged from a net downstream movement of minus 1,869 to a high of 20.750. The total estimate of passage along the north bank of the river from 21 June to 15 July was 184,000. There was no relationship between north bank daily sonar estimates and testnet catches at the mouth of the Yukon River by time lagged data, neither was there a relationship between sonar counts and commercial salmon catch in the same commercial fishing district on a daily basis.

Possible reasons for no relationship between sonar counts and testnet catches at the mouth, or commercial catches in the same district are listed below:

1. The transducer pod was deployed approximately 23 m (75 ft) offshore and, because of the rocky bottom and swift currents, a lead could not be anchored from near the pod to shore. So fish swimming between the pod and shore were not enumerated.

2. We know that fish were swimming between the shore and the pod, because of gillnet catches in that zone. Also, fish were enumerated for one day with a 2° transducer mounted on frame and placed about 6 m (20 ft) from shore, where the water depth was 0.8 m (2.5 ft).

3. The area in which the pod was deployed is an eddy. Fish were milling in-the eddy, so downstream swimming fish were subtracted from upstream swimming fish. More upstream than downstream moving fish may have been between the shore and the pod, than offshore of the pod.

4. Commercial fishing effort is virtually concentrated on the south bank along this reach of the Yukon River. Downstream of Pilot Station, where the main channel forks at Hills Island (Figure 3), there is more fishing effort in the south fork than the north. Virtually all fishing effort in the north fork is along the south bank (i.e. Hills Island).

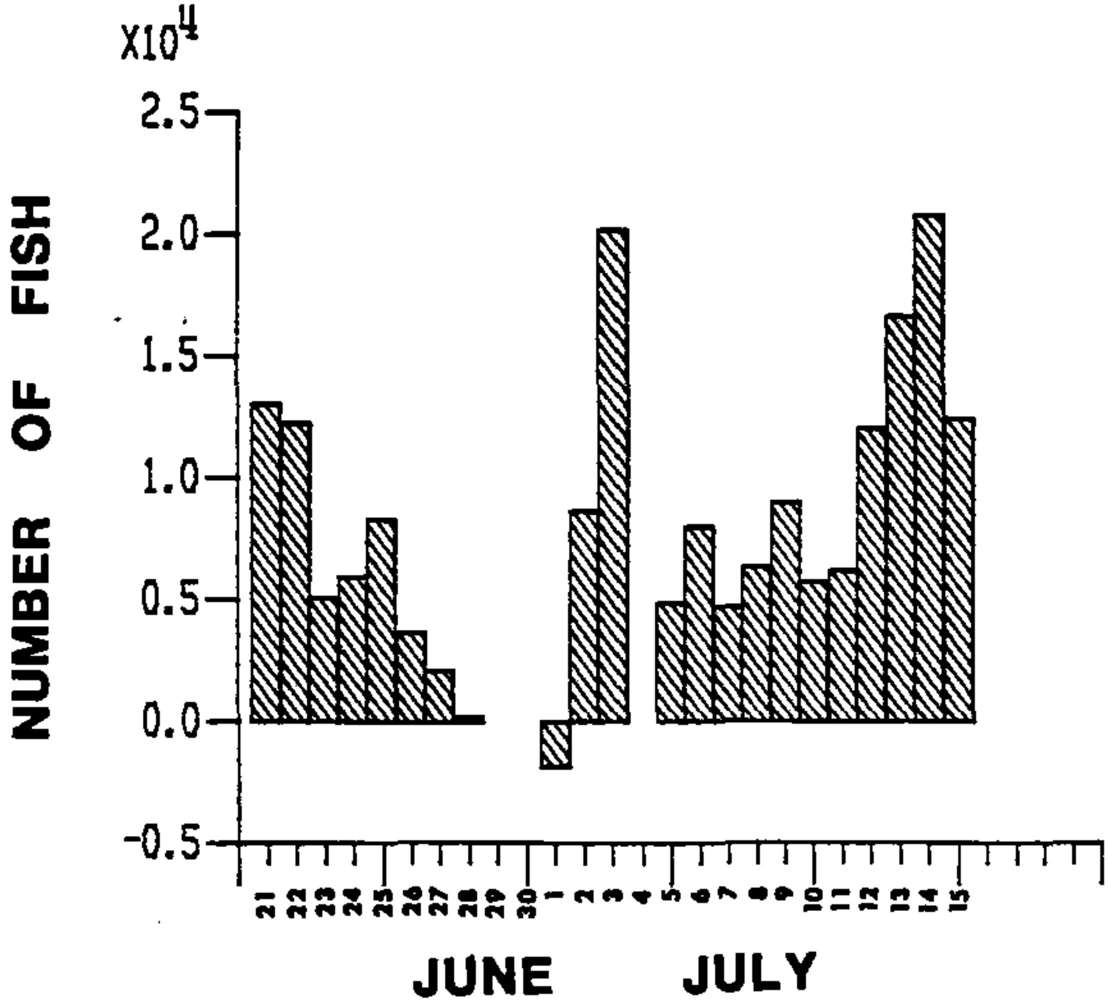

Figure 35. Sonar counts of salmon from the north bank of the lower Yukon River, near Pilot Station; 1983.

SUMMARY

Hydroacoustic feasibility studies were conducted in the lower Kuskokwim River near Bethel in 1980 and 1981. Similar studies were conducted in the lower Yukon River near Pilot Station in 1982 and 1983 Two sonar systems were used: a single-hit unit designed specifically to count salmon, and a multiple-hit unit that was designed for a wide variety of applications.

The single-hit system was tested in the Kuskokwim River in 1980 and 1981. It was compared with the multiple-hit system on the Yukon River in 1982. Only the multiple-hit system was used on the Yukon River in 1983.

The single-hit unit printed counts on a paper tape. The counts were supposed to be fish, but were found to be generated by ambient river noise, debris, rain, waves, and boat engines as well as fish. There was no way to determine directional movement of targets from the single-hit system, and no way to separate fish counts from non-fish counts. This system was inaccurate and unreliable as a tool for enumerating adult salmon in the field tests to which it was subjected.

The multiple-hit system consisted of a general purpose transceiver, a 2°, 6°, and 10° transducer, and a chart recorder that provided echograms showing directional movement of targets. River noise, debris, and boats were uniquely recorded and easily distingushed from upstream swimming fish. The multiple-hit sonar system is recommended for continued use in enumeration of adult salmon in large silt-laden rivers.

Bottom profiles of the Yukon River were determined by fathometer and sextant. The profiles provided us with a two-dimensional plot for determining transducer deployment sites and aiming angles.

In this rearch of the Lower Yukon River, the river stage (height of the water surface above an established datum plane) is directly related to the current velocity. Salmon swimming speeds were compared with river height (i.e. current velocity) to determine if there was a relationship.

Salmon swimming speeds were determined from the lengths of target traces on echograms, the range of entry and exit points of fish traces from the zero line (transducer) of the echogram, and the angle transected by a fish as it passes through the acoustic beam, which is pointed downstream at a certain angle. This is an oversimplification of the procedures, which appear in Apppendix I. The grand mean and standard deviation of all pooled swim speed samples is 0 601 ± 0.334 m/s (1.972 ± 1.096 ft/s). These data translate to 51.9 km/day (32.3 mi/day).

Swim speed frequency distributions were not normally distributed, so mean swim speed and river stage by day were ranked. Spearman's rank correlation coefficient was significant at the 5% level of probability. The result implies that fish swim speed may be directly related to river height. Surface current velocities were taken during the study; estimates of near bottom (95% of depth) velocities were estimated with a vertical-velocity curve. For example, a high surface current velocity was measured at 155 cm/sec (5 ft/s). The respective near-bottom current velocity was estimated at 80.2 cm/sec (2.6

ft/s). We speculate that at higher current velocities, more energy is spent by fish to surpass the flow, which may result in comparatively faster swim speeds (relative to ground speed) than at a lower river stage with its attendant lower velocity currents.

Horizontal distribution of salmon was determined. The frequency of occurrence was higher near shore and decreased with distance offshore. The majority of counts was within 95m (312 ft.) from shore. Mid-channel interrogations revealed few fish targets (i.e. one fish per four hours).

Vertical distribution of salmon shows no consistent trend through time. Scattergrams and resultant low coefficients of correlation indicate that one cannot predict abundance of salmon throughout the water column from sampling a single statum.

Diel distribution data indicate no consistent trend in daily fish passage. The lack of a diel pattern means that sampling effort must be spread uniformly through each 24 hour period.

Sampling time analysis used the coefficient of variation of sequentially pooled fish target counts from 3 minute echogram time blocks. The results imply that the optimal sampling time has a mean and standard deviation of 22 ± 3.5 minutes.

Arrival time analysis measured the time, in seconds, between successive arrivals of fish as seen on echograms. The distributions of passing fish were of a contagious type, rather than a regular or a random distribution. The low density distribution had a mean of 54 seconds between arriving fish, while medium and high density distributions had means of 20 and 8 seconds between successive arrivals,respectively.

Target strengths of fish were calculated using the indirect method of Ehrenberg et al. (1981). Three piston-type transducers were used: a 2°, 6°, and 10°. Preliminary target strengths were corrected using an off-axis formula obtained from Dahl (1982). Corrected target strengths ranged from -15 7dB for the 10° transducer to -23.6dB using the 2° transducer. The 6° transducer provided a target strength of -23.0dB. This measured target strength and the overall mean target strength of -21.94dB compare favorably with the -24dB measurement of Dahl (op. cit.) during laboratory measurements of a 61 cm. salmonid.

Real time estimates were made by expanding beam area counts to sampled sector area counts, where sector areas were determined form river profile transects. Daily estimates of fish passage ranged from a net downstream movement of minus 1,869 to a high of 20,750. The total estimate of fish passage along the north bank of the river from 21 June to 15 July 1983 was 184,000.

ACKNOWLEDGEMENTS

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Appendix A: Description of the single-hit sonar system.

Preface:

The single-hit system, also known as the fan-scan, was developed by the Bendix Corporation. It was tested in the lower Kuskokwim River in 1980 and 1981, and in the lower Yukon River in 1982.

The Kuskokwim and Yukon Rivers are large, silt-laden systems, with swift currents. Salmon enumeration problems are similar in both rivers. Results of the fan scan testing on the Kuskokwim River were inconclusive, because of a tidal effect, non-fish echo sources, and inability to determine directional movement of echo sources. Results of testing the unit in the Yukon River indicated that most of the recorded counts were caused by river noise.

The fan scan sonar was designed for use in water depths of 25-50 feet. It will not function properly in shallow water, because the oblique upward scanning beams (about 45 degrees from horizontal) are just skimming the surface at a very severe angle. This will only sometimes return an echo, depending on the angle of incidence of any surface waves at that instant.

System Components:

The fan scan sonar system consists of the following physical components:

1. Counter
2. Two transducers
3. Beam selector box

4. Oscilloscope
5. Boat detector
6. Gel cell battery
7. Solar panel

The shore based counter houses the transmitter/receiver, a microprocessor to process and store data, an auto-ranging device, and a thermal printer. The counter face contains two semicircles of 32 light emitting diode lights. Each semicircle corresponds to the elements of a single transducer; each transducer generates 32 separate sound beams; hence, each light corresponds to a beam. A simultaneous short burst of sound,("beep"), is produced, and a liquid crystal display maintains cumulative counts for each beam. The counts for any particular beam of either transducer are viewed by dialing the beam number corresponding to either of the two transducers.

Each beam can be ranged manually by 1 foot increments or automatically at operator-selected time intervals of 7.5, 15, 30 and 60 minutes. The maximum range per beam is 15.24 m (50 ft). A dead range area of 1.52 m (5 ft) surrounds the transducers. The oscilloscope can only monitor from 2.13 to 15.24 m (7 to 50 ft) beyond the transducers. Counts and ranges for each beam are printed automatically each hour or upon demand by depressing a manual print button for either of the memory banks assigned to its respective transducer.

Each transducer consists of a 15.24 cm (6 in) diameter sphere of ABS plastic filled with fluorocarbon fluid (Fluorinert, manufactured by 3-M Corp.; and Fluor Lube, manufactured by Hooker Corp.), which acts as a lens for focusing the sound beams. The ceramic transducer elements are positioned along the inside base of the sphere. The sphere is attached to a base structure which assures that the acoustic beam is always oriented such that the 32 beams are perpendicular to the current flow and presumably, the migration path of fish. Orientation is supposed to be automatically assured due to the hydrodynamic characteristics of the transducer base assembly, referred to as a pod in this manuscript. Each transducer is connected to the counter by 152 m (500 ft) of electrical cables.

The principal of operation is that the counter sequentially transmits 100 micro-second bursts of 300 kilohertz ultrasound to individual ceramic elements of both transducers. When these elements sequentially transmit and receive, an acoustic coverage in the shape of a fan is produced. This fan, comprised of 32 separate beams, is 4.37 degrees wide parallel to the direction of fish passage by 187.9 degrees wide perpendicular to the direction of fish passage. Beam numbers 1 to 10 are single-element, circular in cross section, and each covers 4.37 degrees of arc. Beams 11 to 21 are double-element, ellipsoidal in cross-section, and each covers 8.74 degrees of arc. Beams 22 to 32 have the same configuration as beams 1 to 10. Each element is aimed so that adjacent sound beams do not overlap within the fifty foot counting range.

Salmon crossing the sound curtain reflect echoes to the same transducer element. The echoes are amplified, processed and stored in individual computer memories (one for each beam, i.e. 64 memory units). The content of each memory is printed out hourly on paper tape. A maximum of 9,999 counts per hour per transducer is possible. Every echo of sufficient amplitude, based on target strength threshold, is considered a single fish by the counter.

The repetition rate of this system is set to presume a constant fish swimming speed of 0.3 m/s (1.0 ft/s), or about 24 km (15 mi) per day. This rate was determined under field conditions on the Kuskokwim River during the chum run in June and July 1980 and based on tag and recovery studies conducted in the Kuskokwim River (ADF&G 1961, 1962, 1966, 1969, 1970). The repetition rate can be adjusted for perceived differences in fish swimming speed.

A beam selector box contains 32 toggle switches and is used to self-test the system by simulating one or two fish, respectively, in each beam. The beam selector box is also used to select individual beams for oscilloscope viewing, if desired. This allows for the individual ranging of beams as they are viewed on the oscilloscope, tailoring the fan in conformance to bottom contours and the surface. When bottom debris is a problem, the beams are decreased in range to exclude the debris and, if necessary, shut off by decreasing the counting range to zero.

The oscilloscope is viewed to provide information on the vertical distribution of fish in the water column, distance of targets from the transducer, and recurrent rhythmic patterns that may indicate debris on the bottom. By viewing return echoes the operator is able to judge swimming speed and the accuracy of the counter itself.

A boat detector is used to automatically shut down the system when engine noise from a passing boat is detected. This prevents false counts from accumulating in the memory units. When the engine noise has diminished to a level below which the system will count, then the system is automatically reactivated.

Power for the entire system is provided by a 12 volt gel cell battery charged by a 2 ampere solar panel. A fan scan sonar system block diagram is presented in Figure A-1. A descriptive key of system components is presented in Table A-1.

Deployment:

The sonar pod was deployed by resting the pod (in a horizontal position) on the gunwale of a skiff. The skiff was allowed to back downstream until the line between the anchor and the pod was tight. The pod was then slid quickly across the gunwale in such a manner that the two downstream pointing legs entered the water a split-second before the upstream leg (tied to the anchor line).

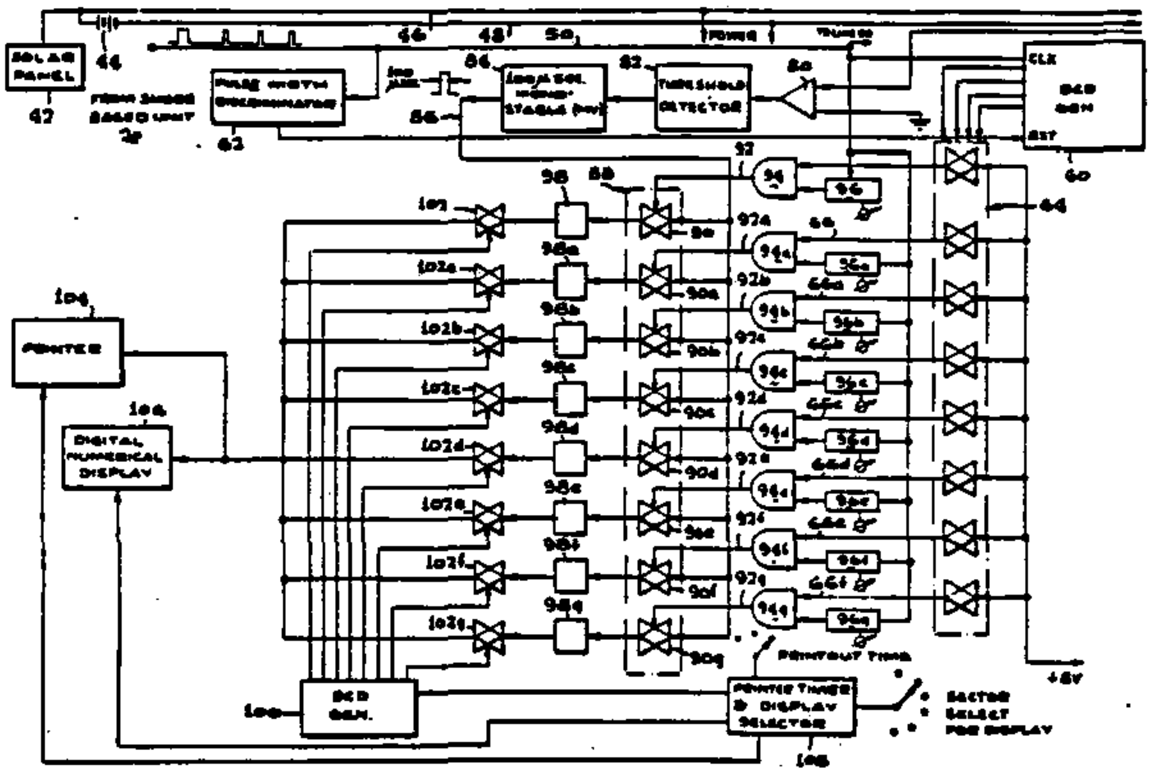
Also attached to the upstream pod leg was a 3/4 inch diameter nylon line that ran to shore and was tied to a tree or to an anchor that was driven into the ground. The electrical cable ran from the transducer to the shore-based electronics.

Retreival:

The sonar pod was retreived by first detaching the electrical cable from the shore-based counter, which was turned off. The cable was coiled on the floorboards of the skiff as the skiff was guided to the pod position by having the nylon shore-line (still secured to a shore position) run hand-over-hand across the bow of the skiff.

When the impulse cable and nylon line lead straight down (assuming that neither was fouled on bottom debris), the pod was lifted to the surface by pulling on the nylon line by hand or by electric winch, depending upon the force of the river current and whether the pod was stuck by sediments or debris. After the upstream oriented leg broke the surface, the pod was wrestled (literally)into the skiff.

Figure A-1 goes here



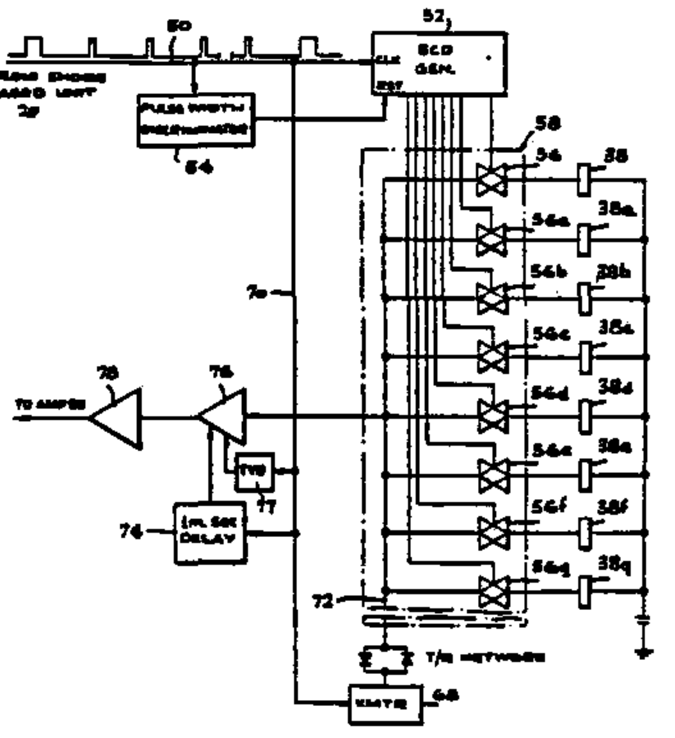


Figure A-1. Block diagram of the Acoustic Fan Scan Salmon Counter.

Table A-1. Key To Fan Scan Sonar Block Diagram Presented In Figure A-1.

20	Shore-based electronics unit (counter)
38	Transducer Elements
42	Solar panel
44	12 volt battery
46	Positive direct current line
48	Ground wire
50	Pulse train thru a wire from the counter to a BCD generator
52	First BCD (binary coded decimal) generator
54	Pulse with discriminator for first BCD generator
56	Successively closed switches
58	Digital switching unit
60	Second BCD generator
62	Pulse with discirminator for second BCD generator
64	Electronic switching unit
66	Output lines corresponding to each of the transducer elements
68	Transmitter
70	Wire conecting transmitter to timing and reset pulse train on wire 50
72	Wire transmitting a burst of 30 pulses of approximately 300 KHz having duration of 100 microseconds
74	Timing circuit
76	Preamplifier
78	Buffer
80	Amplifier
82	Threshold detector

84 100 microsecond monostable multivibrator. Each output pulse from the multivibrator, which represents one fish count, is a 100 microsecond pulse of 8-volt magnitude.

86 Wire carrying count signals from multivibrator to electronic switches in a switching unit (88)

88 Switching unit

90 Electronic switches in switchin unit (88)

92 Wires connecting electronic switches to corresponding AND (analog digital) circuits

94 AND circuits

96 Range gates activated by timing pulses on wire 50

98 Pulse counters

100 Third BCD generator

102 Electronic switches connecting the BCD generator to an output line from one of the pulse counters (98)

104 Printer

106 Digital numerical display device

108 Printer timer and display selector

Appendix B: Description of the multi-hit sonar system.

The multiple-hit sonar system consisted of the following components:

1. BioSonics Model 101 echo sounder.

2a. Ross 250 E chart recorder/sounder that was modified by Biosonics, Inc. for use with a BioSonics 101 sounder. This unit was used in 1982.

2b. EPC Model 3200S chart recorder/sounder. This unit was used in 1983.

3. BioSonics Model SP500 dual-axis transducer rotator.

4. One each two degree, 6 and 10 degree matched transducers, manufctured by BioSonics, Inc.

5. Single channel Tektronics Model 323 oscilloscope.

6. A thresholding device manufactured by BioSonics that was used in 1983.

Power to the system was provided by a Honda Model EM1600 generator or two 12 volt car batteries hooked in series through a 24/115 VAC converter.

The BioSonics Model 101 echo sounder incorporates the following features (BioSonics 1979):

1. A highly accurate 20 log R and 40 log 10R TVG (time varied gain)

amplifier with a deviation from ideal less than ± 0.5 dB over a 110 db gain dyanmic range.

2. Selectable absorption coefficient loss compensation, both standard and user selected values.

3. Selectable transmitting power is variable from 50 to 1000 watts in 3 dB steps: -13, -10, -6, -3, and -0.

4. Selectable receiver gain is variable from -18 dB to +24 dB in 6 dB steps with an accuracy of ± 0.2 dB per step.

5. Three (3) standard receiver outputs (reference frequency of 420 kHz, 8 kHz for recording, and detected for data analysis) which eliminate, in most applications, the need for interfacing electronics for data recording or real time processing.

6. Variable bandwidth with selections of 10, 5, 2, and 1 kHz.

7. Transmit pulse width variable from 0.1 mullisecond (ms) to 9.9s in 0.1-ms steps.

8. Transmit pulse serparation variable from a 0.1 second (s) to 9.9 in 0.1-s steps.

9. Built-in calibration circuit with both continuous wave and pulsed operation modes with accurate separation between pulses from 0.1m to

99.9m in 0.1m steps.

10. Triggerable either externally or internally to allow for use with or without a chart recorder.

11. Control over receiver output with blanking from time of trigger to selected blanking distance. Blanking distance is adjustable from 0.1m to 999.9m in 0.1m steps.

12. The receiver contributes no more noise to the signal than the source.

A BioSonics Model 101 echo sounder block diagram is shown in Figure B-1. When a trigger command is received, a transmission pulse is generated within the Calibrator-Transmitter Board. The Power Amplifier Board accepts the low-level transmission pulse and presents the transducer with an amplified version. Received signals (echos) are amplified and filtered by the Pre-amp, TVG Board. The Receiver Board provides additional amplification and signal conditioning. The Control Board controls many of the receiver characteristics. A calibration signal can be slected in place of the transducer signals to observe receiver characteristics.

Operating characteristics of the BioSonics echo sounder (Wirtz and Acker 1979) are as follows:

<u>Transmitter</u>:

The purpose of the transmitter is to present the transducer with a high-powered reference frequency pulse upon command. The transmitter can be triggered by an external signal or by the signal from an internal pulse generator. A pulse width timer gates the transmitter on for an interval ranging from 0.1ms to 9.9ms in 0.1ms steps. A crystal oscillator operating at a rate 20 times the transmission frequency determines the transmission frequency.

Power Amplifier:

The power amplifier accepts low-level transmission pulses from the calibrator-transmitter board and amplifies the signal to a level ranging from 50 to 1000 watts. The power amplifier is matched to the transducer by a wideband transformer.

Control Circuitry:

The main function of the control circuitry is to produce the control voltage for the TVG amplifier and to provide the blanking and range control signals. A crystal oscillator operating at a frequency of $5x\ 10^3$ x sound velocity is used as a timing reference for all the control signals.

The receiver output is blanked (clamped to zero) whenever the echo sounder is triggered. This prevents erroneous receiver output due to interference from the transmitter and during the time that the TVG amplifiers are inoperative. The blanking timer is started on completion of the transmission pulse. The receiver output is unblanked when the blanking distance is reached.

The range timer determines the effective distance over which the TVG amplifiers operate. It starts on completion of the transmission pulse and holds the TVG amplifier control voltages at its current value when the selected range is reached. The gain of the receiver increases until the set range and is then frozen.

Receiver:

The receiver accepts low-level electrical signals from the transducer. The unit signals are amplified, filtered and processed in other ways in order to present a useful signals to peripheral instruments operating in conjunction with the echo sounder. A mixer is used to convert the basic echo sounder frequency to 8kHz, which is suitable for most tape recorders.

Calibrator:

An internal calibrator provides stable reference signals in order to determine receiver characteristics. The calibrator signal is generated by switching between precision + 10V and -10V references at the same rate as the transmission frequency. The signal may be continuous wave or pulsed with widths equal to the transmission pulse. Separation between pulses may be selected from 0.1m to 99.9m in 0.1m increments. Any of four different amplitudes (20dB) increments may be selected. The "pulse" mode may be used to establish an exact measurement.

The BioSonics Model 101 sounder was slaved to the Ross and to the EPC chart recorders. The chart paper used with the Ross recorder was 22.9 cm (9 in) wide. A chart speed of one inch per minute was routinely used with the BioSonics sounder. A faster chart speed produced target traces of much greater length. Significant additional data were not gained by the elongated traces, and paper conserved. The Ross recorder had four ranges for each of three triggering repetition rates; these are presented in Table B-1. All three ping rates, but only ranges 1 and 2 were routinely used.

The EPC chart recorder used paper having a dispaly width of 48.8 cm (19.2 in). Although this recorder/ sounder can range to 5852 m (19200 ft), the maximum range used during this study was 365 m (1200 ft), because the BioSonics Model 101 sounder had a factory set (though optional) range of 2.5 to 250 m (820 ft). The minimum range used (and available on the EPC) was 11.3 m (37 ft). Pulse repretition rates, in this study, ranged from 8 to 2 pings per second. Table B-2 presents EPC chart speeds, ranges, and ping rates.

Figure B-1 goes here

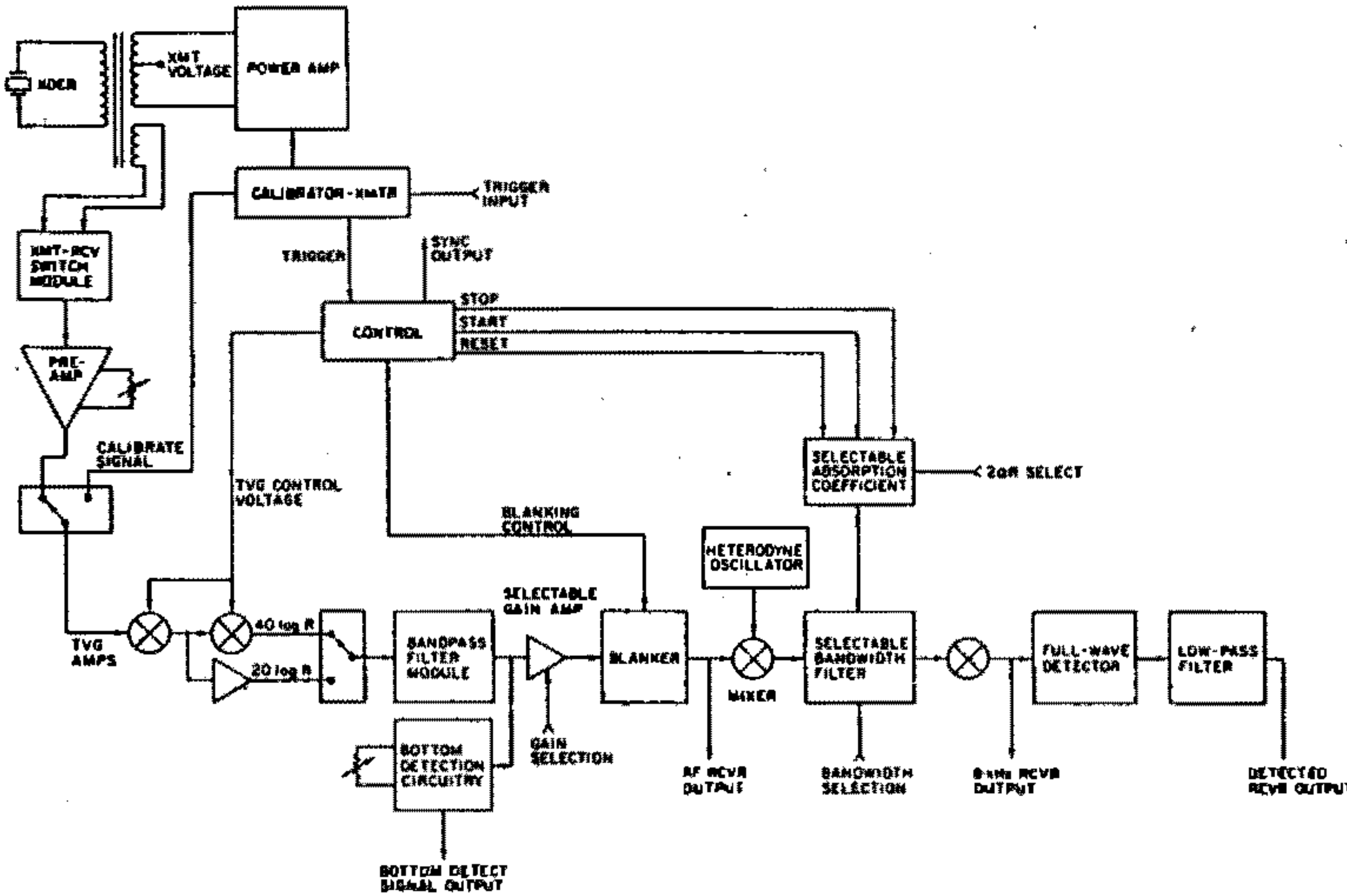


Figure B-1. Block diagram of the BioSonics Model 101 Echo Sounder. From: Wirtz and Acker 1981.

Table b-1 goes here

Table B-1. Range Selection according to triggering repetition rate in the Ross Model 250E sounder/chart recorder.

Repetition Rate (Per Second)	Range Displayed Feet (meters)			
	1	2	3	4
12.0	0 - 50 (15.24)	50 - 100 (30.48)	100 - 150 (45.72)	150 - 200 ([illegible])
4.0	0 - 150 (45.72)	150 - 300 (91.44)	300 - 450 (137.16)	450 - 600 (182.88)
2.5	0 - 250 (76.20)	250 - 500 (152.40)	500 - 750 (228.60)	750 - 1000 (304.80)

Table b-2 goes here

Table B-2. Range, pulse repetition rate, and chart speed of the EPC 3200S chart recorder/sounder that were used in 1983.

	1/--	1/--	1/--	1/--	1/--	1/--
Time Base: Second/Sweep	64	32	16	8	4	2
Pulse Repetition Rate	8	8	8	8	4	2
75	180	180	180	180	90	45
100	135	135	135	135	[illegible]	34
150	90	90	90	90	45	22
200	68	68	68	[illegible]	34	17

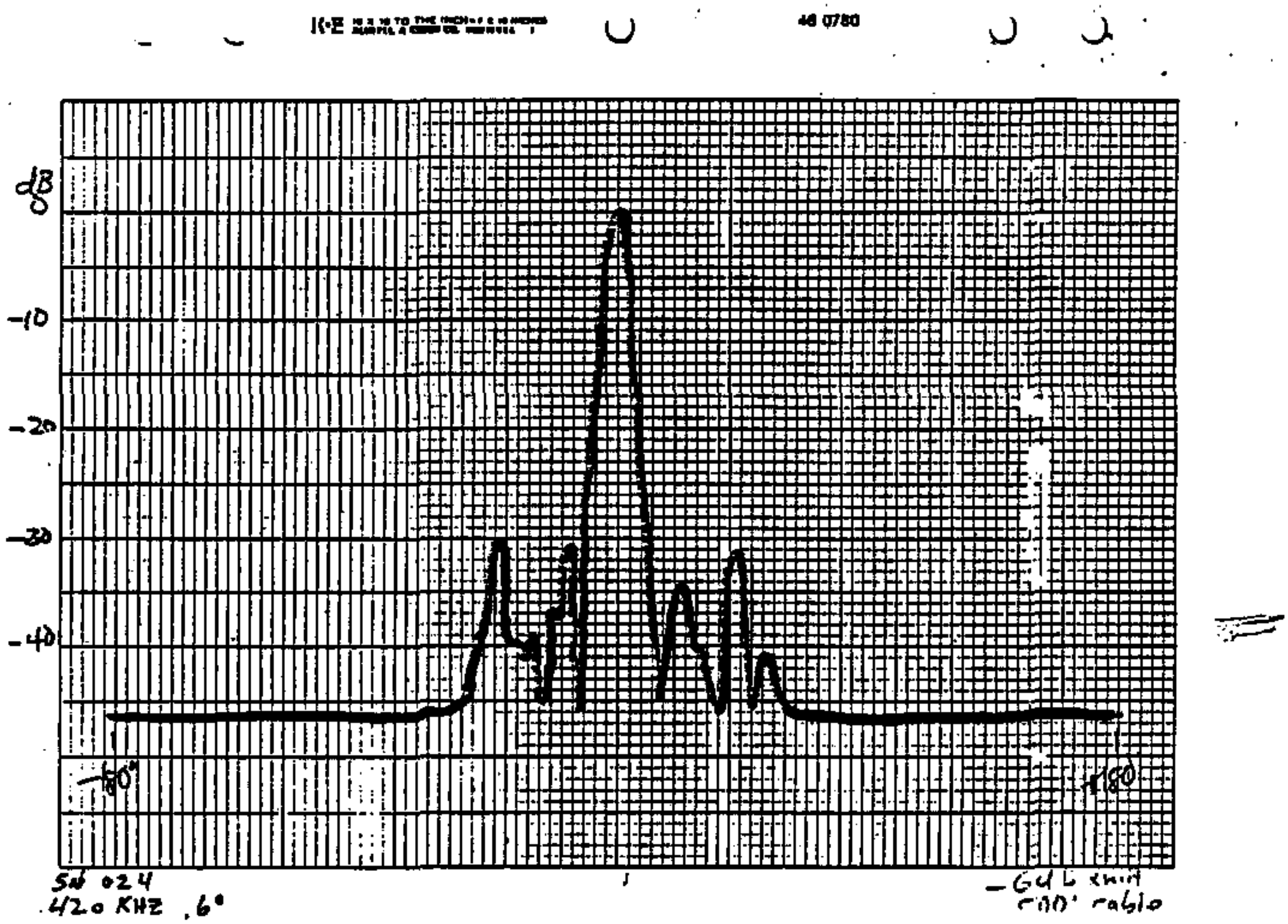
APPENDIX C: Calibration Data for the Multiple-hit-hydroacoustic System used on the Lower Yukon River during 1982 and 1983.

Appendix C-1 goes here.

APPENDIX Table C-1. Calibration data for BioSonics transducers. All measurements in decibels (dB) referenced to 1 micro-Pascal. Sl = source level. All Sx (receiving sensitivity) measurements were made at 25 m using 40 log R.
* The second receiver is 6.75 dB greater than the main receiver.

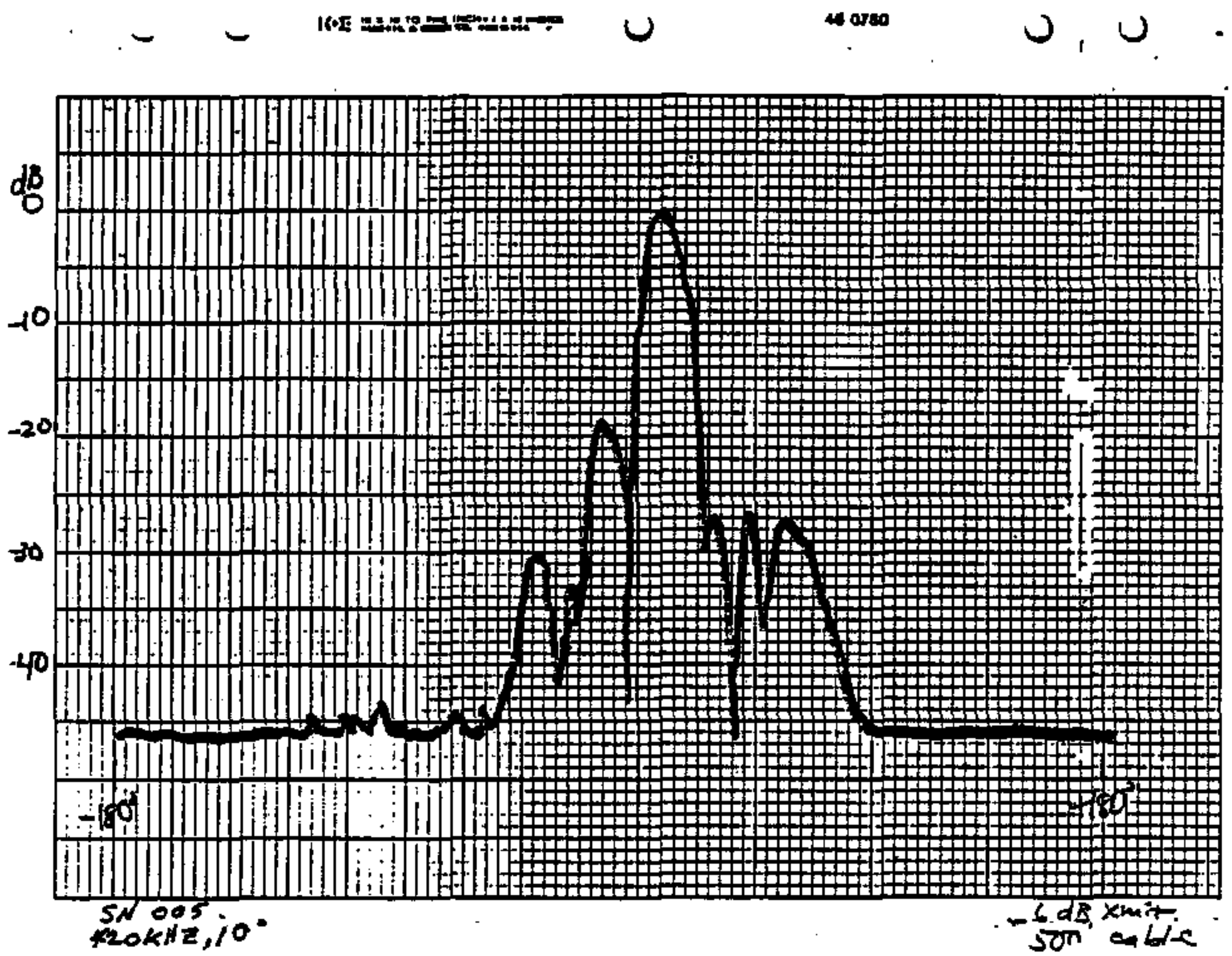
Serial Number	Beam Angle	Cable Length Feet	Pulse Width ms	Receiver Gain dB	Transit Gain dB	Main Receiver Sl dB	Main Receiver Sx dB	2nd Receiver* Sx dB
005	10	500	0.5	0	0	213.6	-130.04	-123.0
24	6	500	0.5	0	0	218.4	-123.80	-117.0
016	2	500	0.5	0	0	222.0	-114.80	-108.0

appendix c-1 again goes here



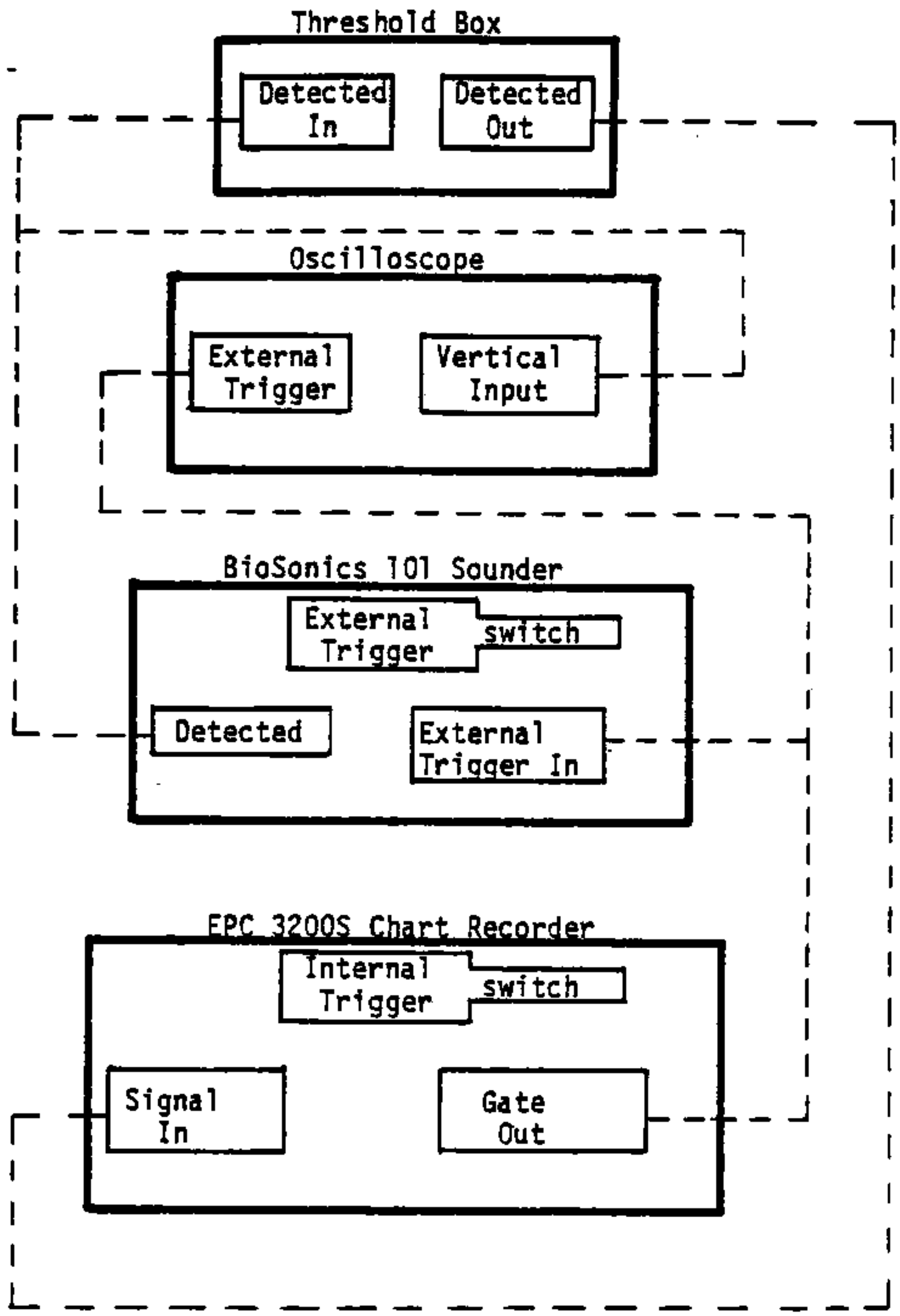
APPENDIX Figure C-1   Beam pattern plot of the 6° transducer showing the main lobe and side lobes.

appendix fig c-2 goes here



APPENDIX Figure C-2 Beam pattern plot of the 10° transducer showing the main lobe and side lobes.

appendix c-3 goes here



APPENDIX Figure C-3. Block diagram showing the wiring configuration when the BioSonics Model 101 transceiver is externally triggered (i.e. is the Slave) and the EPC Model 3200S chart recorder is internally triggered (is the Master); in association with threshold box and oscilloscope.

APPENDIX D: Procedure for Determining River Profiles, Slant Range and Straight-Offshore Distance Using a Sextant and Fathometer

a. Desired scanning angle of transducer will be about 45° downstream.

b. Using a fathometer, determine a suitable location to deploy the transducer assembly. The location should be within 100 feet of shore, between 3 and 8 feet deep, and with bottom contours falling away moderately to deep water. Do not select a location where a constant eddy is evidenced.

c. Drop a tight-lined, anchored buoy at the deployment site (A) (Figure D-1) and measure distance to shore with tape measure. Mark this point on shore (B). Standing at (B), with sextant, turn 90° upstream and measure distance on this line to a point (C) on shore equal to distance from (A) to (B). Turn 45° shoreward from (C) and mark a point (D) about 100 feet away on this line. Place a 4x 4 ft. sheet of plywood at (C). Place a 2 x 8 ft. sheet of plywood at (D). Paint each a different color of fluorescent paint (i.e. one orange, the other green with red stripes).

d. Measure 1,000 feet (in the upstream direction on the north bank) (in the downstream direction on the south bank), respectively, from point (C). Place a 4 x 4 ft. sheet of plywood at this point (E). This sheet should be painted the same color as (C). Points (C) and (D) form a 1,000 foot primarily baseline. They should be braced vertically, facing the river.

e. Measure 500 feet along the primary baseline from point (C) and situate, vertically, a 2 x 4 ft. plywood marker (F) painted uniquely different from (C) and (E). The distance (C-F) serves as the secondary baseline.

f. Measure 250 feet along the primary baseline from point (C) and situate, vertically, a uniquely painted 2 x 4 ft. plywood marker (G). The distance (C-G) serves as a tertiary baseline.

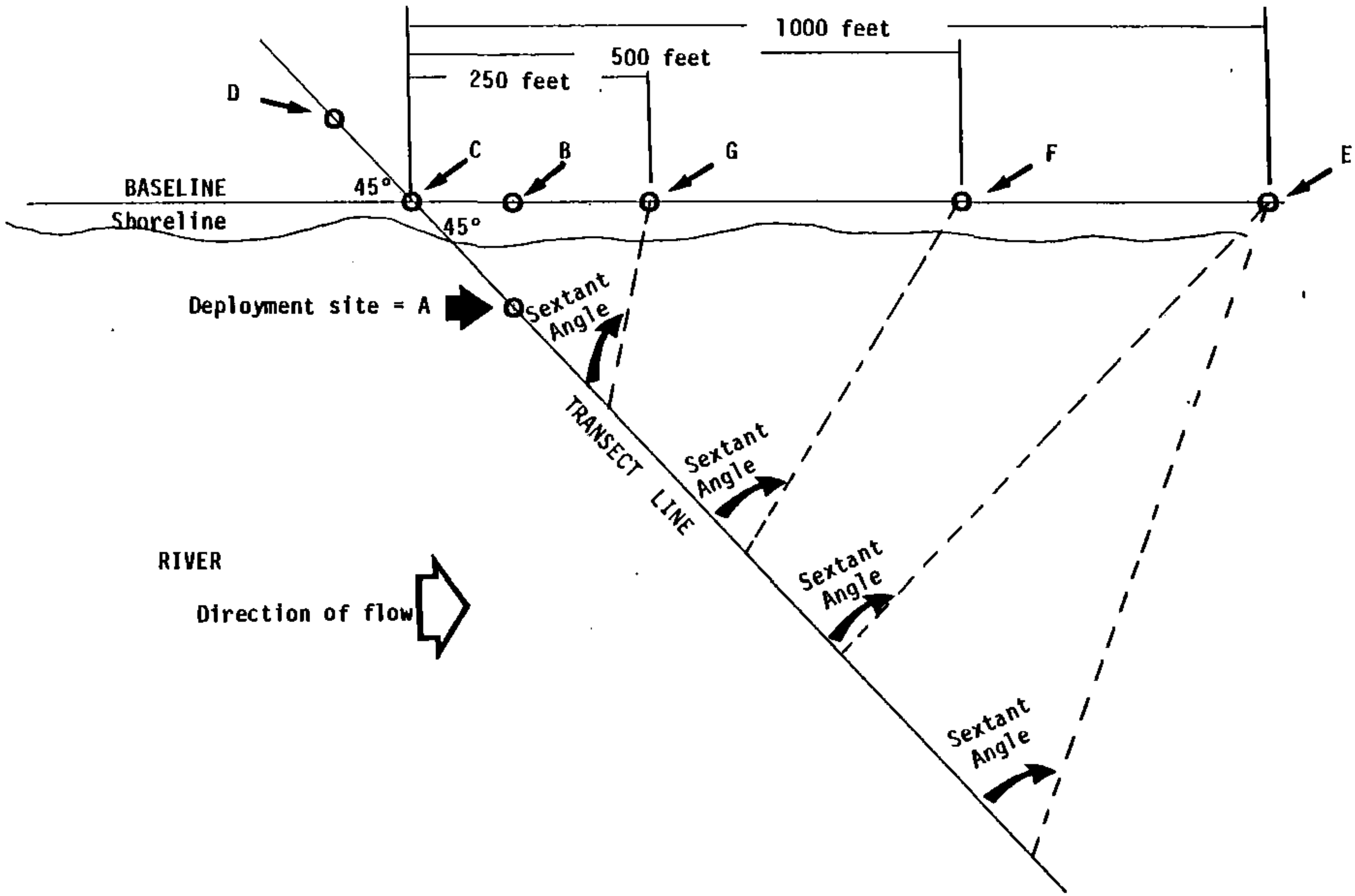
g. With fathometer and sextant in skiff, run a transect from offshore to near-shore along the line-of sight markers (buoy at A, plywood at C and D). For each position and depth reading, maintain skiff stationary in the current on the line of sight. Record angle with sextant to primary baseline points until angle exceeds limits of sextant, then sight on secondary, then tertiary baseline points.

h. Use law of sines to determine distances to baseline points (Figure D-2).

i. Use sine of aiming angle to determine straight off-shore distance from slant range (Figure D-3). Same answer will result by using cosine or resultant angle: 90° minus aiming angle.

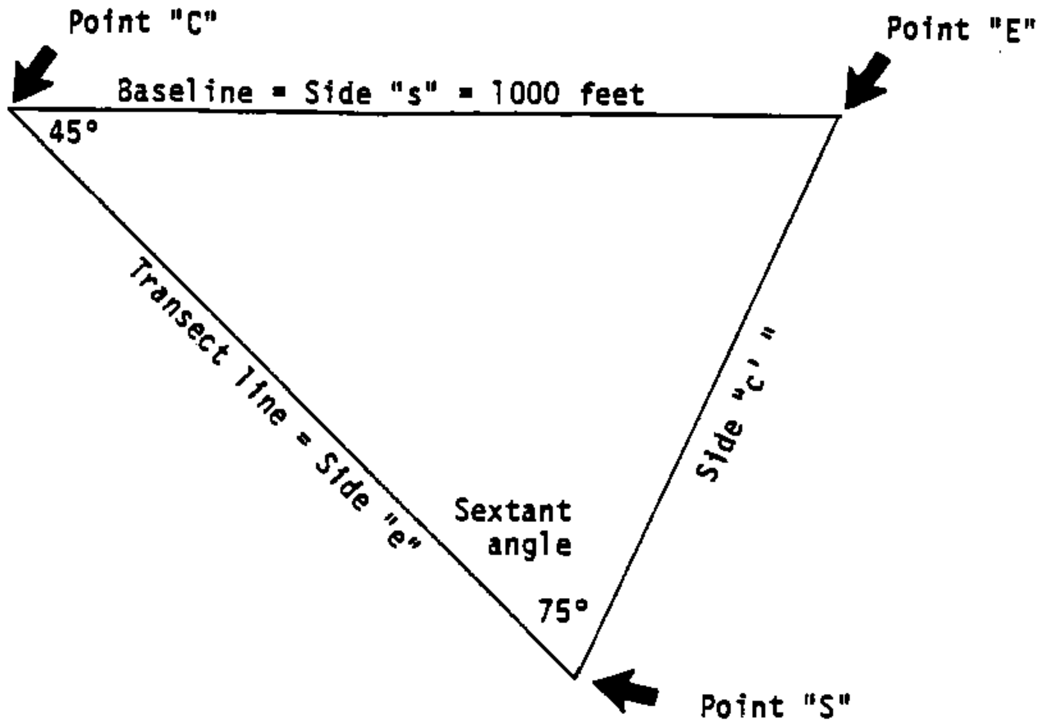
j. Plot slant and straight-offshore distances and corresponding depths to get bottom profile and river cross-section (surface to bottom).

appendix fig d-1 goes here



APPENDIX Figure D-1. Layout of the triangulation method for determining river profile.

appendix fig d-2 goes here



1. Aiming angle = 45°.
2. Baseline distance = 1000 feet.
3. Sextant angle = 75° (in this example).
4. Therefore, the angle at Point "E" = 180°- (45°+75°) = 60°.
5. Law of Sines:

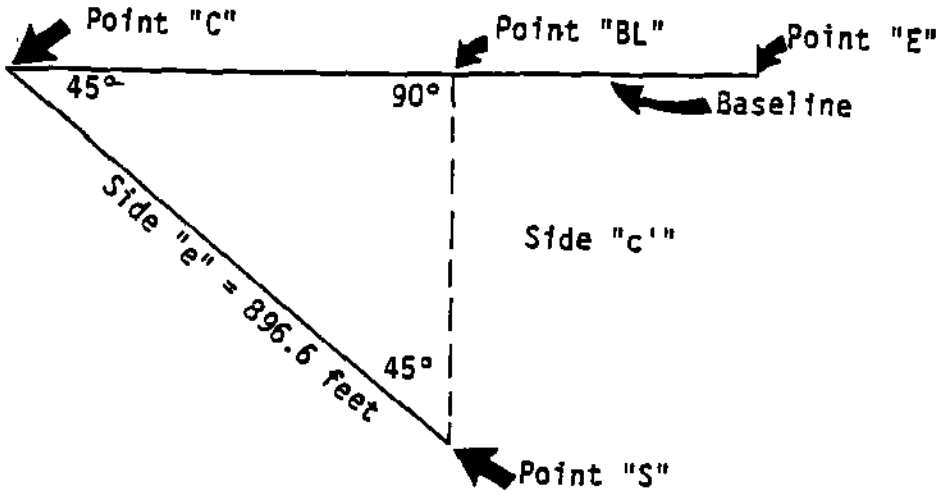
$$\frac{c'}{\text{Sine } C} = \frac{s}{\text{Sine } S} \text{ ; therefore } c' = \frac{s \text{ Sine } C}{\text{Sine } S} \text{ ; } c' = 732.05 \text{ feet.}$$

6. Since angle E = 60°; $\frac{e}{\text{Sine } E} = \frac{s}{\text{Sine } S}$; $e = \frac{s \text{ Sine } E}{\text{Sine } S}$

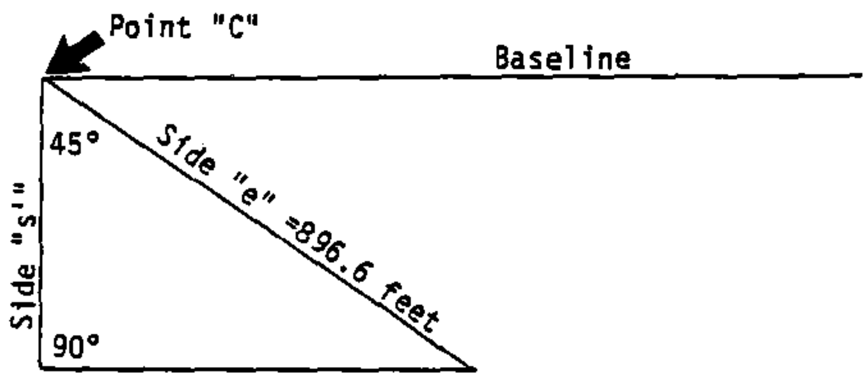
7. So, e = 896.5755 feet.

APPENDIX Figure D-2. Determining distances from baseline points to survey stations along the transect line using aiming and sextant angles.

appendix d-3 goes here



1. Sine angle C = $\frac{\text{Side c'}}{\text{Side e}}$; Sine 45° = $\frac{c'}{896.6}$; c' = 633 9 feet.



2. Cosine of resultant angle, when aiming angle is subtracted from 90°.

   a. 90° - 45° = 45°

   b. Cosine angle C = $\frac{\text{Side s'}}{\text{Side e}}$; Cosine 45° = $\frac{s}{896.6}$; s' = 633.9 feet.

APPENDIX Figure D-3. Determining the straight-offshore distance from the slant range and the aiming angle.

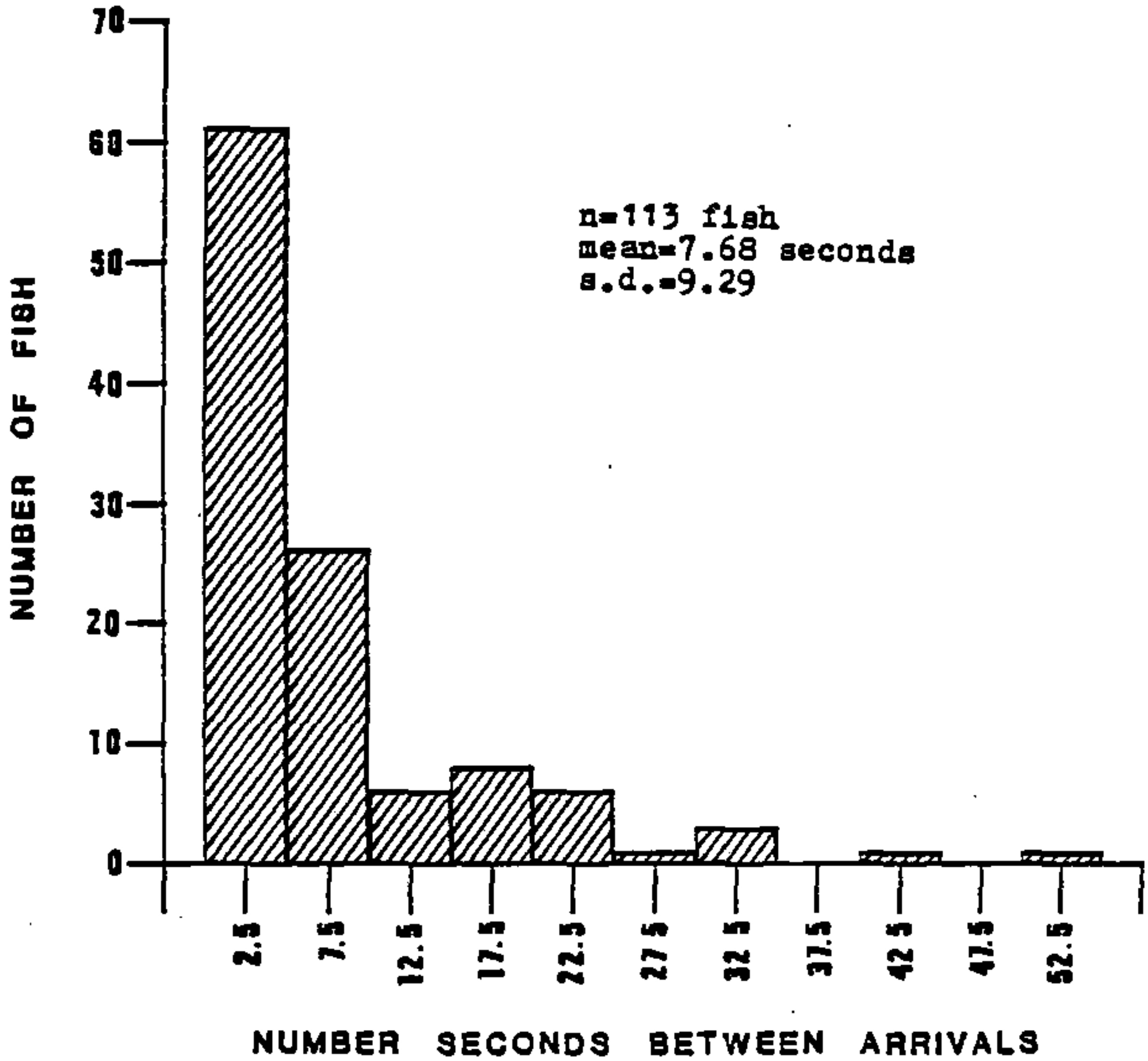


Figure 33. Time between successive arrivals of fish. High density. Used a 2 degree transducer; 1100-1115, 2 July 1983. Lower Yukon River, near Pilot Station.

appendix j goes here -4

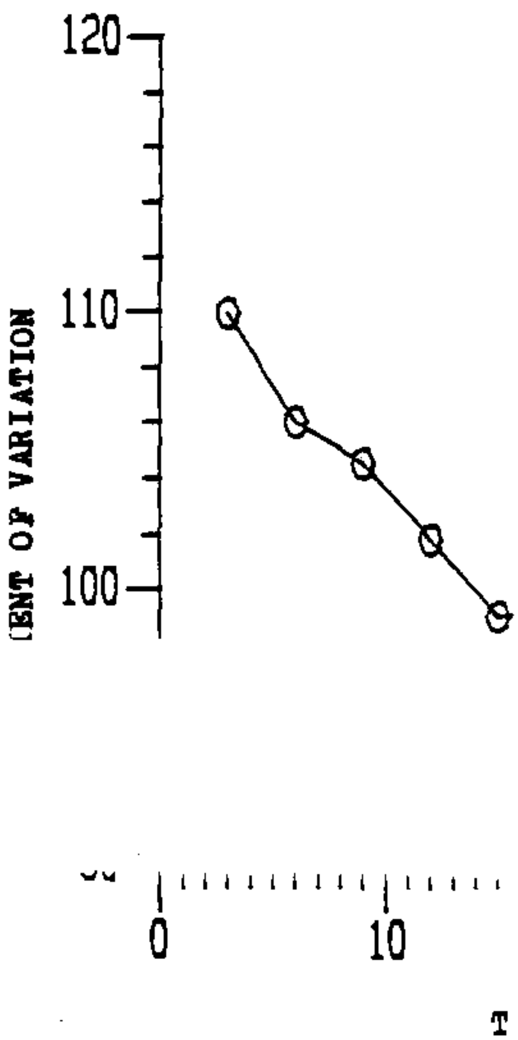


Figure 30. Co
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Lower Yukon Ri

appendix j goes here -6

Table 3. Chi-square goodness of fit test for arrival time distributions. -Data collected from the north bank, lower Yukon River, near Pilot Station, June and July 1983. Time group refers to fish whose time intervals (in seconds) between sucessive arrivals at the acoustic beam correspond to the observed number of fish per group. The Poisson distribution corresponds to the expected frequencies.

Low Density

Time Group (seconds)	Observed	Expected (Poisson)
0 - 20	60	3.99
21 - 25	5	20.67
26 - 30	9	42.83
31 - 35	2	39.13
36 - 40	7	17.57
41 - 570	46	4.82

Chi-square = 1218.72 > X^2 99.5; 5 d.f. = 16.75

Medium Density

Time Groups (seconds)	Observed	Expected (Poisson)
0 - 10	56	10.44
11 - 15	14	48.50
16 - 20	14	46.20
21 - 180	35	13.86

Chi-square = 278.13 > X^2 99.5; 3 d.f. = 12.84

High Density

Time Group (seconds)	Observed	Expected (Poisson)
0 - 5	61	57.47
6 - 10	26	52.27
11 - 55	26	3.25

Chi-square = 172.40 > X^2 99.5; 2 d.f. = 10.60

appendix j goes here -8

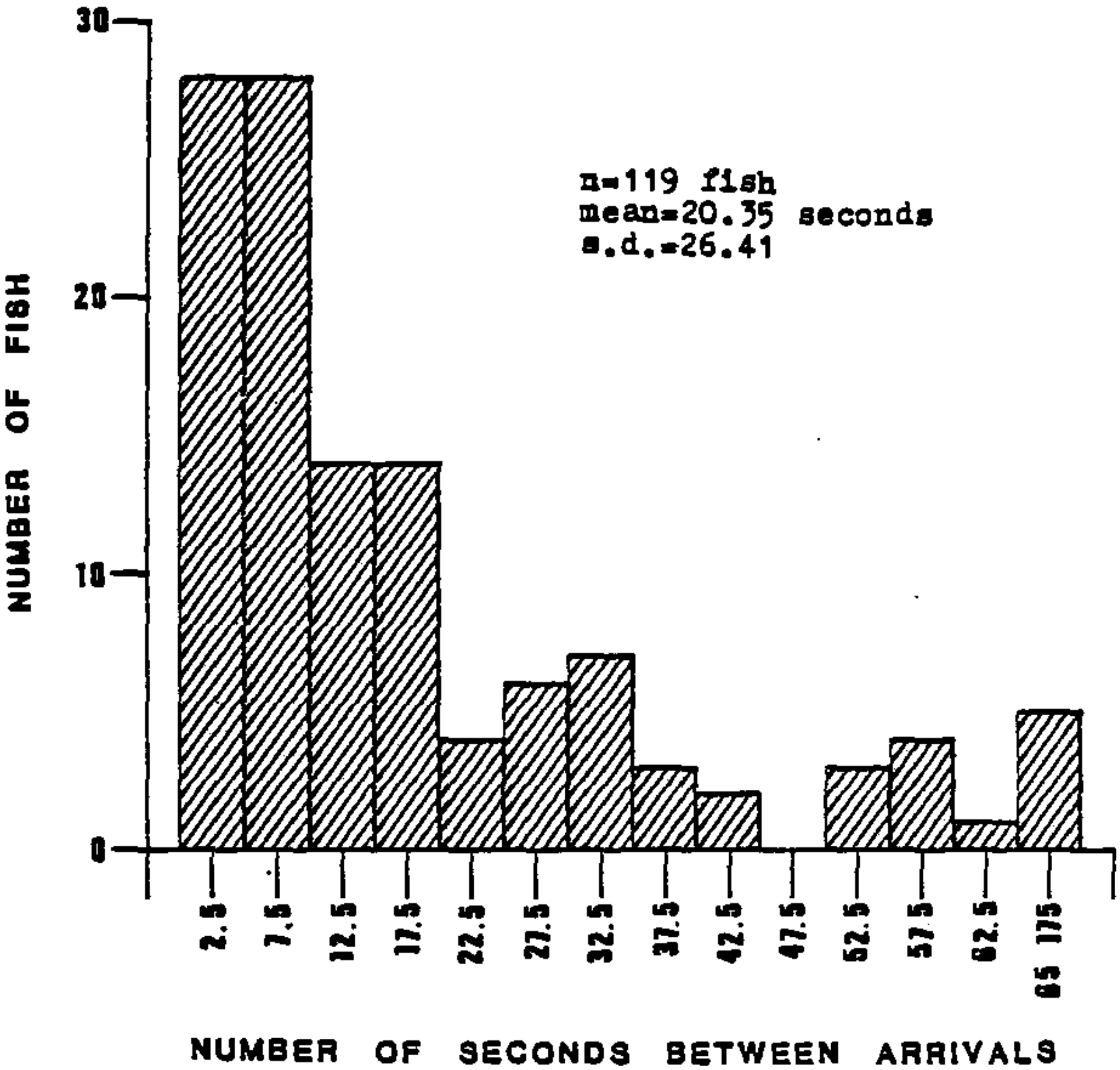


Figure 32. Time between successive arrivals of fish. Medium density. Used 6 and 10 degree transducers; 0815-1215; 2 July 1983. Lower Yukon River, near Pilot Station.

APPENDIX E. Environmental Observations Recorded at the Main Channel Sonar Site, Lower Yukon River Near Pilot Station, 1983

Appendix E page 1 goes here.

Appendix E   Environmental observations recorded at the main channel sonar site, lower Yukon River near Pilot Station, 1983.

Date	Time	Temperature F° Air	Temperature F° Water	Wind Direction and Estimated Velocity (mph)	Wave Height (Feet) Estimated	Total Observed sky Cover	Precipitation (24 Hours	Cumulative Drop In Water Level	Remarks on Water Level
6-8	1200	58	54	NW 13 MPH	0-0.5	1	G		
6-9	1215	47	54	NW 8 MPH	0-0.5	2	G	0	RISING
6-10	1308	60	55	N 0-5 MPH	0	1	G	+6	RISING
6-11	1210	66	55.5	N 0-5 MPH	0	2	G	+12.5	RISING
6-12	1200	68	56	0	0	3	G	+20.5	RISING
6-13	1230	65	56	NNW 0-5 MPH	0	3	A	+33	RISING
6-14	1308	62	56	NNW 0-5	0	1	G	+35.125	RISING
6-15	1215	59	56	0	0	2	G	+41.625	RISING
6-16	1230	52	56	0	0	3	G	+46.625	RISING
6-17	1230	55	56	0	0	2	G	+46.625	FALLING
6-18	1230	65	56	0	0	2	G	+45.625	FALLING
6-19	1300	62	57	0	0	2	F A	+43.125	FALLING
6-20	1221	67	56	0	0	1	G	+38.375	FALLING
6-21	2216	71	57	NNW 0-2 MPH	0	1	G	+32.625	FALLING
6-22	1310	68 F	57 F	NNW 0-2 MPH	0	3	G	+24.625	FALLING
6-23	1200	65 F	57 F	NNW 0-5 MPH	0	3	F	+19.125	FALLING
6-64	1200	59 F	58 F	N 0-5 MPH	0.5	3	A	+14.625	FALLING
6-25	1630	63 F	60 F	E 5-10	0.5	3	G	+6.625	FALLING

Code: Sky

0. No observation
1. Clear sky, cloud covering not more than 1/10 of sky
2. Cloud covering not more than 1/2 of sky
3. Cloud covering more than 1/2 of sky
4. Completely Overcast
5. Fog or Thick Haze

Code: Precipitation

A. Intermittent Rain
B. Continuous Rain
C. Snow
D. Snow and Rain Mixed
E. Hail
F. Thunderstorm w/ or w/o Precipitation
G. No Precipitation

Appendix E page 2 goes here.

Appendix E Environmental observations recorded at the main channel sonar site, Lower Yukon River near Pilot Station, 1983.

Date	Time	Temperature F° Air	Temperature F° Water	Wind Direction and Estimated Velocity (mph)	Wave Height (Feet) Estimated	Total Observed Sky Cover	Precipitation (24 Hours	Cumulative Drop In Water Level	Remarks on Water Level
6-26	1200	62	62	E 5-10	0-0.5	2	A	+0.125	FALLING
6-27	1200	68	62	ESE 0-5	0	3	G	-7.125	FALLING
6-27	1730	62	64	SE 0-5	0	3	G		FALLING
6-28	1200	64	64	0	0	4	G	-11.375	FALLING
6-29	1315	68	64	0	0	2	A	-14.125	FALLING
6-30	1300	62	64	E 0-5	0	3	F	-15.625	FALLING
7-1	1315	64	64	0	0	3	A	-17.125	FALLING
7-2	1300	54	64	W 0-5	0	4	A	-17.125	FALLING
7-3	1300	58	64	0	0	2	A	-16.625	RISING
7-4	1200	60	64	N 0-5 MPH	0	1	G	-15.125	RISING
7-5	1215	65	64	N 5-10 MPH	0.5	1	G	-14.625	RISING
7-6	1200	67	64	ESE 0-5 MPH	0	3	A	-14.625	RISING
7-7	1435	62	64	ESE 0-5 MPH	0	3	A	-13.875	RISING
7-8	1130	62	64	E 0-5 MPH	0-0.5	3	A	-13.625	RISING
7-9	1900	62	64	0	0	3	A	-13.625	STEADY
7-10	1145	60	64	ESE 0-5	0	3	G	-14.125	FALLING
7-11	1430	60	65	WSW 0-5	0-0.5	4	A	-13/625	RISING
7-12	1200	66	64	WSW 0-5	0	3	A	-13.625	STEADY
7-13	2000		64	0	0	4	A	-14.125	
7-14	1215	58	64	0-5	0-0.25	4	A	-15.125	
7-15	1900	57	64	0-5	0-1.0	4	A	-15.125	
7-16	1200	54	65	W	1.0-1.5	4	A	-17.125	

Code: Sky

0. No observation
1. Clear sky, cloud covering not more than 1/10 of sky
2. Cloud covering not more than 1/2 of sky
3. Cloud covering more than 1/2 of sky
4. Completely Overcast
5. Fog or Thick Haze

Code: Precipitation

A. Intermittent Rain
B. Continuous Rain
C. Snow
D. Snow and Rain Mixed
E. Hail
F. Thunderstorm w/ or w/o Precipitation
G. No Precipation

APPENDIX F: Normalizing constants for the 2° and 6° transducers by area of partitioned range appendix Table f-1 goes here

Appendix F Table F-1. Normalizing constants for the 2° and 6° transducers by area of partitioned range. Used to establish horizontal distribution of fish by straight off-shore range on echograms.

Total Range m	Area m²		Partitioned Range m	Area m²	Normalizing Constant
0 - 5	1.31		0 - 5	1.31	10.00
0 - 10	5.24	>	5 10	3.93	3.33
0 - 15	11.78	>	10 - 15	6.54	2.00
0 - 20	20.94	>	15 - 20	9.16	1.43
0 - 25	32.72	>	20 - 25	11.78	1.11
0 - 30	47.12	>	25 - 30	14.40	0.91
0 - 35	64.14	>	30 - 35	17.02	0.77
0 - 40	83.78	>	35 - 40	19.64	0.67
0 - 45	106.03	>	40 - 45	22.25	0.59
0 - 50	130.90	>	45 - 50	24.87	0.53
0 - 55	158.39	>	50 - 55	27.49	0.48
0 - 60	188.50	>	55 - 60	30.11	0.44
0 - 65	221.22	>	60 - 65	32.72	0.40
0 - 70	256.56	>	65 - 70	35.34	0.37
0 - 75	294.52	>	70 - 75	37.96	0.35
0 - 80	335.10	>	75 - 80	40.58	0.32
0 - 85	378.30	>	80 - 85	43.20	0.30
0 - 90	424.12	>	85 - 90	45.82	0.29
0 - 95	472.55	>	90 - 95	48.43	0.27
0 -100	523.60	>	95 - 100	51.05	0.25
0 -105	577.27	>	100 - 105	53.67	0.24
0 -110	633.55	>	105 - 110	56.29	0.23
0 -115	692.46	>	110 - 115	58.91	0.22
0 -120	753.98	>	115 - 120	61.52	0.21
0 -125	818.12	>	120 - 125	64.14	0.20

Table
appendix E-2 goes here

Appendix F Table F-2. Normalizing constants for the 6° transducer by area of partitioned range. Used for oscilloscope counts, to establish horizontal distribution of fish by offshore distance.

Total range m.	Area m²	Partitioned range m.	Area m²	Normalizing constant
0 - 16.46	14.19	00.00 - 16.46	14.19	10.00
0 - 32.92	56.74	16.47 - 32.92	42.55	3.35
0 - 48.38	122.55	32.93 - 48.38	65.81	2.16
0 - 96.76	510.69	48.39 - 96.76	388.14	0.37

APPENDIX G. Peak Voltage Values from Oscilloscope Reading Collected from 23-28 June 1983 appendix Table g-1 goes here

Peak Voltage	N	(E/E_{min})	$(E/E_{min})^2$ (N)
.4	47	----	----
.5	80	----	----
.6	102	1.00	102.00
.7	89	1.17	121.83
.8	78	1.33	137.97
.9	38	1.50	85.50
1.0	30	1.67	83.67
1.1	20	1.83	66.96
1.2	33	2.00	132.00
1.3	17	2.17	80.05
1.4	13	2.33	70.58
1.5	21	2.50	131.25
1.6	13	2.67	92.66
1.7	6	2.83	48.05
1.8	5	3.00	45.00
1.9	2	3.17	20.10
2.0	6	3.33	66.53
2.1	1	3.50	12.25
2.2	2	3.67	26.94
2.3	4	3.83	58.68
2.4	1	4.00	16.00
2.5	0	4.17	0.00
2.6	1	4.33	18.75
2.7	0	4.50	0.00
2.8	3	4.67	65.43

$\sum_{i=.6}^{2.8} N_i$ 485 1482.24

$\tilde{E}^2 = 1482.24/485 = 3.05$

$\tilde{A} = 2.01$

APPENDIX Table G-1. Peak voltage and $(E/E_{min})^2$ from oscilloscope readings on 23 June 1963 with a 6" transducer. ($C^2 = 3715.4$)

appendix Table g-2

Peak Voltage	N	(E/E_{min})	$\left[(E/E_{min})^2 (N)\right]$
.4	11	----	----
.5	34	----	----
.6	54	----	----
.7	56	1.00	56.00
.8	43	1.14	55.88
.9	21	1.29	34.95
1.0	19	1.43	38.85
1.1	14	1.57	34.51
1.2	8	1.71	23.39
1.3	15	1.86	44.97
1.4	7	2.00	28.00
1.5	10	2.14	45.80
1.6	4	2.29	20.56
1.8	1	2.57	6.60
1.9	1	2.71	7.34
2.0	2	2.86	16.36
2.1	1	3.00	9.00
2.2	1	3.14	9.86
$\sum_{i=.7}^{2.2}$	205		455.11

$$\tilde{E}^2 = 455.11/205 = 2.22$$

$$\tilde{A} = 1.44$$

APPENDIX Table G-2. Peak voltage and $(E/E_{min})^2$ values from 2100, 23 June to 1640, 25 June 1983 with a 16 transducer. $(C^2 = 1169.5)$.

appendix Table 3

Peak Voltage	N	(E/E_{min})	$\left[(E/E_{min})^2 (N)\right]$
.3	1	----	----
.4	2	----	----
.5	4	----	----
.6	11	1.00	11.00
.7	9	1.17	12.32
.8	4	1.33	7.08
.9	4	1.50	9.00
1.0	6	1.67	16.73
1.1	2	1.83	6.70
1.2	3	2.00	12.00
1.3	7	2.17	32.[illegible]
1.4	3	2.33	16.25
1.5	1	2.50	6.25
1.6	1	2.67	7.13
1.7	1	2.83	8.01
1.8	0	3.00	0.00
1.9	0	3.17	0.00
2.0	2	3.33	22.18
2.1	0	3.50	0.00
2.2	1	3.67	13.47
2.3	1	3.83	14.67
2.4	0	4.00	0.00
2.5	1	4.17	17.37
2.6	0	4.33	0.00
2.7	0	4.50	0.00
2.8	0	4.67	0.00
2.9	0	4.83	0.00
3.0	1	5.00	25.00

$$\sum_{i=.6}^{3.0} N_i = 58 \qquad 236.16$$

$$\tilde{E}^2 = 4.11$$

$$\tilde{A} = 2.02$$

APPENDIX Table G-3. Peak voltage and $(E/E_{min})^2$ (N) values from daytime 24 June 1983 with 6^0 transducers. (C^2 = 1169.5) appendix Table g-4

Peak Voltage	N	(E/E_{min})	$\left[(E/E_{min})^2 (N)\right]$
.20	41	—	—
.24	48	1.00	48.00
.28	37	1.17	50.65
.32	24	1.33	42.45
.36	16	1.50	36.00
.40	13	1.67	36.26
.44	6	1.83	20.09
.48	4	2.00	16.00
.52	6	2.17	28.25
.56	5	2.33	27.14
.60	14	2.50	87.50
.64	10	2.67	71.29
.68	6	2.83	48.05
.72	4	3.00	36.00
.76	2	3.17	20.10
.80	4	3.33	44.36
.84	2	3.50	24.50
.88	0	3.67	0.00
.92	1	3.83	14.67
.96	0	4.00	0.00
1.00	0	4.17	0.00
1.04	0	4.33	0.00
1.08	1	4.50	20.25
1.12	2	4.67	43.62
1.16	3	4.83	69.99
$\sum_{i=.24}^{1.16}$	200		785.17

$\hat{\tilde{B}}^2 = 3.77$

$\tilde{A} = 2.43$

Appendix Table G-4. Peak voltage and $(E/E_{min})^2$ (N) values from 0130-1530 26 June 1983 with a 2^0 transducer. ($C^2 = 1316.2$)

APPENDIX H. Determination of corrected target strength and effective beam size.

The downstream aiming angle of the transducer was used as the off-axis orientation measure. The expected increase in target strength, in dB, for each period was then calculated in the following manner:

(1) Use the downstream aiming angle as "X" in the equation in Figure H-1.

(2) This equation provides "Y", the off-axis angular correction in dB.

(3) Add the absolute value of "Y" to the calculated target strength.

The results are the corrected target strengths as listed in text Table 4.

The effective beam width is a function of the mean target strength, threshold, and downstream aiming angle. Assuming that the mean target strength and threshold were constant throughout the run, then the aiming angle determines the effective beam width. Using the transducer half-angle measurement as a function of dB drop (Table H-1) then the effective beamwidths, as a function of downstream aiming angle, can be ploted as in Figure H-2.

The steps used to determine the effective the effective beam widths are presented in the following:

(1) Enter an aiming angle (0 to 45 degrees) as the "X" value in the

equation shown in Figure H1. This provides "Y', the angular off-axis correction in decibels (dB).

(2) Add the value of "Y" to the value of the grand mean target strength (-21.94 dB).

(3) Subtract the absolute value ofthe sum in (2) above from the absolute value of the threshold target strength.

appendix h-1 goes here (fig)

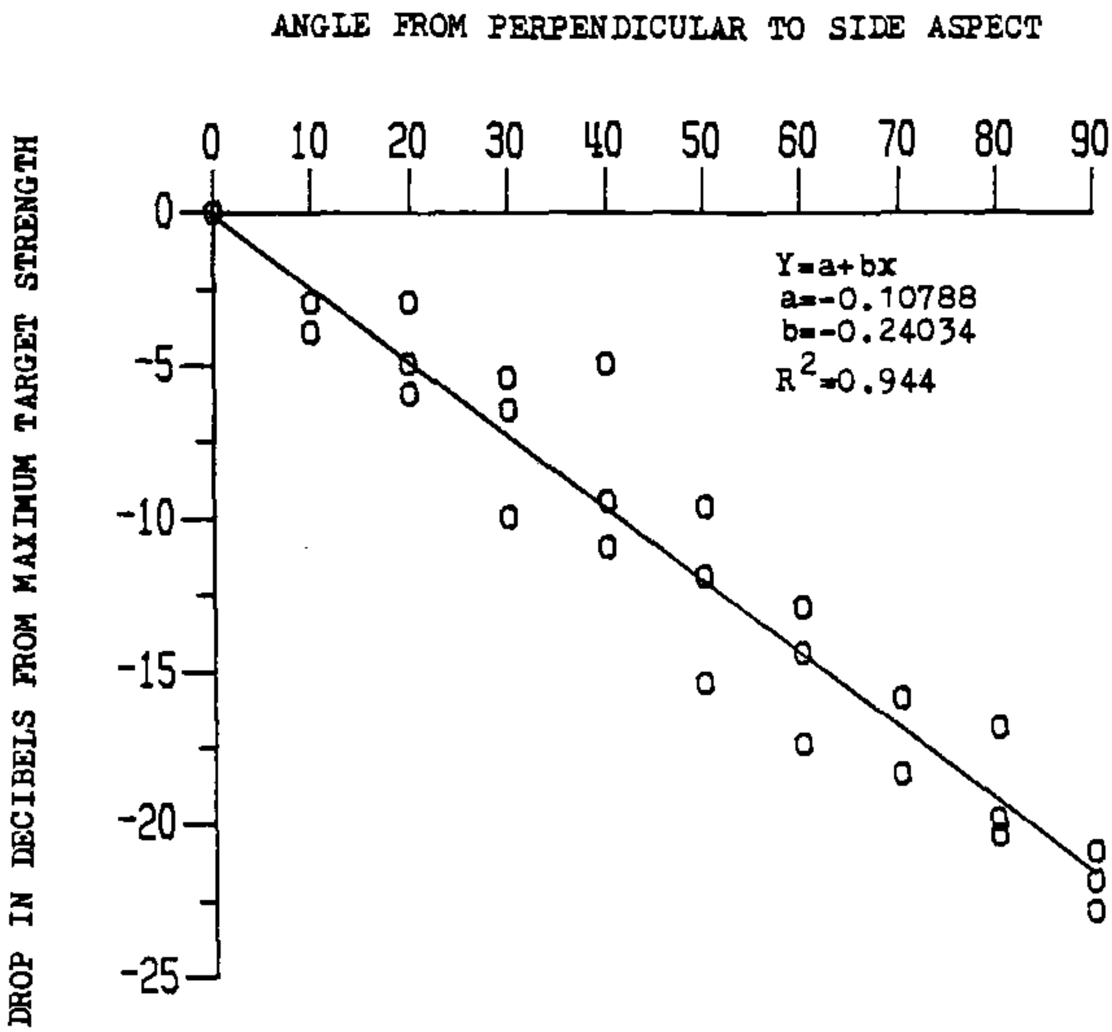


Figure H-1. The drop in decibels from maximum target strength at 10 degree intervals for three fish. Data from Dahl (1982).

table h-1 goes here

APPENDIX TABLE H-1. Correction table for determining the effective corrected beam angle from the difference between the target strength used in the field (-34.5 dB) and corrected target strengths listed in text Table 4.

dB Drop	Half angles of transducers read from polar plots — Transducers 2	6	10
0	0	0	0
1	1.00	1.33	1.60
2	1.00	1.60	2.40
3	1.00	2.00	3.20
4	1.50	2.40	4.00
5	1.50	3.20	5.60
6	1.70	4.00	6.00
7	1.70	4.00	6.00
8	2.00	5.60	6.80
9	2.00	5.60	6.80
10	2.00	5.60	7.60
11	2.00	6.00	8.00
12	2.00	6.00	8.00
13	2.10	6.00	8.80
14	2.10	6.00	9.60
15	2.10	6.00	9.60

figure h-2 goes here

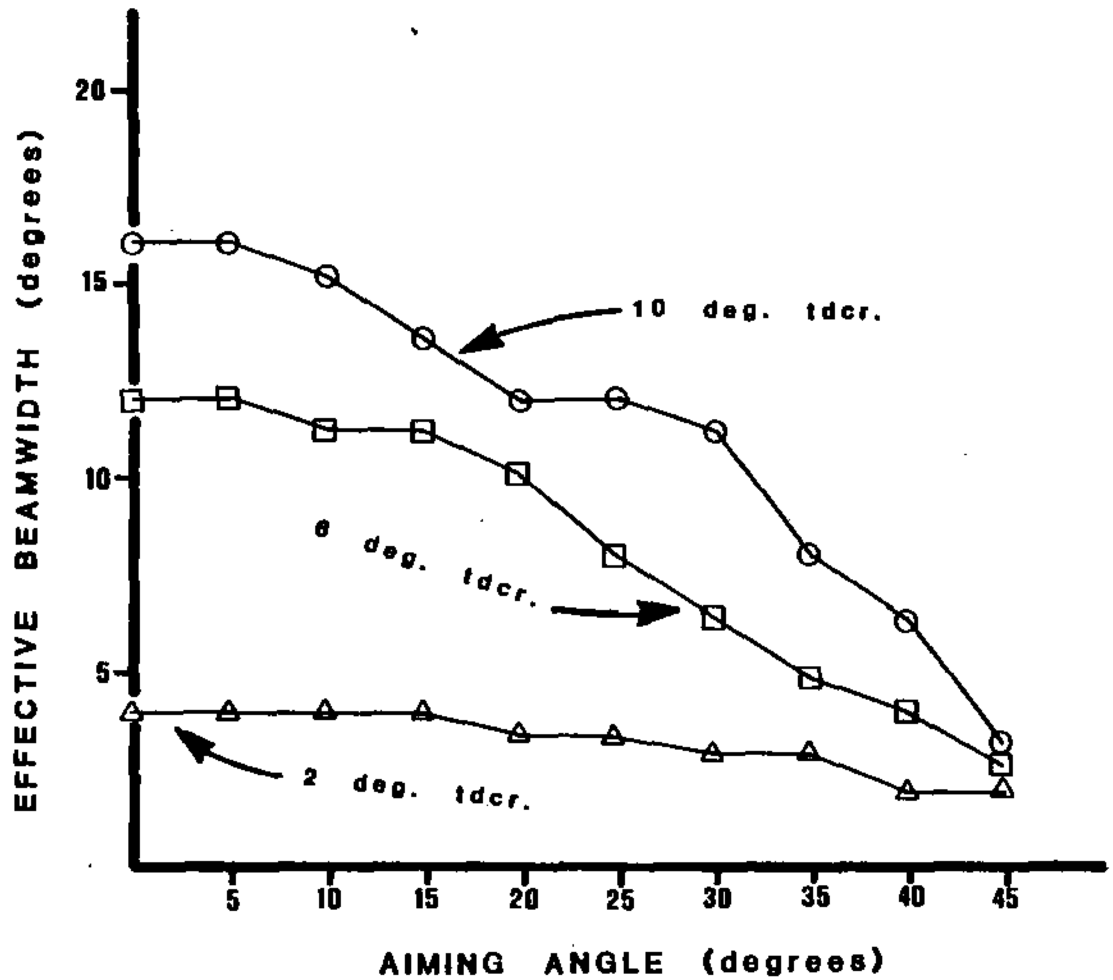


Figure H-2. Effective beamwidths of three transducers (2 ,6 , and 10) for a population target strength of -21.9 dB and a threshold of -34.5dB.

APPENDIX I: Derivation of fish swimming speed. The method is provided following discussions with Ivan Frohne and John Ehrenberg (pers. comm. 1984).

The model is described below:

A side-scan sonar is pointed downriver at angle as measured from a perpendicular to river flow or, more precisely to salmon travel. The following expressions are used in the model:

$$S = D/t$$

where: S = estimated swimming speed.
t = the time from first to last detection.

$$D = \quad d_1 2 + d_2 2 - 2\ d_1\ \text{Cos}\ (\ )$$

where:

D = the distance traveled by the salmon while in sonified by the acoustic beam.

d_1= range at first detection.

d_2= range at final detection.

= Angle transected by fish as it passes through the acoustic beam.

Figure I-1 illustrates the model.

The known quanitites in Figure I-1 are d_1, d_2 (with $d1$ d_2), and . Unknowns are and D. Note that the acoustic axis (dotted line) bisects the angle between d_1 and d_2.

The acoustic beam is approximately conical, with a nominal beam angle of either 2° or 6°, and the salmon will move along a chord parallel to the major axis of an ellipse formed by traversing the beam. The assumption is that the salmon remains at a constant depth. So it is easier to treat the beam angle as unknown and ignore the three-dimensional aspects of the problem.

Because d_1 d_2, it is true that: $\sin(90° + 0 - /2) = (d_1/d_2) \sin (90° - 0 - /2)$

This follows from the law of sines, which states that:

$$\frac{\sin A}{a} = \frac{\sin B}{b}$$

$$\sin A = \frac{\sin B}{b}$$

Hence:

$$\sin(A + B) = \sin A \operatorname{Cos} B + \operatorname{Cos} A \sin B$$

$$\sin(A-B) = \sin A \operatorname{Cos} B - \operatorname{Cos} A \sin B$$

To get:

$$\sin(90°+ 0) \cos(\bar{2} - \cos(90°+ 0 \quad \sin(\bar{2})$$

$$= \frac{d_1}{d_2} \sin(90°- 0) \cos\left(\frac{-}{2}\right) - \cos(90°- 0) \sin \frac{-}{2}$$

or:

$$\cos\left(\frac{\_}{2}\right) \sin(90° + 0) \quad \frac{d_1}{d_2} \sin(90° - 0)$$

$$= \sin(\_) \quad \cos(90°+ 0) - \frac{d_1}{d_2} \cos(90° - 0)$$

or:

$$\frac{\sin \overline{2}}{\cos \_} = \tan \frac{}{\tan(2)} = \frac{\sin(9° = 0) - d1 \sin(90° 0) / d_2}{\cos(90°- 0) - \frac{d1}{d_2} \cos(90°- 0)}$$

$\cos$ 2

$$= 2 \text{ Tan-1} \frac{\frac{d_1}{d_2} \quad \sin (90° - 0) - \sin (90° + 0)}{\frac{d_1}{d_2} \quad \cos (90° - 0) - \cos (90° + 0)}$$

Referring again to Figure I-1, notice that if, for small > 0, /2 = 0 + 0, so that triangle side d_2 points <u>upstream</u>, D will be larger than when /2 = 0 - 0, but d_2 will be the same in each case. Thus 0 must be chosen large enough so that /2 __ 0. When d_2 is perpendicular to fish travel,

$D = d_1 2 - d2^2$

This is the maximum permissible value of D, i.e.

$0 \_\_ D \_\_ \quad d_1 2 - d_2 2$

This maximum permissable value occurs at = 2 0.

Also, note that d_1 d_2 d1 cos , so that

$\_\_ \cos\text{-}1 \quad (d_{2/d1})$

To summarize, must be no larger than any of 2 tan $^{-1}$C, 2 0, or cos $^{-1}(d_{2/d1})$:

$= \min [2 \tan^{-1} C, 2\ 0, \cos^{-1} (d_{2/d1})]$

With an estimate of (say 2), D can be estimated as

$\dot{D} = d_1 2 + d_2 2 - 2 d_1 d2 \cos (\dot{})$

by the law of cosines.

with $\dot{D}$, and t, an estimate of swimming speed is

$\dot{S} = \dot{D}/t.$

Fig. I-1 goes here

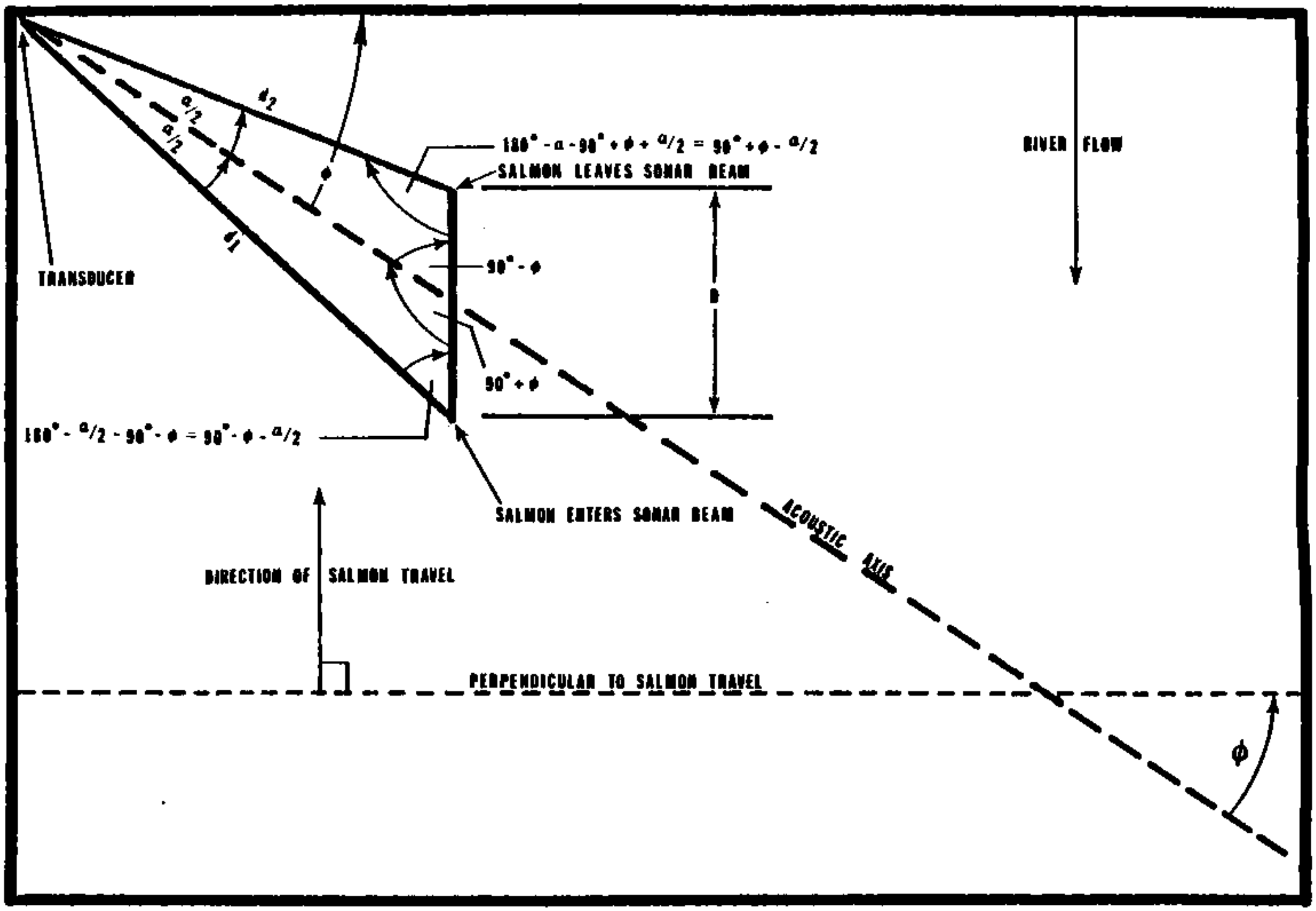


Figure I-1. Aerial view schematic of side scan sonar set-up for measuring salmon swimming speeds, with trigonometric diagram for solution of the measurement. Unknowns are α and D. Knowns are d_1, d_2 (with $d_1 > d_2$) and ϕ. Note that the large, internal dashed line (acoustic axis) bisects the angle α between d_1 and d_2. (After Frohne 1984, pers. comm.).

APPENDIX J: Swimspeed Program Documentation:

Program Name: YUKSWIM.BAS

Written by: Fritz Funk, with

modifications by Dave Mesiar

Date: May 30, 1984

appendix j goes here -l

appendix j goes here -2

appendix j goes here -3

appendix j goes here -4

appendix j goes here -5

appendix j goes here -6

appendix j goes here -7

appendix j goes here -B

appendix j goes here -9

Swimspeed Program Documentation

Program Name: YUKSWIM.BAS
Written by : Fritz Funk, with modifications by Dave Mesiar
Date : May 30, 1984

The program YUKSWIM.BAS estimates velocity of individual fish in meters per second. In its current form, it accepts data from the file YUKONSPD.DTA, processes it, and outputs it to the file YUKTABL.DAT. Data required are listed below in the order in which they appear in the data file YUKONSPD.DTA:

SITE - The program is designed to estimate fish velocities from either of two sites or both sites combined.

DATE - The data entered must fall within time periods set up in lines 230-270 and 1090-1150.

XANGLE - The angle (in degrees) that the transducer is aimed downstream from a line perpendicular to the river flow.

BEAMWIDTH - Beam size (degrees). The program is designed to accept data from either of two beam widths or both beams combined.

TIMEBASE - A reading from the chart recorder in seconds/sweep.

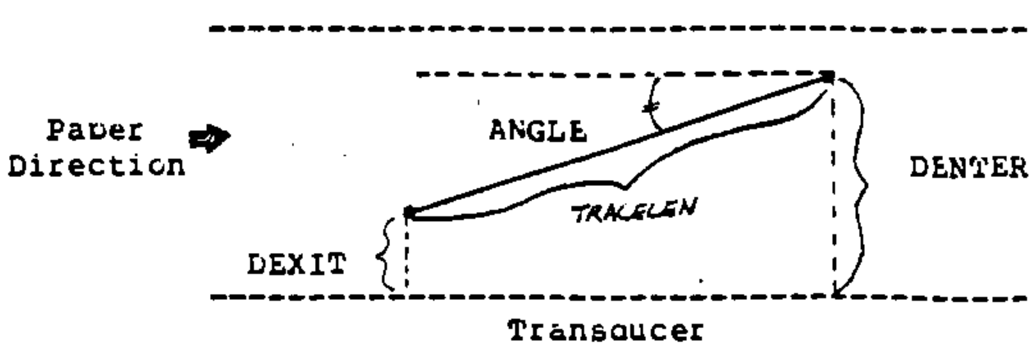
CHARTSPEED - The speed with which paper moves through the chart recorder in mm/sec.

DENTER - The fish's distance (in mm) from the transducer at the point of entry into the beam, from the chart recording.

DEXIT - The fish's distance (in mm) from the transducer at the point of exit from the beam, from the chart recording.

TRACELEN - The length (mm) of the trace made by the fish's passage through the beam, from the chart recording.

ANGLE - Angle of the trace (in degrees) on the chart recording as diagrammed below.



```
10 REM YUKSWIM.BAS     YUKON RIVER SONAR ANALYSIS
20 REM Swimming speed Analysis
30 REM Written by Fritz Funk, modified by Dave Mesiar 5/30/84.
31 REM This program estimates individual fish velocities from sonar data.
32 REM In its current form it accepts data from the file YUKONSPD.DTA.
33 REM processes it. and outputs to the file YUKTABL.DAT.  Data required
34 REM in the order they appear in YUKONSPD.DTA are  (1) SITE; (2) DATE;
35 REM (3) XANGLE - the angle (degrees) that the beam is aimed downstream from
36 REM a line drawn perpendicular to shore; (4) BEAMWIDTH - (degrees);
37 REM (5) TIMEBASE - in seconds/sweep. from the chart recorder; (6) CHARTSPEED
38 REM the speed with which paper moves through the chart recorder in mm/sec;
39 REM (7)DENTER- distance (mm) of fish from transducer upon entering beam. from
40 REM the chart recorder; (8)DEXIT - distance (mm) of fish from transducer when
41 REM leaving the beam; (9)TRACELEN - length (mm) of the trace on the chart
42 REM recorder; (10)ANGLE-angle(degrees)of the trace on the chart recorder from
43 REM a line drawn parallel to the shoreline.
50 REM The program will also draw histograms of swimspeed frequencies when
51 REM connected to a plotter.
60 PRINT CHR$(4): PRINT "YUKON RIVER SONAR ANALYSIS": PRINT
70 PRINT:PRINT "YUKSWIM.BAS - Swimming speed Analysis": PRINT
75 DEF FNARCCOS(X)= -ATN(X/SQR(1-X*X))+1.5708
80 DEF FNDEG2RAD(DEGREES) = 2 * 3.14159 * DEGREES/360
85 DEF FNRAD2DEG (RADIANS) = 57.2958*RADIANS
90 DIM PERIODLABELS$(7).SWIMSPD(350,7):  REM SWIMNEW(strata-periods)
110 WIDTH LPRINT 255
230 DATA " sampling period 1 (June 21- 1983)."
240 DATA " sampling period 2 (June 23- 1983)."
250 DATA " sampling period 3 (June 25, 1983)."
251 DATA " sampling period 4 (June 27- 1983)."
252 DATA " sampling period 5 (July  2, 1983)."
253 DATA " sampling period 6 (July  3. 1983)."
254 DATA " sampling period 7 (June 21-July 3. 1983)."
270 FOR, I = 1 TO 7: READ PERIODLABELS$(I): NEXT I
280 PRINT:INPUT "Choose Beam width (10 or 6 or 0 for both)";BEAMTYPE
290 IF BEAMTYPE <> 10 AND BEAMTYPE <> 6 AND BEAMTYPE <> 0 THEN GOTO 280
300 PRINT:INPUT "Choose desired site (1-2 or 3 for all)"; SELECTSITE
310 IF SELECTSITE <> 1 AND SELECTSITE <> 2 AND SELECTSITE <> 3 THEN GOTO 300
315 OPEN "O",3-"A:YUKTABL.DAT"
320 OPEN "I",2."A:YUKONSPD.DTA"  : NREAD = 0: NSELECT = 0
330 PRINT CHR$(4): PRINT "YUKON RIVER SONAR ANALYSIS": PRINT
340 FOR STRATUM  = 1 TO 3: FOR PERIOD  = 1 TO 7 : SWIMSPD(STRATUM,PERIOD) = 0:
EXT PERIOD: NEXT STRATUM
350 WHILE NOT EOF(2)
360     INPUT#2,SITE.DATES,XANGLE.BEAMWIDTH.TIMEBASE.CHARTSPEED,DENTER.DEXIT.TR
ELEN,ANGLE
370     NREAD = NREAD + 1
380     PRINT AT(3.0) "Reading record number",NREAD;"   Records selected:";NSEL
T
400     DATE = VAL(DATES): GOSUB 1090
410     IF SELECTSITE < 3 THEN IF SITE <> SELECTSITE THEN GOTO 610
420     IF BEAMWIDTH <> BEAMTYPE AND BEAMTYPE <> 0 THEN GOTO 610
430        NSELECT = NSELECT + 1
440        D1 = DENTER
450        D2 = DEXIT
455           IF D2 >= D1 THEN GOTO 610
```

```
460 .       ALPHA = BEAMWIDTH
470         R = TRACELEN
480         G = CHARTSPEED
482         TB=TIMEBASE
484         RE=TB*750
486  .      PW=487.5
    AOI= ANGLE
            DENOM = (R/G)*COS(FNDEG2RAD(AOI))
540         SPEED = 0
545 GOSUB 2900
546 EFFWID = FNRAD2DEG(EWA)
547 PRINT AT(10,0) "Effective beam width is";EFFWID;
551         IF DENOM > 0 THEN SPEED = (((D1*RE/PW)^2 + (D2*RE/PW)^2) - (2*(D1*RE
W)*(D2*RE/PW))*COS(EWA))^.5/DENOM
552 DIST = SPEED*DENOM
553 PRINT AT(12,0) "Distance (m) traveled through beam is";DIST;
560         IF SPEED < MIN THEN MIN = SPEED
565 PRINT#3.DATES,BEAMWIDTH.XANGLE.D1.D2.R.ANGLE.EFFWID,DIST.SPEED
570         IF SPEED >MAX THEN MAX = SPEED
580         STRATUM = INT((SPEED/4)*40)
590         SWIMSPD(STRATUM,PERIOD) = SWIMSPD(STRATUM,PERIOD) + 1
600         SWIMSPD(STRATUM,      4) = SWIMSPD(STRATUM,      4) + 1
610 WEND
620 PRINT CHR$(4): PRINT "STIKINE RIVER SONAR ANALYSIS"
630 PRINT:PRINT "Input processing completed...."
640 PRINT: PRINT NREAD;" Input records were read"
650 PRINT: PRINT NSELECT;" Records were selected for this period"
660 PRINT "MIN,MAX",MIN.MAX
670 PRINT:PRINT "Number of Fish per Minute"
680 PRINT: PRINT "Stratum","Period 1","Period 2","Period 3","Period 4","Per  o
  "Period 6","Period 7":PRINT
    FOR STRATUM = 0 TO 39
700    PRINT STRATUM;: FOR PERIOD = 1 TO 4: PRINT SWIMSPD(STRATUM,PERIOD);: NE
 PERIOD:PRINT
710 NEXT STRATUM
720 NOBS = NSELECT
730 FOR I = 1 TO 1400: TIME = I: NEXT I: REM PAUSE
740 GOSUB 1160
750 END
760 REM SUBROUTINE to collect yes/no from terminal. Prompt is PROMPT$.
770 REM
780 INPUT YESNO$
790 IF YESNO$ =  "NO" OR YESNO$ =  "no" THEN YESNO$ =  "NO": GOTO 830
800 IF YESNO$ = "YES" OR YESNO$ = "yes" THEN YESNO$ = "YES": GOTO 830
810 PRINT: PRINT " **** Response must be YES or NO.  Retype response ....":
T
820 GOTO 780
830 RETURN
840 REM  end yes/no
850 REM
    REM SUBROUTINE TO RETURN DECIMAL TIME FROM HOURS AND MINUTES%
870 REM
880 IF VAL(TIMESTR$) < .001 THEN TIME = 0: RETURN
890 HR% = INT(VAL(TIMESTR$)/100)
900 MINUTES% = VAL(RIGHT$(TIMESTR$,2))
    TIME = HR% + MINUTES%/60
    RETURN
```

```
930 REM  end decimal time
940 REM
950 REM SUBROUTINE to return Horizontal stratum
960 REM       input parameters: AVGDIST. BEAMWIDTH. TIMEBASE
970 REM       Returns: STRATUM ==> outer edge of 10 m stratum
980 REM
990 DISTM = ((TIMEBASE*750*AVGDIST/223.5)*COS(FNDEG2RAD(XANGLE+.5*BEAMWIDTH
1000 STRATUM = INT((DISTM)/10 + 1
1010 RETURN
1020 REM SUBROUTINE to return normalizing constant for this stratum
1030 REM        input parameters stratum (1/10 of distance),beamwidth
1040 DEF FNAREA(R.ANGLE) = (3.14159 * (R^2) * ANGLE/360)
1050 DEF FNNORM(R.ANGLE) = 10 * FNAREA(10.ANGLE) /  (FNAREA(R.ANGLE) - FNAREA(R-
10,ANGLE) )
1060 NORM = FNNORM(STRATUM*10.BEAMWIDTH)
1070 RETURN
1080 REM
1090 REM SUBROUTINE TO COMPUTE PERIOD NUMBER. GIVEN DATE
1100   PERIOD = 0:  REM Compute Period
1110       IF DATE = 621831  THEN PERIOD = 1
1120       IF DATE = 623831 THEN PERIOD = 2
1130       IF DATE = 625831 THEN PERIOD = 3
1131       IF DATE = 627831 THEN PERIOD = 4
1132       IF DATE = 702831 THEN PERIOD = 5
1133       IF DATE = 703831 THEN PERIOD = 6
1140       IF PERIOD = 0 THEN PRINT "DATE ERROR AT NREAD,SITE.DATE.TIME. "NREAD;S
ITE;DATE;TIMES;: END
1150   RETURN
1160 REM Now plot the Swimming speed on the pen plotter.
1170 PRINT:PRINT
1180 PRINT CHR$(4): PRINT:PRINT "DMP-29 GRAPHICS PROGRAM ":PRINT:PRINT
1190 DIM SITELABELS$(3),BEAMLABELS$(7)
1200 DATA " Site 1", "Site 2", "All Sites"
1210 FOR I = 1 TO 3: READ SITELABELS$(I): NEXT I
1220 DATA "All Beam Widths"," ","Beam Width 2"," "," "," ","Beam Width 6"
1230 FOR I = 0 TO 6: READ BEAMLABELS$(I): NEXT I
1240 T1$ = " " + SITELABELS$(SELECTSITE) + ",  " + BEAMLABELS$(BEAMTYPE)
1250 PRINT "MAIN TITLE IS: "; T1$
1260 NX$ = " Swimming Speed (m/s)": NY$ = " Frequency"
1270 LPRINT ";: HA EF P1 50,70 O  V4":        REM INITIALIZE PLOTTER. ORIG., VELO
-
1280 DEF FNCENT(L$,CHRHEIGHT) = (LEN(L$)*CHRHEIGHT*6/7)/2: REM CALC CENT OF STRI
NG
1290 S$ = "S13": X1 = 100: Y1 = 2200: L$ = T1$: GOSUB 2200
1300 DATA "  Period 1"
1310 DATA "  Period 2"
1320 DATA "  Period 3"
1330 DATA "   All Periods"
1340 FOR I = 1 TO 4: READ PERIODLABELS$(I): NEXT I
1350 XLEN = 400: YLEN = 400
1360 DATA 200,1400
1370 DATA 1100,1400
1380 DATA 200,400
1390 DATA 1100,400
1400 FOR PERIOD = 1 TO 4
1410 READ XO: READ YO
1420 T1$ = PERIODLABELS$(PERIOD)
```

```
  PRINT "MAIN TITLE IS: ";T1$
   IF SELECTSITE = 2 THEN YDMAX=10  ELSE YDMAX = 10
   XDO = 0:XDMAX = 4  :NXTICS =8:        REM SET DATA  X ORIGIN AND MAX
   YDO = 0: NYTICS = 5
   REM
   REM END OF INITIALIZATION
   REM
 ) XDLEN = XDMAX-XDO:YDLEN=YDMAX-YDO:                     REM CALC DATA SPANS
 0 XSCALE = XLEN/XDLEN:YSCALE=YLEN/YDLEN:PRINT:PRINT:  REM SCALE DATA TO PLOT
 0 GOSUB 1690:                  REM DRAW AXES, TIC MARKS, TIC LABELS AND TITLES
 0 REM
 0 REM MAIN APPLICATION PROGRAM GOES IN BELOW HERE
 0 REM
 0 FOR XX = 0 TO 39 STEP 1
70     IX = XX/10
80     IY = SWIMSPD(XX,PERIOD)
90     IF IY > 0 THEN GOSUB 2580
00 NEXT XX
510 NEXT PERIOD
620 REM FINISH
630 REM END OF MAIN APPLICATION PROGRAM SECTION
540 REM FINISH
550 REM
560 REM
 70 LPRINT "PC 2 @": REM RETURN PEN, RESET AND DESELECT PLOTTER
 80 RETURN
690 REM DRAW AXES
700 X1=XO:Y1=YO:X2=XO+XLEN:Y2=Y1:GOSUB 2090
1710 X1=X2: Y1=Y2-2: X2=XO: Y2=YO-2: GOSUB 2090
17   X1=XO:Y1=YO:X2=XO:Y2=YO+YLEN:GOSUB 2090
17   X1=X2-2: Y1=Y2: X2=XO-2: Y2=YO: GOSUB 2090
1740 REM DRAW  X AXIS TIC MARKS
1750 TICLEN = 30
1760 FOR IX = 0 TO NXTICS
1770    X1=XO + IX*XLEN/NXTICS: Y1 = YO - TICLEN
1780     X2 = X1: Y2 = YO
1790     GOSUB 2090
1800 NEXT IX
1810 REM DRAW Y AXIS TIC MARKS
1820 TICLEN = 30
1830 FOR IY = 0 TO NYTICS
1840     X1 = XO-TICLEN: Y1 = YO + IY*YLEN/NYTICS
1850     X2 = XO:Y2 = Y1
1860     GOSUB 2090
1870 NEXT IY
1880 REM X AXIS TIC LABELS AND THEN TITLE
 90 FOR IX = 0 TO NXTICS STEP 2
 00     L$ = STR$(XDO + IX*XDLEN/NXTICS)
  0     X1 = XO + IX*XLEN/NXTICS - (LEN(L$)+.75)*27.84*6/7/2:Y1 = YO - CINT(2.5*
 LEN)
  0     S$ = " S12 ": GOSUB 2200
  0 NEXT IX
  0 X1 = XO + XLEN/2 - FNCENT(NX$,27.84):Y1 = YO - CINT(4.5*TICLEN)
  0 L$ = NX$: S$ = "S12": GOSUB 2200
     M Y AXIS TIC LABELS AND THEN TITLE
    OR IY = 0 TO NYTICS
 0      L$ = STR$(YDO + IY*YDLEN/NYTICS)
```

```
1990    X1 = XO - TICLEN - 2*FNCENT(L$,27.84):Y1 = YO + IY*YLEN/NYTICS - 35.5
2000    S$ = "S12":GOSUB 2200
2010 NEXT IY
2020 X1 = XO - 7*TICLEN:Y1 = YO + YLEN/2 - FNCENT(NY$,27.84)
2030 L$ = NY$: S$ = "S42 ": GOSUB 2200
2040 REM WRITE MAIN TITLE
2050 NYT = 3
2060 X1 = XO + XLEN/2 - FNCENT(T1$,41.76): Y1 = YO + YLEN +  CINT(NYT*YLEN/10
2070 L$ = T1$:S$ = "S12": GOSUB 2200
2080 RETURN
2090 REM
2100 REM SUBROUTINE TO DRAW A LINE FROM X1.Y1 TO X2.Y2
2110 REM     IF LINTYP$ IS SET AND NOT "L0" LINE TYPE IS NON-SOLID
2120 REM
2130 IF LINTYP$ = "" THEN LINTYP$ = "L0"
2140 X1$ = STR$(CINT(X1)):Y1$ = STR$(CINT(Y1))
2150 X2$ = STR$(CINT(X2)):Y2$ = STR$(CINT(Y2))
2160 PRINT AT(18,0) "LINE DRAW FROM ";X1;Y1;"  TO ";X2;Y2
2170 LPRINT "U ";X1$;",";Y1$,LINTYP$;" D ",X2$;",";Y2$;" U ": LINTYP$ = "L0"
2180 RETURN
2190 REM
2200 REM CHARACTER STRING PLOTTING SUBROUTINE. START X1.Y1
2210 REM                       STRING S$ = "S12+" OR EQUIVALENT (ROTATION.HEIGHT)
2220 REM                       STRING L$ IS STRING TO BE WRITTEN
2230 REM
2240 X1$ = STR$(CINT(X1)):Y1$ = STR$(CINT(Y1))
2250 LPRINT " U ";X1$;",";Y1$;" ";S$;L$;CHR$(95);" U "
2260 RETURN
2270 REM
2280 REM
2290 REM SUBROUTINE TO DRAW  CURVE WITH SEGMENTS FROM X1.Y1 TO X2.Y2
2300 REM WITHOUT LIFTING PEN
2310 REM     IF LINTYP$ IS SET AND NOT "L0" LINE TYPE IS NON-SOLID
2320 REM
2330 IF LINTYP$ = "" THEN LINTYP$ = "L0"
2340 X1$ = STR$(CINT(X1)):Y1$ = STR$(CINT(Y1))
2350 IF NCTRAZWQS < 1 THEN LPRINT " U ";X1$;",";Y1$
2360    NCTRAZWQS = NCTRAZWQS+1
2370 PRINT " LINE DRAW TO ";X1.Y1
2380 LPRINT "D ";LINTYP$;",";X1$;",";Y1$: LINTYP$ = "L0"
2390 RETURN
2400 REM
2410 REM SUBROUTINE TO DRAW A LEGEND STARTING AT XLEGEND,YLEGEND
2420 REM     STRING IS L$, LINE TYPE IS LINTYP$, SPACING BETWEEN SUCCESIVE
2430 REM     LEGENDS IS YLEGINC. ALL ARE IN UNITS OF XLEN/10 OR YLEN/10
2440 X1 = XO + XLEGEND*XLEN/10
2450 Y1 = YO + YLEN - YLEGEND*YLEN/10 - NLEGEND*YLEGINC*YLEN/10
2460 X2 = X1 + XLEN/10:Y2=Y1:GOSUB 2100
2470 X1 = X2 + 10
2480 S$ = " S12 ":GOSUB 2190
2490 NLEGEND = NLEGEND + 1
2500 RETURN
2510 REM DRAW A HORIZONTAL HISTOGRAM BAR AT IY TO HEIGHT IX (BOTH IN DATA UNIT
2520 REM
2530 YINC = YDLEN/(NYTICS*2)
2540 Y1=(IY-YDO-YINC)*YSCALE+YO:X1=XO:Y2=Y1:X2=(IX-XDO)*XSCALE+XO:GOSUB 2..
2550 X1=X2: Y2= (IY-YDO+YINC)*YSCALE+YO: YMID = (Y1+Y2)/2: GOSUB 2090
```

```
 0 RETURN
 0 REM DRAW A HISTOGRAM BAR AT IX TO HEIGHT IY (BOTH IN DATA UNITS)
 0 REM
 0 XINC = XDLEN/(NXTICS*2.5)
 0 X1=(IX-XDO)*XSCALE+XO:Y1=YO:X2=X1:Y2=(IY-YDO)*YSCALE+YO:GOSUB 2100
 0 Y1=Y2: X2= (IX-XDO+.5*XINC)*XSCALE+XO: GOSUB 2100
   X1=X2:Y2=YO:GOSUB 2100
 0 RETURN
 0 REM This subroutine computes the effective beam width at the
 5 REM depth the salmon is traveling.  The salmon is assumed to
 10 REM be heading exactly 0 degrees (upriver), or XANGLE must
 15 REM be corrected to measure from the perpendicular to
 20 REM the direction of salmon travel.
 25 REM
 926 PRINT AT(14,0) "denter is";DENTER;
 927 PRINT AT(15,0) "dexit  is";DEXIT;
 000 EWR=DENTER/DEXIT
 010 IF EWR > 1 THEN 3030
3020 EWA = 0: GOTO 3120
3030 EWM = FNDEG2RAD(90-XANGLE)
3040 EWP = FNDEG2RAD(90+XANGLE)
3050 EWC = EWR*SIN(EWM)-SIN(EWP)
3060 EWC = EWC/(EWR*COS(EWM)-COS(EWP))
3070 EWA = 2!*ATN(EWC)
3080 TESTB = 2!*FNDEG2RAD(XANGLE)
3090 TESTC = FNARCCOS(DEXIT/DENTER)
3100 IF (TESTB < EWA) THEN EWA=TESTB
3110 IF (TESTC < EWA) THEN EWA=TESTC
3120 RETURN
3130 PRINT FNRAD2DEG(EWA);" degrees. ";EWN%;" iterations."
     RETURN
3  REM END OF SUBROUTINE FOR EFFECTIVE BEAM WIDTH CALCULATION
3150 REM
Ok
```

SITE	DATE	XANGLE	BEAM WIDTH	TIME BASE	CHARTSPEED	DENTER	DEXIT	TRACELEN	ANGLE
1	062183	41.0	06.0	0.03	1.50	184.0	179.0	05.0	51.0
1	062183	41.0	06.0	0.03	1.50	240.0	234.0	05.0	74.0
1	062183	41.0	06.0	0.03	1.50	228.0	221.0	06.0	76.0
1	062183	41.0	06.0	0.03	1.50	381.2	376.2	07.0	78.0
1	062183	41.0	06.0	0.03	1.50	414.9	406.9	08.0	76.0
1	062183	41.0	06.0	0.03	1.50	316.4	313.4	06.0	70.0
1	062183	41.0	06.0	0.03	1.50	315.4	312.4	06.0	80.0
1	062183	41.0	06.0	0.03	1.50	181.0	175.0	06.0	85.0
1	062183	41.0	06.0	0.03	1.50	100.0	095.0	05.0	85.0
1	062183	41.0	06.0	0.03	1.50	406.9	391.9	08.0	78.0
1	062183	41.0	06.0	0.03	1.50	193.0	188.0	05.0	85.0
1	062183	41.0	06.0	0.03	1.50	339.4	332.4	06.0	67.0
1	062183	41.0	06.0	0.03	1.50	353.2	345.2	07.0	80.0
1	062183	41.0	06.0	0.03	1.50	437.9	425.9	06.0	78.0
1	062183	41.0	06.0	0.03	1.50	391.2	379.2	07.0	80.0
1	062183	41.0	06.0	0.03	1.50	412.9	393.9	08.0	80.0
1	062183	41.0	06.0	0.03	1.50	112.0	104.0	08.0	80.0

Swimming speed input data file sample (YUKONSPD.DTA)

DATE	BEAMWIDTH°	XANGLE°	DENTER (mm)	DEXIT (mm)	TRACELENGTH (mm)	ANGLE°	EFFECTIVE BEAMWIDTH (m)	DISTANCE ACROSS BEAM (m)	SPEED (m/sec)
062183	6	41	[illegible]	179	5	51	1.81542	.3	.167643
062183	6	41	240	234	5	74	1.66836	.4	.45922
062183	6	41	228	221	6	76	2.05476	[illegible]	.508756
062183	6	41	[illegible]	376.2	7	78	.870048	.351215	.36198
062183	6	41	[illegible]	406.9	8	76	1.28304	.562717	.436128
062183	6	41	[illegible]	313.4	6	70	1.04303	.351606	.257006
062183	6	41	[illegible]	312.4	6	80	.629752	.21072	.303371
062183	6	41	181	175	6	85	2.22128	.421565	1.21036
062183	6	41	100	95	5	85	3.37893	.35159	1.21019
062183	6	41	406.9	391.9	8	78	2.47484	1.05506	.951477
062183	6	41	193	188	5	85	1.72966	.351693	1.21055
062183	6	41	339.4	332.4	6	67	1.37333	.492373	.315033
062183	6	41	353.2	345.2	7	80	1.50975	.562717	.694401
062183	6	41	437.9	425.9	8	78	1.83097	.844003	.761139
062183	6	41	391.2	379.2	7	80	2.05292	.843931	1.04142
062183	6	41	412.9	393.9	8	80	3.10347	1.33607	1.44264
062183	6	41	112	104	8	80	4.87921	.562273	.607121
062183	6	41	128	120	8	82	4.25023	.562398	.757681
062183	6	41	204	194	10	78	3.31103	.703147	.507289
062183	6	41	176.5	160.5	11.3	64	6.25227	1.12391	.340332
062183	6	41	294.2	280	14.3	82	3.25894	.998534	.752592
062183	6	41	451.1	444.6	7.3	61	.956431	.457015	.193699
062183	6	41	480.6	471.6	9	78.5	1.24575	.632909	.529093
062183	6	41	139	131	8	85	3.90418	.562466	1.21002
062183	6	41	197	192	5	84	1.69409	.351726	1.00948
062183	6	41	226.5	216.5	8	77	2.36934	.562676	.468997
062183	6	41	445.6	422.4	24	76	3.5221	1.63137	.42146
062183	6	41	437.9	423.9	14	75	2.14105	.984747	.407652
062183	6	41	401.9	387.2	16	69	2.45515	1.03379	.270442
062183	6	41	276.7	268.7	8.2	81	1.93324	.562636	.657913
062183	6	41	247.7	231.9	15.5	86	4.34054	1.1107	1.54066
062183	6	41	232	227.5	4.3	79	1.29075	.31643	.578495
062183	6	41	185.7	180	6.2	87	2.05427	.400662	1.85303
062183	6	41	235.5	231.2	4.6	79	1.21436	.302426	.516633
062183	6	41	184	178	6.1	82.5	2.18447	.422002	.795011
062183	6	41	466.6	444.6	23	76	3.18174	1.54699	.417037
062183	6	41	403.9	386.2	18	82	2.9523	1.24469	.745284
062183	6	41	333.4	321.4	12	83.5	2.41529	.843877	.931605
062183	6	41	232.5	220.5	12.4	83	3.49075	.843804	.837553
062183	6	41	242.5	233.5	9.5	79	2.49169	.632981	.52379
062183	6	41	194.5	183.7	11	82	3.76265	.759321	.743987
062183	6	41	234	227	7.2	79	2.00128	.492327	.537541
062183	6	41	178	172	5.7	81	2.25936	.421565	.709835
062183	6	41	177.5	172	5.4	83.5	2.07407	.386798	.949112
062183	6	41	482.6	467.1	16.2	78	2.15105	1.0902	.485513
062183	6	41	312.4	289.2	24.5	71.5	5.08009	1.6305	.314607
062183	6	41	360.2	350.2	10.5	69	1.85529	.703299	.280357
062183	6	41	370.2	354.2	17.5	73	2.91181	1.12514	.329853
062183	6	41	416.9	389.9	30	82	4.72373	2.03842	.732326
062183	6	41	431.9	416.9	15.9	77.5	2.32909	1.05503	.459856
062383	10	44.3	436.9	413.9	25	68	3.17345	3.03857	.366633
062383	10	44.3	261	236.5	25	79	5.77774	3.2339	.766663
062383	10	44.3	211	203	9	65	2.26864	1.057	.314023
062383	10	44.3	169	177.5	12.2	70	3.68315	1.51506	.411379
062383	10	44.3	86.5	74.5	12	82	8.73515	1.56138	1.06998
062383	10	44.3	52	47.5	4.7	72	5.30678	.594106	.462233

Sample output from data output file YUKTABL.DAT, produced by program YUKSWIM.BAS

appendix table k-1 goes here

APPENDIX K: Coefficient of Variation Data Used in the Discussion of Sampling Time Analysis

APPENDIX Table K-1

Coefficient of variation data by additive 3-minute time blocks for mid-water to near-bottom scanning with a 6° transducer. North bank of lower Yukon River, near Pilot Station; 25 June to 3 July 1983.

Statistics 1/	Time (minutes) 3	6	9	12	15	18	21	24	27	30
N	75	39	26	19	15	13	11	9	8	7
Sum	1539	1581	1581	1487	1456	1581	1534	1308	1308	1248
Mean 2/	20.52	40.54	60.81	78.26	97.07	121.62	139.45	145.33	163.50	178.29
S. Dev. 2/	13.62	25.66	37.33	45.32	54.69	68.31	73.95	70.55	79.89	89.88
C.V. 2/	66.37	63.29	61.39	57.91	56.34	56.17	53.03	48.54	48.86	50.41
S.E. C.V. 2/	7.26	9.62	11.37	12.14	13.15	14.07	14.13	13.88	14.85	16.55

1/
N = number of "t" minute time blocks in the sample.
Sum = number of fish counts for N, t-minute time blocks.
Mean = average number of fish counts per N, t-minute time blocks.
S. Dev. = standard deviation of the mean.
C.V. = coefficient of variation.
S.E. C.V. = standard error of the coefficient of variation.

2/ Rounded data.

appendix table k-2 goes here

APPENDIX Table A-2

Coefficient of variation data by additive 3-minute time blocks for near surface scanning with a 2° transducer. North bank of lower Yukon River, near Pilot Station; 2 and 3 July 1983.

Statistics [1]	Time (minutes) 3	6	9	12	15	18	21	24	27	30
n	30	15	10	7	6	5	4	3	3	3
Sum	57	57	57	49	57	57	49	39	33	57
Mean [2]	1.90	3.80	5.70	7.00	9.50	11.40	12.25	13.00	11.00	19.00
S. Dev. [2]	1.73	2.57	2.83	2.52	5.24	4.98	3.20	3.61	2.00	8.89
C.V. [2]	91.00	67.61	49.66	35.95	55.20	43.68	26.14	27.74	18.18	46.78
S.E. C.V. [2]	19.15	17.08	13.57	10.76	20.32	16.24	9.65	12.16	7.66	22.98

[1] n = Number of "t" minute time blocks in the sample.
Sum = Number of fish counts for n, t-minute time blocks.
Mean = Average number of fish counts per n, t-minute time blocks.
S. Dev. = Standard deviation of the mean
C.V. = Coefficient of variation.
S.E. C.V. = Standard error of the coefficient of variation

[2] Rounded data.

appendix table k-3 goes here

APPENDIX Table K-3

Coefficient of variation of data by additive 3-minute time blocks for mid-water scanning with a 2° transducer. North bank of lower Yukon River, near Pilot Station; 2 and 3 July 1983.

Statistics 1/	Time (minutes) 3	6	9	12	15	18	21	24	27	30
n	25	12	8	6	5	4	3	3	2	2
Sum	78	75	75	75	78	73	66	75	54	61
Mean 2/	3.12	6.25	9.38	12.50	15.66	18.25	22.00	25.00	27.00	30.50
S. Dev. 2/	2.35	4.18	4.34	7.66	6.77	6.70	10.39	15.52	16.97	16.26
C.V. 2/	75.35	66.89	46.30	61.29	43.38	36.72	47.24	62.10	62.85	53.32
S.E. C.V. 2/	15.57	18.79	13.84	23.42	16.09	14.63	23.19	33.74	42.05	33.39

1/

n = number of "t" minute time blocks in sample.

Sum = number of fish counts for n, t-minute time blocks.

Mean = average number of fish counts per n, t-minute time blocks.

S. Dev. = standard deviation of the mean.

C.V. = coefficient of variation.

S.E. C.V. = standard error of the coefficient of variation.

2/ Rounded data.

appendix table k-4 goes here

APPENDIX Table K-4

Coefficient of variation data by additive 3-minute time blocks for near-bottom scanning with a 2° transducer. North Bank, lower Yukon River, near Pilot Station; 2 and 3 July 1983.

Statistics 1/	Time (minutes) 3	6	9	12	15	18	21	24	27	30
N	25	12	8	6	5	4	3	3	2	2
Sum	339	322	322	322	339	322	254	322	219	246
Mean 2/	13.56	26.83	40.25	53.67	67.80	80.50	84.67	107.33	109.50	123.00
S. Dev. 2/	6.57	12.10	18.50	22.06	26.24	32.15	32.59	40.50	51.62	52.33
C.V. 2/	48.46	45.11	45.96	41.11	38.71	39.94	38.50	37.73	47.14	42.54
S.E. C.V. 2/	8.31	10.92	13.70	13.73	13.95	16.22	17.89	28.33	24.82	

1/ N = Number of "t" minute time blocks in sample.
Sum = Number of fish counts for N, t-minute time blocks.
Mean = Average number of fish counts per N, t-minute time blocks.
S. Dev. = Standard deviation of the mean.
C.V. = Coefficient of variation.
S.E. C.V. = Standard error of the coefficient of variation.

2/ Rounded data.

appendix table k-4 goes here

APPENDIX Table K-5

Coefficient of variation data by additive 3-minute time blocks for pooled (near-surface, mid-water, and near-bottom) scanning aspects with a 2° transducer. North bank of lower Yukon River, near Pilot Station; 2 and 3 July 1983.

	Time (minutes)									
Statistics 1/	3	6	9	12	15	18	21	24	27	30
N	80	39	26	19	16	13	10	9	7	7
Sum	474	454	454	446	474	452	369	436	306	364
Mean 2/	5.92	11.64	17.46	23.47	29.62	34.77	36.90	48.44	43.71	52.00
S. Dev. 2/	6.52	12.34	18.25	23.90	29.34	34.56	35.09	46.68	46.88	49.91
C.V. 2/	109.96	105.99	104.52	101.83	99.05	99.38	95.09	96.36	107.25	95.97
S.E. C.V 2/	16.07	21.62	25.87	28.96	30.13	33.62	35.64	38.39	52.07	43.24

1/ N = Number of "t" minute time blocks in sample
Sum = Number of fish counts for N, t-minute time blocks.
Mean = Average number of fish counts per N, t-minute time blocks.
S. Dev. = Standard deviation of the mean.
C.V. = Coefficient of variation.
S.E. C.V. = Standard error of the coefficient of variation.

2/ Rounded data.

appendix table k-5 goes here