3A91-05

YUKON RIVER SONAR ESCAPEMENT ESTIMATE

1987

by

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Regional Information Report[1] No. 3A91-05

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Chief Fisheries Scientist's Office
Sonar and Technical Services
333 Raspberry Road
Anchorage, Alaska 99518

February 1991

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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 08 June and 06 September 1987. 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 mm (4.0 inch) to 215.9 mm (8.5 inch) stretched mesh were used to capture fish. Catches were adjusted for gill net selectivity and effort, and were used to estimate species proportions. A total of 1,870,468 fish passed the sampling site; 75 percent traveled along the left bank while 25 percent traveled along the right bank. The program estimated passage of 98,194 chinook salmon, 836,857 summer chum salmon, 615,123 fall chum salmon, and 213,672 coho salmon during the time period sampled. Peak passage occurred on 04 July, 08 July, 02 August, and 02 September for chinook, summer chum, fall chum, and coho 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 in 1987 provided management with timely in-season run strength estimates for the second consecutive season. The 1987 field season focused on the following Pacific salmon species; chinook salmon *(Oncorhynchus tshawytscha)*, chum salmon *(O. keta)*, and coho salmon *(O. kisutch)*. 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 08 June and 06 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 in 1986.

Two sites, one on the left bank and one on the right bank, were used in 1987 (Figure 1). The left bank bottom 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 bottom 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 1987 followed that used the previous year 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 1987. 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, 1330 to 1700, 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 and two 4°x15° elliptical-beam transducers were used on the left bank. On the right bank, a 420 Khz Biosonics transceiver activated one 4°x15° elliptical-beam transducer to alternately sample surface and bottom strata. 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 ten 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 periodically 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.

This procedure was used frequently in the early season on the left bank due to flooding conditions which resulted in a very unstable bottom substrate and changing river bottom profiles. Transducer assemblies were moved frequently and at times were moved as far as 500 m along the shoreline to obtain a suitable and stable sampling area. Unstable conditions prevailed through the month of June and, to a lesser extent, into July and August. Because of constant relocation and drastically changing bottom conditions it was determined that some modifications to sampling configuration and equipment were necessary. A variety of methods were experimented with during this time period. As a result, the left bank offshore transducer assembly was not deployed while high water conditions existed. This prevented loss of equipment and decreased the work load imposed on the crew due to equipment becoming stuck on the river bottom. Sampling was conducted using the nearshore transducer assembly operated at the transmitting range of 96 m. As the water level receded and the bottom substrate stabilized, deployment of a modified transducer stand for the offshore stratum was possible.

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:

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

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

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

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. Unstable river bottom conditions on the left bank resulted in periods of time during which no acoustic data were collected in the offshore stratum. Estimation of these missing data 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. Fish passage for days on which no sampling occurred was estimated as the average of one day preceding and one day subsequent to the day in question.

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 are based on either catch of 120 fish of 300 mm or greater length (snout to tail fork), or the total catch over a time period (usually three to six days) during which species composition was observed to be fairly consistent. 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 the right bank throughout the season. It was necessary to change drift gill netting areas on the left bank to complement hydroacoustic sampling areas for the month of June. Also, reduced water levels 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 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 are adjusted for sampling effort and for differential probability of being captured among species, length categories, and gill net mesh sizes. The relative standardized CPUE by species are used to apportion expanded fish counts.

Estimation of Relative Abundance. For a detailed explanation of the theory and method used to determine relative abundance refer to the 1989 Yukon Sonar project annual report (LaFlamme and Mesiar 1990).

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 08 June through 06 September in 1987. 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 4.2, 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 right bank sampling site.

Daily and seasonal fish passage estimates by bank are summarized in Appendix Tables 1, 2, and 3. A total of 1,870,468 fish passed the sampling site; 75 percent (1,396,814) and 25 percent (473,654) of the total passed the left and right banks (Figure 4). The highest daily passage (89,166 fish) occurred on 08 July.

Estimation of Missing Data

Left bank fish counts from 08 June through 02 July were estimated using the right bank fish counts from the same time period. This time period corresponds to when the left bank offshore stratum was not sampled completely due to problems experienced with flooding and uneven bottom conditions. In-season comparisons of early season left bank sonar data with other run strength indicators showed an underestimation of fish passage on the left bank. These indices included the lower river test fishery, commercial fishery catch, right bank sonar data, and the on-site test fishery on both the left and right banks.

Correlation analysis was completed to examine relationships between four measures of run strength: left bank fish counts, right bank fish counts, left bank gill net CPUE and right bank gill net CPUE (Appendix Table 25). For the period 04-18 July left bank fish counts were highly correlated with right bank fish counts (r^2 = 0.93), supporting our contention that left bank estimates for this time period are accurate. Attention was then focused on the 08 June through 03 July time period. A strong correlation between right bank fish counts and gill net CPUE (r^2 = 0.70) was observed which led us to conclude that the right bank sonar data was consistent with other indices of abundance during the 1987 early season and was the logical estimator for early season left bank fish passage. The mean of daily left and right bank proportions of total fish passage for the period 04-18 July was used to estimate left bank fish passage between 08 June and 02 July (Appendix Table 24).

The mean right bank percentage of total daily counts is 32.3 percent and the standard deviation is 4.7 percent. Fish counts for 03 July were interpolated from adjacent days counts due to the lack of right bank sonar data for this day. Interpolation resulted in estimation of 39,368 fish past the site; 27,657 fish passed the left bank site while 11,711 fish passed the right bank site.

Species Allocation

Estimation of Species Proportions

Sampling of the migrant fish population for use in estimation of species proportions began on 08 June and continued through 06 September. The catch totaled 3,184 fish, of which 1,840 (58 percent) were captured on the left bank and 1,344 (42 percent) were captured on the right bank.

A total of 287 chinook salmon were captured in 190.5 (7.5 in) and 215.9 mm (8.5 in) mesh gill nets, which were fished 110 times (358.85 fm-hrs) and 128 times (456.29 fm hrs). The majority (75 percent) were gilled or wedged; the remaining 25 percent were tangled. Forty one percent of the gilled fish were caught in 190.5 mm (7.5 in) gear and the remaining 59 percent were caught in 215.9 mm (8.5 in) gear. Catch (gilled and tangled) on the left bank totaled 213 chinook salmon (74 percent) while catch on the right bank totaled 74 chinook salmon (26 percent). No chinook salmon were captured in nets drifted offshore to check for extended fish distribution.

Summer chum salmon catches totaled 1,427 in 139.7 mm (5.5 in) and 165.1 mm (6.5 in) gill nets. These nets were fished 180 times (583.31 fm-hrs) and 147 times (495.80 fm-hrs). Of the fish captured, 1,331 (93 percent) were gilled or wedged and 96 (7 percent) were tangled in both gear sizes. Sixty nine percent of the gilled fish were captured in the 139.7 mm (5.5 in) mesh nets. A total of 781 fish (55 percent) were gilled or tangled on the left bank while 646 (45 percent) were caught on the right bank.

A total of 869 fall chum were captured in 139.7 mm (5.5 in) and 165.1 mm (6.5 in) gill nets. Seven hundred eighty fish (90 percent) were gilled or wedged, and of these, 58 percent were captured in the 165.1 mm mesh nets. A total of 576 fish (66 percent) were captured on the left bank while 293 (34 percent) were captured on the right bank.

Coho salmon gill net catches in 139.7 mm (5.5 in) and 165.1 mm (6.5 in) mesh gill nets totaled 425 fish. The majority (83 percent) were either gilled or wedged with 241 (68 percent) and 112 (32 percent) in each mesh size. A total of 171 (40 percent) were captured on the left bank while 254 (60 percent) were captured on the right bank.

The remainder of the gill net catch was composed of pink salmon and non-salmon species captured in 101.6 mm (4.0 in) and 127 mm (5.0 in) nets. These two nets were fished 86 times (320.23 fm-hrs) and 77 times (282.43 fm-hrs). Only 21 pink salmon were captured in 1987. Non-salmon catches totaled 155 fish. 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 (78 percent) of the fish captured were either gilled or wedged with 93 (64 percent) and 52 (36 percent) in the 101.6 mm (4.0 in) and 127 mm (5.0 in) gill nets. Fish catches were distributed evenly between left and right banks.

Length frequencies, regression coefficients and statistics, and selectivity coefficients and curves used to estimate the number of fish of each species encountering each of the two nets fished are presented by species in Appendix Tables 4 through 23 and Appendix Figures 1 through 18. These estimates, as well as raw catch, catch adjusted for net selectivity, wedging probability and effort appear in Appendix Tables 30 and 31. Summer chum salmon dominated the species composition (Figure 5) between 08 June and 18 July, comprising between 70 and 80 percent of the population. Fall chum salmon were the most abundant species between 19 July and 28 August, although coho salmon and non-salmon species dominated on some days due to the pulsed entry pattern of the fall chum salmon. Coho salmon predominated after 29 August.

Estimation of Daily Passage

The total estimated fish passage of 1,870,468 fish is apportioned to species in Table 1, and histograms of daily fish passage by species are shown in Figures 6 and 7. Time periods and species proportions used in this analysis are presented in Table 2. 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 3. Estimates are discussed by species in the following text.

The estimated chinook salmon escapement past the sampling site was 98,194 fish or 5.2 percent of the total salmon escapement. The highest daily passage occurred on 04 July when 7,426 chinook were counted. Most chinook salmon (78 percent) traveled along the left bank. The migration was in progress at project start-up on 08 June and continued until 25 July. The mean date of chinook salmon migration was 29 June (s.d.= 9)

Summer chum salmon were the most abundant species counted; an estimated 836,857 passed the site between 08 June and 18 July. This escapement level represents 45 percent of the total fish passage in 1987. Highest daily passage occurred on 08 July, when 78,018 fish were counted. The majority (68.1 percent) passed along the left bank. The migration was in progress when the project became operational on 08 June; a total passage of 1,256 summer chum were counted on this date. The mean date of migration is 02 July (s.d.= 8). The migration was complete by 18 July.

An estimated 615,123 fall chum salmon passed the sonar site representing 32.9 percent of the total fish passage in 1987. The highest daily passage (56,323) occurred on 02 August. The largest segment of the fall chum run (87 percent) passed along the left bank. Fall chum were present at river mile 123 from 19 July until the last day of operation (06 September). Although the fall chum run was not complete, daily passage had dropped to 1,622 fish per day. The mean date of migration is 13 August (s.d.= 12).

The coho salmon run consisted of an estimated 213,672 fish through the last day of operation in 1987. The coho run comprised 11.4 percent of the total season fish passage. The highest daily passage was 16,018 coho salmon on 02 September. Sixty eight percent passed the left bank and 32 percent passed the right bank. Coho salmon were present at the site from 01 August 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 3,459 fish. Based on the days sampled, the coho run mean date of migration is 25 August (s.d.= 8).

All non-salmon species were pooled to apportion hydroacoustic counts. Total estimated passage in 1987 was 106,625 fish representing 5.7 percent of all fish passage. The peak daily passage was 4,972 fish on 31 July. A total of 71,290 fish (67 percent) passed the left bank while 35,335 fish (33 percent) passed the right bank. These species were present from 08 June through the last day of counting. Whitefish species accounted for the majority of non-salmon species intercepted in 1987. They were present from 28 June through the last day of counting.

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 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 should be developed to help alleviate some of the difficulties caused by left bank river bottom instability. The risk of equipment loss and the amount of effort expended retrieving equipment must be minimized. 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. A model for fish passage estimation based on the relationship between left and right bank sonar counts and utilizing the available historical database should be developed to improve accuracy.

Precision of sonar counts has not been addressed to date. A thorough analysis of the data should be completed to determine whether the sampling scheme in use provides estimates of fish passage that are within the limits of accuracy and precision acceptable for use in commercial and subsistence fishery management. Such analysis would also indicate how personnel resources may be most efficiently utilized to maximize the value of the data collected.

Species Allocation

Estimation of Species Proportions

In addition to rendering the sonar equipment inoperable for a substantial period of time during the early season, the left bank river bottom also caused problems for the species allocation portion of the project. The shifting conditions of the river bottom within the testfishing sites dictated both the area and amount of time fished with certain nets. 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 in time or within the area of fish migration may result in over- or under-representation of certain species depending on whether or not species are temporally or spatially segregated. This results in inconsistencies in calculated left bank gill net CPUE.

At least three sources of variance exist in the species proportion estimator. Selectivity coefficients of the gill nets for each species have been estimated based on only current year length frequency data. Small catches, combined with the degree of stratification required to use this technique, results in sample sizes that are smaller than desired and selectivity coefficient estimates that are highly variable. Additionally, the division of the catch from two mesh sizes into three groups for selectivity adjustment, wedging probability estimation, and subsequent combination into a CPUE value for the species, is based on an arbitrarily chosen selectivity/length threshold. The sensitivity of wedging probability and CPUE values to choice of a threshold value should be examined and the resultant variance should be estimated. The third source of variance is that resulting from the estimation of multinomial proportions.

Estimation of Daily Passage

The Yukon River Sonar project in 1987 provided daily in-season run strength information to fishery managers on a timely basis, despite problems encountered with early season left bank data collection. The validity of these data, as judged from comparison with the sum of commercial and subsistence catch and survey-based escapement estimates, is discussed by Sandone (1990). Consistent production of timely escapement information with associated confidence intervals 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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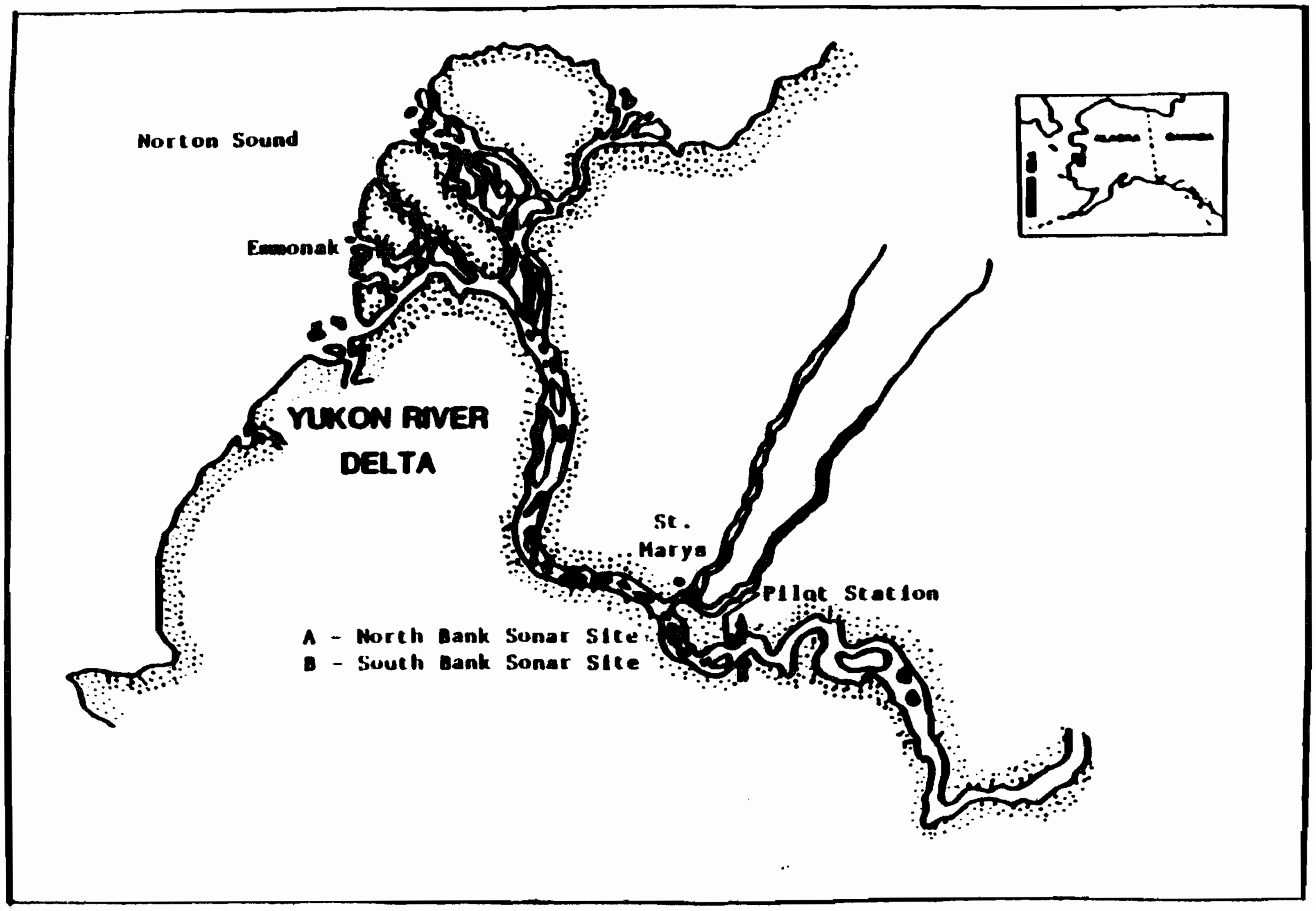

Figure 1. Map of the lower Yukon River showing the two sites used for hydroacoustic escapement enumeration in 1987.

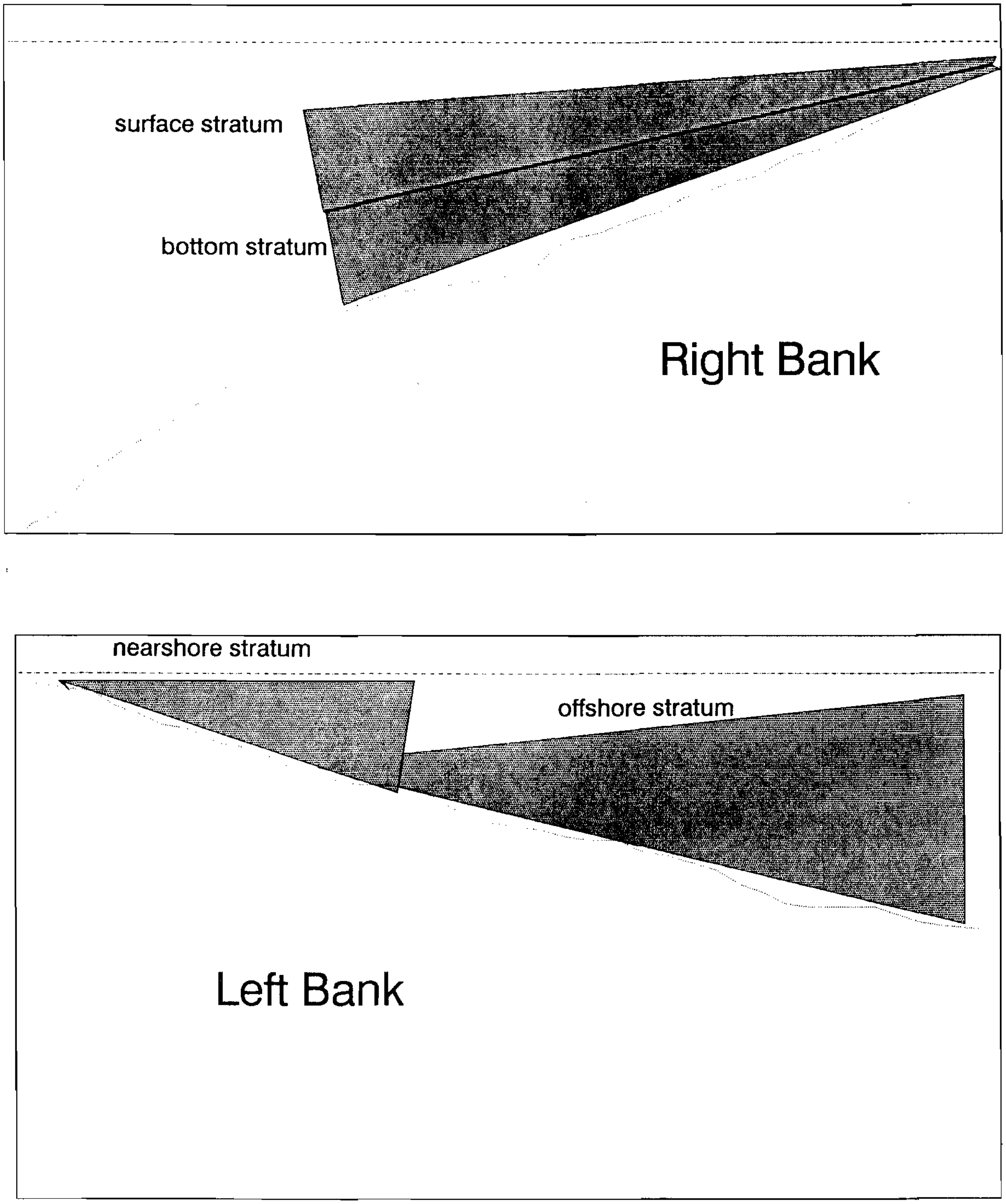

Figure 2. Areas of the Yukon River cross section sampled hydroacoustically at km 197 in 1987.

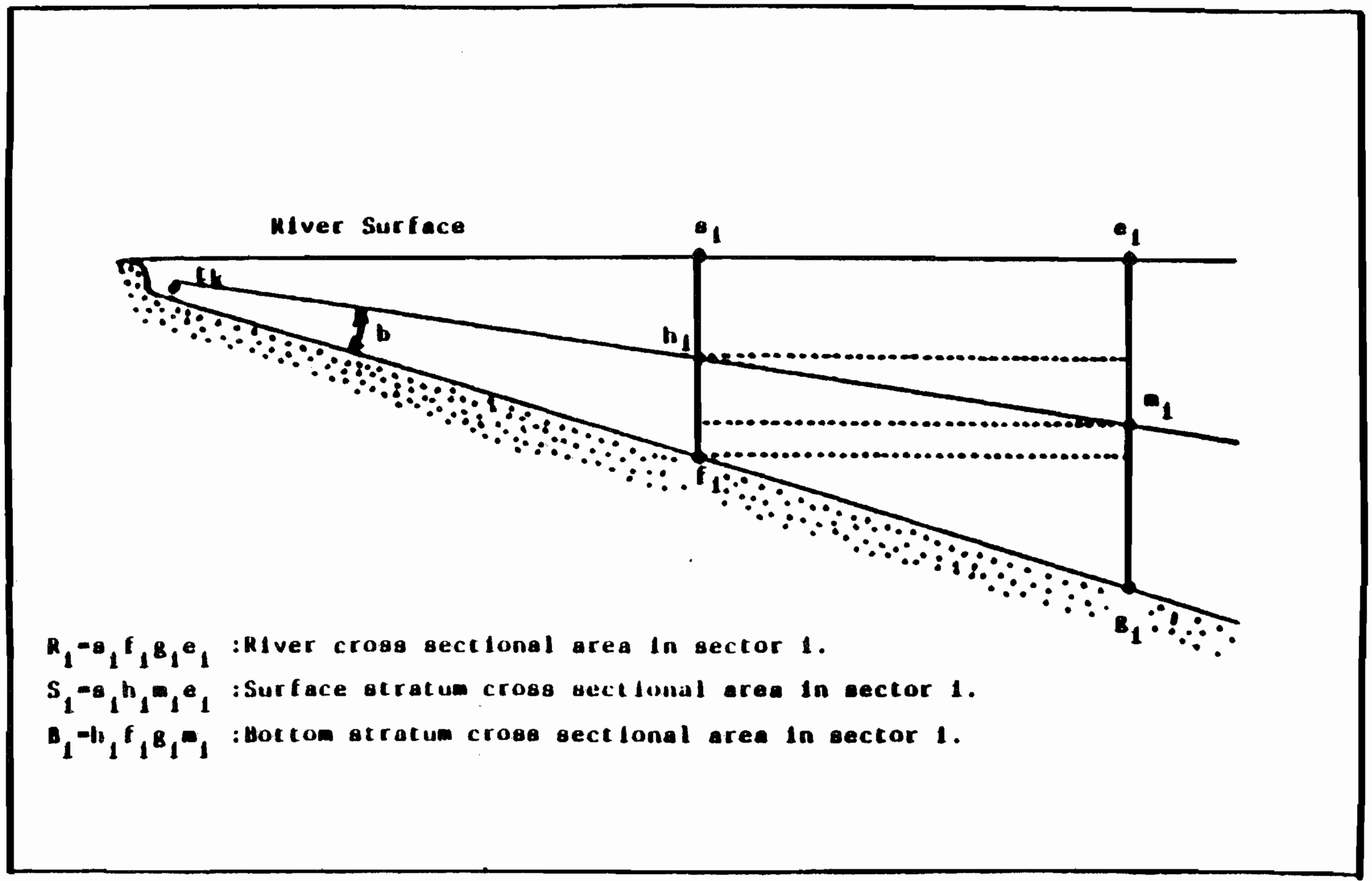

Figure 3. Geometric representation of Yukon River and hydroacoustic beam cross sectional areas used for calculation of spatial expansion factors for counts of fish obtained hydroacoustically in 1987.

Yukon River Sonar, 1987

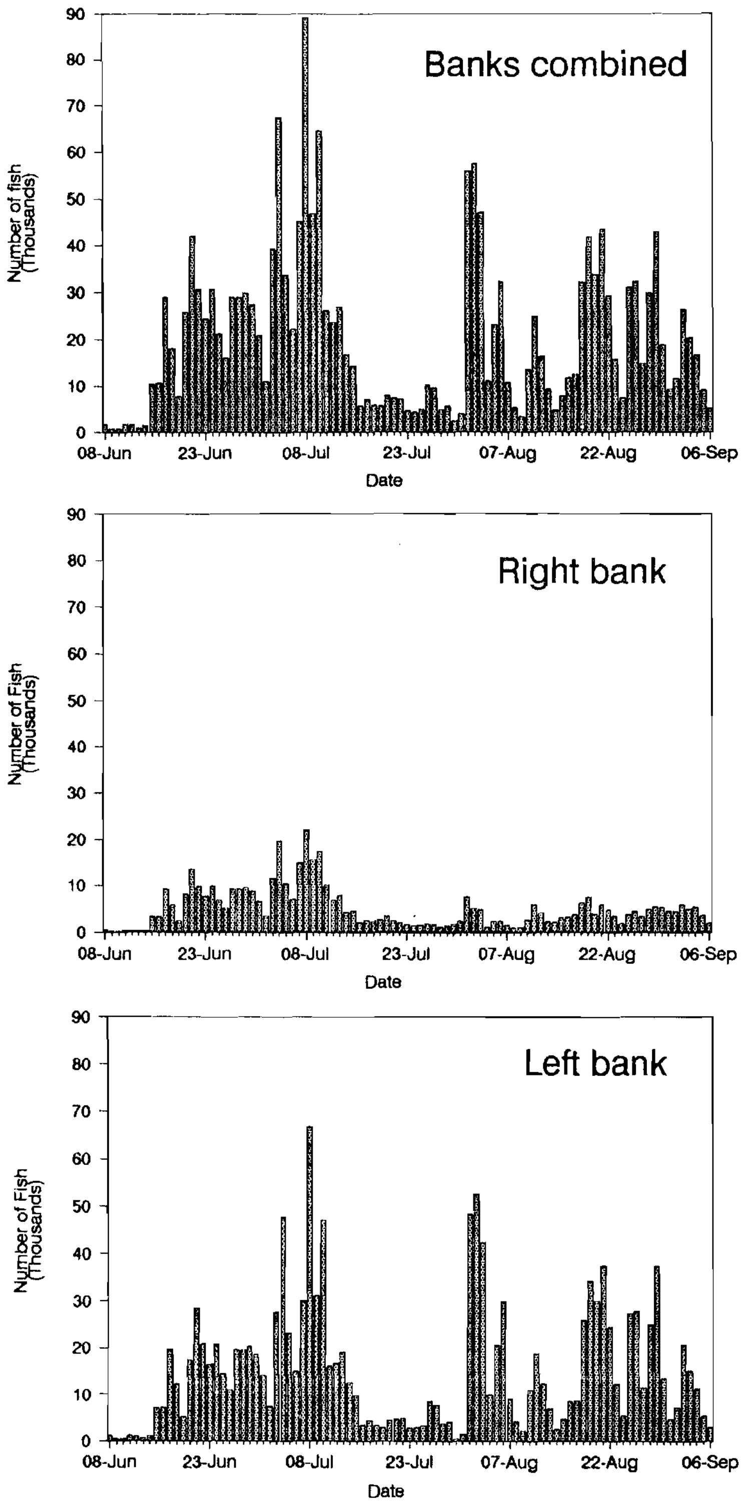

Figure 4. Daily fish passage estimates for combined banks, right bank, and left bank at km 197, Yukon River, 1987.

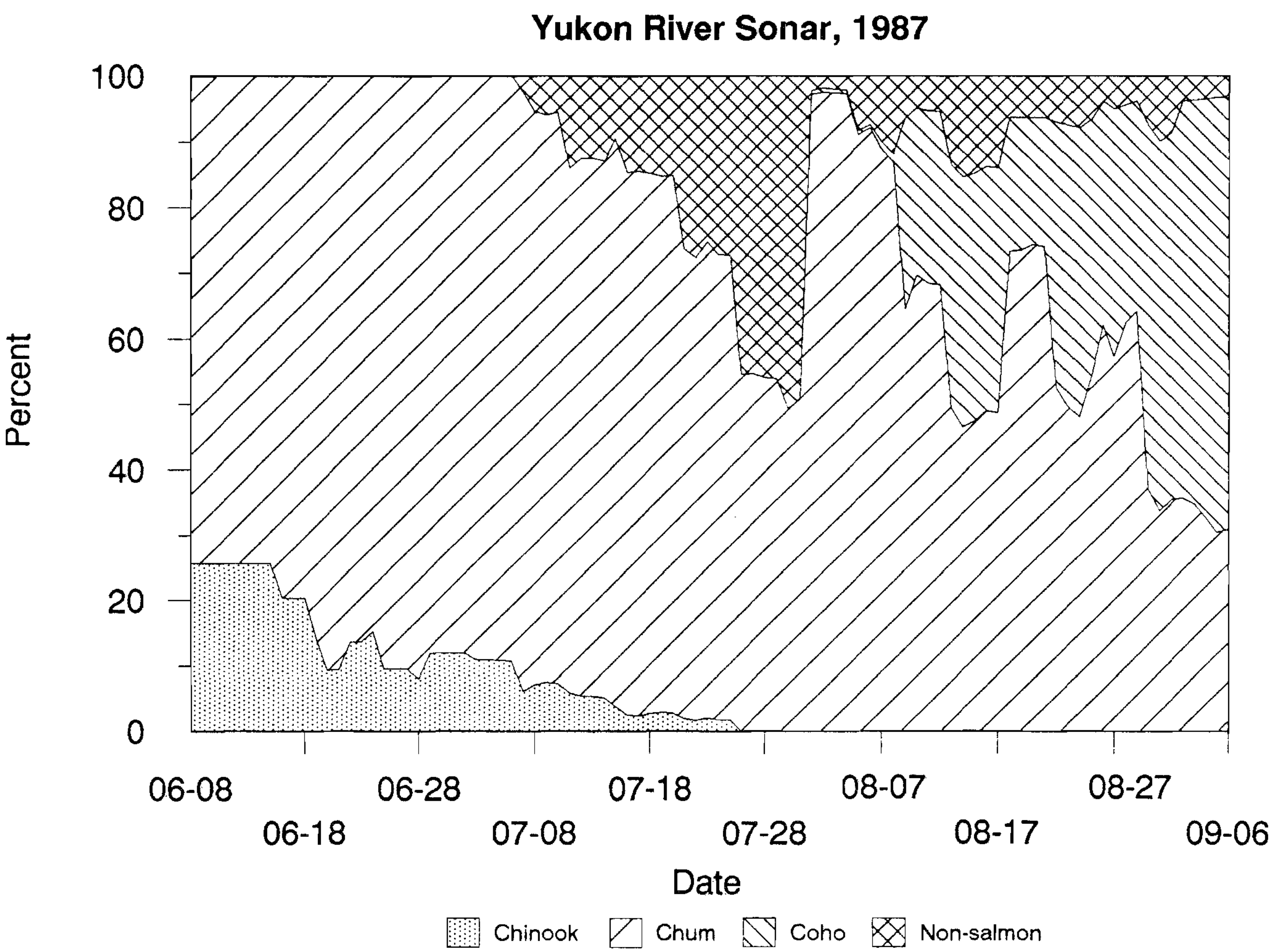

Figure 5. Species proportions between 08 June and 06 September at km 197, Yukon River, 1987.

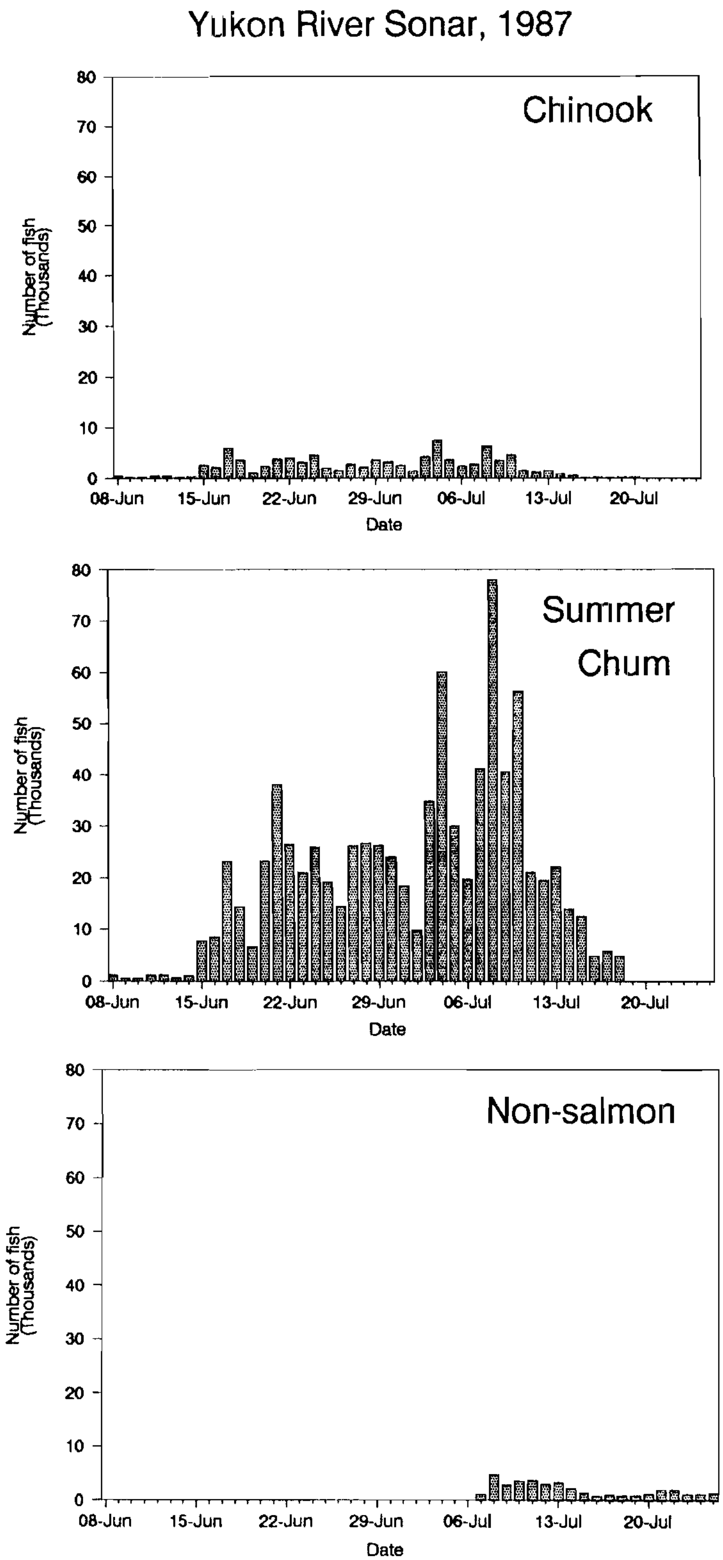

Figure 6. Daily fish passage estimates for chinook salmon, summer chum salmon, and non-salmon species at km 197, Yukon River, 1987.

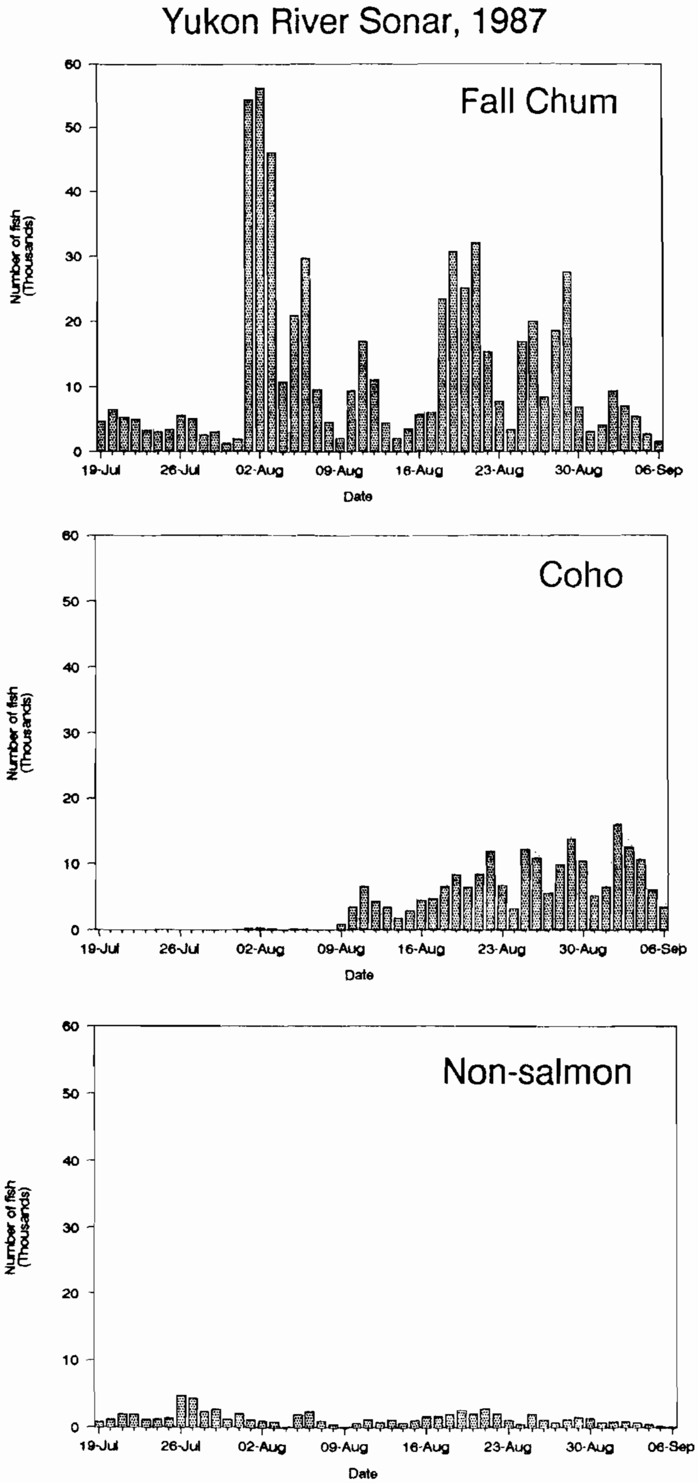

Figure 7. Daily fish passage estimates for fall chum salmon, coho salmon, and non-salmon species at km 197, Yukon River, 1987.

Table 1. Estimated escapements of chinook, summer chum, fall chum, and coho salmon, and non-salmon species past km 197, Yukon River, 1987.

Chinook	Summer Chum	Fall Chum	Coho	Non-salmon	Total
98,194	836,857	615,123	213,672	106,625	1,870,468

Table 2. Species allocation time periods and species proportions for left and right bank Yukon River sonar escapement estimates, 1987.

Right Bank

Dates	Chinook	Summer Chum	Fall Chum	Coho	Non-salmon	n
08-15 June	0.162	0.838				27
16-19 June	0.177	0.823				86
20-23 June	0.022	0.978				153
24-27 June	0.070	0.930				49
28 June-02 July	0.018	0.982				100
03-07 July	0.056	0.944				83
08-11 July	0.096	0.796			0.107	73
12-15 July	0.097	0.863			0.040	63
16-20 July	0.049	0.764			0.187	33
21-25 July	0.052	0	0.891		0.057	41
26-31 July	0	0	0.472		0.528	43
01-04 August	0	0	0.906		0.094	67
05-08 August	0	0	0.564	0.067	0.369	27
09-12 August	0	0	0.460	0.420	0.120	28
13-17 August	0	0	0.389	0.406	0.205	54
18-21 August	0	0	0.636	0.302	0.063	89
22-27 August	0	0	0.141	0.709	0.150	75
28 August-01 September	0	0	0.251	0.592	0.157	107
02-06 September	0	0	0.140	0.842	0.018	88

Left Bank

Dates	Chinook	Summer Chum	Fall Chum	Coho	Non-salmon	n
08-15 June	0.302	0.698				77
16-18 June	0.215	0.785				126
19-21 June	0.128	0.872				107
22-24 June	0.190	0.810				53
25-28 June	0.108	0.892				101
29 June-02 July	0.168	0.832				63
03-06 July	0.132	0.868				53
07-10 July	0.063	0.901			0.036	71
11-14 July	0.035	0.805			0.160	71
15-20 July	0.009	0.869			0.122	57
21-25 July	0	0	0.624		0.376	50
26-31 July	0	0	0.562		0.438	53
01-04 August	0	0	0.982	0.007	0.011	127
05-08 August	0	0	0.950	0	0.050	75
09-12 August	0	0	0.755	0.213	0.032	59
13-17 August	0	0	0.528	0.361	0.112	44
18-21 August	0	0	0.756	0.180	0.064	101
22-25 August	0	0	0.599	0.348	0.054	57
26-29 August	0	0	0.698	0.281	0.021	89
30 August-06 September	0	0	0.417	0.539	0.044	109

Table 3. Run timing parameters, based on hydroacoustic escapement estimates of chinook, summer chum, fall chum, and coho salmon at river km 197, Yukon sonar, 1987.

Species	Run Timing Parameters[1/]			
	Start	End	Mean	S.D. of Mean
Chinook	08 June	25 July	29 June	9
Summer chum	08 June	18 July	02 July	8
Fall chum	19 July	06 Sept.	13 August	12
Coho	01 August	06 Sept.	25 August	8

[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.