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Division of Commercial Fisheries
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Estimation of Fall Chum Salmon Abundance On the Tanana and Kantishna Rivers Using Mark Recapture Techniques, 1999

by

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State of Alaska Tony Knowles, Governor

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PROJECT SPONSORSHIP

The Bering Sea Fisherman's Association funded operation of one fish wheel used to tag salmon.

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ABSTRACT

Mark-recapture techniques were used to produce in-season and post-season abundance estimates of fall chum salmon (*Oncorhynchus keta*) for the fifth consecutive year on the Tanana River and for the first year on the Kantishna River in 1999. Chum and coho salmon were captured and tagged using a fish wheel located on the right bank of the Tanana River immediately upstream of the Kantishna River mouth and recaptured in a fish wheel located approximately 76 km upriver on the right bank. In the Kantishna River, chum and coho salmon were captured in a fish wheel on the left bank of the river approximately 9 km upstream of its terminus on the Tanana River and recaptured in two fish wheels approximately 113 km upstream in the Toklat River. All fish wheels operated 24 hours per day unless interrupted by mechanical problems. All healthy chum (based on appearance) and coho salmon, captured at the tagging wheels from 17 August through 2 October on the Tanana River and from August 16 through September 29 on the Kantishna River, were marked with color-coded spaghetti tags and released. The final in-season Bailey model abundance estimate for the upper Tanana River is 97,843 (SE = 19,362) chum salmon past the tagging wheel site. The final in-season Bailey population estimate for the Kantishna River is 27,199 (SE = 3,562) fall chum salmon past the tagging wheel site. No coho salmon abundance estimates were generated due to the low number of tag returns.

KEY WORDS: Yukon River, mark-recapture, population size, escapement, migration rate, run timing.

INTRODUCTION

The Yukon River drainage is the largest in Alaska (854,700 km^2), comprising nearly one-third the area of the entire state. Five species of anadromous Pacific salmon return to the Yukon River and its tributaries and are utilized in subsistence, personal use, commercial and sport fisheries. The Tanana River is the largest tributary of the Yukon River. It flows northwest through a broad alluvial valley for approximately 700 km to the Yukon River at Tanana Village, draining an area of 115,250 km^2. Chum salmon, *O. keta,* return to the Yukon River in genetically distinct summer and fall runs (Seeb et al.1995). Summer chum salmon begin to enter the Yukon River in early May, and fall chum salmon begin to enter in mid-July. Fall chum salmon migration typically peaks around mid-September in the Tanana River and migration continues into early October. Spawning occurs from October through November, primarily in areas where upwelling ground water prevents freezing. Fall chum salmon are larger on average than summer chum salmon, have higher oil content, and are an important subsistence and personnel use item in the Upper Yukon and Tanana Rivers.

The Tanana River drainage is a major producer of fall chum salmon and contributes significantly to the various in-river fisheries. The most recent 5-year (1995-1999) average total harvest of fall chum salmon in the Tanana River was 45,697 fish, approximately 21% of the entire Yukon River drainage's average catch for those years (Bergstrom et al. 2000). For management purposes, the Alaska Department of Fish & Game divides the Alaska portion of the Yukon River into a total of 13 districts and subdistricts. The Tanana River (District 6) is divided into three Subdistricts, 6A – 6C (Figure 1). Tanana River summer and fall chum salmon are managed as distinct stocks, with 16 August dividing summer and fall seasons. Although some overlap in their migrations does occur, this date has been selected for management purposes based on average historical run timing. Subsistence and personal use fisheries are open for two 42-hour periods per week, with the exception of the "Old Minto" area where subsistence fishing is allowed five days a week. Commercial fishery openings occur by emergency order with a maximum of one 42-hour period per week (24 hours per week in Subdistrict 6-A). The Tanana River commercial guideline harvest range is 2,750 to 20,500 fall chum salmon, but the harvest level may be exceeded if escapement goals and subsistence needs are satisfied. In 1999 it became evident that the fall chum salmon run was much weaker than had been anticipated, and no commercial fishery was permitted.

Aside from information provided by this project, management decisions for the Tanana River are partially based on catch-per-unit-effort (CPUE) data from department-contracted "test" fish wheels and fishery performance data. Data obtained from these sources are used in-season to qualitatively assess run-strength. However, these data have serious limitations, including an inability to assess absolute run strength. Fish wheels are susceptible to inconsistencies in efficiency, both within and among years. Although attempts are made to fish test wheels at the same location each year, conditions at a given location may change in relation to water level, current and channel location. The Tanana River is very dynamic, and these factors are known to fluctuate widely. This variability reduces the reliability of test fish wheel data for making in-season management decisions.

Managers also rely on aerial and ground surveys of selected fall chum salmon spawning areas. For example, ADF&G has established fall chum salmon minimum escapement goals of 33,000 in the Toklat River, a tributary of the Kantishna River, and 11,000 in the Delta River (Buklis 1993). Intensive annual foot surveys are conducted on spawning grounds in each of these rivers to estimate salmon escapement. In addition, a sonar project using Bendix gear was operated in the Toklat River from 1994 to 1996 to develop a better assessment of escapement to this system because it is an important fall chum salmon tributary (Barton 1997). A main river sonar project, located at river mile 123 near the village of Pilot Station, estimates passage of all salmon species in the lower Yukon River. While projects also exist that estimate spawning escapement of fall chum salmon for some Yukon River tributaries (Chandalar, Delta, Toklat and Sheenjek Rivers), until 1995 there has never been a fully operational, on-going program to estimate fall chum salmon population size in the Tanana River. While estimates provided by the main river sonar project may be valuable for the drainage as a whole, operational aspects and the cost of combining acoustic estimates of abundance with stock identification techniques complicate determination of the strength of the Tanana River fall chum salmon component. The United States Fish and Wildlife Service (USFWS) implemented a mark-recapture project located at Rampart Rapids on the Yukon River, 58 km upriver of the Tanana-Yukon River confluence, in 1996 to estimate population size of fall chum salmon in the Yukon River above the village of Rampart (Gordon et al.1998). Results from this project have the potential to verify Tanana River population estimates. Although in-season assessment of drainage-wide Yukon River fall chum salmon run strength is extremely important, it may not accurately reflect the strength of the Tanana River run component in a given year due to differences in run strength and run timing between Tanana and non-Tanana stocks. Consequently, a reliable in-season estimate of run strength (like the Tanana River tagging project) for the Tanana River would prove very useful for management.

Previous efforts, limited to one or two years, have been made to estimate population size and identify fall chum salmon spawning areas in the Tanana River. Buklis (1982) estimated population size, including Kantishna River stocks, using mark-recapture methods in 1979 and 1980. Estimates were 676,241 and 383,770, respectively. These estimates were 253% and 125% higher than estimates of harvest plus observed escapement in those years and thought to be positively biased due to mark-recapture assumption violations. In 1990, dual-beam sonar was operated near Manley Hot Springs (LaFlamme 1990) to estimate passage of salmon in the Tanana River. Although conditions in the Tanana River may not favor use of sonar at some locations due to changes in water level and heavy debris and silt loads (Buklis1982), the project near Manley Hot Springs appeared feasible. However, it was not continued in subsequent years because of budget limitations. In 1989, Barton (1992) used radio-telemetry to identify spawning areas in the upper Tanana River. He estimated that Delta River stocks comprised between 11% and 24% of the fall chum salmon in the Tanana River drainage above Fairbanks in that year and that main stem spawning was more extensive than was previously thought. An estimate of 121,556 +/- 45,107 (95% C.I.) fall chum salmon above Fairbanks was obtained during that study. However, radio-telemetry is not considered to be economically feasible as an annual monitoring tool.

The Tanana River fall chum salmon mark-recapture project was initiated in 1995 (Cappiello and Bromaghin, 1997). Two tag deployment wheels and two tag recovery wheels were used to sample each riverbank with equal effort. In 1995, a 6-hour per day tag deployment schedule was used and 4,174 fish were tagged. However, the left bank recovery wheel fall chum salmon catch was approximately 3% of the right bank recovery wheel catch. After testing for bank orientation, it was determined that the left bank tag deployment wheel was unnecessary, and it has not been used since. The Bailey closed-population estimator (Seber, 1982) was used in 1995 to estimate 268,173 +/- 42,330 (95% C.I.) fall chum salmon in the Tanana River above the Kantishna River.

In 1996, a 12-hour per day tag deployment schedule was used and 4,016 fish were tagged using only one fish wheel. The Bailey model was used for making in-season population estimates. However, post-season data did not satisfy model assumptions, as the probability of recapture was not constant through time (Cappiello and Bruden 1997). Therefore, a model that could accommodate temporal stratification (Darroch, 1961) was used to produce a post-season estimate of 134,563 +/- 33,212 (95% C.I) fall chum salmon that passed the tag deployment wheel subsequent to August 15, 1996. It was unclear why the probability of recapture varied temporally, although it may have been due to changing efficiencies of the tag deployment and/or recovery wheels with respect to changing water level, current, or abundance of fish in the river (Cappiello and Bruden, 1997).

Cappiello and Bruden (1997) recommended that tag deployment be conducted over the maximum possible number of hours to increase sample size and decrease the variability of the estimate. A 12-hour tag deployment schedule was also used in 1997, although chum salmon caught overnight were also tagged to potentially increase the sample size of marked fish used in the abundance estimation. After testing model assumptions, fish held overnight and those tagged during the 12-hour daily tagging schedule were used in the population abundance estimate in 1998 (Hebert and Bruden 1998). The Darroch model was used again in 1997 and resulted in an estimated 71,661 ± 23,277 (95% C.I.) fall chum salmon upstream of the Kantishna River. (Hebert and Bruden 1998). In 1998, the marked proportion in the recovery wheels was not consistent through time (Cleary and Bruden 2000). Consequently, the Darroch model was used once more for the Tanana River estimate. The 1998 abundance estimate for fall chum salmon upstream of the tagging wheel site was 62,384 (+/- 23,669). In 1999, one tagging wheel and one recovery wheel was used in the Tanana River. In order to estimate the abundance of Kantishna River stocks, a single tagging wheel was operated in the Kantishna River and two recovery wheels were operated on the Toklat River in 1999. The Bailey closed population model was used to generate Tanana and Kantishna River population estimates in 1999.

METHODS

Objectives

Objectives for the 1999 season were to: (1) provide in-season and post-season abundance estimates of fall chum and coho (O. kisutch) salmon in the upper Tanana and Kantishna Rivers; (2) estimate migration rates for fall chum and coho salmon; and (3) estimate run timing of selected stocks in the Tanana River drainage (e.g., Delta River) and the Toklat River (Kantishna River drainage).

Sampling

Tag Deployment

On both the Tanana River and Kantishna River one fish wheel was used to capture fall chum and coho salmon for tagging in 1999. Each wheel was owned and operated by a private contractor. The Tanana River wheel was located on the right bank approximately 8 km upstream from the mouth of the Kantishna River. Historically, this has been considered a relatively consistent site for fish wheel operation due to stability of the river channel and current. The fish wheel was positioned within 100 meters of the 1995-1998 tag deployment wheel locations. The contracted Kantishna River tagging wheel, funded by the Bering Sea Fisherman's Association (BSFA), was located approximately 9 km above the mouth on the left bank of the river (Figure 2). Both tagging wheels were equipped with two baskets, each basket measuring 2.5-3 m in width with a dip capacity of approximately 4 m, and a live box measuring 2.4 x 1.2 x 0.06 m (length, width, depth) and constructed of spruce poles and one-half inch plywood was submerged on the offshore side of the fish wheel. A maximum of three fish leads, ranging from 2 to 5 meters in length, were installed shoreward as needed depending on the distance of the wheel from the river bank. Contractors examined their respective wheels at least once daily to determine overall operating efficiency and check for any damage, including tears, rips or holes in the baskets or live-box, and remove any accumulated debris. Occasional adjustments to the fish wheels were required to maximize operating efficiency, e.g., moving the wheel laterally or raising or lowering the axle to allow baskets to turn as close to the bottom as possible, lengthening or shortening onshore fish leads, and adding or removing basket paddle boards to accommodate changes in river current.

The two tag deployment wheels were each operated 24 hours per day, unless interrupted by debris accumulation or wheel relocation. The Tanana River wheel was operated from 16 August until icing conditions prevented the wheel from turning on October 2. On the Kantishna River, the tagging wheel was operated from 16 August until 29 September. A 12-hour tag deployment schedule was maintained daily at each location from 08:00 to 20:00, with a 24-hour catch-day designated as 08:00 to 08:00 the following day. The sampling crew checked the live-box at each wheel in approximately 4-hour intervals (07:30, 12:00, 16:00 and 19:30). Sampling was performed by a four-member crew aboard a 22-foot riverboat which was tied alongside the fish wheel. All chum salmon and coho salmon were individually removed from the live-box with a dipnet and transferred to a sampling table. A 30 cm, hollow core, individually numbered spaghetti tag (Floy Tag and Manufacturing Inc., Seattle, WA)[2] was inserted into the dorsal musculature, posterior to the dorsal fin, with a 16 cm applicator needle. Tags were secured in place with an overhand knot tied closely to the body. Chum salmon were tagged with orange tags and coho salmon were tagged with white tags. The right pelvic fin was partially clipped as a

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[2] Mention of trade names does not constitute endorsement by ADF&G.

secondary mark on both fall chum and coho salmon. Other data recorded were: (1) length, measured from mid-eye to fork of tail (MEFT) and recorded to the nearest 5 cm; (2) sex, as determined by external physical appearance; (3) condition, determined by external physical aberrations subjectively judged as having the potential to affect survival or migration; and (4) color, by grading exterior as light or dark based on ventral, lateral and fin coloration. Fish were also categorized as day fish, caught between 08:00 and 20:00, or night fish, caught between 20:00 and 08:00 and held in the live-box for up to 12 hours. Total handling time per fish was approximately 1 minute. Data were recorded for all chum and coho salmon contained in the live-box during each sampling session. All chinook salmon, *O. tshawytsha,* were enumerated by sex and released, while other species were identified, enumerated, and released.

Physical data were collected at the tag deployment wheels daily during the earliest sampling session (~07:30 hrs) and included the number of wheel revolutions occurring over a 15-minute interval. Additionally, meteorological data and water temperature and level were recorded once per day at approximately 10:00 at the tagging camp. Data collected after each sampling session were entered into a computer spreadsheet upon return to camp. A data summary for the previous 24-hour tagging day was reported daily to the ADF&G Fairbanks office via cellular or satellite telephone.

Tag Recovery

One state contracted tag recovery fish wheel was located in the upper Tanana River on the right bank approximately 76 km upriver from the tag deployment fish wheel. Two tag recovery wheels were operated by ADF&G on opposing banks in the Toklat River approximately 113 km upstream of the Kantishna tagging wheel (Figure 2). Design, size and construction materials of recovery wheels and live-boxes were similar to those of the tag deployment wheels. The Tanana River recovery wheel also serves as an ADF&G management test fish wheel and is operated during both the summer and fall fishing seasons.

Tag recovery effort began on 16 August on the Tanana and Toklat Rivers to ensure that fish tagged at the tag deployment wheels had a non-zero probability of recapture at the recovery wheels. Recovery wheels operated 24 hours per day through 5 October on the Tanana River and through 29 September on the Toklat River, when icing conditions prevented tag recovery. Like the tag deployment wheels, recovery wheels were inspected daily and adjusted as necessary. All chum and coho salmon were enumerated by sex. The color and identification number of all recaptured tags were recorded. All chum and coho salmon not bearing tags were examined for the presence of a secondary mark, a right pelvic fin clip. Additionally, all chinook salmon were enumerated by sex, while other species were enumerated daily. The ADF&G office in Fairbanks was contacted daily via satellite or cellular telephone to report summary data for the previous day.

Tag recoveries were made by department personnel on the Toklat River, Delta River, and Delta Clearwater River and by USGS personnel on Bluff Cabin Slough (upper Tanana River).

Data Analysis

Diagnostic Statistical Tests

A series of statistical tests were used to test mark-recapture model assumptions. The significance level for all tests was

$$\alpha = 0.05.$$

The tagging schedule was designed to capture and tag fall chum salmon in proportion to daily abundance, which would satisfy an assumption of many mark-recapture models. The degree to which this objective was achieved is difficult to assess directly; however, if the objective was achieved, then the proportion of the recovery wheel catch bearing tags, termed the "marked proportion", should be constant over time. Although a chi-square test of homogeneity could be used to test the hypothesis that the daily marked proportion was constant over time, in previous years and this year as well, many of the observed proportions were quite small, and the distribution of the test statistic may be poorly approximated by the chi-square distribution. For that reason, the distribution of Pearson's chi-square test statistic was estimated using Monte Carlo simulation in a FORTRAN computer program (RANDTEST). Under the hypothesis that the marked proportion was constant over time, that parameter was estimated as the ratio of the total number of marked fish captured in the recovery wheels to the total number of fish captured in the recovery wheels. The simulation consisted of randomly generating daily numbers of recaptured fish bearing tags, as a binomial random variable, conditioned on the actual number of fish examined for tags each day and the assumed constant marked proportion. A total of 10,000 such data sets were randomly generated, and the chi-square test statistic was computed for each data set. The p-value of the test was estimated as the proportion of the randomly generated test statistics that exceeded the value of the test statistic computed from the observed data. The same randomization technique and test statistic described above was used to test if the proportion recaptured was constant over time. Separate analyses were performed for the Tanana and Kantishna Rivers.

Fish held in the live-box overnight and tagged and released during the first visit to the tagging wheel each morning had longer average holding time than fish tagged and released during the day, and they might therefore suffer increased stress. A Smirnov test (Conover 1980) was used to test the assumption that the travel time distributions of day and night fish were equal. A two-sample binomial test (Johnson and Bhattacharyya 1996) was used to test that day and night fish had equal probabilities of recapture. If both of these tests were non-significant, day and night fish could be pooled in subsequent analyses.

A two-sample binomial test (Johnson and Bhattacharyya 1996) was used to test the hypothesis that the marked proportion was equal in the two Toklat River recovery wheels. A non-significant binomial test would indicate that fish tagged in the lower Kantishna River are dispersing to both banks as they move up the Toklat River, in which case the data from the two recovery wheels could be pooled. Pooling the data from the two recovery wheels is desirable to reduce the variance of the abundance estimate.

Most mark-recapture models assume that fish have homogeneous probabilities of capture in at least one of the capture events (Seber 1982), and tests of selectivity are important diagnostics tools in salmon mark-recapture studies. Fish wheels are often thought to be selective with respect to size or sex of the fish. In addition, holding fish overnight in the live box could conceivably affect the probability of recapture in the recovery wheels. Whether or not the fish was held in the live box overnight was coded as an indicator variable termed "held." Unfortunately, the lack of length data from the recapture wheels precludes full examination of selectivity. However, logistic regression (Agresti 1990) was used to model the probability of recapture as a function of the predictor variables held, sex, and length. All possible interaction terms among the 3 predictive variables were included in the model. Non-significant terms of a similar order, beginning with the 3-way interaction, were removed from the model and a reduced model was fit until the best model possible was obtained. The presence of heterogeneous capture probabilities with respect to sex and size of fish would require the use of a stratified abundance estimate.

Abundance Estimate

The Bailey closed-population model for sampling with replacement (Seber 1982) was used to provide both in-season abundance estimates of chum salmon for both the Tanana and Kantishna Rivers. The number of tags deployed was decreased by 5% to account for a tagging-induced mortality. Although the true mortality caused by tagging and handling is unknown and inestimable under the circumstances of this study, the mortality rate of 5% has been used in previous years of the study and is similar to the 5.2% of radio-tagged fall chum salmon in the Tanana River that did not proceed upstream (Barton 1992). Final model selection for abundance estimation depended on post-season data analysis, which is presented in detail in the results.

Migration Rate

Travel time between the tagging and recovery wheels was calculated to the nearest day for all recaptured fish by subtracting the date of tagging from the date of its first recapture. Migration rate was calculated by dividing the distance between the tag deployment wheel and recovery wheels (76 km on the Tanana River and 113 km on the Kantishna River) by travel time.

Stock Timing

Chum and coho salmon spawning in the Delta River were counted by ADF&G personnel weekly by ground survey and numbers of live and dead salmon were recorded. Ten surveys were conducted on the Delta River from 30 September to 7 December. Foot surveys were also conducted in mid - October in the Toklat River Springs area to count the number of live and dead chum and coho salmon and also to collect tags deployed from the Kantishna River tagging wheel. In addition, United States Geological Survey (USGS) personnel conducted ground surveys in August and September on Bluff Cabin Slough on the upper Tanana River. In all locations, tags were retrieved to determine the date that tags were deployed from the tagging wheel sites on the Tanana and Kantishna Rivers.

RESULTS

Sampling

Tag Deployment

A total of 2,164 fall chum salmon and 478 coho salmon tags were deployed from the Tanana River tagging wheel from 16 August through 2 October (Figures 3 and 4, Appendices A and B). Of the chum salmon tagged, 1,099 were day fish and 1,065 were night fish. Of the coho salmon tagged, 314 were day fish and 164 were night fish. In the entire catch at the Tanana tagging wheel, 26 chum and 3 coho salmon were not tagged, either as a result of death in the live-box or escape. At the Kantishna River tagging wheel, a total of 1,139 chum salmon and 138 coho salmon tags were deployed from 16 August to 29 September (Figures 5 and 6, Appendices C and D). Of the chum salmon tagged, 640 were day fish and 499 were day fish. Of the coho salmon tagged, 84 were day fish and 54 were night fish. Of the entire catch, 31 chum and 5 coho salmon were not tagged.

The peak catch occurred on 25 and 29 September for coho and chum salmon, respectively, at the Tanana River wheel. The peak CPUE at the Kantishna River tagging wheel occurred on 17 and 28 September for chum and coho salmon respectively (Figure 3 through 6), (Appendices A through D). Minor adjustments were made to the Tanana and Kantishna River tagging wheels during the project. These adjustments were moving the wheel away from the riverbank as the water level dropped, raising or lowering the wheel and adding paddles to the wheel.

Tag Recovery

A total of 1,226 chum salmon (appendix E) and 784 coho salmon (Appendix F) were examined for marks in the Tanana River recovery wheel. Of the salmon captured, 23 chum and 4 coho were tagged. In the Toklat recovery wheels, 1,413 chum salmon and 139 coho salmon were examined, of which 54 (28 day fish and 26 night fish) chum and 3 tagged coho salmon were tagged (Appendices G through J). One chum salmon was recaptured twice; one chum salmon recaptured had been released from the Tanana tagging wheel and one tagged chum salmon was recaptured from the USFWS tagging project near Rampart Rapids. No tag loss was detected between the tagging and recovery wheels on either Tanana or Kantishna Rivers.

The proportion of fall chum salmon caught in the Tanana Recovery wheel bearing tags varied over time and no tagged chum salmon were captured from September 18 through October 2 (Figure 7). The proportion recovered was also highly variable with earlier tagged chum salmon more likely to be captured (Figure 8). Compared to the Tanana River recovery wheel, the marked proportion in the Toklat River recovery wheels was fairly consistent. The longest time period when observed marked proportions were zero was August 29 though September 2

(Figure 9). In addition, the proportion of tags subsequently recaptured in the Toklat River recovery wheels was greatest in the later component of the fall chum salmon migration (Figure 10).

A total of 371 chum salmon and 15 coho salmon tags were returned by various sources other than project recovery wheels (Table 1). The majority of tags (128) were recovered from foot surveys conducted on the Delta River. Other areas where a significant number of tags were recovered include the Toklat River, where 62 chum salmon tags were recovered during foot surveys of the Toklat River Springs area (Figure 11), 44 from the Tanana River near Nenana, 31 from Bluff Cabin Slough and 22 from the Kantishna River. One chum salmon tagged in the Tanana River on August 27 was captured in November in a gill net under the ice near the village of Kotlik.

Data Analysis

The number of coho salmon marked and the number of tagged coho salmon subsequently recaptured were collectively judged insufficient for use in parameter estimation. For that reason, the abundance and migration rate of coho salmon were not estimated.

Migration rate

A total of 23 fall chum salmon were recaptured at the Tanana River recovery wheel between 16 August and 5 October. The mean travel time for day fish was 28.95 km/day (n = 8) and 16.37 km/day (n=14) for night fish, excluding one day fish with an extreme travel time of 31 days with a combined mean of 24 km/day. The migration rate between the Kantishna River tagging wheel and the Toklat River recovery wheels was 20 km/day (n = 26) for day fish and 22 km/day (n = 28) for night fish, with a combined mean of 21 km/day. Excluding one fish with a travel time of 31 days, the chum salmon captured at the Tanana River tagging wheel required a maximum of 11 days to migrate to the Tanana River recovery wheel (Figure 12 and 13). Approximately 79% of the tagged chum salmon took 1-4 days to migrate to the recovery wheel, while approximately 15% required 6-9 days and 6% required 11 days to migrate to the recovery wheel. In the Kantishna River, tagged chum salmon required a maximum of 13 days to migrate to the Toklat River recovery wheels. Approximately 33% required 1-4 days, 62% in 5-7 days and the remaining 5% took 9-13 days to migrate to the recovery wheels (Figure 14 and 15).

Diagnostic Statistical Tests

The binomial test for the equality of marked proportions in the two Toklat River recovery wheels was not significant (p = 0.607). For that reason, data from the two wheels was pooled and treated as a single recapture event.

The Monte Carlo test that the marked proportion in the recapture wheels was constant through time was not significant for either the Tanana River (p = 0.8590) or the Kantishna River (P = 0.0886). The Monte Carlo test that the probability of recapture was constant through time was not significant for the Kantishna River (p = 0.5366), but was significant for the Tanana River (p

= 0.0022). This suggests the need to temporally stratify the Tanana River data for purposes of abundance estimation. However, after examination of the available data, the number of recaptured tags (23) was judged insufficient to permit stable estimation using a temporally stratified model, so a pooled Bailey estimator (Seber 1982) was used.

The Smirnov test of the equality of travel time distributions of day and night fish was not significant for either the Tanana River ($p = 0.778$) or the Kantishna River (0.0873). Similarly, the two-sample binomial tests for the equality of recapture probabilities of day and night fish were not significant for either the Tanana River ($p = 0.3689$) or the Kantishna River ($p= 0.5104$). For that reason, day and night fish were pooled for purposes of abundance estimation.

Logistic regression models, intended to investigate potential differences in capture probabilities as a function of various explanatory variables, were not employed because of the small number of fish that were recaptured.

Abundance Estimate

Tagging began on 16 August and we used data from the recovery wheels beginning on 17 August. Based on the distribution of travel times for day fish (Table 2 and 3), we assumed that some of the unmarked fish captured in the recovery wheels between 18 and 23 August passed the tagging wheel before it was operational. The capture of unmarked fish in the recovery wheels that did not pass the tagging wheel while it was operational is a violation of the closure assumption and would positively bias the abundance estimator. For that reason, a method to subset the data was adopted.

We used the distribution of travel times for marked fish to remove a proportion of the unmarked fish between 18 and 23 August. For each day, the number of unmarked fish was multiplied by the appropriate cumulative frequency, which resulted in a final vector of the daily number of unmarked fish captured in the recovery wheels (Table 4 and 5). We assumed that the distribution of travel times of marked fish was an accurate representation of the distribution of travel times of unmarked fish. This assumption is not testable, and it could be that marked fish have longer travel time than unmarked fish because of a need to "recover" from the tagging process. However, the travel times of marked fish are the only information available to estimate the proportion of unmarked fish early on in the recovery wheel catches that passed the tagging wheel location while it was operational.

Tagging ended on 2 October and 29 September and recovery efforts ended on 5 October and 29 September on the Tanana and Toklat River respectively. Similar to the unmarked fish at the beginning of the study, a proportion of the fish tagged between 27 September and 2 October did not pass the recovery wheels while they were operational. Using the distribution of travel times for day and night fish, the corresponding number of day night fish released between 27 September and 2 October was reduced (Table 4 and 5). The reduced data set obtained using this method was used to estimate abundance.

The Bailey closed-population model for sampling with replacement was used to estimate the abundance of both the Tanana and Kantishna River populations (Figures 16 and 17). The final Tanana River population estimate was 97,843 (SE 19,362) fall chum salmon past the tagging wheel site (Table 6). The 95% confidence interval was (59,894; 135,792) and the coefficient of variation was approximately 0.2. The final abundance estimate for the Kantishna River was 27,199 (SE 3,562) chum salmon past the tagging wheel site. The 95% confidence interval was (20,218; 34,180) and the coefficient of variation was approximately 0.13 (Table 7.)

The 1999 subsistence harvest estimate in the Tanana River for Districts 6B and 6C was approximately 10,017 fall chum salmon (Borba and Hamner 2000). There were no commercial chum salmon openings in the Tanana River during 1999. Removal of reported subsistence harvest from the chum salmon abundance estimate leaves an estimated escapement in the upper Tanana River of approximately 87,826 fall chum salmon.

Stock Timing

A list of locations from which tags were recovered is given in table 1. A total of 128 chum salmon tags were recovered during surveys of spawning grounds in the Delta River between 30 September and 7 December 1999. The median tag deployment date was 20 September, and tagging dates ranged from 25 August through 1 October (Figure 18). The median tag deployment date for tags recovered in the Delta River was September 14 in 1995, 1996 and 1997 and September 27 in 1998. The absolute number of tags recovered in 1995-1998 was 39, 183, 26 and 55, respectively. Thirty one tags were recovered by USFWS personnel from Bluff Cabin Slough, a side channel of the Tanana River located several kilometers upstream of the mouth of the Delta River. They included one tag deployed in 1995, one from 1996 and one from 1997. Among the coho salmon tags returned by anglers, two tags were returned from the Delta Clearwater River, and three from Seventeen Mile Slough, one from the Nenana River. One tag was returned from a coho salmon captured in a gill net in the Tanana River near Fairbanks. No coho salmon tags were recovered in the Delta River, nor were any tagged coho salmon observed in the vicinity.

DISCUSSION

The water level of the Tanana River in 1999, as measured by a United States Geological Survey gauge near Nenana, was below the normal 1996 –1998 average during 1999 (Figure 19). There were few problems with fish wheel operation, excepting of minor problems with the Kantishna tagging wheel.

The CPUE (catch per unit effort) of chum salmon in the Tanana River tagging wheel was similar to the CPUE in 1997 and 1998 until approximately 6 September, when catches rates began to increase (Figure 20). The CPUE at the Tanana River recovery wheel was similar to the catches at the tagging wheel until 9 September, when the CPUE at the recovery wheel began to decrease (Figure 3). This roughly coincides with the beginning of a gradual decrease in the water level of the Tanana River, which suggests the wheel was operating at reduced efficiency. No tagged chum salmon were captured in the Tanana River recovery wheel from 17 September through 2

October which is unprecedented since the inception of the project and as a result the Bailey abundance estimate increased rapidly during this time period.

Aerial surveys of the main stem Tanana River were conducted in mid-October. Heavy ice cover obscured most of the channels but fall chum salmon were present in small numbers in open water areas (Barton, personal communication). Although fall chum salmon abundance appeared to be below average in magnitude in 1999, the Delta River escapement of 16,334 was more than twice the 1998 escapement of 7,804. In addition, 6% of the fall chum salmon tagged at the Tanana River tagging wheel were recovered in the Delta River, compared to only 3.2% in 1998.
The 1999 Tanana River escapement estimate although below average, is the second highest escapement among these years. Estimates of spawning escapement to the upper Tanana River from 1995-1998 were 183,267, 83,447, 62,448, 50,100 fall chum salmon, respectively.

The season average rate of 24 km/d for Tanana River chum salmon (day and night fish combined, excluding one chum salmon that took 31 days to reach the recovery wheel) was unlike fall chum migration rates observed in 1996 (31 km/d), 1995 (26 km/d) and 1998 (30 km/d) and documented by other studies (Milligan et al.1984; Buklis and Barton 1984). It is unclear why the migration rates were dissimilar to previous year, however, it may be due to the small sample size (23 tags recovered at the Tanana River recovery wheel) compared to other years.

The abundance estimate in this study represents the number of fall chum salmon that passed the tagging sites between 16 August and 5 October on the Tanana River and from 16 August through 29 September on the Kantishna River. However, our estimates can be considered conservative since it is reasonable to assume there are late summer chum salmon that are migrating past the tagging wheel sites before the tagging has begun and late fall chum migrating past the tagging wheel site after tagging and recovery efforts have ended.

Few tagged coho salmon were recaptured in the Tanana or Kantishna River recovery wheels (0.8% in the Tanana and 2.2% in the Kantishna River). Therefore, population estimates were not generated for the Tanana or Kantishna Rivers. In addition, no tagged coho salmon were observed in the Delta River or Toklat River Springs area. However, through tags returned by anglers and personal use fisherman, limited information was acquired concerning distribution of coho salmon in the Tanana River drainage (Table 1).

In the Kantishna River tagging wheel, the CPUE was quite low for the early tag deployment phase. This may be due to operational difficulties that were encountered, such as the wheel stalling due to lack of current and debris buildup. The wheel was adjusted on several instances and occasionally moved within the general vicinity of its original location. These difficulties were remedied during the first ten days of the wheel operation after the wheel contactor added paddleboards and made other adjustments. The Toklat River recovery wheels chum salmon CPUE was very similar to the catch at the Kantishna tagging wheel (Figure 5) and few operational problems occurred.

The ground survey counts at the Toklat River Springs (thought to be one of the major fall chum salmon spawning areas in the Tanana River drainage) were significantly less than the estimated abundance in the lower Kantishna River. The expanded ground survey count was 4,551 (Bergstrom et al. 2001) chum salmon at the Toklat River Springs, while approximately 27,000 fall chum salmon were estimated to have passed the tagging wheel site on the Kantishna River. These estimates suggest the abundance of fall chum salmon migrating in the Kantishna River above the Toklat River may be greater than previously assumed. However, a local pilot conducting cursory aerial surveys in the Bearpaw River area in mid-October reported few fall chum salmon in both the Toklat River Springs area and in tributaries in vicinity of the Bearpaw River.

The 1999 Tanana River estimated escapement based on the tagging estimate was 97,843 fall chum salmon, which is 77% of the 1995-1999 average escapement of 126,925. Other indications of a weak fall chum return in 1999 include the Yukon River sonar passage estimate, which was 510,891 fall chum salmon (Pfisterer and Maxwell 2000). However, the 1997-1999 historical Yukon River sonar season average is 487,751 chum salmon. The ADF&G test fish wheel located on the left bank of the Yukon River near the village of Tanana caught approximately 50% of its 1994-1999 average annual fall chum salmon catch (Bergstrom et al. 2001.). Moreover, spawning ground surveys in the Toklat River revealed an escapement of approximately 4,551 chum salmon in 1999, which is 14% of the minimum escapement goal of 33,000 (Bergstrom et al. 2001). This is one of the lowest escapements on record for the Toklat River. However, despite indications that Tanana River fall chum escapement was poor, the spawning escapement in the Delta River was 16,534 chum salmon (United States/Canada Yukon River Joint Technical Committee 2000), which is approximately 69% greater than the minimum escapement goal of 11,000. Consequently, it appears that although overall Tanana River escapement was poor, the Delta River run strength was better than expected.

RECOMMENDATIONS

Model development efforts should continue in order to provide more refined in-season and post-season tools for population estimation. Other data analysis tools should be explored and developed to test as many assumptions as possible. For example, the lack of sex and length samples from the recovery wheel catch precludes full investigation of selective sampling. The current tag-deployment site on the Tanana River has been used since project inception. Fewer tags were deployed and recovered in the last five years than desired, reducing the estimation precision. In view of the fact that only 23 tags were recovered at the Tanana recovery wheel, consideration should be given to operating the recovery wheel on the opposite bank or moving the wheel to a more suitable location as the water level decreases. Most of the tags recovered in 1998 (61%) were from the opposite (left) bank, which was not used in 1999.

There were some minor difficulties this year with the Kantishna River wheel because of the water velocity at the wheel location. There were several occasions when the wheel stalled due to the slow current. Consideration should be given to using a three-basket wheel, as this may solve the problems with the wheel stalling. We also recommend that day and night fish continue to be tagged to increase sample size, when possible. Based on results from 1997 though 1999, tagging fish which are held in a live-box overnight for up to 12 hours does not have a detectable effect on their probability of recapture when the number of fish in the live-box is low. Pooling data from day and night-fish can substantially increase the number of marked fish, which significantly reduces the variance of the abundance estimate. Day and night fish should be pooled only after tests are performed to verify that no differences exist between them. However, in years of high abundance night fish may have to be excluded from the abundance estimate if an increase in live box time or density proves to have an effect on travel time.

Since 1981, fish wheels have been used on the Yukon and Tanana Rivers to estimate run strength and timing of salmon runs. The USFWS, who conduct a mark-recapture study on the Yukon River near Rampart Rapids, have preliminary evidence that delayed mortality may be occurring above the project recovery wheels (Knudsen et al. in prep). In 1999, fifteen fish wheels were used to monitor salmon runs in the Yukon River drainage by the Alaska Department of Fish and Game (ADF&G), the USFWS, and the Canadian Department of Fisheries and Oceans. If delayed mortality is occurring, these projects have the potential to affect several thousand chum salmon due to the number of fish wheels that are operated each year.

Numerous studies that have measured changes in plasma cortisol from blood samples in response to various stimuli (Barton 1997). Plasma cortisol concentrations, as well as other blood chemistry parameters, have been found to be useful as indicators of stress in fishes (Barton 1997). Stress from tagging and handling has been well documented by various studies of salmonids and other fishes (Barton 1997). Documenting levels of typical blood chemistry stress indicators from fall chum salmon would be a benefit to all of the agencies that operate fish wheels on the Yukon and Tanana Rivers. In addition, results may enable fishery managers to operate fish wheels to minimize salmon injury and mortality by modifying tagging and fish wheel procedures.

With the exception of some aerial survey data, there is little information about escapement in the upper Kantishna River drainage. An additional recovery wheel (funded by the USFWS and contracted by the National Park Service) will be operated on the upper Kantishna River approximately 3 km downstream of the Bearpaw River mouth in 2000. This wheel will not be used for generating in season population estimates (at least in the first year) but rather to examine the proportion of tagged chum salmon in the upper Kantishna River and for general information for run timing and strength of the upper Kantishna River stock.

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Table 1. Number of tags returned by location from fall chum and coho salmon tagged in the Tanana and Kantishna Rivers, 1999. a

Recapture Location	Number of Tags	
	Chum	Coho
Chena River, Hodgkins Slough	1	
Delta River	128	
Tanana River, near Nenana	44	
Tanana River, Bluff Cabin Slough	31	
Tanana River, near Fairbanks	4	1
Tanana River recovery wheels	23	4
Toklat River recovery wheels	54	3
Toklat Springs	62	
Kantishna River	22	1
Delta Clearwater River		2
Seventeen Mile Slough		3
Nenana River		1
Yukon River, north mouth, near Kotlik	1	
Yukon River, near Marshall	1	
Total	371	15

[a] One tag recovered in Gieger Creek was deployed in 1996.

Table 2. Counts and cumulative proportions of travel time between the tag deployment and recovery wheels on the Tanana River used in the data reduction for the Bailey estimator, 1999.

Travel Time (days)	Day Tag Count	Day Tag Cumulative Proportion	Night Tag Count	Night Tag Cumulative Proportion	Combined Count	Combined Cumulative Proportion
1	1	0.13	0	0.00	1	0.05
2	4	0.63	4	0.29	8	0.41
3	0	0.63	2	0.43	2	0.50
4	3	1.00	3	0.64	6	0.77
5	0	1.00	0	0.64	0	0.77
6	0	1.00	2	0.79	2	0.86
7	0	1.00	1	0.86	1	0.91
8	0	1.00	0	0.86	0	0.91
9	0	1.00	1	0.93	1	0.95
10	0	1.00	0	0.93	0	0.95
11	0	1.00	1	1.00	1	1.00
Total	8		14		22	

Table 3. Counts and cumulative proportions of travel time between the tag deployment wheel on the Kantishna River and recovery wheels on the Toklat River used in the data reduction for the Bailey estimator, 1999.

Travel Time (days)	Day Tag Count	Day Tag Cumulative Proportion	Night Tag Count	Night Tag Cumulative Proportion	Combined Count	Combined Cumulative Proportion
0	0	0.00	1	0.04	1	0.02
1	0	0.00	0	0.04	0	0.02
2	0	0.00	0	0.04	0	0.02
3	1	0.04	3	0.15	4	0.09
4	7	0.29	6	0.38	13	0.33
5	11	0.68	9	0.73	20	0.70
6	4	0.82	3	0.85	7	0.83
7	3	0.93	2	0.92	5	0.93
8	0	0.93	0	0.92	0	0.93
9	0	0.93	1	0.96	1	0.94
10	0	0.93	0	0.96	0	0.94
11	1	0.96	0	0.96	1	0.96
12	0	0.96	1	1.00	1	0.98
13	1	1.00	0	1.00	1	1.00
Total	28		26		54	

Table 4. Observed and adjusted number of releases at the tag deployment wheel and observed and adjusted number of unmarked catches at the recovery wheel used in the Bailey model to estimate abundance of fall chum salmon in the Tanana River, 1999.

	Releases at Tagging Wheel					Unmarked Catches at Recovery Wheel		
Date	Day Tags Released	Estimated Proportion Passing Recovery Wheels	Night Tags Released	Estimated Proportion Passing Recovery Wheels	Adjusted Tags Released	Unmarked Catch	Estimated Proportion Passing Tagging Wheel	Adjusted Unmarked Catch
8/16	6	0.95	18	0.95	23	8	0.05	0
8/17	19	0.95	19	0.95	36	28	0.41	11
8/18	12	0.95	13	0.95	24	17	0.50	9
8/19	13	0.95	18	0.95	29	31	0.77	24
8/20	14	0.95	19	0.95	31	15	0.77	12
8/21	8	0.95	3	0.95	10	10	0.86	9
8/22	10	0.95	12	0.95	21	29	0.91	26
8/23	7	0.95	5	0.95	11	27	0.91	25
8/24	7	0.95	10	0.95	16	35	0.95	33
8/25	13	0.95	11	0.95	23	31	0.95	30
8/26	17	0.95	9	0.95	25	24	1.00	24
8/27	15	0.95	17	0.95	30	25	1.00	25
8/28	4	0.95	10	0.95	13	29	1.00	29
8/29	9	0.95	12	0.95	20	27	1.00	27
8/30	5	0.95	13	0.95	17	22	1.00	22
8/31	17	0.95	22	0.95	37	11	1.00	11
9/1	19	0.95	13	0.95	30	50	1.00	50
9/2	11	0.95	17	0.95	27	27	1.00	27
9/3	14	0.95	22	0.95	34	17	1.00	17
9/4	13	0.95	27	0.95	38	18	1.00	18
9/5	8	0.95	22	0.95	29	24	1.00	24
9/6	13	0.95	33	0.95	44	13	1.00	13
9/7	22	0.95	27	0.95	47	60	1.00	60
9/8	34	0.95	24	0.95	55	50	1.00	50
9/9	16	0.95	29	0.95	43	55	1.00	55
9/10	34	0.95	32	0.95	63	11	1.00	11
9/11	33	0.95	34	0.95	64	37	1.00	37
9/12	37	0.95	35	0.95	68	21	1.00	21
9/13	68	0.95	32	0.95	95	52	1.00	52
9/14	45	0.95	26	0.95	67	33	1.00	33
9/15	29	0.95	22	0.95	48	26	1.00	26
9/16	26	0.95	23	0.95	47	25	1.00	25
9/17	29	0.95	20	0.95	47	38	1.00	38
9/18	16	0.95	24	0.95	38	22	1.00	22
9/19	19	0.95	16	0.95	33	18	1.00	18
9/20	19	0.95	27	0.95	44	17	1.00	17
9/21	32	0.95	17	0.95	47	9	1.00	9
9/22	29	0.95	18	0.95	45	13	1.00	13
9/23	48	0.95	41	0.95	85	20	1.00	20
9/24	46	0.95	43	0.95	85	19	1.00	19
9/25	53	0.95	51	0.88	95	13	1.00	13
9/26	39	0.95	32	0.88	65	15	1.00	15
9/27	55	0.95	39	0.81	84	22	1.00	22
9/28	45	0.95	46	0.81	80	11	1.00	11
9/29	34	0.95	27	0.75	52	15	1.00	15
9/30	13	0.95	0	0.61	12	15	1.00	15
10/1	0	0.95	22	0.61	13	10	1.00	10
10/2	24	0.59	13	0.41	20	8	1.00	8
10/3						20	1.00	20
10/4						15	1.00	15
10/5						15	1.00	15

Table 5. Observed and adjusted number of releases at the tag deployment wheel and observed and adjusted number of unmarked catches at the recovery wheels used in the Bailey model to estimate abundance of fall chum salmon in the Kantishna and Toklat Rivers, 1999.

	Releases at Tagging Wheel					Unmarked Catches at Recovery Wheels		
Date	Day Tags Released	Estimated Proportion Passing Recovery Wheels	Night Tags Released	Estimated Proportion Passing Recovery Wheels	Adjusted Tags Released	Unmarked Catch	Estimated Proportion Passing Tagging Wheel	Adjusted Unmarked Catch
8/16	4	0.95	3	0.95	7	0	0.02	0
8/17	6	0.95	0	0.95	6	4	0.02	0
8/18	4	0.95	6	0.95	10	4	0.02	0
8/19	8	0.95	0	0.95	8	6	0.09	1
8/20	6	0.95	5	0.95	10	6	0.33	2
8/21	4	0.95	5	0.95	9	3	0.70	2
8/22	6	0.95	4	0.95	10	1	0.83	1
8/23	8	0.95	4	0.95	11	5	0.93	5
8/24	11	0.95	1	0.95	11	4	0.93	4
8/25	1	0.95	0	0.95	1	2	0.94	2
8/26	6	0.95	10	0.95	15	4	0.94	4
8/27	7	0.95	2	0.95	9	15	0.96	14
8/28	6	0.95	8	0.95	13	8	0.98	8
8/29	8	0.95	5	0.95	12	9	1.00	9
8/30	10	0.95	5	0.95	14	7	1.00	7
8/31	3	0.95	1	0.95	4	8	1.00	8
9/1	3	0.95	5	0.95	8	15	1.00	15
9/2	11	0.95	5	0.95	15	11	1.00	11
9/3	8	0.95	5	0.95	12	12	1.00	12
9/4	10	0.95	9	0.95	18	9	1.00	9
9/5	17	0.95	11	0.95	27	15	1.00	15
9/6	5	0.95	9	0.95	13	11	1.00	11
9/7	12	0.95	11	0.95	22	7	1.00	7
9/8	9	0.95	8	0.95	16	8	1.00	8
9/9	5	0.95	11	0.95	15	3	1.00	3
9/10	9	0.95	2	0.95	10	9	1.00	9
9/11	0	0.95	0	0.95	0	9	1.00	9
9/12	16	0.95	12	0.95	27	13	1.00	13
9/13	24	0.95	22	0.95	44	19	1.00	19
9/14	40	0.95	31	0.95	67	21	1.00	21
9/15	38	0.95	19	0.95	54	22	1.00	22
9/16	38	0.95	25	0.95	60	26	1.00	26
9/17	47	0.9	52.0	1.0	92	18	1.00	18
9/18	49	0.9	42.0	0.9	83	42	1.00	42
9/19	37	0.9	25.0	0.9	55	59	1.00	59
9/20	33	0.9	15.0	0.9	43	44	1.00	44
9/21	11	0.9	20.0	0.9	27	32	1.00	32
9/22	29	0.9	17.0	0.9	40	26	1.00	26
9/23	16	0.8	12.0	0.8	22	22	1.00	22
9/24	15	0.6	8.0	0.7	15	21	1.00	21
9/25	16	0.3	4.0	0.4	6	18	1.00	18
9/26	12	0.0	14.0	0.1	2	15	1.00	15
9/27	12	0.0	14.0	0.0	1	22	1.00	22
9/28	20	0.0	32.0	0.0	1	18	1.00	18
9/29						10	1.00	10

Table 6. Daily and cumulative catch statistics and Bailey abundance estimates of fall chum salmon in the Tanana River, 1999 a

Date	Adjusted (Releases)	Examined For Tags	Recaptures	Abundance	95% Confidence Bounds Lower	Upper	Standard Error	CV
8/16	23	0	0					
8/17	59	1	0					
8/18	83	8	0					
8/19	112	24	0					
8/20	143	35	0					
8/21	154	43	0					
8/22	175	68	0					
8/23	186	93	0					
8/24	202	124	0					
8/25	225	155	1	17,555	379	37,293	10,070	0.57
8/26	250	178	1	22,369	427	47,540	12,843	0.57
8/27	280	204	2	19,129	520	37,738	9,494	0.50
8/28	294	234	3	17,269	2,261	32,277	7,657	0.44
8/29	314	262	4	16,514	3,427	29,601	6,677	0.40
8/30	331	286	6	13,569	4,282	22,856	4,738	0.35
8/31	368	297	6	15,664	4,938	26,390	5,473	0.35
9/1	398	349	8	15,476	6,008	24,944	4,831	0.31
9/2	425	377	9	16,063	6,697	25,429	4,779	0.30
9/3	459	396	11	15,184	7,056	23,312	4,147	0.27
9/4	497	414	11	17,186	7,980	26,392	4,697	0.27
9/5	525	439	12	17,767	8,598	26,936	4,678	0.26
9/6	569	452	12	19,825	9,590	30,060	5,222	0.26
9/7	616	514	14	21,147	10,937	31,357	5,209	0.25
9/8	671	565	15	23,735	12,613	34,857	5,675	0.24
9/9	713	620	15	27,671	14,687	40,655	6,624	0.24
9/10	776	632	16	28,893	15,726	42,060	6,718	0.23
9/11	840	670	17	31,311	17,422	45,200	7,086	0.23
9/12	908	692	18	33,116	18,803	47,429	7,303	0.22
9/13	1,003	745	19	37,410	21,626	53,194	8,053	0.22
9/14	1,071	778	19	41,713	24,103	59,323	8,985	0.22
9/15	1,119	804	19	45,037	26,015	64,059	9,705	0.22
9/16	1,166	830	20	46,138	27,103	65,173	9,712	0.21
9/17	1,212	870	22	45,896	27,778	64,014	9,244	0.20
9/18	1,250	892	22	48,530	29,366	67,694	9,778	0.20
9/19	1,283	910	22	50,815	30,743	70,887	10,241	0.20
9/20	1,327	927	22	53,539	32,386	74,692	10,792	0.20
9/21	1,374	936	22	55,973	33,856	78,090	11,284	0.20
9/22	1,418	949	22	58,567	35,421	81,713	11,809	0.20
9/23	1,503	969	22	63,384	38,327	88,441	12,784	0.20
9/24	1,587	988	22	68,238	41,257	95,219	13,766	0.20
9/25	1,686	1,001	22	73,448	44,402	102,494	14,819	0.20
9/26	1,754	1,016	22	77,554	46,879	108,229	15,651	0.20
9/27	1,843	1,038	22	83,252	50,315	116,189	16,805	0.20
9/28	1,929	1,049	22	88,059	53,216	122,902	17,777	0.20
9/29	1,987	1,064	22	92,003	55,594	128,412	18,576	0.20
9/30	2,000	1,079	22	93,909	56,740	131,078	18,964	0.20
10/1	2,021	1,089	22	95,774	57,863	133,685	19,342	0.20
10/2	2,056	1,097	22	98,148	59,294	137,002	19,823	0.20
10/3	2,056	1,118	23	95,857	58,686	133,028	18,965	0.20
10/4	2,056	1,132	23	97,084	59,432	134,736	19,210	0.20
10/5	2,056	1,141	23	97,843	59,894	135,792	19,362	0.20

[a] The number of tags deployed was adjusted for a 5% mortality.

Table 7. Daily and cumulative catch statistics and Bailey abundance estimates of fall chum salmon in the Kantishna River, 1999. a

Date	Adjusted (Releases)	Examined For Tags	Recaptures	Abundance	95% Confidence Bounds Lower	Upper	Standard Error	CV
8/16	7	0	0					
8/17	12	0	0					
8/18	22	0	0					
8/19	29	1	0					
8/20	40	4	0					
8/21	48	10	1	269	57	545	141	0.52
8/22	58	13	1	398	70	814	212	0.53
8/23	69	23	2	552	90	1,058	258	0.47
8/24	81	30	2	848	109	1,638	403	0.48
8/25	82	33	2	935	113	1,811	447	0.48
8/26	97	45	3	1,106	180	2,032	472	0.43
8/27	105	65	3	1,728	260	3,196	749	0.43
8/28	119	79	4	1,894	427	3,361	749	0.40
8/29	131	93	4	2,452	543	4,361	974	0.40
8/30	145	118	4	3,439	746	6,132	1,374	0.40
8/31	149	139	4	4,160	892	7,428	1,668	0.40
9/1	157	174	4	5,482	1,159	9,805	2,206	0.40
9/2	172	200	4	6,900	1,448	12,352	2,782	0.40
9/3	184	236	5	7,256	1,950	12,562	2,707	0.37
9/4	202	253	5	8,538	2,289	14,787	3,189	0.37
9/5	229	281	5	10,747	2,870	18,624	4,019	0.37
9/6	242	306	5	12,366	3,295	21,437	4,628	0.37
9/7	264	331	7	10,943	3,881	18,005	3,603	0.33
9/8	280	348	7	12,201	4,322	20,080	4,020	0.33
9/9	295	358	7	13,223	4,681	21,765	4,358	0.33
9/10	306	379	8	12,906	5,002	20,810	4,033	0.31
9/11	306	399	10	11,116	4,914	17,318	3,164	0.28
9/12	333	432	13	10,290	5,168	15,412	2,613	0.25
9/13	376	478	14	11,997	6,211	17,783	2,952	0.25
9/14	444	527	15	14,641	7,788	21,494	3,497	0.24
9/15	498	578	16	16,949	9,235	24,663	3,936	0.23
9/16	558	638	16	20,961	11,407	30,515	4,874	0.23
9/17	652	678	16	26,026	14,154	37,898	6,057	0.23
9/18	738	755	16	32,802	17,820	47,784	7,644	0.23
9/19	797	895	21	32,445	19,349	45,541	6,682	0.21
9/20	843	981	26	30,648	19,453	41,843	5,712	0.19
9/21	872	1,047	31	28,547	18,957	38,137	4,893	0.17
9/22	916	1,106	35	28,157	19,233	37,081	4,553	0.16
9/23	942	1,160	38	28,033	19,493	36,573	4,357	0.16
9/24	964	1,213	46	24,892	17,988	31,796	3,523	0.14
9/25	983	1,263	50	24,355	17,870	30,840	3,309	0.14
9/26	1008	1,292	51	25,056	18,447	31,665	3,372	0.13
9/27	1033	1,327	52	25,876	19,114	32,638	3,450	0.13
9/28	1082	1,361	53	27,282	20,216	34,348	3,605	0.13
9/29	1082	1,382	54	27,199	20,218	34,180	3,562	0.13

[a] The number of tags deployed was adjusted for a 5% mortality.

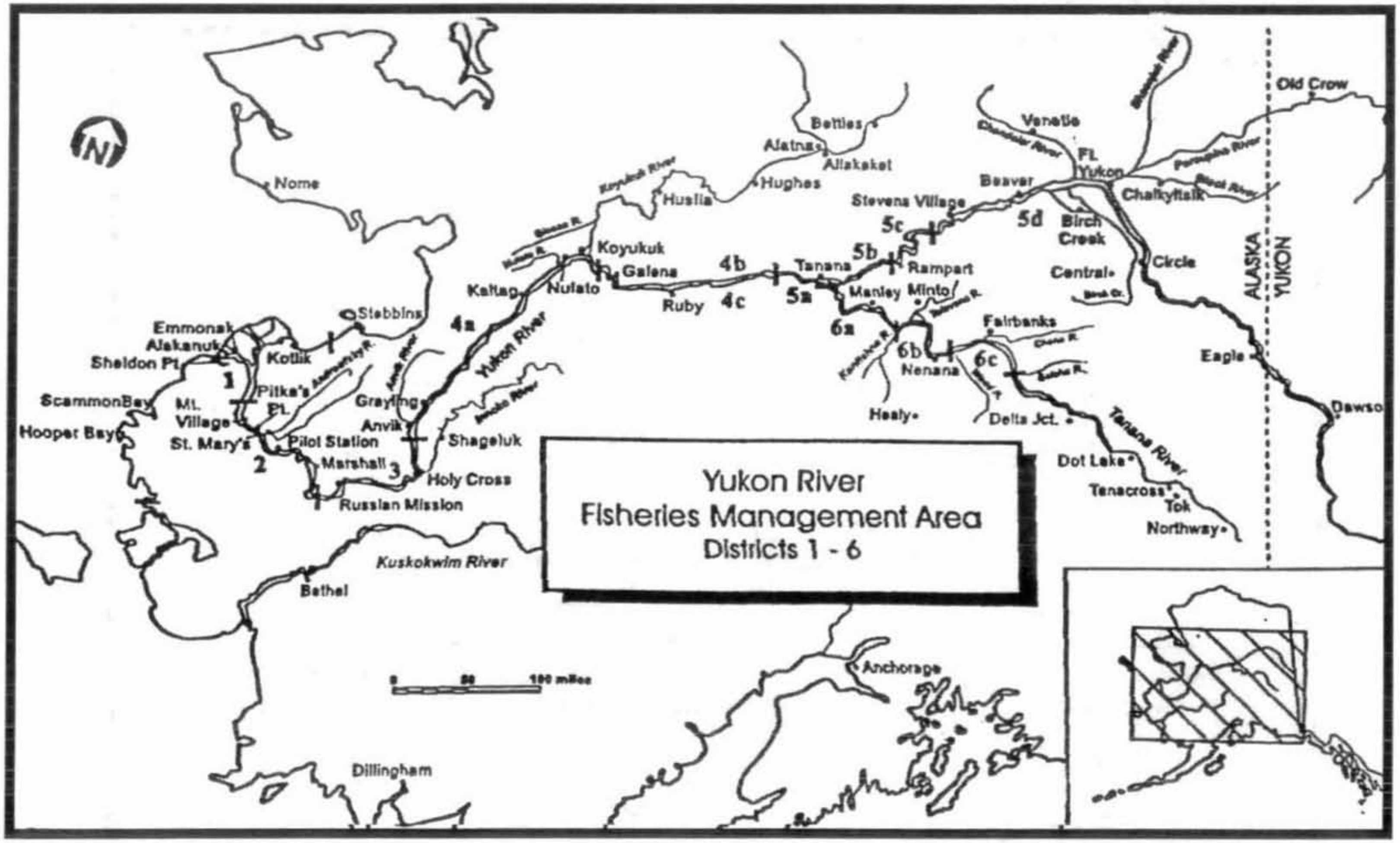

Figure 1. Fisheries management districts and subdistricts in the Yukon River and Tanana River drainages.

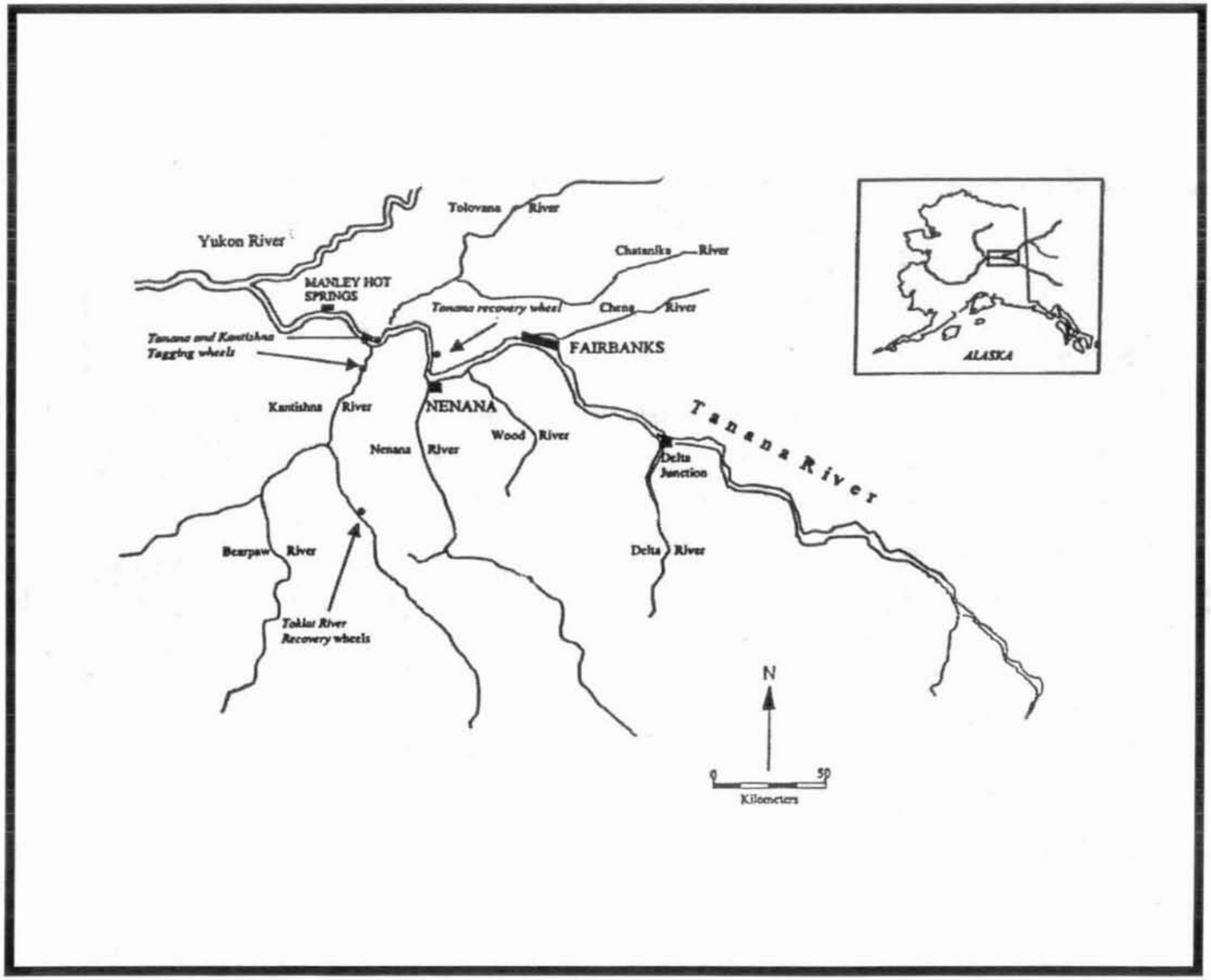

Figure 2. Location of the tag deployment and recovery fish wheels used on the Tanana and Kantishna Rivers.

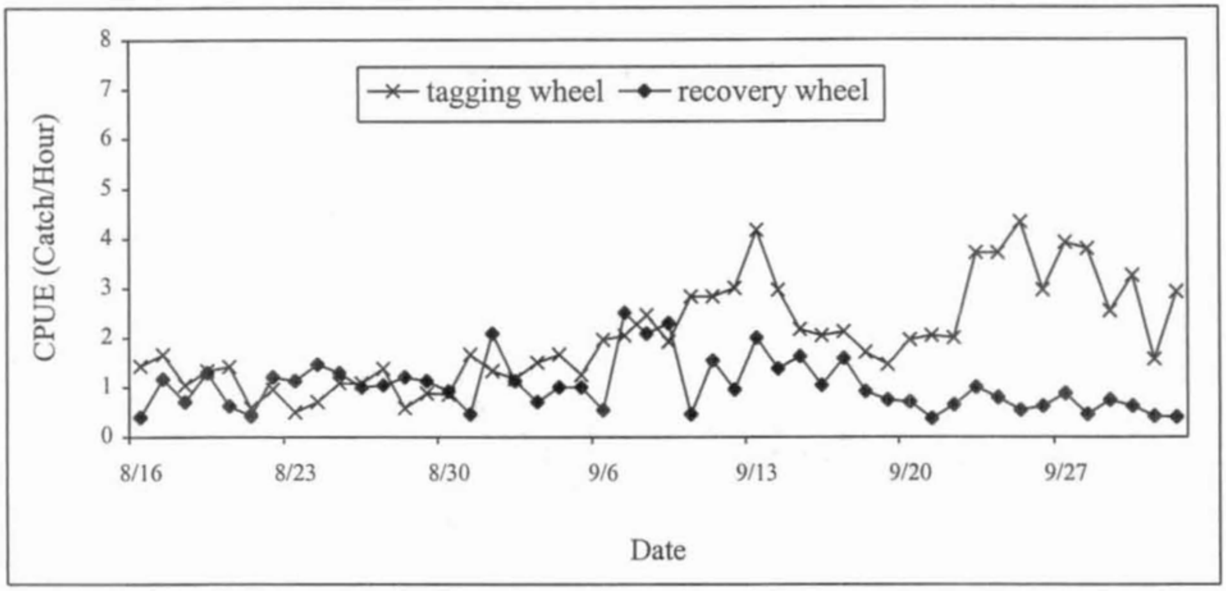

Figure 3. Daily catch-per-unit-effort (CPUE) of fall chum salmon at the tag deployment and recovery wheel, Tanana River, 1999.

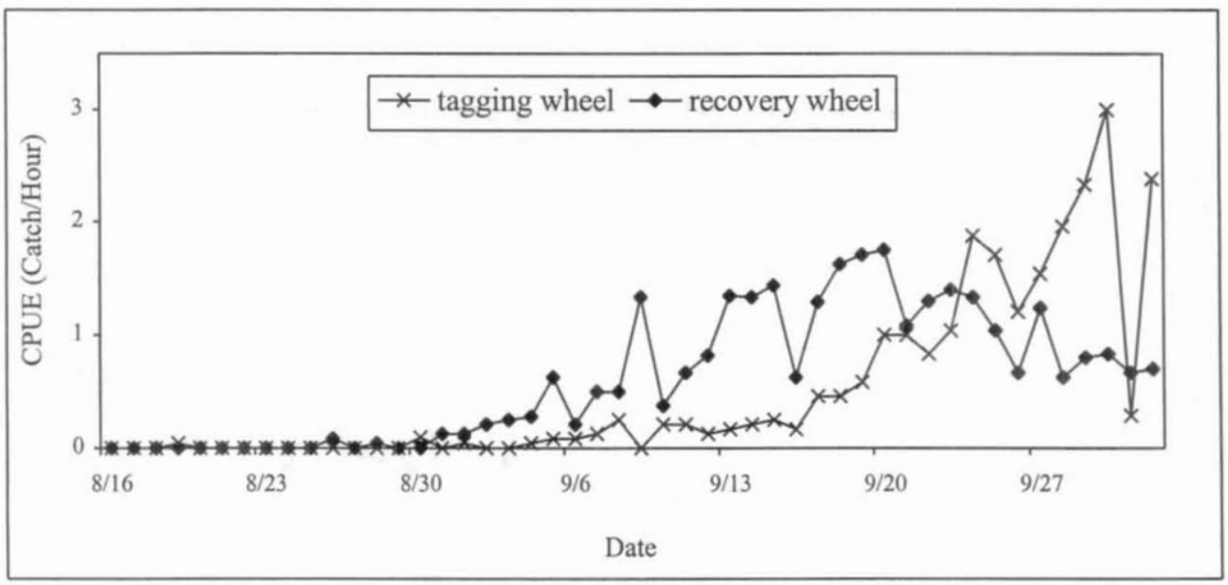

Figure 4. Daily catch-per-unit-effort (CPUE) of coho salmon at the tag deployment and recovery wheel, Tanana, River, 1999.

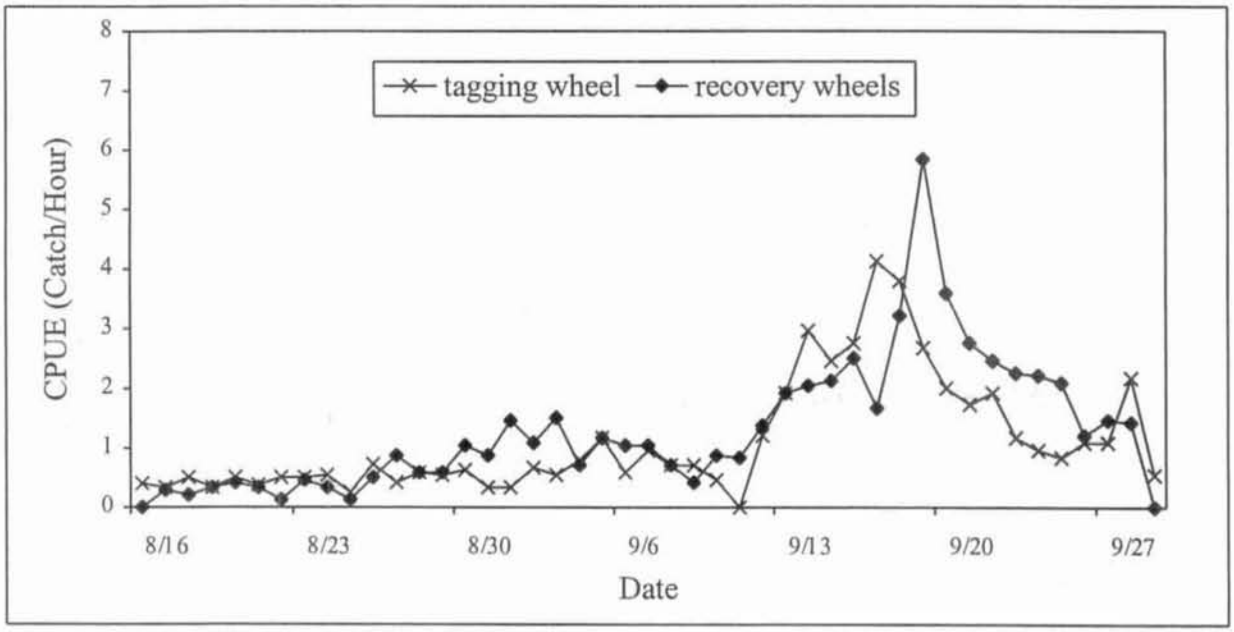

Figure 5. Daily catch-per-unit-effort (CPUE) of fall chum salmon at the Kantishna tag deployment wheel and the Toklat River recovery wheels, 1999.

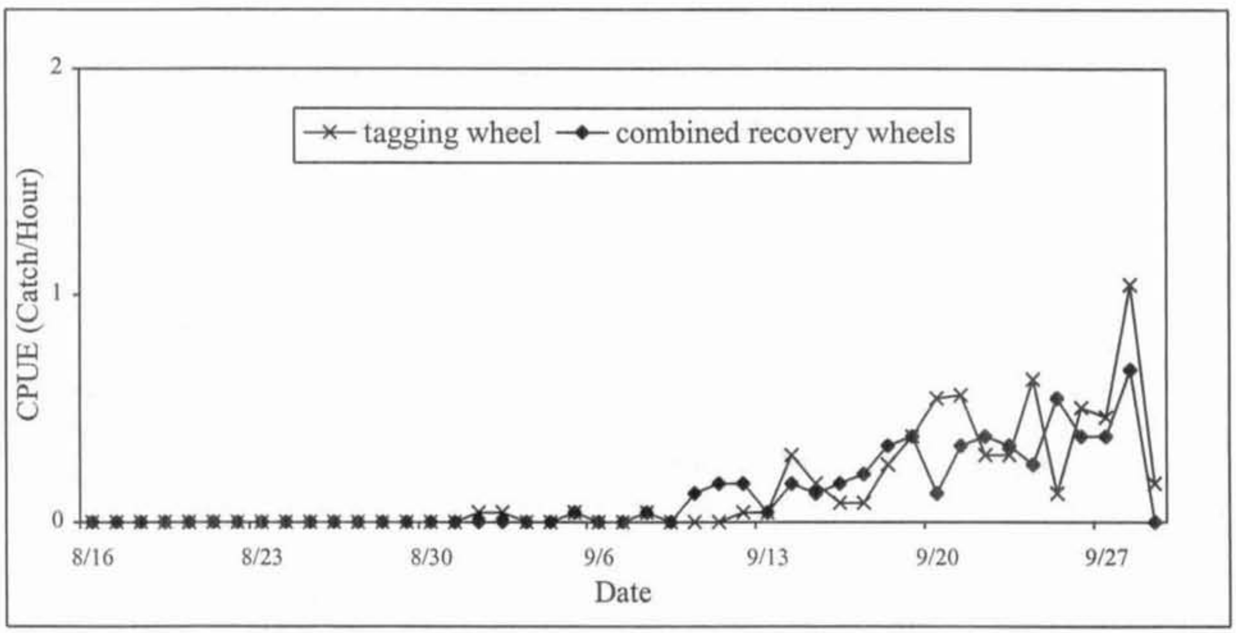

Figure 6. Daily catch-per-unit-effort (CPUE) of coho salmon at the Kantishna tag deployment wheel and the Toklat River recovery wheels, 1999.

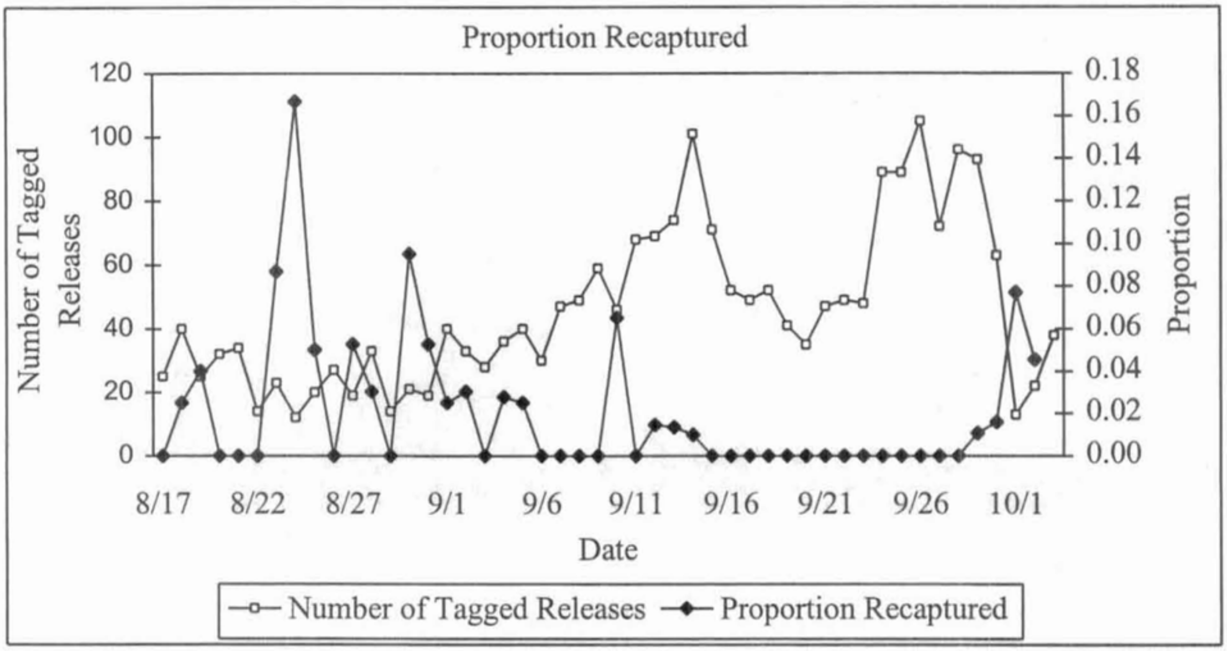

Figure 7. Proportion of tagged chum salmon released at the tagging wheel that were subsequently recaptured at the recovery wheel, Tanana River, 1999.

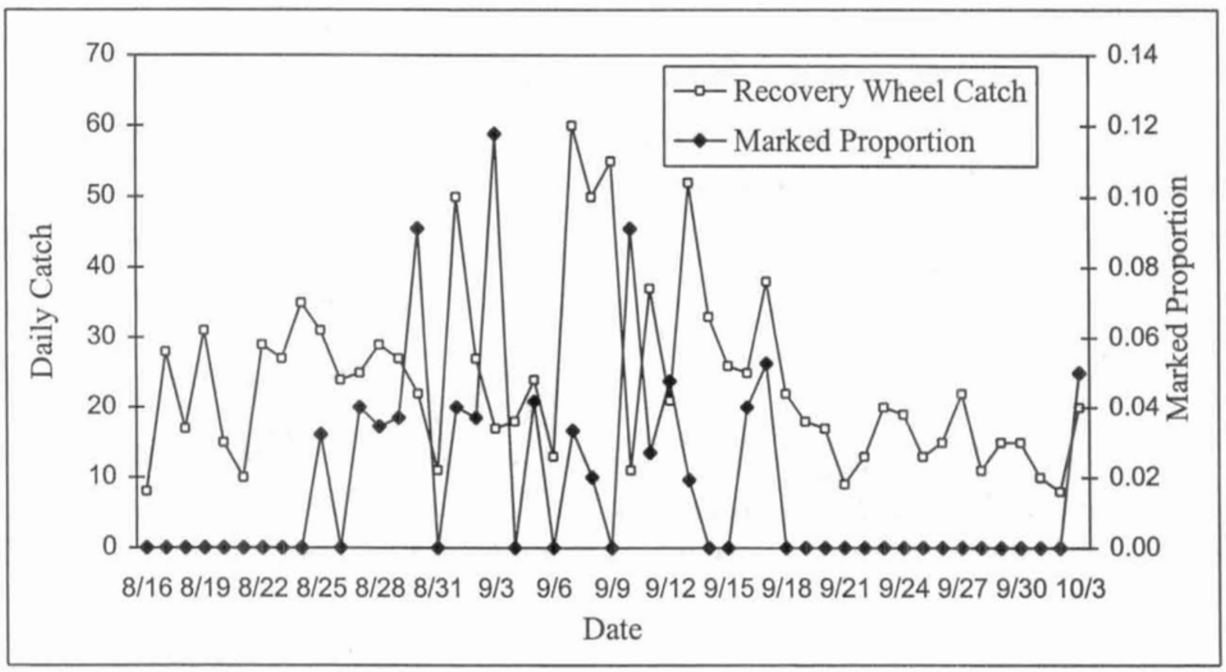

Figure 8. Proportion of recovery wheel fall chum salmon catch bearing tags, Tanana River, 1999.

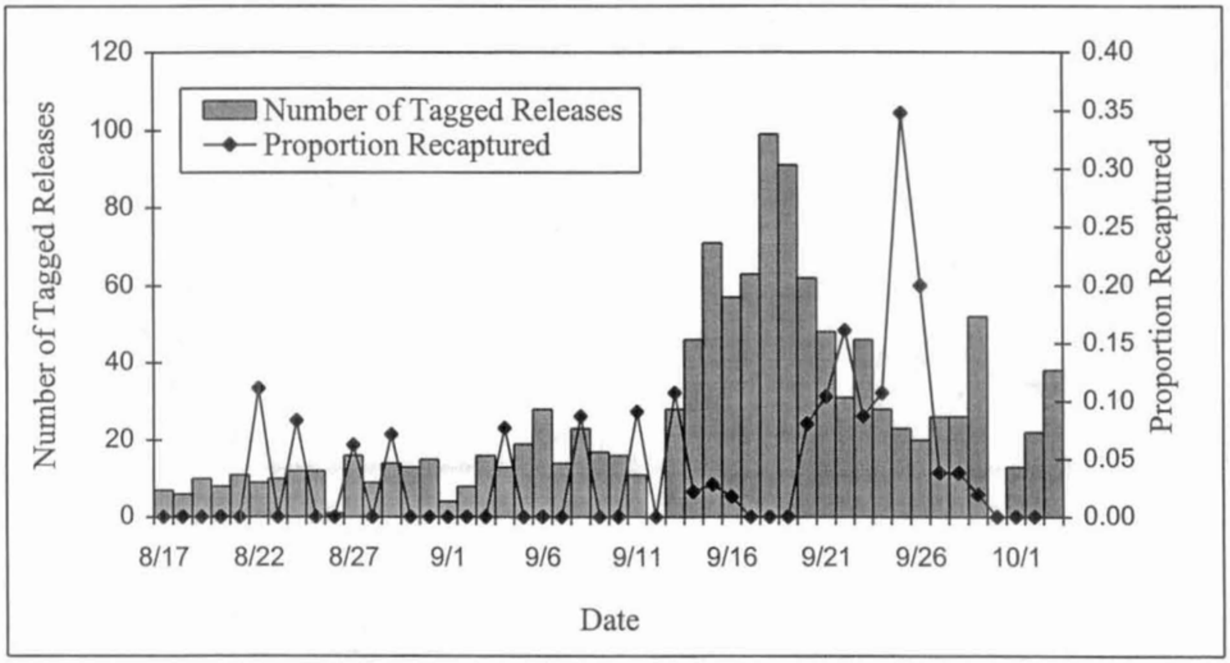

Figure 9. Proportion of tagged fall chum salmon released at the Kantishna River tagging wheel that were subsequently recaptured at the recovery wheels, Toklat River, 1999.

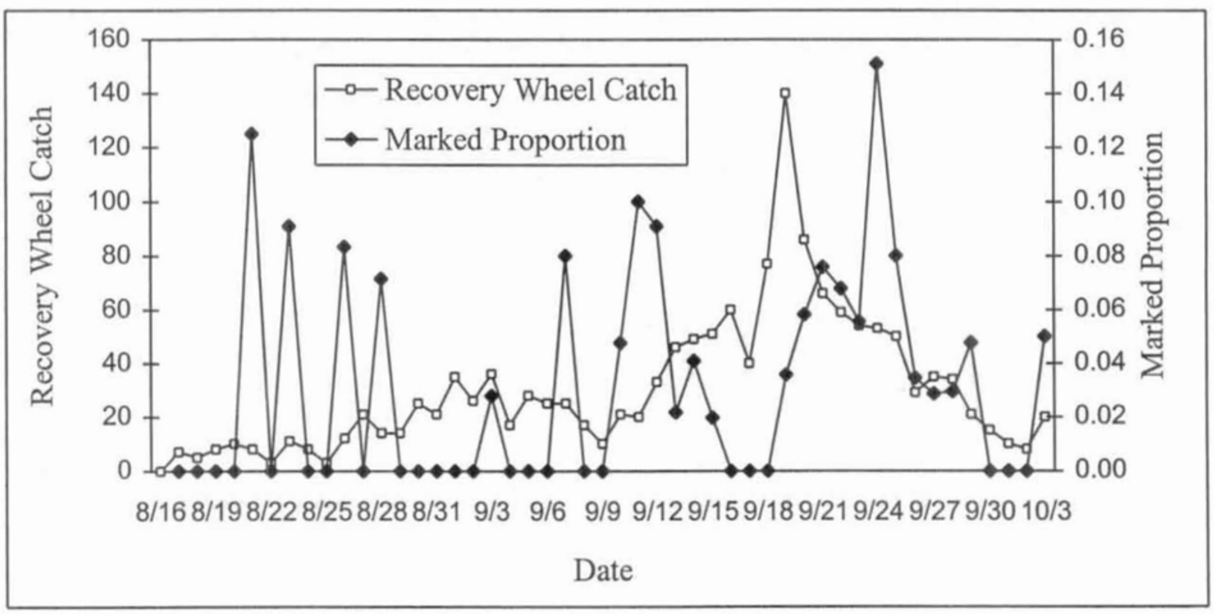

Figure 10. Proportion of recovery wheel fall chum salmon catch bearing tags (both wheels combined), Toklat River, 1999.

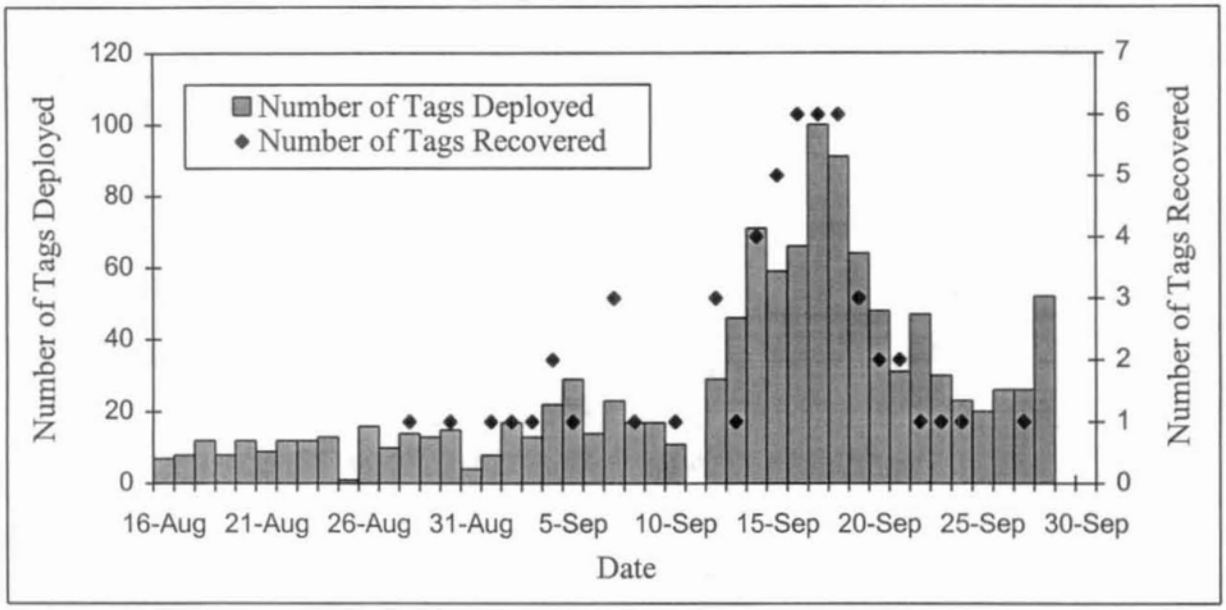

Figure 11. Number of fall chum salmon tags recovered at the Toklat River Springs by date tagged and the daily number of tags deployed on the Kantishna River, 1999.

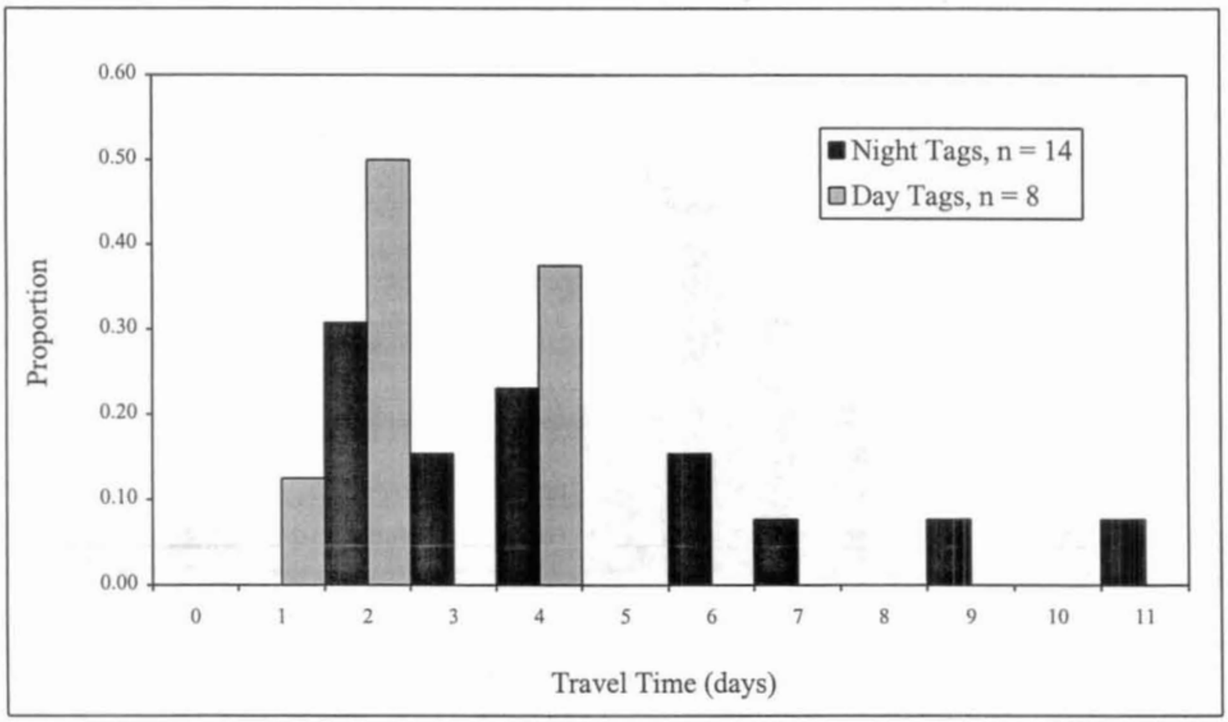

Figure 12. Travel time between the tagging and recovery wheels for day and night tagged chum salmon that were recaptured at the recovery wheel, Tanana River, 1999.

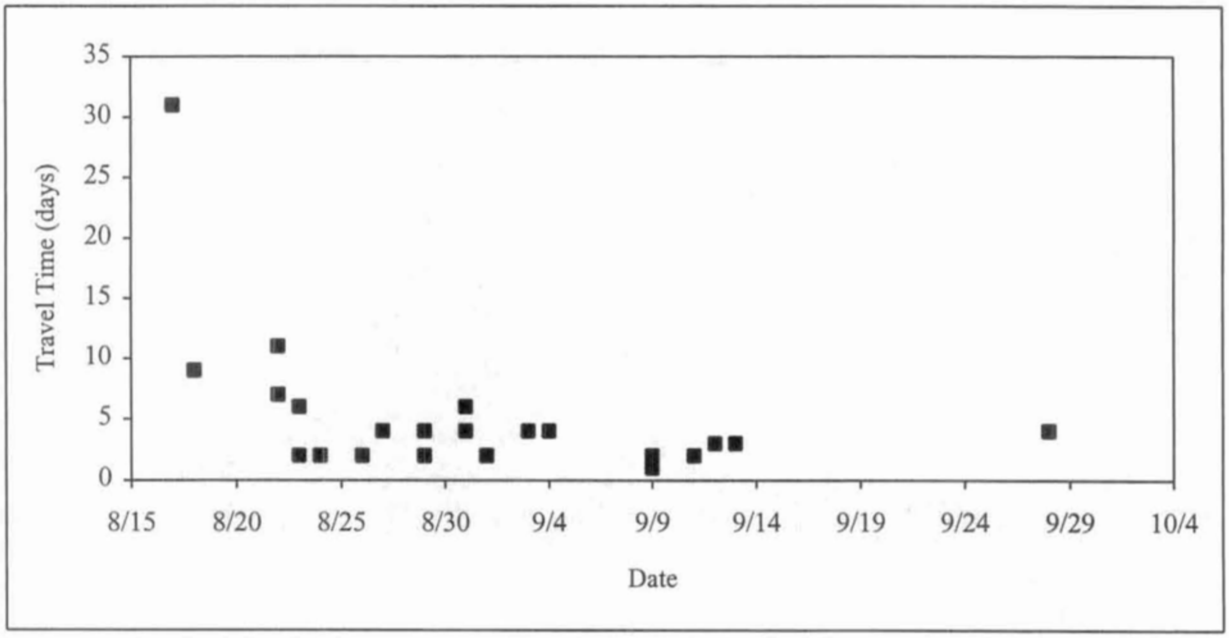

Figure 13. Travel time between the Tanana River tag deployment and recovery wheels for fall chum salmon, 1999.

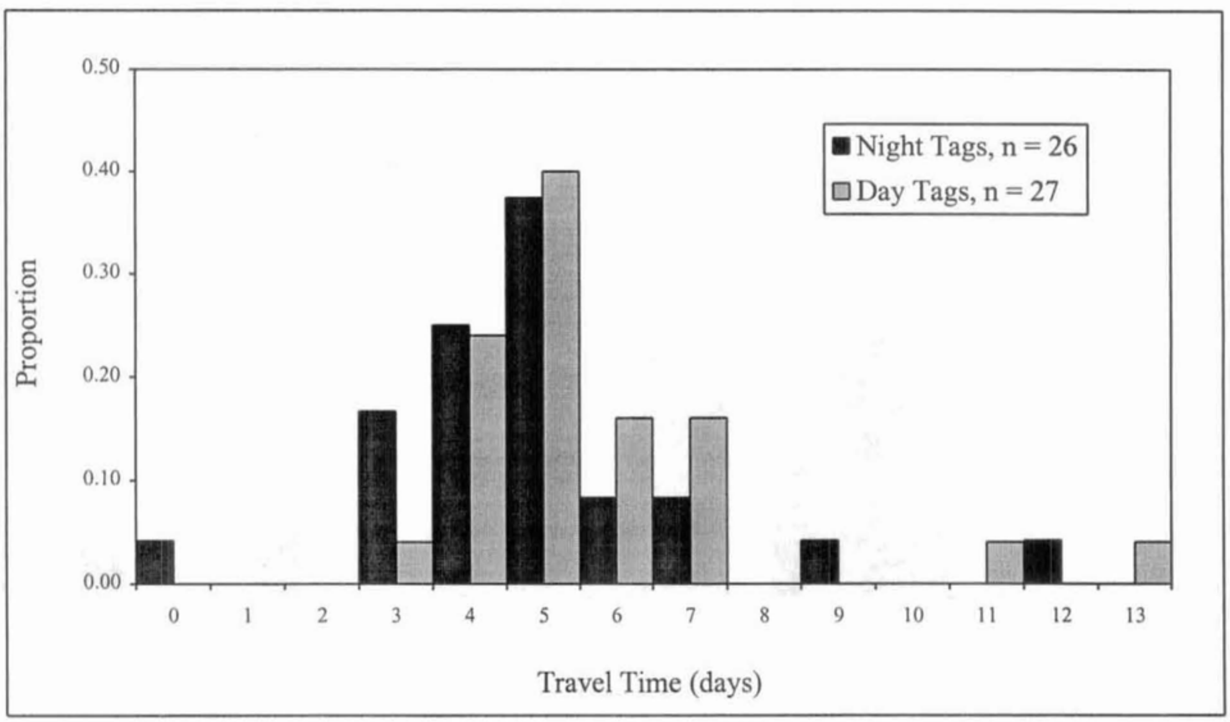

Figure 14. Travel time in days between the Kantishna River tagging wheel and the Toklat River recovery wheels for day and night tagged chum salmon, 1999.

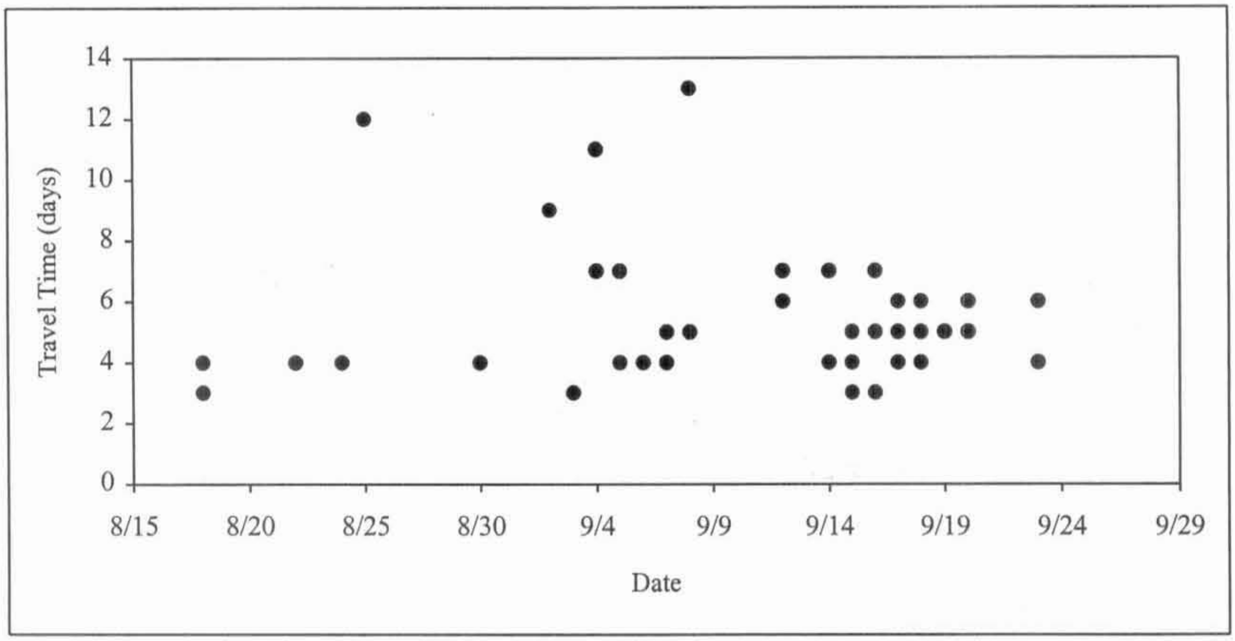

Figure 15. Travel time between the Kantishna River tagging wheel and the Toklat River recovery wheels for fall chum salmon, 1999.

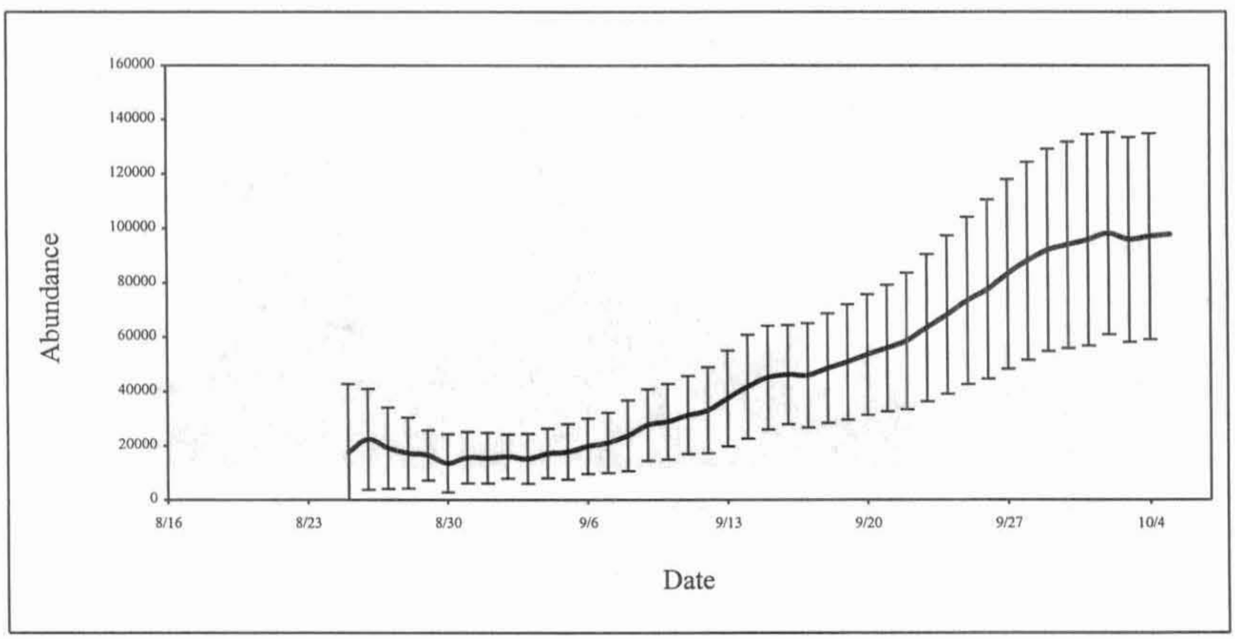

Figure 16. Abundance estimates and 95% confidence intervals of fall chum salmon using the Bailey mark-recapture model, Tanana River,1999.

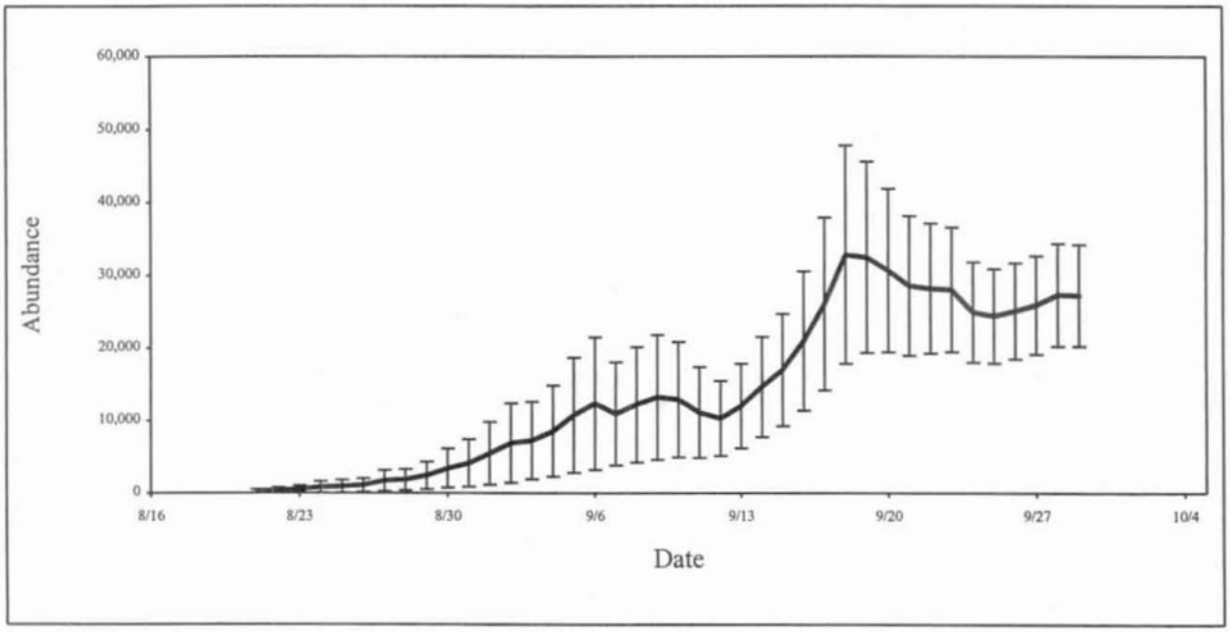

Figure 17. Abundance estimates and 95% confidence intervals of fall chum salmon using the Bailey mark-recapture model, Kantishna River, 1999.

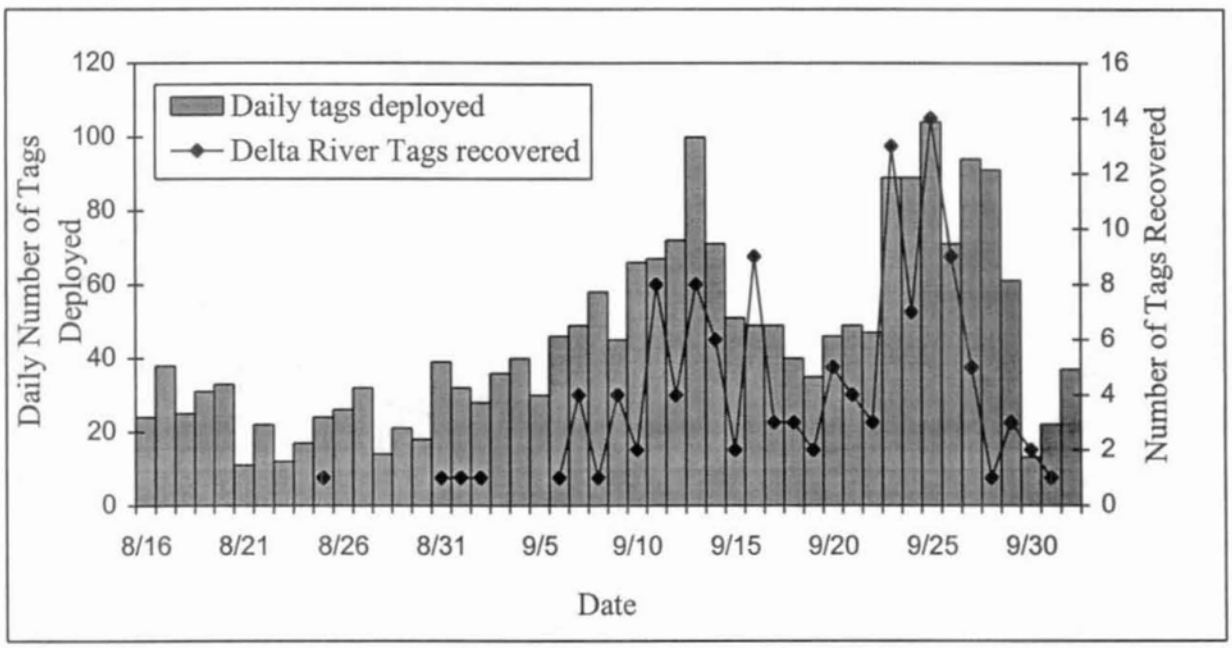

Figure 18. Number of tags recovered from fall chum salmon on the Delta River spawning grounds by date tagged on the Tanana River, 1999.

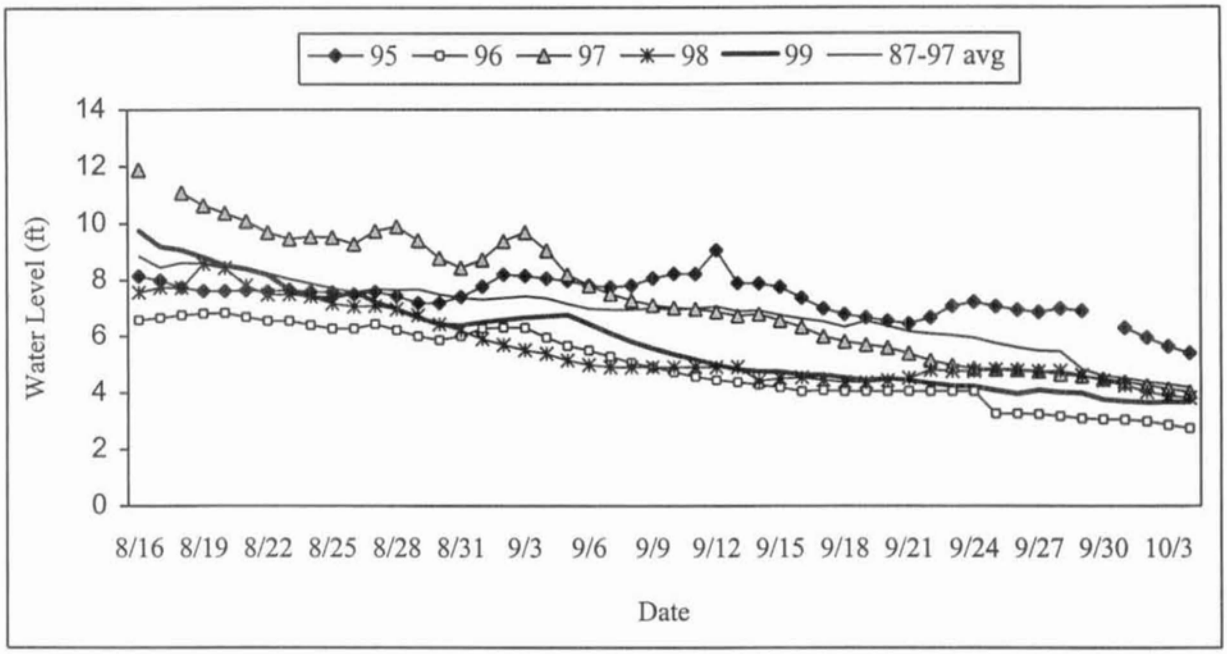

Figure 19. Daily water level on the Tanana River, 1995-1999, as measured by a U.S. Geological Survey gauge located near Nenana.

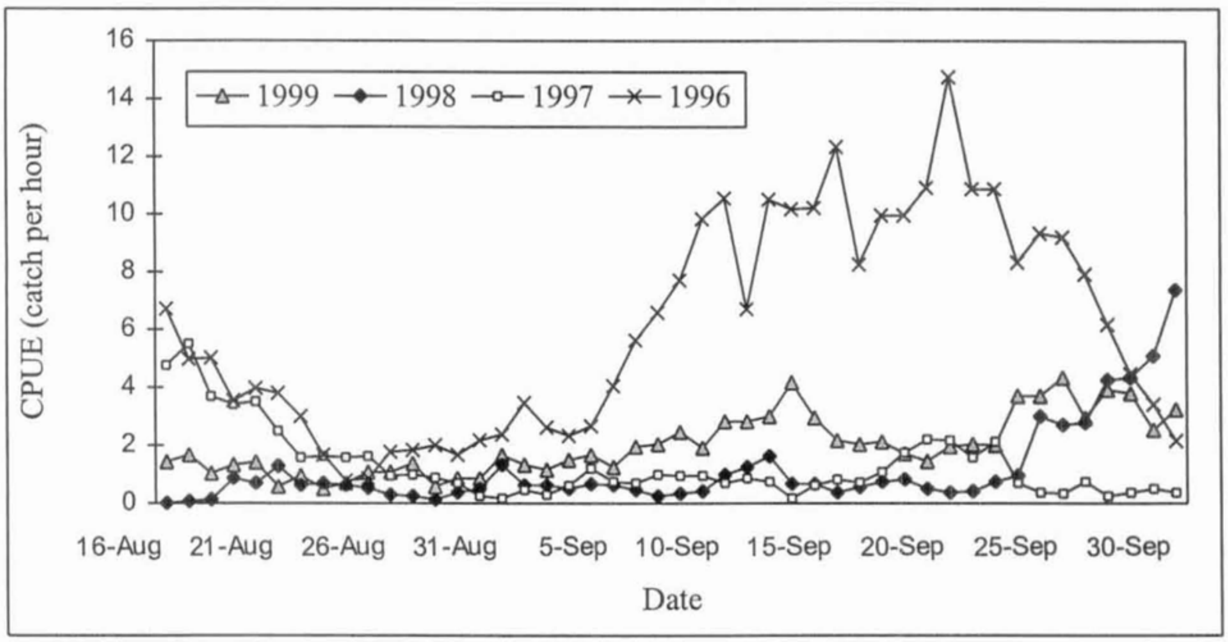

Figure 20. Daily catch-per-unit effort at the Tanana River tagging wheel 1996 through 1999.

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