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YUKON RIVER SONAR ESCAPEMENT ESTIMATE

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by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES[1]

[1] Appendices to this report have been compiled in a separate document (RIR 3A92-07).

ABSTRACT

The Yukon River sonar project has estimated daily upstream passage of chinook salmon *(Oncorhynchus tshawytscha)*, summer and fall chum salmon *(O. keta)*, and coho salmon *(O. kisutch)* since 1986. The project was operational in 1990 from 5 June through 4 September. Fish passage for each species was estimated by a two-component process: (1) estimation of total fish passage with single-beam sonar, and (2) estimation of species proportions by test-fishing with gill nets of six different mesh sizes. Species apportionment analytical procedures were modified in 1990 to use data from more nets per species. Improved net selectivity curves were developed which enabled use of data from both gilled and tangled fish. Variance estimates for seasonal passage numbers were also developed. A total of 1,696,586 ± 35,054 (s.e.) fish were estimated to have passed upstream through the sonar beams in 1990, 22% along the right bank and 78% along the left bank. Included were an estimated 98,101 ± 9,994 chinook salmon (excluding fish <700 mm long), 931,498 ± 33,234 summer-run chum salmon, 249,577 ± 10,656 fall-run chum salmon, and 77,316 ± 3,648 coho salmon. Bank-to-bank transects with downward-looking sonar were initiated in 1990 and the data used to estimate passage of fish offshore, beyond the range of the side-looking sonar, during August and September. Transect data suggest that an additional 504,744 ± 62,609 fish passed offshore beyond sonar range.

KEY WORDS: salmon, hydroacoustic, Yukon River, escapement, species apportionment, net selectivity

INTRODUCTION

Salmon (*Oncorhynchus* spp.) are harvested for both commercial and subsistence purposes over more than 1,600 km of the Yukon River in Alaska and Canada. Management of the fishery requires in-season knowledge of run strength and escapement levels. Such information is difficult to obtain in the Yukon River due to its large size, multiple channels, and highly turbid water.

Management of the fishery has been based on information obtained from several sources, each having unique strengths and weaknesses. Visual surveys of clear-water spawning tributaries provide stock-specific indices of escapement. These indices, however, are highly dependent on survey timing and spawner stream life, may not be representative of total system escapement levels, and most importantly are not available for in-season management use. Hydroacoustic estimates of salmon escapement in spawning tributaries have similar limitations for in-season management of Yukon drainage fisheries. Gill-net test fishery catches near the river mouth provide in-season indices of run-strength, but use of these data is confounded by gill net selectivity, changes in net site characteristics, and varying fish migration routes through the multichannel river mouth.

Hydroacoustic estimates of fish passage in the mainstem Yukon River complement information obtained from the sources mentioned above. The sonar is deployed at river km 197, above the unstable banks and multiple channels of the Yukon Delta, yet close enough to the mouth to provide timely and accurate escapement information. Salmon migrate from the mouth to the sonar site in approximately three days; and there is only one major spawning tributary (the Andreafsky River) below the sonar site.

The Yukon River sonar project has provided fishery managers with estimates of daily fish passage since 1986. The 1990 season focused on chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), and coho salmon (*O. kisutch*). Project objectives were (1) to provide daily and seasonal passage estimates for the three target species, and (2) to calculate the precision of such estimates.

METHODS

Hydroacoustic Sampling

Sample Design

Two sites were used for hydroacoustic (sonar) sampling, one on either bank of the river. The right (north) bank has a stable, rocky bottom with a steep, constant slope from shore. Two transducers, both deployed within 5 m of shore and sampling to a range of 86 m, were used on the right bank. One was aimed low along the river bottom and a second was aimed higher and covered much of the remaining water column. The left (south) bank is comprised of silt and sand, and contours can be quite dynamic, depending on hydrologic conditions. One near-shore and one off-shore transducer were deployed on the left bank due to a more complex bottom slope and a tendency for fish to migrate further from shore. The first transducer was deployed within 5 m of shore and the second near a break in the bottom slope; total range was 86 m to 155 m. Changeable bottom topography required that we occasionally relocate transducers to obtain an improved aim. Both left-bank beams were aimed along the bottom.

Sonar samples were collected during three sample periods beginning at 0600, 1400, and 2130 daily. Samples were 2.7 hours long and consisted of four 20-minute subsamples. On the left bank subsamples were collected alternately from each of the two strata (e.g., 0600-0620 onshore stratum, 0640-0700 offshore stratum, 0720-0740 onshore stratum, 0800-0820 offshore stratum, etc). On the right bank subsamples from both strata were collected concurrently during every other 20-minute time segment (e.g., 0600-0620 lower and upper, 0640-0700 lower and upper, 0720-0740 lower and upper, 0800-0820 lower and upper).

Equipment and Procedures

Shore-based Sonar. Echosounding and transducer remote aiming equipment, as well as procedures used in their operation, were identical to those used in 1989 (LaFlamme and Mesiar 1990).

Downward-looking Sonar. Bank-to-bank transects with a Lowrance X15 recording fathometer were initiated on 5 June to monitor the river channel for presence of fish outside of shore-based sonar range. Transects began and ended within 100 m upstream or downstream of the sonar transducers on either bank of the river; six to 12 transects were completed daily through 25 July. Transects were discontinued temporarily from 26 July to 12 August due to low fish passage between runs of summer and fall chum salmon. On 10 August sonar counts and test fishing CPUE fell off unexpectedly on the left bank. Bank-to-bank transects between 13 and 15 August revealed fish deflecting from a left-bank nearshore migration path to mid-river, apparently orienting to a sandbar that began approximately 2 km upstream and ended about 100 m downstream from the transducer locations. In response, we resumed bank-to-bank transects on 15 August (two sets of six transects daily), and used the data to estimate the proportion of fish travelling outside the range of the shore-based sonar beams.

Analytical Methods

Direction of Travel. Detected targets appear as dark traces on the paper output of the EPC and Biosonics chart recorders. Since most targets travel roughly parallel to the bank, and transducer beams were aimed slightly downstream, targets changed in range (distance from the sonar transducer) over time, i.e., the traces were slanted on the chart paper. Assuming that travel was approximately parallel to the bank, angle of the trace was diagnostic of direction of travel. Targets changing from long range to short range were classified as upstream-bound and targets changing from short to long range as downstream-bound. Targets which did not change in range were classified as having an unknown direction of travel. Targets of each classification were counted for each of five range intervals (sectors) in a stratum (beam). Downstream oriented targets were assumed to be primarily debris and were not included in daily fish passage estimates. A fraction of targets with unknown orientation were added to the upstream targets, based on the relative proportion of upstream and downstream targets in that sector during that 20-minute sample, i.e.,

$$n_{(i,j)}=u_{(i,j)}+\frac{u_{(i,j)}}{u_{(i,j)}+d_{(i,j)}}z_{(i,j)} \tag{1}$$

where: n= net number of upstream oriented targets
u= upstream oriented targets
d= downstream oriented targets (assumed debris)
z= targets with unknown orientation
i= stratum
j= sector

Spatial Expansion. The shore-based sonar system does not ensonify the entire water column on either bank, and from 1986 to 1989, sonar passage estimates for the right bank upper stratum were expanded to account for the un-ensonified zone. Expansion factors were calculated by sector, based on the ratio of total water column cross-sectional area to theoretical beam cross-sectional area (Laflamme and Mesiar 1990). We did not utilize such expansions for 1990 data because the following two required assumptions do not hold: (1) that the sonar beams are conical and their exact dimensions are known, and (2) that fish distribution is uniform, or at least equally dense inside and outside of the beam. Recent studies of sonar signal attenuation at 420 kHz (Skvorc in prep.) have indicated that beam shape is not conical. Furthermore, the second assumption has not been tested and now seems implausible.

Temporal Expansion. Target counts for each range sector were converted to sector passage rates (fish per hour) by dividing by count duration (e.g., 20 minutes = 1/3 hour). These sector passage rates were then summed by transducer and the resulting transducer passage rates (one for each of 4 samples) were averaged for each 2.7 hour sonar period (Appendix A). The period passage rates for transducers 1 and 2 were summed for the right bank and rates for transducers 3 and 4 summed for the left bank. Finally, these bank passage rates were averaged over the three sonar periods per day and multiplied by 24 hours/day to yield estimates of daily fish passage by bank.

Missing Data. Equipment malfunction, severe wave action, or the need to re-deploy transducers occasionally resulted in missing sonar data. When individual subsamples within a sonar period were missed (<5% of all periods), fish passage was simply estimated based on existing subsamples for that period. When one or two complete periods were missed on a stratum (once on each stratum, on 4 July), we substituted interpolated values, i.e., the average of passage estimates for the periods preceding and following the missing period(s). No complete days of hydroacoustic sampling (on all strata) were missed during the 1990 season.

Offshore Fish Passage. Transect chart recordings were digitized to record the relative locations of targets, left and right banks, and deepest point of the river channel. From this information, depth and distance from shore were calculated for each target. The diameter of the fathometer beam was assumed to increase linearly with range (depth), causing deep targets to have a higher probability of detection than shallow targets. Therefore, to correct for unequal detection probability, we weighted individual targets by the inverse of their depth.

Targets were classified into two categories: those which were within the range of the shore-based sonar and those which were not. Daily numbers of targets (weighted by 1/depth) were summed by category and by bank. We chose the top of the sandbar (352 meters from the right bank) as the boundary between left and right banks in 1990. The width of the (frozen) river (970 m) at the sonar site was measured directly on 5 December 1991. The ratio of (1) targets beyond sonar range to (2) targets within sonar range was multiplied by the corresponding daily estimate of onshore fish passage to obtain an estimate of offshore passage (Appendix B). Test-netting results from the sonar site and from the river mouth indicated that fish began migrating offshore on approximately 10 August. Therefore offshore-to-onshore ratios derived from 15-18 August transect data were applied retroactively to sonar counts from 10 to 14 August.

Equipment and Procedures

Gill nets were drifted through or near the sonar range on each bank to estimate species composition of upstream-bound fish. Because of the size selectivity of gill nets, six different mesh sizes were utilized over the course of the season: 8.5" (216 mm), 7.5" (191 mm), 6.5" (165 mm), 5.5" (140 mm), 5" (127 mm) and 4" (102 mm). All nets were 25 fathoms (45.7 m) long and 7.6 meters deep; and were constructed of Momoi MTC-50 multifilament nylon twine.

Gill-netting took place during two sample periods daily, usually at 0900-1200 and 1700-2000 hours. During each sample period, three or four nets were drifted once or twice per bank for a total of 16 to 24 drifts per day. All drifts with one net were completed before switching to the next net; drifts were done on alternate banks so there were a minimum of 20 minutes between drifts on a given bank. From 6 June through 25 July, 7.5" and 8.5" nets were drifted twice per bank during each period (total 16 drifts/day), and the remaining mesh sizes were each drifted once per bank during one period (total 8 drifts/day). After 25 July, when chinook salmon were no longer present, 7.5" and 8.5" nets were omitted, and the 5.5" and 6.5" nets were drifted twice per bank per period. Four and five inch nets were drifted twice per bank on alternate periods in a day.

Four times were recorded for each drift: net start out (net starting out of boat, SO), net full out (FO), net start in (SI), and net full in (FI). Drift time was calculated as (FO-SO)/2 + (SI-FO) + (FI-SI)/2. Drifts were targeted to be 8-10 minutes in duration but were shortened when necessary to avoid snags or to limit catches during times of very high fish passage. Captured fish were identified to species and measured for length (salmon species mid-eye to tail fork, non-salmon species snout to tail fork).

Several modifications were made to test netting procedures during the 1990 season to better fit fishing conditions and fish behavior. From 19 July to 12 August, additional drifts ("beachwalks") with 4" and 5" mesh were made close to shore to monitor fish passage in the first range sector.

One end of the net was controlled from a boat, while a technician walked the other end along shore.

Beginning in mid-August, bank-to-bank transects showed substantial fish passage offshore, and test-net catches were unusually low at the sonar site on the left bank. Beginning 10 August, as discussed above, transect data were used to estimate offshore fish abundance. On 11 August the left bank test-netting site was moved approximately 0.5 km downstream, below the terminus of the Atchuelingok bar, in hopes of better sampling fish that had moved far offshore by the time they reached the sonar site. Test-net catches increased immediately upon moving downstream and the new site was used for the remainder of the season.

Analytical Methods

Species proportions were derived from testfishing data based on relative catch-per-unit-effort (CPUE), under the premise that catches of each species are proportional to their relative abundance. However gill nets are size-selective, i.e., they capture efficiently only those fish within relatively narrow size ranges. 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 gill net data.

Gill-Net Selectivity. Net selectivity 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. Two methods were utilized: that of McCombie and Fry (1960) for chinook and chum salmon, and that of Holt (Peterson 1966) for coho salmon, pink salmon *(Oncorhynchus gorbuscha)*, and whitefish *(Coregonus nasus* and *C. pidchian)*. Both are based on comparison of numbers of fish caught in different mesh sizes, within length classes. The McCombie and Fry method utilizes data from many mesh sizes and makes no assumptions about curve shape. The Holt method, which assumes that selectivity curves are normal with equal variance, was used when there were inadequate numbers of mesh sizes to utilize the McCombie and Fry method. Holt selectivity curves were truncated for length classes in which the data did not appear to conform to the assumption of normality. Resulting curves are shown in Figure 1.

Species Proportions. Relative CPUE, adjusted for net selectivity, was used to calculate daily species proportions. Adjusted CPUE (defined below) was calculated by 20 mm length class, then length class CPUE's were summed for each species. Summed CPUE for a given species, divided by the total CPUE for all species, was used as the estimated proportion of that species for the day.

Adjusted CPUE for a given length class was calculated as adjusted catch, divided by effort (fathom-hours) expended in catching that length class (Figure 2). 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.

From one to four mesh sizes were used to estimate the abundance of each species (Table 1). Data from fish with unknown probability of capture (size outside the range of estimated selectivity curves) were discarded as anomalous; however few fish (8%) fell into this category. We lacked selectivity estimates for sheefish *(Stenodus leucichthys)*, cisco *(Coregonus sardinella* and *C. laurettae)*, and other minor species (totalling 5% of all fish caught). If we opted to make no selectivity adjustments for these species, their relative abundance would be underestimated since catches of other species were multiplied by adjustment factors greater than one. So instead, we calculated the mean adjustment factor for species with selectivity curves, and multiplied it (1.44) by all catches of species without curves, regardless of length.

Missing Data. When test-net data were insufficient to estimate species proportions or variances, data were pooled for two or more consecutive days to generate the required estimates (9-10 June, 12-13 June, 4-5 July, 8-10 July, 13-14 July, 19-20 July, 28-29 July, 1-3 August, 9-10 August, 17-18 August, 1-2 September, 3-4 September).

Daily Fish Passage. Daily estimates of fish passage, by species and by bank, were obtained by multiplying total fish passage by estimated species proportions. Left and right bank species passage estimates were then added to obtain daily (within-sonar-range) species passage estimates.

Beginning 7 July, non-target species pink salmon and whitefish became abundant on the left bank near shore to the apparent exclusion of larger salmon. From this day forward, sonar counts in stratum 3, sector 1 (0 to 19 meters from the left bank) were excluded when calculating daily fish passage. Similarly, catches from left bank beachwalks (see METHODS, p. 6), initiated on 7 July to monitor nearshore species composition, were excluded when calculating species proportions for the left bank.

Estimates of offshore fish passage (beyond the range of the sonar) were not apportioned to species in 1990.

Variance Estimation

As detailed above, estimates of daily passage by species were generated by multiplying estimates of (1) fish passage through the sonar beams by (2) species proportions derived from test gill-netting. From 10 August to 4 September, we also estimated (3) the ratio of offshore to onshore fish, using bank-to-bank transect data. All three of the above estimates are subject to sampling error. To estimate the variance of daily onshore species passage estimates [product of (1) and (2)], and the variance of offshore passage estimates [product of (1) and (3)], we first estimated the variance of each individual component.

Fish Passage Through Sonar Beams

Sonar sampling periods, each 2.7 hours long, were obtained at regular (systematic) intervals of 8 hours. Treating the systematically sampled sonar counts as a simple random sample would overestimate the variance of the total, since sonar counts were highly autocorrelated (Wolter 1985). Brannian (1986) recommended the following variance estimator (Equation 2, modified from Wolter 1985), based on squared differences of successive observations and roughly equivalent to stratifying the season into 16-hour blocks.

$$\textit{Total fish passage } (\hat{Y}_i):\quad v\hat{a}r(\hat{Y}_i) = e_t^2 \frac{1-f}{n_1} \sum_{j=2}^{n_1} \frac{(\hat{y}_{ij}-\hat{y}_{i,j-1})^2}{2(n_1-1)} \quad (2)$$

where: $\hat{Y}_i$ = estimated number of fish (all species) passing sonar site during day i

$\hat{y}_{ij}$ = estimated number of fish passing sonar site during 2.7 hour sampling period j

f = primary stage sampling fraction = 2.7 hrs / 8 hrs = 0.33

n_1 = number of sampling periods per day (usually 3)

e_t = temporal expansion factor = 24 hrs / 2.7 hrs = 9.0

Species Proportions

Total fish passage was allocated to species by drifting a suite of gill nets twice daily (morning and evening) on each bank. Species proportions were estimated from relative daily CPUE (pooled for morning and evening drifts), after adjusting for the effects of gill net selectivity (Figure 3). In order to estimate variances of these proportions, we generated two replicate sets of species proportion estimates, one each for the morning and evening sets of drifts. Variance of the proportions were calculated after Cochran (1977:64), weighting each replicate by total (all species) CPUE (Equation 5).

where: $\hat{p}_i$ = estimated proportion of one species (e.g. chinook

$$\textit{Spp proportions } (\hat{p}_i)\text{:} \quad v\hat{a}r(\hat{p}_i) = \frac{1}{n_2}\sum_{k=1}^{n_2}\left(\frac{m_{ik}}{\overline{m}_i}\right)^2 \frac{(\hat{p}_{ik}-\hat{p}_i)^2}{n_2-1} \quad (3)$$

salmon) out of total fish passage during day i

n_2 = number of test-fish samples per day (usually 2)

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

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

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

Offshore to Onshore Ratios

Calculating the variance of offshore to onshore ratios parallels exactly that of species proportions. Two sets of transects were done daily and separate ratios were generated from each. Squared deviations from the pooled daily ratio were weighted by the number of targets within the beams for each transect set.

$$\textit{Offshore/onshore ratio } (\hat{r}_i)\text{:} \quad v\hat{a}r(\hat{r}_i) = \frac{1}{n_3}\sum_{l=1}^{n_3}\left(\frac{t_{il}}{\overline{t}_i}\right)^2 \frac{(\hat{r}_{il}-\hat{r}_i)^2}{n_3-1} \quad (4)$$

where: $\hat{r}_i$ = estimated ratio of offshore to onshore targets on day i

n_3 = number of transect sets per day (usually 2)

t_{il} = number of targets within sonar range during transect set l of day i

$\overline{t}_i$ = mean number of targets within sonar range on day i

$\hat{r}_{il}$ = estimated offshore:onshore ratio during transect set l of day i

Species Passage Estimates

Sonar-derived estimates of total fish passage were largely independent of gillnet-derived estimates of species proportions. Therefore we calculated the variance of their product (daily onshore species passage estimates) after Goodman's (1960) formula for variance of the product of two independent random variables (Equation 5).

$$\textbf{\textit{Species passage}} \quad (\hat{z}_i = \hat{Y}_i * \hat{p}_i)$$

$$\hat{var}(\hat{z}_i) = \hat{Y}_i^2 \hat{var}(\hat{p}_i) + \hat{p}_i^2 \hat{var}(\hat{Y}_i) - \hat{var}(\hat{Y}_i)\hat{var}(\hat{p}_i) \quad (5)$$

where: $\hat{z}_i$ = estimated passage of one species during day i.

Finally, daily variance estimates for the two banks were added and then summed over the season. Coefficients of variation were calculated in the customary way (square root of the variance divided by the point estimate).

Offshore passage estimates (10 August - 4 September) were the product of onshore sonar counts and offshore-to-onshore ratios. Variance of these estimates was calculated by applying Goodman's (1960) method in the same fashion as above (Eq. 5), except that the offshore-to-onshore ratio $\mathbf{r}_i$ was substituted for species proportions $\mathbf{p}_i$.

We developed SAS program code (Appendix F) to calculate passage estimates and their variances. Rbase for DOS was used for data entry, storage, and retrieval.

RESULTS

We operated the sonar project from 5 June through 4 September in 1990. Excluding the first sector (0-19 m range) of the left bank nearshore stratum after 6 July, an estimated 1,696,586 ± 35,054 (s.e.) fish passed upstream through the sonar beams during this period, 1,318,612 ± 34,529 (78%) along the left bank and 377,975 ± 6,043 (22%) along the right bank. Bank-to-bank transect data indicated that an additional 504,744 ± 62,609 fish passed beyond the range of the sonar from 10 August through 4 September (Appendix C). Distribution of fish among the two banks and the offshore zone (≥10 August) varied considerably over the season (Figure 3).

We captured 8,776 fish during 2,016 drifts with gill nets (total 14,311 minutes fished) during the season, including 4,914 fish in 1,042 drifts on the right bank and 3,862 fish in 974 drifts on the left bank. The catch included 5,067 chum salmon, 926 chinook salmon, 1,272 coho salmon, 512 pink salmon, 52 sheefish, 319 whitefish, and 39 cisco (Appendix D).

Total upstream fish passage within the sonar beams was comprised of an estimated 156,028 chinook salmon, 1,181,075 chum salmon, 77,316 ± 3,648 (s.e.) coho salmon, and 282,167 fish of other species. Chinook salmon were comprised of 98,101 ± 9,994 fish greater than 700 mm in length, and 57,927 ± 5,257 "jacks" shorter than 700 mm. Most (931,498 ± 33,234) of the chum salmon passed during the early "summer" season (through 18 July); the remainder (249,577 ± 10,656) passed during the late "fall" season (19 July and after). The additional 504,744 ± 62,609 fish which passed offshore after 9 August were of unknown species composition. Chinook salmon passage peaked on 7 July (10,152), chum salmon on 19 June (70,781), and coho salmon on 23 August (6,664)(Figure 4).

DISCUSSION

Hydroacoustic Sampling

The Yukon River's changing morphology resulted in increased logistic difficulties associated with hydroacoustic sampling on the left bank. The sampling site is now located immediately downstream from a bend in the river, just upriver from a point of land growing by sediment deposition. Current velocity decrease downstream of the point causes deposition of sediment and debris. The result in 1990 was a high number of man-hours spent relocating transducer tripods and uncovering buried transducer cables. Furthermore, fish may not travel parallel to the bank at the present site, compromising our ability to differentiate upstream- vs. downstream-bound fish (see METHODS).

The mid-river sandbar that is thought to have shifted fish migration offshore was probably caused by very low water level and flow rates in 1990. The sandbar consists largely of sediment transported by the Atchuelingok River, which empties into the Yukon River approximately one mile upstream of the sonar site. The sandbar extends downstream during the ice-free season, and has been detected upstream of the sonar site in previous years. It is thought that low flow rates in 1990 resulted in decreased sediment transport and the consequent extension of the Atchuelingok bar to a point approximately 100 m downstream from transducer sites (for the first time since the project's beginning). It appeared that fish orientation to the riverbanks became confused after reaching the bar; some fish remained oriented to the bank, others oriented to the bar, still others could be found in midstream. Bank-to-bank transect data collected during 15-17 August showed fish below the bar to be considerably more bank-oriented than fish in the stretch of water containing the bar and the sonar sites. The probability of the Atchuelingok bar reaching the sonar site in future seasons remains unknown; therefore bank-to-bank transects must be continued on a daily basis to monitor fish utilizing migration corridors outside of shore-based sonar beams (due to the reappearance of the Atchuelingok bar or other factors).

Consideration is now being given to relocating the left bank site. Relocation of the sonar site downstream approximately 500 m would allow more accurate estimation of fish passage due to less reliance on bank to bank transect data, and would at the same time minimize manpower demands in the future by avoiding the zone of sediment deposition. This solution would improve and simplify hydroacoustic sampling procedures while minimizing testfishing problems (discussed below).

Our daily estimates of the ratio of offshore (beyond sonar range) to onshore (within sonar range) fish varied considerably from 15 August to 4 September. While this may be simply a reflection of the spatial variability of the fall chum run, it may also have been influenced by some weaknesses of the technique itself. A problem with bank-to-bank transects to be addressed is the surface "dead range" of the down-looking transducer. In order to detect fish in the deep portions of the river channel, the gain (signal amplification) setting of the echosounder must be increased to a level at which the surface 1.5 - 2.5 m of the water column are sacrificed due to that portion of strip charts being "blacked out" by amplified acoustic noise. The extent to which fish avoid the downward-looking sonar beam due to boat noise is also unknown.

It will be difficult to improve the precision and accuracy of offshore passage estimates given our present technology. Four man-hours were required to complete two sets of six transects daily in 1990. Possible solutions to the acoustically noisy "dead range" include using transducers of lower frequency for bank-to-bank transects. No feasible means of eliminating boat avoidance are known at this time.

Species Apportionment

Analytical procedures used in-season changed substantially in 1990 from those used in previous years. Greater numbers of mesh sizes were used to estimate the abundance of each species, and new net selectivity estimates were generated using data from both gilled and tangled fish (see METHODS). Variance estimates were developed, and SAS programs (Appendix F1), rather than Lotus 123 worksheets, were used to calculate passage and variance estimates. Our new net selectivity estimates are improved over past years, yet are still based on the untested assumption that the peak capture efficiency is equal for all mesh sizes (Hamley 1975). At present, we know of no practical way to circumvent this assumption.

Consideration should be given at this time to the value of passage estimates for pink salmon and non-salmon species, groups not currently managed for in harvest regulations on the Yukon River. The chief advantage in not estimating passage of pink salmon and non-salmon species would be to logistically simplify both data collection and analytical procedures. Currently, weirs extending from the shore to transducer locations insure that fish traveling very close to the shore must travel through the sonar beams. On the left bank, very few fish traveling in the nearshore area are targeted salmon species (chum, coho, and chinook salmon). If passage estimates of pink salmon and non-salmon species were deemed unnecessary, the weir could be removed, allowing these species to travel closer to the bank, behind the transducers. Beachwalks could also be discontinued. That part of the most nearshore range sector still utilized primarily by pink salmon and non-salmon species could be filtered out at the echosounder to further eliminate counting non-targeted fish. A process similar to this (though more technically involved) is used on the Kenai River sonar project. Bank-oriented pink and sockeye salmon are filtered out of sonar counts because the target species (chinook salmon) is known to utilize the channel farther offshore than non-targeted salmon species. Periodic test-fishing behind and directly in front of the nearshore transducer would insure that significant numbers of targeted species were not missed because of this modification. On the right bank, fast current results in use of nearshore areas by all fish species, both targeted and non-targeted. An in-shore weir is needed to keep fish within the effective detection range of the transducer.

The submerged debris deposited on the left bank due to low current velocity in 1990 periodically made testfishing on that bank very difficult. Many man-hours were spent mending nets and dragging drift areas with cables to remove snags. With the appearance of the Atchuelingok bar in August, it was necessary to move the testfishing site on the left bank several hundred meters downstream in order to catch fish before they were partially deflected toward midstream by the bar. Relocating the left-bank site several hundred meters downstream to an area of higher current velocity, as discussed earlier, may alleviate these problems. This project generally tends to be very labor intensive, and manpower resources are often stretched to the limit. Any design simplification possible (while maintaining project integrity) will make future project management easier and more trouble-free.

We have no direct way to estimate the species composition of the 504,744 $\pm$ 62,609 fish estimated to have passed offshore between 10 August and 4 September 1990. However, during the following year offshore fish were predominantly chum salmon. In 1991, we drifted gillnets just offshore of the left bank sonar range and estimated that chum salmon comprised 84% of offshore fish, versus only 51% chum salmon nearshore (within sonar range) during the same period. Chum salmon comprised 56% of nearshore fish from 10 August to 4 September 1990. If chum salmon proportion was greater offshore than nearshore in 1990 as in 1991, then at least 0.56 X 505,000 = 283,000 chum salmon passed offshore in 1990.

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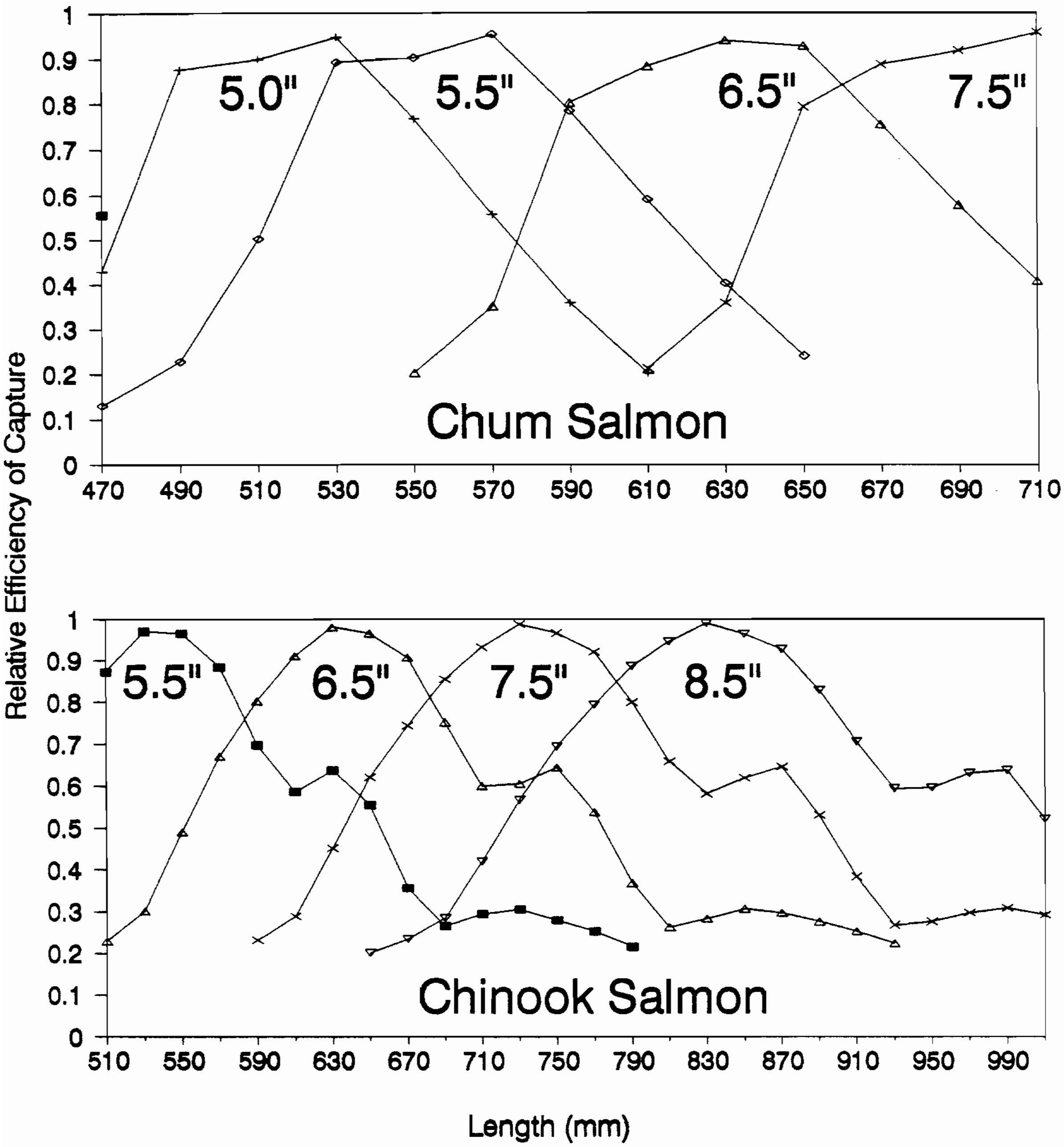

Figure 1a. Net selectivity curves used to adjust catches of chum salmon and chinook salmon for unequal probability of capture, Yukon River sonar, 1990.

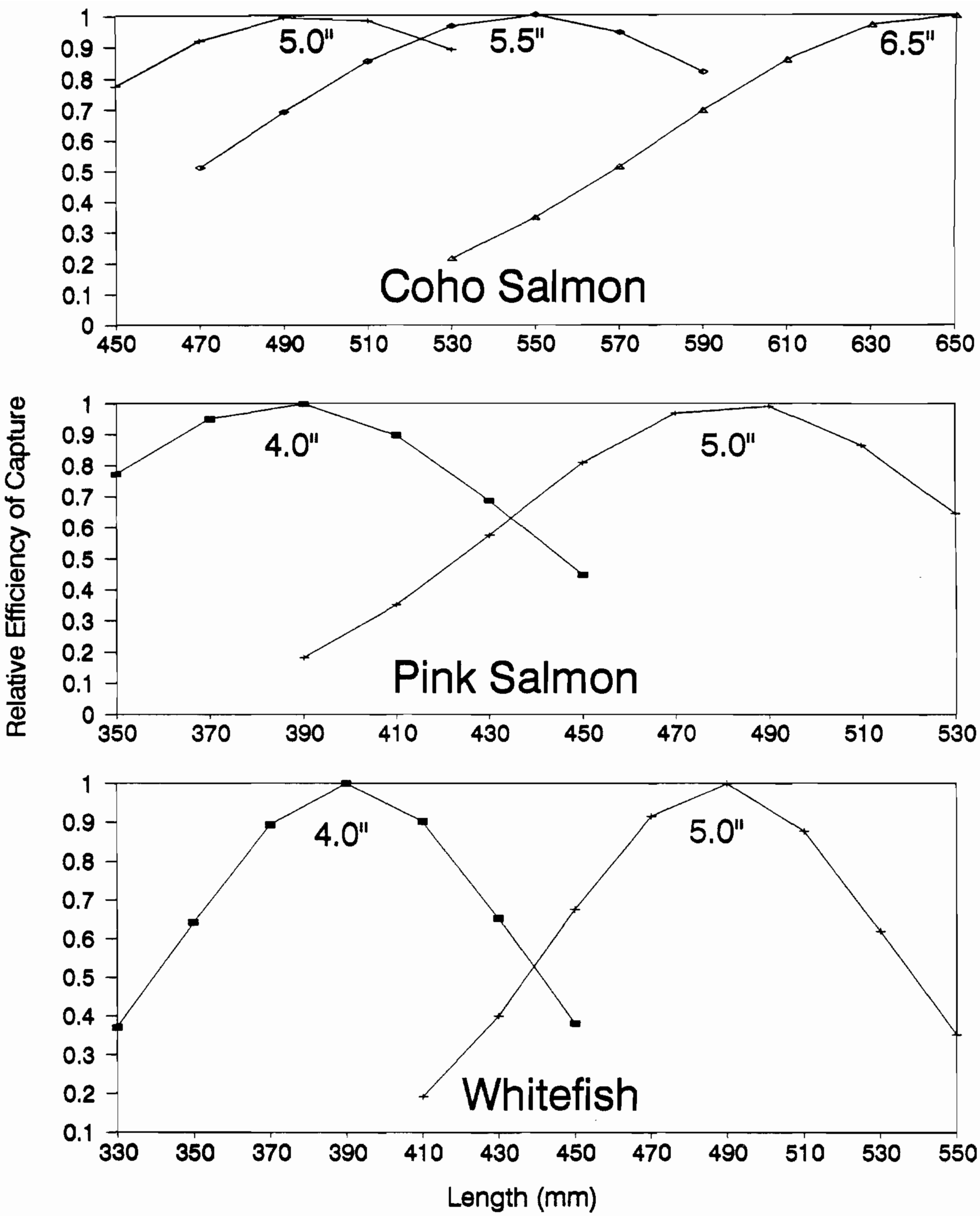

Figure 1b. Net selectivity curves used to adjust catches of coho salmon, pink salmon, and whitefish for unequal probability of capture, Yukon River sonar, 1990.

Table 1. Mesh sizes used to determine relative abundance of fish species present in the Yukon River 1990. Data from meshes with a "1" in the appropriate column were used to calculate relative CPUE for that species. Catches of species with "Y" in the last column were adjusted for net selectivity.

	4.0	5.0	5.5	6.5	7.5	8.5	ADJUST?
CHINOOK	0	0	1	1	1	1	Y
SCHUM[1]	0	1	1	1	1	0	Y
FCHUM[2]	0	1	1	1	1	0	Y
COHO	0	1	1	1	0	0	Y
PINK	1	1	0	0	0	0	Y
SHEEFISH	0	0	1	1	1	0	N
WHITE	1	1	0	0	0	0	Y
JACK	0	0	1	1	1	0	Y
OTHER	1	1	1	0	0	0	N
CISCO	1	0	0	0	0	0	N

(1) Summer-run chum salmon
(2) Fall-run chum salmon

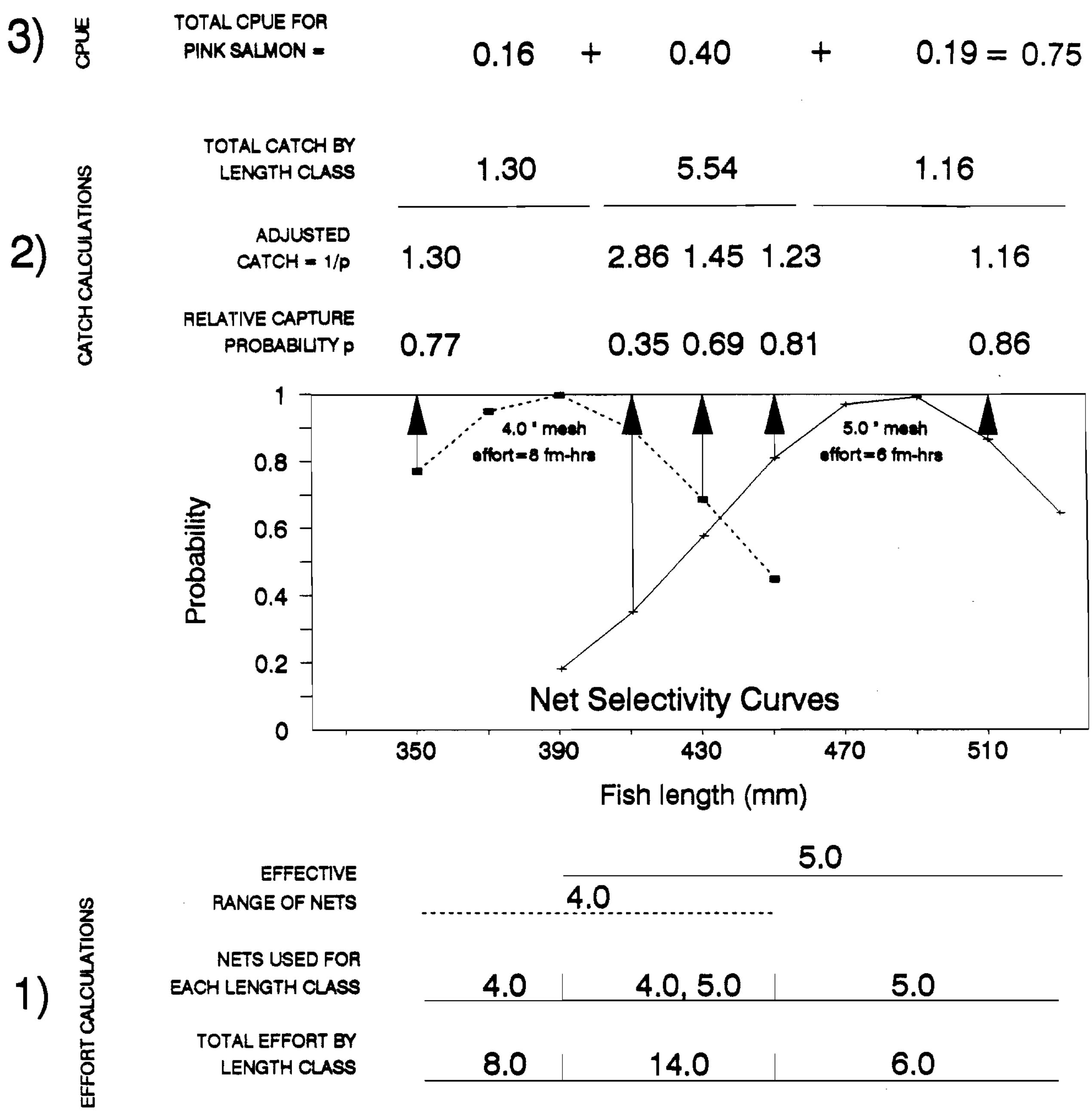

Figure 2. An example of how daily adjusted CPUE is calculated for one species (pink salmon). In this example two pink salmon (of lengths 350 mm and 430 mm) were caught in drifts with 4" mesh nets, and three pink salmon (410, 450, and 510 mm) were caught in 5" mesh nets. Total effort for 4" mesh nets 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.

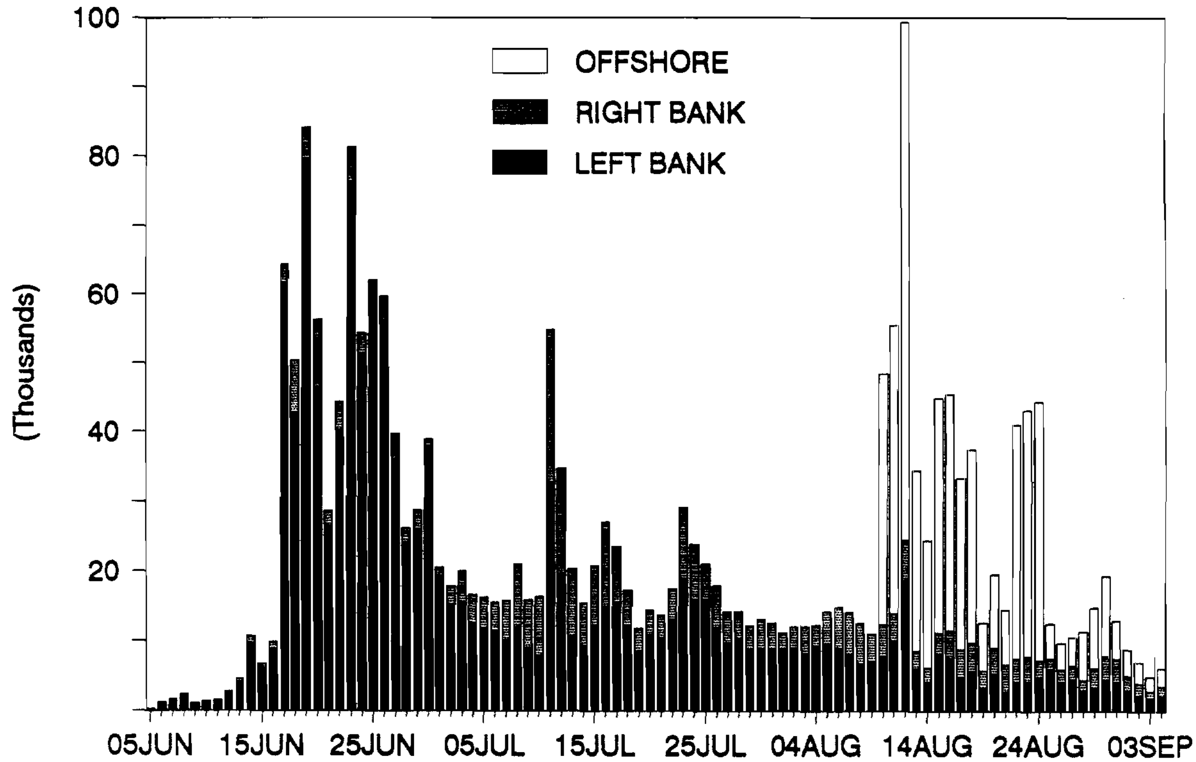

Figure 3. Estimated daily fish passage, by location, Yukon River 1990.

Table 2. Daily estimates of 1990 Yukon River onshore fish passage, by species, within range of the shore-based sonar; and offshore passage beyond sonar range (after 9 August).

DATE	ONSHORE TOTAL	CHINOOK	JACK	SCHUM	FCHUM	COHO	OTHER[1]	OFFSHORE TOTAL
05JUN	275	0	0	218	0	0	57	
06JUN	1,185	377	0	561	0	0	247	
07JUN	1,613	249	279	1,026	0	0	58	
08JUN	2,356	36	0	2,242	0	0	78	
09JUN	1,082	196	0	822	0	0	63	
10JUN	1,420	244	0	1,014	0	0	161	
11JUN	1,502	679	266	476	0	0	81	
12JUN	2,766	647	81	1,861	0	0	177	
13JUN	4,572	1,062	153	3,059	0	0	299	
14JUN	10,736	1,356	1,024	8,080	0	0	276	
15JUN	6,758	535	883	5,078	0	0	262	
16JUN	9,954	932	1,762	7,260	0	0	0	
17JUN	64,361	4,430	6,709	53,190	0	0	32	
18JUN	50,315	2,731	3,433	43,914	0	0	237	
19JUN	84,079	7,450	5,280	70,927	0	0	423	
20JUN	56,315	1,784	3,838	50,693	0	0	0	
21JUN	28,663	2,200	929	24,960	0	0	574	
22JUN	44,362	9,821	5,449	29,026	0	0	66	
23JUN	81,179	4,607	4,871	70,781	0	0	920	
24JUN	54,375	2,056	1,177	51,088	0	0	54	
25JUN	62,018	5,959	2,239	53,787	0	0	33	
26JUN	59,715	7,626	1,087	51,002	0	0	0	
27JUN	39,766	4,486	8,444	26,685	0	0	151	
28JUN	26,209	3,535	3,612	17,847	0	0	1,215	
29JUN	28,821	2,437	838	25,151	0	0	395	
30JUN	38,901	2,138	1,002	34,381	0	0	1,380	
01JUL	20,594	1,261	492	18,289	0	0	552	
02JUL	17,831	245	1,978	14,450	0	0	1,158	
03JUL	20,050	5,445	0	14,153	0	0	451	
04JUL	16,755	1,303	43	9,008	0	0	6,401	
05JUL	16,354	1,234	47	8,773	0	0	6,300	
06JUL	15,561	3,126	1,100	6,591	0	0	4,744	
07JUL	15,861	10,152	0	4,113	0	0	1,596	
08JUL	21,060	1,090	156	15,845	0	0	3,970	
09JUL	15,935	890	119	11,952	0	0	3,044	
10JUL	16,478	770	148	11,781	0	0	3,779	
11JUL	54,767	0	0	50,001	0	0	4,766	
12JUL	34,729	399	393	29,470	0	0	4,467	
13JUL	20,379	549	16	14,953	0	0	4,860	
14JUL	15,511	424	10	11,972	0	0	3,105	
15JUL	20,894	717	0	18,684	0	0	1,492	
16JUL	27,132	355	0	20,594	0	0	6,183	
17JUL	23,550	316	0	20,767	0	0	2,468	
18JUL	17,364	69	0	14,973	0	0	2,322	
19JUL	11,943	629	0	0	9,127	0	2,187	
20JUL	14,450	784	0	0	11,391	0	2,274	
21JUL	13,739	75	0	0	6,340	0	7,324	
22JUL	17,484	0	0	0	11,052	0	6,432	
23JUL	29,139	0	0	0	20,502	0	8,637	

(continued)

Table 2. p. 2 of 2.

DATE	ONSHORE TOTAL	CHINOOK	JACK	SCHUM	FCHUM	COHO	OTHER[1]	OFFSHORE TOTAL
24JUL	23,954	159	0	0	15,958	0	7,837	
25JUL	21,140	0	0	0	5,204	0	15,937	
26JUL	18,043	0	0	0	264	0	17,779	
27JUL	14,240	0	0	0	1,300	0	12,940	
28JUL	14,280	0	0	0	1,694	0	12,586	
29JUL	12,265	0	0	0	1,502	0	10,763	
30JUL	12,993	606	0	0	10,678	0	1,709	
31JUL	12,660	0	68	0	6,067	0	6,525	
01AUG	11,179	0	0	0	1,479	0	9,700	
02AUG	12,089	0	0	0	1,628	0	10,460	
03AUG	12,146	0	0	0	1,701	0	10,445	
04AUG	12,313	0	0	0	615	0	11,697	
05AUG	14,331	0	0	0	4,252	0	10,079	
06AUG	14,939	0	0	0	6,208	265	8,467	
07AUG	14,186	0	0	0	7,542	71	6,573	
08AUG	12,652	0	0	0	4,441	0	8,211	
09AUG	11,097	0	0	0	2,992	111	7,994	
10AUG	12,452	0	0	0	3,484	131	8,836	36,020
11AUG	13,944	0	0	0	12,258	146	1,540	41,525
12AUG	24,600	0	0	0	22,849	1,219	532	74,596
13AUG	8,675	0	0	0	7,457	1,218	0	25,815
14AUG	6,208	0	0	0	4,136	1,618	454	18,377
15AUG	11,222	0	0	0	10,536	686	0	33,572
16AUG	11,567	0	0	0	9,781	1,576	210	33,826
17AUG	8,748	0	0	0	4,789	3,959	0	24,588
18AUG	9,725	0	0	0	5,390	4,335	0	27,749
19AUG	5,737	0	0	0	2,922	2,672	143	6,899
20AUG	8,898	0	0	0	6,817	2,081	0	10,662
21AUG	6,469	0	0	0	3,407	2,701	361	7,940
22AUG	7,367	0	0	0	1,691	4,684	991	33,579
23AUG	7,734	0	0	0	1,071	6,664	0	35,340
24AUG	7,247	0	0	0	1,691	5,132	424	36,996
25AUG	7,435	0	0	0	1,395	6,040	0	5,030
26AUG	5,921	0	0	0	2,127	3,436	357	3,829
27AUG	6,452	0	0	0	1,781	4,613	58	4,116
28AUG	4,344	0	0	0	2,163	1,048	1,132	7,011
29AUG	6,129	0	0	0	2,835	2,884	410	8,707
30AUG	7,818	0	0	0	3,064	4,754	0	11,572
31AUG	7,312	0	0	0	1,084	5,542	686	5,546
01SEP	4,983	0	0	0	1,212	3,612	159	3,764
02SEP	3,958	0	0	0	966	2,865	127	2,988
03SEP	2,816	0	0	0	1,277	1,420	119	2,090
04SEP	3,466	0	0	0	1,457	1,833	175	2,607
	=======	=======	=======	=======	=======	=======	=======	=======
	1,696,586	98,101	57,927	931,498	249,577	77,316	282,167	504,744
S.E.	35,054	9,994	5,257	33,234	10,656	3,648		62,609
C.V.	0.02	0.10	0.09	0.04	0.04	0.05		0.12

(1) Estimates for other species do not include fish passing with 19 m of shore on left bank after 6 July.

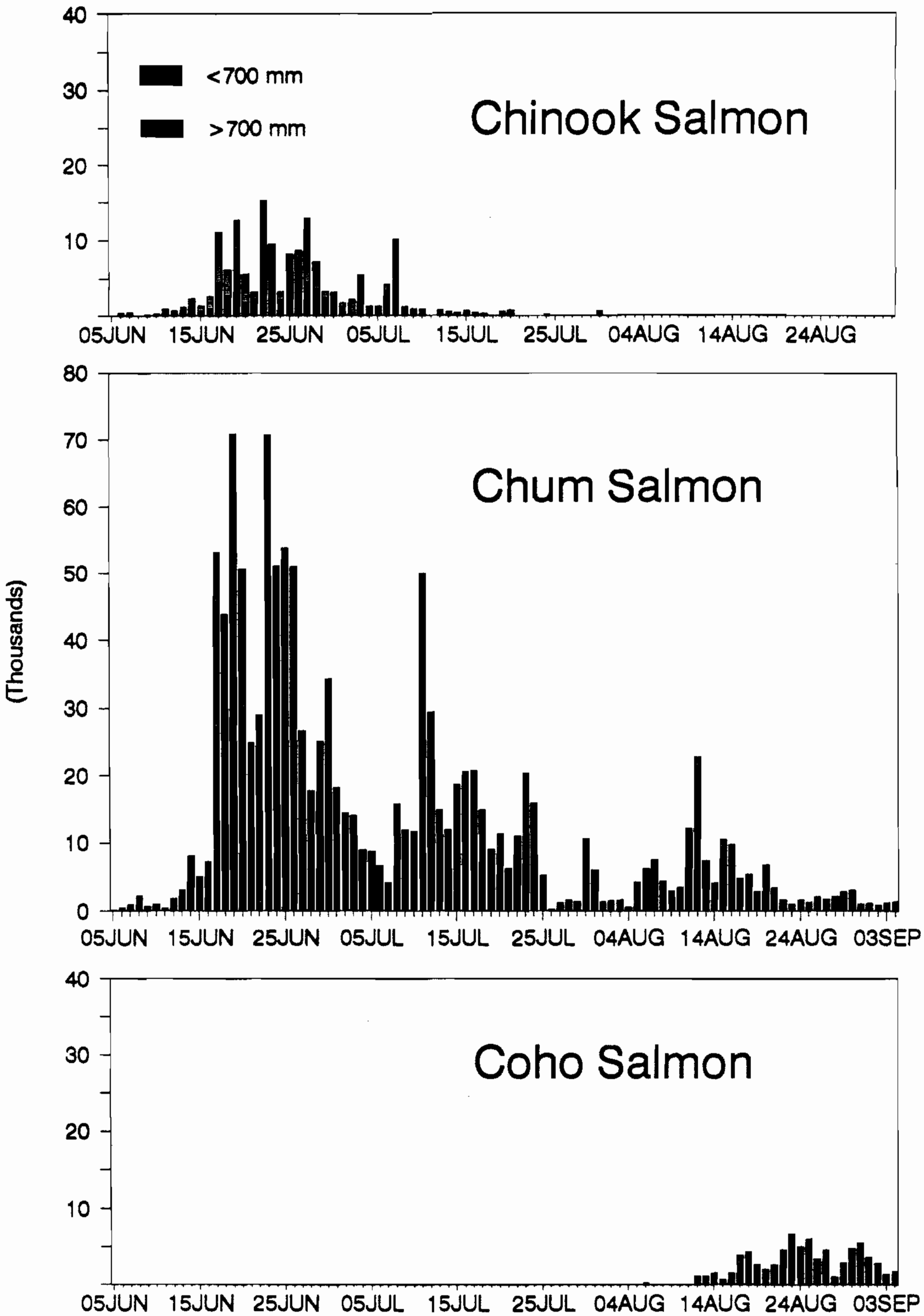

Figure 4. Estimated daily passage of chinook, chum, and coho salmon, Yukon River 1990.