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Tanana River, Alaska, Fall Chum Salmon Radio Telemetry Study

by

Louis H. Barton

July 1992

Alaska Department of Fish and Game

Division of Commercial Fisheries

Fishery Research Bulletin

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ABSTRACT

Yukon River fall chum salmon *Oncorhynchus keta* were captured by fish wheel in the Tanana River from mid-August to early October in 1989 and externally tagged with low frequency (48-50 MHz) radio transmitters to estimate total spawning abundance upstream of Fairbanks, Alaska. Subsequent tracking of tagged fish identified approximately 18 different fall chum salmon spawning areas within the Tanana River floodplain between upper Salchaket Slough and the Little Gerstle River, in addition to spawning areas in two tributary streams. The proportion of fall chum salmon passing Fairbanks destined for the Delta River was estimated at 17.6% ±6.5% (95% confidence interval) and represented the greatest proportion of tagged fish to any site-specific spawning area. This information, together with an independent estimate of the number of Delta River spawners (21,342), resulted in a total spawning escapement estimate upstream of Fairbanks of 121,556 ±45,107 fish (95% confidence interval). Although no previously undocumented major spawning areas were discovered in the upper Tanana River, the comparatively smaller mainstem spawning areas, when taken collectively, in some years represent a more substantial contribution to total Tanana River fall chum salmon spawning escapement than previously realized.

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INTRODUCTION

The Yukon River is the largest river in Alaska, flowing over 3,200 km from its source in British Columbia, Canada, to the Bering Sea. The drainage totals approximately 854,700 km^2, two-thirds of which is in Alaska (Figure 1). Chum salmon *Oncorhynchus keta* return to the Yukon River drainage in distinct summer and fall runs, each supporting various commercial and subsistence fisheries.

Fall chum salmon are larger individually and less abundant than summer chum salmon. The smaller population size may be related to strict spawning habitat requirements which are limited throughout the drainage and within streams (Buklis and Barton 1984). Whereas summer chum salmon spawn primarily in runoff streams throughout the lower portion of the Yukon River drainage, fall chum salmon migrate farther upstream and spawn in spring-fed tributaries where upwelling ground water keeps spawning grounds relatively ice-free throughout the winter months.

Major fall chum spawning streams in the Alaskan portion of the drainage include the Chandalar, Sheenjek (Porcupine River drainage), and Tanana Rivers (Barton 1984). In the Canadian portion of the drainage major spawning streams include the Fishing Branch and Kluane Rivers and portions of the mainstem Yukon River between Fort Selkirk and Carmacks.

Most of these rivers are typical glacial streams with turbid, silt-laden water and broad, braided channels. Fall chum spawning takes place in anabranches, floodplain channels and sloughs, or portions of tributary streams with upwelling ground. High-flow spring and summer runoff carrying large amounts of sediment results in scouring and shifting of channels in most years. This influences the location and amount of available spawning area.

The glacial nature of these streams has made accurate assessment of spawning escapements extremely challenging. This is particularly the case in the upper portion of the Tanana River drainage where compre-

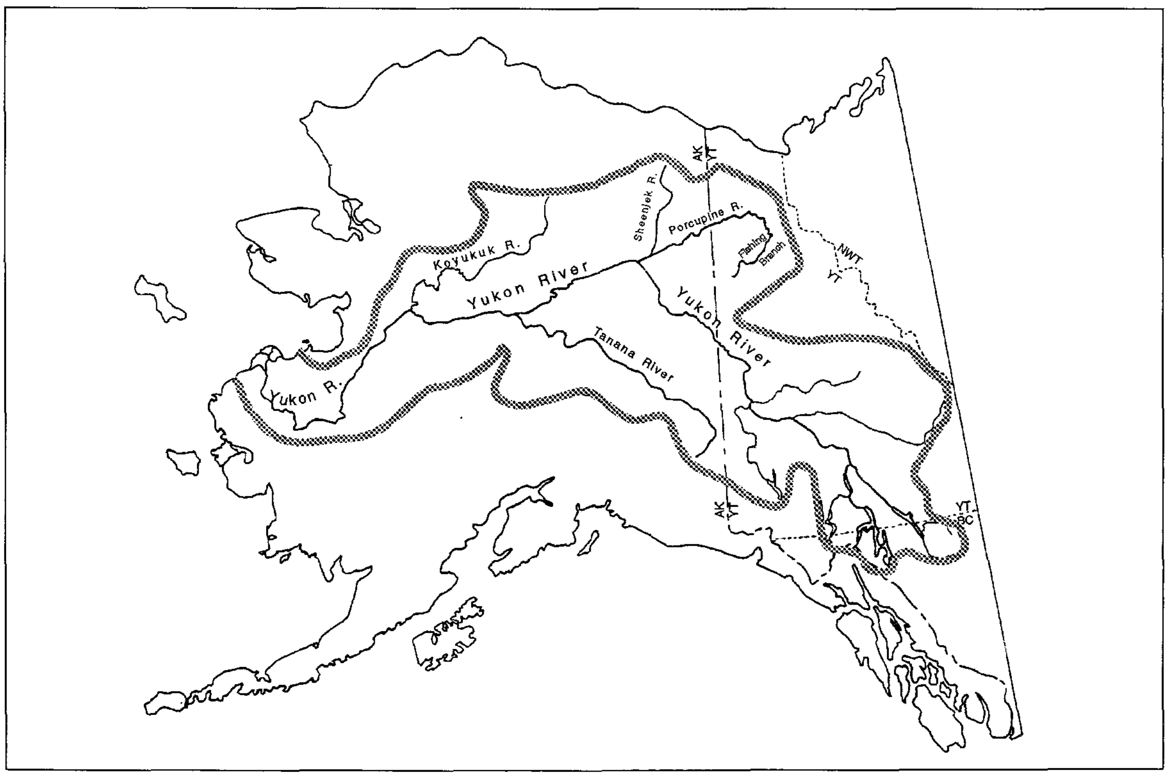

FIGURE 1.—The Yukon River drainage, indicated by shaded line.

hensive escapement assessment studies are lacking. The Tanana River flows northwest through a broad alluvial valley for approximately 700 km to the Yukon River at Tanana village, draining an area of approximately 115,250 km^2 (Figure 2). The Tanana basin is bounded on the south by the Alaska Range. This mountain range is capped extensively with glaciers which are assumed to be the greatest source of runoff to the Tanana River (Anderson 1970). Maximum flow of glacial streams occurs in July and August which coincides with peak melting of glaciers. Flow of nonglacial streams rises sharply in May during the spring snowmelt, generally recedes during the summer months, and slightly increases during the early fall rainy period.

Major fall chum spawning areas in the Tanana River drainage exist in the Toklat River (Kantishna River drainage) and the upper mainstem Tanana River between the Delta and Delta Clearwater Rivers, i.e., the vicinity of Big Delta including the Delta River. Currently, interim fall chum escapement objectives exist for the Toklat River (>33,000) and the Delta River (>11,000). During the past decade (1980-1989), annual escapements have averaged approximately 13,700 in the Delta River and approximately 19,000 in the Toklat River (Bergstrom et al. 1991). The Delta River is conjectured to represent the majority of spawners using the Big Delta region.

In addition to the spawning areas in the Big Delta region, fall chum have also been documented spawning at several other locations in the mainstem Tanana River between upper Salchaket Slough and Billy Creek (Barton 1984; ADF&G *Undated*). Spawning at these locations has been observed primarily in smaller side channels or sloughs of the mainstem where upwelling ground water makes visibility possible only in some years. However, the extent of open water or open leads varies annually in these areas. Ice, snow cover, and mainstem turbidity hinder visibility, often making spawning areas difficult to locate and unsuitable as index areas. Limited observations on the number of spawners observed in these areas have represented only a fraction of those observed spawning in the Big Delta region. As such, these areas have not been believed to be major fall chum producers.

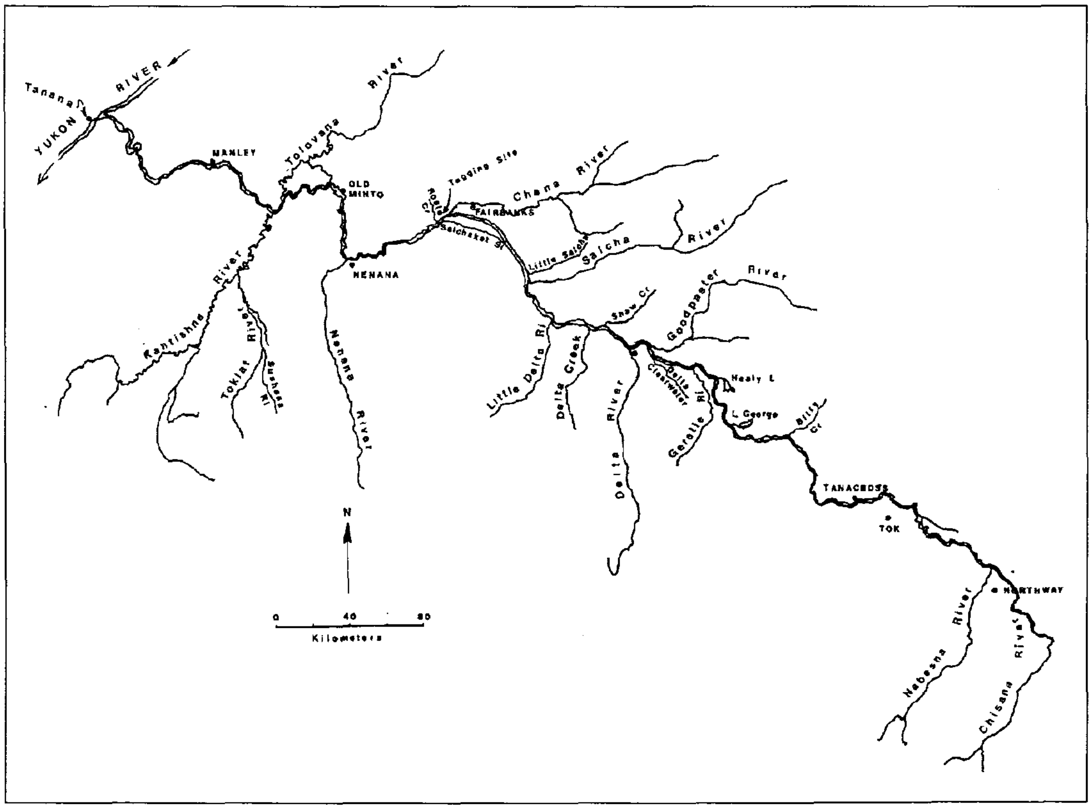

FIGURE 2.—The Tanana River drainage.

Low escapements to most fall chum spawning areas throughout the Yukon River drainage in the years 1982-1984 led to more conservative harvest management strategies beginning in 1983, and particularly since 1986 when the progeny from those brood year escapements began returning. In that year (1986) the Alaska Board of Fisheries (BOF) adopted the Yukon River Fall Chum Salmon Management Plan; a management plan designed to reduce overall exploitation rates on Yukon River fall chum salmon and increase spawning escapements. In the spring of 1988 the BOF also adopted the Tanana River Salmon Management Plan. Although the Tanana River was not specifically identified as a "terminal harvest area", that plan sanctioned exceeding Tanana River regulatory guideline harvest ranges in years of strong salmon returns provided that managers determined inseason that both escapement requirements and subsistence needs would still be met. To maintain adequate spawning levels and yet maximize fishery harvests, the Alaska Department of Fish and Game (ADF&G) needed more knowledge concerning escapement abundance and distribution.

In 1988 I undertook a preliminary investigation to determine the feasibility of using radio telemetry to examine run timing and determine whether or not other major spawning areas exist in the mainstem Tanana River—possibly similar to those in the Big Delta region—but had gone unnoticed because of ice cover or mainstem turbidity levels (Barton 1989). Radio telemetry had been successfully used to study Pacific salmon in large glacial rivers of southeastern and southcentral Alaska and portions of northwestern British Columbia by Hammarstrom et al. (1985), Eiler et al. (1988), Eiler (1989), Bendock and Alexandersdottir (*In press*), and Booth, (*In press*). These investigators used telemetry techniques to collect information on fish movements, behavior, run timing, and distribution, and spawning habitat characteristics. In the preliminary 1988 investigation, I found that external application of transmitters worked and that tagged fish could be relocated in the Tanana River drainage (Barton 1989). However, no new major spawning areas were identified.

Based on results of the work conducted in 1988, I undertook a more extensive study in 1989. Specific objectives of the 1989 study were to:

(1) determine spawner distribution with the intent of documenting any previously unknown fall chum salmon spawning areas; and

(2) estimate the total number of fall chum salmon which spawned upstream of Fairbanks, particularly the number of non-Delta River spawners.

To meet these objectives, radio telemetry techniques were used to monitor spawning distribution and to determine the proportion of fish passing Fairbanks that were destined for the Delta River. In addition, an independent population estimate for the number of Delta River spawners was to be attempted using replicate ground surveys and salmon stream-life data.

MATERIALS AND METHODS

Transmitter Deployment

Chum salmon were captured by fish wheel on the north bank of the Tanana River approximately 11 km downstream of Fairbanks and tagged with radio transmitters (see Figure 2). Distance to the tagging site from the mouth of the Tanana River was 339 km.

Destination of radio-tagged fish was viewed as a binomial random variable; i.e., tagged chum salmon either migrated to the Delta River or they did not. Based on the normal approximation to the binomial and correcting for bias, a minimum sample size of 185 transmitters was needed to achieve 80% precision and 0.05 accuracy for the estimate of the proportion of the run passing Fairbanks destined for the Delta River. A total of 200 transmitters were obtained for deployment.

An attempt was made to tag and release fall chum salmon in proportion to temporal run abundance at the tagging site. A schedule was developed regarding the rate of transmitter deployment based upon the mean dates of passage and associated standard deviations of run timing observed by Barton (1989) in experimental fish wheels at Manley, Nenana, and Fairbanks in 1988 (Appendix A). These statistics were based upon a time-density model developed by Mundy (1982, 1984) and were calculated from the proportion of the total passage occurring each day. Whereas the calculated mean date of passage is a measure of the central tendency of the run, the standard deviation is a measure of run dispersion.

In 1988 Barton (1989) observed the mean day of fall chum passage at Fairbanks on September 13 (SD = 6.8); 1 d later than mean passage at Nenana (September 12, SD = 9.1) and 6 d later than mean passage at Manley (September 7, SD = 8.2). The central half of the run (25%-75%) passed the Fairbanks site over an 11-d span from September 7-18, compared to 14 d (September 5-18) at Nenana and 10 d (September 2-11) at Manley. Based on these observations, the period of September 7–20 was targeted for deploying the central half (100) of the 200 transmitters in 1989. Inseason experimental fish wheel catches, as they developed at Manley and Nenana, were used to adjust the 1989 tag deployment schedule at Fairbanks, if necessary, to account for differences in run timing between 1988 and 1989.

Fall chum salmon were tagged with low frequency radio transmitters within the 48 to 50 MHz range, each of which was separated by a minimum of 10 kHz. The transmitters were manufactured by Advanced Telemetry Systems (ATS) of Isanti, Minnesota[1]. Each transmitter had an air weight of approximately 15 g, a minimum active lifespan of 100 d, a 30 cm teflon-coated whip antenna, measured approximately 38 mm long by 19 mm in diameter, and possessed a base pulse rate of 75-80 transmissions per minute. Each tag was also equipped with a mortality sensor: activated by a mercury switch once a transmitter had remained motionless for 3-5 hours, it resulted in an approximate doubling of the base pulse rate.

Individual transmitters were modified for external application by epoxying two Petersen needles on to each transmitter. Needles were affixed so that transmitters could be secured to the left side of fish immediately below the dorsal fin. Sleeves, modified intravenous 14-gauge by 140-mm catheters, were slipped over each needle to help facilitate insertion. Transmitters were secured in place with Petersen discs; antennae trailed toward the caudal fin (Figure 3).

Chum salmon were placed in a tagging cradle, sexed by external examination, tagged, and measured

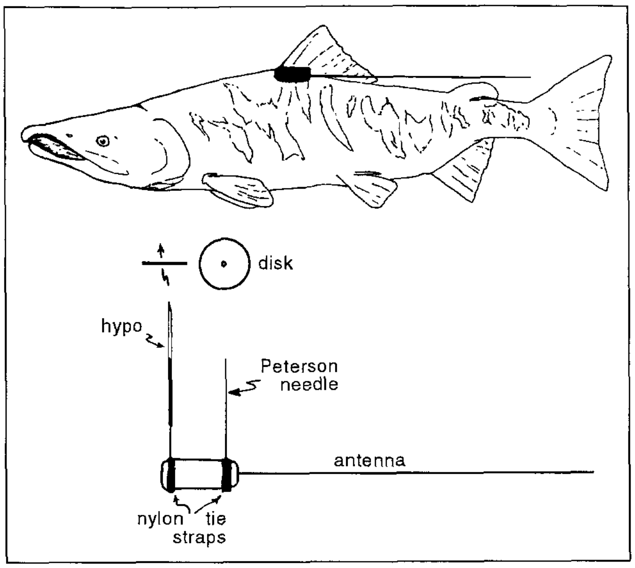

FIGURE 3.—Application and placement of radio transmitters on chum salmon, 1989.

from mid-eye to the fork of the tail before being placed in a holding tank; anesthesia was not used. The entire tagging procedure took approximately 1.5-2.0 minutes. Tagged fish were held for 20-30 minutes to ensure they were in a vigorous state prior to release at the tagging site. During the holding period transmitters were monitored for frequency drift with a portable receiver.

In an attempt to ensure only fall chum salmon were tagged, chum salmon that were highly water-marked, dark ventrally, and small in size were considered likely to be summer chum salmon and were not tagged. This was particularly germane to the first few days of tagging when a few summer chum salmon were still observed passing the tagging site.

Radio Telemetry Operation

Tracking radio-tagged salmon was accomplished by aerial and ground surveys, as well as by using a remote data logger. Aerial tracking was the primary means of locating and monitoring fish movement between the tagging site and their final destination. To facilitate tracking and recording of tagged fish, Tanana River distances to selected geographical features and prominent landmarks were measured using

[1] Use of a company's name does not constitute endorsement.

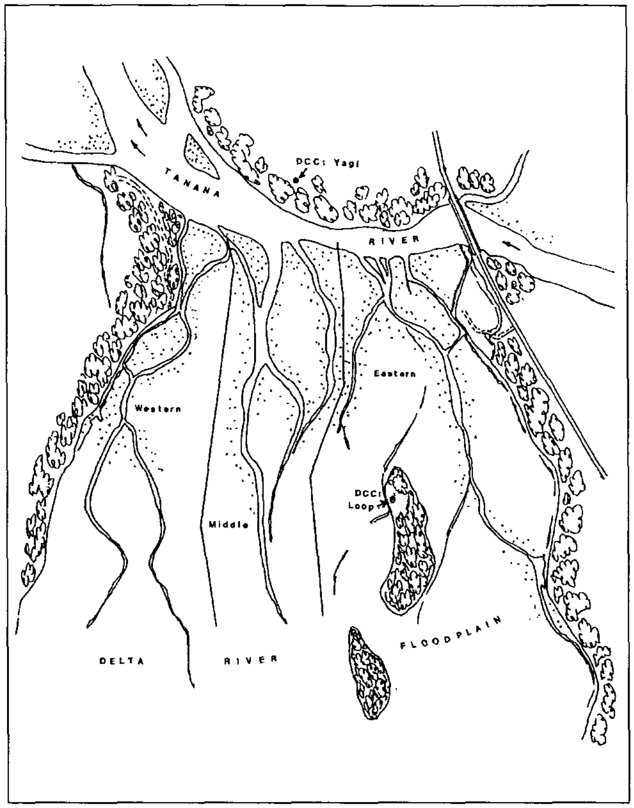

FIGURE 4.—Lower Delta River floodplain and chum salmon spawning channels, 1989.

a digitizing table and Universal Transverse Mercator map interpretation software (Appendix B).

Aerial tracking was conducted with single-engine, fixed-wing aircraft equipped with a single directional loop antenna affixed to one of the wing struts. Surveys were flown at altitudes of 300-500 m and air speeds of 160-190 km/hr (85-105 knots). An ATS receiver that continuously scanned through preprogrammed frequencies at a rate of 1 to 2 sec per frequency was used to locate tagged fish. When a signal was received, the scanning mode of the receiver was manually interrupted to allow the surveyor to locate the tagged fish (transmitter) from which the signal was being generated.

Fish location was generally determined to within approximately 2-3 km during early aerial surveys when reception was primarily of signals from moving fish as distinguished by the base pulse rate. However, an attempt was made to locate as precisely as possible each tagged fish generating a mortality signal. The location of each tagged fish was marked on USGS topographical maps (1:63,000). Aerial photographs taken in 1988 of portions of the upper mainstem Tanana River between approximately the Salcha and Gerstle Rivers were used to help interpret topographical maps and more accurately locate spawning areas and tagged fish.

Aerial surveys were occasionally supplemented with ground surveys (foot and boat) to more precisely locate individual tagged fish. This was generally the case when, in the vicinity of the Delta River, a large number of congested signals had been detected from a previous aerial survey. Ground surveys were also conducted using an ATS scanning receiver and directional loop antenna.

An ATS programmable Data Collection Computer (DCC), connected to a scanning receiver, was used to monitor passage of tagged fish by the Delta River as well as provide documentation of tagged fish spawning within the Delta River. The DCC and accompanying receiver were originally positioned with a 20-element Yagi antenna approximately 50 m high on a bluff overlooking the lower Delta River floodplain (Figure 4). The DCC was subsequently repositioned with a directional loop antenna directly to the Delta River floodplain in an attempt to reduce interference with signal reception. The precise range of reception was determined by placing several transmitters of known frequency at selected locations. Reception range included all of the Delta River floodplain spawning sloughs as well as that portion of the mainstem Tanana River extending directly along the mouth of the Delta River.

The DCC programmed the receiver to scan specific frequencies at a rate of 2-4 sec per frequency every 4 hr, and store recorded data. The DCC was internally powered by a lithium battery pack; the receiver was externally powered by a deep cycle 12-V battery which in turn was connected to a 3.1-A, 45-W solar panel made by Atlantic Solar Products, Inc. of Baltimore, Maryland[2]. When the receiver detected a signal, the DCC recorded and stored the Julian date, time

[2] Use of a company's name does not constitute endorsement.

(hour and minute), preprogrammed channel number (corresponding to a particular frequency), and the number of pulses detected for that frequency.

Population Estimation Methods

Delta River

A map of Delta River open water areas in 1989 was prepared by drawing the approximate location of channels using high altitude aerial photographs taken of the spawning areas in November 1988 and photographs obtained at various land-based and aerial angles in 1989 (see Figure 4).

Foot surveys of the Delta River spawning area were made weekly from late September through November. Both live and dead chum salmon were enumerated in each series of spawning channels; i.e., eastern, mid- or main river, and western channels. Polaroid sunglasses were worn to reduce surface glare. A riverboat was used to gain access to western spawning channels when the main river channel was too high to allow crossing by foot.

Two methods were used to estimate the population of Delta River fall chum spawners as described by Barton (1986). The first method involved plotting counts of live salmon by survey date and estimating the total number of salmon days, i.e., the area under the curve. Whereas, total salmon days provides an estimate of the number of live salmon if stream residence time is 1 d, division by stream residence time yields an estimate of the total population:

$$N_D = \left(\frac{1}{T}\right) \sum_{i=1}^{s-1} D_{i,i+1} \left(\frac{L_i + L_{i+1}}{2}\right), \qquad (1)$$

where:

N_D = the fall chum spawning population of the Delta River,

S = the number of surveys conducted,

$D_{i,i+1}$ = the number of days between survey i and survey $i+1$,

L_i = the number of live salmon observed on survey i, and

T = the stream residence time.

Residence time was based upon stream life data collected from the Delta River in 1973 and 1974 (Trasky 1974, 1976).

Another method was also used to estimate total abundance in 1989. The number of live salmon on a specified day was the sum of the number of live fish remaining from the previous survey(s) and the number of new fish entering the stream subsequent to the previous survey. The number of fish that had spawned and died between surveys was estimated from Trasky's studies on stream residence time (Appendix C). Total run size was approximated by summing the numbers of new salmon estimated entering in each time interval and by adding this estimate to the number of carcasses counted on the last survey minus the estimated number of carcasses previously counted as live fish. This method of estimating total abundance is represented by

$$N_D = \sum_{i=1}^{S} B_i + C_S - \sum_{i=1}^{S-1} (1 - P_{Si}) B_i , \qquad (2)$$

where B_i is the number of new fish entering the stream subsequent to the i^{th} survey, and is calculated as:

$$B_i = L_i - \sum_{j=i}^{i-1} P_{ij} B_j , \; i > 1. \qquad (3)$$

Note that $B_1 = L_1$, and

C_S = the number of carcasses observed on survey S, and

P_{ij} = the proportion of the salmon that entered on day j that are still alive on day i (from Appendix C).

Upper Mainstem Tanana River

The proportion of chum salmon spawning upstream of Fairbanks (N_T) was estimated as

$$N_T = \frac{N_D}{p_D} , \qquad (4)$$

where N_D is the estimated spawning population for the Delta River and p_D is the estimated proportion of tagged fish released that were assigned to the Delta River. The variance of N_T was estimated using the delta method described by Seber (1982):

$$V(N_T) = \frac{V(p_D)\, N_D^2}{p_D^4} \quad . \qquad (5)$$

The approximate 95% confidence interval for the estimate of N_T was constructed using

$$N_T \pm z_{(1-\frac{\alpha}{2})} \sqrt{V(N_T)} \quad . \qquad (6)$$

The approximate 95% confidence interval for the estimate of p_D was constructed using

$$p_D \pm z_{(1-\frac{\alpha}{2})} \sqrt{V(p_D)} \quad . \qquad (7)$$

RESULTS

Transmitter Deployment

Fall chum salmon run timing in 1989 was judged very similar to that observed by Barton (1989) in 1988 (see Appendix A). Mean day of passage at Manley occurred on September 7 in both years. Mean passage at Nenana was observed as only 1 d earlier in 1989 than in 1988 (September 11 vs. 12). Corresponding standard deviations for 1989 were 11.9 at Manley and 9.0 at Nenana. Therefore, no inseason adjustments were made to the tag deployment schedule.

A total of 210 radio transmitters was deployed on fall chum salmon from August 18 to October 2, 1989 (Table 1). Ten of these included transmitters which were redeployed after fish originally tagged had been captured in commercial, sport, personal use, or subsistence fisheries. An additional 11 fishery recoveries were made subsequent to the tagging phase of the study. Recoveries by fishery and location are shown below:

	Upstream of Tag Site	Downstream of Tag Site
Commercial Fishery	9	2
Personal Use Fishery	7	0
Sport Fishery	1	0
Subsistence Fishery	0	2

The male:female ratio of tagged fish was 1.00:0.81; or 116 males (55%) and 94 females (45%). Males averaged 18 mm larger than females with a mean length of 603 mm (SD = 33.4); females averaged 585 mm (SD = 27.9). Tagging was terminated on October 2 to move the fish wheel to a secure place prior to winter freeze-up.

TABLE 1.—Deployment rate of radio transmitters on Tanana River chum salmon captured by fish wheel near Fairbanks in 1989.

Date	Targeted Deployment Schedule	Actual Deployment No.	Actual Deployment Percent	Cumulative Deployment No.	Cumulative Deployment Percent
Aug 18	3	3	1.4	3	1.4
Aug 19					
Aug 20					
Aug 21	3	3	1.4	6	2.9
Aug 22					
Aug 23	5	1	0.5	7	3.3
Aug 24		5	2.4	12	5.7
Aug 25	5	1	0.5	13	6.2
Aug 26					
Aug 27					
Aug 28	5	12	5.7	25	11.9
Aug 29					
Aug 30	5				
Aug 31					
Sep 01	10	13	6.2	38	18.1
Sep 02					
Sep 03	10	10	4.8	48	22.9
Sep 04					
Sep 05	10	7	3.3	55	26.2
Sep 06					
Sep 07	10	13	6.2	68	32.4
Sep 08	10	11	5.2	79	37.6
Sep 09					
Sep 10					
Sep 11	10	10	4.8	89	42.4
Sep 12	10	11	5.2	100	47.6
Sep 13	10	10	4.8	110	52.4
Sep 14	10	10	4.8	120	57.1
Sep 15	10				
Sep 16					
Sep 17					
Sep 18	10	15	7.1	135	64.3
Sep 19	10	15	7.1	150	71.4
Sep 20	10				
Sep 21		18	8.6	168	80.0
Sep 22	10	19	9.0	187	89.0
Sep 23					
Sep 24	10				
Sep 25					
Sep 26	10	11	5.2	198	94.3
Sep 27		8	3.8	206	98.1
Sep 28	5				
Sep 29	5				
Sep 30	5				
Oct 01					
Oct 02		4	1.9	210	100.0

Radio Telemetry Surveys

Background noise in the 48-50 MHz range in the Big Delta area prevented correct identity of specific transmitter signals with the DCC. Noise resulted from Alyeska Pipeline Service Company microwave re-

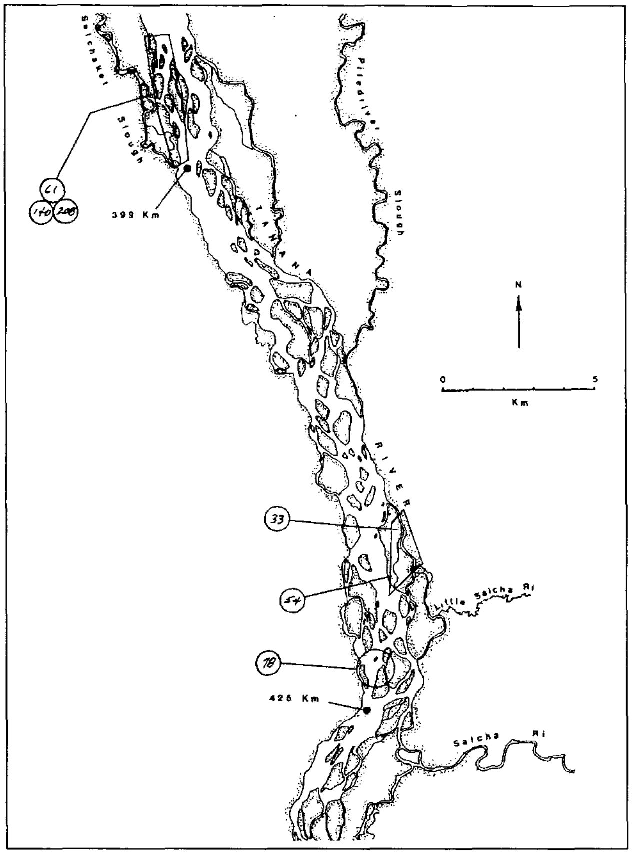

FIGURE 5.—Chum salmon spawning locations in the Tanana River between Salchaket Slough and the Salcha River isolated by radio telemetry, 1989. Encircled numbers identify individual radio transmitters.

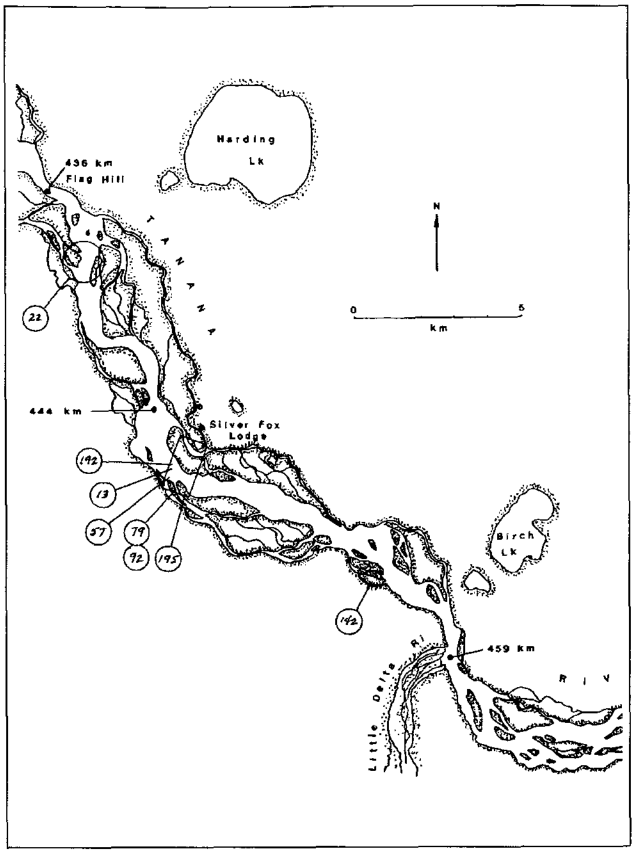

FIGURE 6.—Chum salmon spawning locations in the Tanana River between Harding Lake and the Little Delta River isolated by radio telemetry, 1989. Encircled numbers identify individual radio transmitters.

flectors on the Trans-Alaska Pipeline System (TAPS) and local HAM radio operators. Thus, all tracking results were based upon aerial and ground surveys.

Eight aerial tracking surveys were flown upstream of the tagging site between August 29 and November 27, four of which were flown as far upstream as Billy Creek. On October 12 a single aerial survey was flown downstream of the tagging site; this included the mainstem Tanana River to the Kantishna River confluence, as well as the lower 90 km of the Kantishna River. Four additional ground surveys were made from October 13 to November 17, primarily in the Big Delta area. Tributaries examined included the Salcha River, Little Delta River, Delta River, Delta Creek, as well as Salchaket Slough and portions of the Chena River, Richardson Clearwater River, Delta Clearwater River and Goodpaster River.

Tracking results over the course of the study revealed 11 of the 210 transmitters (5.2%) were located immediately at or some distance downstream of the tagging site (Appendix D). Seventeen of the remaining 199 tagged fish were subsequently recovered in various upstream fisheries, leaving 182 potentially available for tracking to upstream spawning areas. Specific spawning areas were determined with reasonable certainty for 131 of these fish: 97 were associated with approximately 18 different spawning areas within the Tanana River floodplain between upper Salchaket Slough (km 399) and the confluence of Little Gerstle River (km 617) and 34 tracked to spawning areas in 3 tributary streams (10 in the Salcha River, 1 in the Richardson Clearwater River, and 23 in the lower Delta River).

Six different spawning areas were identified in the mainstem Tanana River between upper Salchaket Slough and Little Delta River, based upon the movement and locations of 14 tagged fish. Specific spawning areas were observed in mainstem channels or

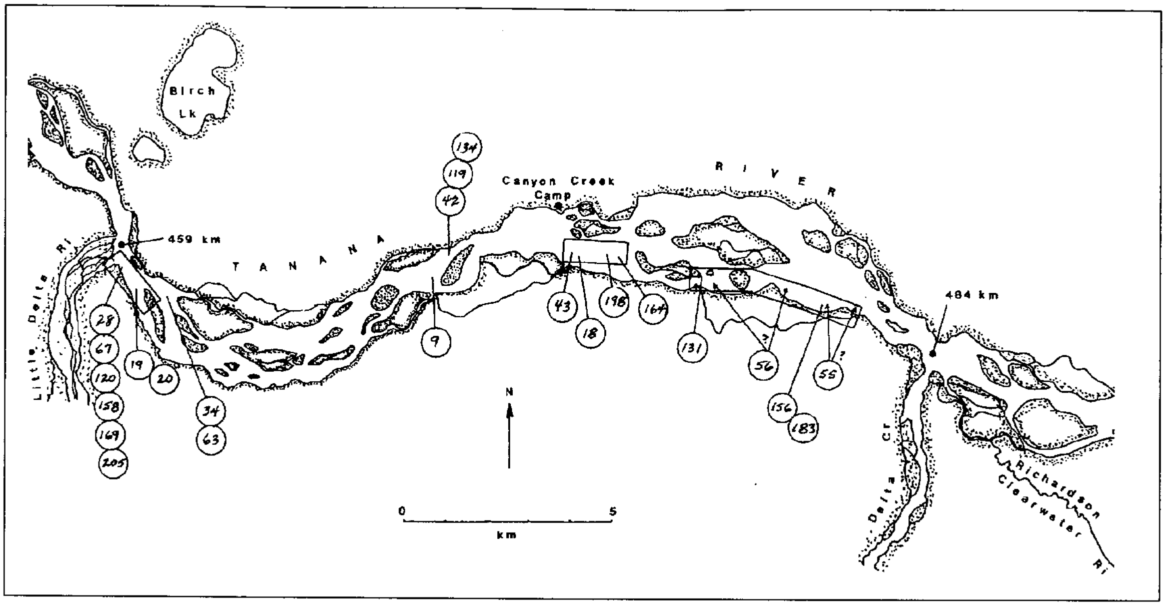

FIGURE 7.—Chum Salmon spawning locations in the Tanana River between Little Delta River and Delta Creek isolated by radio telemetry, 1989. Encircled numbers identify individual radio transmitters.

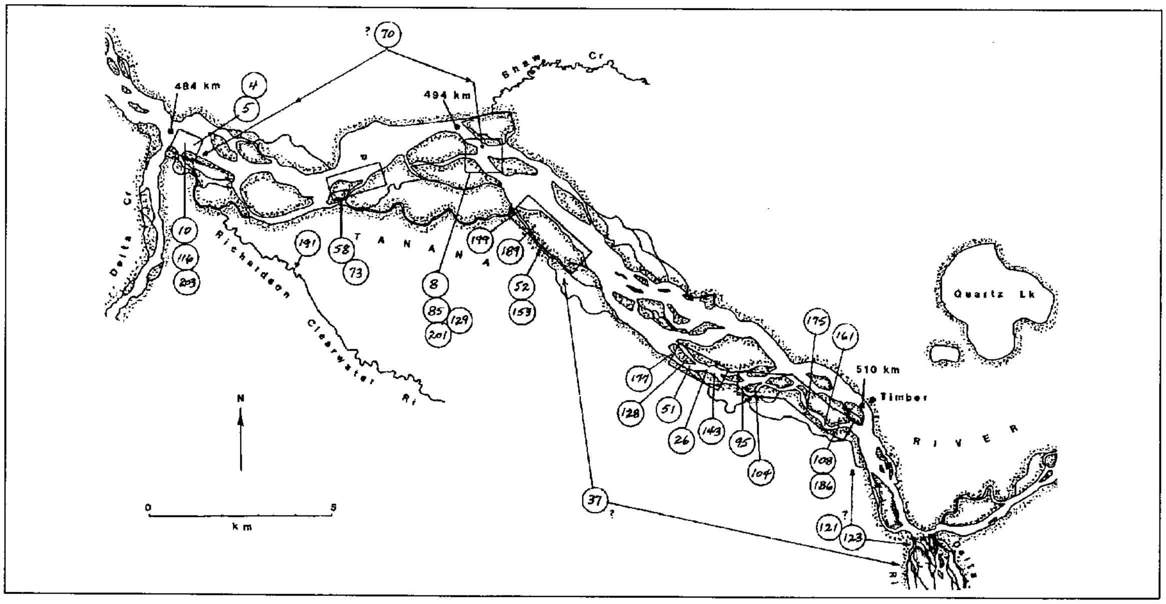

FIGURE 8.—Chum Salmon spawning locations in the Tanana River between Delta Creek and the Delta River isolated by radio telemetry, 1989. Encircled numbers identify individual radio transmitters.

sloughs near upper Salchaket Slough, the mouths of the Little Salcha and Salcha Rivers, Flag Hill, Silver Fox Lodge, and approximately 5 km downstream of Little Delta River (Figures 5, 6). The three spawning areas observed between Little Salcha River and Flag Hill were previously unknown.

Based upon the movement of 23 tagged fish, 4 spawning areas were located between the mouths of

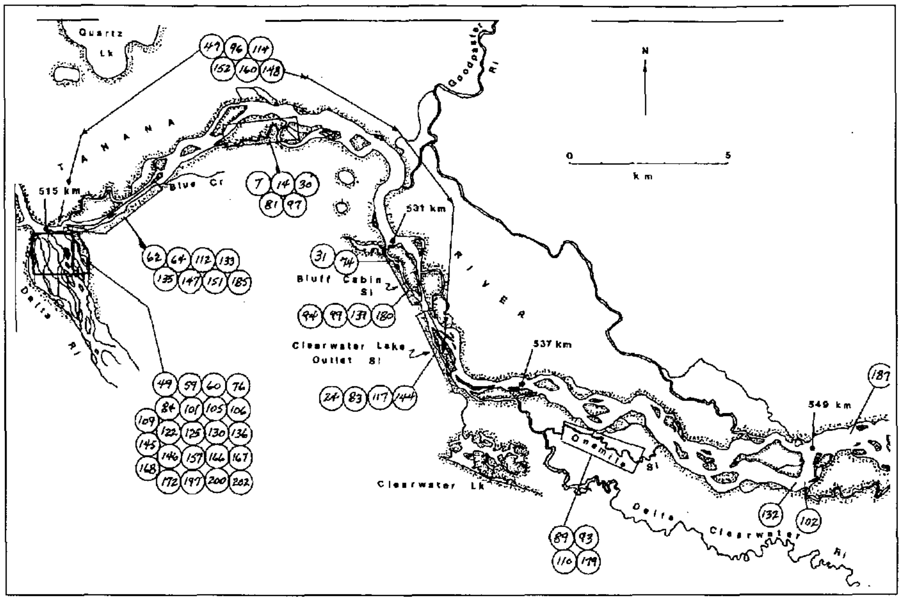

FIGURE 9.—Chum Salmon spawning locations in the Tanana River from the Delta River to approximately 35 km upstream that were isolated by radio telemetry, 1989. Encircled numbers identify individual radio transmitters.

the Little Delta River and Delta Creek (Figure 7). Ten of these fish were documented in a single slough on the south side of the Tanana River floodplain immediately upstream of Little Delta River.

At least 8 tagged fish spawned between Delta Creek and Shaw Creek, 5 of which spawned immediately upstream of the mouth of Delta Creek (Figure 8). Additionally, two different spawning areas were located between Shaw Creek and the Delta River based upon the movement of 19 tagged chum salmon. Eight were associated with several mainstem sloughs in the middle and western Tanana River floodplain extending 5-6 km upstream of Shaw Creek. Another 11 spawned in a series of side channels and sloughs on the western side of the Tanana River floodplain which extended approximately 5 km downstream of Timber.

The proportion of tagged chum salmon determined to be Delta River spawners (p_D) was approximately 17.6% of the 131 fish for which spawning destination was isolated; this represented the greatest proportion to any site-specific spawning area (Figure 9). Another 30 tagged fish spawned at previously known areas of the mainstem Tanana River extending from just upstream of the Delta River to the Gerstle Rive. Of these, 13 spawned along the south bank Tanana River from the Delta River to approximately 5 km upstream of Blue Creek, 6 in Bluff Cabin Slough, 4 each in Clearwater Lake Outlet Slough and Onemile Slough, and 3 in mainstem Tanana River sloughs located approximately 7-10 km upstream of Onemile Slough.

Only three tagged fish were believed to have spawned upstream of the Gerstle River: two in Tanana River floodplain sloughs within a 4-5 km stretch just upstream of Healy Lake outlet stream and the third in the mainstem Tanana River near the mouth of George Creek (km 618). These tagged fish were the farthest found upstream.

Overall, 107 of the 131 fish for which spawning location could be determined, or approximately 82%, were tracked to spawning areas upstream of the Little Delta River, including those observed in the Delta and Richardson Clearwater Rivers. Location of spawning could not, in all cases, be precisely identified to a particular channel or slough for radio-tracked fish. This was not only a function of the size of the study area and the extreme braided and turbid nature of the Tanana River, but was also a function of the lag time between tracking surveys and fish detection, as well as fish movement patterns. Therefore, specific spawning areas could not be determined for 51 of the 182 fish potentially available for tracking upstream of the tagging site. These included 19 tagged fish from which signals were eventually lost, another 19 fish for which spawning destination could only be determined to lie within a rather broad region due to fish movement patterns, 8 fish from which movement patterns precluded determining area of spawning, and 5 tagged fish which were never located after release. The 19 lost signals included 10 fish last located between Silver Fox Lodge and Timber, 7 between the tagging site and upper Salchaket Slough, and 2 between the Delta River and Goodpaster River. Of the 19 fish whose spawning destination could not be fixed to a site specific area, 10 were believed to have spawned somewhere downstream of the Delta River (i.e., they were non-Delta River spawners). The other 9 likely spawned somewhere in the Big Delta region between Shaw Creek and Clearwater Lake Outlet Slough.

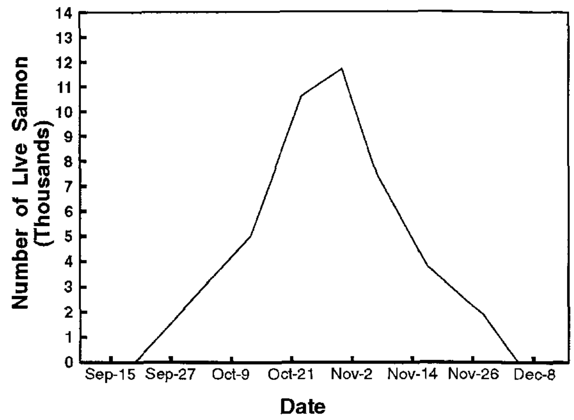

FIGURE 10.—Spawner abundance curve for Delta River chum salmon, 1989.

Population Estimates

Several ground surveys of the lower Delta River floodplain spawning areas were made from mid-September through November to enumerate chum salmon spawner abundance (Appendix E). Unseasonably warm fall temperatures resulted in higher and more turbid water conditions than normal well into October, hindering early observations. Thus, it was not possible to precisely pinpoint time of entry into all channels. Salmon were first observed in the eastern floodplain channels on September 20. Although western floodplain channels did not clear enough for a thorough survey prior to October 13, chum salmon were observed present no later than October 4. Similarly, midriver channels were not clear prior to October 23, but chum salmon were observed present at least as early as October 10.

Peak of spawning was judged, based upon the proportion of dead salmon appearing over time, to have been similar but slightly earlier in the eastern versus western floodplain channels. Peak spawning occurred substantially later in midriver channels. The peak survey count for the entire lower Delta River floodplain was obtained on October 31 when 17,540 chum salmon were enumerated (11,703 live and 5,837 dead). On that survey approximately 58% and 43% of the fish in the eastern and western channels were dead, compared to only 6% in the midriver channels.

A spawner abundance curve was estimated for the Delta River based upon survey observations from September 20 to November 28 (Figure 10). In this exercise September 15 and December 5 were subjectively taken as the inclusive dates within which chum salmon entered the Delta River. Results from the October 10 and 26 surveys were excluded due to poor survey conditions or incomplete coverage of the spawning areas on those days. Using equation (1) the total number of salmon days was estimated to be 388,416. Division by a mean residence time of 18.2 d yielded a population estimate of 21,342 chum salmon. Using equation (2) the estimated number of new salmon entering the Delta River between subsequent surveys was calculated and presented in Table 2. Summation of these estimates produced a total Delta River population estimate of 16,502 chum salmon.

The estimate of N_D (21,342 fish) using the spawner abundance curve from equation (1) was considered the better of the two estimates of the total number of Delta River fall chum salmon spawners in 1989. This was because the estimate using equation (2), 16,502 fish, was even lower than the 17,540 salmon estimated present during the peak survey of October 31. This was probably due to turbid water conditions early in the survey season and the presence of surface ice later in the season, conditions which foster low fish counts. Even though the equation (1) estimate of 21,342 fish was better, it could be conservative for the same reasons.

Using the estimates of p_D = 0.175572 and N_D = 21,342 in equation (4), produced an estimate of the Tanana River fall chum salmon spawning escapement upstream of Fairbanks (N_T) of 121,556 fish ±45,107 fish (95% confidence interval). The variance estimate was 529,647,250 (equation 5). An estimator of the variance of N_T was derived using the delta method

TABLE 2.—Delta River fall chum salmon population estimate based upon the summation of the estimated number of new salmon entering the river in 1989 during each interval of time between surveys.

Survey Day	Date	Interval (days)	Sep 20 Dead	Sep 20 Live	Oct 13 Dead	Oct 13 Live	Oct 23 Dead	Oct 23 Live	Oct 31 Dead	Oct 31 Live	Nov 07 Dead	Nov 07 Live	Nov 17 Dead	Nov 17 Live	Nov 28 Dead	Nov 28 Live	Dec 7 Dead	Dec 7 Live
1	Sep 15																	
		5																
6	Sep 20		(0)[a]	12[b]														
		23	10															
29	Oct 13			2	(723)	5,018[b]												
		10	2		437													
39	Oct 23			0		4,581	(2,775)	6,029[b]										
		8			2,188		271											
47	Oct 31					2,393		5,757	(5,837)	3,552[b]								
		7			1,746		1,531		121									
54	Nov 07[c]					647		4,226		3,431	(6,938)	-857[c]						
		10			647		3,448		1,439									
64	Nov 17					0		778		1,993			(8,039)	1,025[b]				
		11					778		1,844				139					
75	Nov 28							0		149				885	(5,937)	866[b]		
		9							149				540		46			
84	Dec 07									0				345		820		0[b]
			12		5,018		6,029		3,552		0		679		46			
Population Estimate[d]:																		16,502

[a]Numbers in parentheses are actual number of carcasses observed on a given survey. Dead fish shown below these numbers are salmon which died in interval of time between subsequent surveys based upon stream residence time data from Trasky (1974, 1976).

[b]Estimated number of new fish entering the stream. Live fish shown below these numbers are those remaining alive on subsequent surveys based upon stream residence time data from Trasky (1974, 1976).

[c]Results of this survey were excluded from the population analysis. Counts on this survey, particularly of live salmon, were low due to encroaching darkness while surveying mid-river channels.

[d]Population estimate is the summation of new fish entering stream.

(equation 5; Seber 1982), which only accounts for the variance in the estimate of p_D. The estimated number of Delta River spawners (N_D) was obtained by a complex manner, and no estimate of its variance is readily available. For this reason, the variance of N_T is conditioned on the estimate of N_D and is an underestimate of the true variance of N_T. The estimated non-Delta River fall chum spawning population upstream of Fairbanks in 1989 was 100,214 fish (N_T - N_D), representing more than 82% of the upper Tanana River fall chum spawning escapement.

Stock Timing

A chi-square goodness-of-fit test (Mendenhall 1966) between the number of radio tagged fish recovered and the number of those expected to be recovered based upon actual releases by 9-d strata, indicated there was no significant difference ($\alpha = 0.05$) in rate of recovery by date of release (observed chi-square = 1.60, $P \approx 0.90$, df = 5). However, based upon examination of recoveries by spawning location versus date of release, run timing differences were evident for some spawning stocks or stock groupings in 1989 (Table 3; Figure 11).

An early component was composed of Salcha River fish with a mean date of passage at the tagging site estimated as September 1 (SD = 11.09). Mean day of passage for mainstem spawning stocks which spawned downstream of Shaw Creek was September 10 (SD = 11.08), which was very similar to the mean passage of mainstem spawning stocks located upstream of the Delta River (September 11; SD = 8.41).

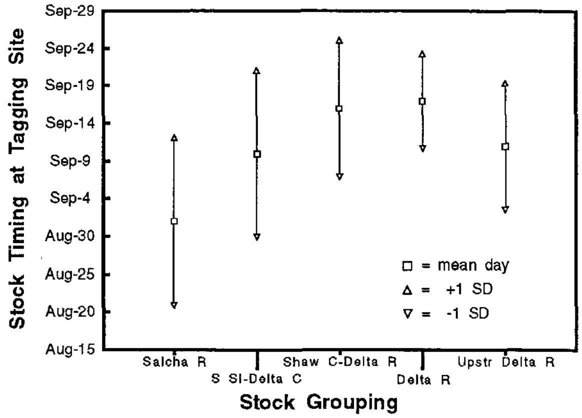

FIGURE 11.—Spawner abundance curve for Delta River chum salmon, 1989.

The latest component was composed of fall chum salmon destined for mainstem spawning areas from Shaw Creek to the Delta River, including the Delta River. Approximately 93% of these fish had been released at the tagging site after September 3 and 74% after September 12. Mean date of passage at the tagging site for these two stock groupings combined was estimated as September 16 (SD = 7.71).

Because recovery rates did not vary over time but stock contributions to the run did vary over time, results of the chi-square test also indicate the probability of recapture was equal for both Delta River and non-Delta River stocks.

TABLE 3.—Estimated run timing of Tanana River chum salmon stocks that spawn upstream from Fairbanks based upon subsequent recoveries of radio-tagged fish released August 18 through October 2, 1989.

Estimated Spawning Area	No. Tagged Salmon Located	Mean Day of Passage at Fairbanks	Variance	Standard Deviation	Percent Tagged Fish Recovered Which Were Released After	
					Sep 3	Sep 12
Salcha River[a]	10	Sep 01[a]	122.9	11.09	20	20
Salchaket Slough to Delta Creek	45	Sep 10	122.9	11.08	71	42
Shaw Creek to Delta River	19	Sep 16	82.6	9.09	90	68
Delta River	23	Sep 17	39.5	6.28	96	78
Upstream of Delta River	33	Sep 11	70.7	8.41	79	46

[a]Believed to be summer chum salmon.

DISCUSSION

Estimates of the proportion of Tanana River fall chum salmon passing Fairbanks and spawning in the Delta River (p_D) and the number of Delta River spawners (N_D) were used to obtain an estimate of the total upper Tanana River fall chum spawning escapement (N_T). Two important assumptions were related to tag deployment which, if violated, would have contributed to a biased estimate of p_D. These were (1) that no differential bank orientation by stock existed at the tagging site, and (2) that salmon were tagged in proportion to their relative run strength at the tagging site. The critical aspect of these assumptions was that the Delta River stock had to be tagged in proportion to its relative contribution to the total run. This was equally relevant to the probability of recapture; i.e., every tagged fish had to have an equal probability of recapture.

A decision to operate only one fish wheel was made during initial design of the project based upon results of 1979 and 1980 tagging studies conducted in the Tanana River near Manley (Buklis 1981). Buklis found no significant difference in bank orientation or run timing between Toklat and upper Tanana River fall chum salmon stocks. Indication that the assumption held true in 1989 is supported by 16 tagged fish released at the Fairbanks fish wheel site. These fish were subsequently recovered in various fisheries within approximately a 10- to 12-km portion of the Tanana River immediately upstream of the tagging site. Seven of these recoveries were made along the north bank and nine were made along the south bank.

Run passage at Fairbanks was assumed to be the same as that observed at Nenana with a 1- to 2-d lag time, based upon run timing characteristics observed at experimental fish wheels in 1988 (Barton 1989). In order to test compliance with assumption 2, experimental fish wheel catches at Nenana and tag deployments at Fairbanks were grouped into five, 9-d strata. Assuming that tags were deployed in proportion to the number of fish passing Fairbanks, the proportionality constant was estimated as 0.0218 using ordinary least squares techniques (Neter et al. 1990). A chi-square goodness-of-fit test (Mendenhall 1966) was then employed to test the hypothesis that tags were deployed in proportion to run size. The number of tags which should have been deployed was estimated based upon the estimated proportionality constant and run timing information. Results of the hypothesis test indicated that tags were deployed in proportion to the size of the run (observed chi-square = 6.6427, $P \approx 0.18$, df = 4). Therefore, it is unlikely assumption 2 was violated from the standpoint of run timing.

In a review by Bromaghin (1990) of Yukon River tagging studies conduced in 1987 and 1988 by DFO, fish wheels were not found to be very selective on chum salmon by size or sex. I assumed that fish wheel catch selectivity on chum salmon in this study, if existent, was minimal. However, I also tested assumption 2 above based upon sex and found that the sex ratio of tagged fish was not significantly different ($\alpha = 0.05$) from the sex ratio of chum salmon subsequently sampled from the Delta River spawning grounds (observed chi-square = 2.3375, $P \approx 0.15$, df = 1).

The second part to obtaining an estimate of the proportion of chum salmon passing Fairbanks destined for the Delta River, p_D, involved using radio tracking results to estimate the number of Delta River fish tagged versus non-Delta River fish tagged. To do this we needed to know if summer chum salmon had been tagged. Although an attempt was made to ensure that only fall chum salmon were tagged, it is reasonable to assume that an unknown number of summer chum salmon were also tagged, particularly during the initial phases of tag deployment. Summer chum salmon were observed passing the experimental wheel site at Nenana in 1989 as late as August 15; peak passage occurred in late July. Transmitter deployment was initiated at the Fairbanks tagging wheel on August 18.

The Salcha River is the largest known summer chum producing tributary stream in the Tanana River drainage; peak spawning generally occurs during the first half of August. All spawners have not necessarily reached the spawning ground, or for that matter even entered the river, when spawning peaks. For example, of 10 fish tracked into the Salcha River, 8 had been tagged between August 18 and September 3. Of these, 3 were judged to have spawned in the vicinity of the Richardson Highway bridge, and 5 were believed to have spawned farther upstream, in vicinity of the TAPS crossing, although the farthest was tracked to approximately 10 km upstream of the TAPS. The two remaining Salcha River chum salmon were tagged and released on September 19 and 22 and were believed to have spawned near the Richardson Highway bridge. All of these fish spawned at known summer chum spawning areas.

Although the Salcha River was first surveyed on October 10, 9 of the 10 fish eventually tracked into that stream were located, and all were generating mortality signals indicating that spawning had taken place prior to that date. These nine fish had not been detected in surveys of the mainstem Tanana River since early September. Although fall chum salmon have been documented spawning in the mainstem Tanana River near the mouth of the Salcha River, it is likely the 10 tagged fish tracked into the Salcha River were summer chum salmon that had been tagged near the end of the summer chum run as it passed Fairbanks.

Assuming the 10 radio tagged fish tracked into the Salcha River were summer chum salmon, then no more than 121 of the 131 fish for which spawning destination was determined were fall chum salmon. Consequently, this would increase the estimated proportion of the Delta River fall chum component passing Fairbanks in 1989 from 17.6% to approximately 19.0%. However, to obtain the best estimate of p_D, the 10 chum salmon mentioned earlier and believed to have spawned in the Tanana River at some location downstream of the Delta River, should also be included in the non-Delta River component. Thus, the estimate of p_D remains 17.6%, ±6.5% (95% confidence interval) with an estimated variance of 0.001104937.

CONCLUSIONS

Because a variance can be calculated for p_D, it is a valid estimate. Thus, it can be stated with confidence that the estimate of the proportion of non-Delta River fall chum stocks ($1\text{-}p_D$) passing Fairbanks in 1989 greatly exceeded the Delta River component. By comparison, less confidence can be placed on the estimate of the total number of chum salmon passing Fairbanks (N_T) because the variance for that estimate is conditioned upon the estimated number of Delta River spawners (N_D) for which there is no variance estimate.

Although three new fall chum salmon spawning areas were identified in the mainstem Tanana River from this telemetry study, none were considered to be "major" spawning areas. Results show however, that at least in some years, the numerous and relatively smaller spawning areas in the mainstem river, when taken collectively, contribute more substantially to total Tanana River fall chum salmon spawning escapement than previously realized. Further, results of this study illustrate the need for a comprehensive Tanana River fall chum salmon escapement enumeration program.

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APPENDIX

Appendix A.—Comparison of fall chum salmon run timing at experimental wheels operated in the Tanana River in 1988 and 1989; 1988 data from Barton (1989).

Test Wheel	Year	Project Dates of Operation	Duration (days)	Mean Day of Passage		Central Half Run Passage (25%–75%)	Median Day (50% of Run)	Peak Daily Passage
				Date	SD			
Manley	1988	Aug 13–Sep 27	46	Sep 07	8.2	Sep 02–Sep 11	Sep 06	Sep 04
Nenana	1988	Aug 23–Sep 30	39	Sep 12	9.1	Sep 05–Sep 18	Sep 10	Sep 08
Fairbanks	1988	Sep 01–Sep 30	30	Sep 13	6.8	Sep 07–Sep 18	Sep 12	Sep 12
Manley	1989	Aug 09–Sep 28	51	Sep 07	11.9	Aug 30–Sep 15	Sep 07	Sep 11
Nenana	1989	Aug 08–Sep 28	52	Sep 11	9.0	Sep 06–Sep 17	Sep 12	Sep 12

Appendix B.—Listing of Tanana River distances.

Location	Distance	
	Kilometers	Miles
Tanana River, mouth (Subdistrict 5/6 Boundary)	0	0
Manley Hot Springs Slough, mouth	93	58
Kantishna River, mouth	150	93
Toklat River, mouth	233	145
Barton Creek, mouth	257	160
Sushana River, mouth	282	175
Tolovana River, mouth	164	102
Old Minto	211	131
Nenana (bridge crossing)	259	161
WoodRiver, mouth	290	180
Rosie Creek, mouth	338	210
Salchaket Slough (downstream mouth)	341	212
Chena River, mouth	351	218
Salchaket Slough (upstream mouth)	399	248
Salcha River, mouth	425	264
Flag Hill	436	271
Benchmark 735	444	276
Little Delta River, mouth	459	285
Delta Creek, mouth	484	301
Richardson Clearwater River, mouth	488	303
Shaw Creek, mouth	494	307
Timber	510	317
Delta River, mouth	515	320
Blue Creek, mouth	518	322
Goodpaster River, mouth	529	329
Bluff Cabin Slough (downstream mouth)	531	330
Clearwater Lake, outlet	536	333
Delta Clearwater River, mouth	537	334
Gerstle River, mouth	563	350
Healy Lake, outlet	582	362
George Creek, mouth	618	384
Billy Creek, mouth	663	412
Tanacross	751	467
Nabesna River, mouth	912	567
Chisana River, mouth	912	567

Appendix C.—Pooled fall chum salmon stream residence time data for the Delta River, 1973 and 1974 (data from Trasky 1974, 1976).

Stream Residence Time (days)	Eastern Channels Number Salmon	Eastern Channels Salmon Days	Mid-river Channels Number Salmon	Mid-river Channels Salmon Days	Western Channels Number Salmon	Western Channels Salmon Days	All Channels Combined Total Salmon	All Channels Combined Salmon Days	All Channels Combined Cum	All Channels Combined Cum % Dead	All Channels Combined Cum % Live
1	0	0	0	0	0	0	0	0	0	0.0	100.0
2	0	0	1	2	2	4	3	6	3	1.1	98.9
3	0	0	0	0	0	0	0	0	3	1.1	98.9
4	0	0	2	8	0	0	2	8	5	1.9	98.1
5	2	10	0	0	0	0	2	10	7	2.7	97.3
6	0	0	1	6	0	0	1	6	8	3.0	97.0
7	0	0	1	7	0	0	1	7	9	3.4	96.6
8	0	0	2	16	1	8	3	24	12	4.5	95.5
9	1	9	0	0	1	9	2	18	14	5.3	94.7
10	2	20	5	50	2	20	9	90	23	8.7	91.3
11	0	0	12	132	1	11	13	143	36	13.6	86.4
12	2	24	7	84	1	12	10	120	46	17.4	82.6
13	4	52	10	130	1	13	15	195	61	23.1	76.9
14	2	28	3	42	0	0	5	70	66	25.0	75.0
15	1	15	11	165	1	15	13	195	79	29.9	70.1
16	5	80	8	128	2	32	15	240	94	35.6	64.4
17	6	102	9	153	7	119	22	374	116	43.9	56.1
18	7	126	15	270	0	0	22	396	138	52.3	47.7
19	1	19	11	209	5	95	17	323	155	58.7	41.3
20	11	220	8	160	1	20	20	400	175	66.3	33.7
21	10	210	6	126	3	63	19	399	194	73.5	26.5
22	8	176	4	88	2	44	14	308	208	78.8	21.2
23	3	69	1	23	4	92	8	184	216	81.8	18.2
24	4	96	2	48	2	48	8	192	224	84.8	15.2
25	4	100	0	0	2	50	6	150	230	87.1	12.9
26	7	182	1	26	3	78	11	286	241	91.3	8.7
27	3	81	0	0	4	108	7	189	248	93.9	6.1
28	3	84	0	0	2	56	5	140	253	95.8	4.2
29	2	58	0	0	5	145	7	203	260	98.5	1.5
30	0	0	0	0	2	60	2	60	262	99.2	0.8
31	0	0	0	0	1	31	1	31	263	99.6	0.4
32	0	0	0	0	0	0	0	0	263	99.6	0.4
33	0	0	0	0	1	33	1	33	264	100.0	0.0
Total	88		120		56		264		264		
Average	20.0		15.6		20.8		18.2				

Appendix D.—Destination of radio-tagged chum salmon released in the Tanana River near Fairbanks, 1989.

Destination	Tanana River Distance (km)	Transmitter or Fish Number	Total
TAGGING SITE (Rosie Creek Bluffs)	~339		
TRANSMITTERS LOCATED DOWNSTREAM OF TAGGING SITE			
Fishery recoveries near Nenana	~259	2,71,88	3
Fishery recovery near Tanana	~0	204	1
Tracked—just downstream of tagging site		66,69	2
Tracked—lower end Salchaket Slough	~341	65,75	2
Tracked—just upstream of Hot Slough		188	1
Tracked—Mouth Totatlanika River		80	1
Tracked—Mouth Swanneck Slough	~207	86	1
Downriver Transmitters	11		
FISHERY INTERCEPTIONS UPSTREAM OF TAGGING SITE			
Commercial		27,36,38,68,155,162,165,170,174	9
Personal Use/Subsistence		23,100,118,163,171,178,207	7
Sport Fish—vicinity Piledriver Slough	~387	113	1
Upriver Catches	17		
PRECISE SPAWNING AREA UNDETERMINED			
Transmitters never located		32,72,77,150,206	5
Transmitters tracked but eventually lost		11,15,29,35,39,45,46,50,53,82,87, 91,124,126,141,154,182,193,194	19
Unknown destiny due to fish movement		44,90,103,107,127,190,196,209	8
Estimated "region" of spawning			
Downstream of Delta River		6,111,115,137,149,159,173,176,181,210	10
Possible Delta River spawners			
Delta R—Clearwater Lk Outlet Sl	~515–535	47,96,114,148,152,160	6
Shaw Creek—Delta River	~494–515	37	1
Timber—Delta River	~510–515	121,123	2
Precise Destiny Unknown	51		
SPAWNING AREA DETERMINED			
Vicinity of upper Salchaket Sl. (~399)	~397–403	61,140,208	3
Vicinity of Little Salcha River (~418)	~417–420	33,54	
Salcha River (proper)		1,3,16,17,21,25,40,48,138,184	10
Vicinity of Salcha River mouth (~425)	~425	78	1
Vicinity Flag Hill (~436	~438–439	22	1
Silver Fox Lodge - Little Delta River	~445–459	13,57,79,92,142,192,195	7
Little Delta River - Delta Creek	~459–484		
Vicinity of Little Delta River mouth	~459–461	19,20,28,34,63,67,120,158,169,205	10
Vicinity Canyon Cr. Camp–Delta Cr	~468–484	9,18,42,43,55,56,119,131,134,156,164,183,198	13
Delta Creek–Shaw Creek	~484–494	4,5,10,58,70,73,116,203	8
Richardson Clearwater River	~488	191	1
Shaw Creek –Timber	~494–510		
Vicinity Shaw Creek (~494)	~494–499	8,52,85,129,153,189,199,201	8
Vicinity Timber (~510)	~504–510	26,51,95,104,108,128,143,161,175,177,186	11
Delta River (~515)	~515	49,59,60,76,84,101,105,106,109,122,125,130,136 145,146,157,166,167,168,172,197,200,202	23
Vicinity South Bank Tanana (~ 516-525)			
Delta River to Blue Creek	~516–520	62,64,112,133,135,147,151,185	8
Blue Creek + 5 km	~520–525	7,14,30,81,97	5
Bluff Cabin Slough (~531)	~531–533	31,74,94,99,139,180	6
Clearwater Lake Outlet Slough (~535)	~533–536	24,83,117,144	4
One Mile Slough (~539)		89,93,110,179	4
Onemile Slough - Gerstle River	~540–549	102,132,187	3
Gerstle River - Little Gerstle River	~563–617	98	1
Vicinity Healy Lake outlet (~582)	~576–588	12,41	2
Destination Determined			131
Total tags applied			210
Potentially available upstream			182

Appendix E.—Delta River fall chum salmon ground surveys, 1989.

	Eastern Channels			Mid or Main River Channels			Western Channels			Total Delta River Area		
Date	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total
Sep 15			Turbid			Turbid			Turbid			Turbid
Sep 20	12	0	Partly Clear			Turbid			Turbid	12	0	12
Sep 25		6	Turbid			Turbid			Turbid	0	6	6
Sep 28		7	Turbid			Turbid			Turbid	0	7	7
Oct 04		6	Partly Clear			Turbid			Turbid[a]	0	6	6
Oct 10	1,857	227	2,084[b,c]			Turbid[a]	Not Surveyed			1,857	227	2,084[c]
Oct 13	3,093	400	3,493			Turbid[a]	1,927	323	2,250	5,020	723	5,743[c]
Oct 23	5,137	1,888	7,025	3,226	100	3,326	2,247	787	3,034[d]	10,610	2,775	13,385[d]
Oct 26	3,469	2,280	5,749[e]	2,509	116	2,625[e]	1,048	644	1,692[d,e]	7,026	3,040	10,066[e]
Oct 31	2,979	4,131	7,110	7,113	471	7,584	1,611	1,235	2,846[d]	11,703	5,837	17,540[d]
Nov 07	937	4,603	5,540[d]	5,951	1,098	7,049[f]	560	1,237	1,797[d]	7,448	6,938	14,386[d]
Nov 17	206	4,083	4,289[d]	3,589	3,956	7,545	Not Surveyed			3,795	8,039	11,834[c,d]
Nov 28	12	503	515[d]	1,880	4,362	6,242[d]	8	1,107	1,115[d]	1,900	5,972	7,872[d]

[a] Salmon present.

[b] Fair survey. Extreme lower end (mouth) was turbid and unsurveyable.

[c] Incomplete survey of area.

[d] Some surface or shelf ice present.

[e] Poor survey. Counts are quite conservative because only one person, alone, walked the east, middle, and west channels.

[f] Counts, particularly of live fish, are low due to encroaching darkness near end of survey.