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KUSKOKWIM RIVER SONAR PROGRESS REPORT, 1989 - 1990

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ABSTRACT

A study to determine the feasibility of using dual-beam sonar to count salmon migrating up the Kuskokwim River in western Alaska began in 1988 and continued through 1989 and 1990. A site with characteristics favorable to use of sonar gear was identified and facilities were constructed in 1988. Resolution of equipment problems that plagued the 1988 program resulted in nearly continuous sampling during both 1989 and 1990. Fish spatial distribution information from bank-to-bank transects sampled with downward-looking sonar and fish counts from horizontally-aimed sonar transducers were used to calculate daily passage estimates. These estimates were given to commercial fishery managers in 1990, but were considered preliminary and were not incorporated in the management working group decision-making process.

Spatial distribution data collected from gillnets and bank-to-bank transects in 1990 support previous observations of cross-river fish distribution with shore and surface concentration. Time series analysis of temporal distribution indicates early season correlation of fish passage with time of day, and a later shift to high correlation with tide level. Length frequency information collected from gillnets fished in 1990 showed a significant size difference between salmon and non-salmon species ($p=0.0001$). Target strength data collected during the two years were not analyzed due to suspected attenuation of 420 kHz sound in fresh water. There was little correlation between unadjusted sonar counts and test fishery gillnet abundance indices. A significant correlation was found, however, between test fishery CPUE and sonar passage estimates adjusted for whitefish presence ($r=0.52$, $p=0.05$). While correlation analysis indicated some relationship between commercial catch per unit effort in districts 13 and 14 and sonar estimates of fish passage two days previous to the fisheries in 1990, the correlations were not statistically significant at $p \leq 0.05$. This may be attributed to differences in time and area sampled by the two gear types and by selectivity of test-gillnets for salmon-size fish.

KEY WORDS: Salmon, sonar, hydroacoustic, escapement, Kuskokwim River

INTRODUCTION

Kuskokwim River salmon stocks are harvested for both commercial and subsistence use. Exploitation occurs throughout 1,100 km of river with the most intensive fishery located between the river mouth and km 218. Management of the fishery resource requires assessment of migratory timing, run strength and escapement levels. Silty water and an extensive, braided river channel preclude visual enumeration of migrating chinook *(Oncorhynchus tshawytscha)*, sockeye *(O. nerka)*, coho *(O. kisutch)*, and chum (*O. keta*) salmon, making accurate estimation of these characteristics difficult. Management decisions have historically been based on abundance indices obtained from test-gillnet fisheries, and on escapement indices obtained in upriver spawning tributaries. The need for more accurate and timely escapement data prompted initiation of a project to determine the feasibility of using hydroacoustic (sonar) techniques to estimate daily and seasonal fish passage.

In 1988 a site with characteristics favorable to the use of sonar gear was identified and camp facilities were constructed. Transducers were deployed on both banks of the river between 15 June and 23 August. Fish spatial distribution was examined by sampling a bank-to-bank transect with a downward-looking transducer between 4 June and 22 August. These data revealed distribution of fish throughout the water column with highest concentrations near the shores and the surface. Feasibility of estimating fish passage was established through temporal and spatial expansion of sonar samples and subsequent favorable correlation with other indices of fish abundance. Details of the 1988 research are found in Hyer et al. (1990).

The focus of the 1989 and 1990 field seasons was collection of fish distribution and species separability information necessary to further project development. Objectives included determining if fish species migrating past the sonar site were separable through statistical analysis of target strength estimates, collecting information on the spatial and temporal distribution of salmon and whitefish, identifying tidal and temporal effects on fish passage, and estimating total fish passage using data collected from side-looking and downward-looking transducers.

METHODS

Site Description

The sonar site is located at river km 130 (Figure 1). This site was selected after conducting extensive surveys of the lower river for physical characteristics favorable to counting fish with sonar, and has been used each year since 1988. It is on the main river channel, has a V-shaped bottom profile and minimal tidal influence, and is close to Bethel and the lower river fishery. The river is approximately 360 m wide with a maximum depth of 12 m (Figures 2 and 3). The right bank bottom is sandy near shore grading to mud approximately 5 m offshore. The left bank is more steeply sloped, with a muddy bottom composition. Water flow is affected by daily tidal fluctuations and occasional flow reversal. The site may be circumvented by any of three shallow sloughs (Church, Straight, and Steamboat) as shown in Figure 1.

The width of the river, combined with equipment and personnel limitations, precluded sampling from both banks. Therefore we chose to sample only the right bank with fixed-aspect side-looking sonar, and we estimated passage through the rest of the river with data from bank-to-bank transects with downward-looking sonar.

Sonar Data Acquisition

Equipment

Sonar equipment used at the site included a Biosonics[2] model 101 dual-beam transceiver, Biosonics model 151 multiplexer, Biosonics model 281 echo signal processor (ESP), Nicolet model 310 digital storage oscilloscope, and Biosonics model 111 thermal chart recorder. To optimize the area ensonified in 1989 we used a two-transducer system (Figure 4). Initially, we deployed a Biosonics 3° x 7° elliptical dual-beam transducer to sample 100 m. This range was decreased to 40 m on 07 July and an Acoustic Transducers Inc. 1.7° x 3.7° dual-beam elliptical transducer was deployed to sample the range between 40 and 187.5 m. In 1990 we used a single Biosonics 6° x 15° circular dual-beam transducer sampling to 100 m (Figure 4). Each transducer was attached to a tripod-mounted Remote Ocean Systems pan and tilt unit positioned approximately 2 m offshore. The pan and tilt system permitted aiming to approximately one tenth of one degree precision. Transducers were aimed so as to maximize ensonification of passing fish. The transmitted frequency of the echo sounder was 420 kHz with a pulse width of 0.4 ms. The pulse repetition frequency (PRF) was 4.0 Hz.

Bank-to-bank transects were ensonified with a Lowrance X-15 recording fathometer and 22° transducer. The transducer was attached to the stern of a skiff, fathometer settings were standardized, and we attempted to keep boat speed consistent between transects.

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[2]Use of specific brand names in this publication is for archival purposes only and does not constitute endorsement by the State of Alaska, Department of Fish and Game.

Data Collection

The sonar system collected data 24 hours per day, seven days per week, with approximately one 15-minute break every eight hours for maintenance and generator refueling. Data acquisition was only interrupted by equipment breakdown, standard target work, 4th of July 1990, or when changing river level prompted movement of tripods and subsequent re-aiming of transducers. Each day was divided into three eight-hour periods (0800-1600, 1600-0000, 0000-0800). A single fisheries technician operated the equipment and recorded notes pertaining to data acquisition and the sampling environment during each operating shift. The multiplexer was programmed to control echo sounder parameters, sample time and stratum. Sampling began at the top of the hour and continued in 15 minute intervals. During each sample interval the technician recorded water level and river current direction, and tallied fish traces in 20 m range strata. This information was recorded on field data collection forms and later entered to electronic format. Linear interpolation was used to estimate fish passage during missed sample periods.

Fish Distribution

Spatial

The spatial distribution of fish migrating past the sonar site is evaluated for two reasons. First, it enables positioning of the transducer for optimal fish detection. Secondly, the information is used to expand counts from the side-looking sonar to estimate total passage. We collected information on fish spatial distribution by sampling a bank-to-bank transect with a Lowrance X-15 fathometer and downward-looking transducer. The 22° transducer was attached to the transom of the boat and operated on a straight line cross-river transect approximately 15 m downstream from the side-looking transducers. Transects were sampled 12 times daily; six samples each were collected at 1100 and 1700 hours. Sample times remained constant so that all tide stages were sampled over the duration of the study. Each transect provided a chart recording of the water column from approximately 2 m below the transducer face to the river bottom. We circled those targets thought to be fish on the chart recordings, identifying them for further processing.

Analysis of the transect data for visual representation and quantification of spatial distribution involved setting all chart recordings to a common scale, adjusting numbers of observed targets to compensate for varying sample volumes with depth, and determining the proportion of observed targets within range of the horizontally-aimed beams. Scaling individual chart recordings using actual river width (360 m) and maximum river depth (12 m) corrected sampling irregularities incurred due to varying river conditions and boat speed. This was accomplished with the digitizing program KDIG.C (Appendix A) and a digitizing pad. The program assigned range and depth coordinates to each fish trace on the scaled chart recording. Estimation of the actual fish distribution in the river cross-section required adjustment of fish numbers detected at each depth to account for increasing sample area and probability of fish detection with depth. This was adjusted for by expanding individual fish by C:

$$C=\frac{r}{r_t}$$

where: r = maximum depth

r_t = depth of the target

The cumulative proportion of the expanded observed total number of fish within the range of the side-looking transducers was calculated each day for use in spatial expansion of daily fish counts as described below.

Temporal

Temporal patterns of fish movement were examined using time-series analysis. The relationships between fish movement, daylight, and water level were evaluated. Results of this investigation will be published in a separate report.

Fish Passage Estimation

Estimation of total fish passage in 1989 and 1990 differed due to differences in available data between the two years. In 1989 bank-to-bank transect data was not collected and sonar range extended as far as 187.5 m from the transducer. Therefore, we expanded fish traces observed in the side-looking sonar beams post-seasonally to account for spatial distribution using cumulative horizontal transect information from 1988. A horizontal multiplier of 3.34 was used initially when the 3° x 7° transducer beam effectively covered the entire water column over the counting range. With the addition of the 1.7° x 3° transducer on 7 July, both vertical and horizontal expansions were necessary because the narrower transducer beam covered only the upper portion of the river. Accounting for fish in the unensonified area with this transducer configuration resulted in a spatial expansion multiplier of 4.64.

The number of fish passing the sonar site in 1990 was estimated with data from both the right bank side-looking transducers and the bank-to-bank transects. The inverse of the proportion of fish observed within the range of the shore-based transducers on the bank-to-bank transect chart recordings was multiplied by the daily total number (temporally expanded) of fish counted with the side-looking transducers to arrive at daily fish passage estimates. We assumed that the side-looking sonar beam filled the water column in 1990 making spatial expansion unnecessary within its range.

Target Strength Estimation

Dual-Beam Data Processing

Dual-beam sonar hardware and software was used to collect and process target strength information on individual echoes for use in separating whitefish species from salmon. Echoes were evaluated based on several user-defined criteria, including minimum narrow and wide beam voltage threshold (filters small fish and spurious echoes), maximum narrow and wide beam voltage threshold (filters bottom echoes), minimum and maximum pulse widths (filters noise-corrupt echoes), and start depth (removes near-field data) (MacLennan and Simmonds, 1992).

Echoes meeting the above requirements were passed from the dual-beam echo signal processor to storage on the microcomputer hard drive. The following data are stored for each echo: sequential number of the ping producing the echo, echo number, wide beam voltage, narrow beam voltage, range from the transducer, and wide- and narrow-beam pulse widths at the one-half power points. Data associated with each valid echo were stored in a file with a unique name generated by the computer based on input from the operator prior to the onset of the sample.

Data files were processed with dual-beam data processing (DBDP) software. This software uses 26 input parameters to filter out invalid echoes, compute target strength, and combine valid echoes into logical groups which represent individual tracked fish. The parameter file was calibrated through repeated comparison of chart recorder output and DBDP output file (.EKO file) information, with accurate program-generated echo groupings as the objective. The program first filters out invalid echoes based on wide and narrow beam voltage, beam pattern factor, pulse width, and distance from the transducer. Grouping of echoes into individual fish was determined by minimum number of pings, maximum change in range between consecutive echoes, and maximum time allowed between consecutive echoes.

Two files were produced by DBDP for each data file input. One of these, the .EKO file, listed all echoes which had been combined to represent individual fish. This file included, among other statistics, range and target strength. The second file (the .FSH file) contained information pertaining to grouped echoes. Mean target strength, beam pattern factor, wide and narrow beam pulse widths and voltages were stored here.

Standard Target

Dual-beam processing parameters for target strength estimations were determined using information collected from a lead sphere of known acoustic size (-26 db). The sphere, or standard target, was suspended from a buoy at varying ranges in front of the transducer. The transducer was aimed so the target appeared as close to the maximum response axis on both beams as possible. Echoes from the sphere were collected using the ESP. This information was iteratively processed with DBDP, and the parameters affecting target strength were adjusted at each iteration until the standard target data was processed to its known acoustic size. The adjusted parameters were used to calculate target strengths of tracked fish. This process was repeated periodically during the summer to ensure the accuracy of DBDP's processing parameters. Standard target information was collected six times in 1989 between 10 and 35 m range with the Biosonics transducer and between 50 and 105 m with the ATI transducer. In 1990, standard target information was collected twice between 30 and 50 m range.

Test Fishing

We fished gillnets in 1990 to collect information on the spatial and temporal distribution of whitefish. Two nets were deployed from the right bank; one was a 6.4 cm stretched mesh net 50 m long by 3 m deep, and the other a 14 cm stretched mesh net 50 m long by 3.5 m deep. Both nets were set perpendicular to the shore and fished for 10 to 60 minutes about 9 m downstream from the side-looking transducer. Nets were fished twice daily on an opportunistic basis. Captured fish were first identified to species and location in the net, then measured (mid-eye to tail fork for salmon, snout to tail fork for other species). Beginning 28 July, catch per unit effort (CPUE) data derived from the gillnets was used to apportion inshore (2-40 m) fish passage estimates to species, primarily to separate whitefish from the salmon counts. Lack of inshore test fishing data from 1989 precluded estimation of species composition in that year.

We drifted a gillnet beyond the range of the set nets to further describe spatial distribution of whitefish in 1990. Between 23 and 29 July, the 6.4 cm stretched mesh net was drifted six times. Each drift began up river from the sonar site and continued for 15 minutes with the inshore end of the net approximately 50 m from shore. Captured fish were processed as described above.

Sonar Estimates vs. Non-Acoustic Abundance Indices

CPUE data from the Bethel test fishery and the commercial fishery are used by area managers as indices of salmon abundance in the main channel of the Kuskokwim river (Molyneaux 1990). The relationship between these indices and the 1990 salmon counts was evaluated using correlation analysis. CPUE data were compared to daily salmon passage estimates derived from sonar counts. No comparisons of 1989 sonar counts and non-acoustic abundance indices were made because these estimates were not apportioned to species.

We checked for correlation between sonar estimates of fish passage and commercial CPUE data from statistical areas 335-13 and 335-14 in District W1. Sonar passage estimates from the day of the commercial period as well as from one through four days prior to the commercial period were examined. Commercial catch CPUE was calculated as:

$$CPUE=\frac{n}{pt}$$

n = number of fish captured
p = number of permits fished
t = number of hours fished

The data included commercial catches from 25 and 29 June, 5, 9, and 14 July, 1 August, 6 August, and 10 August.

We also examined Bethel test fish CPUE data (Molyneaux, 1990) and daily sonar fish passage estimates for correlation. CPUE values for all species were combined for each day and compared to the daily estimates of fish passage from the sonar project. Additionally, we used inshore set net data to adjust sonar estimates for whitefish passage, and correlated the resultant salmon passage estimates with CPUE from the Bethel test fish project.

RESULTS

Sonar Data Acquisition

Resolution of the equipment problems that plagued the 1988 program resulted in nearly continuous sampling during both 1989 and 1990. We collected a total of 1,476 hours of data between 10 June and 15 August 1989. We counted 241,448 valid targets within 187.5 m of the right bank during this time period. In 1990, the sonar equipment was operational from 2 June through 14 August. We collected a total of 1,664 hours of sonar data which contained 488,158 target traces within 100 m range. Expansion of counts for time not sampled was minimal in both years since the sonar gear was running nearly 24 hours per day.

The ESP collected 1,260 hours of data between 2 June and 14 August 1989. An additional 224 hours of data was collected from 6 June through 9 July 1990 and 13 through 17 July 1990.

Fish Distribution

Concern over the applicability of data collected with the downward-looking transducer to fish spatial distribution and abundance estimation in 1989 prompted suspension of that portion of the program. In 1990, however, having verified that sufficient numbers of fish were available to the gear and having developed the application through analysis of 1988 data, we resumed transect sampling. Between 2 June and 14 August 1990 we recorded 888 bank-to-bank transects. A total of 3,635 individual fish were identified yielding 16,701 fish when expanded to account for increased sample area with range from the transducer. Transects indicated fish distribution throughout the water column with highest passage occurring within 40 m of the shore (Figure 5). Similarly, 76 percent of the targets detected with side-looking transducers in 1989, and 59 percent of those detected with side-looking transducers in 1990, were within 40 m of the transducer face.

Visual analysis of transect data over time suggests that fish were mostly distributed in nearshore and surface areas from 2 through 16 June, and began to utilize mid-river and river bottom areas between 16 June and 16 July. From 16 July through 13 August fish were again most heavily distributed near the surface and shores.

Preliminary results of time series analysis of fish passage data suggest that fish passage is not consistently related to tide, but that it varies initially with time of day and late in the season is correlated with tide stage.

Fish Passage Estimation

Expansion of 1989 side-looking transducer data to unensonified areas of the river resulted in a total passage estimate of 1,235,692 fish (Table 1, Figure 6). In 1990, the total abundance estimate was 1,472,460 (Table 2, Figure 6). Adjustment to exclude whitefish resulted in a final estimated passage of 1,051,937 salmon.

Target Strength Estimation

MacLennan and Simmonds (1992) reported attenuation of high frequency sonar signals with range in fresh water. We have observed a direct relationship between 420 kHz signal attenuation and conductivity in several Alaskan lakes. Since effective sampling range is inversely proportional to water conductivity, small fish close to the transducer could reflect signals at intensities equal to those of larger fish at distance. We were not aware in 1989 and 1990 that signal attenuation existed at a level that would impact our assessment of fish stocks.

Because it has the potential to confound estimation of target strength, we have chosen not to proceed with analysis of these data until its effect is known.

Test Fishing

Test fishing efforts in 1990 consisted of 53 sets with the 6.4 cm (stretched) mesh gillnet and 47 sets with the 14 cm gillnet between 16 June and 12 August (Appendix B). A total of 280 salmon, 400 whitefish and 7 arctic char were caught. Captured salmon consisted of 25 chinook, 29 coho, 43 sockeye, 156 chum, and 27 pinks. Whitefish began to comprise a majority of the catch by the end of July, and remained abundant through the end of the sonar operation. There was no detectable spatial separation between species; both salmon and non-salmon species were intercepted from 2 through 50 m from shore. Fifty-six percent of all salmon and sixty-five percent of all whitefish were caught farther than 25 m from shore (Figure 7). Twenty-six whitefish and four salmon were caught during the six drifts with 6.4 cm mesh net. The fish were found throughout the length and depth of the net.

Although spatial separation between salmon and non-salmon species was not observed, there is a significant size separation (Figure 8). The mean length of non-salmon species (368 mm, s.d.= 43, n= 458) is significantly less than that of salmon (580 mm, s.d.= 324, n=282). Comparison of whitefish size with that of temporally overlapping species (chum and coho salmon) was accomplished with a Wilcoxon 2-sample test in SAS software. This test indicates significant (p=0.0001) size differences between whitefish and chum salmon, and between whitefish and coho salmon.

Sonar Estimates vs. Non-Acoustic Abundance Indices

Figure 9 shows sonar passage data (unadjusted and with whitefish removed) and commercial CPUE data. Sonar estimates were much lower than CPUE data between 25 June and 5 July. After 5 July, the data trends are similar. There were no statistically significant ($p \leq 0.05$) correlations of commercial catch and sonar passage data. However, if we eliminate data collected prior to 5 July, the best correlations are between commercial CPUE and sonar estimates from two days prior to the commercial opening for both statistical areas 335-13 (r=0.73, n=6) and 335-14 (r=0.75, n=6).

Daily fish passage estimates, unadjusted and adjusted to remove whitefish, are shown with Bethel test fish CPUE values in Figure 10. While the trends in the data are similar, there are some differences. CPUE data track with sonar data through about 07 July. Sonar estimates then remain at high levels while CPUE estimates decline. Peak values in both data sets correspond through 03 August, although CPUE values are much lower than sonar estimates. After 03 August, CPUE values rise while sonar estimates are level or declining. Bethel test fish CPUE was better correlated with sonar estimates adjusted for whitefish (r=0.52, p=0.05, n=74), than with unadjusted sonar data (r=0.28, p=0.05, n=74).

DISCUSSION

Most of the objectives of this project were accomplished during the 1989 and 1990 field seasons. The equipment problems experienced in 1988 were resolved, field operations were streamlined, and by mid-season 1990 we were providing area fishery managers with daily estimates of salmon abundance. We have improved our understanding of fish spatial and temporal distribution, have identified tidal and temporal effects on fish passage, and have collected data which will help to determine separability of fish species by target strength. We feel that several problems require resolution, however, before this project can produce estimates on which management decisions may be confidently based.

The sonar site appears to be relatively stable. No major changes were noted in bottom topography or flow patterns through mid-August, 1990, although some minor localized bank erosion occurred at and near the right bank site. One target of persistent public criticism is the location of the site in an area where three sloughs provide alternate passage routes outside of ensonified waters. Because there are no other suitable sonar sites in the lower Kuskokwim River based on the 1988 surveys, we have attempted to document presence or absence of salmon in the sloughs. Use of the portable sounder in slough areas in 1988 and 1989 indicated presence of fish of unknown species. Species composition information is lacking however, because gillnets proved difficult to deploy and retrieve in the narrow, fast moving, snag-filled slough areas.

If we continue to use the current sonar site, we will eventually have to address the question of how many salmon travel in the sloughs. Limited fiscal and personnel resources require that we give attention first, however, to accurately estimating fish passage through the main river channel.

The problems initially experienced with equipment on this project with generators, the multiplexer, and the echosounder have been solved. In 1989, the sonar gear sampled the river 93 percent of the time available. Scheduled maintenance required an additional 3.1 percent, and mechanical breakdowns and unscheduled work (e.g., standard target work) accounted for only 3.9 percent of the time. In 1990 the sonar gear sampled the river 95 percent of the time, scheduled maintenance required 3.1 percent, and other work accounted for 1.9 percent of the available time.

We are currently implementing solutions to two other long-standing equipment-related problems. First, the recognition of attenuation as a potential cause of confusion in estimation of target strength has led to change of operating frequency from 420 kHz to 120 kHz. Modifications are being made to echosounders and new transducers are being built to operate at this frequency. This gear will be used during the 1992 field season. Secondly, ensonification of the left bank of the river will begin in 1992. Because the river is too wide to run cables from one side to the other, and due to insufficient funding for support of an additional camp, equipment and personnel for the left bank, we explored the possibility of transmitting sonar signals via radiotelemetry. A radiotelemetry system was developed in the winter of 1991-92 and will be implemented and field tested at the sonar site in 1992.

Data collection procedures varied between 1989 and 1990. The most notable difference is the lack of bank-to-bank transect data in 1989. Lack of 1989 data resulted in use of 1988 distribution data for estimation of 1989 fish passage, and acceptance of the assumption that fish distribution did not change significantly between the two years. We believe that this is a reasonable assumption since neither river morphology nor species proportions differed appreciably in 1988 and 1989. A second difference in procedures between the two years is the transducer beamwidths, configuration, range, and aiming. The two narrow beam transducers ($3^{\circ}x7^{\circ}$ and $1.7^{\circ}x3.7^{\circ}$) used in 1989 were aimed as near as possible to the surface and covered a total range of 187.5 m, while the wider beam ($6^{\circ}x15^{\circ}$) transducer used in 1990 was oriented as near as possible to the river bottom and covered only 100 m. The 1989 passage estimation method requires the assumption that fish are distributed uniformly through the water column, while the 1990 method assumes that the sonar beam effectively filled the water column over the range sampled.

It appears that the first of these two assumptions is untrue based on expanded bank-to-bank transect distribution data which shows heavy concentration of targets near the river banks and surface. There are several areas of uncertainty (discussed below) surrounding use of the bank-to-bank transect technique and data. It is, however, the best information available at this time. If the true fish spatial distribution is greater near the shores, moderate near surface and bottom, and light in remaining areas, as the bank-to-bank information suggests, then estimates of abundance generated for 1989 may be biased. Another troubling piece of information from the 1989 data is the difference in expansion factors used with the two transducer configurations. The increased expansion factor calculated for use upon adding a transducer to the system indicates that we actually lost ensonified area by adding equipment. Care should be taken in the future to avoid adding complexity with no coincident gain in efficiency.

The assumption that the sonar beam filled the water column in 1990 would be true based on transducer specifications, theoretical beamwidth, and river bottom slope. Attenuation, however, may narrow the expected coverage of the beam and result in violation of the assumption. This error would bias fish passage estimates low.

Fish spatial distribution data collected during bank-to-bank transects are affected by several factors, related to both the acquisition equipment and the application. There is some uncertainty about true fish distribution as a result of the loss of information at the river surface. One of the reasons for this uncertainty is the difficulty with which data from the first few meters of river depth is interpreted from the chart recordings. This appears to be a function of the sensitivity setting used. The problem is intensified by "noise" from surface turbulence caused by boats or rain. A second source of uncertainty is the potential change in fish distribution caused by scattering of fish as the boat traverses the river. Motor noise or pressure waves generated by the boat's movement may cause salmon to move away from the source, and out of transducer range. Both of these sources of error would tend to cause underestimation of the number of fish in waters near the surface. The effect is likely to have its most pronounced results near shore, where water is shallow and fish are most likely to scatter when the boat approaches.

Other potential sources of error arise from the fact that the Lowrance is not a scientific echo sounder, and we know very little about its operating characteristics. The machine operates at 217 kHz. The time varied gain (TVG), however, is unknown as is the shape of the beam. We assume a triangular longitudinal beam cross-section when adjusting detected target numbers. If in fact the beam does not spread uniformly with range, then the target distribution estimated will not be representative of the actual distribution. As with the TVG, we do not know what the effect of the sensitivity (gain) adjustment is on the Lowrance. We may have recorded much smaller targets along the bank-to-bank transects than we did with the side-looking sonar. If those targets were distributed the same as salmon-sized targets, there would be no problem. If they were distributed differently, however, they would bias the fish passage estimates. For example, if small fish detected by the fathometer are concentrated near the river banks, estimates of salmon passage will be biased low. Conversely, if small fish are concentrated offshore, salmon estimates will be biased high.

Bank-to-bank transect data collection was initiated in order to address fish distribution questions and to provide information on which estimates of fish passage through unensonified portions of the river could be based. Such estimates, while admittedly less than optimal, help to evaluate how the overall project is working. As technology and applications develop, this technique will surely be phased out of the quantitative program and relegated to a more appropriate role of detecting presence or absence.

The side-looking sonar data is affected by three primary factors: transducer beam size, aiming, and, to an unknown extent, attenuation. As previously discussed, the effect of transducer beam size and aiming on fish passage estimates depends on fish distribution. The choice of transducer beam size, as well as the aim, is determined by the river bottom slope at the sonar site. Attenuation, however, would reduce beam width and cross sectional area of the river actually sampled from that calculated to have been sampled with a given 420 kHz transducer. The most probable effect of attenuation on total passage estimates is to cause underestimation. Attenuation would also impact our ability to accurately set voltage thresholds to exclude small fish from detection. If the sonar signal attenuates with range, the effect of a voltage threshold also varies with range. If a threshold is set to exclude fish smaller than, for example, 450 mm at 20 m range, fish larger than 450 mm would be excluded at ranges greater than 20 m. We are thus forced to use very low thresholds, which means that we count small fish and add to the problems of species apportionment.

Conversion of equipment to 120 kHz is expected to lessen the effect of attenuation and associated problems discussed above. Another benefit of this modification is the anticipated improvement in accuracy of target strength estimates. Dual-beam data collected in 1989 and 1990 for target strength measurement proved too variable for use in species separation. The variability observed may have been due to the confounding effect of signal attenuation. We are optimistic that we will eventually be able to measure target strength and use that data to apportion fish passage estimates to species using the 120 kHz system.

Results of fishing gillnets to determine spatial distribution of fish indicate that other species (primarily whitefish and cisco) are present through 100 m from shore. They may be present at longer ranges, but we did not sample these areas. Data from set nets show the peak of both salmon and whitefish distributions between 25 and 35 m from shore. This is probably an anomaly caused by the interaction of the net and the river current. We attempted to set the gillnets perpendicular to the shoreline. River current, however, usually caused the net to bow downstream. The pressure of the water on the net, and particularly on mesh toward the outer end of the net, caused those meshes to be stretched and ineffective. Also, it is likely that this end of the net acted as a fence which fish avoided, and their movement distorted the distribution of catch with range from what is normal. Finally, the depth of the nets fished (3.0 and 3.5 m) did not permit fishing the entire water column. Water depth at 50 m from shore is between 5 and 7 m. Future gillnetting should be attempted only at high slack tide, when the net can be set perpendicular to shore and fished efficiently along its entire length. Nets which sample the entire water column should be purchased for further examination of fish distribution.

It appears from our initial data that spatial segregation between salmon and other species will not provide the basis for apportioning sonar counts to species. We are encouraged, however, by the differences in length frequency distributions between salmon and other species based upon fish captured in the gillnets. While acoustic separation of similarly sized species such as chum and sockeye salmon may or may not be possible, it seems possible that whitefish and cisco may be distinguished from salmon species by target strength due to statistically significant differences in size.

The low correlation between sonar-derived fish passage estimates and Bethel test fish CPUE indices may be partially explained by differences in spatial and temporal sampling design, and by the effect of gillnet selectivity. The test fishery samples the top 5 m of the river for approximately two hours twice daily, while sonar sampled the entire river 24 h per day. Furthermore the test fishery begins data collection one hour after each high tide. Initial time-series analysis results, as noted previously, indicate that fish passage is not consistently related to tide, but that it varies initially with time of day and late in the season is correlated with tide stage. The test fishery uses gillnet meshes that target salmon-sized species to index salmon abundance. Sonar, on the other hand, was unable to discriminate salmon-sized targets from smaller targets. Sonar therefore may have overestimated salmon passage during periods of high whitefish and cisco abundance.

The lack of significant correlation between commercial CPUE and sonar passage estimates may be explained by any of a number of factors including differences in the availability of fish to each of the gear types and uncertainties surrounding bank-to-bank transect data and side-looking sonar data. The analysis indicates that commercial CPUE data is best correlated with sonar passage estimates from two days previous. This is consistent with Baxter's (1970) documentation of swimming speed for Kuskokwim River salmon. He found that the average rate of travel for salmon ranges between 0.45 km/hr (pink salmon) and 1.4 km/hr (chinook salmon).

The progress made with this project in 1989 and 1990 lies in the areas of uncertainty we have exposed for further development. Future years study should focus on these areas. The two developments to be implemented in 1992 (conversion to 120 Khz and radiotelemetry of left bank data) hold promise for bringing the project toward the long term goal of producing accurate estimates of Kuskokwim River salmon passage.

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Table 1. Daily estimated fish passage in the Kuskokwim River between 18 June and 15 August 1989, with expansion factors developed from 1988 transect data.

Julian Date	Date	Raw Counts	Adjusted Counts 1/	Expanded Counts 2/	Expansion Factor
169	18-Jun	2,052	4,477	14,968	0.2994
170	19-Jun	1,327	1,464	4,895	0.2994
171	20-Jun	1,064	1,201	4,015	0.2994
172	21-Jun	1,520	1,621	5,420	0.2994
173	22-Jun	1,429	1,507	5,038	0.2994
174	23-Jun	1,951	2,128	7,115	0.2994
175	24-Jun	2,431	2,652	8,867	0.2994
176	25-Jun	3,903	4,306	14,397	0.2994
177	26-Jun	1,675	1,869	6,249	0.2994
178	27-Jun	482	526	1,759	0.2994
179	28-Jun	459	489	1,635	0.2994
180	29-Jun	485	523	1,749	0.2994
181	30-Jun	837	945	3,159	0.2994
182	01-Jul	361	407	1,361	0.2994
183	02-Jul	691	745	2,491	0.2994
184	03-Jul	866	934	3,123	0.2994
185	04-Jul	145	994	3,323	0.2994
186	05-Jul	2,006	2,292	7,663	0.2994
187	06-Jul	2,074	2,212	7,396	0.2994
188	07-Jul	1,379	8,274	38,430	0.2155
189	08-Jul	7,368	7,772	36,098	0.2155
190	09-Jul	5,555	5,734	26,633	0.2155
191	10-Jul	3,804	4,246	19,721	0.2155
192	11-Jul	3,521	3,714	17,250	0.2155
193	12-Jul	2,553	2,883	13,391	0.2155
194	13-Jul	2,207	2,552	11,853	0.2155
195	14-Jul	3,459	3,953	18,360	0.2155
196	15-Jul	2,955	3,187	14,803	0.2155
197	16-Jul	4,936	5,384	25,007	0.2155
198	17-Jul	5,830	6,018	27,952	0.2155
199	18-Jul	5,288	5,578	25,908	0.2155
200	19-Jul	4,325	4,325	20,088	0.2155
201	20-Jul	3,155	3,328	15,458	0.2155
202	21-Jul	2,685	2,864	13,302	0.2155
203	22-Jul	3,978	4,196	19,489	0.2155
204	23-Jul	5,128	5,350	24,849	0.2155
205	24-Jul	5,346	5,702	26,484	0.2155
206	25-Jul	6,526	6,594	30,627	0.2155
207	26-Jul	7,990	8,074	37,501	0.2155
208	27-Jul	7,939	8,464	39,313	0.2155
209	28-Jul	10,091	10,416	48,379	0.2155
210	29-Jul	11,898	12,415	57,664	0.2155
211	30-Jul	9,276	9,473	43,999	0.2155
212	31-Jul	9,480	9,785	45,448	0.2155
213	01-Aug	7,479	7,720	35,857	0.2155
214	02-Aug	9,730	10,043	46,647	0.2155
215	03-Aug	10,336	10,555	49,025	0.2155
216	04-Aug	8,124	8,744	40,613	0.2155
217	05-Aug	7,684	8,995	41,779	0.2155
218	06-Aug	9,851	10,507	48,802	0.2155
219	07-Aug	7,653	10,347	48,059	0.2155
220	08-Aug	5,148	6,960	32,327	0.2155
221	09-Aug	5,249	8,260	38,365	0.2155
222	10-Aug	3,171	4,228	19,638	0.2155
223	11-Aug	834	1,703	7,910	0.2155
224	12-Aug	1,364	1,662	7,719	0.2155
225	13-Aug	1,440	1,486	6,902	0.2155
226	14-Aug	784	1,344	6,242	0.2155
227	15-Aug	171	684	3,177	0.2155
Totals		241,448	274,811	1,235,692	

1/ Adjusted for missed time only.
2/ Expanded for unensonified area

Table 2. Daily estimated fish passage in the Kuskokwim River between 02 June and 14 August 1990, with expansion factors developed from 1990 transect data.

Julian Date	Date	Raw Counts	Expansion Factor	Estimated Fish Passage	Adjusted Fish Passage
153	02-Jun	239	0.3728	641	641
154	03-Jun	101	0.3222	313	313
155	04-Jun	184	0.2998	614	614
156	05-Jun	94	0.3240	290	290
157	06-Jun	66	0.3026	218	218
158	07-Jun	94	0.2739	343	343
159	08-Jun	200	0.2791	717	717
160	09-Jun	467	0.2776	1,682	1,682
161	10-Jun	407	0.2787	1,460	1,460
162	11-Jun	465	0.2690	1,729	1,729
163	12-Jun	397	0.2652	1,497	1,497
164	13-Jun	259	0.2679	967	967
165	14-Jun	364	0.2639	1,379	1,379
166	15-Jun	438	0.2632	1,664	1,664
167	16-Jun	319	0.2626	1,215	1,215
168	17-Jun	763	0.2619	2,913	2,913
169	18-Jun	1,613	0.2648	6,091	6,091
170	19-Jun	2,348	0.2623	8,952	8,952
171	20-Jun	4,729	0.2687	17,600	17,600
172	21-Jun	4,293	0.2733	15,708	15,708
173	22-Jun	4,150	0.2721	15,252	15,252
174	23-Jun	3,506	0.2780	12,960	12,960
175	24-Jun	3,425	0.2782	12,577	12,577
176	25-Jun	4,584	0.2796	16,395	16,395
177	26-Jun	3,855	0.2747	14,033	14,033
178	27-Jun	5,090	0.2785	18,276	18,276
179	28-Jun	5,056	0.2780	18,187	18,187
180	29-Jun	5,542	0.2761	20,072	20,072
181	30-Jun	4,936	0.2773	17,800	17,800
182	01-Jul	3,014	0.2784	10,826	10,826
183	02-Jul	8,154	0.2786	29,268	29,268
184	03-Jul	9,575	0.2778	34,467	34,467
185	04-Jul	10,152	0.2796	36,307	36,307
186	05-Jul	10,728	0.2814	38,124	38,124
187	06-Jul	9,292	0.2753	33,752	33,752
188	07-Jul	9,771	0.2774	35,224	35,224
189	08-Jul	8,630	0.2800	30,821	30,821
190	09-Jul	10,201	0.2919	34,947	34,947
191	10-Jul	7,977	0.3046	26,188	26,188
192	11-Jul	10,599	0.2971	35,675	24,307
193	12-Jul	11,767	0.3036	38,758	13,940
194	13-Jul	14,602	0.3086	47,317	47,317
195	14-Jul	13,388	0.3032	44,156	20,245
196	15-Jul	6,647	0.3003	22,135	6,570
197	16-Jul	7,377	0.3028	24,363	6,304
198	17-Jul	9,383	0.3024	31,028	10,971
199	18-Jul	14,053	0.3072	45,602	14,043
200	19-Jul	22,525	0.3039	74,120	27,485
201	20-Jul	15,842	0.3167	50,022	45,027
202	21-Jul	13,009	0.3282	39,043	24,970
203	22-Jul	10,397	0.3366	30,888	18,841
204	23-Jul	10,904	0.3445	31,652	18,018
205	24-Jul	8,914	0.3510	25,396	13,019
206	25-Jul	13,880	0.3597	38,588	17,169
207	26-Jul	9,877	0.3630	27,209	14,566
208	27-Jul	12,155	0.3670	33,120	18,714
209	28-Jul	11,230	0.3693	30,409	17,661
210	29-Jul	8,911	0.3695	24,116	11,962
211	30-Jul	6,420	0.3758	17,084	12,417
212	31-Jul	5,904	0.3769	15,665	7,224
213	01-Aug	7,449	0.3794	19,634	10,588
214	02-Aug	7,320	0.3837	19,077	6,348
215	03-Aug	5,220	0.3869	13,492	4,329
216	04-Aug	5,367	0.3917	13,702	7,002
217	05-Aug	6,553	0.3956	16,565	16,565
218	06-Aug	5,794	0.4002	15,970	6,893
219	07-Aug	5,072	0.4037	12,564	7,071
220	08-Aug	5,741	0.4041	14,207	9,103
221	09-Aug	8,728	0.4210	20,732	17,032
222	10-Aug	8,374	0.4188	19,995	19,995
223	11-Aug	5,640	0.4203	13,419	10,777
224	12-Aug	6,441	0.4218	15,270	8,141
225	13-Aug	7,433	0.4223	17,601	10,078
226	14-Aug	5,215	0.4200	12,417	5,776
Totals		473,609		1,472,460	1,051,937

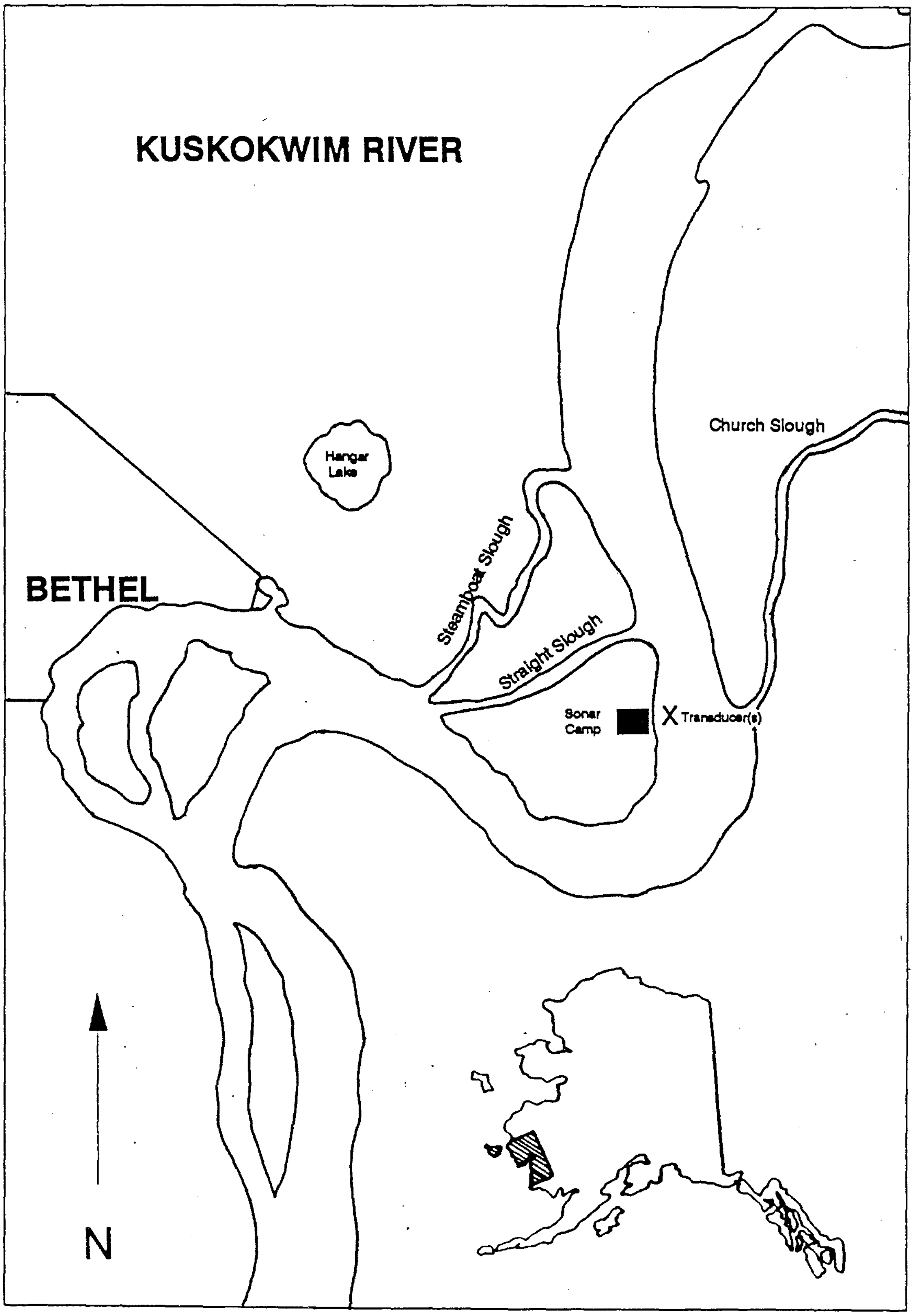


Figure 1. Map of the Kuskokwim River showing location of the 1989 and 1990 sonar site.

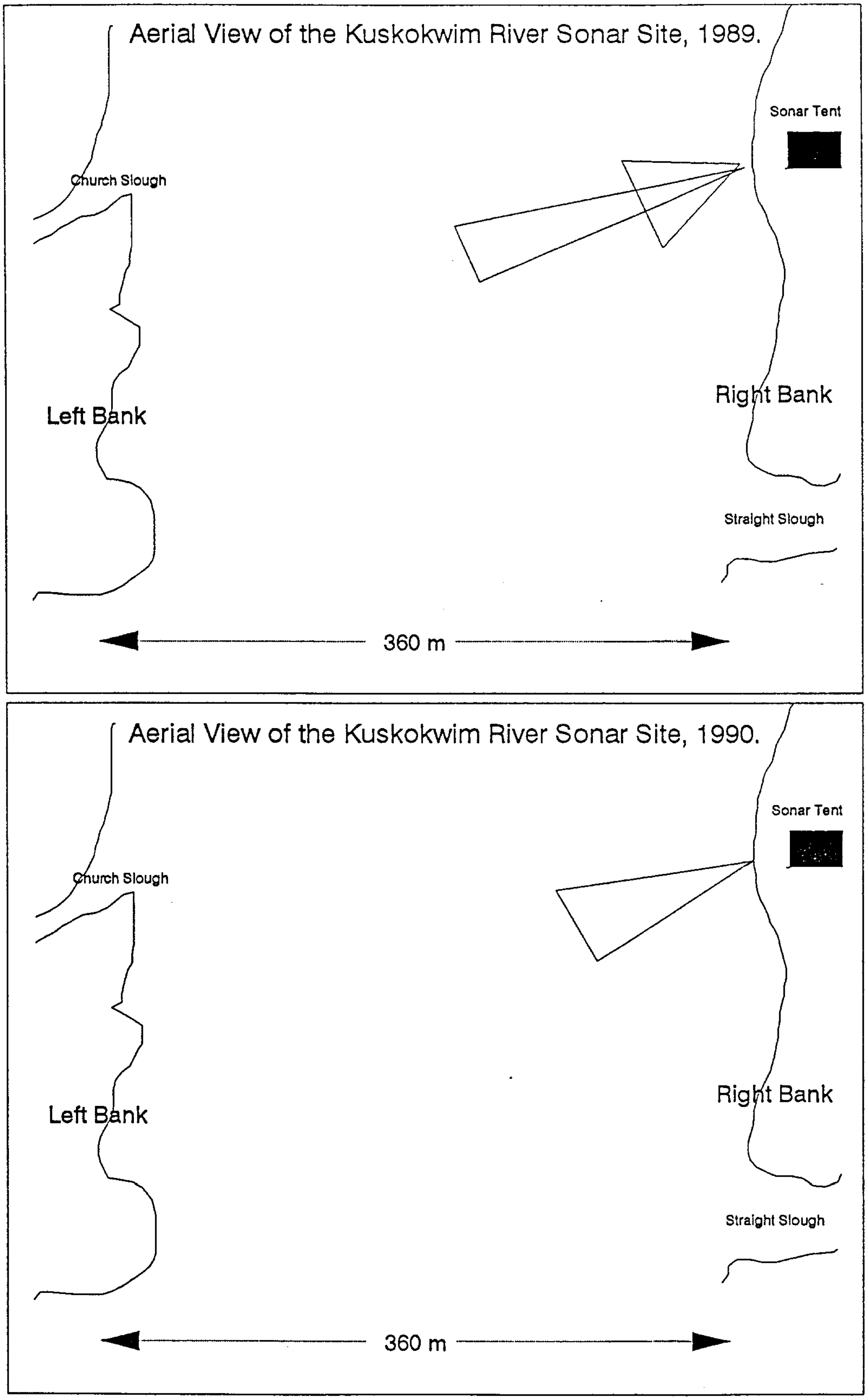
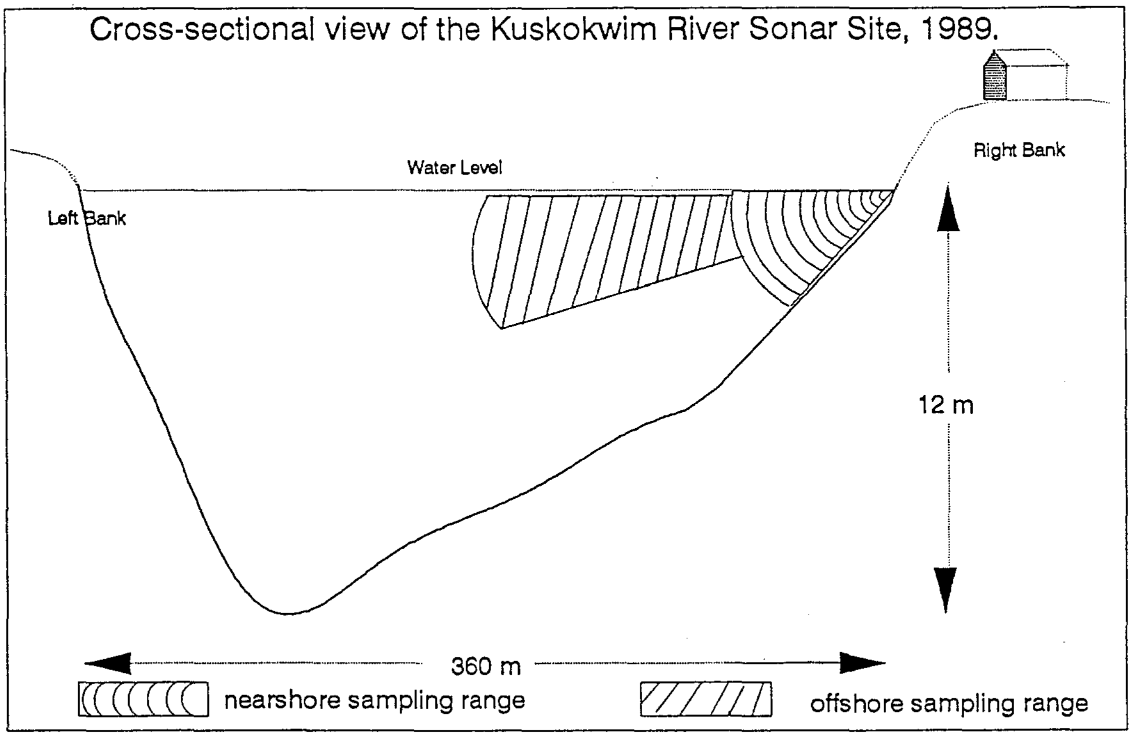


Figure 2. Aerial view of the Kuskokwim River sonar site in 1989 and 1990.



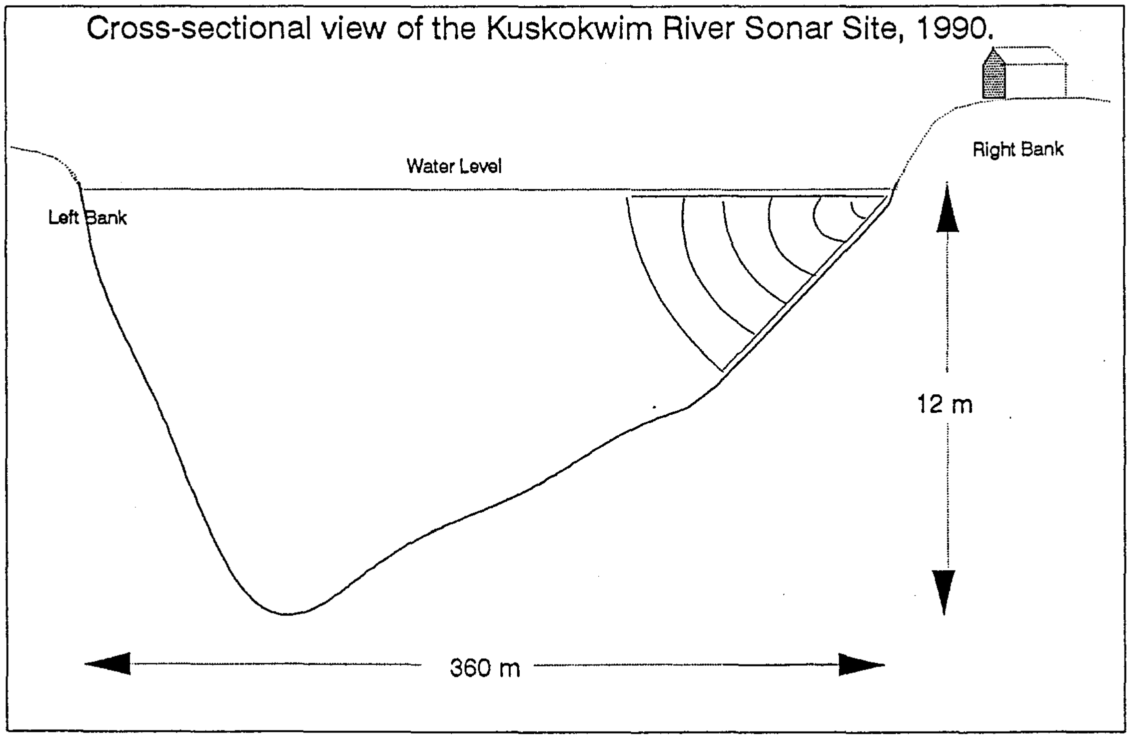


Figure 3. Depth profile of the Kuskokwim River sonar site, 1989 and 1990.

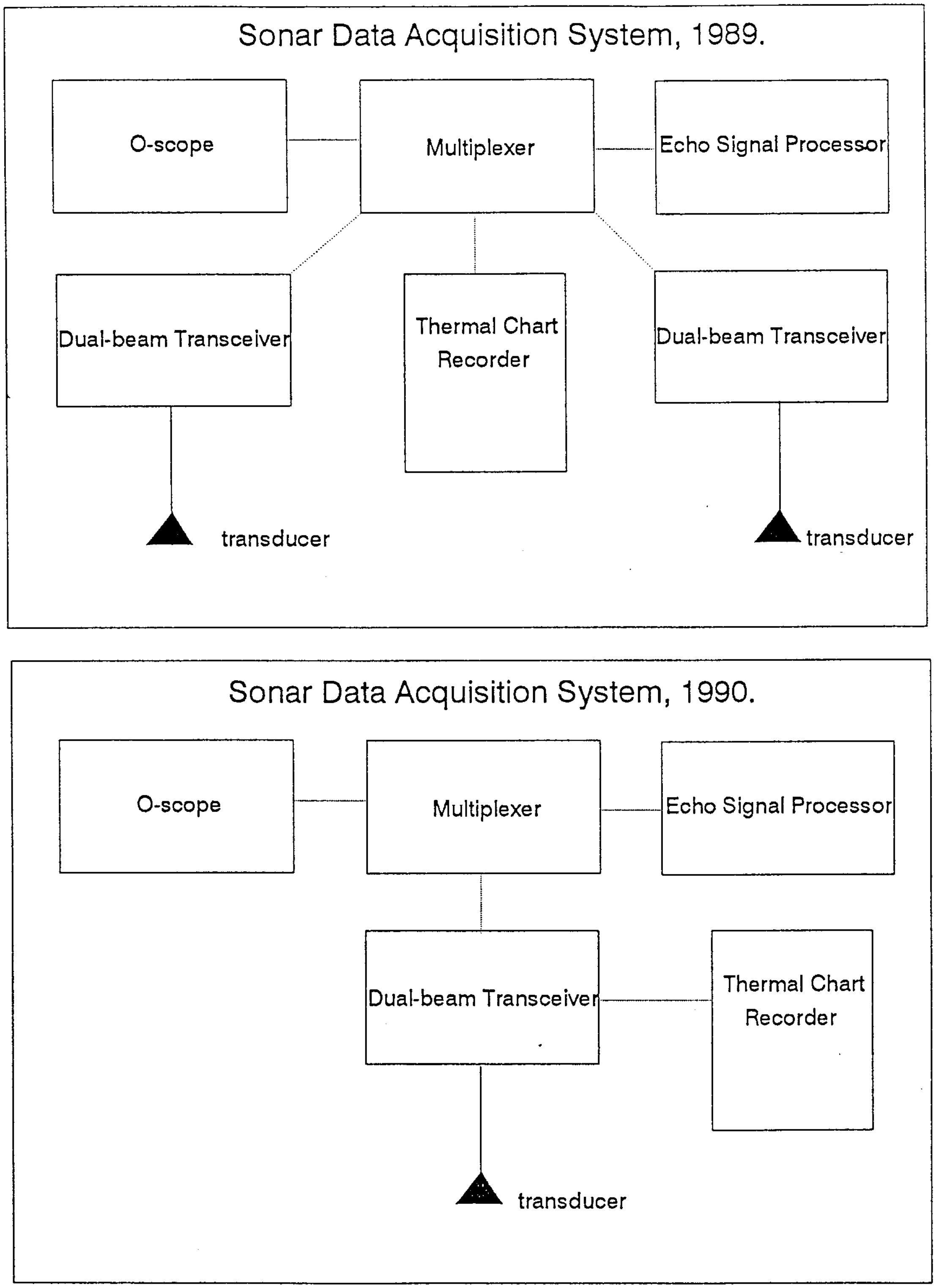


Figure 4. Kuskokwim River sonar data acquisition system, 1989 and 1990.

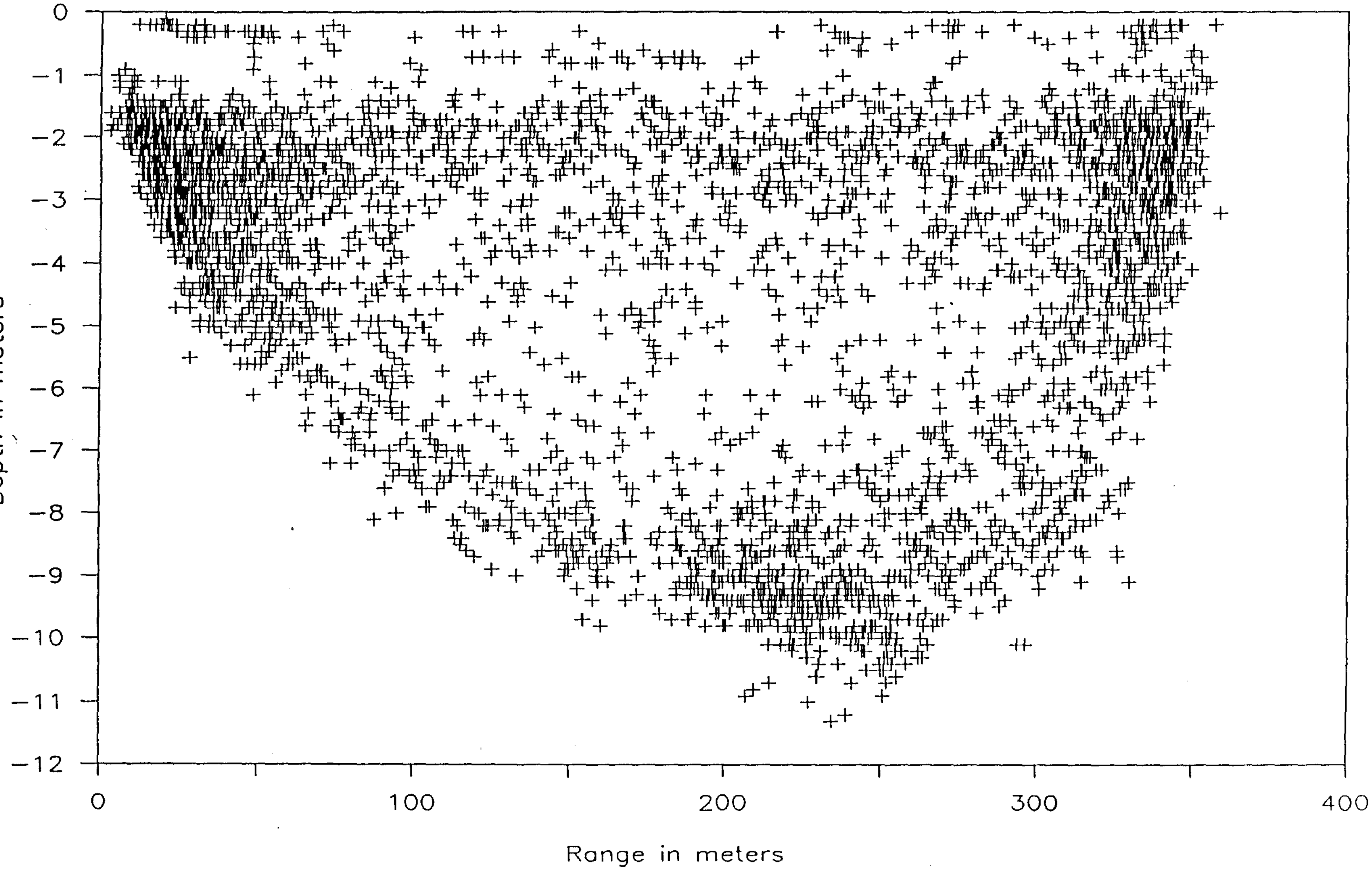


Figure 5. Unadjusted spatial distribution of targets detected by the Lowrance X-15 fathometer in the Kuskokwim River between 02 June and 14 August, 1990.

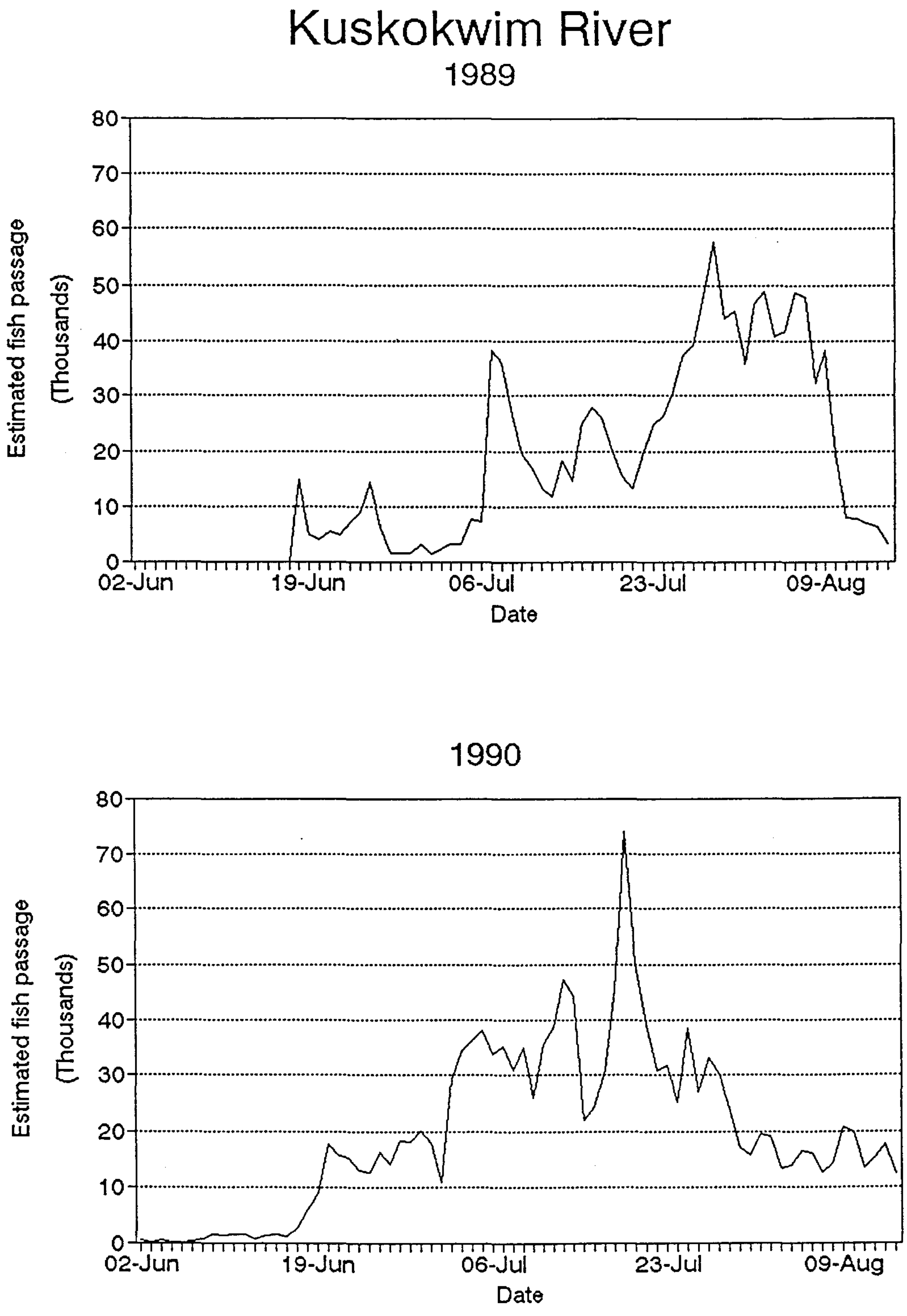


Figure 6. Sonar-estimated daily fish passage in the Kuskokwim River between 10 June and 14 August, 1989, and between 02 June and 11 August, 1990.

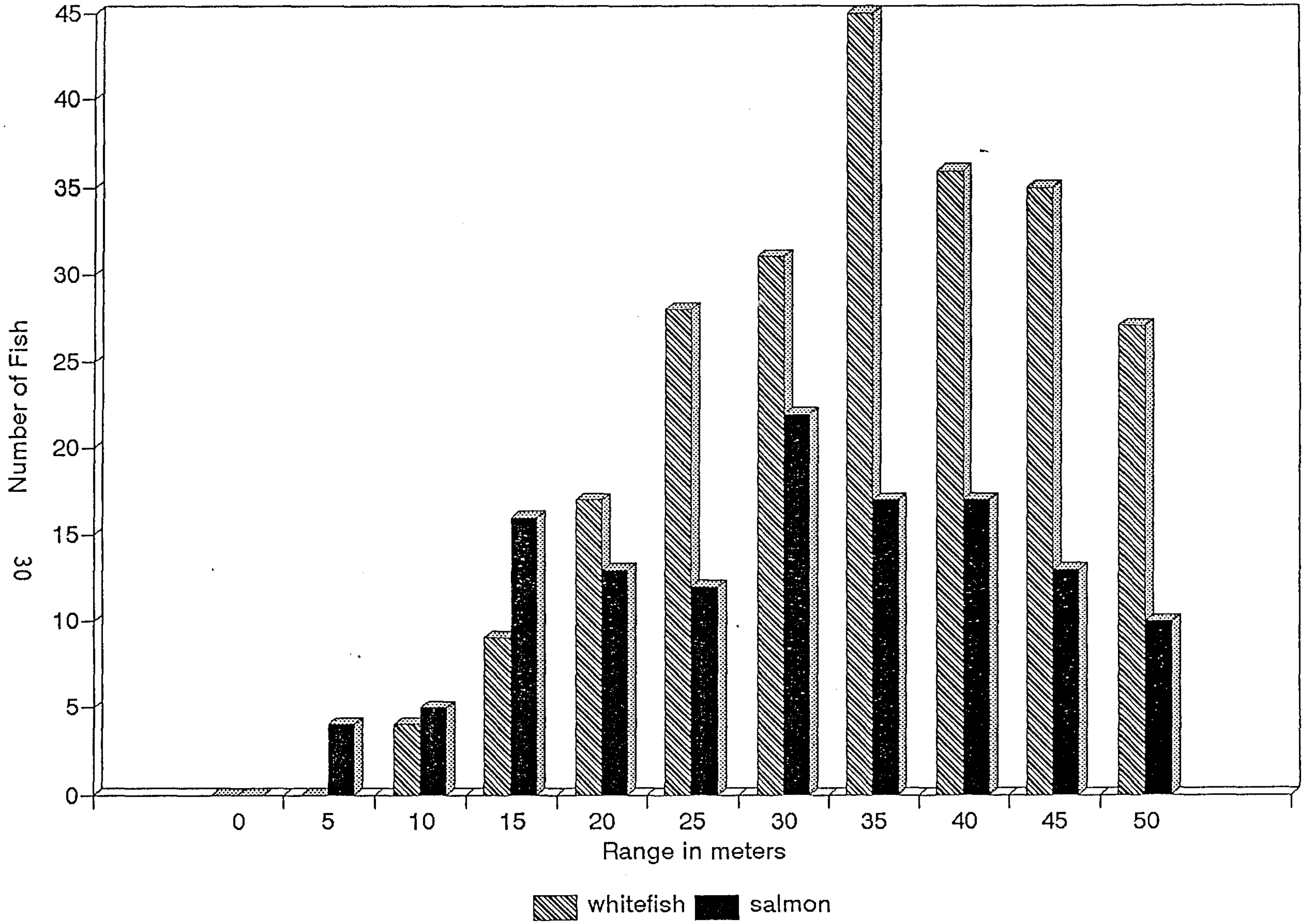


Figure 7. Catches of whitefish and salmon by five meter range increments from 6.4 and 14 cm mesh set gill nets fished at the Kuskokwim River sonar site in 1990.

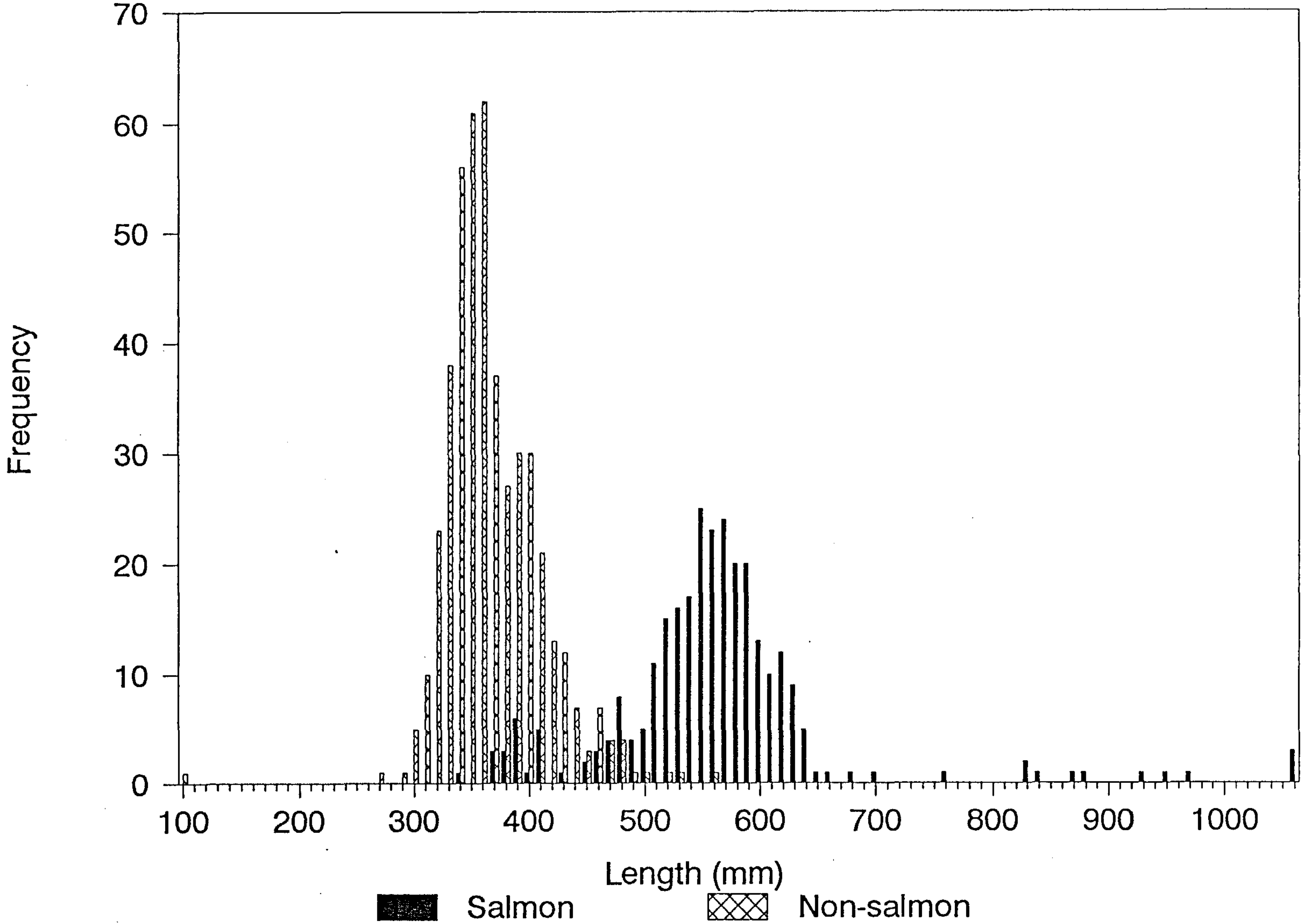


Figure 8. Length frequency distribution of salmon and other species caught in 6.4 and 14 cm mesh gill nets at the Kuskokwim river sonar site in 1990.

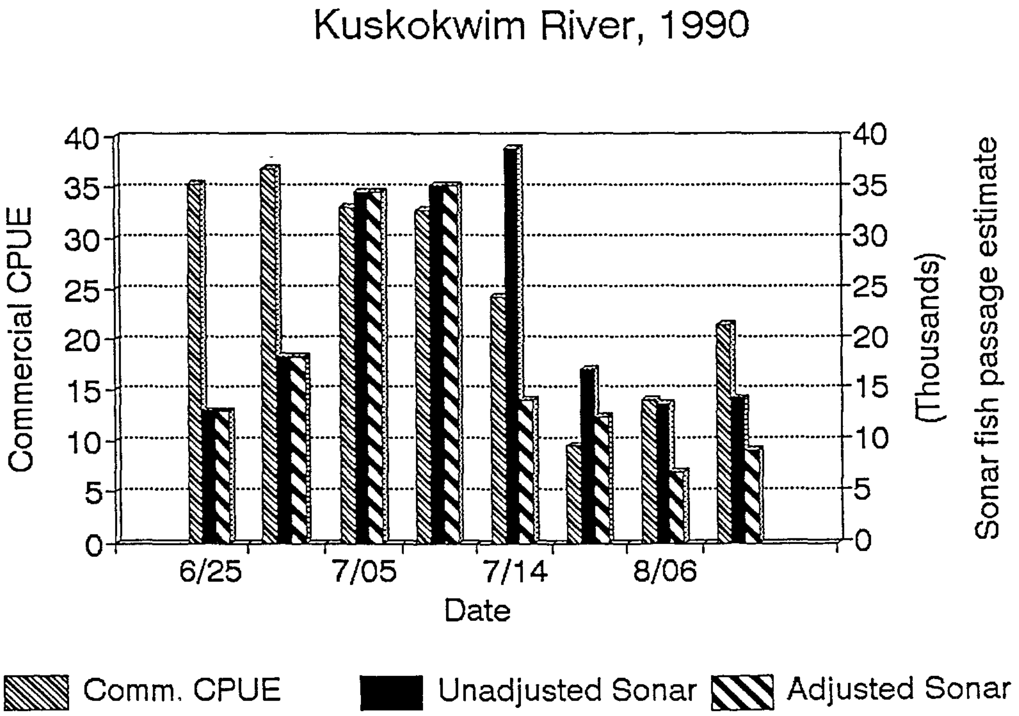


Figure 9. Kuskokwim River commercial fishery CPUE from statistical areas 335-13 and 335-14, and sonar-estimated fish passage (unadjusted and adjusted to remove whitefish) two days prior to the commercial fishery opening, 1990.

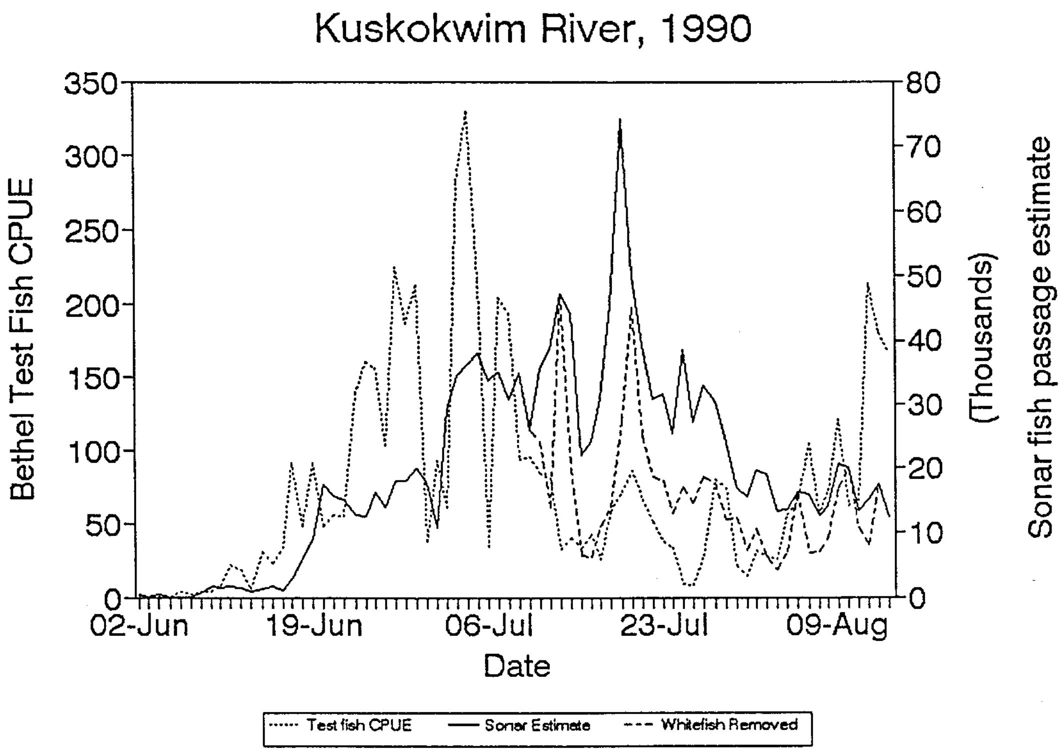


Figure 10. Bethel test fishery CPUE and sonar fish passage estimates (unadjusted and adjusted to remove whitefish) over time, Kuskokwim River, 1990.

APPENDIX

APPENDIX A: KDIG.C DIGITIZING PROGRAM

```
/***************************************************************************
kdig.c    :  (Kuskokwim digitizing) excepts input in the form of an
             ASCII BCD  stream.  This version is written to receive a
             26 byte stream produced by a Summagrapic  Microgrid.  The
             stream is converted into X and Y coordinates.
answrok   :  toggle for user input error-checking routine
answr     :  user input y or n

***************************************************************************/

#include<stdio.h>
#include"constant.h"

main()
{
     int answrok = 0;
     char answr;

     void header();
     void button_value();
     void data_acquire();
     void fish_location();

     header();

     while(!(answrok))
     {

        printf("\nDo you want to map fish location within the river cross-\n");
        printf("sectional area ? (Y or N):");
        scanf("%1s",&answr);

        if(((answr == 'Y') || (answr == 'y')) || ((answr =='N') ||
             (answr == 'n')))
             answrok = 1;
        else
             printf("\n\n*****ERROR*****  Try again .....");
     }

     if(answr == 'Y' || answr == 'y')
     {
        button_value();
        data_acquire();
     }
}
```

(continued)

```
/*************************************************************************
constant.h : This file contains the defined constants accessed by the
           functions of kdig.c  If you want to change the value of any
           constant or add a new constant, simply:
             1.  change the value in this file
             2.  recompile all functions with: cl /AL /c *.c
             3.  relink all functions with : link /NOE *.obj
*************************************************************************/
#define MAXCOL            3
#define MAXROW          150
#define MAXFILE          26
#define MAXWIDTH        800
#define MAXDEPTH         25
#define YELLOW_BUTTON     1
#define WHITE_BUTTON      2
#define BLUE_BUTTON       3
#define GREEN_BUTTON      4
#define X_POSITION        1
#define Y_POSITION        2
#define FLAG_POSITION     3

extern float fish[][MAXCOL];



/***********************************************************************
 function header    :  a list of directions for configuring the digitizing
                      table.

           c      :  carriage return expected from user
***********************************************************************/

#include<stdio.h>

void header()

{

     char c;

     printf(" C O N F I G U R E   D I G I T I Z I N G   T A B L E \n\n");

     printf(" 1) Turn on the digitizer\n");
     printf(" 2) Plug digitizer cable into micro RS-232 port\n");
     printf(" 3) Put a map on the digitizing table\n");
     printf(" ---Strike Carriage Return when ready ---\n");
```

(continued)

```
   fflush(stdin);     /* clear keyboard buffer */
     if((c=getchar()) == '\n')
     return;
}




/**********************************************************************
function button_value  : This function provides and introduction to the user.

            c    : carriage return expected from the user.
**********************************************************************/

#include<stdio.h>

void button_value()

{
     char c, answr;

     printf("\nThis option will allow you to map fish spatial distribution");
     printf("\nfrom a bank-to-bank chart recording produced by a Lowrance X15");
     printf("\nfathometer. The program scales each individual chart recording");
     printf("\nusing the actual width and depth of the river.  Each fish trace");
     printf("\nis  given  coordinates  using  this  scale.   The  left  bank
represents");
     printf("\nthe (0,0) position.  All measurements are calculated from this");
     printf("\nposition.");

     printf("\n\nThe following is a list of the colored buttons on the puck
and\n");
     printf("their values :\n\n");
     printf("WHITE represents the left bank.\n");
     printf("GREEN represents the right bank.\n");
     printf("Only one point must be entered for each bank. \n");
     printf("The YELLOW key will be used to record fish location.\n");
     printf("BLUE is the river bottom (at the deepest point).  This point MUST
be\n");
     printf("entered last to signal the end of the transect data and insure
proper\n");
     printf("calculation of the data. If an error occurs the transect will not
be\n");
```

(continued)

```
     printf("recorded.\n");
     printf("---Strike Carriage return when ready---\n");

     fflush(stdin);  /* clear keyboard buffer */

     if((c=getchar()) == '\n')
     {
        return;
     }
}


/*************************************************************************
function data_acq     : This function acts as an interface between the data
                   acquisition function bitdat and the data processing
                   functions load_farry and fish_location

answr                 : user input y or n
answrok               : toggle for user input error-checking routine
count                 : indicates array row
depth                 : actual river depth
depthok               : toggle for user input error-checking routine
fileok                : toggle for user input error-checking routine
f_flag                : flag signaling button used to record point
fp1                   : file pointer
OUTfile               : output file name
key                   : user input signal for exit program
riverw                : actual river width
widthok               : toggle for user input error-checking routine
X_fish                : x coordinate for input point
Y_fish                : y coordinate for input point

**************************************************************************/

#include<stdio.h>
#include<bios.h>
#include"constant.h"

extern void fortran bitdat();
extern void load_farry();
extern void fish_location();


data_acquire()
{

     FILE *fopen(), *fp1;
     int X_fish, Y_fish,key,answrok,fileok,widthok,depthok,count;
     int riverw,depth;
```

(continued)

```
    char OUTfile[MAXFILE],answr;
     float x_fish,y_fish,f_flag;

     count = 0;
     answrok = 0;
     fileok = 0;
     widthok = 0;
     depthok = 0;

     fflush(stdin);

     while(!(answrok))       /*  open file for output   */
     {
        printf("\nDo you want the output written to a file ? (Y or N) : ");
        scanf("%1s",&answr);

        if ((( answr == 'Y') || (answr == 'y')) || ((answr == 'N' )||
             (answr == 'n')))
             answrok = 1;
        else
             printf("\n\n*****ERROR***** Try again.....");
     }

     if (answr == 'Y' || answr == 'y')
     {

        while(!(fileok))   /* error checking to determine if file exists  */
        {
             printf("\nEnter filename for output :");
             scanf("%s",OUTfile);

             if((fp1=fopen(OUTfile,"r")) == NULL)
               fileok = 1;
             else
             {
                close(fp1);
                printf("\n*****ERROR***** File exists.....");
             }
        }



        fileok = 0;

        while(!(fileok))
        {
            if((fp1 = fopen(OUTfile,"w")) == NULL)
               printf("\n****ERROR****  Try again.....");
            else
            {
```

(continued)

```
                fileok = 1;
            }
        }

    }

    widthok = 0;

    while(!(widthok))        /*   user inputs river width    */
    {
       printf("\nEnter the river width in meters: ");
       scanf("%d",&riverw);

       if((riverw <=0) || (riverw > MAXWIDTH))
       {
           printf("\n*****ERROR***** Try again.....");
           widthok = 0;
       }
       else
           widthok = 1;
    }

    depthok = 0;

    while(!(depthok))        /*   user inputs river depth     */
    {

       printf("\nEnter the river depth in meters: ");
       scanf("%d",&depth);

       if((depth <=0) || (depth > MAXDEPTH))
       {

            printf("\n****ERROR**** Try again.....");
            depthok = 0;
       }
       else
            depthok = 1;
    }

    printf("\nConnecting to serial port 1. Type 'q' to exit\n");
    printf("\nPress a key on the mouse to input a point, Hit q on\n");
    printf("on the computer to quit.\n");

/*   A infinite loop for data collection is entered until the user enters a Q or
*/
/*   q from the keyboard.     */
```

(continued)

```
     while(1)
     {

          if(_bios_keybrd(_KEYBRD_READY))
        {

/* check for quit signal (q) from the keyboard   */

             key = _bios_keybrd(_KEYBRD_READ) & 0xff;
             if ((key =='q') || (key =='Q'))
             {
                  printf("\nExiting...\n");
              exit(0);
            }

        }
        count++;   /*   count each point entered through bitdat   */

        bitdat(&x_fish,&y_fish,&f_flag);
/*          printf("\nfirst bitdat %f %f %f",x_fish,y_fish,f_flag);*/

        if(f_flag != BLUE_BUTTON)  /*  check for end of transect signal */
        {
            printf("\nloop one");
            load_farry(&x_fish,&y_fish,&f_flag,&count);
        }
        else
        {
            printf("\nloop two");
            load_farry(&x_fish,&y_fish,&f_flag,&count);
            fish_location(fp1,&count,&riverw,&depth,&answr);
            count=0;
            printf("\n Press any key on the mouse to continue data entry.\n");
        }
    }
     close(fp1);
}
```

(continued)

```
/***************************************************************************
function fish_location  : This function calculates the X and Y coordinates of
                    each point using the scaled width and depth of the
                    river.
answr                   : user input y or n
count                   : indicates array row
depth                   : actual river depth
fp1                     : output file pointer
greencount              : number of occurances of the green button
no_error                : toggle for error code
riverw                  : actual river width
Scale_Depth             : scaled river depth
Scale_Width             : scaled river width
transectok              : toggle indicating on errors in transect
whitecount              : number of occurance of the white button
x                       : loop counter
Xblue                   : x coordinate for blue button
Xgreen                  : x coordinate for green button
Xwhite                  : x coordinate for white button
X_fish                  : calculated x coordinate for fish
Yblue                   : y coordinate for blue button
Ygreen                  : y coordinate for green button
Ywhite                  : y coordinate for white button
Y_fish                  : calculated y coordinate for fish

***************************************************************************/

#include<stdio.h>
#include<math.h>
#include"constant.h"

void fortran beep();

fish_location(fp1,count,riverw,depth,answr)

FILE *fp1;
char *answr;
int *count,*riverw ,*depth;
{

     int transectok,no_error,whitecount,greencount,x;
     float Xwhite,Ywhite,Xblue,Yblue,Xgreen,Ygreen,Scale_Width;
     float Scale_Depth,X_fish,Y_fish;


     transectok = 0;
     whitecount = 0;


/*  check for coordinates corresponding to the white button  */
```

(continued)

```
     {
        if(fish[x][FLAG_POSITION] == WHITE_BUTTON)
        {
             whitecount++; /* count occurrences of white button */
             Xwhite = fish[x][X_POSITION];
             printf("\n xwhite %f",Xwhite);
             Ywhite = fish[x][Y_POSITION];
             printf("\n ywhite %f",Ywhite);
        }
     }
     greencount = 0;

/* check for coordinates corresponding to the green button  */

     for(x=1;x<=*count;x++)
     {
        if(fish[x][FLAG_POSITION] == GREEN_BUTTON)
        {
             greencount++;  /*   count occurrences of green button  */
             Xgreen = fish[x][X_POSITION];
             printf("\n xgreen %f",Xgreen);
             Ygreen = fish[x][Y_POSITION];
             printf("\n ygreen %f",Ygreen);
        }
     }

     Xblue = fish[*count][X_POSITION];
     printf("\n xblue %f",Xblue);
     Yblue = fish[*count][Y_POSITION];
     printf("\n ybule %f",Yblue);

/* make sure white and green buttons only occur once  */

     if((whitecount != 1) || (greencount != 1))
        transectok = 1;

     no_error = 0;

/* if no errors in white or green coordinates process the rest of the  */
/* points                                                               */

     if(!(transectok))
     {

/* calculate scaled width and depth of the river  */
        if(Xwhite < Xgreen)
             Scale_Width = (((float)*riverw)/(Xgreen - Xwhite));
        else
             Scale_Width = (((float)*riverw)/(Xwhite - Xgreen));
```

(continued)

```
        printf("\nrvrwdth %d",*riverw);
        printf("\n scale_width %f", Scale_Width);
        Scale_Depth = (((float)*depth)/(Yblue - Ywhite));
        printf("\n scale_depth %f", Scale_Depth);

        printf("\n\nCoordinates for each fish");
        printf("\n   Range in      Depth in");
        printf("\n    meters        meters");

        for(x=1;x<=*count;x++)
        {

/* calculate coordiantes for points corresponding to yellow button */

             if(fish[x][FLAG_POSITION] ==  YELLOW_BUTTON)
             {    if(Xwhite < Xgreen)
                    X_fish = (fish[x][X_POSITION] - Xwhite)*Scale_Width;
                else
                    X_fish = (Xwhite - fish[x][X_POSITION])*Scale_Width;
                Y_fish = (Ywhite - fish[x][Y_POSITION])*Scale_Depth;
                printf("\n      %3.1f            %3.1f",X_fish,Y_fish);

             /*   print to file   */

                if((*answr == 'Y') || (*answr == 'y'))
                  printf("\n************");
                   fprintf(fp1,"\n%3.1f %3.1f",X_fish,Y_fish);
             }
        }
        no_error = 1;
        fprintf(fp1,"\n");
     }
     else


        if(!(no_error))     /*   error message    */
        {
             beep();
             printf("\n****ERROR**** Enter transect again !!!\n");
             beep();
        }
}
```

(contined)

```
      SUBROUTINE BITDAT(X_FISH,Y_FISH,F_FLAG)

       INTEGER*2 A(26),IPORT,IFCT,IUART
       INTEGER I
       CHARACTER*1 C(26)
       REAL X_FISH, Y_FISH, F_FLAG

       OPEN(20,FILE = 'TMPWRK.SPC')

       DO 10 I=1,23
           A(I)=0
 10    CONTINUE

       IPORT=1
       IFCT=0

       I=IUART(IPORT,IFCT)

       IFCT=1

       DO 20 I=1,23
            A(I)=IUART(IPORT,IFCT)
 20    CONTINUE

       DO 30 I=1,23
            IF (A(I).GT.127) A(I)=A(I)-128
 30    CONTINUE

c       WRITE(*,*)(A(I),I=1,23)

       DO 60 I=1,23
            C(I)=CHAR(A(I))
 60    CONTINUE
       WRITE(*,*)(C(I),I=2,19)
C       DO 70 I=1,26
C            A(I)=ICHAR(C(I))
c 70    CONTINUE

       WRITE(20,*)(C(I),I=2,19)

       REWIND(20)

       READ(20,80)X_FISH,Y_FISH,F_FLAG
 80    FORMAT(F7.3,2X,F7.3,1X,F2.0
 300   CONTINUE
       CLOSE(20,STATUS='DELETE')
       RETURN
       END
```

(continue)

APPENDIX B: Kuskokwim River sonar test fishing results, 1990

Date	Mesh (cm)	Minutes Fished	Chinook Catch	Coho Catch	Sockeye Catch	Pink Catch	Chum Catch	Whitefish Catch	Other Catch
16-Jun	14	65	0	0	0	0	0	0	0
17-Jun	14	43	1	0	0	0	0	0	0
18-Jun	14	60	0	0	0	0	0	0	0
19-Jun	14	65	3	0	0	0	0	0	0
20-Jun	14	75	0	0	0	0	0	0	0
21-Jun	14	60	1	0	0	0	0	0	0
22-Jun	14	65	2	0	0	0	0	0	0
23-Jun	14	70	0	0	2	0	0	0	0
24-Jun	6.4	95	1	0	0	0	2	0	0
24-Jun	14	40	2	0	3	0	1	0	0
26-Jun	14	65	5	0	0	0	2	0	0
27-Jun	14	65	2	0	0	0	0	0	0
28-Jun	14	65	0	0	2	0	0	0	0
28-Jun	14	60	0	0	0	0	0	0	0
29-Jun	14	60	0	0	2	0	0	0	0
30-Jun	14	60	0	0	3	0	0	0	0
01-Jul	14	135	0	0	4	0	1	1	0
01-Jul	14	60	0	0	2	0	2	0	0
02-Jul	14	75	0	0	3	0	1	0	0
02-Jul	14	75	0	0	0	0	3	0	0
03-Jul	14	55	0	0	11	0	0	0	0
05-Jul	14	57	0	0	1	0	3	0	0
06-Jul	14	70	0	0	0	0	1	0	0
07-Jul	14	65	2	0	2	0	11	0	0
07-Jul	14	65	0	0	1	0	1	0	0
08-Jul	14	91	3	0	4	0	23	0	0
09-Jul	6.4	65	0	0	0	1	0	0	0
10-Jul	6.4	60	0	0	0	0	0	0	0
10-Jul	14	65	0	0	0	0	1	0	0
10-Jul	14	65	1	0	1	1	15	0	0
11-Jul	14	60	0	0	0	0	2	0	0
11-Jul	14	60	0	0	0	0	1	0	0
11-Jul	6.4	60	0	0	0	0	2	8	0
11-Jul	6.4	60	1	0	1	0	0	0	0
13-Jul	14	30	0	0	0	0	1	0	0
13-Jul	6.4	20	0	0	0	0	2	0	1
14-Jul	14	30	0	0	0	0	1	0	0
14-Jul	6.4	30	0	0	0	0	1	7	0
15-Jul	6.4	60	0	0	0	0	0	9	0
15-Jul	6.4	45	0	0	0	0	0	0	0
15-Jul	6.4	60	0	0	0	0	0	3	0
15-Jul	6.4	30	0	0	0	0	0	3	0
15-Jul	6.4	35	0	0	0	0	0	2	0
15-Jul	6.4	45	0	0	0	0	0	1	0
15-Jul	6.4	35	0	0	0	0	0	0	0
16-Jul	14	60	0	0	0	0	0	0	0
16-Jul	6.4	75	0	0	0	0	1	3	0
17-Jul	6.4	80	0	0	0	0	0	8	0
18-Jul	6.4	60	0	0	0	0	0	0	0
18-Jul	14	60	0	0	0	0	0	0	0
18-Jul	6.4	60	0	0	0	0	1	1	0
19-Jul	6.4	15	1	0	0	0	0	51	1
20-Jul	14	60	0	0	0	0	3	0	0
20-Jul	6.4	20	0	0	0	4	0	8	1
21-Jul	6.4	20	0	0	0	2	15	18	0
21-Jul	14	60	0	1	0	0	0	0	0
23-Jul	6.4	15	0	0	0	2	1	18	1
23-Jul	6.4	15	0	0	0	0	1	11	0
23-Jul	6.4	15	0	0	0	0	1	2	0
23-Jul	6.4	15	0	0	0	0	8	3	0
23-Jul	14	60	0	0	0	0	0	0	0
25-Jul	6.4	15	0	0	0	0	0	14	0
25-Jul	14	45	0	1	0	0	0	0	0
25-Jul	6.4	15	0	0	0	0	0	15	0
26-Jul	6.4	15	0	1	0	0	0	21	0
26-Jul	14	65	0	1	0	1	2	2	0
26-Jul	6.4	15	0	0	0	1	0	13	0
27-Jul	6.4	60	0	0	0	0	0	7	0
28-Jul	14	60	0	3	0	0	0	1	0
28-Jul	6.4	30	0	0	0	0	0	8	0
28-Jul	6.4	15	0	0	0	0	0	7	0
29-Jul	14	60	0	2	0	0	0	0	0
29-Jul	6.4	30	0	0	0	0	0	4	0
29-Jul	6.4	15	0	0	0	0	0	0	0
30-Jul	6.4	60	0	9	0	4	10	33	2
30-Jul	14	60	0	3	0	3	15	1	0
31-Jul	6.4	15	0	0	0	0	0	2	0
31-Jul	14	15	0	0	0	0	2	1	0
01-Aug	14	13	0	0	0	2	0	0	0
01-Aug	6.4	15	0	1	0	1	0	9	0
02-Aug	6.4	15	0	0	0	0	1	31	1
02-Aug	14	15	0	1	0	0	1	0	0
03-Aug	14	15	0	0	0	0	0	0	0
03-Aug	6.4	15	0	0	0	0	0	13	0
04-Aug	6.4	15	0	0	0	0	0	13	0
04-Aug	14	15	0	1	0	0	3	0	0
05-Aug	14	15	0	0	0	0	3	0	0
05-Aug	6.4	15	0	0	0	0	0	0	0
06-Aug	6.4	15	0	1	0	2	4	20	0
07-Aug	14	15	0	1	1	1	7	8	0
07-Aug	6.4	15	0	0	0	0	0	15	0
08-Aug	14	15	0	0	0	0	0	0	0
08-Aug	6.4	15	0	1	0	0	0	4	0
09-Aug	6.4	15	0	0	0	0	0	3	0
09-Aug	14	15	0	0	0	0	0	2	0
10-Aug	6.4	15	0	1	0	0	0	0	0
10-Aug	14	15	0	0	0	1	0	0	0
11-Aug	14	15	0	0	0	0	0	0	0
11-Aug	6.4	15	0	1	0	1	0	1	0
12-Aug	14	15	0	0	0	0	0	0	0
12-Aug	6.4	15	0	0	0	0	0	1	0
Totals		4299	25	29	43	27	158	400	7