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KUSKOKWIM RIVER SONAR PROGRESS REPORT, 1991

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

A project to determine the feasibility of using dual-beam sonar to estimate Kuskokwim River salmon passage near Bethel in western Alaska began in 1988 and continued through 1990. By mid-July 1990 daily passage estimates were calculated. These estimates were considered preliminary and not used for fishery management. In 1991 the project was operational from 2 June through 13 August. Daily passage estimates were calculated using fish spatial distribution information obtained from bank-to-bank transects and fish counts obtained with side-looking sonar. The passage estimates were apportioned to species using drift gillnet test fishing data collected with a suite of mesh sizes. These estimates were provided to commercial fishery managers to be incorporated in the decision-making process. An attempt to separate whitefish from salmon through analysis of dual-beam data was unsuccessful due to the confounding effects of uncompensated attenuation of 420 kHz sound in freshwater. Length frequency information collected from gillnets showed a bi-modal length distribution of whitefish that was substantially smaller than the lower end of the length distribution of all salmon species except pink salmon.

KEY WORDS: salmon, sonar, hydroacoustic, escapement, Kuskokwim.

INTRODUCTION

Kuskokwim River salmon stocks are harvested for both commercial and subsistence use. Exploitation occurs throughout 1,498 km of river with the most intensive commercial fishery located within 218 km of the river mouth. Management of the fishery resource requires estimates of migratory timing, run strength and escapement. The deep silty water of the Kuskokwim River precludes visual observation of migrating chinook *(Oncorhynchus tshawytscha)*, sockeye *(O. keta)*, coho *(O. kisutch)*, chum *(O. keta)*, and pink *(O. gorbuscha)* salmon. Management decisions have historically been based on commercial fishery performance data, on relative abundance data obtained from gillnet test fisheries, and on escapement indices obtained in upriver spawning tributaries. The need for 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 conducive to the use of sonar equipment was identified, camp facilities were constructed, and transducers were deployed on both banks. Fish spatial distribution was examined through sampling of a bank-to-bank transect using a downward-looking non-scientific fish finding fathometer. The data revealed distribution of fish throughout the water column with highest concentrations near the shores and the surface. The feasibility of estimating fish passage was established through temporal and spatial expansion of shore-based side-looking sonar samples and subsequent favorable correlation with other indices of fish abundance. Details of the 1988 research may be found in Hyer et.al. (1990).

Hydroacoustic sampling continued in 1989 and 1990 using procedures established in 1988 (Mesiar et. al. 1994). Equipment problems encountered in 1988 were resolved in 1989 and data collection procedures were streamlined. By July 1990 daily passage estimates were calculated. These estimates were considered preliminary and not used as a basis for management decisions. Continued collection of fish spatial distribution data in 1990 corroborated earlier observations of cross-river fish distribution (Hyer et. al. 1990, Mesiar et. al. 1994). Gillnet catches further indicated that a large proportion of the nearshore fish passage was comprised of whitefish.

The primary goal of the 1991 field season was to provide daily and seasonal estimates of fish passage for inseason use by fishery managers. Other objectives included collection of dual-beam data to investigate the potential of estimating the species composition of fish migrating past the sonar site through statistical analysis of target strength estimates, and using information collected from test nets to describe the size distribution of whitefish and cisco.

METHODS

Sonar Data Acquisition

Site Description

The sonar site is located on the Kuskokwim River at river km 130 (Figure 1). This site was selected in 1988 after conducting extensive surveys of the lower river for physical characteristics favorable to counting fish with sonar. It is on the main river channel, has a V-shaped bottom profile, minimal tidal influence, is close to Bethel and is near a subdistrict boundary in the lower river commercial fishery. At this point the river is approximately 360 m wide with a maximum depth of 12 m (Figure 2). The right bank is sandy near shore grading to mud approximately 5 m offshore while the left bank is more steeply sloped, with a muddy bottom. The bottom profile is nearly linear outward from both banks. Water flow is affected by daily tidal fluctuations and occasional flow reversal. The site is circumvented by three sloughs but fish passage in these shallow sloughs is believed to be negligible.

Equipment

Sonar equipment used to collect data at the site included a Biosonics[1] model 101 dual-beam transceiver, Biosonics model 151 multiplexer, Biosonics model 281 echo signal processor (ESP) card installed in a Compaq Deskpro 386 personal computer, Nicolet model 310 digital storage oscilloscope (DSO) and Biosonics model 111 thermal chart recorder (Figure 3). Initially we deployed a Biosonics 6^0 x 15^0 circular dual-beam transducer to sample from 2 m to 100 m on the right bank. This transducer was replaced with an International Transducer Corporation (ITC) 3^0 x 10^0, 7^0 x 21^0 elliptical dual-beam transducer on 9 June. The sampling range was not altered. To further optimize the area ensonified the 6^0 x 15^0 transducer was redeployed on 22 June with a limited sampling range (2 m- 40 m). The ITC transducer continued sampling 40 m-100 m. Each transducer was attached to a tripod mounted Remote Ocean Systems (ROS) model PT-25 pan and tilt unit. The ROS model PTC-1 pan and tilt control unit permitted aiming to approximately 0.3 degrees precision. Both tripods were positioned side by side approximately 2 m offshore and the transducers were aimed to maximize detection of fish passing within the respective ensonification ranges. The echo sounder was configured to transmit at 420 kHz with a pulse duration of 0.4 ms. The pulse repetition frequency (PRF) on the nearshore transducer was initially set to 5.5 pings per sec. This rate was increased to 15 pings per sec on 29 June. The offshore area was sampled at PRF of 5.5 pings per sec. throughout the period of data collection.

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[1] Use of product names in this text are for archival purposes only and do not constitute endorsement by the Alaska Department of Fish and Game.

Sampling Procedure

The sonar system collected data 24 hours per day, seven days per week, with approximately one 15 minute break every eight hours for generator maintenance and refueling. Otherwise, data collection was only interrupted for equipment repair, acoustic standard target data collection, or when dropping river levels forced us to move the tripods and re-aim the transducers. Each day was divided into three 8 hour shifts (0800-1600, 1600-0000, 0000-0800). Each shift was further broken down into 32, 15 min. samples. A single fisheries technician operated the equipment and recorded observations relevant to the sampling environment and system performance during each operating shift in the on-site project log book.

The entire system was controlled by the multiplexer which was programmed with the appropriate PRF and sample sequence for each transducer. Sampling began at the top of the hour and continued in 15 minute intervals. When two transducers were employed, sampling alternated between the transducers on an hourly basis. At the beginning of each sampling interval the technicians recorded the water level and current direction of the river. Fish traces from the previous 15 min. sample were then tallied in 20 m range increments. This information was recorded on field data collection forms and ultimately entered onto electronic format.

Fish Passage Estimation

Daily estimates of fish passage were calculated for 2 June through 13 August. Down-looking acoustic fish distribution data established the proportion of fish migrating within the range of the side-looking transducers. This information was used to expand fish counts from the side-looking sonar to calculate daily passage estimates. The daily passage estimates were apportioned to species using catch data from a suite of gillnets drifted at the sonar site.

Fish Distribution

Information on fish spatial distribution was collected by sampling bank-to-bank transects with a Lowrance X15 fathometer and downward-looking transducer. Transects were run bank-to-bank in a straight line approximately 15 m downstream from the side-looking transducers. Originally the transects were conducted 12 times daily; six samples each were collected at 1100 and 1700 hours. Starting 26 June an additional six transects were conducted at 0500. Sample times remained constant so that all tide stages were sampled over the duration of the project. Each transect provided a chart recording of the water column from 2 m below the transducer face to the river bottom. Detected fish were identified and circled on the chart recording for further processing.

Chart recording transect data were standardized to a common scale to correct for irregularities incurred during sampling due to varying river conditions and boat speed. This was accomplished with a digitizing pad and software written specifically for this purpose (Appendix A.1). Each chart was scaled to the actual river width (360 m) and maximum river depth (12 m). The program assigned paired x,y coordinates to each fish trace based on range and depth. These paired coordinates were then written to a file on a microcomputer hard drive.

Sonar Counts

The total number of fish passing within the range of the side-looking transducer was calculated each day. Initially, when continuously sampling with one transducer, missed sample values were estimated as the mean of the individual sample values before and after the missed sample. Counts were then divided into near shore (0 m- 40 m) and offshore (40 m- 100 m) strata and a daily total for each was calculated. Once the second transducer was added, counts were expanded temporally for each stratum (nearshore, offshore). First, the proportion of the day sampled in each stratum was calculated by dividing the number of samples collected per stratum by 96 (total 15 minute samples possible in 24 hours). Next, sonar count estimates were calculated by dividing the total count for each stratum by the portion of the day sampled in that stratum.

Data Processing

Daily passage estimates were calculated using an internally developed software application (Appendix A.2) created in a commercial statistical package. This program first adjusted the downward-looking sonar counts for the differential probability of detection as a function of depth due to geometric beam spreading. To adjust for the increased probability of fish detection that occurred with increasing sample depth, each individual target was expanded by C:

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

where: r is the maximum depth
r_t is the depth of the target

Next each fish trace was classified by range from the right bank and placed into one of three categories: the area sampled by the onshore transducer (0 m- 40 m), the area sampled by the offshore transducer (40 m- 100 m) and the area not sampled by the side looking sonar (100 m- 360 m). To ensure that the transect data were sufficient to estimate in-the-beam to out-of-the-beam ratios, down-looking data for three or more consecutive days were pooled into report periods.

Expansion factors were calculated for each report period as follows:

$$E_i = \frac{T_{si} + T_{bi}}{T_{si}}$$

where: E_i = Expansion factor for report period i.
T_{si} = Number of targets offshore (40 m-100 m) for report period i.
T_{bi} = Number of targets beyond the beam (100 m- 360 m) for report period i.

Offshore fish counts from the side-looking sonar were multiplied by the expansion factor to generate estimates of fish passage between 40 m and 360 meters. This was added to the nearshore (0 m- 40 m) count from the side-looking sonar to produce an estimate for the entire river. Down looking detections from 0 m- 40 m were not included in the expansion process. Targets detected from 0 m- 40 m in range are extremely sensitive to depth compensation because all nearshore detections are shallow. In addition, setnets revealed the presence of non-target resident species at 0 m- 40 m that may or may not be migratory. Non-migratory nearshore fish would have had a greater probability of repeated detection because of their longer resident time in the sampling area.

Test Fishing and Species Apportionment

This was the first year data from the Bethel test fishery (BTF) was used to apportion sonar fish passage estimates to species. To accommodate the needs of the species apportionment program the test fishery was expanded to improve the project's effectiveness on a wider range of fish sizes. All modifications and additions were incorporated in such a way as not to affect data collection for the traditional Bethel test fishery. This was necessary to insure Bethel test fish CPUE comparability with past years. Methods for the traditional Bethel test fishing project are described separately from methods used exclusively for species apportionment.

1991 Bethel Test Fishery

The methods and location used in the 1991 Bethel test fishery were similar to those used since 1984 (Molyneaux 1994). Following each high tide a series of gillnet drifts was conducted in the Kuskokwim River near Bethel. The drifts were performed by one of two alternating two-person crews using a 6.1 m (20 ft) skiff and 90 m (50 fathom) gillnets. Each series of drifts began one hour after the published high slack tide for Bethel which insured that all drifts were conducted in water flowing downstream. Drifts began approximately 5 km (3.5 mi) upstream of Bethel, where Straight Slough diverges from the main channel (Figure 1). Each drift was conducted at one of three stations across the width of the main channel. The duration of each drift was approximately 20 minutes and the mean fishing time was calculated as half the time it took to both deploy and retrieve the net, plus the time the net was fully deployed. The river distance traversed by each drift varied depending on water and channel conditions but the distance was generally less than 3 km (2 mi). To avoid conflict with commercial fishermen no drifts were conducted during commercial fishing periods.

Drifting began on 2 June and continued through the morning tide on 31 August. Through 10 July two different mesh sizes were used in the test fishery; the first two drifts of each tide were conducted with 20.3 cm (8 in) stretched mesh gillnets and the second two drifts were performed with 13.6 cm (5-3/8 in) stretched mesh. Different mesh sizes were used to accommodate the size specific selectivity of the larger mesh for larger chinook salmon and the smaller mesh for smaller chinook and other species of salmon. For each tidal drift series, one of six unique permutations from a repeating random fishing schedule was used to determine which mesh size would be fished at each station (Table 3). The result was that no station was fished with the same mesh size twice during a single tide. However, this design dictates that one station was fished twice during each tide, first with 20.3 cm gear then with 13.6 cm gear, while the other two stations were fished only once, one station with the 20.3 cm gear and the remaining station with the 13.6 cm mesh. Which station was missed by which mesh size varied with the random fishing schedule. This incomplete sampling was caused by fiscal constraints on the original experimental design but was consistent with past years.

Gillnet specifications were as follows: The 20.3 cm and 13.6 cm mesh gillnets were 50 fathoms in length and approximately 6.7 and 5.8 m deep, respectively. The webbing was manufactured by Nagura Net Company and hung at a 2:1 ratio. The 20.3 cm mesh webbing had 225d #24 twine, 35 meshes deep by 100 fathoms, with a color code of NG80 (light green). The 13.6 cm webbing was 225d #18 twine, 45 meshes deep by 100 fathoms, with a color code of NG45 (light green).

By 15 July the chinook salmon migration in the lower Kuskokwim River was essentially over so use of the larger 20.3 cm mesh nets was discontinued for the remainder of the season. Until 1990 four drifts continued to be conducted over the three stations each tide even though only the 13.6 cm mesh gillnet was in use after 15 July. The random fishing schedule was used to determine the drift sequence, which station would receive a replicate drift, and was an attempt to collect data which would allow variance estimation. Results of the duplicated drifts were then averaged. However, the duplicated fourth drift was shown to be unnecessary (Molyneaux 1994). The practice was discontinued in 1990 in favor of fishing each of the three stations once using a modified fishing schedule (Table 3).

The catch for each drift was tallied by species and by station. Fish lengths, measured from mid-eye to fork of tail, were collected for use in the species apportionment program. Weather conditions, water temperature and water clarity data were also recorded during the first drift of each tide. At the end of each tidal series of drifts the catch was sold to a local processor or donated to individuals desiring the fish for personal use. The data was recorded in the office log and entered into the species apportionment computer program.

Additional Species Apportionment Drifts

The information used to apportion the sonar estimates included all data from the Bethel test fish project plus data from four additional gillnet drifts conducted immediately after each Bethel test fish drift series. The first two species apportionment drifts were conducted with a 10.2 cm (4.0 in) mesh gillnet (100 fathoms of web, 70 meshes deep, twine type MT50, shade SH3, double knotted, Momoi Fishing Net Manufacture, Ltd.). The second pair of drifts were made with a 16.5 cm (6.5 in) mesh gillnet (100 fathoms of web, 45 meshes deep, twine type MT50, shade SH3, double knotted, Momoi Fishing Net Manufacture, Ltd.). The web used in each gillnet was hung at a 2:1 ratio for a total length of 50 fathoms. The drifts were performed in the same location as the Bethel test fish project and the same field methods were employed.

Drifting began on 2 June and continued through the 13 August when the sonar project ceased operations for the season. A fishing schedule similar to that used in the Bethel test fish project was used to determine which mesh size would be fished at each station (Table 3).

The catch for each drift was tallied by species and station. Fish lengths, measured from mid-eye to fork of tail, were also recorded. The catch was sold to a local processor or used for personal consumption. The data was recorded in the office log and entered into the species apportionment computer program.

Analytical Methods

The analytical procedures described here follow those of the lower Yukon River sonar project (Fleischman et al 1992), with two exceptions: gillnets of different mesh sizes were used, and test-fish data were pooled into longer temporal strata ("report periods"). Kuskokwim River report periods were at least three days long, and were extended if necessary to include data from at least 20 captured fish. Yukon River sonar project report periods were one day long in duration.

Species proportions were derived from test fishing data based on relative catch-per-unit-effort (CPUE). Under this technique it is assumed that catches of each species are proportional to their relative abundance. However, gillnets are size-selective, i.e., they capture efficiently only those fish within relatively narrow size ranges (Fleischman et al op.cit.). Moreover, capture efficiency is variable within those ranges. Therefore we required estimates of net selectivity, to account for unequal capture probability, before we could estimate species proportions from gillnet data.

Gill-Net Selectivity.

Three methods were used to estimate net selectivity: (1) the McCombie and Fry method (1960) for chinook and chum salmon, (2) the Holt method (Peterson 1966) for coho, pink salmon and whitefish (*Coregonus nasus* and *C. pidchian*), and (3) the method described by Kawamura (1972) for sockeye salmon. Methods 1 and 2 are both based on comparing numbers of fish caught in different mesh sizes, within length classes. Method 1 utilizes data from many mesh sizes and makes no assumptions about curve shape. Method 2, which assumes that selectivity curves are shaped like normal probability curves with equal variances, was used when there were inadequate numbers of mesh sizes to use method 1. Method 2 selectivity curves were truncated for extreme length classes which deviated from the data and did not appear to conform to the assumption of normality. Method 1 and 2 curves were estimated from five years (1986-1990) of Yukon River sonar test-fishing data, including more than 30,000 fish captured (gilled, wedged, or tangled) in six mesh sizes and classified into 20 mm length classes. Method 3 estimates relative capture probabilities from empirical length-girth relationships. Data for sockeye were from 1984 Bristol Bay catches of sockeye salmon in four different mesh sizes (Bue 1986). Resulting curves are shown in (Figure 7).

Species Proportions and Passage Estimates.
Relative CPUE, adjusted for net selectivity, was used to estimate both the nearshore and offshore species proportions for each report period. Both nearshore and offshore adjusted CPUE (defined below) were calculated by 20 mm length class, then length class CPUE's were summed for each species in each stratum. Summed CPUE for a given species in a stratum, divided by the total CPUE for all species in the stratum, was used as the estimated proportion of that species in the stratum.

Adjusted CPUE for a given length class was calculated as adjusted catch, divided by effort (fathom-hours) spent catching that length class (Figure 8). Heights and ranges of selectivity curves governed how both catch and effort were calculated. Catches of fish in a given length class were first adjusted for unequal probability of capture by dividing by the height of the selectivity curve (specific to species and net) for that length value. Effort expended in catching fish of a given length class was calculated by summing fathom-hours for all nets which captured those fish with known probability, i.e., nets for which the selectivity curve had been estimated for that length value. Two or three mesh sizes were used to estimate the abundance of each species (Table 4).

Nearshore and offshore estimates of species passage for each report period were obtained by multiplying the stratified fish passage by the estimated species proportions for the respective stratum. Total daily passage by species was calculated by adding the nearshore and offshore estimates of species passage.

Variance Estimation.
Variance of daily species proportions were calculated after Cochran (1977:64), weighting each replicate test-fish sample by total (all species) CPUE.

Spp proportions ($\hat{p}_i$): $$\hat{var}(\hat{p}_i) = \frac{1}{n_2} \sum_{k=1}^{n_2} \left(\frac{m_{ik}}{\overline{m}_i}\right)^2 \frac{(\hat{p}_{ik} - \hat{p}_i)^2}{n_2 - 1}$$

where: $\hat{p}_i$ = estimated proportion of one species (e.g. chinook salmon) out of total fish passage during report period i

n_2 = number of test-fish samples per report period

m_{ik} = test-fishing CPUE during sample period k of report period i

$\overline{m}_i$ = mean test-fishing CPUE during report period i

$\hat{p}_{ik}$ = estimated proportion of one species out of total fish passage during sample period k of report period I

The standard errors for total passage for each species (T_s) were calculated:

$$se(T_s) = \sqrt{\sum\left(N_{od}{}^2V_{osd} + N_{nd}{}^2V_{nsd}\right)}$$

where: N_{od}=Number of offshore counts on day d
V_{sod}=Variance of offshore proportion of species s on day d
N_{nd}=Number of nearshore counts on day d
V_{nsd}=Variance of nearshore proportion of species s on day d

We developed an application in a commercial statistical software package (Appendix A3) to calculate passage estimates and their variances. A commercial data base program was used for data entry, storage, and retrieval. The species apportionment software used in 1991 has since been modified. The effects of the modifications are marginal and statistically insignificant, therefore the data has not been reprocessed. The changes to the species apportionment software would not have resulted in a change to any management decision.

Set-Net Test Fishing

Two set gillnets were fished on the right bank solely to collect information on whitefish size distribution. The data collected from the setnets were not used to apportion sonar counts to species. One was a 6.4 cm (2.5 in) mesh net, 50 m long and 3 m deep, and the other was a 10.3 cm (4.0 in) mesh net, 45 m long and 3.5 m deep. The nets were fished simultaneously with the 6.4 cm net deployed approximately 9 m downstream from the transducer and the 10.3 cm net set approximately 15 m downstream from the transducer. Both nets were set perpendicular to the shore and fished for 20 to 240 minutes. Fishing took place once daily with the sets beginning during the daylight high slack tide. Captured fish were identified to species and measured mid-eye to fork of tail (salmon species) or snout to fork of tail (other species). Data from the 1991 Bethel salmon test-fishing project (Molyneaux 1994) were also incorporated for size distribution analysis.

Target Strength Estimation

Dual-beam data processing

Dual-beam hardware and software was used to collect data to evaluate the potential of estimating target strengths of detected echoes returned from free-swimming fish in hopes of eventually separating salmon sized targets from smaller resident species. Echoes were accepted based on the following user-defined criteria: Minimum narrow beam voltage threshold (smallest accepted echo was equivalent to -41 dB), minimum and maximum half-power pulse widths (0.360 ms and 0.470 ms), and minimum range (removes data collected in the near-field).

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

Data files were processed with a commercial dual-beam data processing program called Tracker (version 3.15). This software required 33 user input parameters which it used to compute target strength, filter out invalid echoes, and combine valid echoes into logical groups which represent individual tracked fish. To filter out invalid echoes, Tracker first determined whether an individual echo met minimum acceptance criteria based on wide and narrow beam voltage, beam pattern factor, pulse width, and distance from the transducer. Echoes from individual fish were then grouped according to user-defined tracking criteria including; minimum number of pings, maximum change in range between consecutive echoes, and maximum time allowed between consecutive echoes. To ensure that the program was accurately grouping echoes from fish, these three parameters were calibrated through repeated comparison with the associated chart recordings.

Two files were produced by Tracker for each input data file. The .EKO file listed grouped echoes representing individual fish and included statistics for each individual echo such as: range, target strength, wide and narrow beam voltage, wide and narrow beam pulse width and beam pattern factor. The second file, the .FSH file, provided mean values of these statistics for each fish tracked. Ideally, these two files would be used to monitor the target strengths of fish migrating past the sonar throughout the season.

Standard Target

We attempted to adjust the dual-beam processing parameters based on information collected from a tungsten-carbide sphere of known acoustic size (-41 dB). The transducer was aimed to position the target (suspended from a boat) as close to the maximum response axis (MRA) as possible. Echoes from the sphere were collected using the ESP. This information was iteratively processed with Tracker, and the parameters affecting target strength were adjusted at each iteration until the appropriate target strength estimates were achieved. The resulting parameters were to be used to calculate target strengths of tracked fish. Standard target information was collected on 10 separate occasions; four times at ranges between 17 m and 34 m using the Biosonics transducer and six times at ranges between 18 m and 75 m with the ITC transducer.

RESULTS

Sonar Data Acquisition

The project was operational from 2 June through 13 August. Due to equipment limitations all acoustic sampling was restricted to the right bank. During this time 230,194 fish were detected by the side-looking sonar. Data collection was continuous with the exception of one 10 h period between 3 June and 4 June when an equipment failure caused data loss.

ESP data collection began on 8 June and continued through 3 August. Sampling was continuous as long as weather permitted. There were several periods during the season when heavy rain caused the signal to noise ratio (SNR) to decrease below 10 dB. On these occasions, the ESP was shut down and dual-beam data were not collected.

Fish Passage Estimation

Fish distribution sampling using downward-looking sonar equipment began on 2 June and continued through 13 August. A total of 11,250 fish traces were identified on 1,153 transects yielding 34,234 fish when corrected for probability of detection as a function of depth. Transect data indicated 35 percent of the fish migrating past the sonar site were within range of the side-looking sonar. Expansion factors fluctuated between 3.06 and 7.17 with a mean of 4.70 and a s.d. of 1.01 (Table 1). Expansion of the side-looking sonar counts for the unensonified area resulted in a final estimated passage of 796,049 fish (Table 2). Daily fish estimates fluctuated with the peak passage occurring on 25 July and the lowest passage occurring on 3 June (Figure 4). Transect data substantiated earlier observations (Mesiar et. al. 1994) of fish dispersed throughout the water column (Figure 5) with the highest concentrations occurring near the surface (0 - 3 m) and near shore (0 - 40 m).

Test Fishing and Species Apportionment

The project estimated a total passage of 62,297 chinook salmon, 104,335 ± 6,256 sockeye salmon, 333,711 ± 7,621 chum salmon, 129,491 ±3,093 coho salmon, 5,863 ± 994 pink salmon, 158,523 ± 8,383 whitefish and 1,829 ± 376 other fish between 2 June and 13 August. Chinook salmon were comprised of 48,900 ± 2,500 fish greater than 630 mm in length and 13,397 ± 1,068 "jacks" shorter than 630 mm in length.

Setnet test fishing efforts from 5 July through 13 August resulted in 35 sets of the 6.4 cm (stretched) mesh gillnet, and 36 sets using the 10.3 cm (stretched) mesh gillnet (Appendix B.1).

The catch included 813 whitefish and cisco, 20 chum salmon, 3 sockeye salmon, 74 pink salmon and 53 coho salmon. The length frequency distribution (Figure 6) with the incorporated Bethel salmon test-fishery project data (Molyneaux 1994) consists of three major modes which correspond to cisco (310 mm), whitefish (390 mm), and salmon species excluding pink salmon (570 mm). Few pink salmon were sampled, but they appeared to overlap the whitefish distribution between 450 and 460 mm.

Target Strength Estimation

Mesiar et. al. (1994) reported attenuation of 420 kHz sonar signals at levels greater than previously reported in freshwater systems (Francios and Garrison 1982, Urick 1983, MacLennan and Simmonds 1992). They reported that effective sampling range is inversely proportional to water conductivity, causing small fish close to the transducer to reflect signals at intensities equal to those of larger fish at greater distances. Prior to the 1991 field season, we did not fully understand that the effect of uncompensated signal attenuation on beam shape would prevent our ability to accurately assess fish abundance at range. Because it confounds target strength estimation as well, we have chosen not to proceed with analysis of those data.

DISCUSSION

Data collection procedures did not vary greatly from those established in 1990. The most noticeable change was the addition of a second transducer. Problems were initially encountered with the large beam size (6° x 15°) and long sampling range (100 m). At low-tide, noise likely resulting from surface reverberation occurred at ranges between 60 m and 100 m. Because of the width of the beam at these ranges we were unable to change the aim to minimize the noise. Although single-beam information was acquired, the noise severely limited our ability to collect accurate dual-beam information. This prompted us to change to the narrower (3° x 7°) ITC transducer. Although the change alleviated the noise problem a second difficulty was encountered with the river bottom shape. Localized erosion caused some rounding of the river bottom near the right bank at the sonar site. This may have allowed some fish migrating near the river bottom to pass undetected. Therefore, we used the wider beam (6^{0} x 15^{0}) Biosonics transducer to sample near shore (2 m- 40 m) and the ITC transducer to sample offshore (40 m- 100 m).

Visual analysis of transect data over time indicated an increase in fish utilizing mid-river and river bottom areas during 17 June through 1 August. From 2 August - 13 August fish were again most heavily distributed near the surface. We noted increased fish passage within 60 meters of the right bank beginning 1 July continuing through 13 August.

Fish spatial distribution data are affected by several factors, related to both the acquisition equipment and its 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 near-field effect, which causes the first few meters of river depth to be unreadable on the chart recordings. The depth of this effect 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 scattering of fish associated with boat avoidance that probably occurs as the boat traverses the river. Both of these sources of error would tend to cause underestimation of the number of fish near the surface. The effect is likely to have its most pronounced results near shore, where water is shallowest and fish are most likely to scatter when the boat approaches.

Other potential sources of error arise from the fact that the down-looking fathometer we used was not a scientific echo sounder, and we are unsure about certain operating characteristics. The machine operates at 193 kHz, a frequency which is likely to be less affected by attenuation. The time varied gain (TVG) function, however, is unknown as is the exact shape of the beam. We assume a conical beam shape when adjusting detected target numbers. The degree to which effective beam shape diverges from the ideal spherical spreading will influence our ability to accurately adjust for the differential probability of detection with depth. In addition, the sensitivity (gain) adjustment is relative only, and we are not able quantify exact changes in gain associated with changes to the sensitivity setting used. Therefore, we can not verify that both the side and down looking sonar are thresholded to detect identical size classes of targets.

Since fish passage estimates are the product of data from the bank-to-bank transects and the side-looking sonar, they are subject to several known and potential sources of error associated with data acquisition equipment and techniques. Some of these have been discussed. The bank-to-bank transect technique has inherent weaknesses, yet it has been the only feasible way of estimating cross-river fish distribution and offshore fish passage in large rivers. It is unlikely that we will be able to ensonify the entire river in the near future. Therefore we will continue to rely on bank-to-bank transect data and will make every attempt to improve the technique.

The confounding effects of 420 kHz attenuation in fresh water results in uncertainty about the exact reduction in effective beam width and cross-sectional area of the river sampled with a given 420 kHz transducer. Our original calculations were based on the nominal beam widths of the transducers when we quantified the area of the river sampled. Consequently, we actually ensonified a smaller area than we originally assumed. Attenuation also limits our ability to set voltage thresholds to exclude small fish from detection. Since attenuation causes the echo voltage of a target to decrease at a rate greater than simple 2-way range-dependent spherical spreading reduction, a voltage threshold set to exclude small targets near the transducer will exclude progressively larger targets as the distance from the transducer increases. We are thus forced to use very low thresholds, which results in the potential of counting extremely small fish at closer ranges adding to the species apportionment problems.

We anticipate using 120 kHz equipment for the 1992 field season. Conversion of the equipment is expected to solve attenuation-associated problems. We are optimistic about our ability to measure target strength and use that data to eventually apportion fish passage estimates to species using the 120 kHz system.

Test fishing results reconfirmed our observation of a substantial size difference between commercially-targeted salmon species and other species. Pink salmon and whitefish displayed an overlap in length between 350 mm and 460 mm; therefore it is likely that separating acoustic returns from these species will not be possible without the use of gillnets. It is probable that no attempt will be made to assess pink salmon abundance using acoustic data in the Kuskokwim River because they are not a commercially-targeted species.

The distribution and abundance of resident nearshore fish (whitefish and cisco) revealed by set gillnets is an assessment issue whose resolution will impact species apportionment. In 1991, the offshore information collected by the Bethel salmon test fish project was the only data used to apportion sonar counts to species and no nearshore counts were apportioned to resident species. The species composition process will require further modification if the abundance of resident fish caught nearshore is indicative of a difference in the spatial distribution of migratory and resident species.

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Table 1. Kuskokwim River sonar side-looking expansion factors based on the spatial distribution of targets detected in downlooking transects by report period, 1991.[a]

Report Period	Date	Targets Onshore (0-40m)	Targets Offshore (40-100m)	Targets Beyond the Beam (100-360m)	Expansion Factor
1	12-Jun-91	35	138	722	6.22
2	16-Jun-91	86	164	539	4.29
3	19-Jun-91	148	175	396	3.25
4	22-Jun-91	29	105	328	4.11
5	25-Jun-91	85	106	255	3.41
6	28-Jun-91	204	331	1,462	5.41
7	1-Jul-91	222	245	995	5.05
8	4-Jul-91	407	509	1,667	4.27
9	7-Jul-91	438	494	2,096	5.25
10	10-Jul-91	750	690	2,531	4.67
11	13-Jul-91	537	335	949	3.83
12	16-Jul-91	238	271	988	4.65
13	19-Jul-91	142	84	517	7.17
14	22-Jul-91	207	258	915	4.54
15	25-Jul-91	591	600	2,316	4.86
16	28-Jul-91	488	351	1,032	3.94
17	31-Jul-91	161	88	180	3.06
18	3-Aug-91	252	325	1,621	5.98
19	6-Aug-91	199	172	722	5.21
20	9-Aug-91	272	371	1,577	5.25
21	13-Aug-91	358	182	583	4.21
		5,849	5,994	22,391	
				Mean	4.696667
				Standard Deviation	1.008158

[a]All targets are corrected for increased probability of detection as a function of depth.

Table 2. Daily sonar counts and estimated fish passage by species in the Kuskokwim River between 2 June and 13 August 1991.

Report Period	Date	Sonar Counts[a]	Total Chinook Passage[b]	Total Jack Passage[b]	Total Sockey Passage[b]	Total Chum Passage[b]	Total Pink Passage[b]	Total Coho Passage[b]	Whitefish Passage[b]	Other Passage[b]	Total Daily Fish Passage[b]
1	6/2	575	715	118	31	150	0	0	160	0	1,175
1	6/3	264	501	82	22	105	0	0	163	0	874
1	6/4	346	694	114	30	146	0	0	233	0	1,217
1	6/5	429	887	146	39	187	0	0	302	0	1,561
1	6/6	2,073	2,707	445	119	569	0	0	643	0	4,483
1	6/7	2,160	3,030	498	133	637	0	0	778	0	5,076
1	6/8	1,553	2,340	385	103	492	0	0	643	0	3,963
1	6/9	693	691	114	30	145	0	0	104	0	1,084
1	6/10	1,123	1,091	179	48	229	0	0	155	0	1,702
1	6/11	2,512	2,108	347	93	443	0	0	174	0	3,164
1	6/12	2,899	3,515	578	154	739	0	0	760	0	5,747
2	6/13	1,051	99	326	748	882	0	0	639	0	2,694
2	6/14	877	91	298	684	807	0	0	638	0	2,517
2	6/15	708	70	231	530	625	0	0	477	0	1,933
2	6/16	657	75	245	562	664	0	0	566	0	2,112
3	6/17	799	256	206	1,292	246	0	0	0	0	2,000
3	6/18	779	272	219	1,372	261	0	0	0	0	2,124
3	6/19	1,093	411	331	2,076	395	0	0	0	0	3,214
4	6/20	3,037	2,135	888	5,966	2,180	0	0	0	65	11,233
4	6/21	2,268	1,693	704	4,732	1,729	0	0	0	53	8,911
4	6/22	4,346	2,357	981	6,587	2,406	0	0	0	64	12,395
5	6/23	3,096	1,201	359	2,001	4,058	0	0	480	0	8,099
5	6/24	2,957	1,071	320	1,784	3,619	0	0	408	0	7,201
5	6/25	2,773	1,121	335	1,868	3,788	0	0	461	0	7,573
6	6/26	3,273	928	329	2,427	9,894	0	0	659	0	14,237
6	6/27	4,100	952	339	2,492	10,158	0	0	629	0	14,571
6	6/28	5,310	1,179	419	3,087	12,581	0	0	764	0	18,030
7	6/29	5,148	1,324	939	4,408	6,656	0	0	1,668	0	14,995
7	6/30	7,239	1,620	1,148	5,394	8,143	0	0	1,849	0	18,154
7	7/1	7,618	1,337	947	4,457	6,727	0	0	1,194	0	14,662
8	7/2	4,597	773	238	3,885	3,519	88	0	870	19	9,392
8	7/3	4,360	686	211	3,444	3,120	78	0	708	15	8,261
8	7/4	5,375	779	240	3,912	3,543	88	0	710	15	9,286
9	7/5	6,389	838	0	4,689	3,171	0	0	2,771	0	11,470
9	7/6	9,493	1,263	0	7,069	4,781	0	0	4,342	0	17,454
9	7/7	11,570	1,681	0	9,402	6,361	0	0	7,041	0	24,484
10	7/8	11,989	767	0	4,027	9,425	0	0	6,709	57	20,985
10	7/9	12,846	864	0	4,540	10,625	0	0	9,576	82	25,687
10	7/10	11,611	814	0	4,277	10,005	0	0	10,481	89	25,666
11	7/11	10,276	422	0	1,146	10,698	375	0	7,159	78	19,879
11	7/12	10,646	460	0	1,245	11,625	407	0	9,353	102	23,192
11	7/13	6,473	251	0	684	6,373	224	0	3,203	35	10,769
12	7/14	5,423	286	56	151	6,758	141	0	2,230	87	9,708
12	7/15	4,351	251	49	133	5,959	124	0	2,452	96	9,064
12	7/16	3,024	173	33	91	4,088	85	0	1,638	64	6,173
13	7/17	4,812	164	0	234	9,603	0	123	2,250	125	12,499
13	7/18	7,397	272	0	387	15,889	0	204	3,961	220	20,934
13	7/19	4,400	130	0	186	7,643	0	98	1,549	86	9,693
14	7/20	3,577	0	0	44	4,187	281	338	267	0	5,117
14	7/21	6,319	0	0	117	10,991	737	886	1,343	0	14,073
14	7/22	7,294	0	0	103	9,788	657	790	847	0	12,185

-Continued-

Table 2. (Page 2 of 2)

Report Period	Date	Sonar Counts[a]	Total Chinook Passage[b]	Total Jack Passage[b]	Total Sockey Passage[b]	Total Chum Passage[b]	Total Pink Passage[b]	Total Coho Passage[b]	Whitefish Passage[b]	Other Passage[b]	Total Daily Fish Passage[b]
13	7/19	4,400	130	0	186	7,643	0	98	1,549	86	9,693
14	7/20	3,577	0	0	44	4,187	281	338	267	0	5,117
14	7/21	6,319	0	0	117	10,991	737	886	1,343	0	14,073
14	7/22	7,294	0	0	103	9,788	657	790	847	0	12,185
15	7/23	11,883	0	0	189	13,415	0	1,010	3,580	48	18,243
15	7/24	11,396	0	0	193	13,680	0	1,031	4,596	62	19,561
16	7/25	15,836	0	0	332	14,238	300	3,186	14,040	124	32,220
16	7/26	14,278	0	0	279	11,987	253	2,683	10,526	93	25,821
16	7/27	15,744	0	0	307	13,181	279	2,950	11,073	98	27,888
17	7/28	12,453	700	0	0	5,848	608	8,761	5,344	24	21,285
17	7/29	8,820	461	0	0	3,849	400	5,766	3,409	15	13,900
17	7/30	7,579	396	0	0	3,310	344	4,959	2,944	13	11,967
18	7/31	7,200	0	0	0	2,787	127	7,038	1,197	0	11,150
18	8/1	6,336	0	0	0	3,495	159	8,823	1,992	0	14,469
18	8/2	5,280	0	0	0	2,389	109	6,033	1,055	0	9,586
19	8/3	5,167	0	0	0	1,107	0	8,455	712	0	10,274
19	8/4	6,144	0	0	0	1,550	0	11,851	1,218	0	14,619
19	8/5	4,279	0	0	0	903	0	6,900	592	0	8,395
19	8/6	4,197	0	0	0	780	0	5,959	427	0	7,165
19	8/7	5,088	0	0	0	1,033	0	7,895	643	0	9,571
20	8/8	3,072	0	0	0	552	0	5,024	353	0	5,929
20	8/9	3,168	0	0	0	490	0	4,466	252	0	5,208
20	8/10	3,238	0	0	0	446	0	4,060	191	0	4,697
21	8/11	5,034	0	0	0	368	0	7,228	215	0	7,810
21	8/12	6,802	0	0	0	413	0	8,141	147	0	8,701
22	8/13	4,244	0	0	0	79	0	4,831	9	0	4,919
	Totals	391,216	48,900	13,397	104,335	333,711	5,863	129,491	158,523	1,829	796,049
	Cumulative se		2,500	1,068	6,256	7,621	994	3,093	8,383	376	

[a]Adjusted for missed sample time

[b]Expanded for unensonified area using spatial expansion factors

Table 3. The drift schedule used to determine the sequence (#) of stations and the mesh sizes (in) to be fished during each tidal drift series of the Bethel test fishery from 2 June through 15 July (A) and 16 July through 31 August (B).

A:

Schedule Number	Station 1	Station 2	Station 3
1	8.0 (1)		8.0 (2)
		5.4 (3)	5.4 (4)
	6.5 (8)		6.5 (7)
	4.0 (5)	4.0 (6)	
2	8.0 (1)	8.0 (2)	
	5.4 (4)		5.4 (3)
		6.5 (5)	6.5 (6)
	4.0 (7)		4.0 (8)
3		8.0 (1)	8.0 (2)
	5.4 (3)	5.4 (4)	
	6.5 (6)		6.5 (5)
		4.0 (7)	4.0 (8)
4	8.0 (1)	8.0 (2)	
		5.4 (4)	5.4 (3)
	6.5 (8)	6.5 (7)	
	4.0 (5)		4.0 (6)
5		8.0 (1)	8.0 (2)
	5.4 (3)		5.4 (4)
		6.5 (8)	6.5 (7)
	4.0 (6)	4.0 (5)	
6	8.0 (1)		8.0 (2)
	5.4 (4)	5.4 (3)	
	6.5 (7)	6.5 (8)	
		4.0 (6)	4.0 (5)

B:

Schedule Number	Station 1	Station 2	Station 3
1	5.4 (1)	5.4 (2)	5.4 (3)
	6.5 (7)		6.5 (6)
	4.0 (4)	4.0 (5)	
2	5.4 (3)	5.4 (1)	5.4 (2)
		6.5 (4)	6.5 (5)
	4.0 (6)		4.0 (7)
3	5.4 (2)	5.4 (3)	5.4 (1)
	6.5 (5)		6.5 (4)
		4.0 (6)	4.0 (7)
4	5.4 (1)	5.4 (3)	5.4 (2)
	6.5 (7)	6.5 (6)	
	4.0 (4)		4.0 (5)
5	5.4 (2)	5.4 (1)	5.4 (3)
		6.5 (7)	6.5 (6)
	4.0 (5)	4.0 (4)	
6	5.4 (3)	5.4 (2)	5.4 (1)
	6.5 (6)	6.5 (7)	
		4.0 (5)	4.0 (4)

Table 4. Mesh sizes used to apportion Kuskokwim River sonar passage estimates to species and whether the count was adjusted for net selectivity.

SPECIES	GILLNET MESH SIZE				ADJUST?
	4.0	5.4	6.5	8.0	
Chinook	N	Y	Y	Y	Y
Jack Chinook	N	Y	Y	N	Y
Sockeye	N	Y	Y	N	Y
Chum	N	Y	Y	N	Y
Pink	Y	Y	N	N	Y
Whitefish	Y	Y	N	N	Y
Coho	N	Y	Y	N	Y
Other	Y	Y	Y	N	N

Y=yes, N=no

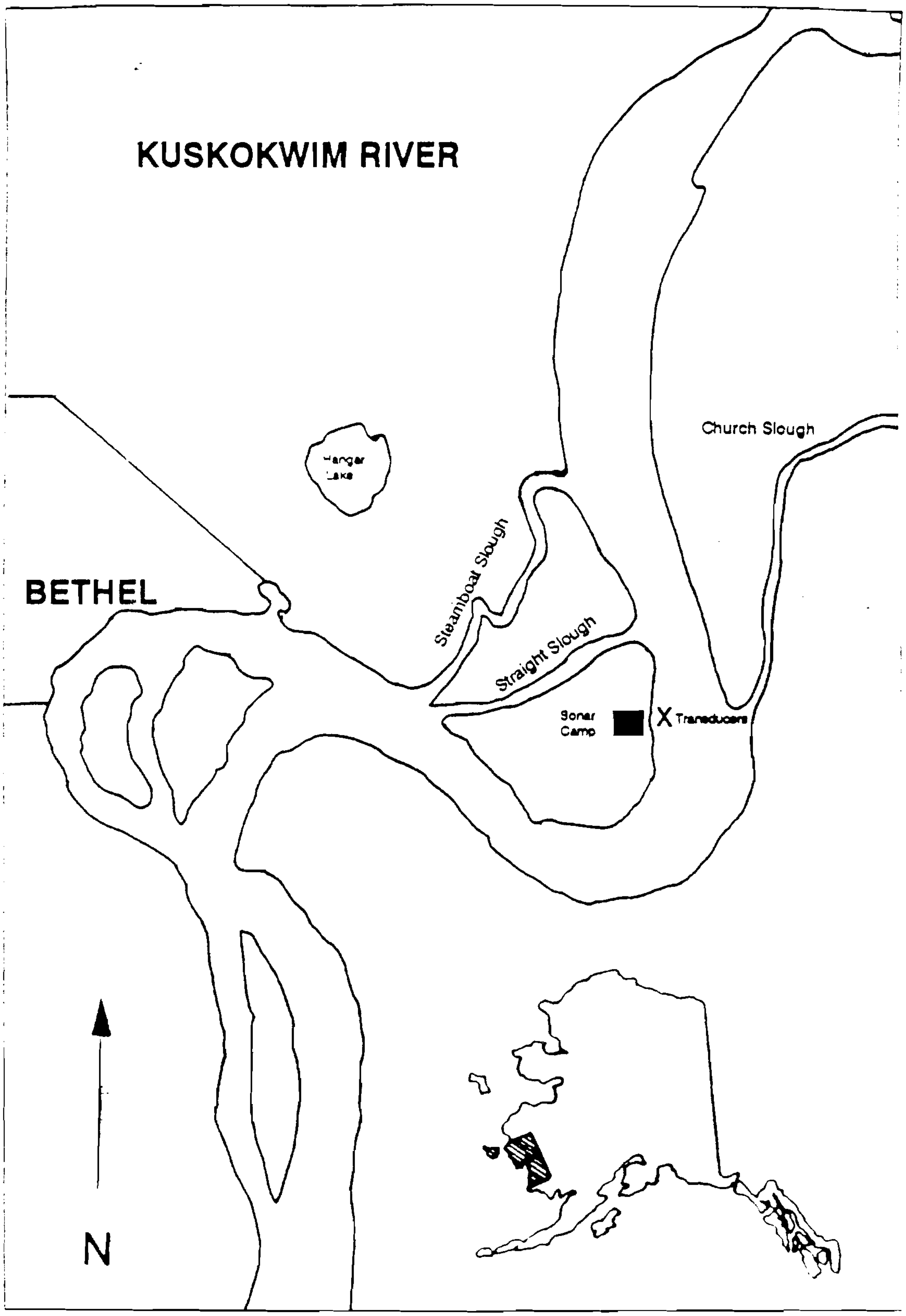
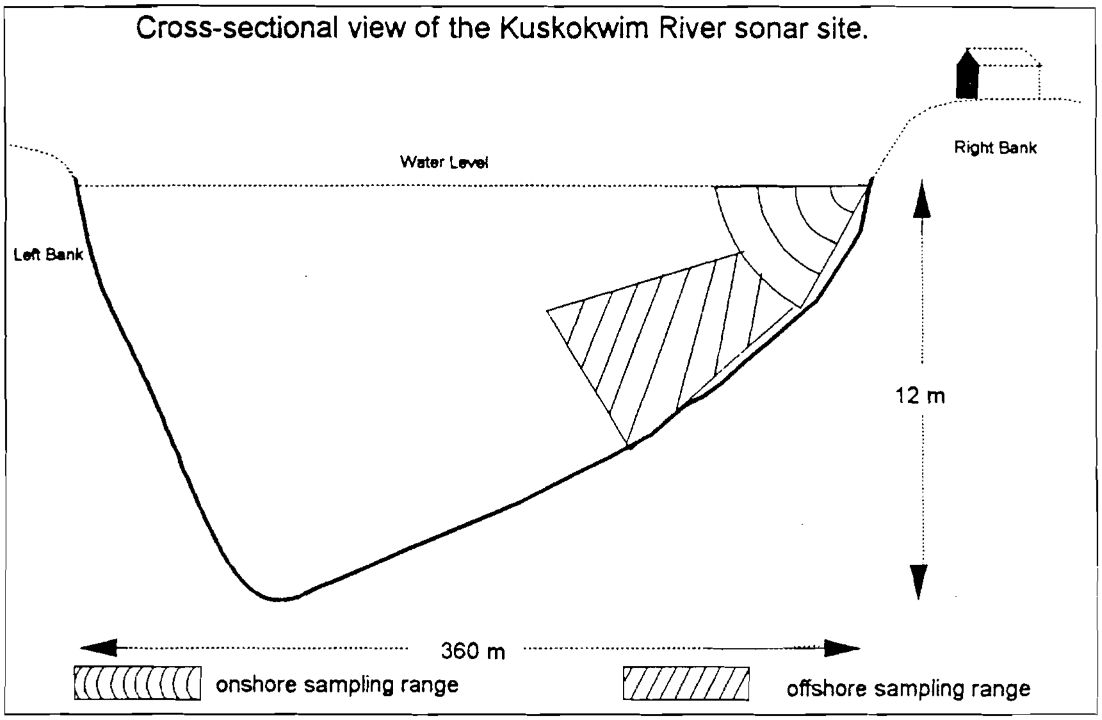


Figure 1. Map of the Kuskokwim River showing location of the 1991 sonar site.



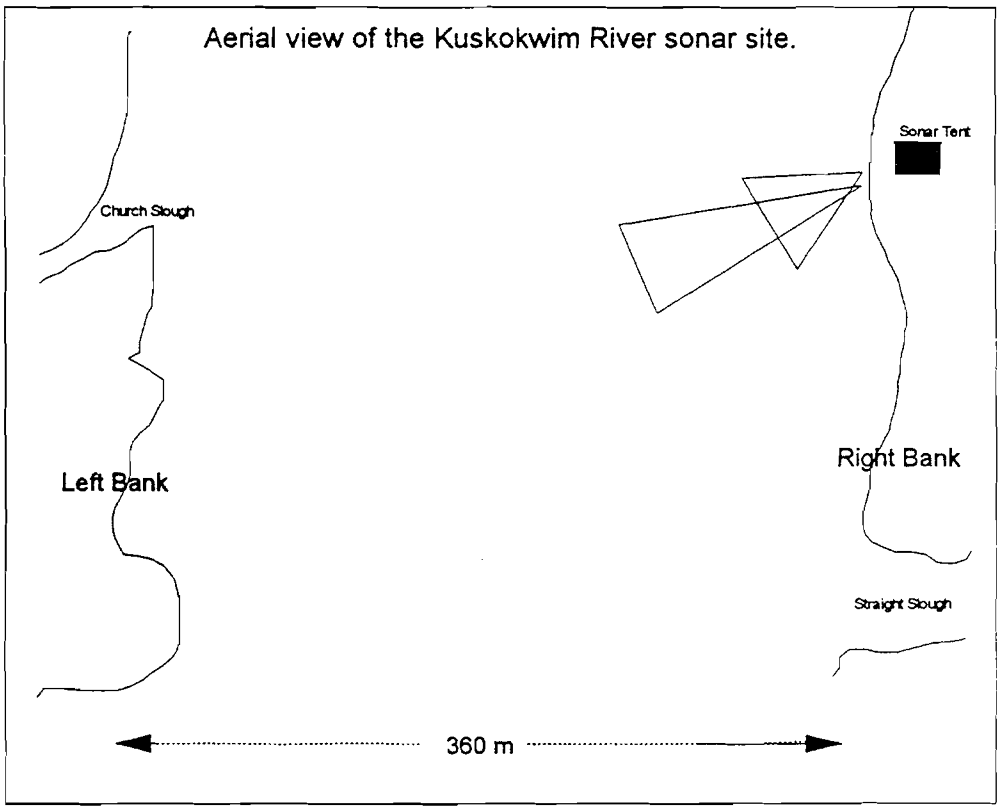


Figure 2. Cross-sectional and aerial view of the Kuskokwim River sonar site in 1991. Not drawn to scale.

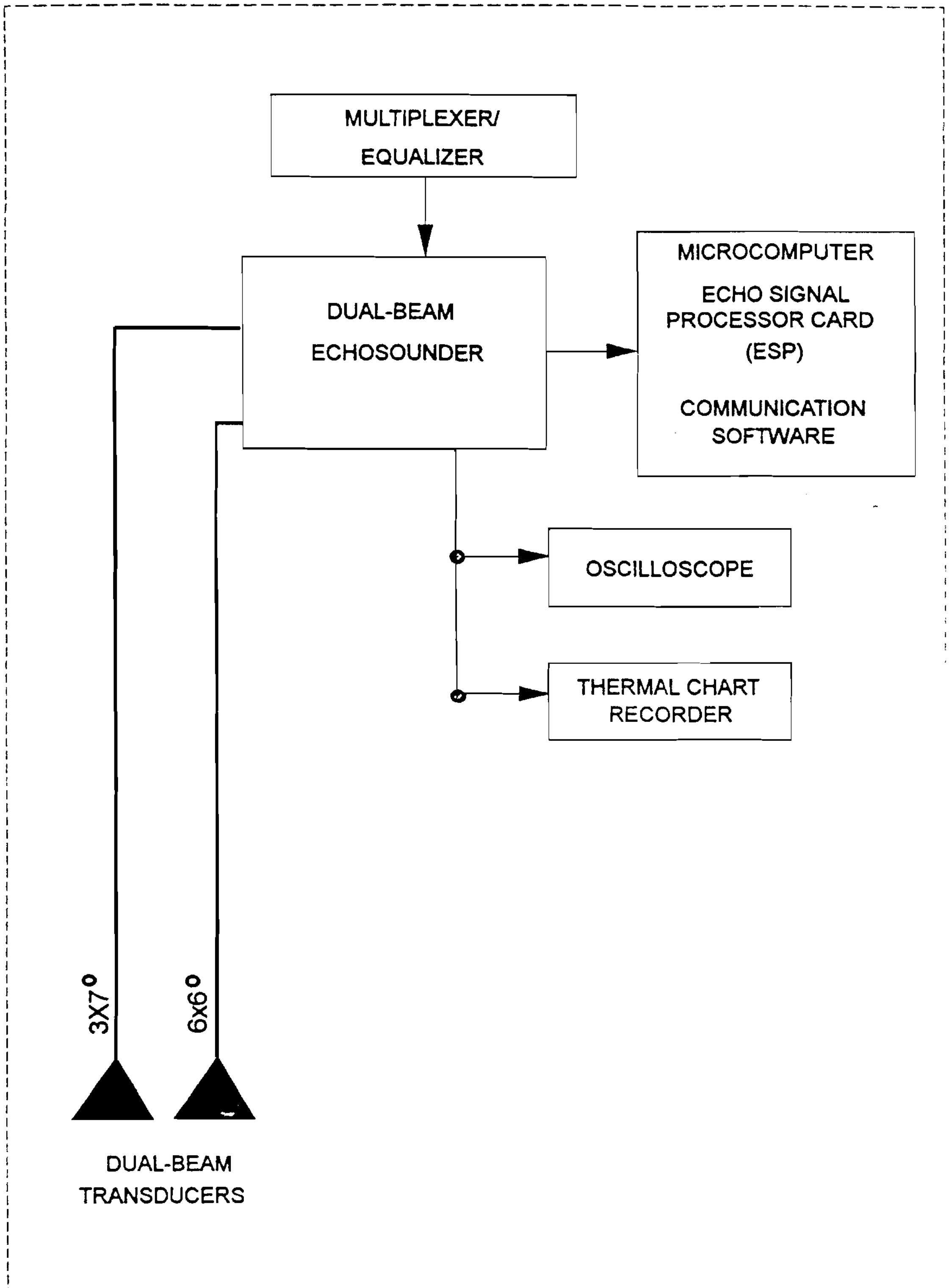


Figure 3. Kuskokwim River sonar data acquisition system, 1991.

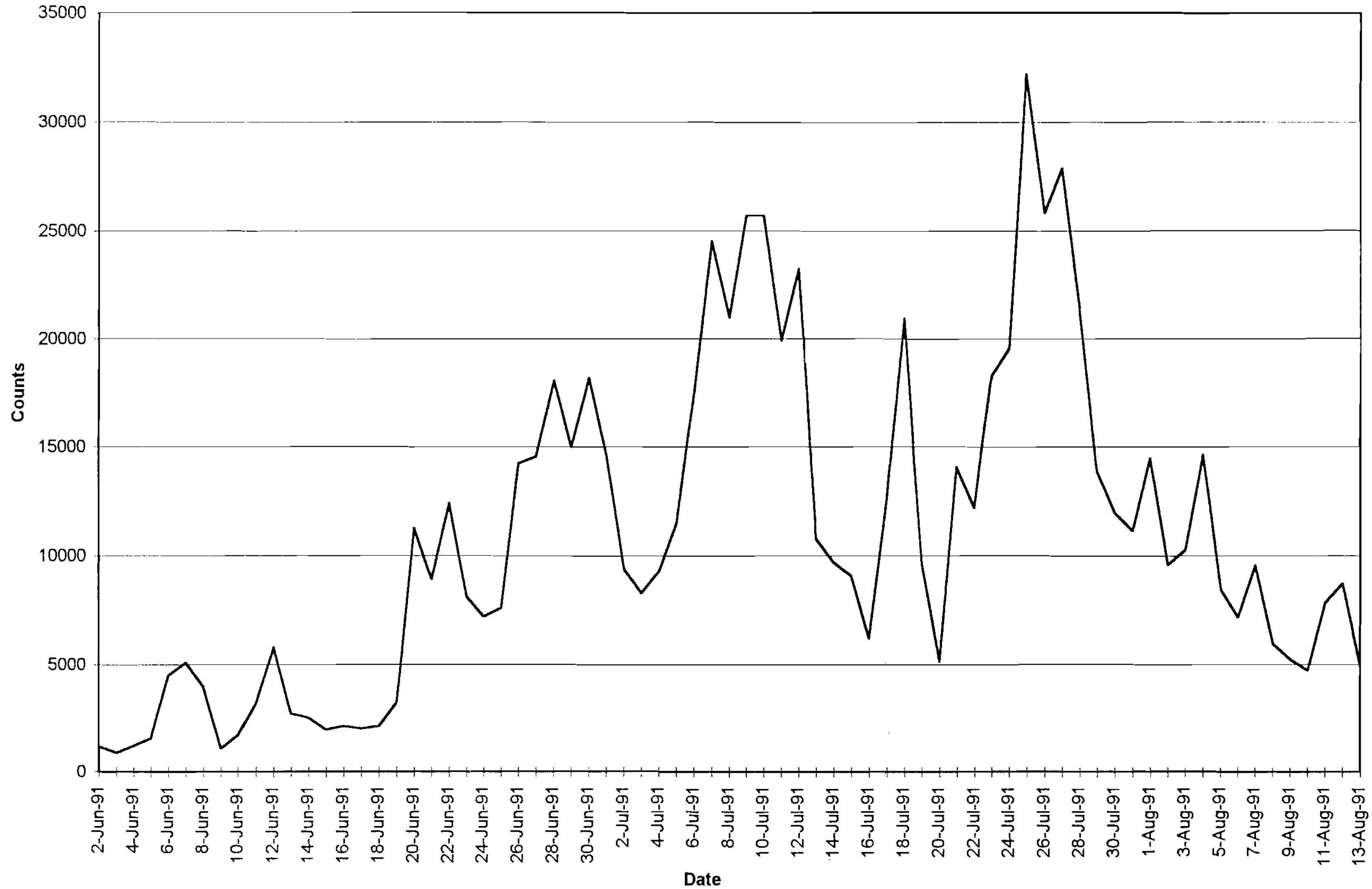


Figure 4. Sonar estimated daily fish passage in the Kuskokwim River between 2 June and 13 August, 1991.

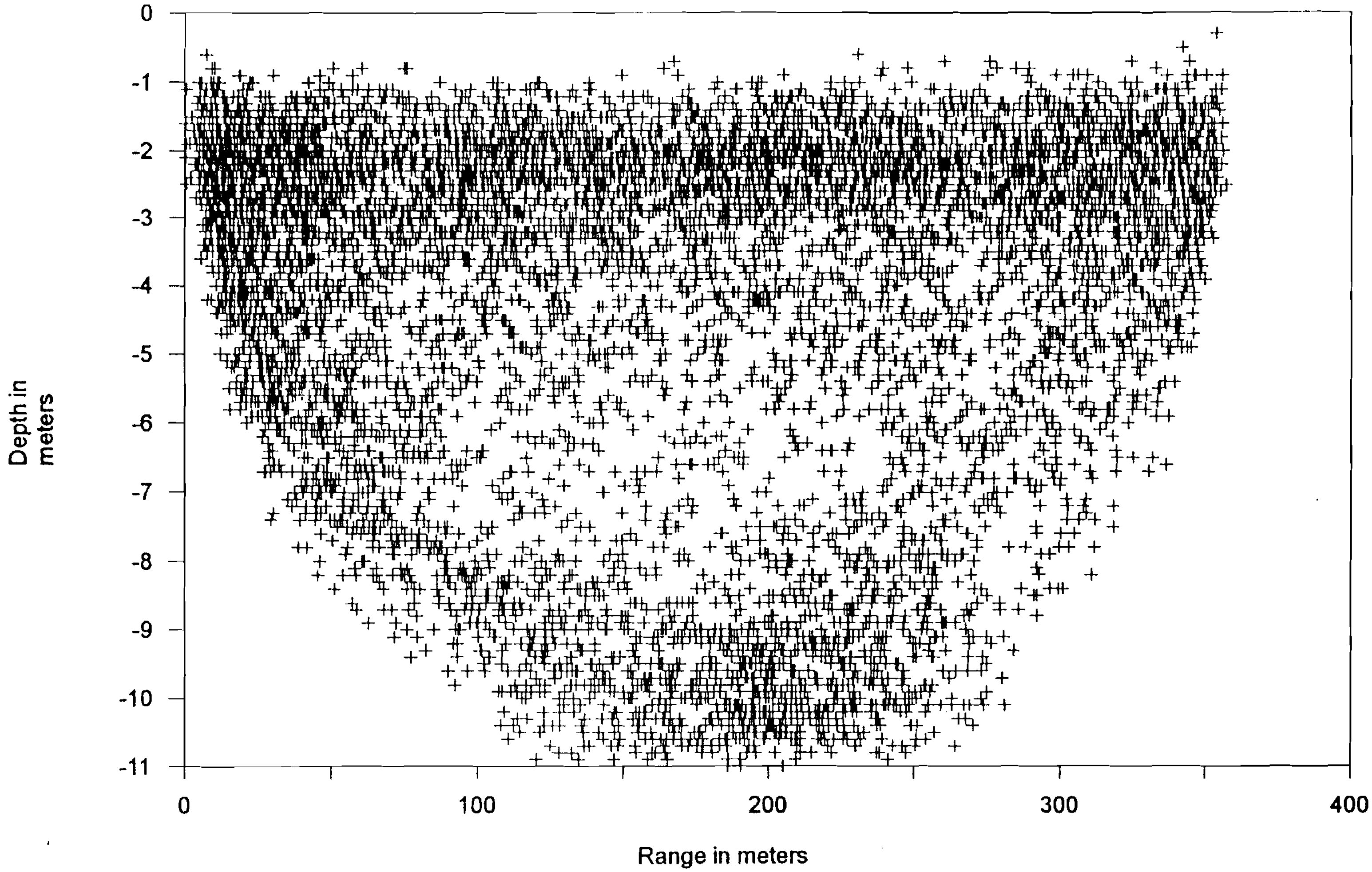


Figure 5. Unadjusted spatial distribution of targets detected in down-looking transects in the Kuskokwim river between 2June and 13 August, 1991.

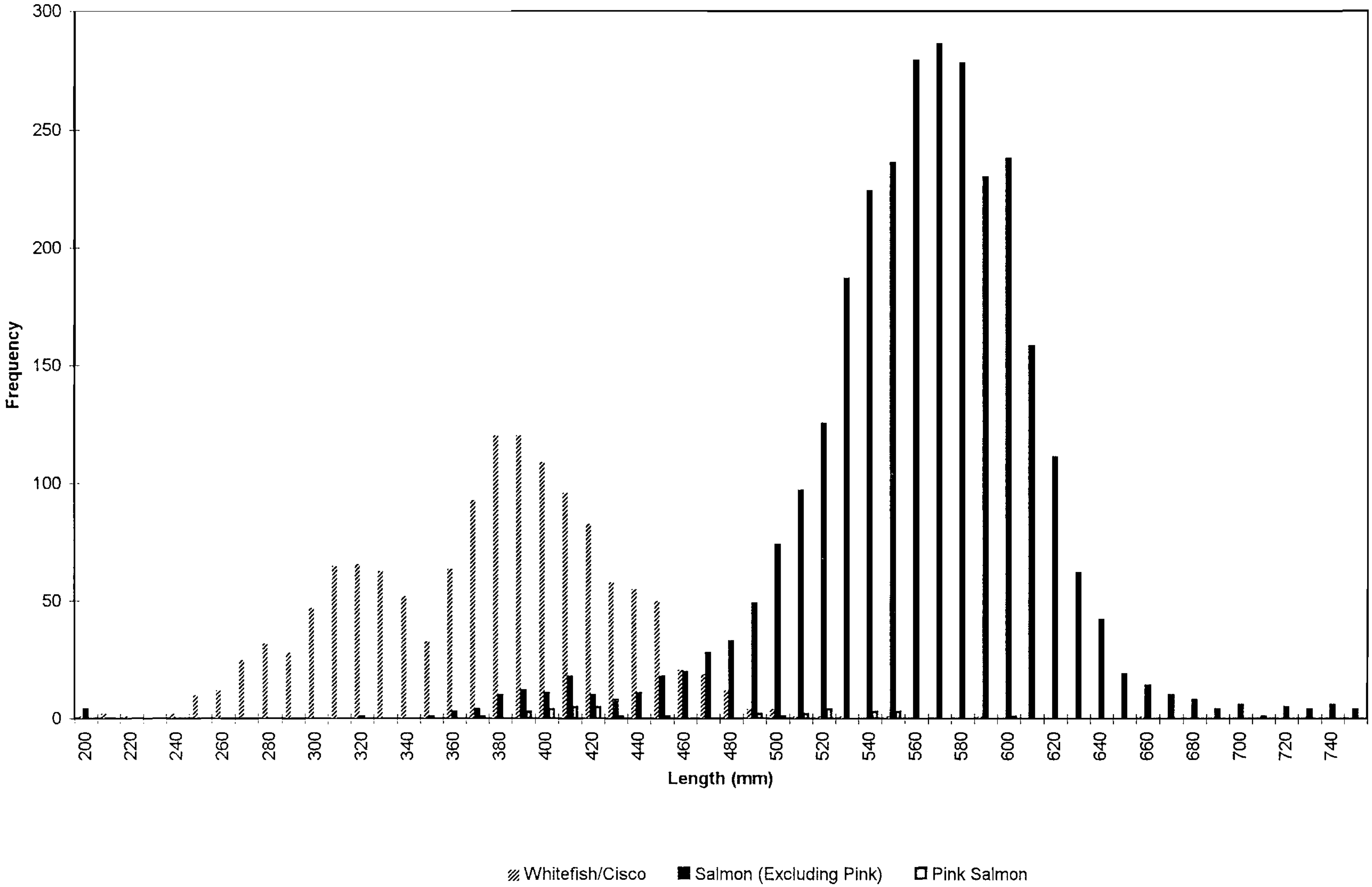


Figure 6. Length frequency distribution of fish caught in set and drift gillnets at the Kuskokwim River sonar site by species group, 1991.

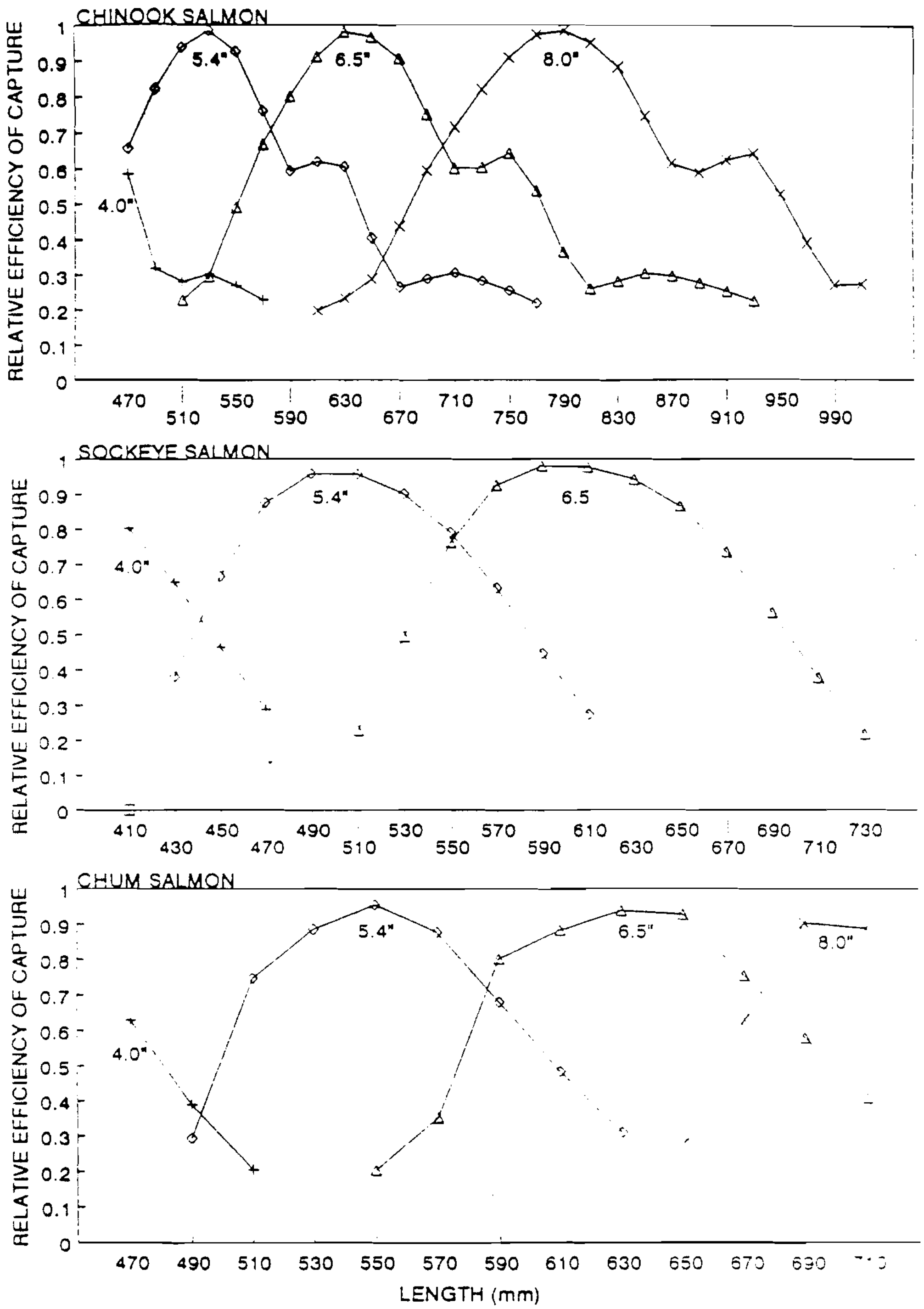


Figure 7a: Net selectivity curves used to adjust catches of chinook, sockeye and chum salmon for unequal probability of capture, 1991.

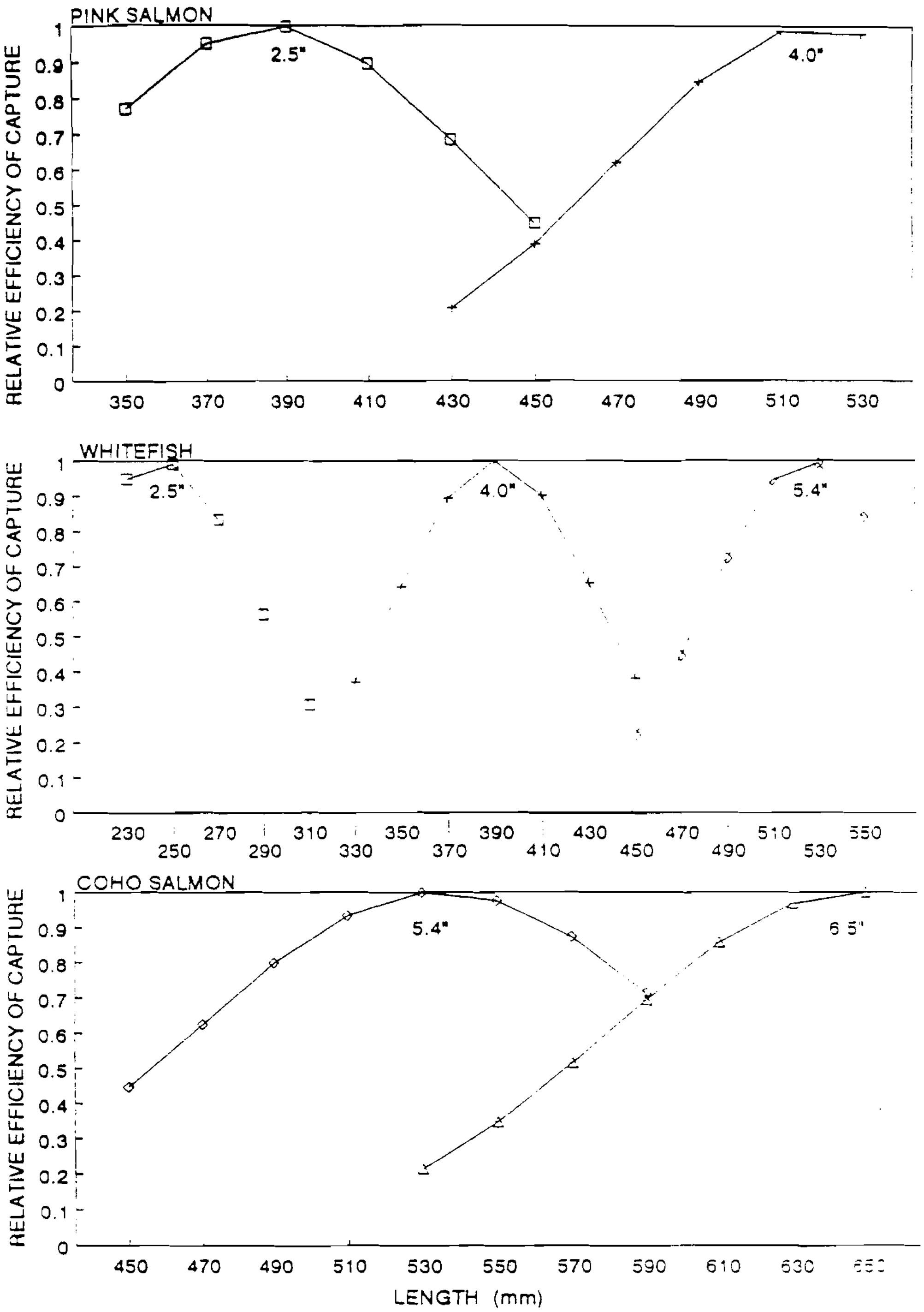
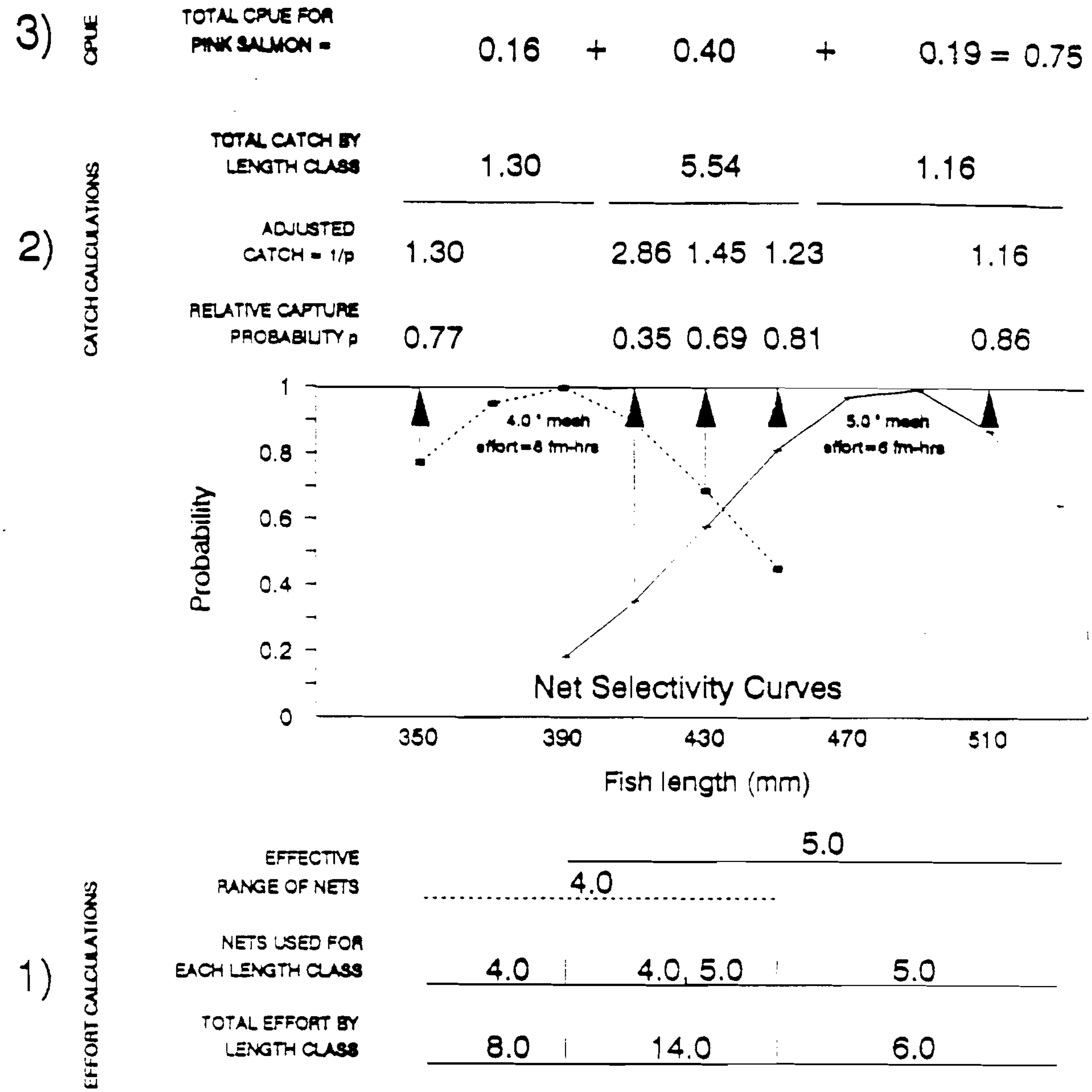


Figure 7b. Net selectivity curves used to adjust catches of pink salmon, whitefish and coho salmon for unequal probability of capture, 1991.



In this example two pink salmon (of lengths 350 mm and 430 mm) were caught in drifts with 4" mesh nets and three pink salmon (410, 450, and 510 mm) were caught in 5" mesh nets. Total effort for 4" mesh nets was 8 fathom hours; effort for 5" mesh nets was 6 fathom hours. First, each net is assigned a range of pink salmon lengths which are susceptible to capture by that net, based on estimated net selectivity curves. Where net ranges overlap, daily effort for both nets are summed. Second, catches of each fish are adjusted upwards, based on estimated selectivity curves for each net, to account for differential capture probabilities for different length fish. Adjusted catches are summed by length class. Finally, adjusted catches for each length class are divided by the appropriate effort (from step 1), and the adjusted CPUE's summed over all length classes. This number, divided by total CPUE for all species and all length classes, is used as an estimate of the proportion of pink salmon present.

Figure 8. An example of daily adjusted CPUE calculation for one species (pink salmon)

APPENDIX A

APPENDIX A1: 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 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();
        }
}
```

(continued)

APPENDIX A1: (page 11 of 11)

```
      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
```

APPENDIX A2: KOFFSHOR.SAS used to generate passage estimates using side-looking and downward-looking sonar data, Kuskokwim River sonar, 1991.

```
title1 'Kuskokwim River Sonar In-Season Data Processing Programs';
title2 'KOFFSHOR.SAS: uses transect data to expand offshore
counts';
options linesize=79 pagesize=59;

*READ SONAR COUNT AND RANGE INFORMATION FROM AN EXTERNAL FILE;
data rawcnts;
  infile 'f:\karen\rAWCNTS.DAT' firstobs=12;
  input reportno day month year onshore rcutoff offshore maxsonar;
  date =mdy(month,day,year);
  drop month day year;
  format date date7.;
  run;

*SUM PASSAGE OVER REPORT PERIODS, CREATE AND PRINT NEW DATASET WITH REPORT
PERIOD  PASSAGE ESTIMATES;
proc summary data=rawcnts nway;
  class reportno; id date;
  var onshore offshore rcutoff maxsonar;
  output out=reptcnts sum(onshore offshore)= mean(rcutoff
maxsonar)=;
  run;

data reptcnts; set reptcnts;
  format onshore offshore comma9.0;
  label onshore='ONSHORE PASSAGE' offshore='OFFSHORE PASSAGE'
        rcutoff='RANGE CUTOFF' maxsonar='MAXIMUM SONAR RANGE'
        reportno='REPORT PERIOD NUMBER' date='ENDING DATE';
  run;

title3 'SONAR PASSAGE ESTIMATES AND RANGE INFORMATION BY REPORT
PERIOD';
footnote1 'NOTE: This program does not process onshore sonar
counts';
proc print data=reptcnts noobs label;
  var reportno date rcutoff maxsonar onshore offshore;
  sum onshore offshore;
  run;

*READ TRANSECT DATA FROM EXTERNAL FILE;
*WEIGHT TARGETS BY INVERSE OF DEPTH;
*USE 10 METER DEPTH AS POINT OF REFERENCE (WEIGHT=1);
data xsects;
  infile 'f:\karen\xsects.dat' firstobs=4;
  input day month year ampm transect range depth;
  date=mdy(month,day,year);
  weight=10/abs(depth);
```

(continued)

```
  drop month day year;
  run;

*MERGE TRANSECT AND SONAR COUNT DATA SETS, CLASSIFY TARGETS AS IN OR OUT OF
BEAM;
data location;
  merge xsects(in=a) rawcnts(drop=onshore offshore); by date;
  if a;
  if range gt maxsonar then location='OUT     ';
  else if (range ge rcutoff and range le maxsonar)
          then location='IN      ';
  else if range lt rcutoff then location='ONSHORE';
  run;

*PLOT TRANSECT DATA BY REPORT PERIOD;
title3 'PLOTS OF RAW TRANSECT DATA BY REPORT PERIOD';
footnote1;
options pagesize=20;
proc plot data=location uniform;
  plot depth*range=location / vref=0  vaxis=-12 to 0 by 2
                                      haxis=0 to 400 by 50;
  by reportno;
  run;
options pagesize=59;

*SUM WEIGHTED TARGETS BY LOCATION WITHIN EACH SET OF TRANSECTS;
*TRANSECTS SETS ARE REFERRED TO AS REPLICATES WHEN CODING DATASET NAMES;
proc summary data=location nway;
  class reportno date ampm location;
  var weight;
  output out=replloc sum=locsum;
  run;

*TRANSPOSE TARGET SUM DATA BY TRANSECT SET, I.E., PLACE TARGET SUMS FOR ALL
 LOCATIONS ON ONE LINE FOR EACH TRANSECT SET;
proc transpose data=replloc out=replwide;
  by reportno date ampm;
  var locsum; id location;
  run;

*GENERATE NUMBERS NEEDED TO CALCULATE EXPANSION FACTOR AND ITS
VARIANCE;
*PRINT HYPOTHETICAL EXPANSION FACTORS BY TRANSECT SET;
*REFERENCE: COCHRAN 1977 STATISTICAL METHODS P. 155, EQUATIONS
6.10, 6.12;
data xvarcalc; set replwide;
  if in=. then in=0; if out=. then out=0;
```

(continued)

```
  total=in+out;
  rplfactr=total/in;
  xsquared=in**2;
  ysquared=total**2;
  xy=in*total;
  format date date7. total in onshore 5.0 rplfactr 6.2;
  label ampm='TRANSECT SET' in='TARGETS IN BEAM'
        onshore='ONSHORE TARGETS (not used)'
        total='TOTAL OFFSHORE TARGETS' rplfactr='EXPANSION FACTOR';
  run;

title3 'FATHOMETER TARGET LOCATION AND REPLICATE EXPANSION FACTORS,
BY TRANSECT SET';
footnote1 'NOTE:  Targets are weighted by the inverse of depth.
              ';
footnote2 'Onshore targets excluded before calculating expansion
factors.        ';
footnote3 'Above expansion factors are by transect set and are not
actually used.';
proc print data=xvarcalc label noobs;
  var reportno date ampm onshore total in rplfactr;
  sum onshore total in;
  run;

*SUM WEIGHTED TARGETS, PLUS SQUARE AND CROSS-PRODUCT TERMS BY
REPORT PERIOD;
proc summary data=xvarcalc nway;
  class reportno;  id date;
  var total in xsquared ysquared xy;
  output out=xvarfctr sum(total)=reptsum sum(in)=reptinsm
                      sum(xsquared)=ssx sum(ysquared)=ssy
sum(xy)=sxy
                      mean(in)=reptinmn n=n;
  run;

*MERGE EXPANSION FACTOR DATA WITH PASSAGE DATA, CALCULATE REPORT PERIOD
EXPANSION FACTOR AND COEFFICIENT OF VARIATION, MULTIPLY BY PASSAGE ESTIMATES;
data offshorx; merge xvarfctr(drop=_type_ _freq_)
reptcnts(drop=_type_ _freq_);
  rptfactr=reptsum/reptinsm;
  offshorx=rptfactr*offshore;
  var=(ssy+rptfactr**2*ssx-2*rptfactr*sxy)/(n*(n-1)*reptinmn**2);
  cv=sqrt(var)/rptfactr;
  offshrse=cv*offshorx;
  format reptsum reptinsm 5.0 rptfactr cv 5.2 offshorx offshrse
comma7.0;
  label reptinsm='TARGETS IN BEAM' cv='COEFFICIENT OF VARIATION'
```

(continued)

APPENDIX A2: (page 4 of 4)

```
        reptsum='TOTAL OFFSHORE TARGETS' rptfactr='EXPANSION
FACTOR'
        offshorx='EXPANDED OFFSHORE PASSAGE' offshrse='PASSAGE
STANDARD ERROR'
        date='ENDING DATE';
  run;

*PRINT FINAL RESULTS;
title3 'EXPANSION FACTORS AND EXPANDED OFFSHORE PASSAGE ESTIMATES,
BY REPORT PERIOD';
footnote3;
proc print data=offshorx label noobs;
  var reportno date reptsum reptinsm rptfactr offshorx offshrse cv;
  sum offshorx;
  run;

*BTF.SAS, WHICH APPORTIONS THE EXPANDED OFFSHORE COUNTS GENERATED BY THIS
 PROGRAM, REQUIRES PASSAGE ESTIMATES BY DAY AND STANDARD ERRORS BY REPORT
 PERIOD.  THE FOLLOWING STATEMENTS COLLATE AND PRINT THE DATA IN A FORMAT
 COMPATIBLE WITH BTF.SAS;
data btfin;  merge rawcnts(keep=reportno date onshore offshore)
             offshorx(keep=reportno rptfactr offshrse); by
reportno;
  dayoffsh=rptfactr*offshore;
  format onshore dayoffsh comma9.0;
  label onshore='ONSHORE FISH PASSAGE (1)' dayoffsh='OFFSHORE FISH
PASSAGE'
        offshrse='STD ERROR OF OFFSHORE PASSAGE (2)';
  run;

title3 'DAILY EXPANDED (OFFSHORE) FISH PASSAGE';
title4 'Expansions based on transect data pooled by report
period.';
footnote1 'NOTES: (1) Onshore numbers not expanded nor otherwise
altered by this program';
footnote2 '       (2) Standard error applies to offshore passage
for entire report period';
proc print noobs label data=btfin;
  var reportno date onshore dayoffsh offshrse;
  sum onshore dayoffsh;
  run;
```

APPENDIX A3: SAS code used to apportion sonar counts to species, 1991

```
*BTF.SAS: USES BETHEL TESTFISH DATA TO APPORTION OFFSHORE FISH COUNTS AND
      INSHORE SALMON COUNTS FROM KUSKOKWIM SONAR;

title1 'Kuskokwim River Sonar Species Apportionment Program';
options linesize=120 pagesize=47;
libname ksave 'c:\sas\save\';

data daycnts;
 infile 'c:\sas\DAYCNTS.DAT' firstobs=4;
 input reportno day month year salmon1 fish23 se23;
 date =mdy(month,day,year);
 drop year month day;
 format date date7.;
 label salmon1='INSHORE SALMON' fish23='OFFSHORE FISH' se23='OFFSHORE FISH S.E.';
 run;

/*title2 'ESTIMATED FISH PASSAGE, BY DAY';
proc print label data=daycnts;
 var reportno date salmon1 fish23 se23;
 sum salmon1 fish23;
 run;*/

data dc2; set daycnts;
 range=1; dayrngps=salmon1; stdrngps=0;    output;
 range=2; dayrngps=fish23;  stdrngps=se23; output;
 run;

proc sort data=dc2; by reportno range; run;
proc summary data=dc2 nway;
 var dayrngps; id stdrngps;
 output out=reptcnts sum=rangpasg;
 class reportno range;
 run;

*READ DATA FROM RBASE EXPORT FILE, ONE LINE FOR EACH FISH, PLUS ONE LINE FOR
 ANY DRIFTS DURING WHICH NO FISH WERE CAUGHT;
*CALCULATE EFFORT IN FATHOM HOURS;
*NOTE THERE IS NO CONTINGENCY FOR DRIFTS SPANNING MIDNIGHT;
data testfish;
 length species $ 8;
 infile 'c:\rbfiles\tfishdat.dlm' delimiter=',';
 informat date mmddyy. startout fullout startin fullin time8.;
 format date date7. startout time5.;
 input reportno date tideno driftno station mesh spcode length fathoms
    startout fullout startin fullin;
 if fullout lt (startout-82800) then do;
  fullout=fullout+86400;
  startin=startin+86400;
  fullin=fullin+86400;
  end;
 if startin lt (fullout-82800) then do;
  startin=startin+86400;
```

```
   fullin=fullin+86400;
   end;
 if fullin lt (fullout-82800) then do;
   fullin=fullin+86400;
   end;
 drifmins = (startin-fullout)/60 + (fullout-startout)/(2*60) +
         (fullin-startin)/(2*60);
 if length=0 then lclassmp=0;
 else lclassmp= round(length+10,20)-10;
 drop fullout startin fullin length;
 if spcode = 1 and lclassmp gt 630 then species = 'CHINOOK ';
 if spcode = 1 and lclassmp le 630 then do;
   spcode = 8; species = 'JACK'; end;
 if spcode = 2 then  species = 'SOCKEYE';
 if spcode = 3 then  species = 'COHO';
 if spcode = 4 then  species = 'PINK';
 if spcode = 5 then  species = 'CHUM';
 if spcode = 6 then  species = 'WHITE';
 if spcode = 7 then  species = 'OTHER';
 if spcode = 0 or spcode = . then species = 'NONE';
 if mesh=2.5  then meshcode=1;
 if mesh=4.0  then meshcode=2;
 if mesh=5.4  then do;
              mesh=5.375;
              meshcode=3;
              end;
 if mesh=6.5  then meshcode=4;
 if mesh=8.0  then meshcode=5;
 run;

*COUNT THE NUMBER OF FISH OF EACH SPECIES IN EACH DRIFT;
proc sort data=testfish;
 by reportno date tideno driftno;
 run;
proc summary data=testfish nway;
 by reportno date tideno driftno;
 class mesh station startout species;
 var spcode; id fathoms drifmins;
 output out=sppcatch n=sppcatch;
 run;

proc transpose data=sppcatch out=tfsummar;
 var sppcatch; id species;
 by reportno date tideno driftno mesh station startout fathoms drifmins;
 run;

data spplist;
 chinook=0; jack=0; sockeye=0; chum=0; pink=0; coho=0; white=0; other=0;
 run;

data tfsummar; set tfsummar(in=a) spplist;
 if a;
```

```
fathhrs= fathoms*drifmins/60;
 format date date7. startout time5. fathhrs 8.2;
 label fathhrs='FATHOM HOURS' reportno='REPORT NO.' tideno='TIDE NO.'
     driftno='DRIFT NO.' drifmins='MEAN FISHING TIME';
 run;

proc sort data=tfsummar out=print; by date tideno driftno; run;
title2 'SUMMARY OF TESTFISH RESULTS, BY DRIFT';
proc print data=print label noobs;
 var reportno date tideno driftno startout mesh station;
 sum fathhrs chinook jack sockeye chum pink coho white other;
 run;

data historic; set tfsummar(drop=startout pink white other);
 if mesh=5.375 or mesh=8.0 or driftno=0;
 if chinook=. then chinook=0;  if jack=. then jack=0;
 if sockeye=. then sockeye=0;  if chum=. then chum=0;
 if coho=. then coho=0;
 chinook=chinook+jack;
 chincpue=100*(chinook)/fathhrs;
 sockcpue=100*sockeye/fathhrs;
 chumcpue=100*chum/fathhrs;
 cohocpue=100*coho/fathhrs;
 format chincpue sockcpue chumcpue cohocpue drifmins mesh 5.1 fathoms 3.0;
 label chincpue='CHINOOK CPUE' sockcpue='SOCKEYE CPUE' chumcpue='CHUM CPUE'
     cohocpue='COHO CPUE' chinook='CHINOOK CATCH' sockeye='SOCKEYE CATCH'
     chum='CHUM CATCH' coho='COHO CATCH';
 run;

title2 'CPUE BY DRIFT, 5.375" AND 8.0" MESH ONLY';
proc print data=historic noobs label;
 var date tideno driftno station mesh fathoms drifmins chinook chincpue
    sockeye sockcpue chum chumcpue coho cohocpue;
 sum chinook sockeye chum coho;
 run;

proc summary data=historic nway;
 var chinook chincpue;
 class date tideno;
 output out=chintide sum(chinook)= mean(chincpue)=;
 run;

data smalmesh; set historic;
 if mesh=5.375;
 run;

proc summary data=smalmesh nway;
 var sockeye sockcpue chum chumcpue coho cohocpue;
 class date tideno;
 output out=scctide sum(sockeye chum coho)=
                mean(sockcpue chumcpue cohocpue)=;
 run;
```

```
data histtide;
 merge chintide scctide;
 by date tideno;
 format chincpue sockcpue chumcpue cohocpue 5.1;
 label chincpue='CHINOOK CPUE' sockcpue='SOCKEYE CPUE' chumcpue='CHUM CPUE'
    cohocpue='COHO CPUE' chinook='CHINOOK CATCH' sockeye='SOCKEYE CATCH'
    chum='CHUM CATCH' coho='COHO CATCH';
 run;

title2 'MEAN CPUE BY TIDE';
title3 'chinook 5.4" and 8" nets; sockeye, chum, and coho 5.4" net only';
proc print noobs label data=histtide;
 var date tideno chinook chincpue sockeye sockcpue chum chumcpue coho cohocpue;
 sum chinook sockeye chum coho;
 run;

proc summary data=histtide nway;
 class date;  var chincpue sockcpue chumcpue cohocpue;
 output out=histday sum=;
 run;

data histday; set histday;
 format chincpue sockcpue chumcpue cohocpue 5.1;
 label chincpue='CHINOOK CPUE' sockcpue='SOCKEYE CPUE' chumcpue='CHUM CPUE'
    cohocpue='COHO CPUE';
 run;

title2 'TIDAL CPUE SUMMED BY DAY';
proc print noobs label data=histday;
 var date chincpue sockcpue chumcpue cohocpue;
 run;

*SUM EFFORT FOR ALL DRIFTS WITH EACH MESH BY TIDE;
proc summary data=tfsummar nway;
 class reportno date tideno mesh;
 var fathhrs;
 output out=effort1 sum=meffort;  *(MESH EFFORT);
 run;

*FINALLY, REARRANGE DATA TO PUT EFFORTS FOR ALL MESHES ON A SINGLE LINE;
proc transpose data=effort1 out=effort2;
 var meffort; id mesh;
 by reportno date tideno;
 run;
data effort; merge effort1(drop=_type_ _freq_) effort2(drop=_name_);
 by reportno date tideno;
 rename _2d5   =effort1;
 rename _4     =effort2;
 rename _5d375 =effort3;
 rename _6d5   =effort4;
 rename _8     =effort5;
```

```
run;

*READ IN AN EXTERNAL FILE WHICH SETS WHICH MESHES WILL BE USED TO ESTIMATE
 CPUE FOR EACH SPECIES, AND WHICH SPECIES CATCHES WILL BE ADJUSTED FOR NET
 SELECTIVITY;
data specmesh;
  infile 'c:\sas\kspecmsh.dat' firstobs=17;
  length species $ 8;
  length adjust $ 3;
  input species usemesh1-usemesh5 adjust;
  run;

*MERGE SPECIES-MESH PAIRING DATA INTO TESTFISH DATA SET;
*DELETE FISH WHICH WERE NOT CAUGHT IN MESHES TARGETING THAT SPECIES;
proc sort data=testfish; by species; run;
proc sort data=specmesh; by species; run;
data tfsm;
  merge testfish(in=a drop=fathoms drifmins) specmesh;
  by species;
  if a;
  if mesh=0 then delete;
  array usemesh{5} usemesh1-usemesh5;
  if usemesh{meshcode}=0 then delete;
  run;

*MERGE NET SELECTIVITY CURVE DATA INTO TESTFISH (+SM) DATA SET;
proc sort data=tfsm; by species mesh lclassmp; run;
data tfsmns; merge tfsm(in=b) ksave.nsallmsh; by species mesh lclassmp;
  if b;
  run;

*MERGE EFFORT DATA INTO TESTFISH (+SM+NS) DATA SET;
*DECLARE ARRAYS;
proc sort data=tfsmns; by reportno date tideno mesh; run;
data tfsmnsef; merge tfsmns(in=c) effort; by reportno date tideno mesh;
  if c;
  array usemesh{5} usemesh1-usemesh5;
  array prob{5} p1-p5;
  array effort{5} effort1-effort5;
  *FOR MAJOR SPECIES, ADJUST CATCH (I.E., 1 FISH) FOR NET SELECTIVITY;
  *IF NET SELECTIVITY IS NOT KNOWN FOR THIS FISH, THEN SET CATCH TO ZERO;
  meanprob=0.7;
  if adjust='Y' then adjcatch=1/p;
  if adjust='N' then adjcatch=1/meanprob;
  if adjcatch=. then adjcatch=0;
  *SUM EFFORT FOR ALL MESHES TARGETING THIS SPECIES DURING THIS TF PERIOD;
  *IF SPECIES IS ADJUSTED FOR NET SELECTIVITY, THEN DO NOT CONSIDER THOSE
   MESHES FOR WHICH NET SELECTIVITY IS NOT KNOWN FOR THIS FISH;
  *FINALLY, CALCULATE ADJUSTED CPUE FOR EACH FISH;
  sumeff=0;
  do imesh=1 to 5;
    if adjust='Y' then do;
```

```
      if prob{imesh} = . then usemesh{imesh}=0;
      end;
    if effort{imesh}=. then effort{imesh}=0;
    sumeff=sumeff+effort{imesh}*usemesh{imesh};
    end;
  adjcpue=adjcatch/sumeff;
  format date date7. startout time5.
        meffort effort1-effort5 sumeff adjcatch 5.2;
  run;

*OPTIONAL PRINTOUT FOLLOWS: SHOWS INTERMEDIARY CALCULATIONS ON TESTFISH
DATA;
data print; set tfsmnsef(obs=100);
title2 'PART OF DATA SET WORK.TFSMNSEF';
title3 'ONE LINE PER FISH, EACH LINE ALSO HAS INFORMATION ON NET SELECTIVITY';
title4 'CURVE PARAMETERS AND EFFORT FOR EACH MESH DRIFTED DURING THAT
PERIOD';
  run;
  proc print data=print;
  var reportno date tideno driftno startout station mesh species spcode lclassmp
      adjcatch usemesh1-usemesh5 meffort effort1-effort5 sumeff adjcpue;
  run;

*SUM ADJUSTED CPUE FOR EACH SPECIES DURING EACH TESTFISH PERIOD;
proc summary data=tfsmnsef nway;
  class reportno date tideno spcode;
  var adjcpue adjcatch; id startout species;
  output out=spcpue sum=spcpue spcatch;
  run;

data spcpue; set spcpue; range=2; run;

data salmonly; set spcpue;
  if spcode<=5 or spcode=8;
  range=1;
  run;

data spcpue; set salmonly spcpue; run;

*TRANSPOSE BY ALL BUT SPECIES (CODE), CREATING A SEPARATE VARIABLE FOR CPUE
OF
 EACH SPECIES;
proc transpose data=spcpue out=spcpwide;
  by range reportno date tideno;
  var spcpue;
  id spcode;
  run;

proc summary data=spcpue nway;
  class range reportno date tideno;
  var spcatch;
  output out=catch sum(spcatch)=adjcatch;
```

```
 run;

*SUM CPUE'S FOR ALL SPECIES DURING A GIVEN TESTFISH PERIOD;
data spcpwide; merge spcpwide catch; by range reportno date tideno;
 array cpue{8} _1-_8;
 sumcpue=0;
 do i=1 to 8;
   if cpue{i} = . then cpue{i} = 0;
   sumcpue= sumcpue + cpue{i};
   end;
 format _1-_8 adjcatch sumcpue 6.2;
 run;

*SUM CPUE, FOR EACH SPECIES AND FOR ALL SPECIES, ACROSS ALL TIDES
 WITHIN EACH REPORTING PERIOD;
*CALCULATE THE AVERAGE TOTAL (ALL SPECIES) CPUE IN EACH REPORT PERIOD;
*COUNT THE NUMBER OF TESTFISH PERIODS IN EACH REPORT PERIOD;
proc summary data=spcpwide nway;
 class range reportno;
 var _1-_8 sumcpue;
 output out=rncpue sum=rnspcp1-rnspcp8 rnsmcp
             mean(sumcpue)=rnmncp  n=n;
 run;

*MERGE THE ORIGINAL DATA SET WITH THE SUMMARIZED DATA SET, THEN CALCULATE:
 ESTIMATED PROPORTION OF EACH SPECIES DURING EACH TESTFISH PERIOD,
 ESTIMATED PROPORTION OF EACH SPECIES DURING EACH REPORT PERIOD,
 AND A WEIGHTED SQUARED DEVIATION OF THE TESTFISH PERIOD PROPORTION FROM
 THE REPORT PERIOD PROPORTION;
data varcalc;
 merge spcpwide rncpue;
 by range reportno;
 array cpue{8} _1-_8;
 array rnspcp{8} rnspcp1-rnspcp8;
 array phatpr{8} phatpr1-phatpr8;
 array phatrp{8} phatrp1-phatrp8;
 array sqrdev{8} sqrdev1-sqrdev8;
 weight=sumcpue/rnmncp;
 do i=1 to 8;
   phatpr{i}=cpue{i}/sumcpue;
   phatrp{i}=rnspcp{i}/rnsmcp;
   sqrdev{i}=(weight**2)*(phatpr{i}-phatrp{i})**2;
   end;
 label phatpr1='CHINOOK' phatpr2='SOCKEYE' phatpr3='COHO' phatpr4='PINK'
 phatpr5='CHUM' phatpr6='WHITE' phatpr7='OTHER' phatpr8='JACK';
 format phatpr1-phatpr8 4.3 adjcatch 5.1;
 run;

*PRINT SPECIES PROPORTIONS BY TIDE;
proc sort data=varcalc out=print; by range reportno date tideno; run;
title2 'ESTIMATED SPECIES PROPORTIONS AND TOTAL ADJUSTED CATCH, BY TIDE';
run;
```

```
proc print noobs label data=print;
 var reportno date tideno adjcatch
    phatpr1 phatpr8 phatpr2 phatpr5 phatpr4 phatpr3 phatpr6 phatpr7;
 by range;
 run;

*SUM THE SQUARED DEVIATIONS BY REPORT PERIOD;
proc summary data=varcalc nway;
 class range reportno;
 var sqrdev1-sqrdev8 adjcatch;
 id phatrp1-phatrp8 n date;
 output out=varprop sum=smsqdv1-smsqdv8 adjcatch;
 run;

*AND CALCULATE THE VARIANCE OF THE REPORT PERIOD PROPORTION (COCHRAN 1977);
data varprop; set varprop (drop = _type_ _freq_);
 array varprp{8} varprp1-varprp8;
 array smsqdv{8} smsqdv1-smsqdv8;
 array stdprp{8} stdprp1-stdprp8;
 array cvprop{8} cvprop1-cvprop8;
 array phatrp{8} phatrp1-phatrp8;
 do i = 1 to 8;
  varprp{i}=smsqdv{i}/(n*(n-1));
  stdprp{i}=sqrt(varprp{i});
  if phatrp{i} gt 0 then cvprop{i}=stdprp{i}/phatrp{i};
  else cvprop{i}=0;
  end;
 format phatrp1-phatrp8 5.3 stdprp1-stdprp8 3.2 adjcatch 5.1;
 label phatrp1='CHINOOK' phatrp2='SOCKEYE' phatrp3='COHO' phatrp4='PINK'
 phatrp5='CHUM' phatrp6='WHITE' phatrp7='OTHER' phatrp8='JACK';
 label stdprp1='se' stdprp2='se' stdprp3='se' stdprp4='se'
 stdprp5='se' stdprp6='se' stdprp7='se' stdprp8='se';
 run;

data out; set varprop;
 format phatrp1-phatrp8 stdprp1-stdprp8 5.4;
 file 'c:\sas\reptprop.sht';
 put reportno date range phatrp1-phatrp8 / @13 stdprp1-stdprp8;
 run;

title2 'ESTIMATED SPECIES PROPORTIONS AND STANDARD ERRORS, BY REPORT PERIOD';
proc print label data=varprop noobs; by range;
 var reportno date adjcatch phatrp1 stdprp1 phatrp8 stdprp8 phatrp2 stdprp2
           phatrp5 stdprp5 phatrp4 stdprp4 phatrp3 stdprp3
           phatrp6 stdprp6 phatrp7 stdprp7;
 run;

*
*NOW MERGE DATA SET CONTAINING COUNTS WITH DATA SET CONTAINING
PROPORTIONS,
 AND CALCULATE SPECIES PASSAGE ESTIMATES AND THEIR ESTIMATED VARIANCE;
*;
```

```
*GENERATE DAILY CUMULATIVE PASSAGE NUMBERS;
proc sort data=varprop; by reportno range; run;
data daypasg;
 merge dc2 varprop(in=a drop=date);
 by reportno range;
 if a;
 array phatrp{8} phatrp1-phatrp8;
 array rngpsg{8} rngpsg1-rngpsg8;
 do i=1 to 8;
  rngpsg{i}=phatrp{i}*dayrngps;
  end;
 format dayrngps rngpsg1-rngpsg8 8.;
 run;

proc summary data=daypasg nway;
 class date;  id reportno;
 var rngpsg1-rngpsg8;
 output out=dp2 sum=psg1-psg8;
 run;

data dpcum; set dp2;
 array psg{8} psg1-psg8;
 array cp{8} cp1-cp8;
 retain cp 0;
 do i = 1 to 8;
  cp{i}=cp{i} + psg{i};
  end;
 run;

*CALCULATE VARIANCE BY REPORT PERIOD;
data rangevar;
 merge reptcnts varprop(in=a);
 by reportno range;
 if a;
 array phatrp{8} phatrp1-phatrp8;
 array varprp{8} varprp1-varprp8;
 array rngpsg{8} rngpsg1-rngpsg8;
 array varrp{8} varrp1-varrp8;
 array stdrp{8} stdrp1-stdrp8;
 varrngps=stdrngps**2;
 do i=1 to 8;
  rngpsg{i}=phatrp{i}*rangpasg;
  varrp{i}=(rangpasg**2)*varprp{i} + (phatrp{i}**2)*varrngps +
       varrngps*varprp{i};
  stdrp{i}=sqrt(varrp{i});
  end;
 format rangpasg rngpsg1-rngpsg8 8. varrngps varprp1-varprp8
      varrp1-varrp8 e9. phatrp1-phatrp8 5.3;
 run;
```

```
*SUM THE PASSAGE ESTIMATES AND THEIR STANDARD DEVIATIONS FOR BOTH RANGES
IN EACH
 REPORTING PERIOD;
*STANDARD DEVIATIONS RATHER THAN VARIANCES ARE SUMMED UNDER THE
(CONSERVATIVE)
 ASSUMPTION THAT THE INSHORE AND OFFSHORE PASSAGE ESTIMATE ERRORS ARE
PERFECTLY
 CORRELATED, RATHER THAN UNCORRELATED (INDEPENDENT). IN ACTUALITY THEY
ARE
 NEITHER: THEY ARE NOT INDEPENDENT BECAUSE THE OFFSHORE SPP PROPORTIONS
ARE
 APPLIED TO INSHORE COUNTS, AND THEY ARE NOT PERFECTLY CORRELATED BECAUSE
THE
 OFFSHORE ESTIMATES INCLUDE A COMPONENT OF VARIANCE DUE TO WHOLE RIVER
EXPANSION;

proc summary data=rangevar;
 var rngpsg1-rngpsg8 stdrp1-stdrp8;
 id date;
 output out=reptstat sum=psg1-psg8 stdpsg1-stdpsg8;
 by reportno;
 run;

data reptstat; set reptstat(drop = _type_ _freq_);
 array varpsg{8} varpsg1-varpsg8;
 array stdpsg{8} stdpsg1-stdpsg8;
  do i = 1 to 8;
   varpsg{i}=stdpsg{i}**2;
   end;
 format psg1-psg8 7. varpsg1-varpsg8 e9.;
 label reportno='REPORTING PERIOD';
 label psg1='CHINOOK' psg2='SOCKEYE' psg3='COHO' psg4='PINK' psg5='CHUM'
   psg6='WHITE' psg7='OTHER' psg8='JACK';
 run;

proc summary data=reptstat;
 var psg1-psg8 varpsg1-varpsg8 date;
 output out=cumstat sum(psg1-psg8)=
             sum(varpsg1-varpsg8)=
             max(date)=;
 run;

data cumstat; set cumstat (drop=_type_);
 rename _freq_=nreports;
 array psg{8} psg1-psg8;
 array varpsg{8} varpsg1-varpsg8;
 array stdpsg{8} stdpsg1-stdpsg8;
 array cv{8} cv1-cv8;
 do i = 1 to 8;
  stdpsg{i}=sqrt(varpsg{i});
  if psg{i}=0 then cv{i}=0;
  else cv{i}=100*stdpsg{i}/psg{i};
```

```
  end;
 run;

data std; set cumstat (keep=stdpsg1-stdpsg8);
 rename stdpsg1=cp1; rename stdpsg2=cp2; rename stdpsg3=cp3; rename stdpsg4=cp4;
 rename stdpsg5=cp5; rename stdpsg6=cp6; rename stdpsg7=cp7; rename stdpsg8=cp8;
 type = 'STD ERROR';
 run;

data cv; set cumstat (keep=cv1-cv8);
 rename cv1=cp1; rename cv2=cp2; rename cv3=cp3; rename cv4=cp4;
 rename cv5=cp5; rename cv6=cp6; rename cv7=cp7; rename cv8=cp8;
 type = 'C.V. (%)';
 run;

data missing;
 cv1=.; cv2=.; cv3=.; cv4=.; cv5=.; cv6=.; cv7=.; cv8=.;
 run;

data print; set dpcum missing std cv;
 format cp1-cp8 7.;
 label cp1='CHINOOK' cp2='SOCKEYE' cp3='COHO' cp4='PINK'
     cp5='CHUM'  cp6='WHITE'  cp7='OTHER' cp8='JACK';
 label type='.';
 run;

title2 'CUMULATIVE PASSAGE BY DAY, DERIVED FROM 3+ DAY REPORTING PERIOD
PROPORTIONS';
proc print data=print label noobs;
 var type reportno date cp1 cp8 cp2 cp5 cp4 cp3 cp6 cp7;
 run;
```

APPENDIX B

APPENDIX B1: Kuskokwim River sonar test fishing results, 1991.

Date	Mesh	Minutes Fished	King Catch	Coho Catch	Red Catch	Pink Catch	Chum Catch	Other Catch
07/05	10.3 cm	40	0	0	0	0	0	2
07/05	10.3 cm	31	0	0	0	0	0	2
07/05	6.4 cm	45	0	0	0	0	0	0
07/06	10.3 cm	29	0	0	0	0	0	1
07/09	6.4 cm	20	0	0	0	0	0	1
07/09	10.3 cm	20	0	0	0	0	0	4
07/09	6.4 cm	31	0	0	0	0	0	1
07/10	10.3 cm	33	0	0	0	0	0	1
07/11	10.3 cm	30	0	0	0	0	0	0
07/11	6.4 cm	30	0	0	0	0	0	2
07/12	6.4 cm	30	0	0	0	0	0	2
07/13	6.4 cm	300	0	0	0	0	2	15
07/13	10.3 cm	390	0	0	2	5	2	63
07/14	6.4 cm	140	0	0	0	0	0	16
07/14	10.3 cm	125	0	0	0	2	0	6
07/15	6.4 cm	120	0	0	0	0	0	4
07/15	10.3 cm	120	0	0	0	1	0	12
07/16	6.4 cm	125	0	0	0	0	0	7
07/16	10.3 cm	115	0	0	0	2	2	4
07/17	6.4 cm	115	0	0	0	0	0	3
07/17	10.3 cm	115	0	0	0	0	0	1
07/18	6.4 cm	190	0	0	0	0	0	5
07/18	10.3 cm	185	0	0	0	0	1	3
07/19	6.4 cm	240	0	0	0	0	0	12
07/19	10.3 cm	245	0	0	0	1	1	13
07/20	6.4 cm	210	0	0	0	0	0	6
07/20	10.3 cm	210	0	0	0	0	0	6
07/21	6.4 cm	340	0	0	0	0	0	5
07/21	10.3 cm	285	0	1	0	5	1	2
07/22	6.4 cm	165	0	0	0	0	0	29
07/22	10.3 cm	180	0	1	0	3	1	35
07/23	6.4 cm	203	0	0	0	0	0	22
07/23	10.3 cm	157	0	0	0	1	1	26
07/24	6.4 cm	175	0	0	0	0	1	24
07/24	10.3 cm	180	0	1	0	1	0	11
07/25	6.4 cm	280	0	0	0	0	0	28
07/25	10.3 cm	260	0	1	0	2	1	26
07/26	6.4 cm	146	0	0	0	0	0	55
07/26	10.3 cm	150	0	0	0	0	2	32
07/27	6.4 cm	125	0	0	0	0	0	20
07/27	10.3 cm	120	0	5	0	2	3	31
07/28	6.4 cm	120	0	0	0	0	0	14
07/28	10.3 cm	135	0	3	0	1	0	13
07/29	6.4 cm	150	0	0	0	1	0	18
07/29	10.3 cm	160	0	1	0	3	1	10
07/30	6.4 cm	170	0	0	0	0	0	12
07/30	10.3 cm	175	0	0	0	5	0	1
07/31	6.4 cm	190	0	0	0	0	0	13
07/31	10.3 cm	170	0	1	0	4	0	3
08/01	6.4 cm	121	0	0	0	1	0	15
08/01	10.3 cm	125	0	1	1	5	0	1
08/02	6.4 cm	148	0	0	0	1	0	6
08/02	10.3 cm	123	0	0	0	9	0	0
08/03	6.4 cm	170	0	0	0	0	0	3
08/03	10.3 cm	180	0	3	0	8	0	1
08/04	6.4 cm	135	0	1	0	1	0	17
08/04	10.3 cm	155	0	2	0	2	0	1
08/05	6.4 cm	210	0	2	0	0	0	16
08/05	10.3 cm	175	0	7	0	1	0	7
08/06	6.4 cm	210	0	0	0	0	0	20
08/06	10.3 cm	200	0	6	0	1	1	1
08/07	6.4 cm	180	0	1	0	0	0	27
08/07	10.3 cm	155	0	5	0	3	0	6
08/08	6.4 cm	255	0	0	0	0	0	13
08/08	10.3 cm	215	0	7	0	2	0	13
08/09	6.4 cm	175	0	1	0	0	0	4
08/09	10.3 cm	155	0	0	0	0	0	14
08/10	6.4 cm	85	0	0	0	1	0	4
08/10	10.3 cm	85	0	0	0	0	0	10
08/11	6.4 cm	90	0	0	0	0	0	7
08/11	10.3 cm	137	0	3	0	0	0	3
		=====	=====	=====	=====	=====	=====	======
		10804	0	53	3	74	20	813