MARK-RECAPTURE POPULATION SIZE ESTIMATE OF FALL CHUM SALMON IN THE UPPER TANANA RIVER, 1997

by

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ABSTRACT

Mark-recapture techniques were used to produce in- and post-season population estimates of fall chum salmon (*Oncorhynchus keta*) in the Tanana River for the third consecutive year in 1997. Chum salmon were captured and tagged in one fish wheel located on the right bank of the Tanana River and recaptured in two fish wheels, on opposing banks, located approximately 76 km upriver, in 1997. All fish wheels operated 24 hours per day unless interrupted by mechanical problems. All healthy chum salmon captured in the first event were marked with spaghetti tags and released. During tag deployment fish were divided into two categories: "day fish", caught between 08:00 and 20:00, and "night fish", caught between 20:00 and 08:00. Night fish were marked to assess differences between fish held in a live-box for up to 12 hours and those held for up to four hours. The tag deployment wheel operated from 16 August through 30 September 1997. Totals of 719 day fish and 565 night fish were marked. Tag recovery wheels operated from 16 August through 4 October 1997. The right bank recovery wheel caught a total of 1,588 chum salmon, of which 30 were original tag recaptures. The left bank wheel caught 2,565 chum salmon of which 74 were original tag recaptures. A high water event during the early portion of the season altered the efficiency of tag deployment and tag recovery wheels during that time. Since the capture probabilities were not constant over time, a stratified model (Darroch model) was used to estimate that 71,661 +/- 23,278 (95% C.I.) fall chum salmon passed the tag deployment site after 15 August 1997. We believe that a mark-recapture program, using fish wheels to capture fish, is a feasible method of estimating fall chum salmon population size in the Tanana River upstream of the Kantishna River. Although the project should continue to be closely monitored, continuing in a developmental phase is no longer necessary, as the project is judged to have performed adequately under highly variable environmental conditions.

KEY WORDS: Yukon River, Tanana River, *Oncorhynchus keta,* chum salmon, 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 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 (*Oncorhynchus keta*) return to the Yukon River in distinct summer and fall runs. Fall chum salmon enter the Tanana River by mid-August with peak migration typically centered around mid-September. Migration continues into early October, with spawning taking place from mid-October through November, primarily in areas where upwelling spring water prevents freezing. Chum salmon entering the river prior to mid-August are considered to be summer-run fish, although some overlap in run-timing with fall fish does exist. Fall chum salmon are on average larger, have a higher oil content and are a more desirable food source than summer chum salmon.

Fall chum salmon originating in the Tanana River drainage are important for subsistence and personal use particularly in the upper portions of the river, and for commercial use in both the Tanana and Yukon Rivers. From 1986 through 1995, average annual total harvest of fall chum salmon in the Tanana River was 78,474 fish, or approximately 22% of the entire Yukon River drainage harvest (Bergstrom et al. 1997). Thus, the Tanana River is considered to be a major producer of Yukon River fall chum salmon, contributing significantly to the various in-river fisheries.

The Alaska Department of Fish and Game (ADF&G) has management responsibility for fisheries in the Alaska portion of the Yukon River drainage. For management purposes, the drainage is divided into a total of 13 districts and subdistricts. The Tanana River (District 6) is divided into four subdistricts, 6A - 6D (Figure 1). Tanana River summer and fall chum salmon are managed as distinct stocks, with 16 August dividing the end of the summer season from the beginning of the fall season. Although some mixing of stocks occurs, this date has been selected for management purposes based on average historical run timing. Typically, few chum salmon are in the Tanana River in mid-August. Subsistence and personal use fisheries are open for two 48-hour periods per week. Commercial fishery openings occur by emergency order for 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 20,000 fall chum salmon, but that level of harvest may be exceeded if escapement goals and subsistence needs are projected to be satisfied.

Apart from the results of this project, management decisions for the Tanana River are based on catch-per-unit-effort (CPUE) of Department contracted "test" fish wheels, as well as fishery performance data. Data obtained from these sources provide an index to qualitatively assess run-strength among years. These data have serious limitations, including an inability to assess absolute run strength for management of subsistence, personal use or commercial fisheries. Fish wheels are susceptible to inconsistencies in efficiency, both within and among years. Although attempts are made to fish most test fish wheels at the same locations, conditions at a given location may change from year to year in relation to water level, current, channel location or other topographic considerations. These factors are known to fluctuate widely in the Tanana River, and this variability reduces the reliability of indicator fish wheels for making in-season management decisions.

Managers also rely, to a limited extent, on aerial and ground surveys of selected spawning areas that are considered major producers of fall chum salmon. 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 surveys are conducted on spawning grounds in each of these rivers to estimate salmon escapement. In addition, a sonar project was operated in the Toklat River from 1994 to 1996 to develop a better assessment of escapement for that important fall chum salmon tributary (Barton 1997).

Although programs exist or are being developed to provide estimates of population size of fall chum salmon in the mainstem Yukon River (e.g. Pilot Station sonar project), as well as in some of its tributaries (e.g. Sheenjek, Chandalar, Delta), there has never been a fully operational, on-going program implemented to estimate fall chum salmon population size in the Tanana River. The current Pilot Station sonar project attempts to estimate passage of all salmon species in the lower Yukon River. While estimates provided by that project may be valuable for the drainage as a whole, strength of the Tanana River run component cannot be addressed due to the lack of reliable stock identification techniques. A mark-recapture project, located approximately 58 km upriver of the Tanana-Yukon River confluence, was implemented by the U.S. Fish and Wildlife Service in 1996 to estimate population size of fall chum salmon in the Yukon River above the village of Rampart (Gordon, et al. 1998). This project continued in a developmental phase in 1997. If successful, results from this project could potentially help verify Tanana River population estimates in future years. Although in-season assessment of drainage-wide Yukon River fall chum salmon run strength is extremely important, it may not reflect strength of the Tanana River run component in a given year, due to differing stock strengths. Consequently, a reliable in-season estimate of run strength for the entire Tanana River would prove extremely useful for management.

Previous attempts, 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 (1981) 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 thought to be positively biased due to assumption violations, because they were 253% and 125% higher than estimates of harvest plus observed escapement in those years. 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 (Buklis 1982), 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 radiotelemetry 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 mainstem spawning was more prevalent than previously thought. An estimate of 121,556 +/- 45,107 (95% C.I.) fall chum salmon above Fairbanks was obtained during that study. However, radiotelemetry 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) and has continued in a developmental phase for three years. The objectives have been to: (1) develop and determine the feasibility of a mark-recapture program to estimate in-season and post-season population size of fall chum salmon in the upper Tanana River, upriver of the Kantishna River, (2) estimate migration rates and (3) estimate run timing of selected stocks (e.g. Delta River) in the Tanana River drainage. A tested mark-recapture program could provide a management tool capable of assessing absolute numbers of fish and potentially allow for more accurate in-season projections of escapement.

In 1995, two tag deployment wheels and two tag recovery wheels were used (Cappiello and Bromaghin 1997) to sample along each river bank with equal effort; however, the left bank fall chum salmon catch was approximately 3% of the right bank wheel. After testing for bank orientation of fish caught in left and right bank wheels, it was determined that the left bank tag deployment wheel was unnecessary and 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 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 which 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 changing abundance of fish in the river (Cappiello and Bruden, 1997).

Tag deployment effort has increased each year since project initiation in an attempt to increase the number of tags deployed. In 1995 a 6-hour per day tag deployment schedule was used and 4,174 fish were tagged. In 1996 a 12-hour per day tag deployment schedule was used and 4,016 fish were tagged, using only one fish wheel. Cappiello and Bruden (1997) recommend that tag deployment be conducted over the maximum possible number of hours to improve sample size and decrease variability of the estimate. Although a 12-hour tag deployment schedule was also used in 1997, all chum salmon caught during off-schedule periods were tagged as well to potentially increase sample size.

METHODS

Sampling

Tag Deployment

One fish wheel was used to capture fish for tagging. The wheel, owned and operated by a private contractor retained by ADF&G, was located on the right bank of the Tanana River, approximately 8 km upriver from the Kantishna-Tanana River confluence (Figure 2). Historically, this has been considered a relatively consistent site for fish wheel operation due to stability of river channel and current. The wheel was positioned within 100 meters of the 1995 and 1996 tagging deployment wheel locations. The fish wheel was equipped with two baskets. The supporting frame and raft were constructed of spruce logs and poles. Baskets measured 12 feet long, from proximal (axle) to distal ends, and were also constructed of spruce poles and wire fencing materials. A live-box, measuring 8ft.x 4ft.x 2ft. (length, width, depth), 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, constructed of spruce poles and ranging from 6 ft. to 15 ft. in length, were installed as needed depending on distance of wheel from river bank. The contractor examined the fish wheel at least once daily for tears, rips or holes in the baskets or live-box as well as to determine overall operating efficiency. To maximize operating efficiency, adjustments to the fish wheel were occasionally required. Such measures included moving the wheel toward or away from the bank or raising/lowering the axle to allow baskets to turn as close to the bottom as possible; lengthening or shortening onshore fish leads; and, adding/removing paddle boards to and from the baskets to accommodate changes in river current. The fish wheel was located approximately 300 meters downriver from the field camp and was always within view.

The tag deployment wheel operated from 16 August to 1 October, 1997. The wheel was operated 24 hours per day, unless interrupted by mechanical problems or wheel relocation. A 12-hour tag deployment schedule was maintained daily from 08:00 to 20:00. A 24-hour catch-day was designated as 08:00 to 08:00 the following day. The live-box was checked by the sampling crew at approximately 4-hour intervals (07:30, 12:00, 16:00 and 19:30). Sampling was performed by a three person crew aboard a 22-foot outboard powered boat while tied along side the fish wheel. All chum 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 15 cm applicator needle. Tags were secured in place with an overhand knot tied close to the body. The right pectoral fin was partially clipped as a secondary mark. Other data recorded were: (1) length, measured from mid-eye to fork of tail (MEFT) and accurate to the nearest 50 mm, (2) gender, as determined by external physical attributes, (3) condition, determined by external physical conditions 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

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

coloration. Fish were also categorized as day fish, caught between 08:00 and 19:59 and held in the live-box for up to four hours, or night fish, caught between 20:00 and 07:59 and held in the live-box for up to 12 hours. Total handling time per fish was typically 30 seconds. Data were recorded for all chum salmon found in the live-box during each sampling session. All coho salmon *O. kisutch* and chinook salmon *O. tshawytsha* were enumerated by gender while all other species captured were enumerated and released.

Physical data were collected at the tag deployment wheel during the 07:30 sampling session. The number of wheel revolutions were recorded over a 15 minute interval, and air and water temperatures measured with a hand held thermometer. Additionally, precipitation, cloud cover and wind direction were recorded twice daily, at approximately 08:00 and 16:00.

After each sampling session, data were immediately 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 telephone.

Tag Recovery

Two tag recovery fish wheels were located on opposite banks, approximately 76 km upriver from the tag deployment fish wheel (Figure 2). Design, size and construction materials of recovery wheels and live-boxes were similar to those of the tag deployment wheel. Recovery wheels were owned and operated by a second private contractor retained by ADF&G and Bering Sea Fishermen's Association (BSFA). The Right Bank recovery wheel also served as an ADF&G management test fish wheel, and operated during summer and fall fishing seasons.

Operation of tag recovery wheels began on 16 August to ensure that fish tagged at the tag deployment wheel all had a non-zero probability of recapture at the recovery wheels. Recovery wheels operated 24 hours per day, unless encumbered by mechanical problems, through 20:00 on 4 October, 1997. Like the tag deployment wheel, recovery wheels were inspected daily and adjusted as necessary to maintain fishing efficiency. At each wheel, all chum salmon were enumerated by gender with a hand held counter and recorded in a data book at the wheel site. Chum salmon bearing tags were also enumerated by gender and tag identification numbers recorded on site. All chum salmon not bearing tags were examined for the secondary mark (fin clip). Additionally, all coho salmon were enumerated by gender while all other species were enumerated daily. The ADF&G office in Fairbanks was contacted daily via cellular telephone to report summary data for the previous 24-hour catch.

A $200 lottery was held to encourage commercial, subsistence and recreational fishermen to report tags they recovered. Volunteer recoveries provided qualitative information about migration rate, run timing and spawning location. Tag recoveries were also made during regular surveys of spawning grounds conducted by ADF&G.

Data Analysis

Diagnostic Statistical Tests

In-Season

Only day fish were used for in-season population estimation, since complete testing of model assumptions for night fish could not be conducted until post-season. If night fish had a different probability of recapture than day fish, the validity of the in-season estimate could have been compromised by their use. Additionally, by using only day fish, in-season methods were more comparable to previous years.

A test was performed to determine whether the marked proportion of chum salmon in recovery wheels was constant throughout the tag recovery period. An assumption of most mark-recapture models is that all individuals have an equal probability of initial capture. In a situation where the entire population moves past a fixed sampling station, equal effort requires sampling a constant proportion of the run over time. If the probability of capture at the tagging wheel was constant through time, and if there was complete mixing of tagged and untagged fish between the wheels, the marked proportion in the recovery wheels should be constant through time. Because of small sample sizes, a randomization technique was developed and used to test if the marked proportion was constant through time, rather than using a chi-square test of homogeneity. The test is implemented in a FORTRAN program (RANDTEST, Jeff Bromaghin, ADF&G, Anchorage), that uses simulation to approximate the distribution of the chi-square test statistic (see Cappiello and Bromaghin 1997). All statistical tests conducted in-season and post-season were performed at the $\alpha = 0.05$ significance level.

Post-Season

Day and Night Fish

A series of tests were performed to identify statistical differences in capture probabilities and migration rates between day and night fish. Pooling day and night fish would increase the realized tagged proportion of the population and subsequently increase the sample size of tag returns. Pooling, if appropriate, offers the benefit of improving the precision of the population estimate and would offer potential for meeting minimum sample size requirements in years of poor catches or weak run strength. A Kolmogorov-Smirnov test (Conover, 1980) was conducted with the Statistical Analysis System (SAS) (SAS Institute 1988) to determine if the distribution of travel times, in days, between the tag deployment and tag recovery wheels, differed between day and night fish. An identical test was conducted to determine if there were differences between the distribution of fish lengths of day and night fish. In addition, logistic regression

(Hosmer and Lemeshow 1989) was used to model the probability of recapture (response variable), as a function of the variable "held" (fish held overnight in live-box coded as "1" or not held overnight coded as "0"), a live-box stress index (product of the number of fish in the live-box and the duration of time spent), and other variables that might affect the probability of recapture (discussed subsequently). Such a test would reveal whether a fish held in a live-box for up to 12 hours would be more susceptible to recapture in the recovery wheels than fish processed during the daytime tag deployment schedule.

Testing of Assumptions

Both in-season and post-season analyses included tests to determine whether the marked proportion was constant through time. Additionally, we tested the hypothesis that the proportion recaptured was constant through time during post-season analysis. These tests were conducted using the program RANDTEST.

A Cochran-Mantel-Haenszel Test (Agresti, 1990) was performed to determine whether the marked proportions (proportion of recovery wheel catches bearing tags) of chum salmon were different in the two recovery wheels, controlling for the effect of recovery stratum. The results of the test would indicate if there was a problem of bank orientation for right bank tagged fish. If the marked proportions were not different, pooling data from the two recovery wheels would be appropriate.

In addition to examining whether the probability of recapture changes through time, it is necessary to test if the probability of recapture is affected by physical aspects of the fish. Fish wheels can be selective with respect to the size or gender of fish, which appeared to be the case during this study in 1996 (Cappiello and Bruden, 1997). Logistic regression was used to model the probability of recapture as a function of length, gender and condition. The logistic regression also included the variable "held" which indicated whether it was a day or night fish and a stress index variable. A subset of the two-way interactions of these main effects were also included in the model.

Population Estimates

In-season

To provide timely in-season population estimates, data analysis must be conducted without the benefit of a complete data set, and must be performed without the opportunity for exhaustive assumption testing. This means that an in-season estimator must be relatively robust and simple enough to quickly produce results with reasonable precision. In-season population estimates were conducted using the Bailey model (Seber 1982), which is a closed population model and a variation of the Petersen model. The estimator is a function of (1) the number of individuals marked in the first event and released into the population and (2) the proportion of individuals captured in the second event (recovery wheels) which bear marks:

$$\hat{N} = \frac{(E+1)}{(R+1)} * (M+1)$$

where $\hat{N}$ is an estimate of population size, E is the number of individuals examined for marks during the recovery phase, R is the number of individuals recaptured for the first time, and M is the number of individuals marked and released into the population. We assumed 5% mortality due to handling and tagging stress and reduced the number of fish marked (M) by this amount for analysis purposes. This mortality rate was used in previous years (Cappiello and Bromaghin 1997; Cappiello and Bruden, 1997) and is similar to that observed by Barton (1992) in an external radio telemetry study of chum salmon conducted in the Tanana River.

Post-season

Estimates were produced post-season with the Darroch model (Darroch 1961), which accommodates data temporal stratification. This model was chosen after the complete data set was reviewed and statistical tests of assumptions were conducted. Stratified Population Analysis System (SPAS) computer software was used to provide stratified estimates (Arnason et al. 1996). The model uses maximum likelihood techniques to develop estimates for each defined stratum based on a matrix of tag releases and recaptures. The following notation appears in Darroch (1961). In the model there are i tagging strata and j recovery strata. Let a_i = the number of tagged fish released in stratum i (analogous to Bailey "M"), c_{ij} = the number of tagged fish released in stratum i that are recaptured in the recovery stratum j (analogous to Bailey "R"), and let b_j = the number of tagged and untagged fish captured in recovery stratum j (analogous to Bailey "E" minus "R"). The stratified estimate of the number of fish in the population ($\hat{N}$) was

$$\hat{N} = b'C^{-1}a$$

where b' is a vector with elements b_j, C is a matrix of the c_{ij}, and a is a vector with elements a_i.

Migration Rate

Length of time for tagged fish to travel from tag deployment wheel to recovery wheel (travel time) was calculated to the nearest day for each recaptured fish. Migration rate was then calculated by dividing the distance between tag deployment wheel and recovery wheels by travel time. A Kolmogorov-Smirnov test (Conover 1980) was conducted to determine if the distribution of travel times differed for (1) day and night fish, and (2) males and females.

Stock Timing

Spawning ground surveys in the Delta River were conducted weekly, from 26 September through 4 December and the numbers of live and dead chum salmon were recorded. Observed tags were removed from fish when possible, to determine the date that those fish had passed the tag deployment wheel.

RESULTS

Data Collection

Tag Deployment

Unusually high water level (Figure 3), or low catch rates, prompted relocating the tag deployment wheel on two occasions: 3 September and 16 September. Each relocation was within approximately 100 meters of the initial site. Movement of the wheel was delayed on both occasions until there was a high degree of concern over low sample sizes. Movement of the wheel was curtailed in an attempt to minimize variation in wheel, due to physical characteristics of the fishing site. This was necessary in order to meet the assumptions of the Bailey estimator.

A total of 1,284 tags were deployed from 16 August through 30 September (Appendix A). Of these, 719 were day fish and 565 were night fish. Of the entire chum salmon catch, 40 fish (3%) were not tagged. Eight of those fish were reproductively mature (ripe), nine were mortalities found in or next to the live-box, and 11 escaped during processing. The remainder of the untagged catch consisted of fish with severe injuries or other physical abnormalities that may have affected survival or migration. During 1995 and 1996, totals of 4,083 and 4,016 chum salmon were tagged, respectively, during approximately the same time period.

CPUE at the tag deployment wheel was higher during the first week of tag deployment than for the remainder of the season (Figure 4). The highest catch of chum salmon occurred on the first day of wheel operation (16 August) and then steadily declined until the end of August. Subsequent to the first wheel relocation on 3 September, CPUE increased slightly and remained relatively steady through mid-September. After the wheel was relocated a second time on 16 September, catches increased for approximately one week before starting a steady decline. No observable peak of fish passage was apparent at the tag deployment wheel.

Tag Recovery

Neither tag recovery wheel was relocated during the recovery phase, although minor adjustments were made as needed. Although the left bank recovery wheel experienced a precipitous decline in catch rate (Figure 4), catches were not as low as observed at the tag deployment wheel prior to mid-September. Also, the use of two recovery wheels lessened the concern about low numbers of tag recaptures, and was a factor in the decision to not relocate recovery wheels during periods of low catches.

A total of 104 tagged fish were recaptured in recovery wheels. This figure includes releases of both day and night fish, and one fish that was identified only by its secondary mark. Of these fish, 30 were recaptured in the right bank wheel and 74 in the left bank wheel. In addition, one tagged fish was recaptured twice in the right bank recovery wheel. A total of 4,153 chum salmon were examined for marks in both recovery wheels: 1,588 in the right and 2,565 in the left bank wheel (Appendices B.1 and B.2).

A total of 76 tags were returned by various sources other than project recovery wheels (Table 1). The highest percentage of tags were recovered from fish located in spawning areas of the Delta River and Tolovana River. Nine tags were recovered from locations downriver from the tag deployment wheel (e.g. Toklat River, Yukon River).

Data Analysis

Diagnostic Statistical Testing

Day and Night Fish

Neither the indicator variable "held" nor the stress index variable were significant predictors of the probability of recapture in the logistic regression. The maximum number of captured fish in the live-box was 72, which occurred during an overnight catch on the first day of wheel operation. The number of fish in the live-box was below 30 during 98% of daily tag deployment periods. Although live-box density information was not reported in 1995 or 1996, the maximum number of fish in the live-box was substantially higher in previous years. In 1995 and 1996, a typical number of fish held over a 4-hour period, during peak run timing, was 200 to 400 fish (Cappiello and Bromaghin 1997; Cappiello and Bruden 1997).

No differences were detected between the distribution of travel times of day and night fish (Kolmogorov-Smirnov, p=1.000). In addition, no differences where found between the distribution of MEFT lengths of fish caught at the tag deployment wheel during day or night (Kolmogorov-Smirnov, p=0.2581).

The results of these nonparametric tests, combined with the lack of a detectable relationship between stress from overcrowding in the live-box and probability of recapture, led us to pool data from day and night fish. This action increased the number of tags deployed and subsequently recaptured from 64 to 104, and reduced variance in the final estimate.

Pooling Data

The results of the Cochran-Mantel-Haenszel Test indicated that there were no differences in the marked proportions in the two recovery wheels, controlling for the effect of recovery stratum

(CMH=0.24, df=1, p=0.877). In recovery stratum 1, 4.5% and 5.6% of the left and right catches, respectively, bore tags. In recovery stratum 2, 1.4% and 0.9% of the left and right bank catches, respectively, bore tags. Consequently, data from the two banks were pooled.

A logistic regression model was performed, using the SAS Logistic procedure (SAS Institute 1988) to model the probability of recapture as a function of gender, length, and condition. In addition, the variable held and the stress index were also modeled. A variable termed "time" was included in the model that indicated whether a fish was tagged in one of two time strata, defined in the Population Estimate section of this report. All two-way interactions between gender, length and condition were included in the model. A total of 1,270 fish with complete information were included in the model, with 102 of these being subsequently recaptured. Terms remained in the model if the Wald test statistic was significant. A likelihood-ratio test indicated that only the variable "time" (Wald $\chi^2 = 29.95$, $p \approx 0.001$) influenced the probability of recapture. The need for stratification by gender, length or condition was not detected.

Stratification

As the project progressed, it became less likely that the marked proportion of the population was constant over time. Under the hypothesis that the marked proportion was constant over time, it was estimated as the ratio of the total number of marked fish to the total number captured in the recovery wheels after 18 August (i.e. 104/3898 = 0.0267). A chi-square test statistic was computed using the observed data and the estimated marked proportion, resulting in a test statistic of 143.83 (46 df). As mentioned previously, simulation techniques were used to estimate the distribution of the test statistic because many of the observed proportions were at or close to zero (Figure 5). The proportion of randomly generated test statistics that exceeded 143.83 was 0.000, which is an estimate of the P-value associated with this test statistic. If the assumption of complete mixing was met, this suggests we did not apply tags to a constant daily proportion of fish passing the tag deployment wheel.

Two periods were identified, 16-25 August and 26 August-30 September, based on the marked proportions over time in the recovery wheels (Figure 5) and water level. During the first week of tag recovery (beginning after 18 August), the marked proportion averaged approximately 6%, compared to approximately 1% for the remainder of the project. The first interval corresponded to a period of very high water level (above or near 1987-1996 maximums) early in the tag deployment phase of the project. The second period corresponded to water levels that remained below recorded maximums and decreased to average and below average levels (see Figure 3).

The proportion recaptured (i.e. probability of recapture) in the recovery wheels followed the same pattern through time as the marked proportion (Figure 6). Under the hypothesis that the proportion recaptured was constant over time, it was estimated as the ratio of the total number of recaptures to the total number of marked fish released, 104/1284 = 0.081. A chi-square test statistic was computed using the observed data and the estimated proportion of recapture, resulting in a test statistic of 130.01. The proportion of randomly generated test statistics that exceeded this value was 0.000, which is an estimate of the p-value associated with this test statistic. The probability of recapturing a tagged fish was 0.023 in the right bank wheel and 0.057 in the left bank wheel. The daily proportion fluctuated considerably over the study period, ranging from 0.00 to 0.50, although much of the variation was probably due to small sample size (Figure 6).

Failure to meet the assumptions of an equal marked proportion and proportion recaptured through time led us to use a stratified estimator, with two strata defined temporally, to estimate population size (Table 2). Tag release strata were defined as (1) 16 August through 25 August and (2) 26 August through 30 September. A total of 105 recaptures were used in the model, including one tagged fish caught in the recovery wheels twice. Tag recovery strata were lagged by 3 days (average migration time from tag deployment wheel to recovery wheels) and defined as (1) 19 August through 28 August and (2) 29 August through 4 October (Table 3).

Data Reduction

Most tagged fish required between two and seven days to travel from the tag deployment wheel to the tag recovery wheels. Assuming tagged and untagged fish migrated at the same rate, a proportion of the untagged fish passing the recovery wheels from 19 August through 22 August may not have passed the tag deployment site while it was operational. The capture of unmarked fish in the recovery wheels that did not pass the tagging wheel while it was operational is in violation of the closure assumption of closed population mark-recapture models. Therefore, for that period the daily unmarked catch in the recovery wheels was reduced by the estimated proportion of fish (using travel times) that would not have passed the tag deployment wheel while it was operational (Table 3). Similarly, a proportion of tagged fish released during 28 September through September 30 were removed from analyses because they were less likely to have reached the recovery wheels prior to termination of the study. Additionally, we reduced the number of tagged fish released by 5%, the assumed handling and tagging mortality rate (see Cappiello and Bromaghin 1997; Cappiello and Bruden 1997; Barton 1992).

Population Estimate

Using the Darroch model, with temporal stratification as defined above, 71,661 (SE=11,876) fall chum salmon are estimated to have passed the tag deployment wheel from 16 August through 30 September. The 95% confidence interval (C.I.) was (48,384; 94,939) and the coefficient of variation (C.V.) was approximately 0.17. The Darroch point estimate is approximately 75% higher than the final preliminary in-season estimate, determined using the Bailey model ($\hat{n}$ = 40,972). Population estimates and standard errors of individual strata are presented in Table 4.

The final population estimate includes those fish that were caught in subsistence and personal use fisheries upstream from the tagging site in addition to an unknown number of fish that moved up the Tolovana River (a tributary of the Tanana River 6 km upriver from the tag deployment wheel) or returned to downstream locations. The 1997 reported subsistence harvest in the Tanana River above the tag deployment wheel was approximately 9,213 chum salmon. There were no commercial chum salmon openings in the Tanana River during 1997. Removal of reported subsistence harvest from the chum salmon population estimate leaves an estimated potential spawning escapement of 62,448 fall chum salmon in the upper Tanana River.

For comparison, final population estimates for 1995 and 1996 were 268,173 (CV 0.08) and 134,563 (CV 0.12), respectively, and estimates of spawning escapement were 183,267 (1995) and 83,447 (1996).

Migration Rate

Overall, tagged fish required an average of 3.6 days to travel the 76 km (21 km/day) between the tag deployment wheel and tag recovery wheels. The mode of travel time was three days and 97% of tagged fish completed the trip in two to seven days (Table 5). Although the distribution of travel times for males and females were not significantly different (Kolmogorov-Smirnov, $p=0.1015$), males had a larger range (1 to 12 days) than females (2 to 6 days).

Generally, fish tagged during the first 10 days of the study required more time than those tagged later to cover the distance between study wheels (Figure 7). Fish tagged during 16 August through 25 August generally took 3 to 4 days, whereas fish tagged after 25 August required 2 to 3 days. Tagged fish required an average of 3.5 days in 1995 and 2.5 days in 1996 to cover the same distance (Cappiello and Bromaghin 1997; Cappiello and Bruden, 1997).

Tagged fish bound for the Delta River appeared to move upriver more slowly beyond the recovery wheels. Tagged fish recovered in the Delta River traveled at an average rate of 8.5 km/d (after subtracting half of the days since the previous week's observations), whereas the average migration rate of tagged fish traveling between tag deployment and recovery wheels was 21 km/d. This suggests that beyond the tag recovery wheels chum salmon rate of travel decreased, at least for the Delta River stock.

Stock Timing

A total of 26 tags were recovered during surveys of spawning grounds in the Delta River. These tags were recovered during 10 weekly surveys of the Delta River between 26 September and 1 December, 1997. The median tag deployment date was 14 September and tagging dates ranged from 6 September through 29 September (Figure 8). Four tags were recovered from Bluff Cabin Slough, located in the Tanana River near the mouth of the Delta River. Absolute numbers of recoveries in the Delta River were comparable to 1995 (n=39), but, low compared to 1996 (n=183).

DISCUSSION

A primary objective of this study is to determine the feasibility of providing accurate and reliable in-season and post-season population estimates. Part of this objective is to assess the performance of mark-recapture techniques using fishwheels to capture fish over a range of river conditions and run strengths. This year provided an opportunity to observe project response to extremes in two elements that are crucial for proper evaluation of the project: (1) water level, and (2) run strength.

The water level of the Tanana River, as measured by a U.S. Geological Survey gauge near Nenana, set record daily highs for the first week of tag deployment and was at or near 1987-1996 maximums for an additional week. Water level did not drop to the mean daily level (1987-1996) until approximately 12 September. The effect of the high water event on the efficiency of tag deployment and tag recovery wheels is unknown, but appeared to be coincident with unusual catch patterns.

Although the recovery wheels were not relocated during the study period, catch patterns were thought to have been directly affected by water level. During periods of high water, a slough on the right bank becomes accessible to migrating chum salmon as an alternative to the main channel, where the right bank tag recovery wheel was located. An unknown number of chum salmon may have circumvented the right bank wheel through the slough, which would explain the comparatively low catch during the first two weeks of tag recovery wheel operation. However, because two wheels were used for tag recovery, the concern over low catch or low numbers of tag recaptures was lessened.

Following post-season data analysis it was determined that assumptions of the Bailey model were not met by the data. Although the earliest in-season Bailey estimates provided during mid-September were close to the Darroch stratified estimate, the values of the two estimates diverged as the season progressed. Disparity of the two estimates at the end of the season is likely a result of the high water event during the early part of tagging, and lack of precision in the estimates due to low sample sizes. Although the point estimates were quite different at the season's end, the confidence intervals did overlap. It was clear by late-September that temporal stratification would be necessary to account for the bias associated with the changes observed in the proportion marked and probability of recapture through time. However, the simplicity of the Bailey model, timeliness of estimates, and the lack of a complete data set were important factors in the decision to provide in-season population estimates using non-stratified data.

Temporal stratification may be possible given adequate sample size, even without a complete data set. This could result in more accurate in-season estimates during years when stratification is imminent. If assumption testing is performed in-season using the most recent data, the need to stratify may be detected. However, use of the Darroch model is dependent upon larger sample sizes of tag recaptures, which may not be achieved every year. Larger sample sizes are needed since population estimates are made within each strata. Although stratified in-season estimates would remain preliminary until testing of the complete data set could be conducted, they may better reflect population size and thus be more useful to managers.

Although chum salmon catch in the project wheels was low, minimum threshold sample sizes were achieved such that population estimates could be calculated. Enough tags were deployed daily to provide for recoveries throughout the study period. The low number of tags deployed made daily tag recovery variable, which was reflected in both the daily marked proportion and the daily proportion of recaptures. Although the low numbers of tags decreased estimate precision, there is no reason to believe bias in the point estimate, caused by fluctuations in these proportions, was not removed by stratified modeling.

Because the extreme high water may have changed the river channel and current around the study site, there was concern that we were no longer catching fish in the main current of the river and potentially catching less robust salmon that may have been more vulnerable to the fish wheels than in previous years of the study. Given the data available, we did not qualitatively observe anything suggesting that our marked sample was not representative of the population as a whole. Equal proportions of tagged fish were recovered in right and left recovery wheels, indicating there was no bank orientation of right bank tagged fish. In addition, very few fish (approximately 0.4%) were recaptured more than once in either tag deployment or tag recovery wheels. In 1995 and 1996, approximately 3.7% and 6.4% of the fish were captured more than once in recovery wheels. Recapture rates in 1997 do not suggest that fish were more vulnerable to capture than in previous years. Finally, results of the logistic regression modeling suggest that physical attributes such as gender, length and condition did not affect probability of recapture, and presumably, initial capture. Our qualitative observations did not indicate that fish passing the wheels were not representative of the population. However, this assumption is very difficult, if not impossible, to test and we have no rigorous means to make comparisons.

Migration rates were difficult to interpret because of the high water event. Fish traveled faster after the high water crested. The season average rate of about 21 km/d is less than migration rates measured in 1995 (26 km/d) and 1996 (31 km/d) (Cappiello and Bromaghin 1997), as well as those found by others (Milligan et al. 1984; Buklis and Barton 1984). We feel the slower migration rates were probably due to the record high water event and not of significant biological concern.

The phenomenon of reduced migration rates as chum salmon approach the Delta River raises caution about the use of assumed migration rates below our study site and in the Yukon River. Although the precise reason(s) for reduced migration rate associated with Delta River chum salmon is unknown, conceivable factors may include fish holding near the rivers' confluence, deteriorating body condition, or decreased water flow affecting homing ability. The observed decrease in Delta River chum salmon migration rates is not thought to be necessarily associated with high water events in 1997 since a similar trend in reduced rates was also observed in 1996. Migration rates should continue to be examined in future years to determine whether a pattern of reduced migration rate exists as fish near the Delta River. If chum salmon slow down as they approach major river junctions or natal streams, then caution should be used when assuming fixed, in-river migration rates (e.g. to predict arrival of fish at selected spawning areas).

Although chum salmon catch was low at the tag deployment and recovery wheels, later comparison of catches to test fish wheels and subsistence wheel catches indicated that the most likely reason for low catch was a weak return to the Tanana River drainage rather than river conditions or fish wheel efficiency. The ADF&G test fish wheel located on the left bank of the Yukon River near the village of Tanana caught, less than a third of its average fall chum salmon catch from 1994 through 1996. Similarly, average fall chum salmon CPUE (catch per hour as measured by ADF&G personnel) in selected Tanana River subsistence fish wheels was approximately 6, compared to approximately 14 and 17 in 1996 and 1995, respectively. In addition, spawning ground surveys in the Toklat and Delta Rivers revealed that their respective escapement goals of 33,000 and 11,000 spawners were not achieved, another indication that the 1997 Tanana River fall chum salmon run was very weak.

RECOMMENDATIONS

(1) The Bailey model should be used for in-season estimates. However, if Bailey model assumptions of sampling are not satisfied, we recommend use of stratified models for in-season estimates, when appropriate and sample size allows. During some years, in-season estimates produced by this project may only be reliable if there exists flexibility in the modeling to account for known or suspected bias. Even if exhaustive testing of data cannot be completed in-season, post-season stratification may be imminent, and it is under this scenario that in-season stratification should be considered. In-season stratification has potential to correct for bias due to sampling assumption violations that are beyond the control of study design. It should be recognized that in-season stratified modeling requires more time for data management essential to producing the estimate. Therefore, the estimate could not be provided on a daily basis due to the longer process involved in generating the estimate.

Model development efforts should continue to provide a more refined in-season and post-season tool for population estimation. Other data analysis tools should be explored and developed to test as many assumptions as possible.

(2) We also recommend that day and night fish continue to be tagged to improve sample size, when possible. Had we not done so this year, our precision would have been much less, due to the weak return and very low catch. Plans to tag day and night fish may require in-season modification since information on run strength improves after project initiation. During years of strong runs, attempting to tag all day and night fish may result in an inability to process fish quickly enough to maintain high survival and low stress from live-box overcrowding. This may require temporary discontinuation of tagging night fish. During such years, options will be available for data analysis. For example, once acceptable daily sample sizes of day fish are achieved, previous night fish may be removed from analysis, or stratification used if they are included. If both groups of fish are included without stratification, the assumption of a constant marked proportion may be violated. In either case, tests of this assumption should be conducted.

Based on results from this year, tagging fish which are held in a live-box overnight for up to 12 hours does not have a detectable effect on fish when the number of fish held in the live-box is low (e.g. < 70 fish). Pooling data from day and night fish can potentially double sample size of marked fish, which significantly reduces variance. Although no effects of long-term holding were observed this year, observations made in subsequent years on stronger runs may provide insight on live-box stress and its effects on probability of recapture, migration rate and survival. Day and night fish should be pooled only after a series of tests are performed to verify that no differences exist as a result of long-term (12 hour) holding in the live-box. Future data analysis should include a live-box stress function to examine stress level effects on fish behavior, particularly their probability of recapture.

As a minor recommendation, we suggest that different color tags be applied to day and night fish in future years. This would eliminate communication problems that occurred this year. For each tag recapture, color of tag would be reported so that day and night tags could be immediately separated for in-season data analysis purposes.

(3) We recommend considering locating the tag deployment wheel upriver from the Tanana-Tolovana confluence or beginning a recapture program in the Tolovana River. The number of tags recovered in the Tolovana River indicate there may be a significant number of chum salmon entering that river which are not accounted for in the present study design. Virtually all tags recovered in the Tolovana River were deployed during the first few days of tag deployment, suggesting that these fish represent the tail-end of the summer chum salmon run, even though they pass the tag deployment wheel after the date (16 August) separating summer and fall chum salmon for management purposes. Nonetheless, the Tolovana River should be evaluated to provide a more accurate assessment of fall chum salmon abundance upriver of the tag deployment wheel.

(4) Results from this study indicate that a mark-recapture program, using fish wheels to capture fish, continues to be a feasible method of providing fall chum salmon population estimates in the upper Tanana River. We recommend that this project be removed from developmental status. Although it should continue to be closely monitored, the performance of the project during the past three years is probably a reasonable indication of performance in future years. Run sizes, ranging from above average to well below average, have been observed and the range in precision of estimates is considered likely to be representative of what to expect in subsequent years. Precision of the estimate in 1997 was affected by low sample sizes. The CV of the estimates has increased with each year of decreasing run size.

If a run size is projected to be extremely weak, options to increase precision for that year, such as use of a second tagging wheel, should be considered. This could compensate for low catches in a single wheel, and potentially increase precision of the abundance estimate.

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Table 1. Number of tags by location from fall chum salmon tagged in the Tanana River, 1997, that were returned by various fisheries participants and other entities.

Recapture Location	Number of Tags
Delta River	26
Salcha River	2
Tanana River, Fairbanks	1
Tanana River, Nenana	7
Tanana River, Bluff Cabin Slough	4
Tanana River, Minto	1
Tolovana River (Chatanika)	25
Toklat River	7
Nenana River	1
Yukon River, Rampart	1
Yukon River, Fort Yukon	1
Total	76

Table 2. The number of tagged fish recaptured by tagging and recovery strata, the number of tagged fish released in each tagging strata, and the number of unmarked fish caught in the recovery wheels by recovery strata on the Tanana River, 1997.

Tagging Strata	Recovery Strata 8/19-8/28	Recovery Strata 8/29-10/4	Total	Tags Deployed
8/16-8/25	76	3	79	563
8/26-9/30	0	26	26	654
Total	76	29	105	1,217
Unmarked	1,325	2,511	3,836	

Table 3. 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 Darroch model to estimate abundance of fall chum salmon in the Tanana River, 1997.

		Releases at Tagging Wheel			Unmarked Catches at Both Recovery Wheels		
Strata Definition	Date	Tags Released	Estimated Proportion Passing Recovery Wheels	Adjusted[a] Tag Releases	Unmarked Catch	Estimated Proportion Passing Tagging Wheel	Adjusted[a] Unmarked Catch
Release Stratum 1	16-Aug	109	0.95	104	32	0.01	0
	17-Aug	55	0.95	52	91	0.24	22
	18-Aug	55	0.95	52	133	0.61	81
Recovery Stratum 1	19-Aug	82	0.95	78	125	0.79	99
	20-Aug	83	0.95	79	147	0.89	131
	21-Aug	57	0.95	54	158	0.94	149
	22-Aug	38	0.95	36	184	0.98	180
	23-Aug	39	0.95	37	155	0.98	152
	24-Aug	38	0.95	36	130	0.99	129
	25-Aug	37	0.95	35	124	0.99	123
Release Stratum 2	26-Aug	22	0.95	21	103	0.99	102
	27-Aug	23	0.95	22	89	1.00	89
	28-Aug	21	0.95	20	97	1.00	97
Recovery Stratum 2	29-Aug	15	0.95	14	127	1.00	127
	30-Aug	5	0.95	5	132	1.00	132
	31-Aug	4	0.95	4	117	1.00	117
	1-Sep	10	0.95	10	68	1.00	68
	2-Sep	7	0.95	7	62	1.00	62
	3-Sep	11	0.95	10	94	1.00	94
	4-Sep	27	0.95	26	108	1.00	108
	5-Sep	17	0.95	16	73	1.00	73
	6-Sep	17	0.95	16	93	1.00	93
	7-Sep	24	0.95	23	78	1.00	78
	8-Sep	22	0.95	21	108	1.00	108
	9-Sep	23	0.95	22	95	1.00	95
	10-Sep	17	0.95	16	131	1.00	131
	11-Sep	20	0.95	19	101	1.00	101
	12-Sep	18	0.95	17	97	1.00	97
	13-Sep	4	0.95	4	122	1.00	122
	14-Sep	14	0.95	13	93	1.00	93
	15-Sep	19	0.95	18	47	1.00	47
	16-Sep	12	0.95	11	55	1.00	55
	17-Sep	26	0.95	25	49	1.00	49
	18-Sep	41	0.95	39	43	1.00	43
	19-Sep	52	0.95	49	50	1.00	50
	20-Sep	49	0.95	47	39	1.00	39
	21-Sep	34	0.95	32	39	1.00	39
	22-Sep	51	0.95	48	41	1.00	41
	23-Sep	17	0.95	16	57	1.00	57
	24-Sep	9	0.94	8	57	1.00	57
	25-Sep	8	0.94	8	55	1.00	55
	26-Sep	17	0.94	16	55	1.00	55
	27-Sep	6	0.93	6	38	1.00	38
	28-Sep	9	0.93	8	24	1.00	24
	29-Sep	12	0.89	11	26	1.00	26
	30-Sep	8	0.85	7	13	1.00	13
	1-Oct	0	0.75	0	18	1.00	18
	2-Oct	0	0.58	0	38	1.00	38
	3-Oct	0	0.23	0	20	1.00	20
	4-Oct	0	0.01	0	19	1.00	19

[a] Adjustments were made by applying a 5% mortality rate to tagged fish and subtracting a proportion of fish not expected to pass wheels, based on migration rate.

Table 4. Results of parameter estimates, by strata, of Tanana River chum salmon population size estimates, 1997 as generated by the Darroch model.

Tagging Strata	Population Estimate	Standard Error	Probability of Capture	S.E. of P(Capture)
8/16-8/25	9815	1093	0.0574	0.0064
8/26-9/30	61846	12088	0.0106	0.0021

Table 5. Counts, frequencies, and cumulative frequencies of travel times between the tag deployment and recovery wheels on the Tanana River, 1997, used in the truncation of the data for the Darroch estimator.

Travel Time (d)	Count	Frequency	Cumulative Frequency
1	1	0.010	0.010
2	24	0.233	0.243
3	38	0.369	0.612
4	19	0.184	0.796
5	10	0.097	0.893
6	5	0.049	0.942
7	4	0.039	0.981
8	0	0.000	0.981
9	1	0.010	0.990
10	0	0.000	0.990
11	0	0.000	0.990
12	1	0.010	1.000

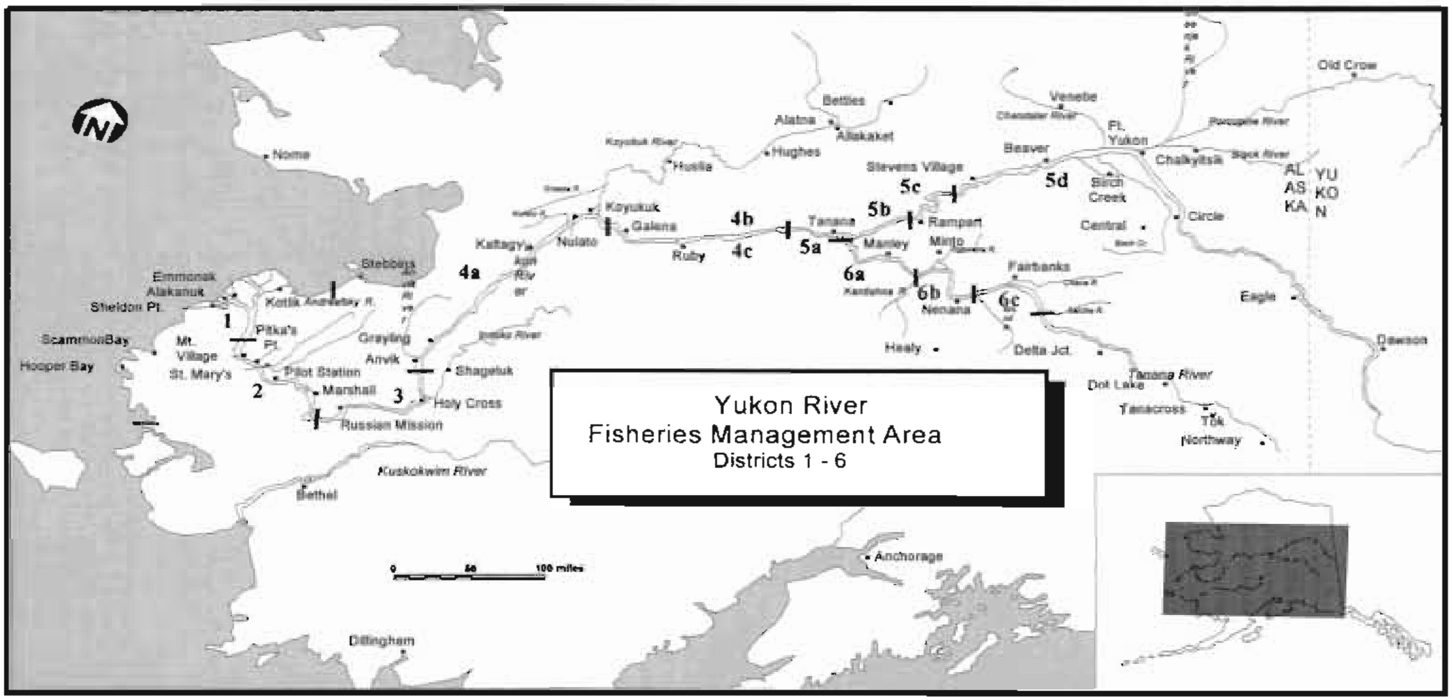

Figure 1. Fisheries management districts and subdistricts in the Yukon River and Tanana River drainages.

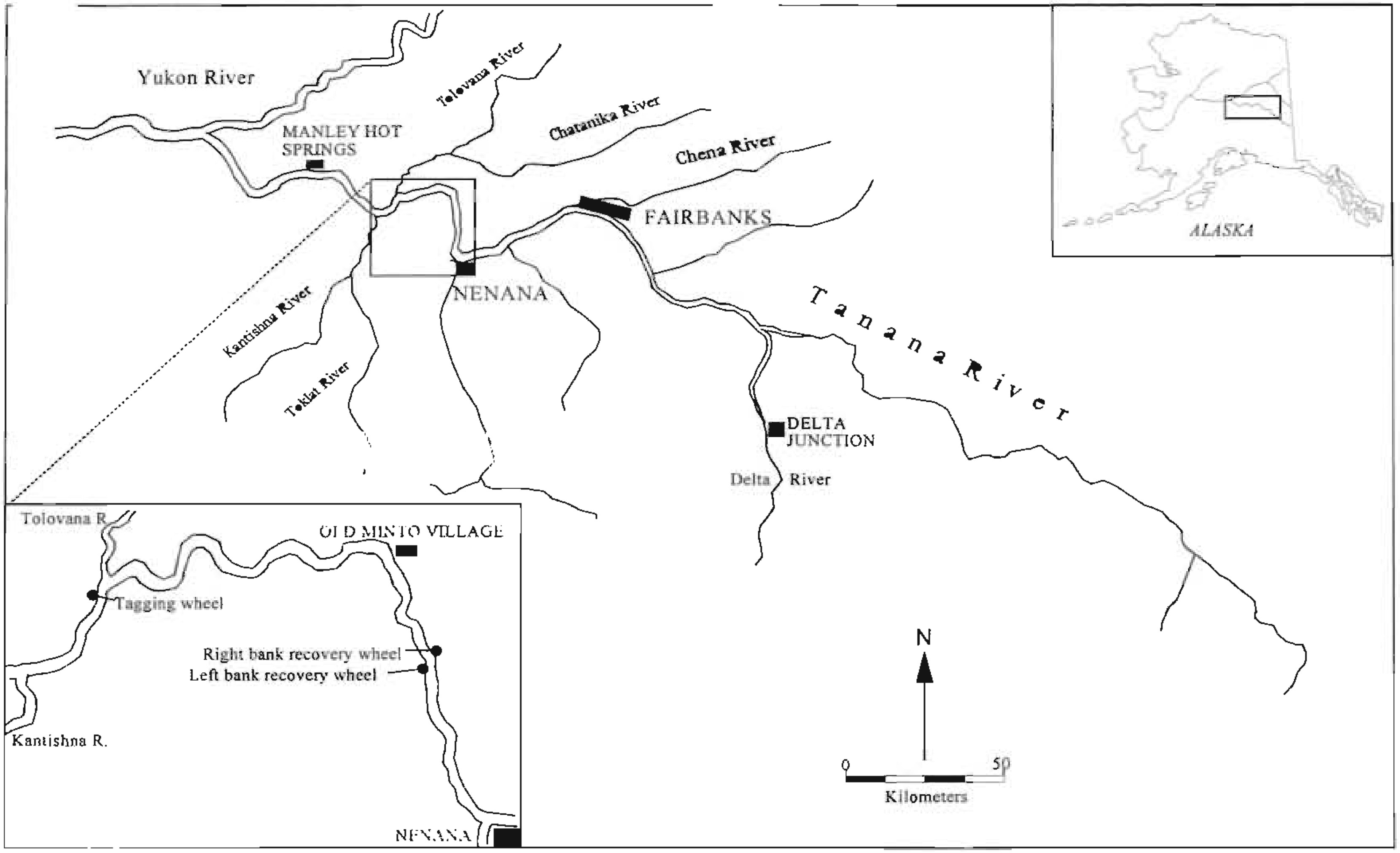

Figure 2. Location of tag deployment fish wheel and tag recovery fish wheel used for the 1997 Tanana River fall chum salmon tagging project.

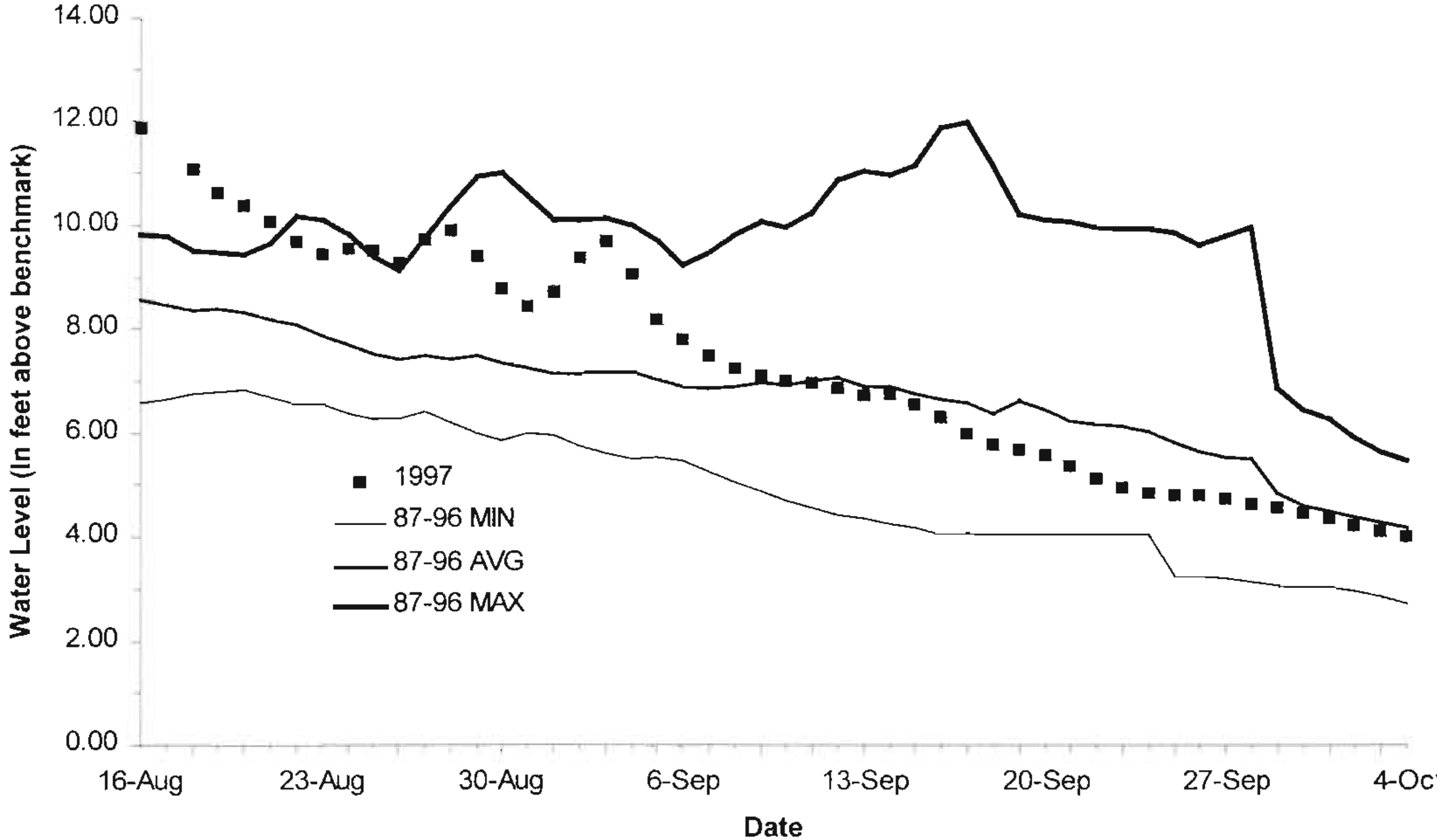

Figure 3. Daily water level of the Tanana River, 1997 as measured by a US Geological Survey gauge located near Nenana.

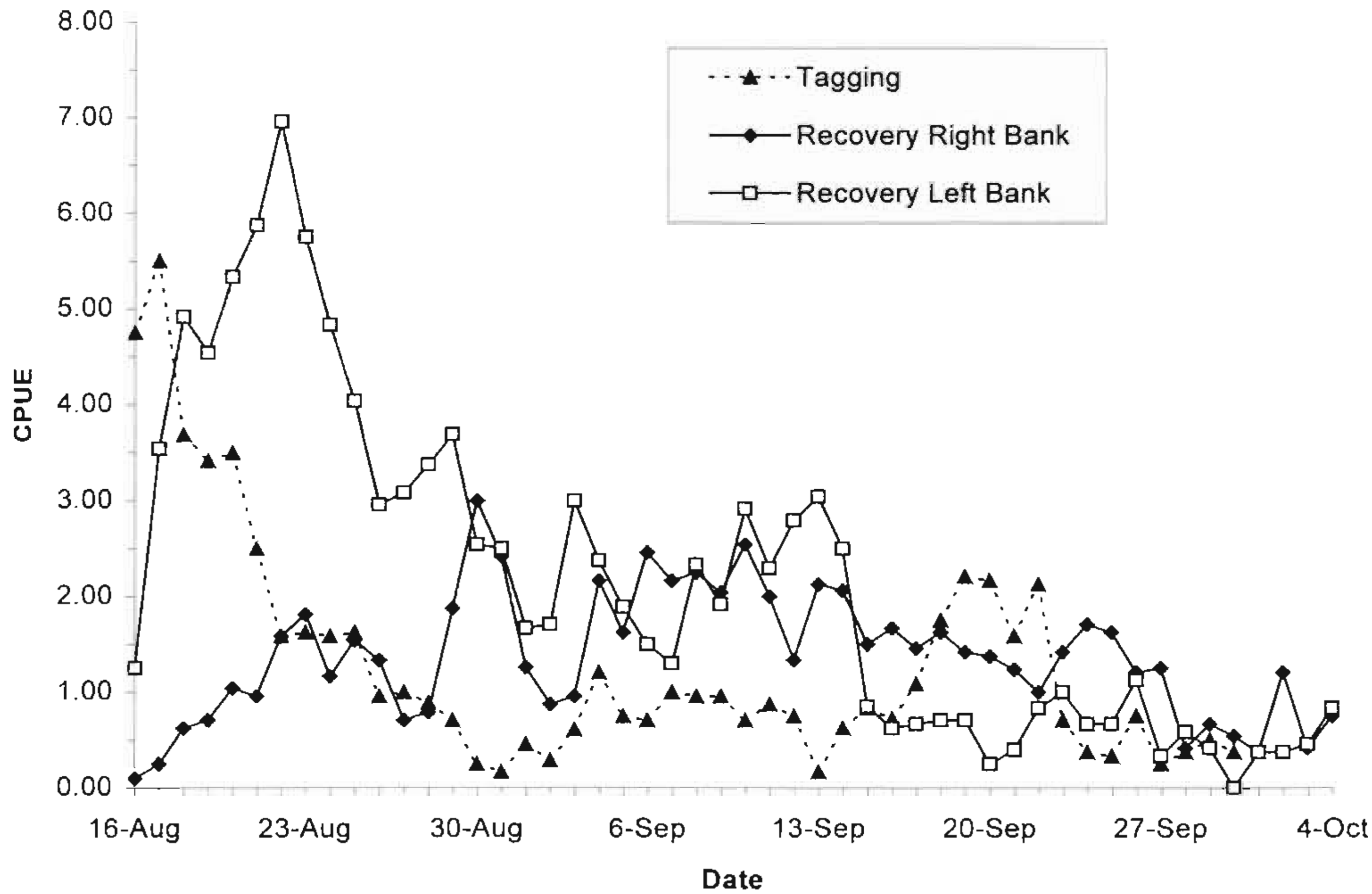

Figure 4. Daily catch-per-hour-effort (CPUE) of fall chum salmon at the tag deployment and recovery fish wheels on the Tanana River, 1997.

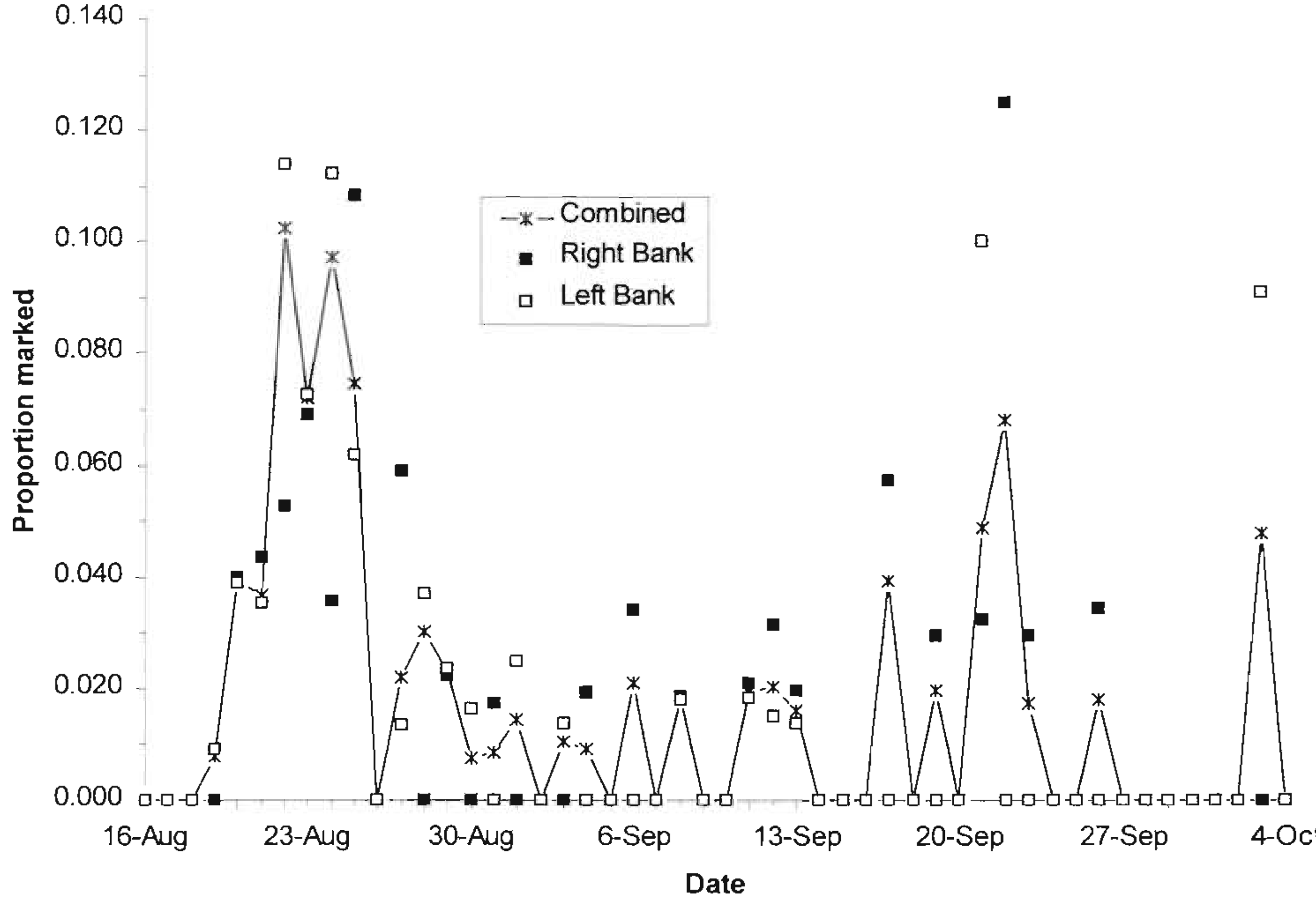

Figure 5. Daily proportion of marked fall chum salmon captured in the recovery wheels, Tanana River, 1997.

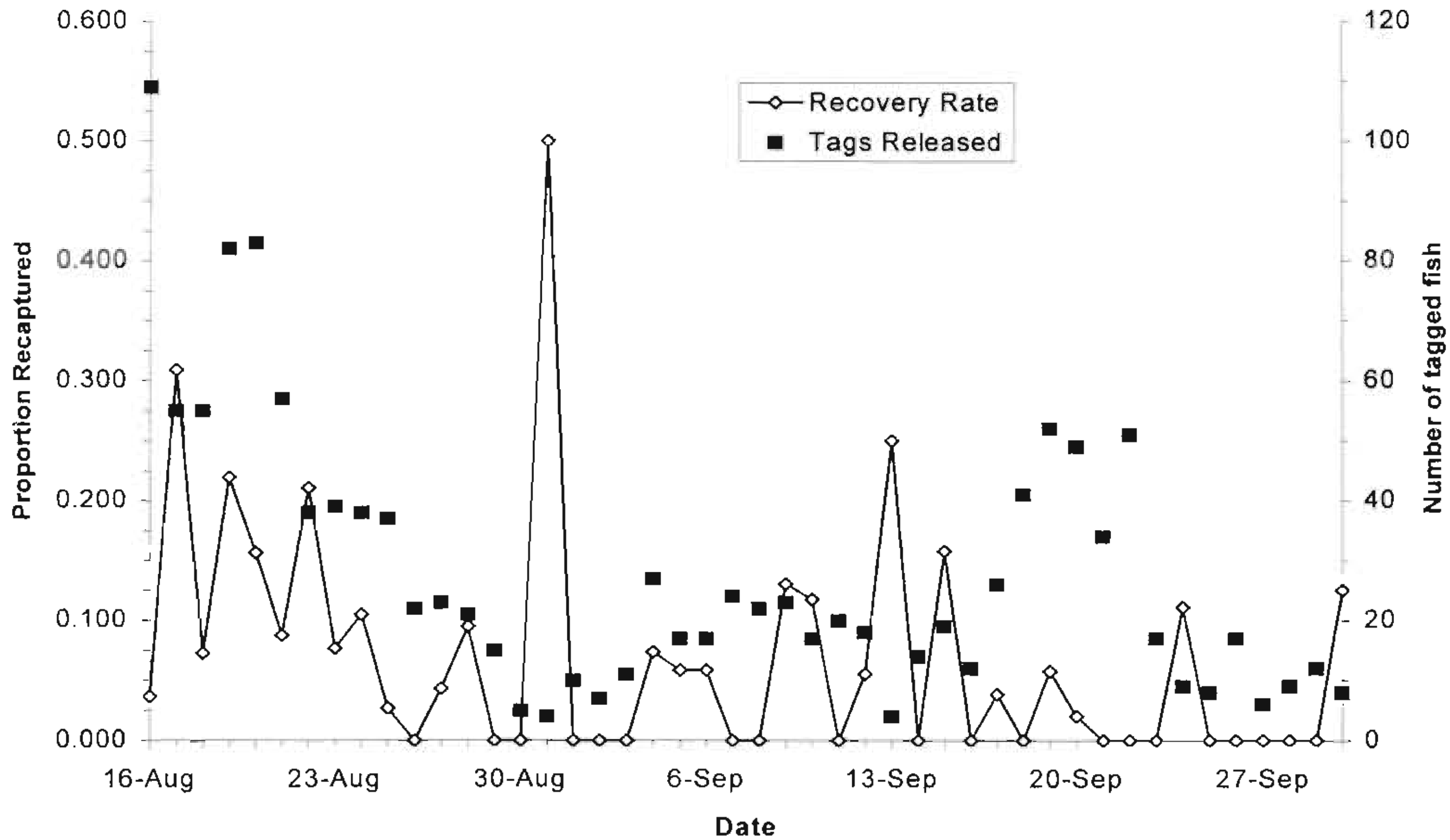

Figure 6. The daily proportion of tagged fall chum salmon that were recaptured in the recovery wheels, and the number of tags that were deployed, Tanana River, 1997.

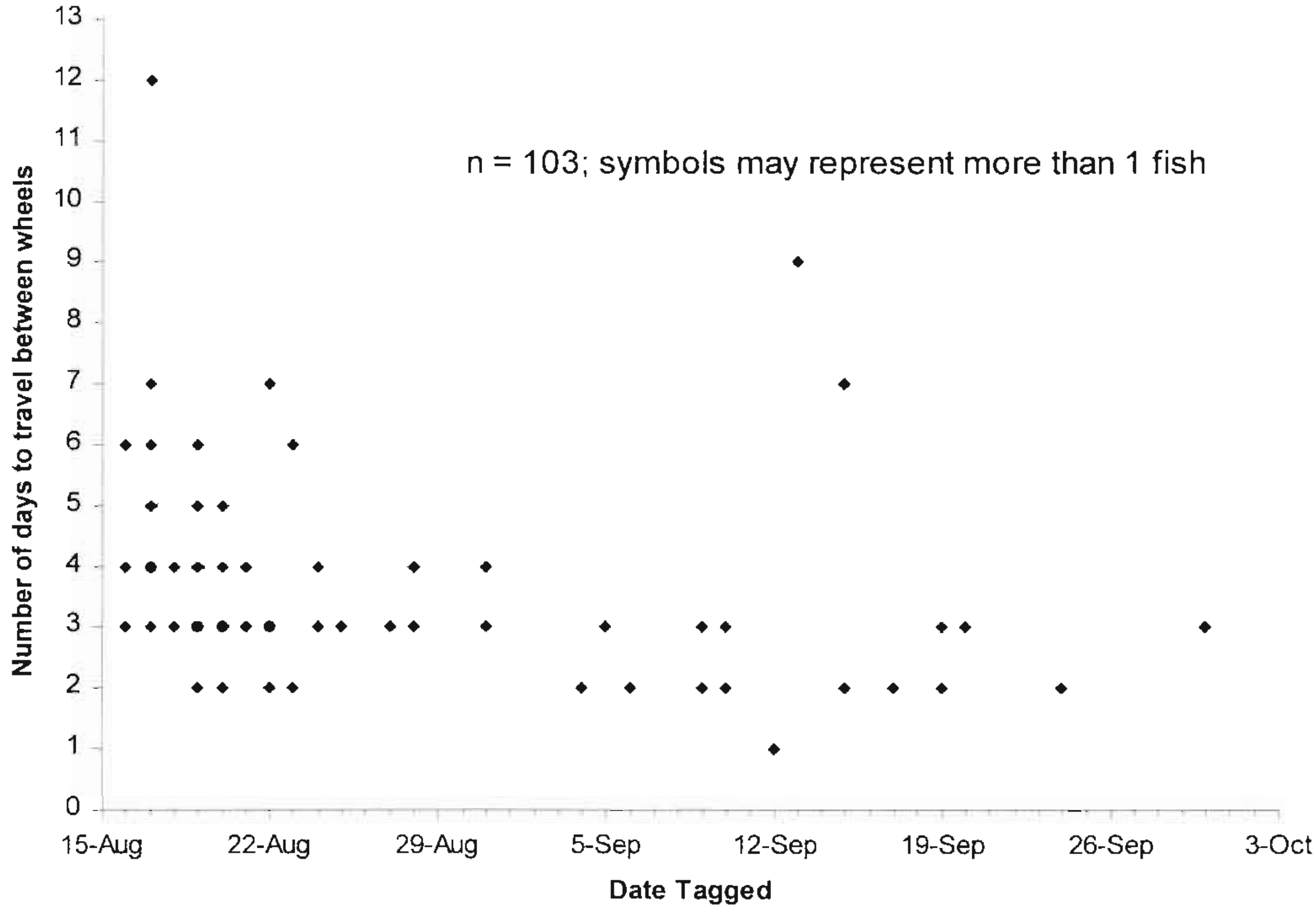

Figure 7. Travel time by date of tagged fall chum salmon being recaptured between the tag deployment and recovery wheels on the Tanana River, 1997.

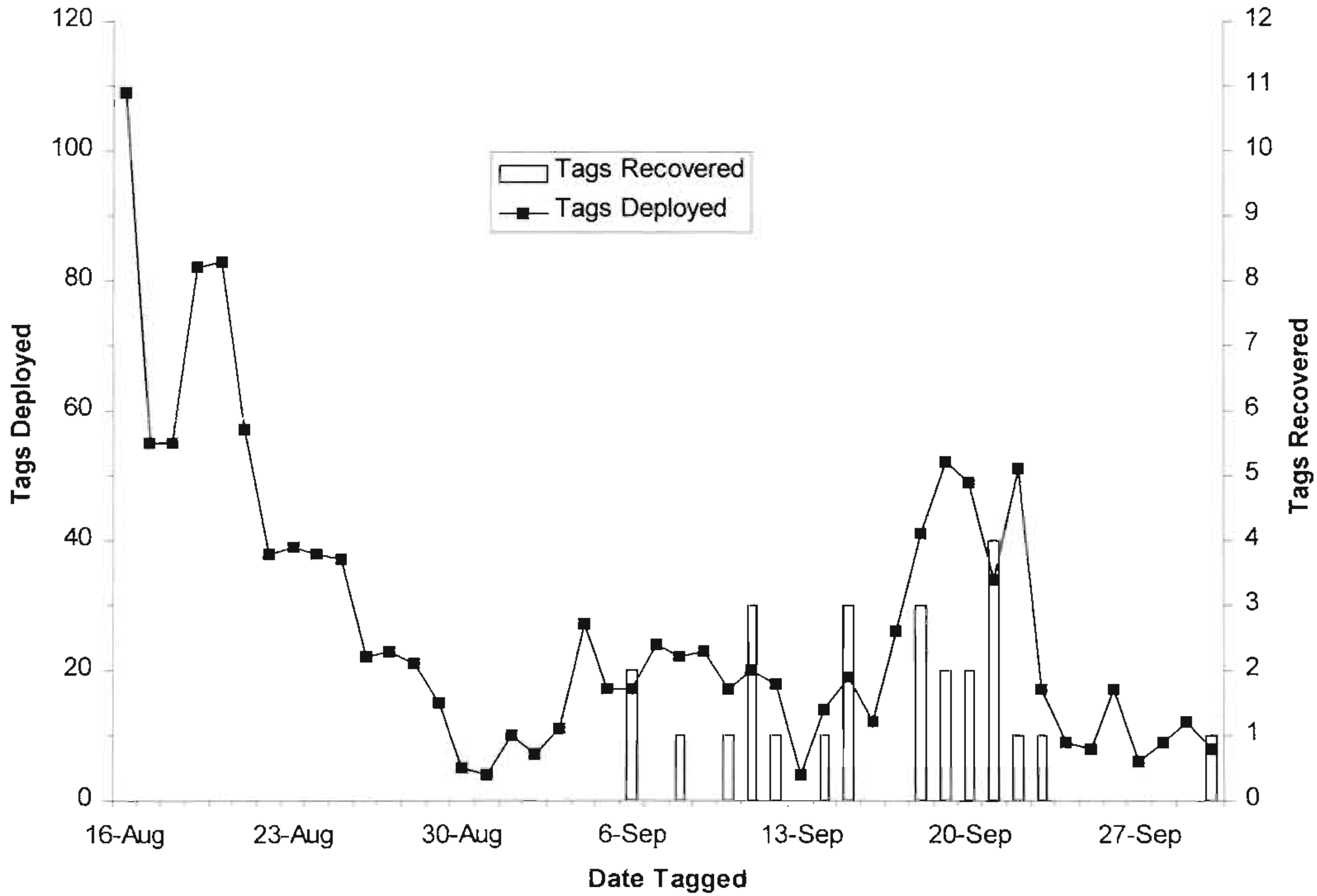

Figure 8. Number of tags recovered from fall chum salmon at the Delta River spawning grounds by date tagged in the Tanana River, 1997. The daily number of tags deployed is shown for comparison.

Appendix A. Daily effort and catch of fall chum salmon in the Tanana River tag deployment wheel, 1997.

Date	Hours Fished	Tagged Male	Tagged Female	Tagged Total	Not Marked Male	Not Marked Female	Not Marked Total	Moralities Male	Moralities Female	Moralities Total	Total Male	Total Female	Total Total
16-Aug	24	46	63	109	3	2	5	1	2	3	49	65	114
17-Aug	10	24	31	55	0	0	0	0	0	0	24	31	55
18-Aug	16	17	38	55	2	2	4	0	0	0	19	40	59
19-Aug	24	34	48	82	0	0	0	0	0	0	34	48	82
20-Aug	24	41	42	83	1	0	1	0	0	0	42	42	84
21-Aug	24	27	30	57	2	1	3	0	0	0	29	31	60
22-Aug	24	17	21	38	0	0	0	0	0	0	17	21	38
23-Aug	24	26	13	39	0	0	0	0	0	0	26	13	39
24-Aug	24	24	14	38	0	0	0	0	0	0	24	14	38
25-Aug	24	19	18	37	0	2	2	0	0	0	19	20	39
26-Aug	24	5	17	22	1	0	1	0	0	0	6	17	23
27-Aug	24	13	10	23	1	0	1	0	0	0	14	10	24
28-Aug	23.5	7	14	21	0	0	0	0	0	0	7	14	21
29-Aug	24	11	4	15	2	0	2	0	0	0	13	4	17
30-Aug	24	3	2	5	0	1	1	0	0	0	3	3	6
31-Aug	24	1	3	4	0	0	0	0	0	0	1	3	4
1-Sep	24	8	2	10	0	1	1	0	0	0	8	3	11
2-Sep	24	3	4	7	0	0	0	0	0	0	3	4	7
3-Sep	18	5	6	11	0	0	0	0	0	0	5	6	11
4-Sep	24	12	15	27	1	1	2	0	0	0	13	16	29
5-Sep	24	9	8	17	1	0	1	1	0	1	10	8	18
6-Sep	24	9	8	17	0	0	0	0	0	0	9	8	17
7-Sep	24	13	11	24	0	0	0	0	0	0	13	11	24
8-Sep	24	12	10	22	1	0	1	0	0	0	13	10	23
9-Sep	24	7	16	23	0	0	0	0	0	0	7	16	23
10-Sep	24	6	11	17	0	0	0	0	0	0	6	11	17
11-Sep	24	7	13	20	1	0	1	0	0	0	8	13	21
12-Sep	24	12	6	18	0	0	0	0	0	0	12	6	18
13-Sep	24	1	3	4	0	0	0	0	0	0	1	3	4
14-Sep	24	2	12	14	1	0	1	0	0	0	3	12	15
15-Sep	24	11	8	19	0	1	1	0	0	0	11	9	20
16-Sep	18	4	8	12	0	1	1	0	0	0	4	9	13
17-Sep	24	11	15	26	0	0	0	0	0	0	11	15	26
18-Sep	24	23	18	41	1	0	1	0	0	0	24	18	42
19-Sep	24	24	28	52	0	1	1	0	1	1	24	29	53
20-Sep	24	16	33	49	3	0	3	0	0	0	19	33	52
21-Sep	24	14	20	34	1	3	4	1	2	3	15	23	38
22-Sep	24	23	28	51	0	0	0	0	0	0	23	28	51
23-Sep	24	7	10	17	0	0	0	0	0	0	7	10	17
24-Sep	24	2	7	9	0	0	0	0	0	0	2	7	9
25-Sep	24	3	5	8	0	0	0	0	0	0	3	5	8
26-Sep	24	8	9	17	0	1	1	0	0	0	8	10	18
27-Sep	24	1	5	6	0	0	0	0	0	0	1	5	6
28-Sep	24	4	5	9	0	0	0	0	0	0	4	5	9
29-Sep	24	3	9	12	0	0	0	0	0	0	3	9	12
30-Sep	24	2	6	8	1	0	1	0	0	0	3	6	9
Total		577	707	1284	23	17	40	3	5	8	600	724	1324

Appendix B 1. Catches of fall chum salmon in the right-bank recovery wheel, Tanana River, 1997.

	Hours	Tagged			Not Marked			Total		
Date	Fished	Male	Female	Total	Male	Female	Total	Male	Female	Total
16-Aug	20	0	0	0	0	2	2	0	2	2
17-Aug	24	0	0	0	4	2	6	4	2	6
18-Aug	24	0	0	0	8	7	15	8	7	15
19-Aug	24	0	0	0	8	9	17	8	9	17
20-Aug	24	1	0	1	11	13	24	12	13	25
21-Aug	24	0	1	1	10	12	22	10	13	23
22-Aug	24	1	1	2	18	18	36	19	19	38
23-Aug	16	1	1	2	12	15	27	13	16	29
24-Aug	24	1	0	1	14	13	27	15	13	28
25-Aug	24	2	2	4	17	16	33	19	18	37
26-Aug	24	0	0	0	17	15	32	17	15	32
27-Aug	24	0	1	1	9	7	16	9	8	17
28-Aug	24	0	0	0	11	8	19	11	8	19
29-Aug	24	1	0	1	22	22	44	23	22	45
30-Aug	24	0	0	0	36	36	72	36	36	72
31-Aug	24	0	1	1	38	19	57	38	20	58
1-Sep	23	0	0	0	13	16	29	13	16	29
2-Sep	24	0	0	0	10	11	21	10	11	21
3-Sep	24	0	0	0	13	10	23	13	10	23
4-Sep	24	0	1	1	28	23	51	28	24	52
5-Sep	24	0	0	0	25	14	39	25	14	39
6-Sep	24	2	0	2	31	26	57	33	26	59
7-Sep	24	0	0	0	34	18	52	34	18	52
8-Sep	24	0	1	1	28	25	53	28	26	54
9-Sep	24	0	0	0	31	18	49	31	18	49
10-Sep	24	0	0	0	30	31	61	30	31	61
11-Sep	24	0	1	1	26	21	47	26	22	48
12-Sep	24	0	1	1	12	19	31	12	20	32
13-Sep	24	1	0	1	30	20	50	31	20	51
14-Sep	16	0	0	0	16	17	33	16	17	33
15-Sep	20	0	0	0	18	12	30	18	12	30
16-Sep	24	0	0	0	22	18	40	22	18	40
17-Sep	24	2	0	2	13	20	33	15	20	35
18-Sep	16	0	0	0	13	13	26	13	13	26
19-Sep	24	1	0	1	14	19	33	15	19	34
20-Sep	24	0	0	0	12	21	33	12	21	33
21-Sep	25	1	0	1	17	13	30	18	13	31
22-Sep	24	2	1	3	8	13	21	10	14	24
23-Sep	24	1	0	1	14	19	33	15	19	34
24-Sep	24	0	0	0	16	25	41	16	25	41
25-Sep	24	0	0	0	16	23	39	16	23	39
26-Sep	24	0	1	1	8	20	28	8	21	29
27-Sep	24	0	0	0	11	19	30	11	19	30
28-Sep	24	0	0	0	5	5	10	5	5	10
29-Sep	24	0	0	0	4	12	16	4	12	16
30-Sep	24	0	0	0	5	8	13	5	8	13
1-Oct	24	0	0	0	3	6	9	3	6	9
2-Oct	24	0	0	0	10	19	29	10	19	29
3-Oct	24	0	0	0	2	8	10	2	8	10
4-Oct	12	0	0	0	2	7	9	2	7	9
Total		17	13	30	775	783	1558	792	796	1588

Appendix B 2. Catches of fall chum salmon in the left-bank recovery wheel, Tanana River, 1997.

	Hours	Tagged			Not Marked			Total		
Date	Fished	Male	Female	Total	Male	Female	Total	Male	Female	Total
16-Aug	24	0	0	0	17	13	30	17	13	30
17-Aug	24	0	0	0	34	51	85	34	51	85
18-Aug	24	0	0	0	44	74	118	44	74	118
19-Aug	24	1	0	1	56	52	108	57	52	109
20-Aug	24	2	3	5	61	62	123	63	65	128
21-Aug	24	2	3	5	73	63	136	75	66	141
22-Aug	24	7	12	19	80	68	148	87	80	167
23-Aug	24	2	8	10	72	56	128	74	64	138
24-Aug[a]	24	6	6	13	58	45	103	64	51	115
25-Aug	24	3	3	6	41	50	91	44	53	97
26-Aug	24	0	0	0	37	34	71	37	34	71
27-Aug	24	1	0	1	33	40	73	34	40	74
28-Aug	24	2	1	3	43	35	78	45	36	81
29-Aug	23	2	0	2	50	33	83	52	33	85
30-Aug	24	1	0	1	30	30	60	31	30	61
31-Aug	24	0	0	0	37	23	60	37	23	60
1-Sep	24	0	1	1	20	19	39	20	20	40
2-Sep	24	0	0	0	20	21	41	20	21	41
3-Sep	24	1	0	1	35	36	71	36	36	72
4-Sep	24	0	0	0	26	31	57	26	31	57
5-Sep	18	0	0	0	16	18	34	16	18	34
6-Sep	24	0	0	0	21	15	36	21	15	36
7-Sep	20	0	0	0	15	11	26	15	11	26
8-Sep	24	1	0	1	30	25	55	31	25	56
9-Sep	24	0	0	0	21	25	46	21	25	46
10-Sep	24	0	0	0	33	37	70	33	37	70
11-Sep	24	1	0	1	30	24	54	31	24	55
12-Sep	24	0	1	1	37	29	66	37	30	67
13-Sep	24	1	0	1	34	38	72	35	38	73
14-Sep	24	0	0	0	28	32	60	28	32	60
15-Sep	20	0	0	0	10	7	17	10	7	17
16-Sep	24	0	0	0	7	8	15	7	8	15
17-Sep	24	0	0	0	7	9	16	7	9	16
18-Sep	24	0	0	0	6	11	17	6	11	17
19-Sep	24	0	0	0	4	13	17	4	13	17
20-Sep	24	0	0	0	3	3	6	3	3	6
21-Sep	25	1	0	1	4	5	9	5	5	10
22-Sep	24	0	0	0	8	12	20	8	12	20
23-Sep	24	0	0	0	12	12	24	12	12	24
24-Sep	24	0	0	0	8	8	16	8	8	16
25-Sep	24	0	0	0	9	7	16	9	7	16
26-Sep	24	0	0	0	16	11	27	16	11	27
27-Sep	24	0	0	0	2	6	8	2	6	8
28-Sep	24	0	0	0	7	7	14	7	7	14
29-Sep	24	0	0	0	5	5	10	5	5	10
30-Sep	24	0	0	0	0	0	0	0	0	0
1-Oct	24	0	0	0	2	7	9	2	7	9
2-Oct	24	0	0	0	3	6	9	3	6	9
3-Oct	24	1	0	1	5	5	10	6	5	11
4-Oct	12	0	0	0	6	4	10	6	4	10
Total		35	38	74	1256	1236	2492	1291	1274	2565