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YUKON RIVER SONAR ESCAPEMENT ESTIMATE

1988

by

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ABSTRACT

The Yukon River sonar project was designed to provide estimates of daily escapement past lower-river commercial and subsistence fisheries for chinook, summer and fall chum, and coho salmon. The sampling site, located at river km 197, has been used for this purpose since 1985. Fish passage was estimated through temporal and spatial expansion of fish counts obtained through hydroacoustic gear deployed on both banks of the river between 2 June and 14 September 1988. A gill net test fishery sampled the migrant fish population to provide information on which to base apportionment of sonar counts to species. Six gill nets ranging from 101.6 to 215.9 mm stretched mesh were used to capture fish. Catches were adjusted for effort and were used to estimate species proportions. A total of 3,398,168 fish passed the sampling site; 70 percent traveled along the left bank while 30 percent traveled along the right bank. The program estimated passage of 80,791 chinook salmon, 1,870,406 summer chum salmon, 505,195 fall chum salmon, 265,740 coho salmon, and 538,036 pink salmon during the time period sampled. Peak passage occurred on 25 June, 20 June, 11 August, 17 August and 16 July for chinook, summer chum, fall chum, coho salmon, and pink salmon.

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

INTRODUCTION

Yukon River salmon stocks are harvested for both commercial and subsistence use. Although the most intense fishery occurs within 240 km of the river mouth, salmon stocks are exploited over more than 1,600 km of river in Alaska and Canada. Management of the fisheries resource requires timely knowledge of run strength and escapement levels. Such information, however, is difficult to obtain in the Yukon River due to its large size, multiple channels, and highly turbid water. Fishery managers therefore base their decisions on information obtained from several sources, each of which has unique strengths and weaknesses.

Visual surveys of distant clear-water spawning tributaries provide stock specific indices of escapement. These indices, however, are highly dependent upon survey timing and spawner stream life, may not be representative of system escapement levels, and are not available for in-season management use. Similarly, sonar estimates of salmon escapement in spawning tributaries are not timely enough to provide a basis for decision making, and only provide information for a single fish stock. Test fishery gill net indices obtained near the river mouth provide in-season information, but interpretation of this information is confounded by gill net selectivity, changes in net site characteristics, and inter-annual variability in fish migration paths through the three river mouth channels.

Estimation of fish passage in the mainstem Yukon River attempts to solve the problems associated with other abundance indexing and estimating methods. Location of the sonar sampling site at River km 197 limits the delay between the lowermost commercial fishery and the point of estimation to approximately three days migration time. Additionally, there is only one important spawning tributary (Andreafsky River) downstream from the sonar sampling site, making it possible to estimate the number of salmon returning to most of the Yukon River drainage.

The Yukon River sonar project has provided management with timely in-season run strength estimates since 1986. The 1988 field season focused on the following Pacific salmon species; chinook salmon *(Oncorhynchus tshawytscha)*, chum salmon *(O. keta)*, coho salmon *(O. kisutch)*, and pink salmon *(O. gorbuscha)*. Specific objectives of the project were as follows:

1. Estimate, by time period, the number of fish migrating past river km 197 through:
   a. estimation of the number of fish passing river km 197 between 2 June and 14 September and,
   b. estimation of the species composition of the fish using drift gill nets of several different mesh sizes.
2. Monitor migratory run timing of salmon.

Study Area Description

The Yukon River flows approximately 2415 km from its source in the Canadian Yukon Territory to its mouth in Norton Sound along Alaska's northwest coast. The lower 193 km consists of an extensive delta area with multiple channels and unstable banks. Near the village of Pilot Station (river km 196) the river narrows to a single channel with relatively stable banks. At river km 197 the river is approximately 670 m wide and reaches a maximum depth of 27 m. The combination of physical conditions including a single channel, stable river banks, relatively narrow channel width, high water velocity, and proximity to lower river fisheries resulted in the choice of this location for deployment and operation of hydroacoustic equipment in 1983 (Mesiar et al., 1986), and continued use through 1988.

Two sites, one on the left bank and one on the right bank, were used in 1988 (Figure 1). The left bank is comprised of silt and sand. Bottom contour and stability vary with hydrologic conditions; high flow rates cause dramatic changes in bottom profile over short periods of time. The right bank is comprised of gravel and cobble and remains extremely stable throughout the season.

METHODS

There are two fundamental components of fish passage estimation in locations of temporally mixed species. First is estimation of the total number of fish passing the sampling site. Second is determination of species composition of the fish.

Hydroacoustic Counting

Sampling Design

The sampling design used in 1988 followed that used in previous years and documented by Mesiar et al. (1986). Experience at the sonar site has demonstrated that fish travel within 100 m of shore on the left bank and within 50 m of shore on the right bank (Nickerson and Gaudet 1985; Mesiar et al. 1986). Spatial stratification for hydroacoustic sampling was based on this knowledge as well as on knowledge of river bottom characteristics on each bank.

The left bank bottom varies within a season due to changing hydrologic conditions and silt/sand composition. As in the past, two strata, near-shore and off-shore, were ensonified due to offshore fish distribution and irregularities of the river bottom profile (Figure 2). The near-shore stratum encompassed the area from the shoreline to the break in the slope, and the off-shore stratum continued from that point to a distance of 96 m for a total range of approximately 160 m. The shallow bottom gradient, transducer beam dimensions, and fish orientation to the river bottom eliminated the need for sampling separate bottom and surface strata.

The right bank is characterized by a fairly even, stable bottom with a steep gradient (Figure 2). The lack of large bottom irregularities allows deployment of one system with two transducers to ensonify the horizontal distance necessary for detection of all migrant fish. The steep gradient requires separation of the water column into two discrete strata. The bottom stratum grazes the river bottom from shore to 96 m range and conforms to the dimensions of the acoustic beam. The surface stratum includes the remaining portion of the water column.

Based on prior analysis of the coefficient of variation of fish counts in sample intervals of five to 60 minutes (incremented by five minute steps) (Nickerson and Gaudet, 1985) a sample interval of 20 minutes was used in 1988. Sampling frequency was determined by the level of precision and accuracy deemed acceptable by fishery managers. A total of 12 sample intervals for each of the four strata are required to estimate fish passage p_i with accuracy d=0.1 and precision (α) of a one in ten chance of missing the interval $p_i \pm d$.

Each of the four strata was ensonified for four 20-minute intervals during each of three 3.5-hour time periods within each 24-hour day. The 3.5-hour time periods were 0600 to 0930 hours, 1330 to 1700 hours, and 2030 to 0000 hours.

Equipment and Procedures

Similar hydroacoustic equipment complements were used on each bank of the river. A 420 Khz Biosonics transceiver, one 4°x15° elliptical-beam transducer (nearshore) and one 6° circular-beam transducer (offshore) were used on the left bank. On the right bank, a 420 Khz Biosonics transceiver activated two 4°x15° elliptical-beam transducers (surface and bottom) with alternate pings through a Biosonics model 151 multiplexer. The transceiver emitted eight pings sec^{-1} for both right bank strata and for the left bank nearshore stratum. Four pings sec^{-1} were emitted during left bank offshore sampling. The pulse width on both left and right banks was 0.4 ms.

Transducers were attached to a tripod-mounted pan and tilt unit which allowed remote aiming, or to a stationary, manually positioned tripod used in shallow water conditions. All transducers were aimed approximately 15 degrees downstream to facilitate determination of target direction using change-in-range techniques (Appendix 1). Both sites included in-shore weirs downstream of the nearshore transducers. These were designed to deflect nearshore migrants through the acoustic beam. The right bank site also included a boom log positioned above the transducer to deflect debris.

Detected targets having voltage levels higher than a pre-set threshold level, (based on the smallest sized fish to be detected), were displayed on EPC model 3200 chart recorders. Targets appeared as dark traces within any of five range intervals on the chart recording paper. Technicians initiated sampling sequences and monitored chart recorder output.

Optimal positioning of transducers as well as spatial expansion of hydroacoustic data requires knowledge of river bottom contours. River bottom profiles (depth at distance from a reference stake) were obtained each day on the left bank, and once per week on the right bank. Both formal and informal bottom profiles were measured. Formal profiles, used for spatial expansion, were measured for each change of transducer position. One end of a 100 m fiberglass tape was held at the reference stake while the other end was carried out into the river in a boat. At three m range intervals a mark was made on a Lowrance X15 recording fathometer. The resultant depth/distance points comprised the bottom profile used for spatial expansion. Since spatial expansion of the data is dependant upon river cross sectional area, which varies with water depth, a reference depth was measured when the season's first bottom profiles were obtained, and water depth relative to that reference was measured and recorded each day.

Informal bottom profiles were also recorded with a Lowrance X15 fathometer, but distance from shore was not accurately measured as the recordings served only to give an impression of river bottom slope and irregularity for optimal transducer placement. A series of up to eight left bank bottom profiles obtained at 25 m intervals along a 200 m section of shoreline was evaluated each day to determine location of the bottom conditions most conducive to detection of fish with sonar. If the site in use at the time of bottom profile evaluation was not the most favorable, transducer repositioning to the best location was scheduled and completed within eight hours. Transducer movement at a particular site, which coincided with change in water level, was measured relative to the reference stake used for bottom profile measurement.

Analytical Methods

Technicians monitored chart recorder output during each 20 minute sample interval, classifying and counting detected targets in each of the five range intervals (sectors) in a stratum. Targets were categorized as one of the following: 1) upstream directed and assumed to be fish (u); 2) downstream directed and assumed to be debris (d); or 3) direction unknown (z). The number of upstream targets in each sector and sample interval was increased by a proportion of the targets of unknown direction resulting in the net number of upstream directed targets (n). The increase was determined from the ratio of upstream targets to all targets of known direction (u+d), or:

$$n_{i,j}=u_{i,j}+\left[\frac{u_{i,j}}{u_{i,j}+d_{i,j}}\,(z_{i,j})\right]$$

Each day the net number of upstream-directed targets in each beam sector and stratum was expanded to portions of day and areas of the beam not counted. Methods of spatial and temporal expansion are detailed in the following two sections.

Spatial Expansion. Total ensonification of the water column was not possible on the right bank. To expand net upstream fish counts for areas of the water column not sampled, beam characteristics and water cross-sectional area were quantified. For each range sector (i) of the beam in stratum k, area expansion factors were expressed as the ratio of water cross-sectional area to beam cross-sectional area. Area in each sector of the beam was calculated as $a_{i,k}$:

$$a_{i,k}=\left[\left((0.5)\,(r_{i,k}^{2})\right)\frac{b\pi}{180}\right]-\left[\left((0.5)\,(r_{i-1,k}^{2})\right)\frac{b\pi}{180}\right]$$

where: $a_{i,k}$ = area (m^2) within sector i and stratum k.

$r_{i,k}$ = distance (m) from transducer to the outer edge of sector i in stratum k.

b = beam width (degrees).

River cross-sectional areas were estimated using measurements of water level and transducer position relative to a fixed reference point, river bottom profiles, and hydroacoustic beam range. These methods are more readily visualized with the aid of the drawing presented in Figure 3. Beginning and ending ranges relative to the reference stake were calculated for each sector of the beam in a stratum. Water depths at each range were obtained from a bottom profile and were adjusted for changes in water level occurring since bottom profile measurement. Sonar beam width at range defined the upper corners of the bottom stratum, and this area was calculated as the sum of the areas of a rectangle and two right triangles. The surface stratum area for sector i was then derived as the area defined by the range beginning and end points and the two upper corners of the bottom stratum (the sum of areas of a rectangle and a right triangle). Count expansion required defining the following parameters for each of the three hydroacoustic beams used:

R_i = River cross-sectional area in sector i.
S_i = Surface stratum cross-sectional area in sector i.

B_i = Bottom stratum cross-sectional area in sector i.
s_i = starting range in sector i.
e_i = ending range in sector i.
f_i = starting depth of the bottom stratum in sector i.
g_i = ending depth of the bottom stratum in sector i.
h_i = starting depth of the surface stratum in sector i.
m_i = ending depth of the surface stratum in sector i.
t_k = relative transducer position in location k.
b = beam width in degrees.

Then:

$$R_i=0.5(e_i-s_i)(g_i+f_i)$$

$$S_i=0.5(e_i-s_i)(m_i+h_i)$$

$$B_i=\left(\frac{\tan b}{360}\right)(e_i-s_i)((e_i-t)+(s_i-t))$$

Temporal Expansion. The spatially expanded daily net number of upstream moving targets for each sector ($n_{i,d}^{exp}$) was divided by the proportion of the time period sampled to estimate $N_{i,d}$, the temporally and spatially expanded estimate of the number of fish in sector i on day d.

$$N_{i,d}=n_{i,d}^{exp}\frac{(24)(60)}{t_{i,d}}$$

where: $N_{i,d}$ = estimated fish passage in sector i on day d

$n_{i,d}^{exp}$ = net number of upstream targets in sector i on day d expanded for areas not sampled

$t_{i,d}$ = time (minutes) sampled in sector i on day d

Implicit in expanding the number of targets is the assumption that fish are uniformly distributed within the area or time strata being expanded.

Estimation of Missing Data. Fish passage estimates for days on which no sampling occurred was accomplished with a model developed using standard correlation analysis. Left bank fish count data were examined to determine the level of correlation with left and right bank gill net CPUE and with right bank fish count data. Data were stratified temporally to correspond with known changes in species composition. A modification in drifting technique, described below, allowed a more direct comparison between the drift CPUE indices and sonar count estimates.

Species Allocation

Sampling Design

Perhaps the most difficult component of the escapement estimation program is the allocation of sonar counts to species. The presence of migratory and resident species, with similar migratory timing and behavior and different sizes and body shapes, are primary causes of difficulty in estimation of species proportions. Gill nets are the most appropriate sampling tool available in this environment because they will capture all salmon species present and can be deployed in the spatial strata that are sampled hydroacoustically. The breadth of the size distribution of fish in the river, however, is greater than the breadth of fish sizes that may be effectively captured in any one mesh size of gill net. Therefore, it is necessary to use a suite of mesh sizes to sample the fish population.

For each fish species or similarly-sized species group encountered in the Yukon we chose two gill net mesh sizes which together would effectively capture fish throughout the entire range of previously documented lengths. Thus, two mesh sizes fished for chinook salmon, two mesh sizes fished for chum and coho salmon, and two mesh sizes fished for pink salmon, whitefish, and other species.

Since species composition varies between river banks, a stratified systematic sampling design was employed with left and right bank strata. Waters along each bank were sampled between 1000 and 1300 and between 1700 and 2000 hours each day. Time periods for allocation purposes were based on catch of 120 fish of 300 mm or greater length. Sample size was determined from multinomial proportions estimation theory (Thompson 1987) for accuracy (d) of 0.1 and precision (α) of a one-in-ten chance of not having the correct species proportion (p_i) within the interval $p_i \pm d$ for all i categories, where i equals three categories of fish present in the river at a given point in the salmon migration.

Equipment and Procedures

Six gill nets measuring 45.7 m (150 ft) long and 7.6 m (25 ft) deep were used for test fishing. Mesh sizes (stretched) were 101.6 mm (4.0 in), 127.0 mm (5.0 in), 139.7 mm (5.5 in), 165.1 mm (6.5 in), 190.5 mm (7.5 in), and 215.9 mm (8.5 in). Drifts of approximately 10 minutes duration were made alternately along left and right banks. Care was taken to maintain similar effort among mesh sizes. Gill nets were drifted through the same areas on each bank throughout the season. Reduced water levels, however, resulted in fish distribution to greater ranges on the left bank after August, necessitating establishment of inshore and offshore drifts. Fish distribution remained unchanged on the right bank and the inshore ends of the nets were fished as close as possible to shore.

To calculate total fishing time four parameters were measured for each drift: 1) net start out; 2) net full out; 3) net start in; 4) net full in. At the end of each drift the net was hauled into the boat as quickly as possible and fish were disentangled. Each fish was identified to species, measured (mid-eye to tail fork for salmon and snout to tail fork for non-salmon), and checked for signs of wedging or tangling.

Analytical Methods

Gill nets capture fish in one of two ways; individuals may be wedged between the dorsal fin and the gill opercula, or they may become tangled in the web by their teeth or maxillaries. The probabilities of these events are specific to fish length, gill net mesh size, and species. Catches in 1988 were adjusted only for sampling effort among species and gill net mesh sizes. Gill net mesh selectivity coefficients were not estimated and catches were not adjusted for selectivity. The relative standardized CPUE by species, as calculated in-season, are used to apportion expanded fish counts.

Estimation of Relative Abundance. Two mesh sizes of gill net targeted each species present in the river. Chinook salmon were targeted with 190.5 and 215.9 mm (7.5 and 8.5 inch) mesh; chum and coho salmon were targeted with 139.7 and 165.1 mm (5.5 and 6.5 inch) mesh; and pink salmon and other species were targeted with 101.6 and 127 mm (4 and 5 inch) mesh. Each species also has some probability of being captured in mesh sizes other than those specifically targeting it. For example, most chum salmon are caught in 139.7 and 165.1 mm (5.5 and 6.5 inch) meshes, yet a considerable number are also captured in 101.6 and 127 mm (4 and 5 inch) meshes. In order to use all of the fish caught to estimate species apportionment, we adjusted catches of each species in two mesh size pairs for effort, and then used the sum of the resulting indices for each species to determine percent species composition. A generalized equation for the index of abundance of each species, k_s, is:

$$k_s = [(f_{w_1} + f_{t_1} + f_{w_2} + f_{t_2}) \frac{e_{n_1} + e_{n_2}}{e_{t_1} + e_{t_2}}] + [(g_{t_1} + g_{t_2}) \frac{e_{t_1} + e_{t_2}}{e_{n_1} + e_{n_2}}]$$

where f_{w1} = number of target species wedged in target mesh 1.
f_{w2} = number of target species wedged in target mesh 2.
f_{t1} = number of target species tangled in target mesh 1.
f_{t2} = number of target species tangled in target mesh 2.
e_{t1} = effort in mesh size 1 targeting species of interest.
e_{t2} = effort in mesh size 2 targeting species of interest.
e_{n1} = effort in mesh size 1 not targeting species of interest.
e_{n2} = effort in mesh size 2 not targeting species of interest.
g_{t1} = number of non-target species tangled in non-target mesh 1.
g_{t2} = number of non-target species tangled in non-target mesh 2.

Species proportions for temporal and spatial strata are expressed as P_s:

$$P_s = \frac{k_s}{\sum_{1}^{s} k_s}$$

Estimation of Daily Fish Passage. Estimates of daily passage for each species were calculated by integrating the results of the hydroacoustic counting and species apportionment segments of the project. Daily estimates for species s on bank b were calculated as $N_{s,b}$, where:

$$N_{s,b} = P_{s,b} N_{b,d}$$

and: $P_{s,b}$ = the proportion of species s on bank b during the time period.
$N_{b,d}$ = the number of fish passing bank b on day d .

Migratory Run Timing. The mean date of migration and associated standard deviation for each fish species present in the Yukon River while the project was operational was calculated following the method outlined by Mundy (1982).

RESULTS

Hydroacoustic Counting

Estimation of Total Daily Passage

The Yukon sonar project was operational from 2 June through 14 September in 1988. A temporal expansion factor of six resulted from four hours of sampling within each 24-hour day. Spatial expansion factors on the right bank ranged from 1.0 (no expansion) to 3.2, depending on water level and fish distance from the transducer. Spatial expansion factors remained relatively constant throughout the season due to the stability of the river bottom at the sampling site.

Daily and seasonal fish passage estimates by bank are summarized in Appendix Tables 1, 2, and 3. A total of 3,398,168 fish passed the sampling site; 70 percent (2,387,769) and 30 percent (1,010,399) of the total passed the left and right banks (Figure 5). The highest daily passage (175,822 fish) occurred on 20 June.

Estimation of Missing Data

Right bank sonar data and left and right bank CPUE data from 04 June through 30 June showed varying levels of correlation with left bank sonar data. For this sampling period left bank fish counts were most highly correlated with right bank counts (r^2 = 0.90). This relationship (Y = 2554.5+2.66X) was used to estimate fish passage on the left bank in-season for July 01, 1988.

Species Allocation

Estimation of Species Proportions

Sampling of the migrant fish population for use in estimation of species proportions began on 02 June and continued through 14 September. The 101.6 mm (4.0 in) mesh net was fished 145 times (322.49 fm-hrs), the 127 mm (5.0 in) mesh was fished 139 times (326.38 fm-hrs), the 139.7 mm (5.5 in) mesh was fished 284 times (871.60 fm-hrs), the 165.1 mm (6.5 in) mesh was fished 268 times (840.86 fm-hrs), the 190.5 mm (7.5 in) mesh was fished 122 times (393.16 fm-hrs), and the 215.9 mm (8.5 in) mesh was fished 157 times (526.45 fm-hrs). The catch totaled 6,394 fish, of which 3,153 (49 percent) were captured on the left bank and 3,241 (51 percent) were captured on the right bank. Right bank catch was higher than that on the left bank due to better fishing conditions (no snags) and higher total effort levels.

A total of 266 chinook salmon were captured in 190.5 and 215.9 mm mesh gill nets. The majority (64 percent) were gilled or wedged; the remaining 36 percent were tangled. Fifty six percent of the fish were caught in 215.9 mm (8.5 inch) gear and the remaining forty four percent of the gilled fish were caught in 190.5 mm (7.5 in) gear. Catch on the left bank totaled 178 chinook salmon (67 percent) while catch on the right bank totaled 88 chinook salmon (33 percent). No chinook salmon were captured in nets drifted offshore to check for extended fish distribution.

Summer chum salmon catches totaled 2,484 in 139.7 (5.5 inch) and 165.1 mm (6.5 inch) gill nets. Of these, 2,146 (86 percent) were gilled or wedged and 338 (14 percent) were tangled in both gear sizes. Sixty three percent of the fish were captured in the 139.7 mm (5.5 in) mesh nets. A total of 1,172 fish (47 percent) were caught on the left bank while 1,312 (53 percent) were caught on the right bank.

A total of 1079 fall chum were captured in 139.7 (5.5 in) and 165.1 mm (6.5 in) gill nets. Nine hundred seventy six fish (90 percent) were gilled or wedged, and of these, 56 percent were captured in the 165.1 mm mesh nets. A total of 555 fish (51 percent) were captured on the left bank while 524 (49 percent) were captured on the right bank.

Coho salmon gill net catches in 139.7 (5.5 in) and 165.1 mm (6.5 in) mesh gill nets totaled 547 fish. The majority (79 percent) were either gilled or wedged with 251 (63 percent) and 179 (37 percent) in the 139.7 and 165.1 mm nets. A total of 130 (24 percent) were captured on the left bank while 417 (76 percent) were captured on the right bank.

A total of 837 pink salmon were captured in 101.6 mm (4.0 in) and 127.0 mm (5.0) mesh gill nets. Six hundred six fish (72 percent) were gilled or wedged with 338 (56 percent) and 268 (44 percent) in each mesh net. A total of 592 (71 percent) were captured on the left bank while 245 (29 percent) were captured on the right bank.

The remainder of the gill net catch was composed of sockeye salmon and non salmon species. Only seven sockeye salmon were captured in 1988. Non-salmon catches, however, were substantial. Non-salmon species included humpback whitefish *(Coregonus pidschian)*, broad whitefish *(C. nasus)*, Least cisco *(C. sardinella)*, sheefish *(Stenodus leucichthys)*, northern pike *(Esox lucius)*, burbot *(Lota lota)*, and dolly varden *(Salvelinus malma)*. The majority (73 percent) of the 198 fish captured were either gilled or wedged with 100 (69 percent) and 44 (31 percent) in the 101.6 (4.0 in) and 127 mm (5.0 in) gill nets. A total of 120 fish (61 percent) were caught on the left bank while 78 fish (39 percent) were caught on the right bank.

Summer chum salmon dominated the species composition (Figure 6) between 02 June and 08 July, comprising between 65 and 100 percent of the population. Pink salmon were predominant between 09 July and 25 July; fall chum salmon were the most abundant species between 26 July and 15 August. Coho salmon dominated from 16 August to termination of sampling.

Estimation of Daily Passage

The total estimated fish passage of 3,398,168 fish is apportioned to species in Table 1, and histograms of daily fish passage by species are shown in Figures 7 and 8. Left bank, right bank, and combined bank estimates of fish passage by day and species are listed in Appendix tables one through three. Migratory timing statistics appear in Table 2. Estimates are discussed by species in the following text.

The estimated chinook salmon escapement past the sampling site was 80,791 fish or 2 percent of the total salmon escapement. The highest daily passage occurred on 25 June when 7,996 chinook were counted. Most chinook salmon (78 percent) traveled along the left bank. The migration was in progress at project start-up on 02 June and continued until 18 July. The mean date of chinook salmon migration was 22 June (s.d.= 20).

Summer chum salmon were the most abundant species counted; an estimated 1,870,406 passed the site between 02 June and 18 July. This escapement level represents 55 percent of the total fish passage in 1988. The majority (72 percent) passed along the left bank. The migration was in progress when the project became operational on 02 June; a total of 624 summer chum were counted on this date. The mean date of migration is 25 June (s.d. = 23). The migration was complete by 19 July.

An estimated 505,195 fall chum salmon passed the sonar site representing 15 percent of the total fish passage in 1988. The highest daily passage (52,005) occurred on 11 August. The largest segment of the fall chum run (78 percent) passed along the left bank. Fall chum were present at km 197 from 19 July until the last day of operation (14 September). Fall chum daily passage had dropped to 514 fish per day. The mean date of migration is 06 August (s.d. = 12).

The coho salmon run consisted of an estimated 265,740 fish through the last day of operation in 1988. The coho run comprised only 8 percent of the total season fish passage. The highest daily passage was 13,657 coho salmon on 17 August. Coho salmon were more evenly distributed between banks than were other species; 49 percent passed the left bank and 51 percent passed the right bank. Coho salmon were present at the site from 29 July through the termination of sampling. The migration was not yet complete on the last day of operation, as indicated by an estimated daily count of 5,414 fish. Based on the days sampled, the coho run mean date of migration is 27 August (s.d. = 10).

An estimated 538,036 pink salmon passed the site between 28 June and 16 August, comprising 16 percent of the total fish passage. Highest daily passage (33,556) occurred on 16 July. Seventy two percent of the pink salmon passed the left bank of the river. The mean date of migration is 20 July (s.d. = 22).

All non-salmon species were pooled to apportion hydroacoustic counts. Total estimated passage in 1988 was 138,002 fish representing 4 percent of all fish passage. The peak daily passage was 4,587 fish on 21 July. A total of 79,329 fish (58 percent) passed the left bank while 58,672 fish (42 percent) passed the right bank. These species were present from 02 June through the last day of counting. Whitefish species accounted for the majority of non-salmon species intercepted in 1988.

DISCUSSION

Hydroacoustic Counting

Estimation of Total Daily Fish Passage

Hydroacoustic fish passage estimates, though extremely precise, may be subject to bias attributable to errors in fish counting, or to errors in expansion factor development and species composition. First, there may exist areas of the river cross section utilized by salmon that are not being sampled. In the Yukon River the nearshore water column is intensively sampled and data gathered to date suggests that fish are not migrating in mid-river areas. Changes in the dynamic riverine environment, however, may prompt changes in fish behavior. Mid-river areas should therefore be systematically sampled each year to assure that all migratory pathways are either ensonified or otherwise accounted for.

Another counting problem is downstream-directed targets counted as debris which may in fact be fish. Some downstream-directed fish traces are easily identified from trace patterns on chart recordings. Other, less easily identifiable traces may require qualification through establishment of some type of ground truth project. Recent work on the left bank of the Yukon with a transducer aimed directly upstream showed that 12 percent of the 1500 targets passing through the beam were moving downstream. Identification of targets may be accomplished through use of gill nets or dual-beam target strength information.

Spatial expansion factors, used only on the right bank in 1988, may also bias fish passage estimates if the true cross-sectional area of the beam is different from that calculated based on acoustic parameters under which the system is operating. This is a property of average fish target strength and attitude (position in the sonar beam) which varies within and between years and should be frequently measured.

These errors are probably consistent over time and, if occurring, will be manifest in consistent differences between sonar and other estimates of population size. Controlling bias requires careful and continuous evaluation of bottom topography, calculation of beam size, and identification of downstream-moving targets and fish migratory pathways.

Other factors associated with counting passing targets contribute to variance in fish passage estimates. The most serious of these factors on the Yukon is the physical instability of the left bank site. The constantly shifting bottom sediments at this location make transducer deployment and operation a continual challenge. A site that appears perfectly suited for transducer location may change in a matter of hours to one that is unusable. Rapidly changing water levels tend to erode or deposit bottom sediments with the net effect being burial of the transducer. This both reduces sampling and increases personnel costs. Changes in transducer pod design and retrieval procedures have alleviated some of the difficulties caused by left bank river bottom instability. The risk of equipment loss and the amount of effort expended retrieving equipment have been cut substantially. Until another method of transducer deployment is found, however, there will continue to be days with reduced sampling on the left bank and subsequent estimation of passage through interpolation or modeling based on the right bank fish passage.

Species Allocation

Estimation of Species Proportions

The technique used to estimate species proportions assumes that fish temporal and spatial distribution does not differ between species, with the exception of pink salmon and whitefish which are known to travel near shore. Non-random deployment of nets within the area of fish migration may result in over- or under-representation of certain species depending on whether or not they are uniformly distributed in time and space.

Comprehensive post-seasonal analysis of relative species abundance was not performed using methods consistent with other years. Personnel constraints and labor intensive procedures were limiting factors in determining the extent of post-season analysis of species composition data. Relative standardized CPUE by species (i.e., catches adjusted for sampling effort among species and paired gill net mesh sizes), was used consistently between years for in-season species apportionment. Analysis of in-season and post-season (adjusted for net selectivity) species composition for 1986, 1987, and 1989 revealed 11 percent, 8 percent, 5 percent, and 6 percent average change in total estimates of chinook, summer chum, fall chum, and coho salmon. This level of change between in- and post-season estimates is within the estimated $\pm$15 percent confidence limits around passage estimates. Procedures first employed in 1990 adjust for gill net selectivity in-season and alleviate the need for post-season analysis of species composition data. Yukon sonar data from 1986 through 1989 will be run through the same analytical procedure as 1990 data so that the results are as comparable as possible between years of operation.

Estimation of Daily Passage

The Yukon River sonar project in 1988 provided in-season run strength information to fishery managers within twelve hours of cessation of sampling each day. Post season comparison shows approximate agreement between sonar-based escapement estimates and the sum of commercial and subsistence catch and survey-based escapement estimates. For a more complete discussion of these data see Sandone (1990). Consistent production of timely escapement information will help to make the sonar project an integral part of lower Yukon River fishery management strategy for all managed species.

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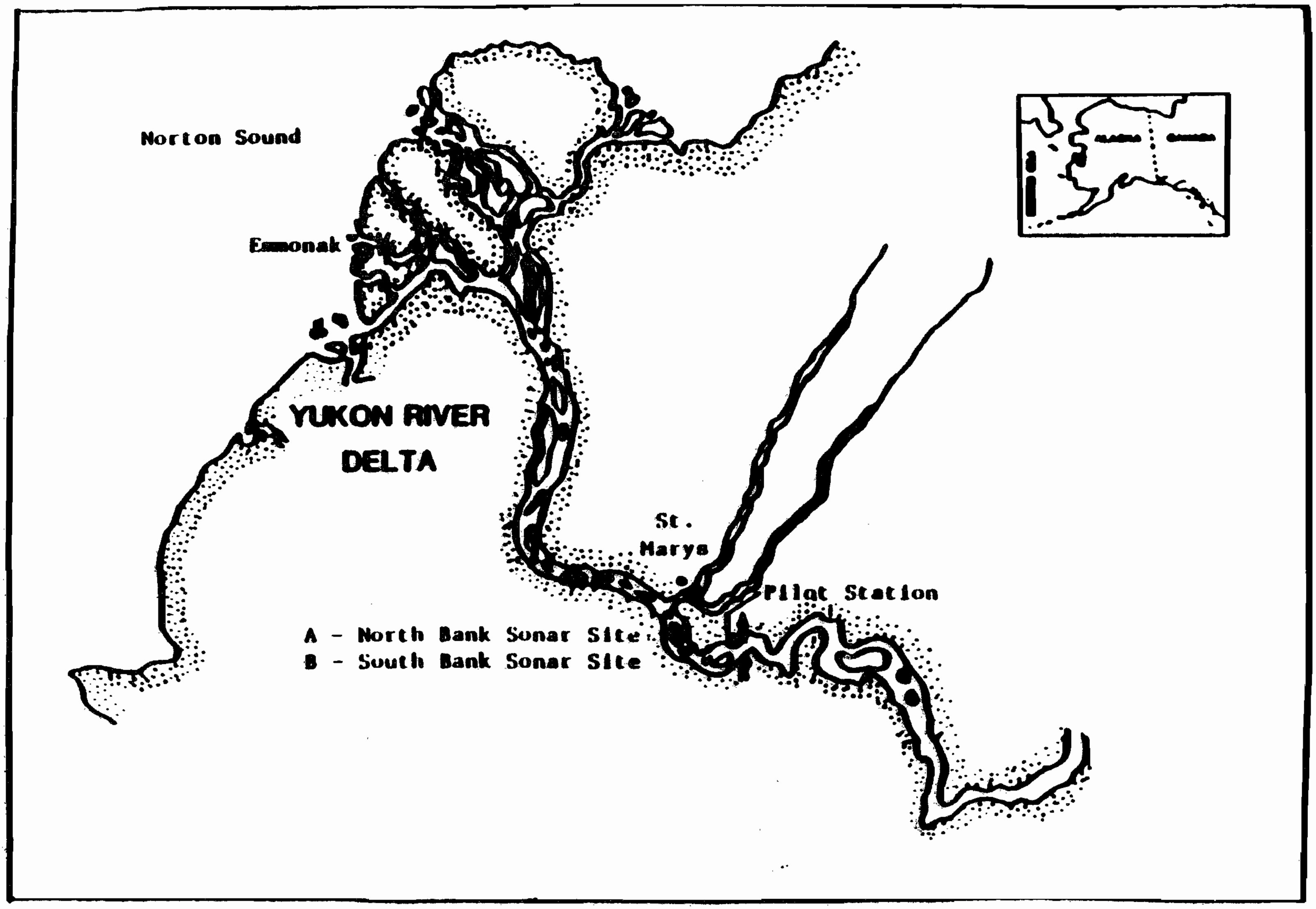


Figure 1. Map of the lower Yukon River showing the two sites used for hydroacoustic escapement enumeration in 1988.

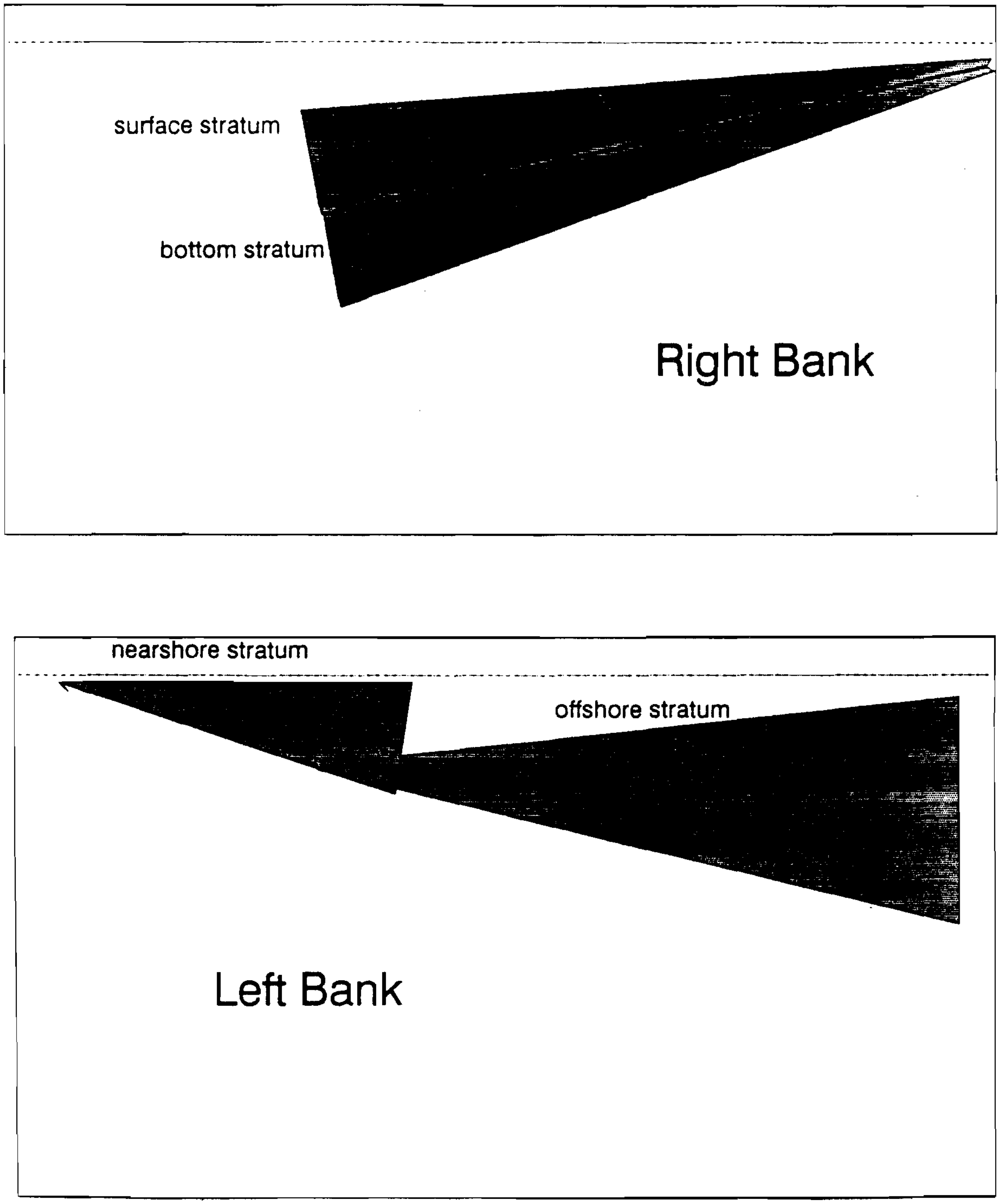


Figure 2. Areas of the Yukon River cross section sampled hydroacoustically at km 197 in 1983.

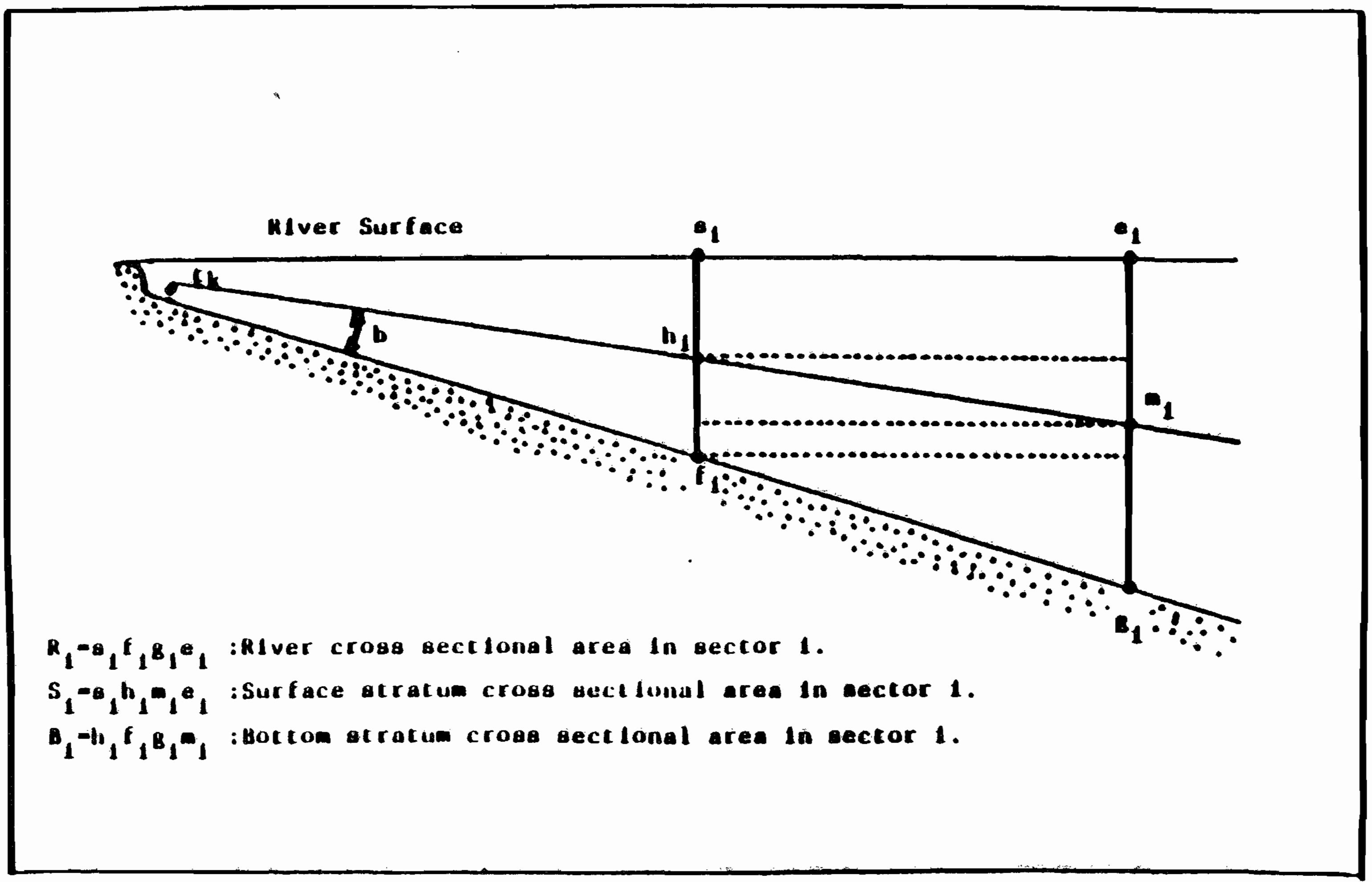


Figure 3. Geometric representation of Yukon River and hydroacoustic beam cross sectional areas used for calculation of spatial expansion factors for counts of fish obtained hydroacoustically in 1983.

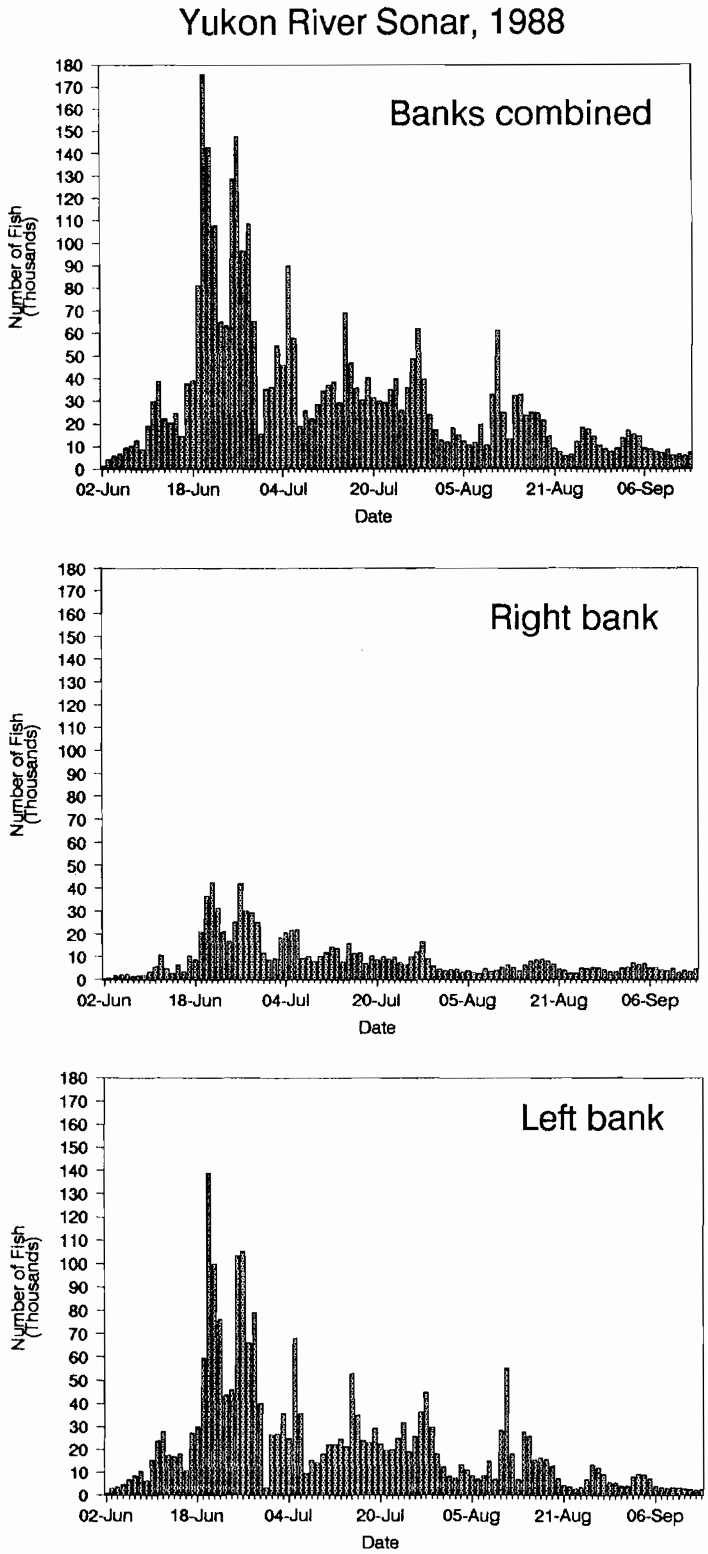


Figure 4. Daily fish passage estimates for combined banks, right bank, and left bank at km 197, Yukon River, 1988.

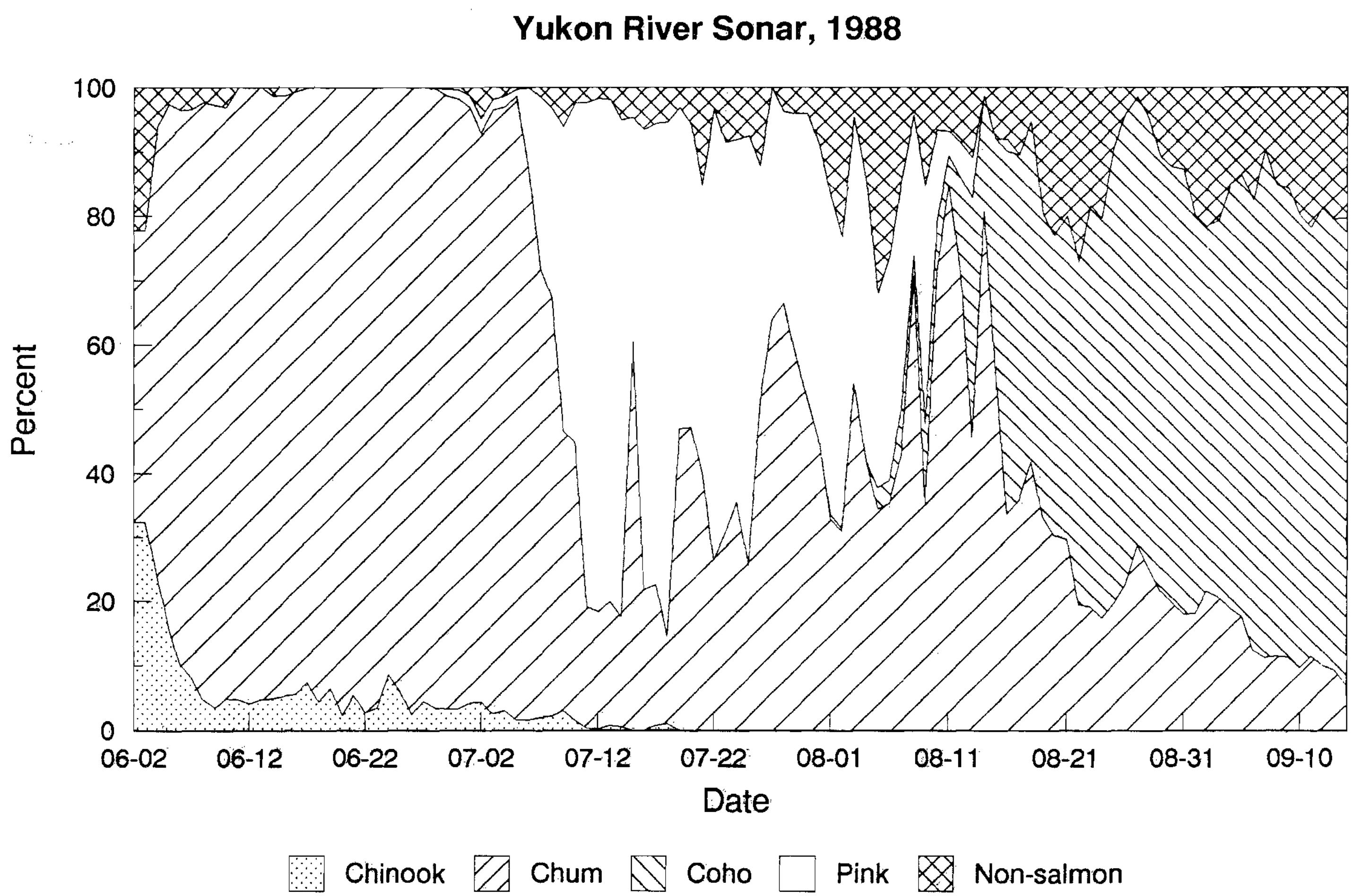


Figure 5. Species proportions between 02 June and 14 September at km 197, Yukon River, 1988.

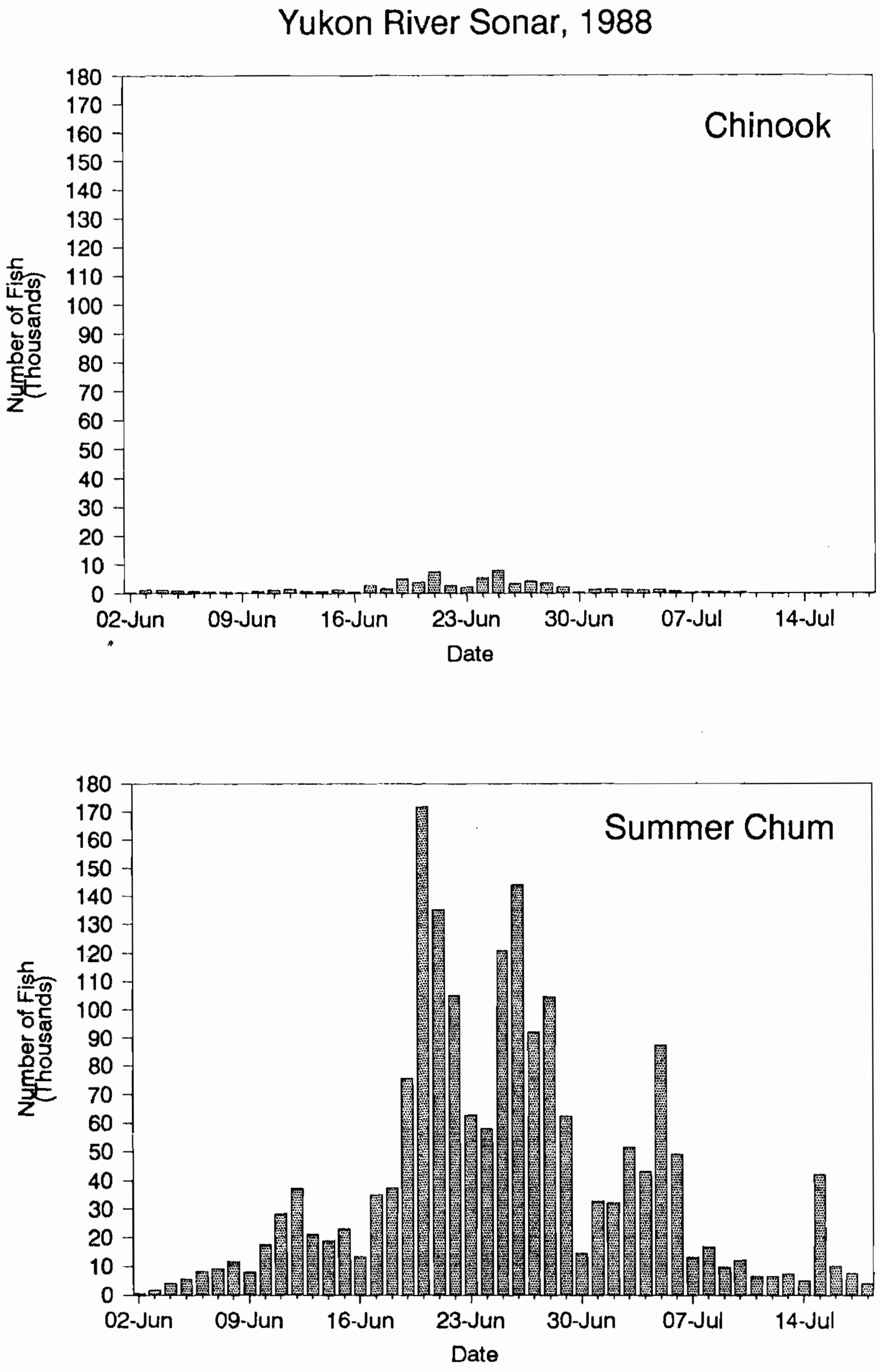


Figure 6. Daily fish passage estimates for chinook salmon and summer chum salmon at km 197, Yukon River, 1988.

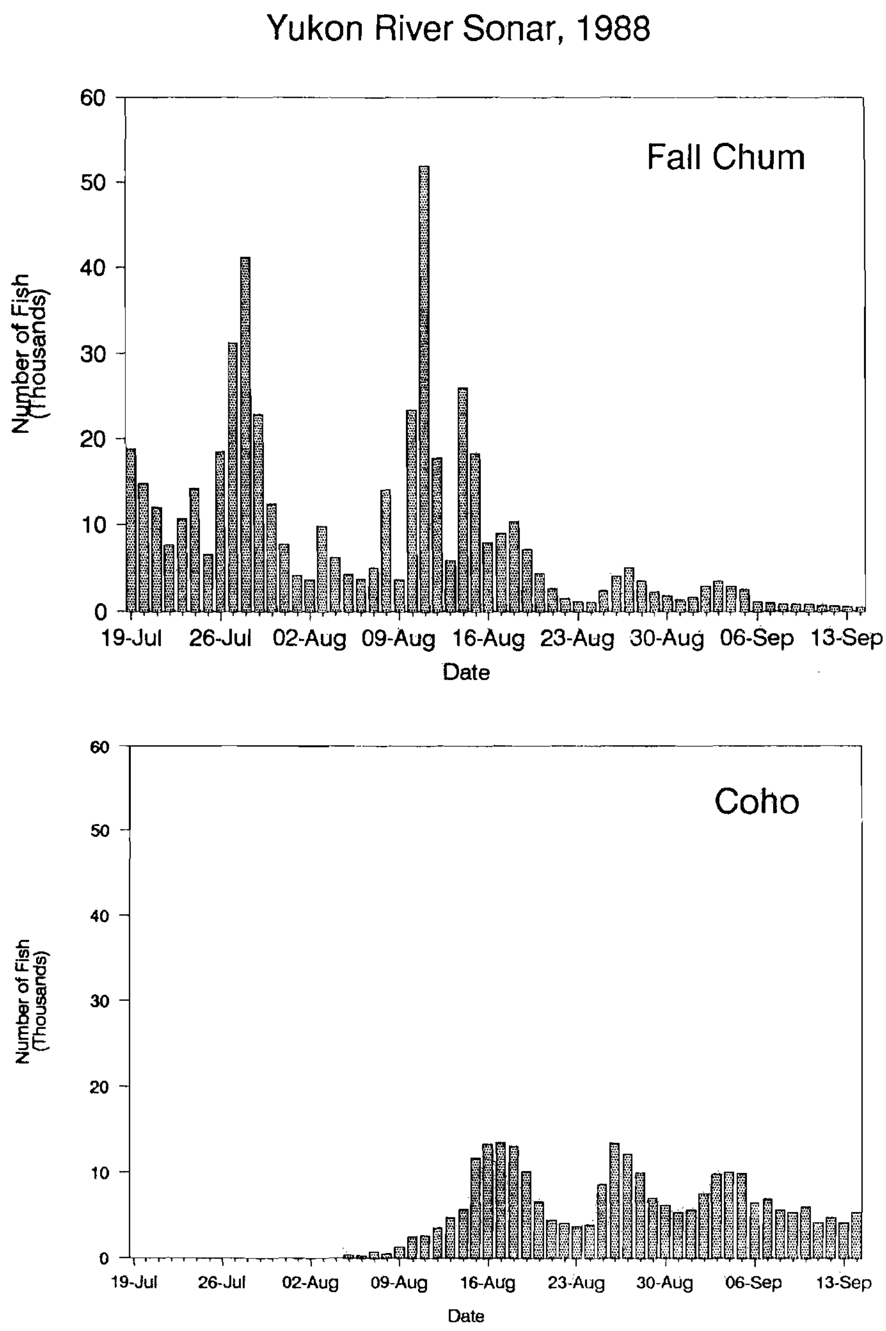


Figure 7. Daily fish passage estimates for fall chum salmon and coho salmon at km 197, Yukon River, 1988.

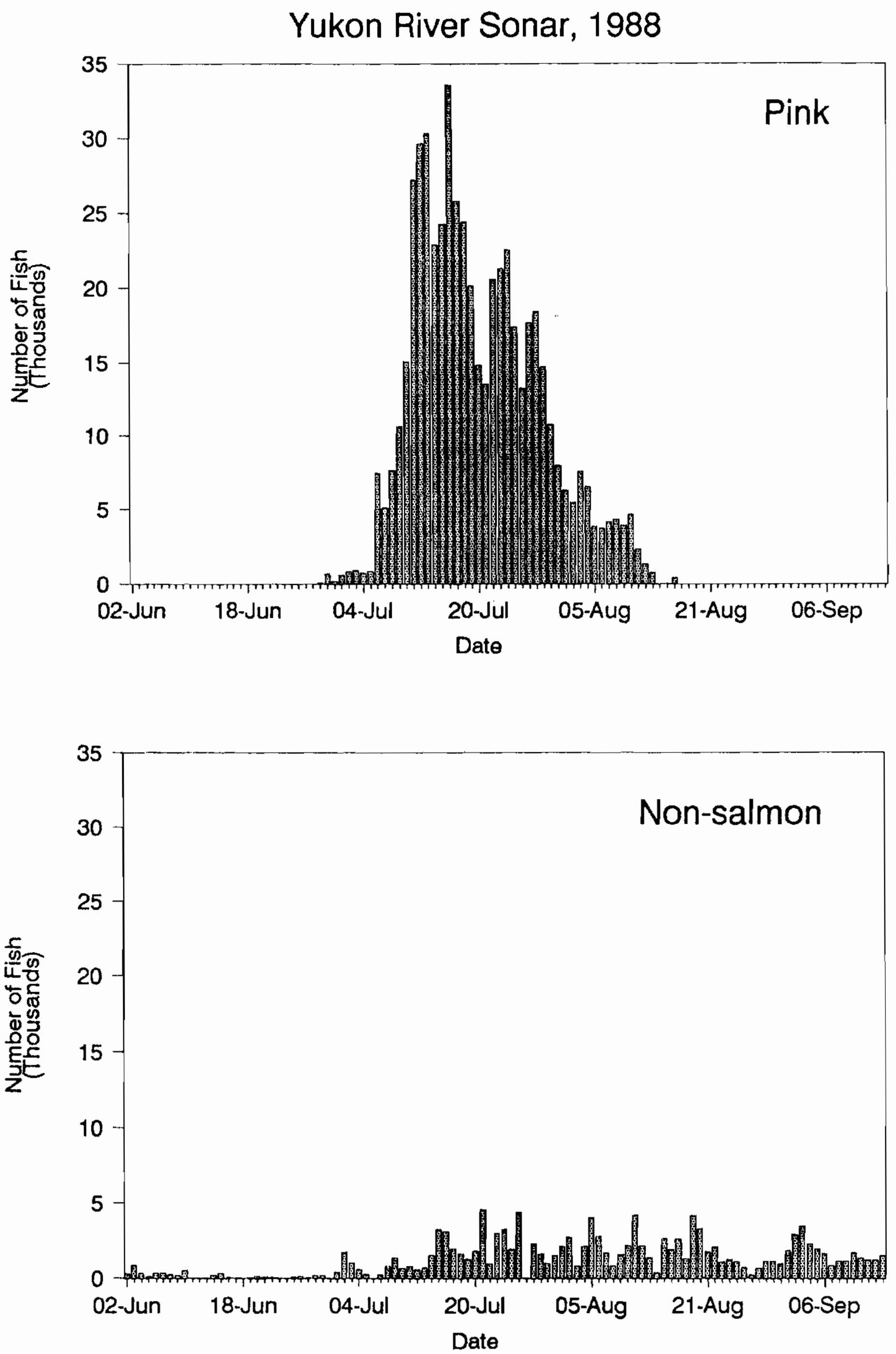


Figure 8. Daily fish passage estimates for pink salmon and non-salmon species at km 197, Yukon River, 1988.

Table 1. Estimated escapements of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species past km 197, Yukon River, 1988.

Chinook	Summer chum	Fall chum	Coho	Pinks	Non-salmon	Total
80,791	1,870,406	505,195	265,740	538,036	138,002	3,398,168

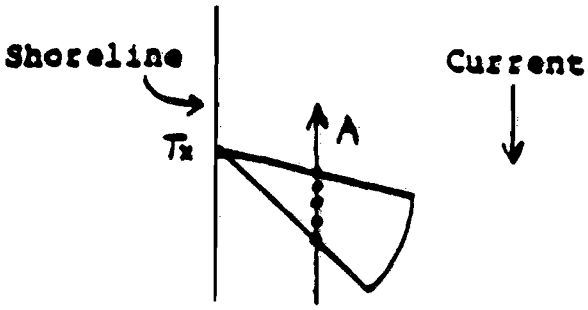
Table 2. Run timing parameters, based on hydroacoustic escapement estimates of chinook, summer chum, fall chum, coho, and pink salmon at river km 197, Yukon sonar, 1988.

Species	Run Timing Parameters[1/]			
	Start	End	Mean	S.D. of Mean
Chinook	02 June	18 July	22 June	20
Summer chum	02 June	18 July	25 June	23
Fall chum	19 July	14 Sept.	06 August	12
Coho	29 July	14 Sept.	27 August	10
Pink	28 June	16 August	20 July	22

[1/] Run timing is based on the counts obtained during project operation. The actual run timing may differ depending on the portion of the escapement occurring before and after project start-up and termination dates.

Appendix 1 . Criteria for classification of targets.

Classification of echogram traces as upriver migrant fish (as opposed to debris, boat traffic, or water turbulence) was based on direction of movement, amount of time spent in the beam, surface turbulence associated with the target, and width and intensity of the recorded trace. Direction of movement was determined using change-in-range techniques. The figure below shows a cross section of an acoustic beam.



The trajectory of a fish passing through the beam is represented by vector A. Marks on the line identify positions along the trajectory where the fish is ensonified during successive transmissions. As the fish moves along its upstream trajectory, its slant range from the transducer decreases. Downstream movement is evidenced by increasing slant range. Determination of target direction separated debris from fish and boats. In order to distinguish fish from upstream directed boats, observations made at the time of detection and post season analysis of trace size, intensity, and associated turbulence were used. The presence of surface turbulence distinguished boat traffic from fish movement.

Appendix Table 1. Daily sonar counts of chinook, summer chum, fall chum, coho and pink salmon, and non-salmon species for both banks combined, Yukon River Sonar, 1988.

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
02-Jun	1,374	445	624	0	0	0	305
03-Jun	4,103	1,329	1,863	0	0	0	911
04-Jun	5,885	1,407	4,114	0	0	0	365
05-Jun	6,906	1,105	5,621	0	0	0	180
06-Jun	9,657	985	8,324	0	0	0	348
07-Jun	10,503	851	9,295	0	0	0	357
08-Jun	12,693	597	11,804	0	0	0	292
09-Jun	8,743	297	8,201	0	0	0	245
10-Jun	19,241	943	17,702	0	0	0	596
11-Jun	29,998	1,410	28,558	0	0	0	30
12-Jun	38,874	1,594	37,241	0	0	0	39
13-Jun	22,556	1,060	21,473	0	0	0	23
14-Jun	20,306	995	19,047	0	0	0	264
15-Jun	24,819	1,315	23,156	0	0	0	347
16-Jun	14,607	818	13,687	0	0	0	102
17-Jun	37,862	2,840	34,984	0	0	0	38
18-Jun	39,237	1,687	37,511	0	0	0	39
19-Jun	81,261	5,282	75,898	0	0	0	81
20-Jun	175,822	3,868	171,778	0	0	0	176
21-Jun	143,122	7,729	135,250	0	0	0	143
22-Jun	108,126	2,919	105,098	0	0	0	108
23-Jun	65,295	2,220	63,010	0	0	0	65
24-Jun	63,546	5,465	58,017	0	0	0	64
25-Jun	128,961	7,996	120,836	0	0	0	129
26-Jun	147,799	3,547	144,104	0	0	0	148
27-Jun	96,671	4,350	92,224	0	0	0	97
28-Jun	108,702	3,696	104,680	0	0	109	217
29-Jun	65,500	2,162	62,422	0	0	721	197
30-Jun	15,536	513	14,744	0	0	218	62
01-Jul	35,403	1,487	32,819	0	0	637	460
02-Jul	36,394	1,565	32,209	0	0	837	1,783
03-Jul	54,900	1,373	51,551	0	0	933	1,043
04-Jul	46,204	1,386	43,431	0	0	785	601
05-Jul	89,995	1,440	87,385	0	0	900	270
06-Jul	57,812	925	49,372	0	0	7,458	58
07-Jul	19,075	362	13,334	0	0	5,093	286
08-Jul	25,869	543	16,841	0	0	7,631	854
09-Jul	22,460	674	9,770	0	0	10,646	1,370
10-Jul	28,606	458	12,358	0	0	15,104	687
11-Jul	34,703	104	6,559	0	0	27,207	833
12-Jul	37,064	74	6,709	0	0	29,652	630
13-Jul	38,754	271	7,441	0	0	30,306	736

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Appendix Table 1. Daily sonar counts of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species for both banks combined, Yukon River Sonar, 1988 (continued).

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
14-Jul	29,641	148	5,069	0	0	22,912	1,512
15-Jul	69,697	0	42,167	0	0	24,255	3,276
16-Jul	46,866	0	10,170	0	0	33,556	3,140
17-Jul	35,947	252	7,836	0	0	25,846	2,013
18-Jul	30,515	305	4,120	0	0	24,412	1,678
19-Jul	40,305	0	0	18,880	0	20,155	1,270
20-Jul	31,467	0	0	14,822	0	14,825	1,820
21-Jul	30,240	0	0	12,113	0	13,540	4,587
22-Jul	29,384	0	0	7,753	0	20,628	1,003
23-Jul	35,108	0	0	10,752	0	21,342	3,014
24-Jul	40,022	0	0	14,218	0	22,541	3,263
25-Jul	26,093	0	0	6,691	0	17,429	1,974
26-Jul	36,208	0	0	18,538	0	13,242	4,428
27-Jul	48,929	0	0	31,217	0	17,699	12
28-Jul	61,960	0	0	41,214	0	18,442	2,303
29-Jul	39,315	0	0	22,925	19	14,728	1,644
30-Jul	24,224	0	0	12,442	18	10,755	1,008
31-Jul	17,360	0	0	7,820	0	7,988	1,552
01-Aug	12,739	0	0	4,180	100	6,305	2,155
02-Aug	12,060	0	0	3,736	60	5,468	2,796
03-Aug	18,323	0	0	9,884	0	7,569	871
04-Aug	14,967	0	0	6,278	0	6,517	2,171
05-Aug	12,678	0	0	4,362	426	3,842	4,050
06-Aug	10,771	0	0	3,795	385	3,761	2,831
07-Aug	11,783	0	0	5,051	836	4,167	1,730
08-Aug	19,958	0	0	14,108	614	4,348	887
09-Aug	10,632	0	0	3,747	1,326	3,930	1,630
10-Aug	32,855	0	0	23,421	2,547	4,687	2,200
11-Aug	61,298	0	0	52,005	2,729	2,344	4,221
12-Aug	24,917	0	0	17,754	3,647	1,329	2,186
13-Aug	12,922	0	0	5,892	4,812	805	1,414
14-Aug	32,241	0	0	26,001	5,801	0	439
15-Aug	32,818	0	0	18,330	11,830	0	2,659
16-Aug	23,941	0	0	8,038	13,498	436	1,969
17-Aug	25,405	0	0	9,092	13,657	0	2,656
18-Aug	24,946	0	0	10,422	13,182	0	1,342
19-Aug	21,701	0	0	7,209	10,263	0	4,229
20-Aug	14,485	0	0	4,385	6,757	0	3,344
21-Aug	8,980	0	0	2,667	4,522	0	1,791
22-Aug	7,825	0	0	1,526	4,176	0	2,123

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Appendix Table 1. Daily sonar counts of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species for both banks combined, Yukon River Sonar, 1988 (continued).

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
23-Aug	6,033	0	0	1,155	3,766	0	1,112
24-Aug	6,450	0	0	1,126	4,018	0	1,306
25-Aug	12,366	0	0	2,428	8,774	0	1,164
26-Aug	18,432	0	0	4,119	13,537	0	776
27-Aug	17,618	0	0	5,075	12,278	0	265
28-Aug	14,394	0	0	3,621	10,078	0	695
29-Aug	10,614	0	0	2,301	7,162	0	1,151
30-Aug	9,188	0	0	1,815	6,233	0	1,140
31-Aug	7,874	0	0	1,419	5,452	0	1,002
01-Sep	9,300	0	0	1,686	5,773	0	1,841
02-Sep	13,599	0	0	2,932	7,731	0	2,936
03-Sep	16,950	0	0	3,485	9,944	0	3,521
04-Sep	15,496	0	0	2,930	10,224	0	2,342
05-Sep	14,596	0	0	2,580	10,021	0	1,995
06-Sep	9,414	0	0	1,177	6,581	0	1,656
07-Sep	8,913	0	0	1,011	7,020	0	882
08-Sep	7,799	0	0	898	5,714	0	1,187
09-Sep	7,451	0	0	845	5,440	0	1,166
10-Sep	8,708	0	0	848	6,127	0	1,734
11-Sep	6,325	0	0	727	4,225	0	1,373
12-Sep	6,700	0	0	667	4,789	0	1,244
13-Sep	6,038	0	0	566	4,240	0	1,233
14-Sep	7,439	0	0	514	5,414	0	1,511
TOTAL	3,398,168	80,791	1,870,406	505,195	265,740	538,036	138,002

Appendix Table 2. Daily sonar counts of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species for the right bank, Yukon River Sonar, 1988.

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
02-Jun	611	198	277	0	0	0	136
03-Jun	990	321	449	0	0	0	220
04-Jun	2,172	519	1,518	0	0	0	135
05-Jun	2,182	349	1,776	0	0	0	57
06-Jun	2,763	282	2,382	0	0	0	99
07-Jun	1,804	146	1,597	0	0	0	61
08-Jun	2,055	97	1,911	0	0	0	47
09-Jun	2,275	77	2,134	0	0	0	64
10-Jun	3,673	180	3,379	0	0	0	114
11-Jun	5,921	278	5,637	0	0	0	6
12-Jun	11,046	453	10,582	0	0	0	11
13-Jun	5,024	236	4,783	0	0	0	5
14-Jun	3,236	159	3,035	0	0	0	42
15-Jun	6,669	353	6,222	0	0	0	93
16-Jun	3,801	213	3,562	0	0	0	27
17-Jun	10,694	802	9,881	0	0	0	11
18-Jun	9,148	393	8,745	0	0	0	9
19-Jun	21,461	1,395	20,045	0	0	0	21
20-Jun	37,114	817	36,260	0	0	0	37
21-Jun	42,978	2,321	40,614	0	0	0	43
22-Jun	31,754	857	30,865	0	0	0	32
23-Jun	21,300	724	20,555	0	0	0	21
24-Jun	17,181	1,478	15,686	0	0	0	17
25-Jun	25,529	1,583	23,921	0	0	0	26
26-Jun	42,391	1,017	41,331	0	0	0	42
27-Jun	30,227	1,360	28,837	0	0	0	30
28-Jun	29,647	1,008	28,550	0	0	30	59
29-Jun	25,480	841	24,282	0	0	280	76
30-Jun	12,260	405	11,635	0	0	172	49
01-Jul	8,975	377	8,320	0	0	162	117
02-Jul	9,734	419	8,615	0	0	224	477
03-Jul	18,869	472	17,718	0	0	321	359
04-Jul	21,180	635	19,909	0	0	360	275
05-Jul	21,987	352	21,349	0	0	220	66
06-Jul	22,176	355	18,939	0	0	2,861	22
07-Jul	9,655	183	6,749	0	0	2,578	145
08-Jul	10,477	220	6,821	0	0	3,091	346
09-Jul	8,174	245	3,556	0	0	3,875	499
10-Jul	10,438	167	4,509	0	0	5,511	251
11-Jul	12,233	37	2,312	0	0	9,591	294
12-Jul	14,671	29	2,655	0	0	11,737	249
13-Jul	14,010	98	2,690	0	0	10,956	266

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Appendix Table 2. Daily sonar counts of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species for the right bank. Yukon River Sonar, 1988 (continued).

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
14-Jul	8,341	42	1,426	0	0	6,447	425
15-Jul	16,315	0	9,871	0	0	5,678	767
16-Jul	11,738	0	2,547	0	0	8,404	786
17-Jul	12,055	84	2,628	0	0	8,667	675
18-Jul	7,463	75	1,008	0	0	5,970	410
19-Jul	10,785	0	0	3,850	0	6,245	690
20-Jul	8,937	0	0	3,995	0	3,941	1,001
21-Jul	10,500	0	0	5,975	0	3,203	1,323
22-Jul	9,290	0	0	2,815	0	5,472	1,003
23-Jul	10,178	0	0	2,799	0	5,893	1,486
24-Jul	8,012	0	0	2,179	0	4,567	1,266
25-Jul	6,783	0	0	1,757	0	3,771	1,255
26-Jul	10,265	0	0	5,297	0	3,716	1,252
27-Jul	12,431	0	0	7,508	0	4,910	12
28-Jul	16,849	0	0	8,778	0	6,908	1,163
29-Jul	9,447	0	0	4,960	19	4,015	453
30-Jul	6,136	0	0	3,356	18	2,203	558
31-Jul	4,760	0	0	2,537	0	1,476	747
01-Aug	4,276	0	0	1,377	13	731	2,155
02-Aug	4,530	0	0	1,472	14	770	2,274
03-Aug	4,835	0	0	3,056	0	1,774	5
04-Aug	3,789	0	0	1,697	0	1,042	1,050
05-Aug	4,114	0	0	1,855	263	1,312	683
06-Aug	3,511	0	0	1,573	246	1,120	572
07-Aug	3,209	0	0	1,062	417	0	1,730
08-Aug	5,034	0	0	4,405	614	0	15
09-Aug	3,639	0	0	775	1,088	902	873
10-Aug	4,314	0	0	1,165	949	0	2,200
11-Aug	5,742	0	0	2,865	999	0	1,878
12-Aug	6,749	0	0	3,408	2,484	0	857
13-Aug	5,806	0	0	2,015	3,182	0	610
14-Aug	4,223	0	0	393	3,391	0	439
15-Aug	6,917	0	0	3,929	2,220	0	768
16-Aug	8,375	0	0	2,513	4,983	436	444
17-Aug	8,863	0	0	3,997	4,857	0	9
18-Aug	9,153	0	0	3,615	5,428	0	110
19-Aug	8,772	0	0	1,947	4,781	0	2,044
20-Aug	7,157	0	0	1,116	4,287	0	1,753
21-Aug	4,720	0	0	618	2,992	0	1,109
22-Aug	4,242	0	0	484	2,986	0	772

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Appendix Table 2. Daily sonar counts of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species for the right bank, Yukon River Sonar, 1988 (continued).

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
23-Aug	3,117	0	0	362	2,238	0	517
24-Aug	3,225	0	0	213	2,332	0	680
25-Aug	5,407	0	0	270	3,980	0	1,157
26-Aug	5,082	0	0	849	3,471	0	762
27-Aug	5,630	0	0	1,143	4,234	0	253
28-Aug	5,208	0	0	479	4,557	0	172
29-Aug	4,675	0	0	496	3,913	0	266
30-Aug	3,622	0	0	351	3,010	0	261
31-Aug	3,786	0	0	401	3,139	0	246
01-Sep	5,428	0	0	776	3,658	0	993
02-Sep	5,623	0	0	827	4,245	0	551
03-Sep	7,664	0	0	1,127	5,403	0	1,134
04-Sep	6,631	0	0	643	5,703	0	285
05-Sep	7,363	0	0	714	6,332	0	317
06-Sep	5,464	0	0	328	4,491	0	645
07-Sep	5,645	0	0	282	4,781	0	581
08-Sep	4,683	0	0	187	3,554	0	941
09-Sep	4,263	0	0	153	3,253	0	857
10-Sep	5,321	0	0	96	3,810	0	1,415
11-Sep	3,508	0	0	60	2,498	0	951
12-Sep	4,122	0	0	95	3,026	0	1,002
13-Sep	3,716	0	0	41	2,735	0	940
14-Sep	4,994	0	0	50	3,780	0	1,164
TOTAL	1,010,399	22,652	532,073	111,087	134,374	151,541	58,671

Appendix Table 3. Daily sonar counts of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species for the left bank, Yukon River Sonar, 1988.

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
02-Jun	763	247	346	0	0	0	169
03-Jun	3,113	1,009	1,413	0	0	0	691
04-Jun	3,713	887	2,595	0	0	0	230
05-Jun	4,724	756	3,845	0	0	0	123
06-Jun	6,894	703	5,943	0	0	0	248
07-Jun	8,699	705	7,699	0	0	0	296
08-Jun	10,638	500	9,893	0	0	0	245
09-Jun	6,468	220	6,067	0	0	0	181
10-Jun	15,568	763	14,323	0	0	0	483
11-Jun	24,077	1,132	22,921	0	0	0	24
12-Jun	27,828	1,141	26,659	0	0	0	28
13-Jun	17,532	824	16,690	0	0	0	18
14-Jun	17,070	836	16,012	0	0	0	222
15-Jun	18,150	962	16,934	0	0	0	254
16-Jun	10,806	605	10,125	0	0	0	76
17-Jun	27,168	2,038	25,103	0	0	0	27
18-Jun	30,089	1,294	28,765	0	0	0	30
19-Jun	59,800	3,887	55,853	0	0	0	60
20-Jun	138,708	3,052	135,518	0	0	0	139
21-Jun	100,144	5,408	94,636	0	0	0	100
22-Jun	76,372	2,062	74,234	0	0	0	76
23-Jun	43,995	1,496	42,455	0	0	0	44
24-Jun	46,365	3,987	42,331	0	0	0	46
25-Jun	103,432	6,413	96,916	0	0	0	103
26-Jun	105,408	2,530	102,773	0	0	0	105
27-Jun	66,444	2,990	63,388	0	0	0	66
28-Jun	79,055	2,688	76,130	0	0	79	158
29-Jun	40,020	1,321	38,139	0	0	440	120
30-Jun	3,276	108	3,109	0	0	46	13
01-Jul	26,428	1,110	24,499	0	0	476	344
02-Jul	26,660	1,146	23,594	0	0	613	1,306
03-Jul	36,031	901	33,833	0	0	613	685
04-Jul	25,023	751	23,522	0	0	425	325
05-Jul	68,008	1,088	66,036	0	0	680	204
06-Jul	35,636	570	30,433	0	0	4,597	36
07-Jul	9,420	179	6,585	0	0	2,515	141
08-Jul	15,392	323	10,020	0	0	4,541	508
09-Jul	14,286	429	6,214	0	0	6,772	871
10-Jul	18,168	291	7,849	0	0	9,593	436
11-Jul	22,470	67	4,247	0	0	17,616	539
12-Jul	22,393	45	4,053	0	0	17,915	381
13-Jul	24,744	173	4,751	0	0	19,350	470

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Appendix Table 3. Daily sonar counts of chinook, summer chum, fall chum, coho, and pink salmon, and non-salmon species for the keft bank, Yukon River Sonar, 1988 (continued).

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
14-Jul	21,300	107	3,642	0	0	16,465	1,086
15-Jul	53,382	0	32,296	0	0	18,577	2,509
16-Jul	35,128	0	7,623	0	0	25,152	2,354
17-Jul	23,892	167	5,208	0	0	17,178	1,338
18-Jul	23,052	231	3,112	0	0	18,442	1,268
19-Jul	29,520	0	0	15,030	0	13,910	580
20-Jul	22,530	0	0	10,827	0	10,884	819
21-Jul	19,740	0	0	6,138	0	10,338	3,264
22-Jul	20,094	0	0	4,938	0	15,156	0
23-Jul	24,930	0	0	7,953	0	15,449	1,528
24-Jul	32,010	0	0	12,039	0	17,974	1,997
25-Jul	19,310	0	0	4,934	0	13,657	719
26-Jul	25,943	0	0	13,241	0	9,527	3,176
27-Jul	36,498	0	0	23,709	0	12,789	0
28-Jul	45,111	0	0	32,436	0	11,534	1,141
29-Jul	29,868	0	0	17,965	0	10,713	1,190
30-Jul	18,088	0	0	9,086	0	8,552	450
31-Jul	12,600	0	0	5,283	0	6,512	805
01-Aug	8,463	0	0	2,803	87	5,574	0
02-Aug	7,530	0	0	2,264	46	4,698	522
03-Aug	13,488	0	0	6,828	0	5,794	866
04-Aug	11,178	0	0	4,581	0	5,476	1,121
05-Aug	8,564	0	0	2,506	163	2,529	3,367
06-Aug	7,260	0	0	2,222	139	2,641	2,258
07-Aug	8,574	0	0	3,988	419	4,167	0
08-Aug	14,924	0	0	9,704	0	4,348	872
09-Aug	6,993	0	0	2,972	237	3,027	757
10-Aug	28,541	0	0	22,257	1,598	4,687	0
11-Aug	55,556	0	0	49,139	1,730	2,344	2,344
12-Aug	18,168	0	0	14,346	1,163	1,329	1,329
13-Aug	7,116	0	0	3,878	1,630	805	805
14-Aug	28,018	0	0	25,608	2,410	0	0
15-Aug	25,901	0	0	14,401	9,609	0	1,891
16-Aug	15,566	0	0	5,526	8,515	0	1,525
17-Aug	16,542	0	0	5,095	8,800	0	2,647
18-Aug	15,793	0	0	6,807	7,754	0	1,232
19-Aug	12,929	0	0	5,262	5,482	0	2,185
20-Aug	7,328	0	0	3,268	2,470	0	1,590
21-Aug	4,260	0	0	2,049	1,529	0	682
22-Aug	3,583	0	0	1,043	1,190	0	1,351

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Appendix Table 3. Daily sonar counts of chinook, summer chum, fall chum, coho and pink salmon, and non-salmon species for the left bank, Yukon River Sonar, 1988 (continued).

Date	Total Daily Count	Chinook Daily Count	S.Chum Daily Count	F.Chum Daily Count	Coho Daily Count	Pink Daily Count	Non-salmon Daily Count
23-Aug	2,916	0	0	793	1,528	0	595
24-Aug	3,225	0	0	913	1,687	0	626
25-Aug	6,959	0	0	2,157	4,795	0	7
26-Aug	13,350	0	0	3,271	10,066	0	13
27-Aug	11,988	0	0	3,932	8,044	0	12
28-Aug	9,186	0	0	3,142	5,521	0	524
29-Aug	5,939	0	0	1,805	3,249	0	885
30-Aug	5,566	0	0	1,464	3,223	0	879
31-Aug	4,088	0	0	1,018	2,314	0	756
01-Sep	3,872	0	0	910	2,114	0	848
02-Sep	7,976	0	0	2,106	3,486	0	2,385
03-Sep	9,286	0	0	2,359	4,541	0	2,387
04-Sep	8,865	0	0	2,287	4,521	0	2,057
05-Sep	7,233	0	0	1,866	3,689	0	1,678
06-Sep	3,950	0	0	849	2,090	0	1,011
07-Sep	3,268	0	0	729	2,239	0	301
08-Sep	3,116	0	0	710	2,159	0	246
09-Sep	3,188	0	0	692	2,187	0	309
10-Sep	3,387	0	0	752	2,317	0	318
11-Sep	2,817	0	0	668	1,727	0	423
12-Sep	2,578	0	0	572	1,763	0	242
13-Sep	2,322	0	0	525	1,505	0	293
14-Sep	2,445	0	0	465	1,633	0	347
TOTAL	2,387,769	58,139	1,338,333	394,108	131,366	386,495	79,329